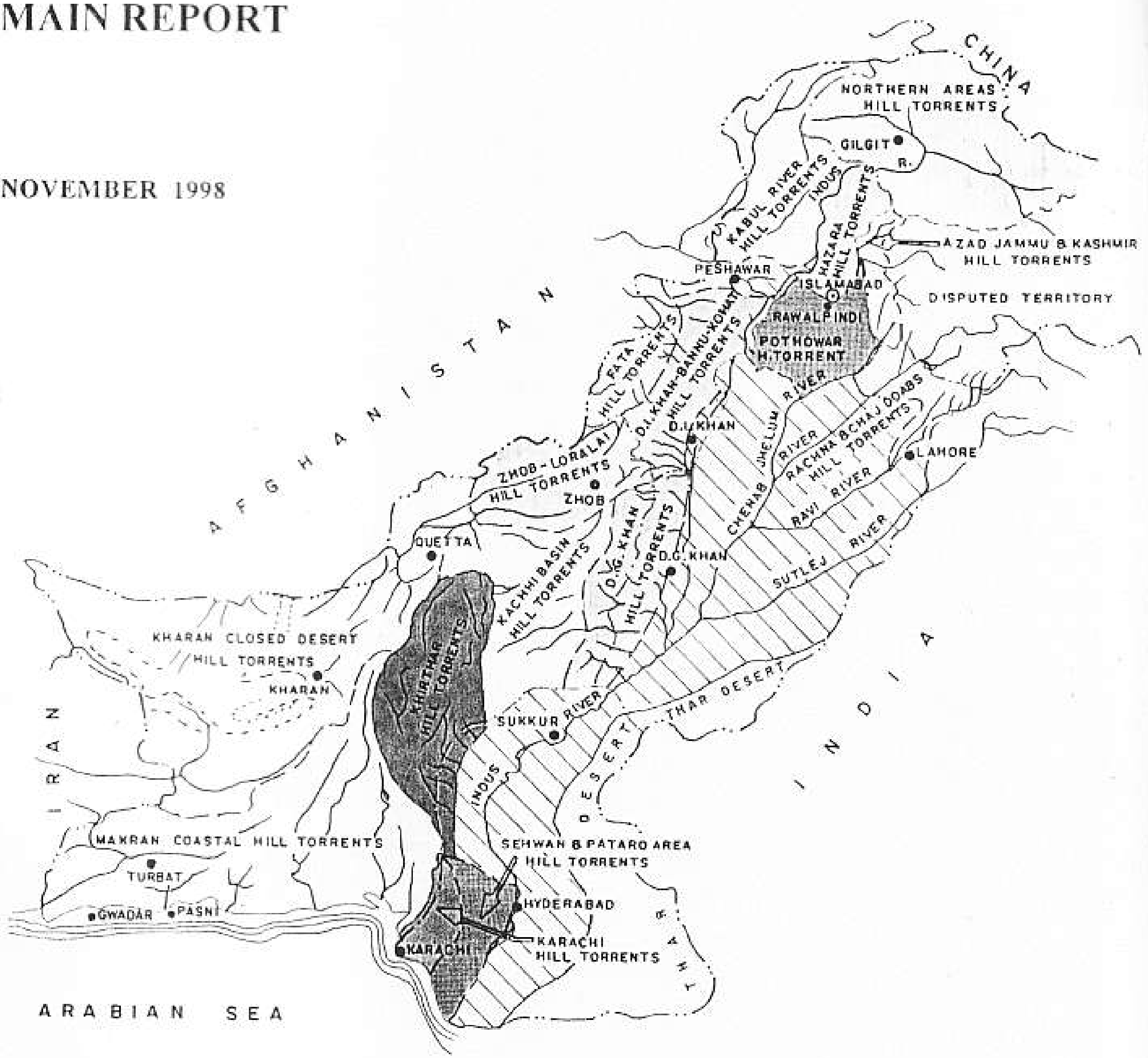
ISLAMIC REPUBLIC OF PAKISTAN
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF HILL TORRENTS OF PAKISTAN

MAIN REPORT



NOVEMBER 1998

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD.
1-C, BLOCK-N, MODEL TOWN EXTENSION
LAHORE - PAKISTAN

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Abiana	Irrigation Water Charge
Awahndha	The field water inlet
Bachat	Left over, remains, residual
Bajra	Millet
Basti	Village
Bharai	The first irrigation, literally filling up
Bund	A field for cultivation in Rod Kohi encircled by embankments that allow water to store before seeping in Barani Rainfed area
Bundat	The plural of a bund
Bunna	The inner middle surface of a bund
Chab	A structure made from brush wood and bushes kept in place by a log spanning the channel bed secured by two wooden pegs at each end allowing a proportion to be diverted and another to flow downstream
Chak	Area commanded by a Mogha
Chehr	A collective labor or work gang
Chur	A small hill torrent
Darrah	The gorge through which the hill torrents emerge into the plain
Daur	Cycle, particularly of water rotation
Gabion	Stone/rock bound in wire bags.
Gandah	Earthen dam across the entire width of a stream bed -- high enough to divert the water into the channels used for conveying flows into the bundat that have to be irrigated.
Gatti	Field bund for diverting water.
Ghair haqooq	Without rights - customary or legal.
Haqooq	Area/Channel having water rights
Haqooq-i-Abpashi	The rights of irrigation
Jora	Literally pair; a pair of oxen;
Jowar	Sorgham
Kala Pani	Perennial Flow
Kamara	Common structures at all levels of the system, constructed collectively, which are necessary to convey the water upto the individual field that is to be irrigated

Khad	A deep branch of a hill torrent
Kamarajat	Plural of kamara
Khula	Shallow channel offtaking from main channel.
Karah	Blade for moving earth
Katcha	Construction work, using local materials
Kharif	The hot(summer) season (April to September)
Korday Kamary	Water diversion structures built collectively when the streams are dry
Lath	Embankment, particularly of a bund
Maqasma	Farmers made distributor
Mauza	Village
Markaz	Center/Sub Divisional Office/Tehsil Office
Meth	Silt
md	Man Days
Mogha	Outlet from Minor or a tributary into Watercourse
Mouza	A revenue circle or estate
mt	Metric Tons
Nai	Natural stream
Nain	Branch of hill torrent
Nakka	Outlet from Watercourse into farm ditch
Nallah	Hill torrent channel
Non-Haqooq	Area/Channel having no water rights
Pacca	Construction work using fabricated materials such as bricks, cement, iron and steel.
Pachad	It means west side of any reference line.
Pachad Area	In D.G.Khan and Rajanpur districts, the area lying on the western side of the canal irrigated area to the toe of the hills.
Pehar	A portion of the day -- 3 hours
Patri	Rainfed land with low embankments
Patwari	Village Level Employee of the Revenue or Irrigation Department.
Peechdar	Irrigators
Pora	Sowing or seeding in rows by dropping with a pouring instrument
Pookha	A system of turns by draw
Purda	Veil
Rabi	The cold winter season (October to March)

Rivaj-e-Abpashi	Rules for diverting water in natural channels
Rod/Rud Kohi	Flood irrigation from hill torrents
Sad	A small diversion bund/dam
Saropa	Head
Sardar	Head/Chief of Tribe
Saropa gandah	The gandah at the head or the one above
Salai	A spur for the guiding water proportionately into two separate channels
Sailaba	Land depending upon seepage/flood waters
sp	Spray
Sum	A portion or share of water
Shakh	Branch of a hill torrent used as water channel
Summa	The proportion or share of a particular group
Tehsil	Sub-unit of a district
Union Council	Rural administrative unit comprising some villages.
Wah	A large man made and sometimes natural channel
Wahal	The section within a bund used to convey water upto the banna
Wahi	A relatively small distribution channel usually man made
Wakra	A smaller gandah made for diversion on to individual fields as opposed to one for a collective channel
Wandara	Flow guide embankment
Warabandi	System of water allocation on watercourse level in which each farmer is allotted a day and time of the week and a duration for the diversion to his field from the Nakka
Zam	Perennial Hill Torrent
Zimindar	Land Owner

LIST OF ABBREVIATIONS

Ac.ft	Acre feet
ADB	Asian Development Bank
ADBP	Agricultural Development Bank of Pakistan
ADP	Annual Development Programme
ACS	Additional Chief Secretary
AEC	Atomic Energy Commission
AHG	Agrar-und Hydrotechnik GmbH
AMC	Antecedent Moisture Content
AO	Agricultural Officer
CRBC	Chashma Right Bank Canal
DBG	Drainage Beneficiaries Group
Cft	Cubic Feet - Cusec
CCA	Cultural Command Area
DA	Director of Agriculture
DCC	Derajat Canal Circle
DDA	Deputy Director of Agriculture
EADA	Extra Assistant Director of Agriculture
EC	Electric Conductivity
ECSE	Electric Conductivity of Soil Extract
Ft	Feet
FA	Field Assistant
FGWZ	Fresh Ground Water Zone
FP Bund	Flood Protective Bund
FSL	Full Supply Level
GCA	Gross Command Area
GDP	Gross Domestic Product
GNP	Gross National Product
GOP	Government of Pakistan
HC Test	Hydraulic Conductivity Test
Ha.m	Hectare Meter
H.T.	Hill Torrent
HYV	High Yielding Variety
HTFP Bund	Hill Torrent Flood Protection Bund

ICB	International Competitive Bidding
IFAD	International Fund for Agricultural Development
ISRP	Irrigation System Rehabilitation Project
JICA	Japan International Cooperation Agency
Km	Kilometer
KW	Kreditanstalt fur Wiederaufbau
Kg	Kilogram
LCB	Local Competitive Bidding
MAF	Million Acre Feet
MCM	Million Cubic Meters
MFAC	Ministry of Food & Agriculture
MM	Man month
mm	Millimeter
NESPAK	National Engineering Services of Pakistan (Pvt) Ltd.
NSL	Natural Surface Level
NWFP	North Western Frontier Province
OFD	On Farm Drainage
OFWM	On Farm Water Management
PARC	Pakistan Agriculture Research Council
PERI	Punjab Economic Research Institute
PHE	Pakistan Health Engineering
PID	Punjab Irrigation Department
PIDA	Provincial Irrigation & Drainage Authority
PLL	Precision Land Levelling
PTDP	Private Tubewell Development Project
RD	Reduced Distance in 1000 feet
Rs	Rupees
SCARP	Salinity Control and Reclamation Project
SCF	Standard Conversion Factor
SWR	Standard Wage Rate
TOR	Terms of Reference
USSCS	United States Soil Conservation Serive
USDA	United States Department of Agriculture
WAPDA	Water and Power Development Authority
WUA	Water User Association

CONVERSION FACTORS

Length

1	meter (m)	3.281 feet (ft)
1	foot (ft)	0.305 m
1	kilometre (km)	0.621 miles
1	mile	1.610 km
1	furlong (1/8 mile)	200 m

Area

1	hectare (ha)	2.471 acre (ac)
1	acre (ac)	0.405 (ha)
1	square kilometre (km^2)	0.386 square miles
1	square mile	2.590 km^2

Volume

1	million cubic (Mm^3)	810.7 acre feet (AF)
1	million acre feet (MAF)	1,233 Mm^3

Discharge

1	cubic metre per second (m^3/s)	35.31 cubic feet per second
1	cubic foot per second (ft3/s)	28.32 litres per second (l/s)
1	l/s/ha	14.30 ft^3/s per 1000 acre

Weight

1	kilogram (kg)	2.202 pound (lb)
1	pound (lb)	0.454 kg
1	metric ton (t)	1.000 kg
1	maund (md)	37.33 kg, often taken as 40 kg

FOREWORD

AUTHORIZATION & PRINCIPAL OUTPUT

The preparation of Master Feasibility Report for Flood Management of Hill Torrents of Pakistan was assigned to NESPAK under Contract between Federal Flood Commission (FFC), Ministry of Water & Power, Government of Pakistan and National Engineering Services Pakistan Limited (NESPAK) signed on 11th June 1995. The primary objective of the study was to provide a basic framework for orderly and integrated development of land and water resources of hill torrents of Pakistan.

The hill torrents emerge from different mountain ranges and form a secondary network of natural surface drainage system. Hill torrent watersheds constitute distinct basins and sub-basins and vary largely in hydrologic characteristics. The areal orientation of hill torrents and rivers divides the country into the following three major basins:

- Indus River Basin (944,580 sq. km of which 551,211 sq. km lies in Pakistan)
- Mekran Coastal Basin (123,025 sq. km)
- Kharan Closed Desert Basin (121,860 sq. km)

Within these three units, there are innumerable hill torrents which have been grouped into 14 major zones.

SCOPE OF SERVICES

The original Scope of Services required the preparation of a single Master Feasibility Report for the management and conservation of flood flows of major hill torrents of Pakistan. However, during the course of studies, the Consultants were asked to prepare four 'Core Project' reports, selecting one hill torrent area with maximum development potential in each Province. The Consultants were advised to carry out indepth studies for these Core Projects to prepare "Bankable Documents", worthy of presentation to financing agencies.

An integrated Master Plan was required for all the remaining areas to be taken as 'Sub-projects'.

REPORT PRESENTATION

Accordingly, in the greater national interest and without involving additional remunerations, NESPAK carried out extensive field visits and detailed studies for the areas selected as 'Core Projects'. Selection of optimal technology for conservation of flows, consistent with the potential land resources formed a part and parcel of all the Core Projects. Availability of flows was determined and a development strategy for irrigated agriculture was formulated, matching with the consumptive use of suitable cropping pattern and intensity for orderly and pragmatic use of land and water resources of each hill torrent area. Bankable Documents have been prepared for the hill torrents of the following areas:

- DI Khan, NWFP;
- DG Khan, Punjab
- Khirthar Range (Gaj Nai), Sindh; and
- Indus Basin Component, Balochistan.

In order to prepare Master Planning Report for the remaining sub-basins, field visits were carried out to different areas to identify potential sites for water conservation. During the visits, discussions were held with Provincial Irrigation Department (PID) engineers, Non Government Organizations (NGOs), public representatives and beneficiaries. Studies were carried out to quantify the availability of flows and land resources for each sub-basin.

To make the Master Planning Report more useful for the Provinces and Federal Agencies, separate Supporting Volumes have been prepared for each Province and the three Federal Agencies as shown in Fig F.1. Core Project Report for each Province has also been included in the Supporting Volume of the respective Province to make it a self contained document on Provincial basis.

FLOOD MANAGEMENT OF HILL TORRENTS OF PAKISTAN
REPORT LAYOUT

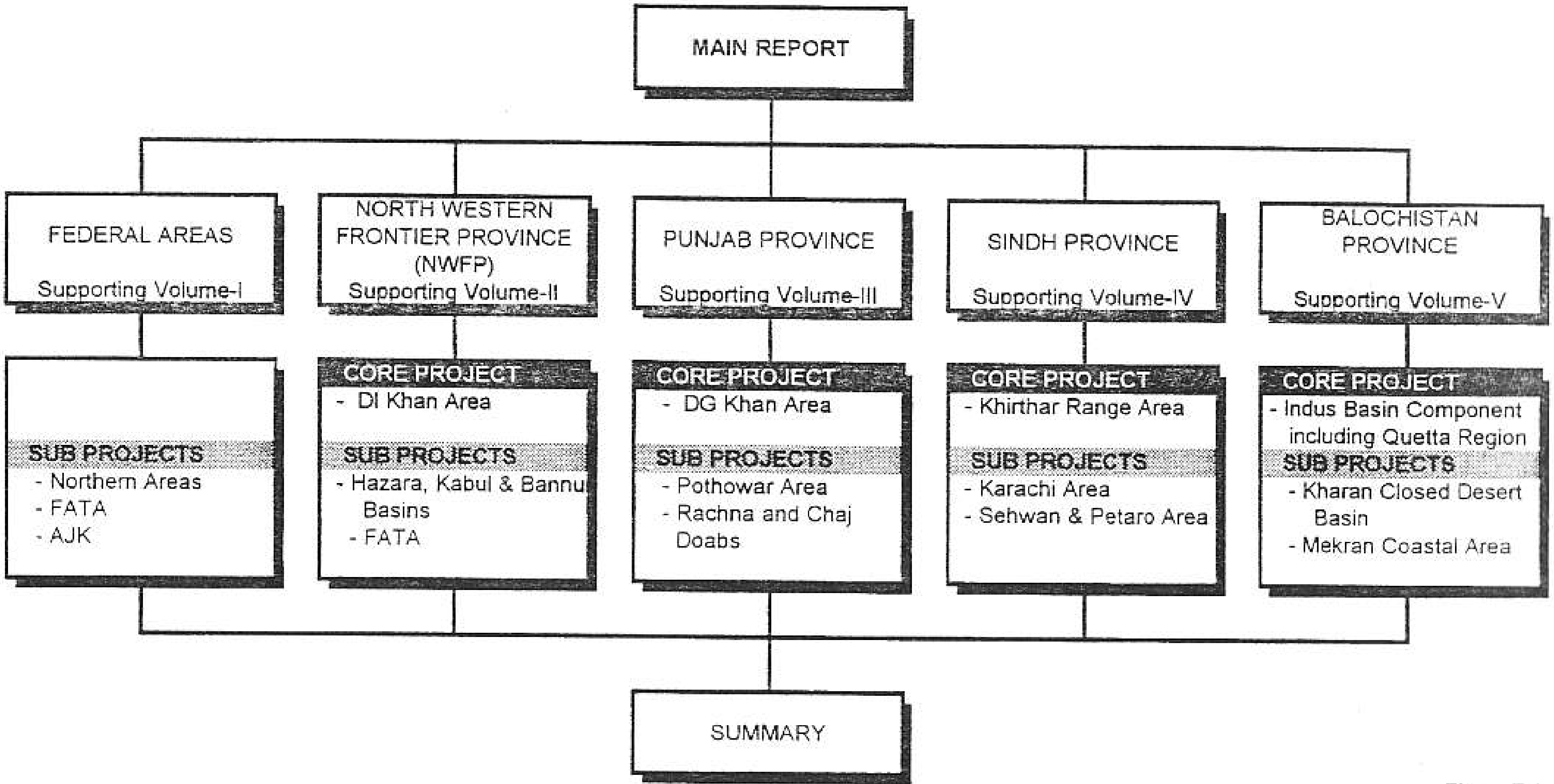

Fig. F.1

This Report Comprises ten sections. The first four sections give an overall view of Hill Torrents of Pakistan. These sections also give the Planning Strategy and Design of Structures for the hill torrents. Section-5 to Section-9 present the summaries of the Supporting Volumes of this Project, which have been presented separately. Section-10 provides the Recommendations for the Project.

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1. INTRODUCTION

Complexity of conservation and management of floodflows of hill torrents has been posing a serious challenge to the ingenuity of engineers and planners in Pakistan. Despite the deterrents like difficult approach conditions, generally inhospitable weather prevailing in major parts of hill torrents, and uncertainty in the quantum and time of occurrence, harvesting of this fresh water resource has a great lure for investment. Exploitation of perennial fresh water resources (rivers, lakes, groundwater) is fast approaching the saturation limit, and as such, the flows of hill torrents are becoming an increasingly important benediction having large development potential.

The availability of water has determined the course of empires in many civilizations.When made available, its use for irrigating crops has been practised for thousands of years by the peoples of different parts of the world. But only since the late 1800's, man has applied scientific knowledge to water drylands to increase crop production. Proper use of soil and water resources has changed millions of acres of once barren wasteland and desert into productive farms supporting prosperous communities.

In view of rapidly increasing population of Pakistan, there is growing pressure to use all water resources including those of hill torrents. Government of Pakistan is very keen for harnessing the floodflows of hill torrents, so as to minimise the flood damages and to use these flows for development of sustained irrigated agriculture in these regions. Management of hill torrents would serve as a platform to initiate other development activities in these regions. Water conservation would unlock the gateway for a full range of development of complementary resources in these areas. Communication system, mineral resources, industry, education and other sectors of the economy would get an impetus due to development of water and land resources of the hill torrent basins.

Pakistan, as a nation, is faced with the stark reality that out of 40 million population of these areas, nearly 30 percent suffers from chronic malnutrition. It is now well recognized that poverty and malnutrition are inter-related. In these regions increasing agricultural production is a major means of overcoming poverty. Majority of population lives in rural areas where the most intractable poverty problems are encountered.

Major areas traversed by hill torrents constitute nearly 65 percent of total area of Pakistan and encompass entire Balochistan (with its three component basins i.e Makran Coastal Basin, Indus Basin and Kharan Closed Desert Basin). The other major hill torrent areas include Derajat Plains of DG Khan and DI Khan; Pothowar Plateau, Kurram and Kohat Basin, Kabul and Swat River Basins, Hazara and Kohistan Basin. Khirthar, Karachi and Petaro Hill Torrents, Federally Administered Tribal Area (FATA), Federally Administered Northern Area (FANA) and Azad Jammu & Kashmir. All the major hill torrents have been shown on Exhibit M-1.1.

Major constraint in the use of floodflows is that quantity and distribution of rainfall, both in time and space, are unfavourable for agriculture: annual rainfall is low, uncertain and patchy. Flows are generally laden with high silt charge which in some areas preclude their management through dams/reservoirs. Paradoxical as it may sound, inspite of deficiency of water, major part of floodflows is lost resulting in serious damage to the areas. Flashy floodflows, in the light of uncertainty of their occurrence, add complexity to their economic management. Abject poverty in the areas affected by the hill torrents calls for a rational and scientific management of floodflows. Majority of people in these areas live below poverty line which underlines the necessity for making concerted efforts for fulfilling the aspirations of the people for socio-economic amelioration and settled life. This essentially requires the marshalling of hill torrent flows, not only to safeguard the people from frequent onslaught of hill torrents, but also to use it for development of flood irrigated agriculture in the area.

Increased farm incomes in hill torrent areas, and access to low-cost food and fibre are the two important pre-requisites to break the vicious circle of poverty and malnutrition. For the socio-economic amelioration of these areas, all road signs point to one destination alone - the effective conservation and development of land and water resources, without which these areas are likely to plunge for ever in the nightmare of economic backwardness. Great potential exists in the hill torrent areas for conservation of water resources by constructing various type of interventions described in detail in the following sections of this document. Large parcels of cultivable areas are frequently found in hill torrent basins which can be developed for agriculture by utilizing conserved flows of hill torrents.

2. PROJECT AREA

2.1 GENERAL

The innumerable hill torrents in Pakistan constitute a secondary network of natural surface drainage system. Most of these emerge from different hill ranges as shown on Exhibit M-2.1. The areal orientation of these streams constitutes three major basins:

- Indus River Basin (944,580 sq km of which 551,211 sq km lies in Pakistan).
- Makran Coastal Basin (123,025 sq km).
- Kharan Closed Desert Basin (121,860 sq km).

Within these three units, there are a number of hill torrents which can be grouped into the following areas according to administrative boundaries (Exhibit M-1.1).

I. <u>Federal Areas & Azad Kashmir</u>

- Northern Areas Hill Torrents
- Federally Administrated Tribal Areas (FATA) Hill Torrents
- Azad Jammu and Kashmir Hill Torrents

II. <u>North Western Frontier Province (NWFP)</u>

- DI Khan Hill Torrents
- Hazara, Kabul and Bannu Basins Hill Torrents (HKB Basins)
- FATA Hill Torrents[1]

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[1]. FATA is located in NWFP, but is under Federal Administration, thus, it has been covered under Federal Areas.

III. Punjab Province

- DG Khan Hill Torrents,
- Pothowar Area Hill Torrents
- Rachna & Chaj Doabs Hill Torrents

IV. Balochistan Province

- Indus Basin Component(including Quetta Region) Hill Torrents
- Kharan Closed Desert Basin Hill Torrents
- Makran Coastal Area Hill Torrents

V. Sindh Province

- Khirthar Range Hill Torrents
- Karachi Hill Torrents
- Sehwan & Petaro Hill Torrents

NESPAK and other Consultants have already prepared Master Planning Studies for some of the basins/sub-basins of Pakistan. Some of the works recommended in these studies have already been executed. Of the DG Khan Hill Torrents, the structures proposed for Kaha have been executed under Flood Protection Sector Project, while those designed for Pilot Project (Mithawan and Vidore Hill Torrents) have been partially implemented by JICA and World Bank. The channelization of Kalpani Nallah (Mardan), Kassi and Shaldara Nallahs (Quetta) have been completed under Flood Protection Sector Project.

2.2 FEDERAL AREAS & AZAD KASHMIR HILL TORRENTS

2.2.1 Northern Areas Hill Torrents

Northern Areas (NA) of Pakistan comprise difficult, mountainous terrain. The region encompasses five districts - Diamer, Ghizer, Ghanche, Gilgit, and Skardu; and comprises an area of about 70,500 sq km with a total population of over 900,000. There are only two all-weather roads: Karakoram Highway (KKH)and Gilgit-Skardu Road. In addition, a few other roads are under construction.

The flood problems of NA are characterized by erosion of river banks due to high velocity of flows. Vast tracts of land with human dwellings, infrastructure, orchards and crops are washed away. Massive landslides, glacier dam breaks and avalanches play havoc in the area, causing loss of life and cutting communication links, thus making the rescue operations almost impossible.

Landslides are caused due to heavy snow melt. The historic floods of 1841, 1858, 1929 and 1976 were caused by the glacier dam breaks, and landslides. In 1841, the flood in Shyok River was caused by the failure of a dam created by a glacier. A 20 km long temporary lake of 0.8 km width had been created. Breaching of the dam resulted in high peaked flood wave, which submerged the Attock Fort under 10 m of muddy water. The February, 1858 flood was caused by temporary impounding of water due to land slide and was among the most disastrous ones. The river stage rose by 21 m at Attock and caused a high velocity back-flow in Kabul River. Consequently, the girders of Attock Railway Bridge have been placed at a height of about 34 m above the low flow level. In 1929, Kundan Glacier moved across Shyok River in Baltistan creating a temporary lake. The barrier burst afterwards and sudden release of stored water caused severe flooding downstream. Similarly, Mom Hill Glacier created a lake on Hunza River in 1976, which submerged the Pak-China Friendship Bridge of KKH by about 40 m. A long reach of KKH was destroyed during the flood resulting from breaching of this glacier.

The Northern Areas generally include large glaciers, perpetual-snow covered peaks and contiguous mountain ranges comprising hard rocks. Alluvial soils with weathered soft materials are found only in small patches. The infiltration/percolation capacity of such areas is low and the rate of runoff is generally high. Most of the hill torrents have perennial flows due to frequent snow fall in the area. The hill torrents of the area are enlisted in Supporting Volume-I of this Report.

2.2.2 FATA Hill Torrents

Federally Administered Tribal Areas (FATA) of Pakistan occupy the country's North-Western Region along 545 km of Durand Line. This is an area of strategic significance ever since 1849 Sikh British War.

FATA encompasses seven contiguous agencies - Bajaur, Mehmand, Kurram, Orakzai, Khyber, North Waziristan and South Waziristan; and four Tribal Territories (TT) - Peshawar, Kohat, Bannu and DI Khan. All agencies except Orakzai share common border with Afghanistan. FATA, spread over 27,220 sq km of barren mountains and valleys, is home to of about four million people. Hardly 15 percent population is literate, 50 percent is supplied with potable drinking water, while per capita income approximates to one-third of that of the national average.

Of the total area, nearly 19 percent (5,180 sq km) is plain. Only about seven percent of the total area has been brought under cultivation. The area has narrow wadis, which have been converted into terraced farms where rain and spring water is used for irrigation. About 0.03 million hectares area is under forests. Total water utilization is about 1,070 million cubic meter (0.87 million acre-feet). The average annual rainfall varies from 250 millimetres (mm) to over 800 millimetres with an average of about 430 mm.

FATA Development Corporation (FATA DC) established in 1972, as a result of Government of Pakistan's policy to accelerate the socio-economic uplift of the area, aims at providing the basic facilities of life. Water, being an essential requirement for drinking and agriculture, occupies the top priority. Hill torrents flows provide the most potential resource of water. Due to higher altitude of terrain, the climatic conditions are favourable for growing fruits like apricot, almond, peaches, grapes and apples etc. Water conservation and irrigation projects are therefore attractive from the economic stand point as the orchards support high valued returns. Major hill torrents of the area are enlisted in the related part of Supporting Volume-I of this Report.

2.2.3 Azad Jammu and Kashmir Hill Torrents

Major part of Azad Jammu and Kashmir (AJK) is covered by mountains and narrow valleys lying along the steep banks of hill torrents. The plain area is limited to about 19 percent, and extensive terracing has been done in the vicinity of the streams. The cultivated land is the most valuable and is considered as a precious asset due to its limited availability. But, these valuable agricultural tracts are extensively eroded during floods; the houses are submerged and communication links remain cut-off. Serious erosion and overflooding takes place in plain areas of Muzaffarabad, Rawala Kot, Kotli and Mirpur districts.

Azad Jammu and Kashmir hill torrents drain an area of 13,290 sq km. The terrain of the area is hilly comprising generally hard rocks due to which the seepage rates are very low. The area receives intense rainfall during monsoon season.

The frequency as well as the intensity of floods in (AJK) have increased manifold on account of rapid denudation of mountains. The floods in Mahl, Poonch, Bhimber, Sukaiter and other rivers/nallahs have become almost a regular feature. These floods affect village populations, agricultural lands, communication systems, infrastructure and other private and public properties.

In different areas of AJK, more than 12,000 hectares (ha) of land have been affected by erosion and overbank flooding.

Bhimber, Sukaiter and Randium Nallahs affect large number of villages alongwith Bhimber Town itself. The most seriously affected areas of AJK are Jatli, Barnala and Tandali which need immediate attention. Bhimber Nallah, on its way to Chenab River, often plays havoc in Gujrat City and its adjoining areas. The economic management of floods of the area is an absolute necessity. Major hill torrents of the area have been enlisted in Supporting Volume-I of this Report.

2.3 NWFP HILL TORRENTS

North Western Frontier Province, inclusive of Federally Administered Tribal Areas (FATA) comprises 101,741 sq km with a total population of about 21 million. The entire population of the Province depends upon waters of hill torrents except some parts of big cities like Peshawar, DI Khan, and Mardan etc, where the domestic requirements are partially fulfilled from groundwater. The irrigated agriculture mainly depends upon hill torrents, whose flood plains possess promising development potential as is obvious from the following statistics.

Feature	NWFP+FATA Sq.Km	NWFP Sq.Km	FATA Sq.Km
Reported Area	83,452	56,232	27,220
Cultivated • Net Sown • Current Fallow	19,294 15,723 3,570	17,495 14,102 3,393	1,798 1,621 177
Uncultivated Area • Culturable Waste • Forest • Not Available (NA) for Cultivation	64,158 10,449 13,363 40,346	38,736 8,662 13,051 17,024	25,422 1,787 312 23,323
Cropped	21,040	18,771	2,270
Area Sown more than Once	5,317	4,669	648

Source: FATA Development Statistics, 1995-96.

NWFP has ancient flood history. However, the floods of 1841, 1858, 1956, 1973, 1976, 1978, 1988 and 1992 were among the most serious ones which caused widespread loss of life, damage to infrastructure and properties. Floods of 1841 & 1858 were because of glacier dam breaks in the headwater areas. The 1956 flood brought about by the Gomal Zam destroyed the town of Kulachi. The floods of 1973, 1976, 1978, 1982 & 1992 affected large number of villages and inflicted large monetary losses. Almost the entire Province is prone to recurring on-slaught of floods caused by hill torrents and warrants comprehensive planning for flood conservation and management. An integrated flood planning would provide a rational basis for conservation of flows and their utilization for sustained agriculture development in the area. The Province comprises the following major hill torrent areas:

- DI Khan Division;
- Hazara, Kabul and Bannu (HKB) Basins; and
- FATA

A bankable document for flood water management/conservation of DI Khan Hill Torrents (Zams) has been prepared as Supporting Volume-II of this Report. The main features of this study are also summarized in Chapter 6 of this Report to give a brief review of land and water potential of the entire Province.

HKB Basins is one of the maximum rainfall receiving areas of Pakistan. KKH passes through the area, and provides a unique communication link of Northern Areas to other parts of the country. Floods in Siran River and its tributaries damage the road at places. Serious erosion of precious lands and village settlements takes place during high precipitation periods. Kunhar River and its tributaries affect Garhi Habib Ullah Town and Naral Area, where erosion and landslides take place due to floods of short duration and high peak. These damages can be minimized by proper management of flood flows in the watershed areas depending upon the availability of water conservation sites.

A brief description about FATA has already been presented in Section 2.2.2.

2.4 PUNJAB PROVINCE HILL TORRENTS

Punjab Province faces serious problem of hill torrent flooding in DG Khan and Rajanpur districts, Federal Capital Islamabad and Rawalpindi, Narowal, Gujrat, Zafarwal and Pasrur areas of Rachna and Chaj Doabs.

2.4.1 DG Khan Hill Torrents

Hill Torrents affecting DG Khan and Rajanpur Districts emerge from Suleiman Range. Entire population and agriculture of Pachad Area is badly affected by the annual floods of about 200 hill torrents of the area, of which 13 are major. DG Khan Canal System is severely damaged whereby the irrigation supplies are disrupted and the agricultural production is badly affected. Monetary losses during the recent floods aggregated to over Rs 2,000 million. NESPAK prepared a Master Planning Report in 1982 for the flood management of the area. There is large conservation and development potential for the flood flows of hill torrents. The structures proposed for the flood management of Kaha Hill Torrent have been constructed under Flood Protection Sector Project (FPSP). A part of the proposed measures for Mithawan and Vidora hill torrents has been executed by JICA and World Bank.

Supporting Volume-III presents problems and land and water development potential of the hill torrents of Punjab Province in greater detail.

2.4.2 Pothowar Area Hill Torrents

Numerous hill torrents drain Pothowar Plateau comprising about 22,600 sq km. Major streams of the area are Soan, Haro, Kanshi, Kahan and Banuhan rivers and Lai Nallah.

Soan and Haro are the tributaries of Indus River, while Kanshi, Kahan and Banuhan drain into Jhelum River. Lai Nallah originates from Margala Hills in Islamabad and outfalls into Soan River.

Kahan Nallah and its tributaries drain Siwalik Range area and outfall into Jhelum River. Near its outfall into Jhelum River, it causes serious erosion on its left bank and threatens the Nanginan Village, Chak Gunja, Raju Pindi and Garh Mahal villages. Flashy flows in the river during monsoon season, increase the damages manifold and inflict heavy losses to village abadies and standing crops.

Lai Nallah is formed by the confluence of four tributaries - Saidpur Kas, Kanitawali Kas, Tinawali Kas and Bedrawali Kas, all originating from Margala Hills. These streams traverse through the Federal Capital and unite near Dhok Bajalian to form the Lai Nallah. Thereafter, it passes through the thickly populated area of Rawalpindi City. Lai Nallah drains an area of 240 sq kms which generates flashy flows and high peaks during flood season.

Flood peaks in Lai Nullah have been menacing the city of Rawalpindi since the last six decades. Flashy floods overspilling the banks and heading up back into the tributaries on left and right, have caused heavy damages to the property during 1957, 1966, 1972, 1976, 1977, 1978, 1981, 1982, 1985 and 1988. The areas of Gwalmandi, Mohanpura, Ratta Amral, Dhoke Ratta, Madina Colony, Dhok Chirag Din, Nadeem Colony, Dhok Elahi Bakhsh etc have been repeatedly inundated.

Feasibility studies for the channelization of Lai Nallah have already been done by the Consultants. However, the execution of the plan is yet awaited.

2.4.3 Rachna & Chaj Doab Hill Torrents

The northern part of Rechna and Chaj Doab comprises Sialkot, Gujranwala, Sheikhupura and Gujrat districts of Punjab Province. It encompasses an area of about 18,000 sq kms with a population of over five million. Palkhu, Aik, Bein, Basantar and Deg nallahs are the main hill torrents of the area which bring about flashy and damaging floods almost every year.

Floods in the basins of these nallahs generally result from excessive monsoon rainfall due to large Tropical Depressions. There were super floods in Ravi and Chenab Rivers during 1950, 1954, 1955, 1957, 1959, 1973, 1975, 1976 and 1988 which caused severe flooding and heavy damage in the area. The contribution of nallahs to the river floods was considerable and caused heavy losses to life and property. Total recorded inundation due to these nallahs during the super floods of 1955, 1959, 1973, 1975 and 1976 was about as 1.2 million ha.

2.5 SINDH PROVINCE HILL TORRENTS

Sindh Province generally faces serious floods from Lower Indus River, where the floodflows from the entire Indus Basin are accumulated. However, hill torrents emerging from Khirther Range affect almost entire area of Larkana and Dadu districts in case there are breaches in FP Bund. The hill torrents play havoc in the country's largest city-Karachi, which is also the greatest socio-economic centre of Pakistan. The major hill torrent areas are briefly described in the following Sections.

2.5.1 Khirthar Range Hill Torrents

Khirthar Hill Torrents of Sindh drain an area of about 16,100 sq km, in a long stretch of about 240 km along the right command of Sukkur Barrage. The Sukkur Barrage Project constructed in 1930's included a bund (FP Bund) at the western limit of its command to protect agricultural lands from flood-waters of Khirthar Range Hill Torrents. Flood flows, after striking FP Bund, are diverted to south, eventually entering Hamal and Manchar lakes. Gaj Nai is the major hill torrent among numerous small ones that cause flooding havoc in the area.

FP Bund has been breached a number of times during major floods. The floods of 1948, 1956, 1959, 1975, 1976, 1978 and 1995 have caused 12,15,7,6,54 2 and 34 breaches in the bund respectively. The 1976 flood alone inflicted tangible losses to the tune of over Rs 300 million in the area. During the flood of 1995, monetary losses aggregated to over Rs 3,000 million in Dadu District through the breaches in FP Bund.

The unprecedented losses due to Gaj Nai in the area warrant immediate attention for its management. This will provide relief to FP Bund and canal command area of Sukkur Barrage.

A management plan for Gaj Nai is presented in Supporting Volume-IV of this Report.

2.5.2 Karachi Area Hill Torrents

Karachi Metropolitan Area is the most populous in Pakistan with over 8 million inhabitants. Karachi is the country's major seaport and principal industrial town. The economic and social activities of Karachi have been badly disrupted by major floods in 1967, 1973, 1977, 1978 and 1988. Flooding in Karachi Area occurs along Malir and Layari Nadis; and many smaller tributaries like Organi, Gajro and Chakhura Nallahs. These streams traverse the Metropolitan Area and even the normal floods inflict heavy damages due to extensive encroachments of their flood plains.

Major floods since 1967 have claimed 457 human lives. The monetary losses during major floods aggregate to over Rs 3 billion and nearly 100,000 houses were destroyed. The streams of Karachi Area bring about high peak floods of small durations which cause havoc.

Total drainage area of these torrents is over 3,000 sq km. Major hill torrents of the area have been enlisted in Supporting Volume-IV of this Report.

2.5.3 Sehwan and Petaro Area Hill Torrents

The streams emerging from hills between Manchar Lake and Karachi Area are included in this group. Most important of these is Baran Nai, which crosses Indus-Super Highway, Pakistan Railways Main Line and the Pakistan National Highway. It also crosses the Kotri Baghar Feeder (KBF) Canal through a super passage to outfall into the Indus River. Monsoon generated floods in the Nai inflict heavy damage to houses, infrastructure, agriculture and irrigation system, almost every year. Other major hill torrents of the area are the four hill torrents outfalling into Kinjhar (Kalri) Lake.

2.6 BALOCHISTAN HILL TORRENTS

Balochistan, areally the largest Province of Pakistan, is extensively traversed by numerous hill torrents. It encompasses about 347,000 sq kms area with a 750 km long coastline along the Arabian Sea. The area receives about six million hectare-meters (Mham) of equivalent rainfall and the entire population depends upon rainwater, even for drinking purpose, except some big cities, where groundwater is being exploited.

The hill torrents of Balochistan bring in flashy floods due to sudden cloud bursts in their catchments. During dry period, most of the hill torrents remain dry and the crops face shortage of irrigation supplies. Floods causing extensive damage in Balochistan occurred during the year 1972, 1975, 1976,1978, 1981 and 1988 resulting in monetary losses aggregating to over Rs 3,500 million. The 1973 flood claimed 33 human lives while the 1981- flood resulted in the death of 59 persons in Quetta city.

Major hill torrent areas of the Province are:

- Indus Basin Component;
  (Kachhi Plain & Zhob-Loralai Area)
- Kharan Closed Desert Basin;
- Makran Coastal Basin.

These are briefly described in the following.

2.6.1 Indus Basin Component

Indus Basin component has two major hill torrent areas - Kachhi Plain and Zhob-Loralai Basin.

2.6.1.1 Kachhi Plain Hill Torrents

Kachhi Plain Hill Torrents drain about 25,000 sq kms area. Seven major hill torrents namely Chattar, Lahri, Talli, Nari, Bolan, Sukhleji and Mula bring about serious floods in Kachhi Plain. During the 1973, 1975, 1976, 1978, 1988 and 1994 floods, Sibi and Kachhi Districts suffered considerable losses. In 1975, more than 540 villages, 7,000 houses and 50,000 people; and crops over 40,000 ha were affected. In 1976, about 200,000 people were affected and monetary losses were about Rs 200 million. Bolan Dam was overtopped and washed away. The 1978 flood caused a monetary loss of Rs 50 million. The floodflows during 1988 caused 61 breaches in Pat Feeder Canal and resulted in a monetary loss of more than 120 million. During 1994 flood, there were 114 breaches in the Pat Feeder Canal.

2.6.1.2 Zhob-Loralai Hill Torrents

Zhob-Loralai Area is situated north-east of Quetta city. Major rivers of the area are Gomal and Zhob which generally flow north-east and receive waters from numerous hill torrents. Total drainage of hill torrents of the area is about 37,550 sq kms. Hill Torrents floods in the area often inflict heavy damages.

Bankable document for water conservation of Indus Basin Component of Balochistan including Quetta Valley has been prepared. Summary of the document is given in the Main Report to provide overall view of the land and water conservation potential of the Province.

2.6.2 Kharan Closed Desert Basin Hill Torrents

Kharan Closed Desert Basin (KCDB) is very dry with a few streams that flow the year round, and drain into shallow lakes called Hamun-i-Lora and Hamun-i-Mashkhel etc. The basin comprises an area of about 120,200 sq km. Major streams of the basin are Pishin Lora, Rakhshan River, Mashkhel River, Baddo River, Luti River and Morajen Nallah. Nearly all the flows of these rivers go waste and limited agricultural activities are currently in practice in the area. The flood management/conservation of these would bring about an economic uplift in the area.

Kharan Desert Closed Basin includes Quetta Valley hill torrents. But due to hydrometeorologic similarities, it has been included in Indus Basin Component for the purpose of floodflow conservation.

2.6.3 Makran Coastal Hill Torrents

Numerous torrents emerge from the hills bordering Kharan Desert. These streams form the main drainage network of coastal plains and all of them drain into Arabian Sea. Total drainage area of the basin is approximately 123,025 sq km., of which only 162,000 ha are cultivated with a low cropping intensity. Major rivers of the basin are Dasht, Hingol, Porali, Hub, Shadi, Basol, Bhairi etc. Major rivers and some of their tributaries possess perennial flows, which are being utilized for domestic as well as commercial purposes.

2.7 POPULATION

Demographic pressure in Pakistan has put great stress on the need for development of available land and water resources. The population of Pakistan since the beginning of this century is given in **Table 2.1**.

Table 2.1

Population of Pakistan

Year	Population (million)
1901	16.6
1911	19.4
1921	21.1
1931	23.5
1941	28.3
1951	33.7
1961	42.9
1972	65.3
1981	83.8
1998	130.6

Source: 1. Pakistan Development Statistics, Statistical Bulletin No.42, P&I WAPDA.

2. PTV.

Table 2.1 indicates that population of Pakistan was doubled from 1901 to 1951 in a span of 50 years. Thereafter, it is doubling after every 22-23 years. This rapid increase in population has put great pressure on food and fibre requirements of Pakistan.

2.8 AGRICULTURE

Agriculture has been and continues to be the principal driving force of the national economy, accounting for about 23.5 percent of GDP and together with agro based industries contributing about 70 percent of export earning. Nearly 50 percent of labour is engaged in agriculture sector. Economic viability of the country despite rapid industrialization still largely depends upon its agricultural development. Agricultural primary commodities contribute 20 to 25 percent of total export. Development of agriculture has to be given a proper place in any development scenario of national economy.

Agricultural development in the last five decades has increased at a rate of 3.5 percent while the increase in food crops production has gone up at a rate of about 2.5 percent. The gap between demand and availability has been widening due to rapid increase in population. Agriculture development programme for 8th 5-year Plan (1993-98) envisaged increase in the production of major food and cash crops through provision of better agricultural inputs, irrigation and drainage facilities, credit and price support. The average annual growth targets are 4% for wheat, 5% for sugarcane, 10% for cotton, 6% for rice and 16% for oil seeds. Wheat occupies about 8 million hectare (Mha), cotton about 2.6 Mha and rice 2.5 Mha. Cotton and rice together provide major source of export earnings while wheat is the staple food for the nation. Cotton and rice are kharif crops which are adversely affected by inundation during high flood peaks in the rivers and hill torrents. During kharif about 28 percent area is occupied by cotton, 25 percent by rice, 7 percent by sugarcane and 6 percent by maize. Of the total cultivated area of 21.60 Mha, 76 percent is irrigated against a corresponding figure of 25 percent for India and 35 percent for Indonesia. Irrigated area increased from 8.4 Mha 1947 to 12.5 Mha in 1967. This further increased to about 15 Mha in 1979-80 and to 16.8 Mha in 1989-90 due to construction of Tarbela Reservoir, and exploitation of groundwater resources. Since then, there has been no major change in the irrigated agriculture in Pakistan. In fact, the perennial surface sources of fresh water have already been exploited close to saturation thus leaving hill torrents as a major area for development of irrigated agriculture.

Although Pakistan has the best combination of land, water and climate resources, the national crop yields are low as compared to world average and some other countries having the same agroclimatic conditions. The yields of some of the major crops of other countries and Pakistan are compared in the following table:

Name of Crop	Yield Kg/Ha							
	World Average	USA	China	Egypt	Mexico	India	Pakistan	World Highest
Wheat	2,430	2,570	3,430	X	4,210	2,510	2,081	(France) 7,034
Rice	3,651	6,718	5,869	8,173	X	2,943	2,433	(Egypt) 8,173
Cotton	1,712	2,006	2,523	2,916	2,381	925	1,671	(Egypt) 2,916
Sugarcane	61,108	76,251	X	110,748	X	69,197	46,748	(Egypt) 110,748
Maize	4,330	8,697	5,033	X	2,440	1,653	1,481	(Itly) 8,971

* Not the major producer

Source:- Agricultural Statistics of Pakistan 1995-96

A number of interacting factors contribute to this low productivity, the most important of which are:

- Research for the development of new varieties not compatible with local conditions;
- Lack of education of farming community;
- Lack of integrated national policies for agriculture;
- Sub-standard farm inputs;
- Traditional methods of farming;
- Financial returns not compatible with agricultural inputs;
- Improper agricultural extension services; and
- Use of adulterated fertilizers/pesticides etc.

The gap between the potential and actual farm yields can be bridged through improvements in the factors listed above.

Water and agricultural statistics of Pakistan from 1946-47 to 1996-97 are given in Table 2.3. The review of tabulated data indicates that cropped and irrigated areas increased by about 100 percent during the reporting period. The surface supplies increased by about 62 percent through the construction of a number of link canals and dams (Mangla & Tarbela). The cropped area increased after the irrigation supplies were enhanced each time and it attained an almost equilibrium conditions within few years. Groundwater resources have contributed in supplementing supplies at the formgate. Presently, cropped area has attained an equilibrium conditions under the existing available water supplies (surface/groundwater). Almost groundwater withdrawals are being used to the optimal limit and hardly any potential exists for additional withdrawals.

In order to study horizontal (increase in area) and vertical (yield/unit area) potential of agriculture, area, production and yield for major crops since 1947-48 to 1995-96 were reviewed.

Table 2.4 gives the historical data of area, production, yield and their incremental percent from 1947-48 to 1995-96. The perusal of the table indicates that there has been reasonable horizontal and vertical expansion during the last almost five decades.

A critical review of Tables 2.2-2.4 indicates large potential exist for both horizontal and vertical expansion in agriculture, if additional water resources can be made available at the farmgate and better inputs/management practices are used in the fields. One of the potential water resources of Pakistan is the floodflows of hill torrents which has been discussed in detail in the subsequent sections of this report and Supporting Volumes.

TABLE 2.[illegible]

WATER & AGRICULTURAL STATISTICS OF PAKISTAN

(AREA, MILLION HECTARE)

Period	Canal Withdrawals (MAF)	Availability At Farmgate MAF (Canal + Tubewells)	Cultivated Area	Net Sown	Cropped Area	Irrigated Area (Tubewells/Wells only)	Remarks
1946-47	67.36	41.16 (40.12 + 1.04)	14.69	10.68	11.63	8.40 (0.40)	
1959-60	82.22	53.90 (49.85 + 4.05)	16.85	12.85	15.25	10.25 (0.95)	Construction of three link Canals from 1950-60
1960-61	82.38	52.52 (48.35 + 4.17)	18.12	13.27	14.86	10.40 (1.07)	
1971-72	86.05	71.37 (51.24 + 20.13)	19.09	14.34	16.60	11.82 (1.45)	Construction of Mangla Dam in 1967
1976-77	98.07	84.57 (58.40 + 26.17)	19.76	15.07	18.21	13.52 (% 70)	Construction of Tarbela Dam in 1976
1980-81	107.40	94.61 (62.03 + 32.58)	20.30	15.41	19.33	14.84 (1.96)	
1985-86	96.34	104 + 73 (65.63 + 39.10)	20.68	15.77	19.81	15.79 (2.04)	
1987-88	109.10	112.22 (71.24 + 40.38)	20.76	14.72	19.52	15.68 (2.46)	
1990-91	109.60	119.62 (75.64 + 43.98)	20.96	16.11	21.82	16.75 (2.62)	
1994-95	-	129.05 (81.23 + 48.42)	21.55	16.13	22.14	17.20 (2.75)	
1995-96	-	130.85 (82.43 + 48.42)	21.54	16.28	22.59	17.58 (3.00)	
1996-97	-	130.96 (82.65 + 4831)	21.55	16.24	22.61	17.60 (3.07)	

(AF = 1,233 m^3)

Source:- 1. Agricultural Statistics of Pakistan 1995-96.
2. Report of the National Commission on Agriculture, March 1988.

TABLE 2.4

HISTORICAL DATA OF MAJOR CROP PRODUCTION & YIELDS

Year	Area, (000ha)	Production (000 tons)	Yield/ha (kg)
1 Wheat			
1947-48	3,953.90	3,354	848
1995-96	8,376.50	16,910	2,018
Percent Increase	212	504	238
2 Rice			
1947-48	789.90	692.90	877
1995-96	2,181.80	3,970	1,835
Percent Increase	276	573	209
3 Sugarcane			
1947-48	189.40	5,529.30	29,194
1995-96	963.1	4,520.00	47,000
Percent Increase	508	817	161
4 Cotton		(Million Bales)*	
1947-48	1,236.80	1.106	159
1995-96	2,997.30	10.650	601
Percent Increase	242	963	378

* Bale - 375 Lbs

Source:- (a) Pakistan Development Statistics, Statistical Bulletin No.42, P&I Publication No.292.

(b) Agricultural Statistics of Pakistan 1995-96.

2.9 MACRO-ECONOMIC FEATURES

Over the last ten years, Pakistan's economic growth has been fluctuating between 2.3% and 7.7%. The annual growth target in GDP for the Eighth Five Year Plan Period (1993-98) is 7 percent. However, actual growth rate is lagging behind. For 1997 GDP growth was 1.5%.

The per capita income is estimated at US$ 470. Pakistan's social indicators remain seriously behind those of other countries with comparable levels of development, with 34% of the population living below the poverty line. The labour force participation is only about 28%.

Economic planning has been beset by a number of major constraints: a narrow and vulnerable export base which largely relies on the receipts from cotton and rice, and a low saving ratio which leads to a high dependence on external borrowing. Pakistan's total external debt stands at about US$ 32.0 billion as long and short term loans in addition to internal loans at about Rs 1,100 billion at the end of June 1997. External loans include short, medium and long term loans from the financial market and the IMF and private unguaranteed credits. Internal and external loans amount to about 90% of GDP. Consequently, debt servicing is US$ 5.9 billion, the single largest expenditure of the Federal Budget and equals some 69% of the export earnings. During the year 1971, the loans stood at US$ 3 billion, with debt servicing to about Rs 1.5 billion. The loan increased to US$ 8 billion in 1981 while debt servicing was Rs 6 billion. The debt increased to US$ 14 billion in 1988 and US$ 21 billion in 1991 while debt servicing increased to Rs 120 billion in 1991. The budget deficit (1995/96) runs at 6.3% of GDP and the current account balance has a deficit of 6.6% of GDP. In order to curb food prices, the Government has to import more wheat. During 1996-97 import bill for agricultural commodities like wheat edible pulses, tea, sugar etc was over US$ 2 billion.

Inflation was 13% in 1995, 11% in 1996 and 13.83% in February 1997, largely because of price hike of essential food items and imported fuel. Pakistan's financial problems relate to the need to restore equilibrium in balance of payments and to improve the budgetary management through a combination of reduced Government expenditures, increased user charges/cost recovery, and increased domestic resource mobilization.

Exports during 1996-97 amounted to US$ 8.26 billion as compared to export worth US$ 8.71 billion in the previous year. Trade deficit during 1996-97 was US$ 3.37 billion as compared to US$ 3.09 for 1995-96. Since 1947-48, the trade deficit aggregates to over US$ 52 billion. The deficit has been as under:

Years	Trade Deficit (US$ billion)	Aggregate Deficit (US$ billion)
1950-51 to 1959-60	1.10	1.10
1960-61 to 1969-70	3.84	4.94
1970-71 to 1979-80	9.80	14.74
1980-81 to 1989-90	22.24	36.98
1990-91 to 1996-97	15.20	52.18

Source:- Misc; relevant publications.

