PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

(PEDO)

GOVERNMENT OF KHYBER PAKHTUNKHWA

DARAL KHWAR HYDROPOWER PROJECT

APPLICATION FOR GENERATION LICENSE

June 2016

PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

Government of Khyber Pakhtunkhwa Peshawar

Daral Khwar Hydropower Project

No.381/PEDO/PM/DKHP/
Dated Peshawar 14th June 2016

To

The Registrar
National Electric Power Regulatory Authority (NEPRA)
Nepra Tower Attaturk Avenue (East),
G-5/1, Islamabad.

Subject: **36.6 MW Daral Khawr Hydropower Project, District Swat, Khyber Pakhtunkhwa, Application for Generation License**

1. I, Muhammad Irfan, Project Manager, Daral Khawar Project of Pakhtunkhwa Energy Development Organization (PEDO) being the duly Authorised representative of PEDO by virtue of authority letter No.5618/PEDO/CEO dated 14-06-2016. hereby apply to National Electric Power Regulatory Authority for the grant of a Generation Licence to PEDO for 36.6 MW Daral Khawr Hydropower Project, pursuant to the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997.

2. I, certify that the documents-in-support attached with this application are prepared and submitted in conformity with the provisions of the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999 and undertake to abide by the terms and provisions of the above-said regulations. I further undertake and confirm that the information provided in the attached documents-in-support is true and correct to the best of my knowledge and belief.

3. A BANK DRAFT for the sum of Rupees **286,016-** (Rs. Two Hundred Eighty Six Thousand and Sixteen Only) being the non-refundable licence application fee calculated in accordance with Schedule II to the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, is also attached herewith.

Regards

(Muhammad Irfan)
Project Manager
Daral Khawar HPP,
PEDO, Swat

Check List for Examination of
New Generation Facility (Hydel) - Licence Application

Name of Company: **Pakhtunkhwa Energy Development Organization (PEDO)**
Capacity: 36.6 MW
Prepared/Updated on: 13.06.2016

Regulation #	Information/Documents Required	Compliance		Remarks
		Yes	No.	
3(1)	Authorization from Board Resolution / Power of Attorney	Yes		Attached
3(3)	Application fee (including Indexation)	Yes		Bank Draft Attached
3(4)	Three copies of Application	Yes		Attached
3(5)(a)(i)	Certificate of incorporation	Yes		PEDO is a public sector organizatio\n and therefore it is not required.
3(5)(a)(ii)	Memorandum and articles of association	Yes		PEDO is public sector organization and is exempt under Section 24 of NEPRA therefore it is not required
3(5)(a)(iii)	Annual Return statements or in lieu thereof		No	PEDO is public sector organization and therefore it is not required to submit Annual Return Statement.
3(5)(b)	Profile of experience of the applicant its management, staff and its members in power sector.	Yes		Brief of PEDO is Attached
3(5)(c)	CVs of applicant's Senior Management and Technical professionals	Yes		Attached
3(5)(d)(i)	Cash balance & bank certificates	Yes		PEDO is public sector organization and therefore it is not required
3(5)(d)(ii)	Expression of interest to provide credit or financing along with sources and details thereof	Yes		Funding by Government of Khyber Pakhtunkhwa
3(5)(d)(iii)	Latest financial statements	Yes		PEDO is public sector organization and therefore it is not required
3(5)(d)(iv)	Employment records of Engineers & Technical Staff	Yes		CVs of Senior Officials of PEDO are Attached.
3(5)(d)(v)	Profile of Sub-contractors	Yes		Profile of M/s SINOTECH and M/s SHPE Attached.
3(5)(d)(vi)	Verified references w.r.t. experience of the Applicant and its sub-Contractors	Yes		EPC awarded under PPC rules after ICB and complete verification of contractors.
3(5)(e)	Encumbrance on assets	Yes		Funding by Government of Khyber Pakhtunkhwa
3(5)(f)	Technical and financial proposal for Operation, maintenance, planning and development of the generation facility.	Yes		EPC executed and work in progress under the EPC signed with consortium of SINOTECH/SHPE/GRC of China.
3(5)(g)(a)	Type of Technology	Hydel		Details provided in Prospectus
3(5)(h)	Feasibility Report	Yes		Attached
3(5)(i)	Prospectus	Yes		Attached

Schedule II				
1.	Location (location maps, site maps) land	District Swat		Details provided in Prospectus
2.	Plant: run of river, storage, weir	Run of River		Located on Daral Khawar, a right tributary of River Swat.
3.	Head: Minimum, maximum			Max Net Head =294.0m Min Net Head = 275.15m
4.	Technology: Francis, Pelton, etc. Size, number of units.	Pelton		2 x 15.3MW= 30.6MW 1x 6.0MW = 6MW
5.	Tunnel (if proposed): length, diameter	Yes		Length 3071m Diameter 3.2m
6.	ESSA (Environmental and Social Soundness Assessment)	Yes		Approval Letter Attached
7.	Detailed feasibility report	Yes		Copy Attached
8.	Resettlement issues	No		Settled
9.	Consents			EIA and land acquisition already approved. Customs and other duties at concessionary rates will be applicable as per GOP/ Govt of Khyber Pakhtunkhwa Policy. PESCO Consent Attached
10.	Infrastructure development			Included in EPC Contract Page ER-122 of Employer's Requirement (Copy Attached). + Access Road to Intake Complex. (8 km)
11.	Interconnection with National Grid Co. distance and name of nearest grid, voltage level (single line diagram)	Yes		Madyan, Swat 10 km from Daral Khwar HPP 132 kV, Consent Letter of PESCO Attached
12.	Project cost, information regarding sources and amounts of equity and debt.			Project Cost 8.32 Billion **Financial Plan & Mode of Financing (PC-1)** Annual Dev Program (ADP) = 20% Hydel Dev Fund (HDF) = 80%

13.	Project schedule, expected life			Construction period: 36months, Extended to 42 months. Project life 30 years,
14.	Peaking/base load operation			Base load

15.	Plant characteristics: generation voltage, power factor, frequency, automatic generation control, ramping rate, control metering and instrumentation			Gen. Voltage : 11 KV P.f : 0.8 Frequency: 50 Hz, Interconnection at 132 KV with PESCO grid station at Madyan. (Consent Letter Attached)
16.	System studies load flow, short circuit, stability.			Copy attached.
17.	Training and development			Details provided in Contract (See Pg ER-16 to ER-19, Employer's Requirement (Copy Attached))

Schedule I - 3(1)

AUTHORIZATION LETTER

P E D O

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

Government of Khyber Pakhtunkhwa Peshawar

No.5618/PEDO/CEO
Dated Peshawar 14th June 2016

TO WHOM IT MAY CONCERN

Mr. Muhamamd Irfan S/o Abdur Rauf bearing CNIC No 17301-1409318-3 is hereby appointed as authorized representative of Pakhtunkhwa Energy Development Organization (PEDO), for the purpose of filing an application for Determination of Tariff for Daral Khawar Hydropower Project and to submit before NEPRA, an application for grant of Generation License for the said project. He is also authorized to attend any meeting(s) and discussion related to the determination of tariff and grant of generation license and to provide any information & documents needed in this regard.

(Akbar Ayub Khan)

Chief Executive Officer
PEDO

Article – 1

Definitions

(1) **In this Licence**:

a. "Act" means the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 (XL of 1997);
b. "Authority" means the National Electric Power Regulatory Authority constituted under Section 3 of the Act.
c. "Licensee" means Pakhtunkhawa Energy Development Organization (PEDO).
d. "Rules" mean the National Electric Power Regulatory Authority Licensing (Generation) Rules, 2000.

(2) Words and expressions used but not defined herein bear the meaning given thereto in the Act or in the Rules.

Article – 2

Application of Rules

This Licence is issued subject to the provisions of the Rules, as amended from time to time.

Article – 3

Generation Facilities

(1) The location, size, technology, interconnection arrangements technical limits, technical functional specifications and other details specific to the generation facilities of the licensee are set out in Schedule - I to this Licence.
(2) The net capacity of the generation facilities is set out in Schedule - II hereto.
(3) The Licensee shall provide the final arrangement, technical and financial specifications and other details specific to generation facilities before commissioning of the generation facilities.

Article – 4

Term

(1) The Licence is granted for a term of ***thirty (30) years*** after the commercial operation date.
(2) Unless revoked earlier, the licensee may, ***ninety (90) days*** prior to the expiry of the term of the licence, apply for renewal of the Licence under the Licensing (Application and Modification Procedure) Regulation, 1999.

Article – 5

Licence Fee

The Licensee shall pay to the Authority the Licence fee in the amount and manner and at the time specified in the National Electric Power Regulatory Authority (Fee) Rules, 2002.

Article – 6

Tariff

The Licensee shall charge from its consumers only such tariff which has been approved by the Authority.

Article – 7

Competitive Trading Arrangement

(1) The Licensee shall participate in such measures as may be directed by the Authority from time to time for development of the Competitive Trading Arrangement. The Licensee shall in good faith work towards implementation and operation of the aforesaid Competitive Trading Arrangement in the manner and time period specified by the Authority:
Provided that, any such participation shall be subject to any contract entered into between the Licensee and another party with the approval of the Authority.

(2) Any variation and modification in the above mentioned contracts for allowing the parties thereto to participate wholly or partially in the Competitive Trading Arrangement shall be subject to mutual agreement of the parties thereto and such terms and conditions as may be approved by the Authority.

Article – 8

Maintenance of Records

For the purpose of sub-rule (1) of Rule 19 of the Rules, copies of records and data shall be retained in standard and electronic form and all such records and data shall, subject to just claims of confidentiality, be accessible by the authorized officials of the Authority.

Article – 9

Compliance with Performance Standards

The Licensee shall conform to the relevant NEPRA rules on Performance Standards as may be prescribed by the Authority from time to time.

Article – 10

Compliance with Environmental Standards

The Licensee shall conform to the environmental standards as may be prescribed by the relevant competent authority from time to time.

Article – 11

Provision of information

(1) The obligation of the licensee to provide information to the Authority shall be in accordance with Section 44 of the Act.

(2) The licensee shall be subject to such penalties as may be specified in the relevant rules made by the Authority for failure to furnish such information as may be required from time to time by the Authority and which is or ought to be or have been in the control or possession of the licensee.

Schedule – 1

It contains the following information / drawings / sketches relating to the Power Plant Equipment and related System which are attached here with:

Plant Details

- General Information
- Plant Configuration
- Fuel Details
- Emission Values
- Installed Capacity
- Derated Capacity
- Expected Life
- Operation Record
- Cooling System
- Plant Characteristics
- Other details specific to the generation facility of the licensee such as:
    - Technical Limits of the Plant
    - Site Plan of Daral khawar Power Plant
    - General Layout of entire Daral khawar Power Plant
    - Interconnection Arrangements with National Grid

Plant Details

1. General Information

- Name of Applicant - **Pakhtunkhwa Energy Development Organization (PEDO)**
- Address of the registered office ----------- PEDO House, 38/B-2, Phase V, Hayatabad, Pwshawar
- Plant Location ------------------------------------ Near Bahrain, District Swat,, Khyber Pakhtunkhwa
- Type of Facility ------------------------------------ High Head Hydropower Project

2. Plant Configuration

- Low Head Hydropower turbines ------------------------ N.A
- Capacity of the Power Plant (Net Power Output)----- 36.234 MW
- Type of Technology -- High head hydropower generation
- Number of Units / Capacity : 2 Nos. 15.3MW +1 No. 6.0MW = 36.6MW
- Power Plant Make and Model --------------------------- High head Pelton turbines
- Commissioning Date -- July 2016

3. Fuel Details

- Type of Fuel -- Hydropower Generation
- Fuel (Imported / Indigenous) ----------------------------- N .A
- Fuel Supplier -- N.A
- Water Use Agreement -- With Irrigation Deptt. GoKPK

4. Emission values

- SOx -- NA
- NOx -- NA
- CO --- NA
- PM10 --- NA

- Installed Capacity --- **36.6** MW

5. Derated Capacity --- **36.60 MW**
6. Expected Life of the Facility -------------------------------- 30 years
7. Operation Record --- New Plant to be commissioned by July 2016

8. <u>Plant Characteristics</u>

- Generating Voltage -- 11 KV
- Frequency --- 50 Hz
- Power Factor --- 0.8
- Automatic Generation Control -------------------------- Yes
- Ramping Time -- 5 minutes
- Alternative Fuel --- No
- Auxiliary Consumption ---------------------------------- 366 KW
- Time required to Synchronise -------------------------- 3 minute

SCHEDULE – II

The Net Capacity of the Licensee's Generation Facility

- Gross Installed Capacity of the Plant (ISO) --------- 36.6 MW
- Derated Capacity of the Plant ------------------------- 36.6 MW
- Auxiliary Consumption of the Plant ------------------- 0.366 MW at 1% of Installed.
- Net Capacity of the Plant ------------------------------ 36.234 MW
- Construction Period ------------------------------------ 36 months
- Expected date of Commercial Operation of the Plant – July, 2016

Note: These are indicative figures provided by the Licensee.

The Net Capacity of the Plant available for dispatch to Power Purchaser will be determined through procedures contained in the EPC Agreements or Grid Code.

Interconnection Arrangement with National Grid for Power Evacuation of the Plant

The project is proposed to be connected with the PESCO nearest 132 KV Grid Station Madyan, for evacuation of energy generated by the project. Consent letter by PESCO attached.

Schedule I - 3(5)(b)

PROFILE OF PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

(PEDO)

GOVERNMENT OF KHYBER PAKHTUNKHWA

Development Activities in Hydro Power Sector of Khyber Pakhtunkhwa

June 2016

CONTENTS

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

1. Introduction

Khyber Pakhtunkhwa province of Pakistan is blessed with huge hydropower potential. This potential remained focus of interest to private investors and international funding agencies. Most of the hydel projects of Pakistan including Tarbela and Warsak hydropower stations are located in KP.

Pakhtunkhwa Energy Development Organization (PEDO), since its inception in 1986, has been instrumental in identifying and exploiting hydel potential in Khyber Pakhtunkhwa. The organization is under the administrative control of Irrigation and Power Department of Provincial Government and is governed by the Board of Directors. PEDO has so far identified a number of promising hydel potential sites of more than 6000 MW capacity which can be developed in a systematic manner either through Public or Private sector.

I. Objectives of the Organization

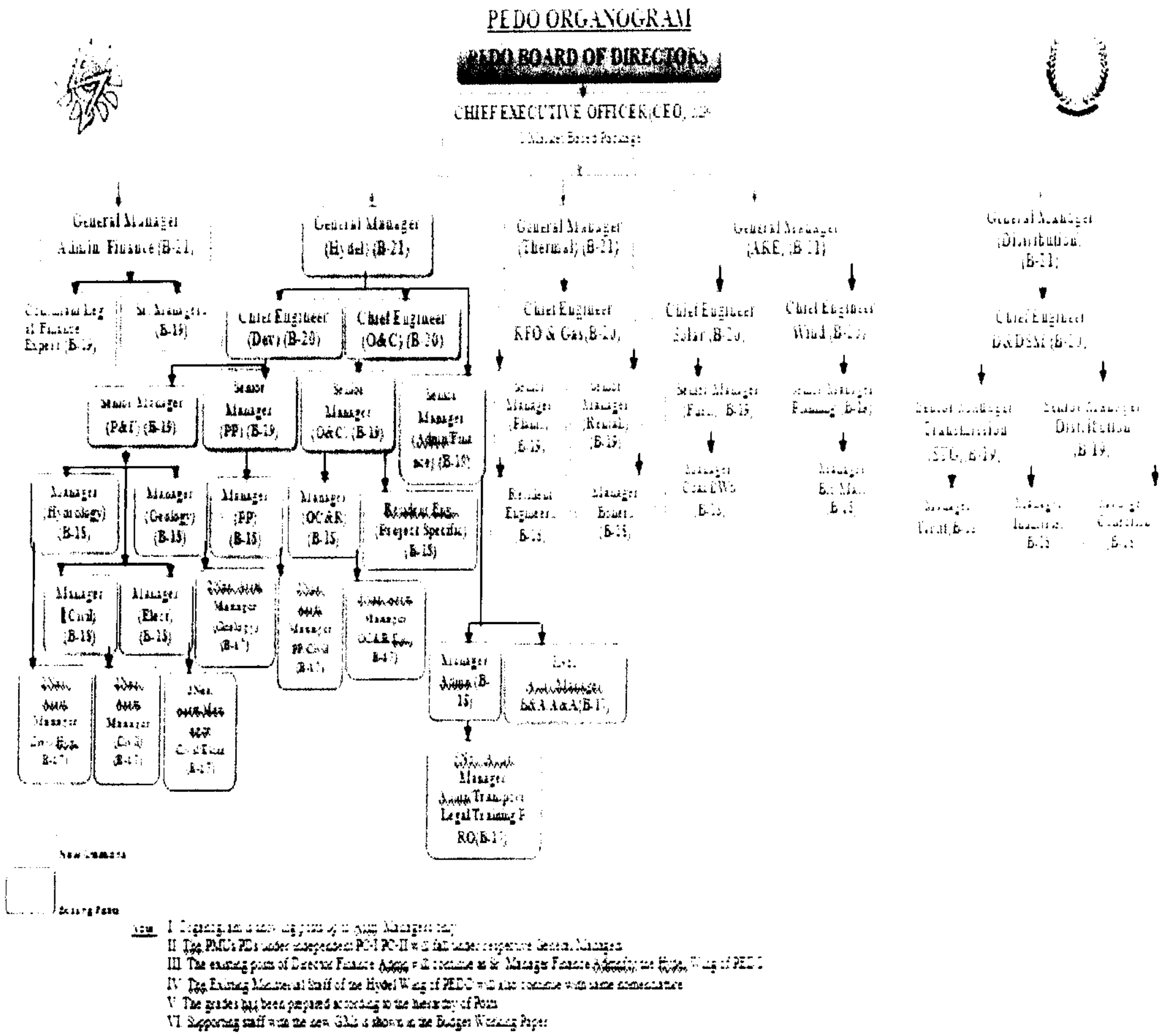
- Prepare comprehensive plan for development of the power and energy resources of the province.
- Frame schemes related to Generation, Transmission and Distribution of power, construction, maintenance and operation of powerhouses.
- Advisory body for the Government of KP in power sector matters regarding hydropower development.
- Conducting feasibility studies, surveys of hydel potential sites etc.
- Implementation of Provincial Hydel Power Policy to promote private sector investment in generation, transmission and distribution of power.

II. Role of PEDO

The Provincial Government has entrusted a dynamic role to PEDO, which mainly oriented towards private sponsors participation power sector projects besides developing projects in public sector. PEDO has established a dedicated Directorate to provide one window facility to private sponsors.

III. PEDO Organization

As eight members Board of Directors under the chairmanship of the Chief Minister of Khyber Pakhtunkhwa governs affairs of PEDO. The members include Minister Irrigation and Power, Minister Finance, Additional Chief Secretary, Secretary Irrigation and Power, Secretary Finance, Secretary Law and Managing Director PEDO. The head office of the Organization is at Peshawar.



2. Achievement by PEDO

PEDO, with the assistance of GTZ (German Agency for Technical Cooperation), has complied a Master Plan for rural electrification in the Northern mountainous areas of KP with particular emphasis on those areas which were not connected to the National Grid System. The Master Plan entails a total potential of more than 6000 MW that has been identified for public and private sector development. The hydropower potential sites are mainly located in the Northern districts of KP i.e. Chitral, Dir, Swat, Indus Kohistan and Mansehra.

I. Small Hydel Potential Sites

The Master Plan envisages small scale potential sites having total capacity of about 240 MW, comprising 53 hydel potential sites. These sites are suitable for regional supply to isolated communities in the mountainous areas of KP. The district wise breakup of sites is as follows:

Sr #	Region	Nos. of Sites	Power Potential (MW)
1	Upper Chitral	12	80
2	Lower Chitral	10	68
3	Kohistan	4	6
4	Swat	5	5
5	Mansehra West	2	19
6	Kaghan Valley	3	13
7	Dir	17	50
	TOTAL	**53**	**241**

II. Medium/Large Hydropower System

During field investigations, some very attractive sites of medium and large hydropower potential were also identified by PEDO.

Sr #	Name of Project / Location	Capacity (MW)	Remarks
1	Kandiah System, Kohistan a. Karang Scheme 454 MW b. Kaigah Scheme 548 MW	1002	Private sector is developing these sites under Federal Power Policy
2	Swat System, Swat a. Upper Scheme A1 101 MW b. Middle Scheme, B1 410 MW c. Lower Scheme C1 148 MW	659	-do-
3	Spat Gah, Kohistan a. Upper Scheme 200 MW b. Middle Scheme 550 MW c. Lower Scheme 500 MW	1250	WAPDA has undertaken the feasibility study through KfW, Germany

4	Chor Nala System, Kohistan a. Scheme C-II 760 MW b. Scheme C-I 650 MW c. Scheme K-II 150 MW	1500	-do-
5	Kunhar River System, Mansehra a. Naran 215 MW b. Suki Kinar 840 MW	865	Private sector is developing these sites under Federal Power Policy

III. Feasibility Studies Completed

Out of the identified sites, PEDO has completed feasibility studies of the following potential sites. These schemes are in various stages of implementation.

Sr #	Name of Project / Location	Capacity (MW)	Remarks
1.	Daral Khwar HPP, Swat	36	Under implementation through ADB Loan
2.	Ranolia HPP, Kohistan	11	-do-
3.	Pehur HPP, Swabi	18	Constructed by PEDO
4.	Summar Gah HPP, Kohistan	28	Suitable for private sector
5.	Batal Khwar HPP, Swat	8	Suitable for private sector
6.	Matiltan HPP, Swat	84	Close to Award of EPC Contract and to start construction in 2016-17
7.	Khan Khwar HPP, Besham	72	Picked up by WAPDA for implementation
8.	Duber Khwar HPP, Kohistan	130	
9.	Allai Khwar HPP, Batagram	120	
10	Shushgai-Zhendoli, Chitral	144	
11	Shogo-Sin, Chitral	132	
12	BooniZait (Tore More Kari) Chitral	350	
13	Balakot HPP, Mansehra	300	
14	Jameshill More Lasht, Chitral	260	
15	Mujigram-Shaghore HPP, Chitral	64	
16	Barikot Patrak HPP, Upper Dir	47	
17	Patrak-Shringal HPP, Upper Dir	22	
18	Istaro-Booni HPP, Chitral	72	
19	Gahrir-Swir Lasht HPP, Chitral	377	
	Total	2275	

3. Hydropower Projects Completed

PEDO, after successful completion of following four small and medium size hydel projects with its own resources is planning to launch number of small, medium and large hydropower projects in view urgency for combating energy crises in the country.

Projects Completed by PEDO

Sr #	Name of Scheme	Location	Capacity (MW)
i	Malakand-III HPP	Malakand	81
ii	Pehur HPP	Swat	18
iii	Shishi HPP	Chitral	1.8
iv	Reshun HPP	Chitral	4.2
Total Installed Capacity			**105**

These projects are not only contributing towards the reduction in load shedding but also generating annual revenue of Rs 2 to 3 billion for the province.

Besides the above completed Hydropower Projects, PEDO is implementing following projects with the assistance of Asian Development Bank (ADB) for the development of Hydropower Potential in Khyber Pakhtunkhwa province which will be completed within three years.

Projects under Construction

Sr #	Name of Scheme	Location	Capacity (MW)
i	Koto, HPP	Dir Lower	40
ii	Karora HPP	Shangla	11
iii	Jabori HPP	Mansehra	10
Total Capacity			**61**

The Honorable Chief Minister has issued special directives for the implementation of hydel projects to address the acute energy crises in the country. In this regard, PEDO prepared an ACTION PLAN which has been approved by the Provincial Government of Khyber Pakhtunkhwa, under which PEDO will construct the following eight (8) Hydel Projects having a installed capacity of 593 MW.

Construction Projects

Sr #	Name of Scheme	Location	Capacity (MW)
1	Matiltan HPP	Swat	84
2	Sharnai HPP	Dir	115
3	Koto HPP	Dir	31
4	Karora HPP	Shangla	10
5	Jabori HPP	Mansehra	8
6	Shushai-Zhendoli HPP	Chitral	144
7	Shogo Sin HPP	Chitral	132
8	Lawi HPP	Chitral	69
Total Capacity			**593**

In order to promote Private Sector Investment in the Hydel Sector the following 6 sites have been offered in the Private Sector.

Sites Offered under Private Sector

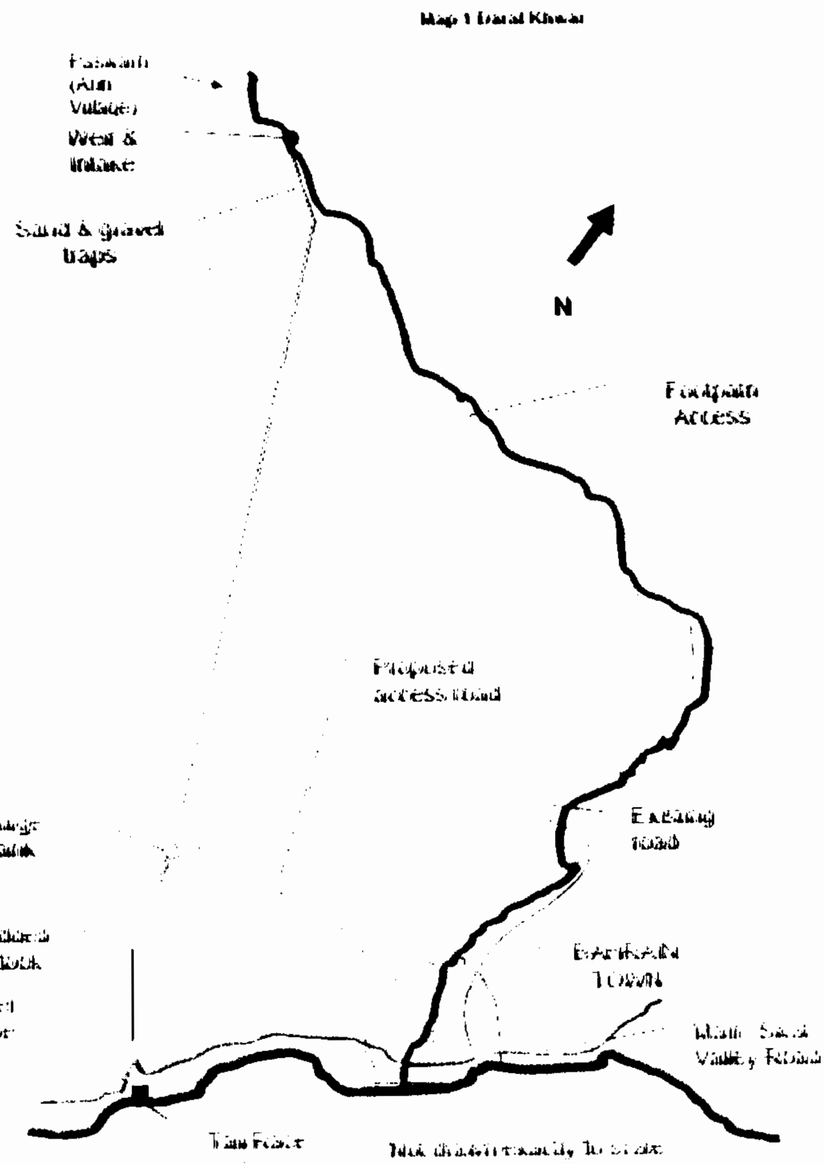
Sr #	Name of Scheme	Location	Capacity (MW)
1.	Arkari Gol HPP	Chitral	99
2.	Naran Dam HPP	Mansehra	188
3.	Shigo Kach HPP	Dir Lower	102
4.	Ghor Band HPP	Shangla	21
5.	Batakundi HPP	Mansehra	96
6.	Nandihar HPP	Batagram	12
Total Capacity			**518**

In order to facilitate the private sector, PEDO has also conducting Pre-Feasibility study of 10 raw sites in various districts of Khyber Pakhtunkhwa Province and these sites have been offered to private sector for development.

Schedule I - 3(5)(i)

PROSPECTUS

Pakhtunkhwa Energy Development Organization (PEDO)
Government of Khyber Pakhtukhwa
Daral Khawar Hydropower Project 36.6 MW
Bahrain, District Swat



Prospectus

PROSPECTUS OF DARAL KHAWR ROJECT (36.6 MW)

1. Project Brief

a. Introduction

Daral Khawr Hydropower Project is a run of the river hydropower project. It is located in the Khyber Pakhtunkhwa Province of Pakistan and on the Daral Khwar Nullah, a right tributary of River Swat near Bahrain Town, in the District Swat of Malakand Division.

b. Background

The Daral Khawr hydropower project was first mentioned as part of the master plan for electrification of mountainous regions in KPK on the basis of proximity power. The master plan was carried out in seven planning regions including the Swat valley. The catchment of the Swat River and its tributaries north of Madyan town represents the planning region of Swat River. The Planning region was divided into four parts:

- the north-western part (System I)
- the northern part (System II)
- the central part (System III)
- the partially electrified southern part (System IV) which is connected to the WAPDA grid.

The long term power system expansion plans developed for the various regions have been based on a least cost solution. As a first outcome of the planning study, the Batal Khwar hydropower project was recommended as a least cost solution with a design capacity of 1.68 MW. The power station should supply System III.

The original two sites at Daral Khawar and Ari Bahrain were combined to the Daral Khwar hydropower project in the 2nd edition of the master plan. The site was estimated at being feasible and selected for the development of a feasibility study which was carried out by GTZ/SHYDO during 1996-1998. The final report is dated May 1998.

Extensive field reconnaissance, topographical survey, hydrological and geotechnical investigations and engineering studies were carried out for the preparation of the GTZ/SHYDO Feasibility study (May, 1998). The study consists of 13 Volumes (2 volumes of Main report and 11 Appendices):

- Volume 1: Main Report
- Volume 2: Main Report: Drawings
- Volume 3: Appendix 2: Power Market
- Volume 4-6: Appendix 3: Topographical Survey
- Volume 7: Appendix 5.1: Geology
- Volume 8: Appendix 5.2: Engineering Geology
- Volume 9: Appendix 6: Environmental Impact Assessment
- Volume 10: Appendix 7: Selection of Plant Layout
- Volume 11: Appendix 8: Hydraulic and Static Calculation
- Volume 12: Appendix 9: Transport & Access Facilities
- Volume 13: Appendix 10: Report on load flow short circuit and Stability Analysis
- Volume 14: Appendix 11: Cost Estimates Civil Works
- Volume 15: Appendix 12: Economic Analysis.

A number of aspects have been investigated and analyzed beyond the requirements of a feasibility study because the project was part of the development of an overall supply strategy for the upper Swat valley and the study was developed in the framework of the German-Pakistani bilateral Technical Cooperation which included a significant capacity building component.

Daral Khwar Hydropower Feasibility Study Daral-Final-01-05-06.

- The study has been critically reviewed in all aspects. In general:
- The project is estimated at being technically feasible
- The technical design is appropriate and represents the best option in general
- The geological and geo-technical, investigations and surveys provide sufficient and reliable data.

In the following review, emphasis has therefore been laid on:

- Discussion and improvement of technical layout where appropriate

Review and update of

- Transport and Access facilities
- Cost Estimates
- Economic and Financial Analyses
- Environmental Aspects
- Resettlement Aspects.

All information from the GTZ/SHYDO study necessary for the presentation of the overall picture has been incorporated in this study. Maps, drawings and figures taken without changes are marked accordingly.

For minor important aspects or for additional information on a more general basis, reference is made to the above mentioned GTZ/SHYDO study as well as to the Regional Development Study on the upper Swat valley; GTZ/SHYDO, 1994.

Feasibility Review by Management Consultants (2008)

M/s Associated Consulting Engineers – ACE (Pvt.) Ltd. in association with ILF Consulting Engineers – Austria have been appointed as the Management Consultants. The scope of the Consultancy Services Agreement includes supervision, coordination and technical input for continuous and diligent services to oversee the execution of Daral Khwar Hydropower Project. The services also include support to the Project starting with the review of Feasibility Report prepared by ADB Consultants, to assist in selection of the EPC Contractor, upto the Final Commissioning of the Project.

This report contains review of the Feasibility Study carried out by Integration Environment & Energy Ltd (2005) and is being submitted in partial fulfillment of reporting requirement as specified in Appendix-B to the MC's consultancy services contract agreement. Following volumes of the feasibility report of ADB Consultants have been reviewed under this report.

- Volume 1.1: Technical Report - Main Report & Annexes - Dok. No. ADB TA No.4425-AK (TAR34339-01)

- Volume 1.2: Technical Report – Appendices
- Volume 2 of 4: Economic and Financial Analysis
- Volume 3 of 4: Environment Assessment
- Volume 4 of 4: Resettlement Plan

It is stated that generally the study is of good quality. However, deficiencies and needed improvements pointed out by ACE / ILF Specialists (in their respective fields) are explained in the forthcoming sections.

Feasibility Review Report was accordingly prepared by ACE / ILF and submitted to the client December 2008. The client approved the revised status of the Project in January 2009.

c. Project Objective

Primary objective of the Project is to generate 36.6 MW hydropower with average annual energy production of 154 GW.

d. Project Components

The Project consists of a intake; weir and diversion works; connection channel; sand trap and headrace tunnel; penstock; valve chamber; powerhouse and tailrace, switchyard; Employer's offices and Colony, and access roads.

e. Salient Project Features

Main components of the Project include Weir, Intake Structure, Connecting Channel, Gravel Spill, Sand Trap, Headrace Tunnel, Surge Chamber, Valve Chamber, Embedded Penstock, Powerhouse, 132kV Transmission Line and 132 KVA Switch Gear.

▪ No. of Units	3
▪ Total Installed Capacity	36.6 MW
▪ Maximum Head / Minimum Head	294m / 275.15m
▪ Design Discharge	15 m^3/s
▪ Weir Type	Fixed Sill
▪ Height above River Bed	5.15 m
▪ Weir Length	39.8 m
▪ Sand Trap Length	99.4 m
▪ Proposed Road	10 Km
▪ Tunnel Length / Diameter	3071 m / 3.2m
▪ Embedded Penstock	840 m long
▪ Surge Tank Cross-Section	19.6 m^2
▪ Mean Annual Energy	149.7 GWh
▪ Turbine	Pelton
▪ Nos. of Turbines	2x 15.3MW and 1x 6.0MW

f. Salient Contract Features and Milestones

• Contract Cost	Rs. 8.32 Billion
• Advance Payment by PHYDO	10 %
• Date of Signing of Contract	11 April, 2012
• Ground Breaking Ceremony	30 April, 2012
• Time for Completion	42 Months

Main Environmental Aspects

Daral Khawar Hydropower Project is one of small and medium sized hydropower projects proposed in the valley systems of Khyber Pakhtunkhwa. Such schemes will help to extend the national power supply and distribution systems to remote areas at the same time project will help in the supply Pakistan's overall energy needs.

Environmental impacts of the scheme during construction and during operations have been considered and discussed in Initial Environmental Examination (IEE) report which has been prepared to discuss and justify the impacts on the environment because of the projects. The report has determined that there would not be any significantly negative impact on the environment. Rather, considering the fact that there would be zero carbon emission, this project would offset equivalent carbon emissions from equivalent thermal capacity project. There will be some very negligible effect on the environment because of the construction activities, but the positive effects because of the project during the construction and during operation outnumber the negative impacts of the project. IEE for the project has been duly approved by the competent authority.

The main environmental impacts of the project relate to:

- Construction of the access road to surge tank and weir sites on steep slopes,
- Partial loss of few houses and loss of agricultural land at the powerhouse and tail race sites,

The latter has the potential to affect the water needs of the population in the valley during the winter months when the river has a much reduced natural flow already. It was supplying micro hydro-projects providing electricity to the people of the main town of Bahrain as well as water to grain grinding mills which, both, have been washed away by the heavy flood of July, 2010. Bahrain is an important tourist destination with a number of hotels and the population is much increased in the summer months. There is no central sewage disposal system in the Khwar or at Bahrain and disposal of human waste to the Khwar already represents a problem. Use of water for human activities is estimated at 400 liters per second or 0.4 m^3/s. Provision more than the requirement has been made for the water to flow in the river and will have no adverse implications for fish life and fish movements to and from the river to the catchments above.

Environmental Mitigation

The main mitigation measures included in the Environmental Management Plan (EMP) are as indicated below:

Summary of Mitigation Measures

	Potential Impact	Mitigation
1	Change in landscape in steep mountain terrain from construction activities	Implementation through detailed EMP including a tree plantation program.
2	Loss of houses and agricultural land	Project components redesigned to minimize loss of houses. Resettlement plan to be implemented with compensation package for loss of land & trees.
3	Reduced water flows in the river from which water is taken for the project impacting small hydro-projects, water mills, drinking water use	Adequate water flow of more than 700 liters/s retained in the river in winter; this will be adequate for human and fish activities.

Compensation is included for the loss of land and trees and there is guaranteed more than 700 liters/s flow of water in the river to supply the existing requirements for human use. At Bahrain where there is a high density of population it is proposed to implement a water supply scheme for town use with 10 fountains.

As well as resettlement and tree compensation, a tree planting program is included in mitigation. Surveys of water quality and fish will take place in the river as a monitoring precaution.

Summary of Mitigation Works

#	Mitigation Measure
1.	Land Acquisition
2.	Plantation of endemic tree species
3.	Water supply to Bahrain
4.	Water quality testing to drinking water standards
5.	Survey fish numbers and movements in the river system
6.	Environment & Resettlement Plan

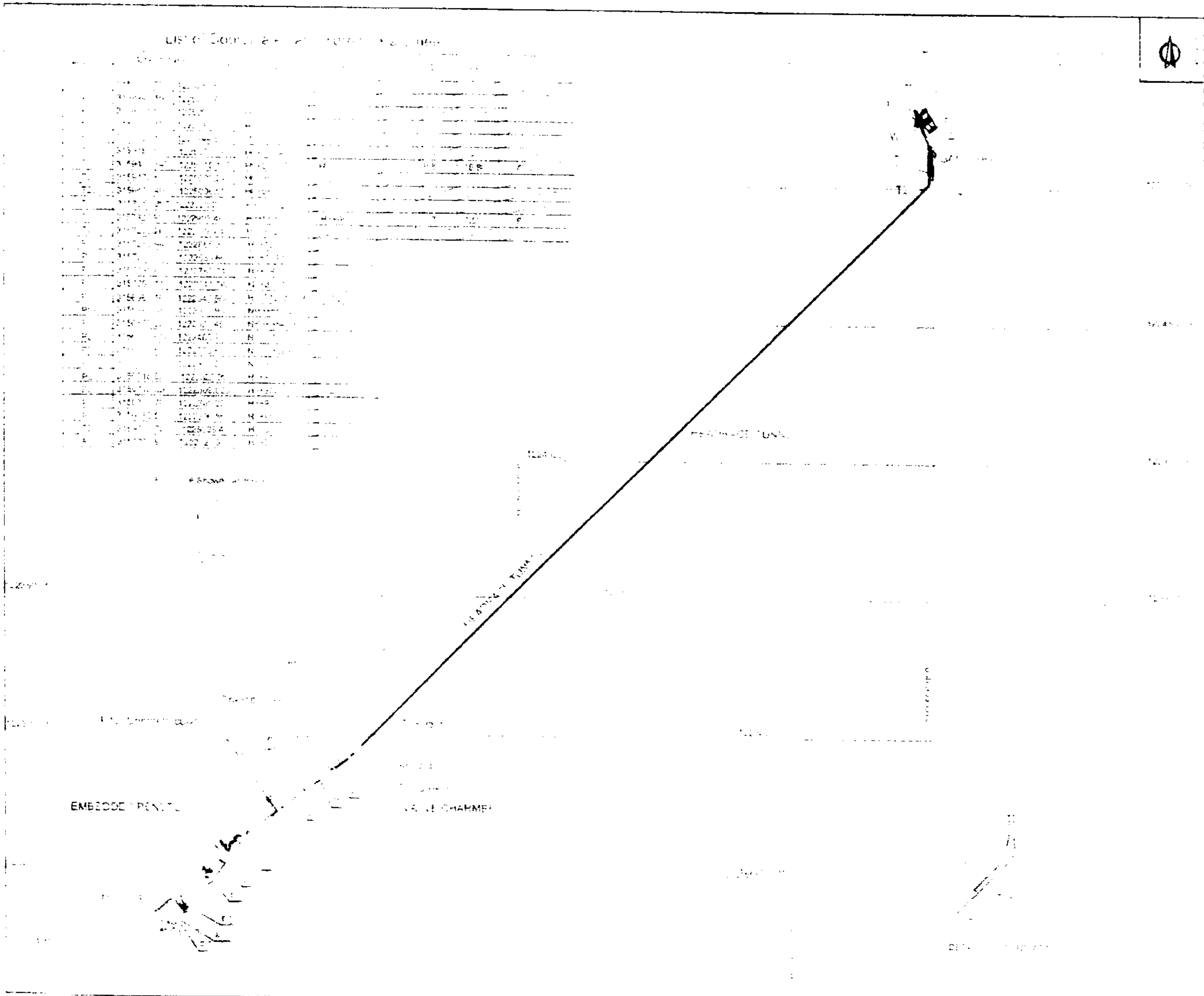
Socio Economic Effects of the Project

Daral Khwar Hydropower Project will play its due role in the socio economic uplift of the people of the adjoining areas in particular and Khyber Pakhtunkhwa and the country in general. Since it is an indigenous resource based project without any fuel element being considered as pass through, the project will contribute in bridging the gap of price differential, which currently Power Purchaser is forced to pay. This will help in easing out the issue of circular debt etc.

The cost of project is approximately 8.32 billion. Majority of the cost would be incurred in local currency, thus saving precious foreign exchange. In addition to this, most of the cost of EPC relates to the local component, which entails support to local contractor and industry especially cement and steel.

Project cost and Tariff

Capital Cost of the project at present on the basis of approved feasibility study is 8.32 billion. The currently envisaged financing structure is based on a debt equity ratio of 80:20. Project life for the purpose of the tariff is estimated to be 30 years. However, in effect it would be 50 years. The sponsors will transfer the project to the Power Purchaser at the end of concession term. However in case Power Purchaser decides to further lease out the project, the sponsors will have the first right. The real benefits of the project will be available when the debt is retired and the project becomes debt free. At that time, electricity from the project will be available at a very nominal price.



Note:

1. The elevation system adopted in the drawing ... contract ... the relationship between current elevation ... (symbol ...) and that used in feasibility ... feasibility study report (symbol ...) is listed as follows: ...
2. The units of elevation and chainage are ... meter ... others are as shown in the drawing.
3. Please refer to the last version drawing "Arrangement ... For Powerhouse (D21026S-SG0106-0...)" for the ... definite arrangement of powerstation.
4. Scale 0 1 2 3 4

	REFERENCE DRAWING
SH. No.	DRAWING N
1	
2	
3	

EMPLOYER

SARHAD HYDEL DEVELOPMENT ORGANIZATION (SHYDO)

EMPLOYER'S REPRESENTATIVE

PROJECT MANAGER DARAL KHWAR HYDROPOWER PROJECT

CONSULTANT

ASSOCIATED CONSULTING ENGINEERS

CONTRACTOR

SINOTEC-SHPE-GRC JV

PROJECT

DESIGN, PROCUREMENT AND CONSTRUCTION OF DARAL KHWAR HYDROPOWER PROJECT (DKHP, CONTRACT NO. ...)

TITLE

General Layout of the Project

DESIGNED	Z ... ZEN...
CHECKED	...
APPROVED	...
SCALE	
DATE	...
DRAWING No.	D2102...

