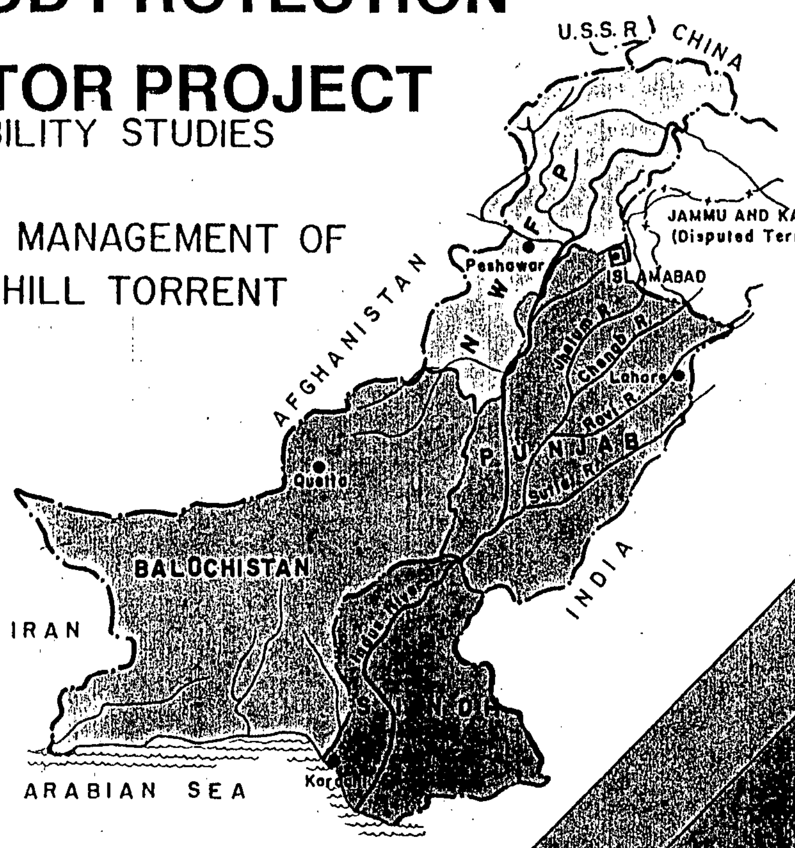
ISLAMIC REPUBLIC OF PAKISTAN

CHIEF ENGINEERING ADVISER/
CHAIRMAN FEDERAL FLOOD COMMISSION
ISLAMABAD

'DUL KHALIQ
Engineer,
NESPAK - (W & A)
LAHORE.

FLOOD PROTECTION SECTOR PROJECT

FEASIBILITY STUDIES FOR FLOOD MANAGEMENT OF KAHA HILL TORRENT



LOAN NO. 837 - PAK (SF)

NATIONAL ENGINEERING SERVICES
PAKISTAN (PVT.) LIMITED
417 - WAPDA HOUSE LAHORE PAKISTAN

IN ASSOCIATION WITH

HARZA

ENGINEERING COMPANY
233 - SOUTH WACKER DRIVE
CHICAGO ILLINOIS-USA

ZAFAR AND ASSOCIATES
4 - MAQBOOL CO-OPERATIVE
HOUSING SOCIETY-KARACHI.

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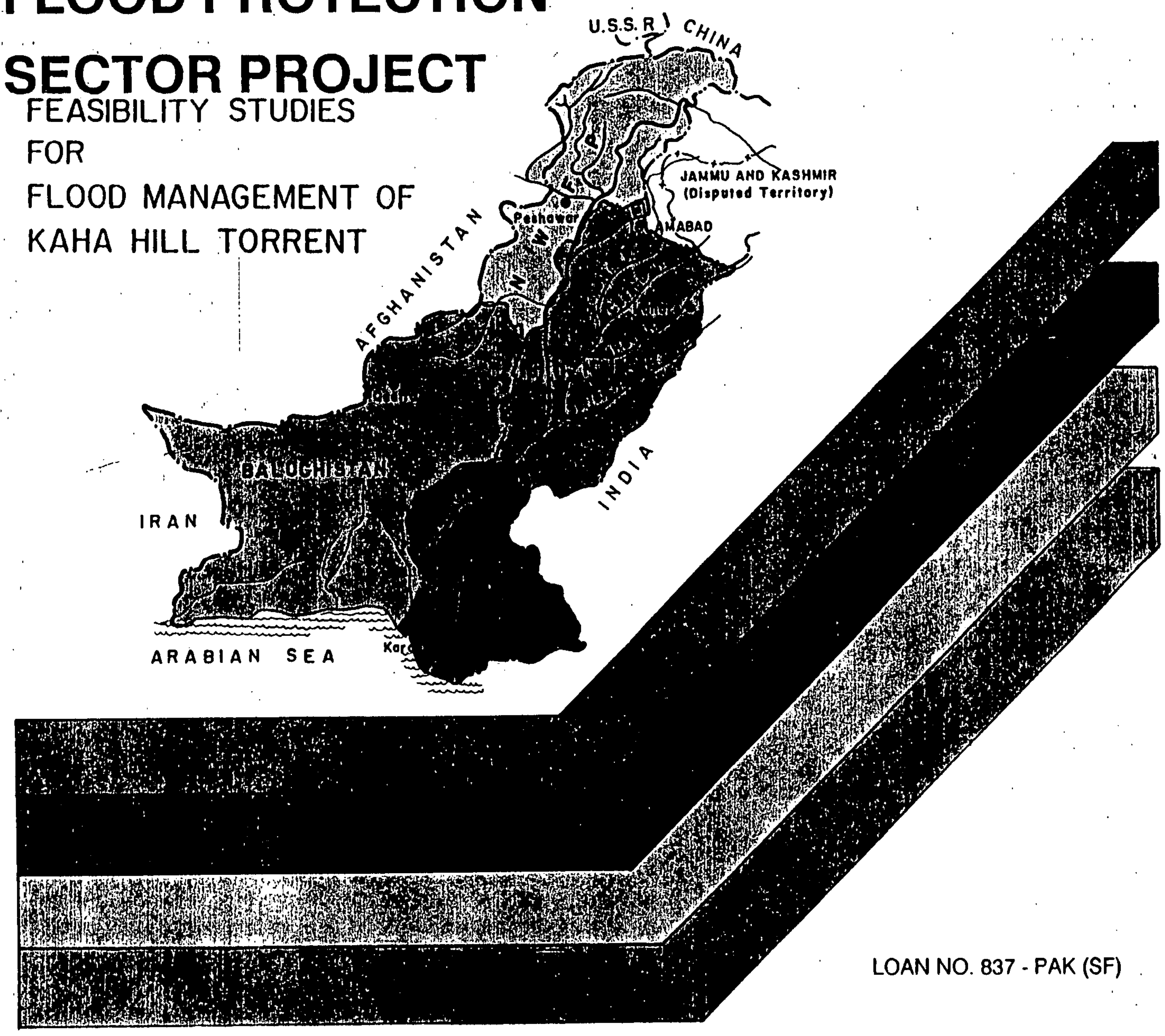

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NESPAK/HARZA/Z & A
CONSULTANTS FOR
FLOOD PROTECTION SECTOR
PROJECT

11 Aibak Block, New Garden Town, Lahore
Ph: 858311, 858712, 853228-30
Telex: 44730 NESPAK PK.
Telefax: (042) 306623

REF. W&A/J-1005/487/25113

DATE March 31, 1990.

The Chief Engineer (Floods),
Federal Flood Commission,
16-D East (Safdar Mansion),
Blue Area,
Islamabad.

FLOOD PROTECTION SECTOR PROJECT
FEASIBILITY STUDIES FOR FLOOD MANAGEMENT
OF KAHA HILL TORRENT

Dear Sir,

We take pleasure in transmitting final Feasibility Report for Flood Management of Kaha Hill Torrent. The report has been finalized in the light of comments received from FFC and the Asian Development Bank and the discussions held with ADB mission on 6th March 1990.

Kaha which is the biggest among the D.G.Khan Hill Torrents, is located on the western side of D.G.Khan, three-fourth of which lies in Balochistan Province while remaining falls in Punjab. It has the maximum flood damage hazard and a large development potential if properly managed.

The report describes the flood problem in perspective, hydrometeorological studies carried out, planning strategy, and various alternatives for flood management with their cost estimates.

Analysis of the precipitation shows that the amount of rainfall and its areal distribution are both unfavourable for sustained agriculture. Annual rainfall is low, uncertain and patchy. However, sudden cloud bursts in the upper catchment often generate shortlived high peaked floods which result in heavy monetary losses in the downstream areas coupled with loss of human life. Floodflows frequently shatter the economy of the area. Thus, harnessing of the hill torrent is urgently called for not only to safeguard the people against frequent onslaught of the hill torrent, but also to utilize the floodflows for the development of planned agriculture in the Kaha Basin.

(Contd...P/2)

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4-Maqbool Coop, Housing Society
Karachi 29 Ph: 433558

The following four different structural alternatives have been considered for optimal management of design flood. These are shown in Exhibit T-1, and are summarised as:

	Alternative	Cost
1.	Disposal to Indus through cross-drainage	Rs 563 million
2.	Disposal through Dajal Branch	Technicall not feasible
3.	Disposal to Indus by Channelization along right bank of Dajal Branch	Rs 405 million
4.	Management in sub-mountain and Pachad Area	Rs 190 million

Alternative-2 was not considered for further consideration, because it was not technically feasible. Alternative-1 and 3 have been studied in more detail technically and financially. Alternative-1 not only has prohibitive cost but also has a disadvantage that it transfers the flood hazard from Pachad area to the area of its disposal point into the Indus. In addition, it squanders the precious water which is direly needed for fertile but thirsty lands in Pachad area of Punjab and drought stricken sub-mountainous region in Balochistan. Alternative-3 though comparatively less expensive than alternative-1 also does not fall in line with our planning strategy that floodflows should be tamed and utilized for the benefits of the area rather than scaring them off into the Indus.

Alternative-4, the recommended alternative, has been prepared not only to protect the area from the recurring flood damages, but also to provide maximum socio-economic benefits to the local people. The cost of the alternative is low and has far reaching effects. Salient features of the recommended alternative are highlighted in Exhibit T-2.

Analysis of agronomic data of Kaha Hill Torrent Basin for the last few years have shown a vast variation in terms of cropped area i.e., ranging from 670 hectares (ha) to about 5,800 ha. Average annual cropped area under pre-project condition is about 2,900 ha with a cropping intensity of 8 percent. With regulation of flood supplies under the post-project conditions, the average annual cropped area would increase to about 20,440 ha. However, in the year of design flood, (25 year return period) about 51,200 ha would come under irrigation raising the cropping intensity to 87 percent.

The net average annual agricultural benefits have been estimated as Rs 14.72 million. In addition, average annual benefits accruing from the incremental safety to canal system, infrastructure and cropped area, work out to be Rs 19.08 million. Summed total annual benefits aggregate to Rs 33.80 million.

(Contd...P/3)

Estimated cost of the proposed plan comes to Rs 190 million. Economic evaluation indicates, that the plan, if implemented as proposed, would correspond to an Internal Rate of Return (IRR) of 17 percent which is reasonably above the opportunity cost. Thus, the works proposed in the plan are technically feasible and represent an economically viable solution to the problem.

We trust that this Report would meet your kind approval. The proposed plans if implemented would go a long way in solving the long outstanding requirements of the area and ushering in a new era of economic prosperity for the people.

Assuring you of our best services at all times, we remain,

Yours faithfully,
for National Engineering Services Pakistan (Pvt) Ltd.

(S. A. BHATTI)
Project Manager

Encl: As above.

FLOOD MANAGEMENT ALTERNATIVES & COSTS-KAHA HILL TORRENT

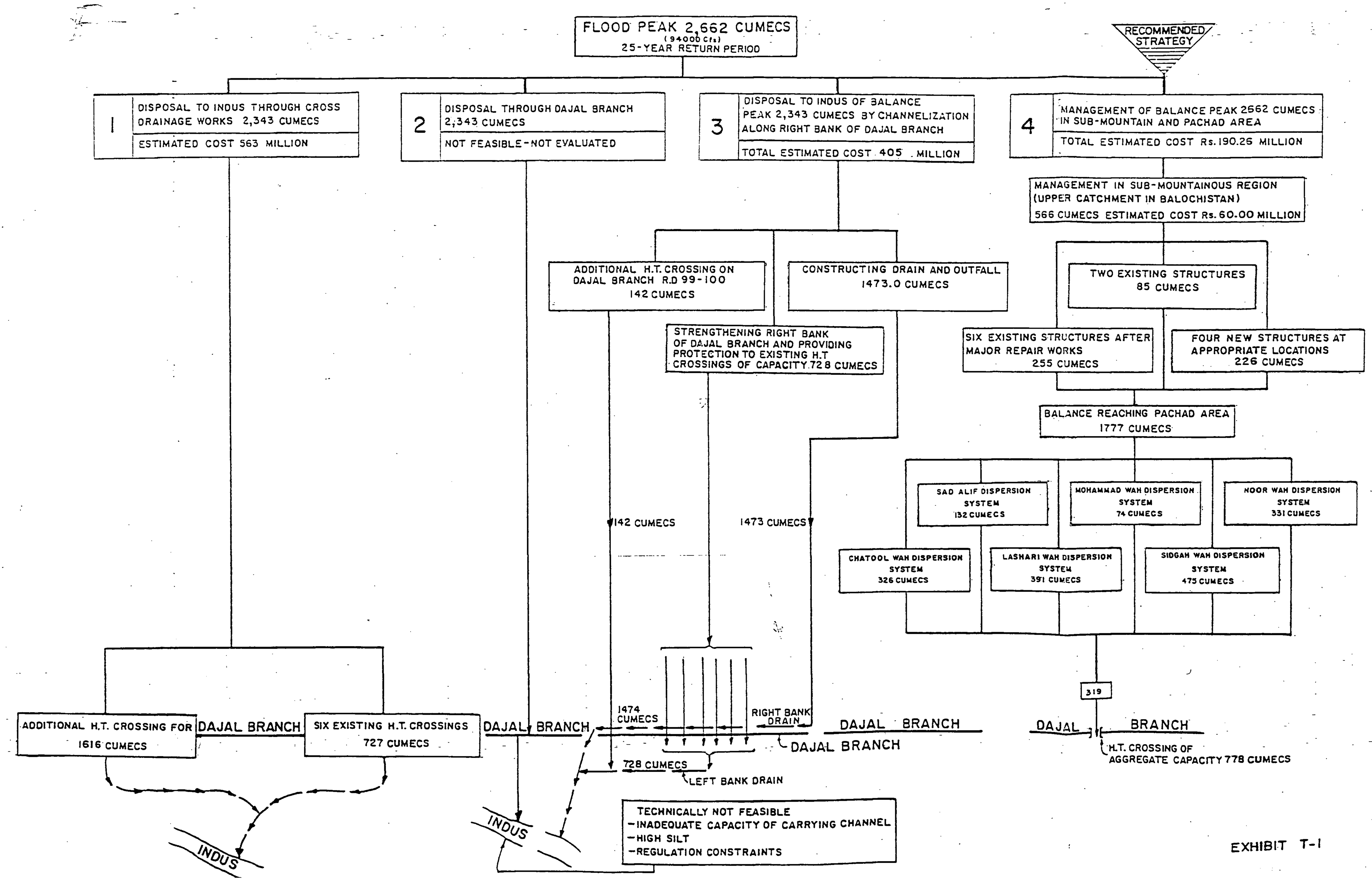
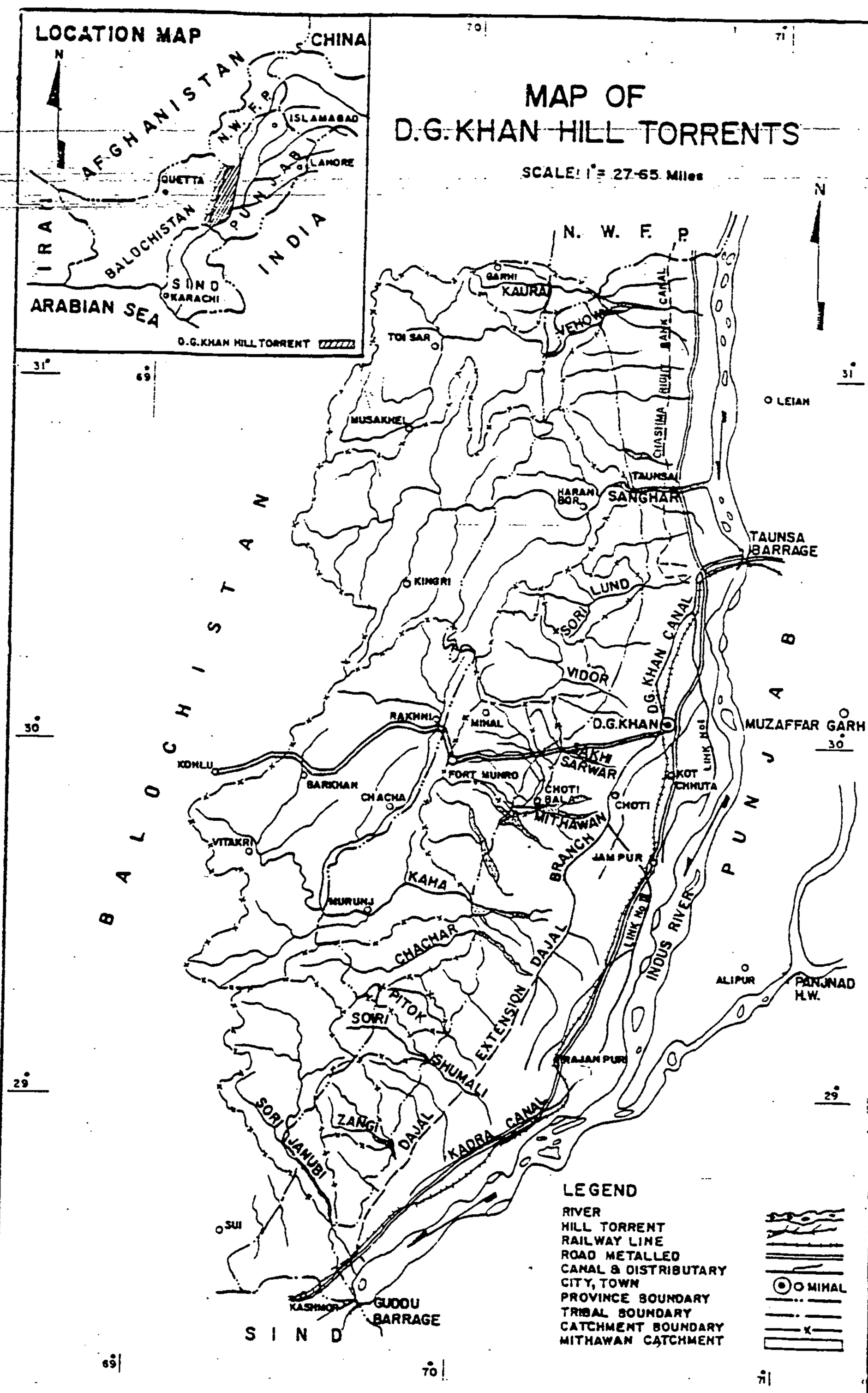
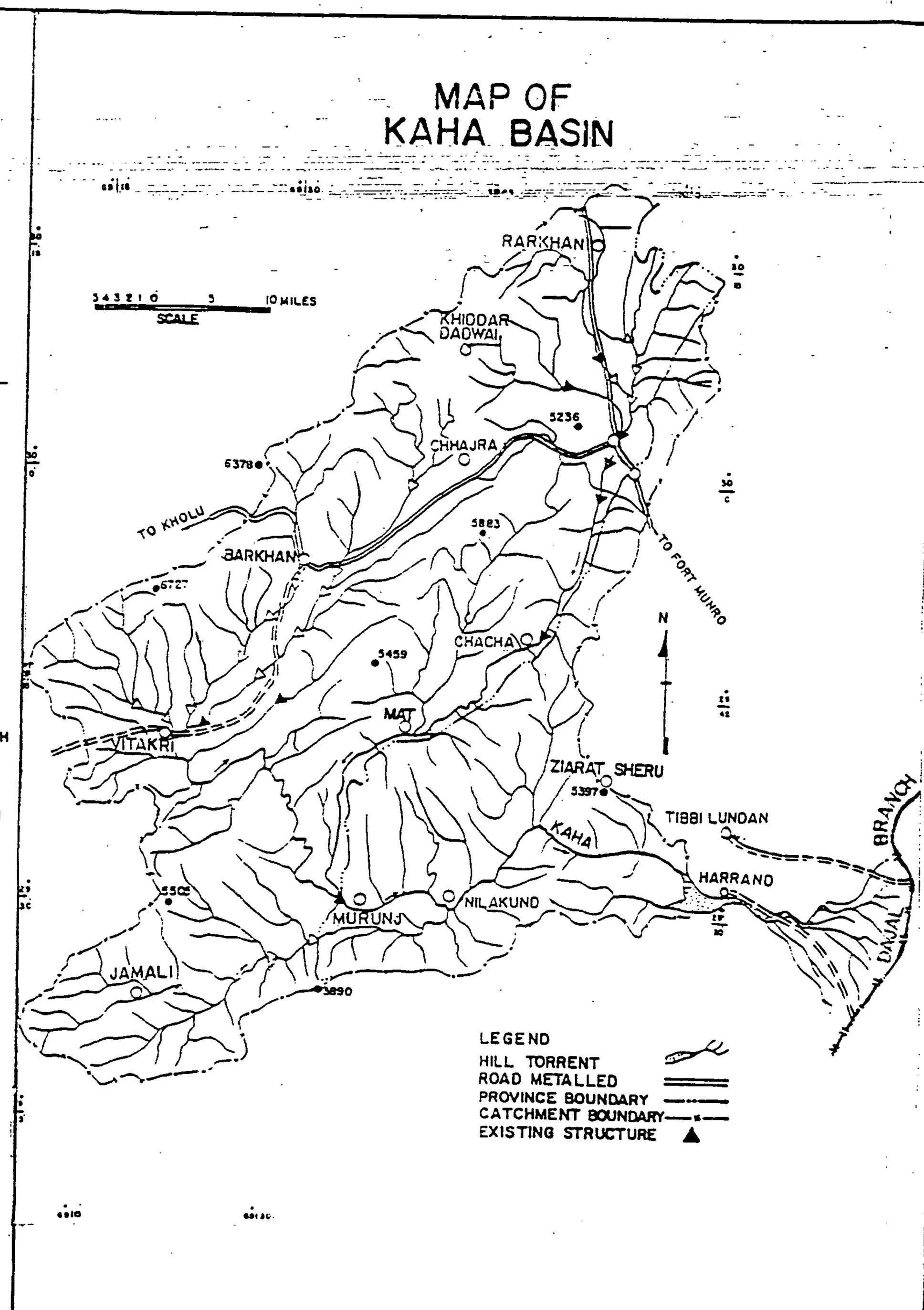


EXHIBIT T-1





CROPPING INTENSITY AFTER MANAGEMENT

RETURN PERIOD	INTENSITY WITH PROJECT	INTENSITY WITHOUT PROJECT
2.33 - YEAR	34 PERCENT	8 PERCENT
5 - YEAR	67 PERCENT	24 PERCENT
10 - YEAR	83 PERCENT	35 PERCENT
25 - YEAR	87 PERCENT	36 PERCENT

STATISTICS OF CULTURABLE AREA

DESCRIPTION	AREA IN HECTARES
CULTURABLE AREA	58,916
ABOVE DARRAH	22,663
BELOW DARRAH	36,253

SALIENT FEATURES OF KAHA BASIN

RAIN FALL PATTERN

MAXIMUM RAINFALL IN MM (INCHES)

1-DAY	74.17 (2.92)
7-DAY	227.84 (8.97)
15-DAY	287.78 (11.33)
1-MONTH	352.81 (13.89)

NO. OF RAIN GAUGE STATIONS.	10
PERENNIAL SUPPLY.	ONE CUMECS (35 CFS)
MAXIMUM ANNUAL RUN-OFF.	130,190 HA-METER
AVERAGE ANNUAL RUN-OFF.	41,500 HA-METER

PEAK DISCHARGES FOR RETURN PERIODS

25 - YEAR	2,660 CUMECS(94,000 CFS)
10 - YEAR	2,240 CUMECS(79,160 CFS)
5 - YEAR	1,860 CUMECS(65,810 CFS)
2.33 - YEAR	1,400 CUMECS(49,420 CFS)

HILL TORRENT CROSSING

CANAL	RD	CAPACITY
DAJAL BRANCH	79+700	283 CUMECS (10,000 CFS)
DAJAL BRANCH	95+280	20 CUMECS (700 CFS)
DAJAL BRANCH	109+770	28 CUMECS (1,000 CFS)
DAJAL BRANCH	123+650	141 CUMECS (5,000 CFS)
DAJAL BRANCH	145+760	198 CUMECS (7,000 CFS)
DAJAL BRANCH	165+760	57 CUMECS (2,000 CFS)

CATCHMENT CHARACTERISTICS

MAJOR TRIBUTARIES	CATCHMENT AREA, SQ.KM.	AVERAGE SLOPE, METER/KM	TIME OF CONCENTRATION, HOURS	TIME TO PEAK, HOURS
RAKHNI NALLAH	1,684	6	16.24	10.82
GAND NALLAH	1,865	9	13.67	9.11
PHILAWAGH NALLAH	1,018	6	14.76	9.84
KAHA NALLAH	1,153	10	7.44	4.96
TOTAL:	5,720			

ECONOMIC PARAMETERS

PARAMETERS	10	15	20	25
DISCOUNTED BENEFITS	280.11	170.55	112.63	78.96
DISCOUNTED COSTS	171.75	150.35	134.95	122.96
NET PRESENT WORTH	108.36	20.20	-22.32	-44.00
BENEFIT/COST RATIO	1.63:1	1.13:1	0.83:1	0.64:1
INTERNAL RATE OF RETURN	17.38 PERCENT			

EXHIBIT T-2

CONTENTS

SECTION - 6
AGRICULTURE AND ECONOMIC EVALUATION

LIST OF TABLES

LIST OF FIGURES

LIST OF EXHIBITS

GLOSSARY OF ENCHORIAL WORDS

BUND	-	Embankment
BUNDED FIELD	-	Fields surrounded by earthen embankments (Lath).
CHAK	-	Village.
CHUR	-	Small hill torrent.
DARRAH	-	The site or the mouth at which a torrent or a Nallah comes out of hills. Below darrah the torrent fans out into different branches.
GANDAH	-	Any obstruction constructed across the bed of a torrent or its branch for diverting floodflows.
HAQOOQ	-	The area or channel having water rights on floodflows of hill torrents.
KALA PANI	-	Perennial flow of a hill torrent.
KAMARA SYSTEM	-	A system prevalent in DG Khan area where work for diversion of floodflows is carried out on a self-help basis in accordance with the share fixed under Minor Canal Act of 1905.
KHARIF	-	Summer Crops starting from April to September.
KHAD	-	A deep branch of a hill torrent.
LATH	-	Earthen embankment constructed around the fields to hold flood water for basin irrigation.
MAQASMA	-	The works constructed for distribution of floodflows according to shares of various off-takes at any distribution site.
NAIN	-	Branch of hill torrent
NON-HAQOOQ	-	The area or channel having no water rights on flood flows of hill torrents.
PACHAD	-	It means west side of any reference line.
PACHAD AREA	-	The area lying on the western side of the reference line. In DG Khan and Rajanpur districts, the area lying on the western side of Canal System upto the toe of hills is called Pachad Area.

PORA	-	Broadcasting of seeds.
RHOD KOHI	-	Hill torrent.
RABI	-	Winter Crops starting from October to March.
SAD	-	A small diversion bund.
SALAII	-	A small embankment.
SAROPA PIANA	-	The upper stream fields on a hill torrent are called Saropa and have prior rights while the lower fields are called Piana and have secondary right over flood flows. This is a relative term and is used for all the fields on a hill torrent with respect to their location to each other.
SHAKH	-	A natural channel off-taking from main hill torrent.
TAROR	-	Flood Water flowing down after breach of diversion bund to areas having secondary or no right.
WAH	-	A natural channel off-taking from branch/shakh.
WAHI	-	A natural channel off-taking from Wah.
WAKRA	-	Any obstruction constructed in wah or wahi for basin irrigation of fields.

FOREWORD

AUTHORIZATION

Preparation of this report was authorized under Contract between the Federal Flood Commission, Ministry of Water and Power, Government of Pakistan, and National Engineering Services Pakistan (Pvt) Ltd., in association with Harza Engineering Company and Zafar & Associates. The assignment has been financed by the Government of Pakistan through Loan No.837 - Pak (SF) of the Asian Development Bank and administered by the Federal Flood Commission, Government of Pakistan. Under the Agreement signed on 5th April 1989, the Consultants were commissioned to provide Engineering Services for the Flood Protection Sector Project Pakistan. Flood management of Kaha Hill Torrent is one of the projects for which engineering services are to be provided by the Consultants.

PRINCIPAL OUTPUTS CALLED FOR CONSULTANCY SERVICES ARE:

The Consultants shall advise and assist Federal Flood Commission and Provincial Irrigation & Power Departments (PIDs) in carrying out the following:

- Prepare Feasibility Studies and PC-Is for Sub-Projects listed in Table-F;
- Detail Design and Tender Documents of Core-Projects and Sub-Projects listed in Table-F;
- Procurement of Bid Evaluation;
- Construction Supervision of projects;
- Standardization of Design; and
- Prepare programme for 'On the Job' training and overseas training for the engineers and technicians of PIDs, WAPDA and Meteorological Department.

REPORT LAYOUT

The report has been presented in six sections. Section-1 briefly outlines the introduction of the project. Section-2 gives the description of the project area. Section-3 relates the flood problems of the area with a brief rundown of the past historic floods, existing flood protection facilities and their evaluation. Hydrometeorologic evaluation and procedures for determining flood peaks for various return periods and run-off are described in Section-4. Various alternatives for flood management with cost estimates and selection of the recommended alternative have been presented in Section-5. Recommended sequence of construction and structural specifications are also described in this section alongwith cost estimates. Agriculture and economic evaluation of the project have been discussed in Section-6.

TABLE - F

SUB-PROJECTS REQUIRING FEASIBILITY STUDIES

Sr. No.	Name of the Projects
1.	River Protection - Ravi River, Ravi Syphon to Balloki Barrage.
2.	River Protection - Chenab River, Qadirabad Barrage to Trimmu Barrage.
3.	Correcting Approach - Panjnad Barrage.
4.	Correcting Approach - Sidhnai Barrage.
5.	Resectioning of 2nd Line Bund Sukkur Barrage - Kotri Barrage.
6.	River Training Works - Kabul River and Swat River.
7.	Bughti (Pat Feeder) Hill Torrents.
8.	Kaha Hill Torrent.
9.	Any other scheme decided by Federal Flood Commission.

LIST OF CORE-PROJECTS

	Name of Core-Projects
1.	Flood Management of Kalpani Nallah, Mardan (NWFP).
2.	Flood Management of Trimmu-Panjnad Reach, Chenab River, (Punjab).
3.	Flood Management of Gudu-Sukkur Reach, Indus River (Sindh).
4.	Flood Management of Quetta City (Balochistan).

SECTION - 1

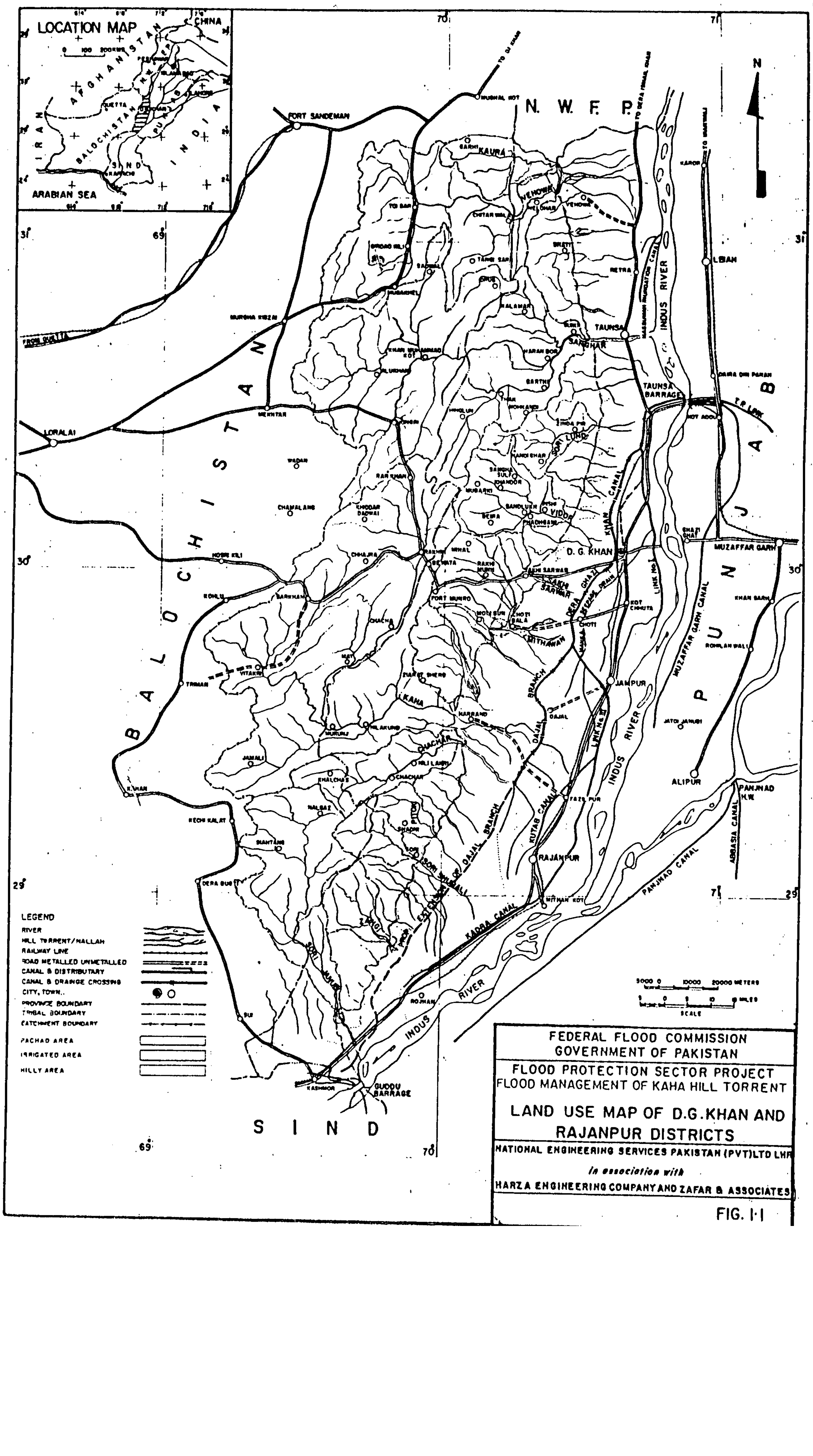
INTRODUCTION

Flooding from hill torrents in different parts of Pakistan constitutes one of the most serious environmental and economic hazards. Most of the settlements in these areas have developed around the banks of hill torrents as the rich alluvial soils transported by the hill torrents onto the plain areas have held much lure for the people. Since the time immemorial, people have been diverting flood flows to their fields by constructing small diversion bunds. These earthen bunds adequately divert low floods, but generally fail in case the flood flows exceed the manageable limits. In case of breaches in the diversion bunds, concentrated flows move downstream damaging standing crops, communication facilities and other infrastructure. It is generally beyond the capacity of the farmers to reconstruct these bunds during the flood season. A major flood, thus, deprives the farmers from the subsequent benefits of low floods also.

The complexity of hill torrents problems in D.G.Khan and Rajanpur districts has been posing a challenge to the ingenuity of engineers and planners. Hill torrents flooding has been the primary constraint in the development of these two districts. The first major development effort in these districts was initiated by the introduction of weir controlled irrigation system in the late fifties when the D.G.Khan Canal System offtaking from Taunsa Barrage was constructed. The canal was hardly in the last phase of completion, when it experienced the first brunt of hill torrents flooding. Twenty hill torrent crossings with an aggregate capacity of 2,920 cumecs (103,100 cfs) were constructed during construction stage of the canals. Paradoxical as it may sound, no planning was done for constructing the carrying channels which could transfer hill torrent flows from the canal crossing to the Indus River. This was tantamount to shifting of flood hazard from Pachad area to canal irrigated areas having more damage potential. Half-baked planning has resulted in over 800 breaches in canal system and inundation of about 300,000 hectares (ha) of irrigated area in the last 15 years. These districts have not been able to achieve the full benefits of the irrigation system, as irrigation losses have aggregated to about Rs 1,200 million in the recent major floods.

The hill torrents are controlled under Canal Act of 1905. Water rights exist for 276,518 ha (683,000 acres), but only about 90,000 ha is presently being irrigated. This reduction is primarily due to changes in socio-economic conditions and to low financial returns from irrigation in the Pachad area.

D.G.Khan and Rajanpur Districts having a population of over two million and covering an area of about 24,000 sq.km (9,400 sq.miles) are uniquely situated as they are bordered by three other provinces of the country. Part of the area is irrigated through the D.G.Khan Canal System offtaking from the Indus River at Taunsa Barrage. The canal runs almost parallel to the river up to about 112 kilometers (70 miles), where it bifurcates into Dajal Branch and Link-III. The two districts can be mainly divided into three categories from the stand-point of land use. (Figure 1.1 shows these areas in detail). Hilly catchments of hill torrents aggregating to about 1.17 million ha (2.9 million acres) forms about 49 percent of the total area. The second category covering about 0.81 million ha (two million acres) is called 'Pachad' area and lies between the hilly catchment and the canal irrigated area of D.G.Khan Canal system and Indus River from Ramak to Taunsa Barrage. The area comprises rich alluvial soils with high fertility transported by hill torrents from Suleiman Range. Presently in only ten percent of this area, terraced irrigation is practiced. The third category roughly covering 0.40 million ha (one million acres) is commanded by the D.G.Khan Canal System offtaking from Taunsa Barrage.



FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

LAND USE MAP OF D.G.KHAN AND RAJANPUR DISTRICTS

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT)LTD LHR
In association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

FIG. 1·1

Hill torrents have been causing damage to areas in D.G.Khan and Rajanpur districts since the time immemorial. Heavy floods have been recorded during 1906, 1917, 1929, 1955, 1967, 1973, 1975, 1976 and 1988. Serious efforts for flood protection were initiated after heavy flood damages in 1929 when Mr. P.Clexton, the then Executive Engineer, Indus Canal Division was deputed to study the problem and propose flood control measures for the area. However, the measures proposed by him were not executed because they were based on inadequate geohydrologic data. Since then, several technical proposals have been drawn-up in response to some impeding flood problems at various times and partially implemented also.

There are more than two hundred hill torrents emanating from the Suleiman Range of which 13 are major. The complex nature of hill torrent flooding warrants comprehensive study of hill torrent flows and their management based upon detailed frequency and risk analysis. In view of the complex nature of the flood problem, there are a number of alternatives which require comprehensive, technical and economic evaluation before the selection and adoption of a final strategy. NESPAK in their National Flood Protection Plan (Phase I & II) for Pakistan, highlighted the problem of the severity of Hill Torrent floodings and recommended that due to the complexity of flood and high flood damage potential, the problem be tackled as a high priority issue and feasibility studies for management of flood-flows of hill torrents be carried out.

Kaha is one of the major hill torrents of the area. It rises in the Suleiman Range in the area lying within the administrative jurisdiction of Balochistan province. Of the 13 major hill torrents emerging from the Suleiman Range, Kaha Hill Torrent has the maximum flood damage potential. In 1984, NESPAK prepared a Master Planning Report (in four volumes) of D.G.Khan Hill torrents in which Kaha Hill Torrent was included. Now the Federal Flood Commission, Government of Pakistan has asked NESPAK/HARZA/Z&A to prepare a feasibility report for flood management of Kaha Hill Torrent on priority basis under the Flood Protection Sector Project. The Project has also been highlighted in the Asian Development Bank (ADB) Mission Report of 1987 and has been given high priority. Irrigation & Power Departments, Governments of Punjab and Balochistan have also shown keen interest in the Project in view of its high flood damage hazard and exceptionally high development potential. It is expected that the Project, on completion, would help bring about a socio-economic revolution for the locals of the area through prevention of recurring flood damages and bringing additional area under flood irrigation.

SECTION - 2

PROJECT AREA

2.1 LOCATION AND EXTENT

Kaha Hill Torrent rises in the Suleiman Range, in the Province of Balochistan, between Kohlu and Vitakri at an approximate altitude of 2,050 meters (6,730 feet) above mean sea level (msl). It enters the Punjab Province near Murunj and debouches onto the Pachad area of D.G.Khan Division at its Darrah near Harrand. Kaha is the biggest hill torrent of Suleiman Range. It has a catchment area of about 5,720 sq.km (2,208 sq.miles) of which nearly 4,450 sq.km (1,718 sq.miles) lies in Balochistan and 1,269 sq.km (490 sq.miles) in Punjab. The catchment area lies between latitude 29° 16'N to 30° 21'N and longitude 11° 69'N to 05° 70'N. Sangarh and Mithawan hill torrents lie in the north of Kaha hill torrent. Dajal Branch lies on the east, Dera Bugti District and Chachar hill torrent, on the south-west and the Kohlu District to the west of the Project area. The D.G.Khan-Loralai Highway passes through the area. Barkhan, Vitakri, Murunj, Rakhani, Bewatta, Mat, Jamali, Chacha and Rarkan are some of the important satellites in the upper areas. The people mostly depend upon meagre subsistance agriculture and cattle raising as a way of life. The Project area alongwith the major towns/villages is shown in Exhibit 2.1.

2.2 PHYSIOGRAPHY

Physiographically the area can be divided primarily into three distinct units. The mountaineous and sub-mountaineous area; the Pachad area and canal irrigated area. The mountaineous and sub-mountaineous area forms part of Suleiman Range with an elevation ranging to more than 2,130 meters (7,000 feet) and lies to the west of the Project area. The slope of the terrain area is primarily from north-west to east. The Pachad area is sandwiched between Suleiman Range and Canal Commanded area in the south. This area has been formed by rich alluvial deposits brought by hill torrents from Suleiman Range. Basin irrigation is practiced since the time immemorial by constructing bunds around the fields to store about one to one and a half meter of flood water.

The third physiographic unit, the canal irrigated area (flood plain) has been formed, mainly by the sediments deposited by Indus River during the sub-recent time. This area has a general slope of about 0.4m per km towards south. There is a comparatively low lying area, running north to south in the middle. The presence of channel scars, old rivers bars, meander scrolls and levees are observed in the flood plain. The width of the area varies from 26 km (16 miles) to 32 km (20 miles).

2.3 CLIMATE

Climate of the area is arid and is characterised by the movement of Monsoon in summer and Westerlies in winter. The summer temperatures are fairly high and winter temperatures are biting cold. Average annual rainfall varies from about 250mm (10 inches) in the extreme southern tip to 380mm (15 inches) in the north-west. Summer rains comprise sixty (60) percent of the annual rainfall in the southern part, and it decreases to about 50 percent in the north-western part. The pattern of rainfall is erratic and patchy. Years of intense rainfall are likely to be followed by long spells of dry years.

2.4 ECONOMY

The economy of the Project area largely depends upon agriculture and livestock. The cropping pattern is largely controlled by the availability of water and mode of irrigation. Lack of infrastructural facilities shortage of water for irrigation and mass illiteracy are among the causes of the low standard of living for the greater part of the population and are the main constraints to the development of the area.

Pachad area is arid and sparsely vegetated where agricultural production is dependent on flood irrigation or soil moisture retention. Only a small part of the rainfall in the catchment area is utilized for agriculture, while a major proportion of it causes serious damage in the command area by flooding as it makes its way from the upper catchments of the hill torrents to flow across the main agricultural area. Cropping intensity in Pachad area varies greatly according to the extent and frequency of floodings. The main products in the canal irrigated area are cotton, rice, wheat and oil seeds whereas sorghum, wheat, pulses, oil seeds and livestock (meat and wool) are of the Pachad area.

In the absence of organized and developed agriculture in the Pachad area, livestock raising is an important supporting occupation for farm families. This is a major source of income for the farmers and its contribution to agricultural development is substantial. Livestock also contribute to security against crop failures in years of exceptionally high floods or drought. The livestock in the area include cattle, goats, sheep, camels, horses and donkeys. Livestock in fact plays a primary role in the economy, for agriculture depends largely on cattle, which are used as draught animals for the construction of bunds, ploughing and carting. On the other hand, the livestock depend on agriculture for the greater part of their feed requirements.

The mode of communication and transport cost affect the economy considerably. Market prices fluctuate from season to season and according to the time of the year.

2.5 HYDROLOGIC BASINS

Catchment area of Kaha Hill Torrent can be divided into the following sub-basins and its tributaries as shown in Fig.2.1:

1.	Rakhni Nallah	- Chhuri Nallah - Chang Nallah - Wandoi Nallah - Gujji Nallah
2.	Gand Nallah	- Wahi Nallah - Karin Nallah - Waram Nallah - Gud Nallah - Warsala Nallah
3.	Philawagh Nallah	- Kunal Nallah - Thadha Nallah - Makhi Nallah
4.	Kaha Hill Torrent (Main Tributary)	- Garo Nallah - Baghi Nallah - Sauri Nallah - Darazho Nallah
5.	Higgan Nallah	- Kala Khosra - Bagga Khosra - Sabegari Nallah

These sub-basins form part of the Indus River Basin as ultimately these outflow into the Indus River. Their catchment areas vary from 1,018 sq.km (393 sq.miles) to 1,865 sq.km (720 sq.miles). The length of the main channels varies from about 76 km (47 miles) to 130 km (81 miles). They rise from an elevation of 700 meters (2,300 feet) to 2,130 meters (7,000 feet) and their level at the confluence point varies from 225 meters (738 feet) to 613 meters (2,010 feet).

All the streams have steep gradients and bring flash-flows which are charged with high-silt content. Gand Nallah is the largest tributary and joins the Rakhni Nallah near Murunj village to make Kaha Nallah at the border of Punjab and Balochistan provinces. Philawagh Nallah joins Kaha Nallah 18 km (11 miles) downstream of Murunj near Nila Kund village. Kaha nallah flows out of its Darrah in different wahs in the Pachad area to irrigate areas of Chaks Harrand, Marete, Lundi Saijidan, etc.

2.6 EXISTING SITUATION

Kaha Hill Torrent drains off an area of about 5,720 sq.km (2,208 sq.miles), of which three-fourth falls in the province of Balochistan and remaining one-fourth lies in Punjab Province. The source of water is rain only. There is about one cumec of 'Kala Pani' (Perennial flow) in Kaha Hill Torrent, which is used for drinking purposes and irrigation on some very small areas within the mountains and the Pachad area.

There are several valleys having very fertile land where barani or flood irrigation is being practised. Low level diversion weirs have been constructed on some of the nallahs for utilizing perennial supplies Kala Pani. for cultivation of crops and to raise gardens of apples and almonds. On some of the tributaries of Kaha, the Government of Balochistan has constructed flood diversion structures to divert flood-flows up to about 30 cumecs to 60 cumecs into excavated irrigation channels. There are eight existing dispersion structures in the upper catchment area (Balochistan Province).

Basin irrigation is being practised in the Pachad area lying between the toe of the hills and Dajal Branch. The total culturable haqooq area between the foothills and Dajal Branch is 36,258 hectares (89,580 acres), but presently irrigation is being practised on about 2,900 ha (7,160 acres). Flood water is diverted into various branches and Wahs with the help of earthen diversion bunds which generally get damaged during floods with the result that a major part of flood waters reaches the Dajal Branch un-used and attacks the right canal bank in the reach RD 70+000 to RD 177+000. To pass flood flows, six hill torrent crossings with an aggregate capacity of 728 cumecs (25,700 cfs) have been provided along Dajal Branch. Flood flows exceeding the capacities of the hill torrent crossing have breached Dajal Branch at various places causing serious damage to the canal system, crops, and property in 1973, 1975, 1976, 1988 and 1989.

2.7 DATA COLLECTION

2.7.1 General

Comprehensive and reliable data provides the ideal basis for proper planning and integrated management of hill torrents flows. For realistic planning, the first pre-requisite is to collect all available data and make a preliminary review and analysis to have some rough estimate of design parameters. However, sometimes the data are limited or non-existent and limitation of time does not permit the observation of requisite data for an ideal study and analysis. Survey maps, aerial photographs, satellite imagery, hydrometeoro-logical and sediment load of flood flows, previous reports and proposals, existing flood protection facilities, and historic flood losses may greatly help in the formulation of an effective flood control plan. In view of the socio-economic nature of the Project, it was planned to interview the authorities of the local government, the civil administration, political agent, and the concerned personnel of the Irrigation and Power Department at Lahore, Multan, D.G.Khan and Kohlu. Given below is the brief description of data collection, interviews.

2.7.2 Precipitation Records

Within and around the Kaha catchment area of 5,720 sq.km (2,208 sq.miles), there are 19 raingauge sites in and around the whole catchment area, where precipitation records have been observed from time to time. Of these, 11 stations are located inside the catchment area, while remaining lie in the close vicinity of the area. The data from these stations are mostly in the form of daily precipitation. The catchment area is so big that rainfall generally does not fall on the whole area at the same time. Available precipitation records are shown on Table-2.1.