During the last 50 years, there were only two years when exports slightly exceeded imports. Above figures indicate that no concerted efforts were ever made to limit imports within the available resources. In addition, the total grants given to Pakistan aggregate to about US$ 14 billion. The contribution of Pakistanis living abroad through official resources is about US$ 45 billion from 1974 to 1997. The aggregate remittances in the 1980's amounted to US$ 22.87 billion. The remittances peaked to US$ 2.89 billion in 1982-83. If the remitted amount had been utilized for infrastructural development and industrialization, the socio-economic conditions of the country would have been entirely different. In addition to this, the foreign exchange remitted through unofficial sources is more than that the remittance through official sources.

The stark reality of Pakistan economic conditions indicate that the economic self-reliance is a challenging task. However, this can be achieved by embarking upon a number of activities including the following:

- Optimal utilization of natural resources like land and water for horizontal and vertical expansion of agriculture, which has great potential for development.

- Utilization of human resources by adopting a comprehensive educational and training programme through private sector and federal and provincial governments;

- Establishment of large number of industrial estates with proper facilities to attract foreign capital, technology and modern management skills. All infrastructural facilities like electricity water, gas, telecommunication services etc to be provided to the investors under 'One Window Services'. The industries to be established may include, electronics, electrical, engineering, chemicals, garments, paper products, fabric/yarn, toys etc; and

- Enhancement of literacy rate as early as possible with special emphasis on higher technical education. Improvement in education through higher investment in social sectors can alleviate poverty and productivity of the rural labour force.

3. PLANNING STRATEGY AND DESIGN OF STRUCTURES

3.1 GENERAL

Availability of water generally does not match with crop water requirements in hill torrent areas. For development of sustained irrigation system, concerted efforts are required to manage flows of torrents. The predicament in proper management is because of a number of factors such as:

- Highly unpredictable and erratic nature of rainfall;
- Short lived and high peaked flows;
- Complexity in economic management of flows;
- Available land resources not compatible with locations of potential conservation sites;
- Lack of attention for conservation of highly complex flows of hill torrents as compared to easily accessible surface water resources of rivers;
- Investment in physical interventions is not very attractive in all areas, specially where low value crops (wheat, jawar etc) are grown;
- Generally, inaccessible approach conditions to conservation sites;
- Lack of marketing facilities for agricultural products in the areas; and
- A host of other socio-economic factors not congenial for large scale development (e.g water rights, tribal territories etc).

These factors necessitate careful planning and evaluation of land and water resources of hill torrent areas. The optimum combination of land and water resources is the key for improving the quality of human environment and development of fauna and flora in the area.

3.2 PLANNING CONSIDERATIONS

The behaviour and development potential of a hill torrent depends upon a number of interacting factors like, hydrometeorology, catchment characteristics, physiographic features of piedmont areas (where generally floodflows debouch after coming out of Darrah) and existing water uses and development potential of land and water resource of each hill torrent basin. The strategy adopted for conservation of flows of various hill torrent areas conforms with the overall national planning for bringing additional areas under cultivation so as to provide more food and to improve socio-economic conditions of the local population. For project planning and decision making, technical, economical, environmental, social and host of other factors have been kept in view. In order to achieve planned objectives, the review and analysis of the following parameters was undertaken, which are considered to be the tools for planning of the water resources projects:

- Collection of Existing Data and Reports;
- Review & Updating of Data/Information;
- Field Investigations and Specific Studies;
- Land & Water Resources Evaluation;
- Irrigation Practices;
- Watershed Management;
- Environmental Studies;
- Socio Economic Aspects;
- Agricultural and Rural Development Studies; and
- Project Organization and Management Studies.

These parameters are briefly discussed in the proceeding sections.

3.2.1 Collection of Existing Data and Reports

3.2.1.1 <u>Data Availability</u>

The proper management of hill torrents flows primarily requires various kinds of data and information. Accurate, consistent and continuous data observed over a sufficient length of period forms the foundations for sound designing and proper operational procedures for a water resource project. However, contrary to the planning needs, the requisite data of most of the hill torrents in Pakistan, either does not exist or is available in fragmentary form. Often the data records are of very short periods and that, too, in non-uniform order. Long gaps are commonly found in the primary data of most of the hill torrents. Following are the major causes for inadequacy in primary data records of hill torrents:

- Inaccessibility to hill torrents due to:
    - difficult terrains,
    - non-existence of basic infrastructure (roads, water supply, electric power) in the areas.
- Non-availability of basic amenities of life in hill torrent areas;
- Long distances of observation sites from the nearby towns/villages etc;
- Non-availability of data observation instruments with the operating agencies;
- Inadequate repair/maintenance facilities for the required equipment/instruments.
- Shortage of skilled instrument operators;
- Lack of awareness of importance of accuracy of primary data;
- Lack of financial resources;
- Lack of proper coordination between various data observation agencies;
- Disturbed socio-political conditions in some of the hill torrent areas; and
- Various types of managerial problems.

In order to study and present an effective and meaningful plan for flood management of hill torrents, synthetic techniques were employed in some cases to generate the data and to fill in the missing links.

3.2.1.2 Data Requirements

Following types of data was required for proper planning and designing of hill torrent structures:

- Survey of Pakistan (GTS) Maps of all major hill torrent areas of Pakistan.
- Soil/land classification maps.
- Topographic maps at different scales

- Maps/information regarding existing vegetation and land cover
- Landuse maps
- Hill torrents catchment maps showing details of all kinds of existing infrastructural facilities.
- Location maps and drawings of existing structures/works
- Satellite images of Project Area
- Meteorological information of each major hill torrent area viz:
  - Inventory and location of hydromet stations;
  - Information regarding weather/climatic factors of the area;
  - Hourly, daily and monthly precipitation records over a sufficient length of time;
  - Daily pan evaporation values alongwith daily temperatures and humidity;
  - Wind speed, direction and durations;
- Stream flow records of each major hill torrent
- Morphological behaviour of stream channels;
- Information regarding flood damages including:
  - loss of life
  - complete/partial damages to katcha/pucca houses
  - loss of cattle head including dairy, pasture and poultry animals
  - losses sustained by the infrastructure and government installations including communication systems, bridges, cross-drainage structures, electric lines, telephone lines, grid stations etc.
  - damage to irrigation systems eg. canal banks, cross regulators/ headworks, outlet structures and closure of canals etc.
  - agricultural losses viz damage to standing crops, loss of land due to erosion, hampering of agricultural operations (no sowing or late sowing), qualitative and quantitative effects on crop production and their yields.
  - break out of diseases, epidemic and famine etc.
  - negative effects on marketing and economy.

- Information regarding damage to flood management structures/works eg.
  - flood diversion/dispersion structures
  - flood control embankments and spur etc
  - type of flood fighting operations carried out pre and post flood events
  - quantities and costs of materials used for flood fighting
- Costs and expenditures on rescue, relief and rehabilitation operations.
- Information regarding local arrangement of flood forecasting and warning system.
- All the existing reports/information regarding past, present and future flood/water management plans.
- Existing patterns of irrigation and water rights
- Year-wise information of areas sown under different crops in Rabi and Kharif seasons with their respective sources of irrigation and yields
- Availability of agriculture extension services in the area
- Agri-marketing facilities
- Availability of manures/fertilizers, improved seeds and agriculture machinery etc.

3.2.1.3 Available Data/Information

The Consultants prepared National Flood Protection Plan Phase-I in 1978. The plan was supplemented and updated in 1987. Both the plans included comprehensive analytical studies including all kinds of required data/information upto 1978 and 1987 respectively. Hence NESPAK's data pool includes different type of data upto 1987 for all the four Provinces and Federal Areas.

In addition, NESPAK has prepared a number of reports of hill torrent areas including:

1. DG Khan Hill Torrents
2. DI Khan Hill Torrents
3. FATA Hill Torrents (4 basins)
4. Ziarat and Harnai Area Hill Torrents
5. Marri Bugti Area Hill Torrents
6. Deg Nallah

7. Reconnaissance Study of Hill Torrents of Pakistan
8. Reports of various Balochistan Hill Torrents

These reports are based on extensive data used for updating hill torrent basin reports after augmenting through the latest available information. Reports and data available in the archives of NESPAK and supplemental data collected from various sources.

3.2.2 Updating of Data Reports, Review & Analysis

All available data and reports were reviewed and need for additional data was identified. For many areas, the primary data was not sufficient; it was supplemented by synthetic data generating techniques. Available information and results derived through analysis for some hill torrent basins were transposed to other basins having scanty/insufficient data, using various synthetic methods.

Frequency analysis of peak flows was carried out to determine flood peaks for various return periods. This analysis was used for designing of conservation structures. Flows for various return periods were determined for development of sustainable irrigation systems. Monthly available runoffs were evaluated and their frequency of availability was determined to match with the requirements of various crops. Supplemental data/reports were collected from different offices. Flood routing computer models were used to estimate available flows at the points of interest ie. conservation sites and in land areas where these were required to be used.

3.2.3 Field Investigations and Specific Studies

Consultants were already well acquainted with different hill torrent areas of Pakistan. During the preparation of National Flood Protection Plans and various feasibility studies undertaken during the currency of Flood Protection Sector Project (FPSP), NESPAK engineers and specialists visited different hill torrent areas in all the four provinces of the country. Some of the hill torrent basins of FATA, AJK and NA were also visited in connection with different projects proposed to be appraised by the local authorities. Rod Kohi Areas of Dera Ismail Khan and Dera Ghazi Khan were visited in detail in the past for preparation of Master Planning Reports. Discussions were held with the concerned departments and agencies, public representatives, NGOs and locals.

However, specific field visits were carried out for all sub-basin areas and information regarding the following aspects was obtained:

- Existing water management structures on various hill torrents, their design parameters, behaviour during various floods, damages and restoration measures used;
- Agronomic aspects of projects located in the sub-basins viz; historical cropping patterns, yields, use of fertilizers, marketing of products etc;
- Changes in landuse patterns, pre and post projects;
- Socio-economic changes;

i) migration of people to and from the Project Area

ii) increase in educational institutions and student enrolments

iii) increase in roads, transport and marketing facilities

iv) drinking water, sewerage and other health facilities;

v) general social up-lift of the people, etc

vi) Latest proportions of riparian water rights

Large number of identified water conservation sites were visited in all the sub-project areas. Interviews of the beneficiaries were held and their response/interest in the project was evaluated. Specific field investigations were carried out to study:

- Mode of water conservation;
- Identification of land areas;
- Type of conveyance systems;
- Existing cropping pattern and yields;
- Any specific problem(s) of project site etc.

3.2.4 Land and Water Resources Evaluation

Land and water resources are the key elements for development of irrigation system of an area. Land resources determine the areas which can be brought under cultivation. However, generally all available area cannot be economically commanded or may not be fit for irrigation. Due to erratic and unpredictable nature of rainfall in most of the areas, available water resources do not match with crop water requirements. In some areas, land resources may be a constraint while in others water resources may be inadequate to bring the potential land resources under cultivation. Another probability may be that both the resources are limited or in abundance. All the four scenarios have been observed in various hill torrent areas. Studies for land and water development potential were carried out in greater detail for Core Projects and the matching of the two basic parameters i.e. land and water resources for different cropping patterns and intensities were studied using various computer packages. For other areas, these studies have been carried out in lesser detail but potential has been determined for development of both the resources.

3.2.5 Irrigation Practices

In all hill torrent areas, a number of water conservation and/or utilization structures have been constructed. Large tracts of land have been developed for irrigated agriculture in the area. Generally, the following types of structures have been constructed:

- Dispersion Structures;
- Diversion Embankments (Salaiis)
- Delay Action Dams;
- Storage Dams;
- Floodwalls;
- Flood Diversion Channels; etc

Flows generated by these structures are being used through the following modes:

- Diversion Channels;
- Karezes;
- Tubewells;
- Open/Dug wells etc.

During field visits, various irrigation practices in different hill torrent basins were observed and their merits and demerits were studied in detail. Irrigation practices vary largely from one area to another depending upon a number of factors. Study of existing irrigation practices greatly helped in evolving and recommending optimal use of water resources likely to be available after the construction of conservation structures. The most frequently used method is to impound the embanked fields to a depth of 1.0 - 1.2 m (3-4 ft) and use the soaked fields for sowing and raising the crop with a couple of additional freshets.

3.2.6 Watershed Management

The hill catchment of a stream is called its watershed. It is the region where most of the rainfall gets converted into run-off and accumulates, through various tributary channels, to form the main stream. Watershed management is a long-term process and requires considerable time before effective flood peak reduction can be realized. Apart from structural measures, the process, inter-alia, includes the following components:

- Water Conservation;
- Soil Conservation; and
- Range Management Practices.

The function of watershed management measures in hilly areas is to check the erosion of valuable patches and land and sediments at source, in addition to shaving off flood peak by providing suitable vegetal cover. The optimal way to manage the floods is to use them in headwater areas if feasible. The most appropriate step, in this direction, is to undertake the development of forests and pastures comprising botanical operations suitable to local geo-environmental conditions. Such measures are widely practised in many parts of the world. The success of the process in Pakistan is dependent upon strict control of grazing and prohibition for deforestation.

3.2.6.1 Water Conservation

Water conservation is generally known to be the most important component of watershed management. Mostly, it involves structural measures for regulation of floodflows for agro-economic development and flood mitigation. Planning and design of structures have been discussed in detail in the following paragraphs. Supporting Volumes I through V of this Report deal in detail with various techniques and specific measures of water conservation recommended for different hill torrent areas of Pakistan.

3.2.6.2 Soil Conservation

Soil conservation techniques are usually associated with terracing, contour ploughing, strip cropping, planting, cover crops or using farm ponds which significantly contribute in flood management and reduction in losses to crops, infrastructure and settlements in the downstream areas. In case the upper catchment does not have proper sites for storage and regulation of floodflows, it can only be reconditioned to provide protective cover to absorb precipitation and thus retard runoff and arrest soil erosion.

Scientific investigations carried out by experts in various parts of the world have shown that the following techniques are very useful for the catchment areas of hill torrents:

- sowing and planting trees along interrupted contour trenches dug on gradients not above 30 degrees to catch rain water to help plant growth;
- contour bunding on mildslopes to hold runoff for increased infiltration and provide moisture to plants raised along earthen bunds;
- contour furrowing of suitable patches of land on easy slopes and reseeding with palatable grasses;

- closure against grazing till revegetation and thereafter providing rotation grazing to a permissible grazing capacity; and
- gully plugging with loose stones and check-damming in dry stone rubble masonry work at suitable intervals to retard the velocity of water in the nallah, thereby improving the flow regime, arresting silt behind the stone structures for preparing planting bed, and raising trees in appropriately protected soil pockets behind the check dams.

Soil conservation in the headwater areas results in lesser sediment transported to downstream reaches thereby reducing deposition in reservoirs and increasing useful lives of dams and weirs.

3.2.6.3 Range Management Practices

Presently, the sparse vegetation cover in watershed areas of hill torrents has been deteriorated through over-grazing by nomadic flocks and uncontrolled exploitation which aggravates the degree of runoff and greatly increase the damage potential of floodflows. As a result of denudation, heavy showers in the catchment generate flood with turbulent flows with high velocity which causes erosion of bed and banks of the streams. Therefore, the existing forest plantation, which have low stocking density, can be considerably improved by additional planting and scientific management practices. However, opportunities for extensive forest development are limited due to over grazing, adverse climatic and physiographic conditions, and limited availability of irrigation supplies.

Under natural climatic conditions, tropical thorn types of forest are suitable for low rainfall areas in which scattered low xerophytic species grow with predominance of thorny hardwood trees. Flora of variance breadth of leaves is suitable for medium to high precipitation areas depending upon the soil water holding capacity and quantum of rainfall.

3.2.6.4 Development Potential

Due to high temperature and paucity of rain, useful vegetation of any economic importance can hardly be grown without irrigation. There is great potential in the catchment area of all major hill torrents for afforestation and pasture development by using zerophetic plants and grasses for shaving off flood peaks. In addition, along the banks of major hill torrents, there is potential for increasing plantation and for improving the existing stock. Field studies carried out included interviews with land owners, spot observations, review of existing development potential and discussions with range management officials. These studies indicate that watershed management practices can be carried out on about ten per cent catchment areas of major hill torrents where soil and moisture conditions are better and suitable. However, plantation in major areas is a difficult task because of generally expensive and inadequate transportation facilities and excessive grazing by sheep.

3.2.6.5 Afforestation in Mountainous Regions

Due to the desolate and bare land of the mountains, heavy showers in the catchments cause streamflow of high velocity which carries heavy silt load and causes damage by eroding stream banks. The volume, peak and timing of runoff can be modified and damages can be minimised by developing sound forest and range management practices.

Afforestation is a lengthy process and would require considerable efforts to establish in view of lack of proper soil profiles, low rainfall and overgrazing.

Suitable species of trees and shrubs can be raised successfully through cooperation of the people of watershed areas. Nursery of the plants may be supplied by the Forest Department and land owners be paid for planting and protection against grazing. Afforestation with the suitable species at proper places play following three main roles in flood hydrology:

- to stabilize soil, minimize erosion and the downstream sedimentation associated with increased flood stages;
- to partially intercept flows; and
- to maintain high infiltration rates.

3.2.6.6 Development of Pastures in Sub-mountainous Regions

The submountain land with more than one percent slope in the catchment of major hill torrents is proposed for pasture development. Some common species of useful grasses can be sown and made to flourish under protective measures against grazing within one and a half years time. At present, considerable part of water is wasted due to excessive surface runoff from sparsely vegetated and excessively grazed submountain lands during almost every storm. Poor grasses and shrubs of stunted bushes can be replaced by sowing standard and drought resistant grasses to restore the depleted vegetation cover in the catchment area.

Grasses play an important role in building the economy of a country. These have a specialized use for erosion control on account of their fine hair like roots that bind the soil particles. Well established top growth provides protection against wind and break force of the rain drops, thereby reducing flow velocities. This prevents erosion of soil and keeps this important natural gift intact for profitable use by man.

Proper types of grasses can be selected after reviewing the meteorological data, soil condition in consultation with range officials. These grasses can play an important role in retarding the stream-flow and also help in minimizing flood losses. The grasses are commonly grazed by all types of livestock. These grasses can be sown through different methods but tuft sowing is useful in hill torrent areas due to low rainfall and is likely to give good results in spreading its roots far and wide. The success of growing these grasses is only possible under strict closure against grazing and proper maintenance. After introducing the grasses, the villagers should be made responsible for protection and maintenance for their livestock development.

Waste lands in the hill torrent areas can be developed as pastures due to climatic and physiographic reasons. Such areas have great potential which can reduce or eliminate fodder shortage and consequently enhance livestock products.

3.2.6.7 Effect of Watershed Management on Flood Peaks and Agriculture

A substantial reduction is anticipated in flood peaks with the proposed watershed and range management measures. The hydrologic soil cover complex (combination of soil type and extent of vegetal cover) would change as a result of improvement in the soil and vegetal cover. The increase in vegetal cover not only decreases the amount of runoff but also increases time to peak by reducing the velocity of over land flow. The change in runoff and increase in the time lag would affect the reduction in peak. In addition, these measures would improve the pastoral economy of the hilly population. The execution of such measures would satisfy the increasing requirements of fuel and agriculture implements. Furthermore, trees and grasses planted through systematic lopping would yield forage for sheep, goats and cattle; and eliminate fodder shortage for livestock.

3.2.7 Environmental Studies

The primary objective of the project study is to conserve floodflows of hill torrents for sustainable irrigated agriculture and development of other socio-economic activities in the areas. The proposed works are likely to have good environmental impact in and around the project sites. The environmental impact has been assessed keeping in view the following:

- Existing quality of hill torrent effluent and interaction on quality after the construction of proposed conservation measures. Water contaminations can be in terms of physical, chemical and bacteriological parameters;
- Interaction of proposed conservation measures on sediment load of floodflows;
- Effects on flora and fauna of the area;
- Impact on animal and bird life (ecology);
- Destruction of or damage to wildlife habitat;

- Aesthetic impact of construction activities and destruction of or interference with scenic and recreational values; and
- Impact of ancillary activities (e.g. disposal of earth, acquisition of gravel and fill).

The anticipated interventions are discussed as under:

- Water quality of hill torrents is generally good for drinking as well as for agricultural purposes except for quite a few cases. The proposed measures would either directly divert floodflows to the fields or it will seep down from detention reservoir/delay action dams and exploited in the downstream areas through karezes, open wells or tubewells. In case of detention reservoirs and delay action dams, water quality is likely to be adversely affected, it is anticipated that this deterioration in quality will be insignificant due to short duration of evaporation opportunity.

- Silt will be deposited in the pond areas of dams/detention reservoirs. This silt in some of the areas would be used for development of parcels of land for irrigated agriculture in close vicinity of banks of hill torrent. The silt free water in the downstream is likely to accelerate erosion of the area and its deposition in the downstream areas. In view of generally gravelly areas, the phenomenon of erosion and deposition may not be very significant. However, research is needed to study the actual situation by carrying out site specific studies at a few sites on a micro level.

- Regular availability of flows would encourage the growth of flora and fauna in the areas. The growth of trees and other wild plants would be beneficial for development of animal birds and wildlife in the areas.

- Construction of proposed measures would have aesthetic impact on the areas. Already some of the reservoirs in the areas are being used for development of fisheries. Large number of trees have also been planted and sites are being used as picnic spots.

- The construction material like boulders, gravel and earth is generally available at the sites of work. This material is planned to be obtained from the nearby areas. The extraction of this material is not likely to adversely affect the biological and physical balance of the areas.

3.2.8 Socio-Economic Aspects

The current population of Pakistan is estimated as 132 million with a geographical area of about 796,000 sq.km. Agricultural sector which primarily consists of cotton, wheat, rice and sugarcane contributes over 23 percent of GDP of $ 61 billion. Of the total area of 79.6 Mha, 26 percent, (over 21 Mha) is cultivated. Irrigated area constitutes about 76 percent of the total cultivated area (about 16 Mha). The production of irrigated area is about 300 percent as compared to barani or rainfed area. Agricultural production remains inadequate to provide needs of the growing population.

Hill torrent watershed encompasses about 65 percent of the entire area of Pakistan and accommodates about 30 percent of the total population. These areas are socio-economically lagging behind as compared to other parts of the country, because of inadequate development of highly complex nature off floodflows of hill torrents. Hill torrents in various parts of the country require different development strategies that fit the specific local requirements, topographic features, potential land and water resources, development opportunities, infrastructural facilities etc. This dictates that site specific research be carried out for each site.

Basic facilities and employment opportunities are grossly inadequate in the areas. Proper development of land and water resources would usher in a new era of socio-economic prosperity in these regions.

3.2.9 Agriculture and Rural Development

Pakistan covers about 79.6 Mha of which about 42 percent is suitable for agriculture and forestry. Barani (rainfed) area is over five million hectares. A part of barani areas can be developed by proper management of hill torrents which emerge from different hill ranges. High evapotranspiration and low rainfall over most of the area makes conservation and development of land and water resources, a necessity for agricultural production and rural development. In view of recurring shortage of foodgrains, there is growing pressure to use all resources of water. The only potential source of water available for exploitation is the hill torrents flows which offer prospects for development to meet the growing demand of water for agriculture.

A comprehensive plan has been prepared (as detailed in Supporting Volumes) for development of sustained agriculture in the Project Area. Management of flows would provide reliable source of irrigation and would greatly enhance the living standard of farmers in rural areas. The specific objectives are to increase the output and raise per capita income in an effective and sustainable manner with particular emphasis on enhancing productivity and improving natural resources management.

3.2.9.1 Rainfed Agriculture

The farmers of barani area grow crops under flood irrigation (Sailaba) and water harvesting (Khushkaba) and also rear modestly small livestock flocks. In rainfed/flood irrigation areas, major crops grown are wheat, barley, sorghum/mung, beans, millet, rapeseed and mustard.

3.2.9.2 Flood Irrigation (Sailaba)

Flood irrigated agriculture is a historic and common phenomenon in the Project Area. Mostly, traditional structures, consisting of temporary earthen bunds are built across main streams and water is diverted to the fields. High flows, however, wash away these bunds thus depriving farmers from the subsequent low flows also. Flood irrigation, is not a high return economic activity as unreliability of floodflows results in low crop yields. It mostly helps subsistence level agriculture. The crops usually grown are wheat, sorghum, barley etc.

3.2.9.3 Water Harvesting (Khushkaba)

Water harvesting or runoff agriculture is practised on all plains and sloping ground with good soil. Mostly, small streams coming from the mountains are plugged to divert water. However, due to small volumes of flows, the average yield is even less than flood irrigated areas.

3.2.9.4 Existing Agricultural Production

Livestock raising and subsistence agricultural production are the main sources of income in hill torrent areas. In flood irrigated areas about 90% of the population is engaged in subsistence agriculture. Existing practices and management levels of agriculture are very low. As a result, enough is not produced to meet the food and financial requirements of farm population. Uncertainty in flood irrigation supply is the basic constraint in agricultural production and rural development. There are continuous flat patches of very fertile land which can be brought under cultivation if water is made available.

Generally the soils of the plain areas have fertility and good soil moisture holding capacity. Once the top layer of soil is dry there is little subsequent evaporation from the soil and low downward percolation. Farmers generally prefer to sow sorghum on the basis of flood supply available during Kharif season. The oilseeds and pulses are grown in the low lying alluvial patches using residual soil moisture. The present annual average cropped area is low which could be increased by proper control and optimum use of floodflows of hill torrents with proposed measures.

3.2.9.5 Potential for Future Development

Existing standards and management levels of agriculture in Project Area are very low. Uncertain flood irrigation supply, traditional agricultural production methods and cropping pattern, use of primitive implements, inefficient irrigation methods, use of sub-standard inputs, lack of credit facilities, ineffective institutional and service organizations are the basic factors impeding agricultural production.

Because of uncertain conditions of irrigation supply, frequent crop failures occur and the investments made in agricultural inputs cannot be recovered. Without reliable irrigation supply, the farmers are not willing to invest in improved agricultural practices and production technologies due to high economic risk.

It is anticipated that with improved conditions through project support, the existing uncertain hill torrent irrigation system will be converted into a reliable irrigation supply system. The improved system of irrigation supply will not only raise the existing low cropping intensity but also enhance the existing subsistence cropping pattern. This will help in planting new cash crops. The reduction in crop failures and proper harvesting of crops will induce the farmers to adopt improved farming techniques.

The use of improved agricultural practices is likely to increase the crop yields and productions about three to four times under 'With' project conditions. The comprehensive agriculture and rural development plans for various hill torrent areas are given in the Supporting Volumes of this Report.

3.2.10 **Project Organization & Management Studies**

Hill torrents are spread over about 65 percent area of Pakistan. Floodflows of hill torrents constitute a very important component of water resources of Pakistan. However, due attention has not been paid so far to properly conserve and utilize this important resource which could play a vital role in the socio-economic uplift of hill torrent areas. Fourteen major hill torrent areas have been recognized in the four Provinces and Federal Agencies of the country.

Punjab Province was the first where efforts were concentrated in 1961 to conserve floodflows of hill torrents by constructing small dams under Agriculture Development

Corporation (ADC). Later, Small Dam Organization was established in Irrigation & Power Department in 1972 under the supervision of a Project Director. This organization has so far constructed 31 dams in Pothowar Area. Hill torrents of DG Khan are being managed by SE Project Circle, DG Khan. However, there are numerous other hill torrents in Mianwali and Gujrat Districts. In addition, there are a number of nallahs in Rachna & Chaj Doab areas.

In NWFP, Small Dam Organization was established under a Project Director (PD) with its headquarters at Peshawar. This Organization has identified a large number of dam sites in various parts of NWFP. However, only one dam has been constructed so far while five are under construction.

In Balochistan, all the work for water conservation and flood management is being looked after by the respective circles and divisions of PIDA, Balochistan. So far over 400 water conservation/development structures have been constructed.

In Sindh Province, the work of Gaj Nai and other hill torrents in its close vicinity is under SE, Southern Sindh Circle at Dadu. However, work of other hill torrents of Khirther Range, Karachi and Khinjar Lake Area is being conducted by the respective Circles/Divisions of PIDA, Sindh. The work for the management of hill torrents in FATA, AJK and Northern Area is tackled by the respective departments.

It has been observed that the work for conservation of hill torrents in four Provinces and Federal Areas requires integrated and rational planning for achieving better results. For this, an authority like Pakistan Rod Kohi Development Authority may be formed for integrated planning of water conservation and development of irrigated agriculture in the areas.

3.3 STRATEGY FOR DESIGNING OF STRUCTURES

3.3.1 General

Development and exploitation of surface water resources of perennial streams (major rivers etc) is approaching the optimal limit in Pakistan. There, is however, considerable scope of development of flows of hill torrents. In order to harness, utilize, manage and control the floods of hill torrents, structural interventions are often resorted to. These structures serve to store, divert, distribute or dispose-off the flows as desired. Generally, the flood management structures built on the hill torrents serve the dual purpose of water conservation and flood control. Such structures are therefore considered to be important elements of hill torrent basin management systems.

3.3.2 **Different Parts of Hill Torrent**

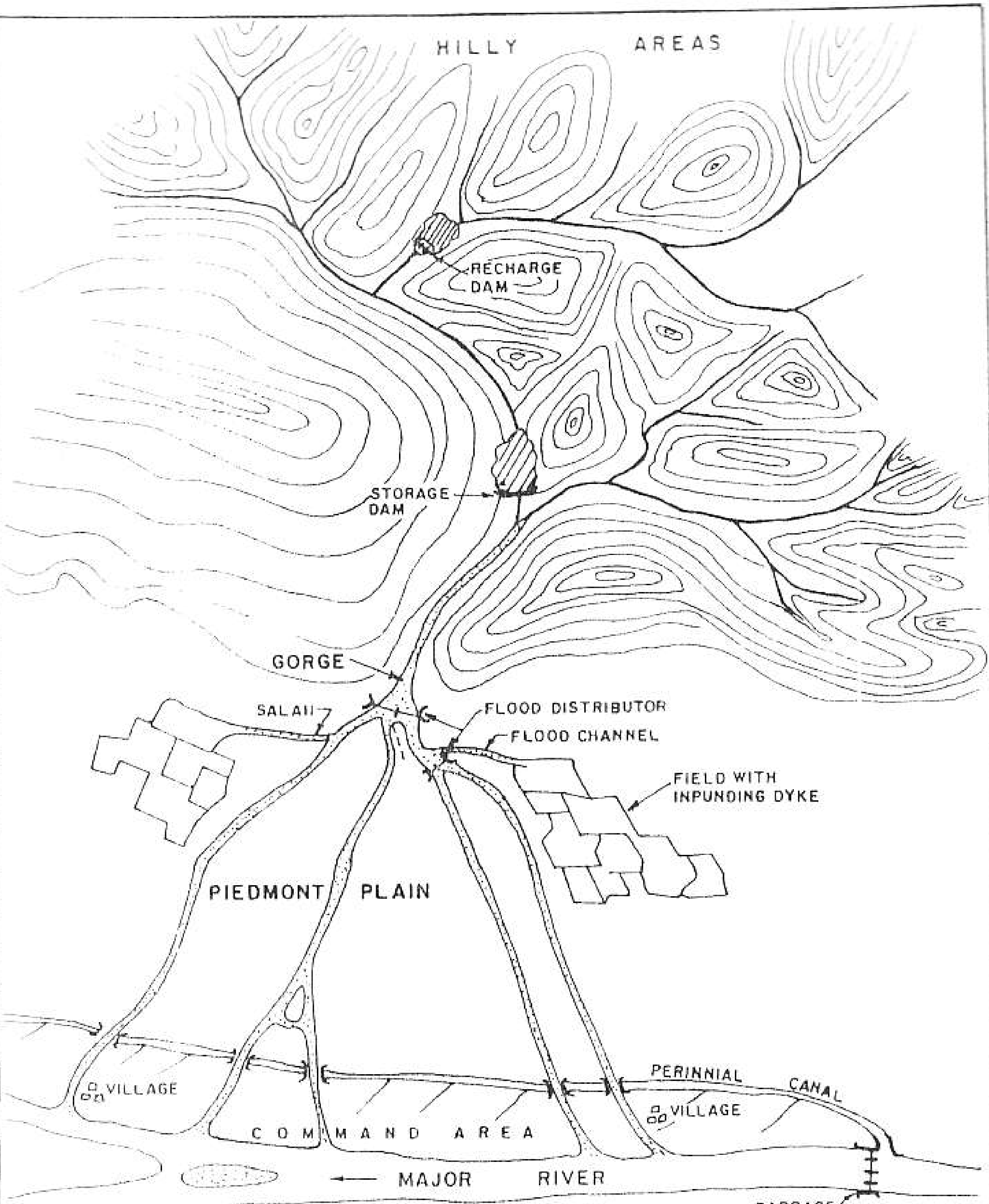
A typical hill torrent can be divided into three (3) distinct reaches as follows (**Figure 3.1**).

- The hilly catchment;
- The gorge; and
- The piedmont plain.

Torrents manifest different characteristics in these regions as briefly described in the following sections.

3.3.2.1 The Hilly Catchment

Depending upon the geographical location of the site, the hilly catchment areas of torrents range from a few square kilometers to several thousand square kilometers. This region is characterised by high altitudes, cool climate and recipient of major parts of rainfall. The runoff descending down the mountainous slopes concentrates into small channels which combine to form larger channels ultimately joining the central limb of the main torrent.



NOT TO SCALE

MAP OF TYPICAL HILL TORRENT

FIG. 3.1

Agricultural land is scarce in headwater regions and farmers have to invest considerable financial resources for making and maintaining strips of arable lands. Due to high altitudes, however, the climate is suitable for orchards and the handsome returns justify investments in land and water management. Bank erosion is the main problem in such areas, where precious orchards are threatened by torrent floods. Bank revetments and gabion walls etc are constructed to combat the erosive action.

Small flood detention dams are generally constructed in this region to augment the groundwater recharge and/or to support irrigation by the stored water in times of need.

3.3.2.2 The Gorge

The flows from contributary, smaller channels accumulate in the main stream and start flowing downstream towards the foothills. The hill torrent then passes through a narrow passage termed as the 'gorge' (Darrah) and comes out of the hilly tracts. The gorge portion is characterized by a steep slope, rough water surface and high energy flow. Gorges apparently form ideal sites for locating dams by virtue of their short spans and strong abutment rocks. However, due to steeper slopes, the reservoir storage available for a given height is comparatively much smaller. If other conditions allow, the upstream end of a gorge may serve to be an advantageous dam site. Gorges are generally not suitable for locating flood control structures other than dams. In some cases they are suitable for the construction of delay action dams which shave off flood peaks and augment groundwater reservoir.

3.3.2.3 The Piedmont Plain

The plain land lying between the foothills and the recipient body (generally a perennial river or coast line), is called the piedmont plain. As the hill torrent comes out of the gorge and debouches onto the piedmont plain, it gets divided into several branches. The plain land of such branching is termed as the 'fan-out area' or "gravelly fan" of the torrent. In fact, the piedmont plains have been formed by the deposition of sediments transported by the hill torrents. Soils of these plains depict the properties of disintegrated rocks of the mountainous catchment areas. The upper layers of deposited material are of recent origin (in geologic terms) and show little resistance to erosion. Several branches of the hill torrent flow across the piedmont plain, along their preferred paths, in the direction of dominant topographic slope. The branching and looping network then descends down, coming close to the recipient body (major river etc). A strip of developed land generally exists along the bank of a major river, which is crossed by the torrent branches as they outfall into the river. While crossing this developed area (canal command etc), the hill torrents generally inflict damage to the infrastructure, cropped land and human settlements.

Since the elevation of plains is low, the climate is generally not suitable for orchards. Field crops like wheat and sorghum are well suited to conditions in this portion. Riparians in the piedmont plains encompass their fields by constructing 0.9m to 1.2m (3 to 4 ft) high earthen dykes and divert the spate to impound the fields. Obliquely placed diversion dykes made of earth and brush wood in the torrent bed are generally used to divert the spate.These dykes remain effective during low spates but are often washed away by high floods.

In the piedmont plains, flood distribution structures are constructed at branching points of the main torrent channel. Such structures not only ensure proper division of flows but also pin down the stream by preventing it to by-pass and form new ravines. Other structures that suit this region include diversion channels, protective earth embankments and Salaii (guide spur) offtakes.

3.3.3 Characteristics of Hill Torrents

A hill torrent possesses different characteristics as compared to perennial streams and rivers. Comprehensive and indepth study of the specific flow regime of a given torrent is essential for proposing appropriate solutions. Major parameters that distinguish hill torrents from perennial streams are given in the following:

3.3.3.1 High Flow Velocities

Steeper topographic slopes cause flow velocities that are much higher than the regular streams. Accordingly:

- the hydrodynamic forces on structural components are greater;
- by virtue of high velocity, the flow has a greater sediment transport capacity and may cause excessive bed and bank erosion; and
- the high velocity flow carries sand particles that may cause damage to the structures etc.

3.3.3.2 Highly Variable Discharges

Hill torrents generally experience flash floods. Steeper valley slopes result in a short "time of concentration" and generate flows with short lived high peaks. The floodflows swiftly descend down, if not checked, to the outfall reach and finally into the recipient body. The hydraulic structures built to manage the flows thus experience:

- Rapidly varying hydrodynamic and hydrostatic forces;
- Shorter time for diversion of required volumes of water; and
- More frequent wetting and thawing.

3.3.3.3 High Sediment Concentrations

Most of the hill torrents in Pakistan originate in denuded or sparsely vegetated catchments formed of sedimentary rocks under various stages of disintegration. The run-off, therefore, carries heavy loads of suspended and rolling sediment. Sediment concentrations of five to seven percent are found in most of the Suleiman and Khirther Range torrents. This high proportion of sediment causes:

- Rapid silting-up of reservoirs behind dams and weirs;
- Clogging up of natural or man-made channels;

- Formation of sand-bars **(Belas)** in front of offtake channel mouths; and
- Damage to structures through impact of coarser particles (boulders etc)

All the above phenomena adversely affect the hydraulic structures on hill torrents. The problem of rolling boulders in flow is, however, limited to a few locations where catchment areas have fragmented rocks.

3.3.4 Planning Aspects

In order to achieve the dual purpose of conservation of and protection from the hill torrent floods, structural measures need to be carefully planned in view of the specific conditions along the reach of interest. For proper planning of such structures, the following studies form a pre-requisite:

- Hydro-meteorology;
- Geomorphology;
- Topography;
- Pedology;
- Agronomy; and
- Sociology

These studies determine the suitability of a particular structure to serve the desired purpose with technical and economic viability.

An important consideration, during the planning phase, is the study of present human settlements and their agricultural and other related practices and activities. Water, being a scarce commodity in such areas, is a serious concern of the various users. Generally, rules for division of available spate among various riparian groups exist as an un-written apportionment accord. These rules should be carefully studied, confirmed and cross-checked before embarking upon selection of site for planning of water conservation in the area.

3.3.4.1 Selection of the Type of Structure

The following types of hydraulic structures are generally used for managing hill torrent flows:

- Dams
  - Storage dams;
  - Delay action dams;
  - Check dams.
  - Multipurpose dams; and
- Weirs
  - Flood distribution/dispersion structures;
  - Bed stabilizers/bed sills/bed bars; and
  - Check and control weirs.

- Dykes
  - Diversion dykes for guiding flow to channels;
  - Cross dykes for small spates;
  - Protection dykes along banks; and
  - Field impounding dykes.

- Channels
  - Flood irrigation channels;
  - Flood diversion channels; and
  - Flood disposal channels.

- Spurs/Groynes/Studs
  - For protection of banks against erosion;
  - For training of active channels; and
  - For protecting human settlements/infrastructure.
  - Creating a region of low velocity to induce siltation.

Choice of one or more structures depends on the specific requirements, the problems to be solved or improvements to be made. Decisions regarding selection would also be guided by the quantity and quality of available flood volume and its temporal distribution and availability of land.

Other important considerations during the planning stage are:

- A master plan should be evolved for the entire network of channels of a particular torrent. Types and sizes of the proposed structure should be optimized according to the availability and intended usage of flood flows.

- Implementation programme should be phased according to availability of funds keeping the priority from upstream end to the downstream.

- Site selection should, in addition to technical considerations, be based on water-rights of various spate users.

- Beneficiary consultations and participation should be ensured in the planning stage so that a general social acceptability of the structural interventions is ensured.

3.3.5 Design Considerations

3.3.5.1 General

Disintegration of the rock surfaces in mountainous catchments is a continuous natural phenomenon. The disintegrated matter i.e. boulders, gravel, pebbles, sand, silt and clay etc is transported to valleys and further downstream by the run-off caused by rainfall and snowmelt. Hill torrents play a primary role in transporting the sediment downstream. The fan-out areas and piedmont plains formed by the hill torrents are,therefore, undergoing continuous morphologic changes.

Keeping these aspects in view, flood management structures on hill torrents have to be designed with a high degree of flexibility. Excessive deposition may impair their function within a short time unless the crest levels etc are raised. On the other hand, the de-silted flow may cause excessive scours in the downstream thereby under-mining structures and eroding the channels in the downstream reaches.

3.3.5.2 <u>General Design Principles</u>

The following basic principles serve as guidelines for arriving at a satisfactory design of hill torrent structures:

- The design should ensure flow distribution according to the existing water-rights of all related spate users.

- Design should be based upon a peak flood that corresponds to a frequency of occurrence which is optimum in view of the cost of structures and its anticipated benefits.

- The design should be flexible enough for incorporating future modification(s) necessitated due to regime changes.

- Maximum use should be made of local materials and labour force to remain cost effective.

- The design should be simple, robust and easy to operate and maintain. It should be free from sophisticated elements e.g moving gates etc, as far as possible.

- Easy access to the project site should be ensured for future maintenance etc.

- Beneficiaries should be consulted and entrusted the duty of continuous watch over the performance and safety of the structure.

Although each structure site has its own specific problems requiring appropriate technical solutions, however, a general description of the design of major components of flood management structures, on hill torrents is given in the following.

3.3.5.3 Dams

Where viable, dams constitute the most effective means of controlling, conserving and utilizing flood flows. In the case of hill torrents, however, there are certain critical parameters that require detailed evaluation before deciding about the implementation of a dam. In Pakistan, most of the hill torrents of Suleiman and Khirther hill ranges have their catchments in the semi-arid to arid climatic zone. The catchment area consists of rock surfaces having little or no vegetative cover. Accordingly, three major problems arise:

- The rainfall is uncertain, patchy and quantitatively inadequate;
- The potential evaporation being very high in the dry climate, evaporation loss of stored water surpasses the inflows; and
- The non-vegetated sedimentary rock surfaces yield a high proportion of sediment thereby appreciably reducing the useful life of the dam due to quick silting up of the reservoir.

One way of overcoming these problems is to construct Delay Action (or Recharge) Dams. The purpose of these dams is to store water in the sub-surface aquifers by way of percolation through reservoir bottom and periphery. Once the water gets deeper down adding to the existing groundwater, it is saved from the threat of quick evaporation and can be withdrawn through wells or other optimal means as and when required. Such dams are usually not provided with a withdrawal system of permanent nature. Nevertheless, withdrawal of stored water in case of dire need can be affected through temporary syphons. Where orchards in the vicinity thrive on groundwater, such dams can substantially augment the supplies through replenishment of the aquifer.

In fact, any type of dam is essentially a recharge dam since there is always seepage through the wetted surfaces of the reservoir. Determination of the quantity and flow path of such seepage, however require extensive studies which may not be justified for small projects.

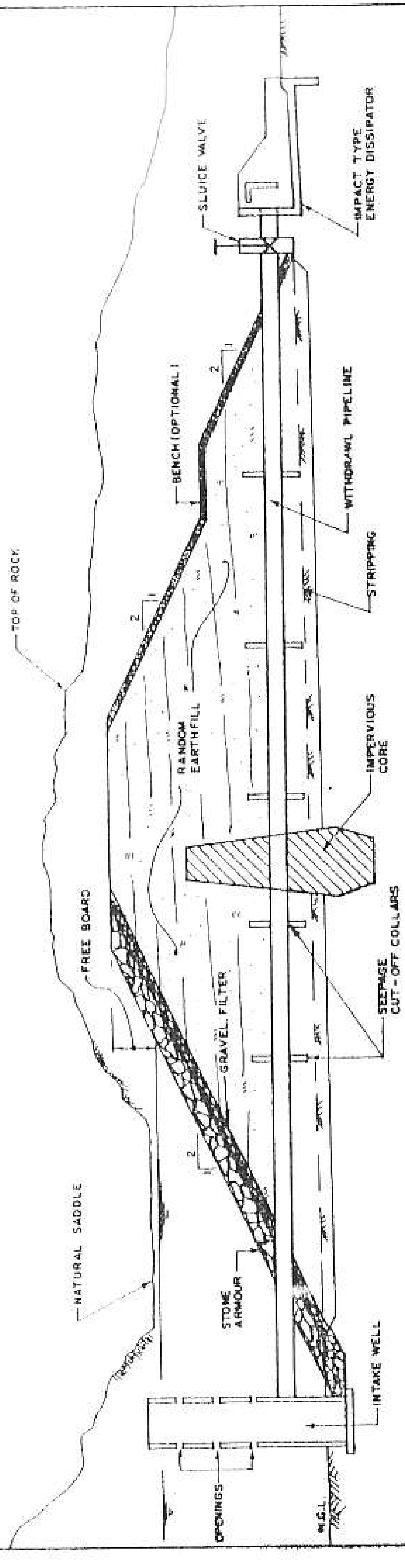
Besides recharge, there are other positive impacts of dams in the hilly areas such as on micro climate and support to livestock for drinking and, sometimes, fish culture. In areas where reservoirs get dried up for intermittent periods, farmers borrow the deposited silt from the bottom to form strips of orchard land. In this way, an automatic desiltation of the reservoir is done in addition to supply of fertile soil.

Check dams are built across selected smaller tributary channels to prevent excessive influx of sediment into the main stream. These dams are usually built as essential components of watershed management programmes launched to enhance the lives of major downstream reservoir.

Small dams of less than 50 ft (15 m) height are generally constructed on the hill torrents. A brief description of the components of a typical multipurpose (except power generation) dam (Figure 3.2) on hill torrent is given in the following.

MAIN BODY: Earthfill is the most common material for constructing the body of the dam. In areas where earth is difficult to borrow, rockfill dams may be constructed. Concrete, being too expensive, is usually not justified economically, specially in view of comparatively short life of hill torrent reservoirs.

Random earthfill compacted in layers of suitable thickness and having a central impervious core of cohesive material forms the main body. The side slopes of trapezoidal section are in the range of 1V:2 to 3 H determined to resist destabilizing forces and to provide adequate cover over the phreatic line. Top widths are generally kept in the range of 20 to 30 ft (6 to 9m) to facilitate access. The upstream slopes are protected by rip-rap or hand pitched stone against the wave splash. A gravel layer of suitable thickness is placed on the downstream earth slope to protect the same against rain and wind erosion.



TYPICAL CROSS SECTION
OF A SMALL DAM

FIG. 3.2

Top level of the main embankment is determined by adding sufficient free-board over the elevation of spillway crest. The free board should, in no case, be less than the depth of flow over crest of the spillway for the peak discharge of 'design flood wave' in reservoir full condition.

SPILLWAY: Natural saddle spillways, if possible in the selected site configuration, can be advantageously used with or without modification. Availability of such natural saddles greatly reduces the cost of spillway. In the absence of natural saddles, the spillways are located at one of the benches or ledges of the confining hills. Sometimes rock excavation has to be resorted to for forming the spillway crest in an appropriate length. Crest length of the spillway is determined to safely pass the peak discharge.

If the spillway crest and downstream slope to the bed of stream are composed of solid rock, energy dissipation measures are not required. However, in case of fragmented, fissured or soft rock formations, concreting of the vulnerable portions is done to reinforce the flow path. Rip-rap or gabion protection is generally provided to separate the spillway from the main embankment.

WITHDRAWL SYSTEM: A withdrawl system in the shape of a bottom outlet is generally incorporated in the body of dams where retrieval of stored water is envisaged. The bottom outlet essentially consists of:

- Inlet Structure;
- Conveyance Pipe-line; and
- Outlet Structure.

The inlet structure is located at a suitable place on upstream side of the dam. A well type inlet structure is desirable as it remains effective even with substantial silting-up of the reservoir. It consists of a concrete cylinder having openings at various levels and the conveyance pipe is connected to its bottom.

Conveyance pipe line may be of concrete or steel of suitable diameter that can release the required discharges at times of need. The pipeline is to be provided with cut-off collars for prevention of seepage along it. The outlet end of pipe is fitted with a sluice-gate for opening or closing as desired.

The outlet structure is generally an impact type energy dissipating box having a downstream basin. This structure provides a smooth transition from the pipe to the earthen conveyance channel on its downstream.

3.3.5.4 Flood Distribution Structures

Flood distributors for hill torrents are essentially a set of low crested weirs separated by divide walls and confined by wing-walls at extremities of natural channels. The crest lengths and elevations are designed to hydraulically distribute the incoming flows to pre-determined proportions according to water rights of various user groups.

Sizing of the structure is based on a 25-year[1] return period flood peak which is the optimal for most of hill torrents of the semi-arid zone in Pakistan. The free-board, is selected to pass the 50-year peak in which case minor damages to the downstream apron are to be tolerated.

A breaching section, if required, is provided in the marginal bund for release of higher flood peaks. The intended portion of earthen embankment is constructed with a top level that gets overtopped as soon as the incoming flow exceeds the critical value and gets washed away thus automatically releasing the excess flow.

Flood distributors generally accommodate offtakes of irrigation channels on the upstream of the weir. These offtakes withdraw proportionate discharges and feed these to the conveyance channels (Canals) leading to the cultivated areas.

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[1] Flood Management of DG Khan Hill Torrents - NESPAK-1984.

Weirs: Weir crests are kept low in view of the sediment deposition that quickly brings the upstream bed elevation up to flush with the crest. Weir crest elevations are generally in the range of 2 to 5 ft above the stream bed. Crest lengths are selected to fit the bed-width of natural water ways as well as to safely pass the design flood peaks. In case of very wide streams, a part of the bed width is blocked by earthen embankment with an optional breaching section.

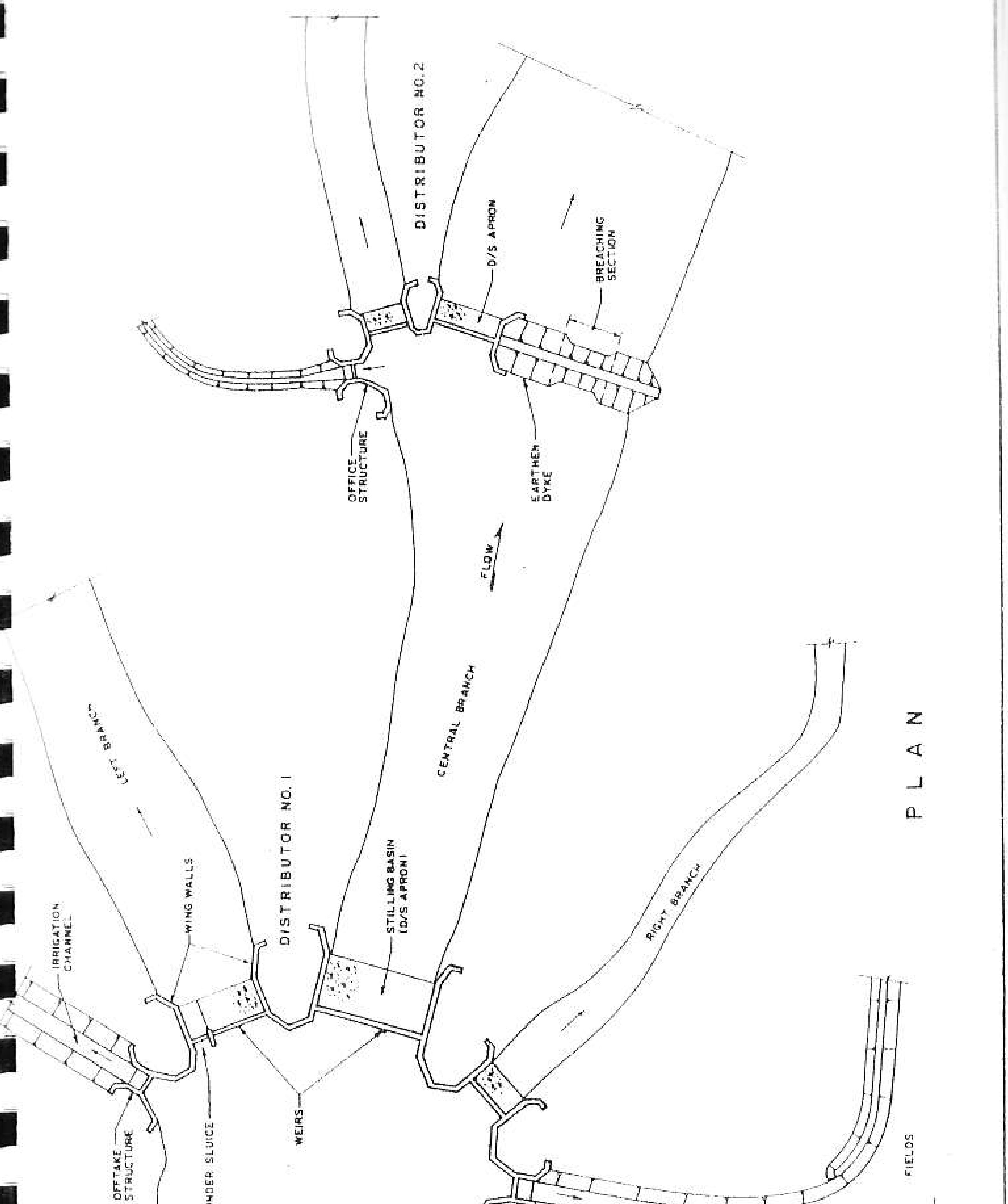
Crests are constructed in stone masonry or gabion boxes. The gabions boxes are made of G.I.Wire of SWG No.8 with mesh size of 6 inches x 6 inches or smaller. Stone from local sources are filled in the boxes and the finished structure is provided with skin concrete layer of 4 to 6 inches thickness. The concrete not only saves the wire from sand abrasion but also from the impact of rolling boulders.

Undersluices with stoplogs closure system are sometimes provided in the weir body where a deep channel is to be maintained towards the irrigation offtakes. Mechanically operated steel gates system generally prove to be too sophisticated for such areas and have often been found non-operational for want of repair/maintenance. Typical layout of a flood distributor structure is shown in Figure 3.3.