Schedule I - 3(5)(d)(v)

PROFILE OF SUBCONTRACTORS

SINOTEC

COMPANY INTRODUCTION

[illegible] itself to the development of global market and seeking extensive cooperation in the world SINOTEC has established extensive services and international information network, the business has covered [illegible] Europe, Africa and other regions since Company has established in 2003

With global engineering contract as its main body, international trade and new high technical products as its wings, SINOTEC is bending itself to becoming a human centered, market oriented and innovation propelled international group enjoying multi capital structure and scientific management

[illegible] the management concept of combining various advantages, SINOTEC associates with many key [illegible] equipment manufacturers and integrates with many electric power survey and design institutes. It also possesses the general contracting capability for design, equipment supply, erection, commissioning and technology service in power field

SINOTEC is familiar with various international standards, and it can provide state-of-the-art power equipment [illegible] professional project design and contracting services according to standards [illegible] IEC, ASTM, BS, DIN [illegible]

[illegible] electric power projects SINOTEC has [illegible] and hydro power generation, transmission, substation and other power fields with rich project [illegible] experience. SINOTEC can provide reliable and stable power resources [illegible] high quality [illegible]

[illegible]

FINANCING CAPABILITY

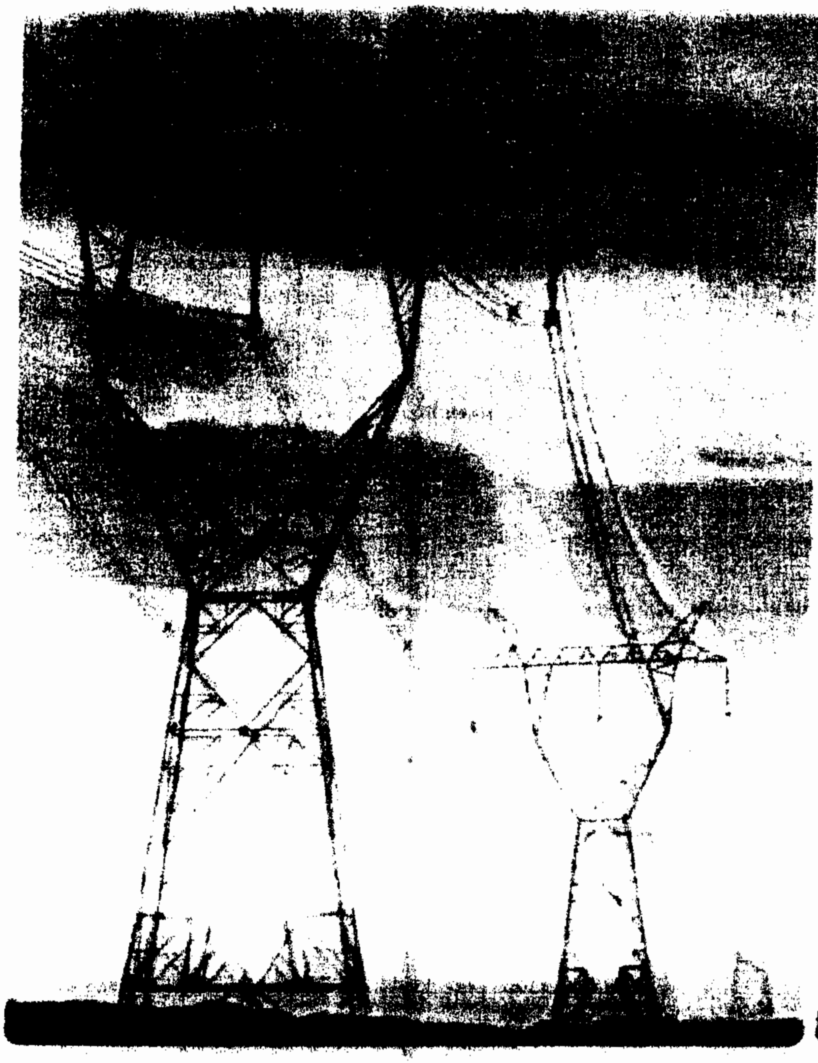
[illegible]

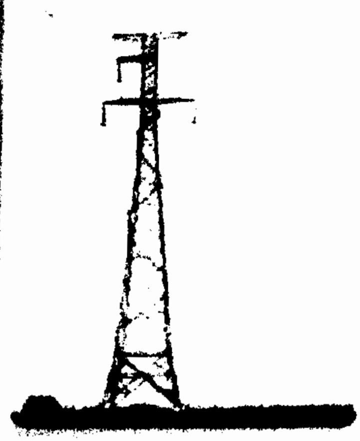
INITIATE A NEW CENTURY OF RENEWABLE SOURCES

Currently countries with coal and petroleum as their main fuel have got environment severely polluted. Under the pressure of daily decreasing fossil fuel reserves exploiting and making use of new energy resources has become an important component of continuous development of world energies. Among these new resources, wind energy, solar energy and geothermal energy are the most potential electricity generating fields. According to the development plan of the wind energy, solar energy and geothermal energy stipulated by the national planning committee, [illegible] 21st century.

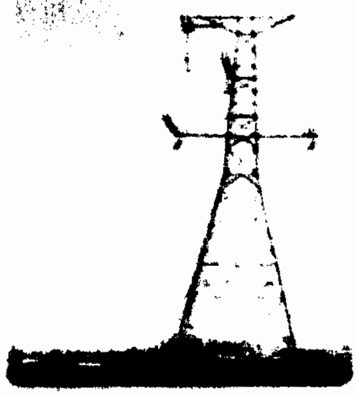
Nowadays, to relieve the situation of energy supply, S[illegible]TEC has also contributed itself to the development and exploration of green energy, as well as wind power generation, geothermal power generation, hydroelectric power station, solar energy etc, and the excellent achievements have been made successfully in west China and some other countries.

POWER INDUSTRY





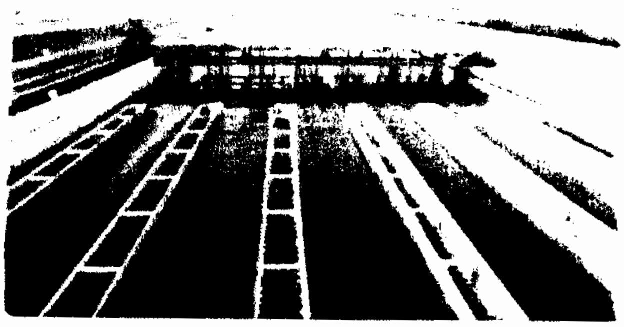
>> Engineering [illegible] and
[illegible]
[illegible]



[illegible]

[illegible]

WATER POWER & IRRIGATION



TELECOMMUNICATION

[illegible] years, SINOTEC has applied itself in the construction of infrastructure of telecommunications and transportation [illegible] SINOTEC to provide highly efficient services for survey design, construction, installation, equipment supply and maintenance for various [illegible] projects. SINOTEC has likewise established long term strategic and cooperative relationships with first-rank Chinese consulting companies as well as various engineering companies in the telecommunication field. SINOTEC consistently possesses professional [illegible] in telecommunication field and is able to implement large-scale engineering projects

SINOTEC

[illegible]

SER. NO.	OWNER Name&Address	PROJECT Description	PROJECT Location	CONTRACT Scope of Work	CONTRACT Duration Completion
[illegible]	Karachi Electric Supply Corporation [illegible] Karachi, Pakistan	[illegible] O.F. Underground Cable Project	Karachi, Pakistan	Route design, [illegible] Cable & Accessories supply, commissioning [illegible] and tests	[illegible]
[illegible]	[illegible] Thermal Power Station Hyderabad, Pakistan	Power Station	Hyderabad, Pakistan	Supply, [illegible] Cable Connection Line	[illegible]
[illegible]	[illegible] Supply [illegible] Karachi, Pakistan	[illegible] O.F. Underground Cable Project	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible] Transmission [illegible] Programme [illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible] 132 [illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible] Cable	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Karachi, Pakistan	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Karachi, Pakistan	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Karachi, Pakistan	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Karachi, Pakistan	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PROFILE OF SHPE

1 Introduction

Hunan Sunny Hydropower Equipment Corporation (hereinafter abbreviated as "SHPE", Website: www.shpe.cn), was launched by Sundo Technology (HK), Limited in 2004 by taking over Hunan Xinning Hydropower Equipment Factory that was established in 1958. The former factory has more than four decades of professional experience in manufacturing hydropower equipment and was one of the leading manufacturers for supplying hydropower equipment internationally, which was authorized by Ministry of Machine-Building Industry of China. It's Turbine and Generator had been selected by China Government to participate HANNOVER MESSE in 1981. SHPE is capable to supply various types of hydro generating set with unit capacity below 50MW together electric & control equipments. While being enjoyed abundant reputation domestically, SHPE had supplied its products to all over the world including but not limited to Kazakstan, Russia, Nepal, Indonesia, Burma, Vietnam, Sri Lanka, Peru, Chile. Etc. SHPE is located in Xinning of Hunan Province where the Danxia Topography for World Natural Heritage –Langshan Mountain is nearby.

Since 2004, Top Standard Enterprise Management Concepts from HK Management Field had been significantly introduced to SHPE. SHPE has gradually implemented scientific management means such as PDCA Cycle (Continuous Improvement Spiral), 6S Theory and BPR (Business Process Reengineering). SHPE has devoted to establishing teamwork with learning Spirit, Innovation, Talent Reserve and Aggressiveness. The technical development and product creativeness will and is to be enforced due to SHPE has combined its technical strength with good cooperation between SHPE and China Institute of Water Resources Hydropower Research, Huazhong University of Science & Technology (HUST) as well as Tianjin Design & Research Institute of Electric Drive ("TRIED").

SHPE sticks to Consulting Based Marketing Concept and Service Oriented Marketing Concept. By virtue of its abundant technical strength and long-term experience, SHPE is able to provide customers from all over the world with comprehensive technical consulting service. SHPE is the first enterprise in hydro industry of China who initiates two years of DLP and Regular Customer Return Visit. Meanwhile, SHPE, as the manufacturer of Electric & Mechanical equipment for hydro power plants, has a long lasting tradition in maintenance and refurbishment of wearing out equipment and low efficient plants. Generally speaking, refurbishment that done by SHPE may result in increased reliability, increased power generation, increased static and dynamic stability and increased efficiency. It is always the objective and desire of SHPE to obtain customer's satisfaction by contributing the utmost interests to domestic and overseas customers.

2 SHPE's Strength Contributing to the Project

SHPE, Guided by the tenet of bringing success to country, society, clients and employees with science and technology, has achieved extraordinary successes.

In virtue of Hunan Xinning Hydropower Equipment Factory's base, SHPE has more than 40 years of experience of designing, manufacturing various type of generators.

Besides, by having obtaining mechanical experts from Tianjin Design & Research Institute of Electric Drive ("TRIED") as SHPE's technical supplement for achieving double regulated horizontal shaft Kaplan turbine with all auxiliary equipment, SHPE is very confident to supply all qualified electric & mechanical equipments for targeted projects.

3 Technical and Producing Capability of SHPE

SHPE is proposed to supply complete electric & mechanical equipments and provide related technical service for the project.

3.1 Design Capability

By technically merging with Tianjin Design & Research Institute of Electric Drive ("TRIED"), SHPE owns more than fifty years of design experience in designing Hydro Mechanical & Electrical System, Turbine and Auxiliaries, Generator and Auxiliaries, LT Switchgear, Protection & Control Panel, Transformer, PLC and SCADA system etc.

3.2 Manufacturing and Testing Ability

SHPE has a grand-scale manufacturing factory certified by ISO9001 with two production and assembly bases (area of 8000 ㎡), one processing center of middle and small components and one processing center of big components, all of which have a total investment of over RMB 100 million. SHPE has successively built a test center of hydro equipments.

Schedule II - 6

EIA Approval Letter

OFFICE OF THE DIRECTOR GENERAL, ENVIRONMENTAL PROTECTION AGENCY, GOVERNMENT OF NWFP, PESHAWAR

No EPA/SHYDO/1701 Dated Peshawar the August 15 2008

To

Deputy Director (P&F),
Sarhad Hydel Development Organization (SHYDO),
Govt. of NWFP, Peshawar

Subject: **Renewable Energy Development Sector Investment Programme Comprising Daral Khwar, HPP, Ranolia HPP & Machai Canal HPP.**

I am directed to enclose herewith Legal Environmental Approval/ Decision Note on IEE of Renewable Energy Development Sector Investment Programme Comprising Daral Khwar, HPP, Ranolia HPP & Machai Canal HPP for your information and further implementation, please

Dr. Amjad Ali Khan
Deputy Director (EIA)
EPA. NWFP

MD(SHYDO)

The NOC from EPA has been received and submitted for information please.

Diary No. 1314
Dated 21-8-08
O/O Managing Director
SHYDO NWFP Peshawar

Good. Expedite activities. 18/8

P.M. Daral Khwar

28/8

P.A.
file

SCHEDULE-VI

Decision on IEE

1.	**Name, address of proponent**:	Mr. Farhat Mahmood, Project Manager, Sarhad Daral HPP, (SHYDO), 313 - WAPDA House Shami Road Peshawar,
2.	**Description of project.**	The Daral Khwar Hydro Power Project is a small scale project with a total capacity of 36.6 MW. From the beginning of construction to the commissioning of the project will take approximately 36 months. The Daral Khwar System has a total catchments area of 250sqm. For the construction of the various elements there will be a permanent loss of 5.7ha land. There are 21 affected persons who will loss a total of 1.63ha of privately owned farm land. An estimated 460 tress will need to be felled. Blasting is also involved in the project.
3.	**Location of project.**	The project is located in District Swat.
4.	**Date of filing of IEE.**	09/06/2008

5. After careful review, the Environmental Protection Agency, Govt. of NWFP has decided to accord approval of the Initial Environmental Examination for Daral Khwar Hydro Power Project (36.6 MW) in Behrain, District Swat, in line with the guidelines issued by Pak. EPA and IEE/EIA Regulations, 2000 subject to the following terms & conditions:-

a) The proponent will adopt all precautionary and mitigatory measures identified in IEE report as well as any un-anticipated impacts during the construction and operation phase of project.

b) Present right of way of irrigation should be protected.

c) Land compensation agreement should be provided to This Agency before starting activities on the site.

d) To minimize erosion, afforestation programme should be planed and implemented in the catchments area of the proposed dam.

6. The proponent shall be liable for compliance of section 13, 14 & 18 of IEE/EIA Regulations 2000, which enunciate the conditions for approval, confirmation of compliance, entry, inspection and monitoring of the proposed project.

7. This approval does not absolve the proponent of duty to obtain any other approval or clearance that may be required under any other law in force.

8. In exercise of the power under Section 12 of Pakistan Environmental Protection Act, 1997, the undersigned is pleased to approve the IEE report of the project with above mentioned terms & conditions

Dated: Peshawar
Tracking/File.No.

DIRECTOR GENERAL
EPA, NWFP.
3rd Floor, SDU Building,
Khyber Road
Peshawar.

Schedule II-9

CONSENT (PESCO)

PESHAWAR ELECTRIC SUPPLY COMPANY

4

Phone # 091-9210538
Fax # 091-9212024

Office of the
Chief Executive Officer
PESCO, Peshawar.

No. GMT/PESCO 2170-73/

Date: 3 /02/2016

Subject: **Minutes of the Meeting regarding Interconnection of Daral Khwar HPP(36.6 MW) with Madyan Sub Station of PESCO.**

Reference: Request of Project Director Daral Khwar HPP PEDO, Swat vide his letter No. 21-23/ PEDO/ PD-DARAL dated: 15.01.2016.

A Joint meeting was held amongst PESCO, Project Management Daral Khwar HPP PEDO, Project Consultants Daral Khwar HPP and EPC Contractor (SINOTEC-SHPE-GRC JV) Daral Khwar HPP on January 21, 2016 at 10:00 Hrs at PESCO HQ under the Chairmanship of General Manager (Tech), PESCO in his office in connection with the Interconnection arrangement of Daral Khwar HPP with 132KV Madyan Grid Station of PESCO at Madyan or with the existing 132 KV Transmission Line of PESCO at Madyan to the Khwaza Khela Grid Station. The List of participants is attached at Annex-I.

The GM (Tech), PESCO welcomed the participants and elaborated that the Daral Khwar HPP, being a Project of National Interest, would be given special preference in the subject matter. He invited the XEN GC PESCO to explain and brief the participants on the status of the Construction of 132KV Madyan Grid Station and rehabilitation of some Gantry Structures of the existing 132 KV Transmission line from Khwaza Khela to Madyan. The XEN GC stated that the Construction work of Madyan Grid station is going on in full swing and will be ready for evacuation of power from Daral Khwar HPP by its scheduled commissioning in July/August, 2016. He further informed that the construction work on the affected towers of the existing line from Khwaza Khela to Madyan will be completed by March, 2016, which will also be ready as 2nd option for taking Power from Daral Khwar HPP.

On a query from GM EPC Contractor (SINOTE-SHPE-GRC JV), the PESCO Representatives told that the Interconnection arrangement and load flow study of Transmission Line from Daral Khwar HPP shall be based on the design parameters of the under construction 132KV Grid Station at Madyan. The PD Daral Khwar HPP, PEDO informed that the Design Drawings of the Transmission Line from Daral Khwar HPP up to Madyan Grid Station of PESCO showing complete profile, alignment, design data, types of towers and conductors are ready for submission to PESCO for their review and record.

However, the Chair, after consultation with other PESCO officers, stated that a Joint Site visit of the Daral Khwar HPP Transmission Line may please may be under taken on any agreed date in the coming weeks to have an overlook of the designed alignment, particularly from the operation and maintenance point of view by PESCO in future. The Participants agreed to the proposal. The XEN GC PESCO added that the Representatives from GSO, PESCO shall also be invited to accompany with on the same visit.

Habib-Marwat PESCO

The Chair told that the Design Documents of Daral Khwar HPP T/Line may be submitted by the Project Management PEDO, Daral Khwar HPP after the Joint Site visit. The Project Director Daral Khwar HPP, PEDO requested the Chair for the conduction of the Site visit in the coming weeks on priority basis and the Chair was very kind to agree to. The GM EPC Contractor requested for provision of the Design Data and Single Line Diagram of the PESCO under Construction Grid Station at Madyan which was agreed to.

Decisions:

1. It was resolved that interconnection arrangement, Load flow study and Design Data of Daral Khwar HPP T/Line shall be based on the design data/parameters of PESCO Grid Station at Madyan.

2. A Joint Site visit of PESCO Representatives and Project Management/Project Consultants/EPC Contractor Daral Khwar HPP shall be made as early as possible.

The meeting ended with vote of thanks from / to the Chair.

c/c

Engr. Fida Ahmed Khan
General Manager (Tech:)
PESCO H/Q Peshawar

Copy to

1. GM (O&M) T&G PESCO, Peshawar.
2. CE (Development) PMU PESCO Peshawar.
3. Mr. Habib Khan Marwat, Project Director Daral Khwar HPP. With the request to circulate copies of minutes of meetings to all concerned of PEDO & Consultants etc.
4. S.O to CEO PESCO for information please.

Annex-I

List of Participants

PESCO

1. Mr. Fida Anmad Khan, GM Tech, PESCO.
2. Mr. Niaz Muhammad GM T&G PESCO.
3. Dr. Amjad Khan, Chief Engineer Development PMU PESCO.
4. Mr. Murad Khan PD GSC PESCO
5. Mr. Fazle Rabbi Addl; Manager PMU
6. Mr. Habib-ur-Rehman XEN GC

PEDO

1. Arbab Khudadad Khan Chief Engineer (Distribution).
2. Mr. Habib Khan Marwat, Project Director Daral Khwar HPP.

Project Consultants

1. Mr. Farzeen Badshah

   Project Manager Consultants Daral Khwar HPP.

EPC Contractor

1. Mr. Fateh Muhammad GM SINOTEC-SHPE-GRC JV.
2. Mr. Shafique Ahmad Design Engineer SINOTEC-SHPE-GRC JV.
3. Mr. Taimoor Design Engineer SINOTEC-SHPE-GRC JV.

21

PESHAWAR ELECTRIC SUPPLY COMPANY

OFFICE OF THE
CHIEF EXECUTIVE PESCO
WAPDA HOUSE, PESHAWAR

PH# 091-9212550
Fax: 091-9212335

No 585-91/SSC(HPPs)

Dated: 24/04/2014.

Mr. Naeem Saleem,
Section Officer (C&C),
Ministry of Water & Power,
Islamabad.

Subject: **MEETING OF THE SENATE STANDING COMMITTEE ON WATER & POWER HELD ON APRIL 9, 2014.**

Ref: Your letter No. 6(12)/-2014-S.S dated 18.04.2014.

As desired, a joint meeting was held between PESCO & PHYDO representatives at PESCO H/Q on 23.4.2014, wherein the following issues pertaining to PHYDO were discussed and finalized:

1. **18 MW Pehur Hydropower Complex-Payment of Arrears on account of Sale of Power to NTDC & Signing of Power Purchase Agreement(PPA) with PESCO:**

• PESCO is purchasing power from Pehur Hydropower Project on an interim tariff rate of Rs.1.0/kWh, as agreed in the meeting held between PESCO & SHYDO on 20.02.2010. The project is connected to the 132 KV Gadoon Grid Station being operated and maintained by PESCO.

• Execution of Power Purchase Agreement (PPA) has been delayed in light of the decision of Ministry of Water & Power dated 03.02.2014, wherein it was decided that CPPA of NTDC shall execute PPAs on behalf of DISCOs for up to 50MW Hydel projects in province/AJ&K. However, CPPA is still reluctant to comply with the Ministry directives. In this regard another meeting was held at PPIB, Islamabad on 09.04.2014 between all stakeholders, and it was decided that:

i. A meeting between PPIB and NTDCL Legal Teams will be held shortly to finalize legal framework and the draft agreement between NTDC and DISCOs regarding Evacuation of Electric Power and Execution of Power Purchase Agreement (PPAs) for up to 50 MW Hydropower Projects in provinces/AJ&K in line with decisions taken in the meeting of 29th October, 2013.

ii. The PPIB and NTDCL legal teams will finalize legal framework within one (1) month.

• It was further agreed between PESCO & PHYDO, that PESCO will submit copy of the draft Power Purchase Agreement to CPPA, Lahore for execution of the agreement with PHYDO and till the finalization of the PPA, CPPA may allow PESCO to purchase power at the NEPRA determined tariff of Rs.4.8159/kWh and also clearance of outstanding dues of Rs.663 Million accumulated due to enhance tariff rate of NEPRA since 01.03.2010.

2. **36 MW Daral HPP, Swat-Evacuation of Power to Madyan Grid:**

NTDC has raised certain reservations on the PESCO's proposed site for construction of 132 kV Grid Station at Madyan. PESCO technical team will be revisiting the site shortly to either opt for the existing site or to select new one. However, in case of any delay in completion of the Madayn Grid, an alternate option for evacuation of power from Daral HPP will be made through PESCO 132 kV Grid Station at Khwazakhela.

3. **69 MW Lawi HPP, Chitral - Evacuation of Power:**

Not relates to PESCO.

4. **Issuance of NOC by PESCO to Private Sector Hydel projects in KP:**

PESCO has already issued NOCs to the private sector Hydel projects in KP.

5. **Arrears of Shishi & Reshun powerhouses Chitral and enhancement of Tariff for these powerhouses:**

It was agreed that the payment/clearance of invoices/arrears pertaining to Reshun & Shishi Hydropower Projects will be resolved by PESCO as per the existing rate of Rs.3.0/kWh. Further, PHYDO will file tariff petition in respect of these power houses at NEPRA regarding the issue for enhancement of tariff/determination of tariff for these power houses.

Brig ® Tariq Saddozai
Chief Executive Officer
(PESCO)

Copy to:

1. Secretary Committee, Room No.326, 3rd Floor, Senate Secretariat, Parliament House, Islamabad.
2. MD PEPCO, WAPDA House, Lahore.
3. MD PPIB, House No.50, Nazimuddin Road, F-7/4, Islamabad.
4. GM (Finance) PESCO.
5. CE (T&G) PESCO for information and necessary action w.r.t Para No.2.
6. Director (O&C) PHYDO, 38/B-2, Phase-V, Hayatabad, Peshawar.

Schedule II - 10

INFRASTRUCTURE DEVELOPMENT

toilets/shower room and ablution area, sufficient lighting and ventilated with fans. The main hall shall be carpeted and a 'Mimbar', PA system installed and all windows to be curtained.

The design and location of the mosque shall be subjected to the Employer's approval.

(c) Residential Accommodation

The Contractor shall provide following minimum residential accommodation for employees of the Employer, Employer's Representative & their families, and advisors etc. along with necessary infrastructure works such as roads, water supply & sewerage system with overhead water tank and sewage treatment plant. All residential accommodation shall include fenced yards. The detail of residential accommodation and internal roads is as under

Type of Building	No. of Buildings	Covered Area of each Building (m^2)	Total Covered Area (m^2)	Plot Size / Unit (m^2)
Type I	1	235	235	500
Type II	3	135	405	750
Type III – Family Flats Ground plus two floors consisting four (4) units per floor	1	500	1500	1000
Type IV - Operators Hostel (Bachelor) Ground plus two floors consisting eight rooms (8) rooms with attached bath/Kitchen per floor	1	500	1500	1000
Guest House – Double Storey with 2 bed rooms on ground and 4 bed rooms on 1st floor	1	280	560	1000
Mosque	1	200	200	600
Hospital (10 Bed)	1	600	600	1800
Shops	1	80	80	300
Office – Double Storey	1	230	460	500
Degree College – Double Storey	1	-	3811	2000
Total			9351	9450

Schedule II - 12

PC-1

10) FINANCIAL PLAN AND MODE OF FINANCING

a) Annual Development Program(ADP)- 20% (Rs. 1,391.68 Million)

20% of the project cost will be met through the Annual Development Programme (ADP) of Govt. of Khyber Pakhtunkhwa.

b) Hydel Development Fund(HDF) - 80% Rs. 5,566.74 Million

80% of the project cost will be met through Hydel Development Fund of Govt. of Khyber Pakhtunkhwa.

c) Total Financing (a + b) **Rs. 6,958.42 Million**

11)PROJECT BENEFITS AND ANALYSIS

i) SOCIAL BENEFITS WITH INDICATORS

The main objective of the Project is to generate electricity and lay down track for hydel project implementation in the near future. It has been planned that Daral Khwar HPP with total capacity of 36.6 MW will be constructed. Annual energy varies from year to year depending on the inflows keeping in view other water requirements. However, average annual energy generated through the construction of subject powerhouse has been estimated as 154 GWh/a.

The revenues of Govt. would increase due to direct and indirect taxation, duties and levies on the production of goods and services that will result from the power generation benefits within the project area as well as from the electricity duty collected by the Federal Government, Government of Khyber Pakhtunkhwa or any other agency. Sales of electricity is the direct revenue which will be collected by SHYDO/Govt of Khyber Pakhtunkhwa.

Indirect or the secondary benefits would include creation of employment opportunities and improved standard of living of the people of the area and vicinity. There will be multiple effects on socio-economic development of the region, communication, infrastructures, forestry, cottage industry, livestock development and other opportunities would open up with construction of this proposed project. These benefits have neither been quantified nor considered in the present analysis. Most of the indirect benefits are difficult to quantify in monetary terms but should not be ignored while making the decision for the implementation of the Project.

GOVERNMENT OF PAKISTAN
Planning Commission
Planning & Development Division
(Public Investment Authorization-III Section)

*****

No. F.1(462) PIA-III/PC/10-11 Islamabad, the 4th August, 2011

Office Memorandum

Subject: Renewable Energy Development Program in Khyber Pakhtunkhwa (Revised).

The undersigned is directed to refer to the M/o Water & Power's O.M No. P-II-2(05)08, dated 6th June, 2011 on the above subject and to say that The Executive Committee of the National Economic Council (ECNEC) in its meeting held on 29-07-2011 considered the subject project and took the following decision:

"The Executive Committee of National Economic Council (ECNEC) considered the summary dated 28th July, 2011, submitted by the Planning Commission/Planning and Development Division on **"Renewable Energy Development Program in Khyber Pakhtunkhwa (Revised)"** and approved the revised Renewable Energy Development Sector Investment Program of the Government of Khyber Pakhtunkhwa as detailed in para-20 of the summary."

2. The para-20 of the summary is reproduced below:-

The revised Renewable Energy Development Sector Investment Program (REDSIP) is submitted for approval of ECNEC at the total cost of Rs. 12984.754 million including FEC Rs. 4343.848 million as detailed below:-

i. Construction of Daral Khwar HPP District Swat, Khyber Pakhtunkhwa (Revised PC-I) with Capital Cost of Rs. 6958.429 million including FEC of Rs. 132.00 million.
ii. Construction of Machai HPP, District Mardan, Khyber Pakhtunkhwa (Revised PC-I) with Capital Cost of Rs. 1198.170 million including FEC of Rs. 875.338 million.
iii. Construction of Ranolia HPP District Kohistan, Khyber Pakhtunkhwa (Revised PC-I) with Capital Cost of Rs. 4277.00 million including FEC of Rs. 2915.00 million.
iv. (a)Construction of SHYDO Office Building (b) Capacity Building Development of SHYDO and Related Entities of Energy & Power Department (Revised PC-I) with Capital Cost of Rs. 373.45 million including FEC of Rs. 273.380 million.
v. Feasibility Study (Revised PC-II) of (a)KOTO HPP (b) JABRO HPP (c)KARORA HPP with Capital Cost of Rs. 177.71 million including FEC of Rs. 148.10 million.

3. Sponsoring agency may issue administrative approval of the subject project in accordance with the above stated decision of ECNEC.

4. A copy of sanction letter, as and when issued, may inter-alia be endorsed to this Division.

5. The receipt of this letter may kindly be acknowledged.

(Sajjad Hussain)
Research Associate
Tel: 9093409

Secretary,
M/o Water & Power,
Islamabad.

P.T.O

3530

Copy to:

1) Secretary, Economic Affairs Division, Islamabad.
2) Member (I&M), Planning Commission, Islamabad.
3) Member (Energy), Planning Commission, Islamabad.
4) Advisor (Development Budget), Planning & Dev. Division, Islamabad.
5) Sr. Chief, Energy Wing, Planning & Dev. Division, Islamabad.
6) Joint Secretary (Dev), Finance Division, Islamabad.
7) J.S. (Committee), Cabinet Division, Islamabad.
8) Chief (PIA), Planning & Dev. Division, Islamabad
9) Project Manager, SHYDO, Govt. of Khyber Pakhtunkhwa, Peshawar.
10) Mr. Zulfiqar Ali, R.O (PIA) Section (One copy for Mr. Jehangir Khan, and one copy for Mr. Saqib Tanveer for data updation).

Copy also forwarded to:-

Additional Chief Secretary (Dev), Planning & Development Department, Govt. of Khyber Pakhtunkhwa, Peshawar.

(Sajjad Hussain)
Research Associate

No. 7(22) ADB-II/03
GOVERNMENT OF PAKISTAN
MINISTRY OF ECONOMIC AFFAIRS & STATISTICS
(ECONOMIC AFFAIRS DIVISION)

Section Officer,
Ph: 9207254
Fax: 9210734

Islamabad, the 19th August, 2011

SUBJECT: **Approval of Revised PC-1s of the Renewable Energy Development Sector Investment Program (REDSIP) by the Executive Committee of the National Economic Council (ECNEC) in its meeting held on 29-07-2011.**

Dear Mr. Liepach,

The Executive Committee of National Economic Council (ECNEC) in its meeting held on 29-07-2011 has approved Revised PC-1s of the following Projects for Renewable Energy Development Sector Investment Program (REDSIP) under Loan No. 2286/2287:-

Punjab Portion			
i.	Construction of 4.04 MW Deg-out Fall Hydel Power Station with Capital Cost of Rs. 1775.00 million with FEC of Rs. 531.00 million	v.	Construction of 4.16 MW Okara Hydel Power Station with Capital Cost of Rs. 2079.00 million with FEC of Rs. 683.00 million
ii.	Construction of 7.64 MW Marala Hydel Power Station with Capital Cost of Rs. 3549.00 million with FEC of Rs. 1110.00 million	vi.	Feasibility Studies of 24.04 MW Hydro Power Stations in Punjab with Capital Cost of Rs. 76.00 million with FEC nil
iii.	Construction of 2.82 MW Pakpattan Hydel Power Station with Capital Cost of Rs. 1321.00 million with FEC of Rs. 382.00 million	vii.	Capacity Building of Irrigation and Power Department for Undertaking Feasibility Studies and Construction of Hydel Power Stations in Punjab with Capital Cost of Rs. 505.40 million with FEC of Rs. 72.87 million
iv.	Construction of 5.38 MW Chianwali Hydel Power Station with Capital Cost of Rs. 2582.00 million with FEC of Rs. 801.00 million		
Khyber Pakhtunkhwa Portion			
i.	Construction of Daral Khwar HPP District Swat, Khyber Pakhtunkhwa with Capital Cost of Rs. 6958.429 million including FEC of Rs. 132.00 million	iv.	(a)Construction of SHYDO Office Building (b)Capacity Building Development of SHYDO and Related Entities of Energy & Power Department with Capital Cost of Rs. 373.45 million including FEC of Rs. 273.380 million
ii.	Construction of Machai HPP District Mardan Khyber Pakhtunkhwa with Capital Cost of Rs. 1198.170 million including FEC of Rs. 875.338 million	v.	Feasibility Study of (a) KOTO HPP (b) JABRO HPP (c) KARORA HPP with Capital Cost of Rs. 177.71 million including FEC of Rs. 148.10 million
iii.	Construction of Ranolia HPP District Kohistan Khyber Pakhtunkhwa with Capital Cost of Rs. 4277.00 million including FEC of Rs. 2915.00 million		

2. Copies of the ECNEC decisions's are forwarded herewith for information and necessary action to ADB.

With regards

Yours sincerely,

(Saif Ullah Butt)
Section Officer (ADB-II)

Dir (F/A).
DD REDSIP

Mr. Werner E. Liepach
Country Director
Pakistan Resident Mission
Asian Development Bank
Islamabad.

Diary No: 385
Dated 24/8/2011
o/o Managing Director
SHYDO Peshawar

P.T.O

Schedule II - 17

Training and Development

1.1.4 Quality Assurance/Quality Control

The Contractor shall implement quality assurance plan in accordance with the requirements of ISO 9001:2000 procedures.

1.1.5 Environmental Compliance

1.1.5.1 General

Reference is made to the environmental requirements given in:

(a) The Law and Regulation of Government of Pakistan and Government of Khyber Pakhtunkhwa, relevant International standards (14001:2004 procedures)

(b) Employer's Requirements for Environmental Protection given in Sub-section 2.8 of Section III, PART II of Bidding Documents.

(c) Sub-clauses of General Condition of Contract and any other clause or sub-clause having any relevance to Environment.

(d) Local traditions and customs of Khyber Pakhtunkhwa.

1.1.5.2 Environmental Compliance & Miscellaneous

The Contractor shall within one month of receipt of Notice to Proceed, appoint an Environmental Inspector for the Works, whose broad responsibilities are to guide the construction personnel on environmental matters, to communicate and to make liaison with the Employer, Management Consultants, Government of Khyber Pakhtunkhwa and local elders.

The Contractor shall provide Environment Management Plan of the Site as defined in sub-Section 2.8 of section III.

If the EPC Contractor constructs a coffer dam partially or fully across the river or erect any other structure in the river bed which can break the supply of perennial river flow for irrigation or drinking purpose to downstream riparian or inhabitants, the Contractor shall ensure a regular supply of perennial river discharge to downstream riparian and inhabitants in accordance with their traditional rights.

1.1.6 Training programme

1.1.6.1 General

The Contractor shall provide a training program in operation and maintenance for the Employer's O&M personnel. The training program will consist of following two main components:

(a) On-the-job Training
(b) Formal O&M Training Seminars

Under both programs, training shall cover operation and maintenance of the entire Project, including civil works and electrical and mechanical equipment

(a) On-the-job Training

The Employer will assign staff to monitor construction activities at the various works fronts. The Contractor will provide informal, on-the-job training as it relates to the O&M of the entire Project, including civil works and electrical and mechanical equipment.

Civil Works

During the civil works construction, the Employer shall provide personnel to monitor the construction of the Project components. The Contractor shall provide on-the-job training and explanations offered by front-line engineers and foreman related to particular design adaptations and construction procedures at main construction fronts, including weir, tunnel, penstocks and powerhouse structure.

Prior to commissioning of the important project components, the Contractor shall perform an inspection of the civil works to verify the readiness of the project hydraulic works. The Employer's O&M personnel shall accompany the Contractor on such inspections, to gain insights into future O&M issues

Electrical and Mechanical Equipment

During the electrical and mechanical equipment erection, assembly and installation the Contractor shall provide informal on-the-job training that will cover aspects of equipment maintenance and operation. The informal training program shall be led by representatives from equipment manufacturers and shall be based on Design Memorandum, Technical Specifications, Drawings and other informational materials necessary for the adequate training and orientation of Employer's O&M personnel. The informal training program shall be conducted during the erection, and testing of all Project equipment, most particularly gates and gate handling equipment.

(b) Formal Training

Formal Training shall include a Basic O & M Program. The Training Programs shall be conducted in a classroom setting, in the Project offices at the construction site. The formal training will incorporate a Quality Control Program within the Formal Training program, including written testing, to ensure that the O&M Personnel are suitably trained and capable of operating and maintaining the Project after it is turned over to the Employer. At least four months prior to initiation of the Formal Training Program, the Contractor shall submit a written plan and schedule for the Program for Employer's review and approval. Such plan shall include course outlines, Curriculum Vitae of the proposed Training Instructors, and a detailed schedule. To initiate the Formal Training, the O & M Manuals must be a minimum of 90 % complete

1.1.6.2 Basic O & M Training Program

The Contractor shall train a total of up to 10 people in the Basic O&M Program. The Trainees shall generally include Employer's staff who participated in the monitoring of the project construction, and are familiar with the works. In general, the Basic O&M Program shall take approximately five days and a total of six hours per day, comprising two three-hour sessions, separated by a two-hour break.

The Basic O&M Program shall primarily explain the provisions and procedures contained in the civil works and equipment O & M manuals. In addition to the various manuals, the class materials will include Drawings, Technical Specifications and other technical and educational material necessary for the complete training of O & M Personnel.

The Contractor Basic Training Program shall cover following Civil Works Manuals.

- Safety Control
- Quality Control
- Survey Control
- Instruments Monitoring
- O&M of Project Civil Components (weir, tunnel, etc.)

The Contractor Basic Training Program shall cover O&M manuals written for all equipment components, particularly gates and gate handling equipment. The classroom training will be supplemented by visits to the project facilities to facilitate the transfer of information and know-how.

1.1.7 Electrical and Mechanical Equipment

The Employer may inspect the manufacturing and testing of electrical & mechanical equipment and workshop facilities at manufacturer's shop. The Contractor shall give at least six (6) weeks notice to the Employer for all important shop tests.

1.1.8 Documentary Film

The Contractor will prepare a documentary film showing all important events of civil construction, assemblies, sub assemblies and erection of all the equipment. The documentary will provide a commentary giving full details of events. Three (3) copies of the documentary Film will be provided to the Employer before completion of the Project. The Contractor will present the Employer the updated documentary film on three (3) month basis for his review and approval.

1.1.9 Operation and Maintenance Manuals

The Contractor shall provide operation and maintenance manuals, for all equipment and civil works structures, should be in English

The Contractor shall provide to the Employer tools and spare parts sufficient for ten (10) years of operation together with a recommended priced list of spare parts. The foreseen mandatory spares are tentatively listed below which the contractor shall revise in its bid as per estimated essential requirement. The Contractor shall construct proper and sufficient storage facilities for such tools and spare parts.

1.2 Basic Design Criteria

1.2.1 General

1.2.1.1 Design Criteria

The permanent works shall be designed according to the latest version of International standards relevant to the particular section of works such as ACI 318-01 and allied codes. The completed work shall be safe, durable and adequate for intended purpose under most severe loading conditions where there are differences between the various standards; the most conservative standards shall be adopted. Whichever standard shall be applied, the latest revision or edition in effect at the time of the invitation of bidders shall be preferred and the Contractor shall make available one copy of such standards in English language. If other standards shall be chosen, the contractor shall supply copies of those standards in English language, clearly identifying or making reference to the particular chapters or sections that shall be applied.

The detail design shall be based upon the design criteria stated herein, the Design Memoranda submitted with his Tender, and additional Design Memoranda and design analysis as necessary to complete the design of the works

Temporary works shall be designed to be safe, reliable, and adequate for all loads and uses, and where they are to be incorporated into the permanent works temporary works shall be designed in strict compliance with the criteria adopted for the permanent works.

1.2.1.2 Compliance with Local Regulations

In addition to the Basic design criteria, the design shall also conform to the requirements of all relevant local, state and federal authorities where approvals for that section of works is needed from the relevant authorities.

1.2.1.3 Economic Life of Works

The design shall be based upon a useful economic life of 100 years for all elements of permanent structural facilities assuming the Employer will perform normal routine maintenance, and not less than 50 years for equipment assuming the Employer will operate the works and perform normal routine maintenance in accordance with the works operation and maintenance manual

Schedule I - 3(5)(h)

FEASIBILITY REPORT

1. Feasibility Report (1998)
2. Feasibility Report (2005)
3. System Studies Load Flow, Short Circuit, Stability

Executive Summary

- The study objective, approach and methodology have been described and the plant's data received from the client is validated.
- The PESCO system data as available with PPI for other studies have been used.
- The interconnection study of Daral Khwar HPP to evacuate its maximum power of 36.6 MW is envisaged and studied in detail for Daral Khwar Hydro power project.
- The following scheme of interconnection of Hydro Power Plant with Madyan 132kV to evacuate its maximum power of 36.6 MW is envisaged and studied in detail:
  - Direct double 132 kV transmission lines of 9.5 km length using Rail conductor to be laid from 132 kV Bus Bar of Daral Khwar HPP till Madyan 132/11 kV substation.

The proposed scheme will require the following equipment at switch yard of Daral Khwar HPP:

- Three breaker panels of 11 kV for connecting three Generating Units.
- Two 132 kV breaker/line bays need to be added for the double circuit from Daral Khwar to Madyan Grid Station.

- Load flow studies have been carried out for the peak load conditions of September 2017 for the proposed scheme considered under normal and contingency conditions.
- Steady state analysis by load flow reveals that proposed scheme is adequate to evacuate the maximum power of 36.6 MW of the plant under normal and contingency condition.
- The short circuit analysis has been carried out to calculate maximum fault levels at Daral Khwar HPP at 132 kV and 11 kV and the surrounding substations in its vicinity. We find that the fault currents for the proposed scheme are much less than the rated short circuit capacities of switchgear installed at these substations. There are no violations of the equipment ratings due to contribution of fault current from Daral Khwar HPP.
- The maximum short circuit levels of Daral Khwar HPP 132 kV and 11 kV have been evaluated for the peak case of 2017 to evaluate the maximum fault currents on Daral Khwar HPP and the 132 kV Substations in its vicinity. The maximum short circuit level of the Daral Khwar HPP 11 kV is 25.22 kA and 27.55 kA and 7.13 kA and 7.53 kA for 3-phase and 1-phase faults in the year 2017. Therefore industry standard switchgear of the short circuit rating of 40 kA would be fine to be installed at 132 kV and 11 kV switch room of Daral Khwar HPP as per PESCO/NTDC requirement taking care of any future generation additions and system reinforcements in its electrical vicinity.

- The dynamic stability analysis of proposed scheme of interconnection has been carried out. The stability check for the worst case of three phase fault right on the 11 kV bus bar of Daral Khwar HPP substation followed by the final trip of 11 kV circuits emanating from this substation, has been performed for fault clearing within 9 cycles (180 ms) and 10 cycles (200 ms). The system is found strong enough to stay stable and recovered with fast damping.
- The proposed scheme of interconnection has no technical constraints or problems, it meets all the criteria of stability under steady state load flow, short circuit currents and dynamic/transient conditions; and is therefore recommended to be adopted.

Report Contents

8. Conclusions

Appendices

Appendix –A: NTDC Latest Generation, Transmission Plan

Appendix –B: Sketches

Appendix –C: Plotted Results of Load Flow for Chapter – 5

Appendix –D: Results of Short Circuit Calculations for Chapter – 6

Appendix – E: Plotted Results of Stability Analysis for Chapter – 7

Appendix – F: Dynamic Data for Stability

1. Introduction

1.1. BACKGROUND

The proposed project is a Hydropower Plant located at approximately 9.5 km from the Madyan 132 kV Grid Station located in the concession of PESCO. The location of Daral Khwar HPP is shown in Appendix-B. The net output planned to be generated from the site is about 36.6 MW of electrical power. The project is expected to start commercial operation by January 2017. The electricity generated from this project would be supplied to the national grid of PESCO through the 132/11 kV Madyan substation of PESCO available in the vicinity of this project.