2.7.3 Surface Run-Off Records

Flood flows record of Kaha Hill Torrent at the Darrah are available for the years 1958-1964 and 1975-1989 in the form of stage above a benchmark level. Perennial discharge is about one cumec (Kalapani). There is no direct outfall into the Indus River. Flood flow reach the right bank of Dajal Branch Canal in reach RD 70 to RD 170 and crosses the canal command area through six drainage crossings. Estimated average annual run-off is 41,530 ha.m (336,400 acre-feet). Available discharge data of Kaha Hill Torrent is:

Name of Stations	Available Data with Period		
	Monthly	Daily	Hourly
1- Darrah	-	1/61 - 5/64	1/61 - 5/64
	-	4/75 - 12/81	4/75 - 12/81, 7/89 - 8.89
2- Dajal Branch Crossings	-	7/78 - 9/78	7/78 - 9/78
	-	2/79 - 9/79	2/79 - 9/79
	-	7/80 - 8/80	7/80 - 8/80, 7.89 - 9/89

2.7.4 Previous Reports & Plans

A number of reports have been written for management of D.G.Khan Hill Torrents. Some of the reports are general and cover the entire project, while others are for specific hill torrents or special problem areas. Most of the flood management plans presented have

TABLE - 2.1

PRECIPITATION RECORD & DURATION

	Name of Stations	Available Data with Period		
		Monthly	Daily	Hourly
1-	Barkhan	1/53 - 12/66	1/53 - 12/55	-
			1/60 - 12/66	-
		4/75 - 4/82	4/75 - 4/82	7/82 - 9/82
2-	Rakni	1/61 - 12/63	1/61 - 12/63	7/82 - 9/82
3-	Chacha	1/61 - 4/67	1/61 - 4/67	-
4-	Vitakri	1/61 - 5/64	1/61 - 5/64	-
5-	Ziarat Sheru	1/61 - 12/54	1/61 - 12/46	-
		1/76 - 5/82	1/76 - 5/82	-
6-	Chhajar	4/75 - 5/82	4/75 - 5/82	-
7-	Mat	3/75 - 5/82	3/75 - 5/82	-
8-	Jam Ali	1/65 - 12/66	1/65 - 12/66	-
9-	Muranj	1/54 - 12/57	1/54 - 12/57	-
		1/61 - 12/67	1/61 - 12/67	-
		1/77 - 1/82	1/77 - 1/82	7/82 - 9/82
10-	Bewatta	4/75 - 5/82	4/75 - 5/82	-
11-	Rarkan	1/61 - 3/63	1/61 - 3/63	-
12-	Chachar	3/75 - 5/82	3/75 - 5/82	-
13-	Nabi Lahri	1/61 - 12/64	1/61 - 12/64	-
14-	Kalkhas	5/52 - 12/57	5/52 - 12/57	-
		1/61 - 12/64	1/61 - 12/64	-
15-	Fort Minro	1/47 - 12/72	1/47 - 12/72	-
		8/75 - 5/82	8/75 - 5/82	-
16-	Mehal	3/75 - 5/82	3/75 - 5/82	-
17-	Mard Bun	7/59 - 12/68	7/59 - 12/68	-
		4/75 - 5/82	4/75 - 5/82	-
18-	Hinglum	1/54 - 3/59	1/54 - 3/59	-
19-	Kohlu	1/63 - 3/74	1/63 - 3/74	1/63 - 3/74

been prepared without due consideration to flood frequency analysis and flood management plans have not been correlated with theoretical return periods of events. In some cases other possible alternatives have not been considered. These reports, however, provide very useful basic data, which has been extensively used for the preparation of this report. Given below is the list of previous reports and plans of Kaha Hill Torrent. These were collected from various offices:

- i- Harrand Dam Scheme by R.B. Kanwar Sain;
- ii- Scheme for constructing Gandas at Boot Hawa Wali near Naushera;
- iii- Scheme for constructing Gandas in Lughari Wah at Tibbi Solgi;
- iv- Scheme for regulating flood water of Kaha Hill Torrent in D.G.Khan District;
- v- Preliminary Note by Mr. G.E.Mead on Kaha Hill Torrent;
- vi- Discharge Table and cross-section of Kaha at Darrah site;
- vii- Report on damages caused by Kaha Hill Torrent by Executive Engineer Rajanpur Division;
- viii- Plan of Kaha Hill Torrent;
- ix- Hydrograph of Kaha Hill torrent for the year 1975-1979;
- x- PlaneTable survey of Kaha Hill Torrent;
- xi- Plan showing routes of Hill Torrents crossing RD 79+500, RD 95+280, RD 145+760 and RD 123+650
- xii- Contour Plan of Kaha 8 kilometer upstream of Dajal Branch;
- xiii- Plan of Kaha Distributor showing crest shape ogee.
- xiv- Report on Harnessing of Hill Torrents and Development of Pachad Area by Mr. Rahmani.
- xv- Flood fighting plan for D.G.Khan Canal Division and Rajanpur Canal Division for the year 1978, 1979 and 1980.
- xvi- Report on Hill Torrents of D.G.Khan by Mr. P.Clexton.
- xvii- Planning and Design Report (Four Volumes) of D.G.Khan Hill Torrents, by NESPAK.

2.8 MEETINGS AND FIELD VISITS

NESPAK experts held discussions with the following officials of various departments to elicit their views about the Project.

2.8.1 Federal Ministry of Water and Power

i- Federal Minister, Water & Power, Government of Pakistan.

ii- Chief Engineering Adviser/Chairman Federal Flood Commission, Government of Pakistan.

iii- Chief Engineer (Floods) FFC, Government of Pakistan.

2.8.2 Irrigation & Power Department Government of Punjab

i- Secretary, Irrigation & Power Department.

ii- Chief Engineer (Drainage & Flood).

iii- Chief Engineer (Multan Zone).

iv- Superintending Engineer (Derajat Circle).

v- Director (Floods).

vi- Executive Engineer (D.G.Khan Division).

vii- Executive Engineer (Rajanpur Division).

2.8.3 Irrigation & Power Department Government of Balochistan

i- Superintending Engineer (Loralai Circle)

ii- Executive Engineer (Kohlu Division).

A multi-disciplinary planning team of NESPAK visited the area and carried out insitu studies for the existing structures. The team held meetings with officers/authorities of different departments/ organizations. The purpose of this visit was to collect additional data and conduct field investigations and surveys in various disciplines of the study in consultation with concerned departments.

SECTION - 3

FLOOD PROBLEM IN PERSPECTIVE

3.1 NATURE AND SEVERITY OF FLOODS

Flood problems in the area are on account of flashy flows resulting from excessive rainfall on the barren hilly catchment areas of Kaha Hill Torrent with little absorption. Flood flows from denuded hill torrents move with steep gradients resulting in high velocities associated with considerable soil erosion. About 12 percent of the catchment area lies above 1,830 metres (6,000 ft) above mean sea level (msl), while 60 percent lies between 1,830m to 915m (6,000 ft to 3,000 ft) and the remaining, below 915m. Of the total catchment area, 22 percent lies in D.G.Khan and Rajanpur districts and remaining 78 percent in Balochistan. Kaha Hill Torrent brings down flashy flows charged with high silt content depending upon the intensity of rainfall and the condition of the soil cover complex at the time of rainfall. For the years 1958 to 1989 and 1975 to 1989, total run-off for each year and maximum peak data are available.

The darrah of the torrent is about 45 km (28 miles) west of Dajal Branch (Photo-3.1). The Pachad area lying between the toe of hills and the canal is very fertile where basin irrigation is being

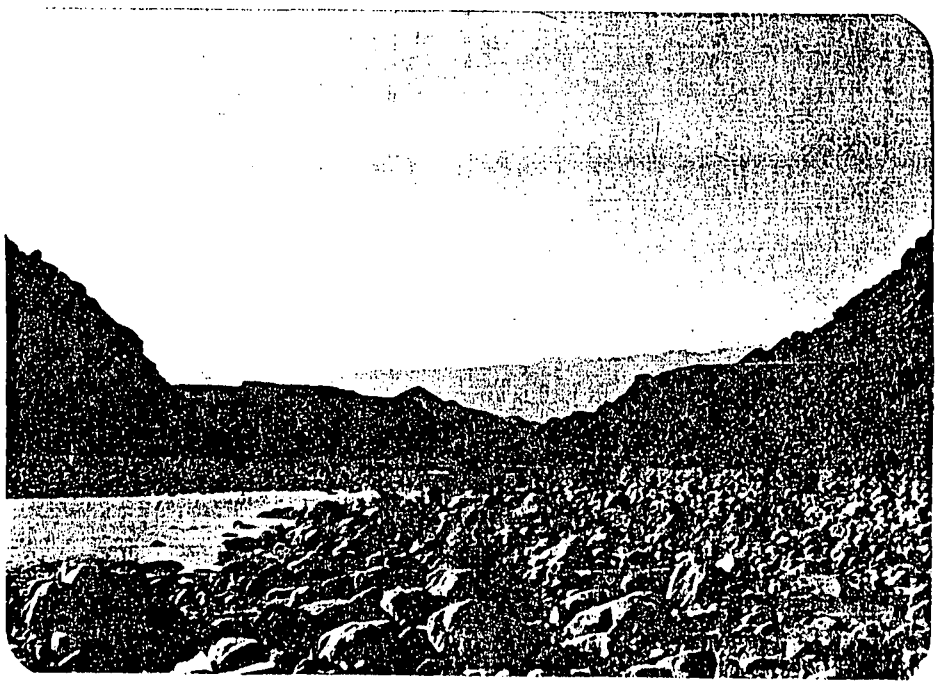


Photo - 3.1
Panoromic View of Kaha Darrah

practised on a part of the area. The culturable Pachad area (haqooq) is about 36,253 ha (89,580 acres). The torrent has also perennial supply 'Kala Pani' of about one cumec at darrah which is being used for irrigation according to water-rights. The torrent after emerging from the hills fans out like most of other major hill torrents of the area, but rejoins again near Basti Mir Mohammad and flows down as one channel upto village Tibbi Solgi, which is situated about 35 km (22 miles) downstream of the darrah. At this site, the torrent splits up into three main branches. The left side channel called Main Leghari Wah, a 'non-haqooq channel, has been closed at the head by constructing a bund known as Leghari Ganda. The right side branch is called Ghawaz Wah and has a right to draw one-third of the flood-flows reaching this site. The remaining two-third of water flows through the central branch for further distribution between Shakh Shumali and Janubi. All the three branches are further sub-divided as they move towards Dajal Branch, (Exhibit 3.1). Originally these channels extended almost upto the Indus River, but have been largely blocked by the construction of D.G.Khan Canal System in 1958. The spreading area for flood flows has also considerably reduced after the construction of D.G. Khan Canal system. Flood flows from the main channels spread both in transverse and longitudinal directions, because of bilateral slopes and hit the canal in an unpredictable manner, generally away from the hill torrent crossings. Kaha hill torrent flows approach Dajal Branch between RD 70 to RD 170 and cross the canal through six (6) hill torrent crossings with an aggregate capacity of 728 cumecs (25,700 cfs) as detailed below:

Sr. No.	Dajal Branch RD	Capacity Cumecs	Capacity (cfs)
1.	79 + 500	283	10,000
2.	95 + 280	20	700
3.	109 + 770	28	1,000
4.	123 + 650	142	5,000
5.	145 + 760	198	7,000
6.	165 + 760	57	2,000
		728	25,700

The total haqooq area lying between the darrah and the Dajal Branch system is about 36,250 ha (89,580 acres), which has the water right as per the Canal Act of 1905. During normal flow, the area is irrigated by utilizing flows of various wahs. During high flows, there are numerous breaches in the earthen bunds constructed by the cultivators and water gushes to DG Khan Canal System with high velocity. There is generally a ponding effect, because the aggregate cross-drainage capacity is less than the flow reaching the canal. High velocities below darrah sometimes result in channel erosion and a major portion of flows start concentrating in one channel, thus depriving the other channels of a share of the flow. This tendency of concentrated flow in one channel has been observed to be one of the major causes of breaches in the canals. The water from the breach is supplemented by the flows through the hill torrent crossings and the combined water moves in the canal commanded area with no natural or man-made drainage channels leading to the Indus River. As the flood flows moves towards the west in the direction of Indus River, generally the river is also in high flood during this period. This results in holding up the flood flow of the hill torrent. This has resulted in the development of a natural drainage line in the south-west direction at a distance of about 7 to 13 km from the river. The river bank is considerably higher than this drainage channel, which makes the hill torrent flow move towards south-west till it finds its way into the Indus.

The system of Pachad formation was very active and dynamic Equilibrium conditions had not been attained when DG Khan Canal System was introduced to intercept quite a percentage of the west-east flow path of the hill torrent. This man-made barrier has resulted into an entirely new flow regimen of the hill torrent.

3.2 SPECIFIC FLOOD PROBLEMS

The flood flows largely exceeding the capacity of the hill torrent crossings, breached Dajal Branch at various places and caused serious damage to the canal system, crops and property in addition to loss of human life during 1973, 1975, 1976, 1977, 1978, 1979, 1988 and 1989. Table 3.1 gives the number of breaches in DG Khan Canal System during the major floods since 1967. Since there is no trans-channel to the Indus River, the flood waters accumulate along the banks of channels and depressions in the canal command area thereby aggravating the problem of water-logging and salinity. There is no proper dispersion structure at any of the distribution site and small diversion bunds constructed for this purpose are frequently damaged, resulting in unequal distribution. For effective flood management, proper distribution structures and training works are required.

3.3 PAST FLOOD EVENTS

In the Pachad area basin irrigation by hill torrents has been practised since centuries. The fields are evenly terraced and bunded, so as to store about one meter depth of water. In the past, the basin irrigation was very effective and used to irrigate an area of about 0.28 million ha (0.68 million acres). A substantial amount of flood water was, thus, utilized in basin irrigation. Due to changes in the socio-economic conditions during the past three decades, the system has gradually deteriorated, and reduced the irrigation to less than 0.04 million ha (0.10 million acres). At present even the normal flood flows are not effectively controlled for irrigation and flow through to cause damage to canal irrigated areas, left of the DG Khan Canal and Dajal Branch. DG Khan Canal and Dajal Branch constructed during the sixties and running almost parallel to the mountain range, serve as the first line of defence against the flood flows from hill torrents. After the construction of CRBC and Dajal Branch extension, these canals will also face the brunt of flood flows from other hill torrents of Suleman Range.

After a long dry spell, heavy rains were experienced in 1967 during the construction stage of Dajal Branch Canal. The heavy rains in 1967 and in the seventies caused abnormal floods and resulted in colossal damages in the irrigated area. Major flood events since 1967 are briefly described in the succeeding paragraphs.

TABLE - 3.1

LIST OF BREACHES TO DG KHAN CANAL SYSTEM

Year	Main Canals and Distributaries	No. of Breaches	Reach RDs
1967	DG Khan Canal	3	317, 325
	Dajal Branch	-	
	Distributaries	-	
1973	DG Khan Canal	-	
	Dajal Branch	-	
	Distributaries	3	
1975	DG Khan Canal	5	14, 15, 18 & 19
	Dajal Branch	-	
	Distributaries	-	
1976	DG Khan Canal	7	
	Dajal Branch	3	
	Distributaries	3	
1978	DG Khan Canal	4	322, 323,
	Dajal Branch	4	R 15 and 16 L 20 and 21
	Distributaries	-	
1986	D.G. Khan Canal	2	
	Dajal Branch	40	
	Distributaries	204	
1989	D.G. Khan Canal	-	
	Dajal Branch	229	
	Distributaries	4	

3.3.1 1967 Flood

The extraordinary heavy rains during March 1967 in the catchment areas caused unprecedented flow in the Mithawan, Kaha, Chachar, Pitok and Sori Hill Torrents. The Kaha Hill Torrent approaches Dajal Branch in six branches and crosses the canal through hill torrent crossings at RD 79+500, RD 95+280, RD 109+760, RD 123+350, RD 145+760 and RD 165+970.

During March 1967 a peak discharge of about 391 cumecs (13,800 cfs) struck Dajal Branch at RD 79+500, where hill torrent crossing was under construction. Structure site was enclosed by a temporary protection bund and flow was by-passed through a temporary diversion. Due to concentration of flood flows on the upstream of the ring bund the right bank of Dajal Branch breached at two places and flood water entered the canal. To dispose it off through its original course, the left bank at RD 78+300 was cut. The flood flows after escaping through the left bank of the canal hit Fateh Distributary between RD 12-20 (Tail) and breached it. Tayyab Distributary was then breached between RD 12-15. A part of flow crossed Tayyab Distributary through Khato Syphon at RD 25 and struck Darkhast Distributary. However, the major portion was diverted along the right bank of Tayyab Distributary from RD 25-41 (Tail) and Leghari Flood Bund, which ultimately hit Dajal Distributary in its tail reach RD 28-33 and washed off its banks from RD 30-33. The Kaha flood water joined the flow of Mithawan and combined waters crossed Dajal-Jampur road between 11 km and 16 km and then accumulated on the right side of Darkhast Distributary and Dhingana Flood Bund which could not withstand its pressure and breached. The flood flows enroute also breached the left bank of Firdous Distributary from RD 38-47 (Tail). The right bank was protected by making strenous efforts. The flood water of Kaha Hill Torrent also passed through the Hill Torrent Crossing at RD 95+200 of Dajal Branch which remained under flow for about five days. This water breached Dajal Distributary between RD 4 to RD 5.

The flood flows of Kaha Hill Torrent also started accumulating in reach RD 100 to RD 102 of Dajal Branch, where it is in a high fill. The water level rose to RL 402.3 against bank RL 404.5. A cut was made at RD 101 of Dajal Branch to relieve the situation. Cross-bunds had been constructed in Dajal Branch for the safe passage of flood water. The magnitude of flow in the reach was so great that it resulted in two breaches in Dajal Branch which washed away the cross-bunds. This caused deposition of slush in the bed of Dajal Branch in the reach RD 101-102. The flood water breached the left bank of Dajal Branch between RD 97-101 at several places. The flood flows escaping Dajal Branch breached Kausar and Firdous Distributaries at a number of places between RDs 0-10. The flood water after breaching these distributaries joined flood flows coming from the structure at RD 79+500 Dajal Branch. The flow of Kaha Hill Torrent also crossed Dajal Branch through hill torrent crossing RD 109+760 and breached Kausar Distributary at several places between RDs 15-25. A part of water of Kaha Hill Torrent moving from north to south along right bank of Dajal Branch, eroded it seriously in the reach RD 114-120, breached both the banks at RD 120, and silted its excavated bed between RD 119-120. A diversion for flood waters had been provided at RD 123 to pass the flood water by constructing cross-bunds in Dajal Branch at RD 123-125. A peak discharge of over 280 cumecs (10,000 cfs) passed through the diversion and the cross-bunds were washed away. This caused severe silting in the canal in reach RD 120-130, where the work of excavation was in process. The canal also breached on the left side at RD 127.

At RD 145+760 of Dajal Branch, another hill torrent crossing was also under construction to pass flood flows of Kaha Hill Torrent. The construction pit was enclosed by a temporary flood protection bund and a temporary diversion was made upstream of hill torrent crossing to safely pass flood flows; but the diversion bund was breached and the foundation pit was flooded. Slush was deposited in the pit and in the excavated bed of Dajal Branch between RD 142-147. The left bank of Dajal Branch also breached between RD 139-140. The flood water of Kaha Hill Torrent coming out from a cut at RD 166 of Dajal Branch entered Abe-Hayat Distributary and over-topped its tail reach. One component of this water also travelled towards Hajipur Distributary causing a number of breaches in the distributary and its minors and silted its excavated bed. Before the onset of the 1967 flood, only the left bank of Dajal Branch had been constructed between RD 160-190 and a pilot channel had been excavated to lead water from hill torrent crossing. Flood water entered the pilot channel resulting in deposition of half meter to one meter of slush and innumerable breaches on the left bank.

3.3.2 1973 Flood

There were heavy rains on Suleiman Range during July and August 1973. On July 17, 1973 the flood flows in Kaha breached the earthen bund built on its main branch for distribution of flood water for basin irrigation. Concentrated discharge flowing in the main stream hit the Dajal Branch in the reach RD 110-132. Outflows through hill torrent crossing at RD 123+650 were about 19 cumecs (6,700 cfs), but excessive inflows resulted in 148 breaches in the right and left banks from RD 115-144. The flood water emerging through the breaches damaged the Naushehra, Zamzam, Islam and Abe-Hayat distributaries. After forcing its way through the abandoned Nur Dhundi Canal (NDC), the flood water ponded up against the Dhundi Kutab Canal (DKC). Due to heading up of water, the right bank of DKC breached at several places but the left bank remained intact and water was drained off through its offtakes.

3.3.3 1975 Flood

During July, August and September 1975, hill torrents of DG Khan District experienced severe floods which caused colossal damage to canals, crops and other private and public properties.

On July 15, 1975, the torrent was in flood and flood water started flowing through the hill torrent crossings at RD 79+500. A peak discharge of over 250 cumecs (8,000 cfs) escaped through it for about three hours. After crossing the canal, the flood water entered Patti Machhi, Izmatwala and Darkhast Jamal Khan villages and flowed towards Darkhast Distributary and Dhingana Flood Bund.

Substantial high flows on a branch of Kaha approached the hill torrent crossing at RD 95+280 Dajal Branch, which exceeded the designed capacity of only 20 cumecs (700 cfs). Floodwater ponded behind the right bank to a water level of 123.1m (403.90 ft) which exceeded the designed water level of 122m (400 ft). The excessive flow accumulated along right bank of Dajal Branch from RD 96-101 and breached both the right and left banks of the canal. The flow then moved towards the east, joined flood flows from the hill torrent crossing RD 79+500 and headed up along Darkhast Distributary. Two causeways and a number of culverts in the Jampur-Dajal Road were insufficient, which resulted in damage to the road near Darkhast Distributary. Flood flows rushed towards south and accumulated on the right side of Darkhast Distributary from RD 39-54 and Dhingana Flood Bund RD 0-28. On July 18, 1975, the ponding up of flood water along Dhingana Flood Bund reached maximum level and breached it at RD 15. The breach developed to a width of 113m (370 ft). The discharge escaping through this breach filled the pocket between Dhingana Flood Bund, Darkhast Distributary and Islam Minor. After crossing Islam Minor the water reached the Jampur-Fazilpur Road and flowed along its right side. Cuts were made in Mohammadpur Minor between RD 11-13 to pass the water towards east and to save the road, but the drainage culverts in the road at 61 to 63 km were not sufficient to cater for such heavy flood discharge. The road breached on July 19, 1975 and water crossed Mohammadpur Minor through the cuts. The cuts in Mohammadpur Minor did not develop and substantial discharge flowed onto the south along west side of the road and over-topped at 64 km. Then it flowed on both sides of the road beyond Mohammadpur Town. Finally, this water flowed towards abandoned Nur Dhundi Canal (NDC) and accumulated in Hamunwala depression.

During August 1975, there were more high rains in the catchment area. The major part of flood flows rushed through the main channel and approached the hill torrent crossings at RD 79+500. On 14th August 1975, a peak discharge of over 481 cumecs (17,000 cfs) passed through the hill torrent crossing against a designed capacity of 283 cumecs (10,000 cfs). The excessive flow resulted in a number of breaches on the right bank between RD 74-85. The flow entering the canal over-topped the left bank at many places between RD 71-86 and caused numerous breaches. The total flow passing through all the breaches and hill torrent crossings was roughly assessed to be about 1,700 cumecs (60,000 cfs). After crossing Dajal Branch, the flood water adopted the same route as followed by flood flows during July 1975. It breached all channels previously damaged in July 1975 and caused excessive damage to Fateh, Tayyab, Lower Manka Distributaries and Razi Minor. On its way it over-topped Rasulpur Sub-Minor and accumulated in the pocket surrounded by abandoned Sohan Branch, Link No.III and Jampur-Dajal Road up to Khanpur Distributary. Relief cuts were made in old Sohan Branch up to its tail RD 8+800. The water released through these cuts travelled towards south along the Jampur-Rajanpur Road and accumulated along old Islam Branch, Mohammadpur Minor, and Kamber Shah Sub-Minor. Two relief cuts were made, one in Kamber Shah Sub-Minor and the other in abandoned Islam Branch. Flows escaping through these cuts over-topped Kamber Shah Sub-Minor from RD 9-32 and joined the flood water flowing towards Hamunwala Lake.

On September 03, 1975, flood water of Kaha Hill Torrent again reached hill torrent crossing RD 79+500. A substantial flow entered Dajal Branch through breaches in the right bank and washed away closure bunds at breaches between RD 77-83 and between RD 96-97 on the left bank. Again on 9th September, the flood flows of a high magnitude passed through hill torrent crossing at RD 79+500 and caused breaches between RD 76-78 in right and left banks of Dajal Branch.

3.3.4 1976 Flood

During the first week of September 1976, flood flows of Kaha Hill Torrent attacked the right bank of Dajal Branch between RD 77 to RD 100 and caused a number of breaches in this reach. The flood flows escaping through breaches and the hill torrent crossings damaged distributaries and moved down to Dhingana Flood Bund after crossing Jampur-Dajal Road. Finally the flood water flowed down to Dhundi Kutab Canal, and after breaching its banks accumulated in Hamunwala Depression.

3.3.5 1977 Flood

Kaha Hill Torrent experienced first flood during early June 1977. A maximum discharge of 142 cumecs (5,000 cfs) passed through the hill torrent crossing RD 79+500 of Dajal Branch. There were no serious damages except three breaches in the banks of Suleiman Distributary.

Again on June 27, 1977 the floodflows hit the Dajal Branch and the flood water passing through the hill torrent crossings RD 145+760 and RD 165+760 breached Islampur Distributary and Abe-Hayat Distributary and joined the flood flows escaping through hill torrent crossings at RD 95+280, RD 109+770 and RD 123+650. The combined flood water moved down and headed up along the left bank of Zamzam Distributary in its tail reach and damaged its banks. Thereafter, it flowed further down after crossing abandoned Nur Dhundi Canal through a cut at RD 165, attacked Dundi Kutab Canal and breached its right bank between RD 93-94 and 94-95.

The third freshet was recorded during last week of July 1976, when a peak discharge of about 210 cumecs (7,445 cfs) passed through the hill torrent crossing RD 79+500. The flood water while moving down caused many breaches in Dhingana Flood Bund.

3.3.6 1978 Flood

DG Khan area traditionally suffers damages from two elements of nature viz; River Indus from its eastern side and hill torrents originating from Suleiman Range from the western side. During the year 1978, the rainfall on Suleiman Range was unprecedented, which resulted in abnormally high floods on some of the hill torrents.

Kaha Hill Torrent was in high flood on July 05, 1978 with a peak of about 2,266 cumecs (80,000 cfs). Dajal Branch breached at about 45 places from RD 100 to RD 168. Flood flows passed through these breaches as well as through the hill torrent crossings. The flow entered Dajal Branch through breaches in the right bank, which resulted in breaches on the left bank at several places. The flood flows also entered offtaking channels of Dajal Branch causing serious damage. After moving along both the banks and through bed of the damaged distributaries, the floodwater accumulated in Hamunwala Depression. Kaha Hill Torrent was frequently in spate upto August 30, 1978.

The railway track was damaged by flood flows of Sori Shumali, Chachar, Kaha and Vidore Hill Torrents. The major damage was done by Kaha from kilometer 278 to 290 where breaches ranged from 15m to 60m in length and two to three meters in depth.

3.3.7 1979 Flood

During the 1979 flood, the first freshet in Kaha Hill Torrent was experienced in July 1979, but due to construction of Gandas on

Leghari Wah, Butt Hawa and Butt Pahore, the floodflow was dispersed without causing much damage. Only a medium flow approached Dajal Branch which crossed through hill torrent crossings RD 79+500 and RD 95+280 Dajal Branch, causing damage to Sultan, Dajal, Firdous Distributaries and Tareen Minor.

During the second freshet, the flood water in excess of the designed capacity (142 cumecs) of hill torrent crossing at RD 123+650 hit Dajal Branch reach. The right bank of the canal was breached at nine places between RD 115-125 and then entered Dajal Branch. The excessive discharge entering the canal passed into downstream offtakes and caused damage to seven distributaries. The flood water escaping through the hill torrent crossings and breaches on its way to the Indus River caused damage to the Dhundi Kutab Canal.

The third freshet in Kaha Hill Torrent was experienced during August 1979. It caused breaches in both banks of Dajal Branch. The flood water of a subsequent freshet entered the canal through these breaches to damage its left bank and the head regulator of Sadiq Feeder. Further downstream, the flood water attacked Dhundi Kutab Canal, which was saved by making a relief cut in its left bank between RD 97 to RD 98.

3.3.8 1986 Flood

During the 1985 Kaha Hill Torrent fexpenenced a discharge of 2,260 cumecs (80,000 cfs) on 9th August 1986. The flood flow approached the right bank of Dajal Branch in the reach RD 67+000. Bagga and Kala Khosro, the two tributaries of Kaha also brought about 700 cumecs (25,000 cfs) which synchronized with the Kaha Hill Torrent peak and caused breaches in the Dajal Branch in a width ranging from 30m to 300m.

The maximum discharge recorded at Hill Torrent crossings at RD 79+500 and RD 95+230 of the Dajal Branch were 342 cumecs (12,000 cfs) and 396 cumecs (14,000 cfs) against their designed capacities of 28 cumecs (1,000 cfs) and 85 cumecs (3,000 cfs), respectively. The flood water damaged upstream and downstream flared wing walls. A cross breach of 130m (400 ft) width occurred just upstream of the hill torrent crossing RD 79+500. The flood water put pressure all along the right bank from RD 100 to RD 190 and resulted in 455 breaches in Dajal Branch at various places.

Further downstream, the flood damaged Kadra Canal System and various distributaries in which many relief cuts were made to ease the situation.

3.3.9 1989 Flood

There was heavy rainfall in the catchment area of Kaha. Floodflows attacked Dajal Branch on 5th July 1989 from RD 100 to tail and breached both its banks in the reach RD 103 to RD 123 in different locations (Photo-3.2). Later, it entered the command area and damaged several offtakes of Dajal Branch and the standing crops of the area (Photo-3.3).

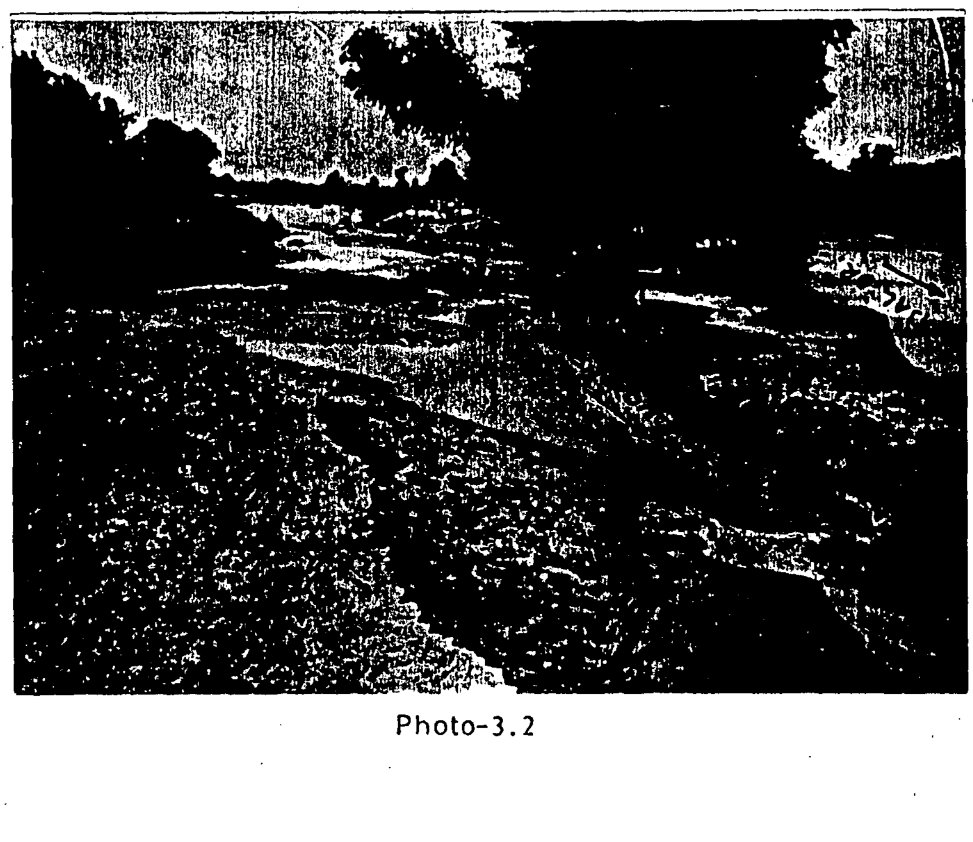


Photo-3.2

Photo-3.3

A second freshet hit on 27th July 1989. It overflowed Dajal Branch at various locations and disrupted the major part of the command area. Flood water after passing through the hill torrent crossings at RD 109+770, 123+650, 165+760 and from the breaches overtopped Dundi Kutab Canal and Raj Distributory. Finally it was escaped into the Indus through relief cuts made in Kadra Canal.

3.3.10 Ecological Imbalance

In addition to inflicting heavy loss of life and property, the floods of Kaha also create ecological imbalance in the area. Normal life remains disrupted for months. The health hazard is created due to contamination of drinking water. Programmes of immunization to human beings and the live stocks have to be launched. The value of property drops as a result of insecurity and uncertainty created by flood. As a result, economic development is hampered seriously.

3.4 EXISTING/PROPOSED FLOOD PROTECTION WORKS AND THEIR EVALUATION

3.4.1 General

For the last three decades, efforts have been made to construct different types of structures to effectively manage floodflows of hill torrents. The earthern and concrete structures constructed to divert floodflows have generally failed. Recently some flexible structures have been constructed using gabions. These structures have had more success in bearing the brunt of floodflows. The currently existing structures built in Balochistan and Punjab are as:

(a) Structures constructed by Irrigation & Power Department, Government of Balochistan:

- i- Churri Irrigation Scheme;
- ii- Rakhni Irrigation Scheme;
- iii- Seakle Irrigation Scheme;
- iv- Dubba Irrigation Scheme;
- v- Catherine Irrigation Scheme;
- vi- Naharkot and Vitarki Irrigation Scheme;
- vii- Chung Nullah Irrigation Scheme;
- viii- Thangurani Irrigation Scheme.

(b) Structures constructed by Irrigation & Power Department, Government of Punjab:

- i- Sad Alif Salaii
- ii- Mohammad Wah Salaii
- iii- Hazoori Wah Salaii
- iv- Khan Wah Salaii
- v- Upper Noor Wah Salaii
- vi- Link Channel Salaii
- vii- Chatool Cross-Structure;
- viii- Lashari Cross-Structure;
- ix- Cross-Structure Jindara Wah
- x- Cross-Structure Hajoo Wah

3.4.2 Evaluation of Flood Management Schemes - Balochistan Province

Out of the eight Irrigation Schemes mentioned above, the following four were inspected:

3.4.2.1 Rakhni Irrigation Scheme:

This scheme has been constructed on Rakhni Nallah very close to Rakhni Town about two kilometers upstream of D.G.Khan, Rakhni Road Crossing.

This scheme was built in early eightees. Initially a stone masonary retaining wall type high level diversion weir was constructed with an ungated, uncontrolled earthen flood channel offtaking behind the left abutment (Photo-3.4).

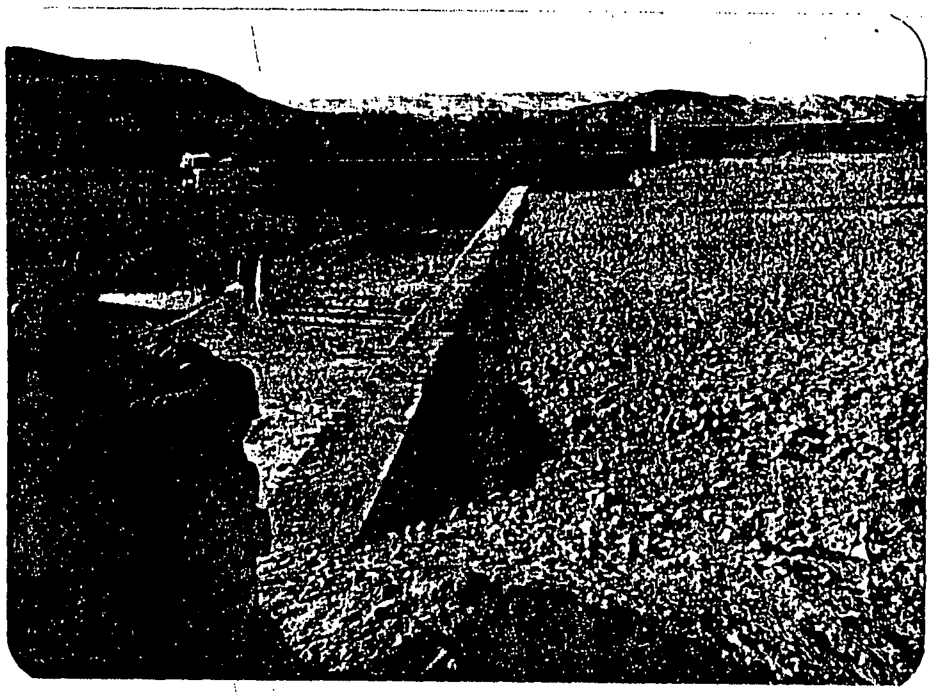


Photo-3.4

Rakhni Irrigation Schcme
A View from Left Abutment of the Main Weir and Extension on the right side

This weir functioned well only for about a year or so when it was outflanked by the river behind its right abutment. This outflanking was probably due to two reasons:

i- Improper location with respect to nallah morphology.

ii- Inadequate length of weir resulting from under-estimation of flood discharge.

Consequently, the weir was extended on the right flank. The extension was built with stone in steel wire crates (gabions) built at site.

This extension weir has a crest which is about one meter higher than the original weir and at an angle of about 25° to the original axis (Photo-3.5). The downstream glacis cistern (apron) and end wall are all built in gabions (see Photo-3.6).

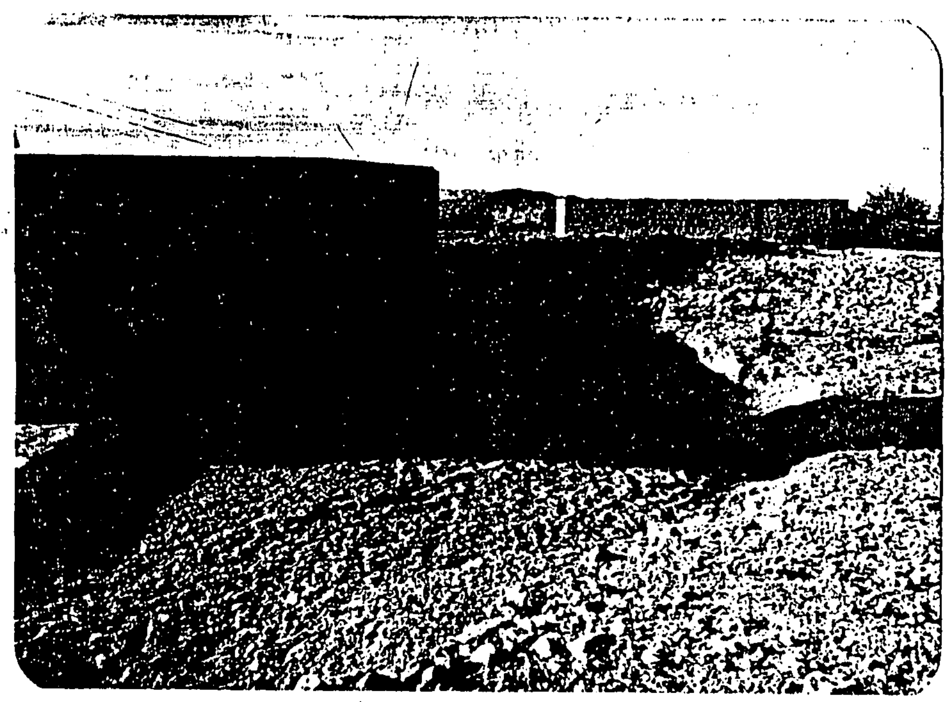


Photo-3.5
Rakhni Irrigation Scheme-Balochistan.
Crest of extension weir one meter higher than original weir.

Photo-3.6

Rakhni Irrigation Scheme Balochistan
Close-up view of right extension weir.

The extension weir itself seems to have behaved well but because its crest is higher than the masonary weir instead of providing relief, it created flow concentration on the left flank which caused outflanking on the left behind the left flood channel intake wall (Photo-3.7).

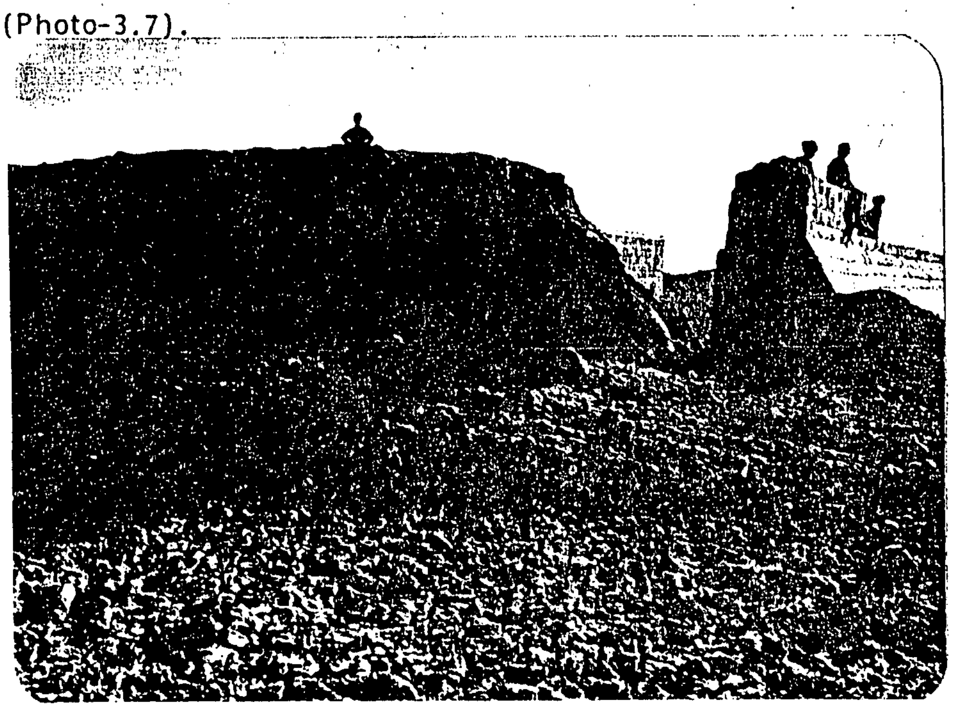


Photo-3.7

Rakhni Irrigation Scheme-Balochistan
Outflanking on the left behind
Left Flood Channel Wall.

This outflanking caused extensive damage to the flood channel downstream.

In order to carry out the necessary repair to the flood channel, the Irrigation Department has temporarily plugged the breach and the channel Intake.

Streamlining and strengthening of the left approach of the Nallah is likely to help avoid outflanking in future.

3.4.2.2 Seakle Irrigation Scheme:

This scheme is situated on Rakhni Nallah two kilometers downstream of D.G.Khan - Rakhni Road crossing. It was constructed of stone masonary in the years 1981-82. Separate channels for perennial and flood water have been built. The structure faced disaster soon after commissioning.

It had under-sluices and gated head regulators to handle flood discharges of 28 cumecs (1,000 cfs) and 3 cumecs (100 cfs) on left and right bank respectively. There is a separate intake for perennial flow (Photo-3.8) and a concrete lined carrying channel of about 0.1 cumecs (3 cfs) capacity (Photo-3.9).

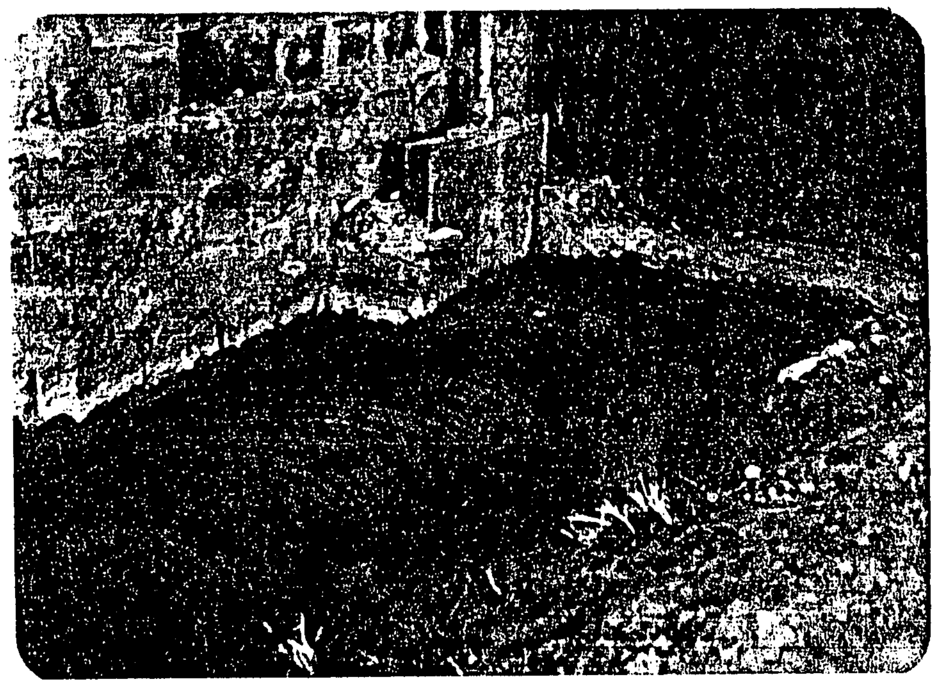


Photo-3.8

Seakle Irrigation Scheme
Perennial Water Intake.

Photo-3.9
Seakle Irrigation Scheme-Balochistan
Perennial Water Channel

The weir was outflanked on both sides causing extensive damage on both flanks. The right canal offtake of 3 cumecs capacity was completely washed out. Considerable length of the weir crest adjacent to right abutment was under scoured and settled (Photo-3.10).

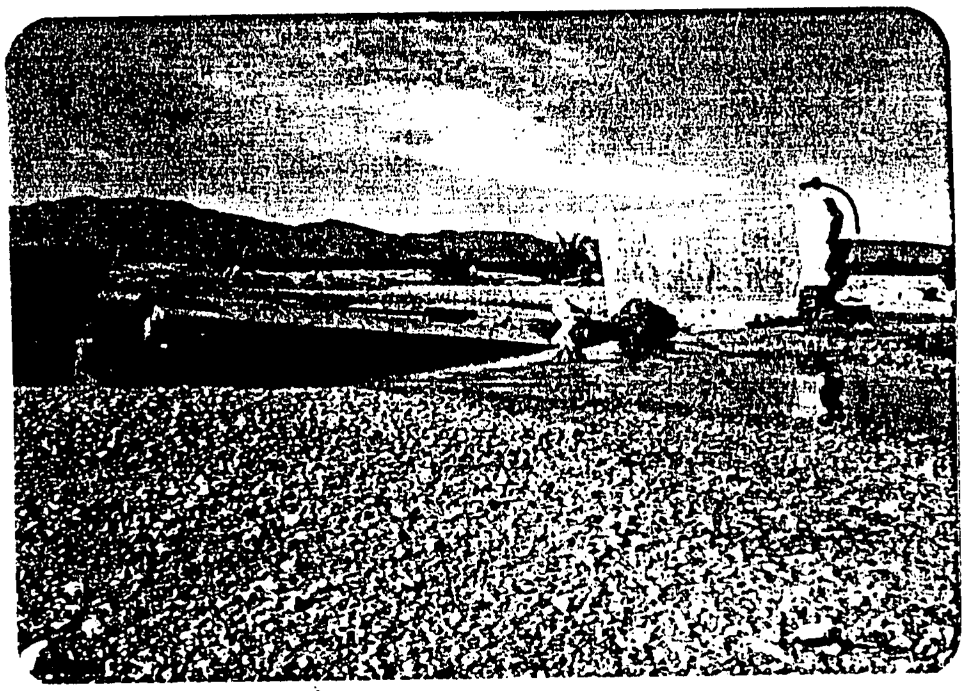


Photo-3.10

Seakle Irrigation Scheme - Balochistan
Outflanking on the Right Flank Remnants
of Right Offtake structure and Abutment.

The failure of the right flank occurred as a result of flow concentration on the right due to oblique approach (Photo-3.11).

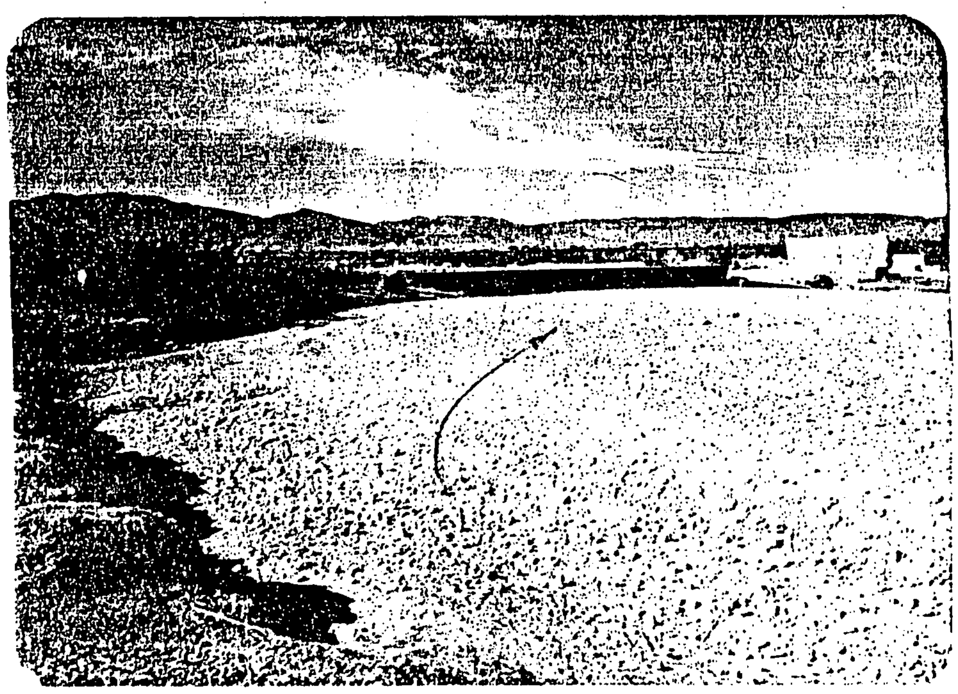


Photo-3.11

Seakle Irrigation Scheme - Balochistan
Oblique Nallah Approach
and Flow Attack on Right Flank.

Left bank of Rakhni Nallah upstream has an earthen channel of about 9.1 cumec capacity (Photo-3.12).

Photo-3.12

Seakle Irrigation Scheme - Balochistan
Earthen Perennial Flow Channel

The outflanking on the left flank damaged the left abutment wall (Photo-3.13).

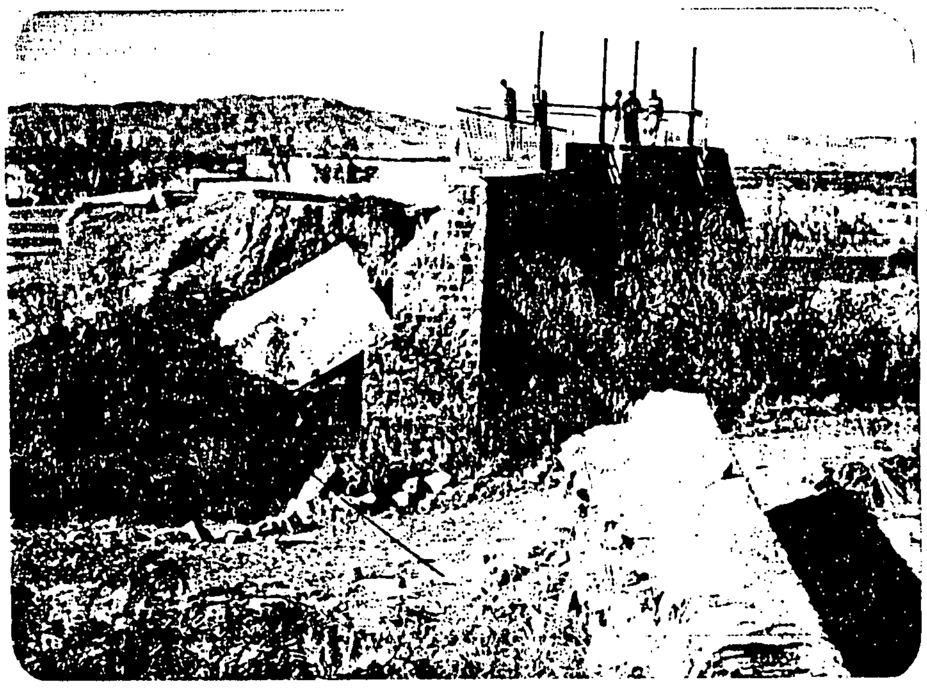


Photo-3.13

Seakle Irrigation Scheme - Balochistan
Outflanking on the Left Side and
Damage to Left Abutment Wall and Other Structure

Oblique approach of the nallah and flow concentration towards the right flank also resulted in an eddy and sediment deposits in front of the left canal offtake (Photo-3.14).