Wing Walls: Wing walls secure the extremities of weir crests and confine the flow. These walls are designed as retaining walls that have to resists the static and dynamic forces of water on one face and the earth pressure of backfill on the other.

Wing walls are also constructed in stone masonry or gabion boxes with a cut-off wall underneath. The cut-off wall acts as an anti-scour device. The top elevation of the wing walls is designed to contain the 50-year flood peak. Top widths are generally kept between 3 to 5 ft to allow pedestrian access for inspection purposes.

Upstream Apron: The retarding flow tends to deposit rather than scour the bed on the upstream side of the weir. However, in view of parallel flow, possibly during low floods, a light upstream blanket of gabion mattress or dry hand packed stones is provided. Thickness of such apron is normally 1.5 to 2.0 ft while length (in flow direction) is 10 to 12 times the height of weir crest above the river bed.



TYPICAL FLOOD DISTRIBUTOR STRUCTURE

FIG.3.3

Downstream Apron: The downstream apron has to contain the hydraulic jump and absorb the impact of falling sheet of flow. Length of the apron is determined by hydraulic jump calculations for the peak discharge. Gabion mattresses with skin concrete on top have been used successfully at several locations in Balochistan. Uplift pressures do not develop in most cases due to short duration of flow. However, where upstream ponding is foreseen for longer periods, weep holes should be provided in the skin concrete layer for dissipation of uplift pressures or else, the floor thickness be increased to resist the forces.

Irrigation Offtakes: Offtakes are located at a short distance upstream of the weir on one or both banks. These are normally open flume type structures constructed in gabion boxes or stone masonry.

Sizing of the offtake is done according to the area to be served. Detailed volumetric availability of water during freshets of various probabilities is determined at the location and other downstream locations and a complete routing analysis is carried out for the entire stream determining the diverted volumes for the various offtakes-against tried capacities. The areas served and the value of outputs vis-a-vis the water rights are optimized by varying the capacities of offtakes.

In order to limit the flow into the offtakes during very high peaks, a breast-wall is incorporated in the offtake structure. The wall converts the weir into an orifice as soon as the head over crest exceeds the desired limit.

Irrigation Canals: These are earthen channels, in cut (fill section in unavoidable short reaches is allowed in exceptional cases), conveying diverted water to the fields to be cultivated. Sizing of these channels is related to the area to be served. However, an important consideration while determining the size of a particular channel is the handling capacity of the farmers. Larger capacities are generally beyond the capability of the farmers while smaller sizes result in lesser water conveyed to the fields during a given freshet. Beneficiary consultation and participation can positively contribute towards evolving a successful design. Regular maintenance is required for the conveyance channels as deposition of sediments or bank erosion may distort the prismatic section and affect discharge capacity.

3.3.5.5 Dykes and Embankments

For single offtakes in the head reaches below gorge, cross weirs are not economically viable. Instead, diversion dykes projecting obliquely to the flow direction are used to divert the spate into open flume type offtake mouths (**Figure 3.4**). Farmers construct such dykes with earth, gravel and brush wood called "Salaiis" which can only stand against low to medium floods. High floods erode and wash away these dykes depriving the riparians of the diversions for rest of the season.

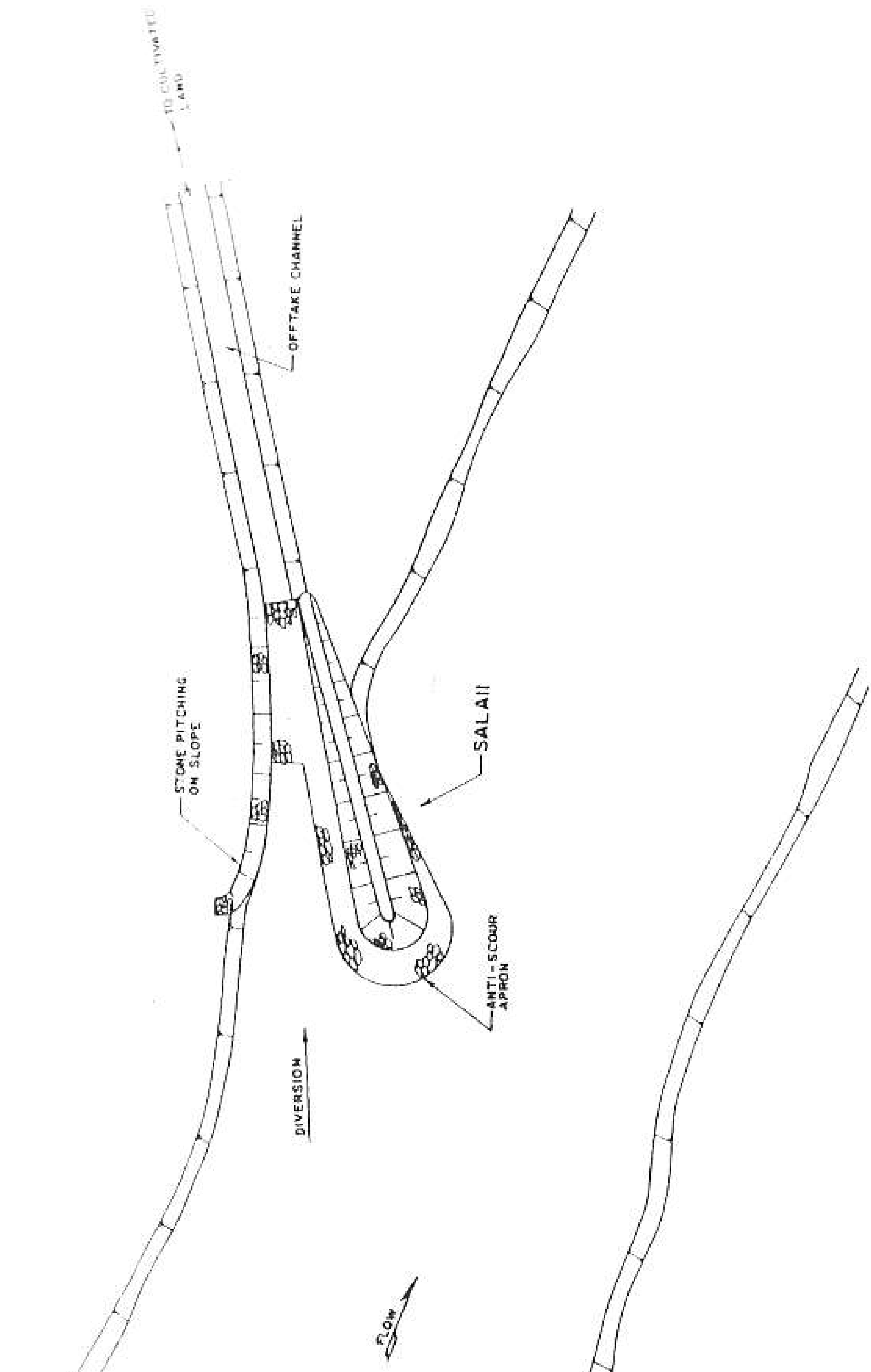
Gabion boxes can be advantageously used for constructing such diversion dykes. An anti-scour apron of gabion mattresses or hand packed stone on the upstream side and around the nose of these dykes in necessary. Alternatively, rubble mounds of large size stones may be constructed with appropriate scour aprons. Regular maintenance is essential for satisfactory operation of the diversion dykes (Salaiis).

Earthen embankments are generally constructed along banks of streams to contain the spillage that would otherwise damage crops, infrastructure or human settlements. Overbank spillage may also cause loss of water resulting in deprivation of downstream riparians having water rights.

Embankments that occasionally come in contact with inundating sheet flows need not be armoured; instead intermittent repair of earthwork proves to be more economical. However, where wave splash, parallel flow and longer contact with water is anticipated, the upstream slopes of embankments should be protected by rip-rap, hand pitched stones or gravel layers. Anti-scour aprons are also included at critical locations where repeated attack by meandering channels is to be checked.

3.3.5.6 Channels

Irrigation Channels for conveyance of spate have already been described under Section 3.3.5.4. Occasionally, earthen channels to divert flood from one stream to another or branches thereof, have to be constructed for proper utilization of spate, and damage aversion. Such diversion channels are usually required to offtake from streams that carry ample spate, but are deficient in cultivable land resources in their flood plains.



TYPICAL PLAN OF DYKE

FIG. 3.4

Disposal Channels are constructed in the tail reaches of the torrents. The torrents generally get divided into several shallow channels that pond up against high embankments of roads, railways and irrigation canals etc. in the settled area near the recipient major river. These channels connect the cross drainage structures (culvert, super passage etc) on the road, railway or canal to the recipient body for safe disposal of residual flows.

Regular maintenance is essential for efficient working of diversion and disposal channels, as deposition, weed growth, encroachments and erosion tend to render these channel ineffective.

3.3.5.7 Spurs/Groynes and Studs etc

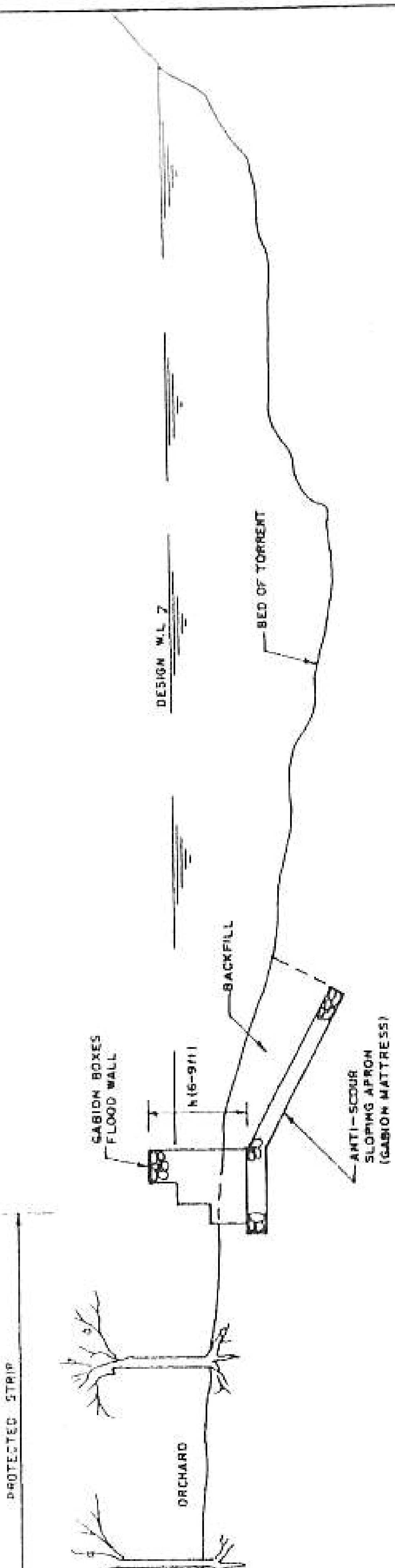
These measures are generally implemented in the upper catchment areas where orchards have been developed close to the stream banks. The process of bank erosion often threatens the strenuously developed orchards and has to be checked by corrective measures.

Spurs are constructed to modify the approach of incoming currents towards a vulnerable location on bank or a weir, bridge or headworks. Gabion boxes have successfully been applied for constructing spurs, groynes and studs on Swat and Panjkora Rivers in the NWF Province.

Physical model testing is required to determine the shape and size of spurs, groynes and studs.

3.3.5.8 Miscellaneous Structures

Several other structures, such as flood walls and slope revetments are also constructed according to local flood management requirements (**Figure 3.5**). Vertical flood walls are constructed where orchards have been developed close to shallow stream banks. The narrow strips of orchard lands are precious and cannot afford to contribute wide strips of land required for constructing embankments.



TYPICAL CROSS SECTION
FLOOD WALL & SECTION

FIG. 3.5

Flood walls are generally constructed in gabion boxes with appropriate apron where required. Buried sloping aprons have proved to be very successful at various locations in Balochistan. Such walls have demonstrated very effective river training capabilities at an economically justifiable cost in the apple orchard strips along Rud Malla Zai area in the Ziarat District and at many other locations in Balochistan.

Stone pitching of sloughing banks is often carried out with appropriate aprons at locations where progressive erosion is threatening valuable investments on agricultural land. Hand packed stones of specified size/weight, in a 1.5 to 2 ft thick layer, are placed over a graded filter material layer of 6 to 9 inches thickness.

4. LAND AND WATER POTENTIAL

4.1 GENERAL

Land and water resources constitute one of the most valuable benedictions of nature for a nation. Availability and wise use of these resources have determined the course of empires in many civilizations. The use of water for irrigating the land has been practised for thousands of years by human beings in the world. However, since late 1800's, man applied scientific knowledge to water the drylands to increase crop production. The scientific techniques for the use of land and water resources have transformed millions of hectares of once barren wastelands and deserts, into fertile productive farms.

Land and water resources are limited while the demand for their use is increasing due to socio-economic pressures in almost all parts of the world. The population of developing countries is increasing at a rate of about 2.5 percent while the rate of increase is about one percent in the developed countries. Total arable land on the earth is about 3,500 Mha, of which about 1,550 Mha is under cultivation.

Nearly 260 Mha (one sixth of the total cultivated area) is under irrigation by canals, tubewells etc and is producing about one-third of the total global food. Rest of the cultivated area i.e. about 1,300 Mha is providing two-third of the world food requirements. Of the total irrigated area of the world, one third is located in China, while India has 18 percent, followed by USA which has nearly 8 percent and Pakistan is placed fourth with about 6.5 percent. Developing countries possess nearly 1,900 Mha (55 percent) of the arable land of which about 750 Mha is under cultivation. Nearly 4 Mha of the cultivated land is going out of production each year due to conversion of crop land to non-agricultural uses like rural settlements, road system, industrial enterprises etc. As this encroachment is proceeding in the same proportion as the growth in population, this negative component can be expected to double in the next three decades with most of it concentrated in the developing countries.

4.2 LAND RESOURCES OF PAKISTAN

Total geographic area of Pakistan is 79.61 Mha. Of this, 'Reported Area' is about 58.10 Mha. The landuse statistics of the country are given in **Table 4.1**. Pakistan has been divided into seven broad regions as follows:

- Northern Mountains
- Rainfed (Barani)
- Irrigated Plains
- Sandy Deserts
- Suleiman Rod Kohi
- Coastal Areas.

The criteria for delineation of the land resource regions are variation in climate, relief, topography, hydrology, soil, vegetation and landuse as well as socio-economic and cultural aspects. Major land degradation issues and problems, their causes and effects and possible remedial measures also differ from one region to another.

4.2.1 Northern Mountains

This region includes Malakand and Hazara Divisions, Northern Areas, and Murree and Kahuta Tehsils of Rawalpindi District covering about 96,340 sq.km

Physiographically, the region is subdivided into mountain slopes, gravelly fans and terraces and piedmont loess and alluvial plains. The region is characterized by steeply and very steeply dissected mountain slopes with high relief amplitude, great variations in regional and altitudinal rainfall; in amount from arid to humid, in seasonality from monsoonal to Mediterranean; in temperature from sub-tropical (in the valleys) to arctic; in high altitude through temperate (cool, cold, very cold) and great altitudinal range between 1,000m to 8,600m. Mountain slopes support mainly unstable, excessively drained shallow to moderately deep gravelly loamy soils on bed rocks, subject to severe sheet, rill and gully erosion (without vegetation cover) and high rainfall erosivity and soil erodibility in humid monsoonal zone.

TABLE 4.1

LAND UTILIZATION STATISTICS OF PAKISTAN

(Million Hectare)

Landuse	1947 1952	1953 1957	1958 1962	1963 1967	1968 1972	1973 1977	1978 1982	1983 1987	1988 1992	1993 1997
OGRAPHICAL AREA	79.61									
orted Area	46.33	46.61	49.46	52.2	53.22	54.09	54.82	57.92	57.9	58.06
est Area	1.38	1.27	1.46	1.92	2.31	2.83	2.82	2.67	3.43	3.48
	(2.98)	(2.72)	(2.95)	(3.68)	(4.34)	(5.23)	(5.14)	(4.61)	(5.92)	(5.99)
t available for Cultivation	20.73	20.68	19.76	18.57	20.13	20.74	20.28	23.42	24.57	24.35
	(44.74)	(44.37)	(39.95)	(35.57)	(37.82)	(38.34)	(36.99)	(40.44)	(42.44)	(41.94)
Culturable Waste	9.19	9.1	11.25	13	11.53	11	11.51	10.68	9.03	8.83
	(19.84)	19.52	22.75	24.90	21.66	20.34	21.00	18.44	15.60	(15.21)
Current Fallow	3.74	3.53	3.9	4.81	4.76	4.69	4.77	4.81	5.2	4.95
	(8.07)	7.57	7.89	9.21	8.94	8.67	8.70	8.30	8.98	(8.53)
Area Sown	11.27	12.03	13.09	13.9	14.49	14.83	15.43	15.76	15.67	16.45
	(24.33)	25.81	26.47	26.63	27.23	27.42	28.15	27.21	27.06	(28.33)
wn More Than Once	1.04	1.3	1.52	1.89	2.14	2.95	3.78	4.41	5.52	5.99
	(2.24)	2.79	3.07	3.62	4.02	5.45	6.90	7.61	9.53	(10.32)
al Cropped Area	12.31	13.33	14.61	15.79	16.63	17.78	19.22	20.23	21.19	22.44
	(26.57)	28.60	29.54	30.25	31.25	32.87	35.06	34.93	36.60	(38.65)
Cultivated Area	–	–	–	–	–	–	–	–	–	21.4
	–	–	–	–	–	–	–	–	–	(36.86)
gated Area	–	–	–	–	–	–	–	–	–	16.68
	–	–	–	–	–	–	–	–	–	(28.73)

e: Figures in parenthesis indicate percentage of Reported Area.

Mountain slopes above 4,500m are under perpetual snow; slopes between 3,300m and 4,500m are occupied by alpine and subalpine pastures; slopes between 900m and 3,300m are under various types of coniferous forests; and slopes between 300m and 900m are under broad leaved shrub. The dissected piedmont plains, loess plains and alluvial plains in the valleys with well drained deep loamy/silty soils are used for arable, rainfed or irrigated farming.

4.2.2 Rainfed (Barani) Lands

This region extends over Pothowar Plateau and Lower Himalayan Piedmont Plains stretching over Rawalpindi Division and northern strip of Gujrat and Sialkot Districts covering 41,600 sq.km.

Physiographically the region is subdivided into dissected loess piedmont river plains, ridges and troughs, weathered rock plains; low mountain ranges and severely gullied land. Altitude ranges between 250m and 900m; rainfall limits the area from semi-arid to subhumid; in seasonality it is monsoonal with mediterranean bias, mediterraneanity increasing towards south-western part of the region; in temperature, hot to very hot in summer and cold in winter.

Agro-climatically the region is subdivided into:

- Subhumid hot subtropical monsoonal in the northern part;
- Semi-arid hot subtropical monsoonal in the central and south western part; and
- Semi-arid very hot subtropical monsoonal/mediterranean in the western and south western part.

Natural vegetation is xerophytic comprising semi ever green wooded shrubland. Soils in the piedmont loess and river plains are very deep; well drained loamy through silty clays and; in ridge and trough, weathered rock plains; and mountain slopes/shallow, excessively drained gravelly loamy. The region is predominantly dry farmed for wheat, maize, sorghum, millets, peanuts and mustard, locally irrigated from small dams and from ground water along main streams. The region also provides grazing opportunities for a large number of sheep and goats all the year round.

4.2.3 Irrigated Plains

This region includes canal command area of Indus Valley in Punjab and Sindh Provinces and Peshawar-Mardan Vale in NWFP covering 165,400 sq.km.

The region is characterized by level to nearly level, old and subrecent river plains; semi-arid to subhumid subtropical monsoonal climate in the northern part, arid to semi-arid in the central and the southern parts and hyperarid tropical marine in the southern extremities and semi-arid subtropical monsoonal/mediterranean in Peshawar-Mardan vale with great diversification in soils, from sandy to clayey, but loamy and clayey soils are dominant. The region contains nearly 20 Mha of cultivable land, about five Mha is suffering from salinity and waterlogging. The region is supplied with irrigation water through world's largest canal network and supplemented by tubewells. Cotton, wheat, rice, sugarcane are the main crops plus subtropical and tropical fruits including mangos, citrus, papaya, coconut and banana. Besides, livestock production is an integral part of the irrigated agricultural system.

4.2.4 Sandy Deserts

This region includes Thal, Cholistan, Thar, and Chagai-Kharan deserts, covering about 123,700 sq.km.

The region is characterized by a huge mass of rolling to hilly sand plains, 70-80 percent areas occupied by sand ridges, 20-30 percent by loamy interridge valleys and locally clayey flats in desert margins; very hot summers and mild winters, strong dusty seasonal winds and severe hazard of wind erosion. Moving sand dunes in marginal desert areas, particularly around habitation centres and is a common scene. Grazing by transhumant livestock (sheep, goats, cattle, camels) is the predominant landuse. Locally in semi-arid zones, marginal rainfed millets, guara, and gram are also grown. Seasonal shortage of forage and drinking water and saline groundwater are the main constraints to livestock production.

4.2.5 Suleiman Rod Kohi

This region includes Rod Kohi areas of DI Khan, DG Khan, Kohlu, Sibi and Kachhi Districts covering together 39,690 sq.km.

The region is the eastern extension of Iranian plateau. It is characterized by steeply dissected mountain slopes with intervening narrow and broad valleys. Mountains are subdivided into moderately high (1,000-2,000m), to high (2,000-2,500m) peaks, the highest one reaching 3,520m above sea level. Upper and major part of the valley comprises gravelly fans and terraces. The region is very dry with implications on environmental fragility, minimum recharge of aquifers and very slow vegetative recovery. Summers are mild, winters cold with occasional snow fall. Rainfall ranges, quantitatively, from hyper-arid to semi-arid. Temperature varies from subtropical to temperate (warm, cool, cold).

Mountain slopes are largely stony and barren. Gravelly fans and terraces contain strongly calcareous (> 30% lime content) gravelly loamy and gravelly clayey soils. The central part of the valley is very deep, moderately calcareous, predominantly loamy, locally clayey.

4.2.6 Coastal Areas

The region includes Gwadar District, southern parts of Lasbela, Karachi, Thatta and Badin Districts covering about 38,750 sq.km.

The region is characterized by heterogenous physiography including low hills, gravelly fans and terraces, narrow piedmont plains, river plains, tidal plains, estuary plains, lagoons and moving sand dunes along the coast under intense arid tropical marine climate. Soils largely have no potential for agricultural development due to their very poor quality, except the piedmont and river plains which have a high to very high potential for agriculture under irrigation. Groundwater is saline except in narrow river plains where it is being exploited for tropical fruit orchards.

4.2.7 Land Classifications

The soils of Pakistan Hill Torrent Areas have been classified into six land capability classes according to the Bureau of Reclamation system (U.S.D.I 1950). The statistics of land capability classes are summarized in **Table 4.2** and are shown in Exhibit M-4.1. These are briefly described below:

4.2.7.1 Class I Arable

This class extends over 12.3% (6.69 mha) of Pakistan Hill Torrent Areas (0.5% in Sindh, 9.0% in Balochistan, 1.7% in Punjab and 1.1% in NWFP). The land is located in the nearly level to gently sloping areas. The component soils are deep, well drained, non-saline, non-sodic loamy (loams, silt loams, silty clay loams, clay loams and sandy clay loams). They are easily workable and have no limitations to roots, air and water penetration. Their available water holding capacity is good. They are highly suitable for a wide range of agricultural crops, fruits and vegetables adapted to the climate of the area.

The management practices are traditional, crop yields are low to moderate. However, if irrigation water is made adequately available, this land can give very high yields under improved agronomic practices including quality seeds and balanced doses of nitrogenous and phosphatic fertilizers.

TABLE 4.2

SUMMARY OF LAND CAPABILITY CLASSES OF PAKISTAN HILL TORRENT AREAS

LAND CAPABILITY CLASS	HILL TORRENT AREAS IN HECTARES					TOTAL	
	SINDH	BALOCHISTAN	PUNJAB	NWFP	NORTHERN AREAS	HECTARES	PERCENTAGE
Class I Arable Land	263,389	4,886,730	936,777	605,338	–	6,692,234	12.3
Class II Arable Land	195,327	793,780	495,096	522,624	29,246	2,036,073	3.8
Class III Arable Land (Moderate Agricultural)	–	–	–	–	62,112	62,112	0.1
Class IV Special Use Land	18,737	4,589,930	1,579,317	5,164,587	829,216	12,181,787	22.4
Class V Provisional Arable Land	395,627	250,690	58,760	9,508	–	714,585	1.3
Class VI Non–Arable Land	2,333,320	24,199,230	2,205,050	1,150,043	2,741,726	32,629,369	60.0
Built–Up Land	25,000	–	41,300	–	3,700	70,000	1.0
Total	3,231,400	34,720,360	5,316,300	7,452,100	3,666,000	54,386,160	100

4.2.7.2 Class II Arable Land

This class covers 3.8% (2.04 mha) of the project area. It includes 0.4% in Sindh, 1.4% in Balochistan, 0.9% in Punjab, 1.0% in NWFP and 0.1% in Northern hill torrent areas. The land consists of flat but slightly low-lying areas having clayey soils of expanding nature. The texture varies from clay to silty clay. The soils shrink and swell on alternate drying and wetting and develop cracks at the surface. Their infiltration rates are low but water holding capacities are high. Due to clayey texture, these soils have difficult workability and seedbed preparation problem and hence the choice of crops is slightly restricted. However, with modern management techniques, high to very high yields of the crops can be obtained. The management practices would include the following:

- Ploughing at an optimum moisture level for better seedbed preparation;
- Green manuring by vetch or Jantar to improve top soil structure and augment nutrient level of the soils;
- Addition of farmyard manure, if available, for soil amelioration;
- Deep ploughing once in 3 to 5 years for breaking plough pan.

4.2.7.3 Class III Arable Land (Moderate Agricultural)

This class occupies a minor extent i.e 0.1% (0.06 mha) of total area and occurs in Northern hill torrent areas only. It is composed of nearly level to gently undulating, shallow gravelly loamy soils underlain by gravelly strata below 30 to 50 cm depth. Due to shallow depth to gravelly strata, it can not be recommended for deep rooted crops especially orchards. However, with better management, optimum yields of shallow rooted crops could be obtained from this land. The management practices should include the following:

- Removal of surface gravels after every ploughing;
- Irrigation with regular interval to maintain available moisture level in the soil;
- Split doses of fertilizer application;
- Emphasis on shallow rooted and drought resistant crops; and
- Green manuring/addition of farm yard manure to improve the physical condition as well as nutrient level of the soil.

4.2.7.4 Class IV Special Use Land

This covers 22.4% (12.18 mha) of Pakistan hill torrent areas. It occurs 0.1% in Sindh, 8.4% in Balochistan, 2.9% in Punjab, 9.5% in NWFP and 1.5% in Northern areas. This land comprises of four sub-classes which includes excessively gravelly loam soils and gullied land, sand dunes and sandy soils, mountainous land with thin soil cover and with little soil cover. Because of its very poor water and nutrient holding capacity, the land is not recommended for irrigated agriculture. It should better be developed as grazing land/forest.

4.2.7.5 Class V - Provisional Agricultural Land

This class stretches over 1.3% (0.72 mha) of the gross area. It exists as 0.7% in Sindh, 0.5% in Balochistan, 0.1% in Punjab and a negligible extent in NWFP. Its occurrence is sporadic. The land has moderate limitations due to incidence of soil salinity. The soils are moderately to strongly saline, loamy, silty, fine-silty and clayey. They are deep to very deep and have weak to moderate subangular blocky structure. Their drainage and infiltration rates are favourable. They can be easily reclaimed provided extra water for leaching is available. After reclamation, the land could be improved to class I/II and be highly suitable for all types of crops of the area.

4.2.7.6 Class VI - Non Arable Land

This class occupies maximum i.e 60% (32.63 mha) of Pakistan Hill Torrent Areas. There are two main types of lands namely, mountainous area and rough broken/gullied lands collectively stretching over 4.3% in Sindh, 44.4% in Balochistan, 4.1% in Punjab, 2.1% in NWFP and 5.1% in Northern hill torrent areas. Besides, there is some portion 0.1% (0.07 mha) of river, torrent beds and built-up areas which are all agriculturally unproductive.

4.2.7.7 Built-Up Land

About one percent of the total hill torrent area is the built-up land. Total area under this catagory is about 0.07 mha.

In order to minimize/control erosion, some zerophytic (drought resistant) plants could be raised on the hilly areas. Major plants species are: Acacia modersta (Phulai), Acacia nilotic (Kikar), Prosopic spicigera (Kandi) and Ziziphus nummularia (Mulha).

4.3 WATER RESOURCES

4.3.1 General

Total water available on the surface of the earth is about $1.4 \times 10^{18}m^3$, of which only 3 percent ($4.2 \times 10^{16}m^3$) is sweet. Of the useable sweet water, 75 percent ($3.15 \times 10^{16}m^3$) is locked up in ice caps and glaciers, 24 percent ($1.01 \times 10^{16}m^3$ is stored in groundwater reservoirs while only one percent ($4.2 \times 10^{14}m^3$ is available as running water in rivers, streams and fresh water lakes on earth. Worldwide, agriculture is by far the largest user of water, 69 percent is used by agriculture compared to 23 percent by industry and eight percent by households.

In developing countries, the agricultural activities consume over 85 percent of total water. On global basis, nearly 60 percent of river flow occurs during flood season of which about 50 percent is being used at present. However, in developed countries, the percent of water use is over 85 percent. In case of Pakistan, about 80 percent of flow is carried by the rivers during the three months of Monsoon, of which about 40 percent moves to the sea unused. Of the total available groundwater ($1.01 \times 10^{16}m^3$) on the earth, 46 percent is available upto an economical depth of about 762m (2,500 ft) and remaining 54 percent is located between 750m to 4,000m depth. In case of Pakistan, groundwater reservoir upto a depth of 762m (2,500 ft) contains about $1.85 \times 10^{13}m^3$ (1.5×10^{10} acre-ft) of water, which is equivalent to over 100 years flow of Indus Basin Rivers of Pakistan. However, quality of groundwater in about 40 percent area is suitable for agriculture, while in other areas it is marginal or hazardous.

4.3.2 Potential Water Resources of Pakistan

Pakistan has the following water resources which have the potential for further exploitation:

- Indus Basin River Flows
- Groundwater
- Hill Torrents Flows

4.3.2.1 Indus Basin River Flows

There has been an aura of uncertainty about the total quantum of potential surface water resources of Indus Basin Rivers which could be exploited without any detrimental effect on the river regime below Kotri Barrage located about 160 km upstream of sea and tidal effects of sea water. **Table 4.3** gives the annual Indus River flows upstream Gudu Barrage and downstream Kotri Barrage from 1941 to 1995. Flows upstream Gudu Barrage and downstream Kotri for the period 1941 to 1995 are shown on **Figure 4.1.2**. The data presented in **Table 4.3**, clearly demonstrate that large volumes are going waste into the sea which could be conserved by making reservoirs at suitable sites on the Indus River.

4.3.2.2 Groundwater

Recharge to groundwater reservoirs is from the following major sources:

- Bed of rivers and hill torrents;
- Irrigated areas;
- Precipitation;
- Snow melt; and
- Flood flow inundations etc.

TABLE 4.3

INDUS BASIN ANNUAL FLOWS U/S GUDU & D/S KOTRI

Year		Discharges			
		Gudu Barrage U/S		Kotri Barrage D/S	
		MAF	MCM	MAF	MCM
	1941	82	101,106	59	72,747
	1942	90	110,970	78	96,174
	1943	119	146,727	107	131,931
	1944	119	146,727	91	112,203
	1945	101	124,533	84	103,572
	1946	114	140,562	91	112,203
	1947	83	102,339	64	78,912
	1948	82	101,106	63	77,679
	1949	109	134,397	92	113,436
	1950	120	147,960	90	110,970
	1951	144	177,552	122	150,426
	1952	79	97,407	44	54,252
	1953	102	125,766	72	88,776
	1954	103	126,999	74	91,242
	1955	102	125,766	73	90,009
Kotri Barrage	1956	109	134,397	74	91,242
	1957	139	171,387	120	147,960
	1958	128	157,824	92	113,436
	1959	130	160,290	91	112,203
	1960	162	199,746	129	159,057
	1961	117	144,261	78	96,174
Gudu Barrage	1962	120	147,960	79	97,407
	1963	78	96,174	35	43,155
	1964	102	125,766	50	61,650
	1965	101	124,533	62	76,446
	1966	100	123,300	49	60,417
	1967	102	125,766	68	83,844
	1968	118	145,494	66	81,378
	1969	102	125,766	48	59,184
	1970	100	123,300	42	51,786
	1971	105	129,465	25	30,825
	1972	108	133,164	22	27,126
	1973	110	135,630	20	24,660
	1974	149	183,717	95	117,135
	1975	52	64,116	8	9,864
Terbala Dam	1976	100	123,300	41	50,553
	1977	128	157,824	78	96,174
	1978	95	117,135	27	33,291
	1979	141	173,853	80	98,640
	1980	78	96,174	30	36,990
	1981	77	94,941	20	24,660
	1982	90	110,970	32	39,456

TABLE 4.3

INDUS BASIN ANNUAL FLOWS U/S GUDU & D/S KOTRI

Year	Discharges			
	Gudu Barrage U/S		Kotri Barrage D/S	
	MAF	MCM	MAF	MCM
1983	108	133,164	11	13,563
1984	114	140,562	31	38,223
1985	80	98,640	45	55,485
1986	63	77,679	11	13,563
1987	100	123,300	28	34,524
1988	78	96,174	18	22,194
1989	108	133,164	52	64,116
1990	70	86,310	15	18,495
1991	100	123,300	42	51,786
1992	114	140,562	53	65,349
1993	82	101,106	35	43,155
1994	113	139,329	90	110,970
1995	115	141,795	64	78,912
Total (1941 - 95)	5,735	7,071,255	3,260	4,019,580
Average (1941 - 95)	104	128,568	59	73,083
Average * (1956 - 95)	105	129,033	51	63,376
Average ** (1962 - 95)	100	123,336	43	53,382
Average *** (1976 - 95)	98	120,464	40	49,505

* Post Kotri Barrage   ** Post Gudu Barrage   *** Post Terbala Dam

INDUS RIVER FLOWS UPSTREAM GUDU BARRAGE AND DOWNSTREAM KOTRI BARRAGE

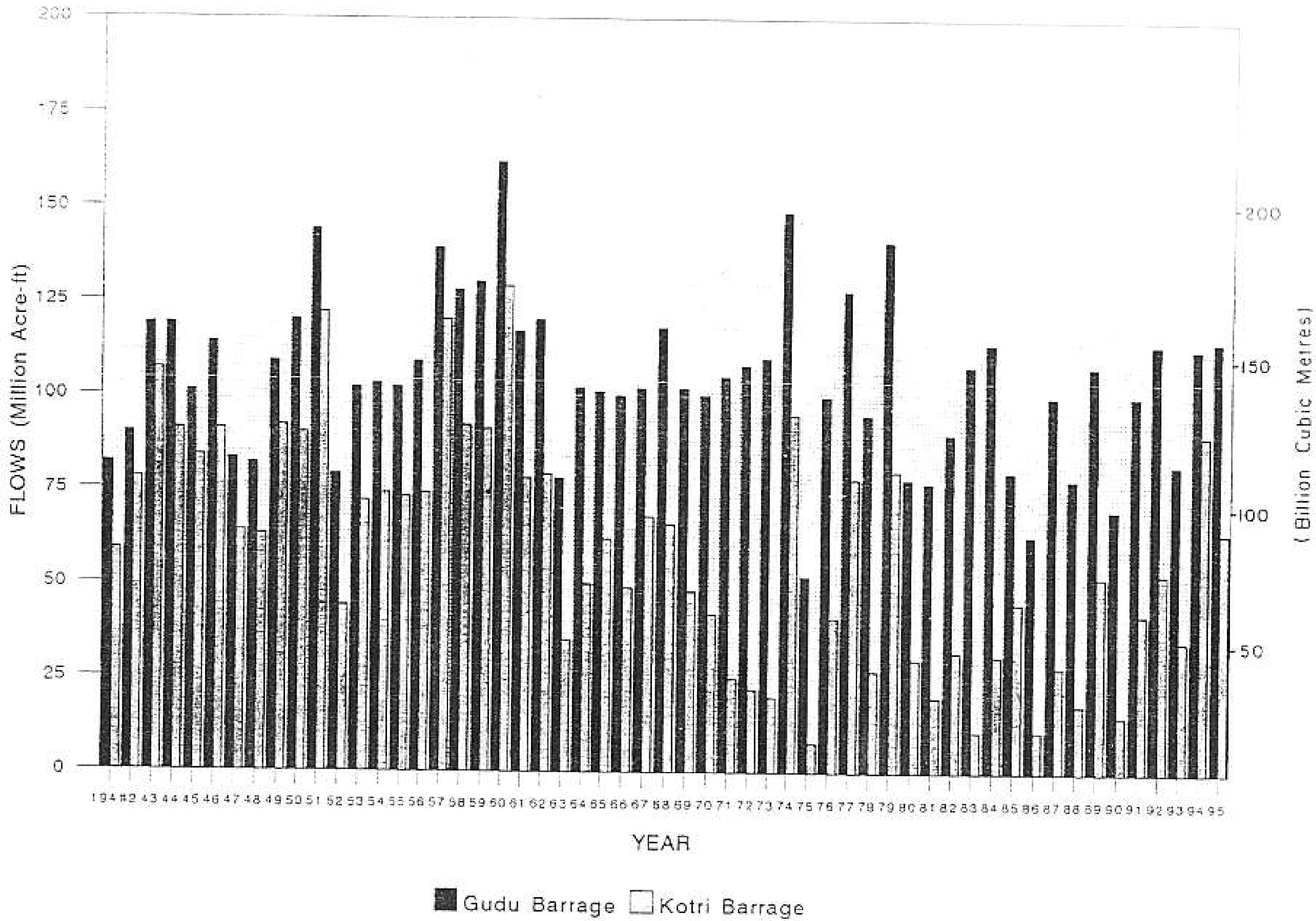


FIG. 4.1

The recharge from these sources is estimated as 68×10^{12} cubic meters or 55 million acre-ft (MAF). Of the total recharge, nearly 62×10^{12} cubic meters (50 MAF) can be exploited, rest is evaporated from the shallow depths and moves from higher elevations to lower ones as regional groundwater to depressional areas or line sources like rivers etc. From the total exploitable recharge, nearly 80 percent is being pumped through tubewells/open wells etc. It has been observed that concerted efforts are required to utilize natural resources of water above 80 percent. The use of high technology has to be resorted to utilize this resource.

Generally, this water is lying as a layer of sweet water over saline water and is spread over an area of about 6.4 Mha (15.86 million acres). Nearly 80 percent ($10 \times 10^9 m^3$) of it can be exploited by utilization of radial collector wells technology*.

Very small amount of this water is already being pumped through radial collector wells or using other technologies like Multiple Well System etc. Alarming shortage of irrigation water for boosting agriculture in some of the saline groundwater areas calls for the adoption of various sophisticated technologies to augment water supplies.

4.3.2.3 Floodflows of Hill Torrents

The hill torrents of Pakistan drain about 65 percent area of the country. The hill torrents possess enormous potential of water which if properly conserved can facilitate in bringing large unproductive areas under sustained agriculture. In addition, management of floodflows would save large number of infrastructure like Chashma Right Bank Canal (CRBC), DG Khan Canal System, Pat Feeder Canal, FP Bund Complex, cities, roads and millions of hectares of agricultural land from frequent flood damages.

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* Source: Optimal Technology for skimming of shallow sweet water overlying saline water, by S.A Bhatti, Chief Flood, NESPAK 1986.

In depth review/analysis of data and studies carried out for hill torrent areas of Pakistan has been given in the five Supporting Volumes of this report while brief review is given in the following chapters of this volume. The studies have indicated that great potential exists for conservation of flood flows of hill torrents and large areas exist in the vicinity of hill torrents where this flow can be used for development of irrigation systems. Table 4.4 gives the culturable waste and water potential of various hill torrent areas of Pakistan. Large parts of culturable waste can be brought under cultivation by conserving water resources of hill torrents. Pakistan has already harnessed the major part of conventional water resources i.e. perennial river and streams. In order to meet the needs of growing population, concerted efforts are required to conserve non-conventional resources of water of which hill torrents occupy the most prominent position.

TABLE 4.4

LAND AND WATER CONSERVATION POTENTIAL
OF HILL TORRENTS OF PAKISTAN

Province	Area	Culturable Waste land		Average Annual Water Conservation Potential	
		(Hectares)	(Acres)	(MAF)	(MCM)
Federal	Northern Area	60,700	149,929	0.940	1,159
	A J Kashmir	33,600	82,992	0.400	493
	FATA *	178,700	441,389	1.500	1,850
	Sub – Total Federal	273,000	674,310	2.840	3,502
NWFP	D I Khan	419,000	1,034,930	0.800	986
	FATA *	178,700	441,389	1.500	1,850
	Hazara, Kabul & Banu	442,300	1,092,481	3.760	4,636
	Sub – Total NWFP	1,040,000	2,568,800	6.060	7,472
Punjab	DG Khan	349,700	863,759	0.854	1,053
	Pothowar	220,800	545,376	1.860	2,293
	Rachna & Chaj Doab	–	–	–	–
	Sub – Total Punjab	570,500	1,409,135	2.714	3,346
Sindh	Khirthar Range	279,300	689,871	0.296	365
	Karachi	64,560	159,463	0.094	116
	Sehwan & Petaro	207,000	511,290	0.330	407
	Sub – Total Sindh	550,860	1,360,624	0.720	888
Balochistan	Indus Basin Component	837,900	2,069,613	4.067	5,015
	Kharan	1,060,500	2,619,435	0.789	973
	Makran	2,781,500	6,870,305	3.000	3,690
	Sub – Total Balochistan	4,679,900	11,559,353	7.856	9,678
	Grand Total	6,935,560	17,130,833	18.690	23,036

* FATA is located in NWFP, but is under administrative control of Federal Government. Hence FATA appears both in NWFP and Federal Areas. However, in grand total, it has been counted once.

5. FEDERAL AREAS OF PAKISTAN

5.1 SUMMARY

Supporting Volume - I, describes the finding made by the Consultants for the Federal Areas. This section of the report briefly discusses the results derived in Supporting Vol-I.

Northern Areas and FATA form the Federal Areas (FAs) which are under the administrative control of a Federal Ministry, Government of Pakistan. In addition, Azad Jammu and Kashmir (AJK) is a separate entity, its overall control is under the same Ministry. The areas under the Ministry of Federal Affairs their location and extent are presented in **Table 5.1**.

Table 5.1
Areal Description of Federal Areas

Name of Area	Area (sq km)	Location	
		Longitudes	Latitudes
Northern Area	72,496	72° 30'E to 78° 20 E	34° 20'N to 37° 05'N
FATA	27,220	69° 20'E to 71° 04 E	31° 04'N to 34° 28'N
AJK	13,291	73° 30'E to 75° 15 E	32° 48'N to 35° 08'N
Total	113,007	72° 30'E to 78° 20 E	32° 48'N to 35° 08'N

These areas are generally inhabitated by two main sociologic classes - the 'Settled' and the 'Tribal'. The 'Settled' area comprises NA and AJK, while FATA comprises seven tribal agencies - Malakand, Mohmand, Khyber, Kurram, North & South Waziristan, Orakzai and Bajaur; alongwith four Tribal Territories/Frontier Regions (TT/FR), ie. FR Bannu, FR Kohat, FR DI Khan and FR Peshawar. Landuse statistics of NA, AJK and FATA are given in **Tables 5.2 to Table 5.4** respectively.

Table 5.2
Landuse Statistics of Northern Areas

Sr. No	Landuse	Area, ha	Percent of Total Area
	Total Geographic Area	7,249,600	100
1	Cultivated Area	69,480	0.96
2	Range Land	3,899,270	53.78
3	Forests	313,000	4.32
4	Mountains	2,615,120	36.07
5	Glaciers	279,200	3.90
6	Rivers, Streams and Lakes	12,800	0.17
7	Culturable Waste	60,700	0.80

Table 5.3
Landuse Statistics of FATA

Sr.No	Landuse	Area, ha	Percent of Total Area
	Total Geographic Area	2,720,000	100
1	Cultivated Area	162,130	5.96
2	Annual Cropped Area	227,00	8.34
3	Area Sown More than once	64,870	2.38
4	Uncultivated Area	2,557,870	94.04
5	Culturable Waste	178,700	6.57

Table 5.4
Landuse Statistics of AJK

Sr.No	Landuse	Area, ha	Percent of Total Area
	Total Geographic Area	1,329,700	100
1	Cultivated Area	172,80	13.00
2	Annual Cropped Area	244,186	18.36
3	Area Sown More than once	71,386	5.37
4	Irrigated Area	18,712	1.41
5	Uncultivated Area	1,123,197	84.47
6	Culturable Waste	33,600	2.53

Water conservation can be carried out in these areas through the construction of small stroage/delay action dams, dispersion structures, check dams etc. The potential of land and water resources of FAs has been discussed in detail in the following sections of this chapter separately for each area.

In NA large number of potential sites exist for the construction of small perennial and flood irrigation schemes. In addition, some sites have been identified where low head dams can be constructed. The Consultants have identified nine schemes in NA, and 31 in AJK. In FATA, the Project Team identified 188 sites, while 75 additional sites for small dams have been located by FATA DC. However, there is potential for more sites where low level dams/dispersion structures can be constructed to conserve flood flows of rivers/nallahs in all the Federal Areas, which can be used to cultivate parcels of land in the close vicinity of rivers. In some areas,, major problem is the erosion of land which can be protected by constructing flood walls along the river banks. Remote sensing and GIS can be used to properly plan for conservation of flows for bringing additional areas under cultivation. Surface water potential of FAs is given in **Table 5.5**.

Table 5.5
Surface Water Potential of Federal Areas

Area	Total Potential		Existing Uses		Balance Available for Development	
	m^3	MAF	m^3	MAF	m^3	MAF
NA	2.00×10^9	1.62	0.84×10^9	0.68	1.16×10^9	0.94
AJK	0.86×10^9	0.70	0.36×10^9	0.30	0.50×10^9	0.40
FATA	2.93×10^9	2.37	1.07×10^9	0.87	1.86×10^9	1.50
TOTAL	5.79×10^9	4.69	2.27×10^9	1.85	3.52×10^9	2.84

FAs are generally mountainous and hills country. These areas are generally known to be land deficient. However, there exist some isolated plain areas. Land is also available along the river/nallah banks and terraced hill slopes. The identified land potential of FAs is summarized as below:

Federal Area	Land Potential	
	ha	acres
NA	60,730	150,000
AJK	33,600	82,990
FATA	178,700	441,390
TOTAL	273,030	674,380

The schemes proposed for NA, AJK and FATA are based upon the field visit and sites identification by the Project Planning Team. The preliminary cost estimates of these schemes are Rs 218 million, Rs 310 million and Rs 2,806 million for NA, AJK and FATA respectively. In addition, provision of Rs 770 million and Rs. 515 million has been made for un-identified schemes in Northern Area & AJK respectively. The aggregate cost for schemes for Federal Areas is Rs 4,619 million. The proposed plan can be substantiated by detailed surveys and field investigations which is only possible through modern techniques like satellite imageries, GIS and GPS. The additional sites are likely to be identified by using the latest state of the art.

5.2 NORTHERN AREAS

5.2.1 Introduction

The entire NA comprise about 7,250,000 ha of which only 0.95 percent is under farming. The area under orchards is 14 percent of the farm area. Northern Areas have considerable potential of horizontal expansion of agriculture (increase in area) because of the availability of large amount of surface flows. Although land is a limiting factor for the development of agriculture, it is available in the form of patches/strips of various sizes in different areas. Large plain areas are also present in some of the valleys. It is imperative to manage the torrent flows to ensure the regular supplies to the existing irrigated areas as well as development of new areas.

The floods of Northern Areas generally cause erosion of river banks due to high velocities. Valuable tracts of land with crops, orchards etc are washed away depriving the beneficiaries from their major source of income. The population of Northern Areas has almost doubled since 1972. The population growth rate as estimated vide 1981 census is 3.8 percent as against the national rate of 3.1. This essentially warrants the optimal utilization of land and water resources to meet the growing needs of food, fibre and shelter as well as the socio-economic amelioration of the area.

5.2.2 Project Area

5.2.2.1 General

Northern Areas are situated between longitudes 72° 30 to 78° 20′ E and latitudes 34° 20′ to 37° 05′ N comprising the northern part of Pakistan. Northern Areas comprise five districts - Gilgit, Skardu, Diamer, Ghizar and Ghanche. NA encompasses 72,496 sq km (27,990 sq miles) having China in the north, State of Jammu and Kashmir in the east, Province of NWFP and Afghanistan in the west and south. Exhibit M-5.1 shows the Northern Areas.

5.2.2.2 Area and Population

As already indicated, the entire area of NA is 72,496 sq km (27,990 sq miles). The population of the area in 1972 was recorded as 416,000 persons, which grew to 650,000 upto 1981. The population growth rate was estimated as 3.8 percent wherefrom it is estimated that the current population of the area is about 900,000. This reveals that the population has grown to more than double since 1972.

Northern Areas comprise rugged mountainous terrain. The physiography is characterized by series of mountainous ranges with sparse to medium vegetal cover. Dry and barren peaks are intermittently found among perpetually snow covered tops and glaciers.

The area is extensively interspersed by rivers and hill torrents. Indus River is the main stream of the natural drainage network. Shigar, Hunza, Gilgit and Astor rivers are the main tributaries which drain different parts of NA. Apart from these, large number of hill torrents of different sizes drain the area. Most of the springs and hill torrents are perennial and are fed by snowmelt of glaciers. A number of lakes are also found in NA.

5.2.2.3 Climate

The climate of the area is cold in winter and hot in summer at the low elevations in parts of Diamer and Gilgit. However, the climate of other districts and valleys e.g. Baltistan, Ghizer, Hunza, Nagar, Darel, Tangir etc is pleasant in summer and cold in winter as they are situated on higher elevations. The rainfall in the areas is scanty and non-homogenous. Mean annual rainfall varies from 375 mm (15 inches) in southern parts of the region to 125 mm (5 inches) in the north with an average annual of 254 mm (10 inches). The areas above 1,500 meters (5,000 ft) msl receive winter precipitation, mostly in the form of snow. Reliable data about the amount of snowfall is not available. The seasonal rainfall distribution indicates that 30 percent is received from December to March, 35 percent during April and May, 30 percent during June-September; and 5 percent in October-November. These statistics reveal that about 70 percent of the precipitation occurs during summer, while October and November are relatively dry months.

5.2.2.4 Economy

Like other parts of the country, agriculture is the main source of economy of Northern Areas. Agriculture sector is based on traditional methods which lead to low level outputs and yields. Due to increase in population, agriculture sector has come under pressure which has necessitated the transportation of foodgrain from other parts of the country. The present state of economic affairs is grossly inadequate for promoting modernization/ development in other sectors and industries. The crops and livestock resources are limited. However, efforts for producing high yielding variety of potato and its marketing in various parts of Pakistan is likely to boost up the agricultural production of the area.

5.2.3 Land and Water Resources

5.2.3.1 Land Potential

Soil and Land Classification Surveys have been undertaken over an area of about 3,666,000 ha (9,059,050 acres). The rest of the area is under glaciers. Class-I (Good Arable) and Class-III (Moderatly Arable) lands occupy 29,246 ha (72,238 acres) and 62,112 ha (153,416 acres) area, respectively. These are the only promising areas available for farming in the entire catchment. Class IV (special use) land covers 829,216 ha (2,048,164 acres) of the study area. These lands may be developed as grazing/range land or for forestry. The remaining (about 75%) area is agriculturally unproductive.

A summary of the component land classes which have been worked out from the land capability classes is presented in **Table 5.6.**

Table 5.6
Summary of Land Capability Classes

Class	Land Capability	Hectare	Acres	%age
II	Good Agricultural Land	29,246	72,238	0.8
III	Moderate Agricultural Land	62,112	153,416	1.7
IV	Special Use Land	829,216	2,048,164	22.6
VI	Agriculturally Un-productive Land	2,741,726	6,775,080	74.8
Unclassified	Built-up Land	3,700	9,144	0.1
Total:		3,666,000	9,058,042	100.0

5.2.3.2 Water Potential

Northern Areas generally receive rainfall during monsoon season and snowfall in winter. The isohyetal map of the area indicates that the average annual rainfall over the area varies from 125 mm in the south to 375 mm in the north. However, the annual mean of precipitation over the entire NA is about 254 mm. This is equivalent to a volumetric amount of $1.47 \times 10^{10} m^3$. Keeping in view the catchment characteristics, it has been estimated that this amount of equivalent precipitation generates about 6.6×10^9 m^3 (5.36

MAF) of runoff, of which about 70 percent directly moves to the major tributaries of Indus River.

Presently, Northern Areas have almost 5,000 small schemes which irrigate grossly about 70,000 ha of land. The annual consumption of water in this area is estimatedly about $8.40x10^8$ m^3. The surplus runoff thus available is over $1.16x10^9$ m^3 (0.94 MAF). This flow can be utilized for exploiting the available land potential of 60,700 ha (culturable waste) Northern Areas by proper conservation.

5.2.4 Perspective Management Plan and Cost Estimates

5.2.4.1 Proposed Plan

Northern Areas of Pakistan are short of flat-lands and plain areas having a soil cover of reasonable depth, which is a pre-requisite for crop production. These patches/strips of land only exist at the foothills, and along the banks of hill torrents/rivers and the plateau. This state of affairs necessitates the adoption of a unified strategy which would essentially comprise the protection as well as development of land areas for utilization of conserved flows. This strategy is based upon the characteristic conditions of the Project Area observed during a comprehensive reconnaissance visit of a team of Consultants experts comprising engineers, planners, hydrologists, and agro-economists.

Nine potential schemes have been identified in NA. These schemes include the construction of small storage dams of varying heights from 7 to 15 meters. These schemes are:

- Gakuch Bala
- Chish
- Jutial
- Satpara
- Dal Nati
- Northang
- Botoga Upper
- Botoga Lower
- Gespian

These schemes are likely to irrigate about 8,500 ha (21,000 acres) of land. In addition to this, there are large number of sites where perennial flood irrigation schemes can be developed. In order to identify these sites use of satellite imageries and GIS would be required due to difficult approach conditions. Preliminary studies carried out from the G.T Sheets & other information have indicated that over 30 additional sites would be identified after in depth studies by use of satellite images & GIS/GPS.