1.2. OBJECTIVES

The overall objective of the Study is to develop an interconnection scheme between Daral Khwar Hydropower Project and PESCO network, for stable and reliable evacuation of 36.6 MW of electrical power generated from this plant. The specific objectives are:

1. To develop schemes of interconnections at 132 kV of which right of way (ROW) and space at the terminal substations would be available.
2. To determine the performance of interconnection scheme during steady state conditions of system through load-flow analysis.
3. To check if the contribution of fault current from this new plant increases the fault levels at the adjoining substations at 11 kV and 132 kV voltage levels to be within the rating of equipment of these substations, and also determine the short circuit ratings of the proposed equipment of the substation at Daral Khwar HPP.
4. To check if the interconnection withstands dynamic stability criteria of post fault recovery with good damping after 3-phase faults on the system.

1.3. PLANNING CRITERIA

The planning criteria required to be fulfilled by the proposed interconnection is as follows:

Steady State:

Voltage	± 5 %, Normal Operating Conditions

Frequency	50 Hz, Continuous, ± 1% variation steady state
	± 5% variation Short Time
	49.5 - 50.5 Hz, Short Time
Power Factor	0.85 Lagging; 0.9 Leading

Dynamic/Transient:

The system should revert to normal condition after dying out of transients without losing synchronism with good damping.

- For 132 kV and above, the total normal fault clearing time from the instant of initiation of fault current to the complete interruption of current, including the relay time and breaker interruption time to isolate the faulted element, is equal to 100 ms (5 cycles).
- For 11 kV the total normal fault clearing time from the instant of initiation of fault current to the complete interruption of current, including the relay time and breaker interruption time to isolate the faulted element, is equal to 180 ms (9 cycles) and 200 ms (10 cycles).

2. Technical Data

2.1. GENERATOR DATA

The electrical parameters of the generators at Daral Khwar HPP as provided by the client are as follows:

Daral Khawr HPP data

Generator data:

S No.	Specification	Daral Khwar Hydro Power Project	
1	No. of Machines in powerhouse	2	1
2	MVA rating of each machine	19.125MVA	7.5MVA
3	Generation Voltage of each Machine	11kV	11kV
4	Electrical inertia (H)	H = 1.97384	H = 1.781
5	Generator step up transformer detail	2 Sets of 26000 KVA	1 Set of 10000 KVA
6	MVA rating	26 MVA	10 MVA
7	Reactance value	12%	12%
8	132kV Double Circuit Line length	About 9.5 Km	
9	Name of Grid Station	132/11kV Madyan Grid Station, Swat	
10	Type of Conductor	ACSR Rail	
11	Name of Employer	Pakhtunkhwa Energy Development Organization (PEDO)	
12	Commercial operation Date (Tentative)	January,2017	
13	Power factor	0.85 lagging, 0.9 leading	

2.2. NETWORK DATA

The 11 kV and 132 kV networks available for interconnection to Daral Khawr Hydro Power Plant are as shown in Appendix-A.

The NTDC/PESCO system data of National Grid have been assumed in the study as already available with PPI.

3. Study Approach and Methodology

3.1. UNDERSTANDING OF THE PROBLEM

Daral Khwar HPP is going to be a medium head hydropower project embedded in the distribution network of PESCO. Daral Khwar HPP is in the vicinity of Madyan Grid Station. This source of local power generation to be embedded in local distribution network at Madyan shall provide great relief to the source substations in the vicinity and also help in terms of improving line losses and voltage profile.

3.2. APPROACH TO THE PROBLEM

The consultant has applied the following approaches to the problem:

- A base case network model has been prepared for the year 2017, which is the commissioning year of Daral Khwar HPP, comprising all 500kV, 220kV and 132 kV system, envisaging the load forecast, the generation additions and transmission expansions for that year particularly in PESCO.
- Month of September 2017 has been selected for the study of the base case because it is high water season and we can judge the maximum impact of the plant on the network in these conditions.
- Performed technical system studies for peak load conditions to confirm technical feasibility of the interconnection schemes. The proposed scheme has been subjected to standard analysis like load flow, short circuit, and transient stability study to check the strength of the machines and the interconnection scheme under disturbed conditions.
- Determine the relevant equipment for the proposed technically feasible scheme.

4. Development of Schemes of Interconnection

4.1 THE EXISTING AND ONGOING NETWORK

The nearest existing PESCO interconnection facilities at the time of commissioning of Daral Khwar Hydro Power Project would be Madyan 132/11 kV Substation

The existing 132 kV network available around the 132/11 kV grid station is shown in Sketch-I & II in Appendix-B.

4.2 THE SCHEME OF INTERCONNECTION OF DARAL KHWAR HPP

Given the nearest interconnection facility is the 132/11 kV substation for Daral Khwar HPP following scheme of interconnection of Hydro Power Plant with Madyan 132kV is envisaged and studied in detail:

- Direct double 132 kV transmission lines of 9.5 km length using Rail conductor to be laid from 132 kV Bus Bar of Daral Khwar HPP till Madyan 132/11 kV substation.

The proposed scheme will require the following equipment at switch yard of Daral Khawr HPP:

- Three breaker panels of 11 kV for connecting three Generating Units
- Two 132 kV breaker/line bays need to be added for the double circuit from Daral Khwar to Madyan Grid Station.

5 Detailed Load Flow Studies

A base case has been developed for the peak load of September 2017, which is the high water season and will allow us to judge the maximum impact of Daral Khwar HPP on the PESCO network, using the network data supplied/authorized by PESCO/NTDC.

5.1 BASE CASE 2017: WITHOUT DARAL KHAWR HPP

The results of load flow for this base case are plotted in Exhibit 0.0 of Appendix-C. The system plotted in this Exhibit comprises 132 kV network feeding Madyan 132/11 kV Substation and its surrounding substations.

The load flow results for the normal case show that the power flows on all the circuits are within their normal rating. We find that there are no capacity constraints in terms of power flow or voltage ratings in the 11 kV or 132 kV network available in the vicinity of Daral Khawr HPP for its connectivity under normal conditions.

The following N-1 contingency tests were run:

Exhibit-0.1	Barikot to Swat 132kV Single Circuit Out
Exhibit-0.2	Chakdara New to Barikot 132kV Single Circuit Out
Exhibit-0.3	Chakdara New to Swat 132kV Single Circuit Out
Exhibit-0.4	Chakdara New to Chakdara 132kV Single Circuit Out
Exhibit-0.5	Chakdara New to Timergara 132kV Single Circuit Out

In the case of contingency conditions, voltage profile of the surrounding system is observed to be very low in Exhibit 0.2, 0.3 and 0.5. Also circuit of Timergara to Chakdara becomes overloaded in the case of the outage of Timergara to Chakdara New.

5.2 PEAK LOAD CASE 2017: WITH DARAL KHAWR HYDRO POWER PLANT

Detailed load flow studies have been carried out for September 2017. The results of load flows with Daral Khawr HPP under normal conditions have been plotted in Exhibit 1.0 in Appendix-C.

The power flows on the circuits are seen well within the rated capacities and the voltages on the bus bars are also within the permissible operating range of ± 5 % of the nominal. We find no capacity constraints on 132 kV circuits under normal conditions i.e. without any outages of circuits.

The following N-1 contingency tests were run:

Exhibit-1.1	Daral Khwr to Madyan 132kV Single Circuit Out
Exhibit-1.2	Barikot to Swat 132kV Single Circuit Out
Exhibit-1.3	Chakdara New to Barikot 132kV Single Circuit Out
Exhibit-1.4	Chakdara New to Swat 132kV Single Circuit Out
Exhibit-1.5	Chakdara New to Chakdara 132kV Single Circuit Out
Exhibit-1.6	Chakdara New to Timergara 132kV Single Circuit Out

Again under contingency conditions due to the outage of Timergara to Chakdara New, the intact Timergara to Chakdara circuit which is on Lynx conductor becomes overloaded. This is an inherent constraint in the PESCO network which is not caused by the study hydropower plant. In fact, Daral Khwar HPP will cause a slight decrease in the overloading of the said circuit. However, the system still requires improvement in the area to overcome this constraint. Also the bus bar voltages of the surrounding system is in the rated limits for Exhibit 0.2, 0.3 and 0.5.

In all the other contingency performed, we find that in the event of outage of any circuit, the intact circuits remain within the rated capacity. Also the bus bar voltages are well within the rated limits in all the contingency events. Thus there are no constraints in this scheme.

5.3 CONCLUSION OF LOAD FLOW ANALYSIS

From the analysis discussed above, we conclude that both the proposed interconnection scheme is adequate to evacuate the 36.6 MW export of power from Daral Khwar HPP under normal conditions. And in case of contingency condition due to the outage of Timergara to Chakdara New, the intact Timergara to Chakdara circuit which is on Lynx conductor becomes overloaded which is less in case of with Daral Khwar HPP. Also the bus bar voltages is in rated limits in case of contingency conditions with Daral Khwar HPP.

6 Short Circuit Analysis

6.1 METHODOLOGY AND ASSUMPTIONS

The methodology of IEC 909 has been applied in all short circuit analyses in this report for which provision is available in the PSS/E software used for these studies. The maximum fault currents have been calculated with the following assumptions under IEC 909:

- Set tap ratios to unity
- Set line charging to zero
- Set shunts to zero in positive sequence
- Desired voltage magnitude at bus bars set equal to 1.10 P.U. i.e. 10 % higher than nominal, which is the maximum permissible voltage under contingency condition.

For evaluation of maximum short circuit levels we have assumed contribution in the fault currents from all the installed generation capacity of hydel, thermal and nuclear plants in the system in the year 2018 i.e. all the generating units have been assumed on-bar in fault calculation's simulations.

The assumptions about the generator and the transformers data are the same as mentioned in Ch.2 of this report.

6.2 FAULT CURRENT CALCULATIONS WITHOUT DARAL KHWAR HPP

In order to assess the short circuit strength of the network of 132 kV and 11 kV without Daral Khwar HPP for the grid of PESCO/NTDC in the vicinity of the site of the plant, fault currents have been calculated for balanced three-phase and unbalanced single-phase short circuit conditions. These levels will not only give us the idea of the fault levels of Madyan 132kV and other grid stations in the vicinity without Daral Khwar HPP but would also help us determine how much the contribution of fault current from Daral Khwar HPP later on may add to the existing levels.

The results are attached in Appendix – D.

The short circuit levels have been represented graphically on the bus bars of 132 kV and 11 kV which are shown in the Exhibit 2.0 attached in Appendix-D.

The fault currents in the Exhibit are given in polar coordinates i.e. the magnitude and the angle of the current. The total fault current is shown below the bus bar.

The tabular output of the short circuit calculations is also attached in Appendix-D for the 132 kV and 11 kV bus bars of our interest i.e. the substations connecting in the 132 kV and 11 kV circuits lying close to Daral Khwar HPP. The total maximum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 6.1. We see that the maximum fault currents do not exceed the short circuit ratings of the equipment at these 132 kV substations which normally are 20 kA, 25 kA or 31.5 kA for older substations and 40 kA for new substations.

Table 6.1
Maximum Short Circuit Levels without Daral Khwar HPP

Substation	3-Phase fault current, kA	1-Phase fault current, kA
Madyan 132kV	**2.67**	**2.72**
K.Khela 132kV	**3.61**	**4.24**
Swat 132kV	**5.57**	**6.65**
Chakdara - New 132kV	**12.77**	**13.36**
Timergara 132kV	**6.61**	**7.34**

6.3 MAXIMUM FAULT CURRENT CALCULATIONS WITH DARAL KHWAR HPP

The fault currents have been calculated for the electrical interconnection of proposed scheme for the 2017 scenario. Fault types applied are three phase and single-phase at the 11 kV bus bar of Daral Khwar HPP itself and other bus bars of the 132 kV and 11 kV substations in the electrical vicinity of Daral Khwar HPP. The graphic results are shown in Exhibit 2.1.

The tabulated results of short circuit analysis showing all the fault current contributions with short circuit impedances on 132 kV and 11 kV bus bars of the network in the electrical vicinity of Daral Khwar HPP and the 11 kV bus bars of Daral Khwar HPP are placed in Appendix-D. Brief summary of fault currents at significant bus bars of our interest are tabulated in Table 6.2

Table 6.2
Maximum Short Circuit Levels with Daral Khwar HPP

Substation	3-Phase fault current, kA	1-Phase fault current, kA
Daral Khwar HPP 11kV	**25.22**	**27.55**
Daral Khwar HPP 11kV	**7.13**	**7.53**
Daral Khwar 132kV	**3.25**	**3.57**
Madyan 132kV	**3.37**	**3.70**
K.Khela 132kV	**4.26**	**4.95**
Swat 132kV	**6.18**	**7.22**
Chakdara - New 132kV	**13.34**	**13.74**
Timergara 132kV	**6.72**	**7.42**

Comparison of Tables 6.1 and 6.2 show slight increase in short circuit levels for three-phase and single – phase faults due to connection of Daral Khwar HPP on the 11 kV bus bars in its vicinity; and some rise on the 132 kV substation of Madyan 132kV, and other substations in plant's vicinity. We find that even after some increase, these fault levels are much below the rated short circuit values of the equipment installed on these substations.

The short circuit level at Daral Khwar HPP 11 kV bus bar is 25.22 kA and 27.55 kA and 7.13 kA and 7.53 kA for 3-phase and 1-phase faults respectively. Therefore industry standard switchgear of the short circuit rating of 40 kA would be fine to be installed at the 11 kV substation of Daral Khwar HPP. It would provide large margin for any future increase in short circuit levels due to future generation additions and network reinforcements in this area.

6.4 CONCLUSION OF SHORT CIRCUIT ANALYSIS

The short circuit analysis results show that for the proposed scheme of interconnection of Daral Khwar HPP, we don't find any violations of short circuit ratings of the already installed equipment on the 132 kV and 11 kV equipment of substations in the vicinity of Daral Khwar HPP Feeder due to fault current contributions from this power house under three-phase faults as well as single phase faults.

The short circuit level at Daral Khwar 11 kV bus bar is 25.22 kA and 27.55 kA and 7.13 kA and 7.53 kA for 3-phase and 1-phase faults respectively for 2017. Therefore industry standard switchgear of the short circuit rating of 40 kA would be fine to be installed at 11 kV substation of Daral Khwar HPP Feeder taking care of any future generation additions in its electrical vicinity.

7 Dynamic Stability Analysis

7.1 ASSUMPTIONS & METHODOLOGY

7.1.1 Dynamic Models

The assumptions about the generator and its parameters are the same as mentioned in Ch.2 of this report.

We have employed the generic dynamic models available in the PSS/E model library for dynamic modeling of the generator, exciter and the governor as follows;

Generator	GENSAL
Excitation System	EXST1
Speed Governing System	HYGOV

7.1.2 System Conditions

We have used the system conditions of September 2017, which represents the high water season. Most of the hydel generators in PESCO power system in the vicinity of Daral Khwar HPP such as Patrind and Jagran would be running nearly at their full output.

We have carried out the Dynamic Stability analysis for Daral Khwar HPP with the proposed interconnection scheme. All the power plants of WAPDA /NTDC from Tarbela to Hub have been dynamically represented in the simulation model.

7.1.3 Presentation of Results

The plotted results of the simulation runs are placed in Appendix-E. Each simulation is run for its first one second for the steady state conditions of the system prior to fault or disturbance. This is to establish that the pre fault/disturbance conditions of the network under study were smooth and steady. Post fault recovery has been monitored for nine seconds. Usually all the transients due to non-linearity die out within 2-3 seconds after disturbance is cleared from the system.

7.1.4 Worst Fault Cases

Three phase faults are considered as the worst disturbances in the system. Normally we apply 3 phase fault on the bus bar of the power plant, followed by tripping of a circuit emanating from that bus, and trip one of the generators of the plant and / or trip one of the inter-bus transformers if there are two voltage levels in the switching station of the plant. Also we apply 3-phase fault at bus bars at far end of the interconnection of the plant and trip circuit or transformer as the case may be. The fault clearing time of 11 kV breakers has been assumed 9 cycles as the switchgear of the medium voltages are slow.

7.2 DYNAMIC STABILITY SIMULATIONS' RESULTS

7.1.5 Three-Phase Fault at 11 kV Daral Khwar HPP: Trip of Single 15.3 MW Generating Unit

We applied three-phase fault on Daral Khwar HPP 11 kV bus bar, cleared fault in 10 cycles (200 ms) followed by trip of Single 15.3 MW generating unit of Daral Khwar HPP. We monitored different parameters for one second pre-fault and nine seconds after clearance of fault (post-fault) conditions and plotted the results attached in Appendix – E and discussed as follows;

Fig. 1.1 Bus Voltages

The bus voltages of 11 kV bus bar of Daral Khwar HPP, and 132 kV substations of Daral Khwar, Madyan, K.Khela and Chakdara New are plotted. The results show quick recovery of the voltages after clearing of fault.

Fig. 1.2 Frequency

We see that the system frequency recovers its normal condition quickly after fault clearance.

Fig. 1.3 MW/MVAR Output of Generators of Daral Khwar HPP

The pre-fault output of a single generator at Daral Khwar HPP was 30.6 MW and it gets back to the same output quickly after fast damping of the oscillations in its output. However MVAR output acquires equilibrium at a new value.

Fig. 1.4 Speed and mechanical power of Generators at Daral Khwar HPP

The speed deviation of the generator, after clearing fault, damps down quickly returning to normal speed as of before fault. The transients in mechanical power also damp quickly and settle to a new equilibrium.

Fig. 1.5 MW/MVAR Flow on Daral Khwar 132/11 kV Single Transformer

Followed by clearing of fault, the trip of the Single 15.3 MW generating unit of Daral Khwar HPP caused the output of 15.3 MW to flow through the 132/11 kV Transformer. We plotted the flows of MW and MVAR on the single Daral Khwar 132/11 kV transformer and see that the power flows on this circuit attains to steady state level with power swings damping down fast.

Fig. 1.6 Rotor Angles

The rotor angles of the generators of Daral Khwar HPP, Patrind, Jagran, Khan Khawr, Dabr Khawr and Warsak P are plotted relative to machines at Allai 220 kV. The results show that the rotor angle of Daral Khwar HPP recovers its normal condition after the first swing and damps down quickly. Similarly the rotor angles of other machines swing little after the fault and damp fast after clearing of fault. The system is stable and very strong in damping the post fault oscillations.

7.1.6 Three-Phase Fault at 132 kV Daral Khawr : Trip of 132 kV circuit between Daral Khwar and Madyan

We applied three-phase fault on Khan Khwr 132 kV bus bar, cleared fault in 5 cycles (100 ms) followed by trip of 132 kV circuit between Daral Khwar and Madyan 132kV. We monitored different quantities for one second pre-fault and nineteen seconds after clearance of fault (post-fault) conditions and plotted the results attached in Appendix – E and discussed as follows;

Fig. 2.1 Bus Voltages

The bus voltages of 11 kV bus bar of Daral Khwar HPP, and 132 kV substations of Daral Khwar, Madyan, K.Khela and Chakdara New are plotted. The results show quick recovery of the voltages after clearing of fault.

Fig. 2.2 Frequency

We see the system frequency recovers back to normal quickly after fault clearance.

Fig. 2.3 MW/MVAR Output of Generators of Daral Khwar HPP

The pre-fault output of generator at Daral Khwar HPP was 30.6 MW and it gets back to the same output quickly after fast damping of the oscillations in its output. However MVAR output acquires equilibrium at a new value.

Fig. 2.4 Speed and mechanical power of Generators at Daral Khwar HPP

The speed deviation of the generator, after clearing fault, damps down quickly returning to normal speed as of before fault. The transients in mechanical power also damp quickly and settle to a new equilibrium.

Fig. 2.5 MW/MVAR Flow on Daral Khawr to Madyan 132kV circuit

Followed by clearing of fault, the trip of the 132 kV circuit from Daral Khawr to Madyan 132 kV circuit caused the entire output of Daral Khwar HPP to flow through the intact circuit of Daral Khwar to Madyan 132 kV. We plotted the flows of MW and MVAR on this intact circuit and see that the power flows on this circuit attains to steady state level with power swings damping down fast.

Fig. 2.6 Rotor Angles

The rotor angles of the generators of Daral Khwar HPP, Patrind, Jagran, Khan Khawr, Dabr Khawr and Warsak P are plotted relative to machines at Allai 220 kV. The results show that the rotor angle of Daral Khwar HPP recovers its normal condition after the first swing and damps down quickly. Similarly the rotor angles of other machines swing little after the fault and damp fast after clearing of fault. The system is stable and very strong in damping the post fault oscillations.

7.1.7 Three-Phase Fault at 132 kV Daral Khawr : Trip of 132 kV circuit between Daral Khwar and Madyan

We applied three-phase fault on Daral Khwar 132 kV bus bar, cleared fault in 9 cycles (180 ms) followed by trip of 132 kV circuit between Daral Khwar and Madyan 132kV. We monitored different quantities for one second pre-fault and nineteen seconds after clearance of fault (post-fault) conditions and plotted the results attached in Appendix – E and discussed as follows;

Fig. 3.1 Bus Voltages

The bus voltages of 11 kV bus bar of Daral Khwar HPP, and 132 kV substations of Daral Khwar, Madyan, K.Khela and Chakdara New are plotted. The results show quick recovery of the voltages after clearing of fault.

Fig. 3.2 Frequency

We see the system frequency recovers back to normal quickly after fault clearance.

Fig. 3.3 MW/MVAR Output of Generators of Daral Khwar HPP

The pre-fault output of generator at Daral Khwar HPP was 30.6 MW and it gets back to the same output quickly after fast damping of the oscillations in its output. However MVAR output acquires equilibrium at a new value.

Fig. 3.4 Speed and mechanical power of Generators at Daral Khwar HPP

The speed deviation of the generator, after clearing fault, damps down quickly returning to normal speed as of before fault. The transients in mechanical power also damp quickly and settle to a new equilibrium.

Fig. 3.5 MW/MVAR Flow on Daral Khawr to Madyan 132kV circuit

Followed by clearing of fault, the trip of the 132 kV circuit from Daral Khawr to Madyan 132 kV circuit caused the entire output of Daral Khwar HPP to flow through the intact circuit of Daral Khwar to Madyan 132 kV. We plotted the flows of MW and MVAR on this intact circuit and see that the power flows on this circuit attains to steady state level with power swings damping down fast.

Fig. 3.6 Rotor Angles

The rotor angles of the generators of Daral Khwar HPP, Patrind, Jagran, Khan Khawr, Dabr Khawr and Warsak P are plotted relative to machines at Allai 220 kV. The results show that the rotor angle of Daral Khwar HPP recovers its normal condition after the first swing and damps down quickly. Similarly the rotor angles of other machines swing little after the fault and damp fast after clearing of fault. The system is stable and very strong in damping the post fault oscillations.

7.3 CONCLUSION OF DYNAMIC STABILITY ANALYSIS

The results of dynamic stability show that the system is very strong and stable for the proposed schemes for the severest possible faults of 11 kV systems near Daral Khawr HPP. Therefore there is no problem of dynamic stability for interconnection of Daral Khawr HPP; it fulfills all the criteria of dynamic stability.

8 Conclusions

- The interconnection study of Daral Khwar HPP to evacuate its maximum power of 36.6 MW is envisaged and studied in detail for Daral Khwar Hydro power project.
- The following scheme of interconnection of Hydro Power Plant with Madyan 132kV to evacuate its maximum power of 36.6 MW is envisaged and studied in detail:
  - Direct double 132 kV transmission lines of 9.5 km length using Rail conductor to be laid from 132 kV Bus Bar of Daral Khwar HPP till Madyan 132/11 kV substation.

The proposed scheme will require the following equipment at switch yard of Daral Khwar HPP:

  - Three breaker panels of 11 kV for connecting three Generating Units.
  - Two 132 kV breaker/line bays need to be added for the double circuit from Daral Khwar to Madyan Grid Station.

- Load flow studies have been carried out for the peak load conditions of September 2017 for the proposed scheme considered under normal and contingency conditions.
- Steady state analysis by load flow reveals that proposed scheme is adequate to evacuate the maximum power of 36.6 MW of the plant under normal and contingency condition.
- The short circuit analysis has been carried out to calculate maximum fault levels at Daral Khwar HPP at 132 kV and 11 kV and the surrounding substations in its vicinity. We find that the fault currents for the proposed scheme are much less than the rated short circuit capacities of switchgear installed at these substations. There are no violations of the equipment ratings due to contribution of fault current from Daral Khwar HPP.
- The maximum short circuit levels of Daral Khwar HPP 132 kV and 11 kV have been evaluated for the peak case of 2017 to evaluate the maximum fault currents on Daral Khwar HPP and the 132 kV Substations in its vicinity. The maximum short circuit level of the Daral Khwar HPP 11 kV is 25.22 kA and 27.55 kA and 7.13 kA and 7.53 kA for 3-phase and 1-phase faults in the year 2017. Therefore industry standard switchgear of the short circuit rating of 40 kA would be fine to be installed at 132 kV and 11 kV switch room of Daral Khwar HPP as per PESCO/NTDC requirement taking care of any future generation additions and system reinforcements in its electrical vicinity.
- The dynamic stability analysis of proposed scheme of interconnection has been carried out. The stability check for the worst case of three phase fault right on the 11 kV bus bar of Daral Khwar HPP substation followed by the final trip of 11 kV circuits emanating

from this substation, has been performed for fault clearing within 9 cycles (180 ms) and 10 cycles (200 ms). The system is found strong enough to stay stable and recovered with fast damping.

- The proposed scheme of interconnection has no technical constraints or problems, it meets all the criteria of stability under steady state load flow, short circuit currents and dynamic/transient conditions; and is therefore recommended to be adopted.

Appendix -F

Dynamic Data For Stability

MANUFACTURER PROVIDED DATA SHEET

1. Generator

Unit 1: 6MW

Direct-axis synchronous reactance (Xd (Sat))	0.868
Direct-axis reactance Xd (un-sat)	0.998
Quadrature-axis reactance Xq(sat)	0.565
Quadrature-axis reactance Xq(un-sat)	0.649
Direct-axis transient reactance (x'd (sat))	0.274
Direct-axis transient reactance x'd (un-sat)	0.315
Quadrature-axis transient reactance x'q (sat)	0.565
Quadrature-axis transient reactance x'q (un-sat)	0.649
Direct-axis sub-transient reactance (x"d (sat))	0.181
Direct-axis sub-transient reactance x"d (un-sat)	0.208
Quadrature-axis sub-transient reactance (x"q (sat))	0.193
Quadrature-axis sub-transient reactance x"q (un-sat)	0.221
Negative sequence (X2 (sat))	0.186
Zero sequence (Xo (sat))	0.054
Leakage reactance(X leak (sat))	0.096
Leakage reactance(X leak (un sat))	0.1104
GENERATOR TIME CONSTANT	
Direct-axis open-circuit transient time constant T'do	3.335
Direct-axis open circuit sub-transient time constant T"do	0.0481
Quadrature axis open circuit sub-transient time constant T"qo	0.034

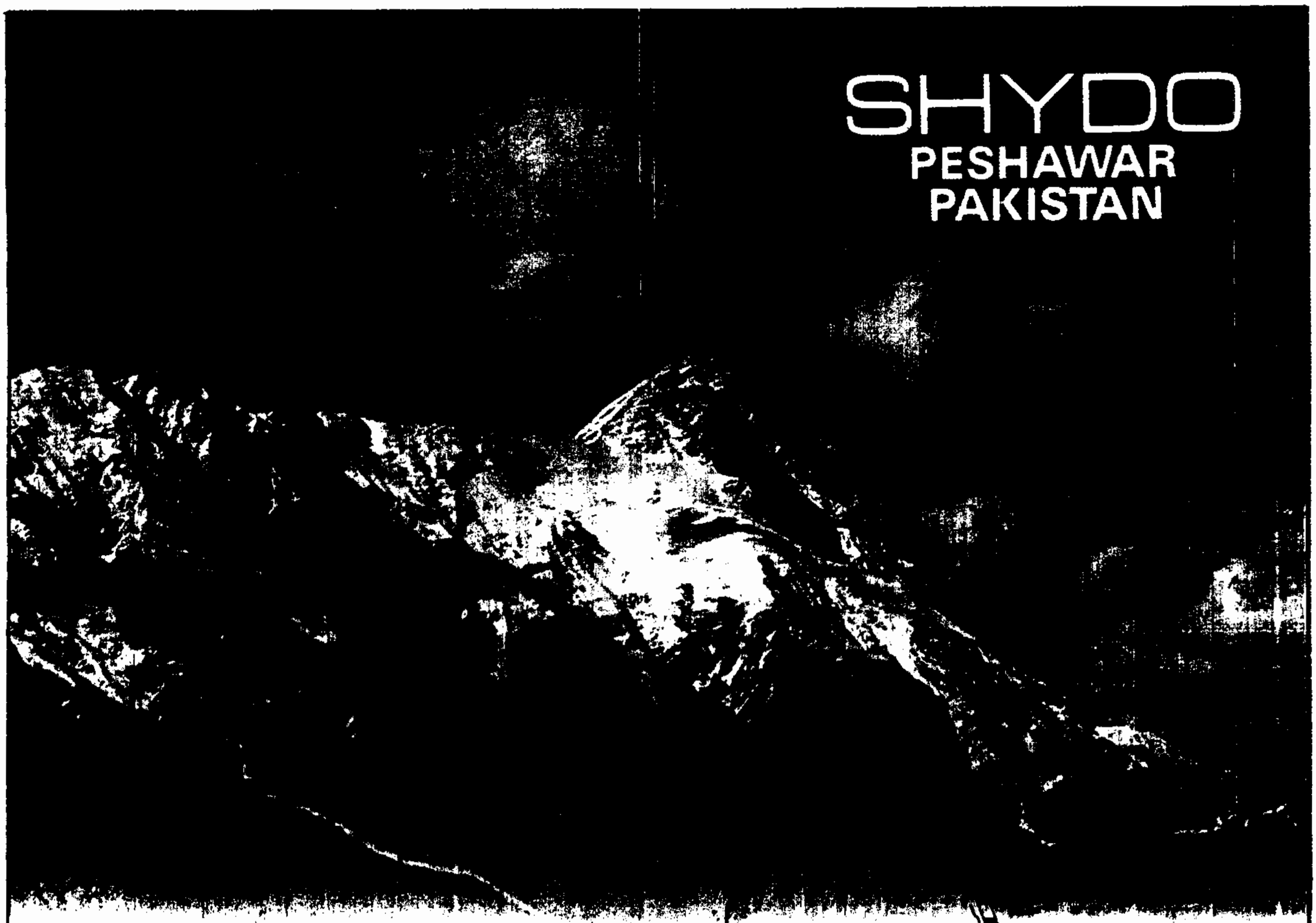
2. Generator

Unit 2 & 3: 15.3MW

Direct-axis synchronous reactance (Xd (Sat))	0.916
Direct-axis reactance Xd (un-sat)	0.998
Quadrature-axis reactance Xq(sat)	0.614
Quadrature-axis reactance Xq(un-sat)	0.669
Direct-axis transient reactance (x'd (sat))	0.264

Direct-axis transient reactance x'd (un-sat)	0.287
Quadrature-axis transient reactance x'q (sat)	0.614
Quadrature-axis transient reactance x'q (un-sat)	0.669
Direct-axis sub-transient reactance (x"d (sat))	0.180
Direct-axis sub-transient reactance x"d (un-sat)	0.196
Quadrature-axis sub-transient reactance (x"q (sat))	0.195
Quadrature-axis sub-transient reactance x"q (un-sat)	0.212
Negative sequence (X2 (sat))	0.187
Zero sequence (Xo (sat))	0.067
Leakage reactance(X leak (sat))	0.098
Leakage reactance(X leak (un sat))	0.106
GENERATOR TIME CONSTANT	
Direct-axis open-circuit transient time constant T'do	4.261
Direct-axis open circuit sub-transient time constant T"do	0.0753
Quadrature axis open circuit sub-transient time constant T"qo	0.055

HYDROPOWER DEVELOPMENT IN MOUNTAINOUS AREAS OF N. W. F. P.



SHYDO
PESHAWAR
PAKISTAN

FEASIBILITY STUDY

DARAL KHWAR

HYDROPOWER PROJECT

MAIN REPORT

Vol. 1 of 2

May 1998

PAKISTAN GERMAN TECHNICAL COOPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

FEASIBILITY STUDY

DARAL KHWAR

HYDROPOWER PROJECT

MAIN REPORT

Vol. 1 of 2

May 1998

FEASIBILITY STUDY
DARAL KHWAR HYDRIOPOWER PROJECT

Vol. 1 of 2

MAIN REPORT

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3. TOPOGRAPHY
4. HYDROLOGY
5. GEOLOGY
6. ENVIRONMENTAL IMPACT ASSESSMENT
7. SELECTION OF PLANT LAYOUT
8. HYDROPOWER DESIGN
9. TRANSPORT AND ACCESS FACILITIES
10. GRID INTERCONNECTION
11. COST ESTIMATES
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DRAWINGS

APPENDIXES

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Appendix 3	TOPOGRAPICAL SURVEY REPORTS (3 Volumes)
Appendix 4	HYDROLOGY REPORT
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EXECUTIVE SUMMARY
DARAL KHWAR HYDRIOPOWER PROJECT

The optimised powerstation output is 35 MW, corresponding to a designed discharge of 15 m^3/s at a gross-head of 318 m achieved from a horizontal conduit length of 3200 m.

The optimised project will produce 148 GWh/year, out of which 29 GWh will be available during 4 hrs / day peak period.

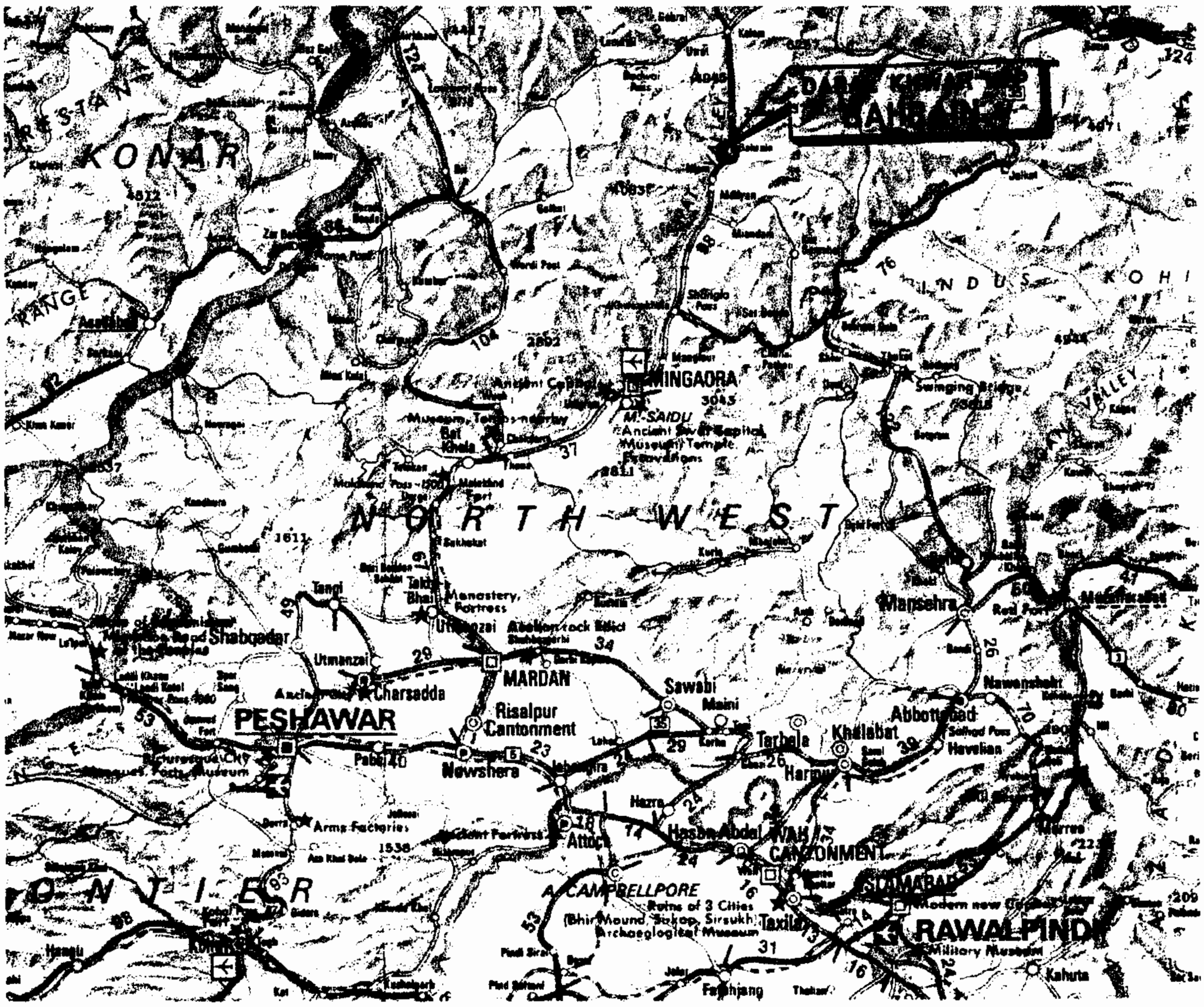
The firm peak capacity available during these four hours all the year is 7 MW.

The total project cost is 38 Millions USD or 1080 USD/kW installed. The energy unit cost is 3.68 USc / kWh. The EIRR works out to be 14.7%. (on LRMC basis)

The construction time is 36 months. The site is accessible around the year on existing road-system.

INTRODUCTION

The project is located in the North - West Frontier Province (NWFP) of Pakistan on the river Daral Khwar in the district Swat. The Daral Khwar is a tributary of the Swat River. The project area is accessible by road at a distance of 185 km from Peshawar, the capital of NWFP.



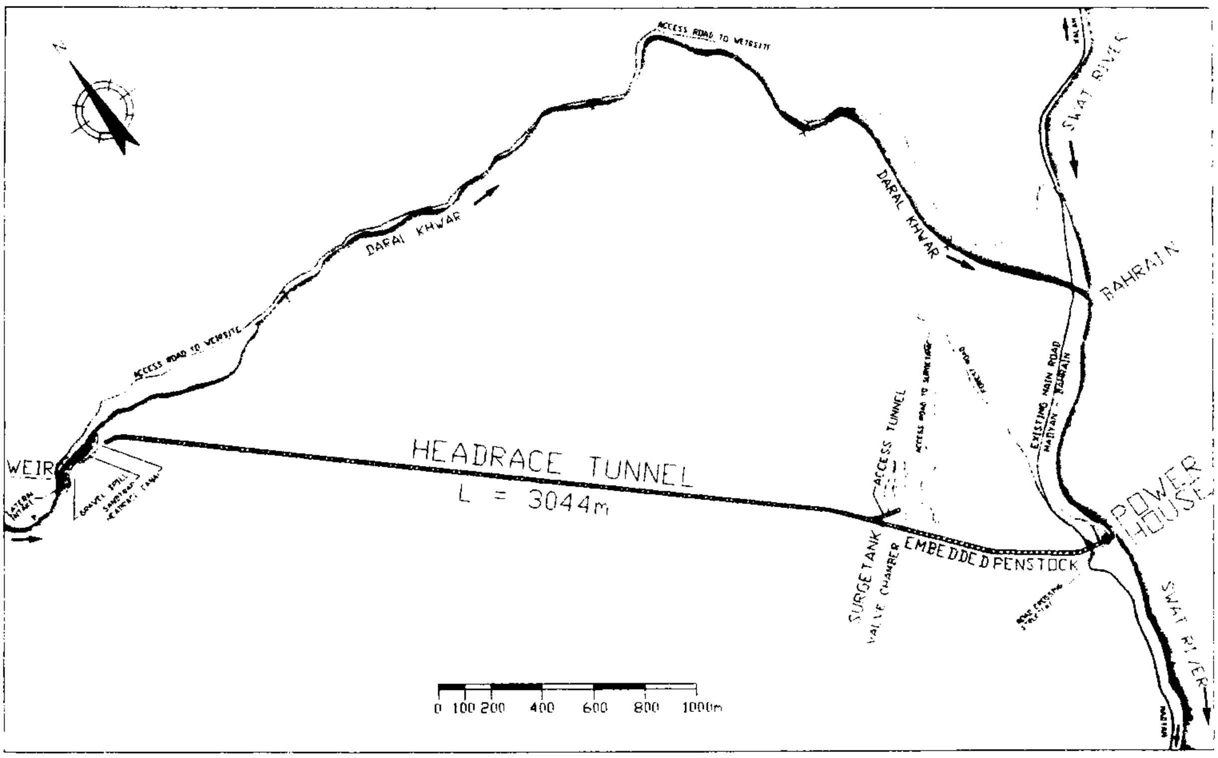
Comprehensive inventory studies for identification of hydropower potential in the mountainous areas of NWFP have been carried out by the govemment of NWFP represented by Sarhad Hydel Development Organization (SHYDO) in collaboration with the German Agency for Technical Co-operation (GTZ). Within this inventory, this project site near Bahrain at the confluence of Daral Khwar with Swat River was selected, and the detailed feasibility study has been prepared.

Extensive field reconnaissance including topographical surveys, hydrological and geological investigations and environmental assessments were carried out. Subsequently, the size of the project was optimised and design criteria determined, followed by engineering studies and feasibility design. Size optimisation is based on a marginal analysis with economic parameters. (ENPV)

PROJECT DESCRIPTION

GENERAL LAYOUT

The intake with the weir is located 4.5 km North West-West of Bahrain at 1718 m.a.s.l. on Daral Khwar river. The water is transferred from there through tunnel and penstock to the powerhouse situated on right bank of Swat River on the main road 2 km south of Bahrain



A small weir of about 40 m length and 3 m height diverts the water to a lateral intake and from there though a short connection tunnel with gravel spill of totally 58 m length to a sand trap and a short headrace canal.

From there a 3040 m long concrete lined head race tunnel with a net diameter of 3.4 m will transfer the 15 m^3/sec of design discharge to the surge tank. The head race tunnel is designed to be used as a reservoir for daily peaking with a volume of about 26,000 m^3.

From the surge tank a mainly burried penstock, 913 m long and 2 m in diameter, will lead to the power house.

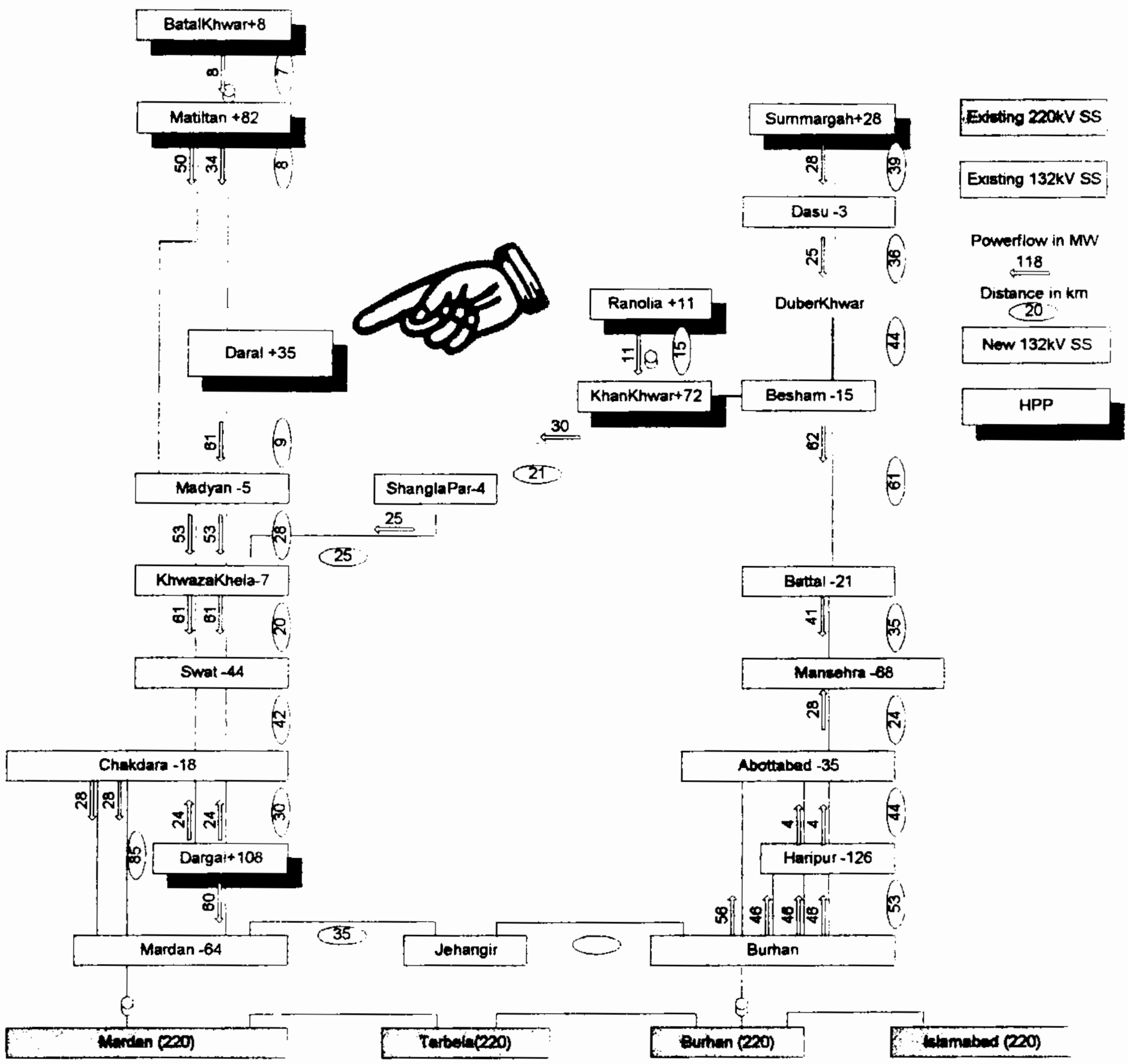
The net-head will vary from 300 m to 308 m.