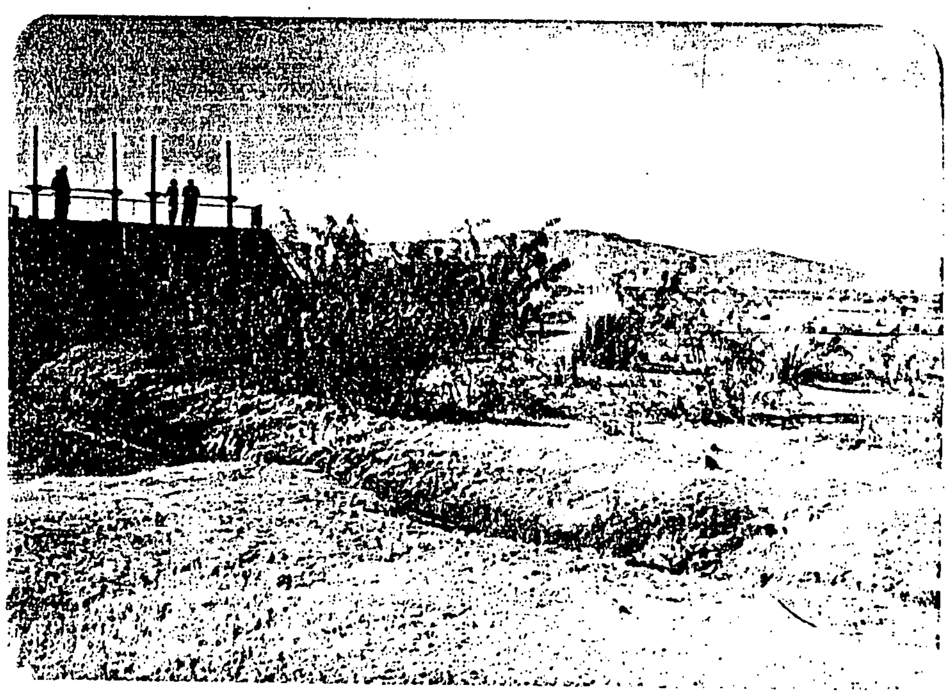


Photo-3.14

Seakle Irrigation Scheme - Balochistan
Masking in Front of Left Canal Offtake.

This masking is about one meter above the bed of the flood intake channel requiring dredging for restoration of the approach channel.

3.4.2.3 Catherine Irrigation Scheme:

This scheme is situated 24 kilometers downstream of Seakle scheme. A low level stone masonary weir has been built to divert perennial flow for irrigation. A small concrete lined irrigation channel offtakes from the right abutment (Photo-3.15).

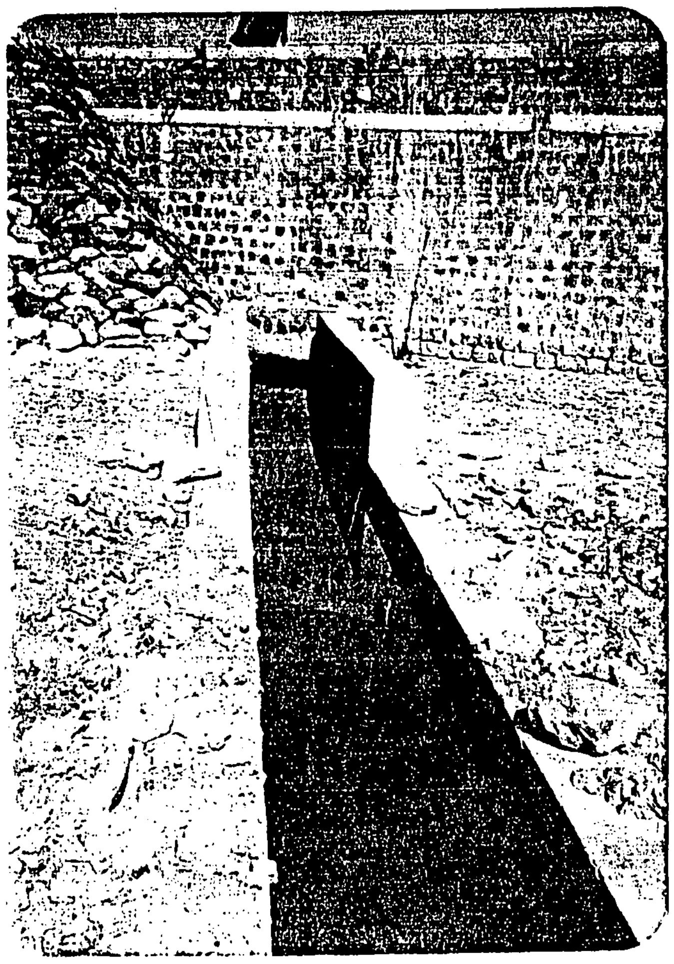


Photo-3.15
Catherine Irrigation Schem - Balochistan
Perennial Canal Offtake.

This scheme was commissioned in 1977 and functioned satisfactorily till 1982.

During the 1982 high flood, the weir was outflanked on the right abutment causing damage to the channel (Photo-3.16).

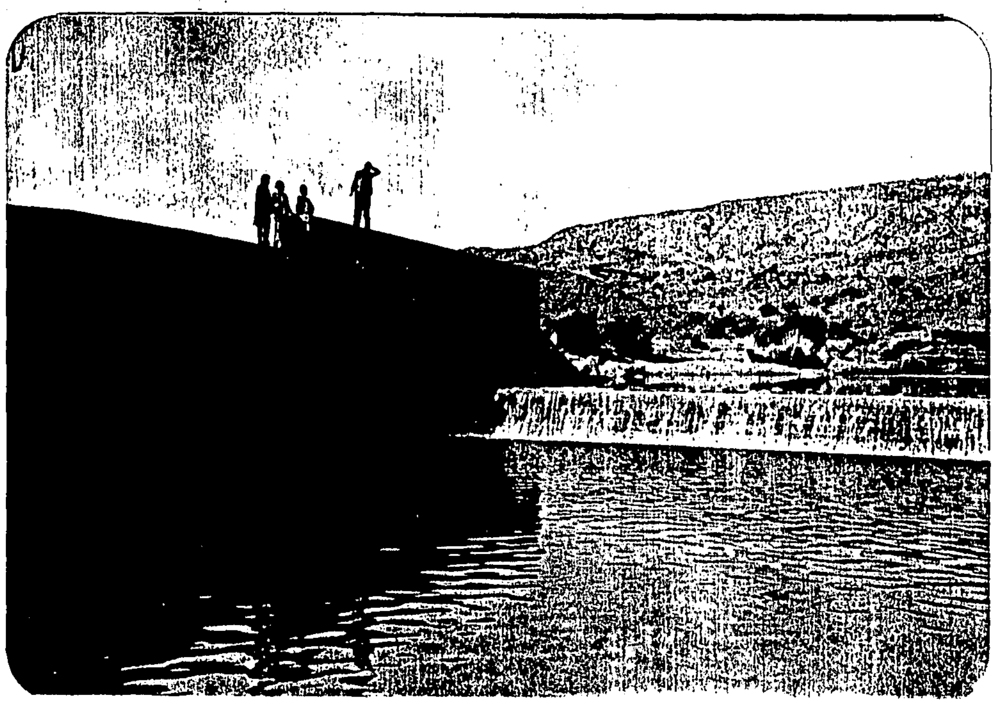


Photo-3.16

Catherine Irrigation Scheme - Balochistan
Oblique Nallah approach
and Outflanking on the Right Flank.

Irrigation Department, Balochistan has built two stone pitched bunds one upstream and the second downstream end of the right abutment wall to block the nallah approach behind the right abutment (Photoes 3.17 & 3.18).

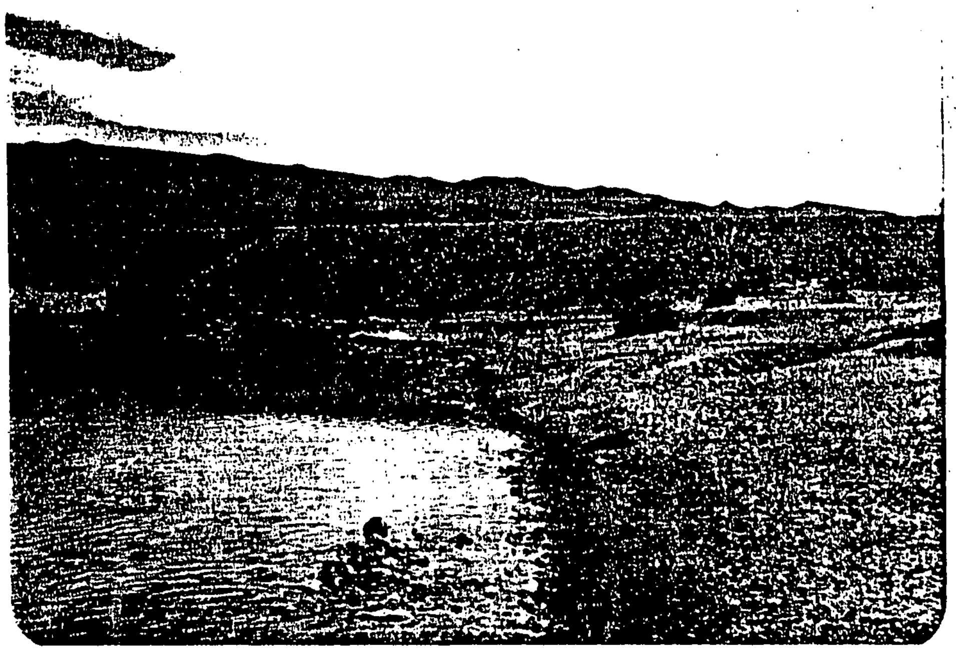


Photo-3.17

Catherine Irrigation Scheme - Balochistan
Upstream Bund at Upstream End of Abutment.

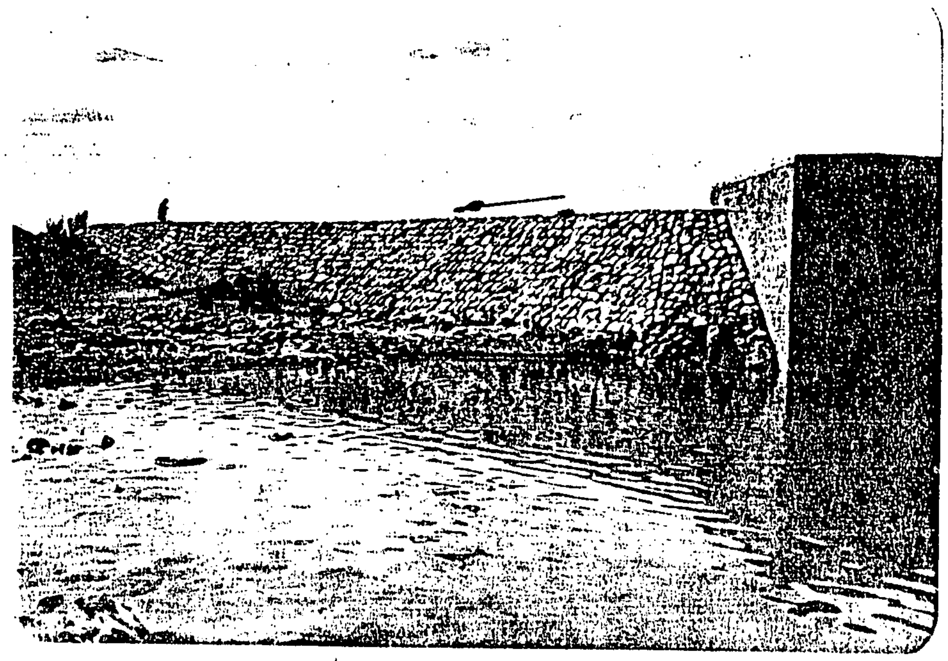


Photo-3.18

Catherine Irrigation Scheme - Balochistan
Downstream Bund at Downstream End of Abutment.

The outflanking has been probably due to oblique approach of the nallah (Photo-3.19).

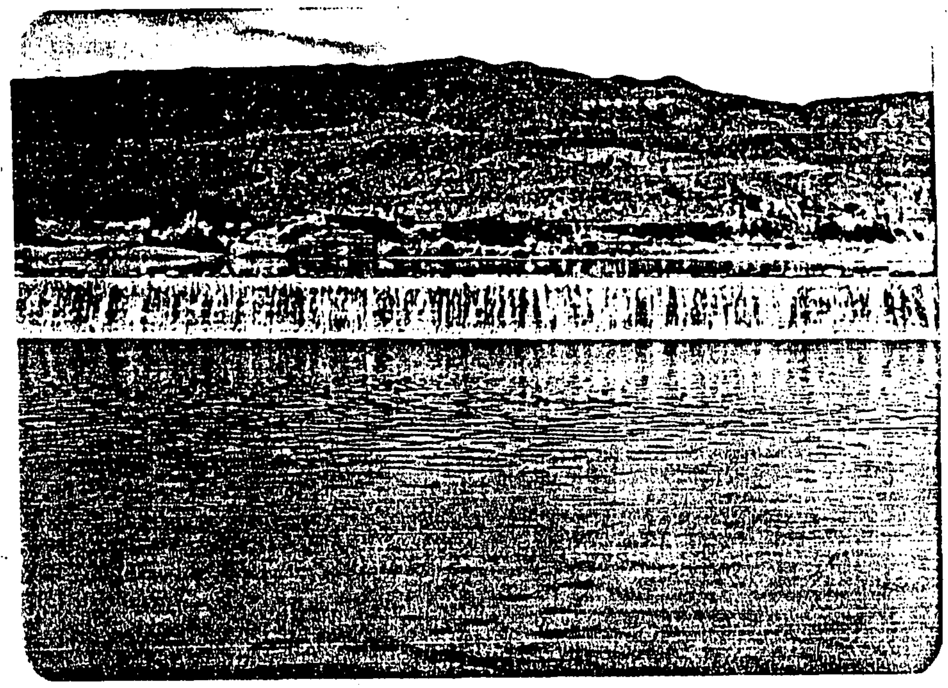


Photo-3.19
Catherine Irrigation Scheme - Balochistan
Oblique Nallah Approach.

3.4.2.4 Churri Irrigation Scheme - Balochistan

This is located on Churri Nallah a tributary of Rakhni Nallah, and consists of high crest level concrete weir built across Churri Nallah with offtakes on both sides. This structure has not functioned properly. The left flood channel has silted up. Some efforts were made in 1982 to restore the structure, but proved futile.

3.4.3 Evaluation of Flood Management Schemes - Punjab Province

Punjab Irrigation Department has built various flexible structures comprised of stones in wire crates (gabions) for the bed control and diversion of flood flows into wahs. These structures are functioning satisfactorily. These structures are cheap in cost, need small O&M and are more suitable for management of floodflows of hill torrents. Major structures are described as under:

3.4.3.1 Lashari Cross Structure

This has been built across Kaha Hill Torrent for feeding Lashari Wah. It consists of stone in galvanized wire cage wooven at site.

This structure was constructed at a cost of about Rs 1.2 million in 1985. There was some damage to the structure during the subsequent floods. The damages were repaired at a total cost of Rs 0.3 million. An area of about 3,200 ha (8,000 acres) is under cultivation during this year. However, it is planned to increase this area to about 4,450 ha (11,000 acres) under ultimate conditions. Photo-3.20 shows portion of the Lashari cross structure and its right abutment.

Photo-3.20
Lashari Cross-Structure - Punjab
Showing Downstream Glacis and Right Guide Bund.

Major damage occurred during 1988 flood. A portion of the downstream stone was washed away. Some modification in the downstream apron was also made to improve hydraulic performance. Photo-3.21 shows the close-up view of the wire crate of construction.

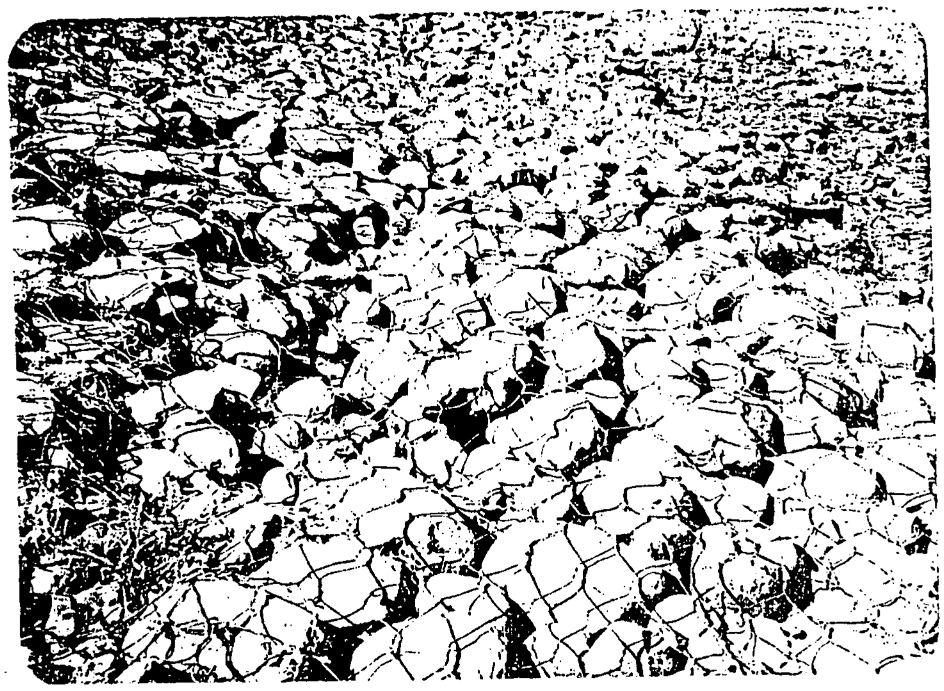


Photo-3.21
Close-up View of Lashari Cross-Structure.

Offtake channel of this cross-structure is Lashari Wah which is drawing about 79 cumecs (2800 cfs) (Phogo-3.22).

Photo-3.22
Lashari Wah Offtake

This structure has functioned for the last 4-5 years and has greatly helped the people of this area by way of improving their socio-economic condition. Local farmers and the beneficiaries of these schemes were interviewed. They showed signs of happiness over the flood management projects being undertaken by the Irrigation Department. According to a rough estimate, the net yearly benefit to the farmers from the Lashari Cross Structure is to the tune of Rs 20.00 million. Photo-3.23 shows the type of yield from the Pachad area.

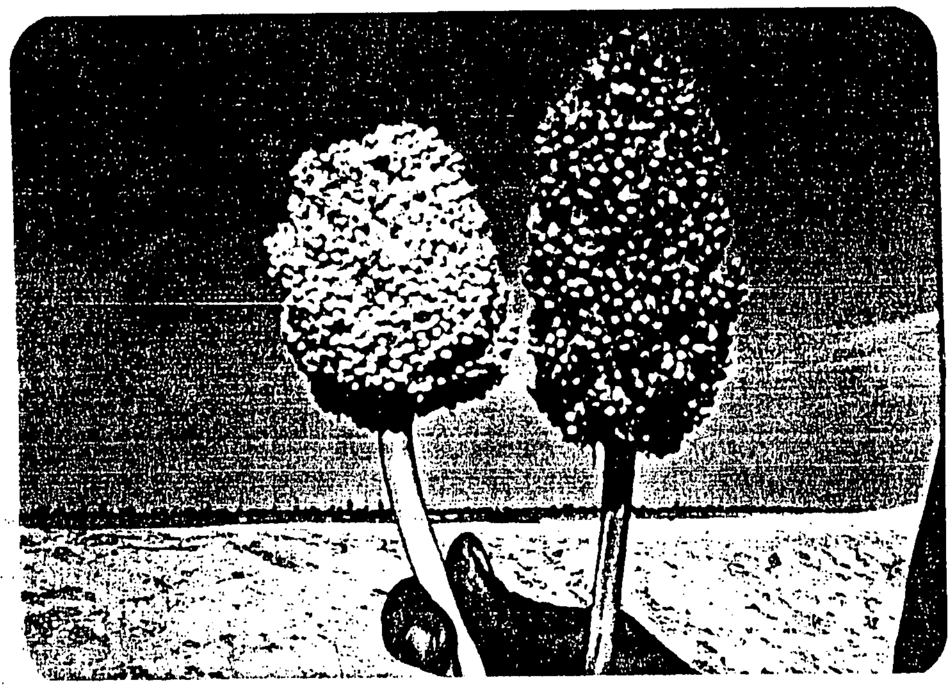


Photo-3.23

Flood Management in Pachad Area Healthy Spike
Head Sorghum depict Agricultural Prosperity
in Pachad Area resulting from
Kaha Hill Torrent Management.

3.4.3.2 Giwaz Wah Cross Structure

This has been built about 1,200m (4,000 ft) downstream of the Lashari Cross Structure during 1988-1989 at a cost of about Rs 2.5 million to feed a network of wahs, the major being Giwaz Wah which carries about 113 cumecs (4,000 cfs). It has also been built with stones in wire crates (Photo-3.24).

Photo-3.24

Flood Management in Pachad Area
Giwaz Cross Structure.

During the 1989 flood, there was some damage to the left flank, where a portion of the weir structure was washed away. Repair has not been done so far (Photo-3.25).

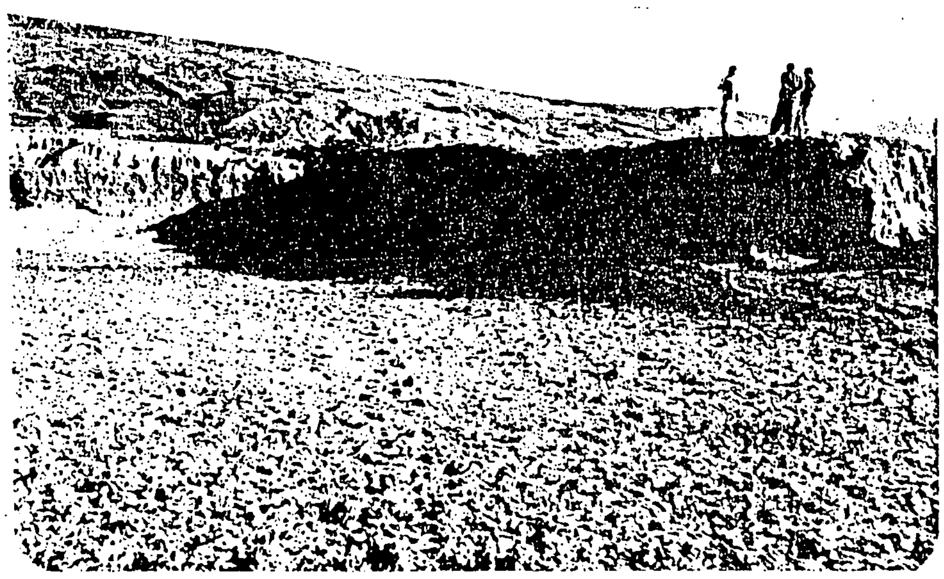


Photo-3.25

Outflank on the Left of Giwaz Wah
Cross-Structure.

iii. Chatool Cross Structure

It is located on Kaha Nallah about 24 km downstream of the darrah. It was constructed with gabions in 1986-87 at a cost of Rs 2.08 millions. The following three Wahs draw water from this structure;

Makwal Wah	31 cumecs
Jhoke Wah	40 cumecs
Chatool Wah	57 cumecs

The structure is functioning normally.

iv. Cross Structure Sad Gah Wah

It is located 34 km downstream of the 'Darrah' to feed Hajoo Wah and Sad Gah Wah. The total diversion is 340 cumecs. It was built at a cost of Rs 2.43 millions using gabions.

v. Mohammad Wah Salaii

It was built on Kaha Nallah during 1988-1989 to divert about 34 cumecs of flood flows into Mohammad Wah. It is a flexible structure consisting of gabions (stones in wire crates) about 245 meters long built at a cost of Rs 0.36 millions. It is functioning well.

vi Sad Alif Salaii

This is located just downstream of the darrah. It consists of a flexible structure built with stones in wire crates to divert the perennial flow of about 1.1 cumecs (Kala Pani) into Nokh Wah. This flow is irrigating about 200 ha on the left bank. The structure which was built in 1985 suffered some damage during 1989 flood. Efforts are being made by the Irrigation Department for its repair during current dry period (1989-90).

SECTION - 4

HYDROMETEOROLOGICAL EVALUATION

Kaha Hill Torrent is the biggest hill torrent of Suleiman Range. The catchment area lies between latitude 29° 16'N to 30° 21'N and longitude 11° 69'N to 05° 70'N and total catchment area is 5,720 sq.km (2,208 sq.miles). The climate of the area is arid to semi-arid and average annual rainfall varies from about 250mm (10 inches) to 380mm (15 inches). Annual isoheytes and monsoon isopercental are shown on Exhibit 4.1. The hills are barren and run-off is generated as a result of excessive rainfall on the hilly catchment areas with little absorption.

Hydrometeorological data of all the major hill torrents of D.G.Khan (including Kaha Hill Torrent) is available in fragmented form for periods varying in length from 5 to 30 years. Most of the observation sites are located in tribal areas, where access conditions are hard and proper supervision of the staff responsible for data observation is a difficult task. Moreover, the agencies responsible for data collection have changed from time to time and the records of field observations have been interrupted in between due to political, administrative or financial reasons, for considerably long periods.

Actual records of flood flows are naturally preferable to theoretical computations. Flood records of Kaha Hill Torrent are available for the years 1959-1964 and 1975 to 1989. Flood flow measurements have been made at its darrah near Harrand by converting gauge heights into discharge using a rating curve prepared for the site.

In view of missing links of the observed data, various analytical techniques have been used to generate run-off records and flood hydrographs. Precipitation data and catchment characteristics have been used to generate run-off synthetically.

Frequency analysis has been carried out to determine run-off for various return periods and synthetic records have been correlated with the observed records. Frequency analysis of synthetically generated data and actually observed data (with missing links synthetically determined), have been used to determine run-off for designing structural measures. Precipitation records and catchment characteristics have been used for synthetic generation of run-off as detailed below.

4.1 AVAILABILITY OF DATA

Methodology for determination of hydrographs and peak discharge for different frequencies primarily depends upon the availability of data. Parameters of interest are precipitation, discharge, type of soil, land use, land treatment, etc.

4.1.1 Precipitation Records

There are 48 sites in and around the whole catchment of D.G.Khan Hill torrents, where precipitation records have been observed from time to time. There is hardly any station where continuous records have been observed. Table-4.1 lists the names of raingauge sites, their location and periods of record which are shown in Exhibit 4.2. Most of these stations are operated by Irrigation Departments of Governments of Punjab and Balochistan, while some are supervised by the district administration authorities or Surface Water Hydrology Project, WAPDA.

Raingauge stations measuring rainfall in the catchment of Kaha are Barkhan, Rakni, Chacha, Vitakri, Mat, Jam Ali, Ziarat Sheru, Chhajar, Muranj, Bewatta and Rarhan. Barkhan located on the western part of catchment, is the only station, which has more than 25 years record, while remaining stations have less than 15 years records. Fort Munro raingauge station lying in close vicinity

TABLE-4.1

LIST OF RAIN GAUGE STATIONS IN DG KHAN AND ADJOINING AREA

(Meters)

Sr. No.	Name of Station	Latitude	Longitude	Elevation	River Basin	Period of Record
1	2	3	4	5	6	7
1-	Ali pur*	29° 20'	70° 50'	102	-	1946-1975
2-	Barkhan**	29° 34'	69° 32'	1,112	Kaha	1960-1965 1975-1982
3-	Bandlukh	30° 10'	70° 18'	527	Vidor	1976-1981
4-	Bandukh	30° 09'	70° 13'	899	Vidor	1975-1981
5-	Bangu Bun	31° 02'	70° 14'	904	"	1964-1966
6-	Beria	30° 08'	70° 10'	1,045	"	1975-1981
7-	Bewatta**	30° 01'	69° 5'	1,128	Kaha	1975-1988
8-	Bharti	30° 34'	70° 22'	556	Sanghar	1956-1958
9-	Chacha**	29° 49'	69° 50'	969	Kaha	1961-1967
10-	Chachar	29° 23'	69° 50'	533	Chachar	1975-1987
11-	Chhajra**	30° 02'	69° 44'	1,219	Kaha	1980-1988
12-	Dera Bugti*	29° 03'	69° 08'	457	-	1962-1969
13-	DG Khan*	30° 04'	70° 38'	122	-	1946-1975
14-	Fort Munro	29° 56'	69° 58'	1,981	Mithawan	1947-1968 1975-1989
15-	Fort Sandeman*	31° 20'	69° 28'	1,417	-	1960-1978
16-	Hinglum	30° 28'	70° 03'	937	Sanghar	1954-1959
17-	Jampur*	29° 39'	70° 36'	117	-	1946-1975
18-	Janm Ali**	29° 24'	69° 21'	762	Kaha	1965-1966
19-	Kala Mar	30° 46'	70° 17'	592	Sanghar	1975-1981
20-	Kalkhas	29° 21'	69° 42'	722	Chachar	1952-1957 1961-1964
21-	Kingri	30° 27'	69° 49'	1,219	Sanghar	

1	2	3	4	5	6	7
22-	Kohlu*	29°54'	69°14'	1,167		1963-1974
23-	Mard Bun	30°18'	70°07'	1,829	Vidor	1959-1968 1975-1989
24-	Mat**	29°43'	69°41'	853	Kaha	1975-1988
25-	Mihal	30°05'	70°06'	1,793	Mithawan	1975-1981
26-	Moli Bun	29°51'	70°08'	427	"	1975-1981
27-	Mubarki	30°15'	70°07'	2,063	Vidor	1947-1948 1955-1958
28-	Multan*	30°10'	71°25'	123	-	1959-1980
29-	Murunj**	29°30'	69°37'	701	Kaha	1954-1957 1961-1965 1977-1988
30-	Musa Khel	30°42'	69°50'	1,347	Sanghar	1946-1965
31-	Muzaffargarh*	30°04'	71°12'	116	-	1946-1975
32-	Nandi Ghar	30°19'	70°21'	610	Sori Lund	1975-1981
33-	Nelo Har	31°08'	70°21'	472	Vehowa	1980
34-	Nili Lakri	29°24'	69°54'	488	Chachar	1961-1964
35-	Nonkandki	30°28'	70°18'	686	Sanghar	1975-1981
36-	Nul Gaz	29°14'	69°34'	683	Sori Janubi	1965-1966
37-	Rajan Pur*	29°20'	70°50'	102	-	1946-1975
38-	Rakhi Muhn	29°37'	70°10'	525	Mithawan	1962-1963 1962-1963
39-	Rarkan**	30°17'	69°53'	351	Kaha	1961-1963
40-	Rakhani**	30°03'	69°55'	1,094	"	1961-1963
41-	Sakhi Sarwar	29°58'	70°18'	579	Sakhi Sarwar	1975-1981
42-	Sangha Sluf	30°16'	70°15'	789	Vidor	1959-1960 1975-1981

1	2	3	4	5	6	7
43-	Shadani	29° 13'	69° 53'	427	Pitok	1961-1963 1975-1981
44-	Sori	29° 07'	69° 54'	183	Sori Shumali	1961-1963 1975-1981
45-	Siah Tang	29° 08'	69° 25'	632	Sori Janubi	1965-1966
46-	Taunsa *	30° 42'	70° 38'	173	-	1946-1980
47-	Vitakri **	29° 41'	69° 23'	937	Kaha	1961--1966
48-	Ziarat ** Sheru	29° 37'	69° 56'	1,418	Kaha	1961-1964 1976-1988

* Stations located outside catchment area of D.G. Khan Hill Torrents.

**Stations measuring Rainfall of Kaha Hill Torrent.

of the catchment area, has 35 years record with short breaks. The records of these stations are mostly in the form of daily precipitation. Hourly records are not available for any station in the catchment area. Therefore, for the intensity pattern, data from nearby hydrologically homogenous stations outside the catchment area have been used. Kohlu which satisfies the condition of hydrometeorologic similarity has been selected for transposition of hourly precipitation data to watershed of Kaha Hill Torrent.

4.1.2 Discharge and Run-off Data

Realistic estimation of discharge and run-off is the major determinant which forms the corner stone of all flood management projects. Long-term data of surface flows greatly facilitate the formulation of flood control plan of an area. The quantity and quality of data determine the probability of uncertainty and consequently the economic viability of design.

The flow records of Kaha Hill Torrent at its darrah are available in the form of stage for 1958 to 1964 and 1975 to 1989. Staff gauge has been installed at the darrah to record the stage at specific times during the flood. The discharge corresponding to a stage is read from the stage discharge curve. This curve is developed by using cross-sections and hydraulic parameters with the aid of Lacey's Formula:

$$Q = \frac{\quad}{\quad} * A * R^{2/3} * S_e^{1/3}$$

Where Q is discharge in cumecs at the cross-section with area A in sq.meter and hydraulic mean depth *R in meter. S_e is the slope of the energy gradient. The cross-sections are observed after the flood subsides. Since the bed, roughness and the width etc., of the nallah at this location do not change with time, hence the values of A&R remain constant. Data observation was discontinued during 1965-1974, but the data gaps have been filled synthetically. Very few complete hydrographs are available. Stages corresponding to rising or recession limbs of the hydrograph are generally missing. The time interval between the measurement of two successive stages is too long for the rapidly varying flow of hill torrents and, thus shape of the run-off hydrograph cannot be explicitly defined. Thus available data is only useful for analysis of peak discharge. Estimation of volume of flood water passing through the darrah for various periods or the determination of the shape of the hydrograph is not feasible.

The observation sites are generally manned by semi-literate persons and are located in areas, where approach conditions are difficult and streneous efforts are required for supervision of field staff. These factors together with lack of understanding towards importance of data observation have affected the quality of data. The results derived from this data, therefore, carry with them the same amount of uncertainty as is inherent in data observation. In order to obviate the shortcomings of the data, various synthetic techniques have been used to supplement the data and to determine hydraulic characteristics. Different statistical procedures were employed to arrive at the realistic design parameters.

4.2 STREAM FLOW DATA ANALYSIS

4.2.1 Frequency Analysis

Hydrologic phenomena generally result as a consequence of highly complex natural events. Structural measures for flood management requires the knowledge of probability of occurrence of an event exceeding an assumed magnitude and risk analysis studies for appropriate designing.

Both under-design or over-design of structures have their merits and demerits. Designing a structure to provide total protection against losses may be impracticable due to prohibitive cost, while low levels of protection may result in unbearable damage for the structure and excessive flood losses in the Project area. Thus, risk analysis forms the foundation for efficient and economical design of all hydraulic structures.

Many probability distributions have been found to be useful for hydrologic frequency analysis. The Log-Pearson Type-III and Gumbel Distribution are preferably used for flood computation. The evidence given in support of various distribution is the ability to fit the plotted data of one or more streams. Various statistical techniques can be used to find, which of the distributions gives a better fit to the data.

Available discharge records with the data gaps filled in were used for frequency analysis. Gumbel, Log Gumbel and Log Pearson Type-III distributions have been used for frequency analysis and the Chi-Square Test was used to find which of the distributions better fit the data.

4.2.1.1 Selection of Data Series

Two types of data are generally used for flood management studies - the partial duration series and the extreme value series. The extreme value series include the largest flood peak or smallest low flow values with each value selected from within equal time intervals in the record. The time interval is usually taken as one water year and the series so selected is the Annual Series. For largest annual discharge peak it is called Annual Maximum Series.

In partial duration series, the data consist of all peak discharges that are greater than a certain base value. The base is generally selected as equal to the lowest annual flood so that at least one flood in each year is included. However, in a long record the base is generally raised so that on the average only three to four floods a year are included. The only other criterion followed is that each peak be individual i.e., be separated by substantial recession in storage and discharge. The use of only flood in each year is the most frequent objection to the use of Annual Maximum Series. Infrequently, the second highest flood in a given year, which is omitted in the above definition may outrank many annual floods. This objection is resolved in partial duration series by listing all floods that are greater than a selected base without regard to number within any given period. The greater number of floods listed might be an advantage particularly if the record is short. However, most of the additional floods are of low discharge and lie on that part of the frequency curve, where it is well defined. The high discharge floods are generally identical with those in annual flood series.

The stream flow records are available with a break of 10 years and the missing data has to be synthetically generated. For annual series, generation of highest peaks of the missing period is required while for partial duration series the peaks above a threshold level have to be evaluated. The reliability of synthetically generated data cannot match with that of observed data. The more the generated values in the data, the more uncertain are likely to be the results. Moreover, from the relationship between extreme value and partial duration series, it is clear that for higher discharges there is very little difference in the magnitude of the flood peaks given by the two series.

4.2.1.2 Synthetic Generation of Stream Flow Data

Peak flow records for Kaha Hill Torrent are available from 1959-1964 and 1975-1989 as shown on Table 4.2. Data observation was stopped during the period 1965-1974. Stream flow data could not be

TABLE 4.2

SYNTHETIC GENERATION OF MISSING STREAM FLOW DATA CUMULATIVE MAXIMUM PEAK DISCHARGE KAHA HILL TORRENT

YEAR	* PEAK DISCHARGE IN CUSECS	CUMULATIVE MAXIMUM PEAK DISCHARGES IN CUSECS	DISCHARGE DATA WITH GENERATED FIGURES		
			CUSECS	CUMECS	
1959	17859	17859	17859	506	
1960	51017	68876	51017	1444	
1961	25448	94324	25448	721	
1962	18978	113302	18978	537	
1963	23602	136904	23602	668	
1964	78264	215168	78264	2216	
1965		237378	22210	629	**
1966		279378	42000	1189	**
1967		323378	44000	1246	**
1968		369378	46000	1302	**
1969		419378	50000	1416	**
1970		468378	49000	1387	**
1971		519378	51000	1444	**
1972		562378	43000	1217	**
1973		618378	56000	1586	**
1974		659378	41000	1161	**
1975		701193	41815	1184	**
1976	32300	733493	32300	915	
1977	30575	764068	30575	866	
1978	118500	882568	118500	3355	
1979	70500	953068	70500	1996	
1980	70519	1023587	70519	1997	
1981	55322	1078909	55322	1566	
1982	39960	1118869	39960	1131	
1983	39800	1158669	39800	1127	
1984	48000	1206669	48000	1359	
1985	55483	1262152	55483	1571	
1986	57226	1319378	57226	1620	
1987	50000	1369378	50000	1416	
1988	55000	1424378	55000	1557	
1989	84820	1509198	84820	2401	

*Source Irrigation Department,Punjab
**Synthetically Generated Figures

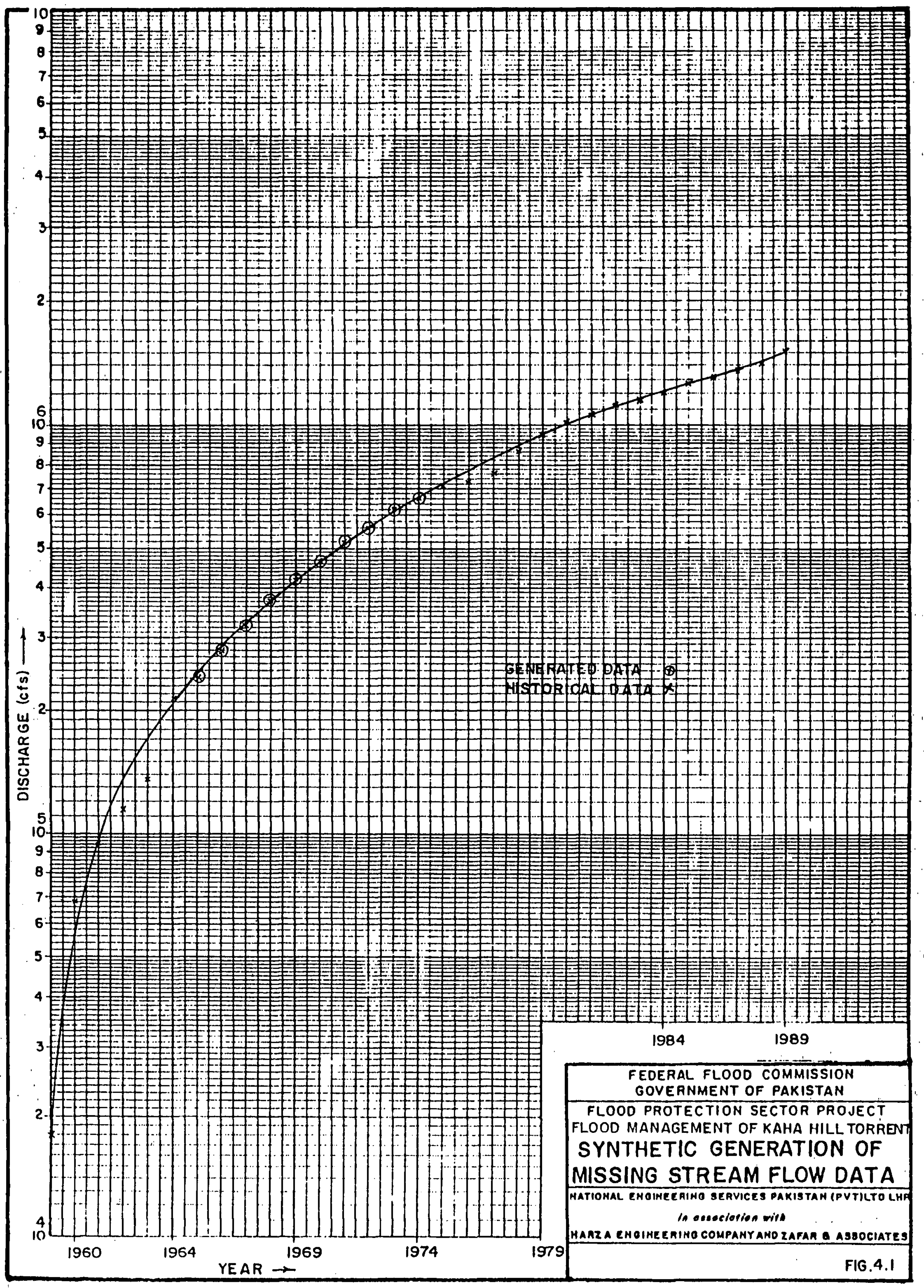
synthetically generated on the basis of precipitation data, which was also missing for the same period. Various alternatives were tried to synthesize the missing flood flow data. There was some overlap of precipitation record of some of the stations in the area or in close vicinity of the project. The precipitation records of the following raingauge stations was used to develop correlationship:

i-	Fort Munro with (1955 - 1989)	Barkhan (1960-65 & 1975 to 1982)
ii-	Fort Munro with (1955 - 1989)	Murunj (1961-1965 & 1977 to 1988)
iii-	Kohlu (out of project area) with (1963 - 1973)	Murunj 1961-1965 & 1977 to 1988)

In addition, precipitation of Fort Munro and annual flood peak at the 'Darrah' was used to develop some relationship. The value of correlation coefficient ranged from 0.1 to 0.6 which was very low. Hence this method was discarded.

It was reported by the concerned engineers of the Irrigation & Power Department, Government of Punjab that the period between 1965 to 1974 was a low flow dry period in DG Khan area. Observation of precipitation and flood flow records were discontinued during this period. Deletion of this period from frequency analysis would produce biased and higher flood flows for different return periods. In order to generate flood flows for the missing period, a method was tried which would only produce normal flows.

For filling of data gaps it has been assumed that the years for which data is unknown adjacent to the group of years for which data is known, experienced similar meteorological conditions. This assumption can further be extended to the point that adjacent years experienced floods having similar magnitudes. Keeping in view the above mentioned assumption the missing data has been generated by the following method.



FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

SYNTHETIC GENERATION OF MISSING STREAM FLOW DATA

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
In association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

FIG.4.1

The cumulative discharges figures are plotted on a semi-log paper keeping years in their sequence on the abcissa and discharges on log side (Fig.4.1). From the plotted points, a curve is drawn extra-polating it upto the last year for which data is unknown. Discharges of the second group are added in the last extra-polated cumulative discharge figures to get the cumulative discharge figures for each of these years. The cumulative discharge figures of the second group are plotted and then conformity with the trend of the curve is checked. If they do not conform to the trend of the curve then curve is readjusted until curve conforms to all the observed discharge figures. Cumulative discharges for the missing years are read from the fitted curve and from these annual peak discharge figures can be determined (Table-4.2). This method has its limitations but is the only way that could be utilized under the present conditions. By the use of this method, the abnormal events cannot be identified. From the studies of flood damages, it is evident that this period did not experience any unusual event.

4.2.1.3 Gumbel or Type-I Extremal Distribution

This is one of the most widely used distributions in flood frequency analysis. Two probability papers have been designed to linearize the distribution so that plotted data can be easily analysed for extra-polation or comparison purposes. The abcissa of both these papers denotes the return period in years, while ordinate is for representing the magnitude of the event. One paper has linear ordinate and the other log ordinate. Plotting position on the probability paper has been determined by using the Wiebull's Formula:

$$T_r = \frac{n + 1}{m}$$

Where T_r is return period in years, n is number of years of record, m is rank of the event in order of magnitude. Annual maximum peak discharge corresponding to the return period (Table-4.3) determined by this formula are plotted on Extremal

TABLE 4.3

ANNUAL MAXIMUM FLOOD FREQUENCY ANALYSIS
KAHA HILL TORRENT

RIVER----------------------------KAHA
SITE-----------------------------DARRAH
PERIOD OF DATA AVAILABLE-------- 1959 TO 1989
NUMBER OF YEARS RECORD(N)------- 31

PROBABILITY ANALYSIS

YEAR	PEAK DISCHARGE IN CUMECS	YEAR	DISCHARGE IN DESCENDING ORDER CUMECS	RANK	RETURN PERIOD (YEAR)	PROBABILITY OF EXCEEDENCE (%)
1959	506	1978	3355	1	32.00	3.13
1960	1444	1989	2401	2	16.00	6.25
1961	721	1964	2216	3	10.67	9.38
1962	537	1980	1997	4	8.00	12.50
1963	668	1979	1996	5	6.40	15.63
1964	2216	1986	1620	6	5.33	18.75
1965	629	1973	1586	7	4.57	21.88
1966	1189	1985	1571	8	4.00	25.00
1967	1246	1981	1566	9	3.56	28.13
1968	1302	1988	1557	10	3.20	31.25
1969	1416	1971	1444	11	2.91	34.38
1970	1387	1960	1444	12	2.67	37.50
1971	1444	1969	1416	13	2.46	40.63
1972	1217	1987	1416	14	2.29	43.75
1973	1586	1970	1387	15	2.13	46.88
1974	1161	1984	1359	16	2.00	50.00
1975	1184	1968	1302	17	1.88	53.13
1976	915	1967	1246	18	1.78	56.25
1977	866	1972	1217	19	1.68	59.38
1978	3355	1966	1189	20	1.60	62.50
1979	1996	1975	1184	21	1.52	65.63
1980	1997	1974	1161	22	1.45	68.75
1981	1566	1982	1131	23	1.39	71.88
1982	1131	1983	1127	24	1.33	75.00
1983	1127	1976	915	25	1.28	78.13
1984	1359	1977	866	26	1.23	81.25
1985	1571	1961	721	27	1.19	84.38
1986	1620	1963	668	28	1.14	87.50
1987	1416	1965	629	29	1.10	90.63
1988	1557	1962	537	30	1.07	93.75
1989	2401	1959	506	31	1.03	96.88

Type-I probability paper and a straight line is fitted through the plotted points. Return periods or probability of occurrence or exceedence of an event is then determined from the fitted line.

Statistical parameters for this distribution are mean and standard deviation. The discharge corresponding to a certain return period can be determined by using these parameters in the simplified equation of Gumbel Distribution:

$$Q_{Tr} = \overline{Q} - 0.45\, S_Q + 0.7797\, S_Q \ln T_r$$

Where $\overline{Q}$ is mean, S_Q standard deviation of discharge data and Q_{Tr} is the magnitude of the event with return period T_r. The Linear Gumbel, Log Gumbel and Gumbel Equation results are given in Table 4.4 and shown in Figs.4.2 to 4.3.

4.2.1.4 Log-Pearson Type-III Distribution

Log-Pearson Type-III Distribution is one of the most widely used for extreme value series. The distribution conforms to the log-normal distribution with skew = 0. The three statistical parameters - Log-Mean, Log-Standard Deviation and Log-skew co-efficient are used for Log-Pearson Type-III Distribution. Skew curve factor K_{Tr} for each return period is obtained from Table-4.5.