5.2.4.2 Cost Estimates

The preliminary estimate of the cost of the individual schemes varies from Rs 10 million to Rs 50 million depending upon the size and location of each dam. Total Cost of the nine dams aggregates to about Rs 218 million. In addition, a provision of Rs 770 million has been made for un-identified sites, which would bring about 30,000 ha additional area under cultivation. This area is about 50 percent of the total culturable waste of the area.

5.2.4.3 Recommendations

The proposed schemes may be executed after comprehensive feasibility studies and detailed designs. More schemes may also be planned with modern survey techniques to overcome the inaccessibility of various parts of the area. The proposed package alongwith cost is given in **Table 5.7.**

5.3 AZAD JAMMU & KASHMIR

5.3.1 Introduction

Erosion of agricultural land along the banks of rivers/nallahs and soil from the slopes of hills is one of the most serious environmental and socio-economic hazards in Azad Jammu and Kashmir. The land areas are generally developed along the vicinity of river banks and by converting the slopes of hills into terraces by strenuous efforts. The high velocity of river currents erode low lying areas alongwith crops and deprive the farmers of their major source of livelihood. Reclamation of agricultural land sometimes takes decades and the

TABLE 5.7

POTENTIAL SCHEMES OF NORTHERN AREAS

SR NO	SCHEME/DAM	HEIGHT, Meters	PRELIMINARY COST, Rs Million	AREA TO BE IRRIGATED, ha
(A)				
1	Gakuch Bala	8	50	2,000
2	Chish Dam	15	30	800
3	Jutial Nallah	15	20	1,000
4	Satpara Dam	15	20	1,500
5	Dat Nati Dam	6	10	400
6	Northang Maidan	7	15	500
7	Botoga Upper	10	25	600
8	Botoga Lower	12	30	1,200
9	Gespian	7	18	500
	TOTAL		218	8,500
(B)	Identified Sites for – Flood Irrigation – Delay Action Dams – Dispersion structures		770	*30000
	Grand Total:–		988	38,500

* Total Culturable waste is 60, 700 ha. It is expected about 50 percent of total could be brought under cultivation after conservation of water resources of the area.

people are subjected to prolonged period of poverty. The erosion of fertile top soils from the hill torrent slopes has resulted in depletion of nutrients content from land, thereby, reducing the yield of crops and degradation of ecological system.

Cultivated area of AJK at the time of independence was about 136,000 ha. Per capita cultivated area has decreased from 0.2 ha to 0.06 ha since 1947 which is about 30% of the original area. In addition, the yield of various crops is 60 percent of the yield of corresponding crops in Pakistan and 20 percent of that of the world average.

This state of affairs warrants optimal planning of land and water resources in order to meet the basic demands of food and fibre for the increased population.

5.3.2 Project Area

The Project Area (AJK), as shown on Exhibit M-5.2, embodies an arc shaped stretch of territory bordering the Indian-held State of Jammu and Kashmir on the east; Province of Punjab on the south and southwest; NWFP on the west; and Northern Areas on the north. Administratively, the area is divided into two Divisions, seven districts, 19 Tehsils and 1,646 villages. The Project Areas is located between longitudes 73° 30'E to 75° 15'E and latitudes 32° 48' N and 35° 08' N. Total area of AJK is 13,291 sq km (5,134 sq miles) which is 35.57 % of the entire area of the State of Jammu and Kashmir while the rest of the area has been occupied by India.

Average annual precipitation in the area ranges from about 500 mm (20 inches) to 1,525 mm (60 inches). The rainfall occures almost throughout the year. Rainfall in the central part of AJK in Muzaffarabad, Rawlakot and Bagh areas is about 1,400 mm (55 inches). The northern and southern parts receive an average of about 900 mm (35 inches) of rainfall. The rainfall is fairly uniform throughout the year and to a great extent can support orchards and other cash crops. The average annual rainfall is about 1140 mm (45 inches).

5.3.3 Land and Water Potential

5.3.3.1 Land Resources

Land resources of AJK are very limited as only about 15.5 percent of the total area is cultivable. The land use statistics are given as under:

Total Geographical Area			-	1,329,700 ha
A)	Area Controlled by Forest Department		-	566,969 ha
	i)	Productive Area	-	378,560 ha
	ii)	Non Productive	-	188,409 ha
B)	Cultivable Area		-	206,390 ha
	i)	Cultivated	-	172,800 ha
	ii)	Culturable Waste	-	33,590 ha
C)	Area not available for Cultivation/Forestry		-	566,341 ha

At present only about 13 percent of the total area is being cultivated with a cropping intensity of about 84 percent.

5.3.3.2 Water Potential

The entire AJK area is drained by the Jhelum River and its tributaries with the exception of a small strip of the area, which is drained by tributaries of Chenab River. From the point of view of drainage, the Project Area can be divided into the following sub-basins:

- Neelum River Basin;
- Upper Jhelum River Basin;
- Punch River Basin; and
- Bhimber Nallah Basin - Chenab River

Neelum River drains the northern high lands of AJK and outfalls into Jhelum River at Muzaffarabad near Domail.

Kunhar River flows along the western boundary of the state and then joins Jhelum River below Muzaffarabad. Kanshi River drains part of the Pothowar area of Punjab and joins Jhelum upstream of Mangla Dam. Several big hill torrents originate in Mirpur District and join Chenab River in Punjab Province. Punch River originates from the Indian held territory and moves in the south west direction. It drains Hajira-Kotli Area and outfalls into Mangla Lake.

It has been estimated that the entire area of AJK receives about $1.52x10^{10}m^3$ of equivalent rainfall where the runoff potential is quite high. Due to uniform distribution of rainfall throughout the year, the moisture conditions of soil remain favourable for substantial runoff generation. The average annual runoff is thus estimated to be about $5.3x10^9m^3$ (4.3 MAF). Over 84 percent of total runoff outfalls in Jhelum River and its tributaries. Slightly over 40 percent of the balanced runoff is being used at present while nearly $0.5x10^9m$ (0.4 MAF) is available for further exploration through conservation measures. The potential volume of water which can be exploited annually is about $4.9x10^8$ m^3 (0.4 MAF). This could be used to irrigate a part of 33,600 ha of culturable waste.

5.3.4 Perspective Management Plan and Cost Estimates

5.3.4.1 General

A report was prepared in 1995 for the water resources planning for AJK with the title "Comprehensive Flood Management Planning (CFMP) in different Areas of Azad Jammu & Kashmir". In this report, 31 sites were identified in various areas of AJK suitable for check dams as given below:

- Bagh District 2 No.
- Kotli District 4 No.
- Mirpur District 25 No.

A number of sites were visited to study their land and water potential. Interviews of beneficiaries were also held to know their views about the construction of check/storage dams for water conservation and to use stored water as a source for development of sustained irrigation system. The list of schemes along the location of site and the corresponding district is given in supporting Volume-1.

5.3.4.2 Recommended Plan

AJK has an area of about 33,600 ha (83,025 acres) as a culturable waste. This area is located as small parcels of land in various parts of AJK. This area is not being cultivated because of non availability of water. The estimated cost for development of perennial/flood irrigation schemes and construction of flood walls and delay action/storage dams is Rs 310 million as given in the (CFMP). **Table 5.8** enlists the name of 31 identified sites, their locations and total estimated cost. In addition, provision has been made for Rs 555 million for unidentified schemes. Thus estimated cost of overall perspective plan is Rs 815 million. The implementation of these schemes is estimated to bring major part of culturble waste of 33,600 ha. In order to study the conjunctive project of land protection and water conservation, the following recommendations are made:

- Satellite imageries be used for exact quantification and location of parcels of culturable waste;

- Sites for delay action/storage dams on various nallahs/tributaries be identified using satellite images and GIS/GPS;
- Water budget analysis be carried out for each conservation site viz-a-viz available land and crop water requirement;

- Mode of commandability be studied for each site in detail; and

- Bankable Documents be prepared for landuse and water conservation of the area.

TABLE 5.8

IDENTIFIED CHECK DAM SITES

S.NO	NALLAH	SITE	DISTRICT
(A)			
1	Jabbar Kas	Birpani	Bagh
2	Sahalian	Shahalian Maldialan	Bagh
3	Tributary of Banaban River	Seri & Parati	Kotli
4	Mehjan Bata	Mehajan	Kotli
5	Tributary of Sheen Kas	Dhallon	Kotli
6	Tributary of Nuhi–Sarota Nallah	Kotla	Kotli
7	Salam	Salam (Bhimber)	Mirpur
8	Vehilli Nullah	Mithi Ret (Bhimber)	Mirpur
9	Mawa Nullah	Paina Da Gora	Mirpur
10	Pawa Ducky	Kanaili	Mirpur
11	Sakhrala Wala Kas/Gora Patni	Qilla Burjan	Mirpur
12	Jhanda Kas	New Jhanda	Mirpur
13	Chanara (chatyar) Kas	Romali	Mirpur
14	Watalah	Kot Jamil	Mirpur
15	Kulian Rohi Nullah	Rohi Shahid	Mirpur
16	Banni Nullah	Banni	Mirpur
17	Suketar	Beta	Mirpur
18	Suketar	Gangrila	Mirpur
19	Dal	Dal	Mirpur
20	Chaukiwala	Chaukri	Mirpur
21	Ambgai	Dal/Mehra	Mirpur
22	Bagh	Chitti Miti	Mirpur
23	Samani Kas	Sairi	Mirpur
24	Samani Nullah	Pind Sohlana	Mirpur
25	Drad Tatali	Drad Jatali	Mirpur
26	Baghsar	Kotla/Chhowa	Mirpur
27	Bandala	Sarai/Dal	Mirpur
28	Uchilli	Sandoa Cross/Sodheri	Mirpur
29	Sahalia	Kund	Mirpur
30	Mangwar	Mangwar, Kaljur	Mirpur
31	Lahanda/Dheri Qasim	Dheri Qasim	Mirpur
	Estimated Cost for Identified Schemes Rs.		310 Million
(B)	Estimated Cost for Unidentified Schemes Rs.		515 Million
	Grand Total Rs.		825 Million

5.4 FEDERALLY ADMINISTERED TRIBAL AREAS (FATA)

5.4.1 Introduction

Inadequate exploitation of land and water resources has been a major cause of backwardness for Federally Administered Tribal Areas (FATA). In 1972, the Federal Government established FATA Development Corporation (FATA DC) to coordinate and accelerate the socio-economic uplift of the area. Since then, considerable progress has been made but it is incommensurate with the potential resources and requirements of the area.

Of the total geographic area, nearly 6.6% i.e. 180,000 ha is under cultivation while another seven percent is culturable waste. About 50 percent of the cultivated area is irrigated while the remaining is rainfed. Per hectare yield in FATA is about one half of that of Pakistan and 20 percent as compared to countries with high yields. Forests occupy only about one percent of the total area. There has only been about 50 percent increase in the cropped area in the last five decades, while the increase in yield has been by about 30 percent during the last 15 years.

The area has a large development potential. The land and water resources of FATA, if properly harnessed, can play a vital role in the uplift of the local economy.

5.4.2 Project Area

5.4.2.1 General

Federally Administered Tribal Areas (FATA), consisting of seven Agencies and Four Frontier Regions, have undergone a maze of geopolitical process. The process of FATA's administrative formation started during Second Afghan War of 1878 with the creation of Khyber Agency and appointment of a special political officer for its administration.

All the seven agencies and four frontier regions are contiguous to each other and are spread over an area of 27,220 sq km with about 3.6 million inhabitants. The area lies between longitudes 69° 20'- 71° 04'E and latitudes 31° 4' - 34° 28'N, and is bounded by Afghanistan on the west, Malakand and Peshawar districts on the north; Kohat, Bannu, and Dera Ismail Khan districts of NWFP on the east, and Balochistan Province on the south as shown in **Fig. 5.1**. FATA primarily consists of dry mountains of heights varying from 610 meters to 2,130 meters. **Table 5.9** presents a summary of the area distribution.

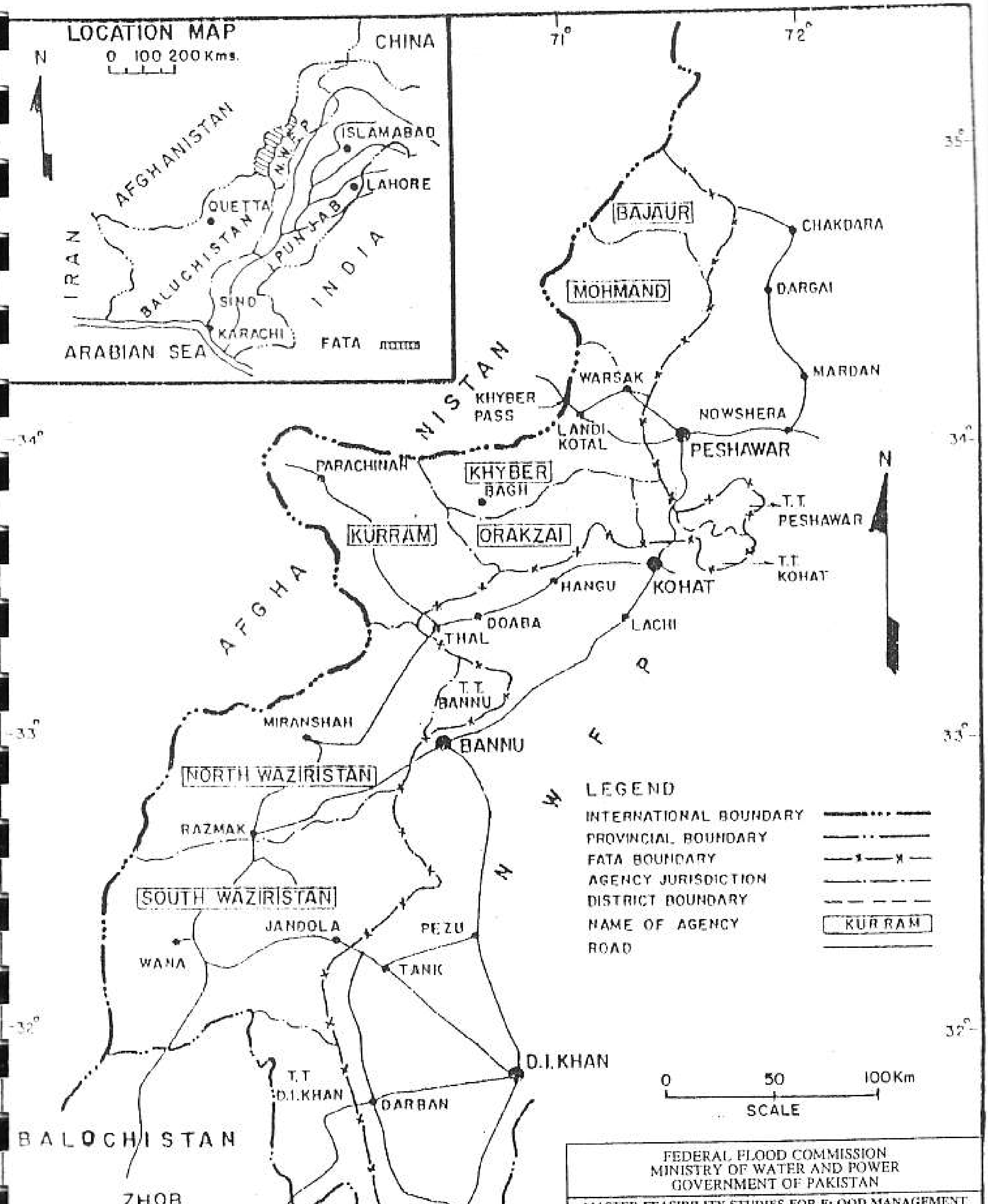
Table 5.9
Fata Area Distribution

Description	Area (sq km)	Percentage of Total Area
Total Geographical Area	27,220	-
Mountains	23,323	85.68
Forests	312	1.14
Valleys/Plains	3,505	13.17
Cultivated Area	1,798	6.60
Irrigated Area	860	3.25
Culturable Waste	1,787	6.57

5.4.3 Land and Water Potential

5.4.3.1 <u>Land Capability Classification</u>

The soils have been classified into four land capability classes under potential conditions according to USBureau of Reclamation System (U.S.D.I 1950) except some modifications made to suit the local conditions. The statistical data of these classes is presented in **Table 5.10**.



FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

FLOOD MANAGEMENT OF FATA HILL TORRENTS

PROJECT AREA MAP

NESPAK
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD

FIG 5.1

The Class I and Class II (very good and good irrigable lands) collectively cover 13.4 % of FATA. These lands are well to moderately well suited for most of the crops adopted to the climate of the area. Class IV land occupies 31.2% of the study area. These are special use lands. The remaining 55.4 % area is non-arable land. The distribution of land capability classes is summarized in **Table 5.10.**

Table 5.10
Summary of Land Capability Statistics of Fata Hill Torrent Areas

Mapping Symbol	Land Capability Class/Sub-Class	Extent	
		ha	%
I-IIs	Class I - II Land	313,407	11.5
I-VIste	Class I - IVste Land	65,777	2.4
I-IVste	Class IVste Land	835,753	30.7
VI	Class VI Land	1,507,063	55.4
Total:		2,722,000	100

5.4.3.2 Water Resources

Water potential of the area is estimated as below:

-	Total Area	=	27,200 sq km
-	Average Annual Rainfall	=	430 mm
-	Equivalent Volume	=	$2.72 \times 10^6 \times 0.43$
		=	10.17×10^9 m^3
		=	9.47 MAF
-	Estimated Runoff (with 25% runoff coefficient)	=	2.37 MAF
-	Existing Water Uses		
	a) Irrigated Area	=	88,000 ha = 217,000 acres
	b) Average Depth of Water/acre	=	1.22 m = 4 ft
	c) Total Water Use		0.217 x 4 = 0.87 MAF
-	Balance available water potential for future development	=	1.50 MAF

This surplus could be used by conservation of runoff by constructing small storage/delay action dams for bringing culturable waste of 178,700 ha (441,400 acres) and by increasing cropping intensity of areas being cultivated through provision of additional water.

5.4.4 Development Plan and Cost Estimate

Preliminary investigations carried out for the Project have helped in the identification of sites for construction of dams. Status of planning studies is summarized as:

- Number of sites identified = 263
- Number of Dam Sites - Preliminary Studies = 28
- Number of Dam Sites - Preliminary Surveys = 160
- Number of 4-Dam Sites - Identified = 75

Summary of the schemes is given in **Table 5.11.** The name of schemes, their location and cost estimates are provided in Supporting Volume-1.

It has been observed that in-depth studies for conservation of flows of hill torrents and their optimal development for sustainable agricultural activities are required for the area.

Detailed Feasibility Investigations for FATA are required to be carried out to identify all potential sites for construction of dams. Latest satellite imageries, GPS and GIS should be used to estimate storage capacities for various heights, land capability and potential for integrated use of land and water resources of the area.

TABLE 5.11

ABSTRACT OF ACTIVITIES ON SMALL DAMS

Sr No	Name of Agency / FR	No. of Sites Identified	Preliminary Studies Carried out	Preliminary Surveys Carried out
(A)				
1	Bajaur	22	5	17
2	Mohmand	26	1	25
3	Khyber	19	1	18
4	FR Peshawar	8	--	8
5	Orakzai	20	--	20
6	FR Kohat	13	1	12
7	Kurram	14	1	13
8	North Waziristan	26	12	14
9	FR Bannu	8	--	8
10	South Waziristan	17	4	13
11	FR DI Khan	15	3	12
	TOTAL	188	28	160
			Estimated Cost	Rs 1,981 Million
(B)	Additional identified sites in South Waziristan and and FR D.I.Khan.	75	Estimated Cost	Rs 825 Million
	Grand Total	263	28	Rs 2,806 Million

6. NORTH WEST FRONTIER PROVINCE

6.1 SUMMARY

NWFP including FATA encompasses an area of 101,741 sq.kms (39,285 sq miles). It is situated between longitude 69° 14'E - 74° 8'E and latitudes 31° 3'N - 36° 57'N. It has a population of about 20 million. The terrain of the Province varies from lofty mountains with rugged valleys to undulated and dissected mountain plateau and flood plains. Kohi-Sufed has a number of cliffs with heights above 4,000 meters above mean Sea level (msl). Sekarum is the highest cliff with a height of about 5,000m. The climate of the area is generally hot during summer and cold during winters. Snowfall occurs during winter in areas having high elevations.

Land and water resources of NWFP present a complex mixture of constraints and abundances. There are areas where land resources are limited and water resources are in abundance, whereas in others it is the reverse. However, in some parts of the area both the resources are abundant. Optimal management of these resources is the dire necessity of the area to develop agriculture which has been and continues to be the principal driving force of the economy of the Province. The Province is heavily dependent for its food and fibre requirement on other Provinces of Pakistan or foreign imports. Of the total area of 101, 741 sq.km, mountainous area encompasses about 51,878 sq.km which is about 51 percent of the total area. Cultivated area is nearly 19,340 sq.km which is about 9 percent of the cultivated area of Pakistan and 19 percent of the total area of the Province. Uncultivated area is 64,200 sq.km which is 63 percent of the total area of NWFP. However out of this, potential exists to bring about 10,100 sq.km (Culturable Waste) additional area under cultivation if harnessing of surplus water resources can be earnestly taken in hand. Of the total cultivated area of 19,380 sq.km, only 8,900 sq.km is irrigated while the balance 10,480 sq.km (about 54%) is rainfed/ barani where yield is about 1/3 of that of the irrigated agriculture. There is, thus, great potential for horizontal (increase in area) and vertical (increase in yield/unit area) expansion of the agriculture of the area.

Average annual rainfall in the Province is 626 mm. Landuse statistics of the Province are given in Table 6.1.

Table 6.1

Landuse Statistics of NWFP

-	Total Geographic Area	=	101,741 sq km
-	Reported Area	=	83,580 sq km
-	Mountainous Area	=	51,678 sq km
-	Cultivated Area	=	19,380 sq km
	• Irrigated	=	8,900 sq km
	• Rainfed	=	10,480 sq km
-	Uncultivated	=	64,200 sq km
	• Culturable Waste	=	10,400 sq km
	• Forests	=	12,900 sq km
	• Not Cultivable	=	40,200 sq km

These statistics indicate that only 8.7 percent area of the Province is under regular/irrigated agriculture. This is hardly 5.7 percent of the entire irrigated area of Pakistan upon which depends nearly 14 percent of total population of the country. This demographic imbalance warrants the exploitation of available land and water resources in order to bridge up the gap between demand and production of agricultural production, especially the food grain.

In order to plan utilization of the water and land potential of NWFP, the Province has been divided into the following three rational zones:

i) Dera Ismail Khan (DI Khan) Hill Torrents (Core Project)

ii) Hazara Kabul Bannu Basin (HKB Basin)

iii) Federally Administered Tribal Areas (FATA)

Brief description of the three basins is given as:

6.1.1 D.I. Khan Hill Torrents

Feasibility level studies have been carried out for DI Khan Hill Torrent area. In all, 25 distribution/dispersion structures and channelization schemes have been proposed, with an estimated cost of Rs 354 million. According to Soil and Land Potential studies carried out for the area, 390,105 ha (963,560 acres) of 'very good' and 'good' agricultural/arable land exists in the area. Rud Kohi (Spate) irrigation system is already commanding an area of 80,000 ha with low irrigation and cropping intensities. Total water potential of the area is 1.33×10^9 m^3 (1.08 MAF) of which 3.46×10^8 m^3 (0.28 MAF) is currently being utilized. Balance runoff 9.88×10^8 m^3 (0.80 MAF) is available for increasing the irrigation intensities of existing cultivable area and for bringing new areas under cultivation. The culturable waste of DI Khan is about 419,000 ha (1,034,930 acres). This land is presently not being irrigated, because of non-availability of water resources. By properly conserving flood flows of hill torrents of the area, major part of culturable waste can be brought under cultivation.

6.1.2 HKB Basins Hill Torrents

In HKB Basin, the position of potential, water conservation sites is as follows:

•	Sites Identified for	=	118 No
-	Pre-feasibility	=	65 No
-	Detailed Studies	=	24 No
-	Feasibility Studies	=	11 No
-	Detailed Design & Tender Documents	=	9 No
-	Under Construction	=	5 No
-	Approved for Feasibility Studies	=	4 No

So far 118 sites have been identified for construction of small dams in HKB Basins. Pre-feasibility studies have been carried out for some of the sites, while 11 promising sites have been selected for feasibility studies. Nine sites were prioritized for detailed design and tender documents. At present, five schemes are under construction stage.

Water Potential of HKB Basin aggregates to about 1.27×10^{10} m^3 (10.26 MAF), of which 8.02×10^9 m^3 (6.50 MAF) is currently being utilized and/or moves to the river system. The balance runoff of 4.68×10^9 m^3 (3.76 MAF) is available for utilization. The culturable waste of HKB basin is about 442,300 ha, which could be brought under cultivation after properly conserving water resources of the area.

6.1.3 FATA Hill Torrents

In FATA, 263 sites for the construction of small dams have been identified where total water potential is 2.93×10^9 m^3 (2.37 MAF). Of this, 1.07×10^9 m^3 (0.87 MAF) is under utilization. The remaining 1.85×10^9 m^3 (1.50 MAF) is available for exploitation. Estimated Cost for the conservation of water resources at 263 sites is about Rs 2,806 million.

Culturable waste of FATA is about 178,700 ha which has potential for irrigated agriculture if water resources of the area could be conserved.

It is recommended that the schemes of the 'Core Project - DI Khan' may be executed after detailed designing. The schemes of FATA for which feasibility studies have been carried may also be included in the package. Detailed feasibilities may be carried out for all the rest of the schemes of HKB Basin and FATA.

As description regarding FATA has already been included in Section-5 of this report, hence this Section deals with DI Khan and HKB Basins only.

6.2 DI KHAN HILL TORRENTS

6.2.1 Introduction

Rod Kohi irrigation is the traditional system practised in the piedmont plains of Suleiman Range since the beginning of 20th century. Initially, the system was quite efficient and it commanded about 200,000 ha (494,000 acres) which has presently been reduced to about 80,000 ha (197,600 acres) due to malfuncting of dispersion structures, their poor maintenance and exodus of agricultural labour to Chashma Right Bank Canal (CRBC) Project and Middle East. The present condition of Rod Kohi system warrants an effective management of the flood flows of hill torrents of the Project Area.

The local farmers construct earthen dykes (Gandas) across smaller branches of torrents that divert flood water to their embanked fields. The Gandas, however, remain functional only during low to medium intensities of incoming flows. Flash floods, especially in the monsoon season, often damage the Gandas and proceed to tail reaches unobstructed with great velocities. The primary reason for this lack of control over high floods is the absence or malfunctioning of control and distribution structures at the branching points.

Restoration and upgrading of the existing structures as well as provision of new control/distribution structures at strategic locations is therefore required for the optimum utilization of flood flows. This will not only boost up the agricultural production and livestock rearing but also minimize the flood losses resulting in economic uplift of the inhabitants of the areas. In order to effectively manage flood flows, in depth studies have been carried out for estimation of available land and water resources for preparing the proposed plans and designs which are presented in the following sections. Efforts have been made to use local materials and manpower for the construction of proposed structures as far as possible. Economic evaluation has been carried out to assess the viability of proposed measures.

6.2.2 Project Area

The Project Area (DI Khan Division) comprises the districts of DI Khan and Tank. It is located between latitudes 31° 15' N - 32° 31' N and longitudes 70° 05' E - 71° 22' E.

Total Area of DI Khan Division is about 9,005 sq kms (3,477 sq miles) with a gross population of nearly one million. The tribal area attached to DI Khan Division is 3,230 sq kms (1,262 sq miles) with a population of abut 150,000. Exhibit M-6.1 shows the Project Area.

Rud Kohi Irrigation System of Damni Area basically comprises 12 flood channels which originate from Suleiman Range through different gorges in the Project Area. Out of these, six major hill torrents are called as 'zams' while the remaining six small hill torrents are named as 'ruds'. The zams ie. Panyala, Tank, Gomal, Shaikh Haider, Daraban and Choudhwan fan out into 19 channels. These are further divided into minor distributaries (wahs) to take water into the fields. This network of channels aggregates to 1,168 km (730 miles) in length. In addition to this, a number of other small channels (wahs) also lie in the Project Area. With the passage of time, a number of diversion weirs/distribution structures have been constructed on the network to divert flow in different channels.

6.2.3 Land and Water Resources

6.2.3.1 Land Capability Classification

The soils of the Project Area have been grouped into four land capability Classes (I, II, IV and VI) according to Bureau of Reclamation System (USDI 1950) except some modifications made to suit the local conditions.

Class-I - Arable (Very Good Agricultural Land)

This class extends over 27.2 percent of the Project Area. The land is located in the nearly level to gently sloping areas. The component soils are deep, well drained, non-saline and non-sodic loamy. They are easily workable to good physical conditions favourable for seed germination and plant growth. Their available water holding capacity is good. They are highly suitable for a wide range of agricultural crops, fruits and vegetables adapted to the climate of the area.

Class-II - Arable (Good Agricultural Land)

The extent of this land is 29.6 percent of the Project Area. The land consists of flat, slightly depressed areas having clayey soils of expanding nature. The texture varies from clay to silty clay which shrinks and swells on alternate drying and wetting and develops cracks at the surface. The infiltration rates are low. Most of the flood water is lost through evaporation which eventually results in the build-up of surface salinity. However, the concentration of salinity is diluted to safe limits due to the deposition of fine sediment transported by the flood water. The land is mostly used for millets in 'Kharif' and wheat and mustard in 'Rabi' season. Due to their clayey texture, these soils have difficult workability and entail seedbed preparation problems and hence the choice of crops is also slightly restricted. However, with scientific management, high to very high yields can be obtained.

Class-IV - Arable (Special Use Land)

This class covers 12.1 percent of the Project Area. It is comprised of sandy and gravelly soils, occurring in the gravelly fans. The land has severe limitations for crop production due to its excessively gravelly and stony nature. It has very high intake rate and rapid internal drainage. Because of its very poor water and nutrient holding capacity, the unit is not recommended for irrigated agriculture. It should better be developed as a grazing land through provision and maintenance of adequate cover of palatable plant species, development of water points and planned rotational grazing. The land can also be used for other non-agricultural purposes.

Class-VI - Non-Arable Land

This class occupies the maximum 31.1 percent of Project Area. It comprises three main types of plains namely, sand dunes, mountains and rough broken land each stretching over 0.3, 10.4 and 20.4 percent respectively. Except for a few shrubs and grasses of low grazing value, these areas are largely bare and cannot be put to significant agricultural use.

The statistics of the above classes are summarized in **Table 6.2**.

Table 6.2
Summary of Land Capability Statistics (DI Khan Hill Torrents Area)

Class/ Sub-Class	Land Capability	Hectares	Acres	%age
Class-I	Very good Agricultural Land (Arable)	186,708	461,170	27.2
Class-II	Good Agricultural Land (Arable)	203,397	502,390	29.6
Class-IV	Marginal/Poor Agricultural Land (Arable/Non-Arable)	82,903	204,770	12.1
Class-VI	Agriculturally unproductive land (Non-Arable)	213,712	527,870	31.1
Total		686,720	1,696,200	100.0

Overall culturable waste of the area is about 197,500 ha. This land is not been cultivated at present due to non-availability of water.

6.2.3.2 Water Resources

Water potential of Project Area is summarized below:

- Total Potential = 1.33×10^9 m^3 (1.08 MAF)
- Existing Uses = 0.34×10^9 m^3 (0.28 MAF)
- Balance Available = 0.99×10^9 m^3 (0.80 MAF)

Properly conserved surplus flows of hill torrents can be used for improving existing cropping intensity and bringing additional areas under cultivation.

6.2.4 The Proposed Plan and Cost Estimates

6.2.4.1 Objectives

Main objective of the proposed package of works is to restore, rehabilitate, improve and enhance agricultural production and allied activities such as livestock through an efficient use of hill torrent flows. Flood protection, which is not the primary objective of this study, would be achieved as an indirect benefit. The overall impact of Project would, thus, be an economic uplift and better living standard for the local inhabitants.

6.2.4.2 Design Considerations

As a general practice, spate irrigation works are designed corresponding to a flood peak with a theoretical return period of 25-year in various parts of the world. NESPAK's previous studies (Risk Analysis Study for DG Khan Hill Torrents) have also indicated that the optimum design return period for construction of flood works in similar areas is about 25 years. The structures have, therefore, been designed for routed flood peaks of 25-year return period. However, free board provision and stilling basins are designed to pass a 50-year flood peak without damage to the main structure.

At a few sites, perennial flow is available in the nallah bed. In order to accommodate this flow, low flow notches have generally been provided in the main weir. Alternatively, special offtakes (using pipe culverts etc) have been provided at some of the locations where perennial flow needs to be separated from the nallah bed. Care has been exercised to make full use of the existing structures by making them functional through elaborate remodelling works. Only those structures, whose rehabilitation may prove to be more expensive than a new one, have been abandoned.

6.2.4.3 The Recommended Package

Results of the hydrologic analysis (updated to 1996) practically conform to those of the previous study carried out by NESPAK in 1993. Most of the proposed structures, especially on five major zams, have therefore been adopted from NESPAK's previous report.

During the field visit in November, 1995, additional sites on Panyala (which has recently been declared as a zam), Suheli and Gajistan torrents were identified and have been included in the proposed package.

In all, 25 distribution/dispersion structures (including remodelling of existing structures) have been proposed. Additionally, provision for channelization to facilitate flow in various branches of Rod Kohi System has also been made.

6.2.4.4 Cost Estimates

The proposed package of development works comprises construction of distributors, weirs and allied facilities, earthworks in remodelling of natural and man made channels, embankments etc. Estimated overall cost of Rs 354 million (1996 price level) is summarized in **Table 6.3**. In addition, 11 schemes estimated to cost Rs. 146 million have been proposed to be executed during 10th Five Year Plan after monitoring the performance of recommended schemes.

6.2.5 Agriculture and Economic Evaluation

6.2.5.1 Economic Feasibility

The criteria for public investment viz; Net Present Worth, Benefit Cost Ratio and Internal Rate of Return have been applied to the discounted cash flows of benefits and costs to examine project economic feasibility. **Table 6.4** summarizes the results of the analysis.

Table 6.4
Economic Parameters

(Rs Million)

Parameters	Rate of Discount (Percent)				
	10	12	15	20	25
Discounted Benefits	396.5	330.8	258.5	181.2	134.2
Discounted Cost	267.3	251.8	232.6	207.8	188.7
Net Present Worth	129.2	79.0	25.90	-26.5	-54.5
Benefit/Cost Ratio	1:1.48	1:1.31	1:1.11	1:0.87	1:0.71

TABLE 6.3

SUMMARY OF COST
(Recommended Package 1996 Price Level)

Sr. No.	Name of Work	Cost (Rs Million)
1	Kot Azam Distributor	45.000
2	Tank Zam Distributor	35.125
3	Mir Sahib Distributor	6.679
4	Diwan Shah Distributor	17.729
5	Niskore/Crostweit Distributor	5.138
6	Sad Paiwal Distributor	24.570
7	Sheikh Haider Zam Distributor	8.997
8	Tarkhoba/Valleri Distributor	4.259
9	Daraban Zam Distributor	13.975
10	Chaudhwan Zam Distributor	11.778
11	Nawabi Spill Weir	3.450
12	Gatta Dasti Spill Weir	7.866
13	Waruki Spill Weir	4.366
14	Tumani Gandi Distributor (Panyala)	15.306
15	Gatta Razaullah Distributor	6.679
16	Kiryani Spill Weir	5.872
17	Gandi Hakim Distributor	21.348
18	Sarwali Distributor (Gajistan)	5.652
19	Ustrana Gandi Distributor (Gajistan)	4.710
20	Tel Nehara Distributor	3.768
21	Sherana Distributor	6.121
22	Zamanwala Distributor	5.187
23	Langar Kot Distributor	2.602
24	Gatta Muhammad Akbar Distributor	7.798
25	Kot Pathan Spill Weir	3.817
	Total Cost of Structures	277.792
	Earthwork for Channelization	50.000
	Total Cost of Civil Works including physical contingency	327.792
	Detailed design & construction supervision @ 5%	16.390
	Engg. & Admin charges @ 3%	9.834
	Total Project Cost	**354.015**
	Say, Rupees 354 million	

The parameters given above indicate that the Net Present worth is positive and Benefit-Cost Ratio exceeds unity even at 17 percent rate of interest. Similarly, the Internal Rate of Return of 17.47 percent is well above the opportunity cost of capital in Pakistan. It is, therefore, established that the project is economically feasible and the public investment thereon is justified.

6.2.5.2 Sensitivity Analysis

In order to assess the impact of a possible decrease in project benefit/or an increase in the project costs, sensitivity analysis has been carried out with the following assumptions:

- Project benefits decline by 10 percent
- cost over-run by 10 percent
- both benefits reduction & cost over-run simultaneously.

The results of the sensitivity analysis based on the discount values of benefits and costs under the above mentioned assumptions are summarized in **Table 6.5**.

Table 6.5
Results of Sensitivity Analysis

Assumptions	Internal Rate of Return (percent)
Base Case	17.47
10% increase in Capital Cost	15.26
10% decrease in Benefits	15.01
Both benefits reduction and cost over-run simultaneously	13.42

Sensitivity analysis indicates that the investment remains economically attractive across the presumed range of assumptions.

6.2.5.3 Socio-economic Impact

The economic analysis presented above is based on the measurable benefits alone. There are a number of effects of socio-economic nature which, though not quantifiable, are equally important and deserve due consideration while deciding the justification of the project.

These effects relate to the improvement in the well-being and welfare of the inhabitants of the area. The proposed project when implemented would go a long way towards transforming the pattern of life by providing irrigated agriculture benefits and reduction of flood damage. This would induce the people to a large extent to settle down and give up their nomadic way of life. The social implications of such a basic change leading to improvement in quality of life are obvious. The additional agricultural production made possible under project conditions would result in an increase in income levels, thereby generating additional demand which, in turn, would result in opening further employment opportunities. Such a process would stimulate economic activity in other sectors as well.

With the socio-economic conditions prevailing in the project area, these effects are of far reaching significance. While considering the justification of the project, these benefits should be given at least as much recognition as the computed economic rate of return.

6.3 HAZARA, KABUL & BANNU BASINS

6.3.1 Introduction

Hazara, Kabul and Bannu (HKB) Basin possesses maximum development potential as compared to other regions i.e. DI Khan and FATA. Major rivers like Kabul, Swat, Kurram, Panjkora and their tributaries traverse through the area. Areally, it covers about 64 percent of the total area of North West Frontier Province. Major part of irrigation system and agricultural area lies in this region. Highest rainfall areas like Abbottabad, Mardan and Malakand are located in this basin.

The climate of the area is highly diversified according to altitude. The northern mountains have snowy winters and cool summers. The mean annual temperature increases markedly toward south. Precipitation in the area is as caused by Monsoon and Western Disturbances.

On the north of the Province, where there are extremes of altitude and climate, higher mountains are bare and rocky. Elsewhere in the north, mountain slopes bear evergreen Oak and Pine; and broad leaved deciduous trees such as pine and poplar grow on warmer bright slopes. There are also extensive mountain grass lands. The hills in the south are sparsely covered with bushes, acacia and grasses. Of the total forest area of about 3.48 Mha of Pakistan, 1.23 Mha is located in HKB Basin. This is about 35 percent of the total forest area of Pakistan and about 12 percent of total geographic area of NWFP.

Northern ridges are generally associated with Himalayan territory: which contain gneiss and granite in upper Chitral. The transverse hills are mostly formed of nummulitic limestone and sandstone. Most of Peshawar Vale is covered with surface gravels and alluvium while rocks of Kohat are mostly sandstone. Bannu Plain is mostly composed of soft sandstone and conglomerates.

The area has a good network of roads connecting major towns and villages of the Province and other parts of Pakistan. Cement, sugar, vegetable ghee, paper and paper board, cigarettes and textile industries have been established. Coal, chromite, limestone, gypsum and fire clay are extracted on commercial scale. About 25 percent of the population is urban while balance is rural.

6.3.2 Project Area

6.3.2.1 Location and Extent

Hazara, Kabul and Bannu Basins encompass an area of 65,516 sq km (25,295 sq miles) and covers the entire north eastern region and central part of settled area of NWFP. The area lies between longitudes 70° 24' - 74° 05'E and latitudes 32° 20' - 36° 55'N.

6.3.2.2 Hazara Basin

Harza Basin is drained by Indus River. Its major tributaries are listed below:

- Kunhar River and its 23 tributaries
- Siran River and its 64 tributaries
- Daur River and its 33 tributaries
- Harrow River and its 20 tributaries

These rivers and their tributaries drain an area of about 17,100 sq km (6,600 sq miles) in NWFP. Exhibit M-6.2 shows Hazara and Kohistan Area Hill Torrents.

6.3.2.3 Swat & Kabul Basins

Swat river originates at an altitude higher than 4,850m (16,000 ft) above mean sea level in Hindu Kush Range. Panjkora River draining Dir area outfalls into Swat River near Hisar Baba. Swat river divides into Khiali river and Abazai river below Munda Headworks. The two branches reunite and join Kabul river near Charsadda. Kalpani Nallah meets Kabul river near Nowshera. Kabul river finally outfalls in the Indus river near Attock. It is the major tributary of Indus river which joins it from the right bank. Exhibits M-6.3 and M-6.4 present Swat and Kabul Basins respectively.

6.3.2.4 Kurram Basin

Bannu Division and a part of Kohat Division are drained by Kurram River through its tributaries - Baran River, Wana Toi, Tori Toi etc. Kurram River originates from Afghanistan and enters Pakistan near Para Chinar. Baran River joins it about 60 km downstream of Bannu and finally joins Indus River 30 km downstream of Kala Bagh Barrage. Exhibit M-6.5 shows Kurram River Basin and adjacent areas.

6.3.3 Land and Water Potential

6.3.3.1 Land Potential

HKB Basins Hill Torrents encompass an area of 65,516 sq.km (25,295 sq.miles) and covers the following administrative areas:

Division	District
Peshawar	Peshawar, Nowshera and Charsadda
Mardan	Mardan, Swabi
Kohat	Kohat, Karak
Bannu	Bannu, Lakki
Hazara	Abbottabad, Haripur, Mansehra and Kohistan
Malakand	Chitral, Dir, Swat and Buner

The area comprises mountain ranges undulating disected sub-mountains and plains surrounded by hills. Landuse statistics of the HKB Basins are given in **Table 6.6**.

Table 6.6

Landuse Statistics of HKB Basins

Total Geographic Area	65,516 sq.km
Reported Area	4,726,953 ha
Cultivated Area	1,456,931 ha
Net Sown	1,195,587 ha
Current Fallow	261,345 ha
Cropped Area	1,660,098 ha
Area Sown more than Once	464,511 ha
Irrigated Area	783,000 ha
Uncultivated Area	3,270,022 ha
Culturable Waste	442,300 ha
Forest	1,255,742 ha
Not Available for Cultivation	1,571,980 ha

Culturable waste of 442,300 ha exists in the area which is presently not under cultivation due to non-availability of any source of irrigation. However, if the water resources can be conserved and used for this area for irrigation it would become productive.

6.3.3.2 Water Potential

Following are the three major sources of water:

- Flows of Kabul, Kurram & Tochi Rivers
- Rainfall falling over the area; and
- Flows generated as a result of snowmelt

Major part of flows of Kabul, Kurram and Tochi rivers falls in the Indus river. However, significant part of tributaries flow of these rivers can be conserved at various sites. Average annual rainfall of HKB Basins is about 755mm (30 inches) which produces a runoff of about $1.26 \times 10^{10} m^3$ (10.26 MAF). A part of his runoff finally flows to Indus river through various tributaries. Snowmelt also contributes to runoff which finally outfalls into Indus river. It has been estimated that HKB Basins have conservation potential of $4.64 \times 10^9 m^3$ (3.76 MAF).

6.3.4 Perspective Development Plan and Cost Estimates

6.3.4.1 General

The Government of NWFP has established Small Dams Directorate (SDD) for the management of water resources of NWFP. Since the creation of SDD, it has identified 118 sites in HKB Basin. Uptodate progress of SDD is as under:

	Activity	Number
•	Reconnaissance of Sites for:-	118
i)	Pre-feasibility Study	65
ii)	Potential Sites for Detailed Study	24
iii)	Feasibility Study	11
iv)	Detailed Design & Tender Documents	9
v)	Construction in Progress	5
vi)	Approved for Feasibility Study (PC-II)	4

A total of 118 sites have been investigated in HKB Basins so far, out of which 65 sites were found appropriate for pre-feasibility studies. Districtwise number of identified sites is given in Table 6.7. The detailed feasibility studies have been completed on 11 sites in the Province. The work on the remaining potential 13 sites will be carried out shortly after the completion of various formalities. These sites are listed as:

- Gandially;
- Sharki;
- Chanda Fateh Khan;
- Zaibi;
- Naryab;
- Palai;
- Auxiliary Kandar;
- Changoz;
- Sanam;
- Kundal; and
- Pail

TABLE 6.7

DISTRICTWISE SUMMARY OF IDENTIFIED DAM SITES - HKB BASINS

Name of District	No. of Identified Sites
1. Kohat	40
2. Karak	11
3. Peshawar	13
4. Dir	12
5. Swabi	6
6. Haripur	6
7. Mansehra	12
8. Charsadda	2
9. Bannu	5
10. Mardan	6
11. Bunner	5
TOTAL:	118

ESTIMATED COST Rs 3,530 Million

6.3.4.2 Detailed Designing

Consequent upon finalization of Feasibility Studies, the detailed design of the following nine sites in the Province has been completed:

1. Gandially Dam Project
2. Sharki Dam Project
3. Chanda Fateh Khan Dam Project
4. Zaibi Dam Project
5. Naryab Dam Project
6. Palai Dam Project
7. Auxiliary Kandar Dam Project
8. Changoz Dam Project
9. Pail Dam Project

6.3.4.3 Construction

In Kohat District, work on two sites (Gandially Dam and Chanda Fateh Khan Dam) has since been started and the remaining two schemes are ready for implementation. These are:

- Naryab Dam Project; and
- Auxiliary Kandar Dam Project.

In Karak District, out of 4 sites, two (Sharki and Zaibi Dam Projects) have been taken up for implementation, whereas, the Changhoz Dam Project is ready for launching. The Pail Dam Project meant purely for drinking water supply has, however, been dropped.

In Charsadda District, Palai Dam construction work has been started.

6.4 CONCLUSIONS AND RECOMMENDATIONS

It has been observed that large potential exists for investigation, planning and development of land and water resources of the Province. There are large number of sites where low cost structures can be constructed. These sites have to be properly investigated and cost effective solutions determined for conservation of water and its use for horizontal and vertical expansion of agriculture in the Province. It has also been seen that the activities for construction of small dams is very slow due to litigation and other social factors. In almost all cases, the costs of schemes have increased many times, due to slow progress of the contractors. For the construction of small dams, only financially sound contractors should be prequalified and Schedule/Charts of Activities be critically monitored to complete the jobs in time. The cost of construction of lowhead dams/diversion weirs is estimated about Rs 3,530 million.

It is recommended that the Province be divided into number of potential zones for identification of conservation sites, investigation and feasibility studies. The feasibility reports should be Bankable Documents which could be presented to financing agencies for provision of funds.

7. PUNJAB PROVINCE

7.1 SUMMARY

7.1.1 Location & Extent

Punjab is the largest Province of Pakistan from the point of view of population. It is bordered on the west by NWFP; on the north by Jammu & Kashmir; on the east by Indian Part of Punjab and on the south by Sindh Province. It is globally located between longitudes 69° 30' to 75° 10'E and latitudes 27° 42' to 34° 00'N. Punjab has an area of about 206,251 sq.km (79,633 sq.miles) and about 76.51 million population; approximately 370 persons per sq km.

Punjab lies in arid to semi arid zones; the rainfall is erratic and does not match with the crop water requirements. The hill torrent areas of the Province suffer from shortage of water, both for municipal and agriculture purposes. One of the biggest impediments in the development of vast fertile cultivable land resource is water. The majority of population of such areas except some big towns has no access to potable water. The agriculture is mainly short of irrigation supplies except Indus River Command Area.

7.1.2 Agriculture

Agriculture plays an important role in the provincial economy. Rapily increasing population is a limiting factor for the development of economy. Large tracts of land in the hill torrent areas of the Province are lying unproductive due to lack of irrigation facilities. The Province lies in arid to semi arid zones of the country, whereby patchy and erratic pattern of rainfall does not support agriculture sector. Only a limited part of hill torrent areas is commanded by flood irrigation and is dependent upon occasional runoff generated by natural precipitation. The agricultural production is thus mainly dependent upon direct rainfall in these areas. The total cultivated area of the Province is about 12.2 Mha (30.15 million acres) with a culturable waste of 1.74 Mha (4.30 million acres). If water can be made available through conservation or other means, the culturable waste has potential for development of agriculture. General landuse statistics of Punjab Province are presented in Table 7.1.

Table 7.1
Landuse Statistics of Punjab

Sr.No.	Description	Area (ha)
1	Total Geographical Area	20,625,100
2	Total Reported Area	17,472,400
3	Total Cultivated Area - Net Sown Area - Current Fallow	12,185,700 11,010,000 1,175,700
4	Total Cropped Area - Area Sown more than Once	15,269,000 4,259,000
5	Total Uncultivated Area - Culturable Waste - Forest - Not Available for Cultivation	5,287,000 1,744,400 477,700 3,064,800
6	Irrigated Area	12,996,300
7	Rainfed/Barani	2,272,700

7.1.3 Project Studies

Punjab Province has three major hill torrent areas:-

- D.G. Khan Hill Torrents
- Pothawar Hill Torrents
- Rechna & Chaj Doab Hill Torrents.

Upper catchment areas of Rechna & Chaj Doab Hill Torrents are located in Indian occupied part of Jammu & Kashmir and in its lower reaches no sites are available for water conservation, hence it has not been studied in detail.

During the currency of report preparation, Consultants were directed by the Client to prepare one Bankable Document for each potential area of a Province as a Core Project. For this study, "DG Khan Hill Torrent Area" was selected for detailed study in consultation with PIDA, Punjab.The proceeding part of this report presents the Core Project in greater detail as compared to Pothowar, Rechna & Chaj Doab Areas.

7.1.4 Land and Water Potential

The land classification of DG Khan Area comprises five main classes, whereas those of Pothowar Area also consist of five classes. These classes alongwith their areal percentage of the respective Component Area is summarized in **Table 7.2.**

Table 7.2
Land Classification of D.G. Khan & Pothowar Areas

Land Class	Description	Percentage	
		DG Khan Area	Pothowar Area
I & II	Arable	18.6	42.0
III & IV	Special Use	8.4	55.0
V & VI	Non Arable	73.0	3.0

Water and land potential of D.G. Khan and Pothowar areas are given in **Table 7.3.**

Table 7.3
Water Potential of D.G. Khan and Pothowar Areas

S/No.	Description		DG Khan Hill Torrent Area	Pothowar Area
1	Average Annual Rainfall, mm		250	675
2	Area, sq km		24,500	22,300
3	Rainfall equivalent m^3		$6.1x10^9$ m^3	$1.51x10^{10}m^3$
4	Annual Runoff	m^3 AF	$1.05x10^9$ 854,000	$2.3x10^9$ 1.860,000
	2.33-Year	m^3 MAF	$1.05x10^9$ 0.854	$2.3x10^9$ 1.86
	5-Year	m^3 MAF	$1.702x10^9$ 1.381	$3.60x10^9$ 2.90
	10-Year	m^3 MAF	$2.30x10^9$ 1.86	$4.6x10^9$ 3.73
	25-Year	m^3 MAF	$3.05x10^9$ 2.474	$5.90x10^9$ 4.83

AF = Acre feet
MAF = Million acre feet

7.1.5 Development Plan

DG Khan Area (Core - **Project)**

- Proposed Delay Action Dams/ Dispersion Structures etc.	40 No
- Estimated Cost of Construction	Rs 1,055 million (A)

Pothowar Area

- Sites Identified for Feasibility Study	21 No
- Sites Identified for Prefeasibility Study	150 No
- Estimated Cost of Construction of 21 dam sites proposed for Feasibility Study	Rs 840 million (B)
- Estimated cost of 150 delay action dams	Rs 3,160 million (C)
Total (B+C)	Rs 4,000 million
Grand Total for Punjab	Rs 5,055 million

7.1.6 **Recommendations**

The feasibility studies for Core Project have been completed. The structures/schemes proposed therein may be executed after detailed designs. For Pothowar Area, 21 dam sites have been recommended for detailed feasibility studies; while nearly 150 sites need pre-feasibility studies in order to appraise their suitability for detailed studies and investigations.

7.2 DG KHAN HILL TORRENT AREA

7.2.1 **Introduction**

The area between the foothills of Suleiman Range and the right bank of Indus River from Ramak to Taunsa Barrage and enclosed between the right bank of DG Khan Canal System and foothills from Taunsa Barrage to Kashmore is locally known as 'Pachad Area'. This area is open to hill torrents flooding debouching from Suleiman Range. The catchment area of hill torrents is spread over 24,500 sq km (9,400 sq miles)

The hill torrents bring in flashy floods of shorter durations and higher magnitudes. Because of steep gradients, flood flows move with high velocity, which result in erosion of banks and beds of the channels. Flood flows debouching onto the plain area, are generally charged with high silt contents, which preclude flood management by dams or detention reservoirs. As the flood flows move on the flatter terrain, they deposit their silt load due to reduction in velocity. The silting and scouring phenomena are largely responsible for frequent changes in flow regime and shifting of flow paths of hill torrents. Unpredictable and erratic nature of floods and high silt contents pose a serious challenge to the ingenuity of flood planners for their economic management.

Low flows of hill torrents are manageable and are utilized by the farmers in sub-mountainous and Pachad Area by the construction of small earthen bunds called 'gandas'. High flows of hill torrents breach earthen diversion bunds and move towards DG Khan Canal System, which has 20 hill torrent crossings with an aggregate capacity of 2,934 cms (103,600 cfs). This capacity is grossly inadequate and consequently results in a number of breaches in DG Khan Canal.