The slope type powerhouse is composed of a machine hall of 30.4 m long, by 16.5 m wide and one adjacent operation building. It houses two vertical shaft Francis type turbine-generator sets of 14.6 MW each and one horizontal-shaft impulse-turbine of 5.8 MW capacity.

A outlet structure will discharge the water into Swat river.

The annual production in total will be 148 GWh out of which 29 GWh as peak energy. The firm capacity is 7 MW. Firm capacity and peak energy refer to four hours daily at 90% availability.

An open 132 kV switchyard is located partly on the roof and partly adjacent to the powerhouse and will be connected with the National-Grid following the grid system development in the area by insertion of Daral Khwar HPP into one circuit of the 132 kV / Double Circuit line from Matiltan to Madian:



COST ESTIMATES AND ECONOMIC ANALYSIS

Detailed cost estimates and BOQ are available in the feasibility report which may be used as a basis for development of tender documents.

The total construction cost works out to about US$ 38 million, with a specific capacity cost of 1080 US$/kW. The economic analysis establish that the project will be technically and economically viable.

The economic analysis has determined the project to be attractive with NPV (at 10% discount rate) to be about 13 Millions US$, the project EIRR works out to be 14.7% on the LRMC basis. The project is therefore, economically attractive.

ABSTRACT OF ESTIMATED COST DARAL KHWAR HYDRIOPOWER PROJECT - 35 MW

Sr. #	Description	Cost in 1000 US$		
		Local	Foreign	Total
A	Preliminary works	2257	0	2257
B	Civil Works	7046	10231	17277
C	Hydraulic steel works	3358	481	3839
D	Hydro-mechanical equipment	252	3137	3389
E	Electrical equipment	1361	6063	7424
F	Transmission system	100	0	100
G	Engineering and administration	727	1185	1922
H	Other charges (Bank charges Insurance, customs duty, Income tax etc.)	1378	0	1378
	Total project cost price level 1997 (42 Rupees/US$)	16478	21108	37586

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

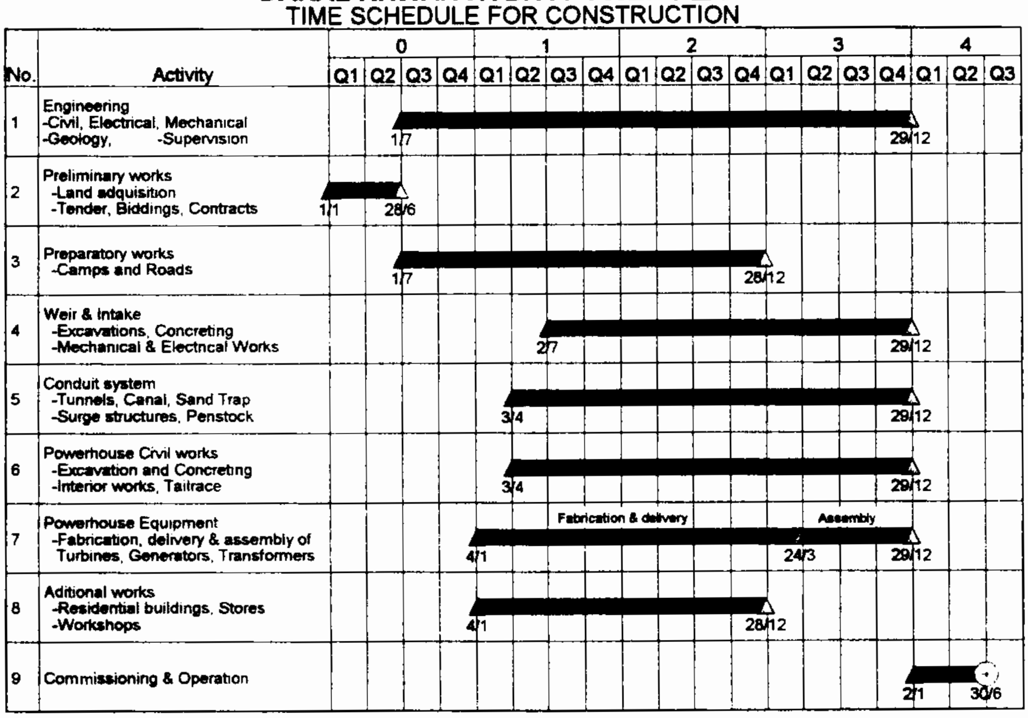
The demography, the ethnic composition of the people, their socio-economic conditions, health and sanitation, land and water use, agriculture, irrigation, forestry, fisheries, flora and fauna, impact on land, water and air and the socio-economic activities have been thoroughly examined. Although the negative impact of the project on the ecology and the inhabitants will be negligible, yet a mitigation plan has been prepared to overcome the problem of perceptible nature.

A significant positive effect is that emission of green-house gases is avoided by replacement of fossil-fired plant capacity by environmentally friendly and renewable hydropower.

Field investigations and engineering studies have led to the conclusion that the project is technically feasible, economically useful and environmentally safe. Daral Khwar Hydropower Project ranks as one of the more promising sites and should be undertaken as soon as possible, whether in the public or in the private sector.

TIME SCHEDULE

DARAL KHWAR HYDROPOWER PLANT
TIME SCHEDULE FOR CONSTRUCTION



A more detailed TIME SCHEDULE is presented in VOLUME 2 of this MAIN REPORT

PRINCIPAL DESIGN FEATURES

Location		
Pakistan, North West Frontier Province (N.W.F.P)		
Swat District, Bahrain		
Organization		
Sarhad Hydel Development Organization (SHYDO)		
River		
Daral Khwar		
Catchment area at dam site		250 km^2
Mean annual discharge		10.76 m^3/s
Total annual flow		341 hm^3
COMPILATION OF MAIN STRUCTURES		
Weir Structure		
Fixed Sill Type		
Height above riverbed		2.5 m
Depth below river bed approx.		6.5 m
4 overflow sections each		8 m wide
1 flushing section		4 m wide
Length of weir structure		48 m
Design flood (100y –flood)		640 m^3/s
Intake		
Lateral Intake 4 section each		2.6 m wide
Stoplogs pockets, Coarse rack Trashrack,		
Spilling section with gate Intake gate		
Connection Tunnel		
Height		5 m
Width		4 m
Cross Section		17.13 m^2
Length without Grave Sp. App.		28 m
Gravel Spill		
Height		6 m
Width		4 m
Cross section		19.25 m^2
Length		30 m
Flushing Gate		
Sand Trap		
No. of Chambers		2
Effective height each		6.25 m
Clear width per chamber		5 m
Total width of sandtrap		13.40 m
effective length		40 m
Total length app.		90 m
Overflow section		
Headrace Canal		
Height, internal		3.4 m
Width, internal		2.5 m
Cross Section		8.5 m^2
Length app.		41 m
Headrace Tunnel		
Horse Shoe type Cross Section	Height	3.3 m
	Width	3 m
Cross Section		8.34 m^2
Length from portal to Surge Tank		3044 m
Slope		0.5 m
Storage Volume		26,000 m^3
Surge Tank (Shaft Type)		
Internal diameter		12 m
Cross section		113.1 m^2
Height		30 m
Penstock Tunnel		
Height		3.05 m
Width		4.4 m
Length		50 m
Valve Chamber		
Width		13 m
Length		11 m
Height (above ground)		8 m
Depth (below ground)		6 m

Emergency Valve Dia		2 m
Maintenance Valve Dia		2 m
Embedded Penstock		
Diameter		2 m
Total Length		910 m
Road Crossing Structure		
Width app.		5.2 m
Length app.		9.6 m
Height app.		13.4 m
Power House (External Type)		
Depth below machine hall floor		10.7 m
Machine hall	Length	30.4 m
	Width	16.5 m
Height above machine hall floor		15.7 m
Total length of Power house		34.4 m
Total width of Powerhouse		29.6 m
Total height of Powerhouse		26.4 m
Tailrace		
Cascade type No. of units		3
Width (Francis / Pelton)		3.25/1.4 m
Height approx.		8 m
Length		15.9 m
Hydro Mechanical Equipment		
Francis Turbines (Number of units)		2
Vertical Shaft Speed		1000 rpm
Net Head		293.3 m
Discharge per unit		6.25 m^3/s
Pelton Turbine (Number of units)		1
Horizontal shaft speed		500 rpm
Net head		290.7 m
Discharge per unit		2.5 m^3/s
Total Turbine Discharge		15 m^3/s
Electrical Equipment		
Generators for Francis Turbines (No. of units)		2
Speed		1000 rpm
Capacity		18 MVA
Generator for Pelton Turbine (No. of units)		1
Speed		500 rpm
Capacity		7.5 MVA
2 main Transformers		11/132 kV
Switchgear		132 kV
POWER AND ENERGY		
Design Discharge		
2 Francis (6.5 m^3/s each)		12.5 m^3/s
1 Pelton		2.5 m^3/s
Total		15 m^3/s
Operation Guidelines		
Stop of generation during periods Q >		50 m^3/s
Minimum restwater		200 l/s
Annual Turbine Run Off		222 Mio m^3
Head		
Headrace water level		1723 m.a.s.l
Tailrace water level		1405 m.a.s.l
Gross Head		318 ml
Losses		
Q_{design} = 15 m^3/s		14.14 m
Lost Head		
Francis units		10.28 m
Pelton unit		12.86 m
Net Head		
Francis units		293.27 m
Pelton unit		290.69 m
Energy Output		
Francis units		29.2 MW
Pelton unit		5.8 MW
Total		**35 MW**
Mean annual energy		148 GWh
Power Factor		0.48 kW

Table of Contents

1.1 INTRODUCTION

The Government of North West Frontier Province (N.W.F.P) represented by SARHAD HYDEL DEVELOPMENT ORGANIZATION (SHYDO) is realising the development of the hydropower resources in the mountainous areas of N.W.F.P.

When systematically developed the available hydropower potentials, the power demand of the province may be covered with sufficient surplus of export to other provinces, thus contributing considerably to meet the future power demand of Pakistan.

Within the inventory of hydropower potential for the Region Swat Valley, a project site at Daral Khwar near Bahrain was identified by SHYDO/GTZ and selected for the development of a Feasibility Study.

The summary of the Feasibility Study describes the Daral Khwar hydroelectric project which was found to be the most favourable solution for the hydroelectric development of Daral Khwar River.

Extensive field reconnaissance, topographical survey, hydrological and geo-technical investigations and engineering studies were carried out for the preparation of the Feasibility Study, in order to establish a project that would be relevant to supply electricity to the National Grid System.

The chapters dealing with the engineering structures are preceded by a description of the results of the above mentioned field investigations as well as those of the study of alternative designs, and a discussion of design criteria such as optimisation of hydraulic structures, determination of turbine discharge and assumptions regarding storage operation of the plant.

As a result of the assessment of field investigations and engineering studies, it is concluded that the project is technically viable, economically feasible and environmentally safe.

The drawings as well as photographs accompanying the Main Report are presented as **"DRAWINGS Vol. 2 of 2"**

1.2 POWER MARKET

The power sector in Pakistan is presently structured around two main vertically integrated public sector utilities. The Pakistan Water and Power Development Authority (WAPDA) is responsible for providing electricity to most of Pakistan except for the city of Karachi which is serviced by Karachi Electric Supply Corporation (KESC). Both WAPDA and KESC are government owned. WAPDA serves a large geographic area of the country. It covers a long North-South area characterised by a low load density. The load centres are located in the centre, the hydel generating plants in the North and the thermal stations in the South. WAPDA peak demand in 1996 was 8,499 MW while the installed capacity was 11,113 MW, of which 4,825 MW was hydel. KESC services the city of Karachi and has high peak load densities. The peak demand in KESC area was 1,503 MW in 1995-96 and installed capacity was 1,948 MW as the generating capacity increased by 210 MW in 1996.

WAPDA has a rather large primary transmission network. Total length of transmission lines was 28,662 km in 1995-96 (inclusive of Secondary distribution), there were 590 grid stations with 31,508 MVA installed power transformer capacity. WAPDA's generation mix has radically changed over years. Hydel generation formed 72% of total generation in 1979-80. This became 43.4% in 1995-96. Total energy sales have grown at 9.89% avg. p.a. over the period 1980-96, the growth rate has decreased to 6.79% avg. p.a. in the last 5 years. Domestic consumption has grown at a high rate of 15.08%, commercial consumption at 9.46% avg. p.a. The system is expanding rapidly although less than 50% of the population is provided with electricity. This entails a high growth in the member of customers which have grown from 2.8 millions in 1980 to 9.48 millions in 1996. Domestic customers have grown at a high rate of 8.57% avg. p.a and are now over 7.8 million (in 1996).

The consumption per customer has grown from 749 kWh/a in 1980 to 1,900 kWh/a in 1996 for domestic customers. Industrial customers consumed 29,430 kWh/a each in 1980. This grew to 57,037 kWh/a each in 1996 an average growth rate of 4.22% p.a. in recent years. This trend has reversed and in the last two years there has been negative growth in the consumption per industrial consumer.

The WAPDA system has been faced with the problem of load-shedding during the last 12 - 14 years mainly due to inadequate investment in generation which lagged behind the power demand. Load shedding increased from 496 MW in 1979 to 2400 MW in 1994. Energy shedding also increased from 1 GWh per annum in 1979 to 5,096 GWh in 1994. This was primarily the result of low reservoir levels at the two main hydel storage (Mangla and Tarbela) during the low water months occurring from December to June. Since 1996 this trend reversed sharply because of the commissioning of several thermal units of WAPDA ad Guddu, Kot Addu and Muzaffaragarh and those of Hubco near Karachi. Another important feature was the stagnation in the growth of demand for supply of power, especially in the industrial sector for various economic and political reasons.

Energy losses have reduced form 32.7% in 1980 to 24.43% in 1996. The transmission losses have reduced from 11% in 1980 to 7.69% in 1996. Similarly, the distribution losses have come down from 19.5% to 13.82% over the same period. Consumption in auxiliaries has risen from 2.22% in 1980 to 2.92% in 1996, mainly due to increased share of thermal generation in total generation, WAPDA arrears have grown from Rs.760 million in 1980 to Rs.14.6 billion in 1996.

The system is projected to grow at about 7.7% from 11,113 MW in 1996 to 55,700 MW in 2018. WAPDA undertakes system expansion planning utilising WASP to develop least cost system generation expansion plans, which are updated every year. Transmission and distribution expansion planning is also undertaken at different levels. Although WAPDA has been attaching increasing importance to hydel generation in the recent years, yet the development of prospective hydel stations did not take place at the desired level because the work on feasibility studies has not been accomplished at the required pace for a number of reasons.

The Power Sector is currently undergoing a somewhat radical transformation. The setting up of the base load thermal and small hydel generation has been earmarked for the private sector. A policy dealing with private sector involvement has been evolved. WAPDA itself is to be broken into privately owned distribution companies; a transmission company; a power dispatch entity; privately owned thermal and small hydel generating stations; and publicly owned large hydel stations. A National Electric Power Regulatory Authority (NEPRA) is also being organised.

1.3 TOPOGRAPHY

See **Figure 1.3** LOCATION OF PROJECT AREA (next page)

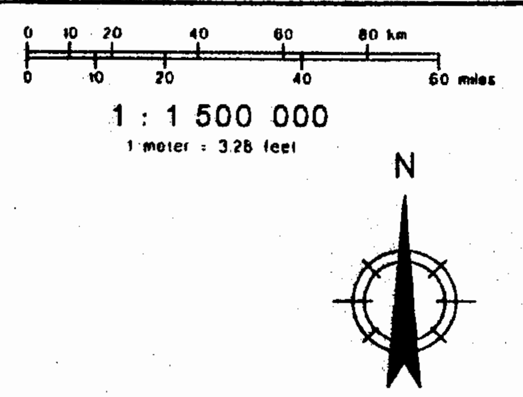
The project area is located in District Swat. Very good maps in the scale of 1:50,000 are available. Some maps have contour lines intervals in meters while other in feet. The highest peak elevations in the northem part are between 5944 to 5041 m a.s.l. These maps were previously used for identification of Hydropower Potential in the Regions of N.W.F.P.

Daral Khwar is a right tributary of the Swat River. The flow direction of Daral Khwar, in its lower section, follows a bend from West- East direction turns to North-South direction before it flows into Swat River. By cutting the mountain ridge between the two valleys, it is possible to use a favourable head for making a hydropower scheme

A prerequisite to the geotechnical investigations and design works was the detailed topographic survey of the proposed sites for the weir/intake, conduit system and powerhouse areas.

For the Main Traverse, a geodetic basic triangulation network was established between 2 points fixed at the outlet (powerhouse) area and 2 at weir/intake area. This was done by conventional survey traverse

The overall length of the traverse was 12 km and 57 stations were set up and cross checked.



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

FEASIBILITY STUDY
DARAL KHWAR HYDROPOWER PROJECT

LOCATION OF THE PROJECT AREA

DATE	JUNE 1997	DRAWN	HINUM
SCALE	1 : 1.5 Mio.	DESIGN	FB / HINUM
DRAWING	676-201	SIGNED	

Data was processed to eliminate out-of-tolerance sets; cross bracing gave additional sets of redundancies when calculating station co-ordinates, using least square methods.

Minor traverses were carried out at both the Inlet and Outlet areas in order to provide a spread of co-ordinated points for the topographic survey work.

Topographic mapping required for the project comprised work both in the office and, more extensively, field surveys over the whole site area.

For the Feasibility Study the following mapping was carried out:

- Medium scale mapping 1:10,000, 1:7,500, 1:5,000
- Detailed mapping scale 1:100, 1:200,1:500
- Bathymetric survey of the Swat River up and downstream of the line of the penstock axis.
- Access road mapping to the weir / intake and surge tank area and structure location.
- Additional survey in the area of the surge tank, in the lower part of the penstock, and for the alignment of access to the powerhouse was necessary during the feasibility study.

1.4 HYDROLOGY

The catchment of Daral Khwar is located in the southern slopes between the Hindu Kush and Himalayan ranges. Daral Khwar is a right tributary that joins the Swat River at the village of Bahrain. The catchment area measured to the confluence with Swat river is 268 km² with a mean elevation of 3,486 m asl. Maximum elevation within the catchment is about 4,200 m asl and minimum at the confluence is about 1,480 m a.s.l. There are no perennial glaciers within the catchment although satellite imagery shows small snow covered areas as late as August.

Estimated mean annual precipitation over the entire catchment of Daral Khwar is about 1,560 mm, compared with mean annual run-off, which is about 1,357 mm.

Available hydrological information of the catchment of Daral Khwar, comprises daily flows of the hydrological station at Bahrain (period of record available Dec1992 - Dec-1995) and low flow measurements taken on Daral Khwar

Since the period of record was short, an extension of the records by regression analysis was performed based on records from Swat at Kalam and Swat at Chakdara (from the year 1962 to 1995).

After analysis of the flow paths, good correlation was demonstrated between the pattern of flows from the long term stations, therefore, it was considered to be sufficient and of good quality and consequently it allows a reliable calculation of flows at the weir site where the catchment area is 250 km². The mean annual flow was calculated to be 10.76 m^3/s and the discharge available 50% of the time 4.37 m^3/s. The monthly minimum and maximum discharges are 1.31 m^3/s and 33.86 m^3/s in January and June respectively.

The regional method for estimation of floods was developed on the basis of available flood records of the hydrological stations in the northern areas of Pakistan. Flood records of 26 stations were analysed and classified in three regions.

Due to the geographical position of the catchment and the characteristics of precipitation and observed floods, the catchment of Daral Khwar was classified to be within the region moderately affected by Monsoon rains.

In this region floods are mainly originated by snowmelt, but rainfall can contribute to maximum floods. The estimated flood of Daral Khwar at the weir site for 10 years of return is approx. 390 m^3/s, for 100 years approx. 640 m^3/s. The estimated flood of Swat river at the powerhouse site is 2,730 m^3/s for 1000 year return period

For the stations Kalam and Chakdara the annual specific suspended sediment loads were obtained by summing the average daily specific suspended sediment carried, and interpolating between if no readings were taken on certain days.

To estimate the discharge of suspended sediment on Daral Khwar at the weir site a linear interpolation was assumed. The mean annual suspended sediment discharge following the method described above was calculated to be some 0.055 10^6 ton/year.

Mean annual bed-load was calculated at 0,17.10^6 tonne/year at the weir site. No bed-load transfer is apparent during low flows. The mean total sediment load was calculated to be 0.225x10^6 ton/year.

1.5 GEOLOGY

For Daral Khwar Project, geological, engineering geological, geophysical, and soil mechanics desk studies, field and laboratory investigations have been carried out starting 15th of January, 1994. Summarising, the main studies consist of geological field mapping, 14 bore-holes, some in-situ permeability tests, 30 test pits, laboratory tests as to petrography and soil mechanics as well as geo-electrical and refraction seismically field investigations. A second investigation campaign as to geophysics was necessary in view of the then still unclassified geological conditions in the surge tank area; reasons for this were the unsatisfying core recovery and the missing in-hole tests concerning groundwater and permeability.

The geological and geophysical investigations led finally to the following conclusions and recommendations:

- The project area is characterised by norites ("a coarse-grained plutonic rock containing basic plagioclase as the chief constituent and differing from gabbro by the presence of orthopyroxene as the dominant mafic material"), belonging to the "Bahrain Pyroxene Granulites" of Kohistan Island Arc.

- Considering among others the important Main Boundary Thrust (MMT) as a source for future earthquakes, the seismic design parameters for the project (50 years lifetime) are recommended as Maximum Design Earthquake (MDE) of 0.25 g with 10 % probability of exceedance with a corresponding return period of 475 years, and as Operation Basis Earthquake (OBE) of 0.15 g with 50 % probability of exceedance and 75 years return period.

- The **weir** site was chosen in the upper Daral valley, where bedrock is outcropping on the right abutment in form of a huge "boulder", and where on the left bank some decametres upstream the bedrock reaches near the river bed.

  Foundation of the flat weir will be necessary within river deposits.

- A roughly 600 m^2 large, three-row-grouting curtain will seal the in-situ remaining alluvions underneath the weir. A geoplastic foil upstream of the weir will reduce seepage quantities by lengthening the percolation path additionally.

- The **sandtrap** is located some 80 m downstream of the intake at the foot of the right bank within river deposits. Slope protections may, safety measures (riprap) against high floods have to be constructed along the sandtrap.

- To connect the weir/intake with the sandtrap, a free-flow **by-pass tunnel** of 60 m length has to be driven through the boulder-like outcrop of norites. Tunnelling may become a routine exercise, as the bedrock shows very good tunnelling properties.

- The short **headrace canal** reaching from the sandtrap to the inlet tunnel portal, following the lower part of the right slope, does not create any difficulties but some protection measures in the vicinity of the portal.

- The low-pressure headrace tunnel of 3,100 m length will cross norites of good quality in its upper approximately 2900-m-section, will, however, meet very bad and unfavourable rock conditions by approaching the surge area. Both, conventional heading and TBM will be possible. Irrespective of the rock class and the different strength of the "outer shell", a regular "inner shell" of 20 cm thick concrete lining should be taken into consideration in view of the water tightness and friction losses. Primary stresses are generally not expected, remnants may, however, not be excluded.

- Due to insufficient investigation results in the surge tank area, a second investigation campaign became necessary, the results of which created even more scientific imponderables.

- Weighing all general geological criteria, viz judging simply upon the field geological mapping works by MAGMA, it came to the understanding that evidences for a post-glacial "Sackung"* event do not exist. All geological criteria and phenomena shall be interpreted as old tectonical movements. Slope stability analyses with assumed parameters resulted in just sufficient safety factors.

- The surge tank is located within a "sheared zone", striking ± parallel to the slope causing special excavation measures, such as pre-stabilisation by grouting; pile walls or drop shaft foundation. Rock bearing capacities for pressure shocks should not be taken into consideration. A pre-construction pilot tunnel for rock mechanical investigations may result in shifting the structure further into the mountain with better rock conditions for a chamber-like surge structure.

- The penstock and access tunnels are situated in same "sheared zone", reducing the rock qualification decisively. The concrete plugs need deep anchors with pre-consolidation measures.

- The embedded 900 m long penstock is expected to have "regular" conditions concerning excavation and backfill. The two fixed points - at the valve chamber and just in front of the powerhouse - get heavy anchor support. The crossing of Madyan-Bahrain-road is accomplished by a concrete structure bearing the new road.

- The powerhouse was, after cost comparison, finally located on the right bank, and will need foundation on terrace deposits. Heavy soil anchors for slope protection and strong erosion protection along the water front in form of concrete embedded ~~riprap~~ are necessary. The tailrace cascade does not need any special treatment except flood protection.

The whole bulk of construction material can be gained by quarrying and/or from muck material. Natural sealing material is not available.

1.6 ENVIRONMENTAL CONSIDERATIONS

Daral Khwar Hydropower Project is proposed to be built near Bahrain Town of District Swat in N.W.F. Province. It is envisaged to utilise run of river to generate 35 MW electric power. A weir with a lateral intake and sand/gravel traps will be constructed cross Daral Khwar, near village Arin, to divert 15 m^3/s discharge into head race channel. Where from the flow will be passed through a 3,100 m long tunnel across the high mountain into the Swat valley. A drop of 290 m will thus be available to operate the turbines installed at the Power House located 1 km south of Bahrain town, along the right bank of river Swat.

The geology, hydrology and sedimentation rates have been considered in determining the feasibility of the Project. The environmental impacts of the project during construction period and later on during operation have been analysed and following aspects, have been investigated.

- Existing water usage and rest water assessment

  To keep some margin for future development and uncertainties of weather it is recommended to base the design of the hydel station on rest water requirements of at least 200 l/s.

* "sackungen Deep-seated rock creep which has produced a ridge-top trench by gradual settlements of a slablike mass into an adjacent valley" (BATES & JACKSON 1982).

- Domestic solid / liquid waste in to Daral Khwar
- Deforestation
- Fish culture
- Displacement of people
- Displacement of wild life
- Disposal of excavated material
- Quarry operation
- Remedial measures to mitigate all environmental ill effects have been suggested. The summary of mitigation cost is as under :

MITIGATION COST

(A) Initial

S.NO.	ITEMS	Amount (Mill. Rs.)
i.	Compensation of trees.	0.20
ii.	Disposal of excavated material with land scaping and plantation.	1.24
iii.	Rehabilitation of quarry with land scaping and plantation.	0.30
iv.	Improving water supply & sewerage system of Bahrain Town.	10.00
v.	Providing sewerage disposal for the houses down stream of weir.	1.00
vi.	Cost of providing power transmission lines to the two water mills, providing electric motors and couplings and other items for conversion.	0.20
	Total	12.94

(B) Annual (Monitoring of quality of water in Daral Khwar) 0.025 Mill. Rs./ year

(C) Land Acquisition (approx. 10 ha) 11.86 Mill. Rs.

As would be observed the Project will have minimal environmental impact and will on the other hand bring substantial socio-economic benefits to the area. The hydropower generation infect on one hand gives impetuss to economic development and on the other hand helps to reduce greenhouse effects, which would be evident from the fact that an altemate source of thermal power generation of equal capacity would produce pollution of the following order.

Fuel	Coal	Oil	Gas
CO_2 emission in Kg	$1.3\text{x}10^8$	$1.02\ \text{x}10^8$	$0.7\ \text{x}10^8$
SO_2 emission in Kg	$1.3\ \text{x}10^6$	$1.02\ \text{x}10^6$	$< 0.44\ \text{x}10^3$
NO_x emission in Kg	$1.3\ \text{x}10^6$	$1.02\ \text{x}10^5$	$< 1.07\ \text{x}10^5$
Particulate emission in Kg.	$1.4\ \text{x}10^5$	$0.26\ \text{x}10^5$	$< 1.3\ \text{x}10^3$

1.7 SELECTION OF PLANT LAYOUT

Daral Khwar Hydropower Project was identified in 1989/1990 during the Inventory of Hydropower Potential in the Region "Swat Valley" (Region 4 of the Master Plan for Hydropower Development in Northem Areas in North West Frontier Province N.W.F.P/Pakistan).

The project was found to be the most suitable within Region 4 due to the favourable topographical, hydrological and geological conditions and its near distance of the National Grid.

In order to take the maximum advantages of the site, various altematives have been studies with variations in

- powerhouse location and type
- design discharge
- turbine type and number

Out of these alternatives, the solution which fitted best in the present environmental, economical and technical boarder conditions has been chosen..

The basic proceeding of selection of alternative, is presented in the flow chart (on the next page)

According to the requirements of work to be carried out for the Feasibility Study, comparison of alternatives including preliminary cost assessment and optimisation of plant layout was prepared as a first step.

Two alternatives for powerhouse location were identified, these were:

- Powerhouse located at the right bank of Swat River.
- Powerhouse located at the left bank of Swat River.

The original identified scheme envisages the powerhouse on the right bank, however anticipating foundation problems at right bank of Swat River (terrace deposits) an alternative on left bank (outcropping rock) was identified and studied for cost (preliminary) comparisons.

The cost comparisons ruled out the left bank alternative.

The final selection of the design discharge, made upon the basis of rough layouts for the defined alternatives on the right bank of Swat River.

The optimisation with impact of economic evaluation parameters, updated hydrological data of Daral Khwar, updated cost estimation on the basis of geological investigations and environmental aspects was the basis for working out the Feasibility Study for final determination of main project features.

A compilation of the results of the cost estimate for the defined alternatives is shown below:

HYDROPOWER PROJECT DARAL KHWAR/BAHRAIN
COMPILATION OF COST ASSESSMENT
FOR FINAL SELECTION OF PLANT LAYOUT

Alternative	Q design (m^3/s)	Grosshead (m)	Losses (m)	Nethead (m)	Capacity (kW)	Total cost 1000 US$	Spec. Cost (US$/kW)
DAR10R	10	310	11.08	298.92	24879	32455	1305
DAR15R	15	311	11.54	299.46	37973	40850	1076
DAR20R	20	312	11.53	300.47	50134	50941	1016

the best design discharge was determined on economic parameters. Benefits were quantified on the basis of LRMC of capacity and energy. The result of this analysis was, that the best final layout of Daral Khwar Hydropower scheme is a design discharge of 15 m^3/s.

The Plant Dimensioning based on the general layout data was carried out.

The main components included in the Plant Dimensioning are listed below:

- Weir with Lateral Intake
- Connection Tunnel with Gravel Spilling Systems
- Sand trap (2 chambers)
- Headrace canal (rectangular section)
- Headrace tunnel and access tunnel
- Surge Tank
- Penstock Tunnel and Valve Chamber
- Embedded Penstock
- Powerhouse with three Pelton turbines
- Tailrace structure

DARAL KHWAR HEPP
DEVELOPMENT OF FEASIBILITY STUDY

IDENTIFICATION OF HYDROPOWER DEVELOPMENT POTENTIAL IN SWAT VALLEY

IDENTIFICATION OF DARAL KHWAR HEPP AND DECISION TO DEVELOP THE PROJECT AS TO FEASIBILITY STAGE

↓

TOPOGRAPHICAL SURVEY	– TOPOGRAPHICAL REPORT
GEOLOGICAL GEOTECHNICAL INVESTIGATIONS	– PRELIMINARY GEOLOGICAL REPORT
ENVIRONMENTAL SURVEY	– PRELIMINARY ENVIRONMENTAL REPORT
DISCHARGE MEASUREMENTS	– PRELIMINARY HYDROLOGICAL REPORT
GEOPHYSICAL INVESTIGATIONS	– PRELIMINARY GEOPHYSICAL REPORT

↓

DEFINITION OF MAIN ALTERNATIVES

POWERHOUSE AT RIGHT BANK OF SWAT RIVER	POWERHOUSE AT LEFT BANK OF SWAT RIVER
Q = 10 m^3/s Q = 15 m^3/s Q = 20 m^3/s	Q = 10 m^3/s Q = 15 m^3/s Q = 20 m^3/s
Q = 30 m^3/s Q = 35 m^3/s	Q = 30 m^3/s Q = 35 m^3/s

PRELIMINARY COST ASSESSMENT FOR 10 ALTERNATIVES
OPTIMISATION AND SELECTION OF PLANT LAYOUT

↓

INTERIM REPORT NO. 1
PRELIMINARY COST ASSESSMENT AND SELECTION OF PLANT LAYOUT

POWERHOUSE AT RIGHT BANK OF SWAT RIVER, Q = 10 m^3/s (10-25 m^3/s)

↓

PRELIMINARY PLANT LAYOUT ON THE BASIS OF SELECTED ALTERNATIVE AND PLANT LAYOUT

↓

INTERIM REPORT NO. 2
DATA REVIEW AND PRELIMINARY PLANT DIMENSIONING

INTERIM REPORT NO. 1	
PRELIMINARY PLANT LAYOUT (FOR Q = 11 m^3/s)	GEOLOGICAL REPORT, GEOPHYSICAL REPORT
TOPOGRAPHICAL SURVEY	ENVIRONMENTAL REPORT

↓

INTERIM REPORT NO. 1a
FINAL SELECTION OF PLANT LAYOUT, Q = 15 m^3/s
(IMPROVED RESULTS OF GEOLOGICAL INVESTIGATION AND REVISED HYDROLOGICAL DATA)

↓

INTERIM REPORT NO. 3
CONCEPTUAL DESIGN
OPTIMISATION OF STRUCTURES AND SELECTION OF ALTERNATIVES

↓

FINAL FEASIBILITY REPORT

FINAL TOPOGRAPHICAL REPORT	HYDROPOWER DESIGN
FINAL GEOLOGICAL REPORT	CIVIL DESIGN
FINAL HYDROLOGICAL REPORT	MECHANICAL DESIGN
FINAL GEOPHYSICAL REPORT	ELECTRICAL DESIGN
FINAL ENVIRONMENTAL REPORT	COST ESTIMATE
TRANSPORT STUDY	ECONOMICAL STUDY
TRANSMISSION LINE STUDY	FINANCIAL STUDY
OTHER STUDIES	

1.8 HYDROPOWER DESIGN

Based on the results of previous studies aimed at the selection of power plant layout, which are presented under Chapter 7, the alternative for design discharge of 15 m^3/s and the powerhouse on the right-bank of Swat river has been adopted for the Feasibility Design.

Since the basic solution of the hydropower project is now defined, design of the main structures is subjected to comparative evaluation in terms of economy, engineering and geology.

The engineering design of the hydropower project covers the following main sections:

1.8.1 Civil Works

The civil design comprises the power plant components grouped as follows:

- Weir with lateral intake

For technical and economical reasons a fixed crest weir with overflow sections for 100-year flood and flushing section has been chosen among others like tyrolean weir or weir with gates. The four-section lateral intake includes a spilling opening with gate.

- Conduit System

The conduit system comprises a short connection tunnel and gravel spill structure conveying the water from the intake towards the two-chamber sandtrap designed to settle and removal of grains size larger than 0.3 mm during full discharge. Downstream, a short headrace canal connects the sandtrap to the 3,044m concrete lined headrace tunnel the cross-sectional area of which has been optimised for the design discharge, tunnel slope and form of operation of the plant. The proposed tunnel support and concrete lining thickness is based on the prevailing geological conditions along the tunnel i.e. rock classification, and on the internal and external water pressure considerations.

Considering the geological conditions for construction at the end of the headrace tunnel, a surge shaft 30 m height 12 m diameter without chambers as a surge tank has been found appropriate to absorb extreme water level oscillations caused by operation and regulation of turbines flow

From the surge tank the waters flows into the aprox. 900 m steel penstock towards the powerhouse turbines. The penstock diameter and wall thickness has been optimised for the design discharge and daily peak and off-peak operation of the plant.

- Powerhouse

Due to the topographical and geological conditions at the proposed site and considering the type of turbines selected an external powerhouse has been chosen.

The elevations of foundation and machine floor have carefully been determined based on the underground water level at the powerhouse site and the estimated water level, during extreme floods, of the adjacent Swat River.

The powerhouse area comprises the following parts:

- The substructure housing mainly the Francis turbines and generators, with some auxiliary rooms and the pit for the Pelton turbine,
- The superstructure, above ground, comprising the machine hall and operating facilities,
- The open switchgear area,
- The residential buildings.

1.8.2 Hydraulic steel works

The design of the hydraulic steel works is based on hydraulic and mechanical considerations. Hydraulic considerations refer to the maximum/minimum velocities of water flow required for a reliable and safe operation of the power plant components.

The gates, trash racks, valves, steel penstock, etc. are dimensioned to permit dependable water flow performance under variable conditions of operation

The mechanical considerations refer to the design of the steel structures i.e. the required thickness and rigidities of the steel parts to resist loads to transport, water pressure and other stresses caused by the operation of mechanisms, and to withstand the effects of corrosion over the useful life time.

1.8.3 Hydromechanical equipment

The design discharge of 15 m^3/s will find the arrangement of 2 vertical Francis units and 1 horizontal Pelton unit for low flow conditions as optimum from the technical and economical points of view. Each Francis unit will have a rated flow of 6.25 m^3/s, a rated mechanical turbine power of 15.7 MW and a turbine speed of 1000 rpm.

The Pelton unit will have a rated flow of 2.5 m^3/s, a rated mechanical turbine power of 6.4 MW and a speed of 500 rpm. The net head for the Francis turbines will vary between 305 m at the maximum reservoir level and the minimum operation discharge and 287 m at the minimum reservoir and maximum operation discharge. The Pelton turbine will have 3.2 m less head dure to its higher setting.

The distribution of rated turbine flow was selected for the units considering the operation cycle of the plant.

1.8.4 Electrical Equipment

This chapter summarises the feasibility design considerations for the electrical installations of the power house. These layouts are the basis of the cost estimates and will also serve as the basis for the future final design.

The electrical equipment consists mainly of:

Two vertical shaft generators of 18 MVA each and one horizontal shaft generator of 7.5 MVA connected via 11 kV cables to the 11 kV main bus.

Two step up transformers of 20/26 MVA (ONAN/ONAF), 11/132 kV, located in 132 kV outdoor switchyard for connection to tow outgoing transmission lines.

Control and protection devices for all functions of the plant including the 132 kV switchyard.

1.8.5 Construction

Temporary site installation plants for construction are required one in the weir area and other in the powerhouse area, for aggregate storage, crushing plants, concrete mixing plants, cement storage and workshops, etc. The site installation plants will use approx. 5,000 m^2 each,. After completion of the main structures the used sites will be restored to the original condition.

Excavations in the weir, conduit system and powerhouse sites will be approx. 160,000 m^3, deposit requirements for surplus excavated material will be approx. 57,000 m^3.The difference will be used as concrete aggregate 31,600 m^3; riprap, pitching, stone works 17,400 m^3; backfilling 54,000 m^3.

The following quantities of concrete would be required:

Weir and intake	7,510 m^3
Conduit system	18,040 m^3
Powerhouse and tailrace	7,550 m^3
Total:	33,100 m^3

Laboratory tests on the proposed concrete aggregates are necessary to determine their suitability. Two crushing plants with a capacity of 40-50 m^4/day each to produce approx. 33,000 m^3 of aggregates within a period of 1-2 years are proposed. A capacity of up to 250 m^3/day each would be required for the mixing plants at the weir and powerhouse areas

The normal concrete strength class will be B25 according to DIN 1045 with a mean cement content 300 kg/m^3. Concrete with special properties will have to be used for tunnel lining.

The concrete for surface structures will have to be transported from the mixing plants by vehicle to platforms at the sites. The method of concrete conveyance (e.g. by crane, with transit mixtures, conveyor belt or pumping) shall have to be determined so as to prevent segregation. Concrete lining of underground structures will need transport to the site and final mixing and placement by pumping.

Estimations on time schedule are based on experiences of modem construction methods with up-to-date equipment.

It is estimated that the construction period for the Hydropower Project will take three years (five year including preliminary works, test operation and commissioning)

Year 0 Preparatory works

- Land Acquisition
- Access roads.
- Design and Tender Documents
- Tendering/Bidding
- Evaluation and Award of Contracts

Construction of access roads are independent activities and can be executed in parallel and completed within one year.

Year 1-3 Construction period (3 years)

All civil works for the weir and intake will be completed in two years, mechanical and electrical works will be finished six months later.

All civil works for the conduit system will be completed in two and a half years; mechanical and electrical works will be finished three months later.

All civil works in the powerhouse area. will be completed in 33 months, mechanical and electrical works will be concluded three months later. Overall power house work needs three years

Additional civil works like residential buildings, stores, workshop etc. are not in the critical path of the time schedule. All of them can be built in two years.

Year 4 Test Operation, Commissioning and Contractual Maintenance Period of the hydropower project would be within 1 year of completion of construction.

Start up and test operation will be possible three years after beginning of construction works and along with the commissioning period six months will be needed.