Annual maximum peak discharges, Q_{Tr}, with return period T_r have been obtained by using the following equation:

$$\text{Log } Q_{Tr} = \overline{\text{Log } Q} + K_{Tr}\, S_{LogQ}$$

Where $\overline{\text{Log } Q}$ is Log Mean of the peak discharges, S_{LogQ}, Log Standard Deviation and K_{Tr} is the skew curve factor corresponding to return period Tr and Log Skewness Co-efficient G_{LogQ}. These terms can be defined mathematically as:

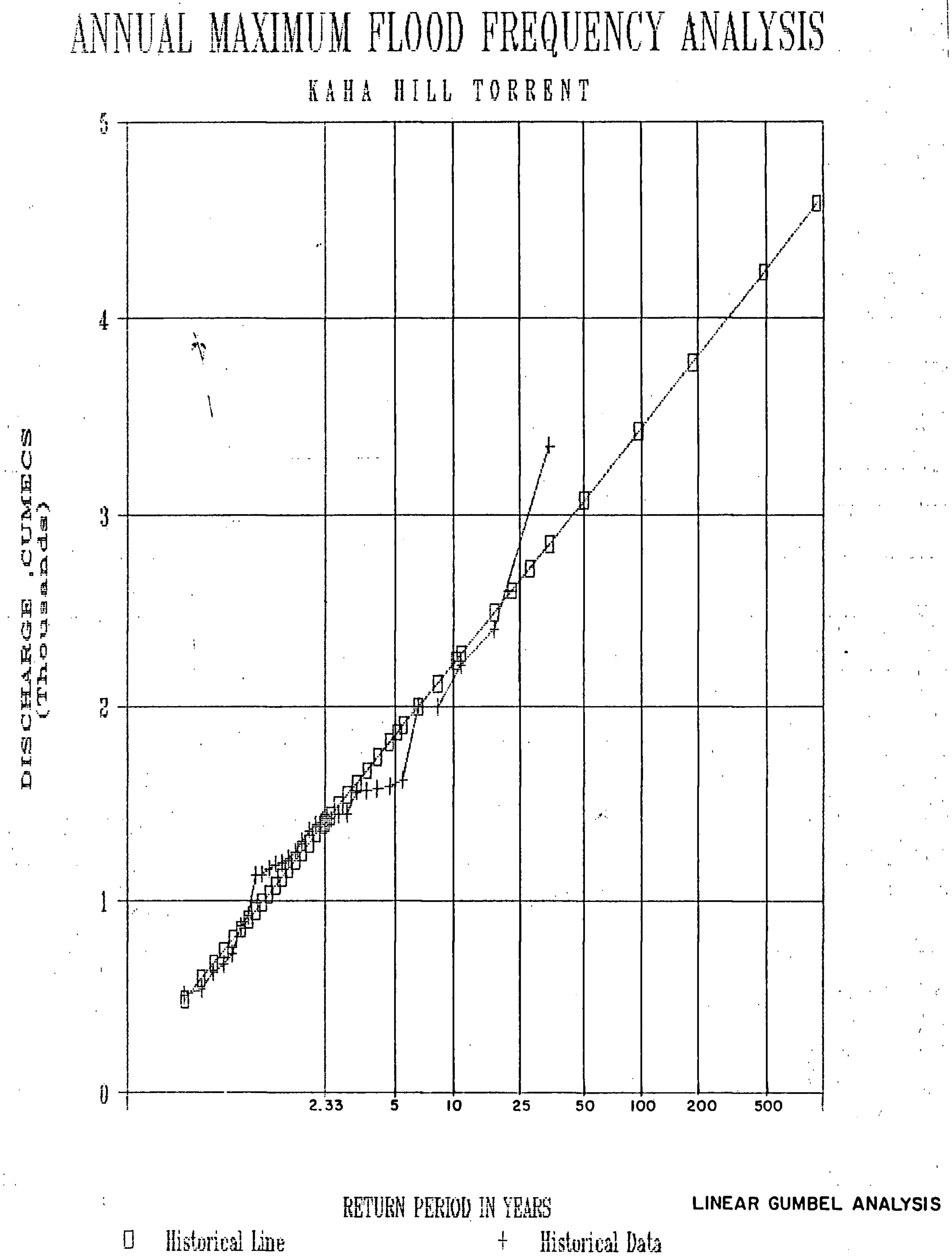
$$\text{Log } Q = \frac{\sum \text{Log } Q_i}{N}$$

$$S \text{ Log } Q = \frac{[\sum (\text{Log } Q - \text{Log } Q)^2]^{\frac{1}{2}}}{(N-1)^{\frac{1}{2}}}$$

TABLE - 4.4

GUMBEL DISTRIBUTION RESULTS (KAHA HILL TORRENT)

Return Period, Years	DISCHARGE IN CUMECS (CUSECS) FROM		
	Linear Gumbel Paper	Log Gumbel Paper	Gumbel Equation
2.33	1,399 (49,420)	1,400 (49,500)	1,499 (52,965)
5	1,858 (65,810)	1,770 (62,500)	1,844 (65,131)
10	2,241 (79,160)	2,152 (76,000)	2,157 (76,175)
25	2,661 (94,000)	2,732 (96,500)	2,570 (90,774)



LINEAR GUMBEL ANALYSIS

Fig. 4.2

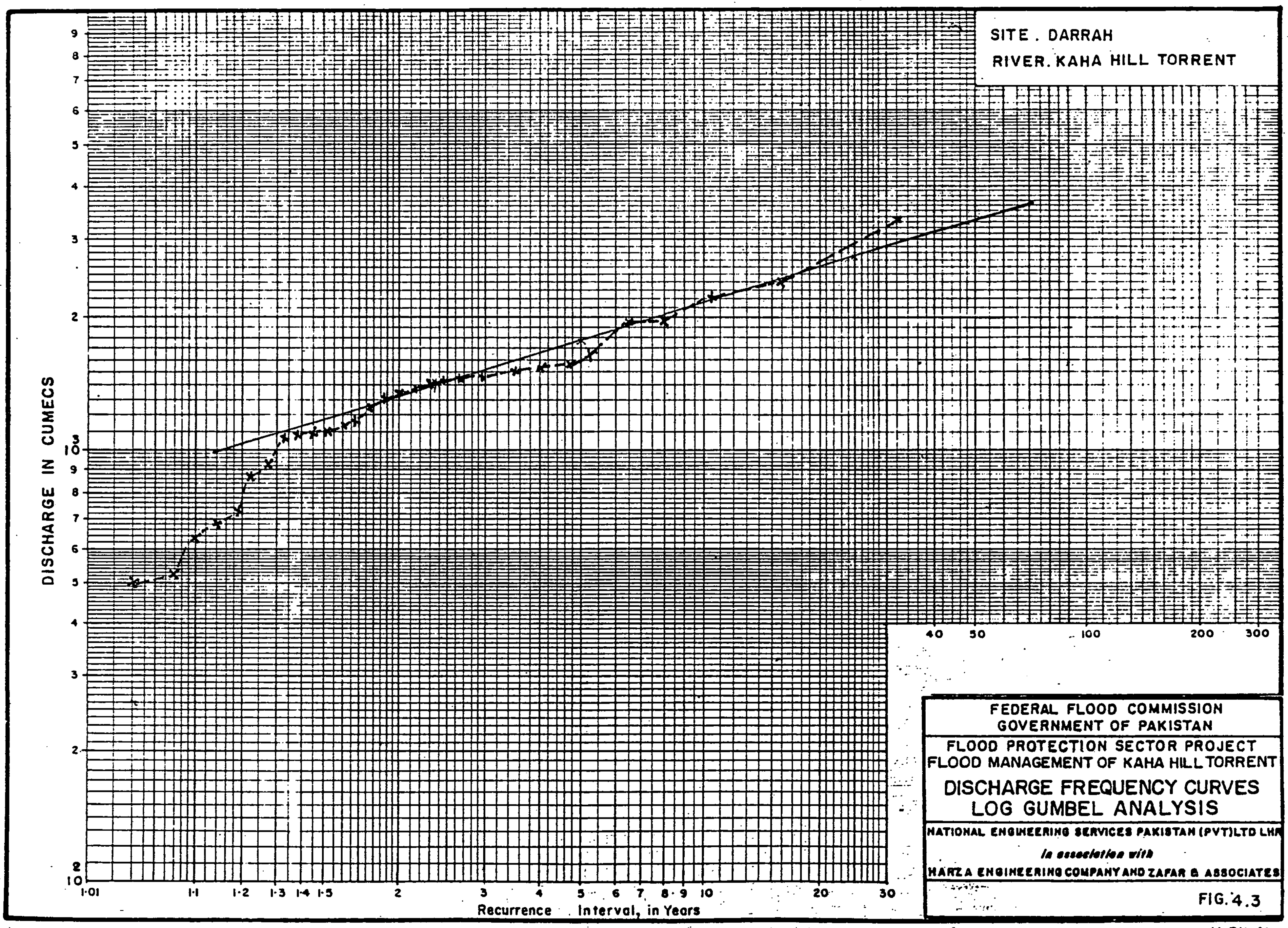


FIG. 4.3

M. BILAL

TABLE-4.5

SKEW CURVE FACTORS -K- FOR USE WITH LOG PEARSON TYPE III DISTRIBUTION

Coefficient of Skew (g)	Recurrence Interval in Years							
	2	5	10	25	50	100	200	1000
	Per cent Chance of Occurrence							
	50	20	10	4	2	1	0.5	0.1
3.0	-0.396	0.420	1.180	2.278	1.152	4.051	4.970	7.250
2.5	-0.360	0.518	1.250	2.262	3.048	3.845	4.652	6.600
2.2	-0.330	0.574	1.284	2.240	2.970	3.705	4.444	6.200
2.0	-0.307	0.609	1.302	2.219	2.912	3.605	4.298	5.910
1.8	-0.282	0.643	1.318	2.193	2.848	3.489	4.147	5.660
1.6	-0.254	0.675	1.329	2.163	2.780	3.383	3.590	5.390
1.4	-0.225	0.705	1.337	2.128	2.706	3.271	3.828	5.110
1.2	-0.195	0.732	1.340	2.087	2.626	3.149	3.661	4.820
1.0	-0.164	0.758	1.340	2.043	2.542	3.022	3.489	4.540
0.9	-0.148	0.769	1.339	2.018	2.498	2.957	3.401	4.395
0.8	-0.132	0.780	1.336	1.998	2.453	2.891	3.312	4.250
0.7	-0.116	0.790	1.333	1.967	2.407	2.824	3.223	4.105
0.6	-0.099	0.800	1.328	1.939	2.359	2.755	3.132	3.960
0.5	-0.083	0.808	1.323	1.910	2.311	2.886	3.041	3.815
0.4	-0.066	0.816	1.317	1.880	2.261	2.615	2.949	3.670
0.3	-0.050	0.824	1.309	1.849	2.211	2.544	2.856	3.525
0.2	-0.033	0.830	1.301	1.818	2.159	2.472	2.763	3.380
0.1	-0.017	0.836	1.292	1.785	2.107	2.400	2.670	3.235
0	0	0.847	1.282	1.751	2.054	2.326	2.576	3.090
-.1	0.017	0.836	1.270	1.716	2.000	2.252	2.482	2.950
-.2	0.033	0.850	1.258	1.680	1.945	2.178	2.388	2.810
-.3	0.050	0.853	1.245	1.643	1.890	2.104	2.294	2.675
-.4	0.066	0.853	1.231	1.606	1.834	2.029	2.201	2.540
-.5	0.083	0.856	1.216	1.567	1.777	1.955	2.108	2.400
-.6	0.099	0.857	1.200	1.528	1.720	1.880	2.016	2.275
-.7	0.116	0.857	1.183	1.488	1.663	1.806	1.926	2.150
-.8	0.132	0.856	1.166	1.448	1.606	1.733	1.837	2.035
-.9	0.148	0.854	1.147	1.407	1.549	1.660	1.749	1.910
-1.0	0.164	0.852	1.228	1.366	1.492	1.588	1.664	1.800
-1.2	0.195	0.844	1.086	1.282	1.379	1.449	1.501	1.625
-1.4	0.225	0.832	1.041	1.198	1.270	1.318	1.351	1.465
-1.6	0.254	0.817	0.994	1.116	1.166	1.197	1.216	1.280
-1.8	0.282	0.799	0.945	1.035	1.069	1.087	1.097	1.130
-2.0	0.307	0.777	0.Ø95	0.959	0.980	0.990	0.995	1.000
-2.2	0.330	0.752	0.844	0.888	0.900	0.905	0.907	0.910
-2.5	0.360	0.711	0.771	0.793	0.798	0.799	0.800	0.802
-3.0	0.396	0.636	0.660	0.666	0.666	0.667	0.667	0.668

.015

$$G_{Log\ Q} = \frac{[\sum (Log\ Q_i - Log\ Q)^3]}{(N-1)\ (N-2)\ (S_{Log\ Q})^3}$$

N is number of years of record.

The three statistical parameters have been calculated using the peak discharge data and are given on Table 4.6. These parameters have been used to evaluate flood peaks corresponding to return periods of 2.33, 5, 10 and 25 years and are listed in Table 4.7. Fig.4.4 shows the plotting of these discharges on Log Normal Probability Paper.

4.2.1.5 Selection of Frequency Distribution:

The frequency curves/lines have been fitted through the plots of historical data on Gumbel Powell probability (both with linear and log ordinate) for Gumbel Distribution and on log-normal probability paper for Log Pearson Type-III Distribution. There is no set criteria for selection of a distribution. Only criteria that is followed is the goodness of fit of the distribution to the data of one or more streams. Goodness of fit of the frequency curves to the historical/synthesized data have been checked by Chi-Square Test[1/]. The magnitudes of Chi-Square parameters which determine the goodness of fit of the frequency curve, have been worked out and compared for all the three types of frequency curves for each hill torrent. The distribution giving least value of Chi-Square parameter is the best fit and is selected for determination of the peak discharges corresponding to various return periods. Linear Gumbel has shown the best result and the peak discharges as estimated for 25-year return period is 2,662 cumecs (94,000 cfs).

4.3 PRECIPITATION DATA ANALYSIS

Short length of historical flood flow data and its quality warrant that the results derived from such data should be supplemented and supported by additional studies.

1/ Handbook of Applied Hydrology by V.T.Chow.

TABLE 4.6

FLOOD FREQUENCY ANALYSIS
LOG PEARSON TYPE III DISTRIBUTION

RIVER..............................=KAHA HILL TORRENT
SITE...............................=DARRAH
PERIOD OF DATA AVAILABLE.......... = 1959 - 1989
NUMBER OF YEARS RECORD (N)........ = 31

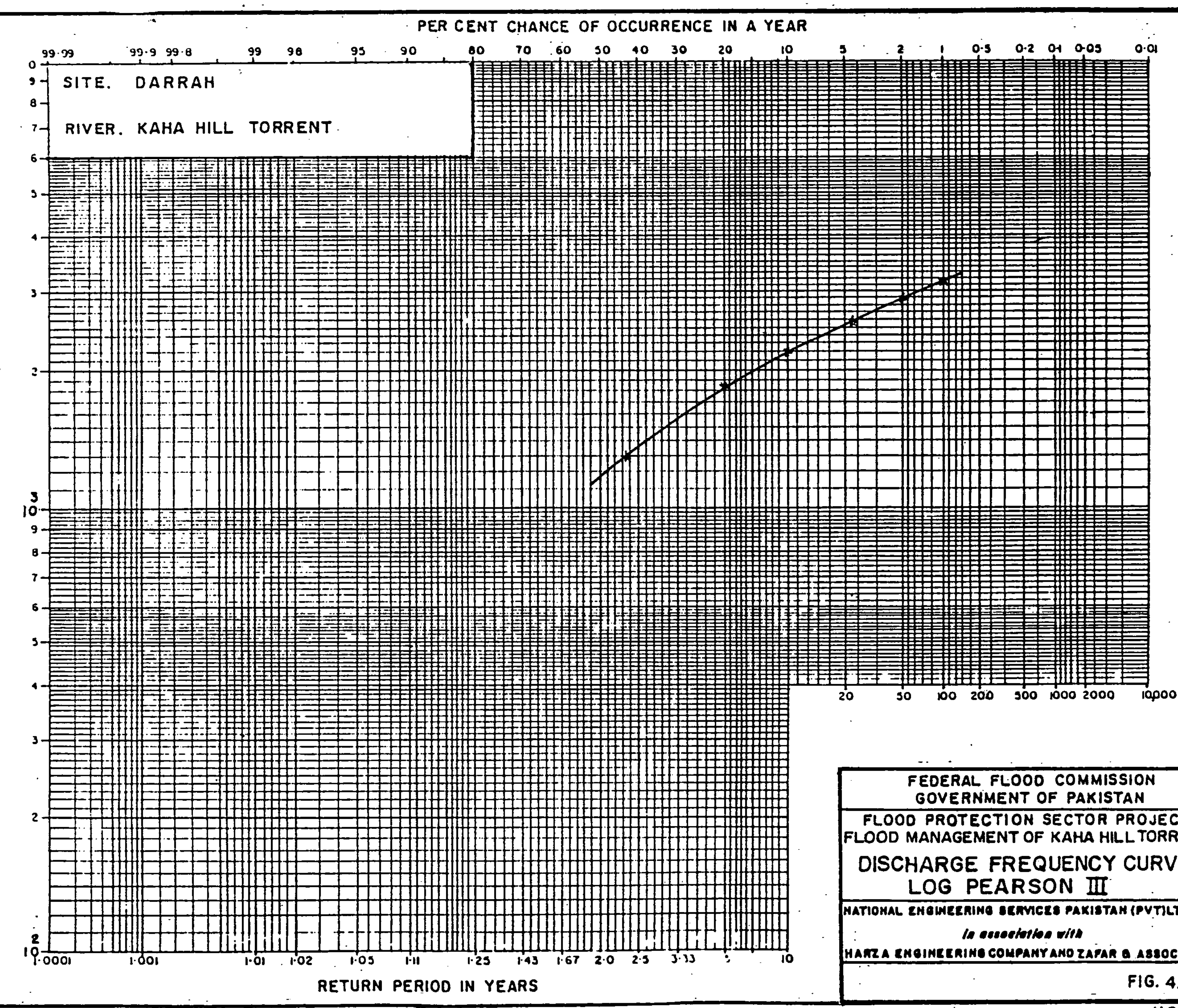
LOG MEAN OF DISCHARGE...........= 3.1022565
LOG STD. DEVIATION OF DISCHARGE..= 0.1858652
LOG SKEW COEFF...................= -0.298242
KTR (25.00 YEARS RETURN PERIOD)= 1.647 (TABLE)
LOG QTR..........................= 3.4083766
DISCHARGE(CUMECS)................= 2561

YEAR	PEAK DISCHARGE CUSECS	PEAK DISCHARGE CUMECS	LOG (Q)	LOG DIFF.	LOG DIFF. SQUARE	LOG DIFF. CUBE
1959	17859	506	2.704	-0.398	0.159	-0.063
1960	51017	1444	3.160	0.057	0.003	0.000
1961	25448	721	2.858	-0.245	0.060	-0.015
1962	18978	537	2.730	-0.372	0.138	-0.051
1963	23602	668	2.825	-0.277	0.077	-0.021
1964	78264	2216	3.346	0.243	0.059	0.014
1965	22210	629	2.799	-0.304	0.092	-0.028
1966	42000	1189	3.075	-0.027	0.001	-0.000
1967	44000	1246	3.095	-0.007	0.000	-0.000
1968	46000	1302	3.115	0.012	0.000	0.000
1969	50000	1416	3.151	0.049	0.002	0.000
1970	49000	1387	3.142	0.040	0.002	0.000
1971	51000	1444	3.160	0.057	0.003	0.000
1972	43000	1217	3.085	-0.017	0.000	-0.000
1973	56000	1586	3.200	0.098	0.010	0.001
1974	41000	1161	3.065	-0.037	0.001	-0.000
1975	41815	1184	3.073	-0.029	0.001	-0.000
1976	32300	915	2.961	-0.141	0.020	-0.003
1977	30575	866	2.937	-0.165	0.027	-0.004
1978	118500	3355	3.526	0.423	0.179	0.076
1979	70500	1996	3.300	0.198	0.039	0.008
1980	70519	1997	3.300	0.198	0.039	0.008
1981	55322	1566	3.195	0.093	0.009	0.001
1982	39960	1131	3.054	-0.049	0.002	-0.000
1983	39800	1127	3.052	-0.050	0.003	-0.000
1984	48000	1359	3.133	0.031	0.001	0.000
1985	55483	1571	3.196	0.094	0.009	0.001
1986	57226	1620	3.210	0.107	0.012	0.001
1987	50000	1416	3.151	0.049	0.002	0.000
1988	55000	1557	3.192	0.090	0.008	0.001
1989	84820	2401	3.380	0.278	0.077	0.022

TABLE - 4.7

LOG PEARSON TYPE III DISTRIBUTION RESULTS

RETURN PERIOD YEARS	PEAK DISCHARGE CUMECS (CUSECS)
2.33	1,292 (45,630)
5	1,823 (64,390)
10	2,158 (76,220)
25	2,561 (90,450)



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FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

DISCHARGE FREQUENCY CURVES
LOG PEARSON III

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FIG. 4.4

There is negligible snowfall in the catchments of Kaha Hill torrent and flood flows are caused by rainfall only. A network of precipitation measuring stations exists in the catchment area and a relatively longer period of record of some of the stations is available. This data has been utilized to estimate flood peaks, flood hydrographs and volume of annual run-off with monthly distribution for the major hill torrents and also at other points of interest for different return periods.

4.3.1 Rainfall Pattern and Distribution[1/]

Precipitation records of the sites were tabulated and maximum rainfall for various periods i.e., one day to seven days, 15 days, monthly, monsoon period (June to September) and annual rainfall were computed. Annual and monsoon isohyetal maps were prepared (Exhibit 4.1), which indicated that rainfall is minimum at the southern extremity of the area and is maximum in the north-western part. The rainfall generally increases at high altitudes. In the north-western part of the area, there is an ellipsoidal belt with rainfall of the order of 380mm (15 inches) with Musa Khel as one of the foci of the elliptical area.

Taking into consideration the annual isohyetes and monsoon isopercentals, the catchment area of D.G.Khan Hill Torrents has been divided into three zones. Zone I, II and III (Exhibit 4.1). The boundaries of the zones are marked along the catchment boundaries of hill torrents so that none of the hill torrents is divided into two or more than two parts, which would otherwise complicate the analysis unnecessarily. In this way Kaha Hill Torrent falls in Zone-III.

Zone-I is the area with the maximum altitudes of about 600m (2,000 ft). The rainfall in this area is minimum and varies between 125mm to 250mm (5 inches to 10 inches), of which 65 percent falls during monsoon. Zone-III is the area with maximum altitudes. The maximum elevation in this area are around 3,000m (10,000 ft). This area is of maximum precipitation and annual rainfall varies

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1/ Planning and Design Report, Volume-I, Flood Management of D.G.Khan Hill Torrents, NESPAK - 1984.

from about 250mm to 370mm (10 inches to 15 inches), of which nearly 55 percent falls in monsoon. Storm sizes during monsoon are of medium to high intensity with short durations.

4.3.2 Design Storm

Analysis of rainfall records indicates that rain storms generally follow a set pattern. There are winter rains which start in January and continue intermittently till April. The intensity of these rains is low and areal extent is generally limited. Moreover, the interval between one shower and the other is often so long that antecedent moisture almost totally evaporates before the onset of the next rain and consequently they produce a very low percentage of run-off. On the other hand, monsoon season which starts from June and lasts till September experiences rainfall storms of moderate intensity and extensive areal coverage. The interval between the two consecutive storms is relatively small, which keeps the soil moisture high and depressions filled so that any significant amount of rainfall is usually reflected in a high flood with high damage potential in the area. It is, therefore, more expedient that design storm should be selected from the pattern of the monsoon season.

Master planning studies carried for D.G.Khan Hill Torrents indicated that flood management measures for Hill Torrents should be designed for a theoretical return period of about 25-year. Flood damages and estimated costs for various return periods were annutized and curves were drawn for major hill torrents of the area. The optimal design return period was determined which varied from about 20 years to 29 years. From these values an average of about 25-year was taken for design purposes. Kaha Hill Torrent being a component of D.G.Khan area is proposed to be managed for the same return period. It may be clarified that the 25-year return period flood has been adopted for the design of structures under normal conditions wherein a free-board of 1.5m has been provided over the maximum design flood level. Under exceptional conditions when floods of higher magnitude are to be passed for short durations the structures will be able to cater for the same through encroachment on free-board without overtopping. Under exceptional circumstances the structures will, therefore, be able to pass floods of upto 100-year return period with minor damage to downstream protection.

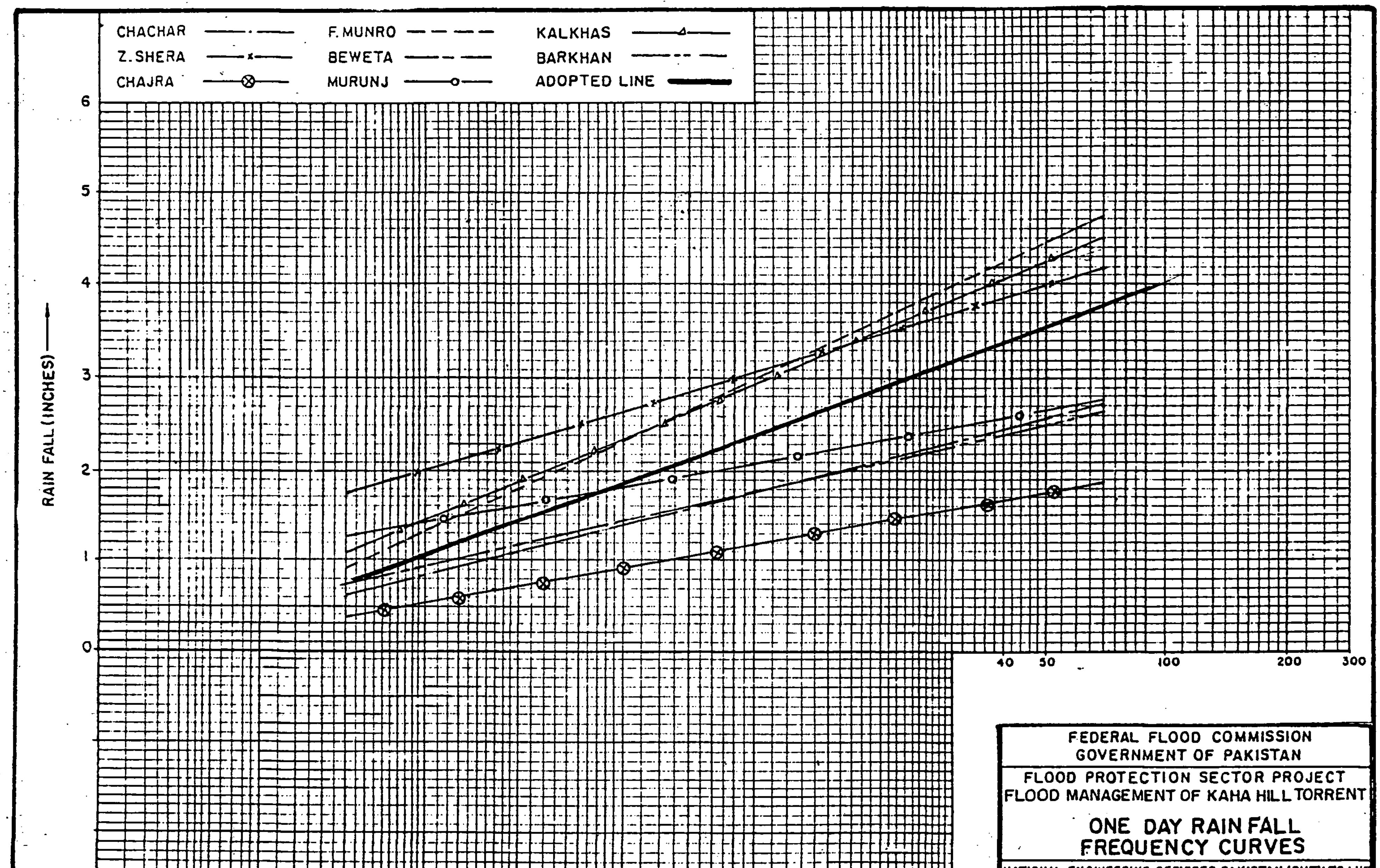
For synthesis of run-off from precipitation, the shape of the run-off hydrograph is governed by the distribution of precipitation within a day, especially for catchments with times of concentration less than one day. In the absence of actual precipitation distribution data, the assumption of uniform precipitation distribution is likely to result in peaks that are too low. It is therefore, imperative to use hourly rainfall for synthesis of run-off hydrographs. However, due to non-availability of hourly rainfall records for Kaha Basin, daily data had to be used for synthesis of run-off hydrographs.

The linear Gumbel method has been used for frequency analysis for one day maximum rainfall data of Chachar, Mard Bun, Fort Munro, Barkhan, Bewatta, Murunj, Ziarat Sheru and Kalkhas raingauge stations. One day rainfalls with their corresponding return periods are plotted on Gumbel Paper and a best fit straight line is drawn through the points (raingauge stations lines) as shown in Fig.4.5. To convert the daily rainfall into true 24 hours rainfall, the results of the frequency analysis of the daily rainfall data have been multiplied by 1.13 factor [1/]. To convert the point rainfall into area rainfall a multiplying factor of 0.735[2/] is used.

4.3.3 Evaluation of Hydrologic Parameters Related to Precipitation and Catchment Characteristics

Estimation of flood peaks/hydrographs from precipitation data involves parameters which can be sub-divided into two groups namely precipitation parameters e.g., magnitude of rainfall in a certain period of time and its distribution both in time and space; and catchment characteristics e.g., area, shape, slopes, soil, vegetal cover etc., of the watershed.

1/ Khan Wirasat Ullah, Report on the Hydrometeorology of Balochistan (Vol.I), Chapter-9.
2/ Flood Estimation - Design Guide - Balochistan Minor Irrigation and Agriculture Development Project.



FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

ONE DAY RAIN FALL FREQUENCY CURVES

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FIG. 4.5

In order to study the time distribution of rainfall, Depth Frequency Curves and Intensity Duration Frequency Curves are used. These curves have been prepared for different return periods.

The recording raingauge station at Kohlu outside the boundary of the catchment, records hourly rainfall; therefore hourly rainfall distribution pattern at Kohlu was selected to provide the hourly pattern of daily rainfall within Kaha catchment.

The data series and the frequency distribution selected for analysing precipitation data are same as that for stream flow data analysis i.e., Annual Series and Gumbel Distribution, so that results derived from the two types of data can be compared.

For the computation of hydrologic parameters, Depth Duration Frequency and Intensity Duration Frequency Curves have been developed for 2.33, 5, 10 and 25 years and have been shown in Figs.4.6 to 4.7. These curves have been used to estimate flood peak corresponding to design storm using the Rational Formula.

4.4 ESTIMATION OF HYDROLOGIC PARAMETERS RELATED TO CATCHMENT CHARACTERISTICS

The part of the rainfall of a watershed which is converted into run-off depends upon the nature of soil; the type and extent of vegetal cover as well as the agricultural practices such as contouring and terracing. US SCS[1/] (United States Soil Conservation Services) have developed a method, which takes into account all these parameters, while estimating run-off from a basin.

In this method, soils are classified in four groups A, B, C & D depending upon the infiltration and transmission rates. Soils in group A have high infiltration and transmission rates and, therefore, are associated with very low run-off potential. Soils in group B and C have intermediate infiltration and transmission rates and have run-off potential higher than A and lower than D, respectively. The effect of the surface conditions have been evaluated by determining 'Land Use' and 'Land Treatment'. Land use in a

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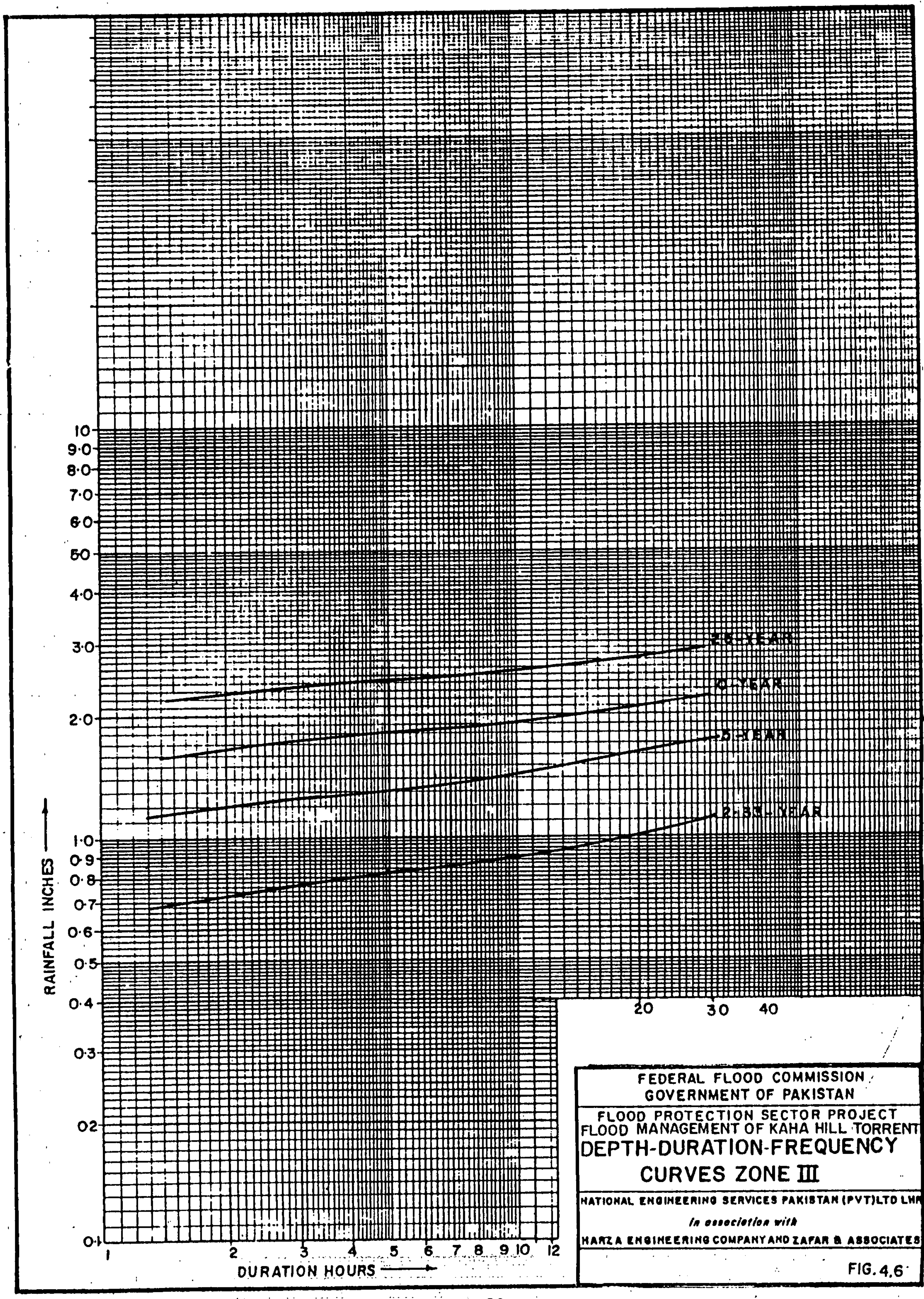
1/ US Department of Agriculture, Soil Conservation Services, Section 4, Hydrology.



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DEPTH-DURATION-FREQUENCY CURVES ZONE III

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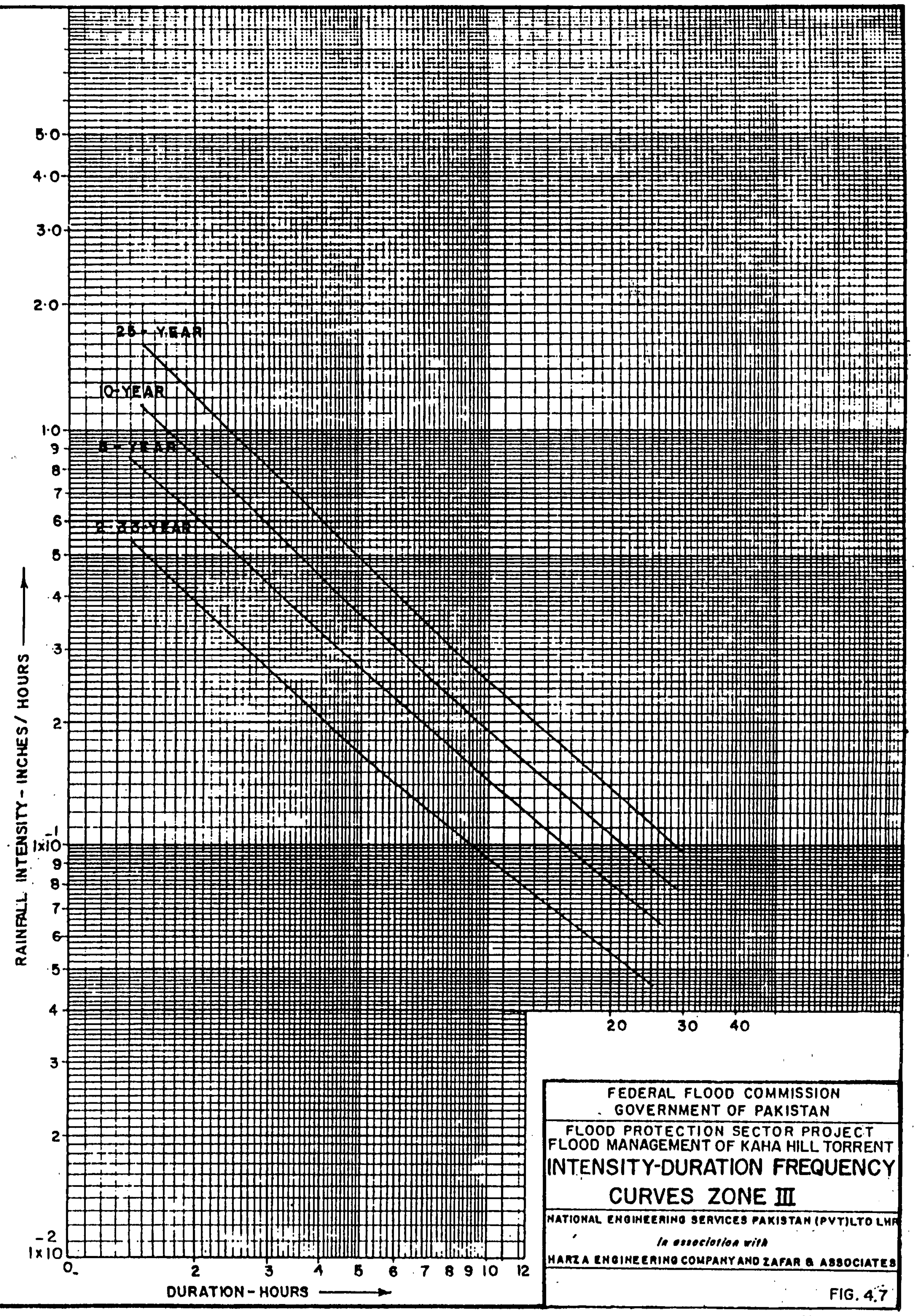
FIG. 4.6



FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

INTENSITY-DURATION FREQUENCY CURVES ZONE III

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FIG. 4.7

M. BILAL

watershed includes every kind of vegetation. Litter and mulch and fallow as well as non-agricultural uses such as water surfaces (Lakes, Swamp, etc) and impervious surfaces (roads, roofs etc). Land treatment applies mainly to agricultural uses and includes mechanical practices such as contouring or terracing and management practices such as grazing control or rotation of crops.

The combination of a hydrologic soil group (Soil) and a land-use and treatment class (cover) is a hydrologic soil cover complex. The run-off generating potential of this complex is represented by a curve number which is determined from tables developed from evaluation of the hydrologic data of the gauged watersheds. The higher the curve number of a complex, the higher is its run-off potential.

The soil moisture conditions prior to occurrence of a rainfall storm also influence the amount of run-off produced. If soil moisture is high, the loss of water by absorption into the ground is less which results in high run-off. Soil moisture conditions or Antecedent Moisture Conditions (AMC) are divided into three categories, I, II and III depending upon the 5-day antecedent precipitation. The classification is described below:

Antecedent Moisture Conditions (AMC)	5-day Total Antecedent Precipitation Inches	
	DORMANT SEASON	GROWING SEASON
I	Less than 0.5	Less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	More than 1.1	More than 2.1

For watershed Kaha Hill Torrent, the above mentioned catchment characteristics have been defined below as an example:

-	Soil Group	C and D
-	Land Use and Treatment	Fallow, Pasture or Range (Fair)
-	Antecedent Moisture Condition (AMC)	Dormant Season
	AMC-I	76
	AMC-II	89
	AMC-III	96

Once the curve number for a hydrologic soil cover complex is known, the direct run-off may be determined by using a standard curve or by the use of the following equation:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

Where Q = Volume of direct run-off in inches

P = The precipitation from which the direct run-off is to be estimated

S = The potential infiltration in inches and is related to curve number as under:

$$S = \frac{1000}{CN} - 10$$

Where CN is the curve number

4.5 SELECTION OF METHODOLOGY FOR DETERMINATION OF DESIGN HYDROGRAPH

Quality and quantity of available hydrologic data determine the methodology to be used for evaluation of various parameters for management of floodflows of a watershed. The stream flow data of Kaha Hill Torrent comprises yearly peak discharges and a few hydrographs. In most cases, the stages corresponding to either rising or recession limbs are missing. Moreover, the time period between the two stage readings is too long to define explicitly the shape of the hydrograph. In view of fragmentry hydrologic data, Kaha Hill Torrent can be classified in the category of ungauged watersheds. Transposition of hydrograph from a gauged site of similar physiographic and climatic conditions is also not feasible as comparable data is not available. Therefore, the only feasible solution was to develop hydrographs from various synthetic techniques. The dimensionless hydrographs of US SCS developed by Victor Mockus[1/] is one of the methods selected for computing hydrographs of various return periods. It was derived from a large number of natural unit hydrographs from watersheds varying widely in size and geographical locations, and, therefore, has the flexibility of fitting on catchments varying widely in size and

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1/ National Engineering Handbook, Section 4, Hydrology, US Department of Agriculture.

meteorological environments. This dimensionless linear hydrograph has its ordinate values expressed in a dimensionless ratio Q/Q_p and its abcissa values at T/T_p. Multiplying ordinate values with peak discharge and abcissa values by time to peak yields the desired unit hydrograph.

4.5.1 Size

The catchment boundaries were drawn from G.T.Sheets obtained from Survey of Pakistan. The area was then measured by planimeter.

4.5.2 Time of Concentration

Modified Kirpich[1/] formula was used for calculating time of concentration which is as follows:

$$Tc = \frac{L^{1.15}}{7700 \times (H)^{0.38}}$$

Where Tc = Time of concentration in hours (28 hours)

L = Length of longest stream in the watershed in feet.

H = Difference of elevation in length L in feet.

4.5.3 Time to Peak

Time to peak, T_p was calculated from T_c by the relation:

$$T_p = \frac{D}{2} + 0.6\ T_c$$

Where T_p = Time to peak in hours (19 hours)

D = Unit storm duration.

1/ Kirpich Z.P. 'Time of Concentration of Small Agricultural Watersheds' Civil Engineering, Vol-10 No.6, Page-362 (June 1940).

4.5.4 Time of Recession

The time of recession, when flow will cease to exist, is calculated by the relation:

$$T_r = 1.67\ T_p$$

Where T_r = Time of recession after peak in hours (32 hours)

4.5.5 Unit Storm Duration

Unit storm duration is the duration of storm for unit hydrograph made from dimensionless hydrograph. For the dimensionless hydrograph of Victor Mockus, it should be 20 percent of time to peak and should not exceed beyond 25 percent.

Unit Storm Duration D is given by:

$$D = 0.133\ T_c \qquad \text{(4 hours)}$$

4.5.6 Peak Rate of Flow

Peak rate of flow has been calculated from the following formula:

$$Q_p = \frac{484 \times A \times Q}{T_p}$$

Where Q_p = Peak rate of flow in cusecs

A = Catchment area in sq.miles

Q = Depth of run-off in inches

T_p = Time of peak in hours

4.5.7 Determination of Unit Hydrograph

Knowing peak discharge and time to peak of the unit bhydrograph, complete unit hydrograph is obtained by multiplying time ratios and discharge ratios of the dimensionless hydrograph with time to peak and peak discharge of the unit hydrograph.

4.5.8 Flood Hydrographs

The magnitude and distribution of rainfall have been obtained from design storm. Computer program has been developed to estimate the resulting flood of each 4.00 hour sub-hydrograph. The results of design flood peak for various return periods are given in Table 4.8. The computer output lists the catchment characteristics for 2.33, 5, 10 and 25-years return period are given in Table 4.9 to 4.12 and are plotted in Figs.4.8 to 4.11.

TABLE - 4.8

FLOOD PEAK WORKED OUT BY
VICTOR MOCKUS METHOD

Return Period Years	Flood Hydrograph Peaks Cumecs	(Cusecs)
2.33	927	(32,744)
5	1,567	(55,340)
10	2,106	(74,376)
25	2,815	(99,436)

TABLE - 4.9

FLOOD HYDROGRAPH - KAHA HILL TORRENT

NAME OF CATCHMENT	=	KAHA HILL TORRENT
RETURN PERIOD	=	2.33-YEAR
AREA DRAINING. SQ.MILES	=	2208.000
2.33-YEAR,24-HOUR POINT RAINFALL	=	1.458
2.33-YEAR,24-HOUR POINT RAINFALL	=	1.458
POINT TO AREA REDUCTION FACTOR	=	0.735
2.33-YEAR,24-HOUR AREAL RAINFALL	=	1.071
ADOPTED STORM 24-HOUR RAINFALL	=	1.071
MULTIPLYING FACTOR FOR		1.000
2.33-YEAR	=	
CURVE NUMBER	=	96.00
S	=	0.4167
0.2S	=	0.0833
0.8S	=	0.3333
TIME TO PEEAK(HOUR)	=	19.000
PEAK DISCHARGES(CUSECS)	=	56246
TIME INTERRVAL(HOUR)	=	4.000

DIMENSIONLESS HYDROGRAPH		UNIT HYDROGRAPH				DESIGN STORM					RESULTING
		Calculated		Adopted		Time	Pattern	Accmltd	Acc:Excess	Inc:Excess	Flood
		T	Q	T	Q		Rainfall	Rainfall	Rainfall	Rainfall	Hydrograph
T/Tp	Q/Qp	Hours	Cusecs	Hours	Cusecs	Hours		Inches	Inches	Inches	Cusecs
0.000	0.00	0.00	0	0.00	0	0.0	0.000	0.000	0.000	0.107	0
0.100	0.10	1.90	5625	4.00	11841	4.00	0.331	0.355	0.107	0.398	1267
0.200	0.20	3.80	11249	8.00	23682	8.00	0.802	0.859	0.505	0.055	7245
0.300	0.30	5.70	16874	12.00	35524	12.00	0.860	0.921	0.560	0.051	13873
0.400	0.400	7.60	22498	16.00	47365	16.00	0.913	0.978	0.611	0.050	21103
0.500	0.500	9.50	28123	20.00	54473	20.00	0.965	1.034	0.661	0.034	28423
0.600	0.600	11.40	33748	24.00	47383	24.00	1.000	1.071	0.695	0.000	32744
0.700	0.700	13.30	39372	28.00	40292	28.00	1.000	1.071	0.695	0.000	31156
0.800	0.800	15.20	44997	32.00	33202	32.00	1.000	1.071	0.695	0.000	28547
0.900	0.900	17.10	50621	36.00	26111	36.00	1.000	1.071	0.695	0.000	24980
1.000	1.000	19.00	56246	40.00	19020	40.00	1.000	1.071	0.695	0.000	20536
1.100	0.940	20.90	52878	44.00	11930	44.00	1.000	1.071	0.695	0.000	15608
1.200	0.880	22.80	49510	48.00	4839	48.00	1.000	1.071	0.695	0.000	10680
1.300	0.820	24.70	46142	52.00	0	52.00	1.000	1.071	0.695	0.000	5993
1.400	0.760	26.60	42774	56.00	0	56.00	1.000	1.071	0.695	0.000	2720
1.500	0.700	28.50	39406	60.00	0	60.00	1.000	1.071	0.695	0.000	1495
1.600	0.640	30.40	36038	64.00		64.00	1.000	1.071	0.695	0.000	650
1.700	0.580	32.30	32670	68.00		68.00	1.000	1.071	0.695	0.000	165
1.800	0.520	34.20	29302	72.00		72.00	1.000	1.071	0.695	0.000	0
1.900	0.460	36.10	25934	76.00		76.00	1.000	1.071	0.695	0.000	0
2.000	0.400	38.00	22566	80.00		80.00	1.000	1.071	0.695	0.000	0

TABLE - 4.10

FLOOD HYDROGRAPH - KAHA HILL TORRENT

NAME OF CATCHMENT	=	KAHA HILL TORRENT
RETURN PERIOD	=	5 YEARS
AREA DRAINING, SQ.MILES	=	2208.000
5 YEARS , 24-HOUR POINT RAINFALL	=	2.147
5 YEARS , 24-HOUR POINT RAINFALL	=	2.147
POINT TO AREA REDUCTION FACTOR	=	0.735
5 YEARS , 24 -HOUR AREAL RAINFALL	=	1.578
ADOPTED STORM 24-HOUR RAINFAL	=	1.578
MULTIPLYING FACTOR FOR 5 YEARS	=	1.000
CURVE NUMBER	=	96.00
S	=	0.4167
0.2S	=	0.0833
0.8S	=	0.3333
TIME TO PEAK(HOUR)	=	19.000
PEAK DISCHARGES(CUSECS)	=	56246
TIME INTERVAL(HOUR)	=	4.000

DIMENSIONLESS HYDROGRAPH		UNIT HYDROGRAPH				DESIGN STORM					RESULTING
		Calculated		Adopted		Time	Pattern	Accmltd	Acc:Excess	Inc:Excess	Flood
		T	Q	T	Q		Rainfall	Rainfall	Rainfall	Rainfall	Hydrograph
T/Tp	Q/Qp	Hours	Cusecs	Hours	Cusecs	Hours		Inches	Inches	Inches	Cusecs
0.000	0.00	0.00	0	0.00	0	0.0	0.000	0.000	0.000	0.225	0
0.100	0.10	1.90	5625	4.00	11841	4.00	0.331	0.522	0.225	0.649	2667
0.200	0.20	3.80	11249	8.00	23682	8.00	0.802	1.266	0.874	0.086	13018
0.300	0.30	5.70	16874	12.00	35524	12.00	0.860	1.357	0.960	0.079	24384
0.400	0.400	7.60	22498	16.00	47365	16.00	0.913	1.441	1.039	0.078	36682
0.500	0.500	9.50	28123	20.00	54473	20.00	0.965	1.523	1.116	0.053	48835
0.600	0.600	11.40	33748	24.00	47383	24.00	1.000	1.578	1.169	0.000	55341
0.700	0.700	13.30	39372	28.00	40292	28.00	1.000	1.578	1.169	0.000	52227
0.800	0.800	15.20	44997	32.00	33202	32.00	1.000	1.578	1.169	0.000	47523
0.900	0.900	17.10	50621	36.00	26111	36.00	1.000	1.578	1.169	0.000	41334
1.000	1.000	19.00	56246	40.00	19020	40.00	1.000	1.578	1.169	0.000	33792
1.100	0.940	20.90	52878	44.00	11930	44.00	1.000	1.578	1.169	0.000	25504
1.200	0.880	22.80	49510	48.00	4839	48.00	1.000	1.578	1.169	0.000	17216
1.300	0.820	24.70	46142	52.00	0	52.00	1.000	1.578	1.169	0.000	9435
1.400	0.760	26.60	42774	56.00	0	56.00	1.000	1.578	1.169	0.000	4205
1.500	0.700	28.50	39406	60.00	0	60.00	1.000	1.578	1.169	0.000	2308
1.600	0.640	30.40	36038	64.00		64.00	1.000	1.578	1.169	0.000	1003
1.700	0.580	32.30	32670	68.00		68.00	1.000	1.578	1.169	0.000	254
1.800	0.520	34.20	29302	72.00		72.00	1.000	1.578	1.169	0.000	0
1.900	0.460	36.10	25934	76.00		76.00	1.000	1.578	1.169	0.000	0
2.000	0.400	38.00	22566	80.00		80.00	1.000	1.578	1.169	0.000	0