Apart from loss of life, property and infrastructural facilities in the command area, it results in suspension of canal supplies to downstream areas for prolonged periods. It has been estimated that average annual damage due to hill torrent flooding in canal command area is about Rs 63 million.

Efforts have been made in the past to manage flood flows, but these were generally short-lived, because they were based on inadequate data and the overall perspective of floodflows of the entire catchment was not taken into account. This report presents a plan for utilization of water potential for the development of agriculture in the area, flood protection being a secondary objective.

7.2.2 Project Area

7.2.2.1 General

The Project Area (Exhibit M-7.1) lies between longitude 69° 10′ E to 70° 49′ E and latitude 28° 27′ N to 31° 20′ N. The catchment area comprising nearly 24,500 sq km (9,400 sq miles), mostly lies in Punjab and Balochistan. DG Khan, Jampur, Rajanpur, Rohjan, Taunsa and Fort Munro are the important cities of Punjab, while Musa Khel, Barkhan, Rakhni and Vitakri are important satellites in Balochistan. DG Khan is connected with other cities of Pakistan by metalled roads, railway line and by air.

Climate of the area is arid and is characterized by the movement of Monsoon in summer and Westerlies in winter. Summer temperatures are fairly high and winters are cold. Average annual rainfall varies from about 125 mm - 375 mm (5 - 15 inch). Pattern of rainfall is erratic and patchy. Years of intense rainfall are likely to be followed by long spells of dry years.

7.2.2.2 Major Hill Torrents

There are over 200 hill torrents which originate from Suleiman Range in the west. Of these, 13 hill torrents have large catchment areas and flood flow potential. **Table 7.4** gives statistics of catchments and cultivated areas of these major streams.

7.2.3 Land & Water Potential

7.2.3.1 Land Potential

The landuse statistics of the Province are presented in the Summary of Province. The cultivable waste of the Project Area has been estimated as 0.35 Mha (0.86 MA). Soil and land classification has been discussed in proceeding paragraphs of this section.

TABLE 7.5

ESTIMATION OF MONTHLY RUNOFF – 25 YEARS RETURN PERIOD

SR. NO.	Months	Kaura		Vehowa		Sanghar		Sori Lund		Vidore		Sakhi Sarwar		Chachar		Pitok		Sori Shumali		Zangi		Sori Janubi	
		Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft	Ha – M	Ac – Ft
1	January	299	2,424	1,725	13,976	3,071	24,890	213	1,730	412	3,338	64	517	352	2,850	91	740	131	1,065	137	1,110	677	5,485
2	February	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	March	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	April	1,626	13,180	9,377	75,990	16,700	135,330	1,161	9,405	2,239	18,148	347	2,813	1,913	15,500	497	4,025	714	5,790	744	6,030	3,679	29,815
5	May	337	2,727	1,940	15,725	3,455	28,000	240	1,945	463	3,755	72	582	396	3,210	103	835	148	1,198	154	1,245	761	6,170
6	June	1,290	10,454	7,437	60,270	13,245	107,330	921	7,460	1,776	14,395	275	2,230	1,517	12,295	394	3,195	567	4,595	590	4,780	2,918	23,645
7	July	1,309	10,605	7,545	61,144	13,437	108,888	934	7,566	1,802	14,600	280	2,265	1,539	12,475	400	3,240	575	4,660	598	4,850	2,960	23,990
8	August	2,262	18,332	13,042	105,690	23,226	188,220	1,613	13,075	3,115	25,240	482	3,910	2,661	21,560	691	5,600	994	8,055	1,035	8,385	5,117	41,465
9	September	1,514	12,272	8,731	70,750	15,547	125,990	1,080	8,755	2,085	16,895	323	2,620	1,781	14,435	463	3,750	665	5,390	693	5,615	3,425	27,755
10	October	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	November	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12	December	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Ha – M = Hectare Meter   Ac – Ft = Acre Feet

4. Where torrent bed is very wide, resulting in an exorbitantly expensive dispersion structure, a fuse plug has been provided to cater for higher floods. The fuse plug is a breachable dyke which would wash away during high floods (greater than 25 year) and release the hydraulic pressure on the structure.

5. All offtakes have been designed to withdraw optimally against a 5-year flood. The withdrawing capacity would gradually increase against higher events.

6. Earthen drainage channels of appropriate capacities have been provided on the left bank of DG Khan Canal to handle the excess volumes of 25-year and higher flows and safely carry them to outfall into the Indus.

7.2.4.2 Recommended Works

Proposed package of works is presented in **Table 7.6** alongwith the cost of civil works. The recommended works comprise:

- Distributors	-	7 No.
- Remodelling of Existing Works	-	1 No.
- Offtake Structures	-	20 No.
- Miscellaneous Works of Remodelling/Flood Protection	-	12 No.
- Flood Carrier Channels	-	7 No. (with miscellaneous allied works)

7.2.4.3 Cost Estimates

Project Costs

For estimation of costs of various works proposed in the recommended package, unit rates have been adopted from the Composite Schedule of Rates published by the Provincial Irrigation Department (Punjab) in 1979. Appropriate premiums have been added to the basic rates to bring these to the 1996 price level.

TABLE 7.6
PROPOSED STRUCTURES

(A)

Hill Torrents	Works	Cost (Rs Million)
KAURA	Remodelling of Sad loharan	5
	Offtake for Kalandar & Changoo wahs	21
	Offtake for Copi Wah	11
	Closure dyke near Kot Mubark	3
	Sub- Total	40
VEHOWA	Restoration works at Vehowa Pick-up weir & Gang Canal	16
	Offtake for Kobhi Wah	11
	Offtake for Leghar Wah	11
	Offtake for Jallo Wah	8
	Offtake for Allah Nawaz Wah	8
	Remodelling & improvement works at Khad Buzdar	5
	Remodelling & distribution works at Pal Leghari	8
	Sub- Total	67
SANGHAR	Offtake for Jat Wah	11
	Distributor for Shakh Shumali & Janubi	35
	Offtake for Sheron Wah	11
	Distributor at Bhagwari Wah	8
	Improvement work at Sad Wanda	3
	Sub- Total	68
SORI LUND	Combined offtake for Jamalar & Nowar Wah	31
	Offtake for Khosa Wah	11
	Offtake for Talli Branch	11
	Offtake for Kaura Wali	11
	Remodelling Jhal Hutwani & Gandh Kaure Wali Bunds	6
	Flood protection bund near village Notak Sakami	5
	Sub- Total	75
VIDORE	Distributor for Phullar & Suchani wahs	85
	Distributor for Suchani & Chabri wahs	65
	Miscellaneous remodelling & flood protection works	30
	Sub- Total	180
SAKHI SARWAR	Multiple Distributor for 5 wahs	30
	Remodelling works at escape weir	5
	Offtake for sub - wah of Puran Wah	5
	Sub- Total	40
CHACHAR	Distributor for Illahi Wah & Ragu Wah	30
	Offtake for Raju Wah	11
	Offtake for Lashari Wah	11
	Miscellaneous remodelling & flood protection works	16
	Sub- Total	68
ZANGI	Distributor for Dilbar Wah & Political Channel	27
	Offtake for Political Channel	11
	Offtake for Shehan Branch	11
	Miscellaneous remodelling & flood protection works	3
	Sub- Total	52
SORI JANUBI	Offtake for Left Channel including escape	20
	Offtake for Gali Wah	11
	Offtake for Sahu Wah	11
	Offtake for Jamal Wah	11
	Miscellaneous remodelling & flood protection works	7
	Sub- Total	60
	TOTAL	650
(B)	Miscellaenous Drainage Channels	185
	Grand Total (A) + (B)	835

The total cost of the project comprises components such as land acquisition, civil works, engineering and administration expenses and physical contingencies etc. The torrent-wise total project costs with the break-up into various components have been presented in **Table 7.7**. The grand total for the entire package sums up to Rs 1,055 million.

7.2.5 Economic Evaluations

7.2.5.1 Summary of Benefits

The annual benefits on account of increase in agricultural production and avoidance of flood damages after the completion of project works are estimated as Rs 41.88 million and Rs 63.25 million, respectively. The aggregate benefits accruing from the project thus, work out as Rs 105.13 million. These are assumed to increase at an annual rate of five percent upto 10th year beyond which it will remain constant.

7.2.5.2 Economic Feasibility

The criteria for public investment viz; Net Present Worth, Benefit Cost Ratio and Internal Rate of Return have been applied to the discounted cash flows of benefits and costs to examine project economic feasibility. **Table 7.8** summarizes the results of the analysis.

The parameters given above indicate that the Net Present worth is positive and Benefit-Cost Ratio exceeds unity even at 13 percent rate of interest. Similarly, the Internal Rate of Return of 13.62 percent is above the opportunity cost of capital in Pakistan. It is, therefore, established that the project is economically feasible and the public investment thereon is justified.

TABLE 7.7

Project Costs
(1996 Price Level)

(Rs. Million)

Sr. No	Hill Torrent	Cost: Land Acquisition	Civil Works: Flood Managemen Structures	Civil Works: Flood Carrier Channels	Total Civil Works Cost including Physical Contingency	Detail Dsg. & Const. Supervision @ 5% of Civil Works	Engg. and Admin. @ 3% of Civil Works	Total
1	Kaura	2.00	40.00	-	44.00	2.00	1.20	49.20
2	Vehowa	4.00	67.00	-	73.70	3.35	2.01	83.06
3	Sanghar	3.00	68.00	-	74.80	3.40	2.04	83.24
4	Sori Lund	8.00	75.00	8.00	91.30	4.15	2.49	105.94
5	Vidore	7.00	180.00	30.00	231.00	10.50	6.30	254.80
6	Sakhi Sarwar	4.00	40.00	12.00	57.20	2.60	1.56	65.36
7	Chachar	6.00	68.00	20.00	96.80	4.40	2.64	109.84
8	Pitok							
		7.00	Nil	65.00 *	71.50	3.25	1.95	83.70
9	Sori Shumali							
10	Zangi	5.00	52.00	30.00	90.20	4.10	2.46	101.76
11	Sori Janubi	4.00	60.00	20.00	88.00	4.00	2.40	98.40
	Total	50.00	650.00	185.00	918.50	41.75	25.05	1,035.30
	Provision for purchase of maintenance equipment							20.00
	GRAND TOTAL							1,055.30

* including associated structures

Table 7.8
Economic Parameters

(Rs Million)

Parameters	Rate of Discount (Percent)			
	10	12	15	20
Discounted Benefits	1166.62	972.61	759.73	532.97
Discounted Cost	943.61	892.06	828.78	747.84
Net Present Worth	223.01	80.55	69.05	-214.87
Benefit/Cost Ratio	1.24:1	1.09:1	0.92:1	0.71:1
Internal Rate of Return	13.62 percent			

7.3 POTHOWAR AREA

7.3.1 Introduction

Pothowar Area is one of the regions of Pakistan where the topography is classified as plateau alongwith intermittent gulleys and ravines; and as such no large canal system can be developed. The physical features of the area dictate the provision of local irrigation system for isolated small tracts of land having topographic uniformity. The scope of such suitable irrigation system is predominantly signified by the existence of a vast land potential of which only about four percent is cultivated with low intensity. Nevertheless the hill torrent flood flows are mostly wasted except where storage arrangements have been provided.

Pothowar Area extends over 2.23 Mha in north and central Punjab. It is a part of barani tract of the Province, whose elevation ranges from 457 m above mean sea level (msl) to about 610 m msl except some isolated mountains of higher elevations. The plateau comprising the districts of Rawalpindi, Attock, Jhelum and Chakwal, forms about 40% of the Punjab Barani Tract (PBT). It has a cultivable area of 1.21 Mha of which only 85,400 ha is presently cultivated. The rest of the area is entirely dependent upon insufficient and erratic rainfall. Through the land is very fertile, the deficiency of irrigation supplies is the root cause of limited and low intensity cultivation. The situation warrants the proper preservation of hill torrents flows and their utilization for expansion of agriculture aiming at socio-economic uplift of the area.

7.3.2 The Project Area

7.3.2.1 General

Pothowar Area, commonly known as "Pothowar Plateau" lies in the north and central Punjab (Exhibit M-7.2). It includes four districts - Attock, Rawalpindi, Chakwal and Jhelum. A small part of Gujrat District also forms part of Pothowar Plateau. The entire plateau comprises about 22,300 sq km, where only about 85,400 ha area is supplied with some form of irrigation facilities. The rest of the area solely depends upon rainfall.

7.3.2.2 Physical and Demographic Features

Soils

Generally speaking, the soils of the area are good and are capable of producing high intensity crops. They are free from waterlogging and salinity. Relatively lesser efforts can bring better results as compared to irrigated areas of the Indus Plains, which have already attained a high level of intensity and yields with a recent decline due to water logging and salinity in some of the areas.

Climate

This area lies in semi arid to sub-humid zone of climatic region with hot summers and cold winters. The average rainfall at Murree in the north-eastern part, where the major torrents originate, is over 1,500 mm whereas that of Tamman in the South-Western part of the area is 295 mm. About 60% of annul rainfall occurs during the monsoon season and 40% in the remaining period. Generally the rainfall intensity goes on decreasing gradually from north-east to south-west. The average annual rainfall covering the plateau is estimated at 675 mm a year. Maximum temperature rises upto 49°C at Dhok Pathan and the minimum temperature falls down to almost 0 °C at Rawal Dam. The temperatures at and around Murree Hills often remains below freezing in winter and causes frequent snowfalls while temperatures are mild and pleasant during summer.

The Project

The Project aims at socio-economic development of the area through management of flood flows of hill torrent. Agriculture development is the main focus of the Project where a number of other related benefits can also be accrued.

7.3.3 Land & Water Resources

7.3.3.1 Land Resources

Pothowar Area is generally known as 'Barani' area of Punjab Province. Due to its specific topographic features, patches of flat lands are available in scattered form. The general land use statistics of the area given in **Table 7.9.**

Table 7.9
Landuse Statistics of Pothowar Area

Sr. No.	Description	Area	
		Hectare	Acre
1	Total Area	2,230,000	5,508,100
2	Cultivable Area	306,200	756,314
3	Cultivated Area	85,400	210,938
4	Irrigated Area	17,954	44,346
5	Fallow	67,446	166,592
6	Culturable Waste	220,800	545,376

This indicates that a good amount of exploitable land (cultivable/fallow) lies in the area.

7.3.3.2 Runoff Estimation

The average annual runoff has been estimated using the annual average precipitation and runoff rainfall coefficient as determined from the actual data. The summary of the results are presented as:

Average Annual Precipitation	=	675 mm (0.675 m)
Catchment Area	=	2.23 Mha
Rainfall Equivalent	=	1.51×10^{10} m^3
Average Annual Runoff (at 31.67 percent)	=	$4.77 \times 10^{10} m^3$ (3.86 MAF)

About $2.47 \times 10^9 m^3$ (2 MAF) of runoff is either detained in depressional areas or is drained into the rivers. Thus, about $2.22 \times 10^9 m^3$ (1.86 MAF) is available for conservation.

7.3.4 Perspective Planning and Cost Estimates

7.3.4.1 Background

During 1940s investigations were conducted to explore water resources potential of hill torrents of Punjab Province but no concrete proposal was made for construction of dams/reservoirs. After independence, the work was again started in 1954 and a Bund Circle of Irrigation Department (Punjab) carried out preliminary investigations in the Pothowar Plateau including Pubbi Hills and Salt Range. In other areas of Punjab, investigations for small and large dams were continued from 1960 to 1967 under the Hill Torrent Division but no well defined Projects materialized.

After dissolution of West Pakistan Agriculture Development Corporation (ADC) in January,1972 Small Dams Organization was retained by the Central Government but finally it was decided to entrust its functions to respective provinces. From February, 1973 the responsibility for development of Barani Areas was entrusted to Irrigation and Power

Department of the Government of the Punjab. Since then the Small Dams Organization is working under PIDA, Punjab.

The work of the Organization has since been concentrated in the districts of Attock, Rawalpindi, Jhelum and Chakwal where most potential dam sites are available. At present the Organization is headed by a Project Director and there are three Maintenance-Cum-Construction Divisions with 11 sub divisions.

7.3.4.2 Completed Projects and Identified Sites

Due to lack of Hydrological data required for Planning and Designing of these Dams, the progress in early stages was slow. The Dams completed in the second plan period (1959-1964) were two in number i.e., Rawal Dam (1962) and Misriot (1963). The progress, however, speeded up in third five year plan (1969 to 1974) when the following dams were completed:

1. Grubh (1966)
2. Ratti Kassi (1970)
3. Nirrali (1970)
4. Doongi (1971)
5. Dhurnal (1971)
6. Dhok Talian (1971)
7. Qila Bandi (1971)

Afterwards the lack of financial allocation became the major constraint. To boost up progress and to make the area self sufficient, a new scheme, "Small Dams Umbrella Project" was introduced in 1986. By the year 1988, 19 dams had been completed covering a command area of 11,336 ha (28,000 acres), later on, under Umbrella PC-I Project, jointly financed by the Federal Government and Asian Development Bank (ADB) Loan, 12 new dams were completed covering a command area of 6,618 ha (16,346 acres). Thus, upto 1997, 31 dams have been completed.

So far about 150 dam sites with an estimated cost of Rs 3,160 million have been identified which are listed in Annexure-I, Supporting Volume-III. Twenty one sites with high development potential have been prioritized with an estimated cost of Rs 2,100 million.

The high priority schemes are listed in **Table 7.10**, while summary of identified dam sites is given in Table 7.11.

Table 7.10
Dams Proposed for Feasibility Studies

Sr.No.	Name of Dam	District
1.	Dhok Ratta Sharif Dam	Chakwal
2.	Tamman Dam	Chakwal
3.	Chakian Dam	Attock
4.	Mial Dam	Chakwal
5.	Ghambir Dam	Chakwal
6.	Chaukandi Dam	Chakwal
7.	Bhagwan Dam	Attock
8.	Dunga Dam	Attock
9.	Minwal Dam	Chakwal
10.	Uthwal Dam	Chakwal
11.	Ugahum Dam	Rawalpindi
12.	Phalina Dam	Rawalpindi
13.	Dhok Minhas Dam	Chakwal
14.	Basal Dam	Attock
15.	Salial Dam	Jhelum
16.	Khai Dam	Chakwal
17.	Munday dam	Chakwal
18.	Chhoi Dam	Chakwal
19.	Lehri Dam	Jhelum
20.	Domeli Dam	Jhelum
21.	Baba Shaheed Dam	Jhelum

Table 7.11

Summary of Identified Dam Sites in Pothowar Area

Name of District	No. of Dam Sites
Attock	87
Rawalpindi	22
Jhelum	35
Chakwal	-
Gujrat	-
Mianwali	1
Khushab	5
	150

7.3.4.3 Recommendations

Small dams in Pothowar Area have been extremely useful and have played a vital role in the development of agriculture. However, the statistics indicate that there is sufficient potential for further land and water resources exploitation. These resources, if fully utilized, can play a vital role in the economy and social and environmental uplift of the area. Surplus water potential of $2.293 \times 10^9 m^3$ (1.86 MAF) exist in the area, which can be conserved and used to irrigate culturable waste of 220,800 ha (545,376 acres) in the area.

Feasibility studies for the proposed 21 dams should be initiated at the earliest and pre-feasibility investigation and studies for the balance identified 150 sites should be initiated.

7.4 RACHNA AND CHAJ DOAB HILL TORRENTS

7.4.1 General

Rechna and Chaj Dob Hill Torrents include the mountainous streams joining Ravi River from the right and Chenab River from both the banks, in the districts of Narowal, Sialkot, Sheikhupura, Gujranwala and Gujrat of Punjab Province.

Major hill torrents are:

(a) Ujh, Bein, Basantar, Deg & Hudiara outfalling in Ravi River

(b) Doara-I, Doara-II, Halsi, Bhimber, Palkhu & Budhi outfalling in Chenab River

The catchment characteristics of these hill torrents (Nallahs) are given in **Table 7.12**.

Table 7.12
Catchment Characteristics of Hill Torrents of Rechna and Chaj Doab

Name of Tributaries	Length		Average Slopes		Catchment Area		Highest Elevation above MSL	
	Km	Miles	M/Km	Ft/Mile	Sq.Km	Sq.Mile	M	Ft
(a) Ravi River Tributaries								
Ujh River	128	80	32	169	1,748	675	4,115	13,497
Bein Nallah	77	48	6	31	896	346	621	2,037
Basantar Nallah	72	45	6	31	632	244	671	2,200
Deg Nallah	258	160	7	37	1,181	456	2,012	6,600
Huddiara Nallah	100	62	0.2	1	1,510	583	259	850
(b) Chenab River Tributaries								
Doara-I	50	31	8.9	47.8	259	100	694	2,276
Doara-II	56	35	8.6	45.5	342	132	714	2,341
Balsi	56	35	2.7	14.5	218	84	381	1,250
Bhimber	103	64	5.1	27.6	1,075	415	762	2,500
Palkhu	121	75	3.3	17.5	2,054	793	619	2,030
Budhi	66	41	2.7	14.4	624	241	222	729

The primary objective of the Project is to enhance the agricultural production of the area by exploiting the water resources of the hill torrents for irrigation of farmlands. The hill torrents are situated in areas of high precipitation and remain in high flows during the Monsoon season. Most of the hill torrents possess considerable perennial flows which provide base flow for urban drainage and industrial effluents.

Floods in the basins of these nallahs generally result from the excessive monsoon rainfall. There were super floods in Ravi and Chenab Rivers 1950, 1954, 1955, 1957, 1959, 1973, 1975, 196, 1988, 1992, 1994 and 1997 which caused severe flooding and heavy damage in the area. The contribution of the nallahs to the river floods was considerable and it inflicted heavy losses to life and property. Total inundation of the area due to nallahs during the super floods of 1955, 1959, 1973, 1975 and 1976 was recorded as 1.2m. ha. **Table 7.13** gives a list of meteorological stations in and around the area which have been considered for the study of the area. Average annual rainfall is about 675 mm in the catchment area of hill torrents outfalling in Ravi River while it is 775 mm for Chenab River tributaries.

TABLE 7.13

INVENTORY OF METEOROLOGICAL STATIONS

Sr No	Name of Station	Latitudes		Longitudes		Height MSL (Meters)	Operating Agency	Period of Available Records
		D	M	D	M			
1	Qila Sobha Singh	74	44	32	13	–	IRR (P)	1977 – 92
2	Zafarwal	74	54	32	20	–	IRR (P)	1977 – 92
3	Ravi Syphon	74	29	31	95	–	IRR (P)	1981 – 92
4	Jassar	74	58	32	07	251	IRR (P)	1901 – 50
5	Sialkot	74	32	32	30	253	PMD	1971 – 92
6	Lahore	74	20	31	33	215	PMD	1963 – 92
7	Gujranwala	74	11	32	10	229	PMD	1971 – 92
8	Shahdara	74	17	31	38	–	IRR (P)	1983 – 92
9	Hafizabad	73	41	32	01	210	PMD	1977 – 79 & 1981 – 90

D :– Degree M :– Minute

IRR(P): Irrigation Department, Punjab
PMD: Pakistan Meteorological Department

7.4.2. Land & Water Potential

Most of the major hill torrents have their catchment areas located in occupied Jammu & Kashir State. There are no potential sites for water conservation in Pakistan. Hence these have not been studied in detail for development of irrigated agriculture in the area.

8. SINDH PROVINCE

8.1 SUMMARY

8.1.1 Location & Extent

Sindh Province is globally located between longitudes 66° 40′ to 71° 05′E and latitudes 23° 45′ to 28° 26′N. It has an area of about 140,914 square km and about 33 million population with a density of 233 persons per sq km. About 30 percent of population is urban. **Fig 8.1** shows the location map and general features of Sindh Province.

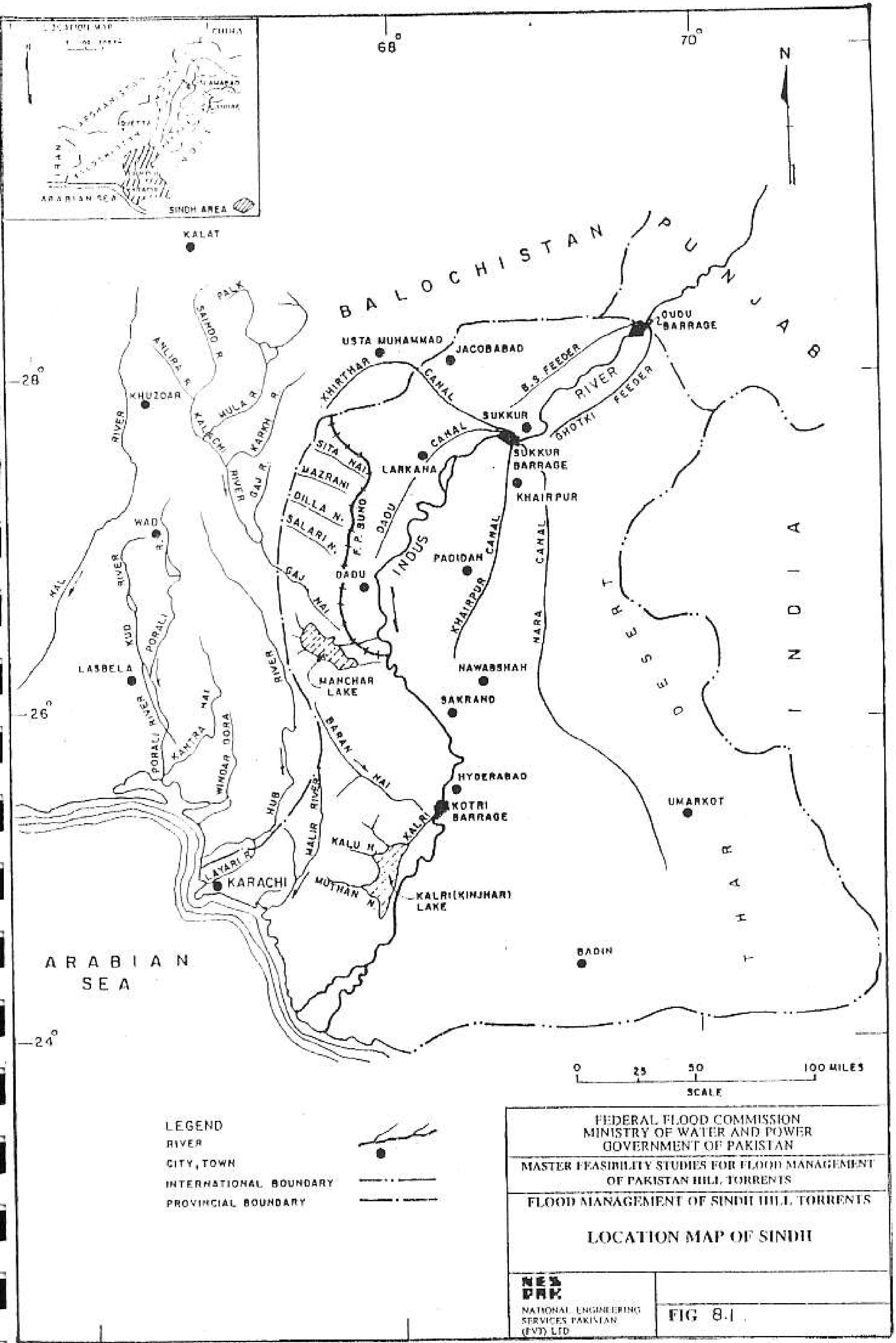
Sindh Province suffers shortage of water, both for municipal and agriculture purposes. Large parcels of land in different hill torrent areas of the Province lie barren and uncultivated for want of water, resulting in low agricultural production. The exploitation of hill torrents flows can provide a potential source of water, which if managed on scientific footings, can increase the existing achievements of agriculture sector.

8.1.2 Agriculture

Landuse statistics indicating land potential of Sindh Province are presented in **Table 8.1**

Table 8.1
Landuse Statistics of Sindh Province

Sr. No.	Description	Area (Mha)
1	Total Geographical Area	14.091
2	Total Reported Area	13.951
3	Total Cultivated Area - Net Sown Area - Current Fallow	5.566 2.915 2.651
4	Total Cropped Area - Area Sown more than Once	4.339 1.424
5	Total Uncultivated Area - Culturable Waste - Forest - Not Available for Cultivation	8.385 1.820 0.578 5.987
6	Irrigated Area	3.161



FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

FLOOD MANAGEMENT OF SINDH HILL TORRENTS

LOCATION MAP OF SINDH

NESPAK
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD

FIG 8.1

8.1.3 Hydrologic Basins

Hydrologically, the Province has three distinct hill torrent areas. These are:

1) Khirthar Range Area
2) Karachi Area
3) Sehwan and Petaro Area

Khirthar Range Area consists of large number of hill torrents of which 24 are major. Total drainage area of these torrents is about 16,100 sq km (6,216 sq mile). Individual hill torrents in Khirther Range except Gaj Nai do not cause any serious damage to FP Bund. However, when flood flows join together and are supplemented by the inflows of Marri Bughti Hills, they assume dangerous proportions and inflict extensive flood damages in Larkana and Dadu districts after breaching through the week portions of F.P Bund. Flood management/water conservation potential of Marri Bughti Hill Torrents has been treated in Supporting Volume-V for Balochistan Province. It is anticipated that after the execution of proposed measures for Marri-Budghti Hills, inflows would considerably reduce along F.P. Bund and damages would be minimised. Of all the hill torrents of Khirthar Range in FP Bund area, only Gaj Nai has conservation potential. Thus, in this report, Gaj Nai has been taken up and studied in detail.

Karachi Area mainly comprises Malir and Liayari Rivers and three tributaries. The aggregate catchment of these torrents is 3,530 sq km (1,363 sq miles) and have considerable land and water potential. Master Planning Studies of this area have been carried out and reported in Supporting Volume-IV of this Report.

Hil Torrents of Sehwan and Petaro Area originate from the lower part of Khirthar Range. These hill torrents have been studied in detail in the report "Flood Management of FP Bund, Baran Nai and Kinjhar Lake Area". The Report has been prepared by a joint venture of Consultants comprising NESPAK (Lahore), ACE (Karachi) and Zaheer-ud-Din Consultants (Karachi) in 1996/97. A brief description of the problems of the area and proposed measures are given in Supporting Volume-IV for Sindh Province while results are summarised in this report.

8.1.4 Land and Water Potential

Land capability classes of the three hill torrent areas of Sindh Province are given in **Table 8.2**, while water potential is given in **Table 8.3**.

Table 8.2
Summary of Land Capability Classes of Hill Torrent Areas of Sindh

(Area in Hectare)

Land Capability Class/Sub-Class	Khirther Hill Torrents Area (ha)	Karachi Hill torrents Area (ha)	Sehwan Petaro Hill Torrents Area (ha)	Total	
				Hectares	%age
I - IIs	292,886	127,423	18,723	438,982	13.6
IIs	19,734	-	-	19,734	0.6
IVs	18,373	-	-	18,737	0.6
Va	1,727	-	386,951	388,678	12.0
Vw	6,949	-	-	6,949	0.2
VI	1,265,817	163,177	904,326	2,333,320	72.2
Built-up Land	-	15,000	10,000	25,000	0.8
	1,605,800	305,600	1,320,000	3,231,400	100

Table 8.3
Runoff Estimation - Sindh Hill Torrent Areas

Sr. No.	Description		Khirthar Range Hill Torrent Area	Karachi Hill Torrent Area	Sehwan & Petaro Area Hill Torrents
1	Average Annual Rainfall, mm		154	206	206
2	Area, sq.km		16,100	3,530	13,200
3	Rainfall equivalent m^3		2.48×10^9	7.30×10^8	2.72×10^9
4	Annual Runoff	m^3 AF	3.65×10^8 296,000	1.16×10^8 94,170	4.07×10^8 330,000
	2.33-Year	m^3 MAF	3.65×10^8 0.296	1.16×10^8 0.094	4.07×10^8 0.330
	5-Year	m^3 MAF	5.763×10^8 0.467	1.80×10^8 0.147	6.10×10^8 0.516
	10-Year	m^3 MAF	6.916×10^8 0.559	2.30×10^8 0.189	7.79×10^8 0.664
	25-Year	m^3 MAF	7.877×10^8 0.638	3.00×10^8 0.244	8.88×10^8 0.757

m^3: Cubic meter *MAF*: Million acre feet.

8.1.5 Water Conservation Practices and Perspective Plan

In order to conserve flows of hill torrents in Sindh Hill Torrent Areas, 11 water management schemes have been executed so far. These schemes are:

-	Irrigation Sluices in Gaj Diversion Bund (Gaj Nai)	9 Nos. (all damaged during 1995 flood)
-	Detention Weirs on Malir River (Karachi Area)	2 Nos.
-	Total	11 Nos.

The Perspective Plan for the Province is as follows:

There are only two hill torrent areas which have potential for development.

- Khirthar Range Area, and
- Karachi Area Hill torrent

The works proposed for these areas with their estimated cost are as follows:-

(A) Khirthar Range Area (Core - Project)

1.	Raising & Strengthening of Gaj Diversion Bund;	Rs 67.00 million
2.	Construction of 10 New Distributors	Rs 66.00 million
3.	Raising & Strengthening of FP Bund RD 32+500 to RD 90+000	Rs 81.00 million
4.	Physical Contingencies, Detailed Design, Construction Supervision, Engineering and Administration	Rs 28.00 million
	Total: (A)	Rs 242.00 million

(B) Karachi Area

1.	Construction of Detention Weir D/S Super Highway on Malir River RD 77+500	Rs 105 million
2.	Remodelling of Weir No.1 RD 19+500	Rs 35 million
3.	Remodelling of Weir No.2 RD 39+500	Rs 30 million
	Total (B)	Rs 170 million
	GRAND TOTAL (A) + (B)	Rs 412 million

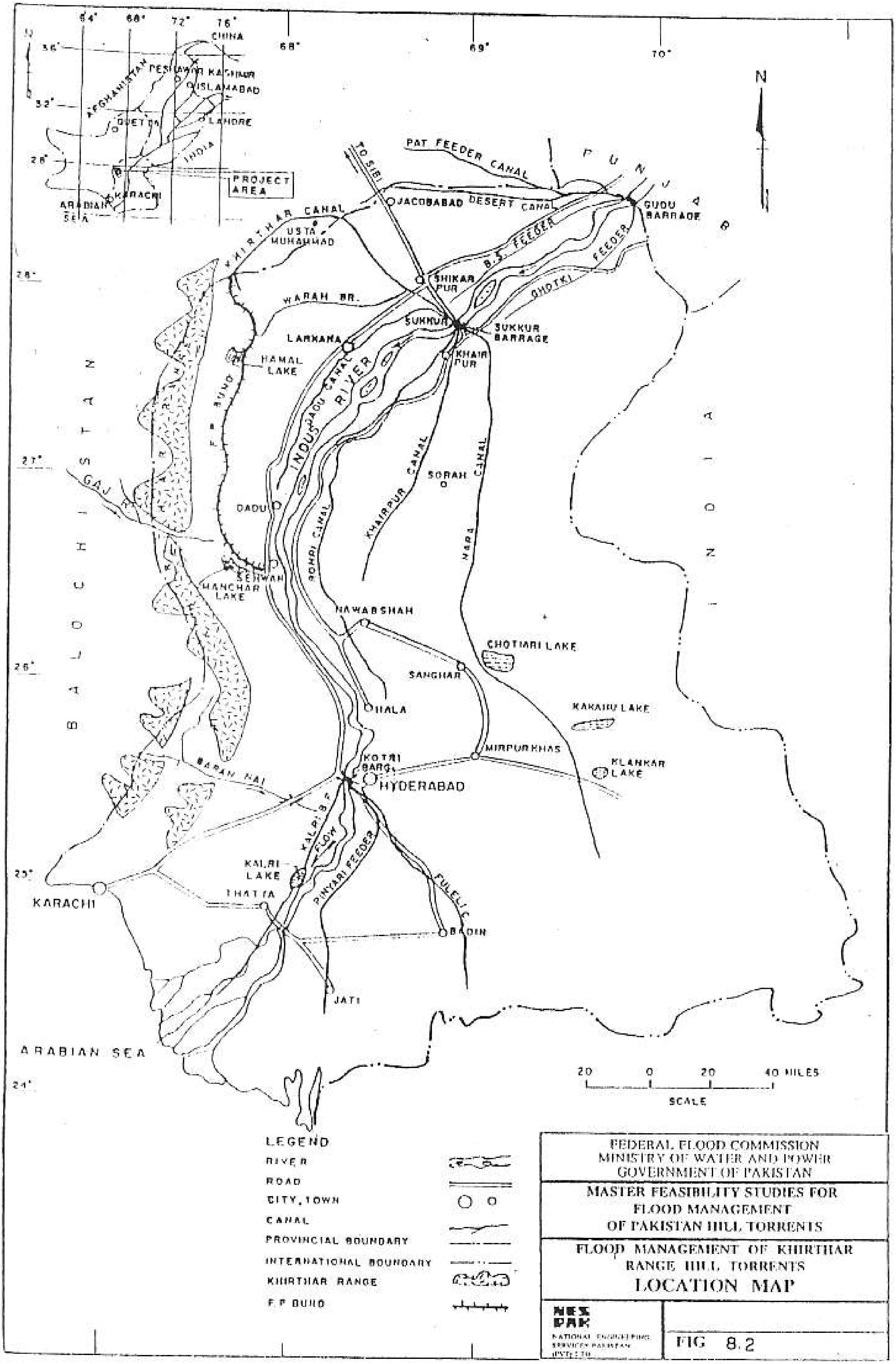
8.1.6 **Recommendations**

The feasibility studies for Core Project have been completed. The structures/schemes proposed therein may be executed after detailed designs. Estimated Cost of proposed works is Rs 242 million. In addition, there is overall potential for more schemes in Khirthar Range Hill Torrents & Sehwan and Petaro Areas Hill Torrents, where lowhead dispersion structures can be constructed for which a provision of Rs 600 million for Khirthar and Rs 300 million for Sehwan & Petaro Areas have been made. These are proposed to be taken up after carrying out Feasibility Studies and Detailed designs for these areas. For Karachi Area, detention weirs have been recommended. Two of the structures require remodelling, while one new site for the construction of detention weir has been explored. The estimated cost of proposed works is Rs 170 million. Feasibility studies for Mole Dam have already been carried out by PIDA Sindh. Its estimated cost is Rs 2,045 million. However, it is out of scope of the present study. Detailed feasibility studies are required for the three weir sites and low head dispersion structures, prior to their execution. Thus, total provision for Sindh Province is Rs 1,312 million.

8.2 KHIRTHAR RANGE HILL TORRENTS

8.2.1 Introduction

Sindh Province of Pakistan has been facing flood problems caused by Khirthar Range Hill Torrents since ancient times. The Province having unique geophysical features, includes almost a continuous hill range (Khirthar Range) all along its western border. Large number of hill torrents, of which 24 are major, originate from this range and debouch onto the plains of Larkana and Dadu districts. Schematic diagram of hill torrents affecting Pat Feeder, Khirthar Canals and FP Bund are given in Fig 8.2. Prior to the construction of Sukkur Barrage Canal System, the flows from these torrents would either spread onto the plains or drain into the Indus River. The development of Sukkur Barrage Canal Command



FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

FLOOD MANAGEMENT OF KHIRTHAR RANGE HILL TORRENTS

LOCATION MAP

NESPAK
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD.

FIG 8.2

(1927-32) necessitated the construction of Flood Protective (FP) Bund to provide protection to the irrigated areas. The FP Bund created an obstruction on the natural flow path of the hill torrents. During monsoon season, the hill torrents generate flashy flows which accumulate against FP Bund and frequently breach it at different places. On the other hand, large parcels of fertile land are available between FP Bund and Khirthar Range which lie uncultivated for want of irrigation supplies. The primary objective of this study is to plan measures to safeguard Sindh Province from the onslaught of hill torrent flows of Khirthar Range through water conservation and management techniques.

The hill torrents of Khirthar Range possess varying hydrologic characteristics. The catchment areas, the lengths of channels and slopes largely differ from torrent to torrent. Nevertheless most of the hill torrents are non-perennial and flow only during rainfall periods. Nearly all of the streams, except Gaj Nai, originate from the Khirthar Range, descend onto the plains with sharp slopes and spread out in the form of shallow channels which generally disappear after a short distance. The area experiences precipitation due to Monsoon as well as Westerly Disturbances, whereby small amount of runoff is generated both during the months of summer and winter seasons. The availability of flood flows and geophysical characteristics of the area generally preclude all hill torrents from the construction of structural measures for water conservations except Gaj Nai.

Gaj Nai is the largest of the streams, which originates from the hill range near Khuzdar in Balochistan Province where it is known as Kurlachi River. It has the largest catchment area (6,860 sq.km) and generates about 3.65×10^8 m^3 (0.30 MAF) runoff during an average year of precipitation. This is the most potential hill torrent for conservation of flows and has large areas where conserved flows can be diverted for development of sustained irrigation system.

The management of hill torrents flows would not only save the area from hill torrents floods but also provide irrigation supplies to a part of cultivable area. The proceeding sections present land and water potential of the area alongwith a feasible plan of development.

8.2.2 Project Background

Khirther Range lies along the western border of Sindh Province. The range forms Sindh, Balochistan provincial boundary from north of Shahdad Kot to south of Sehwan, where it approaches the right bank of Indus River. Foothill of the range comprises piedmont plain enclosed by the alluvial plains of Dadu and Larkana Districts of Sindh Province, which extend upwards in the north to Kachhi Plain and the right bank command areas of Gudu and Sukkur Barrages in Shikarpur and Jacobabad Districts.

Prior to the construction of Sukkur and Gudu Barrages, the entire plain area depended upon the flows of hill torrents and natural precipitation. FP Bund was constructed as part of the Sukkur Barrage Canal Command Area Development Project. It blocks the natural flow path of the hill torrents providing them a new direction towards Indus River through Hamal Lake and Manchhar Lake along the hill side bank of the bund.

The development of Gudu Barrage in 1960s included the construction of Pat Feeder Canal, which created similar barrier on the way of runoff generated in Marri Bughti and Nari Bolan Ranges. The flows of the torrents of these ranges assumed a new path along the right bank of Pat Feeder Canal in a south western direction, ultimately joining the Khirthar Hill Torrents runoff moving along FP Bund. Exhibit M-8.1 and Exhibit M-8.2 show the Khirthar Range Hill Torrents and other features of the area and Fig.8.2 presents a schematic diagram of the hill torrent flows respectively. The following paragraphs deal primarily with Gaj Nai only.

8.2.3 **Land and Water Potential**

8.2.3.1 <u>Land Potential</u>

According to Bureau of Reclamation System, the soils of Gaj Nai Area have been classified into six land classes. Class-I lands are very good arable lands and have no limitations to roots, air water penetration. They are highly suitable for a wide range of agriculture crops and vegetables adopted to the climate of the area. Class IV land is special use land. It comprises of sandy soils and have limitations of very high intake rate, rapid internal drainage and low nutrient holding capacity. It should better be developed as a grazing land. The class VI land is non arable which comprises mountainous areas and excessively gravelly lands. These areas are subject to erosion which could be minimized by planting some xerophytic plant species. They also provide poor grazing to local animals.

The statistics of above land classes is given below:

Class I land	10.9%	(745 km^2)
Class IV land	0.1 %	(10 km^2)
Class VI land	89.0%	(6105 km^2)

8.2.3.2 Water Potential

The runoff volumes for various return periods have been determined by using method of US Soil Conservation Services. Rainfall data of different stations in and around the area was used to estimate precipitations for different theoretical return periods.

Table 8.4
Flow Volumes of Gaj Nai for Different Return Periods

Return Periods	Runoff Volumes	
	m^3	MAF
2.33 Year	$2.48x10^9$	0.30
5 - Year	$3.92x10^8$	0.318
10 - Year	$5.79x10^8$	0.470
25 - Year	$7.75x10^8$	0.629

8.2.4 **Perspective Plan & Cost Estimates**

Various components of the recommended plan for Gaj Nai Diversion Bund are described as under:

8.2.4.1 Sluices

There are nine sluices offtaking from the Gaj Nai Diversion Bund and these convey flood flows for irrigation to the respective command areas. Table 8.5 shows the names of sluices, offtaking RDs, command areas and design discharges. The washed away sluices i.e. Raj Wah L1, Nao Wah L2, Suk Nai L4 and Panj Lawn L5 have been reconstructed and the remaining five sluices repaired.

Table 8.5
Different Parameters of Gaj Diversion Sluices

Sr No.	Name of Offtake/Sluice	Bund RD ft	Command Area		Design Discharge	
			ha	ac	cumecs	cusecs
1	Raj Wah - L1	634	6,653	16,433	36.75	1,298
2	Nao Wah - L2	1,750	3,615	8,929	22.20	784
3	Gul Muhammad Wah - L3	9,600	7,893	19,496	50.65	1,789
4	Suk Nai - L4	11,340	5,018	12,394	34.57	1,221
5	Punjab Lawn - L5	11,700	12,731	31,446	94.31	3,331
6	Haji Khan - L6	14,000	2,093	5,170	16.39	579
7	Gaj Nai - L7	17,500	5,866	14,489	33.41	1,180
8	Pipe Sluice - L8	21,075	202	500	1.70	60
9	Sajan Ji - L9	22,376	811	2,000	13.36	472
Total			44,840	110,755		

8.2.4.2 Distribution Structures

Ten distribution structures on the sluice wahs have been proposed for the distribution of flood flows. These have been proposed at the sites where flood flows are presently *distributed by earthen structures, which only function during low flows. In the event of* high flows, these are damaged which result in uneven distribution of flows. Such flows cannot be properly utilized by the farmers and move downstream resulting in severe damage.

8.2.4.3 Diversion Dykes

Diversion dykes in the bed of Gaj Nai have been proposed to divert low flows to the sluices. The bed of Gaj Nai, downstream of each dyke, has been provided with wire crated stone apron to check scour. Bank raising have been proposed tentatively upstream and downstream of the structures.

8.2.4.4 Raising and Strengthening of Gaj Diversion Bund

The bund has a total length of 9,448 m (31,000 ft). The bund was over topped at a number of places and was washed away in a length of about 914 m (3,000 ft). It is proposed to reconstruct 914 m (3,000 ft) length of the bund and the balance length be raised and strengthened with gabions. The raising of the bund is essential so that it is not overtopped again. The bund has been proposed to be provided with a toe wall of gabions. The Gaj Nai Diversion Bund is shown in Exhibit M-8.3.

8.2.4.5 Raising and Strengthening of FP Bund

Nine Wahs are supplied with flood flows through sluices offtaking from the Gaj Nai. The flood flows are diverted and utilized for irrigation upto a limited flood flow. The excessive flood water affects the FP Bund and ultimately outfalls in the Manchhar Lake.

To protect the FP Bund against excessive flood flows from Gaj Nai, following improvements are proposed for the reach from RD 32+500 to RD 90+000

1. Top level to be raised by 0.91 m (3 ft)
2. Top width to be increased from 6.1 m (20 ft) to 7.62 m (25 ft)
3. Gabions toe wall 1m x 1m to be provided on water side
4. Side slope of the bund (water side) to be strengthened by laying stone pitching over spawl and bajri.

8.2.4.6 Project Cost

Estimated costs of various structures have been summarized in **Table 8.6**. These estimates are based on CSR-1995 of Sindh Province. The total proposed package has been estimated to cost Rs 242.0 million.

Table 8.6
Summary of Cost of Civil Works
(1996 Price Level)

Sr. No.	Name of Work	Cost (Rs Million)
1	Raising & Strengthening of Gaj Diversion Bund - 28,000 Feet	67.00
2	Distributors - 10 Nos.	66.00
3	Raising & Strengthening of FP Bund RD 32+500 to RD 90+000	81.00
	Total of Civil Works Costs including physical contingency	224.70
4	Detail Design & Construction Supervision @ 5% of Civil Works	10.70
5	Engineering & Administration @ 3% of Civil Works	6.42
	GRAND TOTAL	241.82
	Say Rs 242 Million	

8.2.4.7 Economic Feasibility

The criteria for public investment viz; Net Present Worth, Benefit Cost Ratio and Internal Rate of Return have been applied to the discounted cash flows of benefits and costs to examine project economic feasibility. **Table 8.7** summarizes the results of the analysis.

Table 8.7
Economic Parameters

(Rs Million)

Parameters	Rate of Discount (Percent)			
	10	12	15	20
Discounted Benefits	257.9	216.1	170.1	120.8
Discount Cost	207.7	197.0	183.8	166.7
Net Present Worth	50.18	19.12	-13.6	-45.9
Benefit/Cost Ratio	1:1.24	1:1.10	1:0.93	1:0.72
Internal Rate of Return	13.75 percent			

The parameters given above indicate that the Net Present worth is positive and Benefit-Cost Ratio exceeds unity even at 13 percent rate of interest. Similarly, the Internal Rate of Return of 13.75 percent is above the opportunity cost of capital in Pakistan. It is, therefore, established that the project is economically feasible and the public investment thereon is justified. There is also potential for construction of low head dams/dispersion structures in Khirthar Range Hill Torrent Area for which additional provision of Rs 600 million has been made for Khirthar Range Hill Torrents in the Perspective Plan.

8.3 KARACHI AREA HILL TORRENTS

8.3.1 Introduction

Unmanaged floodflows of hill torrents of Malir and Hub rivers adversely affect Karachi Area and frequently imperil the socio-economic well being of the city and its suburbs, depriving the cultivable lands of irrigated agriculture. Karachi is the largest city of the country with an estimated population of about 10 million. In spite of existence of considerable land potential in the catchments of hill torrents, only negligible quantities of agricultural commodities are being produced around the city. The runoff generated in the river basins is currently going waste in the form of floods, which cause heavy death toll and inflict colossal damages to houses, commercial centers, public installations and communication systems. Major parts of foodgrain, vegetables, fruit etc needed for the city are brought from distant areas which could be produced by properly conserving flood flows of Malir

River. The population of Karachi Metropolitan is not only facing dearth of agricultural products but also acute shortage of potable water. The quality of groundwater is generally not fit for drinking; and in spite of massive arrangements for bringing water from distant sources, the water supply remains short due to high population growth rate and influx of people from the other areas.

The fundamental objectives of the Project envisage proper and scientific conservation and utilization of land and water resources of Karachi Hill Torrent Area. This would essentially require a realistic estimation of the quantum of cultivable acreage viz-a-viz the surface runoff exploitable for agricultural development and domestic utilization.

8.3.2 Project Area

8.3.2.1 Location and Extent

Karachi Hill Torrents Catchment Area is nearly triangular in shape, with the base of the triangle along and almost in the direction of the coastline of Arabian Sea passing south of the city area. On its south, is the Arabian Sea; on the north-west and west is Lasbela District of Balochistan, whereas the administrative limit of Sindh and Balochistan Provinces, is determined by the Khirthar Range and Hub River. The parts of the sub-catchments of a few tributaries of Malir River extend over adjacent areas of Thatha District.

Karachi Hill Torrent area lies between longitudes 66° 58′ to 67° 35′ East and latitudes 24° 48′ to 25° 43′ North. The aggregate catchment area is about 3,530 square kilometers (1,363 sq.miles). This mainly includes the catchments of Liayari and Malir rivers alongwith their tributaries. Exhibit M-8.4 presents the Project Area alongwith the major features.

From the economic view point, agriculture occupies the prominent position in the rural area of the Project. Land utilization statistics of the Project Area is as follows:

Total Geographical Area	=	353,000 ha
• Cultivated Area	=	51,000 ha
• Net Area Sown	=	13,000 ha
• Current Fallow	=	38,000 ha
• Average Annual Cropped Areas	=	19,400 ha
• Average Annual Irrigated Area	=	11,400 ha
• Area Annually Sown More Than Once	=	6,000 ha
• Total Uncultivated Area	=	302,000 ha
• Forest Area	=	96,000 ha
• Culturable Waste	=	62,000 ha
• Area Not Available for Cultivation	=	144,000 ha

8.3.3 Land and Water Resources

8.3.3.1 Land Potential

Total cultivated area in the Project is about 51,000 ha of which generally 38,000 ha remains fallow due to non availability of water. In addition, 62,000 ha culturable waste land is available which can be cultivated if water resources can be made available for the area. Thus, cultivable land in the Project Area is about 113,000 ha.

8.3.3.2 Runoff Potential

Liayari River Catchment

The average annual precipitation recorded in Karachi Area is 216 mm (8 inches). The catchment area of the river is 466.20 sq.km (180 sq.mile). The rainfall equivalent is thus nearly 10.07 x 10^7 m^3 (81,600 AF). It has been estimated that nearly 25 percent of this amount 2.50 x 10^7 m^3 (20,400 AF) is annually converted into runoff.

Malir River Catchment

The gauge site is located at Latitude 25° 02' and Longitude 67° 24', on the Super Highway Bridge with a catchment area of 2,235 sq km (863 sq. miles).

The mean annual flow of the river is 64.86 x 10^5 m^3 (52,600 AF) with runoff rainfall coefficient of 14.28 percent.

8.3.4 Perspective Plan and Cost Estimates

8.3.4.1 General

The geo-hydro and physiographic features of Karachi Hill Torrent Area warrant the conservation of floodflows which would serve as a source of recharge to the groundwater aquifer which can be exploited for the development of agriculture in the area. Suitable plan for Malir and Liayari Area is to construct detention weirs and storage dams in accordance with their suitability to the local conditions.

The following are some of the potential sites where water conservation structures can be constructed or improved.

- Mole Dam on Mole Tributary of Malir River;
- Construction of New Detention Weir downstream of Indus Super Highway - National Highway Link Road Bridge, RD 77+500;
- Remodelling of First Detention Weir RD 19+500, Malir River;
- Remodelling of Second Detention Weir RD 38+500, Malir River; and
- Construction of Detention Weirs across Liayari River.

These schemes are discussed hereunder:

8.3.4.2 Mole Dam

The proposed Mole Dam is anticipated to increase the irrigated area from 1,400 ha to 3,100 ha and decrease the fallow land from about 3,000 ha to 1,300 ha in Malir River area. The total agricultural land will increase from 2,500 ha to 4,200 ha. The cropped area will increase from 2,730 ha to 6,150 ha; and the anticipated production would go up from 5.58 tons/ha to about 11 tons/ha. The total quantum of agricultural products in the Project Area will increase from 14,040 tons/year to 62,500 tons/year due to horizontal and vertical expansion of agriculture. The overall incremental benefits would be of the order of Rs 245 million annually, at 1995 price level, apart from 291,400 man days of employment and related socio-environmental benefits. The total cost of Project at 1995 price level is Rs 2,045 million. Detailed discussion regarding this dam is beyond the scope of our present study.