1.8.6 Compilation of Principal Features

River	Daral Khwar		
	Catchment area at weir site	250	km^2
	Mean annual discharge	10.76	m^3/s
	Total annual flow	340.9	Mio m^3
Details of Main Structures			
Weir Structure	Type	Fixed sill	
	Height above riverbed	2.5	m
	Depth below river bed approx.	6.5	m
	4 overflow sections each	8	m wide
	1 flushing section	4	m wide
	Length of weir structure	17	m
	Width of weir structure	48	m
	Design flood (100y - flood)	640	m^3/s
Intake	Type	Lateral	Intake
	4 sections each	2.6	m wide
	Stoplog pockets		
	Coarse rack		
	Spilling section with gate		
	Intake gate		
Connection Tunnel	Height	5.00	m
	Width	4.00	m
	Cross Section	17.13	m^2
	Length without Gravel Sp. approx.	28	m
Gravel Spill	Height	6.00	m
	Width	4.00	m
	Cross Section	19.25	m^2
	Length	30	m
	Flushing Gate		
Sandtrap	No of chambers	2	
	effective height each	6.25	m
	clear width per chamber	5.00	m
	total width of sandtrap	13.40	m
	effective length	40	m
	total length approx.	90	m
	overflow section		
	inlet gates		
	flushing gates		
	fine rack		
	outlet gates		
	spilling canal		
Headrace Canal	Height, internal	3.40	m
	Width, internal	2.50	m
	Cross Section	8.50	m^2
	Length approx.	41	m
Headrace Tunnel	Type of Cross Section	Horse Shoe	
	Height	3.30	m
	Width	3.00	m
	Cross Section	8.34	m^2
	Length from portal to Surge Tank	3,044	m
	Slope	0.5	%
	Storage Volume	26,000	m^3

Surge Tank	Type	Shaft	
	Internal diameter	12.00	m
	Cross Section	113.10	m^2
	Height	30	m
Penstock Tunnel	Height	3.05	m
	Width	4.40	m
	Cross Section	15.02	m^2
	Length	50	m
	Penstock Pipe diameter	2.00	m
Valve Chamber	Width	13	m
	Length	11	m
	Height (above ground)	8	m
	Depth (below ground)	6	m
	Emergency Valve dia	2	m
	Maintenance Valve dia	2	m
	Crane - Capacity	100	kN
Embedded Penstock	Diameter	2.00	m
	Length	840	m
Road Crossing Structure	Width approx.	5.2	m
	Length approx.	9.6	m
	Height approx.	13.4	m
Powerhouse	Type External		
	Depth below machine hall floor	10.7	m
	Machine hall: Length	30.4	m
	Width	16.5	m
	Height above machine hall floor	15.7	m
	Total length of Powerhouse	34.4	m
	Total width of Powerhouse	29.6	m
	Total height of Powerhouse	26.4	m
Tailrace	Cascade type, No of units	3	No
	Width (Francis/Pelton)	3.25/1.40	m
	Height approx.	8	m
	Length	15.9	m
Hydro Mechanical Equipment	Francis Turbines vertical shaft	2	Units
	Speed	1000	rpm
	Net head	293.3	m
	Discharge per unit	6.25	m^3/s
	Pelton Turbine horizontal shaft	1	Unit
	speed	500	rpm
	Net head	290.7	m
	Discharge per unit	2.5	m^3/s
	Total turbine discharge	15	m^3/s
Electrical Equipment	Generators for Francis turbines (No. of units)	2	
	Speed	1000	rpm
	Capacity	18	MVA
	Generator for Pelton turbine (No. of unit)	1	
	Speed	500	rpm
	Capacity	7,5	MVA
	2 Main Tansformers	11/132	kVA
	Switchgear	132	kV

1.8.7 Power and Energy

Design Discharge	2 Francis (6.25 m^3/s each)	12.5	m^3/s
	1 Pelton	2.5	m^3/s
	Total	15.0	m^3/s
Operation Guideline	Stop of generation, flushing section open during periods Q> 50 m^3/s: approx.	1	%
	Minimum rest water	200	l/s
	%age of spilling water when Q> 10 m^3/s:	10	%
	Annual Turbine run-off	222	Mio.m^3
Head	Headrace water level	1,723.0	m asl
	Mean tailrace water level	1,405.0	m asl
	Gross head	318	m
Losses	(at Q_{design} = 15 m^3/s)	14.14	m
Lost head	Francis Units	10.28	m
	Pelton Unit	12.86	m
Net head	Francis Units	293.27	m
	Pelton Unit	290.69	m
Energy output	Francis Units	29.2	MW
	Pelton Unit	5.8	MW
	Power Factor	0.48	
	Mean annual energy	148	GWh

1.9 TRANSPORT/ACCESS-FACILITIES AND HOUSING

1.9.1 Transport of Equipment from Karachi to Bahrain

The transportation of heavy construction and permanent equipment to and within the project area needs careful attention.

Based on the feasibility design, the heaviest pieces of equipment are the rotors of the generators and the three phase transformers with a maximum weight of up to 30 tons. Tractors with dozer blades start form about 6.7 tons (D3B Caterpillar) to about 88 tons (D10 Caterpillar)

The heaviest pieces of equipment will start their journey northwards beginning from the docks at Karachi. For the 2 Francis turbine-generator units and the Pelton turbine-generator unit envisaged, there will be some parts whose weights and dimensions to transport will be unavoidably substantial.

Exceptional loads to be carried:

Item	Weight (T)	Dia (m)	Length (m)
Rotor	30	2.1	3.0
Stator	17	4.0	1.0
Transformer	14	2m x 3.5m x 2.7m high	

The option of transport by railway from Karachi to Dargai and then by road to Bahrain seems more favourable than the option of transport entirely by road.

It is anticipated that suitable railway wagons will be available for the first reach, then the equipment will have to be unloaded at Dargai and loaded on trucks or trailers. With regard to the transformers they might be moved side-ways from the railway wagon over to the trailer without lifting, provided suitable wagons are used. For all other equipment the contractor will provide a mobile crane for lifting the parts. Appropriate cranes are easily available in Pakistan.

For the second reach, the transport by road will be done over a distance of 128 km from Dargai to the project area in Bahrain.

The route Dargai Bahrain has been surveyed, every comer and steep slope, culvert and bridge structure inspected and any difficulties for transportation analysed.

The Bailey bridge at Madyan poses special problems for crossing the Swat River with exceptional loads The most likely altemative to overcome the problems is by means of a barge (or raft).

The following is seen as a pre-requisite for the transporter:

1. a special trailer with multiple axles, each axle limited to a weight of 5 tonnes or less.
2. a special trailer with steering wheels - front and back - to negotiate tight bends.
3. a powerful tractor unit to pull heavy loads up the steeper slopes.

The additional cost of transporting exceptional loads from Dargai to the project area near Bahrain is estimated in 170,500 US$.

The cost of transportation itself and various additional charges of handling the equipment at port of landing etc. is presented in **Chapter 11.**

1.9.2 Access Road and Transport to the Project Area

- Access Road to the Power House

A short access road of approx. 0.4 km length has to be constructed form the main Madyan-Bahrain road, downhill to the elevation 1420 m asl, to reach the Power House and Switchyard areas.

- Access Road to the Access Tunnel, Valve Chamber and Surge Tank

A new road of approx. 1.5 km length will have to be constructed starting at chainage 970 m of the existing forest road to Kulban to the Access Tunnel and Valve Chamber working platforms. Retaining walls and other stabilizing measures will be required to bring the rood to acceptable standard.

In case that a TBM is chosen for the headrace tunnel excavation, it will be necessary to serve the working site by a truckable road.

The access to the Surge Tank branches off from the working platform of the Access Tunnel and is approx. 500 m length

Access Road to the Weir Area

The access road from Bahrain to the Weir site will be approx. 4.8 km length, about 1.2 km has already been constructed,. widening of the existing road to achieve the minimum 6 m width is required. The remaining road length to be constructed is about 3.6 km which will be on the left bank of the river.

It is proposed to erect a bridge over the weir to reach the Intake, Gravel Spill, Sand trap etc. on the right bank of the river.

1.10 GRID INTERCONNECTION

Daral Khwar is located 2 km South of the Bahrain village. The interconnection of the proposed hydropower plant with the national grid is to be seen in the framework of phased High Head Hydro development and grid system expansion. The expansion plan is being developed in a separate study. The choice of voltage levels and layout configuration is developed under economic and technical criteria. Effort is made to conform to WAPDA standards and the standard practices. Deviations are proposed only where absolutely necessary.

The cost of HV transmission lines for mountainous and plain areas was also developed. Energy costs were based on estimates of LRMC. The development of the transmission system is possible along the four valleys: Chitral – Dir – Mardan; Swat Valley – Mardan; Indus Valley – Mansehra – Islamabad; and Kaghan Valley – Mansehra – Islamabad.

The transmission interconnection plan related to the proposed hydropower plant will be realised by inserting Daral Khwar in one circuit of the bypassing Matiltan – Madyan 132 kV/DC transmission line.

The economic cost of the transmission system to be attributed to Daral Khwar was developed based upon the incremental cost of the transmission system. The total cost of transmission with and without High Head Hydels was elaborated and the difference was then attributed as the direct transmission cost of each hydropower plant. The exercise results in a cost of 60.5 $/kW specific transmission cost which is very close to the marginal capacity cost of secondary transmission developed in the Coppers and Lybrand Marginal Cost Study. The economic cost of transmission attributed to Daral Khwar was worked out to be:

Direct Cost	0.8 Mio US$
System Cost	0.8 Mio US$
Total	1.6 Mio US$

This cost is higher than the direct investment cost of 0.8 Mio US$ for connecting Daral Khwar to the system.

1.11 COST ESTIMATES

The cost of constructing Daral Khwar HPP was obtained by considering the following groups:

- Preliminary works which covers the environmental mitigation and land acquisition costs, cost of access roads to the sites of the project components, cost of transporting heavy loads from Dargai to Bahrain, and cost of camps and housing for the construction and supervisory staff.
- Civil works comprise of the cost of the main structures: weir with lateral intake; conduit system i.e. gravel spilling structure, sand trap, headrace canal and tunnel, surge tank, penstock tunnel, valve chamber, penstock civil works; power house and tailrace structure.
- Hydraulic steel works cover the cost of supply, transportation and erection of the hydraulic steel structures e.g. steel penstock, gates, trashracks, etc.
- Hydro-mechanical equipment which covers the cost of supply, transportation and erection of the two main Francis turbines and one Pelton turbine.
- Electrical equipment covers the cost of supply, transportation and erection of generators, transformers, switchgear, low voltage supply, control, protection, communication, lighting and emergency power.
- Transmission system comprises the cost of transmission lines needed to interconnect Daral Khwar HPP to the national grid.
- Engineering and administration which covers the cost of foreign and local consultants to do further site investigation, the detailed design, the preparation of tender and contract documents and supervision of the construction works.
- Other cost comprises bank clearance charges and local insurance; customs duty on imported equipment, machinery and plant; and income tax on payments to the contractors. The two later according to the "Policy Framework and Package of Incentives for Private Sector Hydel Power Generation Projects". May 1995.

Contingencies for the former groups were not taken as a uniform percentage of the basic costs, rather they reflect the uncertainties in the cost estimate of the groups, i.e. for preliminary works 10%; for civil works 15%; for Hydraulic Steel Works, Hydro-mechanical Equipment, Electrical Equipment, Transmission System 5% respectively.

The cost estimate of Civil Works is based on the quantities of the works and on the unit prices.

The unit prices were developed based on international data bases for civil engineering works and adapted to the local and regional conditions where Daral Khwar HPP construction will take place. The unit prices analysis comprises the local and foreign component for the labour, material and plant required for the production of each item.

The unit rates for the hydraulic steel works, Hydro-mechanical equipment, Electrical equipment and Transmission system are based on international market prices as well as on the experience of tenders for similar equipment carried out by WAPDA.

Preliminary works unit rates are based on the regional construction practice.

Price escalation and interest during construction are not included. The price level is 1997 and the exchange rate 42.00 Rs/US$.

The total construction cost at the above stated parameters is about US$ 38 million, and the breakdown is shown in **Table S**. The specific capacity cost is 1080 US$/kW

A breakdown of the construction cost reflects the following as a percentage of the total cost, excluding price escalation and interest during construction.

	Mio. US$	%
• Preliminary works	2.257	6.0
• Civil works	17.277	46.0
• Hydraulic steel works	3.839	10.2
• Hydro-mechanical equipment	3.389	9.0
• Electrical equipment	7.424	19.8
• Transmission system	0.100	0.3
• Engineering and Administration	1.922	5.1
• Other costs	1.378	3.7

Civil works account for about 46% of the total construction cost. Tunnels and surge tank account for about 27% of the total construction cost.

The cashflow schedule of Investment based on the construction schedules is shown below:

Year	Quarter	Cash flow in thousand US$					
		Local		Foreign		Total	
0	1	0		0		0	
	2	0		0		0	
	3	550		0		550	
	4	317	867	0	0	317	867
1	1	401		747		1148	
	2	788		1634		2423	
	3	638		908		1546	
	4	1821	3647	1214	4504	3034	8151
2	1	1723		1782		3504	
	2	1598		1955		3552	
	3	1694		2116		3810	
	4	1839	6853	1813	7665	3652	14518
3	1	1816		3172		4988	
	2	1761		2732		4493	
	3	907		1850		2757	
	4	627	5110	1184	8939	1811	14049
Total		16478		21108		37586	
		37%		63%		100%	

Table S
Daral Khwar Hydropower Project 35 MW, Project Cost Summary

Price Level 1997 (42 Rs/US$) *Price escalation and interest during construction are not included*

ITEM	STRUCTURE	COST IN 1000 US$		
		LOCAL	FOREIGN	TOTAL
A	**PRELIMINARY WORKS**	**2257**	**0**	**2257**
A1	ENVIRONMENTAL MITIGATION COST & LAND ACQUISITION	684	0	684
A2	ACCESS ROADS TO THE MAIN WORKS SITES	1106	0	1106
A3	COST OF TRANSPORTING HEAVY LOADS, DARGAI-BAHRAIN	171	0	171
A4	CAMPS AND HOUSING DURING CONSTRUCTION	297	0	297
B	**CIVIL WORKS**	**7046**	**10231**	**17277**
B1	WEIR AND INTAKE	1156	900	2056
	CONDUIT SYSTEM	4147	8069	12216
B2	CONNECTION TUNNEL AND GRAVEL SPILL	71	147	218
B3	SANDTRAP AND HEADRACE CANAL	990	454	1443
B4	HEADRACE TUNNEL, ACCESS TUNNEL, WORKING PLATFORM	2469	6399	8868
B5	SURGE TANK, PENSTOCK TUNNEL, VALVE CHAMBER, PLATFORM	507	869	1376
B6	PENSTOCK CIVIL WORKS AND ROAD CROSSING STRUCTURE	110	202	312
B7	POWERHOUSE	1313	1262	2575
B8	PERMANENT RESIDENTIAL BUILDINGS / STORES / WORKSHOPS	430	0	430
C	**HYDRAULIC STEEL WORKS**	[illegible]	[illegible]	[illegible]
C10	WEIR, INTAKE	131	32	163
C20	SANDTRAP	93	21	114
C21	VALVE CHAMBER	21	116	137
C22	PENSTOCK	2468	158	2625
C30	POWER HOUSE	42	84	126
C40	TRANSPORT	138	20	158
C50	ERECTION	465	51	516
D	**HYDROMECHANICAL EQUIPMENT**	[illegible]	[illegible]	[illegible]
D100	FRANCIS TURBINES, 2 UNITS, 6.25 m3/s EACH	0	2283	2283
D200	PELTON TURBINE, 1 UNITS, 2.5 m^3/s	0	542	542
D300	TRANSPORT	126	15	141
D400	ERECTION	126	298	424
E	**ELECTRICAL EQUIPMENT**	[illegible]	[illegible]	[illegible]
E1	GENERATORS	137	2048	2184
E2	TRANSFORMERS	68	318	386
E3	132 kV SWITCHGEAR	68	347	415
E4	11 kV SWITCHGEAR AND 11 kV LINE POWERHOUSE INTAKE	249	254	503
E5	0.4 kV AC LOW VOLTAGE & 110 V DC SUPPLY	117	462	579
E6	CONTROL, ALARM, PROTECTION, TELECOMMUNICATION & WATCHES	172	1806	1978
E7	LIGHTING & SMALL POWER AND EMERGENCY DIESEL	204	193	397
E8	VARIOUS	347	635	982
F	**TRANSMISSION SYSTEM**	[illegible]	**0**	[illegible]
G	**ENGINEERING AND ADMINISTRATION**	**727**	**1195**	**1922**
H	**OTHER COST**	**1378**	**0**	**1378**
H1	BANK CLEARANCE AND LOCAL INSURANCE @ 1% OF B TO G	340	0	340
H2	CUSTOMS DUTY @ 2% OF EQUIPMENT, MACHINERY AND PLANT COST OF B TO G	320	0	320
H3	INCOME TAX @ 4% ON PAYMENTS TO THE CONTRACTORS OF B TO G	718	0	718
	TOTAL PROJECT COST	[illegible]	[illegible]	[illegible]

1.12 ECONOMIC ANALYSIS

The proposed hydropower plant was identified during master plan studies aimed at identification of hydropower potential for: rural demand; and for regional and system requirements. These studies pertained to the planning of Swat Valley (District of Swat, parts of Swat Districts that drain into the river Swat north of Madyan) region.

Daral Khwar was ranked as the most promising site. The site was upgraded on economic considerations. LRMC peak and off-peak estimates of capacity and energy at 132 kV level were used as benefits and optimised size was the one when incremental benefits equalled incremental costs. The optimised size of the power plant is 35 MW, 148 GWh/a at a plant factor of 48%.

Project cost estimates were shadow priced to obtain economic cost estimates Tradable were valued at border prices. A SCF of 0.86 was used to convert financial to economic costs. the economic discount rate was argued to be less than 10%, however for the sake of this study a 10% economic discount rate was used for project economic analysis.

The project economic feasibility is assessed in two parts: The first determines that the project would form a part of the least cost expansion plan; the second determines that the least cost plan is economic. The least cost solution was determined by means of WASP runs: use of LRMC estimates; and thermal equivalence analysis. The benefits for economic feasibility were estimated. This for residential customers was Rs.4.85/kWh; for small, medium and large industrial customers it was estimated to be Rs.5.69/kWh and Rs. 4.79/kWh respectively. For agricultural customers this was estimated to be Rs.4.72/kWh.

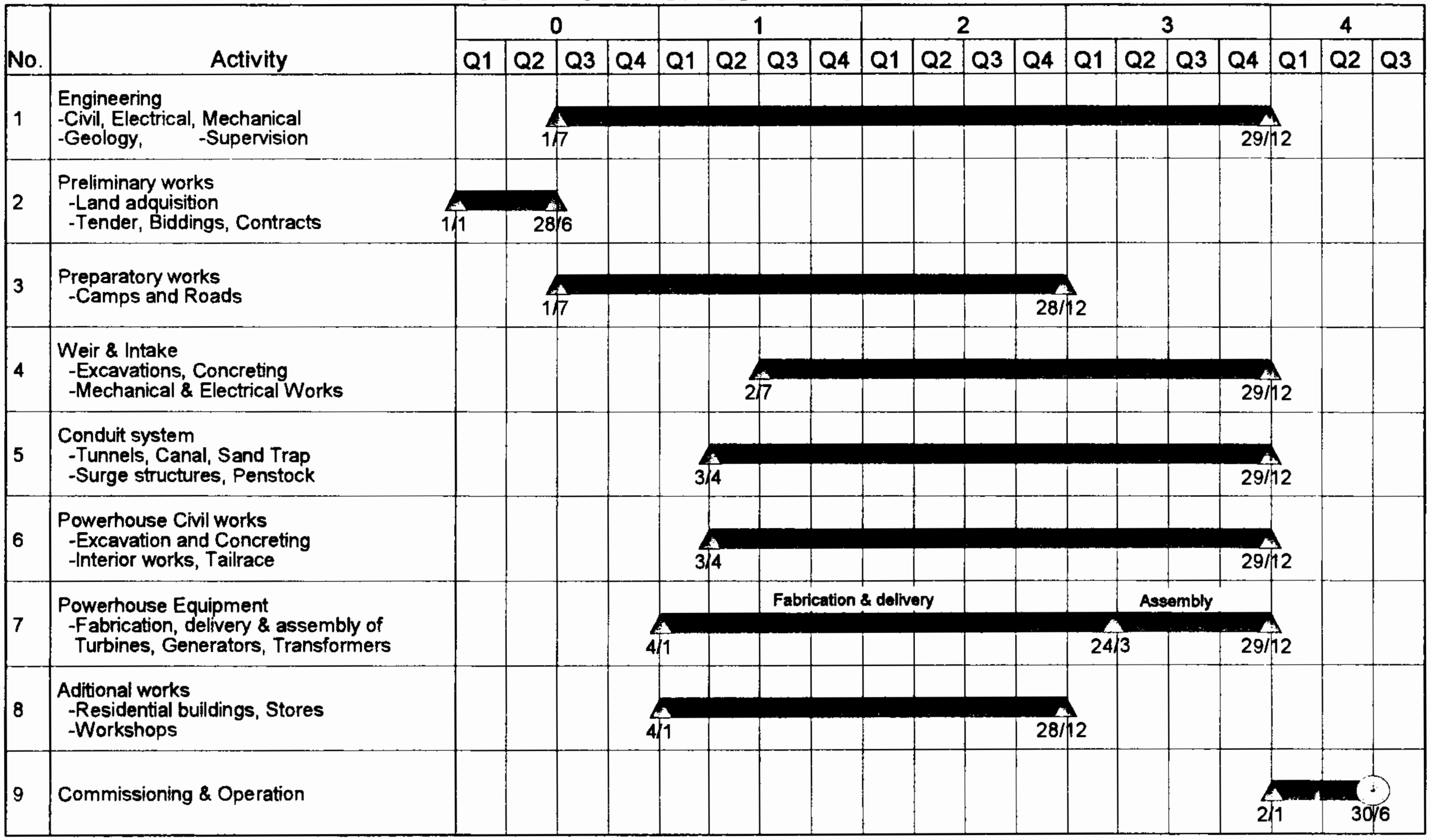
The economic capital cost for the project was estimated to be US$.37.6 millions. This includes direct transmission cost. For economic evaluation the cost was increased to account for administrative overheads, indirect transmission costs and distribution costs.

Economic analysis is summarised as below:

	Economic Feasibility	
	NPV (M.US$)	IRR (%)
• Consumer Surplus Basis	10.50	11.36
• LRMC Basis	13.21	14.68
• Thermal Equivalence Basis	3.21	11.15

The project seems to be economic at the stated parameters. The project should therefore be taken up for construction. The estimated period for construction is 4 years (see bar chart **Figure 12/1**).

DARAL KHWAR HYDROPOWER PLANT
TIME SCHEDULE FOR CONSTRUCTION



A more detailed TIME SCHEDULE is presented in VOLUME 2 of this MAIN REPORT

Figure 12/1

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2.1 THE POWER SECTOR

2.1.1 Background

The Pakistan Water and Power Development Authority (WAPDA), a Government owned statutory body, and the Karachi Electricity Corporation (KESC), a predominantly government controlled, public limited liability company, are responsible for electricity supply in Pakistan. KESC caters to the power needs of the Karachi municipal area and its environs, while WAPDA caters to the power needs of the rest of Pakistan and accounts for about 80 percent of the electricity sales in the country. Both institutions have responsibility for generation, transmission and distribution of power in their respective areas and are subject to the administrative control of the Ministry of Water and power.

WAPDA with a franchise area of about 770,000 sq. km. and an electricity consumption density of 47 MWh/sq. km./year at present (1996[1]) carries out a largely decentralized power distribution operation through eight Area Electricity Boards. KESC, on the other hand has a franchise area of about 6,000 sq. km. and an electricity consumption density of 1,141 MWh/sq. km./year. It at present carries out an essentially centralized power distribution operation.

WAPDA's current installed power generation capacity of 11,113 MW is hydro/thermal based while KESC's installed power generation capacity 1738 MW is purely thermal based. WAPDA's peak generation demand in FY 1996 was 8,278 MW an its energy generation 48,859 GWh; the corresponding figures for KESC were 1,503 MW and 9,377 GWh. WAPDA and KESC are interconnected by power transmission lines at 220 kV and 132 kV having a total power transfer capability of about 850 MW, and, given their combined power generating capacity of 12,166 MW at present, they form one of the largest integrated power systems in the region. Nevertheless, they have tended to operate their power systems rather independently and the power transfer capability between them has not been used to optimize hydro/thermal power generation coordination within the country.

2.1.2 WAPDA's Existing Facilities

WAPDA's current installed generating capacity of 11,113 MW consists of hydro electric plant 4,825 MW. Most of the hydro-electric capacity is located at Tarbela 3,478 MW, Mangla 1,000 MW and Warsak 240 MW. Thermal generating plants are concentrated at Guddu 1,655 MW, Kot Addu 1,088 MW and Jamshoro 710 MW. WAPDA's primary power transmission is carried out at 500 kV and 220 kV. The 500 kV lines connect the major load centers in central and southem Pakistan. Currently, WAPDA's 500 kV transmission system has about 4,239 km of transmission lines and serves about 7,224 MVA of grid substation capacity.

The 220 kV transmission system which supplements the 500 kV system has about 2,449 km of transmission lines and serves about 6,597 MVA of grid substation capacity. Secondary power transmission is carried out at 132 kV and at 66 kV. About 21,974 km of secondary transmission lines serving about 17,687 MVA of grid substation capacity are now in existence. Primary power distribution is carried out at 33 kV and 11 kV through about 173,568 circuit km of distribution line. The low voltage secondary power distribution system based on a 4-wire, 3-phase, 400 V system consists of about 112,072 km of distribution lines.

Generation facilities in the WAPDA system are a hydel thermal mix. Hydels constitute about 43.4% of the total installed capacity. The KESC system on the other hand, has thermal generating facilities only.

2.2 POWER MARKET

During the period FY 1980-96, WAPDA's electricity sales grew from 8,160 GWh to 36,925 GWh at a compound annual rate of 9.89 percent. The growth during the last five years FY 1990-96 has been lower at 6.79 percent a year. WAPDA's electricity generation during these periods grew at lower rates of 9.10 percent and 7.25 percent a year, respectively,

[1] *All figures relate to 1995-96 unless stated otherwise.*

reflecting the gradual reduction, in system loss from 32.7 percent in FY 1980 to 24.43 percent in FY 1996.

A gradual decrease in the overall system load factor is also indicated by the peak power demand growth of 9.03 percent a year during the period. Given the power generation shortages and resulting power supply restrictions that have been required since the early nineteen eighties, it is relevant to note that these power and energy demand figures have been affected by a certain amount suppressed demand which still continues.

The load growth in the WAPDA system is presented as follows: -

WAPDA HISTORICAL TRENDS IN LOAD GROWTH

Financial Year	Gross Generation (GWh)			Energy Sold GWh	System Losses %	Maximum Demand MW	System Load Factor %	Average Revenue Ps./kWh
	Hydro	Thermal	Total					
1980	8718	3406	12124	8160	32.70	2076	66.70	43.95
1981	9046	4160	13206	9068	31.33	2473	61.00	51.69
1982	9526	5242	14768	10288	30.34	2846	59.00	56.78
1983	11366	5126	16492	11587	29.74	3163	59.50	62.01
1984	12822	5230	18052	12762	29.30	3295	62.50	62.74
1985	12245	6532	18777	13756	26.74	3791	56.50	63.82
1986	13804	7251	21055	15504	26.36	3933	61.00	74.40
1987	15251	8379	23630	17745	24.90	4325	63.00	69.59
1988	16689	10762	27451	20702	24.59	5031	62.30	82.89
1989	16974	11924	28898	21982	23.93	5440	60.60	94.44
1990	16925	14502	31427	24121	23.25	5680	63.20	105.73
1991	18298	16137	34435	26585	22.80	6090	64.40	116.51
1992	18647	19419	38066	29267	23.11	6532	66.00	126.81
1993	21111	19680	40791	31272	23.34	7522	62.75	126.15
1994	19436	22960	42396	32131	24.21	8067	59.50	140.77
1995	22858	23268	46126	35032	24.05	8252	59.50	162.58
1996	23206	25653	48859	36925	24.43	8278	67.38	208.70
Growth								
80-96	6.31	13.45	9.10	9.89	-1.81	9.03	0.06	10.23
89-96	4.57	11.57	7.79	7.69	0.30	6.18	1.53	11.99
91-96	4.87	9.71	7.25	6.79	1.39	6.33	0.91	12.37
94-96	9.27	5.70	7.35	7.20	0.45	1.30	6.41	21.76
95-96	1.52	10.25	5.93	5.40	1.58	0.32	13.24	28.37

Source: WAPDA Power System Statistics - March 1997

The significant facts regarding the above statistics are as follows: -

1. Hydel generation has increased at an average rate of 6.31% over the period 1980-1996, this has reduced the share of hydro in total generation from 71.91% in FY1980 to 47.50% in FY 1996. The share of hydro has decreased even more sharply in the last five years. This indicates the increasing weight of thermal generation in the total mix.

2. Energy sales have a lower growth rate in the last five years as compared to the last 16 years. This is possibly due to the recent tariff increase that has dampened growth in sales.

3. System losses have decreased from 32.70 in FY 1980 to 24.43% in FY 1996. This seems to be impressive. In the last five years losses have in fact increased. This is partly due to the increasing weight of thermal generation in total and increased distribution losses (possibly increased non-technical losses) due to the sharp increase in domestic and other tariff.

4. System load factor has decreased from 66.7% in FY 1980 to 67.38% in FY 1996. This is mainly due to the enhanced capacity of WAPDA to meet system peak demand in summer as a result of the Tarbela units 11-14 (1728 MW) available mainly in the summer high water months. The increased ability to meet summer demand has not achieved a matching improvement in the first half of the year, although increased share of thermal has to some extend reduced winter capacity and energy shortages.

5. The average tariff has increased from 43.95 Ps, /kWh in FY 1980 to Ps. 208.70/kWh in FY 1996. In real terms the tariff/kWh has decreased over time. Tariff has not kept up with inflation, although tariff increases in the last 5 years perhaps match inflation.

During the last 16 years domestic customers grew at a rate of 8.57% which has slowed down to 6.04% during the last five years, this is mainly due to slowdown in new rural customer connected in the recent past. Drop in growth in commercial new customers connected could be similarly explained. The essential statistics are as follows:-

WAPDA's Power Market Customers

Financial Year	Domestic Nos	Commercial Nos	Industrial Nos	Agriculture Nos	Public Light Nos	Bulk & Others Nos	Total Nos
1980	2087364	496012	107168	101949	1477	821	2794791
1981	2479453	571800	111484	104108	2090	1010	3269945
1982	2732962	624900	115833	111278	2161	1108	3588242
1983	2989377	674600	119464	114390	2390	1215	3901436
1984	3261362	724516	123508	118265	2511	1483	4231645
1985	3500196	770465	128441	120905	2447	1541	4523995
1986	3780108	834127	133573	124918	2647	1684	4877057
1987	4106424	898118	139537	130034	2801	1772	5278686
1988	4525987	964377	147439	136860	3017	1943	5779623
1989	5077901	1039033	153042	143869	3247	2075	6419167
1990	5467738	1088932	158800	149554	3453	2202	6870679
1991	5805382	1134754	162624	152169	3531	2261	7260721
1992	6219656	1185723	169436	155305	3759	2362	7736241
1993	6622977	1221223	172145	153088	3829	2488	8175750
1994	6995561	1257887	174577	157710	3730	2577	8592042
1995	7376032	1342946	179392	162303	3910	2701	9067284
1996	7783832	1344975	181092	165114	3990	2728	9481731
Growth							
80-96	8.57	6.43	3.33	3.06	6.41	7.79	7.93
89-96	6.29	3.76	2.43	1.99	2.99	3.99	5.73
91-96	6.04	3.46	2.17	1.65	2.47	3.83	5.48
94-96	5.48	3.40	1.85	2.32	3.43	2.89	5.05
95-96	5.53	0.15	0.95	1.73	2.05	0.99	4.57

Source: WAPDA Power System Statistics - March 1997

The rate of growth in customers connected has dampened in the last year for all customer category classes except for domestic customers this can perhaps be explained by : economic slowdown; and financial difficulties faced by WAPDA. Domestic customer growth remained unaffected since rural electrification activity continued by virtue of donor funding, inspite of WAPDA's financial difficulties.

The total domestic and commercial consumption has grown at a smaller rate during the last five years as compared to the last 16 years for reasons presented above. Industrial consumption has grown at a lessor pace in the last five years due to macro economic impact. Tubewell growth has been dampened by price increases and near saturation in pumping potential. Industrial consumption has in fact registered a decrease in the last two years. This is the result of the economic problems faced by the country; due to the macro restructuring of the economy; high energy tariffs; high interest rates; import tariff readjustment; and increased theft due to electricity tariff increases.

Consumption statistics are presented as follows:-

WAPDA's Power Market Consumption

Financial Year	Domestic GWh	Commercial GWh	Industrial GWh	Agriculture GWh	Public Light GWh	Bulk & Others GWh	Total GWh
1980	1564	389	3154	2056	50	947	8160
1981	1858	445	3482	2125	58	1100	9068
1982	2408	574	3960	2357	75	914	10288
1983	2866	634	4417	2546	78	1046	11587
1984	3470	739	4708	2663	75	1107	12762
1985	3888	796	5061	2782	77	1152	13756
1986	4514	875	5894	2880	90	1251	15504
1987	5357	991	6436	3452	110	1399	17745
1988	6290	1054	7236	4394	117	1611	20702
1989	6939	1068	7579	4357	127	1912	21982
1990	7647	1106	8360	5004	148	1856	24121
1991	8618	1152	9114	5595	178	1928	26585
1992	9691	1192	10213	5823	228	2120	29267
1993	11220	1303	10912	5595	195	2047	31272
1994	11964	1318	10532	5742	216	2359	32131
1995	13449	1490	10603	6256	235	2563	34596
1996	14792	1653	10329	6658	301	3192	36925
Growth							
80-96	15.08	9.46	7.70	7.62	11.87	7.89	9.89
89-96	11.42	6.44	4.52	6.24	13.12	7.60	7.69
91-96	11.41	7.49	2.53	3.54	11.08	10.61	6.79
94-96	11.19	11.99	-0.97	7.68	18.05	16.32	7.20
95-96	9.99	10.94	-2.58	6.43	28.25	5.73	5.34

Source: WAPDA Power System Statistics - March 1997

The growth in customer consumption for domestic, commercial, industrial and agricultural has slowed down in the last 5 years as compared to the last 16 years. This is partly explained by the recent tariff increases. Per customer consumption over time is as follows:-

WAPDA's Power Market Per Customer Consumption

Financial Year	Domestic GWh	Commercial GWh	Industrial GWh	Agriculture GWh	Public Light GWh	Bulk & Others GWh	Total GWh
1980	749	784	29430	20167	33852	1153471	2920
1981	749	778	31233	20411	27751	1089109	2773
1982	881	919	34187	21181	34706	824910	2867
1983	959	940	36973	22257	32636	860905	2970
1984	1064	1020	38119	22517	29869	746460	3016
1985	1111	1033	39403	23010	31467	747567	3041
1986	1194	1049	44126	23055	34001	742874	3179
1987	1305	1103	46124	26547	39272	789503	3362
1988	1390	1093	49078	32106	38780	829130	3582
1989	1367	1028	49522	30284	39113	921446	3424
1990	1399	1016	52645	33459	42861	842870	3511
1991	1484	1015	56043	36768	50411	852720	3661
1992	1558	1005	60276	37494	60654	897544	3783
1993	1694	1067	63388	36548	50927	822749	3825
1994	1710	1048	60329	36409	57909	915406	3740
1995	1823	1110	59105	38545	60027	1117647	3866
1996	1900	1229	57037	40324	75439	1170088	3894
Growth							
80-96	5.99	2.85	4.22	4.43	5.14	0.09	1.82
89-96	4.82	2.59	2.04	4.17	9.84	3.47	1.85
91-96	5.06	3.90	0.35	1.86	8.40	6.53	1.24
94-96	5.41	8.30	-2.77	5.24	14.14	13.06	2.05
95-96	4.22	10.77	-3.50	4.61	25.67	4.69	0.74

Source: WAPDA Power System Statistics - March 1997

2.3 CURRENT CRISIS AND MITIGATING STEPS

2.3.1 Load Shedding and Mitigating Steps

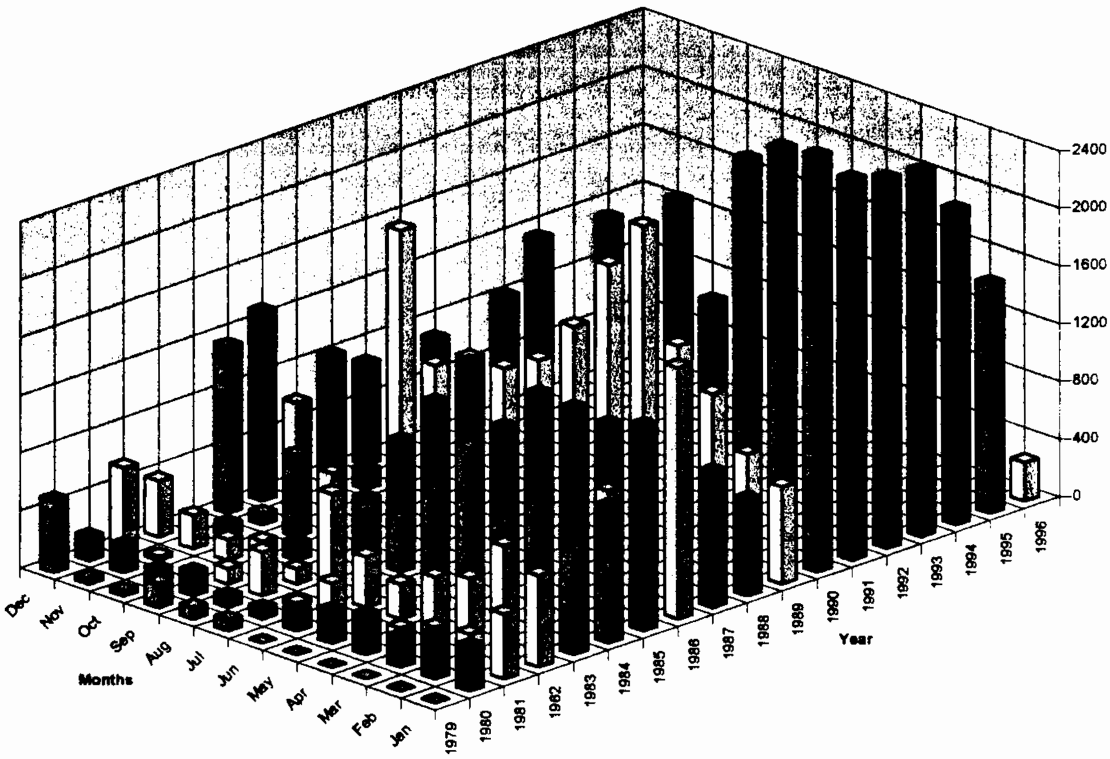
The WAPDA AND KESC Systems are currently supply - constrained in both generation capacity and transmission capability, necessitating selective load shedding during both peak and off-peak periods. Load shedding will continue in the near future until sufficient additional capacity is added to meet growing demand. There is need to meet growing demand but there is greater need to: Correct supply mix distortions which are responsible for inability to meet load; Add new generation to meet growing demands, this new addition should maintain the corrected optimum generation mix;

WAPDA's load shedding is concentrated in early winter and early summer months. These periods are characterized by low hydro-electric capacity or energy availability. Load shedding has been resorted to by WAPDA since FY 1982. The following table illustrates the extent of load shedding over the period 1979-1996.

WAPDA-LOAD SHEDDING-CAPACITY (MW)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
1979	0	0	0	0	0	0	76	80	168	28	35	496	496
1980	300	300	199	272	220	134	74	76	165	97	181	163	300
1981	445	225	190	101	94	251	29	305	106	0	29	562	562
1982	635	760	450	378	246	354	709	104	217	145	231	391	760
1983	295	560	650	323	200	0	330	120	113	15	84	15	650
1984	510	546	806	573	1022	630	366	341	169	560	73	1150	1150
1985	1392	774	1331	1050	1044	1223	1087	541	257	17	168	1307	1392
1986	1746	965	725	263	117	600	110	17	69	74	192	595	1746
1987	630	647	471	586	836	1062	219	529	452	0	125	840	1062
1988	660	770	1026	922	851	880	380	584	947	276	242	700	1026
1989	675	820	1154	1405	2151	1800	1288	975	838	823	692	1546	2151
1990	1663	1392	1089	0	0	496	438	660	806	656	190	706	1663
1991	837	1038	336	554	1047	765	1316	974	737	258	250	284	1316
1992	1128	1108	869	725	973	800	604	857	820	557	242	837	1128
1993	1713	241	244	748	1245	2198	1133	1752	1344	1178	240	1154	2198
1994	2179	2359	2229	2143	2225	2193	0	0	0	0	0	0	2359
1995	1583	183	3	69	622	359	100	159	205	30	34	1127	1583
1996	268	180	35	407	343	437	163	197	554	60	30	40	554
Mean	980	757	695	619	779	834	491	482	459	279	177	672	1271
Max	2179	2359	2229	2143	2225	2198	1316	1752	1344	1178	692	1546	2359
Min	268	180	3	0	0	0	0	0	0	0	0	0	300
STD	593	528	550	523	646	651	441	448	379	341	154	465	597

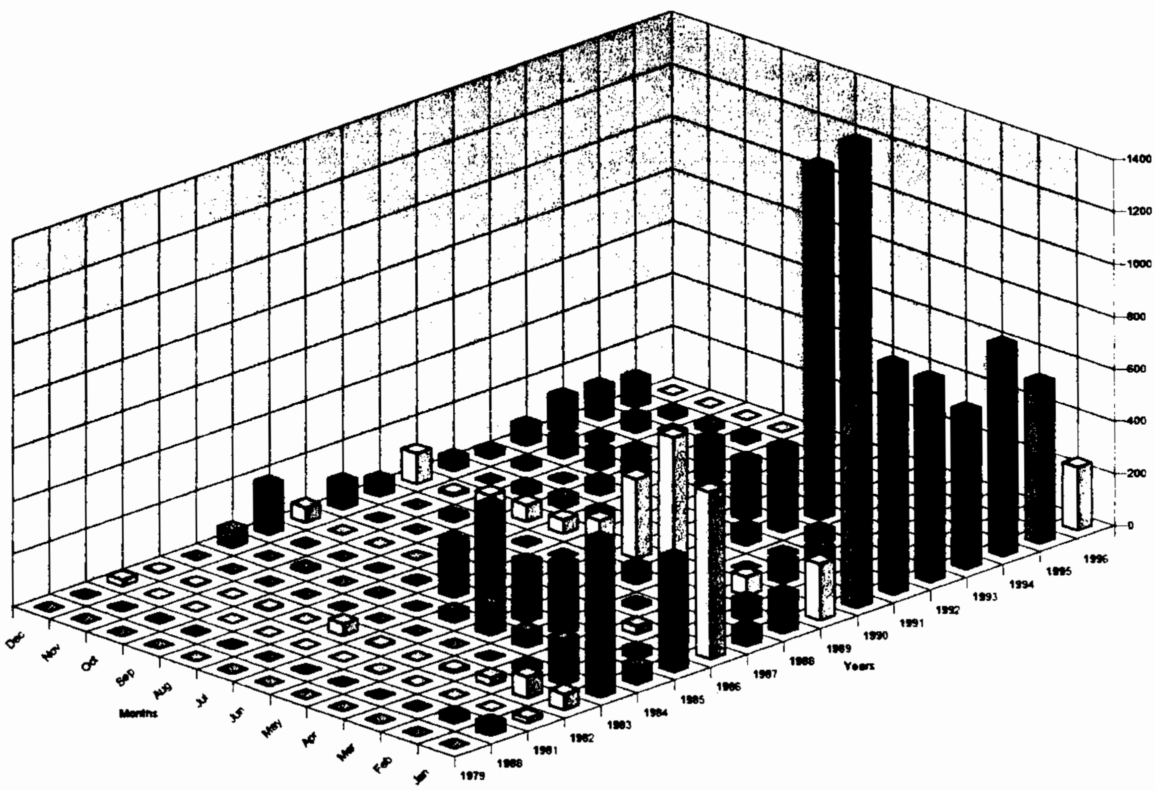
WAPDA Load Shed (MW)



WAPDA-ENERGY SHEDDING-ENERGY (GWh)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
1979	0	0	0	0	0	0	1	0	0				1
1980	45	29	4	2	3	2	1	4	5				103
1981	18	2	1	0	0	2	0	1	1				49
1982	63	81	30	10	1	8	46	1	6				253
1983	237	86	16	2	0	0	1	1	0				344
1984	67	36	77	57	112	41	3	5	1			63	475
1985	330	31	389	239	228	390	209	4	3			190	2015
1986	636	60	32	4	0	33	2	0	0			56	825
1987	62	4	20	15	25	76	1	6	11			102	323
1988	148	74	131	140	61	114	5	6	29			59	785
1989	216	47	73	267	509	304	97	54	63			117	1811
1990	754	176	79	0	0	59	21	32	40			47	1244
1991	151	132	24	10	60	68	56	117	52			26	726
1992	405	361	63	50	90	85	80	75	85	j		75	1517
1993	375	29	30	42	123	205	98	159	63			134	1307
1994	802	504	576	585	1382	1247	66	32	40			127	5462
1995	611	47	26	11	30	34	32	31				107	1005
1996	241	9	5	7	32	44	338						
Mean	304	100	93	85	156	160	45	33	27	19	14	71	1093
Max	802	504	576	585	1382	1247	209	159	85	73	75	190	5462
Min	18	2	1	0	0	0	0	0	0	0	0	1	49
STD	249	131	150	149	330	292	55	46	27	22	22	53	1234

WAPDA Energy Shed (GWh)



The need for load shedding has arisen not only due to the inadequacy of power generating capacity but also due to the fact that WAPDA's major hydropower plants at Tarbela (3478 MW) and Mangla (1000 MW) suffer from the dual constraints of: electrical power output reduction when reservoir levels are low around mid May; and electrical energy output restriction when irrigation needs are low and water releases through the power plants are restricted from mid December to mid February. The second constraint is more serious since restricted electrical energy supply results in a considerable impact on the economy.