TABLE-4.11

FLOOD HYDROGRAPH - KAHA HILL TORRENT

NAME OF CATCHMENT	=	KAHA HILL TORRENT
RETURN PERIOD	=	10 YEARS
AREA DRAINING. SQ.MILES	=	2208.000
10 YEARS, 24-HOUR POINT RAINFALL	=	2.712
10 YEARS, 24-HOUR POINT RAINFALL	=	2.712
POINT TO AREA REDUCTION FACTOR	=	0.735
10 YEARS, 24 -HOUR AREAL RAINFALL	=	1.993
ADOPTED STORM 24-HOUR RAINFAL	=	1.993
MULTIPLYING FACTOR FOR 10 YEARS	=	1.000
CURVE NUMBER	=	96.00
S	=	0.4167
0.2S	=	0.0833
0.8S	=	0.3333
TIME TO PEAK(HOUR)	=	19.000
PEAK DISCHARGES(CUSECS)	=	56246
TIME INTERVAL(HOUR)	=	4.000

DIMENSIONLESS HYDROGRAPH		UNIT HYDROGRAPH Calculated		Adopted		DESIGN STORM					RESULTING Flood Hydrograph
T/Tp	Q/Qp	T Hours	Q Cusecs	T Hours	Q Cusecs	Time Hours	Pattern Rainfall	Accmltd Rainfall Inches	Acc:Excess Rainfall Inches	Inc:Excess Rainfall Inches	Cusecs
0.000	0.00	0.00	0	0.00	0	0.0	0.000	0.000	0.000	0.335	0
0.100	0.10	1.90	5625	4.00	11841	4.00	0.331	0.660	0.335	0.854	3962
0.200	0.20	3.80	11249	8.00	23682	8.00	0.802	1.599	1.189	0.111	18035
0.300	0.30	5.70	16874	12.00	35524	12.00	0.860	1.714	1.299	0.101	33418
0.400	0.400	7.60	22498	16.00	47365	16.00	0.913	1.820	1.401	0.100	50002
0.500	0.500	9.50	28123	20.00	54473	20.00	0.965	1.924	1.500	0.067	66186
0.600	0.600	11.40	33748	24.00	47383	24.00	1.000	1.993	1.568	0.000	74376
0.700	0.700	13.30	39372	28.00	40292	28.00	1.000	1.993	1.568	0.000	69918
0.800	0.800	15.20	44997	32.00	33202	32.00	1.000	1.993	1.568	0.000	63411
0.900	0.900	17.10	50621	36.00	26111	36.00	1.000	1.993	1.568	0.000	54990
1.000	1.000	19.00	56246	40.00	19020	40.00	1.000	1.993	1.568	0.000	44830
1.100	0.940	20.90	52878	44.00	11930	44.00	1.000	1.993	1.568	0.000	33713
1.200	0.880	22.80	49510	48.00	4839	48.00	1.000	1.993	1.568	0.000	22595
1.300	0.820	24.70	46142	52.00	0	52.00	1.000	1.993	1.568	0.000	12231
1.400	0.760	26.60	42774	56.00	0	56.00	1.000	1.993	1.568	0.000	5408
1.500	0.700	28.50	39406	60.00	0	60.00	1.000	1.993	1.568	0.000	2967
1.600	0.640	30.40	36038	64.00		64.00	1.000	1.993	1.568	0.000	1288
1.700	0.580	32.30	32670	68.00		68.00	1.000	1.993	1.568	0.000	326
1.800	0.520	34.20	29302	72.00		72.00	1.000	1.993	1.568	0.000	0
1.900	0.460	36.10	25934	76.00		76.00	1.000	1.993	1.568	0.000	0
2.000	0.400	38.00	22566	80.00		80.00	1.000	1.993	1.568	0.000	0

TABLE - 4.12

FLOOD HYDROGRAPH - KAHA HILL TORRENT

NAME OF CATCHMENT	=	KAHA HILL TORRENT
RETURN PERIOD	=	25 YEARS
AREA DRAINING. SQ.MILES	=	2208.000
25 YEARS, 24-HOUR POINT RAINFALL	=	3.446
25 YEARS, 24-HOUR POINT RAINFALL	=	3.446
POINT TO AREA REDUCTION FACTOR	=	0.735
25 YEARS, 24 -HOUR AREAL RAINFALL	=	2.533
ADOPTED STORM 24-HOUR RAINFAL	=	2.533
MULTIPLYING FACTOR FOR 25 YEARS	=	1.000
CURVE NUMBER	=	96.00
S	=	0.4167
0.2S	=	0.0833
0.8S	=	0.3333
TIME TO PEAK(HOUR)	=	19.000
PEAK DISCHARGES(CUSECS)	=	56246
TIME INTERVAL(HOUR)	=	4.000

DIMENSIONLESS HYDROGRAPH		UNIT HYDROGRAPH Calculated		Adopted		DESIGN STORM					RESULTING
		T	Q	T	Q	Time	Pattern Rainfall	Accmltd Rainfall	Acc:Excess Rainfall	Inc:Excess Rainfall	Flood Hydrograph
T/Tp	Q/Qp	Hours	Cusecs	Hours	Cusecs	Hours		Inches	Inches	Inches	Cusecs
0.000	0.00	0.00	0	0.00	0	0.0	0.000	0.000	0.000	0.487	0
0.100	0.10	1.90	5625	4.00	11841	4.00	0.331	0.838	0.487	1.118	5761
0.200	0.20	3.80	11249	8.00	23682	8.00	0.802	2.031	1.605	0.143	24763
0.300	0.30	5.70	16874	12.00	35524	12.00	0.860	2.178	1.747	0.131	45454
0.400	0.400	7.60	22498	16.00	47365	16.00	0.913	2.312	1.878	0.129	67693
0.500	0.500	9.50	28123	20.00	54473	20.00	0.965	2.444	2.007	0.087	89151
0.600	0.600	11.40	33748	24.00	47383	24.00	1.000	2.533	2.093	0.000	99436
0.700	0.700	13.30	39372	28.00	40292	28.00	1.000	2.533	2.093	0.000	93169
0.800	0.800	15.20	44997	32.00	33202	32.00	1.000	2.533	2.093	0.000	84258
0.900	0.900	17.10	50621	36.00	26111	36.00	1.000	2.533	2.093	0.000	72883
1.000	1.000	19.00	56246	40.00	19020	40.00	1.000	2.533	2.093	0.000	59271
1.100	0.940	20.90	52878	44.00	11930	44.00	1.000	2.533	2.093	0.000	44427
1.200	0.880	22.80	49510	48.00	4839	48.00	1.000	2.533	2.093	0.000	29584
1.300	0.820	24.70	46142	52.00	0	52.00	1.000	2.533	2.093	0.000	15836
1.400	0.760	26.60	42774	56.00	0	56.00	1.000	2.533	2.093	0.000	6960
1.500	0.700	28.50	39406	60.00	0	60.00	1.000	2.533	2.093	0.000	3816
1.600	0.640	30.40	36038	64.00		64.00	1.000	2.533	2.093	0.000	1657
1.700	0.580	32.30	32670	68.00		68.00	1.000	2.533	2.093	0.000	420
1.800	0.520	34.20	29302	72.00		72.00	1.000	2.533	2.093	0.000	0
1.900	0.460	36.10	25934	76.00		76.00	1.000	2.533	2.093	0.000	0
2.000	0.400	38.00	22566	80.00		80.00	1.000	2.533	2.093	0.000	0

FLOOD HYDROGRAPH - KAHA HILL TORRENT

(2.33 YARS RETURN PERIOD)

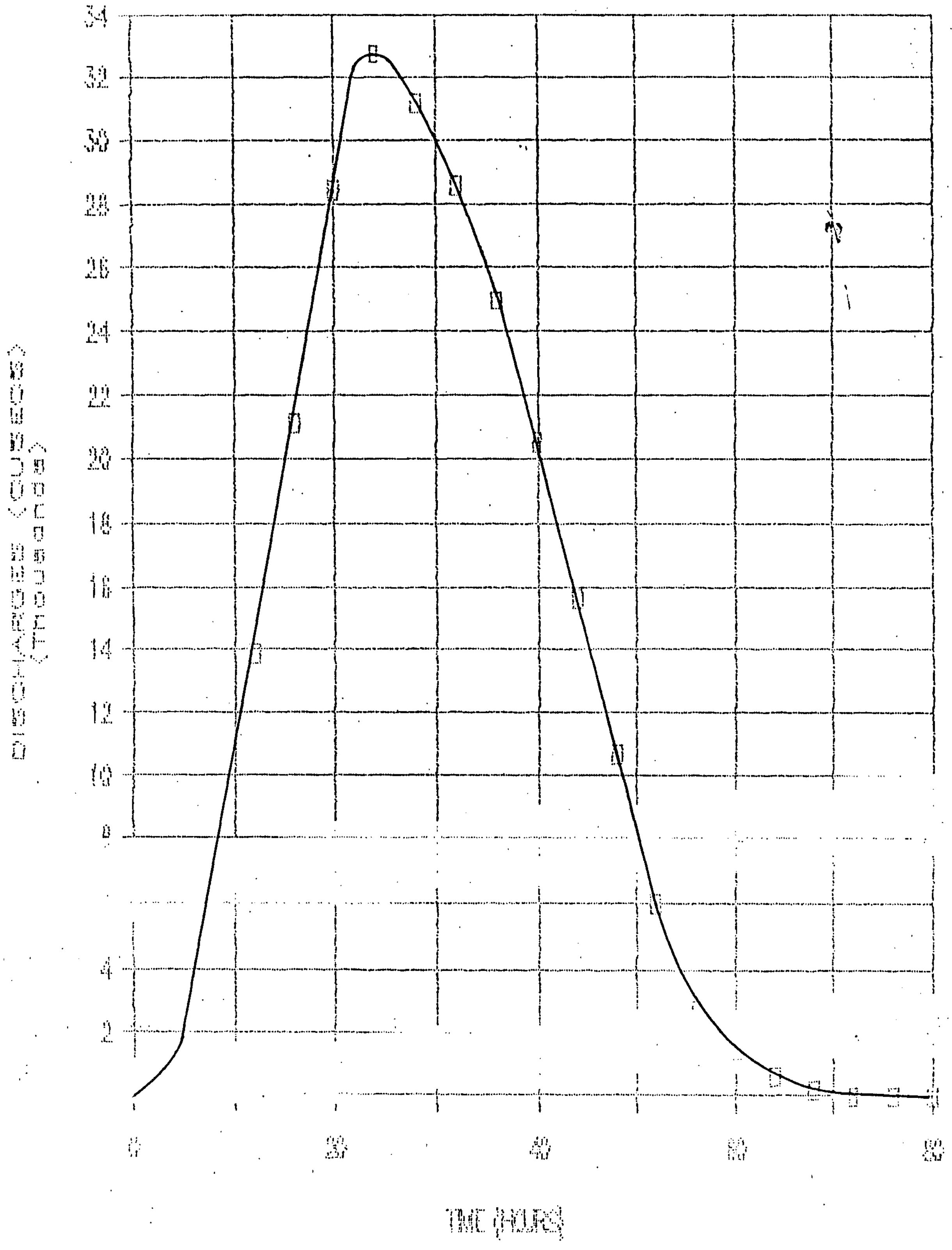

Fig.4.8

FLOOD HYDROGRAPH – KAHA HILL TORRENT

(5 YEARS RETURN PERIOD)

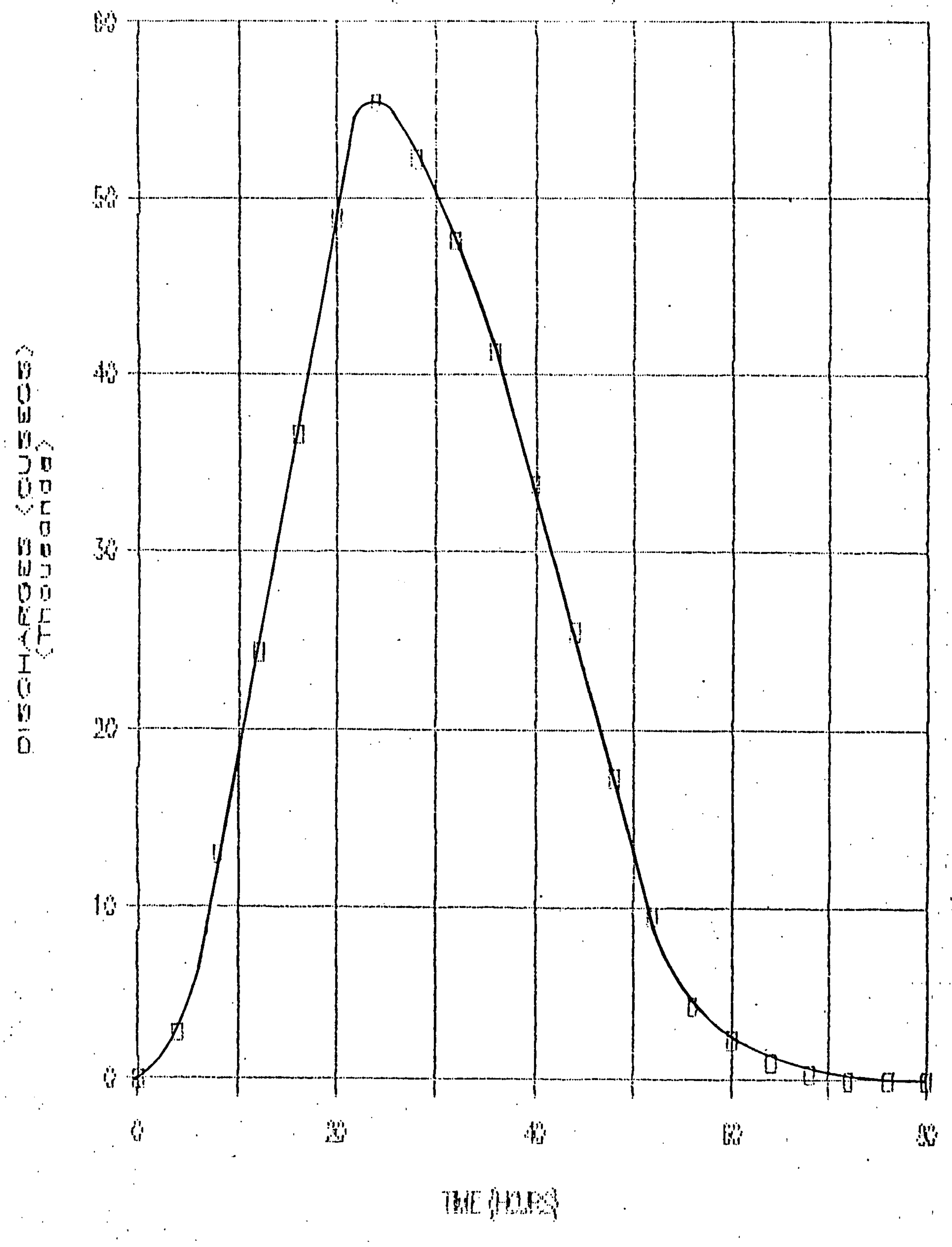

Fig.4.9

FLOOD HYDROGRAPH - KAHA HILL TORRENT

(10 YEARS RETURN PERIOD)

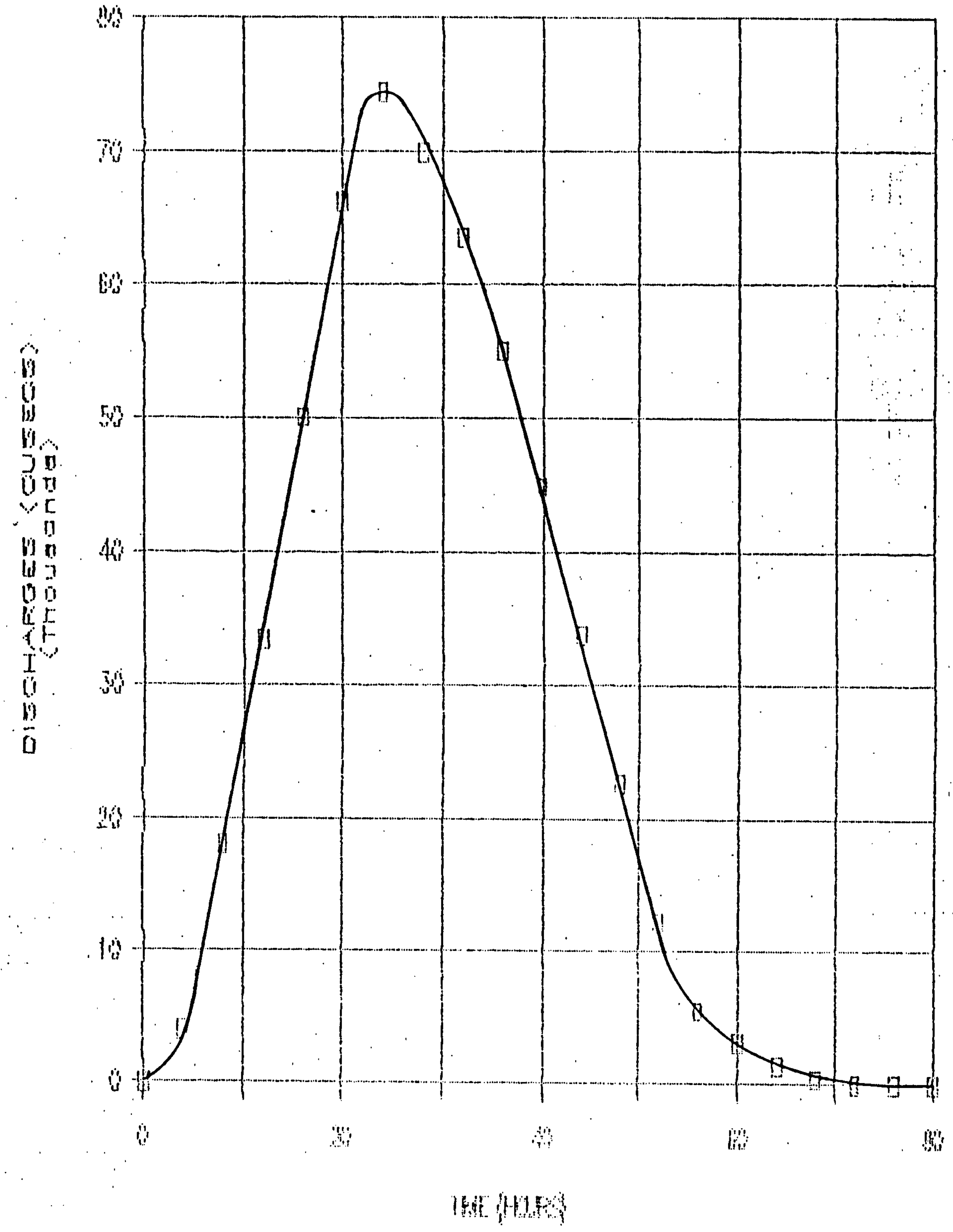

Fig.4.10

FLOOD HYDROGRAPH - KAHA HILL TORRENT

(25 YEARS RETURN PERIOD)

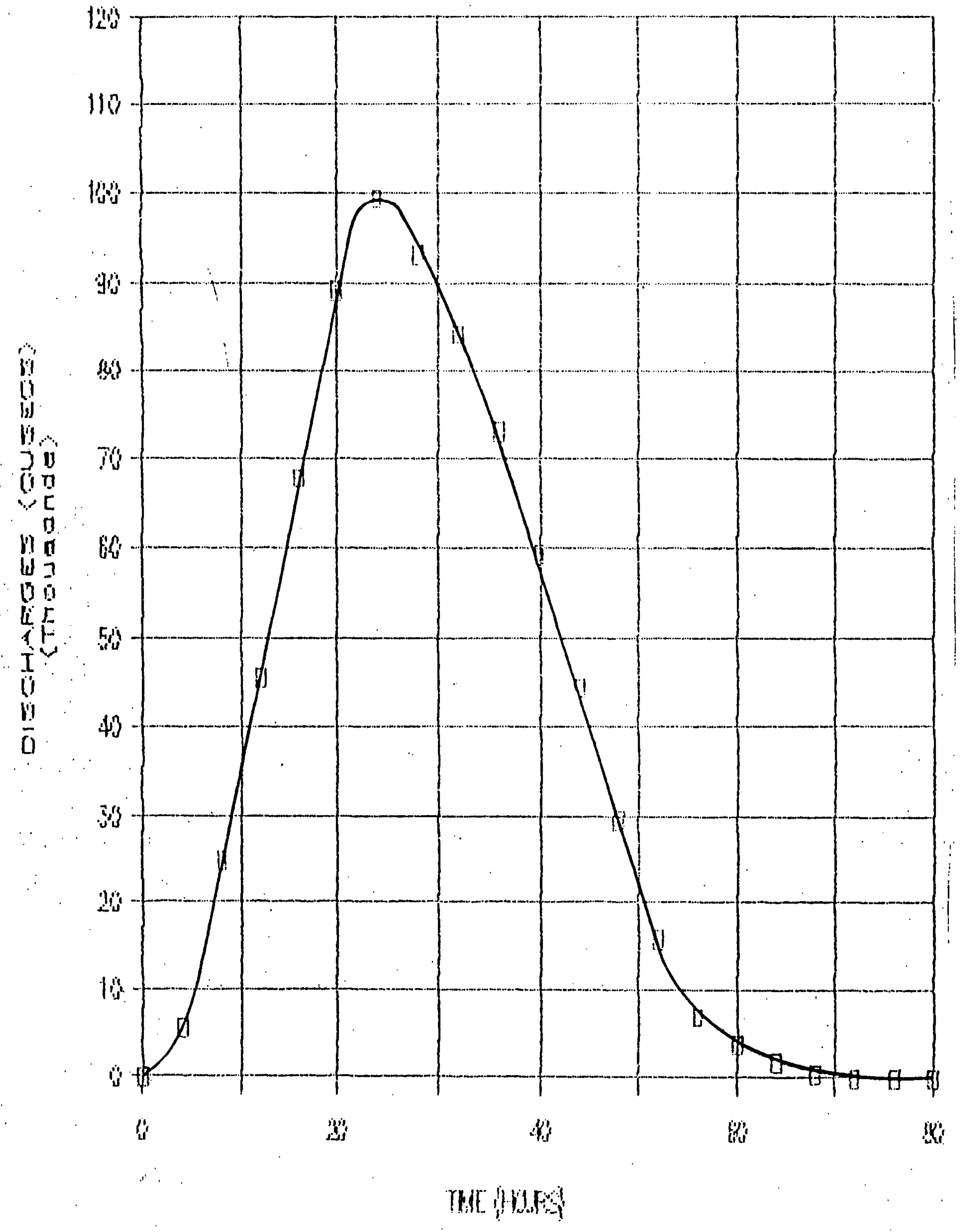

Fig.4.11

4.6 RATIONAL FORMULA

Rational Formula is one of the oldest empirical formula in use. The formula is called rational because the units of quantities involved are numerically consistent approximately.

The rational formula is:

$$Qp = CIA$$

Where Qp is peak discharge in cusecs

C is the run-off co-efficient depending upon the characteristics of the drainage area. It is assumed to be equal to ratio of surface run-off to rainfall of a catchment.

I is intensity of rainfall in inches/hr corresponding to time of concentration of the watershed.

A is catchment area in acres

Table 4.13 gives values of C for different types of soils. The catchment area of Kaha consists of hard rocks with very little vegetal cover. Moreover, steep slopes allow very little amounts to be absorbed and most of the rainfall is converted to run-off. For high intensity storms of high return periods higher values of C are recommended. Therefore, value of C for Kaha with storm intensity of 25-year return period is estimated as 0.70. Intensity of rainfall has been obtained from the intensity duration frequency curves prepared for Kaha (Fig. 4.7). The intensity of rainfall from intensity-duration-curve of 25-years return period against time of concentration of 28.0 hours is 0.10 inches/hr.

Area of Kaha is 571,882 ha (1,413,120 acres). Putting all these values in Rational Formula:

TABLE 4.13 1/

VALUE OF RUNOFF COEFFICIENT, C,
FOR DIFFERENT KINDS OF SOIL

TYPE OF CATCHMENT	VALUE OF C
Rocky & Impermeable	0.80 - 1.00
Slightly Permeable, bare	0.60 - 0.80
Slightly Permeable, partly covered with vegetation	0.40 - 0.60
Cultivated Absorbant Soil	0.30 - 0.40
Sandy Absorbant Soil	0.20 - 0.30
Heavy Forest	0.10 - 0.20

1/ Flood Estimation and Control By B.D. Richards Third Edition, 1955, page 59

$$Qp = CIA = 0.7 * 0.10 * 1,413,120$$
$$= 98,918 \text{ cfs } (2,800 \text{ cumecs})$$

As this formula is recommended for small catchments and there is considerable judgement involved in the estimation of co-efficient of run-off, therefore, result obtained from this formula should be considered as the first approximation of peak discharge.

4.7 SELECTION OF DESIGN HYDROGRAPH

The socio economic analysis of the area affected by Kaha Hill Torrent and the anticipated costs of tentative flood management techniques indicate that flood mitigating system should be designed for 25-year return period. Peak discharge of 25-year return period has been estimated by frequency analysis of both stream flow and precipitation data. Following table compares the results obtained by different methods.

COMPARISON OF RESULTS BY DIFFERENT METHODS

Streamflow Data Analysis 25-year Peak Discharge Cumecs (Cusecs)				Precipitation Data Analysis 25-Year Discharge Cumecs (Cusecs)	
Log Pearson Type-III	Gumbel Distribution (Linear) Ordinate)	Gumbel Distribution (Log) Ordinate)	Gumbel Equation	Rational Formula	Dimensionless Hydrograph Method
2,561 (90,450)	2,660 (94,000)	2,732 (96,500)	2,570 (90,774)	2,800 (98,920)	2,815 (99,440)

Result of Rational Formula give the first approximations of the peak discharge. Dimensionless hydrograph method (Victor Mockus) show the result on higher side. By applying goodness of fit (Chi-Square Test) on stream flow data for all three types of frequency curves (Log Pearson Type-III, Gumbel Distribution and Log Gumbel Distribution). The Gumbel Distribution giving least value of Chi-Square parameter is the best fit. Therefore, peak discharge of 25-year return period has been fixed at 2,662 cumecs (94,000 cusecs).

4.8 RUNOFF

The precipitation data have been used for runoff estimation by calculating the average monthly rainfall for the Project area from the raingauge records. The average monthly rainfall are multiplied by the rainfall of various return periods (Fig.4.5). The runoff volumes have been determined by Soil Conservation Services method.

SECTION - 5

MANAGEMENT OF FLOOD WATER

5.1 GENERAL

Management of floodflows of DG Khan Hill Torrents is a complex problem, because quantity and distribution of rainfall contributing to floodflows is uncertain and patchy. A year with intense rainfall may be followed by a long span of dry years. Flashy floodflows in the light of uncertainty of their occurrence add complexity to their economical management. Flood management of hill torrents has several alternatives or combinations of adjustments. A choice of optimal solution can be made using cost effectiveness technique. Effective flood management requires structural and non-structural measures to be applied in balance. Structural measures minimize the effect of flood water while non-structural measures facilitate in changing the intensity, duration and volume of floodflows. The former types include dikes, flood walls, channel improvements, diversion weirs, reservoirs etc., while later type ecompasses measures like watershed management by terracing, gully control, afforestation or pasture development. Sometimes flood losses may also be minimized by flood warning, flood fighting or evacuation. Flood management of Kaha Hill Torrent has been proposed to be undertaken using both structural and non-structural measures.

5.2 PLANNING STRATEGY AND OBJECTIVES

The key to flood management planning for Kaha Hill Torrents lies in reduction of flood peaks to a threshold level at which the flood threat in the area is significantly reduced. In view of high silt content, and the erratic nature of floodflows, damming or storing of flashy flood water is generally uneconomical. Moderate floods that overflow the plain area are used for terrace irrigation as long as they are within manageable limits. In case of high flows, earthen flood embankments are shattered and run-off gets concentrated along right bank of Dajal Branch. Floodflow after breaching the canal or passing through canal crossings sweeps across the canal command area, where it inflicts severe damage to crops and other infrastructure before finding its way onto the Indus River. The damage potential generally increases after crossing Dajal Branch. On the other hand, shortage of water is the major constraint to the development of the Pachad Area. Thus, the primary objective of the flood management plan is to manage and utilize floodflows in the hilly and Pachad area. This would not only help in reducing flood damages but would usher in a new era of economic development in the area. The goal of flood management planning is to stimulate economic development and to mitigate flood losses to the extent technically and economically feasible.

There is good network of natural channels (wahs) in Pachad area. In order to manage flood flows of Kaha Hill Torrent in Pachad area only distributors are required to be constructed in the main Kaha. However, there are some hill torrents, of which Bagga and Kala Khosra are major, which contribute to the flood flows of Kaha near Dajal Branch Canal. These hill torrents cause large scale erosion of fertile top soil on the left side of Kaha. Frequency analysis of flood flows were carried out and detailed reconnaissance surveys were conducted in the flood plains of these hill torrents to assess the possibility of dovetailing the management of these with the main Kaha. It was found, however, that the morphological features of these hill torrents are entirely different. The flood plains of Bagga and Kala Khosra have no natural wahs (channels). For their proper management, new distribution channels (primary, secondary and tertiary) would have to be constructed in accordance with the availability of water and the land potential, which requires detailed topographic surveys of the catchment area. The management of flood flows of these torrents through construction of new channels would, thus, tantamount to flood irrigation scheme which is beyond the scope of Flood Protection Sector Project.

In order to achieve economical management of flood flows of hill torrents, the planning has been carried out under the framework of the following guidelines:

- •Utilize floodflows right in the area, where they are generated as far as possible;
- Reduce losses and suffering due to flood in an economically sound manner such that benefits of flood damage abatement measures exceed their costs as far as possible;
- Give priority for flood protection to areas of greatest flood damage hazard and/or greatest potential for human suffering, as far as possible;
- Provide, as far as feasible protection from flood damages to cities, irrigation works, communication facilities, and other vital infrastructural installations that lie within the flood plains of the hill torrent;
- Make maximum use of existing flood control/protection facilities by improvement where necessary to bring them to a level of functional capability and reliability that conforms to current standards;
- Obtain maximum flood control utilization of multiple purpose facilities without adversely affecting other functions or compromising the safety of the facility;
- Promote appropriate land use by avoiding the growth of flood vulnerable development in flood hazard areas, and adjusting land use, where possible, to be compatible with the frequency and duration of flooding; and
- To minimise adverse effects on the natural ecosystem and environment.

5.3 MANAGEMENT OF FLOODFLOWS THROUGH NON-STRUCTURAL MEASURES

The damages caused by hill torrent flooding can be controlled to a certain extent by adopting non-structural measures in their catchment areas. These type of measures include soil and water conservation techniques, range management practices, watershed management by terracing, gully control and afforestation or pasture development works in the hills. These measures also greatly help in changing the intensity, duration and volume of floodflows. Sometimes flood losses may also be minimised by flood warning, flood fighting or evacuation. Such operations can be summarised as:

- Sowing and planting along interrupted contour trenches dug on gradients not above 30 degrees to catch rain water to help the plants growth and establish themselves.
- Contour bunding on easy slopes to hold run-off to increase infiltration of water and provide moisture to plants raised along earthen bunds.
- Contour furrowing suitable patches on easy slopes and reseeding with palatable grasses.
- Closure against grazing till revegetation including grass establishes itself, and thereafter providing rotational grazing to a permissible grazing capacity.
- Gully plugging with loose stones and check damming with dry stone rubble masonry work at suitable intervals to retard the velocity of water in the nallahs, thereby improving the flow regimen, arresting silt behind the stone structures for creating planting bed, and raising trees in appropriately protected soil pockets behind the check dams.
- Construction of logging roads to expedite forest management activities.

5.3.1 Watershed Management

Watershed management is a long-term process and requires quite some time before effective flood mitigation can be realised. The function of watershed management in hilly areas is to check the sediments at source and decrease the stream flow by restoration of the forest cover in the upper catchment. The best way to deal with floods is to control them where they are formed. Unplanned deforestation and devegetation are one of the primary causes of floods. Therefore, the most appropriate course of action is to plant trees and develop pastures in the catchment area to improve the vegetation cover in areas subjected to soil erosion and to phase out farm practices that contribute to such erosion. Watershed management serves both for low flow augmentation and flood reduction and it has made great advances in western countries. The success of planting and grassing in Pakistan, particularly in the Project area, is only possible under strict closure against grazing and through proper maintenance of plants and grasses. Presently the sparse vegetation cover has deteriorated through over-grazing by nomadic flocks which aggravates the degree of run-off and greatly increases the damage potential of floodflows. The result is denudation, heavy showers in the catchment generate floods with turbulent flows impregnated with high silt charge, causing erosion of stream banks. These flood damages can be minimized by adopting such measures as:

- Afforestation in mountaineous areas; and
- Pasture development in sub-mountaineous areas.

Other measures which are usually associated with conservation practices, such as, terracing, contour ploughing, strip cropping, planting cover camps, construction of logging roads, fire management or using farm ponds, also significantly contribute in flood abatement and reduction in losses to crops, infrastructure and settlements in the downstream area.

5.3.1.1 Afforestation in Mountaineous Regions:

Due to the desolate and bare land of the mountains, heavy showers in the catchments cause stream flow of high velocity which carry heavy silt load and cause damage as they erode the stream banks. The volume, peak and timing of run-off can be modified by afforestation and the damages can be minimized by developing sound forest management practices.

Afforestation is a long process and difficult to establish in view of lack of proper soil profile, low rainfall and overgrazing. Under natural climatic conditions, tropical thorn type of forest occupies these tracts in which scattered low xerophytic species grow with predominance of thorny hardwood trees. However, good results can be achieved through the co-operation of the people of watershed area. A nursery for recommended plants may be established by the Forest Department and land owners may be paid for planting and protection against grazing. The following drought resistant (xerophytic) trees and shrubs are recommended for land cover in this area:

- Acacia modesta (phulai): A medium sized tree grown on foot-hills as a soil-binding plant. Good for fuel, medium quality shade and timber and leaves good as goat fodder.
- Acacia Arabica (Kikar): A tall tree, susceptible to frost grown for soil-binding, timber and fuel wood. The leaves, tender branches and fruit are relished by goats.
- Prosopis Spicigera: This is familiar by the name of 'Kandi' in the Project area and is the main species of the tract. This tree can be successfully planted by raising in a nursery in the plain and then transplanting to the hill areas during monsoon season. These trees mature within four to five years with limited flood water irrigation under reasonable closure against grazing and through proper maintenance of

the plants. These trees greatly facilitate checking sediment transportation and mitigating runoff contributing to stream flows. In addition, pods and leaves are browsed by cattle and the wood is used for building material and fire-wood.

- Robinia pseudo acacia: This is very suitable high xerophytic tree for hilly area to check the erosion and to increase the water holding capacity of land. Nursery is raised in the cold plain area and then plants are transplanted into the pits and ditches in the hilly area. Its leaves are used as a fodder.

- Ziziphus nummarlaria (Muhla). This tree can be raised through pit and trench sowing method. Seed should be soaked for better germination. The smell of seedling plants is very attractive to wild animals, therefore, strict protection is necessary for their survival. These trees help in shaving off flood peaks. Moreover, the bark is used for tanning and the leaves for fodder. Fire-wood and fruit are relished by the people.

These trees and shrubs play following three main roles in flood hydrology:

- Stabilize silt, minimizing erosion and the downstream sedimentation associated with increased flood stages;

- Provide additional water storage through the effects of interception storage and through evapotranspiration in drying out the underlying soil; and

- Maintain high infiltration rates.

5.3.1.2 Development of Pastures in Sub-mountaineous Regions:

The sub-mountain land with more than one percent slope is proposed for pasture development where some common species of useful grasses can be sown and would flourish under protective measures against grazing within one and a half year. At present there is a high wastage of water due to excessive surface run-off from sparsely vegetated and excessively grazed sub-mountain lands during almost every storm. Poor grasses and shrub of stunted bushes can be replaced by sowing recommended drought resistant grasses for better vegetation.

Grasses play an important role in building-up the economy of a country. They have a specialized use for erosion control on account of their fine hair-like roots that bind the soil particles. Top growth, well established, affords protection against wind and breaks the force of the rain drops. The run-off on such lands is held to the minimum. This prevents erosion of the soil and keeps this important natural gift intact for profitable use by man. Rightly it has been said:

> "Grass[1/] is the forgiveness of Nature - her constant benediction. Forests decay, harvests perish, flowers vanish but grass is immortal. Its tenacious fibres hold the earth in its place and prevent its soluble components from washing into the wasting sea".

Some of the important species of grass which have proved successful in trials at the Soil Conservation Farm, for hilly area area given below:

Agropyron desertorum: This is a perennial cool season, drought tolerant bush grass with an extensive root system. The roots penetrate upto a depth of about 3 meter. Only

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1/ Forming Erodable Lands In West Pakistan - 1967
by Abdul Rashid Khan and M.A.Hameed Chaudhry.

ten to fourteen kg seed is used for sowing one hectare of land for range during September-October and February-March. It is a valuable dry land grass for soil conservation. It can be used with success for abandoned lands even at high elevations.

Bromus marginotus: It is a perennial cool season grass with coarse stems about one meter in height. They are highly shade-tolerant and hence highly desirable. It does best on foot-hill soils that receive 30 to 60 cms rainfall but at high elevations less rainfall is required. Five to seven kg seed is used to sow one ha during summer season.

Elymus siganteus: It is a tall, aggressive, perennial, cool season grass with stout rhizomes. It has been used with success by the Soil Conservation Department on hilly area with average rainfall of 160mm. Two to three kg seed of this grass is used to sow one ha and during September-October and February-March. It not only stabilizes the land, but also continues to grow and provide permanent cover on dunes.

Panicum obtusum: A deep rooted long lived, robust, perennial, warm season tuffed bunch-grass. It is best suited for flood plain and desilting areas. It is an ideal grass for protective planting in catchment areas of the project. It is particularly suited for use in revegetating gullies and areas where other species do not survive, and to improve the soil structure.

Setaria macrostachya: A drought resistant, coarse, warm season, perennial bunch-grass. It is a good grass for reseeding depleted grass-lands and abandoned farm-lands. It establishes a quick ground cover on raw denuded areas.

Sporobolus airoides: It is a deep rooted, warm-season, perennial grass that grows in large tuft branches. Elevation 800 to 2000 meters receiving 200 to 350mm of rainfall is most suitable for it. It becomes implatable after maturity.

These grasses have been selected after reviewing the meteorological data, and soil conditions and after discussion with range officials. These grasses play an important role in retarding the stream flow and also help in minimizing soil erosion. The grasses are commonly grazed by all types of livestock. These grasses are sown through different methods but tuft sowing is useful for this locality due to low rainfall and it will give good results in spreading its roots far and wide. The success of grassing is only possible under strict closure against grazing and proper maintenance. After introducing the grasses successfully, the villagers, will feel the responsibility of protection and maintenance as it would be used by them for livestock development.

This kind of waste land in Pakistan can be developed better as pasture due to climatic or other local reasons. In fact, such areas have great potential for reducing or eliminating the fodder shortage and consequently shortage of livestock products. These areas can also supply timber and fuel-wood which are in short supply.

Our field studies comprised of interviews with land owners, spot observations, and discussions with range management officials. These studies reveal that about ten percent of the catchment area would be available for watershed management. It has been observed that flood peaks have been shaved-off to the extent of 20 percent by implementing afforestation and range management measures in various parts of the world. The afforestation in mountaineous and pasture development in sub-mountaineous areas of the Project would substantially improve the catchment characteristics.

The estimated cost of afforestation under dry conditions may vary from Rs 2,000 to Rs 3,000 per ha. Rehabilitation of area by raising or introducing grasses may cost Rs 400 to Rs 600 per ha. Non-structural measures have been proposed but their cost and interaction on the flood flows have not been accounted for in the report, because of long gestation before these measures can become effective.

5.4 MANAGEMENT OF FLOODFLOWS THROUGH STRUCTURAL MEASURES

5.4.1 General

Complete flood management of hill torrents is a physical impossibility, but flood protection to the extent technically and economically feasible, is a socio-economic necessity for the area. In many parts of the world, floods have been turned to economic advantage. In Egypt the flood of the Nile River was tamed about 5,000 years back and became the life stream for the inhabitants. Similarly, construction of dike system in China dates back to thousands of years. In the present days, with the advancement of modern technology, floodflows have been regulated by the construction of protective works in many parts of the world. Flood control through structural measures is one of the most widely adopted strategy in the world. The flood control by structural measures has become specially popular with adoption of a multipurpose approach to flood management in which the economics of joint use of facilities and of scale often make possible, the provision of flood control at a lower cost than for a single purpose approach.

Field investigations in the Pachad and headwater areas of Kaha Hill torrent were carried out to formulate a flood management plan for the area. In the light of hydrologic studies and reconnaissance of the area, suitable sites were identified which could be used for management of floodflows. Comprehensive hydrologic studies established that a 15-day storm with a 25-year return period would have a peak of 2,662 cumecs (94,000 cfs) at the darrah. Thus, most of the flood with a peak of 2,662 cumecs has to be regulated by the construction of protective works.

5.4.2 Flood Management Strategies

Response to flood problems in the area has been based upon the two principal subject areas of analytical studies; hydrologic and economic aspects of flood problem. Various alternatives for management of floodflows considered are:

- Construction of adequate cross-drainage works on DG Khan Canal System for disposal of floodflows to the Indus River by means of drains in the canal command area.
- Disposal through Dajal Branch.
- Disposal/channelization of floodflows to Indus River along right bank of Canals.
- Management of floodflows in the sub-mountaineous and Pachad areas.
- Combination of various alternatives.

In order to identify and select the optimal solution, all alternatives have been screened through the two basic criteria i.e., technical feasibility and economic viability. Critical review of various alternatives considered is detailed below:

5.4.2.1 Disposal to Indus River through Aqueducts and Drains (Alternative-1)

Disposal of floodflows to the Indus River through old natural watercourse by constructing aqueducts/syphons and carrying channels seemingly looks very attractive. This alternative has been considered in detail. The theoretical flood peak for 25 years return period has been estimated as 2,662 cumecs under the existing conditions of the catchment. This will require channelization of the Main Kaha right from the darrah to Dajal Branch, and the construction of one or a series of additional hill torrent crossings over Dajal Branch and a drain to carry the floodflows to the Indus as shown in Fig.5.1. This alternative has an estimated cost of Rs 563 million (Table 5.1). Figure 5.2 shows typical section of aqueduct over distributaries and Fig.5.3 shows H.T crossing over Dajal Branch.

5.4.2.2 Disposal Through Dajal Branch (Alternative-2)

For disposal of floodflows through Dajal Branch System, a study of following three factors affecting flow regimen of canals would be necessary. These are:

- Efficient Canal Regulation;
- Canal Capacity Vs. Inflow Flood Hydrograph;
- Canal Sedimentation Vs. Silt Charge of Floodflows.

Floodflows of Kaha Hill Torrent generally strike in the reach RD 70 - RD 170 of the Dajal Canal. The capacity of the canal is grossly inadequate to take entire floodflows or peak discharge. The low capacity of intake structure will result in ponding of water along the canal. This would require raising and strengthening of right bank of the canal in addition to increasing its capacity which would be economically infeasible. Moreover, time of travel of the flood wave from the darrah to Dajal Branch is about 4-6 hours, while the travel time of canal water from Taunsa to RD 70 of Dajal Branch is about 30 hours. Thus, the floodflows cannot be disposed of adequately because of time differential between the two. Silt contents studies carried out have shown that in view of a high silt charge of two to four percent, it is not advisable to allow floodflows

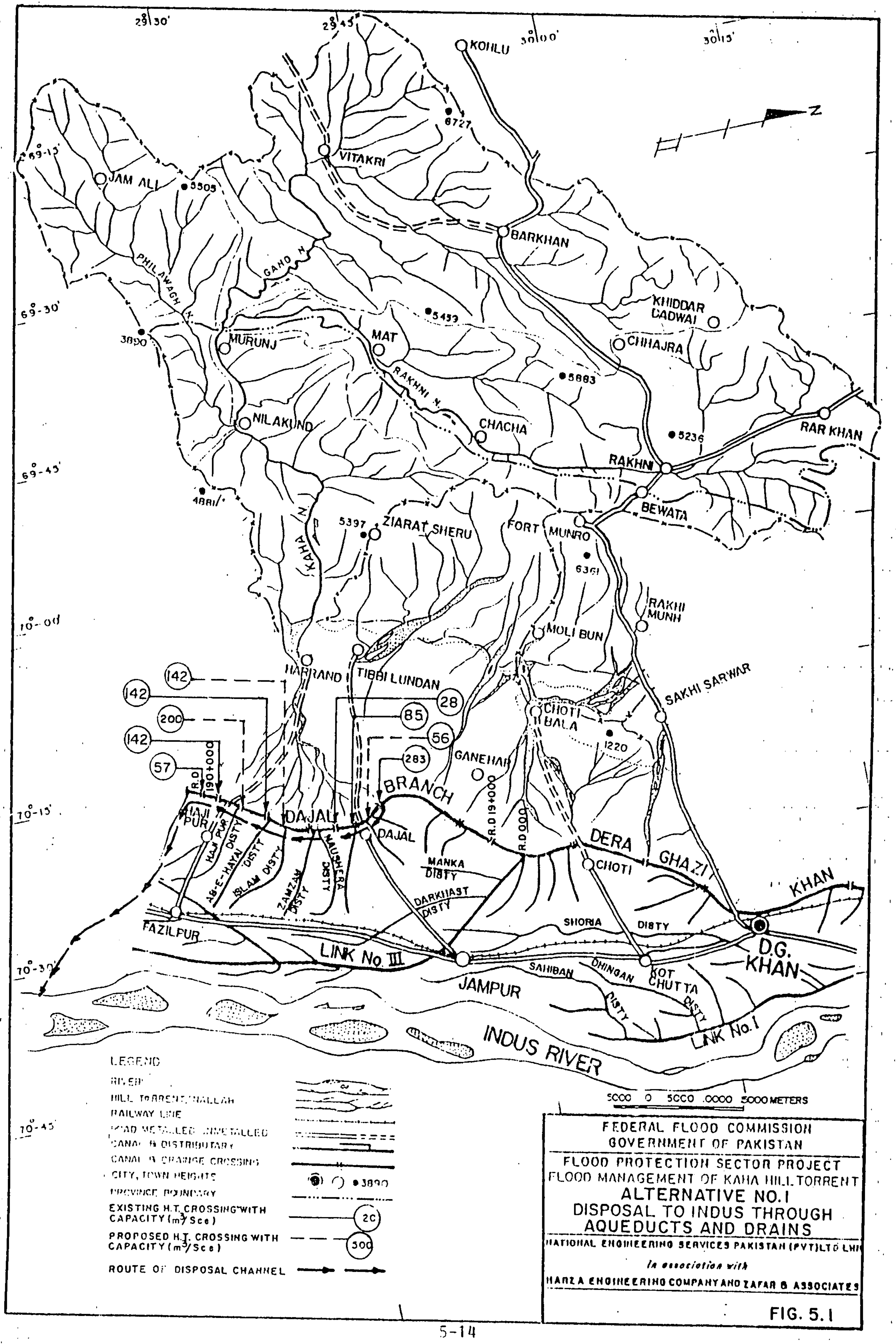

KOHLU
VITAKRI
BARKHAN
JAM ALI
PHILAWAGH N.
GAHO N.
KHIDDAR
CADWAI
CHHAJRA
MURUNJ
MAT
RAKHNI N.
NILAKIND
CHACHA
RAR KHAN
RAKHNI
BEWATA
FORT MUNRO
ZIARAT SHERU
KAHA N.
RAKHI MUNH
MOLI BUN
HARRAND
TIBBI LUNDAN
SAKHI SARWAR
CHOTI BALA
GANEHAR
HAJI PUR
DAJAL
BRANCH
DERA GHAZI KHAN
MANKA DISTY
DARKHAST DISTY
CHOTI
SHORIA DISTY
D.G. KHAN
FAZILPUR
LINK No. III
JAMPUR
SAHIBAN
DHINGAN
KOT CHUTTA
DISTY
LINK No. I
INDUS RIVER
ISLAM DISTY
ZAMZAM DISTY
NAUSHERA
R.D 190+000
R.D 19+000
R.D 0000
5000 0 5000 10000 15000 METERS
LEGEND
RAILWAY LINE
EXISTING H.T. CROSSING WITH CAPACITY (m³/Sec)
PROPOSED H.T. CROSSING WITH CAPACITY (m³/Sec)
ROUTE OF DISPOSAL CHANNEL
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
ALTERNATIVE NO.1
DISPOSAL TO INDUS THROUGH
AQUEDUCTS AND DRAINS
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
In association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

FIG. 5.1

TABLE - 5.1

ALTERNATIVE-1

LIST OF CROSS STRUCTURES AND THEIR ESTIMATED COST

S. No.	TYPE OF STRUCTURE AND CAPACITY (CUMECS)	NAME OF CANAL OVER WHICH TO BE BUILT	APPROXIMATE LOCATION	ESTIMATED COST Million(Rs)	REMARKS
1.	H.T.Crossing 233	Dajal Branch	RD 79+500	-	Existing
2.	Aqueduct 283	Dajal Disty.	RD 1+250	1.00	Proposed
3.	H.T.Crossing 56	Dajal Branch	RD 95+280	-	Existing
4.	Aqueduct 340	Firdous Disty.	RD 1+500	1.50	Proposed
5.	Aqueduct 340	Kausar Disty.	RD 1+500	1.50	"
6.	H.T. Crossing 85	Dajal Branch	RD 107+685	6.00	"
7.	H.T.Crossing 28	Dajal Branch	RD 109+763	-	Existing
8.	Aqueduct 454	Naushera Disty	RD 1+500	2.00	Proposed
9.	Aqueduct 454	Zamzam Disty.	RD 1+500	2.00	Proposed
10.	H.T. Crossing 142	Dajal Branch	RD 121+560	8.00	Proposed
11.	H.T. Crossing 142	Dajal Nranch	RD 123+625	-	Existing
12.	Aqueduct 740	Islam Disty.	RD 2+000	3.00	Proposed
13.	H.T.Crossing 142	Dajal Branch	RD 139+500	8.00	Proposed
14.	H.T.Crossing 200	-do-	RD 145+700	-	Existing
15.	Aqueduct 1082	AB-E-Hayat Disty.	RD 2+000	2.50	Proposed
16.	H.T.Crossing 56	Dajal Branch	RD 177+300	-	Existing
17.	Aqueduct 1138	1-R Minor	-	1.00	Proposed
18.	Aqueduct 1138	Dhundi Katab Canal	-	7.00	Proposed