8.3.4.3 Construction of Detention Weir Across Malir River, Downstream of the National - Super Highway Link Road Bridge - RD 77+500

The salient features of the proposed structure are:

- Design Discharge = 235 cumec (8,300 cusec)
- Length of Weir = 167.6 m (550 ft)
- Crest Level = 69.8 m (229 ft), msl
- Bed level (U/S & D/S) = 67.05 m (220 ft)
- Ground Level = 70.71 m (232 ft)
- Pond Level U/S = 72.84 m (239 ft)
- Pond Level D/S = 71.01 m (233 ft)

The conserved flows are expected to replenish the groundwater for existing wells/tubewells of the area.

A preliminary estimate of the cost of the new weir is Rs 105 million. Detailed studies and investigation for the scheme are required to be carried out.

8.3.4.4 Remodelling of Detention Weir No.1 (First Detention Weir), Across Malir River - RD 19+500

Salient features of the remodelled weir are as follows:

-	Area of Lake	:	292.7 ha (723 acre)
-	Storage Capacity	:	$1.25 \times 10^7 m^3$ (10,124 AF
-	Height of Weir	:	4.3m (14 ft)
-	Length of Weir	:	152.4 m (500 ft)
-	Lake Bed Level	:	21.95 m (72 ft)
-	Crest Level	:	27.12 m (89 ft)
-	Area to be Benefitted	:	8,027 ha (19,826 acre)
-	Height Bank Level	:	31.1 m (102 ft)

The preliminary cost of the Project has been estimated to be Rs 35 million at 1996 price level. This weir is providing recharge to aquifer for existing tubewells which irrigate local agricultural areas.

8.3.4.5 Remodelling of Detention Weir No.2 (Second Detention Weir) Across Malir River, RD 39+500 Upstream of Railway Bridge

Second Detention Weir across Malir River was constructed in 1993. Due to the construction of this weir, tubewell irrigation became possible upto RD 42+000 upstream of Malir River Railway Bridge. Due to the increased withdrawal, the efficiency of the wells in the area has decreased. Moreover, the fertile lands on upstream of RD 42+000 need to be ensured regular well-irrigation supplies. This objective can be achieved if the existing structure of Second Detention Weir is raised. This will create a large lake and enhance the rate of groundwater recharge. The salient features of the remodelled weir are as follows:

- Crest Level : 46.02 m (151 ft)
- Top of Upstream Flank and Return : 49.07 m (161 ft)
- Top of Downstream Flank and Return : 48.16 m (158 ft)

Preliminary cost of the remodelling works has been estimated as Rs 30 million at 1996 price level.

8.3.4.6 Recommendations

Detailed feasibility study for remodelling of Weir No. 1 & 2 and construction of Weir No.3 on Malir River be undertaken. Field visits carried out, interview held with beneficiaries and analysis of data have indicated that large potential exists for development of irrigated agriculture in the area. Remodelling and construction of weirs would greatly help in recharging the groundwater aquifer which can be exploited by installing radial collector wells to skim the shallow sweet water layers. There is over 100,000 ha of land potential which is not being exploited at present due to lack of water. Growth of vegetables and maintenance of livestock in the vast tract of waste land would usher in new era of economic prosperity in the area. Big market of Karachi would provide great opportunity for sale of vegetables and dairy products from the area. Provision of Rs 170 million has been made for hill torrents of Karachi Area.

Liayari River

Due to the deteriorated quality of groundwater, Liayari River aquifer cannot be exploited. In addition, no suitable site for any type of conservation structure is available in its catchment. It is recommended that investigations may be extended to its extreme northern part of catchment, where the possibility of a water conservation scheme might be explored.

8.4 SEHWAN & PETARO AREA

The hill torrents originating from the eastern slopes of Khirthar Range below Manchar Lake Area to Karachi belong to this zone. Major hill torrent of the area are:

- Baran Nai; and
- Hill torrents directly outfalling into Kinjhar Lake

8.4.1 Baran Nai

Baran Nai originates from the Khirthar Range and passes through a narrow gorge known as Darwat Pass. The catchment area of Baran Nai is about 2,600 sq.km (1,000 sq.miles) upto Darwat Pass and over 4,680 sq.km (1,800 sq.miles) upto Kalri Baghar Feeder. Flood flows of Baran Nai have damaged Kalri Baghar Feeder, its infrastructure and agricultural areas. It also crosses National and Supper Highways and Karachi Kotri railway line which are also sometimes damaged by the flood flows of Baran Nai. Dau and Darwat are the two possible sites where flows of Baran Nai could be conserved. Studies carried out by various consultants have indicated that dams are not feasible due to higher cost involved. However, it is recommended that study be carried out to conserve flood flows by constructing low level delay action dams by using boulders available in the bed of the channel.

8.4.2 Hill Torrents Outfalling in Kinjhar Lake

There are a number of hill torrents which directly outfall in Kinjhar Lake. It is fed from the Indus River through KB Feader. Kinjhar Lake embankment were constructed in 1956 consisting of locally available sandy clayey silt. The lake storage is about $1 \times 10^9 m^3$ (0.82 MAF). Recently the embankments have been strengthened by PIDA Sindh. The bunds have been raised to provide 1.5 m (5 ft) freeboard over its conservation level of 16.46m (54 ft). There is, thus, no potential for further consideration.

8.4.3 Conclusions & Recommendations

At present water conservation potential is insignificant, hence detailed studies have not been carried out. However, it is recommended that, studies may be initiated for the construction of low level delay action dams at various suitable sites along Baran Nai for which provision of Rs 300 million has been made.

8.5 PERSPECTIVE PLAN & COST ESTIMATES

Development potential for integrated use of water and land exists in the hill torrent areas of Sindh Province. In Khirthar Hill Torrent area, Gaj Nai has great potential for development. Gaj Diversion Bund (GDB) has been constructed to divert flows of Gaj Nai towards Manchar Lake. Nine number sluices have been constructed in GDB to divert flows. During the field visit, it was observed that GDB has not been designed on scientific lines and it is not optimally aligned. Flood flows are not properly diverted to the offtaking channels. Earthen dispersion structures are constructed by the cultivators which work only during low flows and are damaged as soon as the flood peaks exceed the management capacity of the farmers. After the damaging of diversion structures, flood flows move in one channel and cause retrogression and damage FP Bund because of higher velocities of the concentrated flows. Flood flows are thus wasted out of the area. It is generally not possible to reconstruct the earthen diversion structures for the subsequent flood flows. Thus, it has been proposed to reconstruct the entire diversion system on scientific lines and strengthen a part of FP Bund from RD 32+500 to RD 90+000 which is likely to be affected by the excessive flows of Gaj Nai. The total cost of this package is Rs 242 million (1996 Price level). In addition to this, potential also exists for conserving the flows of Malir Nadi by remodelling the two existing weirs and constructing a new weir. This strategy will facilitate in recharging the ground water aquifer along Malir Nadi. The recharge to the aquifer could be exploited by constructing radial collector wells, a few of which have already been installed in the area. Aquifer test conducted on one of the radial collector well indicated very encouraging results. The cost of this package is Rs 170 million. The studies conducted by various Consultants for hill torrents of Sehwan and Petaro area have indicated that conservation sites on Baran Nai are technically not feasible. However, we are of the view that low head weirs may be constructed at a number of places in the three hill torrent areas which could serve as a source of recharge to ground water reservoirs. Generally the salinity of groundwater increases with depth. Hence in order to skim upper sweet layers, radial collector wells could be constructed in these areas. Provision of Rs 600 million is being made for Khirthar Range Hill Torrents and Rs 300 million for Sehwan and Petaro areas in the perspective plan for this purpose. Thus, a total provision of Rs 1,312 is being made for conservation of hill torrents of Sindh Province.

9. BALOCHISTAN PROVINCE

9.1 SUMMARY

9.1.1 Location & Extent

Balochistan is the westernmost Province of Pakistan. It is bordered on the west and northwest by Iran and Afghanistan; on the north and east by North Western Frontier Province, Punjab and Sindh; and on the south by the Arabian Sea with a coastline about 754 km as shown on Exhibit M-9.1. Globally, it is located between longitudes 60° 50′ to 70° 5′E and latitudes 24° 50′ to 32° 10′N. Balochistan encompasses an area of about 347,200 sq.km and has a population of about 6.5 million.

Lack of irrigation facilities is the fundamental constraint responsible for the low level economy of the Province. The exploitation of hill torrents flows can provide a potential source of water, which if managed on scientific footings, can greatly increase the existing production of agriculture sector.

The landuse statistics of Balochistan Province are given in Table 9.1.

Table 9.1
Landuse Statistics of Balochistan

Sr. No.	Description	Million Hectare (Mha)
1	Geographic Area	34.719
2	Reported Area	18.602
3	Cultivated Area	1.686
4	Cropped Area	0.913
5	Current Fallow Area	0.777
6	Canal Irrigated	0.493
7	Well Irrigated	0.014
8	Tubewell Irrigated	0.215
9	Karezes, Springs	0.095
10	Uncultivated Area	16.915
11	Culturable Waste	4.663

Source: Agricultural Statistics of Balochistan 1994-95

Hill Torrents of Balochistan generate, on the average, 7.86 MAF runoff, whereas the culturable waste has been estimated as about 4.68 M.ha. (11.6 M. acres). Runoff *estimation for the Province is summarized in **Table 9.2**.*

Table 9.2
Water Resources of Balochistan

Sr. No.	Description		Province	Indus Basin Component & Quetta Area (Core Project)	KCD Basin	MC Basin
1	Average Annual Rainfall, mm		158	300	100	150
2	Area, sq.km		347,190	126,725*	97,440**	123,025
3	Rainfall equivalent		55×10^9	38×10^9	9.7×10^9	18.4×10^9
4	Average Runoff Coefficient		0.18	0.15 to 0.30	0.10	0.20
5	Av.Annual Runoff	m^3	9.69×10^9	5.52×10^9	9.7×10^8	3.69×10^9
		Acre ft	7,856,000	4,067,000	789,000	3,000,000
	2.33-Year	m^3	9.69×10^9	5.02×10^9	9.7×10^8	0.369
		MAF	7.856	4.067	0.789	3.000
	5-Year	m^3	1.13×10^{10}	5.85×10^9	1.14×10^9	4.3×10^9
		MAF	9.143	4.740	0.920	3.483
	10-Year	m^3	1.42×10^{10}	7.31×10^9	1.42×10^9	5.44×10^9
		MAF	11.532	5.920	1.149	4.463
	25-Year	m^3	1.70×10^{10}	8.78×10^9	1.70×10^9	6.52^9
		MAF	13.849	7.110	1.379	5.360

MAF = Million Acre ft.
* = Including Quetta Region Area of 24,420 sq.km
** = Excluding Quetta Region Area of 24,420 sq.km
KCD = Kharan Closed Desert
MC = Mekran Coastal

It has been estimated that about 400 existing flood conservation schemes utilize nearly $3.70 \times 10^9 m^3$ (3 MAF) of runoff. Thus, there is great potential to develop another $6.00 \times 10^9 m^3$ (4.86 MAF) by constructing additional structures.

In order to prepare Master Feasibility for Flood Management of Hill Torrents for the entire country, Pakistan has been divided into fourteen major hill torrent areas. Entire Balochistan Province constitutes three major drainage basins. Consequently, this Section comprises three parts dealing with the three basins separately as below:

Part I	=	Indus Basin Component including Quetta Region
Part II	=	Kharan Closed Desert Basin excluding Quetta Region
Part III	=	Mekran Coastal Basin

During the currency of the study, Consultants were directed by the Client to prepare one Bankable Document for each potential area of a Province as a Core Project. Accordingly, "Indus Basin Component including Quetta Region" was selected as Core Project for detailed study in consultation with PIDA, Balochistan. The proceeding part of this report presents the Core Project in greater detail as compared to presentation for other two components. The proposed development plan is as follows:

INDUS BASIN COMPONENT (Core - Project)

Recommended for execution during 9th Five Year Plan (1998-2003)

- Total Identified Schemes	285
- Estimated Cost	Rs 3,768 million (A*)

Recommended for execution during 9th Five Year Plan (1998-2003)

- Delay Action Dams	91 No
- Flood Irrigation Schemes	59 No
- Estimated Cost	Rs 2,757 million

Execution of balance 135 schemes during Ist two years of 10th Plan	Rs 1,011 Million

KHARAN CLOSED DESERT BASIN

- Identified Delay Action Dams	38 No
- Identified Flood Irrigation Schemes	16 No
- Estimated Cost	Rs 640 million (B)**

MEKRAN COASTAL BASIN

- Identified Delay Action Dams	56 No
- Identified Flood Irrigation Schemes	20 No
- Estimated Cost	Rs 1,361 million (C)**
GRAND TOTAL (A+B+C)	Rs 5,769 million

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* As per Feasibility Study carried out by NESPAK

** Cost Estimate given by PID, Balochistan

9.2 INDUS BASIN COMPONENT & QUETTA REGION

9.2.1 Introduction

The Indus Basin component of Balochistan Province including Quetta Valley, is the most attractive area for the development of land and water resources. This part of the Province receives comparatively more rainfall thereby generating larger runoff, only a part of which is currently being used. Some parts of the area also receive snowfall which provides a useful source of perennial flow in a number of streams and recharge to groundwater reservoirs. High altitudes provide good opportunity for special agricultural products comprising the world's best quality of fruits like apple, apricot, pear etc. Dry fruit (Almonds Wallnuts etc.) production is also a special feature of the area, wherefrom it is supplied to all parts of the country.

The area includes a climatically characteristic mountainous region which is unique in production of a special kind of precious forest plant. Ziarat Area produces juniper trees where the world's second largest juniper forest exists.

Total cultivated area in Indus Basin Component including Quetta Region is about 1.14 Mha with a culturable waste of about 0.838 Mha. Total irrigated area is about 0.58 Mha. This area is being irrigated through canals owned both by Government and private cultivators, tubewells, wells, karezes, springs and other sources.

The water potential of the Project Area is as follows:

-	Average annual available runoff	=	$5.02 \times 10^9 m^3$ (4.067 MAF)
-	Currently being used	=	$4.98 \times 10^8 m^3$ (403,200 Acre ft)
-	Additional runoff likely to be used by the proposed structures	=	$2.00 \times 10^9 m^3$ (1.62 MAF)
-	Total uses	=	$2.50 \times 10^9 m^3$ (2.0 MAF)
-	Balance available for future uses	=	$2.52 \times 10^9 m^3$ (2.0 MAF)

The above statistics indicate that in addition to the proposed uses by the newly planned structures, about 2 MAF additional runoff will be available for future uses.

9.2.2 Project Area

9.2.2.1 <u>General</u>

The Project Area (Exhibit M-9.2) consists of Indus Basin Component of Balochistan and covers the entire northern part of Balochistan including Quetta and Pishin Districts. It encompasses Zhob River Basin, Nari Bolan Basin, Kachhi Plain Hill Torrents Basin and Marri Bughti Hill Torrent Basin comprising Quetta, Zhob, Loralai, Sibi and Nasirabad Divisions. The project is spread over an area of 126,725 sq.km. (48,928 sq miles) with an estimated current population of about 3.93 million inhabitants. The average density of population is nearly 31 persons per square kilometer which is comparatively denser than Kharan Closed Desert Basin and Mekran Coastal Areas.

9.2.2.2 Climate and Precipitation

The climate of the Project Area has a wide variation. The hilly areas in the north have bracing cool dry climate. Kachhi Plain is among the hottest places in the country. Most of the area receives low precipitation. However, annual mean precipitation of some parts of Project Area is quite high and is thus classified as semi-arid. The summers are generally too hot except for some high altitude areas which have pleasant climate. The winters are generally very severe and are affected by Siberian Winds. Quetta, Ziarat and some other parts of Project Area receive snowfall during winters. The Project Area has distinct climatic regions comprising:

- Sub-Tropical Continental Low Lands;
- Sub-Tropical Continental High Lands; and
- Sub-Tropical Continental Plateau.

The average annual rainfall over the area varies from 200 mm to 375 mm with an average of 300 mm for the entire area.

9.2.2.3 Agriculture

The Project Area is the most productive part of the Province and contains canal command area having irrigation supplies from Indus River through Pat Feeder and Khirthar Canal systems. The northern parts comprise high lands which are quite suitable for fruit and vegetable production. The Project Area contains maximum part of the cultivated area of Province with higher cropping intensity as compared to other regions of Balochistan. The area has maximum development potential due to comparatively high rainfall and fertile lands generally suitable for all kinds of crops.

9.2.2.4 Hydrologic Basins

There are nine major hydrologic basins as listed below:

- Nari River Basin;
- Kunder River Basin;
- Zhob River Basin;
- Marri Bughti Basin;
- Talli/Chakar River Basin;
- Bolan & Mula River Basin;
- Pishin & Sariab River Basin;
- Musa Khel (Sanghar, Vehova) Basin;
- Upper Kaha Basin

All these basins drain an area of about 126,700 sq.km and generate an average annual flow of $5x10^9m^3$ (4 Million Acre ft). Indus Basin Component has comparatively more potential for development of irrigated agriculture than the other two basins.

9.2.3 Land and Water Resources

9.2.3.1 Land Resources

For development of sustained agriculture in an area, soils and land suitability play a dominant role. The studies carried out for land resource evaluation have indicated that good quality arable land of 2.57 Mha (25.83%) of the total cultivable area of the Province is available in the Project Area. Out of this, 1.14 Mha is being cultivated, while 0.84 Mha is culturable waste. If water could be made available for this area, it can be brought under cultivation.

9.2.3.2 Water Potential Evaluation

The foundation of any successful irrigation enterprise is the availability of adequate quantity of water for sustained crop production. Quantitative evaluation of available flows forms an essential component of all irrigation projects and is therefore a basic requirement for their proper planning. Thus, efforts have been made to determine the availability of this resource for development of irrigation facilities in the Project Area.

For a number of basins, rainfall and runoff record was available which has been used to determine correlation coefficient between rainfall and runoff. The available flow for various return periods have been determined, existing uses have been calculated. These studies have been described in detail in Supporting Volume-V of this report.

Table 9.3 shows the estimated average annual available flows, while **Table 9.4** gives the flows for various return periods. **Table 9.5** provides the existing uses of water and planned uses by the proposed projects for this area.

Table 9.3
Estimated Average Annual Available Flows
(2.33-Year Return Period)

Description	
Nari River Basin	$1050 \times 10^6 m^3$ (0.852 MAF)
Kundar River Basin	$189 \times 10^6 m^3$ (0.154 MAF)
Zhob River Basin	$991 \times 10^6 m^3$ (0.804 MAF)
Marri Bughti Basin	$467 \times 10^6 m^3$ (0.379 MAF)
Talli/Chakar River Basin	$65 \times 10^6 m^3$ (0.053 MAF)
Bolan&Mula/Sharkal Misc Basin	$719 \times 10^6 m^3$ (0.583 MAF)
Pishin & Sariab Area Basin	$764 \times 10^6 m^3$ (0.620 MAF)
Upper Kaha Hill Torrent Basin	$303 \times 10^6 m^3$ (0.246 MAF)
Musa Khel Basin Area	$464 \times 10^6 m^3$ (0.376 MAF)
Total for Project Area	$5015 \times 10^6 m^3$ (4.067 MAF)

Table 9.4
Flows for Project Area for Various Return Periods

2.33-Year	$5{,}015 \times 10^6$ m^3 (4.067 MAF)
5-Year	$5{,}844 \times 10^6$ m^3 (4.74 MAF)
10-Year	$7{,}300 \times 10^6$ m^3 (5.92 MAF))
25-Year	$8{,}767 \times 10^6$ m^3 (7.11 MAF))

Table 9.5
Water Budget Analysis - Project Area

Name of Basin	Existing Uses	Additional Planned Uses
Nari River	$133 \times 10^6 x m^3$ (108,000 acre-ft)	$539 \times 10^6 x m^3$ (437,000 acre-ft)
Kunder River	$20 \times 10^6 x m^3$ (16,000 acre-ft)	$221 \times 10^6 x m^3$ (179,000 acre-ft)
Zhob River	$174 \times 10^6 x m^3$ (142,000 acre-ft)	$197 \times 10^6 x m^3$ (160,000 acre-ft)
Marri Bugti	$26 \times 10^6 x m^3$ (21,000 acre-ft)	$326 \times 10^6 x m^3$ (265,000 acre-ft)
Talli/Chakar	Negligible	$59 \times 10^6 x m^3$ (48,000 acre-ft)
Bolan & Mula	$51 \times 10^6 x m^3$ (41,000 acre-ft)	$354 \times 10^6 x m^3$ (288,000 acre-ft)
Pishin & Sariab	$59 \times 10^6 x m^3$ (48,000 acre-ft)	$236 \times 10^6 x m^3$ (191,000 acre-ft)
Musa Khel (Sanghar & Vehowa)	$3 \times 10^6 x m^3$ (2,200 acre-ft)	$30 \times 10^6 x m^3$ (24,000 acre-ft)
Upper Kaha	$31 \times 10^6 x m^3$ (25,200 acre-ft)	$35 \times 10^6 x m^3$ (28,000 acre-ft)
TOTAL	$497 \times 10^6 x m^3$ (403,200 acre-ft)	$1{,}997 \times 10^6 x m^3$ (1,620,000 acre-ft)

9.2.4 Perspective Plan and Cost Estimates

9.2.4.1 Flood Management Measures

DELAY ACTION/STORAGE DAMS

Keeping in view the characteristics of the Project Area, delay action/storage dams and flood irrigation structures have been planned. Typically, such dams are designed to have heights varying between 10 m and 15 m. The top width of earth embankment varies between 8 m and 10 m and upstream and downstream side slopes of 1:2.5 and 1:3 respectively. Spillways are generally rock-cut or natural saddle type and are proportioned to cater for the 'design storm' with the consideration that reservoir is full before the onset of storm. The emergency freeboard is generally 1.5 m (minimum). For the Project Area conditions, the 'design storm' for spillway has been taken as the 1000-year peak with reservoir full conditions.

Withdrawal of stored water has been conceived in two ways, viz

- Bottom Outlet
- Syphon (Hose pipe type)

Bottom outlets are suitable at locations with lesser sediment inflow and where the main function of dam is storage. Syphon type withdrawal is suitable for all conditions, particularly where smaller outflows are required.

FLOOD IRRIGATION STRUCTURES

The flood flows proceeding through the natural channels have historically been diverted by temporary dykes to irrigate lands by the riparians in Balochistan. Permanent diversion arrangements at these locations would greatly help the riparians to satisfactorily use the spate floods of varying intensities.

A flood irrigation scheme essentially consists of three major components, viz; a weir, an offtake structure and a channel.

The main weir is generally designed against a flood peak with an optimal return period. For the Project Area, the main weir and allied components such as stilling basin and wing walls etc have been designed for a 25-year return period with an emergency free board of 0.6m. The offtake structures have also weirs with breast walls to control the flow automatically for events when the water level in the main stream rises beyond a certain critical level. The design of offtakes has been conceived in such a way that optimum discharge is diverted against a flood peak of 5-year return period.

ASSESSMENT OF IDENTIFIED SCHEMES

The beneficiaries, Provincial Irrigation Department and Consultants (NESPAK) have jointly identified a 297 water conservation and diversion schemes in the Project Area with an estimated cost of Rs.3,768 million. These schemes belong to various structural categories as under:

- Delay Action Dams	169 Nos
- Storage Dams	28 Nos
- Flood Irrigation Scheme	88 Nos
Total:	285 Nos

The schemes as identified were subjected to detailed review for development of the recommended plan for the Project Area. Out of these, finally 150 schemes have been priortized for construction. During 9th Five Year Plan at a cost of Rs 2,757 million estimated. Out of the recommended package, 59 schemes are for flood irrigation and the balance schemes are delay action/storage dams. The remaining schemes have been recommended for execution during the Ist two years of 10th Five Year Plan. **Table 9.6** presents the summary of proposed Investment Schedule. Identified schemes are summarised in **Table 9.7.**

9.2.5 **Project Justification**

The object of public investment for flood management of hill torrents in Project Area is to increase economic welfare of the people of the area. In order to ensure that the use of scarce resources involved in project works is justifiable on economic ground, the Project has been evaluated in terms of benefit cost analysis briefly described in the following.

TABLE 9.6

Summary of Recommended Schemes & Cost Estimates (1996 Price Level)

Rs. Million

Sr. No.	Name of District	Civil Work Cost including Physical Contingency	Detail Dsg. & Const. Supervision @ 5% of Civil Works	Engg. and Admin. @ 3% of Civil Works	Total Cost
1	Quetta	240.00	12.00	7.20	259.20
2	Qilla Abdullah	161.00	8.05	4.83	173.88
3	Pishin	253.50	12.68	7.61	273.78
4	Loralai	449.00	22.45	13.47	484.92
5	Musa Khel	108.00	5.40	3.24	116.64
6	Barkhan	33.93	1.70	1.02	36.64
7	Zhob	297.00	14.85	8.91	320.76
8	Qilla Saifullah	139.00	6.95	4.17	150.12
9	Sibi	162.00	8.10	4.86	174.96
10	Ziarat	115.00	5.75	3.45	124.20
11	Bolan	220.00	11.00	6.60	237.60
12	Nasirabad	374.00	18.70	11.22	403.92
Total		2552.43	127.62	76.57	2756.62
				Say Rs.	2,757 million

Table 9.7

SUMMARY OF IDENTIFIED SITES

S.No.	Name of District	No. of Schemes
1.	Quetta	11
2.	Qilla Abdullah	41
3.	Pishin	45
4.	Lora Lai	34
5.	Musa Khel	14
6.	Bar Khan	11
7.	Zhob	35
8.	Killa Saif Ullah	39
9.	Sibi	21
10.	Ziarat	8
11.	Bolan	16
12.	Nasir Abad	7
13.	Jhal Magsi	1
14.	Dera Bughti	2
	Total	285

9.2.5.1 Project Benefits

Among the measurable benefits, the most important are those which are represented by the increase in agricultural production through intensive use of land made possible by use of controlled water supplies and made available due to proposed Delay Action/Storage Dams and Diversion Weirs. Other measurable benefits are those represented by saving of flood damages due to the incremental safety to Pat Feeder and Khirthar Canals, standing kharif crops, houses and infrastructure.

Agricultural benefits have been measured in terms of expected increase in production of the crops as indicated by the difference in Net Production Value, under 'with' and 'without' project condition. The incremental benefits calculated for the Project Area irrigated through regular supplies by dams in the ultimate year of development (10th Year) are estimated as Rs 957.2 million. Whereas, the incremental benefits accruing through proper flood water distribution and improvement in flood management of hill torrents are estimated as Rs 159.7, Rs 210.6, Rs 255.3 and Rs 285 million against 2.33, 5, 10 and 25 years floods respectively.

In addition, the Project would provide flood protection to canals and command area against floods upto a 25-year return period. Under existing conditions, flashy floods heavily laden with silt enter the Kachhi Plain with enormous velocity and devastate the diversion structures constructed by the cultivators. The flood flows accumulate along the right bank of Pat Feeder and Khirthar Canal and breach the canal banks resulting in heavy losses to crops, houses and infrastructure. These damages would be greatly reduced by the execution of the proposed works. The 1988 peak flood resulting from precipitation corresponding almost to 25-year return period inundated about 46,100 ha agricultural land. The damages due to the direct flooding and the suspension of irrigation supplies were estimated by developing flood damage factors of various types of losses on the basis of 1988 inundation data. The average annual reduction in damages has been estimated as Rs 21.63 million by developing damage frequency relationship.

The annual benefits on account of increase in agricultural production due to regular and flood irrigation are estimated as Rs 95.72 million and 85.63 million respectively in addition to Rs 21.63 million on account of avoidance of flood damages. The aggregate annual benefit accruing from the project thus, work out as Rs 202.98 million, these are projected upto 10th year beyond which it will remain constant.

9.2.5.2 Project Economic Costs

The Project financial costs are estimated as Rs 2,757 million which were converted to economic capital cost as Rs 2,019 million by removing taxes, duties and land acquisition costs. The incremental operation and maintenance costs are estimated at Rs 50.5 million annually. For execution of the project, implementation schedule of 5 years has been proposed due to higher financial outlay of the project and likely availability of financial sources.

9.2.5.3 Economic Feasibility

All economic costs and benefits are expressed in constant 1996 values, and only directly quantifiable costs and benefits have been included in the analysis. The criteria for public investment viz; Net-Present Worth, Benefit-Cost Ratio and Internal Rate of Return have been applied to the discounted cash flows of the benefits and costs to examine project economic feasibility. The results of analysis are summarized as below:

(Rs million)

Parameters	Rate of Discount (Percent)			
	10	12	15	20
Discounted Benefits	4,182	3,156	2,142	1,188
Discounted Cost	1,917	1,780	1,611	1,395
Net Present Worth	2,265	1,376	521	-207
Cost/Benefit Ratio	1:2.18	1:1.77	1:1.32	1:0.85
Internal Rate of Return	18.58 percent			

The parameters given above indicate that the Net Present Worth is positive and Benefit-Cost Ratio exceeds unity even at 18 percent rate of interest. Similarly, the Internal Rate of Return of 18.58 percent is well above the opportunity cost of capital in Pakistan. It is, therefore, established that the project is economically feasible and the public investment thereon is justified.

9.3 KHARAN CLOSED DESERT BASIN

9.3.1 Introduction

Kharan Closed Desert Basin (KCDB) encompasses an area of about 121,860 sq.km (47,050 sq.miles) and is located in the north western part of Balochistan. It is an arid zone surrounded by mountains. It has closed drainage in which small mountain streams discharge into shallow lakes which generally dry up during hot weather. The major streams of the basin include Pishin Lora, Baddo, Rakhsan and Mashkhel. Annual rainfall is very low except Quetta region which has already been dealt in the preceeding section of this report i.e. Indus Basin Component of Balochistan Province, because of hydrologic similarity. Accordingly, out of total area of 121,860 sq.km, about 24,420 sq.km area of Quetta Region has been excluded from this part of the report. This part covers the balance area of 97,440 sq.km.

Scarcity of water has adversely affected the socio-economic development of the area. Conservation of runoff of hill torrents would greatly help in the development of agriculture and other sectors of economy. Major part of runoff is presently going waste into shallow lakes and only a small component is being used for domestic and agricultural purposes. Quality of groundwater is highly brackish. Need for conservation of water can be assessed from the fact that water for drinking and other domestic purposes is transported to the main cities by train from far off places. Quetta-Zahidan Highway passes through the area which has been improved to international standard. The area is rich in mineral deposits. Sandak copper field is located in this area. Conservation and thereby availability of water would pay vital role in the development other natural resources of the area.

Land and water resources of the basin have been identified. Existing use of land and water have been evaluated whereby the available surplus of both the resources has been determined. By virtue of this quantitative analysis, it has been found that additional quantum of both the resources is available to a reasonable extent which merely need their conservation and exploitation on scientific footings. The existing economic conditions of the area warrant the conservation and development of flood flows of hill torrents on priority basis for the socio-economic amelioration of the people who are not presently getting even potable water. The harnessing of these resources would not only boost up the local agriculture but would also open a new era of socio-economic progress in all other sectors.

9.3.2 The Project Area

9.3.2.1 Location and Extent

Kharan Closed Desert Basin (KCDB) occupies northern part of the south-western zone of Balochistan and is situated between longitude 60° 50' - 67° 0'E and latitude 26° 45' - 29° 50'N. On the north and west, it is bounded by international borders of Islamic states of Afghanistan and Iran respectively. On the eastern and southern sides it is enclosed by series of mountainous ranges which determine its limits with the neighbouring basin of Makran Coast. Exhibit M-9.3 shows the Project Area of KCDB.

As already mentioned, KCDB comprises a gross area of 121,860 sq.km (47,050 sq miles). However an area of about 24,420 sq.km of KCDB has been covered under Indus Basin Component part of the Report on Balochistan. Consequently the Project Area being considered in this Part spreads over about 97,440 sq.km. Nushki, Chagai, Dalbandin, Nok Kundi, Kharan and Panjgur are the important cities of the Project Area.

9.3.2.2 Area and Population

Administratively, the Project Area comprises parts of Quetta and Kalat Districts; in addition to Chagi, Kharan and Panjgur Districts. The current population of the Project Area is estimated at about 0.87 million. The current intensity of population is about 5 persons per square kilometer.

The Project Area has varying physiographic features. It comprises alluvial plains of Quetta, Kalat and Panjgur Districts; sandy desert in Chagi and Kharan Districts, and high and dry mountain ranges of Chagi, Singaran, Ras Koh and Siahan.

The economy of the Project Area is mainly based upon agriculture. The average annual cropped/sown area is about 96,560 ha. The total cultivable area including culturable waste is 1,272,000 ha and the area not available for cultivation is 475,300 ha.

The irrigated area is about 163,000 ha, which is only 10 percent of the total cultivable area.

The climate of the area is dry and hot in summer and dry and cool during winter. The average annual rainfall in Nok Kundi Area is about 50 mm. It increases in the east to about 150 mm in the vicinity of eastern part of Saihan Range. There are a few pleasant places in the Project Area. Kalat and Mastung have elevations 2,054 m (6,739 ft) msl and 1,704 m (5,590 ft) above msl respectively.

9.2.2.3 Basin Drainage Pattern

The basin primarily comprises sandy soils and is surrounded by mountainous ranges. It is a region of closed drainage whereby the streams drain into swamps of Lora and Mushkhel that often get dried up during low precipitation periods, and have no water for most part of the year. Nevertheless, heavy rainfalls occasionally produce flash floods. Because of low population densities and limited development, flood damages are not significant. However, flood flows are wasted unutilized. Major streams include Pishin Lora, Rakhshan and Baddo Rivers.

9.3.3 Land and Water Resources

9.3.3.1 Land Capability Classification

The landuse statistics of the area are given in **Table 9.8**

Table 9.8
Landuse Statistics of KCBD

Total Geographic Area	121,730 Sq.km
Area Already Taken up in Indus Basin Component	24,290 Sq.km
Balance Area	97,440 Sq.km
Reported Area	6,460,383 ha
Cultivated Area	211,445 ha
Area Sown	96,561 ha
Current Fallow	114,884 ha
Uncultivated Area	6,249,938 ha
Culturable Waste	1,060,537 ha
Forest	436,375 ha
Area not available for cultivation	4,753,026 ha

The land classification of KCDB is based on the Bureau of Reclamation System (U.S.D.I 1950) except for some modifications made to suit the local conditions. According to the system, six land classes are designated by Roman numerals (I-VI), while subclasses which represent the nature of limitations are shown by small letters used as suffix with the class numerals. Four classes (I to IV), are for arable lands. Class V a provisional class for lands presently unfit but appearing to have potential for agricultural production after treatment. Class VI land is agriculturally unproductive as it does not meet the requirement of a cultivable land.

The soil and land classification regarding the Project Area is summarized in **Table 9.9**

Table 9.9
Summary of Land Capability Classes

Soil Categories	Mapping Unit	Land Class		Area	
		Class	Category	Hectares	Percent
- Loamy & Gravelly	1	Class I & IV	Arable	3,260,345	26.78
- Sandy	2	Class IV	Arable (special use)	1,989,842	16.35
- Playas	3	Class V	Provisional Arable	220,898	1.82
- Hilly/Gravelly	4	Class VI	Non-Arable	6,701,910	55.05
TOTAL :				12,173,000	100.00

9.3.3.2 Water Potential

Balochistan Province falls within the 'Basin and Range' system of Pakistan where natural precipitation is scanty and erratic. KCDB is the most arid part of the Province, where meager amounts of precipitation generate surface runoff of great variability and defy appropriate conservation. High evaporation rates adversely affect the economic viability of surface storage for major commercial use. The area being mostly Sub-Tropical Continental Plateau and sandy desert poses unfavourable conditions for management of water resources.

The average annual rainfall over the area ranges from 50 mm to 200 mm. The rainfall average over the basin is about 100 mm. The entire geographical area being 9,744,000 ha, the average annual rainfall equivalent is about 9.74×10^9 m^3. Keeping in view the geo-climatic factors, the average annual runoff from the entire Project Area is estimated as 9.74×10^8 m^3 (789,264 acre ft).

9.3.4 Perspective Plan and Cost Estimates

9.3.4.1 Development Potential

The land resources of over 1.70 Mha are available of which only 0.21 Mha is being cultivated. Nearly 0.16 Mha area is being irrigated through tubewells, wells, canals and karezes. Further potential exists for bringing over 1.42 Mha of land under cultivation if water resources can be made available. Average annual runoff of about $9.74 \times 10^8 m^3$ (0.8 MAF) is available of which about 0.05 Mham or 0.4 MAF is being used. Thus potential exists to conserve the balance runoff for bringing additional area under irrigation.

9.3.4.2 Proposed Schemes

The Project Planning Team has identified 56 schemes for the conservation and utilization of surface runoff for agro-economic development. Summary of the schemes is given in **Table 9.10**. The estimated cost of these schemes is Rs 640 million. Six of the schemes are for flood irrigation, while 50 pertain to water conservation through delay action dams.

9.3.4.3 Recommendations

In order to develop available land and water resources of the basin, the following detailed investigations should be carried out:

- Water budget analysis of individual sub-basins for various time horizons;
- Availability of water resources as per crop water requirements;
- Availability of potential sites for water conservation;
- Commandability and capability potential of land;
- Volumetric potential of conservation sites;
- Geotech investigations wherever required; and
- Preparation of a Bankable Document.

TABLE 9.10

FLOOD MANAGMENT OF HILL TORRENTS OF BALOCHISTAN
SUMMARY OF POTENTIAL WATER CONSERVATION SCHEMES
KHARAN CLOSED BASIN

Sr. No.	Name of District	Total		DAD		FIS	
		No. of Schemes	Cost (Rs Million)	No. of Schemes	Cost (Rs Million)	No. of Schemes	Cost (Rs Million)
1	Chagai	5	89.00	3	49.00	2	40.00
2	Mastung	19	111.00	19	111.00	–	–
3	Kalat	16	54.00	13	43.00	3	11.00
4	Kharan	7	319.00	6	317.00	1	2.00
5	Panjgur	9	67.00	9	67.00	–	–
	Total	56	640.00	50	587.00	6	53.00

DAD: Delay Action Dam

FIS: Flood Irrigation Scheme

9.4 MAKRAN COASTAL BASIN

9.4.1 Introduction

Makran Coastal Basin (MC Basin) has a total drainage area of about 123,025 sq.km (47,500 sq.miles). It is triangular in shape and encompasses the districts of Khuzdar, Awaran, Turbat, Lasbela and Gawadar. Major rivers of the basin include Malir, Hub, Hingol, Porali, Windor Dhora, Kud, Kech Kaur, Dasht, Shadi Kaur etc. These rivers originate in the mountainous areas bordering Kharan Closed Desert Basin and Gaj and Mula basins of Indus Basin Component of Balochistan and Sindh. The streams move in south westerly direction and discharge into the Arabian Sea. These rivers are prone to occasional flash flooding in response to local heavy rainfalls. High floodflows shatter the temporary diversion dikes constructed by the farmers for irrigating their fields. Major part of runoff is wasted into the sea without being used in the area for development of irrigated agriculture.

The southern part of the Project Area is oriented along 750 km (466 miles) long coastal belt of Arabian Sea. There are a number of sites along the coast where seaports of international level can be developed. At present Gwadar, Pasni, Ormara and Jewani have been developed as seaports. Gwadar is being developed into an international seaport. Important coastal roads are being constructed. These seaports could also provide routes for the foreign trade to Afghanistan and a number of other newly independent countries Central Asia. Construction of proper land routes and development of ports to international level would greatly help in the socio-economic uplift of the area. Proper conservation of floodflows may also provide a prospective source of water for export to the Gulf States.

In this part of the report, the land and water potential of MC Basin has been identified. Existing uses of water have been estimated. Additional available water resources have been evaluated. Water conservation sites for delay action/storage dams and flood irrigation have been identified. Feasibility level studies (as carried out for Indus Basin Component) are recommended for rest of the Project for realistic evaluation of potential of land and water resources to embark upon a programme of socio-economic uplift of the basin.

9.4.2 Project Area

9.4.2.1 Location & Extent

The Project Area is located between longitude 61° 36' - 67° 27'E and latitude 24° 48' - 29° 58' N. It is bordered on the east by the province of Sindh. Islamic Republic of Iran forms common border on the west. Kalat, Kharan and Panjgur Districts of Kharan Closed Desert Basin are located on the north, while 750 km long coast line of Arabian Sea forms boundary on the south. Exhibit (M-9.4) shows the Project Area.

9.4.2.2 Population

According to 1981 census, the population of the Project Area was about 1.12 million with a population density of about 10 persons/sq.km (25 persons/sq mile), while the current population is estimated at about 1.70 million i.e. about 15 persons/sq.km.

9.4.2.3 Agriculture

Agriculture supports the majority of the population of the area. Principal crops in the Project Area are wheat, rice, barley, onion etc. Total cultivated area is about 0.26 Mha of which about fifty percent remains fallow due to non-availability of water. In addition, 2.78 Mha is culturable waste which can be brought under cultivation if water can be conserved and supplied for agriculture. Most of the crop production is in Khuzdar District which produces about 90% of the crops, while Turbat District produces more than 50 percent of fruit. Area under forest in the Project Area is about 192,000 ha of which over 80 percent is in Lasbela District.

Irrigation in the area is practised by the use of civil/private canals, tubewells, open wells, karezes and springs. Total irrigated area is about 58,000 ha, which is about 23 percent of the total cultivated area of the basin.

9.4.2.4 Climate

The climate of area is characterized by both the Monsoon and Western Disturbances though the effect of latter is relatively less. The climate is generally humid and hot in summer and cool and dry in winter. Mean yearly precipitation in the Project Area varies from 125 mm to 200 mm with an average of about 150 mm.

9.4.2.5 Hydrologic Basin

Makran Coastal Basin has been formed by a number of mountain ranges which form the appex of a triangle, whereas the Arabian coastline of 750 km length outlines the base of this triangle. Hub and Halah ranges figure as the eastern limb while Central Makran Range constitutes the western limb of the triangle. Hub, Winder, Porali and Nal (a major tributary of Hingol River) are the major rivers which descend from the eastern ranges while Mahkel, Kech and Dasht are major rivers of Central Makran Range. There are numerous small rivers which originate from Makran Coastal Ranges and individually outfall in the Arabian Sea.

9.4.3 Land and Water Resources

9.4.3.1 Land Resources

Land and water resources of MC Basin have not been exploited so far to their development potential. About 20 percent of the total area has loamy and gravelly soils while 79.8 percent of the area is hilly and gravelly. There are small patches of salt affected areas which can be made cultivable by making some improvement on the land by various measures. The total additional area which can be brought under cultivation after providing water is 2.78 Mha. Thus the total cultivable area of the basin is about 3.04 Mha which is nearly 48 percent of the total cultivable area of the Province. Soil Classification and land capability of basin have been presented in greater detail in Supporting Volume-V. Landuse statistics of Makran Coastal Basin is given in **Table 9.11**.

Table 9.11
Landuse Statistics of Makran Coastal Basin

Total Geographic Area	123,025 Sq.km.
Reported Area	7,363,300 ha
Cultivated Area	256,100 ha
Area Sown	131,200 ha
Fallow Area	124,900 ha
Irrigated Area	58,000 ha
Uncultivated Area	7,107,200 ha
Culturable Waste	2,781,600 ha
Forest	192,000 ha
Area Not Available for Cultivation	4,133,600 ha

9.4.3.2 Water Potential

Precipitation is the main source of water in the basin area. Rainfall data is partially available for 20 sites inside the basin. The average annual rainfall over the area is about 150 mm. There are six stream gauging stations where flow measurements have been carried out or are being observed at present in the Project Area.

Hub River is being observed at Bund Murad Khan, about 30 km (19 miles) north of Karachi. The drainage area of Hub River at Murad Khan is 4,928 sq.km (3,640 sq.miles). Mean annual flow is $4.22 \times 10^{8} m^{3}$ (342,000 acre ft). The river is not perennial and often becomes dry in June. Nearly 50 percent of flow moves during July to September. Maximum discharge of 12,546 cumecs (443,000 cusecs) was recorded in 1978. Sediment load is about 470 cu.m/ sq.km (0.99 acre ft/sq.mile) of the catchment. Average sediment concentration is 0.60% by weight or 6,060 PPM. Rainfall-runoff coefficient is about 29.36%.

Porali River has been gauged at Sinchi Bent about one km upstream from Bela Khuzdar Road crossing and about 35 km north east of Lasbela Town. The drainage area of Porali

River near Sinchi Bent is 4,040 sq.km (1,560 sq.miles). Mean annual flow is about $3.20 \times 10^8 m^3$ (260,000 AF). The highest peak of 1,478 cumecs (52,200 cusecs) was recorded in 1985. Annual average sediment yield is 885 cu.m/sq.km (186 AF/sq mile) of the catchment. Average sediment concentration is 0.84% by weight or 8,360 PPM. Rainfall runoff coefficient is 52 percent.

Winder River is gauged at Goth Aman about 10 km of Karachi Bela Road. Drainage area of Winder River at Goth Aman is 920 sq.km (355 sq.miles). Mean annual flow has been recorded as $6.62 \times 10^7 m^3$ (53,600 AF). Maximum recorded discharge is 1,325 cumecs (46,800 cusecs). Average sediment yield of 1,628 cu.m/sq.km (3.42 AF/sq mile) has been determined at the gauge site. Average sediment concentration is 1.26% by weight or 12,600 PPM. Rainfall-runoff coefficient is 47%.

Kud River is gauged about 3 km upstream from the ancient caves at Mai Gundrani. It is about 20 km north west of Lasbela Town and 30 km upstream of Porali River. Drainage area upto Mai Gundrani is 2,085 sq.km (805 sq.miles). Average annual runoff is $1.36 \times 10^8 m^3$ (110,000 AF). Maximum recorded discharge is 1,546 cumecs (54,600 cusecs). Annual average sediment yield is 2,275 cu.m/sq.km (4.78 AF/sq.mile). Sediment concentration is 3.23 percent or 3,238 PPM. Rainfall-runoff coefficient is 43 percent.

Flow measurements of Dasht River are observed at Mirani Dam site about 40 km west of Turbat. Its drainage area upto Mirani Dam site is 22,533 sq.km (8,700 sq.miles). Mean annual flow is $1.75 \times 10^8 m^3$ (142,000 AF). Maximum discharge of 5,975 cumecs (211,000 cusecs) was observed in 1993. River remains dry for most of the time during the year. Average annual sediment yield is about 238 cu.m/sq.km (0.50 AF/sq.mile). Average sediment concentration is about 1.91 percent or 1,910 PPM. Rainfall-runoff coefficient is 5 percent.

Hydrologic measurements of Hingol River are observed at Agore, with a catchment area of 33,670 sq.km (13,000 sq.miles). Average annual runoff has been recorded as $5.11 \times 10^8 m^3$ (414,000 AF). Annual sediment yield is 270 cu.m/sq.km (0.57 AF/sq.miles), while sediment concentration is 1.42 percent by weight or 1,420 PPM. The rainfall-runoff coefficient is about 10 percent.

Runoff coefficient for the entire basin has been determined in detail in Supporting Volume-V. A mathematical model has been developed between catchment area and runoff. Mathematical model indicates that as catchment area increases, the percentage of runoff decreases. Runoff-Rainfall Coefficient for the entire basin is about 20 percent.

9.4.4 Perspective Plan and Cost Estimates

9.4.4.1 General

Eighty two sites have been initially identified which can be used for conservation of water. Summary of the Schemes has been given in **Table 9.12**. Of the total sites, 63 are for delay action dams, while 19 are comparatively more suited for flood irrigation purposes. Lasbela District has maximum number of sites, where 32 conservation sites have been identified of which 22 are for delay action dams, and 10 for flood irrigation. Turbat District has 17 sites, Khuzdar 19, Gawadar 12 and Awaran two. Total estimated cost of delay action dams is Rs 1,144 million, while cost of 17 flood irrigation schemes is Rs 217 million. The schemes have been discussed in detail in Supporting Volume-V, Balochistan Province.

9.4.4.2 Development Potential

The existing cultivated area in MC Basin is 0.26 Mha. In addition to this there is a culturable waste of 2.78 Mha (6.67 MAc). This area is suitable for cultivation if the water can be supplied for irrigation. Thus, this basin has large tracts of land for development. Of the total cultivated area, about 58,000 ha is being irrigated through canals, wells & tubewells, karezes and springs. It has been observed that average yields of irrigated areas are about three time that of the output of barani areas.

TABLE 9.12

FLOOD MANAGMENT OF HILL TORRENTS OF BALOCHISTAN
SUMMARY OF POTENTIAL WATER CONSERVATION SCHEMES

MAKRAN COASTAL ZONE

Sr No	District	Total		DAD		FIS	
		No. of Schemes	Cost (Rs Million)	No. of Schemes	Cost (Rs Million)	No. of Schemes	Cost (Rs Million)
1	Turbat(Kech)	17	207.00	15	160.00	2	47.00
2	Gawadar	12	295.00	11	265.00	1	30.00
3	Khuzdar	19	228.00	15	186.00	4	42.00
4	Awaran	2	15.00	2	15.00	–	–
5	Lasbella	32	616.00	22	518.00	10	98.00
	Total	82	1361.00	65	1144.00	17	217.00

DAD: Delay Action Dam

FIS: Flood Irrigation Scheme

Average annual rainfall in the area is slightly over 150 mm (6 inches). Volume of equivalent rainfall is $1.85x10^{10}m^3$ (15 MAF). Rainfall-runoff coefficient of various sub-basins varies from 0.05 for large catchment to 0.52 for small catchment with an average of about 20 percent for the entire basin.On the basis of these studies, the runoff for various return periods is as under:

Return Period	Runoff Volums	
	m^3	MAF
2.33-Year	$3.70x10^9m^3$	3.00
5-Year	$4.29x10^9m^3$	3.48
10-Year	$6.66x10^9m^3$	4.46
25-Year	$8.01x10^9m^3$	5.36

Thus, study for the land and water potential indicates that there is large potential for development of both land and water resources of the area. However, land resources are in abundance, while water resources are not sufficient for development of the entire land potential.

9.4.4.3 Recommendations

Out of the three major river basins of Balochistan Province, Bankable Document has been prepared for one basin "Indus Basin Component", while Master Feasibility Studies have been carried out for the other two basins. Following major parameters for Makran Coastal Basin have been determined:

- Land Resource Potential of Basin;
- Water Resource Potential of Basin; and
- Preliminary identification of sites for Delay action Dams and Flood Irrigation Schemes.

In order to prepare Bankable Documents for conservation of water resources and land potential of the area, in depth studies are required to evaluate the following:

1. Water budget analysis of sub-basins in relation to potential of identified delay action dam/flood irrigation sites.
2. Suitability of sites for construction of delay action dams/flood irrigation schemes.
3. Availability of land areas with reference to their capability for growth of various crops.
4. Land areas with their suitability of command i.e. gravity flow or lift.
5. Volumetric availability of water resources in accordance with crop water requirement.
6. Interest/participation of beneficiaries.
7. Economic evaluation of project.
8. Preparation of Bankable Documents.

10. RECOMMENDATIONS

10.1 GENERAL

Floods constitute one of the world's most serious environmental hazards. Four thousand years of recorded history tells of man's repeated efforts to evade the destructiveness of floods. In spite of many years of experience and highly developed scientific techniques, floods continue to play havoc in almost every part of the planet and only in few areas the flood losses have been checked to an appreciable degree. It is a recognised fact that complete flood prevention is economically not viable, but flood protection measures to the extent they are technically and economically feasible should be adopted to safeguard human life and sufferings.

Over the last few decades, modern concepts of integrated flood management have been developed. Especially in cases where the flood management plays a multi functional role in the socio-economic development of an area, a number of interacting factors have to be considered, which, inter-alia, include flood protection, domestic water supply, environmental protection, range management, pasture development, etc. These aspects have to be taken into account for the planning of flood management systems, especially hill torrents flows.

In Pakistan main rivers and hill torrents are two distinct sources of floods. Though the magnitude of river flooding is considerably higher, yet the hill torrents flooding is more widespread, unpredictable and complex. About 65 percent of the country's area is affected by hill torrents where sudden high peaked and short lived floods are generated. High sediment concentrations and extremely variable discharges make their planning a complex issue.

Flood management planning is a continuous process and forms an essential component of water resources management. Thus, interaction of various water resource activities have to be taken into account to refine and modify various planning parameters of flood control strategy.

Human activities like encroachment of flood plain, changes in land-use practices, forestation or/deforestation etc., also significantly affect flood parameters.

Hill Torrents essentially warrant the balanced application of structural and non-structural measures, and the flood plain development in such a way that the economic and social benefits expected to accrue to society are maximised at the cost of minimum investment. A well recognised definition of the national goals and objectives provides a fundamental framework to endeavour the future development in consideration of the competing demand and limitation of resources by formulating a rational system of perceptions and priorities. The interdependence of flood management planning to the overall planning signifies the justification for the preparation of follow-up plans based upon the latest state of art, modern scientific developments and the long-term objectives.

Land and water resources of hill torrents of Pakistan have been evaluated and are summarised in Table 4.4. Abject poverty in the hill torrent areas dictates that implementation of water conservation schemes be undertaken in the shortest period to ameliorate the socio-economic conditions of the people through development of sustained irrigation system. However, in view of financial constraints, a 20-year perspective plan has been prepared. Efforts have been made to make the plan flexible. In view of complex nature of problems, some of the major hill torrent areas would be divided into two to four components for feasibility studies and implementation. The monitoring of executed projects will provide a feed back for refining the planning strategy and design parameters for future projects. The systematic evaluation of projects under actual operating conditions will serve as a watchdog to refine the project activities. **Table 10.1** gives the summary of recommended package while **Fig 10.1** highlights tentative schedule for project studies and execution. Implementation schedule has been prepared in such a way that at any time, it can adjust to the changing needs of the Project Area, population, emerging new development policies, experience gained from the past activities and critical feedback and new scenarios. Flexible targets have been recommended instead of rigid and fixed goals.