The economic impact of the first constraint is less severe since there is less restriction on the amount of electrical energy output; however, the efficiency of water utilization is low. The total impact of load shedding on the economy is substantial and is estimated at about $600 million for FY1991. The fact that the dams at Tarbela and Mangla were built in the late 1960s by the irrigation sector mainly for the benefit of that sector; rapid growth of demand for relatively under priced electricity in the 1970s generated from newly found and under priced gas resources from Sui; inability of the country to embark on a nuclear power generation program although power planning studies in the early 1970s did indicate the feasibility of doing so; and/or; inability to add base load thermal power generating facilities; low priority given to power sector investments in the latter part of the 1970s. The root causes for load shedding can be traced to:

In FY1985 the Government made an effort to eliminate load shedding by FY1990 but realized that funds in the magnitude required could not be made available through the public sector. It was at this point that the Government sought additional resources from the private sector and encouraged private sector sponsored power generation.

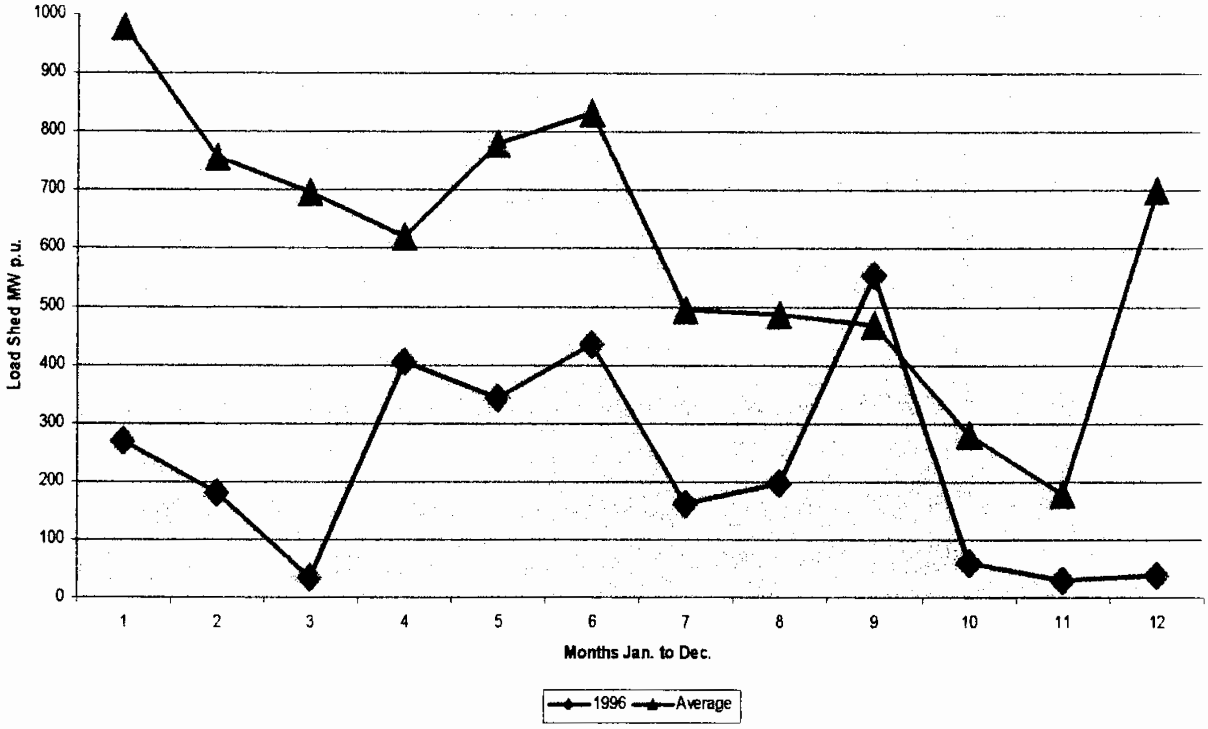
The load shedding profile presented above is undergoing a fundamental change. The system is gradually evolving into a capacity deficient one from the energy deficient system of the near past. WAPDA has made significant investments in base load thermal capacity, through their own investments (2567 MW) and through private initiatives (6,623).

The above means that the power mix is being altered in a rather fundamental manner. The base load capacity being added will result in an end to winter and early year load shedding. The last two years already indicate that the effect of hydrology in December to May period is mitigated by addition of base load capacity. The critical areas for the systems will in future be; The July to August period, this is the maximum demand period. Thermal capacity added will only be partially available due to scheduled maintenance; WAPDA has converted all existing thermal peak load facilities to base load combined cycle facilities. WAPDA therefore will have problems in adequately meeting the daily peak demands almost through out the year.

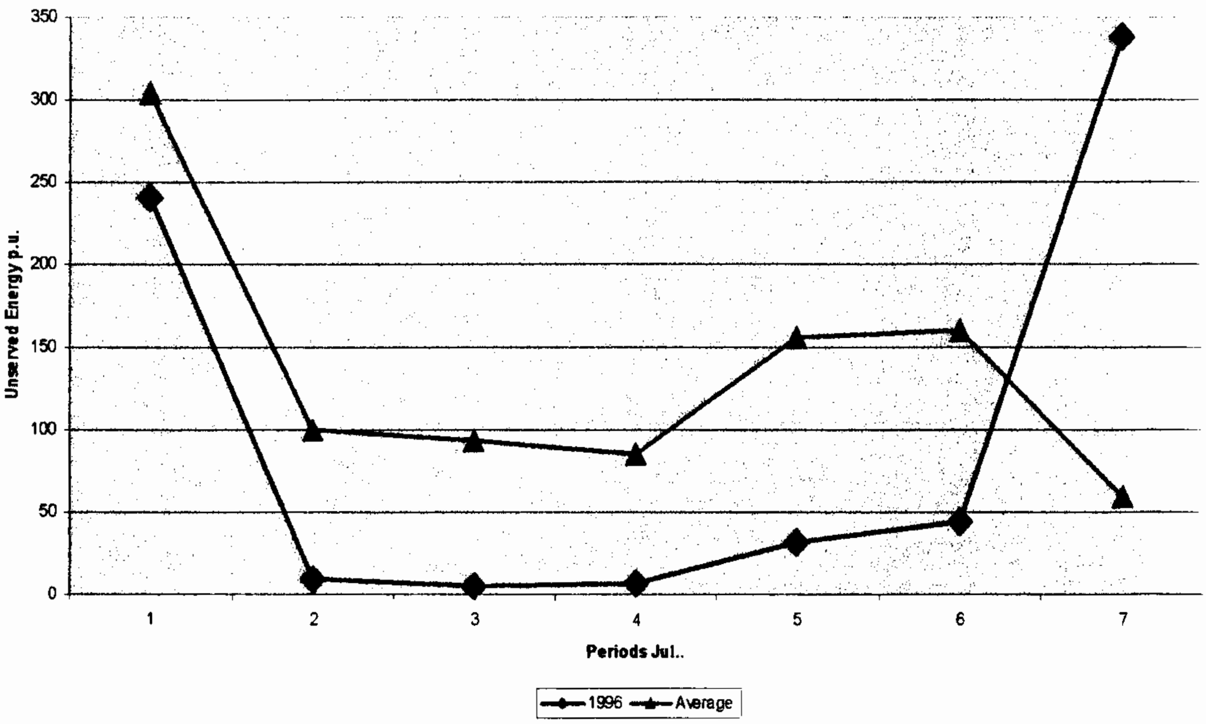
The impact of adding thermal base load capacity upon load shedding is best explained by the graph that follows. The graph shows the comparison of the distribution of load-shed, on average, between 1979-1996 and the load shedding distribution for the year 1996. The graph indicates the mitigation of load shedding in winter months due to addition of base load thermal capacity. These are two observations which need to be made. Firstly the comparison is between average of 17 years and a single year data. Secondly the impact will be enhanced as the IPP's start to come on line, in 1997 Hub River and Kot Addu were on line, other stations will be commissioned in the near future. The point here is to indicate that the system will have problems to meet the summer peak and the daily peak. (Presented on next page).

The comparison between historical energy unserved to planned estimates of unserved energy also supports the above argument. The historical has been winter and early year load shedding (December to May) whereas the long term system expansion plan envisages that the unserved energy will be a function of the peak demand months (June to August), presented on next page.

Load Shed in p.u. WAPDA System
1979-96 Avg. p.u. Compared to 1996 p.u



Comparasion of Unserved
Energy by Months-Plan vrs Historical



WAPDA's Power System Loss & Mitigating Steps

WAPDA's system loss has been reduced from 32.7 percent in FY 1980 to 26.36 percent in FY 1986 and to 24.43 percent in FY 1996. Losses as % of total have decreased at an average of 1.81% over the 16 year period. However in the last 5 years losses as % of total have grown at 1.39% average per year.

WAPDA losses are presented as follows:

WAPDA SYSTEM LOSSES

Financial Year	Units Generated GWh	Consmption Aux. GWh	Thermal Generation GWh	Thermal Generation % total	Units Sold GWh	Losses GWh	Losses[2] %	Average Tariff Ps./kWh
1980	12124	269	3406	28.09	8160	3964	32.70	43.95
1981	13206	344	4160	31.50	9068	4138	31.33	51.69
1982	14768	390	5242	35.50	10288	4480	30.34	56.78
1983	16492	399	5126	31.08	11587	4905	29.74	62.01
1984	18052	400	5230	28.97	12762	5290	29.30	62.74
1985	18777	404	6532	34.79	13756	5021	26.74	63.82
1986	21055	402	7251	34.44	15504	5551	26.36	74.40
1987	23630	406	8379	35.46	17745	5885	24.90	69.59
1988	27451	454	10762	39.20	20702	6749	24.59	82.89
1989	28898	495	11924	41.26	21982	6916	23.93	94.44
1990	31427	623	14502	46.15	24121	7306	23.25	105.73
1991	34435	859	16137	46.86	26585	7850	22.80	116.51
1992	38066	928	19419	51.01	29267	8799	23.12	126.81
1993	40791	942	19680	48.25	31272	9519	23.34	126.15
1994	42396	1112	22960	54.16	32131	10265	24.21	140.77
1995	46126	1199	23268	50.44	35032	11094	24.05	162.58
1996	48859	1429	25653	52.50	36925	11934	24.43	208.70
Growth								
80-96	9.10	11.00	13.45	3.99	9.89	7.13	-1.81	10.23
89-96	7.79	16.35	11.57	3.50	7.69	8.11	0.29	11.99
91-96	7.25	10.72	9.71	2.30	6.79	8.74	1.39	12.37
94-96	7.35	13.36	5.70	-1.54	7.20	7.82	0.44	21.76
95-96	5.93	19.18	10.25	4.08	5.40	7.57	1.55	28.37

Source: WAPDA Power System Statistics, March 1997

WAPDA's losses as % by functions is presented as follows:

[2] Total losses ÷ Total units generated

WAPDA System Losses

Financial Year	Auxiliary Consumption %[3]	Transmission %[2]	Distribution %[2]	Total %[2]
1980	2.22	11.00	19.50	32.70
1981	2.60	10.70	18.10	31.33
1982	2.64	9.20	18.50	30.34
1983	2.42	9.60	17.70	29.74
1984	2.22	9.90	17.20	29.30
1985	2.15	9.40	15.20	26.74
1986	1.91	9.10	15.40	26.36
1987	1.72	8.70	14.50	24.90
1988	1.65	8.50	14.50	24.59
1989	1.71	8.30	13.90	23.93
1990	1.98	8.69	12.58	23.25
1991	2.49	8.69	11.62	22.80
1992	2.44	9.18	11.50	23.12
1993	2.31	8.99	12.07	23.34
1994	2.62	8.77	12.82	24.21
1995	2.60	7.58	13.87	24.05
1996	2.92	7.69	13.82	24.43
Groth				
80-96	1.06	2.45	2.25	2.03
89-96	7.20	-1.50	-0.04	0.08
90-96	5.57	-2.70	1.97	0.68
93-96	6.11	-8.18	7.20	1.52
94-96	-0.87	-13.57	8.19	-0.67
95-96	12.31	1.45	-0.36	1.58

Source: WAPDA Power System Statistics - March 1997

Losses as % of total in auxiliary consumption have increased at an average rate of 1.73% p.a., this growth in the last 5 years has been at a rate of 3.20% average p.a. These can be explained by the fact that share of thermal generation over total generation has grown from 28.09% in 1980 to 41.26% in 1989 to 52.50% in 1996.

The level of power transmission loss has to be considered with the fact that WAPDA's ratio of primary and secondary power transmission circuit kilometers to installed generation capacity in megawatts at 2.6 is perhaps the highest in the region[4]. The above level of WAPDA's transmission loss can, however, be expected to drop with the commissioning of under construction 500 kV lines to Lahore and Peshawar and due to the ongoing secondary transmission and grid station expansion program.

Considering WAPDA's low demand density of about 47 MWh/sq. km/year and rapid distribution network expansion rate of about 10 km/GWh/year the performance in power distribution loss reduction from about 20 percent in 1980 to 13.83 percent in 1996 is quite creditable. This has been achieved through a continued program of well planned distribution system expansion and rehabilitation coupled with a massive drive against non-technical losses.

Distribution technical losses have been reducing in the past years and can be expected to reduce further with continuing technical improvements, including further addition of capacitors for the distribution system. Distribution losses have registered an increase in the last 5 years by 3.53%. This is inspite the energy loss reduction program. This increase is attributed by WAPDA to non-technical losses which have increased in response to increase in domestic tariff.

[3] as percentage of gross generation
[4] *a couple of comparisons are Indonesia (PLN) at 1.6 and Malaysia (NEB) at 1.9; the corresponding figures of net system loss are 16 and 15 percent, respectively*

2.3.2 Constraints to Power Production

Both the hydro-electric and thermal components of the generating system suffer from operational constraints making it difficult to meet the electricity demands of the consumers.

- **Hydro-electric Power Constraints**

Over 90% of hydro-electric energy production is from the two principal storage developments, Mangla and Tarbela. Their current live storage capacities are:

Live Storage	**Mangla**	**Tarbela**
Volume (km^3)	5.6	10.4
Percentage of Annual Inflow	20	14

It can be seen that their live storage volumes are large - but not when compared with their inflow volumes. Furthermore, the operations of these projects are dictated by the needs of irrigation. To a large extent, power is generated as a by-product of reservoir releases made to meet irrigation demands. This is particularly evident in the month of January when, irrigation canal maintenance takes place and the hydro-electric energy production is very low.

- **Thermal Power Constraints**

Most stations normally operating on gas are required to switch to furnace oil or HSD in the winter months when gas demands in the domestic sector are high. There are also sometimes fuel supply constraints, particularly in the winter period, which limit production. The ongoing capacity deficits in the power system places pressure on plant operators, on occasion, to postpone regular maintenance resulting, sometimes, in excessive forced outages.

- **Supply Demand Balance**

The generation system is stressed in relation to the demand at two critical times of the year. The first is the mid-winter period, particularly January, when hydro-electric energy is low and constraints to thermal power production combine to yield large amounts to load shedding. The peak power demands for the country occur in the May-July period, when the storages are not full and insufficient thermal capacity exists to meet the peak load.

2.3.3 Generation Constraints

- **Hydel Availability**

WAPDA depends very heavily on the output of its two major hydel power stations at Tarbela and Mangla. Due to hydrological and operational reasons the outputs from these stations are subject to wide variations. The implication of this is that from late July to early December when hydel output is at full capacity there are generally no power shortages. At other times supply lags demand by 1200 MW (FY 1994). The system experiences considerable shortages of: both capacity and energy during late winter to early summer when reservoir levels are low; capacity late in the summer when demand is rising but hydel capability is decreasing and; energy in end December and early January due to canal closures.

- **Thermal Plant Maintenance**

Thermal maintenance is scheduled for periods when hydel capability is to its peak capacity during July to early December. The recent shift from a hydel dominated system to a hydel thermal mixed system makes this no more fully possible. This requires some thermal maintenance to be scheduled for periods when hydel capability is low thereby adversely effecting unserved energy and system reliability. KESC which schedules its maintenance in winter (due to low load requirements) could contribute to WAPDA's shortfall by rescheduling its maintenance. Lack of proper institutional arrangements and take off pricing arrangements inhibit such arrangements.

- **Hydel Pricing**

The constitutional provision of payment of royalties on 'profits' on hydel generation means that WAPDA has little incentive to optimize hydel operation since savings with respect to avoided thermal cost appear as a cost to WAPDA under current methodology of calculation of 'profits' on hydel generation.

- **Transmission Constraints**

The transmission system ties between WAPDA and KESC have deficiencies of capacity and there are also some technical problems. This has in the past resulted in water being spilled when hydroelectric energy could otherwise be used in the KESC system. WAPDA system transmission has constraints, in the shape of : line and transformer over loading; stability problems; difficulties with control of voltage or reactive power. This has at times resulted in local load shedding merely to meet transmission constraints.

2.3.4 Arrears

Receivables continue to be WAPDA's problem although in recent years recoveries have improved. Arrears are partly a political problem beyond control of WAPDA. Reduction of non-technical losses and receivables is perceived by WAPDA, as a problem related to corruption. WAPDA is evolving a framework for involvement of the private sector in operation of the distribution system. WAPDA has also been given additional powers to recover receivables and use of there powers has improved WAPDA's position on this account. WAPDA arrears are presented as follows:

WAPDA ARREARS

Financial Year	Total Amount Billed M.Rs.	Receipts M.Rs.	Arrears M.Rs.	Accumulate Arrears M.Rs.	Accumulate Arrears % of Year	Arrears as % of Billed
1980	3915.71	3718.37	197.34	756.96	19.33	5.04
1981	4791.82	4607.74	184.08	941.04	19.64	3.84
1982	6012.75	5748.58	264.17	1205.21	20.04	4.39
1983	7367.99	7118.30	249.69	1454.90	19.75	3.39
1984	8213.94	7926.07	287.87	1742.77	21.22	3.50
1985	8991.45	8909.68	81.77	1824.54	20.29	0.91
1986	11759.95	11250.63	509.32	2333.86	19.85	4.33
1987	12583.86	12328.86	255.00	2588.86	20.57	2.03
1988	17436.54	17001.11	435.43	3024.29	17.34	2.50
1989	21158.86	20869.55	289.31	3313.60	15.66	1.37
1990	25965.14	24718.22	1246.92	4560.52	17.56	4.80
1991	31604.70	29634.25	1970.45	6530.97	20.66	6.23
1992	38808.95	36537.71	2271.24	8802.21	22.68	5.85
1993	43514.00	42164.72	1349.28	10151.49	23.33	3.10
1994	49929.08	49006.76	922.32	11073.81	22.18	1.85
1995	62518.48	61353.07	1165.41	12239.22	19.58	1.86
1996	81226.16	78837.36	2388.80	14628.02	18.01	2.94
Growth	20.87	21.03	16.87	20.33	-0.44	-3.31
80-96	21.19	20.91	35.20	23.63	2.02	11.56
89-96	20.78	21.62	3.93	17.50	-2.71	-13.95
91-96	27.55	26.83	60.93	14.93	-9.89	26.18
94-96	29.92	28.50	104.98	19.52	-8.01	57.77
95-96						

Source: WAPDA Power System Statistics, March 1997

2.4 LOAD FORECAST

2.4.1 Various Load Forecasts

Given the forecast rate of growth in population (about 2.6 percent a year), the forecast yearly rate of growth in GDP (6.0 percent), the present percentage of population with access to electricity (46 percent) and the present level of per capita annual electricity consumption (275 kWh), there is continued pressure for; the addition of new consumers to the existing power system; spatial expansion of the power transmission system; and increase in the specific consumption of existing consumers. Hence, the continued increase in the demand for electricity.

WAPDA periodically updates its medium term and long term electricity demand forecast using appropriate computer-based analytical procedures. These procedures utilize load surveys, end-use analysis, regression and extrapolation techniques, and keep in view the effects of continuing improvements in system loss reduction and demand management programs

Estimates (by ADB for the 12th WAPDA project) were of the likely sales forecast for WAPDA and KESC using an econometric model which correlates electricity consumption in different market categories with variables such as real past consumption. Based on this analysis, the estimates for average growth rate for electrical energy generation is to be about 8.8 percent per year up to the year 2000. WAPDA estimates this overall growth rate to be slightly higher at 9.2 percent per year.

The latest WAPDA effort was during the just concluded National Power Plan (NPP), CIDA funded, program. The last WAPDA forecast (1995 - for updating of National Power Plan) is presented as follows:

National Power Plan Base Case Demand Forecast

Financial Year	WAPDA MW	KESC MW	Undiversified MW	Diversified[5] MW
1995	8753	1518	10272	10070
1996	9597	1590	11187	10968
1997	10501	1666	12167	11928
1998	11454	1764	13200	12942
1999	12486	1828	14314	14033
2000	13592	1919	15511	15207
2001	14788	2034	16822	16492
2002	16100	2156	18256	18256
2003	17557	2285	19842	19453
2004	18991	2422	21414	20994
2005	20514	2568	23082	22630
2006	22131	2722	24853	24365
2007	23847	2885	26732	26208
2008	25669	3058	28728	28164
2009	27569	3242	30811	30207
2010	29577	3436	33013	32365
2011	31820	3642	35462	34767
2012	34201	3861	38062	37315
2013	36728	4093	40821	40020
2014	39338	4338	43676	42820
2015	42095	4598	46694	45778
2016	45008	4874	49882	48904
2017	48085	5167	53252	52207
2018	51336	5477	56812	55699
Growth Average p.a.				
95-2005	8.89	5.40	8.43	8.43
95-2018	7.99	5.74	7.72	7.72

Source: NPP, March 1996.

6 *The peak demands of WAPDA system and KESC system do no coincide. A diversity factor of 1.02 is applied to derive the demand at the national level*

The WAPDA forecast uses the Energy Wing forecast (prepared for the long term perspective plan, FY 1988 to FY 2013, as the reference forecast). The energy wing forecast was developed on a countrywide forecasting model called "Respak". This was an end-use model which predicts total energy requirements based on sectoral economic growth, but incorporates adjustment factors for technological change, increased energy efficiency and substitution between fuel types.

The WAPDA-NPP approach has been to develop the load forecast based on historical relationships and to separately estimate the impact of Demand Side Management on energy and demand. The final forecast is then derived deducting the DSM impacts on forecasted energy and demand. The above forecast even without DSM impacts is lower than the initial load forecast based on the energy wing model. This is because of methodology and economic data utilized in the forecast. The NPP forecast is presented as follows:-

The Lybrand and Coopers Tariff study also prepared a forecast, which was based on the Metro-economica energy model (UNDP WASP run 1988). This was a impact input-output model. The above referred study developed the forecast (with new parameters) using the model.

2.4.2 Comparative Discussion of Forecasts

The comparison of the four forecasts is as follows:

Maximum Demand - WAPDA & KESC MW

Financial Year	Energy Wing	NPP[6]	NPP with DSM[7]	L&C[8]
1995	9640	10070	9153	9740
2005	22214	22630	17903	18880
2010	33133	32365	24903	26340

Source: Derived

There was no attempt made to prepare a load forecast for the purposes of this report. However elementary modelling done on WAPDA data (data presented in Volume 3 of 23 - Statistical Appendix - Report No.NPP-10 - November 1993) did result in significantly lower forecast for industrial sales. It would seem that the WAPDA forecast is a higher bound one. This is understandable since WAPDA's funding is a function of forecasted demand. The forecast is higher bound one due to the fact that the past data is distorted.[9]

The other explanation for this deviation could be the methodology used by WAPDA. The WAPDA forecast is such that:

- a short term energy forecast to FY 2000 is based on the power market survey model, a trend analysis.
- a long term forecast (FY 2000 to FY 2018) based on a regression analysis of past consumption trends and relationships, without removing distortions in historical data.

The NPP forecast also does not consider the impact on electricity sales of real price changes. The impact of the forecast on the capacity addition exercise has been lessened by use of Demand Side Management (DSM) impacts to project lower peak demand.

[6] *Latest forecast, March 1995 developed to update the National Power Plan (currently under work).*
[7] *DSM: Demand Side Management, November 1993 version*
[8] *L&C: Lybrand & Cooper - Tariff Study*
[9] *PDA and KESC historical data is 'distorted' in the sence that : domestic consumption includes rural consumption. Weight of rural domestic consumption in total domestic consumption is changing, historical rate of change in weight of rural consumption will not be duplicated in the futura; industrial consumption is based on higher energy intensity due to inefficient use of energy and to larger weight of energy intensive industries, trends which are not likely to persist, industrial consumption and GDP relationship is also flawed since a significant portion of new industrial demand is actually fuel substitution due to grid expansion which does not contribute to increase in GDP, industrial consumption based on historical relationship tends to be on the higher side*

NPP Forecast - DSM Impacts

	WAPDA & KESC				DSM Impacts			After DSM Impacts			
Year	Sales GWh	Generation GWh	Peak Demand MW	Load Factor (%)	Sales Impacts GWh	Generation Impacts GWh	Peak Demand MW	Sales GWh	Generation GWh	Peak Demand MW	Load Factor (%)
1991	32,175	40,914	7,118	65.6	0	0	0	32,175	40,914	7,118	65.6
1992	35,976	46,159	7,694	68.5	0	0	0	35,976	46,159	7,694	68.5
1993	38,413	48,029	8,063	68.0	0	0	0	38,413	48,029	8,063	68.0
1994	41,994	51,984	8,727	68.0	459	568	138	41,536	51,416	8,589	68.3
1995	45,788	56,165	9,429	68.0	917	1.125	276	44,871	55,040	9,153	68.6
1996	49,638	60,430	10,235	67.4	1,376	1.675	414	48,871	58,755	9,821	68.3
1997	53,784	65,086	11,123	68.8	1,834	2.220	552	51,950	62,866	10,571	67.9
1998	58,058	69,789	12,034	66.2	2,293	2.756	690	55,765	67,033	11,344	67.5
1999	62,297	74,742	13,006	65.6	2,751	3.301	828	59,545	71,441	12,178	67.0
2000	66,733	79,928	14,037	65.0	3,210	3.845	966	63,523	76,083	13,071	66.4
2001	72,390	86,671	15,221	65.0	3,980	4.765	1.340	68,410	81,906	13,882	67.4
2002	78,449	93,918	16,494	65.0	4,750	5.687	1.714	73,699	88,231	14,781	68.1
2003	84,940	101,681	17,858	65.0	5,520	6.608	2.088	79,420	95,073	15,770	68.8
2004	91,590	109,632	19,254	65.0	6,290	7.530	2.461	85,299	102,102	16,793	69.4
2005	98,656	118,081	20,738	65.0	7,061	8.451	2.835	91,595	109,630	17,903	69.9
2006	106,165	127,059	22,314	65.0	7,831	9,372	3,209	98,334	117,687	19,105	70.3
2007	114,143	138,597	23,990	65.0	8,601	10.293	3.583	105,542	126,305	20,407	70.7
2008	122,620	146,733	25,770	65.0	9,371	11.214	3.957	113,249	135,519	21,813	70.9
2009	131,500	157,349	27,634	65.0	10,141	12,134	4,331	121,359	145,214	23,304	71.1
2010	140,897	168,582	29,607	65.0	10,911	13.055	4.704	129,986	155,527	24,903	71.3
2011	150,839	180,467	31,694	65.0	11,681	13.976	5.078	139,158	166,491	26,616	71.4
2012	161,358	193,041	33,903	65.0	12.451	14.896	5.452	148,907	178,145	28,451	71.5
2013	172,487	206,345	36,239	65.0	13.221	15.817	6.200	159,266	190,528	30,413	71.5
2014	183,998	220,103	38,655	65.0	13.992	16.737	6.200	170,007	203,366	32,456	71.5
2015	196,125	234,597	41,201	65.0	14.762	17.657	6.573	181,363	216,940	34,627	71.5
2016	208,899	249,865	43,882	65.0	15.532	18.578	6.947	193,367	231,287	36,935	71.5
2017	222,355	265,948	46,707	65.0	16.302	19.498	7.321	206,053	246,450	39,385	71.5
2018	236,528	282,888	49,682	65.0	17.072	20.418	7.695	219,456	262,470	41,987	71.4
Avg. Growth 1992-2018		7.22%	7.44%					7.20%	6.91%	6.74%	

Source: WAPDA - NPP-18, Draft Report, November 1993

2.4.3 Industrial Consumption

The forecast of industrial consumption seems to be overstated. This is possibly the resent of using past data where for a number of reasons, energy intensity increased over time. This trend is not likely to continu as the economy matures or tends towards maturity.

2.4.4 System Load Factor

The system load factor has historically (1968-92) varied between 55% and 65%. The WAPDA System forecast shows the annual system load factor to vary from 68% in 1993 to 65% in 2000 and is shown as constant at 65% from 2000 to 2018. It would seem that WAPDA is over estimating the system load factor.

The conclusion that WAPDA is over estimating system annual load factor has two implications: firstly the demand at system level is underestimated; and secondly the requirement for peak capacity and energy is underestimated. The implication is of significance to High Head Hydel Power Plants which target to supply peak capacity and energy.

2.5 POWER DEMAND SEEN FROM PROJECT PERSPECTIVE

Chapter 10 presents the existing and proposed transmission system as related to the proposed hydro power plant.

2.6 POWER DEVELOPMENT PLAN

2.6.1 Introduction

WAPDA carries out centralized power generation and transmission planning while power distribution planning has been gradually decentralized over the past five years. Generation planning is carried out on a national basis, taking the needs of both WAPDA and KESC into consideration, and is based on the well-established WASP III computer model. WAPDA's generation expansion plan is essentially based on the least-cost generation expansion strategy indicated by these studies. WAPDA has also carried out extensive power transmission planning studies using conventional power system analysis computer model to optimally expand WAPDA's primary power transmission (at 500 kV and 220 kV) and also its secondary power transmission (at 132 kV and 66 kV). CIDA funded (approximately $11 million) long term planning study of the power system has recently been concluded. The output included a detailed long term plan. Currently the study, is being updated. WAPDA's Area Electricity Boards (AEBs) are responsible for all aspects of power distribution planning at the area board level. These AEBs carry out distribution planning using mainly the minicomputer-based CADPAD model for medium voltage work and simpler PC-based models for low voltage work.

2.6.2 Generation Plan

WAPDA's power generation expansion strategy is based on the exploitation of base load, intermediate range and peaking thermal plants using natural gas (to the extent it is available), oil, lignite and coal as fuel and utilization of hydropower resources as far as allowed within present situation. WAPDA's least cost generation development plan for the period FY1994 to FY1999 to meet forecast loads will bring in a total of about 7,981 MW of additional generating capacity consisting of about 284 MW of hydro power plant and about 7697 MW of thermal power plant. About 5,596 MW (73 percent) of this additional thermal power plant is planned for construction and operation by the private sector on a BOT basis.

2.6.3 Transmission and Distribution Plan

WAPDA's major hydro resources are located in the north of the country while thermal facilities and load centers are concentrated in the center and the south. WAPDA has therefore been developing a carefully planned 500 kV power transmission network to efficiently connect the major generating plants to the main load centers.

Further 500 kV transmission lines from Tarbela to Lahore, Lahore to Jamshoro, Guddu to Multan, Multan to Lahore and Jamshoro and Tarbela to Peshawar to the proposed Hab River Thermal Power Project are under implementation mainly with World Bank financing assistance. Complementary investments at the lower transmission voltages of 220 kV and 132 kV have also been carefully planned and implementation is in progress mainly with financing assistance form the World Bank and the ADB.

Investments in power distribution have, in the past, tended to lag behind those for power generation and transmission and resulted in poor quality power supply and high distribution system losses. Since the mid 1980's much greater emphasis has been placed on power distribution investment and reinforcement and on the need for employing modem distribution planning methods. As a result, computer aided distribution planning was introduced in FY1986 together with an accelerated and decentralized program to expand and reinforce WAPDA's power distribution networks through its with Area Electricity Boards (AEBs).

This program has been in progress over the last many years with financing assistance from USAID and the ADB. Reduction of power distribution losses from 17 percent of net generation in FY1984 to 13 percent in FY1994 indicate the effectiveness of the measures that have been taken to improve the distribution system. Distribution losses have registered an increase in the last two years. This has been attributed to higher non-technical losses.

2.6.4 Generation Expansion Planning

WAPDA performs generation expansion planning using WASP III model. The WASP runs are periodically updated, especially before taking expansion decesions and formulating long term expansion plans. The recently concluded CIDA funded National Power Plan Project considerably enhanced WAPDA's technical and infrastructural capability to carry out these generation expansion plans.

2.6.5 Daral Khwar Project and Long Term Optimization Program

The ongoing restructuring and privatization of the power sector has had adverse effect on long term system expansion planning. The privatization concept requires project appraisal and planning to be performed by investors, who will undertaken the technology and demand risks. The March 1994 policy directive and subsequent policy statements are deficient in so far as not to insist upon economic feasibility. The sponsrers is not explicitly required to demonstrate economic feasibility. In any case long term optimization of the power system needs continued public sector attention. Otherwise crucial decisions: on fuel imports; infrastructure for energy; generation mix, would be taken by investors from their own perspective. This is a policy failure, which needs to be corrected.

2.6.6 Role of High Head Hydropower in National Power Mix

Hydropower in general and High Head Hydel Plants in particular are ideally suited to serve peak demand. Owing to rapid start up and flexibility for changing power output quickly, (in rapid response to changes in demand), the high head plants are particularly suitable for load following service and hence for serving the daily peak demand. The high head plants are also suitable for providing spinning reserves for emergencies. In a mixed hydel thermal system the most economic utilization of hydropower will be obtained for smaller ratio of energy versus capacity or for short durations during high demand periods.

The most economic method of meeting demand in a thermal hydel solution would be to supplement base load by intermediate class thermals and peaking by hydel facilities. The existing power mix, in Pakistan, is a thermal hydel mix. the least cost solution to meet future demand is discussed in section 2.8.4. The expansion plan can be summarized as follows:-

	Capacity added upto year 2018
* Combustion Turbines	6800 MW
* Private Sector	1293 MW
* Combined Cycle	8190 MW
* Steam (LSFO)	19800

The least cost solution developed by HEPO/SHYDO/GTZ was developed to indicate the impact of considering the high head hydel schemes identified in northern NWFP and AJK as candidates. This resulted in a slight lowering of the NPV and the thermal part of the energy mix changed as follows:

	Year 2018		
	Base Case	Modified Case	Diff.
* Combustion Turbines	6800	2500	-4300
* Private Sector	12912	1292	0
* Combined Cycle	8190	8190	0
* Steam (LSFO)	19800	19800	0

The least cost solution therefore in itself, high lights the role of high head hydel plants. The role is:-

- Avoided gas fired gas turbine capacity (peaking turbines).
- Avoided fuel and operation cost of thermal power plants.

The least cost solution which considered high head hydels as candidates resulted in 4300 MW less combustion turbine capacity. The high head hydel therefore resulted in:-

TO PROVIDE PEAK CAPACITY
TO MEET DAILY SYSTEM PEAKS

Besides contributing towards capacity availability at peak demand periods the high head hydels also contribute off-peak energy during the hydrology wet periods of the year and result in avoided fuel and operational cost of thermal power plants (there is a cost associated with this in the way of lower plant factors of thermal plants. This can partially be offset by means of adding intermediate class thermal plants instead of base load thermal facilities).

2.7 RURAL EXPANSION PLANS AND DEMAND

The Daral Khwar project is located in regions with significant unserved rural demand. The SHYDO/GTZ programme extensively studied the rural demand of northern mountainous NWFP. The proposed rural electrification plan, for the two regions which are of relevance to the proposed hydropower plant, is as follows:

Region 4 - Swat Valley

- construction of Batal Khwar hydel project near Utror in Upper Swat Valley. Constructed up graded and interconnected to WAPDA system at Madyan to transfer surplus (from rural demand) power to WAPDA. **8100 kW**
- construction of 33 kV transmission system for Upper Swat including interconnection to National Grid at Madyan grid station.
- Status : Feasibility Study available.

2.8 RECENT POLICY DEVELOPMENTS

Pakistan's domestic energy resources are characterized by sizeable reserves of natural gas, substantial hydropower potential, and modest recoverable reserves of crude oil and coal. The country also has a large base of traditional fuels such as fuel-wood and agricultural and animal wastes that mainly meet the energy needs of rural consumers. However, the exploitation of these energy resources has been slow, because of funding constraints and inadequate implementation capability.

As a result, Pakistan's dependence on energy imports remains high. Development of the energy sector is crucial to support continued growth of Pakistan's economy. Recognizing this, the Prime Minister of the present Government, immediately upon taking office in October 1993, set up a high-level Task Force on the Energy Sector to draw up an outline for a new energy policy and to formulate strategies for eliminating load shedding, promoting private sector investment, and enhancing indigenous production of gas and oil. The Task Force published its report in March 1994 and implementation of some of the recommendations is already underway.

A key thrust of the new energy policy is to increase private participation in the energy sector by introducing an attractive package of incentives. The energy policy also aims to achieve the following over the Eighth Five-Year Plan (FY1994-FY1998):

- Accelerate the development of domestic energy resources such as large and small hydro sites, oil, gas and coal as part of the least-cost energy investment program;
- Reduce the losses in the production and transport of energy through the rehabilitation and retrofitting of power system facilities, refineries, and energy intensive industries;
- Restrain the growth in energy demand through demand side measures and investments to improve energy efficiency and conservation;
- Strengthen the operations and management of sector institutions including building-up their environmental managerial capability; and
- Accelerate the process of restructuring and privatizing the energy sector to make it more competitive and efficient.

The petroleum policy announced in February 1994 includes: procedures of competitive bidding for allocation of concessions; establishment of a regulatory board; incentives to local companies; freedom to producers to sea gas; autonomy to OGDC. Oil parity to Arabian/Gulf mode, discount's have been with drawn. LPG parity to FOB price of LPG.

2.8.1 Private Sector Power Generation

In April 1994, the Government announced a comprehensive policy framework and package of incentives to encourage private sector participation in power generation. The main incentives include:

- An attractive bulk tariff of 6.5 US cents per kWh for ten years for sale of electricity to WAPDA/KESC, with a provision for indexation of certain tariff components based on exchange rate, fuel price variations and inflation;
- A comprehensive security package covering power purchase, fuel supply, project implementation, protection against specific force majeure risk and changes in taxes and duties, and assured conversion to, and remittance in, foreign currencies;
- Fiscal incentives including exemption from corporate income tax, equipment import duties and income tax for foreign lenders, access to Foreign Exchange Risk Insurance (FERI) provided by the State Bank of Pakistan, and repatriation of equity;
- Financing arrangements including a provision of up to 40 percent of the capital cost of the project from the Private Sector Energy Development Fund (PSEDF); permission to issue corporate bonds/shares at discounted prices with underwriting allowed by foreign banks, and acceptance of a 80:20 debt-to-equity ratio; and,
- A one-window operation to be facilitated by a newly constituted Private Power Board, which will be responsible for coordinating with the Government agencies concerned, monitoring

the performance of private sector power projects in accordance with the agreements, and safeguarding the interests of the consumers.

The Government envisages that these measures will lead to the installation of 2,700 MW of generating capacity by the private sector over the next four years, including the first private power project of 1,292 MW being set up by the Hub Power Project Company.

The Policy received a mainly thermal response and an separate policy to attract the private sector to invest in small and medium hydel power station is currently under discussion. Privatization of Kot Addu combined cycle power plan (part of the utility privatization plan) has how been settled and a UK based firm has acquired the facility. The private power cell has been reorganized and renamed as Private Power and Infrastructure Board (PPIB).

2.8.2 Private Sector Participation

The initial decision to induct the private sector to the power sector was taken in 1985. Various policy and institutional steps to achieve this objective did not receive a very encouraging recourse. Apart from the Hub River Project there was not much progress on other projects. The March 1994 policy statement caught the attention of the private sector and a large number of requests for participation in the power generation sector were received. These offers were mainly for thermal power stations. Power Purchase Agreements for various projects have been signed. A few have obtained financial closure.

The response of the private sector to the March 1994 initiative has been very encouraging. However attention needs to be paid to the following:

- The response is mainly thermal. Insignificant hydel capacity has been offered. The policy does not differentiate between hydel or thermal, however the contents of the policy are clearly thermal inspired. Special initiatives needs to be taken to utilize the considerable medium output high head hydel potential identified in the NWFP and AJ & K.
- The policy does not require the sponsors to demonstrate economic feasibility. The long range optimization activities being carried out by WAPDA have also been suspended, this seems to be a regression and policy correction is indicated.
- Pricing of bulk power is clearly thermal based. Tariff to provide correct signals to hydel power generation investors need to be elaborated.
- Management, supervision and funding of feasibility studies for medium output, high head hydels need to be formalized and institutionalized.
- The GOP is presently carrying out detailed analysis of issues involved in providing adequate incentives to the private sector for involvement in the hydel sector. A separate hydel policy is expected to be announced in the very near future.

2.9 CURRENT PRICE SITUATION

2.9.1 Tariff

The WAPDA Act requires that WAPDA's tariffs recover all its operating costs (including depreciation and taxes and duties), service its debt and earn a reasonable return on its investment. WAPDA has covenanted with the ADB and the World Bank that its tariffs will be maintained at levels adequate to achieve 40 percent self-financing. WAPDA has generally achieved both these objectives. WAPDA's tariff at present consists of a base tariff (which does not include any element for fuel cost) and a fuel adjustment surcharge (FAS) which seeks to recover fuel expense. WAPDA's average tariff per kWh including FAS increased by about 330 percent from Rs. 0.48 in FY1980 to Rs. 2.08 in FY1996 at a compound rate of 9.6 percent per year.

WAPDA's current tariff basically adopts increasing block tariffs for domestic and commercial consumer and a flat rate energy charge plus a capacity charge based on connected load for others. The tariff also includes provisions for penalties for poor power factor and late payment of bills. Private tubewells have an optional monthly flat rate tariff based on the horsepower rating of the pumpset. The fuel adjustment surcharge (FAS), which is also usually revised annually along with the based tariff, is estimated at the beginning of each financial year by dividing the projected fuel expenses for the coming financial year by the projected electricity sales (kWh) to all consumers during that financial year. Domestic consumers whose electricity consumption is between 150 and 300 kWh per month pay only 20 percent of the FAS and domestic consumers consuming up to 150 kWh per month pay only 10 percent of the FAS.

WAPDA's average tariff, which is about 90 percent of the long run marginal cost of supply, enables WAPDA to meet its financial covenants with the Bank. The Government has agreed to gradually increase the FAS percentage on domestic consumption between 150 and 300 kWh per month. In Addition, as a significant tariff initiated load management measure, the Government has introduced a time-of use tariff for WAPDA's industrial consumers with maximum demand in excess of 40 kW and for WAPDA's bulk supply consumers whose industrial consumption exceeds 70 percent of total consumption. This time-of-use tariff is based on the findings of the Integrated Operations and Tariff Study for WAPDA and KESC.

2.9.2 Electricity Tariff Structure

The tariff structure in Pakistan is characterized by differential tariffs applied to different categories of consumers and to different levels of consumption/voltage supply. The tariff has two components: a base tariff, comprising a capacity charge and an energy charge; and a fuel adjustment charge (FAC), which is calculated on the basis of the average fuel cost incurred in the twelve-month period ending two months prior to the months of billing. an additional surcharge added to the base tariff and the FAC to compute the total electricity charges payable by each consumer.

2.9.3 Present Tariff

The Latest (01-02-1997) WAPDA tariff is presented at the end of this chappter.

2.9.4 Cross Subsidization

WAPDA's current average tariff is close to the average LRMC of supply, although there is substantial cross-subsidization of certain consumer categories; especially domestic consumption below 300 kWh per month and flat rate agricultural (tubewell) consumption. The above table presents an estimate of the cross-subsidization. The GOP in various agreements with the ADB (Asian Development Bank) and the World Bank is committed to gradually ease out this subsidy. Since November 1990 Fuel Adjustment Charges (FAS) has gradually been introduced to the low consumption domestic consumers. The GOP is also gradually increasing the tubewell tariff.

In economic and financial terms the return on supply to different customer category classes in rural areas is summarized as follow:-

RURAL ELECTRIFICATION CUSTOMER ANALYSIS **(Rs./kWh - Return) 1994-95 Price Level**

	Financial Analysis				Economic Analysis	
	Utility		Customer		Society	
	Base	High	Base	High	Base	High
Irrigation Tubewell	-1.77	-0.42	3.84	4.06	-2.36	0.51
Domestic	-2.44	-1.99	1.75	1.99	-1.26	-0.70
Rural Industry	-0.05	0.68	0.06	0.25	-0.58	0.50

Utit. = Utilization

The above analysis indicates that rural electrification results in financial transfers to the customers; financial deficits for the utility; and in economic terms only rural industry and commercial supply is feasible. In financial terms the rural industrial and commercial customers subsidize the tubewell and domestic customers as far as the utility is concerned. All customers in financial terms register a surplus i.e. all rural customers pay below cost of supply.