19.	Aqueduct 1138	Fazil Disty.	-	2.00	Proposed
20.	Aqueduct 1138	Kadra Canal	-	8.00	Proposed
				53.50	

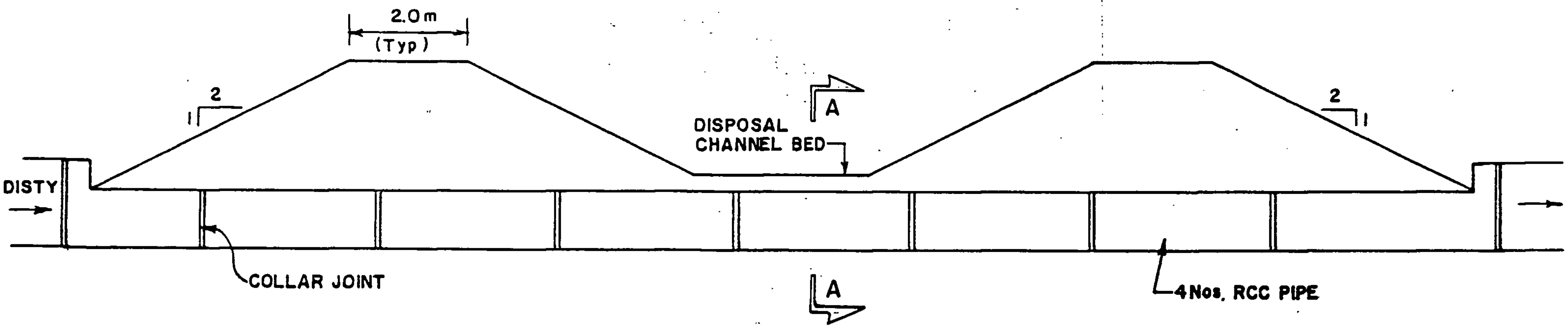
Strengthening of inlets of six existing H.T. Crossings along with channelization of upstream inlet into channel = Rs 10.00 million

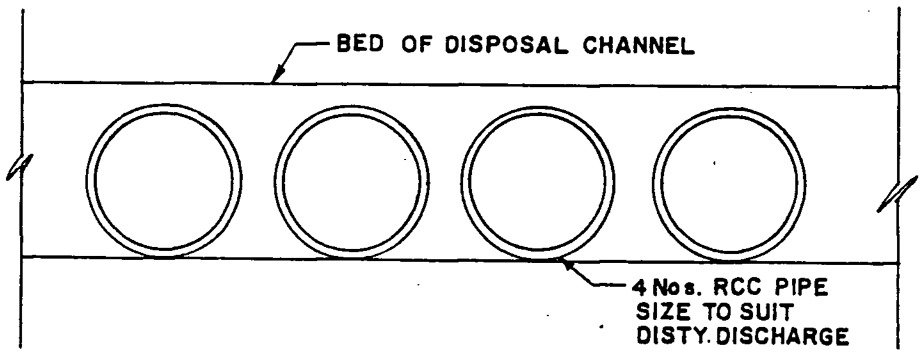
DISPOSAL CHANNEL (52 km total length)

Outfall to 34 km (34 Km) capacity 1138 cumecs	200.00
34 Km to 20 km (15 km) capacity 1000 cumecs	127.00
20km to 10 km (10 km) capacity 500 cumecs	50.00
10 km to 0 (10 km) capacity 350	35.00
	412.00
Compensation of land	75.00
Outfall structure	7.00

SUMMARY

Cross Drainage structures	53.50
Drains	412.00
Land compensation	75.00
Outfall structure	7.00
1 No. A.R. Bridge	4.00
2 Nos V.R. Bridges	5.00
1 No. Railway Bridge	6.00
	562.50 million





SECTION A-A

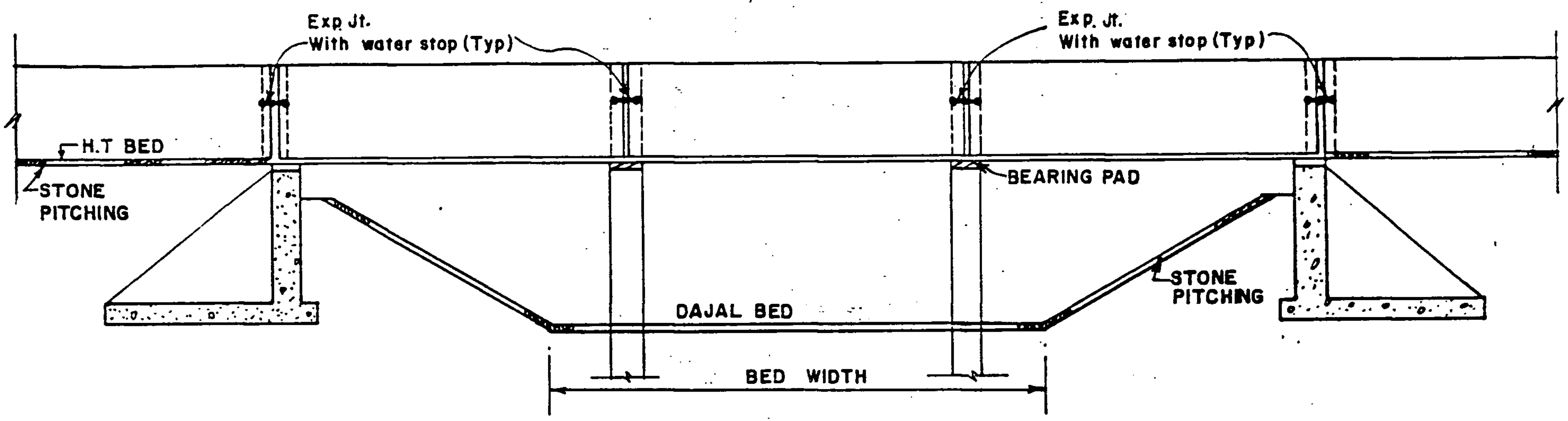
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

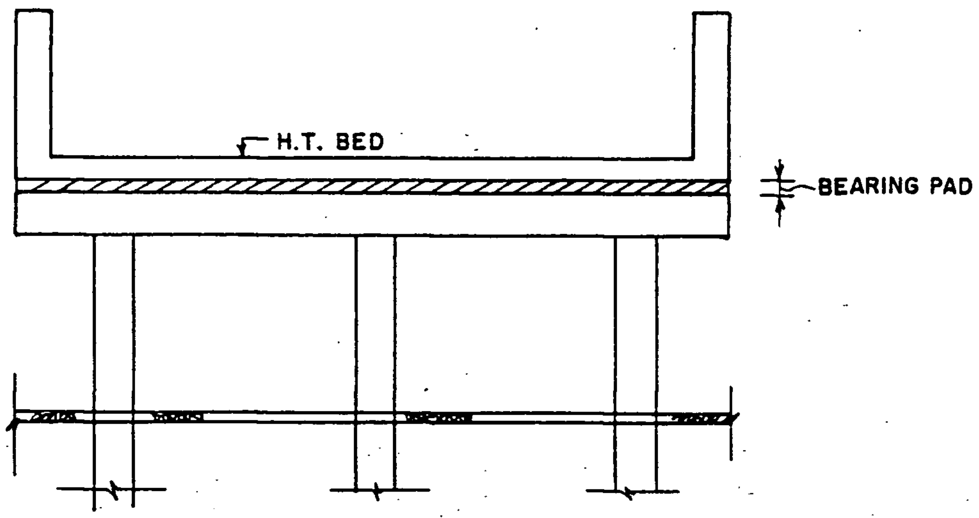
AQUEDUCT OVER DISTRIBUTRIES
TYPICAL SECTION

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
in association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

Fig. 5.2



L-SECTION



X-SECTION

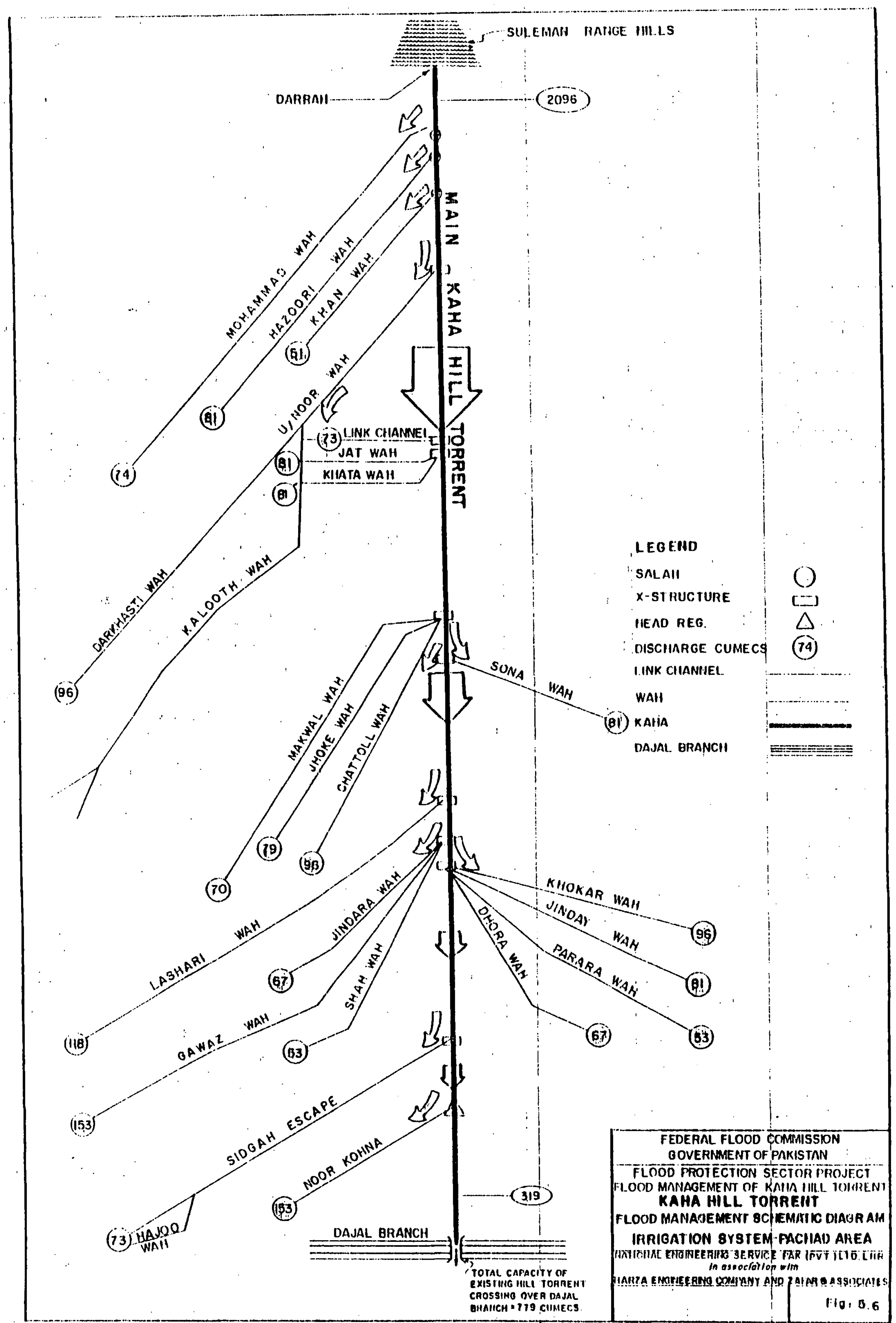
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

H.T. CROSSING OVER DAJAL BRANCH
TYPICAL SECTIONS

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
In association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

Fig. 5.3


SULEMAN RANGE HILLS
DARRAH
2096
MAIN KAHA HILL TORRENT
MOHAMMAD WAH
HAZOORI WAH
KHAN WAH
51
81
74
U/NOOR WAH
73 LINK CHANNEL
81 JAT WAH
81 KHATA WAH
DARKHASTI WAH
KALOOTH WAH
96
LEGEND
SALAH
X-STRUCTURE
HEAD REG.
DISCHARGE CUMECS
74
LINK CHANNEL
WAH
KAHA
DAJAL BRANCH
SONA WAH
81
MAKWAL WAH
JHOKE WAH
CHATTOLL WAH
70
79
98
KHOKAR WAH
JINDAY WAH
PARARA WAH
DHORA WAH
96
81
63
67
LASHARI WAH
JINDARA WAH
SHAH WAH
118
67
63
GAWAZ WAH
153
SIDGAH ESCAPE
NOOR KOHNA
153
73 HAJOO WAH
319
DAJAL BRANCH
TOTAL CAPACITY OF EXISTING HILL TORRENT CROSSING OVER DAJAL BRANCH = 779 CUMECS
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
KAHA HILL TORRENT
FLOOD MANAGEMENT SCHEMATIC DIAGRAM
IRRIGATION SYSTEM-PACHAD AREA
NATIONAL ENGINEERING SERVICE PAK (PVT) LTD LHR
in association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES
Fig: 5.6

to pass through canal. Thus, in view of regulation problems, inadequate capacity of carrying channels and high silt charge, it is technically not feasible to manage floodflows through canal inlets.

5.4.2.3 Disposal/Channelization of Floodflows to Indus River along Right Bank of Canals; (Alternative-3):

Disposal of floodflows to Indus River by channelization along right bank of Dajal Branch, would necessitate its routing to tail of Dajal Branch (RD 190) and then along right bank of Fatehpur Distributary. This would then move in southerly direction to Kadra Canal and finally lead to Indus River through cross-drainage that would have to be constructed at Kadra Canal.

Topographic features of the area along the flood route indicate that there is a high ground at the right bank in the following reaches of Dajal Branch.

1. RD 2.5 - 5
2. RD 20 - 25
3. RD 25.5 - 30.5
4. RD 32.5 - 34
5. RD 34.5 - 35.5
6. RD 38 - 43
7. RD 51 - 54.5
8. RD 60.5 - 67.5

These high areas would have to be channelized to allow floodflows to move along right bank to their final destination - the Indus River. The channelization would require the construction of the following:

1. Six bridges on Dajal Branch from RD 70 - RD 190;
2. Crossing on Kadra Branch;
3. One Railway Bridge;
4. One A.R.Bridge; and
5. Eight cunettes through the high areas listed above.

Figure 5.4 shows the overall plan for this alternative.

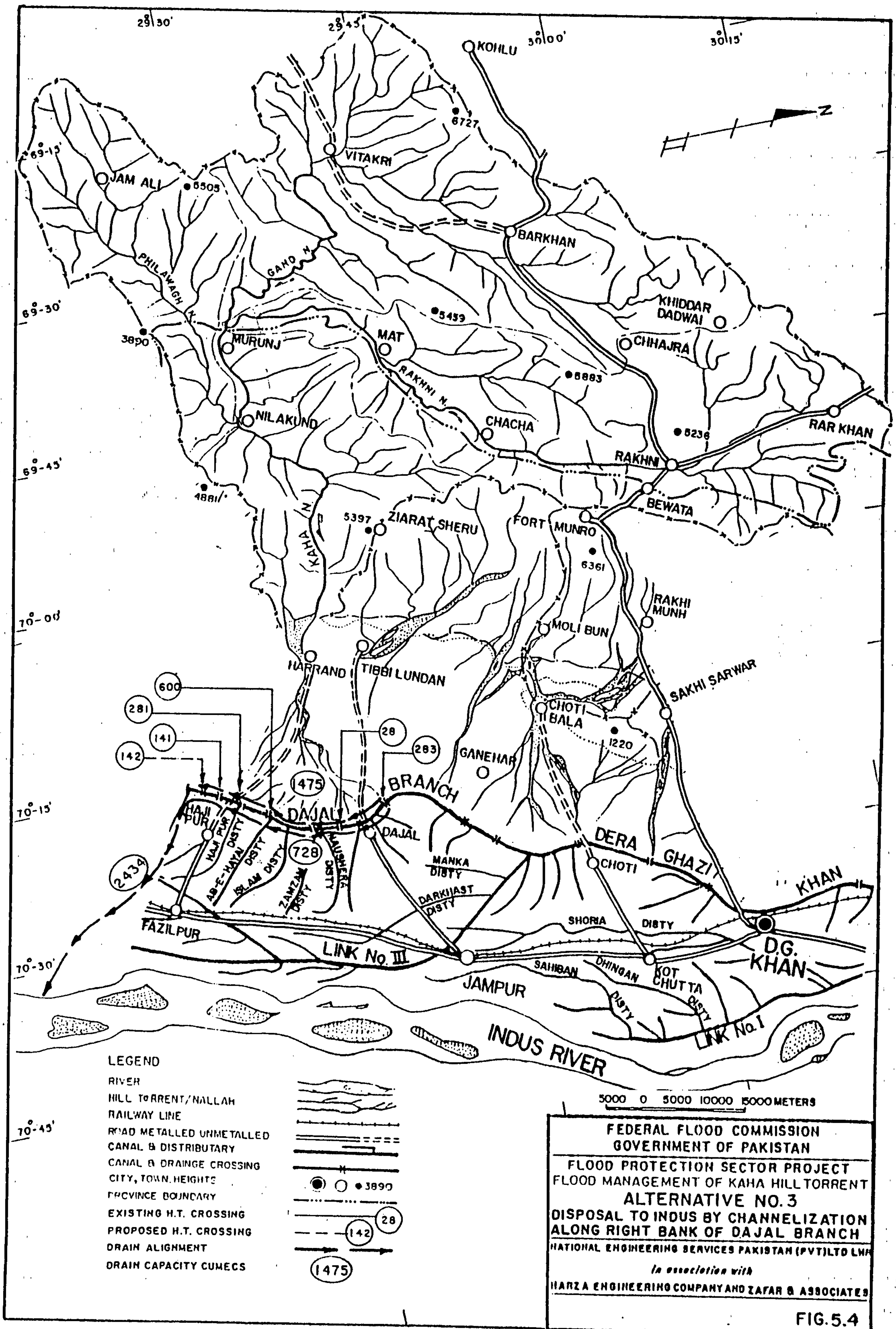
The channelization would also require acquisition of land for the cunettes. The estimated cost of this alternative is Rs 405 million as given in Table 5.2.

5.4.2.4 Flood Management Through Dispersion/ Dispersion Structures (Alternative-4):

Field studies carried out in the project area shows that normal flows below a threshold level are manageable by the local farmers by constructing earthen bunds through which the floodflows are diverted into the fields through the wahs (natural channels). These are stable channels in existence since ages. These wahs are Haqooq channels and have water rights for particular tribe/ family/village. Water diverted into these wahs are further divided according to the share of each farmer. The divided and sub-divided wahs end up into the bunded fields for filling up one after the other. The number of fields which receive water depends upon the intensity and duration of flood in the hill torrent and the amount of water diverted into the wah. Since the distribution system of channels naturally exists hence no expenditure will be incurred on it. In case of high flood, these earthen bunds are shattered, spelling disaster in the area. Hydrologic studies carried out for Kaha Hill Torrent have shown that flood volumes for design flood for a 25-year return period are likely to be of the order of 2,662 ha.m. Effective management presents the following problems:

- Damming is not practicable, because of high silt charge would result in a very limited life of the dam.
- Erratic nature of rainfall results in highly unpredictable run-off pattern.

The detail studies of sub-mountaineous and Pachad areas indicate that a great potential for flood management exists in mountaineous and Pachad areas through the construction of dispersion structures. The villages above the darrah have a total area of 32,400 ha (80,000 acres) of which about 22,700 ha (56,000 acres) are culturable including some parts where terrace irrigation is currently being



KOHLU
VITAKRI
BARKHAN
JAM ALI
MURUNJ
MAT
NILAKUND
CHACHA
RAKHNI
RAR KHAN
BEWATA
KHIDDAR DADWAI
CHHAJRA
ZIARAT SHERU
FORT MUNRO
RAKHI MUNH
MOLI BUN
HARRAND
TIBBI LUNDAN
SAKHI SARWAR
CHOTI BALA
GANEHAR
DAJAL
BRANCH
DERA GHAZI KHAN
CHOTI
FAZILPUR
LINK No. III
JAMPUR
KOT CHUTTA
D.G. KHAN
INDUS RIVER
LINK No. I
LEGEND
RIVER
HILL TORRENT/NALLAH
RAILWAY LINE
ROAD METALLED UNMETALLED
CANAL & DISTRIBUTARY
CANAL & DRAINGE CROSSING
CITY, TOWN, HEIGHTS
PROVINCE BOUNDARY
EXISTING H.T. CROSSING
PROPOSED H.T. CROSSING
DRAIN ALIGNMENT
DRAIN CAPACITY CUMECS
5000 0 5000 10000 15000 METERS
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
ALTERNATIVE NO. 3
DISPOSAL TO INDUS BY CHANNELIZATION ALONG RIGHT BANK OF DAJAL BRANCH
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
In association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

FIG. 5.4

TABLE 5.2

ALTERNATIVE NO. 3

LIST AND COST OF CROSS DRAINAGE STRUCTURES AND THEIR ESTIMATED COST

Sr. No.	TYPE OF STRUCTURE	APPROXIMATE LOCATION	NAME OF CHANNEL	ESTIMATED COST RS. MILLION
1.	H.T.Crossing over Dajal Branch Capacity 142 cumecs	RD 170+00	Dajal Branch	5.00
2.	Aqueduct (300 cumeces) Capacity	Head Reach	Sultan Disty	3.00
3.	Aqueduct (350 cumecs) Capacity	"	Dajal Disty	3.00
4.	Aqueduct (350 cumecs) Capacity	"	Firdous Disty.	3.00
5.	Aqueduct (350 cumecs) Capacity	"	Kausar Disty	3.00
6.	Aqueduct (400 cumecs) Capacity	"	Naushera Disty	4.00
7.	Aqueduct (400 cumecs) Capacity	"	Zam Zam Disty	7.00
8.	Aqueduct (500 cumecs) Capacity	"	Islampur Disty	7.50
9.	Aqueduct (550 cumecs) Capacity	"	Ab-e-Hayat	5.00
10.	Aqueduct (700 cumecs) Capacity	"	I-R Minor	1.00
11.	Aqueduct (1000 cumecs) Capacity	"	Dhundi Kutab Canal	5.00
12.	Aqueduct "	-	Fazil Disty	4.00
13.	"	-	Kadra Canal	5.00
			Total:	55.50

Strengthening of inlets and right bank of six existing H.T crossings. 8.00

Disposal Channel:

1. On right bank of Dajal Branch of Capacity 1474 cumecs length 25 Km	105.00
2. On right bank of capacity ranging from 300 cumecs to 2434 cumecs	138.50
	243.50
1 No. A-R Bridge	5.00
3 No. V-R Bridges	6.00
1 No Railway Bridge	7.00

<u>SUMMARY</u>

Cross Drainage Works	55.50
Strengthening of Existing H.T. Crossings	8.00
Disposal Channel	243.50
Bridges	18.00
Land Acquisition	80.00
Total: Rs.	405.00 Million

practised. Below the darrah, out of a total haqooq area of 41,600 ha (102,760 acres), about 36,253 ha (89,580 acres) are culturable and a natural distribution system is in existence. In addition to this, there is a large 'Non-Haqooq' area which could be irrigated if water can be made available. Thus, there are large tracts of culturable lands in the sub-mountaineous and Pachad areas where floodflows could be dispersed for irrigation. Considering the potential that is available above the darrah, it has been estimated that about 566 cumecs, out of peak of 2,662 cumecs could be absorbed in this area by constructing dispersion works which shall be limited to;

(a) flexible structure across the hill torrent just downstream of wah intake.

(b) upgrading of the wahs at intake by constructing bed-bars alongwith stone protection and stream lining of the wah approach banks.

The remaining 1,777 cumecs would be thus available for utilization in the Pachad area. Kaha Hill Torrent near Tibi Solgi splits-up into three branches known as Lambi Nain, Obhi Nain and Leghari Nain. The later has no water rights while the other two have equal shares. After studying the topography of the area, capacity of the carrying natural channels, the mode of basin irrigation and its past history and interview with the land owners, it has been determined that flow of 1,777 cumecs could be utilized in the Pachad area. Estimated cost of structural measures is Rs 190.26 million. Balance flow of about 319 cumecs would flow down to Dajal Branch and cross over through the existing hill torrent crossings.

5.4.3 Recommended Strategy for Flood Management

Various flood management strategies were considered and comprehensive studies were carried out to evaluate the technical feasibility and economic viability. Basic philosophy in the selection of the strategy was that maximum quantities of floodflows be utilized right in the areas where they are generated i.e., hilly and Pachad areas.

This would greatly facilitate not only the mitigation of flood hazard in the area but would usher in a new era of economic development. Abject poverty in the area warrants that concerted efforts be made for integrated management of floodflows.

5.4.3.1 Comparison of Alternatives:

(i) Disposal of floodflows to Indus River through aqueducts and old channels. This alternative looked technically promising. This strategy has also been recommended by some of the planners in the past. Upon critical examination, however, it has been found that the disposal to the Indus River would deprive the area of the likely irrigation benefits that could accrue from proper management of floodflows. The estimated cost of this alternative is about Rs 563 million. Moreover, it is likely to aggravate flood situation downstream in the riverine area.

(ii) Disposal of floodflows through Dajal Branch: This is technically not feasible as floodflows greatly exceed the carrying capacity of the channel and on account of the other constraints such as; heavy silt load and regulation problems.

(iii) Management of floodflows along right bank of canals and its ultimate disposal to the Indus River: This is likely to cost Rs 405 million. In the revised PC-I Form for extension of Dajal Branch, it has been proposed that a one mile belt along the right bank of DG Khan Canal and Dajal Branch could be brought under cultivation by lift irrigation. Channelization of floodflows would greatly hamper development of these facilities in the area. Moreover, transfer of floodflows would deprive the area of further development which would plunge the area in the nightmare of backwardness for ever. Cost of this alternative is Rs 405 million. Thus, this approach to the flood management is also not very attractive.

The other alternative which primarily aims at management of floodflows in sub-mountaineous and Pachad areas, likely to cost Rs 145 million, would help in providing regulating irrigation supplies to over 60,000 ha for the design flood. This would also boost the cropping intensity from an average annual of 8 percent to 81 percent for the design flood. In view of the merits discussed above, this strategy has been finally selected for management of floodflows of Kaha Hill torrent. This approach also conforms to the basic criteria that maximum quantities of floodflows be utilized right in areas where they are generated i.e., sub-mountaineous and Pachad areas.

5.4.4 Proposed Measures

Flood peak corresponding to 25-years return period is estimated as 2,662 cumecs. Run-off for the design return period is 0.13 million ha.m (Mha.m) which is equivalent to over one million acre-feet (1.05 MAF).

Under the proposed strategy, run-off generated by 25-year return period will be managed in accordance with the land potential available in Balochistan and Pachad areas and balance flow of 319 cumecs would reach Dajal Canal and pass through the hill torrent crossings over the canal. In case of floods of return periods upto 100 years the structures will pass the floods with encroachment on the free-board. Higher discharges will reach Dajal Branch but the extent of damage will be far less as compared with the losses without Project. Encroachment into free-board at higher return period floods is as under:

Return period Years	Discharge cumecs	Free-Board For Guide Banks (m)
25 (Design Return Period)	2,662	1.50
50	3,058	1.08
100	3,427	1.00

It will be seen from the above table that with 0.5m encroachment on the free-board the structure will be able to pass a flood of 100-year return period. In such an event a discharge of about 1,084 cumecs will reach the Dajal Branch.

5.4.4.1 Flood Management in Mountaineous Region

Presently eight structures have been built on various tributaries of Kaha Hill torrent in Balochistan Province. These structures are briefly discussed as under:

1. Chung Nallah Scheme

This is located on Chung Nallah, a tributary of Kaha in the upper catchment above Darrah. It consists of a low level concrete weir for the diversion of perennial flows only. It is feeding just one watercourse.

2. Rakhni Flood Irrigation Scheme

It is located on Rakhni Nallah another tributary of Kaha. It is built of stone masonary. The performance of this flood scheme has been extremely poor. It was outflanked behind the right abutment during one of the recent floods. The weir was extended on the right by building a higher crest weir of gabions almost of length equal to that of the original structure. Later on, it was outflanked on the left behind the intake channel left abutment. Presently the intake channel which was damaged by the 1988 flood is under repair.

3. Churri Irrigation Scheme:

Located on Churri Nallah which is a tributary of Kaha Hill Torrent. It consists of a high level concrete weir for diverting flood flows on both sides. The structures behaviour is unsatisfactory. The channels have almost been silted up.

4. Seakal Irrigation Scheme:

Seakal Irrigation Scheme failed even before it could see the light of the day. There is major damage on both the left and right flanks. A portion of weir crest has been under-scoured and has collapsed and the canal intakes on both sides have been seriously damaged beyond repair. The scheme need to be abandoned and rebuilt at a proper location.

5. Dubba Irrigation Scheme:

This is also located on Rakhni Nallah about 5 km downstream of Seakle Irrigation. It was built for the diversion of perennial flow. The scheme failed during the very first flood after construction in 1964 and since then it has been abandoned.

6. Catherine Irrigation Scheme:

It is on tributary of Kaha and is situated about 24 km downstream of Seakal Scheme. It was built to divert perennial flow for irrigation. It was outflanked on the right and a guide bund was built on the right side to check reoccurrence of outflanking.

7. Nahar Kot & Vitarki Irrigation Schemes:

These two schemes are located on Wahi Karin Nallah. These are low level diversion weirs for perennial flow. There are some flow problem to both the structures.

8. <u>Thangwani Irrigation Scheme</u>:

This was built on Gand Nallah, a tributary of Kaha, during 1982 at a cost of Rs 4.02 million. The Nallah has a perennial discharge of about 0.30 cumecs (10 cfs). In area of about 250 ha is available for cultivation.

Six out of the eight existing schemes mentioned above are in different states of dilapidation. The rehabilitation works to be undertaken for these scheme will range from remodelling to complete reconstruction at suitable locations in accordance with the morphology of these nallahs. This may involve some adjustment of the command area. In the cases of new weir constructions, efforts will be made to adopt the flexible type construction with Gabions. It would cost much less than the rigid rubble masonry construction. All this remodelling will form an integral component of flood management planning being proposed. The repair/remodelling of the eight structureswill cost about Rs 40.00 million and will manage a flood discharge of about 340 cumecs (12,000 cfs) and irrigate an area of about 13,600 ha (33,600 acres)

Four Additional Schemes: In addition to the remodelling of existing eight structures, the following four additional irrigation schemes having large agricultural potential have been selected. The existing and proposed structures are shown in Fig. 5.5.

S.No.	Name of Proposed Scheme	Co-Ordinates	Diversion Capacity (Cumecs)	Area to be Irrigated (Ha)
1.	Thadha Irrigation Scheme	N 29° 20' E 69° 23'	50	650
2.	Warsala Irrigation Scheme	N 29° 37' E 69° 26'	60	780
3.	Dhaula Irrigation Scheme	N 29° 52' E 69° 32'	60	780
4.	Wahi Irrigation Scheme	N 29° 37' E 69° 26'	58	575

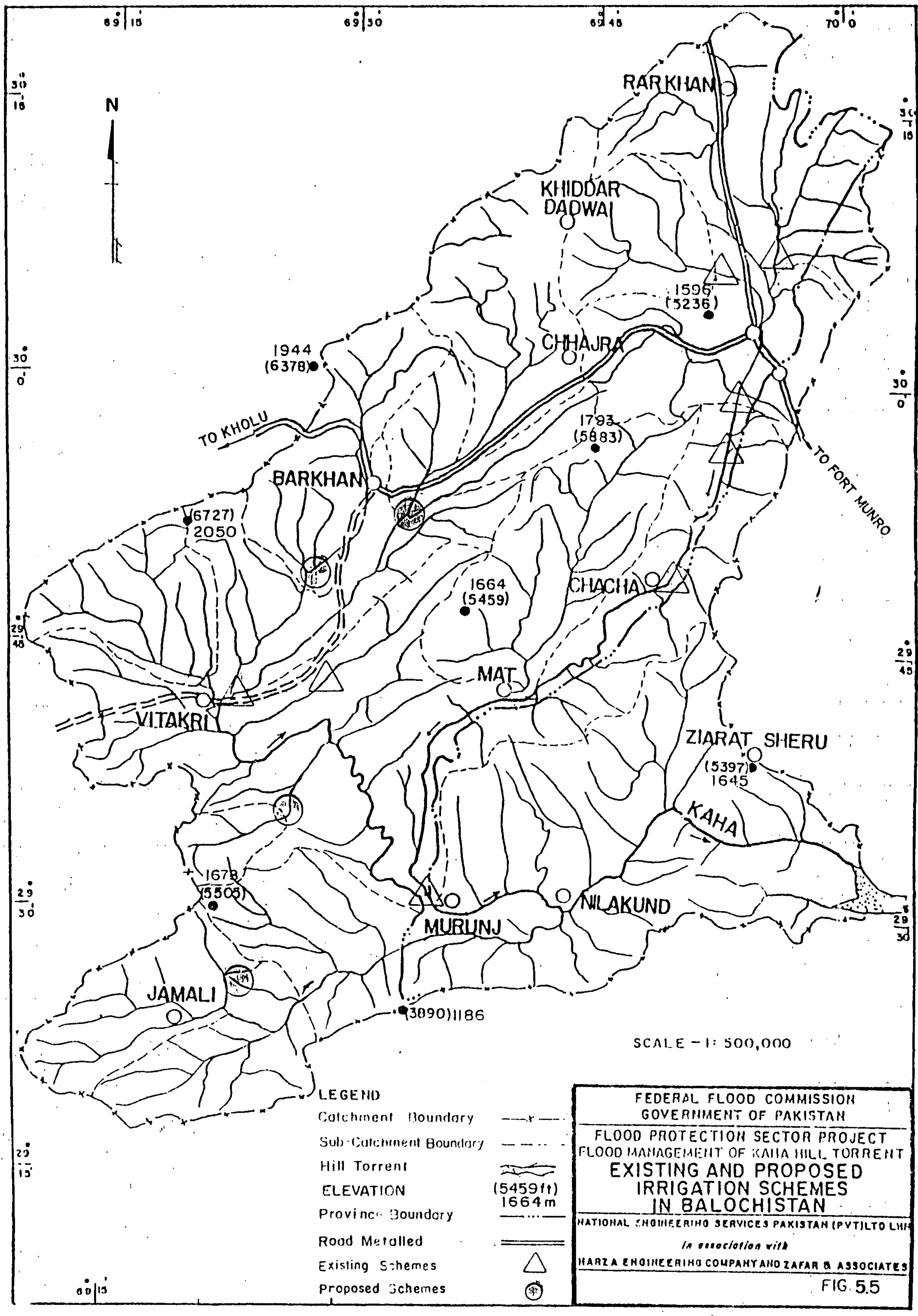

N
RARKHAN
KHIDDAR
DADWAL
1595
(5236)
CHHAJRA
1944
(6378)
TO KHOLU
1793
(5883)
BARKHAN
TO FORT MUNRO
(6727)
2050
1664
(5459)
CHACHA
MAT
VITAKRI
ZIARAT SHERU
(5397)
1645
KAHA
1678
(5505)
NILAKUND
MURUNJ
JAMALI
(3090)1186
SCALE - 1: 500,000
LEGEND
Catchment Boundary
Sub-Catchment Boundary
Hill Torrent
ELEVATION (5459ft) 1664m
Province Boundary
Road Metalled
Existing Schemes
Proposed Schemes
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
EXISTING AND PROPOSED
IRRIGATION SCHEMES
IN BALOCHISTAN
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT)LTD LHR
in association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

FIG. 5.5

5.4.4.2 Flood Management in Pachad Area

The Darrah of the torrent is about 40 km west of Dajal Branch. The Pachad area lying between the toe of hills and the canal is very fertile where basin irrigation is being practised on a part of the area. The culturable Pachad area is about 36,253 ha (Haqooq). The torrent has also perennial supply 'Kala Pani' of about 1 cumec at Darrah which is being used for irrigation according to water-rights. After emerging from hills, the torrent fans out like most other major hill torrents of the area, but rejions near Basti Mir Mohammad Pitafi, then flows down as main Kaha upto village Tibbi Solgi which is situated about 31 km downstream of Darrah. At this site, the torrent splits-up into three main branches. The left side channel called Leghari Wah a 'non-haqooq' channel has been closed at the head by constructing a bund known as Leghari Bund. The right side branch is called Ghawaz Wah and has a right to draw one-third of the floodflows reaching this site. The remaining two-third of flood water flows down through the central branch for further distribution between Shakh Shumali and Janubi.

Kaha flows bring down large quantities of sediment both suspended and bed load. The bed load mainly consists of large size heavy boulders (60-70 cms) and coarse to medium gravel (6-2 cms). The heavier boulders get deposited about 2 kms downstream of Darrah while the gravels travel further downstream to about 5 km in the hill torrent bed before settling.

The suspended sediment mainly comprises fine sand and silt. This suspended material is transported through the wahs upto the fields where it gets deposited due to ponding within the bunds. This fine sand and silt deposition adds fertility to the land. The conveyance systems (wahs) have generally maintained a stable regime, (non-silting non-scouring).

The proposed distribution of floodflows for design flood is given in Table 5.3. It is anticipated that the carrying capacities of the carrying channels (Wahs) decrease with the time by about 10 to 20

TABLE - 5.3

LIST OF WAHS AND THEIR CARRYING CAPACITY AFTER PROPOSED UPGRADING

S.NO.	NAME	CAPACITY(CUMECS)
1.	Mohammad Wah	74
2.	Hazooran Wah	81
3.	Khan Wah	51
4.	Upper Noor Wah	96
5.	Link Channel	73
6.	Khata Wah	81
7.	Jat Wah	81
8.	Chatool Wah	96
9.	Makwal Wah	79
10.	Sona Wah	81
11.	Lashari Wah	118
12.	Jindara Wah	67
13.	Ghawaz Wah	153
14.	Shah Wah	53
15.	Sidwah	73
16.	Hajoo Wah	Part from Sidwah
17.	Dhora Wah	67
18.	Parara Wah	53
19.	Jinday Wah	81
20.	Khokar Wah	96
21.	Noor Khona	153
22.	Makwal Wah	70
	Total:	1777 Cumecs

percent due to silting and masking effects of structures and channels. In that case a part of flood flows would reach Dajal Branch. The existing cross-drainage structure would take care of these escapages.

The Schematic Layout of these Wahs with respect to the darrah of torrent is given in Fig.5.6. The capacity of these wahs have been derived on the basis of actual cross-sections and slopes. The farmers will flood their lands according to the availability of water. Investigations and field surveys have been carried out for determining the working of these Wahs. These investigations indicate that in most cases the bed of the hill torrent near the off-take sites of Wahs has become deeper and the irrigators have to construct high stone cross-bunds for diverting floodflows. The demand of the irrigators is to construct proper stone diversion bunds which could divert the floods. The water rights of these Wahs is based on 'Saropa Paina', so the irrigators after irrigating their fields breach the diversion bunds and allow flood water to flows down to the next Wah. The construction of such an automatic system of diversion of floodflows would be too costly. In view of this, it is proposed to construct flexible type of diversion structures of stone in gabions of varying lengths and heights suited for the site. The estimated cost of these diversion structures is Rs 130.26 million.

Table 5.4 shows the overall plan for the management of 1,777 cumecs in Pachad area. The structures which are under construction will be extended and the receiving Wahs will be upgraded to receive greater discharge with proper intake structures. The now proposed structures will be flexible type Gabion construction which will be cheap in construction and economical to maintain. Figure 5.7 shows typical layout of the proposed distribution/diversion structures and Fig.5.8 shows the proposed guide banks to the structures.

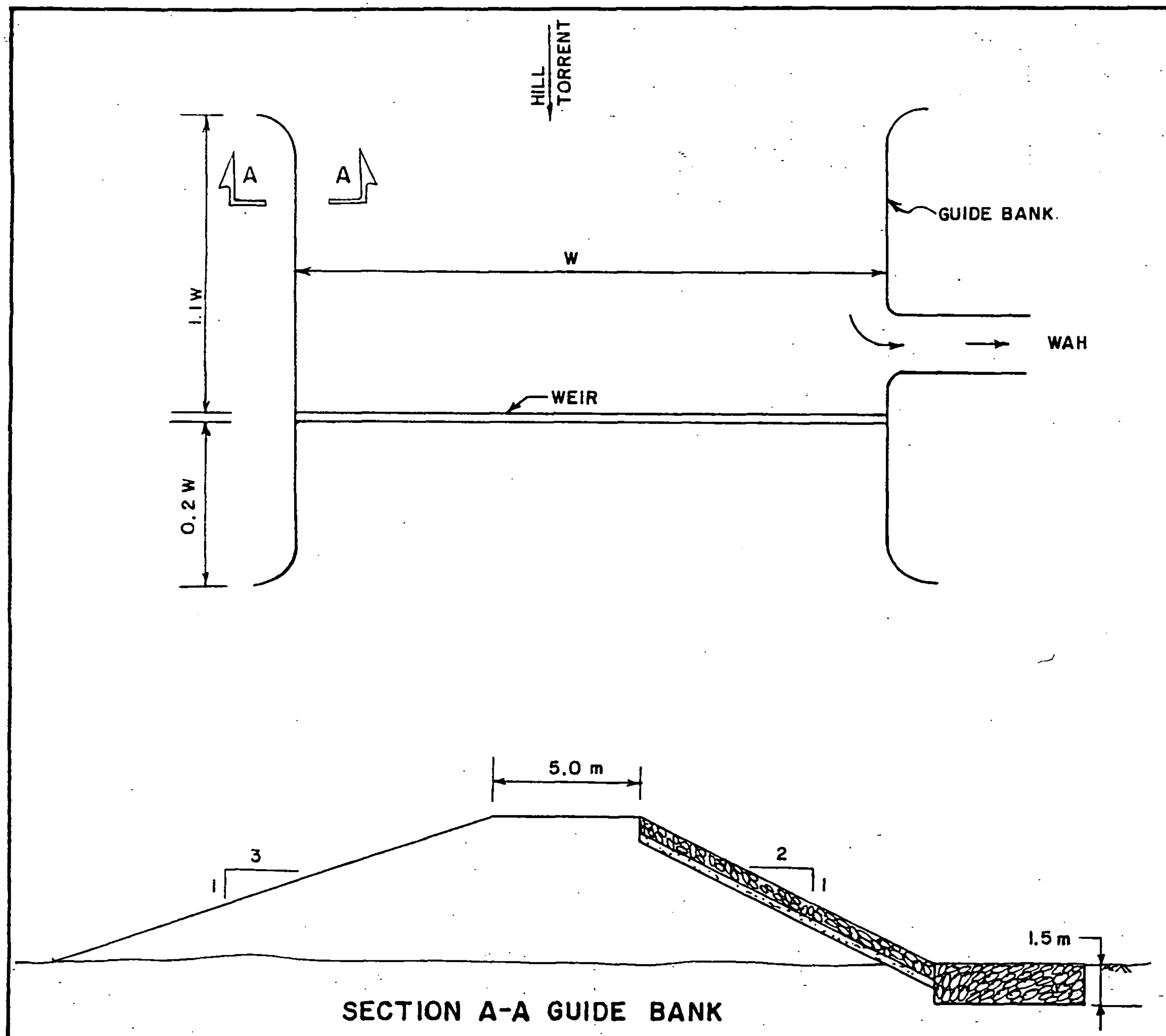
TABLE 5.4
KAHA HILL TORRENT
OVERALL PLAN FOR FLOOD MANAGEMENT
IN PACHAD (PUNJAB)

Rs.M = Rupees Million

Sr. No.	Name of Structure and RD	Name of Offtaking Channel/Wah	Discharge of channel/Wah m^3/sec	Type of Structure	Status	Year of comple-tion	Comple-tion Cost Rs.M	Estimated/improve-ment cost of weir Rs.M	Length of weir/Salaii	Unit Width Discharge Over Weir $q\ m^3/sec$	Lengh of upstream Guide Bank m	Lengh of down-stream Guide Bank m	Maximum Depth of scour Below H.F.L m	Free Board Over Guide Bank m	Estimated Quantities: Earth Work Cu.m	Estimated Quantities: Stone Work Cu.m	Estimated Quantities: Gab-ions Cu.m	Estimated Quantities: Con-crete Cu.m	Cost of Guide Bank Rs.M	Total Cost Rs.M
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16				17	18=9+17
1	SALAII 13+000	MOHAMMAD WAH	76	SALAII	In Progress	-	-	3.00	-	Not Applicable	300	75	2.00	1.50	28125	10795	-	1150	2.25	5.25
2	SALAII 13+000	MAZOORAN WAH	81	SALAII	In Progress	-	-	2.00	-	Not Applicable	300	75	1.90	1.50	27500	15592	-	950	2.25	4.25
3	SALAII 16+000	KHAN WAH	51	SALAII	In Progress			2.50	-	Not Applicable	300	75	2.30	1.50	29508	7237	-	1200	2.25	4.75
4	CROSS STRUCTURE 39+000	UPPER NOOR WAH	96	SALAII	In Progress			1.80	-	2.00	300	75	2.12	1.50	25500	5263	-	1050	2.25	4.05
5	SALAII	LINK CHANNEL	73	SALAII	In Progress			1.20	-	Not Applicable	300	75	1.95	1.50	20000	1645	-	800	2.25	3.45
6	CROSS STRUCTURE 74+000	KHATA WAH JAT WAH	81 41	Weir	Proposed			10.00	670	3.50	737	134	3.08	1.50	130650	22820	18760	6700	11.05	21.05
7	CHATOOL CROSS STRUCTURE 90+000	CHATOOL WAH MAKWAL WAH JHOKE WAH	96 70 79	Weir	Completed	1986-87	2.00	8.10	540	4.00	594	108	3.39	1.50	105300	48158	-	-	8.27	16.37
8	SONA CROSS STRUCTURE	SONA WAH	81	Weir	Proposed	-	-	7.65	510	4.00	561	102	3.39	1.50	99450	17370	14280	5280	7.60	15.60
9	LASHARI CROSS STRUCTURE 99+000	LASHARI WAH	118	Weir	Proposed	1985-86	2.50	8.25	550	3.25	605	110	2.91	1.50	107250	18733	15400	4950	8.58	16.83
10	CROSS STRUCTURE 110+000	JINDARA WAH GHAWAZ WAH SHAH WAH	67 153 53	Weir	Proposed	-	-	6.00	400	4.25	440	80	3.50	1.50	78000	13624	11200	3760	3.86	9.86
11	CROSS STRUCTURE 115+000	SIDWAH NAJOO WAH	73	Weir	In Progress	-	-	5.77	385	3.9	425	80	3.3	1.5	75750	13231	10780	3450	6.06	11.83
12	CROSS STRUCTURE	DHORA WAH PARARA WAH JINDAY WAH KHOKHAR WAH	67 53 81 96	Weir	Proposed	-	-	4.50	300	4.33	330	60	3.55	1.5	58500	10218	8400	2690	4.68	9.18
13	HEAD REG	NOOR KOHNA	153	Weir	Proposed	-	-	3.90	260	3.85	286	55	4.84	1.5	51150	8934	7280	2150	4.09	7.79

Grand Total: Rs 130.26 Million
Total discharge Dispersed: 1,777 Cumecs

Rates:
Earth work =Rs.7.50/Cu.m
Stone Work =Rs.152.80/Cu.m
Gabions =Rs.538/Cu.m
Concrete =Rs.1000/Cu.m



SECTION A-A GUIDE BANK

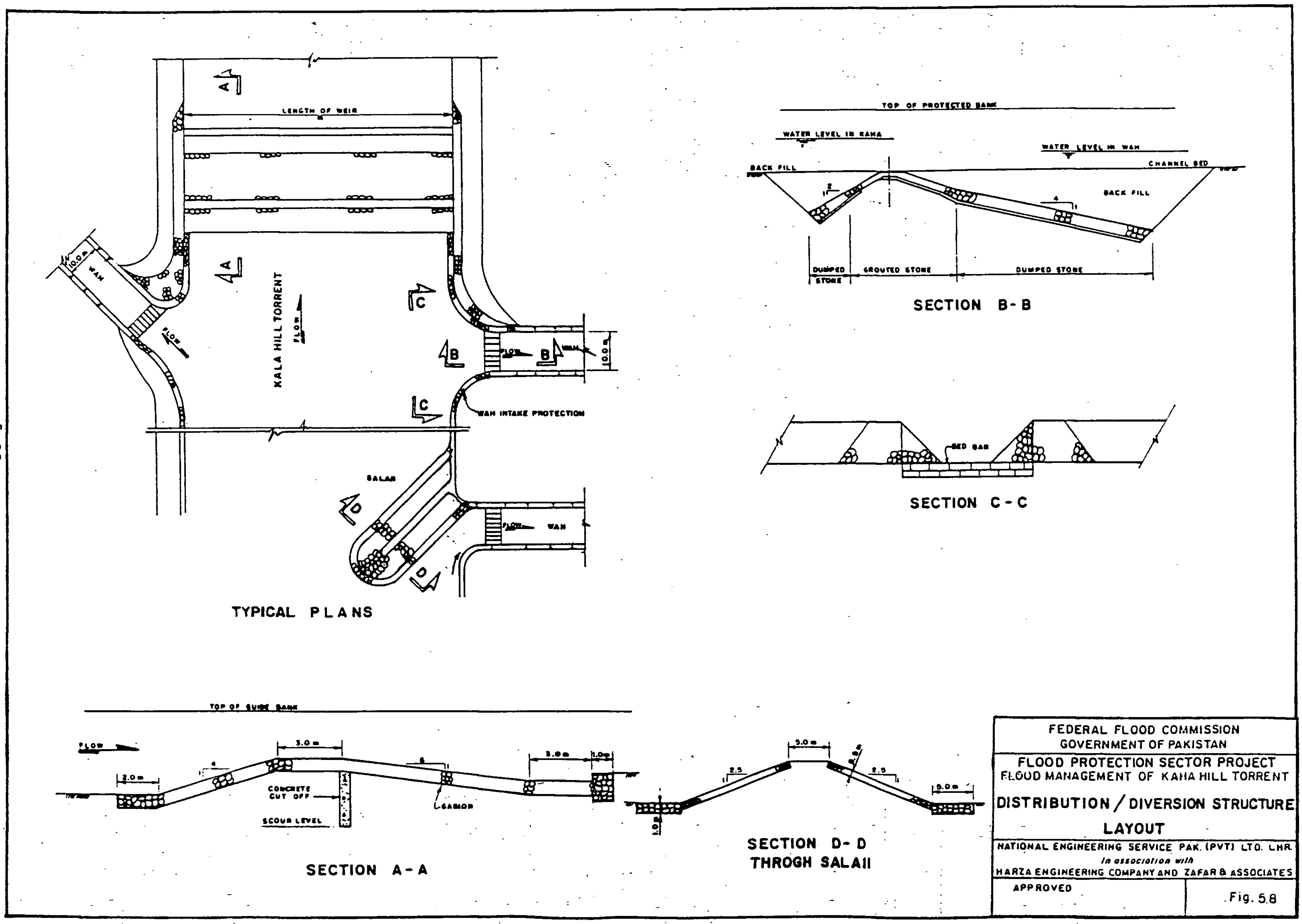
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

DIVERSION STRUCTURES
GUIDE BANKS

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
in association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

Fig.5.7



FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

DISTRIBUTION / DIVERSION STRUCTURE LAYOUT

NATIONAL ENGINEERING SERVICE PAK. (PVT) LTD. LHR.
In association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

APPROVED

Fig. 5.8

5.4.5 Design Parameters

The beds of nallahs in Balochistan are generally eight to ten feet lower than the adjoining land, so the crests of diversion weirs have to be kept high enough with respect to the existing bed levels for feeding the excavated flood channels. These weirs will behave like vertical drop energy dissipator structures. The bottom level of the weir is to be fixed at the expected maximum depth of scour level and the crest level would be kept keeping in view the area to be commanded. Upstream apron is not necessary, since the nallah is likely to silt-up due to heavy silt load. The length of downstream cistern would be fixed from the energy dissipation consideration.