Table 10.1

Summary of Recommended Package

Cost: Rs. million

Area/Region	Number of Conservation Sites, Estimated Cost & Present Status: Total No	Cost	Status	No. of Schemes	Proposed Execution Period: 9th 5-Year Plan (1998-2003) No.	Estimated Cost	10th 5-Year Plan (2003-2008) No.	Estimated Cost	11th 5-Year Plan (2008-2013) No.	Estimated Cost	12th 5-Year Plan (2013-2018) No.	Estimated Cost
FEDERAL AREAS												
(a) Northern Areas	39	988			9	218	10	300	10	250	10	220
		-	Feasibility	-								
		218	Pre-Feasibility	9								
		-	Reconnaissance	-								
		770	Conceptual	30								
(b) AJK	81	825			31	310	20	205	20	205	10	105
		-	Feasibility	-								
		310	Pre-Feasibility	31								
		-	Reconnaissance	-								
		515	Conceptual	50								
(c) FATA	263	2,806			28	414	65	650	90	910	80	832
		-	Feasibility	-								
		414	Pre-Feasibility	28								
		1,567	Reconnaissance	160								
		825	Conceptual	75								
Total for Federal Area	**383**	**4,619**			68	942	95	1,155	120	1365	100	1,157
N W F P												
(a) DI Khan	36	500			25	354	11	146	-	-	-	-
		354	Feasibility	25								
		146	Pre-Feasibility	11								
		-	Reconnaissance	-								
		-	Conceptual	-								
(b) HKB Basins	118	3,530			11	330	30	900	40	1,200	37	1,100
		330	Feasibility	11								
		3,200	Pre-Feasibility	107								
		-	Reconnaissance									
		-	Conceptual									
(c) FATA *	263	2,806			28	414	65	650	90	910	80	832
		-	Feasibility	-								
		414	Pre-Feasibility	28								
		1,567	Reconnaissance	160								
		825	Conceptual	75								
Total for NWFP	**417**	**6,836**			64	1,098	106	1,696	130	2,110	117	1,932
PUNJAB												
(a) DG Khan	40	1,055			40	1,055	-	-	-	-	-	-
		1,055	Feasibility	40								
			Pre-Feasibility									
		-	Reconnaissance									
		-	Conceptual									
(b) Pothowar	171	4,000			25	500	40	940	50	1,200	56	1,360
		-	Feasibility	-								
		840	Pre-Feasibility	21								
		3,160	Reconnaissance	150								
		-	Conceptual									
(c) Rechna and Chaj Doabs	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Total for Punjab	**211**	**5,055**			65	1,555	40	940	50	1,200	56	1,360

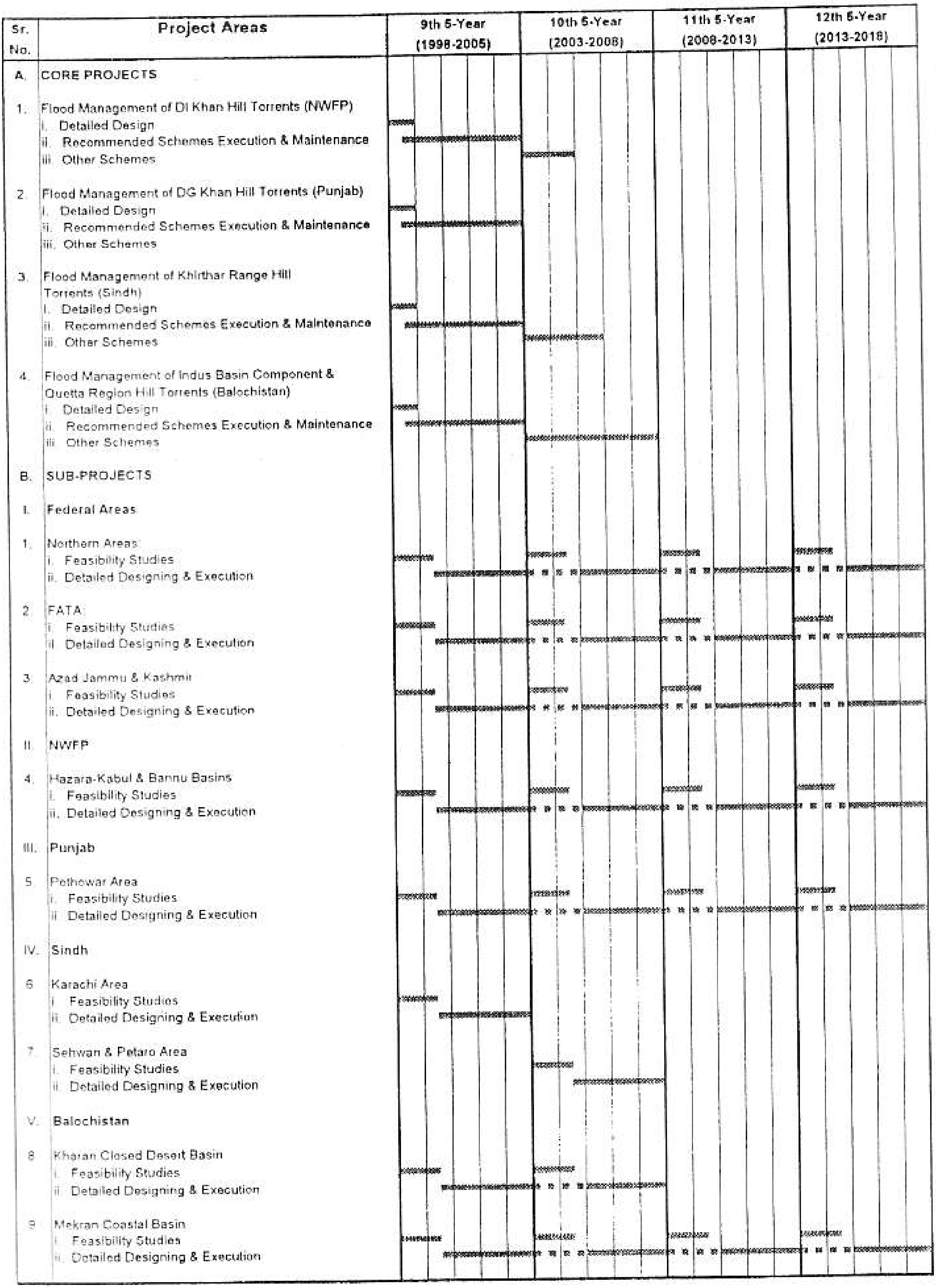
TABLE 10.1

Summary of Recommended Package

Cost: Rs. million

Area/Region	Number of Conservation Sites, Estimated Cost & Present Status				Proposed Execution Period							
	Total No.	Cost	Status	No. of Schemes	9th 5-Year Plan (1998-2003)		10th 5-Year Plan (2003-2008)		11th 5-Year Plan (2008-2013)		12th 5-Year Plan (2013-2018)	
					No.	Estimated Cost	No.	Estimated Cost	No.	Estimated Cost	No.	Estimated Cost
SINDH												
(a) Khirthar Range	25	842										
		242	Feasibility	10	10	242	15	600	-	-	-	-
		-	Pre-Feasibility									
		-	Reconnaissance									
		600	Conceptual	15								
(b) Karachi	3	170										
		-	Feasibility	3	3	170						
		-	Pre-Feasibility									
		3	Reconnaissance									
		-	Conceptual									
(c) Sehwan and Pataro Area	5	300										
		-	Feasibility	-		-	5	300	-	-	-	-
		-	Pre-Feasibility	-								
		-	Reconnaissance	-								
		300	Conceptual	5								
Total for Sindh	33	1,312			13	412	20	900	-	-	-	-
BALOCHISTAN												
(a) Indus Basin Component	286	3,768										
		2,757	Feasibility	150	150	2,757	135	1,011	-	-	-	-
		1,011	Pre-Feasibility	135								
		-	Reconnaissance									
		-	Conceptual									
(b) Kharan Closed Desert Basin	56	640										
		-	Feasibility		20	250	25	300	11	90	-	-
		640	Pre-Feasibility	56								
		-	Reconnaissance	-								
		-	Conceptual	-								
(c) Mekran Coastal Basin	82	1,361										
		-	Feasibility	-								
		1,361	Pre-Feasibility	82	20	300	30	450	20	300	12	311
		-	Reconnaissance	-								
		-	Conceptual	-								
Total for Balochistan	423	5,769			190	3,307	190	1,761	31	390	12	311
GRAND TOTAL	1,204	20,785			372	6,900	386	5,802	241	4,155	205	3,928

* FATA is located in NWFP, but is under administrative control of Federal Government. It is included both in NWFP and Federal Areas. However, in the grand total it has been counted once.



TENTATIVE SCHEDULE FOR PROJECT STUDIES AND EXECUTION

Fig. 10.1

10.2 FUTURE PLANNING

The flood management planning should essentially comprise the utilization of flood flows for economic development, social uplift and accelerated progress in all the relevant and allied sectors. High priority projects recommended for execution after Appraisal and Feasibility/Master Planning studies must occupy a preferred position in the water sector national programme.

The Feasibility Studies have been dealt in detail with the high potential projects (Core Projects) as an immediate step to start the hill torrents water management for agriculture development. Detailed design shall have to be carried out for each site in the light of site specific surveys before the execution of schemes. Master Planning has been undertaken for all Sub-Projects which require feasibility studies and detailed design prior to their execution.

Following are some of the recommendations for further planning and development.

- Arrangement of funding for Core Projects and execution, after detailed design.
- Feasibility Studies of Sub Projects
- Improvement of Data observation and recording System
- Use of Satellite Imageries/GIS/GPS
- Hydrometeorlogical Studies
- Research Studies for Improved Planning & Management of Hill Torrents

A brief discussion regarding each item is presented in the following.

10.3 EXECUTION OF CORE PROJECTS

As already emphasized in the previous sections, one Core Project in each Province was selected on the basis of maximum development potential. Feasibility studies with preliminary designs, cost estimates and economic analysis have been carried out for the Core Projects. It is recommended that these projects be executed at the earliest, after detailed designing.

These projects are:

Sr. No.	Core Project	Province	Schemes	Cost (Rs million)
1	Flood Management of DI Khan Hill Torrents	NWFP	25	354
2	Flood Management of DG Khan Hill Torrents	Punjab	40	1,055
3	Flood Management of Khirthar Range Hill Torrents	Sindh	6	242
4	Flood Management of Indus Basin Component Including Quetta Region	Balochistan	153	2,757
	Total		224	4,408

10.4 FEASIBILITY STUDIES

Fourteen major hill torrent areas have been identified of which one does not have water conservation potential. Feasibility level studies have been carried out for one of the most potential areas in each Province of the country. For the remaining hill torrent areas, Master Planning Studies have been carried out. High cost of investment involved in these projects makes it imperative to evaluate various alternatives to evolve a functional and economic plan through feasibility studies. High priority should be assigned to these projects and due financial allocations be made for studies and implementation. The feasibility studies should also include the prioritization of schemes so that availability of scarce financial resources may be dovetailed and matched in accordance with project requirements. Detail design should be carried out before execution of each scheme.

10.5 IMPROVEMENTS IN DATA COLLECTION

10.5.1 Hydromet & Sediment Data

During the course of Project Studies, serious deficiencies in almost all types of relevant data were observed. Presently Surface Water Hydrology Project (SWHP) of WAPDA and Pakistan Meteorological Department (PMD) generally record the hydrometeorologic/ hydrologic and sediment data in different hill torrent areas. Discharge Division of PIDA

Punjab, Hydrology Division of NWFP and PIDAs of Sindh and Balochistan also operate some hydromet observatories in their areas of jurisdiction. All these formations/agencies use conventional instruments for data observation and recording. The untrained field staff; sampling and laboratory errors and the indigenous methods of data recording and analysis introduce varying degrees of errors. These errors need to be rectified by employing responsible and educated field staff, improving the existing field sampling/measurement and laboratory techniques by providing proper facilities. The data recording network necessarily needs to be intensified. Sediment data is generally recorded on occasional observation basis as suspended sediment concentration for selected hill torrents. This needs to be recorded on continuous basis on all the observation sites. In situ measurements using optical silt meters has practically proved to produce better and quick data, especially in case of hill torrents in Pakistan. This method may be used by various agencies for all major hill torrents.

10.5.2 Soil & Land Classification Data

During the Master Feasibility Studies, the Soil and Land Classification studies were undertaken using Soil Survey of Pakistan Maps on gross basis. Specific studies in this direction would be required for future detailed planning.

10.5.3 Telemetry

The installation of automatic data transmission systems would provide instantaneous information of storms and floods in hill torrents; and would be used in assessing the routed flood peaks/runoff volumes at the site of interest. This could also be used for flood forecasting and warning in hill torrent areas.

10.6 SATELLITE IMAGERIES

Satellite imageries/GIS/GPS should be used for planning conservation measures of flows of hill torrents. This is essential in view of inaccessible approach conditions of almost all hill torrent areas. This approach will greatly help in identification of probable sites for conservation and management.

10.7 HYDROMETEORLOGICAL STUDIES

Inspite of the advanced technical know-how in the fields of meteorology, hydrology and water resources, the available information regarding various parameters of flows at the sites of interest is limited. Annual and seasonal precipitation isohyetal maps for large areas do not fulfil the flood flow evaluation requirements on micro-level. Depth-Area-Duration (DAD) analyses, Probable Maximum Precipitation (PMP), and Probable Maximum Flood (PMF) are available for specific areas only. The current planning requirements of Pakistan warrant the availability of readily prepared, updated and reliable hydrometeorologic evaluations for each sub-basin. This would be useful for planners and designers of water resources and flood control projects. Competent Consultants may be entrusted this large scale task as a first attempt, and the documents, reports and maps prepared by them may then be provided to the concerned agency or research institution for timely refinements and updating. These studies have been carried out and available to the water resources planners and designers in some of the developed countries which are widely being used for project planning.

10.8 RESEARCH IN FLOOD MANAGEMENT PLANNING

Flood management planning essentially requires research for scientific improvements in planning and design processes. It would significantly improve the planning criteria, designs, specifications and management techniques. Research in this direction may, inter-alia, comprise, but not be limited to various aspects as briefly described below;

10.8.1 Channel Morphology

This would include the evaluation of the methods to predict or determine the phenomena of scouring, deposition, meandering and creak formation in relation to normal discharge and the flood flows etc.

In order to manage the hill torrents flows, it is essential that detailed surveys be carried out, with detailed X-sections at short intervals. Observing the X-sections is essential after each extraordinary high flood. Similar survey should also be carried out for all the hill torrents, which could be used to determine channel geometry and flood carrying capacity for proper distribution of flood flows.

10.8.2 Design of Flood Management Structures

This would include the evolution of new design concepts, efficient utilization of local materials and introduction of suitable methods for construction, operation and maintenance.

10.8.3 Non Structural Measures

Research in this area may include:

- the acquisition and use of new equipment and technology of effective flood forecasting and warning system.
- the usefulness of floods e.g recharge to groundwater, agriculture and afforestation in the flood plain etc.
- watershed management of the upper catchment of a torrent basin.
- flood proofing etc. of the irremovable infra-structure or property in the large hill torrent flood plain like Kaha, Barran Nai, Gaj, Pishin Lora and Kurram River etc.
- biological effects of floods e.g investigation of immunisation of human beings and animals etc. from the post flood diseases.
- flood relief operations.

10.8.4 Flood Fighting Measures

This includes:

a) Sufficient/efficient transport system for mobility of staff.

b) Strict watch of flood management structures during and after floods.

c) Communication system be improved by providing wireless equipment in the hill torrent affected areas

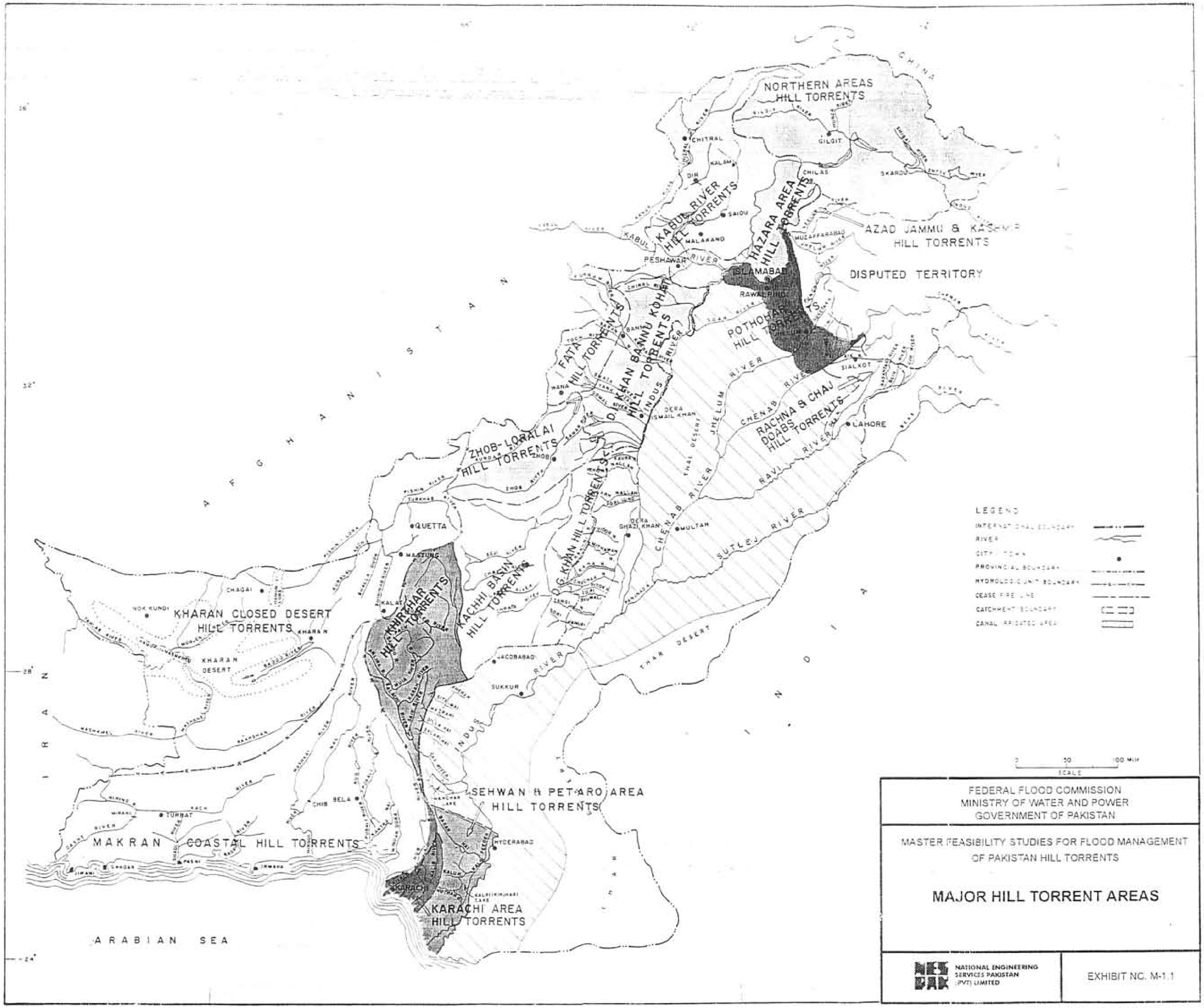
d) Old system of providing lanterns to patrolling staff be eliminated and portable five KVA generators be provided with poles & electric cables.

10.8.5 Watershed Management

Watershed management would, inter-alia, include range/pasture development horticulture and floriculture. Cereculture may also be developed in areas having favourable conditions. These would improve socio-economic/environmental conditions of hill torrent catchment area.

10.9 INSTITUTIONAL SET-UP

The Government of Pakistan may take necessary steps to setup specific formations at Federal as well provincial level with specific mandate for the management of flood flows of hill torrents. This would rationalize the endeavour on uniform and integrated footings and make a headway in order to achieve the project objectives in conformity with the national goals and targets.



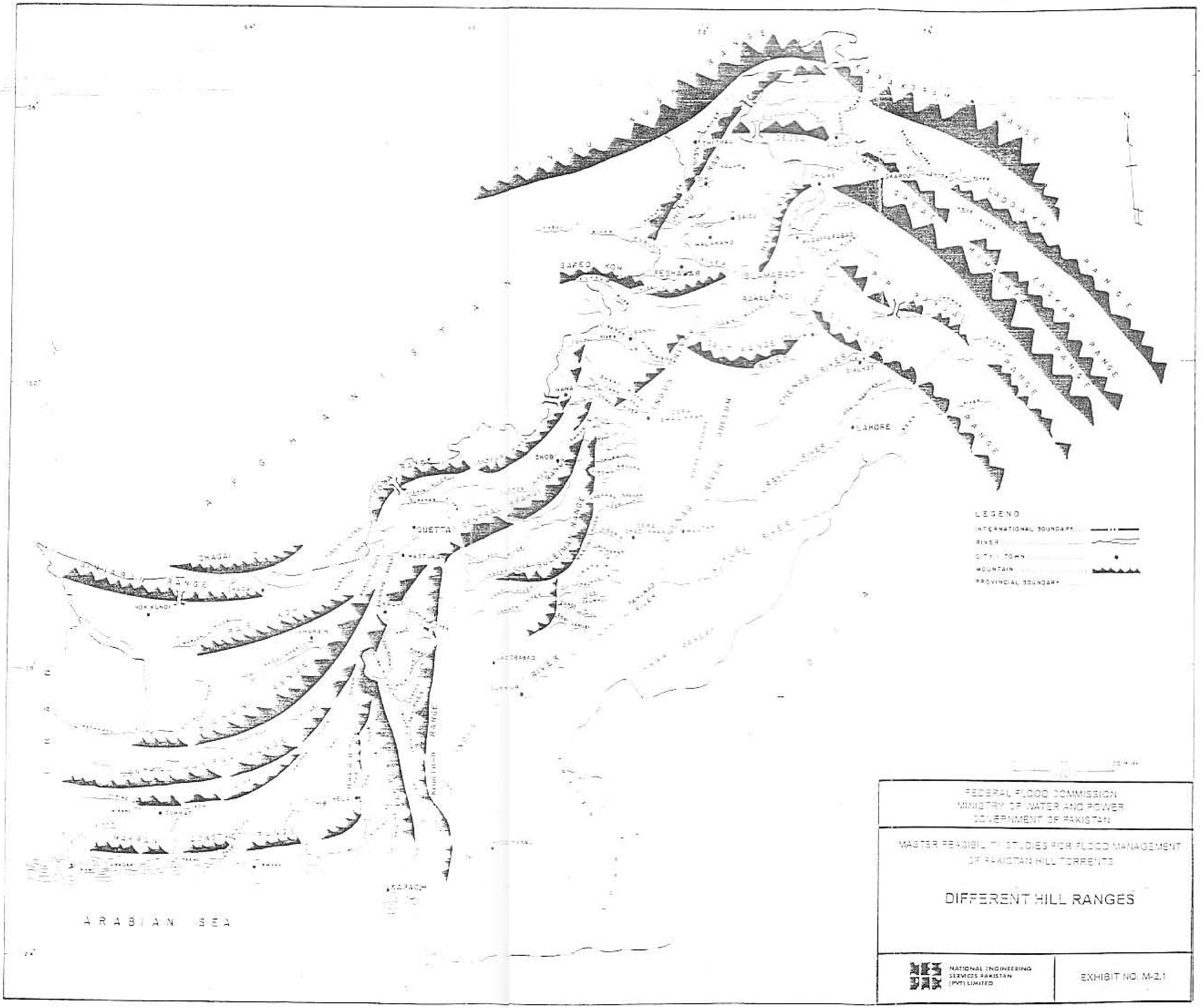
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

MAJOR HILL TORRENT AREAS

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-1.1



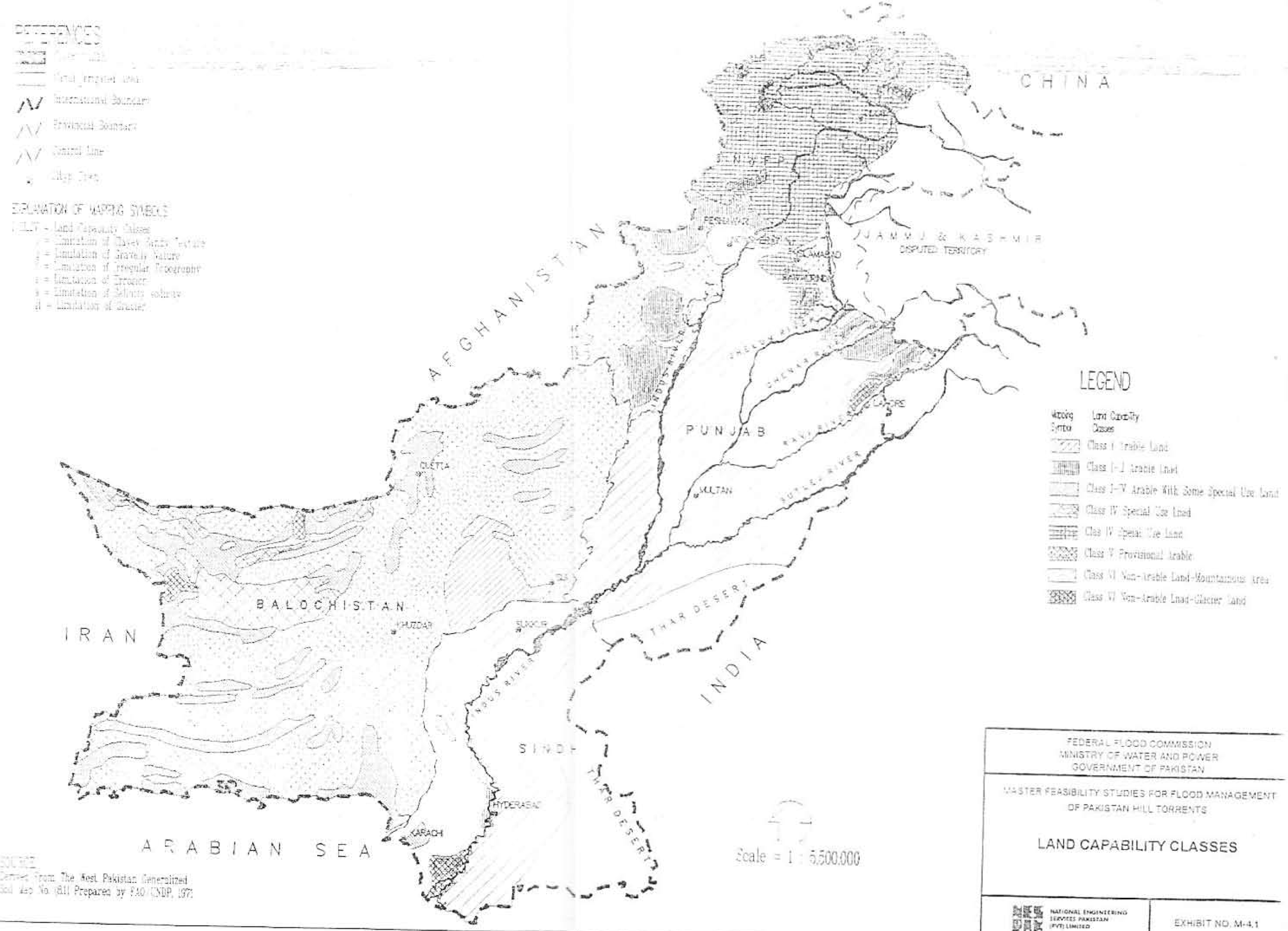
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

DIFFERENT HILL RANGES

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-2.1



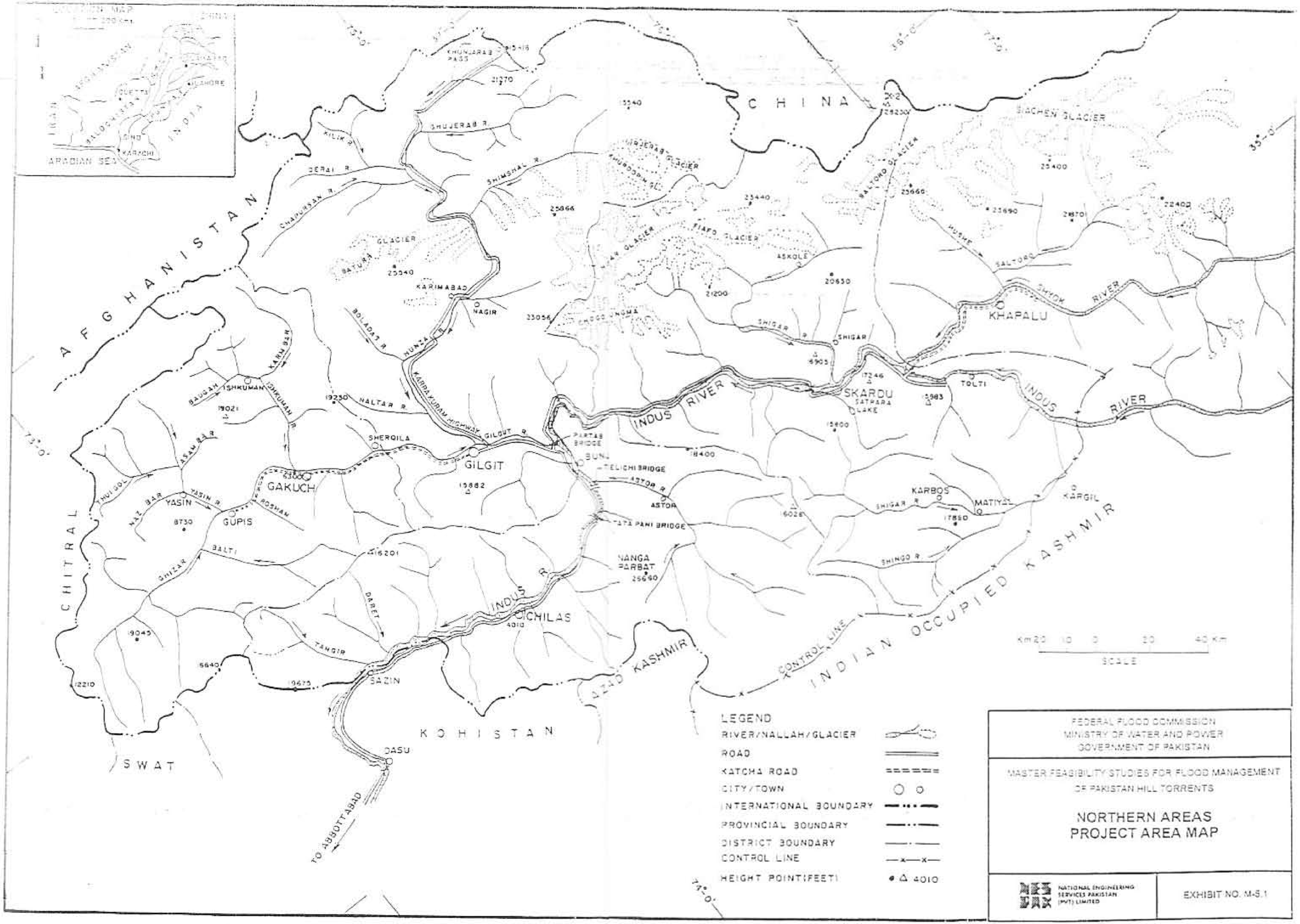
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

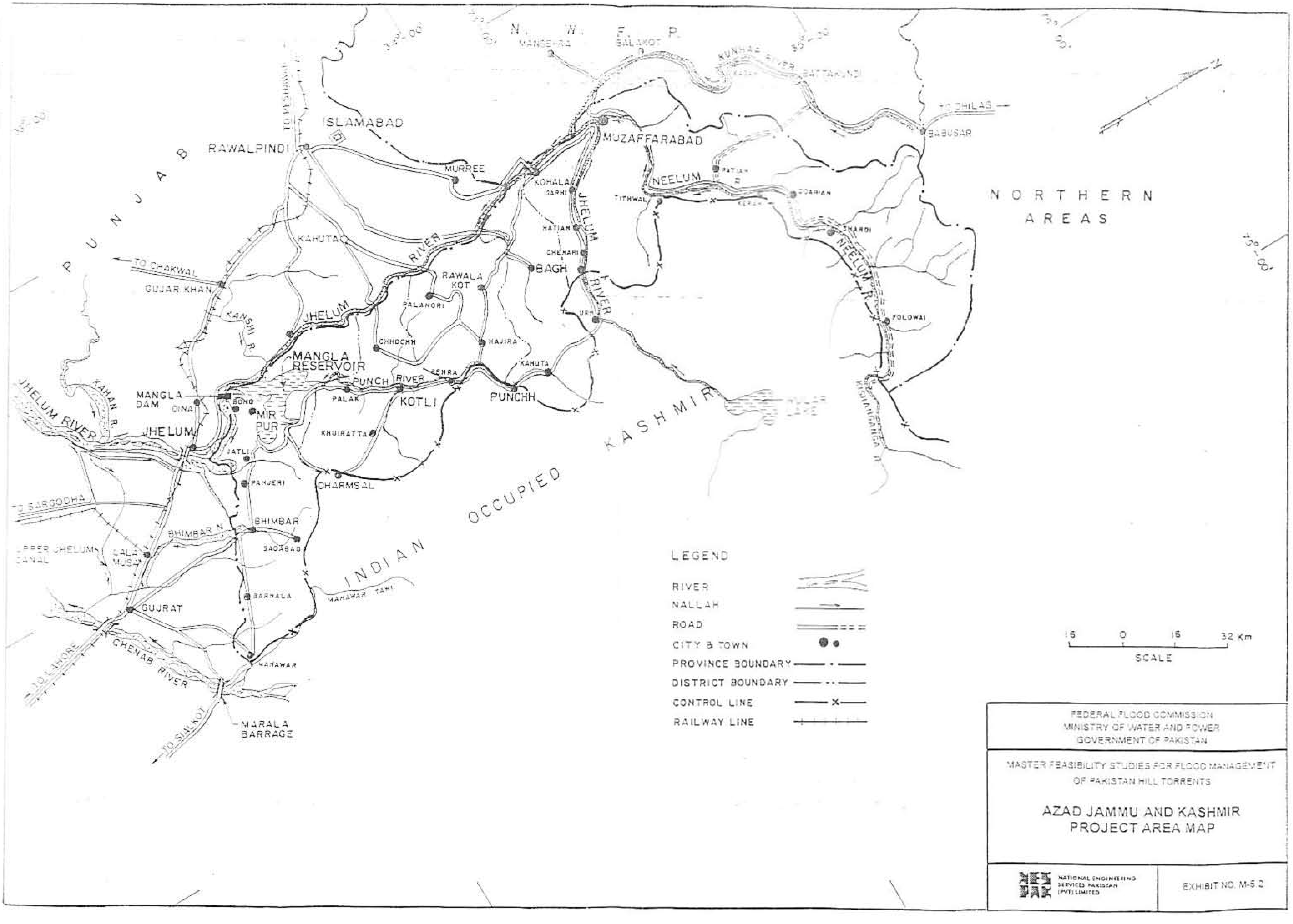
LAND CAPABILITY CLASSES

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-4.1



CHINA
AFGHANISTAN
CHITRAL
SWAT
KOHISTAN
AZAD KASHMIR
INDIAN OCCUPIED KASHMIR
CONTROL LINE
KHUNJARAB PASS
SHUJERAB R.
KILIK R.
DERAI R.
CHAPURSAN R.
SHIMSHAL R.
BATURA GLACIER
SIACHEN GLACIER
BALTORO GLACIER
BIAFO GLACIER
HISPAR GLACIER
CHOGO LUNGMA
SALTORO
HUSHE
K-2
28250
KARIMABAD
NAGIR
HUNZA R.
BOLADAS R.
KARRAKURAM HIGHWAY
HALTAR R.
GILGIT R.
GILGIT
SHERQILA
GAKUCH
ISHKUMAN
KARUMBAR
BAUGAH
ASAMBAR
YASIN
YASIN R.
GUPIS
ROSHAN
NAZ BAR
THUI GOL
SHIZAR
BALTI
DARET
TANGIR
SAZIN
DASU
TO ABBOTTABAD
INDUS R.
CHILAS
4010
PARTAB BRIDGE
BUNJI
TELICHI BRIDGE
ASTOR R.
ASTOR
TATA PANI BRIDGE
NANGA PARBAT
26660
INDUS RIVER
SKARDU
SATPARA LAKE
SHIGAR R.
SHIGAR
SHYOK RIVER
KHAPALU
TOLTI
KARBOS
MATIYAL
KARGIL
SHINGO R.
ASKOLE
Km 20 10 0 20 40 Km
SCALE
LEGEND
RIVER/NALLAH/GLACIER
ROAD
KATCHA ROAD
CITY/TOWN
INTERNATIONAL BOUNDARY
PROVINCIAL BOUNDARY
DISTRICT BOUNDARY
CONTROL LINE
HEIGHT POINT(FEET) 4010
LOCATION MAP
ARABIAN SEA
IRAN
AFGHANISTAN
BALOCHISTAN
PUNJAB
SIND
KARACHI
QUETTA
LAHORE
PESHAWAR
INDIA
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT
OF PAKISTAN HILL TORRENTS
NORTHERN AREAS
PROJECT AREA MAP
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-5.1

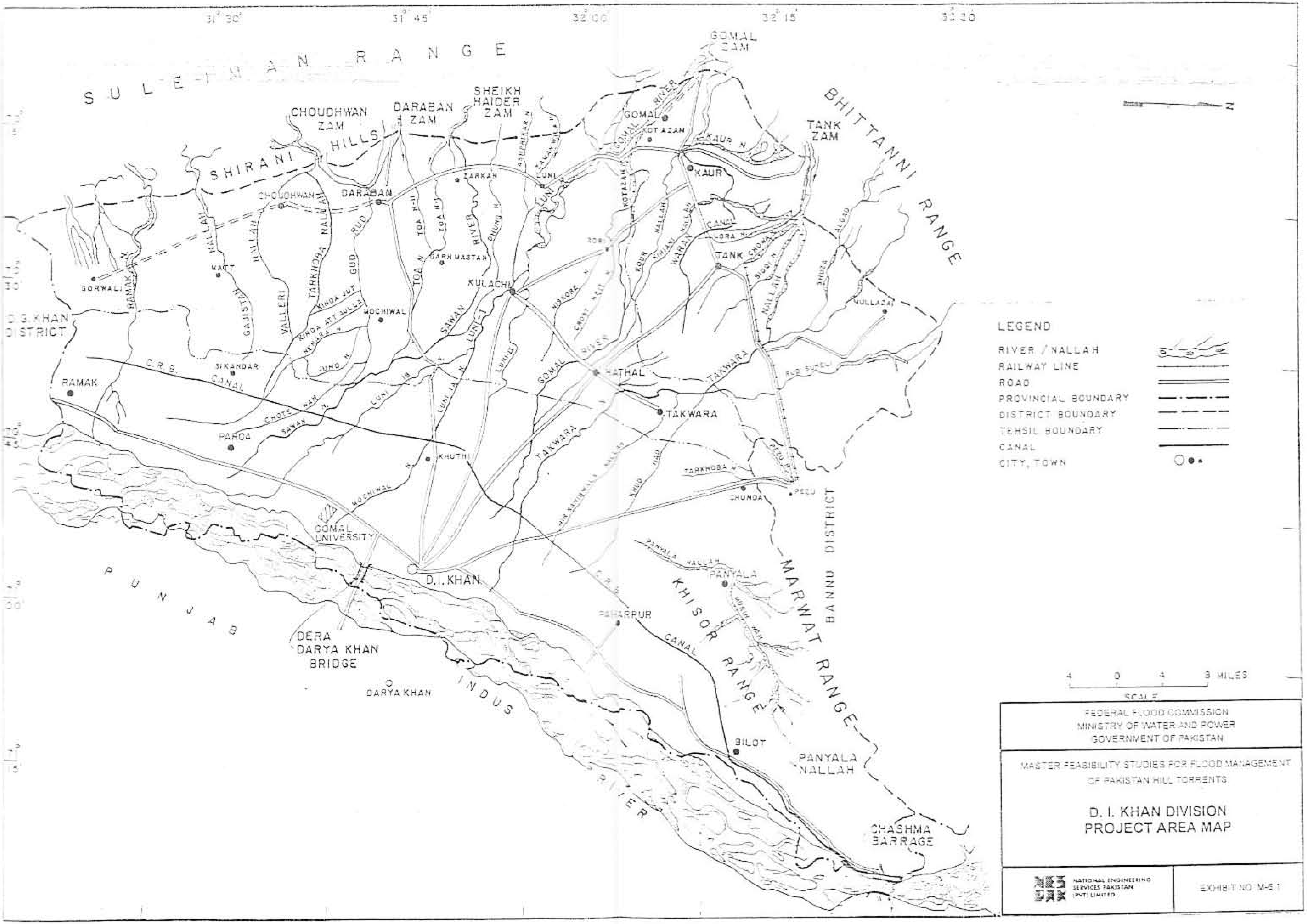


FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

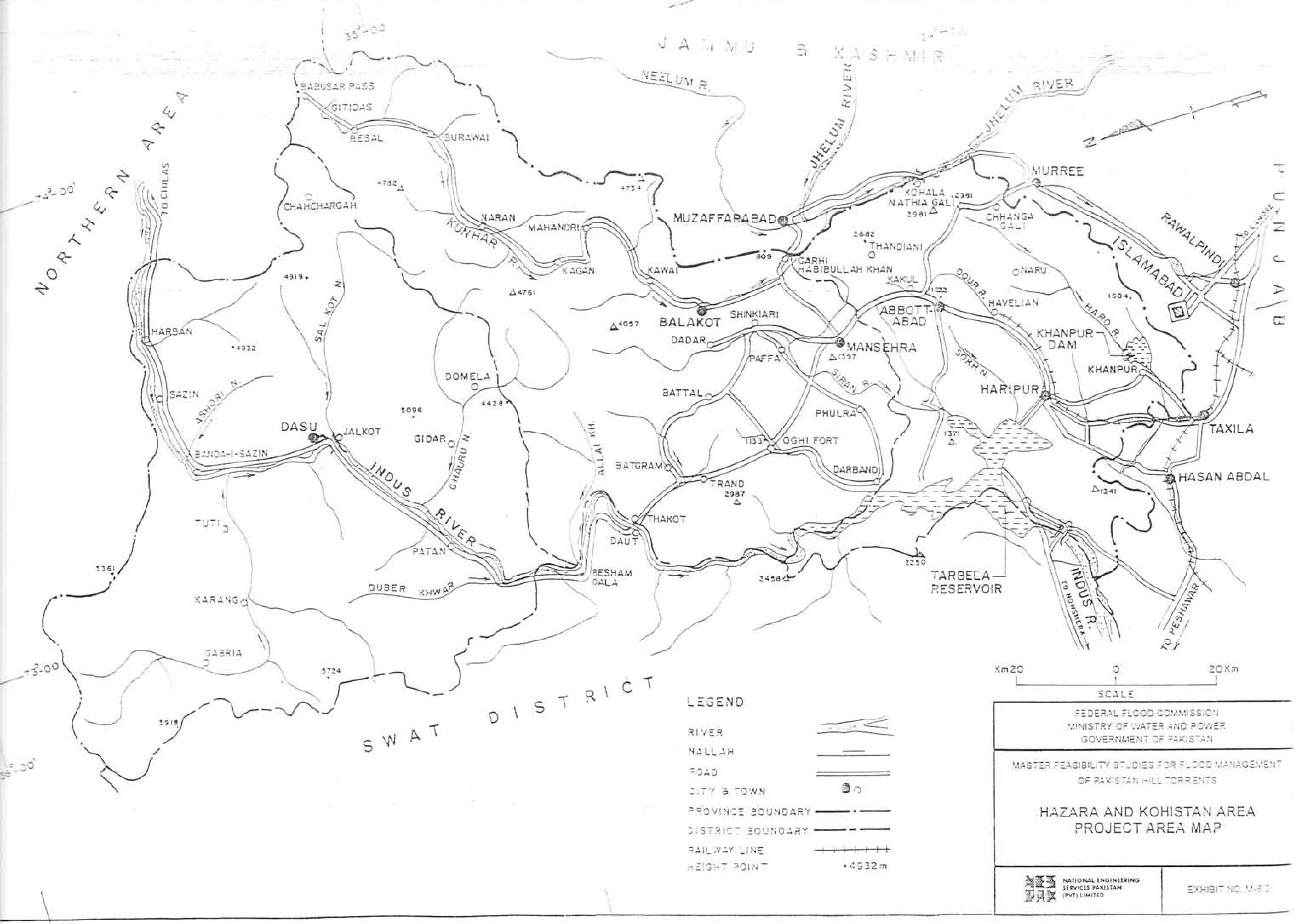
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

AZAD JAMMU AND KASHMIR
PROJECT AREA MAP

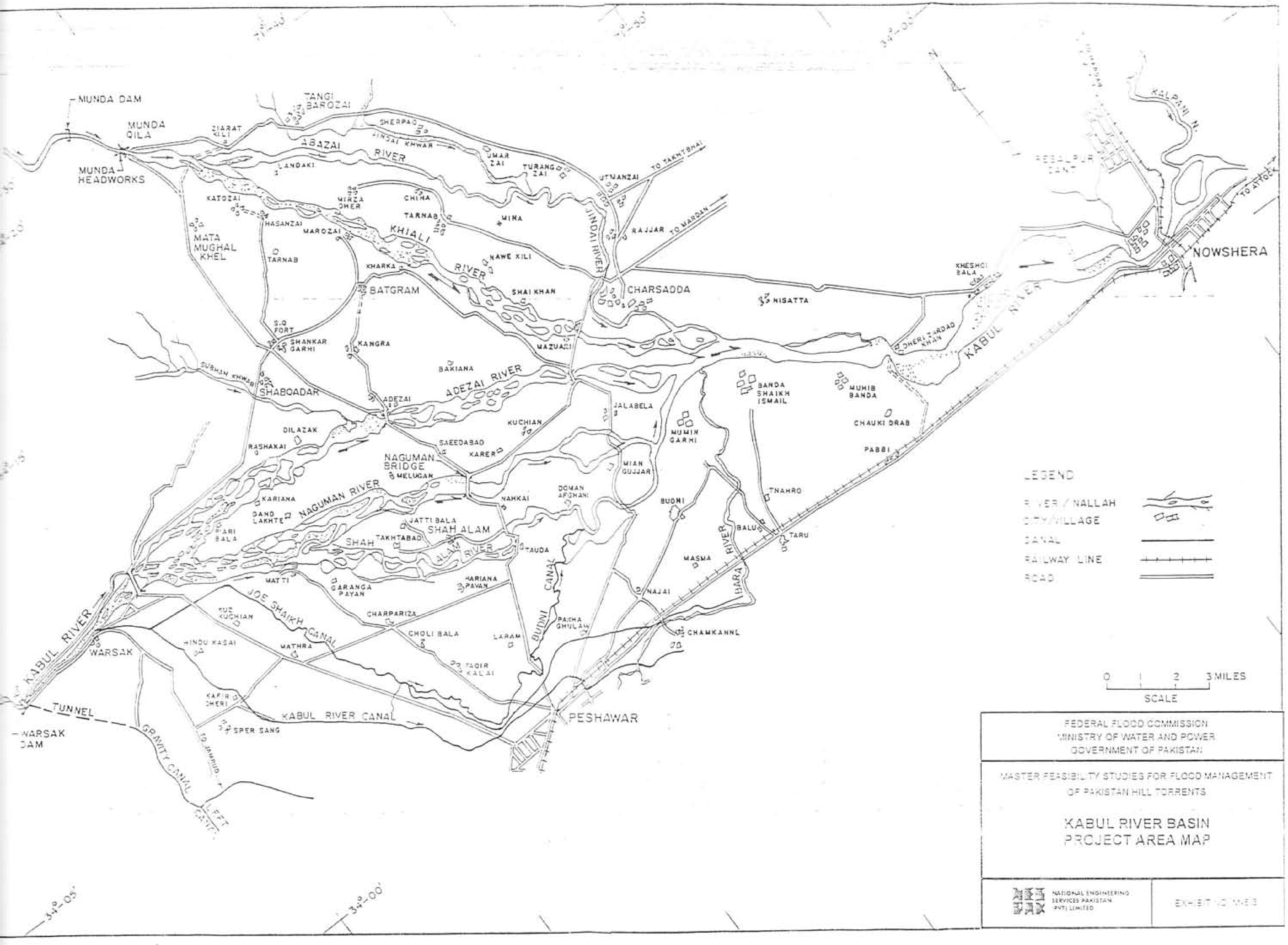
EXHIBIT NO. M-5.2

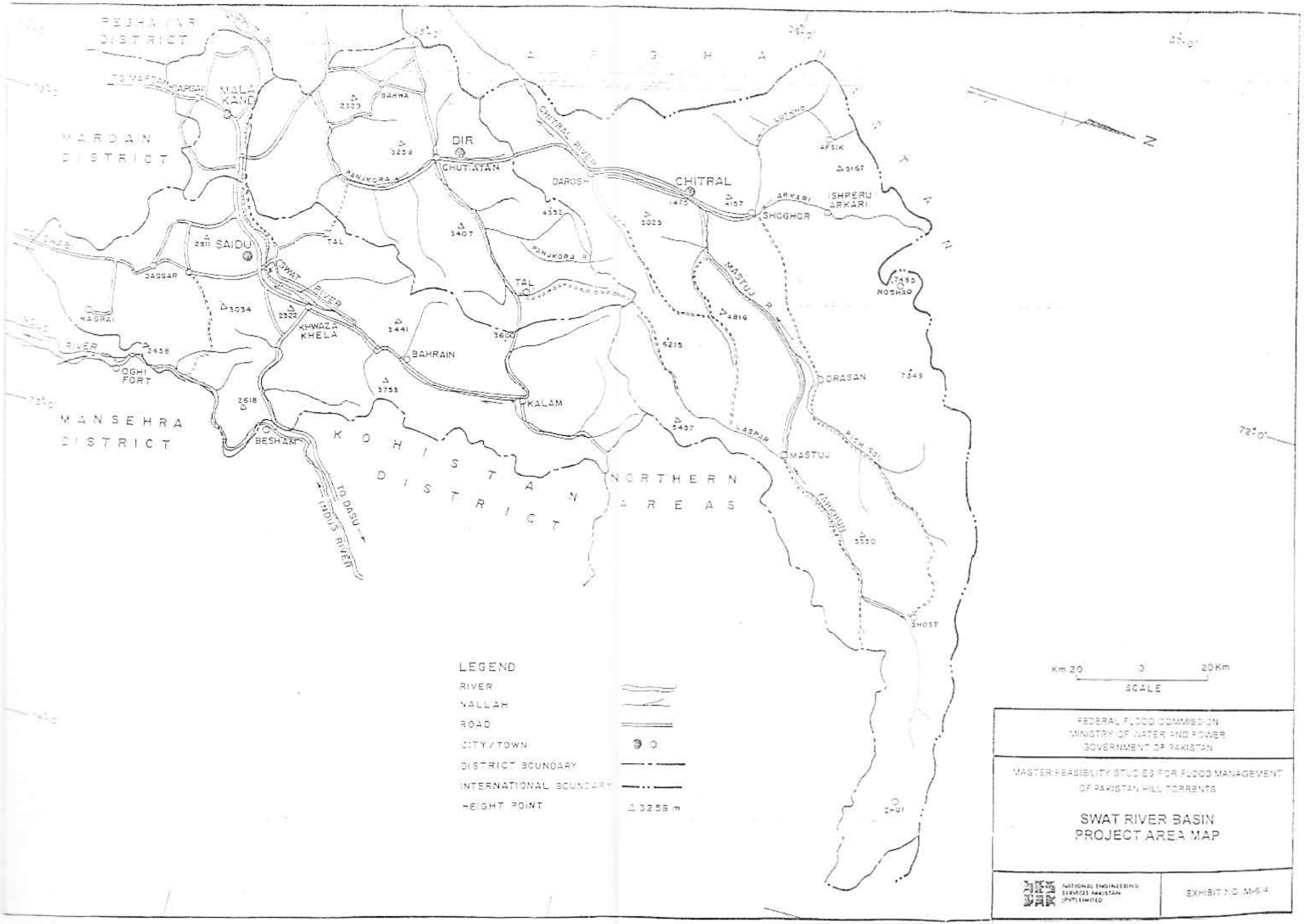


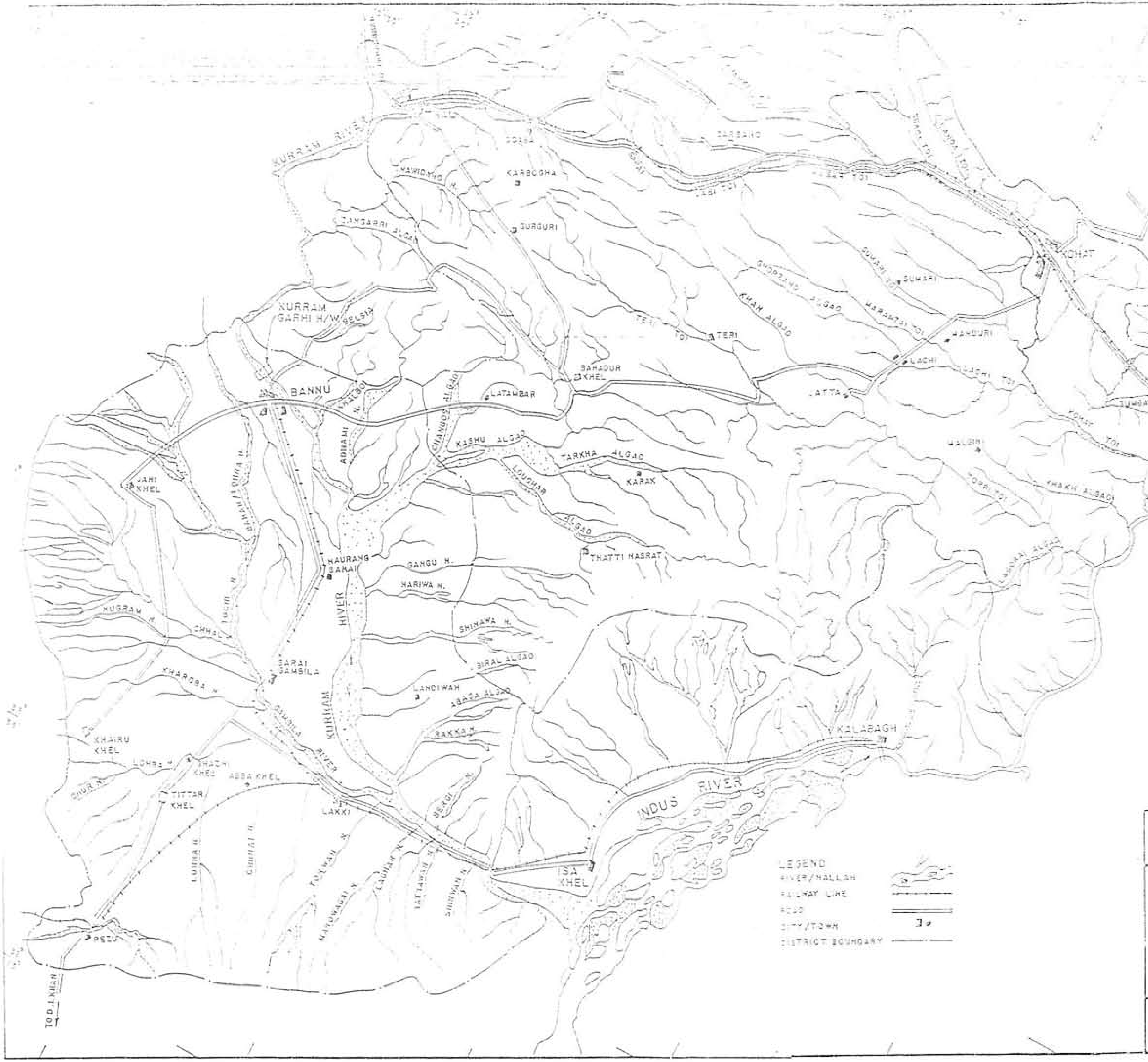
SULEIMAN RANGE
SHIRANI HILLS
CHOUDHWAN ZAM
DARABAN ZAM
SHEIKH HAIDER ZAM
GOMAL ZAM
TANK ZAM
BHITTANNI RANGE
GOMAL
KOT AZAM
KAUR
TANK
DARABAN
CHOUDHWAN
ZARKAH
GARH MASTAN
KULACHI
MOCHIWAL
GORWALI
MATT
SIKANDAR
RAMAK
PAROA
KHUTHI
HATHAL
TAKWARA
CHUNDA
PEZU
NULLAZAI
D.G. KHAN DISTRICT
C.R.B. CANAL
GOMAL RIVER
GOMAL UNIVERSITY
D.I. KHAN
PUNJAB
DERA DARYA KHAN BRIDGE
DARYA KHAN
INDUS RIVER
PAHARPUR
KHISOR RANGE
MARWAT RANGE
BANNU DISTRICT
PANYALA
PANYALA NALLAH
BILOT
CHASHMA BARRAGE
LEGEND
RIVER / NALLAH
RAILWAY LINE
ROAD
PROVINCIAL BOUNDARY
DISTRICT BOUNDARY
TEHSIL BOUNDARY
CANAL
CITY, TOWN
4 0 4 8 MILES
SCALE
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS
D. I. KHAN DIVISION
PROJECT AREA MAP
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-6.1