The subsidized rural electricity will continue in the medium term at least. The GOP is seriously considering restructuring of the power sector, especially privatization of some of the WAPDA activities. The WAPDA privatization plan prepared by a group of consultants (financed by US AID) has recommended the following: -

- Creation of cost centers.
- Privatization of Area Electricity Boards (AEB).
- Initially Faisalabad AEB is to be privatized.
- Privatization of Jamshoro and Kot Addu Power Stations.
- Establishment of a regulatory body.

GOP has in principle accepted the WAPDA privatization plan but due to various reasons has not been implemented so far. GOP has recently decided to restrict WAPDA to add hydel capacity only. All new thermal additions are to be in the private sector. A private sector generation policy has recently been announced by the GOP, this includes a generous bulk rate of 6.5 US cents/kWh and other significant financial and other incentives.

The relevant (to this present appraisal) aspect of the power sector privatization policy of GOP is that even under the private sector control of distribution and generation of electricity, rural subsidies are proposed to be maintained. The privatization proposal contains specific provisions towards special tariffs for rural areas to be funded by the GOP.

The point of relevance here is that industrial consumes are billed much above the economic cost of supply. One cardinal rule of tariff fixation is to never set a tariff which will exceed cost of self generation to a customer. The industrial costumers are finding it increasing feasible (financial) to invest in self generation. The new private sector policy frame work will result in higher tariffs. To pay for the higher bulk supply (generation) tariff WAPDA will require the average WAPDA tariff to be increased, if this increase does not address the inherent imbalance in the tariff structure, it will result in increase in industrial tariffs. A large portion of the industrial demand could be lost to self generation.

SUMMARY OF WAPDA'S CURRENT TARIFFS
(01-02-1997)

Consumer	Capacity Charge Rs/kW/Month	Energy Charge Ps./kWh	FAS Ps./kWh	Addl. Sur. Ps./kWh	Total Tariff Ps./kWh	LRMC Ps./kWh	% of LRMC %
A1 domestic							
50 kWh		54	7	28	89	357	25
51-150 kWh		68	7	46	121	334	36
151-300 kWh		77	15	80	172	322	53
301-1000 kWh		110	75	143	328	322	102
1001-2000 kWh		147	75	192	414	322	128
2001-3000 kWh		147	75	208	430	322	133
3001-4000 kWh		147	75	223	445	322	138
Above 4000 kWh		147	75	237	459	322	142
Minimum/month		10					
Flat Rate FATA		70					
A2 commercial							
First 100 kWh		217	75	188	480	322	149
Over 100 kWh		241	75	201	517	240	216
industrial							
b1 upto 20 kW		119	75	135	329	240	137
b1 20 kW-70 kW	151	60	75	151	287	190	151
b2 41-500 kW	145	67	75	114	256	173	148
b3 upto 3000 KW	140	62	75	110	247	170	146
b4							
Bilk							
c1-400v		82	75	123	280	334	84
licences	110	68	75	130	273	261	105
c2-11 kV		69	75	115	259	240	108
licences	108	65	75	130	270	240	113
c3-66kV/132kV	107	63	75	135	273	183	150
Tubewells							
d		85	75	123	283	249	114
d1-agri							
Punjab	41	49	75	131	255	249	102
NWFP	36	34	75	114	223	249	90
Flat Punjab	147			147			
Flat NWFP	122			122			
g-public lighting		203	75	143	421	316	133
h-Residential Colonies							
h-with trafo		104	75	136	315	249	127
-without trafo		105	75	136	316	249	127
I-Railway Traction		61	75	112	248	207	120

1 *Time of day tariff for B3 and B4 customers is also available. A tariff for co-generation is also available.*

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3.1 GENERAL

The project area of Daral Khwar Hydropower Project is located in District SWAT in N.W.F.P (North-West Frontier Province). The scheme was identified within the planning region Swat Valley (portion of District draining into Swat River). The river is a right tributary of the Swat River.

The highest peak elevations in the northern part are between 5944 to 5041m a.s.l. Some very good maps in scale of 1:50,000 with contour lines are available. Some maps have contour lines intervals in meters while other in feet. These maps were previously used for identification of Hydropower Potential in the Regions of N.W.F.P.

Reference: Report on Surveying & Mapping, Mott Macdonald, December 1993

A pre-requisite to the geo-technical investigations and design works was the detailed survey of the proposed sites for the Weir and Intake Conduit system and Powerhouse areas.

The scope of work was formulated by SHYDO/GTZ in early 1993 and Mott Macdonald Pakistan based in Lahore, were contracted to execute the work.

3.2 CONTROL SURVEY

For the Main Traverse, a geodetic basic triangulation network was established between 2 points fixed at the outlet (Powerhouse) area and 2 at Intake Area. This was done by conventional survey traverse using a one second electronic total station theodolite (SOKKIA SET 2B).

Three sets of reflecting targets were used (each 3 prism) and the data recorded using a SOKKIA SDR33 data logger. The overall length of the traverse was 12 km and 57 stations were set up and cross checked.

The option to use Global Positioning System (GPS) was considered, using the satellite Navigation System NAVSTAT which gives a very high degree of accuracy for relative fixings of reference points. This was allowed for in the ToR, but the survey firm showed that doing it manually was quite feasible and could be done for less than half the price. In the event they did have problems completing the traverse due to trees and steep slopes which made one leg of the traverse extremely difficult. Access for the survey team, too, was a problem, the areas generally only reachable on foot.

Data was processed to eliminate out-of-tolerance sets; cross bracing gave additional sets of redundancies when calculating station co-ordinates, using least square methods.

Minor traverses were carried out at both the Inlet and Outlet areas in order to provide a spread of co-ordinated points for the topographic survey work. There were eventually 8 and 27 stations at the inlet and outlet respectively.

3.3 TOPOGRAPHIC MAPPING

Topographic mapping required for the project comprised work both in the office and, more extensively, field surveys over the whole site area.

- **Medium Scale Mapping - 1:10.000**

  In order to produce an overall map of the site at a scale that would be large enough to identify major features, a portion of the Survey of Pakistan 1:50,000 Topographic Map Sheet No. 43 B/13 was digitised and plotted to a scale of 1:10,000.

  The scope of work encompassed approximately 50 km^2 of the site. The 50 m contours were digitised directly from the map whilst the required 10 m contours were interpolated and added manually. The map was presented on a sheet of DIN A0 size.

  The areas that have been surveyed in detail on the ground i.e. Powerhouse, Weir and Intake area have been partly superimposed onto the map.

- **Detailed Mapping**

  Although the scope of work defines a number of sites for detailed mapping and various activities that should take place within these areas, the whole task was simplified by splitting the site into two main areas as follows:

  1. Weir, Gravel/Sandtraps and Tunnel portal
  2. Surge Tank, Penstock and Powerhouse.

  Finally, there was a requirement to carry out a bathymetric survey of the Swat River covering an area extending 200 m up- and down- stream of the line of the penstock axis.

- **Basic Methods Employed**

  The same equipment was used as for the main traverse, except that the targets were single prism and the pogo stick was extended to 4 m, because of the undulating terrain and dense vegetation, etc.

  The Inlet area comprising the Weir, Sandtrap and Tunnel Portal, required an area 500 m long to be surveyed, centred about the weir axis, (just upstream of the wooden bridge close to Arin village), and extending up the banks to 30 m above water level. Some 4000 points were fed into the data base and eventually plotted on maps using digital mapping techniques.

  The surge tank area, at El 1770, required topographic detailing in a 100 m diameter circle. The terrain is a steep scree slope with dense stunted oak thickets commonly up to 3 m in height.

  Penstock area is some 900 m long, and the survey extended to 50 m either side of it. The upper half is difficult terrain similar to that described for the surge shaft, whereas the lower half comprises gentler slopes and terraced fields.

  The Powerhouse area includes the land from Madyan Road to the Swat River, and 30 m up- and down- stream of the penstock centreline.

  The Tailrace area extends 250 m up- and down- stream of the penstock centre line, and from the river bank to a line 30 m above it.

  In all, the outlet area comprising Surge tank, Penstock, Powerhouse and Tailrace extends some 130.000 m^2 and 9000 survey points.

- **Access Road Mapping**

  The road to the inlet follows the left bank of the Daral Khwar; a strip 30 m wide was surveyed from Bahrain upstream.

  For the access road to the surge tank area, the existing timber trail to Kulban was followed and extended from a bend to the proposed structure location.

  Maximum gradient for both roads was specified as 5 %, giving a combined length of some 6 km. This proved too long in practise, and the road could not be fitted. Steeper slopes were thus allowed, with gradients up to 10 % included in certain small stretches and at the hairpin bends.

  All data was plotted on maps using digital mapping techniques. Pillar survey points were set up, diameter 20 cm standing 1.20 m above ground together with control points which comprise a steel pin in a 30 cm cube of concrete, top surface flush with the ground.

  The co-ordinate system used is the Universal Transverse Mercator Projection. A local co-ordinate system was set up with the origin at point A, adjacent to the proposed Powerhouse. The elevation of the origin was measured approximately using sophisticated altimeters and given the value 1440.00 m asl.

- **Accuracy for the main traverse:**

  Distances were measured to an accuracy of 10 mm + 2 mm/km; angles to 1.5 milligrad and heights ± 8 mm/km - obtained by using precise double levelling with automatic levelling instrument (micrometer parallel plate).

  Incidentally, with NAVSTAT, the accuracy is generally ± 10 mm + 1 mm/km in plan and ± 15 mm for elevations. Accuracy for the topographic survey was ± 5 cm for terrain points and ± 1 cm for buildings etc.

Maps produced

AreaScale	Contour	No of intervals	Drawings
Inlet area contour maps	1:500	5 m	2
- do -	1:100	1 m	8
Surge structure contour maps	1:200	1 m	1
Penstock area contours maps	1:500	5 m	4
- do -	1:200	1 m	6
Powerhouse area	1:100	1 m	6
Tailrace area	1:500	5 m	2
General Layout contour maps	1:5000	10 m	2
- do -	1:7500	10 m	1
- do -	1:10000	10 m	1
Access road to surge structure contour maps	1:1200	2.5 m	1
Access road to Intake area contour maps	1:2000	2.5 m	2
Location of plan sections on River Swat	1:1000	-	1
X-Section of River Swat	1:500	-	2
Long Section of River Swat	1:500	-	1
Long Section of access road to surge structure	1:500	-	3
Long Section of access road to intake area	1:500	-	5
	Total	48 drawings	

Mapping for the headrace tunnel was done using the GT-map 1:50,000 courtesy Survey of Pakistan (SoP)

- **Swat River Profiles**

  The profiles of the Swat River were observed using triangulation techniques with 2 theodolites for position together with the echo-sounder for depth.

  The Continuous Kinematic technique requires two theodolites to be placed, one on a known position called the Reference, and one moving around called the Rover. During the survey the Reference theodolite was either placed on S-37 or S-42 because of their proximity to the river, and the Rover placed in the boat. A manual fix feature on the roving receiver enabled positions to be logged at the same time as fixes on the Echo-Sounder, thus correlating the position to the depth.

  In addition to the depth sounding work, the total station was set up on known stations so that the water level on either side of each cross-section could be observed. The resultant water elevation was subsequently used to derive river bed elevations from the depth readings.

During the survey a close check was kept on the height of the water to ensure there was no significant change that would affect the results.

- **Additional Survey**

An additional survey was undertaken in 1996 in the area surrounding the surge tank structure, covering an area of some 185.000 m^2. The work was done by the SHYDO staff and the results in the form of maps, both on data file (DXF - Format) and on paper, are available in GTZ/SHYDO office, Peshawar.

More survey was necessary in 1997, this time on the downstream side of the penstock - since the axis has had to be changed, and some work was required for finalising the alignment of the access road to the Powerhouse. Topography work started on site in the middle of May, but results are not yet available. However, for finalisation of the Feasibility Study, the results of this survey could be used. The survey covers appr. 40,000 m^2 and the field work was done by SHYDO staff.

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4 HYDROLOGY

Reference: Appendix 4
Hydrological Report, December 1996.

4.1 OBJECTIVES

The amount of water available for power generation, in any river, depends naturally on the amount of water flowing down it. This fundamental fact relies on the meterological data of the area combined with a statistical appraisal to allow long term predictions.

The hydrology of the area depends primarily on the climate; also the topography because of its effect on precipitation and whether run-off will be fast or slow; and geology because, not only does it influence topography, but the underlying rock determines rate of infiltration. Climate depends on the geographical position on the earth's surface, climatic factors are precipitation - and its mode of occurrence, humidity, temperature and wind, all of which in turn directly affect evaporation and transpiration.

These factors are addressed in the Hydrological Report, and during the course of its preparation, all existing hydrological and meteorological data as well as information on evaporation, bed and suspension loads were reviewed.

Based on the available information, it has been possible to describe

- Climatological conditions
- Long-term flow averages
- Peak flows
- Amount of sediment load transport

4.2 CATCHMENT AREA

The catchment of Daral Khwar is located in the southern slopes between the Hindu Kush and Himalayan ranges. Daral Khwar is a right tributary that joins the Swat River at the village of Bahrain. The catchment area measured to the confluence with the Swat river, extends over an area of 268 km^2 with a mean elevation of 3.486 m asl. Maximum elevation within the catchment is about 4.200 m asl and minimum elevation at the confluence is about 1.480 m asl. Due mainly to the geographical position of the catchment there are no perennial glaciers within the catchment, although satellite imagery shows small snow covered areas as late as August.

4.3 CLIMATOLOGICAL DATA

There are no climatological stations in the Daral Khwar catchment but four climatological stations located within adjacent areas have been used to assess the pattern of the climatological parameters in the catchment. There are two at Saidu Sharif and Kalam (operated by SWHP) and new stations of high altitude at Kalam and Shangla Pass.

Available records indicate that precipitation in the catchment occurs throughout the year with two peaks, one in Spring and one in Summer.

Precipitation occurs in larger amounts from December to May rather than from June to November, similarly the maximum daily precipitation recorded at Saidu Sharif and Kalam exceeds by far the maximum daily precipitation from June to November.

Climatological records show that precipitation increases with elevation and latitude. Kalam with 1000 mm/year is higher and more north than Saidu Sharif, where the recorded annual precipitation is about 800 mm. Estimated mean annual precipitation over the entire catchment of Daral Khwar is about 1,560 mm, compared with mean annual run-off, which is about 1,357 mm.

Temperature as recorded at the climatological station at Saidu Sharif varies throughout the year reaching a minimum during December and January and its maximum during June and July. Recorded mean minimum monthly temperature at Saidu Sharif is 8°C during January, and recorded mean maximum monthly temperature is almost 29°C during June.

4.4 WATER AVAILABLE TO THE PROJECT

Available hydrological information of the catchment of Daral Khwar, comprises daily flows of the hydrological station at Bahrain and low flow measurements taken on Daral river just upstream. The information from the station at Bahrain forms the basis for the studies of the Hydroelectric project on Daral Khwar. The catchment area measured to the hydrological station is 266 km^2 with a mean elevation of 3632 m a.s.l.

The operation of the station started in 1992 and records published by SWHP are available from 19.12.92 - 31.12.95. Field data include gauge readings taken 3 times a day at 08:00, 12:00 and 16:00 and regular flow measurements. The station is equipped with automatic equipment comprising water level recorder and data logger. Water level data is recorded on graphs and memory cards. Fourteen flow measurements were available for estimation of the rating curve, processed records gave daily and extreme flows. Information on water quality and sediment sampling for 1992 and 1993 is still under process and is not considered here.

After analysis of the available data of the station, it was considered to be sufficient and of good quality and consequently it allows a reliable estimation of flows to be made.

The series of flows at the weir site were estimated by ratio of catchment areas between the site of the weir and the site of the hydrological station Bahrain. The site of the hydrological station is close enough to guarantee the estimation of flows with confidence. The respective areas are 250 km^2 at the weir site and 266 km^2 at the site of the hydrological station.

Flow duration curves calculated from the daily flows (1962 - 1995) show the following values for the weir site.

Time		Discharge
%	days	m^3/s
100	365	0.61
95	346	1.15
90	328	1.28
70	255	1.94
50	182	4.37
30	110	14.23
10	36	29.61
5	18	36.07

Since the period of record was short, an extension of the records by regression analysis was performed based on records from Swat at Kalam and Swat at Chakdara (from the year 1962 to 1995).

From such an analysis of the flow paths, good correlation was demonstrated between the pattern of flows from the long term stations.

The mean monthly distribution of flows (1975 - 1993) was calculated as follow.

Month	Discharge (m^3/s)
January	1.31
February	1.52
March	3.64
April	10.82
May	23.13
June	33.86
July	27.78
August	14.86
September	5.71
October	2.96
November	1.95
December	1.55
Annual	10.76

4.5 FLOODS

Basic data for calculation of floods of Daral Khwar at Bahrain are available from December 1992 to December 1995. Three years of recorded flood data for estimation of major floods was considered too short, and therefore, a regional approach was used to estimate floods for the design of the relief structures.

The regional method for estimation of floods was developed on the basis of the available flood records of the hydrological stations in the northem areas of Pakistan. Flood records of 26 stations were analysed and classified in three regions.

Due to the geographical position of the catchment and the characteristics of precipitation and observed floods, the catchment of Daral Khwar was classified to be within the region moderately affected by Monsoon rains. In this region floods are mainly originated by snowmelt, but rainfall can contribute to maximum floods.

Also to estimate maximum floods at the site of the power house, the Swat river at the confluence with Daral Khwar was classified within the region moderately affected by Monsoon rains. In this region maximum floods are originated by snowmelt, but extraordinary events during the Monsoon can generate maximum floods.

The coefficients of the formulas for estimation of floods obtained during this work and the estimated floods are comparable with the ones obtained in the other parts of the world in conditions rather different to the ones prevailing in the northem areas of Pakistan. Consequently, the floods calculated with the regional formulas are considered reliable.

The estimation of floods for different periods of return at Daral Khwar/weir site (A = 250 km^2) and Swat River/Powerhouse site (A = 2938 km^2) results in following values:

Location	Estimated Floods for different periods of return (m^3/s)					
	5 years	10 years	50 years	100 years	1000 years	10000 years
Daral Khwar/weirsite	348	395	522	640	857	1078
Swat River/Powerhouse site	1192	1355	1789	2193	2730	3348

4.6 SEDIMENTS

A study of the sediment loads is essential to determine the expected silting of the area upstream of the weir interference of the river flow and sediment transport.

The sediment moving in streams consists of suspended matter and bedload. The suspended sediment load is distributed across the whole section of the river whereas the bedload moves on or near the river bed. Both forms of sediment transport are dependent on the characteristics of the stream such as slope, turbulence etc. as well as on the characteristics of the catchment such as geology, topography, vegetation and rainfall intensity.

The amount of sediment transported is mainly a function of the flow regime of the stream. Information regarding the relationship between flow and sediment transported in conjunction with the flow duration curve is fundamental to the determination of the annual amount of sediment load.

Available data on suspended sediments at gauging stations Kalam (from the year 1963 to 1987) and Chakdara (from the year 1963 to 1986) comprise results of samples taken during flow measurements of the Swat River.

Granulometry of the sediment (distribution of sand, silt and clay particles) is also included for several selected samples.

For the stations Kalam and Chakdara the annual specific suspended sediment load were obtained by summing the average daily specific suspended sediment carried, and interpolating between if no readings were taken on certain days. To estimate the discharge of suspended sediment on Daral Khwar at the weir site a linear interpolation between elevation and specific suspended sediment was assumed. Absolute values were obtained as a product of the specific suspended sediments values and the catchment area. The mean annual suspended sediment discharge following the method described above was calculated to be some 0.055 10^6 ton/year at the weir site.

A sample was taken of the river bed of Daral Khwar, during February '96. The granulometric analysis indicates a grain size distribution closely resembling the fine bed material. The section of the river 50 m up- and down-stream of the weir was surveyed, and the average river slope taken over 1 km. Bedload was calculated with the formula of Smart and Jaeggi for different discharges and a rating curve drawn. Finally daily bed load discharges were calculated from the rating curve and the series of daily flows estimated at Bahrain.

Mean annual bedload was calculated at 0,17.10^6 tonne/year at the weir site. No bedload transfer is apparent during low flows, but is quite evident during floods in spring and summer, and maximum during the monsoon period in July.

Total sediment as the addition of suspended load and bed load was calculated to be 0.225*10^6 tonne/year.

For verification of the bedload calculation, measurements will be initiated by SHYDO.

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5 GEOLOGY

Reference: Annex 5.1: Geology, GBK, December 1996.
Annex 5.2: Geophysical Prospecting, IGH, August 1996.
Field Control of Geological Mapping, MAGMA, August 1996.
Engineering Geology (Volume 1&2), CES, May 1996.

5.1 GENERAL

The geotechnical investigations as to the feasibility study for the Hydro-Electric Power Project Daral Khwar in the District of Swat have been carried out during the period 1994-96. The project has been identified within the studies for the Region Swat Valley of the Masterplan for Hydropower Development in Northern Area of N.W.F.P. It is located near the town Bahrain in the Swat Valley at a distance of 73 km from Mingora.

At the beginning of the investigation works as to feasibility, a second powerhouse alternative was discussed due to obviously better geological conditions on the left Swat bank. An early cost comparison, however, resulted in higher costs because of quite an expensive pipe bridge crossing River Swat. Also for the weir site, alternatives have been under consideration.

5.2 INVESTIGATION WORKS

The following investigation works, for items a through f as described below, were carried out by CES:

a. Desk studies as to regional stratigraphy, tectonics, and seismicity, as well as those concerning hydrogeological and engineering geological relevant problems.

b. Geological field mapping of the project area with emphasis to general stratigraphical and tectonical questions.

c. Sinking of 1 core drillings with in total 522.40 running metres (refer to Annex 5.13).

d. Carrying out 18 water pressure tests (LUGEON), 10 Nos. out of which were "terminated due to high water loss". And executing nine permeability tests (LEFRANC/MAAG) according to borelogs of CES-Report (no calculations available).

e. Excavation of 30 test pits for support of the field mapping and for sampling.

f. Execution of 55 laboratory tests (samples taken from cores and test pits), i.e. 18 grain size analyses, 14 Atterberg limits, nine unconfined compressive strengths, four sulphate content in soil, two chemical water analyses referring to construction material, as well as eight petrographical analysis (thin sections).

g. Seismic refraction investigations in the upper penstock and surge tank area. CMTL – Central Material Testing Laboratory in cooperation and under supervision of IGH, Guatemala, carried out these works in 1996. Additionally, geoelectircal investigations have been executed at the same time.

h. A special geological surface mapping in the penstock slope area has been carried out by MAGMA for control reasons.

In the following, an interpretation of the engineering geological conditions is given, using all available results of the aforementioned investigations.

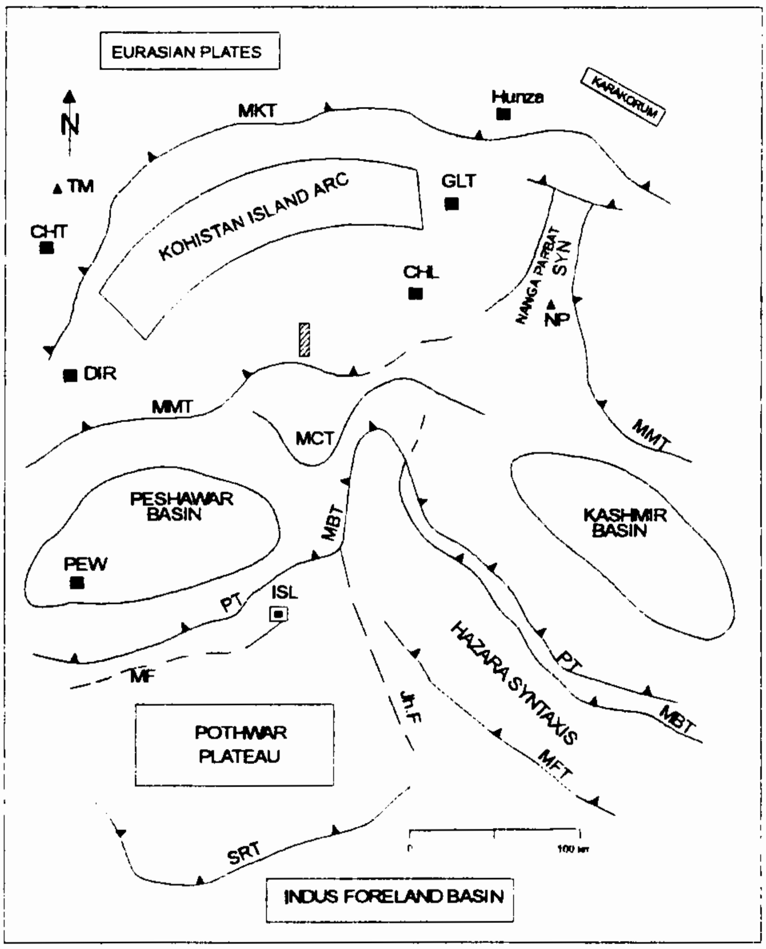
5.3 REGIONAL GEOLOGY

For reasons of completeness the general geological conditions of the project area are described in brief. Petrographic, stratigraphic, tectonic and metamorphic details and descriptions are based on numerous publications e.g. MP WILLIAMS, (1989): "The geology of the Besham Area, North Pakistan: Deformation and Imbrication of the Footwall of the Main Mantle Thrust".

5.3.1 Regional Seismicity

The structural framework of northern Pakistan is dominated by the result of the collision between the northward migrating Indo-Pakistan Plate and the Eurasian Plates. The most important tectonic elements are marked by the following units (from S to N):

- Salt Range Thrust
- Potwar Pleateau
- Panjal Thrust (PT) and Main Boundary Thrust (MBT)
- Peshawar Basin and Kashmir Basin separated by Hazara Syntaxis
- Main Central Thrust (MCT)
- Main Mantle Thrust, indented to the N by Nanga Parbat Syntaxis
- Kohistan Islan Arc Complex
- Main Karakorum Thrust



MBT	Main Boundry Thrust
MCT	Main Central Thrust
MFT	Main Frontal Thrust
MKT	Main Karakorum Thrust
MMT	Main Mantlc Thrust
PT	Panjal Thrust
SRT	Salt Rantc Thrust
Jh.F	Jhelum Fault
MF	Murree Fault
CHL	Chilas
CHT	Chitral
GLT	Gilgit
HNZ	Hunza
ISL	Islamabad
PEW	Peshawar
	Project Area Daral Khwar
TM	Trich Mir (7700 m)
NP	Nanga Parbat (8125 m)

The Northern Megashear along the line Hini-Chalt-Yasin-Drosh used to be considered the only extension of the Indus Suture west of Nanga Parbat. Recent studies by TAHIRKHELI resulted in an assumption of a southern megashear as well, marked by The Thics and high pressure metamorphic rocks, called Main Mantle Thrust (MMT), which traces the southern contact of the Kohistan Island Arc and the Indo-Pakistan continent.

Swat Kohistan is occupied by the so-called Kohistan Island Arc Sequence of Post-Eocene age, consisting of granites, diorites, pyroxene-granulites (norites), garnet granulites, slates, quartzites, and greenstones. Just 10 to 15 km south-east of Madyan and Fatehpur, the Kohistan Island Arc is bordered by the Main Mantle Thrust (MMT), which devides it from the Indian Mass consisting of granities and all kinds of pelitic (slates) and calcareous rocks, called Besham Group, devided in Chail and Banna Formation.

The Island Arc proper consists of a larger number of different rock units belonging to the Kohistan Complex; the incorporated five mainly mafic and ultramafic rock types are from south to north the Patan Gamet Granulites, Jijal Ultramafics, Kamila Amphibolites, Bahrain Pyroxene Granulites, and the Deshai Diorite. Round about Kalam and along Gabral and Ushu River, the main outcrops of Cretaceous Kalam Group (name !) exist, consisting of quartzites, limestones, and slates, accompanied by volcanic rocks and slates of Eocene-aged Dir Group.

In the Swat Valley the rocks of Kalam and Dir Group are said to be in direct contact with dioritic rocks of the Deshai Group. After all relevant geological principles, this is only possible, if the contact is a fault. It applies also for the contact of the Kalam Group occurring south of Chokel Khwar. This phenomenon is derived from theory only and is a matter for further investigation.

The project area is characterized by rocks of the Bahrain Pyroxene Granulites (lows typicus!), consisting of basic to intermediate intrusions, which caused little metamorphism only due to cooler temperature during its initial phase.

5.3.2 Regional Seismicity

The project area is located in the "Hazara-Swat/Kohistan" seismic province and shows mostly E-W trending folds and faults. The deformation within his zone is primarily the result of thrusting and of a deep crustal decollement process associated with the collision between the Indo-Pakistan and Eurasian Plates.

Seismically defined faults have been identified using microseismicity data; shallow seismicity occurs on perpendicular, steeply dipping faults characterized by reverse and strike-slip motion.

Teleseismic data for northern Pakistan shows a concentration of seismic activities in three main zones around the project:

- the Hindukush region in the NW,
- the Daral - Tangier - Haran valley region in NE (Gilgit Agency), and
- the Indus - Kohistan seismic zone in the SE

In Swat valley proper, the seismic activities are generally concentrated more to the south; the centre and northem parts have to date only indicated low activity.

Results of a microearthquake survey have shown a seismic trend similar to that depicted by teleseismic events. Deep seismicity (70 to 300 km) is related to the Hindukush zone, while shallow seismicity (< 25 km) is dominant in the Kohistan area.

Some 50 earthquakes took place during the years 1964 and 1992 within a distance of 100 km, 18 of which were of a Magnitude of $M \geq 5$; the strongest earthquake occurred on 28 December 1974 in the village of Shitgal in Duber Khwar, Pattan area, with a magnitude of 6.2 and the hypocentre at appr. 20 km depth.

The "Seismic Zone Map of Pakistan" shows the project area lies on the edge of "Zone 2: moderate damage; corresponding to Intensity VII of the MM-scale". However, the distance to "Zone 3 (major damages: correspond to Intensity VII and higher of the MM-scale)" in North Mansehra and South Swat regions (< 20 km distance) suggest a more conservative coefficient may be adopted.

To determine the Peak Ground Acceleration (PGA), the attenuation relationships derived by ESTEVA (1974) is adopted.

The theoretical PGA-values for the project area relative to the many individual earthquakes of various magnitudes and distances, evaluated since 1905 (Quetta), vary between 43 cm/s^2 (0.04g) and 210 cm/s^2 ($\approx$ 0.22g). The previously mentioned Pattan earthquake may have reached a PGA-value of 91 cm/s^2 ($\approx$ 0.09g).

Considering the important Main Boundary Thrust (MBT) as a source for future earthquakes with an intensity of M=7 at a depth of 20 km and a minimum horizontal distance of 30 km, an assessment for PGA at Daral Khwar mouth would result in a maximum value of 262 cm/s^2 (≈ 0.27g)

The probabilistic analysis originally developed by CORNELL (1968) is based on

- definition of earthquake sources.
- magnitude frequency relationship,
- attenuation relationship, and
- upper bound magnitude assignment to each earthquake source.

Earthquake sources have been defined as Hazara Arc, Kohistan Island Arc and Hindu Kush Seismic Zone.

Keeping in view the tectonic setting of the area and its historical development, an upper bound magnitude of M=8 have been used in the respective analyses.

The assessment of seismic probabilistic hazard in the project area, affected by fault ruptures during an earthquake, has been made by computer analyses (200 km radius). According to this, the following values have been given for 50% (10%) of probability of exceedance:

- design life of 50 years : 0.15 g (0.24 g)
- design life of 100 years : 0.18 g (0.28 g).

The seismic design parameters for the project (50 years life time) are recommended as Maximum Design Earthquake (MDE) of 0.25 g with 10% probability of exceedance with a corresponding return period of 475 years, and as Operation Basis Earthquake (OBE) of 0.15 g with 50% probability of exceedance and 75 years return period.

5.4 GEOLOGY OF PROJECT AREA

The project area is part of the Kohistan Island Arc and consists of "Bahrain Pyroxene Granulites" of Jurassic to Cretaceous age. They present the western extension of the Chilas Complex as a massive body of calc-alkaline gabbro - norites. The pyroxene granulites generally show well developed foliation and banding. A characteristic criterion is the presence of light pink plagioclases as well as darker greenish hypersthene. Otherwise, the rock is grey, weathering to dark grey or brown. In the area, some intrusions of hornblende-rich pegmatites can be observed with their dark to black, coarse-grained cristals. According to thin cut analyses, mainly plagioclase and pyroxene cristals occur, accompanied by amphiboles, chlorites, epidotes, and sericites. According to the findings, the rock type represents a norite.

Tectonically, three main striking directions of shears/faults have been recognized, i.e. E - W, NE - SW, and NW - SE, and thus being similar to foliation directions and, naturally, to the joint sets. The E-W-trend is the oldest and major one. The so-called shear zone at the penstock slope is said to belong to this trend set, as well as the upstream part of Daral Khwar valley itself. The NE-SW-trend as second important direction follows some main parts of Swat River and is represented by almost one third of joints in the area. The SE-dipping part of it "is said to".... cause downslope movement of the rock bodies because the slope of the surge area are also dipping towards SE" MAGMA. The third, NW-SE-trending fault/joint set can be seen at the Daral Khwar mouth (N 75° E) into Swat River. In the surge area, this system has" .... cut the massive norite body into many loose rock blocks and big boulders, thus causing destabilization of this slope. On this slope the E-W-trending shear zone is not much prominent".

Where the Quaternary deposits in the project area are concerned, CES and MAGMA have obviously different opinions about age, type and character of the loose overburden.

CES: "The Quaternary deposits in this area mainly represent deposition of glacial outwash, debris flow, ... terrace deposits of the present day and ancient Swat River and slope deposits (scree)." "Glacial outwash and debris flow deposits ... suggest three phases of deposition, which inturn indicate three phases of glaciation."

MAGMA: "The Quaternary deposits of the investigated area include river deposits, terrace deposits, and slope deposits". "There was no evidence of glacial outwash found in these terrace deposits. During the three glaciation, as recorded by various workers (Porter 1970) large valley glaciers originating at altitudes of 4000 m or more ... and terminated at altitudes as low as 1700m ...". MAGMA further argues that the glacial outwash should contain debris of the source area, i.e. the higher Swat catchment; the slope and terrace deposits would, however, be composed entirely of pyroxene granulite material, "... while river deposits represent variety of rocks exposed in the upper reaches of Swat River."

The latter theory suits definitely much better the objective circumstances and geological criteria in the area (refer to definition). Irrespective of the academical dispute, the devision into three main types of overburden is obviously correct.

The <u>slope deposits</u> consist of about 70% of angular boulders, cobbles and gravel of norite, accompanied by fine-grained material. Particularly in the higher slope parts, block fields become quite thick. Along the penstock slope, a peculiar "... platform of silty clay representing either, paleo surface of slope movement subsequently filled by finer material or a loess deposit".

The slope "deposits have been formed by in-situ mass wasting ..." and "... are in consolidated to semi-consolidated stage". According to definition, only the slow displacement could have been ment, as the slope in general was said to be "stabilized".

The <u>terrace deposits</u> below the slope deposits (debris slope) are mostly cultivated and are formed by both debris flow material and Swat River deposits, interfingering each other. Those terrace deposits along river Swat are a little different, as they contain relatively young gravel and cobbles of diverse petrographic character of Swat source area, while the higher positioned ones mainly consist of norites.

The young <u>river deposits</u> in both Swat River and Daral Khwar valleys represent the normal fluvial deposits of different size (boulders, cobbles, pebbles, sand, silt) and of different petrography (diorites, norites, granites, quartzites, volcanites et al). The thickness of these deposits may reach from metres to dekametres.

5.5 ENGINEERING GEOLOGICAL ASPECTS

5.5.1 General

For Daral Khwar Project, geological, engineering geological, geophysical, and soil mechanical desk studies, field and laboratory investigations have been carried out.

The geological and geophysical investigations results are sufficient to give basic interpretations of the engineering geological conditions at the weir site, headrace tunnel, surge structure and penstock, also at the powerhouse and tailrace structures.

With respect to tunnelling, and according to the mapping results, only one rock sequence has to be crossed by the by-pass, headrace, assess, and penstock tunnels, i.e. the Bahrain Pyroxene Granulite of Kohistan Island Arc, consisting of norites. The petrographic character is of good and harmless nature, although the rock types normally vary considerably in their strength properties, depending on factors like grain size, porosity, and cementing agents (Kaolinization, chloritization, sericitization); schists, if any, if any, will exhibit very marked strength anisotropy.

The tectonical behaviour is different. Along most of the headrace tunnel, no severe unconformity, fault zone, and/or shear zone has been recognized. In case of smaller faults, which never can be excluded, the character of faults is very likely to be harmless, where shear events, mylonitization, jointing, and weathering is concerned. Otherwise, the morphology would be different in view of long-termed weathering and erosion. Only in the far downstream part of the tunnel, in he surge tank area, weak and disturbed rock zones have been found, which are said to be of tectonic origine.

5.5.2 Weir/Intake

The **weir** site was chosen in the upper Daral valley, where bedrock is outcropping on the right abutment in the form of a huge "boulder", and where on the left bank some dekametres upstream the bedrock reaches near the river bed.

- Foundation of the weir will be necessary within river deposits.
- A 6.5 m depth foundation will reduce seepage through the alluvions underneath the weir. A geoplastic foil upstream the weir. Additionally a geoplastic foil and a cut-off wall upstream the weir will minimize seepage quantities by lengthening the percolation path.
- The intake on the right side will be founded on bedrock.

5.5.3 Sand Trap

The **sandtrap** is located downstream of the intake at the foot of the right bank within river deposits. Slope protections may, safety measures (riprap) against high floods have to be constructed along the sandtrap.

To connect the weir/intake with the sandtrap, a free-flow **by-pass tunnel** which will serve also as a gravel spilling system has to be driven through the boulder-like outcrop of norites. Tunnelling may become a routine exercise, as the bedrock shows very good tunnelling properties.

5.5.4 Headrace

The short **headrace canal** reaching from the sandtrap to the inlet tunnel portal, following the lower part of the right slope, does not create any excavation or foundation difficulties but some protection measures in the vicinity of the portal.

The low-pressure **headrace tunnel** of 3044 m length will cross norites of good quality in its upper approximately 2870-m-section, will, however, meet very bad and unfavourable rock conditions by approaching the surge area. Both, conventional heading and TBM will be possible. Irrespective of the rock class and the different strength of the "outer shell", a regular "inner shell" of 20 cm thick concrete lining should be taken into consideration in view of the watertightness and friction losses. Primary stresses are generally not expected, remnants may, however, not be excluded.

5.5.5 Surge Tank

Due to insufficient investigation results in the surge tank area, a second investigation campaign became necessary.

Weighing all general geological criteria, viz judging simply upon the field geological mapping works by MAGMA, it came to the understanding that evidences for a post-glacial "Sackung" event, i.e. deep-seated rock creep which has produced a ridge-top trench by gradual settlements of a slablike mass into an adjacent valley (BATES & JACKSON 1982), do not exist. All geological criteria and phenomena shall be interpreted as old tectonical movements. Slope stability analyses with assumed parameters resulted in just sufficient safety factors.

The surge tank is located within a "sheared zone", striking ± parallel to the slope causing special excavation measures, such as pre-stabilization by grouting; pile walls or drop shaft foundation. Rock bearing capacities for pressure shocks should not be taken into consideration. A pre-construction pilot tunnel for rock mechanical investigations may result in shifting the structure further into the mountain with better rock conditions for a chamber-like surge structure.

5.5.6 Penstock and Access Tunnels

The penstock and access tunnels are situated in the same "sheared zone", reducing the rock qualification decisively. The concrete plugs need deep anchors with pre-consolidation measures.

5.5.7 Penstock

The embedded 850 m long penstock is expected to have the following conditions concerning excavation and backfill: Except a small rock outcrop downslope of Borehole DP3, the whole penstock slope is covered with loose overburden. In the upper part of the penstock slope, the excavation may become costly due to the many blocks to be pop-shooted.

In the DP3 area, the material turns into a finer-grained slope deposit which can be easily excavated and backfilled. The mostly fine to medium grained slope material can be handled without difficulties, although several big blocks may have to be boulder blasted. Just downstream of Borehole DP3, strongly weathered and highly jointed rock is outcropping, the excavation of which does not create any difficulties due to its broken appearance. Backfill will be possible without further treatment.

The two fixpoints - at the valve chamber and just in front of the powerhouse - get heavy anchor support. The crossing of Madyan-Bahrain-road is accomplished by a concrete structure bearing the new road.

5.5.8 Powerhouse/Tailrace

The powerhouse was, after cost comparison, finally located on the right bank, and will need foundation on terrace deposits. Excavation of the loose terrace deposits, consisting mostly of river pebbles, cobbles, gravel, sand, and little silt with some big boulders between, will create no extraordinary difficulties, as there was found no groundwater above say 1403 m in elevation, i.e. some metres below the deepest foundation level of powerhouse. Concerning settlements and settlements differences have to be investigated in a larger scale after excavation. Compaction measures and/or ground consolidation may become necessary accordingly. Heavy soil anchors for slope protection and strong erosion protection along the water front in the form of concrete embedded riprap are necessary. The tailrace cascade does not need any special treatment except flood protection.

5.5.9 Construction Materials

The whole bulk of construction material can be gained by quarrying and/or from muck material. Natural sealing material is not available.

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6 ENVIRONMENTAL IMPACT ASSESSMENT

Reference **Appendix 6**: Environmental Impact Assessment

6.1 INTRODUCTION

Hydropower potential in the upper reaches of the tributaries of river Indus can be exploited for the indigenous generation of electricity. Exploitation of the existing hydro-potential in Swat area of N.W.F.P is economically viable and provides a useful option for the generation of electricity to the national energy planners.

The hydel policy announced by the Government of Pakistan offers attractive tariffs and concessions to make these schemes lucrative for private entrepreneurs. With the incentives given it is expected that a number of schemes would be taken up for implementation in the near future.

The proposed Project will utilise the water flow in Daral Khwar to produce electric power and thus would help in the socio-economic developments of Swat region and would also help in overcoming shortage of power in the country. The installed capacity of generation would be 35 MW.

Hydel schemes are environment friendly as these do not pollute the atmosphere with green house gases and particulate which are associated with thermal power plants. A thermal power plant would not only require transportation of large quantities of fossil fuel but would also contaminate the atmosphere with the emission of large quantities of CO_2, SO_2, NO_X and particulate matter.

6.1.1 Project Area

The proposed project area is located near Village Arin of Bahrain Tahsil of District Swat. The district of Swat lies from 34^0-09' to $35^0$36 ' north latitude and 72^0-07' to 73^0-00' east longitude.

The district is bounded on the north and east by Gilgit district, on the south and south east by Mansehra district and on the west by Dir district. The total area of the district is 8788 km^2.

Swat is one of the twelve districts constituting the N.W.F.P of Pakistan. The highest administrative authority is the Deputy Commissioner, who is assisted by three Sub-divisional officers. The Swat Sub-division is divided into 8 Tehsils and 35 Union Councils (U.C.s). Saidu Sharif is the capital city of the district and also the seat of the Malakand Commissioner.

6.2 MAIN FEATURES OF THE SCHEME

The proposed site for the Weir is located at an elevation of 1720 m a.s.l. Due to the high design discharge (15 m^3/s), a Weir with lateral intake is proposed. The weir will have a foundation length of 50 m and a height above river bed of 2.5 m. A sand trap with two parallel chambers is planned downstream the weir on the right side of DARAL KHWAR, for excluding sand and gravel from the supply to be diverted to the turbine for generation of electric power.

An approx. three thousand meter long pressure tunnel will take the diverted water across the high mountain to the Swat valley to a surge tank close to Bahrain Town. From the surge tank to the Power house, a steel penstock will drop the water by approx. 290 m to the turbines for generation of electric power.

The proposed site for the Power House is located 1 km south of Bahrain Town between the main road and Swat river. It can be constructed on a flat field, as an external type structures. It is proposed to install three turbines.