Weirs so far constructed in upper catchments in Balochistan are invariably rigid structures built of concrete or stone masonary with impervious downstream floors. Slight differential settlement in the foundation of the structure results in major cracking and consequent collapsing of the whole structure beyond repairable condition. After critical study of the damaged structures in Balochistan, we are not recommending rigid type of concrete or stone masonary structures. Instead, we are proposing flexible type of weir structures constructed with stones in wire crates (gabions). The channels which carry boulders have been recommended to be constructed with gabions built of angle iron cases. The use of 6mm bars has been recommended instead of 8 gauge wire. Weir structures built with gabions will adjust themselves against differential settlement in the foundation, if any, without damage to the weir.

Another likely cause of the failure of irrigation structures is outflanking of floodflows. Following are the possible causes of the outflanking:

(i) High velocity in nallah;
(ii) Oblique approach of nallah to the weir structure.

In the mountaineous areas above the darrah the nallahs follow a sinous curve. Generally long straight reaches of nallah are not available for ideal location of weir sites even if otherwise the site is suitable for a weir structure. In the existing weir structures in Balochistan, the length of crest was not designed for higher floodflows generally encountered in the nallahs, which has resulted in their outflanking and consequent failure.

In order to avoid this type of failure, we propose to provide adequate length of weir with proper protection. Figure 5.9 1/ shows the type of weir proposed for construction in upper catchments in Balochistan. Design criteria for fixing the upstream and downstream bed protection length is given in Fig.5.10 1/.

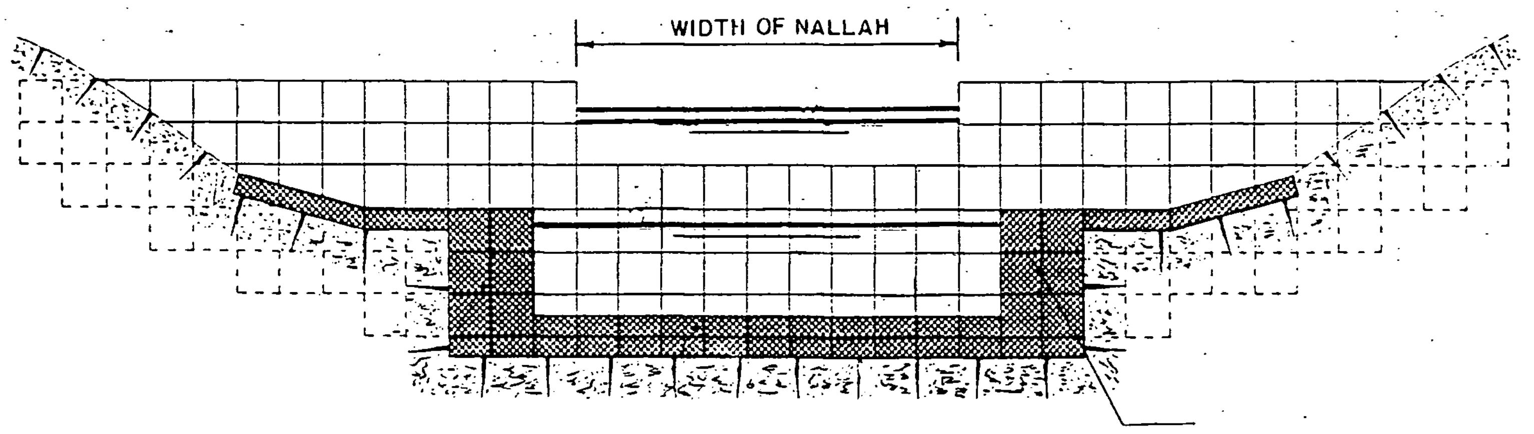
In Pachad area, the nallah slopes are flatter and the beds of the nallahs are not as deep as in Balochistan. In Pachad area, the beds are only four to five feet lower than the adjacent ground. In this area, the silt content in the floods is also comparatively low. Here the height of weir crest need not be very high. In Pachad area too, we intend to provide flexible gabion weir or cross-structure with low crest. Fig.5.11 shows the typical cross-section of weirs/cross-structures proposed.

In order to check movement of the bed against scour/retrogression, the intakes of the wahs will be armoured with gabion structures (Fig.5.12).

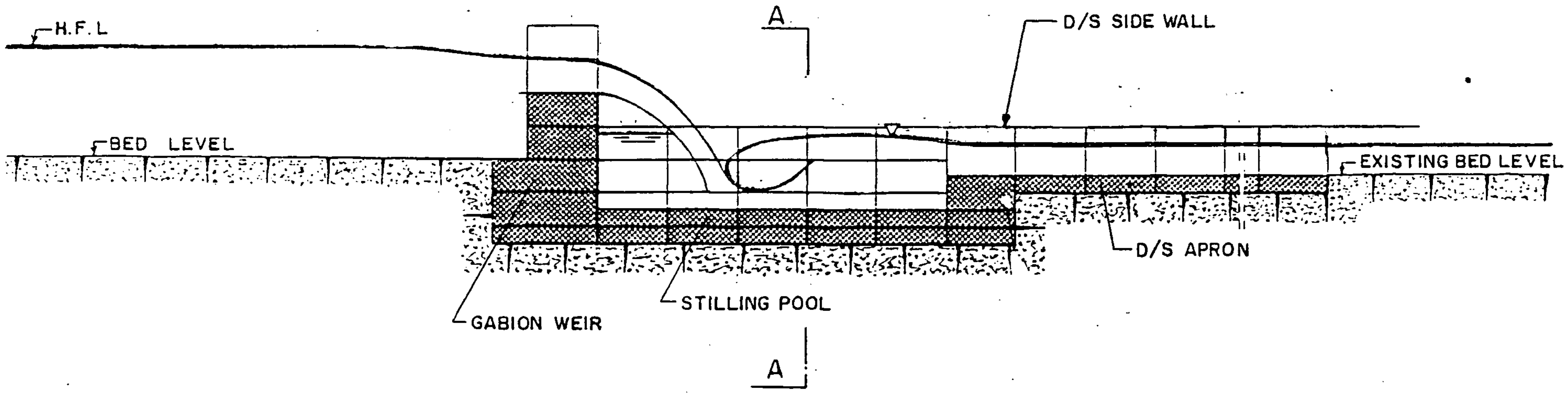
5.4.6 Recommended Sequence of Construction & Costs

Implementation of the proposed works will take three years. Some floods may be experienced during the period of construction. It is, therefore, desirable to carry out the works in such order that there is minimum interruption in the on-going works without aggravating flood problems. The recommended phasing and cost estimates are given in Table 5.5. These costs are based upon 1989-90 price level and likely escalation during the execution of project.

1/ River Engineering by Margrette Petersen.



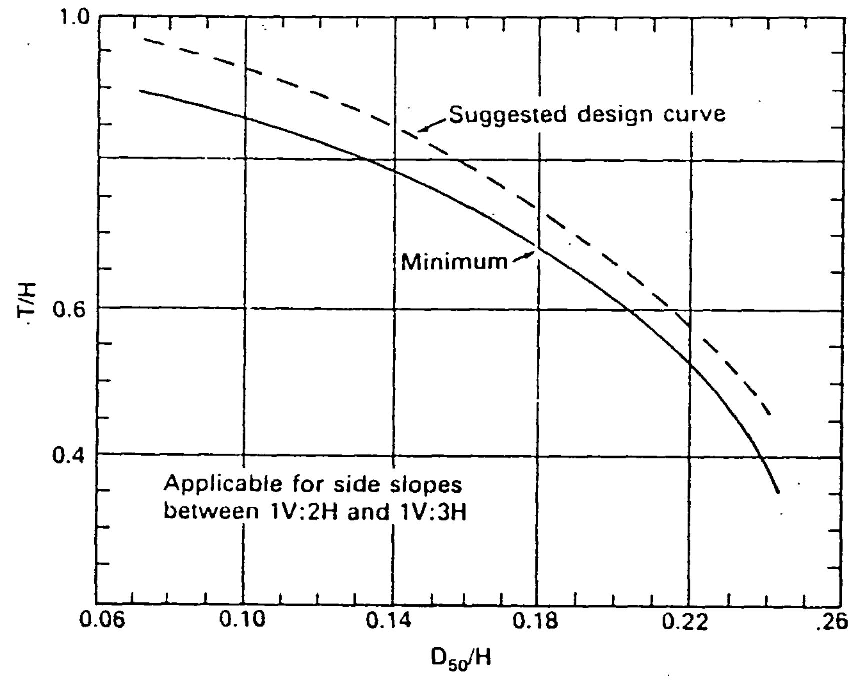
SECTION A-A



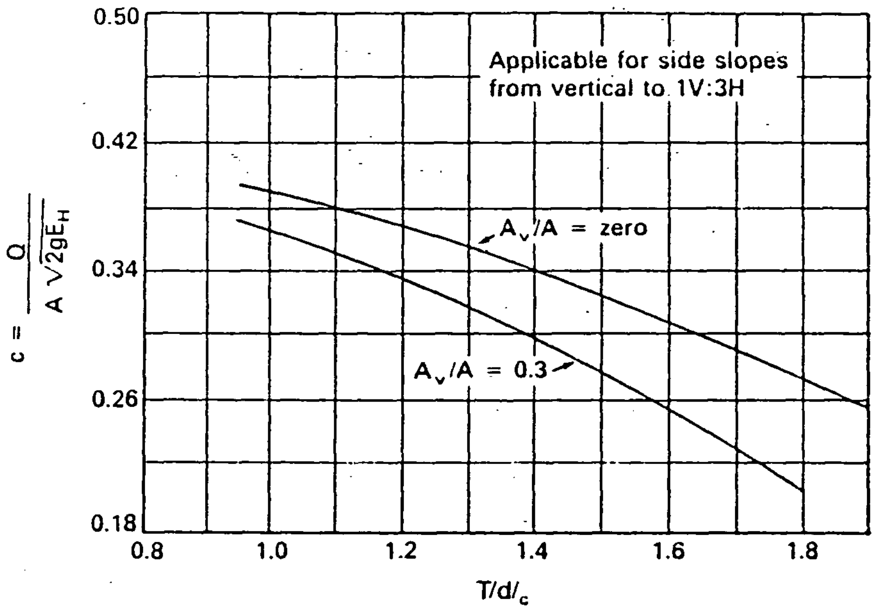
TYPICAL X-SECTION OF DIVERSION WEIR IN UPPER CATCHMENT BALOCHISTAN

Fig.5.9

Source: Maccaferri Gabions Catalog



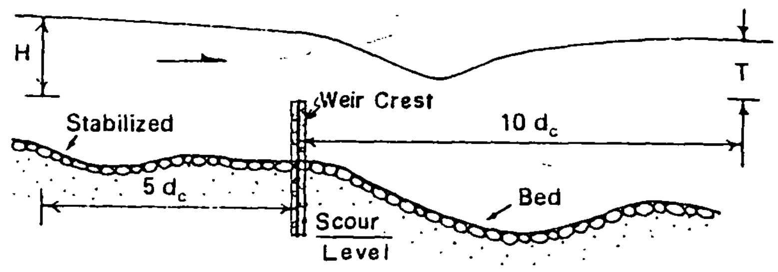
(a) Stone size required



(b) Discharge coefficient

Notes:

- E_H = total head, $H + V^2/2g$ above the crest $5d_c$ upstream of the crest
- T = tailwater depth above the crest $10\ d_c$ downstream of the crest
- d_c = critical depth for trapezoidal crest section
- A = total area above crest $5d_c$ upstream
- A_v = area in end sections of crest $5d_c$ upstream
- Q = total discharge

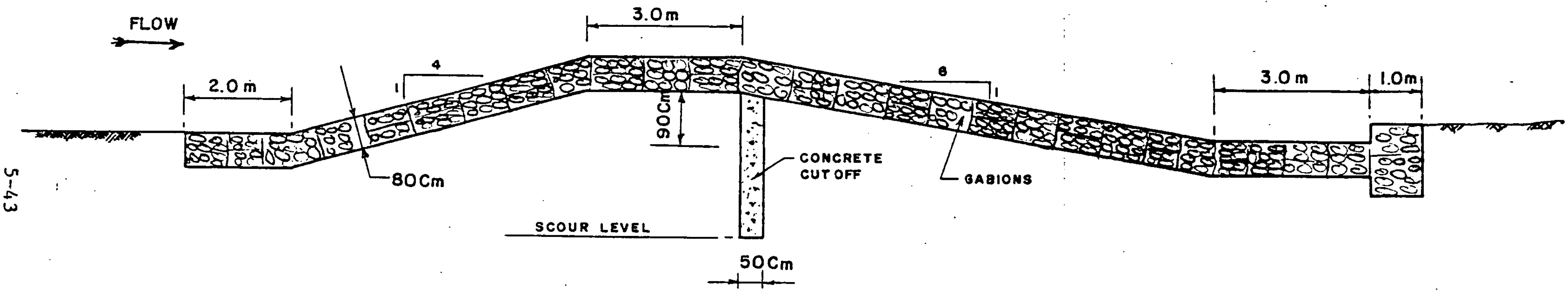


(c) Definition sketch

Source: River Engineering by Margrette Petersen

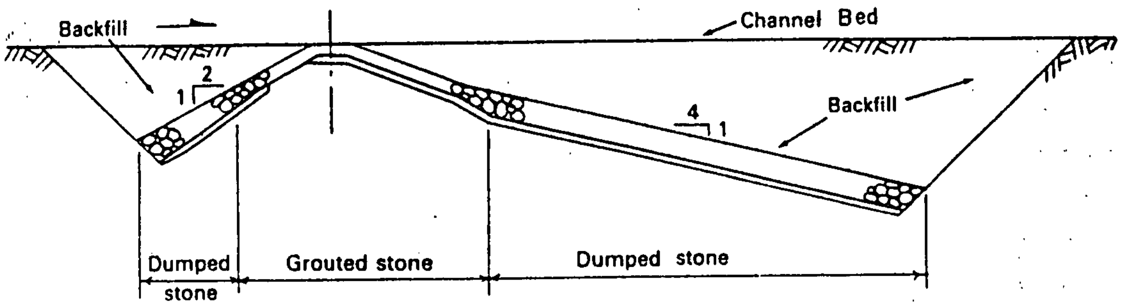
DESIGN CRITERIA FOR GABION AND ROCK SILL

Fig. 5.10

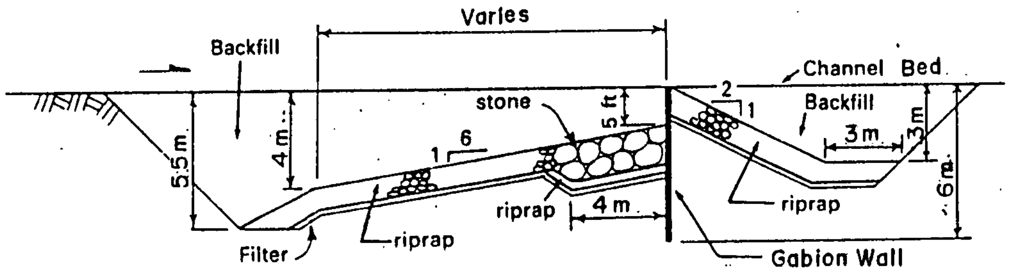


TYPICAL CROSS STRUCTURE
FOR PACHAD AREA

Fig: 5.11



· Alternative (a) Grouted stone stabilizer



Alternative (b) Gabion Wall Cutoff With Stabilizer

Source: River Engineering
By Margrette Petersen

WAH - INTAKE STRUCTURE IN PACHAD AREA

Fig. 5.12

TABLE 5.5

PROPOSED WORKS AND ESTIMATED COSTS

	YEAR	NAME OF WORKS	COST (Rs Million)
UPPER CATCHMENT BALOCHISTAN	YEAR ONE 1990 - 91	REHABILITATION Rakhni Irrigation Scheme Nabar Kot Irrigation Scheme Vitarki Irrigation Scheme	5.00
		NEW SCHEMES Wahi Irrigation Scheme Thadha Irrigation Scheme	10.00 10.00
			Total for Year One 25.00
	YEAR TWO 1991 - 92	REHABILITATION Seakle Irrigation Schemes	5.00
		NEW SCHEMES Warsala Irrigation Scheme Thadha Irrigation Scheme	8.00 7.00
			Total for Year Two 20.00
	YEAR THREE 1992 - 93	REHABILITATION Catherine Irrigation Scheme Thangwani Irrigation Scheme Chung Irrigation Scheme	15.00
			Total for Year Three 15.00

	YEAR	NAME OF WORKS	COST Rs Million
PACHAD AREA PUNJAB	YEAR ONE 1990 - 91	Salaii RD 13 + 000 (Mohammad Wah)	5.25
		Salaii RD 15 + 000 (Hazroon Wah)	4.25
		Salaii RD 16 + 000 (Khan Wah)	4.75
		Cross Structure U/Noor Wah RD 39+000	4.05
		Cross Structure Jat Wah and Upgrading of Wahs	21.05
		Salaii Line Channel	3.45
			Total for Year One 42.80
	YEAR TWO 1991 - 92	Chatool Cross Structure	16.37
		Sona Cross Structure	15.60
		Lashari Cross Structure and Upgrading of Wahs.	16.83
			Total for Year Two 48.80
	YEAR THREE 1992 - 93	Cross Structure Jindara etc.	9.86
		Cross Structure Sidwah	11.83
		Cross Structure Dhora Wah etc.	9.18
		Head Regulator Noor Kohna	7.79
			Total for Year Three 38.66

PROJECT PHASING

YEAR	BALOCHISTAN	PUNJAB	TOTAL Rs Million
1990-91	25.00	42.80	67.80
1991-92	20.00	48.80	68.60
1992-93	15.00	38.66	53.86
	60.00	130.26	190.26

SECTION - 6

AGRICULTURE AND ECONOMIC EVALUATION

6.1 PRESENT AGRICULTURE

6.1.1 General

DG Khan and Rajanpur Districts of Punjab Province cover an area of 2.39 million hectares (5.9 million acres) which consists of 17 percent canal command area, 35 percent Pachad area and 48 percent sub-mountaineous and mountaineous area. Thirteen major and 192 minor hill torrents emanating from Suleiman Range devastate large areas during major floods. Kaha hill torrent has been taken to formulate a technically sound and economically viable solution to the flood problems after studying its behaviour under actual field conditions. The area lies within the Arid Zone of the country and agricultural production is dependent on flood irrigation or soil moisture retention. Only a small part of the rainfall on the catchment area is utilized for agriculture, while the flood flows part cause serious damage to standing kharif crops, canals, roads, railway, and other infrastructure. Deterioration of the vegetative cover through over-grazing by nomadic flocks has aggravated the problem and has increased flood damage potential of the hill torrents. Flood Management of the torrent is proposed against 25-year peak flood in such a way that the maximum water up to the floods of that magnitudecan be utilized in the upper areas where they are generated.

6.1.2 Soils and Land Use

The mountains are almost bare rocks and the valley sides are stony whereas, the soil of Pachad Area is piedmont type with high fertility having good moisture holding capacity. Once the top layer of soil is dry, there is little subsequent evaporation from the soil below the land surface. The catchment area of the Project covered by range which is used mainly for grazing and providing fuel for migratory stock owners from the very sparse vegetative cover. Very small area (less than two percent) is covered with forests on the banks of the hill torrent and its tributaries. On high elevation, a part of area is also used for wheat cultivation by perennial springs. The Punjab piedmont plain has water right on about 41,585 hectares of which 36,253 hectares are culturable area which is about 87.2 percent of the total area. The present annual average cropped area through basin irrigation is only 2,897 hectares which can be increased by proper control and optimum use of floodflows of hill torrent. About 22,663 ha culturable area located in Balochistan can be developed by their implementation of four new irrigation schemes and rehabilitation of eight existing schemes which are not in working orders. It was observed during field investigation that due to highly delapidated condition of the eight existing structures, presently the crop production is almost negligible.

6.1.3 Irrigation Practices

Basin irrigation has been practised in the Pachad area since pre-historic times by constructing small diversion bunds across the main channels for diverting floodflows to the field enclosed by earthen bunds of one to one-half meter (three to five feet) in height. The entire area is terraced and is traversed by a large network of natural channels. During exceptionally wet years flood-flows are so high and sudden that the earthen bunds constructed by cultivators are washed away. A major part of flood water lends to concentrate in depressional areas and strike the canal system causing breaches resulting in extensive damage in the canal irrigated area.

6.1.4 Cropping and Production

In the Pachad area major kharif crops are jawar and bajra while rabi crops are wheat, oil-seed and gram. Crops sown at the lower elevation are mostly sorghum with some rape and mustard. Some wheat is grown in areas with residual water or in case of late floods. The cropping pattern and intensities for Kaha Hill Torrent as a whole, computed on the basis of five years average (1984-85 through 1988-89) are given in Table 6.1. The reason for compiling average of five years is to smoothout the influence of fluctuation in rainfall quantity and timing. Average cropping intensity calculated for the Pachad Area is 8.0 percent with 5.8 percent kharif and 2.2 percent rabi. The cropping pattern in the area is tailored in accordance with the limited and unreliable water supply system. Area, production and average yield of principal crops are given in Table 6.2

Sorghum and bajra as kharif crops are planted in June to August on the entire cultivated and adequately watered area. Later, around September, rape and mustard is seeded into those areas where millet fails to germinate. Millet is harvested in November and oilseeds in January-February. When the last floods occur late in the season, i.e., October and November, a part of the area not flooded earlier in the season is also planted with wheat and gram. A brief description of the crops which are generally sown in the Project area follows.

- Sorghum (jawar); is the most important food crop grown in the Project area. The crop depends for moisture on the diverted flood waters which flow down onto the plains from the mountains with fertile organic matter. This supply is primarily available in the kharif season, and is variable in quantity and timing. The sorghum area, thus, varies considerably according to the duration and number of floods every year. The entire sorghum crop is planted with low yielding, long stemmed indigenous varieties. The straw is considered as important as the production of grain because this is the only available livestock feed throughout the year.

TABLE - 6.1

PRESENT CROPPING PATTERN AND INTENSITIES

Area..... Hectares
Intensity. Percent of CC
CCA...... 36253 Hectare

CROPS	1984-85	1985-86	1986-87	1987-88	1988-89	AVERAGE	INTENSITY
KHARIF							
Jawar	2548	926	4115	309	1185	1817	5.0
Bajra	701	60	535	15	72	277	0.8
K.TOTAL:	3249	986	4650	324	1257	2094	5.8
RABI							
Wheat	580	245	925	315	259	465	1.3
Gram	466	11	99	17	111	141	0.4
Oilseed	450	24	159	14	347	199	0.5
R. TOTAL:	1496	280	1183	346	717	805	2.2
ANNUAL:	4745	1266	5833	670	1974	2899	8.0

Source : Intensities are based on Five Years Cropped Average from 1984-85 to 1988-89 collected from Revenue Office, District Rajan Pur.

TABLE - 6.2

PRESENT CROP AREA, PRODUCTION AND YIELD

CROPS	AREA (HECTARES)	YIELD (Kgs/Hectare)	TOTAL PRODUCTION (M.Tons)
Jawar	1817	430	781
Bajra	277	350	97
Wheat	465	698	325
Gram	141	485	68
Oilseed	199	461	92

Source: Yields are based on Five Years average taken from Punjab Agricultural Statistics.

This is why the cultivators generally prefer to sow jawar/bajra even in late season due to late rainfall. The yield of grain is estimated about 430 kgs and a straw at 2,150 kgs per ha. No fertilizer is used for growing the crops. Smut and stem borer are the major disease problems.

- Wheat: is the second important food crop sown in the Pachad area. In case last floods occur late in the season, i.e., October and November, considerable areas are also planted with wheat. About 90 percent of the wheat grown is of indigenous variety, because of its ability to withstand drought and high straw yield. wheat crop generally receive no moisture in addition to that stored in the soil in the bunded fields. This results in generally very low crop yield of about 698 kgs per hectare.

- Oilseeds: The common oilseed crops grown are rape and mustard, planted in the rabi season. The rabi oilseed crop is grown in the low alluvial patches of the Pachad area using the residual moisture. the crop is planted in those pockets inside the sorghum crop where poor establishment has left gaps. In view of lack of moisture in the soil and likely poor financial return, little efforts are made for the cultivation of oilseed crops. They are looked upon as a bonus. They produce low yields and are sometimes fed green to livestock.

6.1.5 Farm Practices

Bullocks provide power for land preparation in the project area. The standard practice of most of the farmers is to have one or two bullock pairs for cultivation depending upon the size of holding. Farm size is large; about 10 hectares, with an average cultivated area of 2.5 ha, the remainder being fallow. Ploughing of the land is usually not done until the soil has had its first soaking. Because, most of the piedmont soils of the Pachad area have low permeability. Continued ponding or successive floodings are needed to attain saturation levels. The number of ploughings carried out with the wooden bullock plough is only 2-3; much less than in the canal irrigated area. The seedbed tilth is often very poor and seed is planted by 'pora' direct into the ground at the time of first ploughing. Despite this, good germination usually occurs because in sailaba agriculture, the silt is deposited with the first watering, thus producing a fertile seedbed. The farming alluvial is not labour extensive. Average family size is about six persons which, with a pair of bullocks, manages to cultivate about six ha of land per farm in kharif season.

6.1.6 Integration with Livestock

Most of the people of the project area are nomadic and livestock rearing is a traditional activity. They all maintain some farm of sheep and goat flocks as well as bullocks for draught purpose. These animals are fed through stubble grazing and by feeding green fodder which is mostly sorghum.

Sorghum stubble grazing is sold at Rs 50 per ha. Block and bunches of sorghum straw are also sold. This integration of the livestock and the cropping system serve the dual purpose of supplying manure to the cropped land as well as keeping the nomadic sheep flocks in reasonable condition over the winter period.

6.2 FUTURE AGRICULTURE DEVELOPMENT

6.2.1 Potential for Development

The management of floodflows for agriculture development essentially requires a comparative study of pre- and post-project level of production. The development potential of the area, where rainfall is the only source of irrigation, mainly depends on the availability of water in the form of run-off and on the availability of cultivable area.

The annual run-off and total cultivable area of Kaha Hill Torrent against various return periods indicate that only 8.0 percent of the area is irrigated during an average flood year. During high floods, only a small percentage of floodflows are utilized for agriculture and remaining flows generally inundate the canal command area after breaching the Dajal Canal. Therefore, the project has been designed against a maximum peak flood of 25-year return period to minimize such losses by and to use it for the development of project area. Monthwise run-off against 2.33, 5, 10, 25-years flood has been calculated. The available annual run-off for the design flood during various months (June to November) of the year which can be used for sowing kharif and rabi crops, is about 105,383 ha.m. The land use potential in 'haqooq' area of Punjab flood plain is about 36,253 ha which can be developed by spreading the floodflows of peak floods whereas about 22,663 ha culturable area located in Balochistan may be developed by proposed works against design flood. About 96,100 ha.m out of the available run-off against 25-year return period can be spread over 51,200 ha with 1.22 meter (four feet) depth of water assuming 65 percent conveyance efficiency as given in Table 6.3. This area is about 87 percent of total cultivable area. The bunded irrigation of 1.22 meter depth of water also cover about 60 percent field efficiency. Thus, the project irrigation efficiency (the effective use of the irrigation water in crop production) would be 39% that looks more realistic for such project where fields are flooded. As the design diversion capacity of proposed structure is about 2,343 cumecs, therefore, the surplus runoff against design flood of 2,662 cumecs discharge may be passed through the Dajal Canal crossings and inundated the canal command area.

There are two major seasons of sowing crops in the Pachad area i.e., kharif (April to August) and Rabi (September to November). Future production and development 'with' and 'without' project have, therefore, been studied to establish incremental production in the proceeding paragraphs.

6.2.2 Future Cropping Pattern

6.2.2.1 'Without' Project:

The cropping pattern and intensities 'without' project have been estimated after determining the return period of peak floods by using precipitation data. After knowing approximately the return

TABLE - 6.3
FUTURE CROPPING INTENSITIES WITH AVAILABLE IRRIGATION
SUPPLIES FOR DIFFERENT HILL TORRENTS OF PROJECT AREA

Name of Development Area	CCA	Return Period	Available Runoff at Darrah			Irrigation Efficiency	Bunded Irrigation	Cropped Area			Cropping Intensity		
	Hectare	Year	Kharif	Rabi	Annual			Kharif	Rabi	Annual	Kharif	Rabi	Annual
			Hectare Meters			Percent	Centimeters	Hectare			Percent of CCA		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Balochistan Area	22,663	2.33	9,056	2,452	11,508	65	122	4,825	1,306	6,131	21	6	27
		5.00	17,416	4,715	22,131	65	122	9,279	2,512	11,791	41	11	52
		10.00	21,645	5,860	27,505	65	122	11,532	3,122	4,654	51	14	65
		25.00	23,396	6,380	29,776	65	122	12,465	3,399	15,864	55	15	70
Punjab Piedmont Plain (Haqooq Area)	36,253	2.33	21,130	5,720	26,850	65	122	11,258	3,048	14,306	31	8	39
		5.00	40,637	11,000	51,637	65	122	21,651	5,861	27,512	60	16	76
		10.00	50,505	13,672	64,177	65	122	26,908	7,284	34,192	74	20	94
		25.00	51,037	15,270	66,307	65	122	27,192	8,136	35,328	75	22	97
Project Area	58,916	2.33	30,186	8,172	38,358	65	122	16,083	4,354	20,437	27	7	34
		5.00	58,053	15,715	73,768	65	122	30,930	8,373	39,303	53	14	67
		10.00	72,150	19,532	91,682	65	122	38,441	10,406	48,847	65	18	83
		25.00	74,433	21,650	96,083	65	122	39,657	11,535	51,192	67	20	87

periods of peak floods, the areas under crops during corresponding years was estimated from the record of the Revenue Department Rajanpur, which shows quantum of flood flows used in the year. The anticipated cropping pattern against 2.33, 5, 10 and 25 year floods due to additional diversions of flood flows by the execution of on-going projects under 'without' project conditions are shown in Table-6.4. The cropped area against 2.33, 5, 10 and 25-years floods is 2,900, 14,306, 20,437 and 21,418 hectares respectively 'without' project conditions.

6.2.2.2 'With' Project

The available flood water against 2.33, 5, 10, 15 and 25-years flood is assumed to be diverted into 20,437; 39,303; 48,847 and 51,197 hectares terraced fields through an improved system of dispersion structures in the project area. In the light of field investigations carried out and in keeping with the soil characteristics of the area, it has been assumed that 1.22 meter depth of watering is sufficient for the maturity of all kharif and rabi crops of the Project area.

The annual cropping intensity with peak flood of 25-years, for which the facilities are designed would come to 87 percent, with kharif 67 and 20 percent 'with' project condition. Future cropping patterns have been proposed after taking into consideration the major factors such as soil texture, crop suitability, root system, water requirements and drought tolerance as given in Table 6.4. The piedmont soils are well suited to millet (jawar and bajra), oilseed (Taramira) and wheat crops. Jawar an important crop covering 58.4 percent of cropped area has been included in the cropping pattern, in view of its deep root system, low water requirements and better drought tolerance. Rabi oilseeds in winter season suited for drier parts of the project area cover 4.8 percent of cropped area. On the basis of previous experience with the availability of a more dependable water supply and a prolonged flood season, it is reasonable to assume that rabi wheat would subsequently occupy about 6,663 hectares.

TABLE 6.4

FUTURE CROPPING PATTERN UNDER 'WITH' AND 'WITHOUT' PROJECT AGAINST VARIOUS RETURN PERIOD

(Area in Hectares)

Crops	With Project				Without Project				Incremental			
	2.33	5.00	10.00	25.00	2.33	5.00	10.00	25.00	2.33	5.00	10.00	25.00
Jawar	13,955	26,838	33,355	34,410	1,817	9,769	13,955	14,625	12,138	17,069	19,400	19,785
Bajra	2,128	4,092	5,086	5,247	277	1,489	2,128	2,230	1,851	2,603	2,958	3,017
K.Total	16,083	30,930	38,441	39,657	2,094	11,258	16,083	16,855	13,989	19,672	22,358	22,802
Wheat	2,515	4,836	6,011	6,663	465	1,761	2,515	2,636	2,050	3,075	3,496	4,027
Gram	763	1,467	1,823	2,021	141	534	763	799	622	933	1,060	1,222
Oilseed	1,076	2,070	2,572	2,851	199	753	1,076	1,128	877	1,317	1,496	1,723
R.Total	4,354	8,373	10,406	11,535	805	3,048	4,354	4,563	3,549	5,325	6,052	6,972
Annual	20,437	39,303	48,847	51,192	2,899	14,306	20,437	21,418	17,538	24,997	28,410	29,774

6.2.3 Crop Yields and Production

Traditional and subsistence agriculture conditions would perpetuate due to undependable irrigation supply under 'without' project conditions. The historical yield growth rates would not be sustained by the local farmers, who do not have technical know-how and financial resources. It is anticipated that most of the project benefits would accrue from increase in the cropping intensities. However, manageable water supply would also bring improvement in cultural practices and input utilization, resulting in some increase in crop yields. Projection of crop yields against peak floods of various return periods without detail hydrologic studies and field investigation is not possible. Therefore, projected cropping patterns and intensities 'with' and 'without' the project will be used for the assessment of incremental production generated by the project development. However the incremental benefits have been adjusted upward to account for high crop yields in the preceeding paras.

The incremental crop production against 2.33, 5, 10 and 25-years flood has been estimated as given in Table 6.5. It indicates that jawar grain would increase by 8,507 tons, wheat by 2,811 tons and oilseed by 794 tons under ultimate development conditions against designed peak flood (25-years).

Besides, there are some farmers who have abandoned their lands due to the inadequacy of irrigation facilities. It is anticipated that these cultivators would revert to cultivation of such areas. The cropped area yields will be achieved, as in other area with the controlled flood water supply, which will bring about an increase in total production.

TABLE -6.5

INCREMENTAL PRODUCTION IN PROJECT AREA

(M.Tons)

CROPS	WITH PROJECT				WITHOUT PROJECT				INCREMENTAL			
	2.33	5	10	25	2.33	5	10	25	2.33	5	10	25
Jawar	6001	11540	14343	14796	781	4201	6001	6289	5220	7339	8342	8507
Bajra	745	1432	1780	1836	97	521	745	781	648	911	1035	1055
Wheat	1755	3376	4196	4651	325	1229	1755	1840	1430	2147	2441	2811
Gram	370	712	884	980	68	259	370	388	302	453	514	592
Oilseed	496	954	1186	1314	92	347	496	520	404	607	690	794
TOTAL:	9367	18014	22389	23577	1363	6557	9367	9818	8004	11457	13022	13759

6.2.4 Cultural Practices

The yield improving practices which have been proposed for the project area are:

- Improved Cultivation: Permeability of most soil could be significantly improved and the flooding time required for saturation reduced by annual cultivation with a chisel plough and metal elements prior to the commencement of the flood season. This would also improve soil aeration and root penetration;
- Land Levelling and Bunding: Present bund enclosed areas usually range from 4 to 24 ha. As a consequence, the lower section of each area is more thoroughly watered and the top section is often not sufficiently soaked. Construction of more frequent bunds with some land levelling will substantially increase the crop area and improve the efficiency of water use;
- Better Seeding: The crop yields can be increased by sowing crops with improved methods and using clean seed and the recommended seeding rate. Local varieties of sorghum and wheat are preferred because of their drought resistance and high yields of good straw quality. However, improved higher yielding varieties can also be introduced with some reliable water supply after demonstration in the project area. At present, agricultural extension and research services are very poor and inadequate to provide guidance to the farmers at the field level. Therefore, a system would have to be evolved to use adaptive research and at the same time provide the in-service training media needed for field staff. This would bring together the research and extension staff and facilities for the transfer of new technology to the farmers' fields.

- New Crops: Initially, it is expected that cultivators would grow the crops like; kharif sorghum with oilseeds and some wheat. If sorghum prices remain attractive and the feeding of sorghum grain for livestock finishing creates an adequate demand for this crop, it is possible that the traditional crop mix will remain. If on the other hand, sorghum becomes much less profitable than other crops, changes in cropping pattern will occur. With the more reliable water supply and better distribution arising from the above practices there would probably be opportunities for introduction of other kharif crops. For the new crops to be proposed, trials and demonstrations need to be arranged to determine the feasibility of their introduction in the area.
- Plant Protection: Plant protection measures should be introduced on a wider scale to reduce losses from stem borer.

6.3 ECONOMIC EVALUATION

Economic analysis of the project as planned is intended to establish the economic feasibility and soundness of public investment involved as shown by the excess of benefits over costs both measured in efficiency terms i.e., net of taxes and subsidies. The Discounted Cash Flow method has been used in the economic analysis and such parameters as Net Present Value of benefits, Benefit-Cost Ratio and the Internal Rate of Return have been computed to establish the economic feasibility of the selected project design. As a decision rule, the project is economically justified if Net Present Value of benefits is positive. Benefit-Cost Ratio exceeds unity and the Internal Rate of Return is above the average rate of return on investment (opportunity cost of capital) in the economy.

For economic analysis, a period of 25-year after the completion of the project works has been taken, although the life of project works would extend even beyond 25-year. The basic input for economic analysis are the estimated value of the benefits and the project costs over the period of analysis. A description of the methodology used for estimation of values of these inputs follows.

6.3.1 Project Benefits

Benefits of the proposed plan comprise those gains to the economy which can be measured in monetary terms, as well as benefits which, though socially desirable, are not amenable to quantification in monetary terms. Among the measurable benefits, the most important are those, which are represented by the savings resulting from the aversion of flood damages and the increase in the agricultural production from intensive use of land made possible due to available water supplies in conjunction with the flood control works.

6.3.1.1 Benefits Due to Increase in Agriculture Production:

With the management of floodflows of Kaha Hill Torrent it is planned to use all flows up to 10-year return period flood and maximum flows of the order of 2,243 cumecs during design flood in the Pachad area. The benefits from the regulated supply of flood water through proposed dispersion structures irrigating about 51,200 hectares of cropped area (with water from up to 25-year return period) have been measured in terms of net value of the increase in production of the crops.

Net Production Value (NPV): Total incremental crop production value was computed by multiplying the total production of each crop with the prices adjusted to the farmgate. Economic prices of traded project outputs and inputs used were derived from the June 1989 IBRD Commodity Price Forecasts, expressed in constant 1989 rupees with necessary adjustments for shipping, handling and distribution costs. Current local market prices are used for non-traded commodities, appropriately adjusted to reflect economic formgate values. Farm production expenses vary directly with the type of crops and the acreage of each crop grown. The production cost for crops include the money spent on seed, cultivation, hired labour and a small amount to cover the miscellaneous charges. Gross revenue production expenses and net return per hectare are estimated as given in Table 6.6. The incremental benefits accruing through improvement in flood management of Kaha Hill Torrent are, therefore, estimated as Rs 20.20, Rs 29.22, Rs 33.21 and Rs 35.84 million, respectively against 2.33, 5, 10 and 25-years floods as given in Table-6.7.

Average Annual Benefits: The estimated agricultural benefits against floods of various return period have been plotted on normal probability paper in Fig.6.1 to compute average annual agricultural benefits. Computations based on the standard procedure as given in Table 6.8 indicates that annual benefits amounting to Rs 14.72 million would be forthcoming.

6.3.1.2 Benefits Due to Saving of Flood Damages:

In normal years the flood water of Kaha Hill Torrent is utilized in beneficial manner. Fresh silt deposited on the land enriches the soil and helps raise good crops. But during wet years flashy floods heavily laden with silt enter Pachad Area through darrah with enormous velocity and davastate the diversion structures constructed by cultivators. The flood flows accumulate along right bank of Dajal Canal which afford some protection from the torrent with cross-drainage.

Due to inadequate cross-drainage facilities the canal bank is breached and frequent flooding is caused in the low lying areas between main canals and the Indus resulting in heavy losses to property, communications, canals, crops and human life. These damages would be reduced by the proposed works. Using latest historical area

TABLE 6.6

NET RETURN PER HECTARE WITH PROJECT

Value-Per Hectare

Crops	Yield Kgs	Unit Price Rs/ Kg.	Gross Revenue Rs	Seeds Rs	Cultivation Rs	Labour Charges Rs	Misc Rs	Total Cost Rs	Net Return Rs.	Net Return % of G.P.V.
Jawar:										
Grain	430	3.44	1479	112	401	420	47	980	849	46.4
Straw	1750	0.20	350							
Bajra:										
Grain	350	2.45	858	80	300	210	30	620	588	48.7
Straw	1750	0.20	350							
Wheat:										
Grain	698	5.11	3567	487	200	210	45	942	2876	75.3
Straw	1047	0.24	251							
Oilseed	461	4.31	1987	47	200	73	16	336	1651	83.1
Gram	485	6.80	3298	516	200	210	46	972	2326	70.5

NOTE:

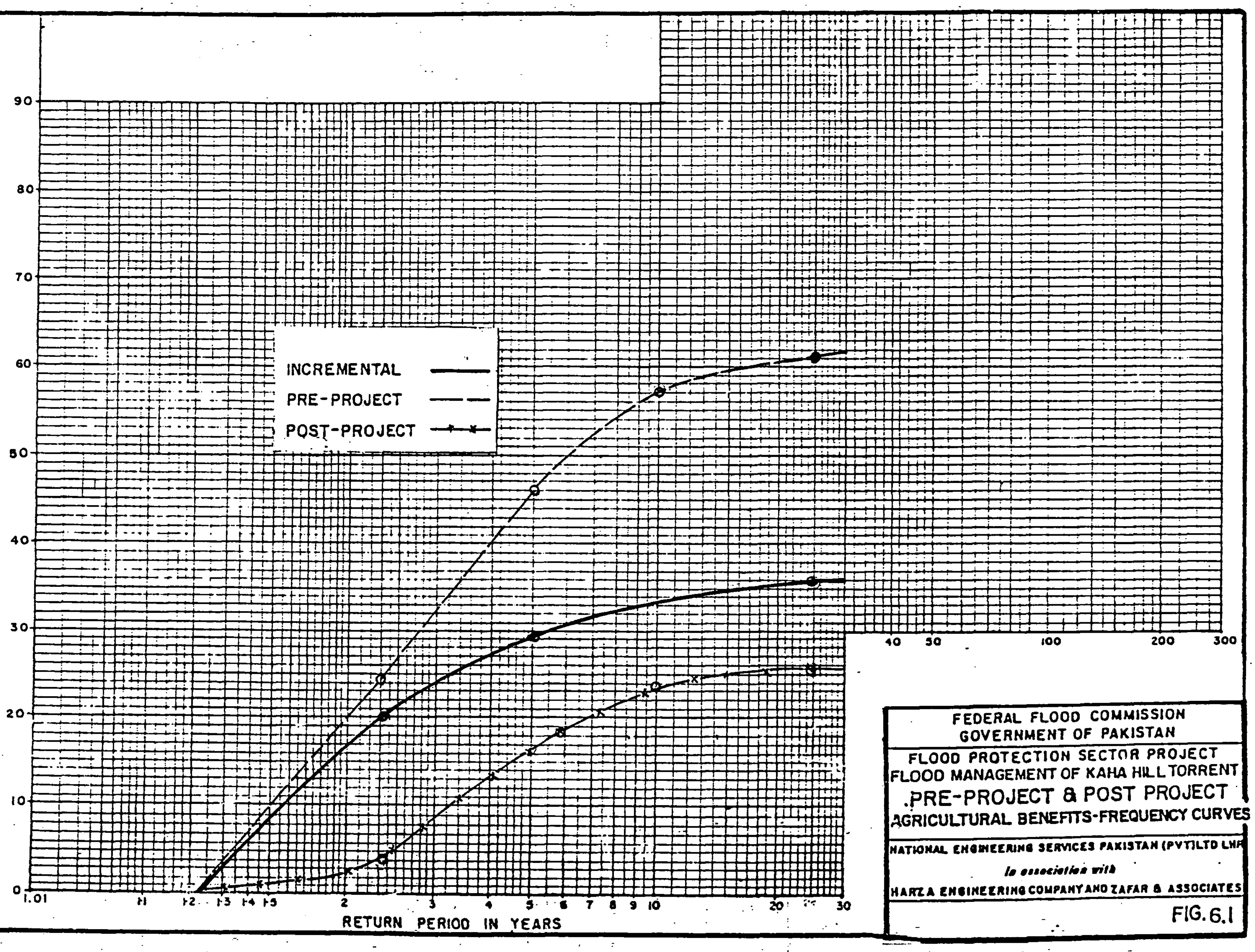
- Yields are based on Five Years average of Rajan Pur District taken from Punjab Agricultural Statistics.
- Input Application Rates are based on Agro-Economic Survey.
- Price of non-traded crops from local market and adjusted to derive Economic Price.
- Price of traded crops taken from World Bank, Commodity Price Forecasts, June, 1989.

TABLE - 6.7

AGRICULTURAL BENEFITS AGAINST VARIOUS RETURN PERIODS

(Million Rupees)

CROPS	GROSS PRODUCTION VALUE				FARM PRODUCTION EXPENSES				NET PRODUCTION VALUE			
	2.33	5.00	10.00	25.00	2.33	5.00	10.00	25.00	2.33	5.00	10.00	25.00
Jawar	22.20	31.22	35.48	36.19	11.90	16.72	19.01	19.39	10.30	14.50	16.42	16.80
Bajra	2.24	3.14	3.57	3.64	1.15	1.61	1.83	1.87	1.09	1.53	1.74	1.77
Wheat	7.83	11.74	13.35	15.38	1.93	2.90	3.29	3.79	5.90	8.84	10.06	11.59
Gram	2.05	3.08	3.50	4.03	0.60	0.91	1.03	1.19	1.45	2.17	2.47	2.84
Oilseed	1.74	2.62	2.97	3.42	0.29	0.44	0.50	0.58	1.45	2.18	2.47	2.84
TOTAL:	36.06	51.80	58.87	62.66	15.87	22.58	25.66	26.82	20.19	29.22	33.21	35.84



FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
PRE-PROJECT & POST PROJECT
AGRICULTURAL BENEFITS-FREQUENCY CURVES
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
in association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES
FIG. 6.1

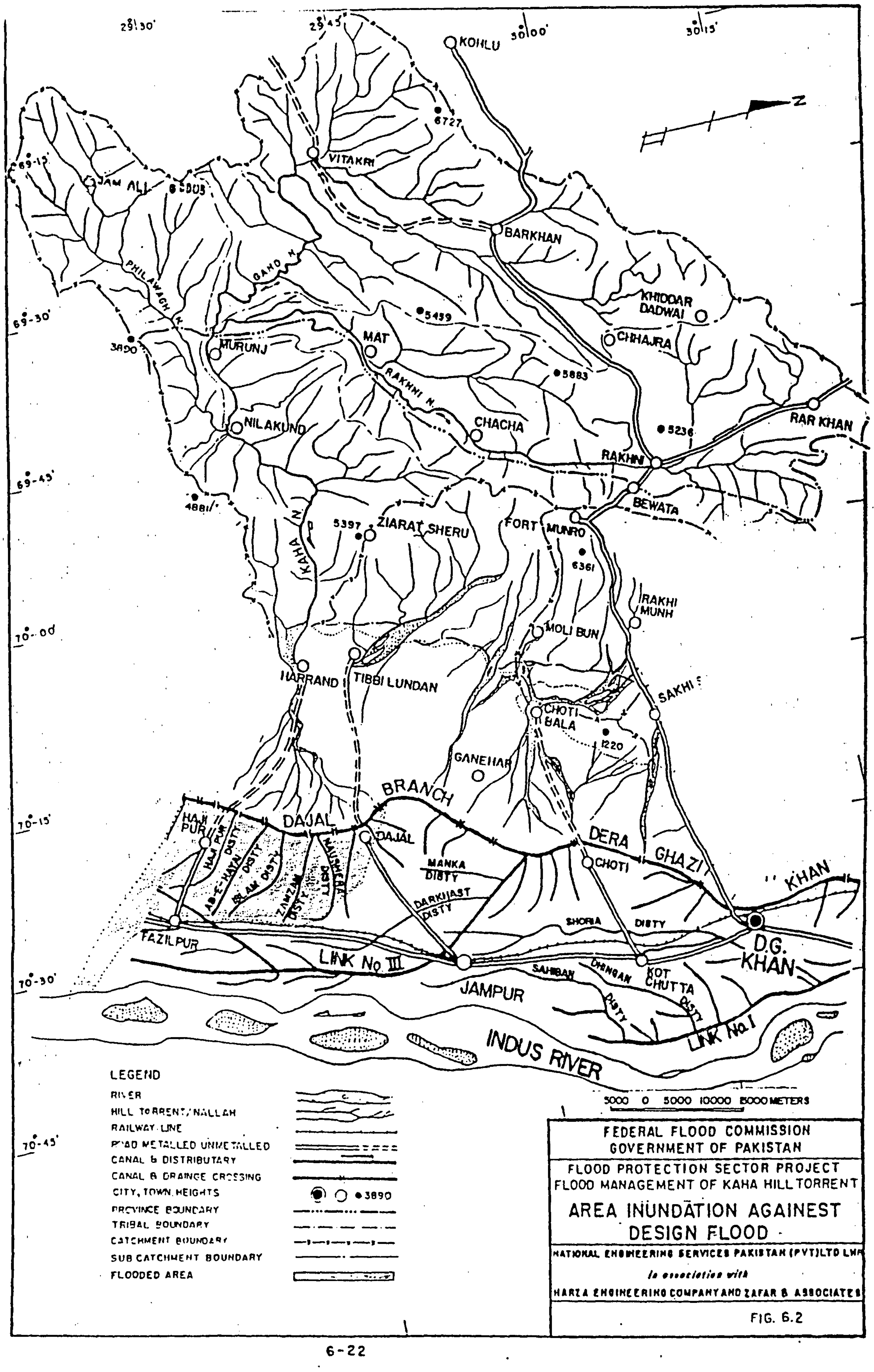
TABLE - 6.8

ESTIMATION OF AVERAGE ANNUAL AGRICULTURAL BENEFITS

FREQUENCY	BENEFITS Rs.Million	AVERAGE BENEFITS Rs.Million	FREQUENCY INTERVAL	ANNUAL BENEFITS Rs.Million
0.83	0.0			
		0.50	0.03	0.02
0.80	1.0			
		4.0	0.10	0.40
0.70	7.0			
		9.00	0.10	0.90
0.60	11.0			
		13.75	0.10	1.38
0.50	16.5			
		18.75	0.10	1.88
0.40	21.0			
		22.75	0.10	2.28
0.30	24.5			
		26.85	0.10	2.68
0.20	29.2			
		31.20	0.10	3.12
0.10	33.2			
		34.30	0.06	2.06
0.04	35.4			
		Average Annual Agricultural Benefits		14.72

inundations against various floods, it is estimated that for the design flood, the inundated area will be about 54,000 ha. The inundation in canal command area will result in considerable damages. As all the area is presently cultivated and high value crops like cotton, rice, sugarcane and orchards are sown. The inundation for the design flood is shown in Fig.6.2, which is based upon the historical route of flood flows. The damages due to the direct flooding and the suspension of the irrigation supplies were estimated by developing flood damage factors of various classes. Application of these factors to the flood water inundated area, yield the extent of damage associated with a flood of given magnitude, intensity and duration. Flood damages principally comprise damage to standing kharif crops, private housing, infrastructure, livestock and stored grain as described below:

Standing Crops: Flood damages to standing crops against design flood (i.e., 25-year) have been estimated by analytical technique that considers the depth, duration and time of flooding, flood susceptability of each crop, cropping pattern, the extent of adverse effects on yields due to flooding, the farm cost, farmgate prices, monthly distribution of flood peaks and cropping intensity. The estimated monthly economic value of potential yield loss is based on the expected economic farmgate gross revenue minus on farm cost that would have been incurred post-dated to the flood event. Monthly net potential flood losses for major kharif crops are detailed in Tables 6.9 to 6.12. This has been done in view of the fact that floods occur mostly during monsoon season. The monthly crop losses per hectare of culturable command area (CCA) are estimated in Table 6.13 by considering the effects on each of the crops relative to the month of flooding and the cropping pattern which are combined with monthly probability of flood occurrence to obtain crop losses per hectare flooded in canal command area. The total crop losses are estimated as Rs 70.6 million by multiplying unit factor with about 54,000 ha inundated by the design flood.