JAMMU & KASHMIR
NORTHERN AREA
PUNJAB
SWAT DISTRICT
NEELUM R.
JHELUM RIVER
JHELUM RIVER
KUNHAR R.
INDUS RIVER
INDUS R.
SAL KOT N.
ASHORI N.
GHAURU N.
ALLAI KH.
DUBER KHWAR
DOUR R.
HARO R.
SIRAN R.
SOKH N.
BABUSAR PASS
GITIDAS
BESAL
BURAWAI
CHAHCHARGAH
NARAN
MAHANDRI
KAGAN
KAWAI
MUZAFFARABAD
GARHI HABIBULLAH KHAN
BALAKOT
SHINKIARI
DADAR
PAFFA
MANSEHRA
KOHALA
NATHIA GALI
CHHANGA GALI
MURREE
THANDIANI
KAKUL
ABBOTT-ABAD
HAVELIAN
NARU
ISLAMABAD
RAWALPINDI
KHANPUR DAM
KHANPUR
HARIPUR
TAXILA
HASAN ABDAL
TARBELA RESERVOIR
PHULRA
BATTAL
OGHI FORT
DARBAND
BATGRAM
TRAND
THAKOT
DAUT
BESHAM QALA
PATAN
DASU
JALKOT
GIDAR
DOMELA
HARBAN
SAZIN
BANDA-I-SAZIN
TUTI
KARANG
GABRIA
TO CHILAS
TO NOWSHERA
TO PESHAWAR
TO LAHORE
4782
4734
4919
4761
4057
4932
5096
4428
809
2682
2981
2381
1122
1604
1397
1133
1371
1341
2987
2250
2458
5361
3724
3918
Km20 0 20Km
SCALE
LEGEND
RIVER
NALLAH
ROAD
CITY & TOWN
PROVINCE BOUNDARY
DISTRICT BOUNDARY
RAILWAY LINE
HEIGHT POINT •4932m
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS
HAZARA AND KOHISTAN AREA
PROJECT AREA MAP
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-5.2


MUNDA DAM
MUNDA QILA
MUNDA HEADWORKS
TANGI BAROZAI
ZIARAT KILI
SHERPAO
JINDAI KHWAR
ABAZAI RIVER
LANDAKI
UMAR ZAI
TURANGZAI
UTMANZAI
TO TAKHTBHAI
KATOZAI
MIRZA DHER
CHINA
TARNAB
MINA
HASANZAI
MAROZAI
KHIALI RIVER
JINDAI RIVER
RAJJAR
TO MARDAN
MATA MUGHAL KHEL
TARNAB
NAWE KILI
KHARKA
BATGRAM
SHAI KHAN
CHARSADDA
NISATTA
KHESHGI BALA
NOWSHERA
KALPANI N.
RISALPUR CANT
TO ATTOCK
S.Q FORT
SHANKAR GARHI
KANGRA
MAZUARI
DHERI JARDAD KHAN
KABUL RIVER
SUBHAN KHWAR
SHABQADAR
BAKIANA
ADEZAI RIVER
ADEZAI
BANDA SHAIKH ISMAIL
MUHIB BANDA
JALABELA
DILAZAK
RASHAKAI
KUCHIAN
MUMIN GARHI
CHAUKI DRAB
SAEEDABAD
KARERA
PABBI
NAGUMAN BRIDGE
MELUGAN
MIAN GUJJAR
KARIANA
NAGUMAN RIVER
NAHKAI
DOMAN AFGHANI
BUDNI
TNAHRO
DAND LAKHTE
JATTI BALA
SHAH ALAM
PIARI BALA
SHAH ALAM RIVER
TAKHTABAD
TAUDA
BALU
TARU
MASMA
BARA RIVER
MATTI
GARANGA PAYAN
HARIANA PAYAN
NAJAI
JOE SHAIKH CANAL
KUZ KUCHIAN
CHARPARIZA
PAKHA GHULAM
CHAMKANNI
KABUL RIVER
WARSAK
HINDU KASAI
MATHRA
CHOLI BALA
LARAM
BUDNI CANAL
FAQIR KALAI
KAFIR DHERI
TUNNEL
KABUL RIVER CANAL
PESHAWAR
WARSAK DAM
GRAVITY CANAL
SPER SANG
TO JAMRUD
LEFT CANAL
LEGEND
RIVER / NALLAH
CITY/VILLAGE
CANAL
RAILWAY LINE
ROAD
0 1 2 3 MILES
SCALE
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT
OF PAKISTAN HILL TORRENTS
KABUL RIVER BASIN
PROJECT AREA MAP
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED


PESHAWAR DISTRICT
MARDAN DISTRICT
MANSEHRA DISTRICT
KOHISTAN DISTRICT
NORTHERN AREAS
AFGHANISTAN
TO MARDAN
DARGAI
MALAKAND
SAIDU
DAGGAR
HAGRAI
OGHI FORT
BESHAM
KHWAZA KHELA
BAHRAIN
KALAM
TAL
DIR
CHUTIATAN
DAROSH
CHITRAL
SHOGHOR
ISHPERU ARKARI
AFSIK
NOSHAO
DRASAN
MASTUJ
SHOST
SWAT RIVER
PANJKORA R.
CHITRAL RIVER
MASTUJ R.
INDUS RIVER
TO DASU
LUTKHO
ARKARI
LASPUR
2323
3258
3407
4332
3025
1470
4157
5161
7485
4816
6235
7349
3034
2322
3441
3600
2436
2618
3753
5457
5550
2811
LEGEND
RIVER
NALLAH
ROAD
CITY / TOWN
DISTRICT BOUNDARY
INTERNATIONAL BOUNDARY
HEIGHT POINT
△ 3258 m
Km 20
0
20 Km
SCALE
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS
SWAT RIVER BASIN
PROJECT AREA MAP
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-6.4



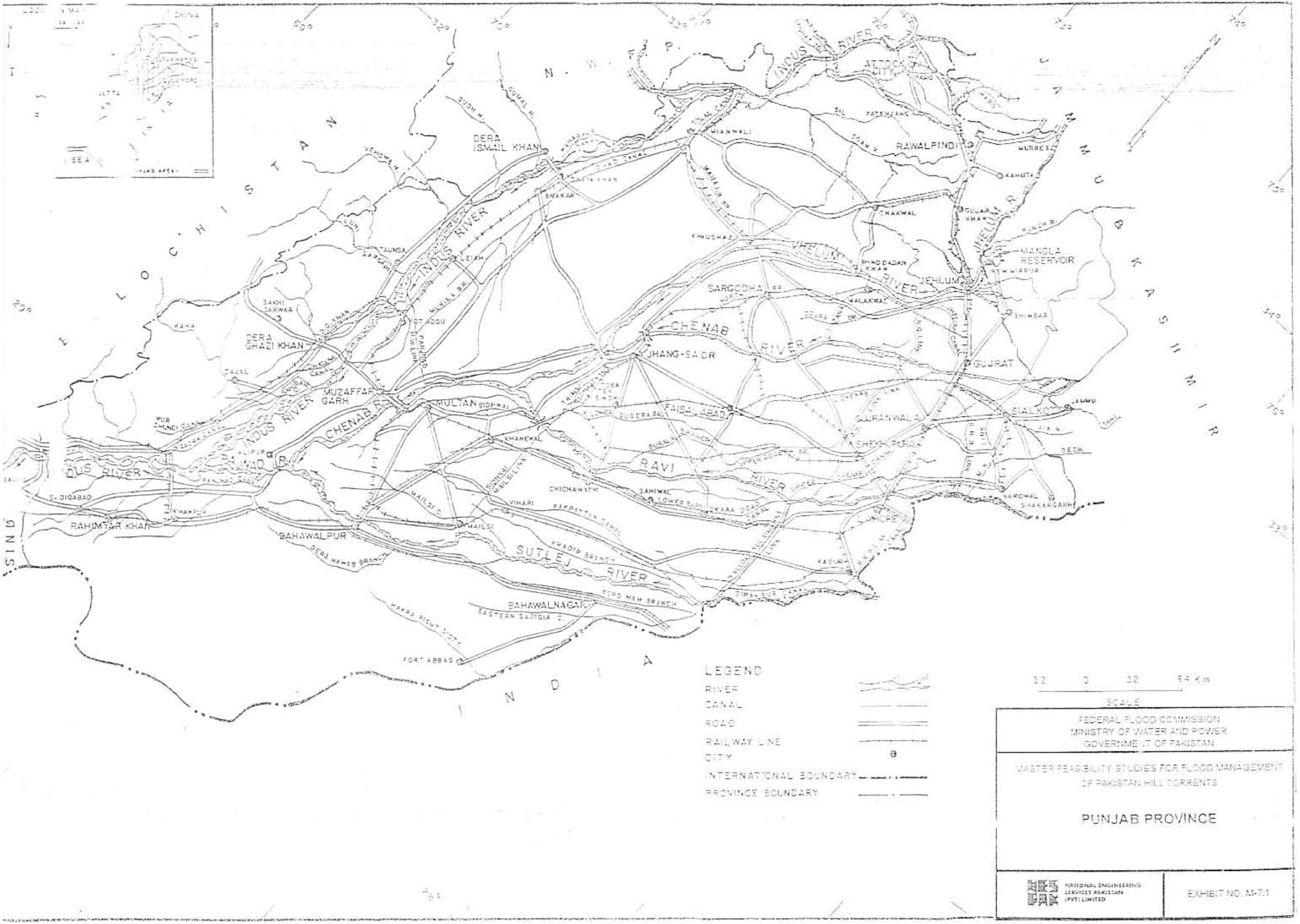
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

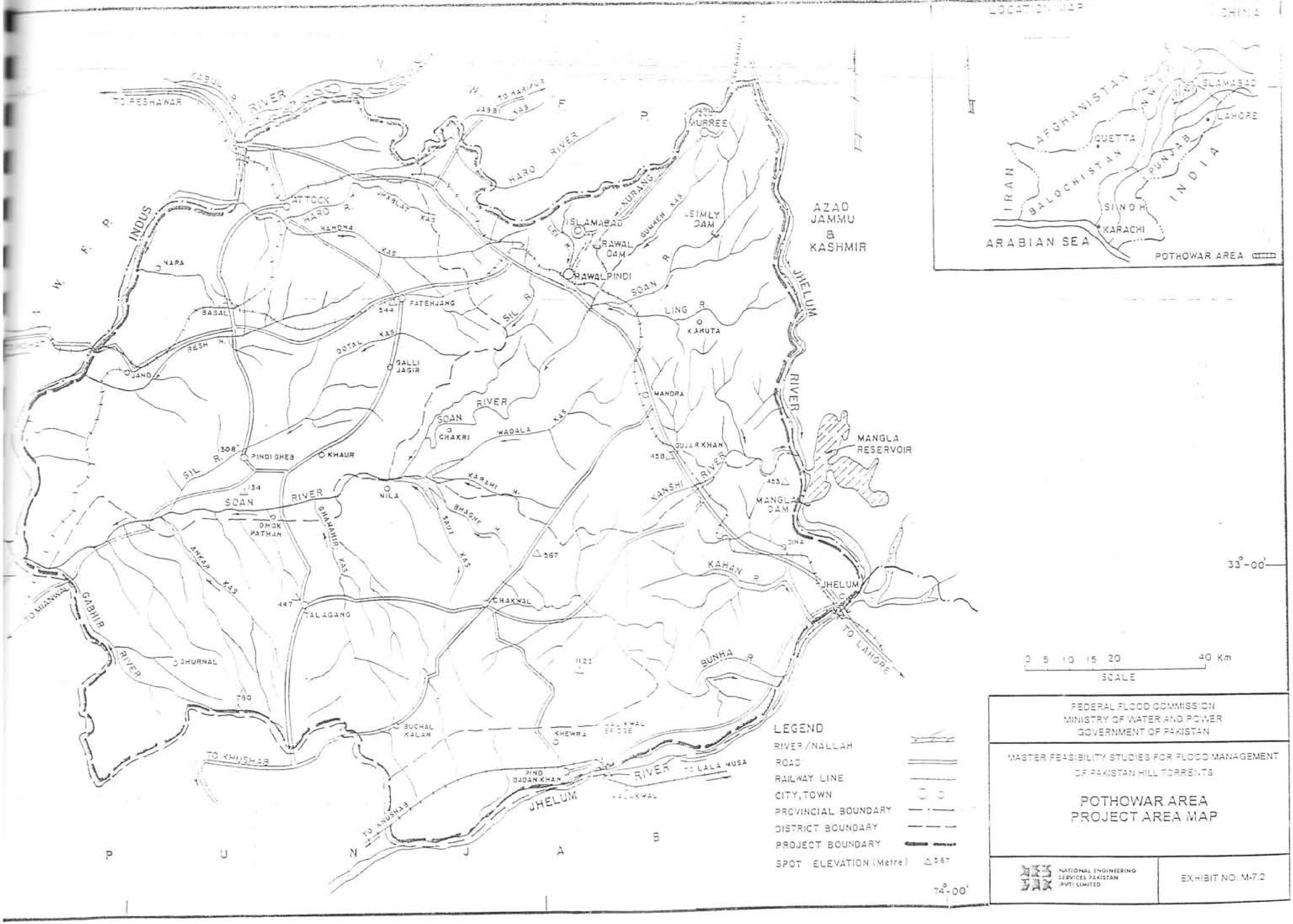
BANNU AND KOHAT AREAS
PROJECT AREA MAP

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-6.5



N.W.F.P.
BALOCHISTAN
JAMMU & KASHMIR
INDIA
SIND
INDUS RIVER
JHELUM RIVER
CHENAB RIVER
RAVI RIVER
SUTLEJ RIVER
ATTOCK CITY
RAWALPINDI
DERA ISMAIL KHAN
BHAKAR
LEIAH
TAUNSA
MIANWALI
CHAKWAL
KAHUTA
MANGLA RESERVOIR
JEHLUM
SARGODHA
PIND DADAN KHAN
SAKHI SARWAR
DERA GHAZI KHAN
JHANG-SADR
GUJRAT
MUZAFFAR GARH
MULTAN
FAISALABAD
GUJRANWALA
SIALKOT
SHEIKHUPURA
KHANEWAL
CHICHAWATNI
SAHIWAL
VIHARI
LAHORE
KASUR
NAROWAL
SHAKARGARH
RAHIMYAR KHAN
BAHAWALPUR
BAHAWALNAGAR
FORT ABBAS
LEGEND
RIVER
CANAL
ROAD
RAILWAY LINE
CITY
INTERNATIONAL BOUNDARY
PROVINCE BOUNDARY
32 0 32 64 Km
SCALE
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT
OF PAKISTAN HILL TORRENTS
PUNJAB PROVINCE
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-7.1



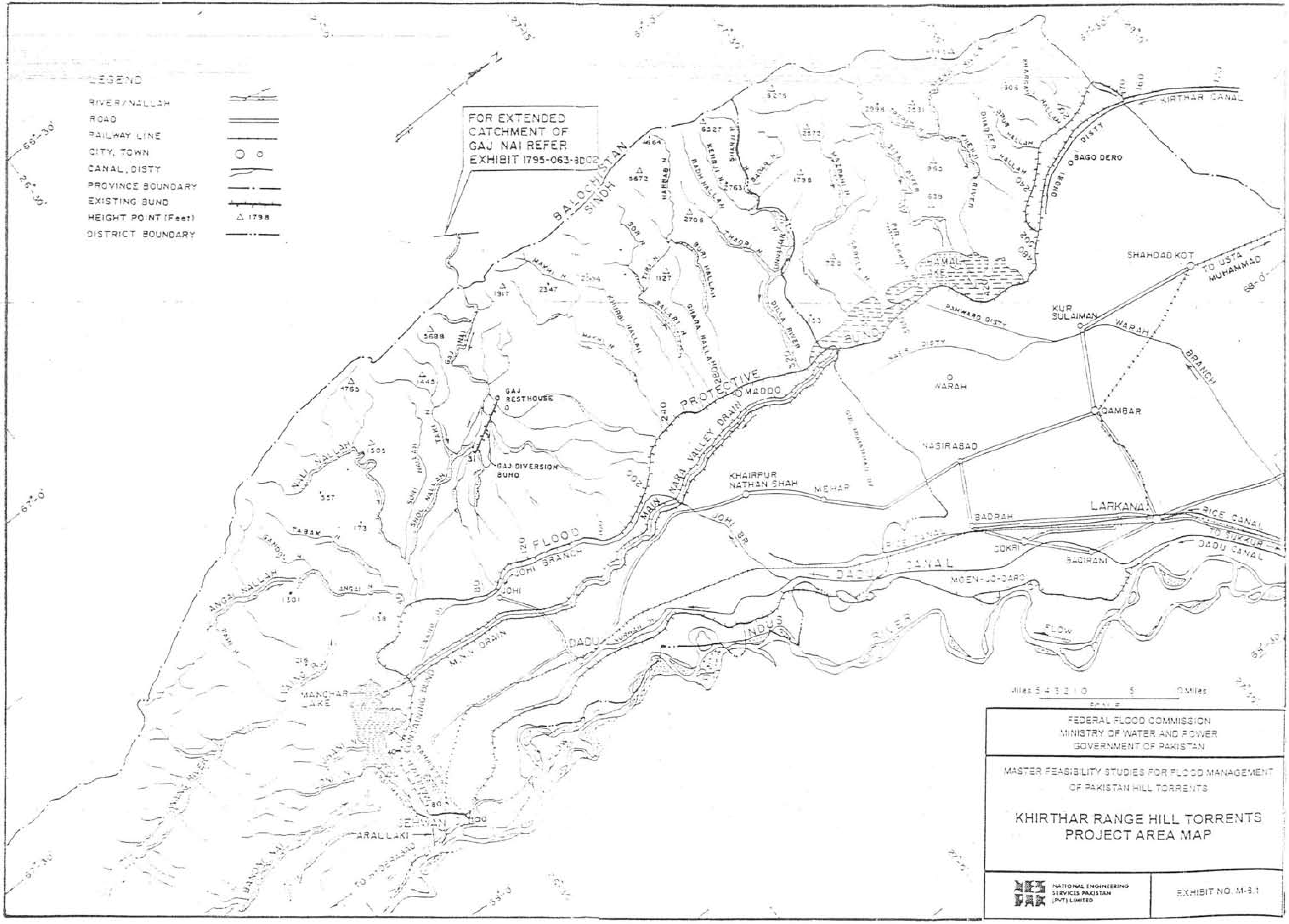
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

POTHOWAR AREA
PROJECT AREA MAP

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-7.2



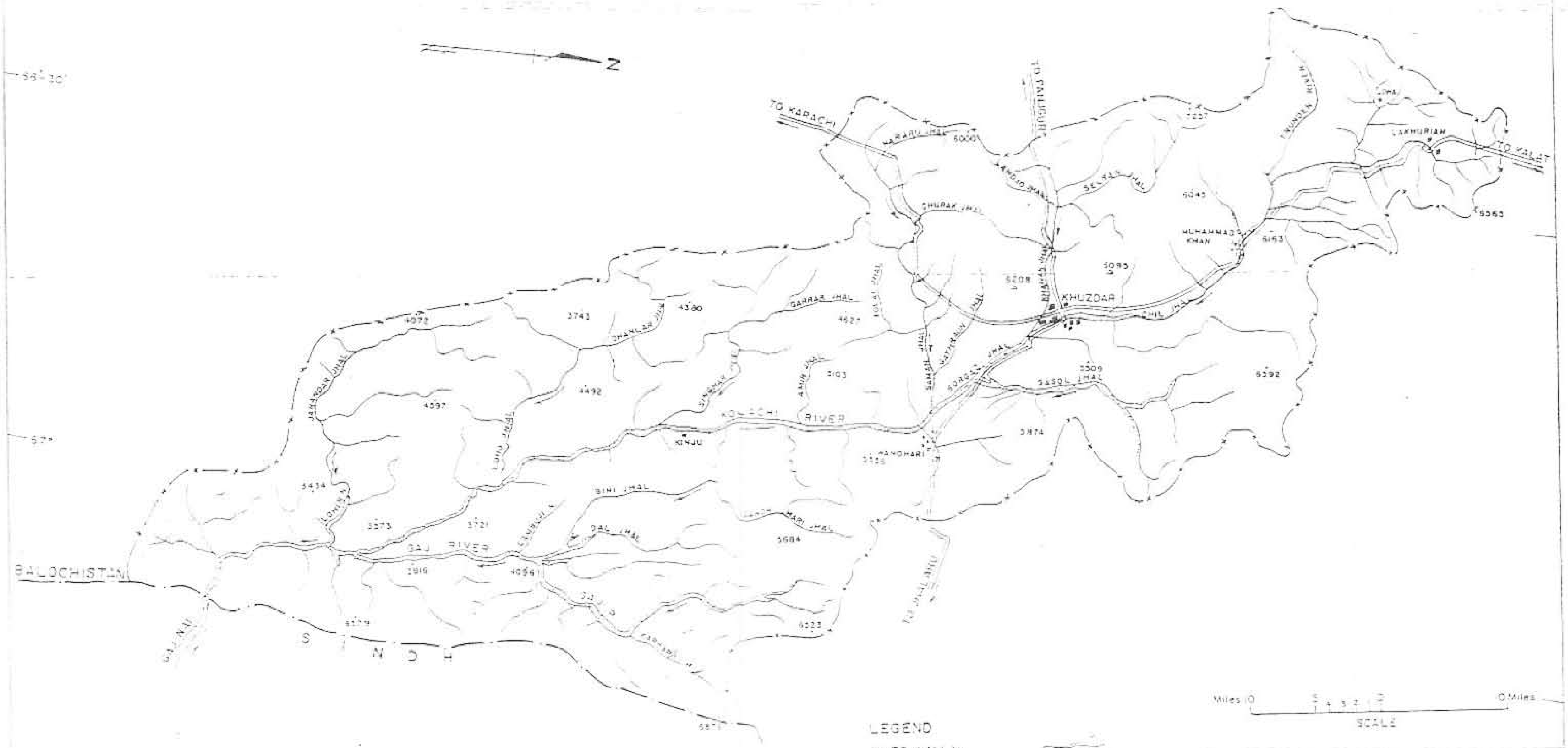
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

KHIRTHAR RANGE HILL TORRENTS PROJECT AREA MAP

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-8.1



LEGEND

RIVER / NALLAH	
ROAD	
CITY, TOWN	
CATCHMENT BOUNDARY	
PROVINCE BOUNDARY	
HEIGHT POINT (FEET)	∆ 6208

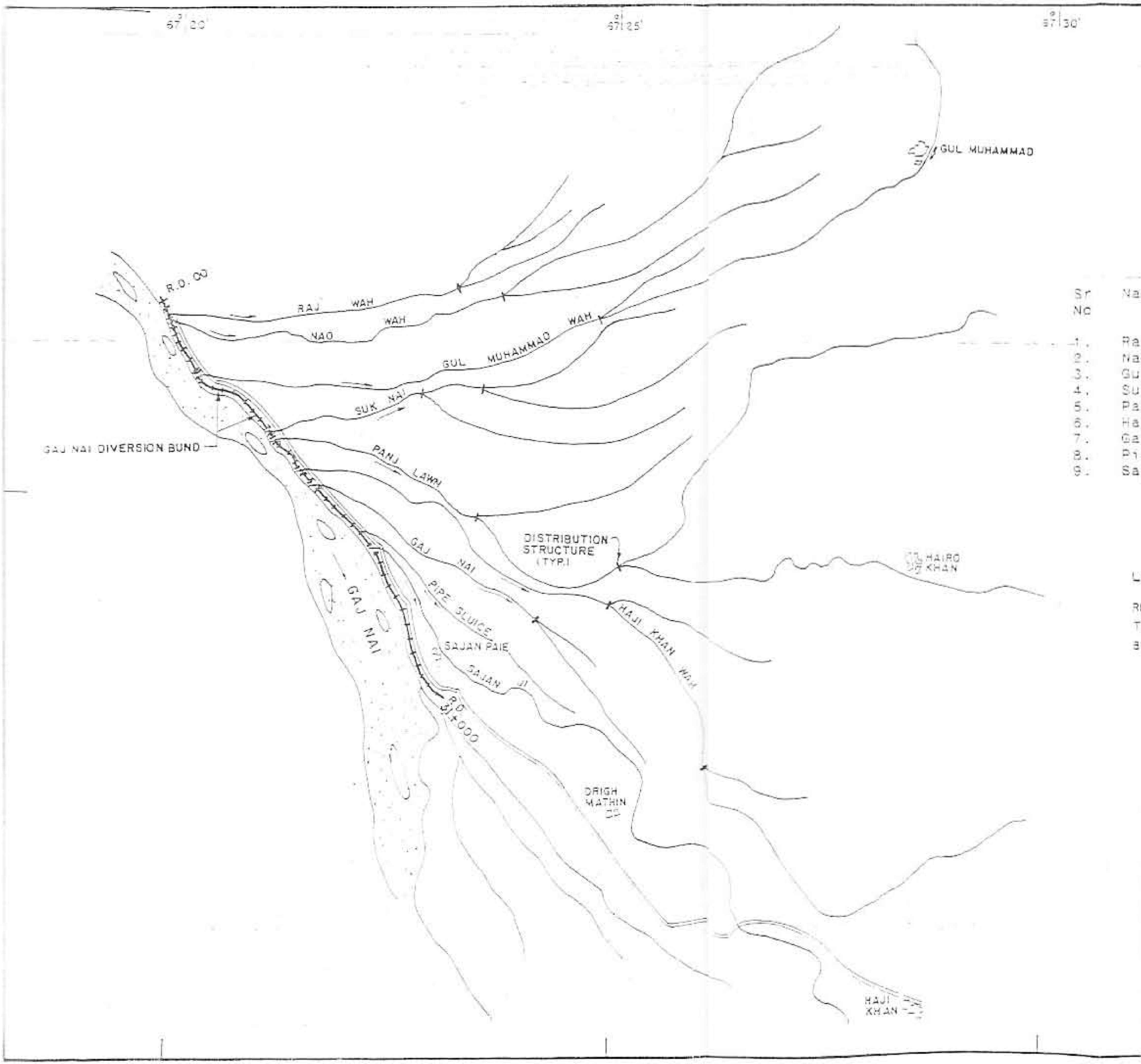
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

EXTENDED CATCHMENT OF GAJ NAI

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-3.2



Sr No	Name of Sluice	Bund RD (ft)
1.	Raj Wah	634
2.	Nao Wah	1750
3.	Gul Muhammad Wah	9600
4.	Suk Nai	11340
5.	Panj Lawn	11700
6.	Haji Khan	14000
7.	Gaj Nai	17500
8.	Pipe Sluice	21075
9.	Sajan Ji	22376

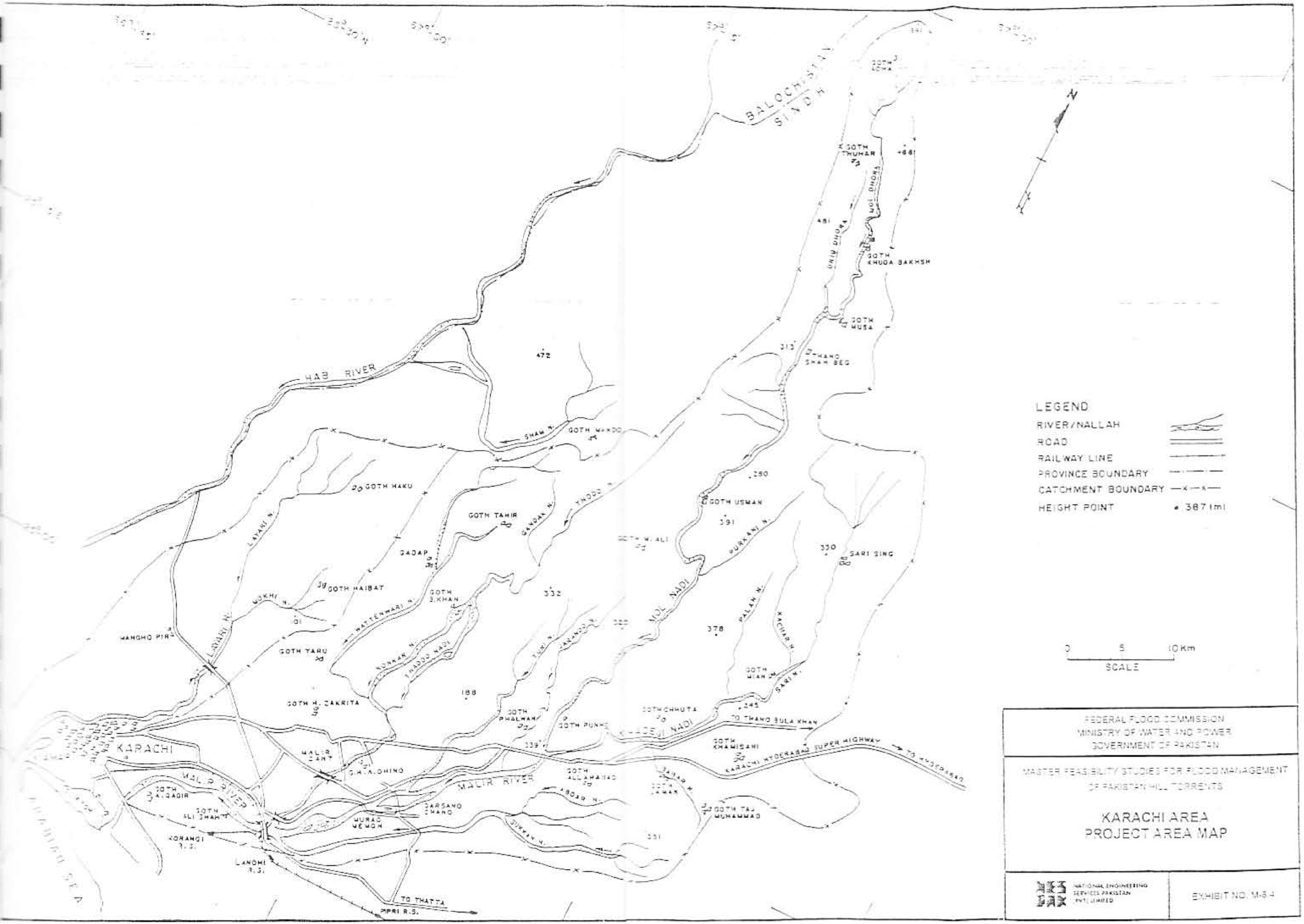
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

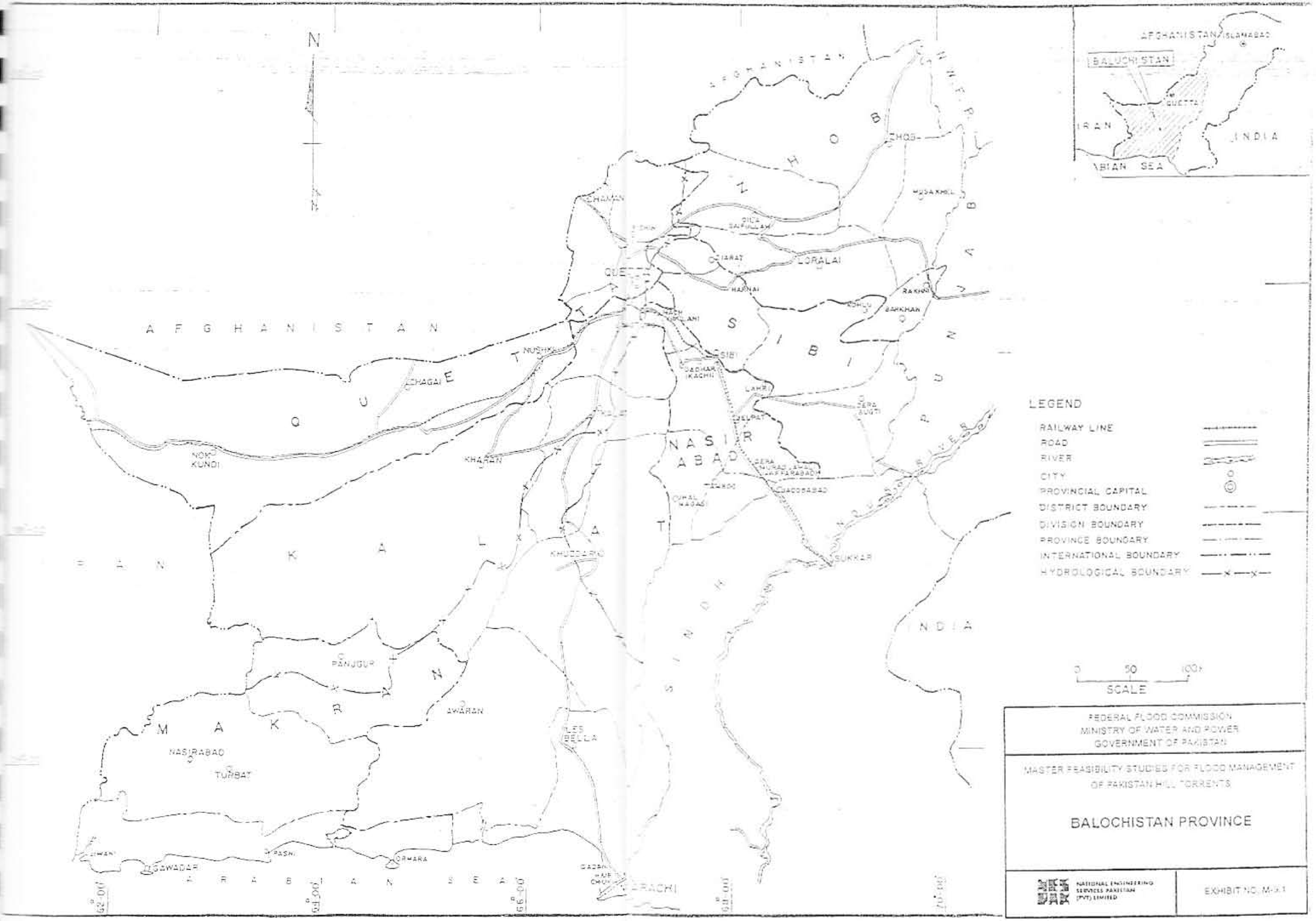
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

LAYOUT PLAN OF SULICES OFFTAKING FROM GAJ NAI

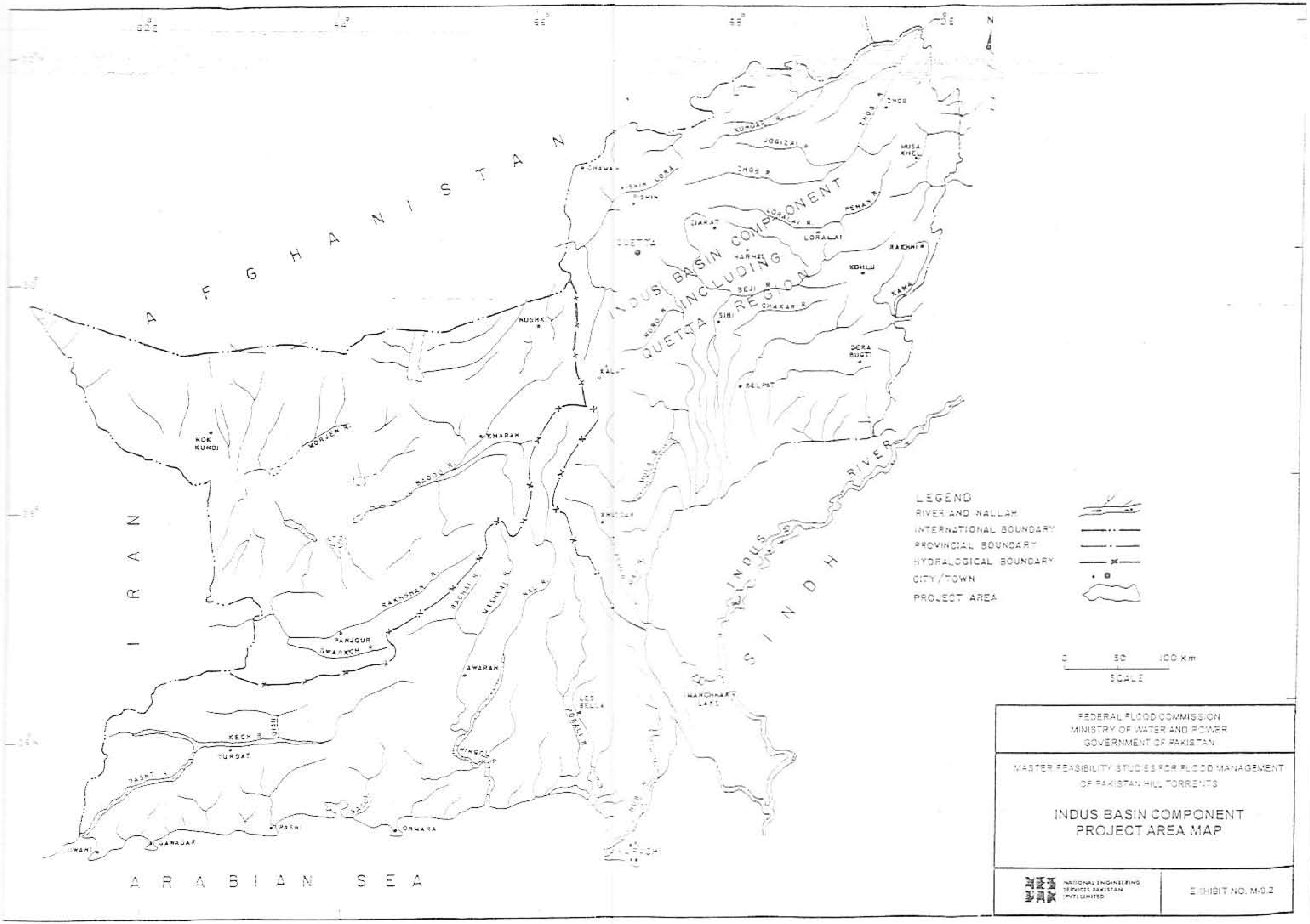
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-6.3

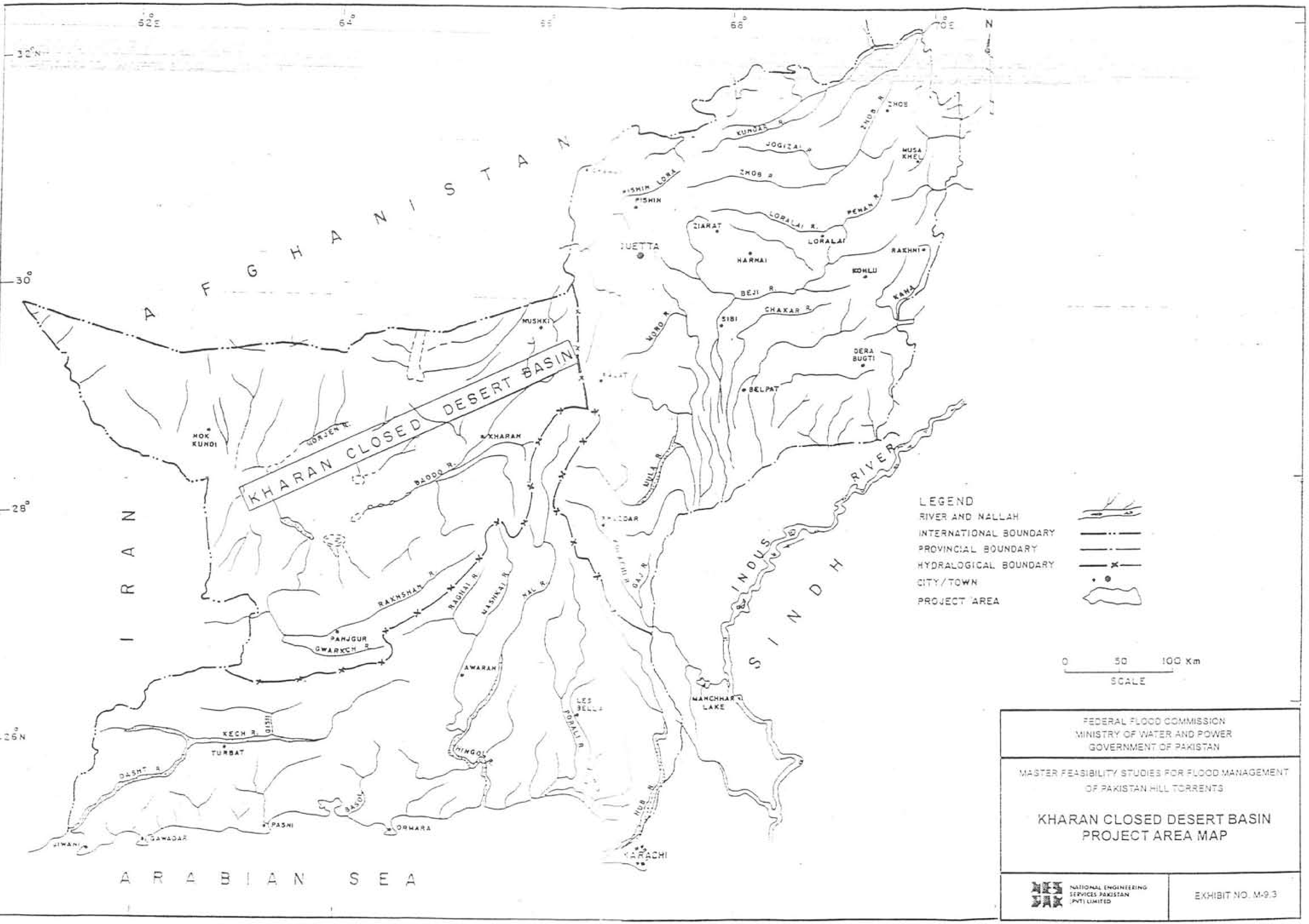

BALOCHISTAN
SINDH
HAB RIVER
KARACHI
ARABIAN SEA
MALIR RIVER
MALIR RIVER
MOL NADI
KHADEJI NADI
LYARI N.
LAYARI N.
MOKHI N.
SHAM N.
THODO N.
GANDAN N.
WATTENWARI N.
SUKKAN N.
THADDO NADI
TUKI N.
JARANDO N.
PURKANI N.
PALAN N.
KACHAR N.
SARI N.
ABDAR N.
SUKKAN N.
GOTH THUHAR
GOTH KHUDA BAKHSH
GOTH MUSA
THANO SHAH BEG
GOTH WANDO
GOTH HAKU
GOTH TAHIR
GADAP
GOTH HAIBAT
GOTH S.KHAN
GOTH USMAN
SARI SING
MANGHO PIR
GOTH TARU
GOTH H. ZAKRITA
GOTH PHALWAN
GOTH PUNHO
GOTH CHHUTA
GOTH KHAMISANI
GOTH MIAN
MALIR CANT
GOTH A. QADIR
GOTH ALI SHAH
KORANGI R.S.
LANDHI R.S.
DARSANO CHANO
MURAD MEMON
GOTH ALLAHABAD
GOTH TAJ MUHAMMAD
TO THANO BULA KHAN
KARACHI HYDERABAD SUPER HIGHWAY
TO HYDERABAD
TO THATTA
PIPRI R.S.
472
481
313
280
391
330
332
378
188
245
339
N
LEGEND
RIVER/NALLAH
ROAD
RAILWAY LINE
PROVINCE BOUNDARY
CATCHMENT BOUNDARY
HEIGHT POINT
• 387 (m)
0 5 10 Km
SCALE
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT
OF PAKISTAN HILL TORRENTS
KARACHI AREA
PROJECT AREA MAP
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-8.4



N
AFGHANISTAN
IRAN
INDIA
ARABIAN SEA
BALUCHISTAN
ISLAMABAD
QUETTA
QUETTA
ZHOB
SIBI
NASIRABAD
KALAT
MAKRAN
PUNJAB
SINDH
N.W.F.P.
CHAMAN
ZHOB
MUSAKHEL
QILA SAIFULLAH
ZIARAT
LORALAI
HARNAI
KOHLU
BARKHAN
RAKHNI
SIBI
LAHRI
DERA BUGTI
NUSHKI
CHAGAI
NOK KUNDI
KHARAN
KALAT
KHUZDAR
JACOBABAD
SUKKAR
PANJGUR
AWARAN
LES BELA
NASIRABAD
TURBAT
JIWANI
GAWADAR
PASNI
ORMARA
KARACHI
INDUS RIVER
LEGEND
RAILWAY LINE
ROAD
RIVER
CITY
PROVINCIAL CAPITAL
DISTRICT BOUNDARY
DIVISION BOUNDARY
PROVINCE BOUNDARY
INTERNATIONAL BOUNDARY
HYDROLOGICAL BOUNDARY
0 50 100
SCALE
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS
BALOCHISTAN PROVINCE
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-9.1



A F G H A N I S T A N
I R A N
A R A B I A N S E A
S I N D H
INDUS BASIN COMPONENT INCLUDING QUETTA REGION
INDUS RIVER
CHAMAN
PISHIN
QUETTA
ZIARAT
HARNAI
LORALAI
KOHLU
SIBI
DERA BUGTI
ZHOB
MUSA KHEL
NUSHKI
KALAT
KHARAN
NOK KUNDI
KHUZDAR
PANJGUR
TURBAT
AWARAN
LES BELLA
MANCHHAR LAKE
JIWANI
GAWADAR
PASNI
ORMARA
KARACHI
KECH R.
DASHT R.
HINGOL
PORALI R.
RAKHSHAN R.
LEGEND
RIVER AND NALLAH
INTERNATIONAL BOUNDARY
PROVINCIAL BOUNDARY
HYDRALOGICAL BOUNDARY
CITY / TOWN
PROJECT AREA
0 50 100 Km
SCALE
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT
OF PAKISTAN HILL TORRENTS
INDUS BASIN COMPONENT
PROJECT AREA MAP
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-9.2



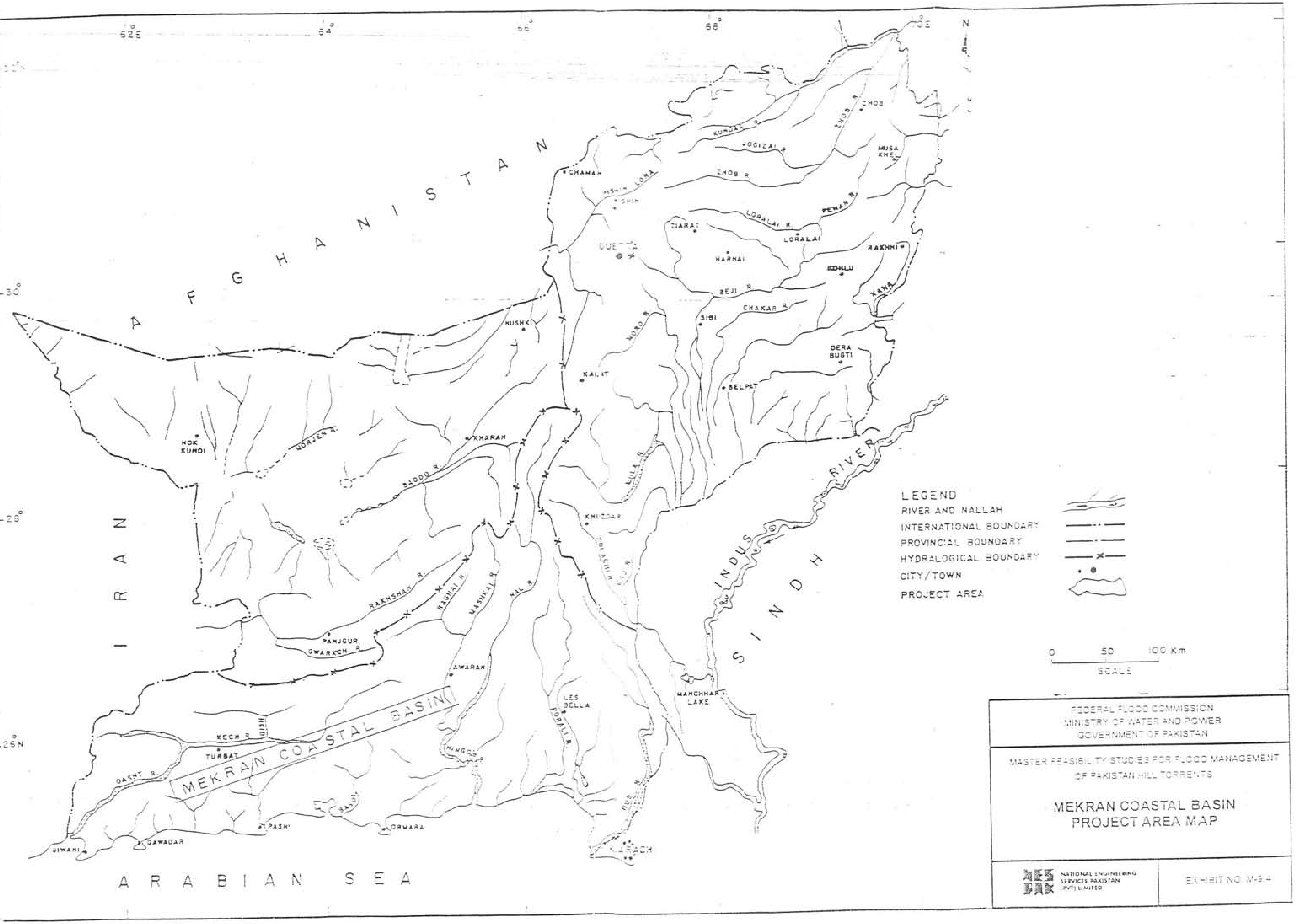
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN

MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF PAKISTAN HILL TORRENTS

KHARAN CLOSED DESERT BASIN
PROJECT AREA MAP

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED

EXHIBIT NO. M-9.3


AFGHANISTAN
IRAN
SINDH
ARABIAN SEA
INDUS RIVER
MEKRAN COASTAL BASIN
CHAMAN
PISHIN LORA
PISHIN
QUETTA
ZIARAT
HARNAI
LORALAI
LORALAI R.
ZHOB
ZHOB R.
KUNDAR R.
JOGIZAI R.
MUSA KHEL
PEHAN R.
RAKHNI
KOHLU
KAHA
BEJI R.
CHAKAR R.
SIBI
DERA BUGTI
BELPAT
NUSHKI
KALAT
MORO R.
KHARAN
NOK KUNDI
MORJEN R.
BADOO R.
MULA R.
KHUZDAR
KOLACHI R.
GAJ R.
RAKHSHAN R.
RAGHAI R.
MASHKAI R.
NAL R.
PANJGUR
GWARGH R.
AWARAN
LES BELLA
PORALI R.
HINGOL R.
HUB R.
KARACHI
MANCHHAR LAKE
KECH R.
NIHING
TURBAT
DASHT R.
BASOL
PASNI
ORMARA
GAWADAR
JIWANI
LEGEND
RIVER AND NALLAH
INTERNATIONAL BOUNDARY
PROVINCIAL BOUNDARY
HYDRALOGICAL BOUNDARY
CITY/TOWN
PROJECT AREA
0 50 100 Km
SCALE
FEDERAL FLOOD COMMISSION
MINISTRY OF WATER AND POWER
GOVERNMENT OF PAKISTAN
MASTER FEASIBILITY STUDIES FOR FLOOD MANAGEMENT
OF PAKISTAN HILL TORRENTS
MEKRAN COASTAL BASIN
PROJECT AREA MAP
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LIMITED
EXHIBIT NO. M-3.4