KOHLU
6727
VITAKRI
BARKHAN
KHIDDAR DADWAI
CHHAJRA
5459
MAT
MURUNJ
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PHILAWAGH N.
RAKHNI N.
5883
5236
RAR KHAN
CHACHA
NILAKUND
RAKHNI
BEWATA
FORT MUNRO
4881
5397
ZIARAT SHERU
KAHA N.
6361
RAKHI MUNH
MOLI BUN
HARRAND
TIBBI LUNDAN
SAKHI S
CHOTI BALA
1220
GANEHAR
BRANCH
DAJAL
HAJI PUR
DERA GHAZI KHAN
CHOTI
MANKA DISTY
DARKHAST DISTY
SHORIA DISTY
D.G. KHAN
FAZILPUR
LINK No. III
JAMPUR
SAHIBAN
KOT CHUTTA
LINK No. I
INDUS RIVER
LEGEND
RIVER
HILL TORRENT/NALLAH
RAILWAY LINE
ROAD METALLED UNMETALLED
CANAL & DISTRIBUTARY
CANAL & DRAINGE CROSSING
CITY, TOWN, HEIGHTS
3890
PROVINCE BOUNDARY
TRIBAL BOUNDARY
CATCHMENT BOUNDARY
SUB CATCHMENT BOUNDARY
FLOODED AREA
5000 0 5000 10000 15000 METERS
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
AREA INUNDATION AGAINST DESIGN FLOOD
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
in association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES
69°15'
69°30'
69°45'
70°00'
70°15'
70°30'
70°45'
29°30'
29°45'
30°00'
30°15'

FIG. 6.2

TABLE - 6.9

ECONOMIC CROP PRODUCTION BUDGET (RS/HA) FOR IRRI-6 PADDY

Item	Units	Units /ha	Price /Unit	Total	Monthly Allocation						
					May a/	Jun	Jul	Aug	Sep	Oct	Nov a/
Revenue											
Paddy	kg	2396	2.42	5798						2899	2899
By-product Credit (1:1.2)	kg	2875	0.10	288						144	144
Total Revenue				6086						3043	3043
Expenses											
Land Preparation	ha	1	1010	1010	283	445	283				
Seed: Input cost	kg	75	2.66	200	40	140	19				
Fertilizer: DAP	kg	125	6.47	809		323	486				
Urea	kg	125	4.31	539		215	324				
Application	md	2	32.00	64		25	39				
Transplanting	ha	1	516	516		206	310				
Weeding	ha	1	329	329			165	165			
Plant Protection Materials	kg	25	18	450				450			
Application	md	0.6	32.00	19				19			
Bund Maintenance	ha	1	338	338		135	76	76	50		
Irrigation	ha	1	202	202	20	81	31	31	20	20	
Harvesting & Threshing	kg	240	1.63	391						195	195
Credit				53	9	9	9	9	9		
Total Expenses				4920	352	1579	1742	750	79	215	195
Net Potential Flood Losses					1166	1518	3097	4839	5589	5668	2840

a/ All months before June and after October.

TABLE - 6.10

ECONOMIC CROP PRODUCTION BUDGET (RS/HA) FOR SEED COTTON

Item	Units	Units /ha	Price /Unit	Total	Monthly Allocation						
					May a/	Jun	Jul	Aug	Sep	Oct	Nov a/
Revenue											
Seed Cotton	kg	976	10.09	9848						3283	6565
By-product Credit (1:1.5)	kg	1464	0.137	201							201
Total Revenue				10049						3283	6766
Expenses											
Land Preparation	ha	1	1301	1301	1301						
Seed: Input cost	kg	24	6.76	162	152						
Fertilizer: DAP	kg	250	6.47	1618	1618						
Urea	kg	125	4.31	539			539				
Application	md	2.5	32.00	80	54		26				
Plant Protection Material	ha	1	1229	1229			307	461	461		
Application	md	5	32.00	160			41	61	61		
Weeding, Bund Maintenance	ha	1	329	329		165	165				
Irrigation	ha	1	202	202	123	13	20	20	13	13	
Picking and filling	kg	976	0.44	429						143	286
Sowing	ha	1	241	241	241						
Credit				68	11	11	11	11	11	13	
Total Expenses				6358	3510	189	1109	553	546	169	286
Net Potential Flood Losses					3691	7201	7390	8499	9052	9598	6484

a/ All months before June and after October.

TABLE - 6.11

ECONOMIC CROP PRODUCTION BUDGET (RS/HA) FOR KHARIF FODDER (FRESH)

Item	Units	Units /ha	Price /Unit	Total	Monthly Allocation						
					May a/	Jun	Jul	Aug	Sep	Oct	Nov a/
Revenue											
Fodder	mt	21	253	5313		266	797	1328	1381	1169	372
By-product Credit	mt	0	0	0							0
Total Revenue				5313		266	797	1328	1381	1169	372
Expenses											
Land Preparation	ha	1	812	812	365	211	179	57			
Seed: Input cost	kg	74	2.53	187	85	48	42	13			
Fertilizer: DAP	kg	125	6.47	809	364	211	177	57			
Application	md	1.25	32.00	40	18	10	9	3			
Sowing	ha	1	55	55	25	14	12	4			
Irrigation	md	3.5	32.00	112	32	32	9	32	9		
Harvesting	mt	21	32.00	550		28	83	38	142	121	39
Credit				22	6	6	6	6			
Marketing	mt	21	27.00	567		29	86	142	147	125	40
Total Expenses				3154	895	589	603	452	298	246	79
Net Potential Flood Losses					2159	3054	3377	3183	2307	1224	301
Adjusted Net Potential Flood Losses					1202	2065	2787	3016	2568	1879	1129

a/ All months before June and after October.

Notes: (i) Adjusted net potential flood loss reflects staggered fodder planting program with 5% of total area in March, 15% in April, 25% in May, 26% in June, 22% in July and 7% in August.

TABLE - 6.12

ECONOMIC CROP PRODUCTION BUDGET (RS/HA) FOR SUGARCANE

Item	Units	Units /ha	Price /Unit	Total	Monthly Allocation						
					May a/	Jun	Jul	Aug	Sep	Oct	Nov a/
Revenue											
Cane	mt	27	314	8478							8478
By-product Credit	mt	0	0	0							0
Total Revenue				8478							8478
Expenses											
Land Preparation	ha	1	615	615	246			369			
Seed: Input cost	mt	4.6	377	1734	694			868	173		
Fertilizer: DAP	kg	125	6.47	809	283			405	122		
Urea	kg	250	4.31	1078		1078					
SOP	kg	125	7.74	968	387			485	96		
Application	md	5	32.00	160	64			80	16		
Planting	ha	1	481	481	192			241	48		
Weeding	ha	1	847	847		635	212				
Plant Protection Materials	ha	1	812	812		271	271	270			
Application	ha	1	77.00	77		25	25	24			
Irrigation	mt	17	32.00	544	109	82	82	82	82	82	26
Harvesting	mt	27	29.41	794							794
Credit				154	62	15	15	15	15	15	15
Total Expenses				9073	2037	2106	605	2839	552	97	835
Net Potential Flood Losses					595	1442	3548	4153	6992	7544	7641

a/ All months before June and after October.

Note: (i) Yields reflect average for Rajanpur District, FY 83-FY87; (ii) By-product tops in lieu of stripping and loading charges; and (iii) 60% of crop planted in autumn, 40% spring planted.

TABLE - 6.13

FLOOD DAMAGE ESTIMATE

CCA(%)	CROP		JUN	JUL	AUG	SEP	OCT
5.4	Paddy	Yield Loss (%)	100	100	100	100	80
		Damages/ha (Rs)	1518	3097	4839	5589	5668
		Damages/ha cca (Rs)	82	167	261	302	245
10.7	Cotton	Yield Loss (%)	100	100	100	100	80
		Damages/ha (Rs)	7201	7390	8499	9052	9598
		Damages/ha cca (Rs)	771	791	909	969	821
1.6	Sugarcane	Yield Loss (%)	30	15	20	30	60
		Damages/ha (Rs)	1442	3548	4153	6992	7544
		Damages/ha cca (Rs)	7	9	13	34	72
8.2	Fodder	Yield Loss (%)	65	75	55	30	30
		Damages/ha (Rs)	2065	2787	3016	2568	1879
		Damages/ha cca (Rs)	110	171	136	63	46
0.7	Orchards	Yield Loss (%)	100	100	100	100	100
		Damages/ha (Rs)	10975	10975	10975	10975	10975
		Damages/ha cca (Rs)	77	77	77	77	77
Total Damages/ha cca/month (Rs)			1047	1215	1396	1445	1261
Probability of flood occurrence			0.125	0.250	0.562	0.047	0.016
Total Weighted Expected Damages (Rs/ha)					1,308		

Flood Description: Deep depth (over 90 cm), 15-days runoff period.

Private housing, Road and Railway: The direct damages regarding these items are derived from concentration of housing, road and railway infrastructures within the flood plain on a unit area basis as reported by 1981 Provincial Census for Punjab and updated to constant 1989 price to reflect present repair or replacement value. Housing damage is estimated as Rs 6.30 million for the design flood on the basis of following assumptions:

Area inundated against design flood	=	54,000 ha
Houses damaged/destroyed	=	1 per 12 ha
Houses values per hectare	=	Rs 1,400
Total Housing damage	=	Rs 6.30 million

The damage to road and railways is estimated as Rs 4.4 million with the assumption that 25 percent of road and railway are damaged as given below:

Road/Railway Damage Cost

Type of road/railway	Density km/km²	Length damaged (km)	Unit repair cost Rs(000)	Losses Rs(million)
Metalled road	0.029	4	416	1.7
Railway	0.015	2	833	1.6
Unmetalled road	0.108	15	74	1.1
Total				4.4

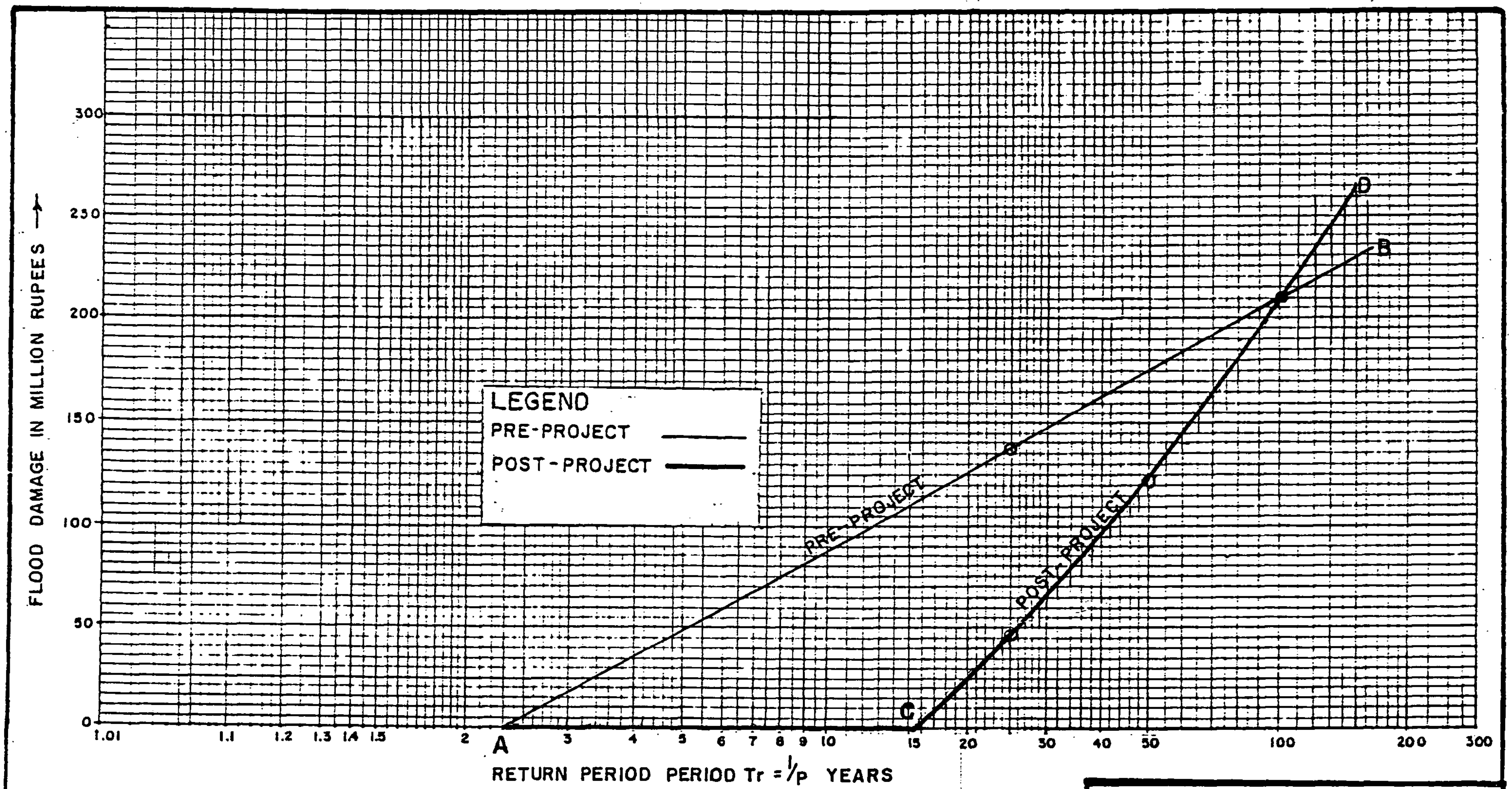
Other direct damages: The damages to irrigation infrastructure, telecommunication facilities, livestock and stored grain are estimated as Rs 32.5 million assuming a ratio of crops/housing/road and railway damages to total direct damages of 1:1.4/ Indirect damages due to suspension of irrigation supplies and traffic are estimated as Rs 22.8 million at 20 percent of total direct damages.

Total Damages: The total losses for various classes against design flood of 25-year return period are estimated as Rs 136.6 million as summarized below:

Flood loss against Design Flood

Class	Value (Rs million)
Standing crops	70.6
Private housing	6.3
Road/Railway	4.4
Infrastructure and other	32.5
Indirect Damages	22.8
Total:	136.6

Average Annual Damages: It is observed that zero damage would occur for floods upto 2.33-year return period due to the considerable work done for flood management in Pachad area during recent years. The damage corresponding to design flood are plotted on normal Probability Paper (Figure 6.3). A smooth curve AB is drawn through 25-year and zero damage points which represent the pre-project damage - frequency relationship. The proposed works would provide full protection against floods of magnitude upto a return period of 15-year. However, it is assumed that the damages caused by floods with return period of more than 15-year would be less as compared to pre-project conditions. As the proposed flexible structures have been designed against 25-year return period on the basis of carrying capacity of wahs water rights and land potential. Therefore, optimum diversion of runoff would be upto 25-year flood beyond which it would remain constant and the excess flood water would inundate the command area after passing through Dajal Branch Crossings. The post-project damage frequency curve would, therefore, represent no damage upto return period of 15-year beyond which it would be less than the pre-project curve as shown in Fig.6.3. The line ACD on Fig.6.3 represents post-project damage frequency curve. The average annual pre and post-project damages are estimated to be Rs 23.02 and Rs 3.94 million as detailed in Tables



FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

PRE-PROJECT AND POST-PROJECT DAMAGE-FREQUENCY CURVES

NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
In association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

FIG: 6.3

TABLE 6.14

ESTIMATION OF AVERAGE PRE-PROJECT FLOOD DAMAGES

Discharge cumecs	Frequency	Damages Rs.Million	Average Damages Rs.Million	Frequnecy Interval	Annual Damages Rs.Million
1,399	0.429	0.0			
			2.50	0.029	0.07
1,451	0.400	5.5			
			13.75	0.100	1.38
1,642	0.300	22.5			
			34.50	0.100	3.45
1,858	0.200	46.5			
			65.75	0.100	6.58
2,241	0.100	85.0			
			97.50	0.033	3.22
2,378	0.067	110.0			
			123.30	0.027	3.32
2,661	0.040	136.0			
			154.50	0.020	3.09
3,058	0.020	172.4			
			191.20	0.010	1.91
Maximum	0.010	210.0			
	Average Annual pre-project damages=				23.02

TABLE 6.15

ESTIMATION OF AVERAGE POST-PROJECT FLOOD DAMAGES

Discharge cumecs	Frequency	Damages Rs.Million	Average Damages Rs.Million	Frequnecy Interval	Annual Damages Rs.Million
1,399	0.429	0.0			
			-	0.029	-
1,451	0.400	0.0			
			-	0.100	-
1,642	0.300	0.0			
			-	0.100	-
1,858	0.200	0.0			
			-	0.100	-
2,241	0.100	0.0			
			-	0.033	-
2,378	0.067	0.0			
			22.60	0.027	0.61
2,661	0.040	45.2			
			83.50	0.020	1.67
3,058	0.020	121.8			
			166.00	0.010	1.66
Maximum	0.010	210.2			
	Average Annual post-project damages=				3.94

6.14 and 6.15 respectively. The average annual reduction in damages is the difference between pre and post-project average annual damages i.e., Rs 19.08 million.

6.3.1.3 Summary of Benefits

The annual benefits on account of avoidance of flood damages and increase in agricultural production after the completion of project works are estimated as Rs 19.08 million and Rs 14.72 million, respectively. The aggregate benefits accruing from the project thus, therefore, work out as Rs 33.80 million. These are assumed to increase at an annual rate of three percent upto 10th year beyond which it will remain constant. This rate of increase seems justifiable on the grounds that there would be enhancement in the value of land on account of high crop yields and more intensive agriculture primarily resulting from the use of improved practices and advanced technology. The total annual benefits for various years after completion of the project works are summarized in Table 6.16

TABLE - 6.16

PROJECT BENEFITS

(Rs million)

Year after completion of project works	Benefits due to saving in flood damages	Agricultural Benefits	Total Benefits
Present	19.08	14.72	33.80
1st	19.65	15.16	34.81
2nd	20.24	15.62	35.86
3rd	20.84	16.08	36.92
4th	21.47	16.57	38.04
5th	22.12	17.06	39.18
6th	22.78	17.58	40.36
7th	23.47	18.10	41.57
8th	24.17	18.65	42.82
9th	24.90	19.21	44.11
10-25th	25.64	19.78	45.42

6.3.2 Project Economic Costs

The total project costs are estimated at Rs 190.26 million and include such works as earthwork and construction of structures. All costs calculated for proposed works are local costs. It is considered that foreign exchange costs directly/indirectly would not be involved. The annual operation and maintenance costs have been estimated at the rate of two percent of the capital expenditure. To arrive at economic costs for use in the economic analysis, a standard conversion factor of 0.9 has been applied. All taxes and custom duties being transfer payments have been excluded from the financial costs. Also interest during construction is not taken as part of economic cost. The total economic costs after these adjustments work out as Rs 171.23 million. The annual phasing of capital costs is given in Table 6.17.

6.3.3 Discounted Cash Flow

In order to bring the benefits and cost on uniform basis streams of benefits and cost have been discounted at various rates of interest. The rate of interest used in the process of discounting is the one representing the opportunity cost of capital.

In this analysis, both the benefits and cost stream have been counted at rates of 10, 12, 15, 20, 25 and 30 percent so as to provide the sensitivity of measure of the results with respect to the discount rate used. The discounted streams of costs, benefits and benefits less costs are given in Tables 6.17 to 6.19.

6.3.4 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 6.20 summarizes the results of the analysis.

TABLE-6.17

DISCOUNTED COSTS

(MILLION RUPEES)

YEAR	CAPITAL COSTS	OPERATION COSTS	TOTAL COSTS	RATE OF DISCOU (PERCENT)					
				10	12	15	20	25	30
1	61.02	-	61.02	55.47	54.48	53.06	50.85	48.82	46.94
2	61.74	1.22	62.96	52.03	50.19	47.61	43.72	40.29	37.25
3	48.47	2.46	50.93	38.26	36.25	33.49	29.47	26.08	23.18
4	-	3.81	3.81	2.60	2.42	2.18	1.84	1.56	1.33
5	-	3.81	3.81	2.37	2.16	1.89	1.53	1.25	1.03
6	-	3.81	3.81	2.15	1.93	1.65	1.28	1.00	0.79
7	-	3.81	3.81	1.96	1.72	1.43	1.06	0.80	0.61
8	-	3.81	3.81	1.78	1.54	1.25	0.89	0.64	0.47
9	-	3.81	3.81	1.62	1.37	1.08	0.74	0.51	0.36
10	-	3.81	3.81	1.47	1.23	0.94	0.62	0.41	0.28
11	-	3.81	3.81	1.34	1.10	0.82	0.51	0.33	0.21
12	-	3.81	3.81	1.21	0.98	0.71	0.43	0.26	0.16
13	-	3.81	3.81	1.10	0.87	0.62	0.36	0.21	0.13
14	-	3.81	3.81	1.00	0.78	0.54	0.30	0.17	0.10
15	-	3.81	3.81	0.91	0.70	0.47	0.25	0.13	0.07
16	-	3.81	3.81	0.83	0.62	0.41	0.21	0.11	0.06
17	-	3.81	3.81	0.75	0.55	0.35	0.17	0.09	0.04
18	-	3.81	3.81	0.69	0.50	0.31	0.14	0.07	0.03
19	-	3.81	3.81	0.62	0.44	0.27	0.12	0.05	0.03
20	-	3.81	3.81	0.57	0.39	0.23	0.10	0.04	0.02
21	-	3.81	3.81	0.51	0.35	0.20	0.08	0.04	0.02
22	-	3.81	3.81	0.47	0.31	0.18	0.07	0.03	0.01
23	-	3.81	3.81	0.43	0.28	0.15	0.06	0.02	0.01
24	-	3.81	3.81	0.39	0.25	0.13	0.05	0.02	0.01
25	-	3.81	3.81	0.35	0.22	0.12	0.04	0.01	0.01
26	-	3.81	3.81	0.32	0.20	0.10	0.03	0.01	0.00
27	-	3.81	3.81	0.29	0.18	0.09	0.03	0.01	0.00
28	-	3.81	3.81	0.26	0.16	0.08	0.02	0.01	0.00
TOTAL	171.23	98.93	270.16	171.75	162.19	150.35	134.95	122.96	113.15

TABLE-6.18

DISCOUNTED BENEFITS

(MILLION RUPEES)

YEAR	PROJECT BENEFITS	RATE OF DISCOU (PERCENT)					
		10	12	15	20	25	30
1	-	0.00	0.00	0.00	0.00	0.00	0.00
2	-	0.00	0.00	0.00	0.00	0.00	0.00
3	-	0.00	0.00	0.00	0.00	0.00	0.00
4	34.81	23.78	22.12	19.90	16.79	14.26	12.19
5	35.86	22.27	20.35	17.83	14.41	11.75	9.66
6	36.92	20.84	18.70	15.96	12.36	9.68	7.65
7	38.04	19.52	17.21	14.30	10.62	7.98	6.06
8	39.18	18.28	15.82	12.81	9.11	6.57	4.80
9	40.36	17.12	14.55	11.47	7.82	5.42	3.81
10	41.57	16.03	13.38	10.28	6.71	4.46	3.02
11	42.82	15.01	12.31	9.20	5.76	3.68	2.39
12	44.11	14.05	11.32	8.24	4.95	3.03	1.89
13	45.42	13.16	10.41	7.38	4.25	2.50	1.50
14	45.42	11.96	9.29	6.42	3.54	2.00	1.15
15	45.42	10.87	8.30	5.58	2.95	1.60	0.89
16	45.42	9.88	7.41	4.85	2.46	1.28	0.68
17	45.42	8.99	6.62	4.22	2.05	1.02	0.53
18	45.42	8.17	5.91	3.67	1.71	0.82	0.40
19	45.42	7.43	5.27	3.19	1.42	0.65	0.31
20	45.42	6.75	4.71	2.78	1.18	0.52	0.24
21	45.42	6.14	4.20	2.41	0.99	0.42	0.18
22	45.42	5.58	3.75	2.10	0.82	0.34	0.14
23	45.42	5.07	3.35	1.82	0.69	0.27	0.11
24	45.42	4.61	2.99	1.59	0.57	0.21	0.08
25	45.42	4.19	2.67	1.38	0.48	0.17	0.06
26	45.42	3.81	2.39	1.20	0.40	0.14	0.05
27	45.42	3.46	2.13	1.04	0.33	0.11	0.04
28	45.42	3.15	1.90	0.91	0.28	0.09	0.03
TOTAL	1080.39	280.11	227.08	170.55	112.63	78.96	57.87

TABLE-6.19

DISCOUNTED CASH FLOW OF NET BENEFITS

(MILLION RUPEES)

YEAR	PROJECT BENEFITS	PROJECT COSTS	NET BENEFITS	RATE OF DISCOU (PERCENT)					
				10	12	15	20	25	30
1	-	61.02	-61.02	-55.47	-54.48	-53.06	-50.85	-48.82	-46.94
2	-	62.96	-62.96	-52.03	-50.19	-47.61	-43.72	-40.29	-37.25
3	-	50.93	-50.93	-38.26	-36.25	-33.49	-29.47	-26.08	-23.18
4	34.81	3.81	31.00	21.17	19.70	17.72	14.95	12.70	10.85
5	35.86	3.81	32.05	19.90	18.19	15.93	12.88	10.50	8.63
6	36.92	3.81	33.11	18.69	16.77	14.31	11.09	8.68	6.86
7	38.04	3.81	34.23	17.57	15.48	12.87	9.55	7.18	5.46
8	39.18	3.81	35.37	16.50	14.29	11.56	8.23	5.93	4.34
9	40.36	3.81	36.55	15.50	13.18	10.39	7.08	4.91	3.45
10	41.57	3.81	37.76	14.56	12.16	9.33	6.10	4.05	2.74
11	42.82	3.81	39.01	13.67	11.21	8.38	5.25	3.35	2.18
12	44.11	3.81	40.30	12.84	10.34	7.53	4.52	2.77	1.73
13	45.42	3.81	41.61	12.05	9.54	6.76	3.89	2.29	1.37
14	45.42	3.81	41.61	10.96	8.51	5.88	3.24	1.83	1.06
15	45.42	3.81	41.61	9.96	7.60	5.11	2.70	1.46	0.81
16	45.42	3.81	41.61	9.06	6.79	4.45	2.25	1.17	0.63
17	45.42	3.81	41.61	8.23	6.06	3.87	1.88	0.94	0.48
18	45.42	3.81	41.61	7.48	5.41	3.36	1.56	0.75	0.37
19	45.42	3.81	41.61	6.80	4.83	2.92	1.30	0.60	0.28
20	45.42	3.81	41.61	6.19	4.31	2.54	1.09	0.48	0.22
21	45.42	3.81	41.61	5.62	3.85	2.21	0.90	0.38	0.17
22	45.42	3.81	41.61	5.11	3.44	1.92	0.75	0.31	0.13
23	45.42	3.81	41.61	4.65	3.07	1.67	0.63	0.25	0.10
24	45.42	3.81	41.61	4.22	2.74	1.45	0.52	0.20	0.08
25	45.42	3.81	41.61	3.84	2.45	1.26	0.44	0.16	0.06
26	45.42	3.81	41.61	3.49	2.19	1.10	0.36	0.13	0.05
27	45.42	3.81	41.61	3.17	1.95	0.96	0.30	0.10	0.03
28	45.42	3.81	41.61	2.89	1.74	0.83	0.25	0.08	0.03
TOTAL	1080.39	270.16	810.23	108.36	64.89	20.20	-22.32	-44.00	-55.28

TABLE - 6.20

ECONOMIC PARAMETERS

(Rs million)

Parameters	Rate of Discount (percent) 10	12	15	20	25	30
Discounted Benefits	280.11	227.08	170.55	112.63	78.96	57.87
Discounted Costs	171.75	162.19	150.35	134.95	122.96	113.15
Net Present Worth	108.36	64.89	20.20	-22.32	-44.00	-55.28
Benefit/Cost Ratio	1.63:1	1.4 :1	1.13:1	0.83:1	0.64:1	0.51:1
Internal Rate of Return			17.38 percent			

The parameters given above indicate that the Net Present Worth is positive and Benefit-Cost Ratio exceeds unity even at 15 percent rate of interest. Similarly, the Internal Rate of Return of 17.38 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.

6.3.5 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 20 percent
- Cost over-run by 20 percent
- Project benefits 20% less while cost turn-out 20% higher.

The results of the sensitivity analysis based on the discount values of benefits and costs under the above mentioned assumptions are summarized in Table 6.21.

TABLE - 6.21

RESULTS OF SENSITIVITY ANALYSIS

Assumptions	Internal Rate of Return
Base case	17.38 %
20% increase in Capital Cost	14.30 %
20% decrease in Benefits	13.75 %
20% decrease in benefit while cost turn-out 20% higher	11.16 %

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

6.3.6 Switching Values

The switching values, which give the extent in (percent) to which the benefits and/or costs must decrease/increase to make the IRR equal to the opportunity cost of capital i.e., 10% have been computed as an additional measures of sensitivity. The analysis, thus, undertaken shows that the project is economically viable even if project costs increase by about 63 percent or project benefits decrease by 39 percent.

6.3.7 Socio-Economic Impact

As already stated the economic analysis presented above is based on the measureable benefits alone. There are a number of effects of socio-economic nature which, though not quantifiable, are equally important and need to be given 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 to transform the pattern of life by providing to the people net benefits of the environment of irrigated agriculture. This would induce the people to a large extent to settle 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.

For 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, as much serious recognition as the computed economic rate of return.

ECONOMIC PARAMETERS

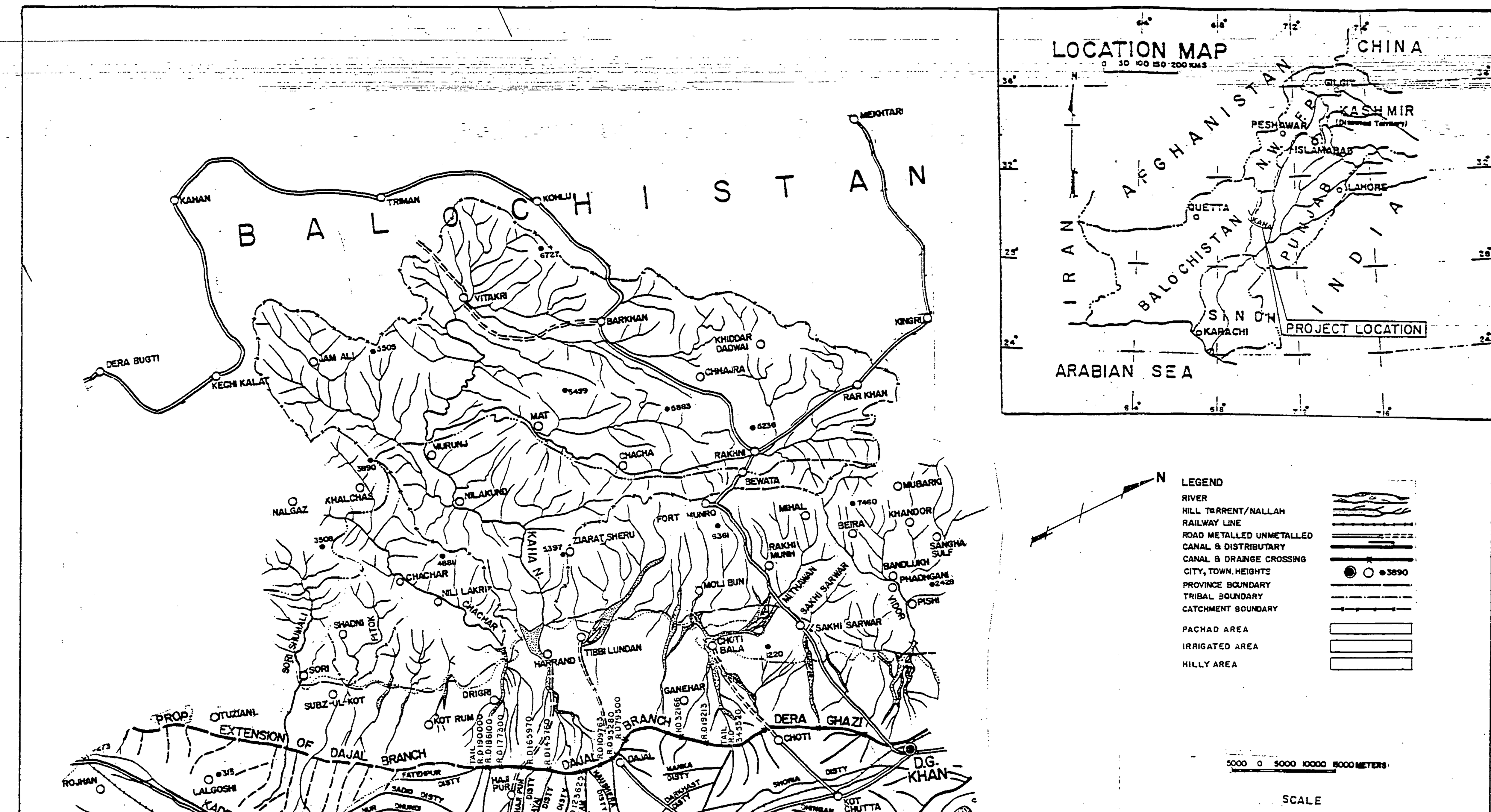
PARAMETERS	10	15	20	25
DISCOUNTED BENEFITS	280.11	170.55	112.63	78.96
DISCOUNTED COSTS	171.75	150.35	134.95	122.96
NET PRESENT WORTH	108.36	20.20	-22.32	-44.00
BENEFIT/COST RATIO	1.63:1	1.13:1	0.83:1	0.64:1
INTERNAL RATE OF RETURN		17.38 PERCENT		

CROPPING INTENSITY AFTER MANAGEMENT

RETURN PERIOD	INTENSITY WITH PROJECT	INTENSITY WITHOUT PROJECT
2.33 - YEAR	34 PERCENT	8 PERCENT
5 - YEAR	67 PERCENT	24 PERCENT
10 - YEAR	83 PERCENT	35 PERCENT
25 - YEAR	87 PERCENT	36 PERCENT

STATISTICS OF CULTURABLE AREA

DESCRIPTION	AREA IN HECTARES
CULTURABLE AREA	58,916
ABOVE DARRAH	22,663
BELOW DARRAH	36,253



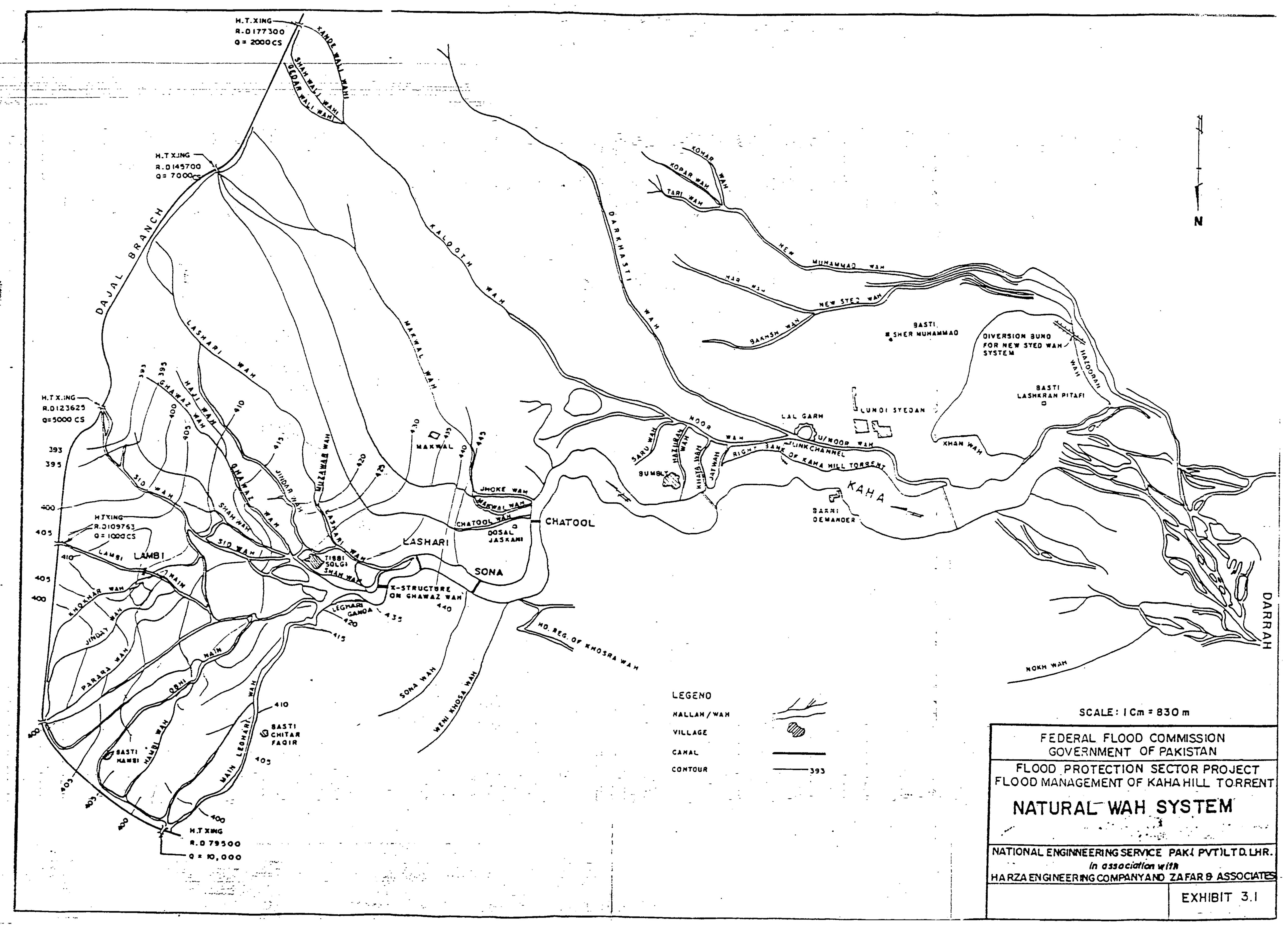
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN

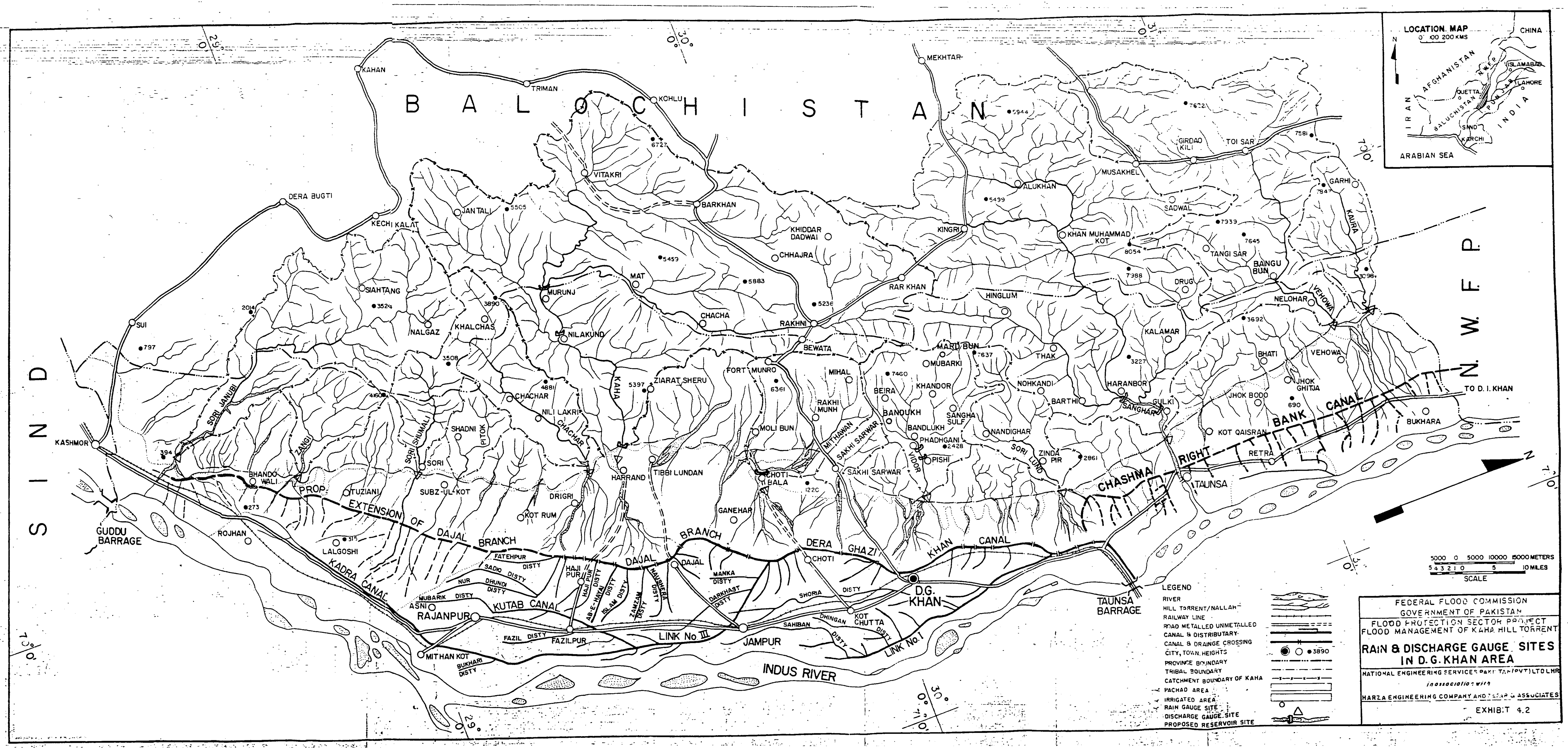
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT

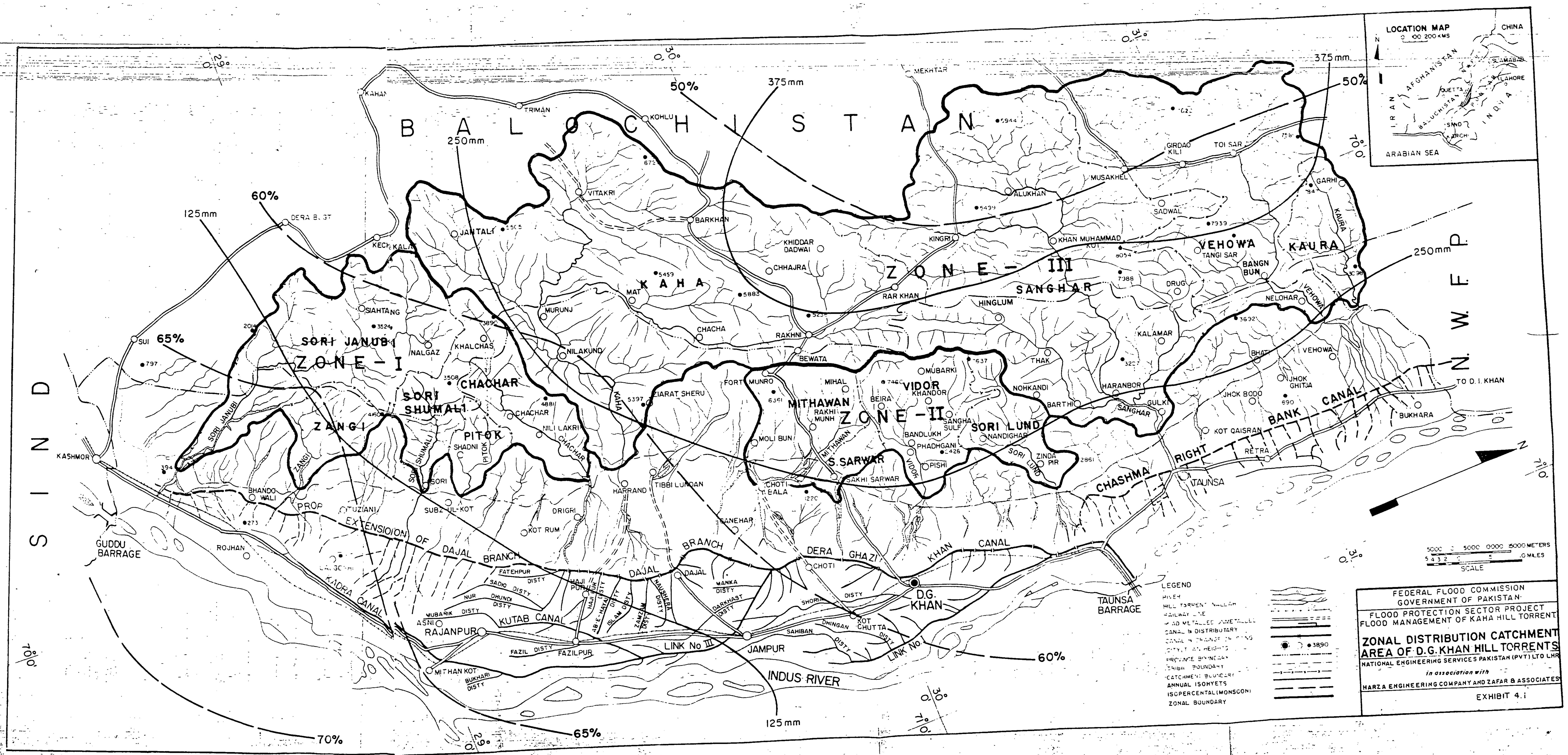
PROJECT LOCATION MAP

NATIONAL ENGINEERING SERVICE PAK.(PVT) LTD. LHR.
in association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES

APPROVED | EXHIBIT 2.1


DAJAL BRANCH
H.T. XING
R.D 177300
Q = 2000 CS
H.T. XING
R.D 145700
Q = 7000 CS
H.T. XING
R.D 123625
Q = 5000 CS
H.T. XING
R.D 79500
Q = 10,000
LASHARI WAH
KALOOTH WAH
DARKHASTI WAH
KOHAR WAH
NEW SYED WAH
BASTI SHER MUHAMMAD
DIVERSION BUND FOR NEW SYED WAH SYSTEM
BASTI LASHKRAN PITAFI
KHAN WAH
LAL GARH
LUNDI SYEDAN
BUMBLI
KAHA
BAZRI DEWANDER
CHATOOL
JHOKE WAH
CHATOOL WAH
DOSAL JASKANI
LASHARI
SONA
LAMBI
X-STRUCTURE ON GHAWAZ WAH
SONA WAH
KHOSRA WAH
BASTI CHITAR FAQIR
BASTI KAWBI
NOKH WAH
DARRAH
N
LEGEND
NALLAH / WAH
VILLAGE
CANAL
CONTOUR
393
SCALE: 1 Cm = 830 m
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
NATURAL WAH SYSTEM
NATIONAL ENGINNEERING SERVICE PAK(PVT)LTD. LHR.
In association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES
EXHIBIT 3.1


BALOCHISTAN
SIND
N.W.F.P.
LOCATION MAP
CHINA
IRAN
AFGHANISTAN
ISLAMABAD
LAHORE
QUETTA
BALUCHISTAN
INDIA
ARABIAN SEA
INDUS RIVER
D.G. KHAN
RAJANPUR
JAMPUR
TAUNSA
TAUNSA BARRAGE
GUDDU BARRAGE
KASHMOR
FORT MUNRO
SAKHI SARWAR
DERA GHAZI KHAN CANAL
DAJAL BRANCH
PROP. EXTENSION OF DAJAL BRANCH
CHASHMA RIGHT BANK CANAL
KADRA CANAL
KUTAB CANAL
LINK No III
LINK No I
TO D.I. KHAN
5000 0 5000 10000 15000 METERS
5 4 3 2 1 0 5 10 MILES
SCALE
LEGEND
RIVER
HILL TORRENT/NALLAH
RAILWAY LINE
ROAD METALLED UNMETALLED
CANAL & DISTRIBUTARY
CANAL & DRAINGE CROSSING
CITY, TOWN, HEIGHTS
PROVINCE BOUNDARY
TRIBAL BOUNDARY
CATCHMENT BOUNDARY OF KAHA
PACHAD AREA
IRRIGATED AREA
RAIN GAUGE SITE
DISCHARGE GAUGE SITE
PROPOSED RESERVOIR SITE
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
RAIN & DISCHARGE GAUGE SITES IN D.G. KHAN AREA
in association with
EXHIBIT 4.2


BALOCHISTAN
SIND
N.W.F.P.
ZONE-I
ZONE-II
ZONE-III
SORI JANUBI
SORI SHUMALI
CHACHAR
ZANGI
PITOK
KAHA
MITHAWAN
VIDOR
SORI LUND
S.SARWAR
SANGHAR
VEHOWA
KAURA
D.G. KHAN
RAJANPUR
JAMPUR
KASHMOR
GUDDU BARRAGE
TAUNSA BARRAGE
TAUNSA
INDUS RIVER
DERA GHAZI KHAN CANAL
DAJAL BRANCH
EXTENSION OF DAJAL BRANCH
KUTAB CANAL
KACHA CANAL
CHASHMA RIGHT BANK CANAL
LINK No III
LINK No I
FORT MUNRO
BARKHAN
KOHLU
TO D.I. KHAN
50%
60%
65%
70%
125mm
250mm
375mm
LOCATION MAP
CHINA
AFGHANISTAN
IRAN
INDIA
ARABIAN SEA
SCALE
LEGEND
CANAL & DISTRIBUTARY
ANNUAL ISOHYETS
ISOPERCENTAL (MONSOON)
ZONAL BOUNDARY
FEDERAL FLOOD COMMISSION
GOVERNMENT OF PAKISTAN
FLOOD PROTECTION SECTOR PROJECT
FLOOD MANAGEMENT OF KAHA HILL TORRENT
ZONAL DISTRIBUTION CATCHMENT
AREA OF D.G.KHAN HILL TORRENTS
NATIONAL ENGINEERING SERVICES PAKISTAN (PVT) LTD LHR
in association with
HARZA ENGINEERING COMPANY AND ZAFAR & ASSOCIATES
EXHIBIT 4.1