6.2.1 Topography

Characteristics for the area are mountains ranging from about 1,000 to 6,200m peak heights increasing from south to north with vegetation mainly between 1,800 and 3,400 m.a.s.l., glaciers are evident at altitudes of 4,000 m.

River Swat which rises in the lofty ranges bordering Chitral in the north and flows south, south-west from its course to Chakdara near the border of Swat district in the south, approximately divides the district into two halves. However, topographicaly Swat may be divided into two tracts, one is the Swat Kohistan or the mountain country on the upper reaches of the Swat river as far south as Mardan and the other is Swat proper which is further sub-divided into par (upper) and kuz (lower) Swat. Starting from an elevation of 600 meters at the junction of the Swat and Panjkora rivers, the valley of Swat rivers rises rapidly to peeks in the north ranging from 4,500 to 6,300 meters above sea level.

6.2.2 Hydrology and Sedimentation

A gauging station was established at Daral on 17-12-92. Data of subsequent years is available for the same. The other hydrological information available in this area is for Kalam gauging station, located on Swat river around 25 kilometres upstream of Bahrain. Alternatively one can also interpolate the data using the specific discharge figures developed for catchments of similar characteristics.

The discharges in the streams of the region are mainly influenced by snow melt from May to June and later by monsoon rains.

The scheme is based on run-of river and only a limited storage in the tunnel is proposed. The sedimentation data at the site has also been collected recently. It is proposed to provide gravel/sand traps at the downstream of the weir to exclude maximum amount of suspended load from the diverted water.

The areas of permanent settlements need irrigation and drinking water and such localities exist only up to about 2,000 m.a.s.l. Moreover there is no apparent conflict between requirements for irrigation and power generation, since irrigation requirements occur during seasons when more water is available in the Khwar than required for generation of power.

6.3 CLIMATE

The project area is located along Swat river surrounded by high mountain peaks. This topographic set up gives rise to strong winds, which keep the temperature of the area lower during Summer. There is some rainfall during summer and snow falls during the months of December to April. During the later period there is also some rainfall.

6.3.1 Temperature

Average daily temperatures of Bahrain area during December to February range from -4 ^{0}C to 7 ^{0}C and between 21^0 C to 35 ^{0}C during June to August. Thus the annual range of temperature of the area is from -4 ^{0}C to 35 ^{0}C. Occasionally however it may rise to 40^0 C during the month of June.

6.3.2 Precipitation

The precipitation is mostly in the form of snowfall on surrounding peaks and a large part of the precipitation occurs during winter. During summer monsoon the area receives only sparse rainfall. Mean annual precipitation is about 1,560 mm.

6.3.3 Waste Disposal

Domestic solid and liquid waste disposal is totally unplanned and unmanaged between the villages of Arin and Jail (short of Bahrain at tail of Daral Khwar) with the result that all the ravines in the vicinity and streets of the village are dumped with garbage, cattle dung and fodder waste. This waste is either removed and used in adjoining fields as manure or carried away by rain water. However this waste has no impact on the project.

6.3.4 Public Health and Diseases

Swat is one of the most backward and economically depressed areas of N.W.F.P. Bahrain however has a proper health centre and hospital with adequate facilities. The complicated cases have to be taken to Saidu Sharif. The drinking water supply is generally not treated properly which commonly results in a source of numerous ailments to the local people. Main diseases are reported to be malaria, dysentery, typhoid, skin infection, cholera, and Leprosy.

6.4 BIOLOGICAL RESOURCES AND FORESTATION

6.4.1 Animal Husbandry

Villagers around the Project area raise goats, sheep, buffalo, cows, donkeys and poultry birds to meet their daily needs. A flock of goat and sheep comprises upto 100 head, cows upto 5, buffaloes 2 to 3, donkeys mules and horses upto 5. Usually flocks are kept near the farms. Selling livestock provides a useful source of income.

6.4.2 Wildlife

Swat area is well known for its forests and has a variety of wildlife, many of which are endangered species.

Important wildlife found in Bahrain area is:

Birds - Snow cock; Black Partridge; Grey Partridge; See – See; Snow Partridge; Monal Pheasant; Tagopan Pheasant; Khalij Pheasant; Koklass Pheasant; Chakoor; Golden Eagle.

Animals - Rhesus Monkey; Markhor; Musk Deer; Black Bear; Brown Bear; Snow Leopard; Flying Squarrel; Common Leopard; Himalayan Ibex; Goral; Wolf; Jackal.

- **Bee Farming (smaller type)**

  Bee farming is practised by the locals. There are three private bee farms in the area. The locals while constructing their houses leave hollow spaces in their walls. These hollows are then occupied by bees which provide honey for the family and the surplus is sold in the market. Honey of this area is famous and has considerable demand amongst tourists.

- **Fisheries**

  There is a Government trout farm at Madyan and other smaller trout farms are being maintained by locals. There is no trout farm at Bahrain. However there is a big demand for trout at this place, which is met by the farms at Madyan. The common fish found in Swat river at Bahrain is Swati, Mullah and Snow Trout which are not a farm fish. It is usually caught by the locals by using hand nets.

6.4.3 Forests

- **Distribution of Forests**

  Total forest area of Bahrain Sub - Division is 39,314 Ha, whereas the forest area around Bahrain village is about 2496 Ha.

- **Legal Position**

On November 10, 1976 the Government decided that a 60% share from income of these forests will go to the locals while 40% will be for Government. Notification was issued vide Government of N.W.F.P, number SOFT (FAD)V-405/77 dated 14.3.1977.

- **Rights and Concessions**

The following privileges are enjoyed by the local people;

1.	Grazing of Cattle	Full rights
2.	Grass cutting	Full rights
3.	Fuel Wood collection	Full rights (no green tree to be cut)
4.	Timber for construction purpose	700 trees (for whole of Bahrain Tehsil)
5.	Share from sale of forests	60% (paid to the locals)

- **Classification**

In general the forest can be classified into the following types according to the variety of vegetation;

- ***Pure Deodar Forests***

These occur at elevations from 1700 meters to 2900 m. They cover 33% of total forested area. At places it is associated with Kail also.

The broad leaf associates are Kalakat, Jijrai, Amlok, Akhrot, Chinar, Kau, Tut and Safida.

- ***Pure Kail Forests***

This type covers about 20% of the forest area, the percentage of Kail in this type varies between 70% to 80%. Broad leaf associates are Kalakat, Batangi, Akhroat, Oak and Bird cheery etc. The growth consists of Vibemum, Rosa, Rubus, Skimmia, Indegofera species, ferns etc.

- ***Pure Fir/Spruce Forests***

This type covers about 47% of forested area. They occupy the highest altitudes (2420 - 3320 m and above). At places they occur mixed with Kail and Deodar.

Broad leafed associates are Holly Oak, Brown Oak, Horse Chestnuts, Walnut, Bird Cheery, Maple and Birch. The undergrowth consists of Viburnum, Skimmea, Rosa, Parrotia, Berberes, Podophylum species, Ferns and grasses.

- ***Mixed Forests of Fir, Spruce, Deodar and Kail***

These forests consist of mixed trees of fir, spruce deodar and some Kail. They occur below the fir/spruce zone.

Broad leafed associates consist of maple, bird cheery, oak, horse chestnut, Tut, Batangi and Amlok.

Undergrowth consists of various grasses, roasa, bivumum and indigofera species.

- ***Grazing lands and Pastures***

The slopes and uncultivated lands are included in this category. The lands located near valley bottom below forest line are individually owned and are being converted into cultivated lands.

The lands inside the forest area are permanent pastures, generally these pastures are rain fed.

The high alpine pastures are located above dense forests areas and occur at altitudes 2700 to 4200 meters. These generally are large pastures and are an important source of fodder for livestock. Upper reaches of these pastures are defined by glaciers, snowline and steepness of slopes.

They consist of a variety of grasses and a number of species of herbaceous plants like Agroshis and potentalla species and Dactyls glomerata, Trifolium repens, Trifolium Thalli, Plantago major, Lotus Alpinus etc.

6.4.4 Game Laws

The tract is covered by Government of N.W.F.P Wildlife Act No. V of 1975 published under Notification No. Leges-1(22)/73 dated 01-08-1975. This provides protection, preservation, conservation and management of all sorts of wildlife in the area.

6.5 SOCIO - ECONOMIC SET UP

6.5.1 Population Figures

Population figures of the area according to 1981 census of Bahrain Tehsil is about 63,000. With 3% annual increase, the present population could be about 100,000.

Families of brothers and cousins live under joint family system. This living provides protection against their enemies and helps in the collective development and utilization of available resources.

6.5.2 Religion, Customs and Ownership

Religion of the entire population is Islam. They speak Pashto and some of the more educated people also understand Urdu/English. Women folk observe parda and lack education. Many men have three wives and have a dozen or more off-spring.

Houses and landed property is individually owned. Holdings are small and with growing population of the area are becoming increasingly small. Forests, pastures and water are the joint property of the people. Gujars, who lead a nomadic life, live with their herds at high altitudes. They take their herds to lower altitudes during winter where they sell some of it and return to their abode during summer.

Historically, the people of the area believe in democratic system of human setup. Jirgas are formed to settle any disputes. Almost all decisions are made by general consensus; influential people are not allowed to dominate these decisions. In order to resolve conflicts, this type of community consensus has proved most effective.

6.5.3 Public Facilities

Swat - Kalam Road is the major source of communication for trade and transport. Bahrain is an important trade centre of the area, where sheep, wool, hide, trout, mushrooms, poultry and honey are sold as local products. Flour, ghee and other edibles, cloth, medicine and gift items for sale to tourists are among important items which are transported from down country for sale in this area. Due to the scenic beauty and cool summers, Bahrain has a great attraction for the tourists, who visit the places in large numbers during summer with the result that hotels. restaurant and gift shops get quite crowded at Bahrain and its vicinities.

Bahrain Tehsil has 35 primary schools for boys and 4 for girls; 2 middle schools for boys and 1 for girls, and 7 high schools. There are 11 health units in Bahrain Tehsil, out of which 3 are located at Bahrain and its outskirts.

6.5.4 Agriculture and other Livelihood

Both irrigated and rain water farming is in practice. Due to snowfall, the snow melt gives rise to a number of springs, and the water used for agriculture. Wheat, maize, potato, rice, vegetable and apple are major agriculture products of the area.

People who have small land holdings, move down after they cultivate their lands where they work as labourers. Most of the them work in Baluchistan in the coal mines. The women and children look after the farms during their absence.

Agriculture, livestock pastures, tourism and timber are the major income generating means. A large number of healthy male folk work outside as labourers on roads, forests, mines etc.

6.6 GUIDELINES AND PROCEDURES

In Pakistan, environmental policy and the approval of environmental standards lie within the purview of Pakistan Environmental protection council, whereas standards of development and enforcement, as well as other environmental programs, are administered by the Environment and Urban Affairs Division of the Ministry of Works, Environment and Urban Affairs. The main legal requirements for a project of this type are based on the Pakistan Environmental Protection Ordinance (EPO) No. xxxvii, "Control of Pollution and Preservation of Living Environment", which was enacted in December 1983. For the Daral Khwar Hydropower Project, the checklist used by the WAPDA DAM Monitoring Organisation was also consulted.

Additionally GOP has established legislation goveming antiquities, endangered species, national parks, wildlife sanctuaries, game reserves, forestry and water management. Major environmental legislation and regulations pertaining to these resources are given in table 1 (next page). An official GOP document of particular interest to this project was prepared by EUAD and the EIA service of IUCN. This document provides EIA guidelines for the energy sector in Pakistan. These guidelines have also been consulted while preparing this ESSA.

Multilateral development organisations such as the World Bank and ADB have established procedures for the evaluation of potential environmental impacts and the adequacy of pollution control measures. These evaluations are concemed with both the natural human environmental Assessment Guidelines, the World Bank detailed guidelines and procedures, and the ADB's EIA guidelines are available and were consulted.

Bilateral funding organisations such as USAID have also established policies for evaluating the environmental consequences of the project. The basic policy for the consideration of the environmental implications of USAID financed activities is embodied in the larger requirements set forth at 22 CFR part 216, "AID Environmental Procedures", which includes a comprehensive set of procedures to be followed, and requirements to be met, in evaluating proposed project. These guidelines were also consulted for this study.

Although several documents and available guidelines were consulted for this ESSA, the checklist used was that required by GOP under the EPO. The format employed in analysing impacts and mitigation options is based on relevant World Bank procedures.

6.6.1 Environmental Impact

- **Scope of Investigations**

  The ESSA (Environmental & Social Soundness Assessment) of Daral Khwar was carried out, keeping in mind three main requirements. First, to assess all possible impacts, both negative and positive, that may occur during the construction and operation of the project. Second, to quantify in economic terms, impacts such as resettlement costs, loss of land, etc., as well as the mitigation measures proposed. Finally, the most important requirement was to assess the impact of the project in accordance with the following documents: environmental guidelines of the World Bank, the ESSA guidelines issued by the WAPDA Private Power Cell, and guidelines of the NWFP EPA.

  Further an explicit statement is required on residual impacts, that is, those adverse impacts that will remain either because they cannot be mitigated or the mitigation as proposed is not sufficient to eliminate them completely.

Table 1
Major Environmental Legislation and Regulations for Pakistan

Type	Authority	Administering Agency	Requirements
Comprehensive Environmental Protection	GOP Ordinance No. XXXVII of 1983	Environment and Urban Affairs Division, Ministry of Works, Environment and Urban Affairs	Environmental Proforma
Protection of Antiquities	Act No. VI of 1977	Ministry of Culture, Archaeology, Sports and Tourism : Department of Archaeology	Provides protection and preservation of historically and archaeological important sites.
Water resources	West Pakistan Act of 1958	WAPDA	Management of Water resources
Wildlife	West Pakistan Wildlife Protection Ordinance of 1959	Zoological Survey : Nation Council for Conservation of Wildlife ; Ministry of Food Agriculture and Cooperatives	Promote conservation and establish limits on hunting
	Provincial Wildlife Protection Ordinance since 1972 and International Conventions ratified by Federal Government	Provincial Wildlife Department	Govern endangered species, wetlands and heritage resources. Empowers Provincial Government's to Protect wild life in protected areas and prohibited trade in protected species
	NWFP wildlife Act. 1975	Government of NWFP, Department of Forestry, Wildlife's Fisheries.	Protection, reservation and management of wildlife
Forests	Forests Act of 1927 No. XVI	Ministry of Food Agricultures and Cooperatives, Government of NWFP, Department of Forestry, Wildlife & Fisheries	Protection, conservation and regulation of exploitation of forests
	Hazara Forest Act, 1936	Government of NWFP, Department of Forests, Wildlife and Fisheries	Protection, conservation and regulation of exploitation of forests
	Hazara Gunzara Rules, 1950	Government of NWFP, Department of Forests, Wildlife and Fisheries	Protection, conservation and regulation of exploitation of forests
Fisheries	The West Pakistan Fisheries Ordinance, 1961	Government of Pakistan, Ministry of Food, Agriculture and Cooperatives	Protection, preservation and management of fisheries
	NWFP Fisheries Rule, 1976	Government of NWFP, Department of Forestry	Protection, preservation and management of fisheries
Fouling of Water	Canal and Drainage Act of 1873	Provincial irrigation Department	Prohibits fouling of canal water, including channels water courses, reservoirs and tubewells, by industrial and domestic pollution, or drainage obstruction

- **Methodology for Data Collection and Analysis**

  Basic data for the project are compiled from relevant chapters of this Regional Power Development study which cover aspects such as engineering and design, hydrology, geology and related aspects, and maps. Additional site specific information and clarification were obtained from local officials working in the Swat District, representatives of line agencies based in Dassu and Patan and field staff working in the project area.

6.7 REST WATER REQUIREMENTS

The catchment area of Daral Khwar at Weir site is 250 km^2. as observed. The hydrology i.e. the mean, monthly minimum, and 90% of the time flows in Daral Khwar at the weir site as given in the Hydrological Study are as follows;

Mean annual discharge	= 10.76 m^3/s
Monthly minimum discharge (January)	= 1.31 m^3/s
Discharge 90% of the time	= 1.28 m^3/s

As regards the environmental impact of the scheme, it is observed that diversion of the flows at Arin Weir/Dam site, for the generation of power is going to deprive the lower riparian of Daral Khwar, between Arin and Bahrain of that much flow. To protect their multifarious needs the required amount of water must be released from Arin Weir round the year, even at the cost of lesser power generation. This is going to be critical in the winter months of low flows, when power generation may have to be reduced substantially.

6.7.1 Existing Water Usage

Due to high altitude, rain and snowfall are the natural sources of land irrigation water. Most of the rain water drains out rapidly due to topographical conditions. The snow on the other hand remains on the ground for some time, melts slowly and farmers channelize it into private canals. A considerable area is thus irrigated by diversion of rain and snow melt water to the fields.

6.7.2 Domestic Usage

There is only a very limited access to safe water supply in the rural area of the region and people mostly use spring water for drinking and household needs.

6.7.3 Basic Parameters for Rest Water Assessment

The following basic parameters underline the study;

i) The crop water requirements exist only between the periods May to August, when the irrigated farming is primarily done. There is almost no requirement during the periods January to April and September till December.

ii) Water Mill requirements exist throughout the year. However, these can be dispensed with after commissioning of the HYDEL station when the water mills can be replaced by electric operated motors. This fact has however not been taken into account for the present study.

iii) The domestic water requirements of the villages close to the Khwar area are presently met from springs, and they do not use KHWAR waters except for bathing and clothes washing.

iv) There is only limited wild life, and their needs are primarily met from a number of springs in the area.

v) There is almost no fish culture during low supply periods (winter months) and whatever fish do exist, travel up the Swat River during summer months.

vi) The inflow into the Khwar from various tributaries joining in the downstream reach was observed in the month of March 1995 when the flow was very low. The flow during the months of May to August would be much higher due to snow melt and rains. The March inflow figures have been used for calculating the rest water availability. For arriving at the Water Mill requirements, the inflow from tributaries has been taken as Nil, which may well be the case in December/January. Thus this estimate is also conservative.

vii) Return flow from Water Mills to the Khwar is taken as 2/3 rd, which gives quite high seepage and other losses.

viii) Present cattle head count in the area is about 600, for which water quantity needed is substantial, and is partly met from springs and partly from the Khwar.

ix) Sanitary water requirements for Bahrain and other village huts along the Khwar have been added for winter months when the supply in the Khwar would not be enough for dilution etc.

x) Water supply to Bahrain is being tapped directly from a tributary and the system is not dependent on flow in the Khwar.

6.7.4 Rest Water Assessment

Appendix 6 provides a Schematic diagram of the various canals and tributaries is attached **(Annexe I)**. This has been used to work out the inflow an outflow points. The statements I and II give the 'Rest Water' calculations for the two periods, i.e., May to August and January to April/ September to December.

As may be observed the requirements for May to August is 140 l/s. The requirements for other months of the year work out to only 80 l/s for the two Water Mills but other requirements of 60 l/s were added. Thus the requirement round the year would be 140 l/s.

6.7.5 Recommendation

To keep some margin for future development and uncertainties of weather we will consider it appropriate to base the design of the hydel station on 'Rest Water' requirements of 200 l/s during low flow period in Daral Khwar.

6.7.6 Domestic Solid/Liquid Waste and Disease

Some waste water and agricultural fields run off flow into the river. The area of concern here is the portion of the river below the intake structure. There are about 50 houses along this section which are contributing waste water to this section. From October to May when very low flow conditions prevail in the stream and lesser dilution is provided to this waste water, a concentrated waste stream may flow down this section and pollute stagnant water ponds formed in places where depressions are available and quantity of flushing water is not enough to wash away the whole width of the stream. As the disposal of waste in the village is not organised and uncontrolled disposal in to the river is practised, it may contribute to the escalations of the above conditions. These conditions can cause mosquito breeding and smell nuisance and provide potential sites for the spread of water based/borne diseases, particularly infantile diarrhoea, dysentery (both bacillary and amoebic) typhoid, malaria and cholera which may become more frequent due to aggravated situation. Apart from releasing minimum rest water downstream of ARIN, it would be an ideal thing to help the villagers around the Khwar banks to develop proper sewerage disposal.

It is also observed that even though Bahrain town, through which Daral Khwar passes at its tail, has a local water supply system for most of the population, fed from springs, some of the houses still draw domestic water directly form the Khwar, while disposal from the houses along the Khwar is also discharged directly into it. This is of-course highly un-hygienic and leads to pollution and diseases.

The implementation of the Project will have no direct impact on this aspect especially when the minimum water needs of domestic use as well as for dilution will be released downstream of the weir even in low flow seasons. However it is suggested that provision may be made in the estimates of this scheme to extend and improve the Municipal water supply of Bahrain town. The source of water supply should either be from springs or the water should be treated if taken directly from the Khwar.

On the other hand a proper sewerage network may be laid and waste water treated before discharging it directly into Swat River. This is all the more important in view of the possibility of higher concentration of pollution (solid/liquid waste) in Daral Khwar during low discharge periods.

6.8 EFFECTS ON THE ENVIRONMENT (DURING CONSTRUCTION)

6.8.1 Displacement of People

As a result of the construction of the Project only a relatively small habitated area would be affected although not a single house will have to be relocated. In this way there would be almost no movement of people from this area. The social effects of moving people is therefore minimal and the scheme should not cause any significant social disruption.

6.8.2 Displacement of Wildlife

Since there does not exist any significant wildlife in the area and the construction area is relatively small, the impact on wildlife would be negligible. Of course rodents, the small number of the birds, reptiles and lizards would be disturbed during construction of the weir and Powerhouse etc., but these will all rehabilitate once the construction phase is over.

The effect on fish movement would be insignificant as there is only limited fish in this Khwar, although the formation of a small reservoir area will encourage the growth of fish culture and certain amount of flora along its periphery.

The other effects would be minor i.e. about 25 trees would be cut and some length of Katcha path on the left bank and lower terraces of agriculture land on right bank would be submerged after the weir construction. The Project cost should include provision for building a peripheral road around the weir to facilitate movement.

6.8.3 Weir

Close to the weir and inlet site there is a small habitation named village Arin. This is occupied by descendants of only one family having seven brothers each living in an independent house. Presently the number of children is 40 and 4 grown-ups. The construction of the weir and inlet will not disturb any house as these are located well above it. A small graveyard belonging to the village families has about 12 graves, and again, this graveyard will also not be disturbed. The size of the pond area will be approximately 1 Ha.

The area to be acquired for the weir, gravel/sand trap and inlet is 2 Ha. There is no agricultural land except a few small fields and only some 25 small trees will have to be cut.

The forest area taken away must be replaced by at least an equal area by planting trees along the road or in the vicinity of weir, gravel and sand traps. The cost of replanting is estimated to be Rs.100,000/- and may be included in the Project estimate.

6.8.4 Construction of Tunnel

The most probable construction methodology would be to start construction of the tunnel from the downstream end. The total muck to be dumped is estimated to be 70,000 cu.m. There is a flat treeless area and deep ravines available close to the site which would make acceptable stock pile areas. The estimated surface area for dumping of the muck would be 4 hactares.

The terraced dumping area can be covered with proper soil for growing crops or planting trees. The cost of the land improvement would be about Rs. 1,120,000 and must be included in the Project Estimates.

About 20 small trees will have to be cut from the dumping areas. The reforestation planned on dumped area will more than offset the damage.

6.8.5 Headrace

The open headrace is relatively short in length and is an extension of weir area, already discussed above.

6.8.6 Effects at Tailrace

The effects at the tailrace is expected to be minor and insignificant, as the water from the Powerhouse discharges directly into the Swat river.

6.8.7 Powerhouse

The proposed Powerhouse is to be located between the main highway and right bank of river Swat. Some level area is available while some terraced land will also have to be taken. Total area needed is 0.5 Ha.

All this area is agricultural land and the farmers will have to be compensated adequately. However there is no habitation on this land, and also there are no trees except a few shrubs. The displacement is therefore not significant, while the development of the area would be much more beneficial to the community.

Close to the powerhouse some operation staff houses will also be built and the sewerage disposal will be made directly into the Swat river after proper treatment. Cost of the sewerage system including treatment plant shall be included in the Project Estimates.

6.8.8 Roads

The construction of new roads would cover about 10 Ha in area. The construction of roads in the vicinity will have the following direct and indirect affects;

- Erosion and drainage problems at various places.
- Driving off wildlife by noise and human activities.
- Cutting of fuel wood and possible shooting at game animals by the road construction crew.

It is envisaged that these affects will not be significant. The road design should include proper drainage and no erosion is thus likely to take place in future. In fact construction of the road would bring social and economic benefits to the area and the people around. During construction it will employ local labour and will economically benefit the area.

6.8.9 Housing Area

The actual impact would depend on the exact location of the housing area. However the operating staff will be relatively small in number and the residential units needed would not affect the land usage significantly. Rather the properly planned and built residences would tend to improve the quality of the life of the people around.

6.8.10 Effects of Transmission Lines

It is expected at the time of construction that the effects of transmission and distribution lines will be limited and would not be serious in the case of project area. Some interruption of agriculture operation may take place during the construction period. In any case this activity is not expected to penetrate significant areas of Agriculture, Wildlife and Forests.

6.8.11 Health

The general health of the people is good and the reported cases of water related and transmitted disease are few. People generally take water from springs. Some people store rain water and then use it for domestic purposes.

There are almost no stagnant water pools in the area to cause insanitary conditions and breeding of mosquitoes etc. It is however true that much improvement is desired in sanitation, personal hygiene and efforts are being made in this direction under various programs of the Government.

6.8.12 Air and Noise Pollution

The proposed site has no industrial units in its immediate surrounding area and presently has clean atmosphere. During the construction phase, movement of heavy machinery and blasting of rocks will cause significant air pollution in the form of dust, exhaust gases and increase in noise level. These pollutants will not only increase ambient dust and noise levels but may also cause respiratory diseases such as bronchitis, silicosis, T.B. etc. The dust level can be significantly decreased by continuously sprinkling the katcha roads with water. Noise level may be reduced by using silencers on the earth moving equipment's exhaust pipes.

6.8.13 Operation Period

The adverse effects of Hydropower projects occur largely during construction; in the operating period the benefits are more. The minor undesirable effects in operation, if any, can be corrected without compromising the benefits of the Project. The obvious advantages are the availability of power to the area, better roads and development of civic amenities.

The operation of a Hydel Power Plant does not create environmental problems as does a Thermal Plant by emitting tonnes of toxic gases which adversely affect the quality of environment.

6.9 MITIGATION OF ENVIRONMENTAL IMPACTS

In all, forty five trees of various species will be cut in the location of various components of the project, i.e. weir, surge tank, powerhouse, etc. The compensation for these trees will be about Rs. 200,000/- inclusive of cost of felling.

Compact forests are located much higher up and will not be affected. Only some wood may be needed for construction purposes which can be purchased from the local market. Therefore there will be no perceptible effect on the forests. It is also proposed to dump all the excavated material in the adjoining ravines or on slopes, to create terraced fields, which would then be planted with trees. This action will mitigate the effect of cutting and felling of trees in the Project area, and on the other hand create additional areas for planned forestation.

6.9.1 Livestock

A discharge of 200 l/s will be available in Daral Khwar downstream of weir for the use of live stock, wildlife and inhabitants, usage even during the low flow period of winter. Pastures in the area are also located beyond the reaches of the environment impact of the project. Thus there will be no adverse impact and no mitigation measure is needed.

6.9.2 Waste Disposal and Diseases

The weir proposed for diversion near Arin is a low height structure of 2.5 m height, which will create almost negligible ponding. Thus there will be no health hazard posed from still water pondage.

Various components of the project are situated at a considerable distance from the human population and do not interfere with the solid and liquid waste disposal system adopted locally.

Only about 50 houses downstream of the weir are releasing waste water into Daral Khwar. It is proposed that proper sewerage system may be provided for these houses.

As also suggested in para 7.6 adequate provision is to be made in the Project estimates for improving and extending domestic water supply network and sewerage system in Bahrain Town.

- *Provision for Bahrain town water supply and sewerage system = Rs. 10.0 million.*

  Based on the present population of Bahrain Town a design population of 35,000 has been adopted for water supply and sewerage system. It is envisaged that out of the total population approximately 50% are affecting Daral Khwar which comes out 17,500 or 2,000 households. Based on experience, cost of providing a sewerage and water supply system per household comes to Rs. 5,000/- per household.

  Total Cost = 2,000x5,000 = Rs. 10 Million.

- *Cost estimate of sewerage system of houses and village huts along the Daral Khwar downstream of weir = Rs. 1.0 million.*

  Only about 50 houses will have to be provided with a proper sewerage system. Since these households are spreadout cost for providing sewerage system to each would be higher i.e., approximately Rs. 20,000/-.

  Total Cost = 50 x20,000 = Rs. 1 Million.

6.9.3 Disposal of Excavation Material

Spoil material, derived from the construction of dam, canal, tunnel, penstock, powerhouse, tailrace etc. which is estimated at about 160,000 m^3, will be dumped in ravines and on hill slopes near the respective structures and close to the exit point of the tunnel, where all the muck from the tunnel can be disposed of. These dumps must be properly levelled and terraced and eventually turned into fields for growing crops. The slopes should be covered with grass for stabilisation as well as grazing. Such dumps can also be used for planned forestation.

Cost of terracing and providing soil on 4 Ha area at Rs. 0.31 million per Ha	= Rs 1.24 Million.

The cost of terracing would be approximately Rs. 7.00/m^3 which includes the cost of transportation of excavated material spreading and formation of terraces etc.

160,000 m^3 @ Rs. 7/ m^3	= Rs. 1,120,000/-
Plantation of trees etc., at 500 trees/Ha @ Rs. 50/tree	= Rs. 100,000/-.
Retaining wall (gabion structure)	= Rs. 20,000/-.
	= Rs. 1.24 million.

Rehabilitation of Quarry Area 2 Ha @ 0.15 mil. per Ha		*= Rs. 0.3 Million*
Plantation of trees etc.		Rs. 24700/- per hectare.
Drainage of quarry area		Rs. 25,000/- per hectare.
Gabion structure		Rs. 45,000/- per hectare.
Earth water		Rs. 25,000/- per hectare.
		Rs. 1,19,700/- per hectare
	≅	Rs. 0.15 million per hectare
For 2 hectare	≅	Rs. 0.30 million.

6.9.4 Conversion of Water Mills on Electricity

To continue the operation of water mills, it is proposed to convert them to run these on electricity. The cost of conversion of existing two water mills will be as under;

Cost of power transmission (service) Lines,
electric motors and its accessories, couplings etc. Rs. 0.2 million

6.9.5 Mitigation Cost

A) INITIAL

S.No.	ITEMS	Amount (Mill)
i.	Compensation of Trees.	0.20
ii.	Disposal of excavated material with land scaping and plantation.	1.24
iii.	Rehabilitation of Quarry with land scaping and plantation.	0.30
iv.	Improving water supply & sewerage system of Bahrain Town.	10.00
v.	Providing sewerage disposal for the houses down stream of weir.	1.00
vi.	Cost of providing power transmission lines to the two water mills, providing electric motors and couplings and other items for conversion.	0.20
	Total	12.94

B) ANNUAL

S.No.	ITEMS	Amount (Mill)
i.	Monitoring of quality of water in Daral Khwar	0.025

6.10 CONCLUSIONS

Hydel power is an environment friendly source of energy as it does not adversely affect the quality of environment. Thermal power plants, due to emission of large quantities of CO_2, SO_2, NO_x and particulates are major source of atmospheric pollution. The estimated emission of these pollutants from a 35 MW plant operating at 48% plant factor are given below.

Fuel	Coal	Oil	Gas
CO_2 emission in Kg	$1.3x10^8$	$1.02\ x10^8$	$0.7\ x10^8$
SO_2 emission in Kg	$1.3\ x10^6$	$1.02\ x10^6$	$< 0.44\ x10^3$
NO_x emission in Kg	$1.3\ x10^6$	$1.02\ x10^5$	$< 1.07\ x10^5$
Particulate emission in Kg	$1.4\ x10^5$	$0.26\ x10^5$	$< 1.3\ x10^3$

On the basis of the foregoing, the proposed High Head Hydropower Project in Swat would create only minor dislocation and disturbance but it would be able to produce and transport energy in an environmentally acceptable manner.

The agricultural area affected is small, while only 45 trees would have to be cut and 1-2 Ha of forest land affected. This, however, can be compensated by the afforestation Programme of planting trees on terraced area created by deposit of excavated material from the tunnel and around different structures, particularly in the new housing area for the project staff. The structures are not going to affect any flora worth conserving. There are no game parks nor bird sanctuaries in the area for protection of wildlife. The survey has shown that there will be little effect on the wildlife due to the construction of the project structures.

There are no archaeological and cultural relics in the Project area which need conservation.

The project will alter the water flow to some extent due to the diversion at Arin, but it will not affect the hydrological feature in the short reach of Daral Khwar upto its outfall, into Swat river. The water rights and existing usage on the downstream of the diversion weir will be protected and rest water needs as assessed, will always be released. The project will not change the nutrient and sediment transport significantly, as storage at the diversion site is not envisaged in this scheme.

The analysis has shown that the project will not alter in any way the risk of disease spreading due to construction of the weir and tunnels. The health of people will not be affected.

The area has land, livestock, forest, water and some mineral resources but the construction of the project will not affect the exploitation of these resources. The area is a tourist attraction and the tourists mostly travel along the road to Kalam valley but the visual impact of the small Powerhouse building at Bahrain and the transmission line will not impair the background scenic beauty. Attempt should however be made to keep aesthetics in view while designing the Powerhouse building.

The overall impact of mitigation measures is tabulated on next pages.

6.11 IMPLEMENTATION AND MONITORING OF MITIGATION PROGRAMME

Being a medium size Hydel power project based on the run of river discharge, it has minimum environmental ill effects. Still following aspects need monitoring;

1. Quality of water at the outfall of Daral Khwar may be observed during low discharge period to ensure the effective implementation and that sewerage water is not thrown into the stream. Also if the water is safe for domestic use.

2. Development of plantation over muck disposal area and quarry area may be monitored annually.

Annual expenses on item '1' including manpower and laboratory test charges will be Rs.25,000/-. The job will be entrusted to local Public Health Department.

The item '2' should be monitored by the Forest Department at no extra cost and the department will have to be entrusted this responsibility

OVERALL IMPACT OF MITIGATION MEASURES

S. No.	Activities /Actions Affecting Environment/Socio-Economic Conditions	Socio-Economic	Mitigation Measures	Overall Impact after Mitigation					References
				No Effect	Significant Negative Effect			Significant Positive	
					Small	Moderate	Major		
A.	**<u>Environmental Problems Related to Project Location</u>**								
1.	Displacement of People	No displacement/ disruption of home and livelihood.	No mitigation measures required.	x					8.1
2.	Encroachment into Precious Ecology	Loss of ecological values	Good planning and offsetting measures.		x				
3.	Encroachment on Historical/ Cultural Values	Loss of historical / cultural values.	Good planning and mitigation measures.	x					
4.	Effect on Wildlife			x					8 2
	a. Livestock	Economic loss	Careful planning plus mitigation measures.	x					
	b. Fisheries	Economic loss	---do---	x					8.2
B.	**<u>Environmental Problems Related to Design</u>**								
1.	Water Rights Conflict.	Impairment of water Supply and land values.	Careful management of water and guarantee of existing usage.			x			8.5
2.	Road Erosion	Damage to land	Careful planning and protective measures.	x					8.8
3.	Excavated Material	Possible damage to Environment	Planned disposal and utilisation of dumping area		x				8.4
4.	Construction of Tunnel	Possible damage to environment	Careful planning and disposal of excavated material.		x				8.4
5.	Weir, Sand trap, Inlet Structure	Loss of ecological values	Proper construction planning and disposal of construction material.		x				8.3
C.	**<u>Environmental Problems Associated with Construction</u>**								
1	Construction hazards	Loss of ecological values	Proper construction planning & disposal of construction material.		x				8.2
	a. Housing for workers	------ do -------	------ do ------		x				8.9
	b. quarying hazard (blasting & hauling)	------ do -------	------ do -------			x			8.5.3
	c. Air and Noise	------ do -------	------ do ------		x				8.12
2.	Access Road	Damage to environment, displacement of people	Proper routing, construction/ environment mitigation.		x				8.8
3.	Tunnel	Possible damage to Environment	Careful planning and disposal of excavated material		x				8.4
4.	Transmission Line	------ do -------	Careful planning		x				8.10

Cont'd

OVERALL IMPACT OF MITIGATION MEASURES

S No.	Activities /Actions Affecting Environment/Socio-Economic Conditions	Socio-Economic	Mitigation Measures	Overall Impact after Mitigation					References
				No Effect	Significant Negative Effect			Significant Positive	
					Small	Moderate	Major		
D.	**Environmental Problems Related to Project Operation**								
1.	Downstream Flow Variation	Disturbance to fish culture/agriculture.	Practically no fish culture exists, however promotion of aquaculture will be attempted. Existing Rights on usage of water to be guaranteed.	x					7.6 & 7.7
2.	Water Oriented Disease	Loss of ecological values	Proper construction planning and disposal of construction material.	x					7.6 & 8.11
E.	**Potential Environmental Enhancement Measures**								
1.	Infrastructure (Road)	Improved transportation of goods, material & people. Improvement in access of line departments	Construction of jeepable road from main road at Bahrain to the village.					x	8.13
2.	Rural Electrification	Improve quality of life of rural people.	Provide electricity to the locals at reduced cost.					x	8.12
3.	Agriculture/Forestry	Improve potential to market products and commercialise wood industry	Proper maintenance and operation of road line and plant additional trees along project alignment					x	9.1
4.	Project Construction & Operation.	Increase permanent employment opportunity & improve economic conditions.	Give preference to local community in terms of unskilled labour and security staff.					x	9.7
5.	Sewerage System	Improve quality of life with decrease in water borne diseases.	Provide sewerage system to a number of houses					x	9.3.1 9.3.2

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7 SELECTION OF PLANT LAYOUT

Daral Khwar Hydropower Project was identified in 1989 / 1990 during the Inventory of Hydropower Potential in the Region "Swat Valley" (Region 4 of the Master Plan for Hydropower Development in Northern Areas in North West Frontier Province N.W.F.P / Pakistan).

The project was found to be the most suitable within Region 4 due to the favourable topographical, hydrological and geological conditions and its near distance of the National Grid.

In order to take the maximum advantages of the site, various alternatives have been studies with variations in

- powerhouse location and type
- design discharge
- turbine type and number

Out of this alternatives, the solution which fitted best in the present environmental, economical and technical boarder conditions has been chosen. The basic proceeding of selection of alternative, is presented in the flow chart (on the next page) the details can be studied in Appendix 7 "Selection of Plant Layout":

- **Appendix 7.1**
  Interim Report No. 1, May 1995
  Preliminary Cost Assessment, Selection of Plant Layout

- **Appendix 7.2**
  Interim Report No. 2, September 1996
  Preliminary Plant Dimensioning, General Data Review
- **Appendix 7.3**
  Interim Report No. 1a, December 1996
  Final Selection of Plant Layout

The finally chosen layout and design features can been seen in chapter 7.3 below.

7.1 STUDY OF ALTERNATIVE DESIGNS

According to the requirements of work to be carried out for the Feasibility Study, comparison of alternatives including preliminary cost assessment and optimisation of plant layout was prepared as a first step.

In the lower section, the flow direction of Daral Khwar has a bend before if flows into the Swat River.

Bypassing the river bend with a tunnel through the mountain ridge between the two valleys it is possible to use the favourable head conditions for a hydropower scheme.

Determination of alternatives was performed by field reconnaissance during November 1994 after provision of basic data including topographical mapping.

7.1.1 Powerhouse Alternatives

Two alternatives for powerhouse location were identified, these were:

- Powerhouse located at the right bank of Swat River.
- Powerhouse located at the left bank of Swat River.

The original identified scheme envisages the powerhouse on the right bank, however anticipating foundation problems at right bank of Swat River (terrace deposits) an alternative on left bank (outcropping rock) was identified and studied for cost (preliminary) comparisons.

The cost comparisons ruled out the left bank alternative.

DARAL KHWAR HEPP
DEVELOPMENT OF FEASIBILITY STUDY

IDENTIFICATION OF HYDROPOWER DEVELOPMENT POTENTIAL IN SWAT VALLEY

IDENTIFICATION OF DARAL KHWAR HEPP AND DECISION TO DEVELOP THE PROJECT AS TO FEASIBILITY STAGE

↓

TOPOGRAPHICAL SURVEY	– TOPOGRAPHICAL REPORT
GEOLOGICAL GEOTECHNICAL INVESTIGATIONS	– PRELIMINARY GEOLOGICAL REPORT
ENVIRONMENTAL SURVEY	– PRELIMINARY ENVIRONMENTAL REPORT
DISCHARGE MEASUREMENTS	– PRELIMINARY HYDROLOGICAL REPORT
GEOPHYSICAL INVESTIGATIONS	– PRELIMINARY GEOPHYSICAL REPORT

↓

DEFINITION OF MAIN ALTERNATIVES

POWERHOUSE AT RIGHT BANK OF SWAT RIVER	POWERHOUSE AT LEFT BANK OF SWAT RIVER
$Q = 10\ m^3/s$ $Q = 15\ m^3/s$ $Q = 20\ m^3/s$	$Q = 10\ m^3/s$ $Q = 15\ m^3/s$ $Q = 20\ m^3/s$
$Q = 30\ m^3/s$ $Q = 35\ m^3/s$	$Q = 30\ m^3/s$ $Q = 35\ m^3/s$

PRELIMINARY COST ASSESSMENT FOR 10 ALTERNATIVES
OPTIMIZATION AND SELECTION OF PLANT LAYOUT

↓

INTERIM REPORT NO. 1
PRELIMINARY COST ASSESSMENT AND SELECTION OF PLANT LAYOUT

POWERHOUSE AT RIGHT BANK OF SWAT RIVER, $Q = 10\ m^3/s$ ($10\text{-}25\ m^3/s$)

↓

PRELIMINARY PLANT LAYOUT ON THE BASIS OF SELECTED ALTERNATIVE AND PLANT LAYOUT

↓

INTERIM REPORT NO. 2
DATA REVIEW AND PRELIMINARY PLANT DIMENSIONING

INTERIM REPORT NO. 1	
PRELIMINARY PLANT LAYOUT (FOR $Q = 11\ m^3/s$)	GEOLOGICAL REPORT, GEOPHYSICAL REPORT
TOPOGRAPHICAL SURVEY	ENVIRONMENTAL REPORT

↓

INTERIM REPORT NO. 1a
FINAL SELECTION OF PLANT LAYOUT, $Q = 15\ m^3/s$
(IMPROVED RESULTS OF GEOLOGICAL INVESTIGATION AND REVISED HYDROLOGICAL DATA)

↓

INTERIM REPORT NO. 3
CONCEPTUAL DESIGN
OPTIMIZATION OF STRUCTURES AND SELECTION OF ALTERNATIVES

↓

FINAL FEASIBILITY REPORT

FINAL TOPOGRAPHICAL REPORT	HYDROPOWER DESIGN
FINAL GEOLOGICAL REPORT	CIVIL DESIGN
FINAL HYDROLOGICAL REPORT	MECHANICAL DESIGN
FINAL GEOPHYSICAL REPORT	ELECTRICAL DESIGN
FINAL ENVIRONMENTAL REPORT	COST ESTIMATE
TRANSPORT STUDY	ECONOMICAL STUDY
TRANSMISSION LINE STUDY	FINANCIAL STUDY
OTHER STUDIES	

7.1.2 Design Discharge

The preliminary optimisation of plant size was based upon the analysis of the following options:-

The weir, located at approximately 1718 m.a.s.l was common to all options. Discharges of 10 m^3/s and higher required a weir with lateral intake. Width of the weir was 40 m, height of weir depended upon discharge. Main weir features and chosen turbines for the design discharge of the options are summarised below:

Discharge Q m^3/s	**10**	**15**	**20**	**30**	**35**
HEIGHT OF WEIR, IN	5.0	6.0	7.0	8.0	9.0
MAX. OPERATIONAL LEVEL. M.A.S.L	1723	1724	1725	1726	1727
Min. Operation level m.a.s.l	1722.50	1723.50	1724.50	1725.50	1726.50
Depth of foundation in centre m	3.0	3.50	4.0	4.50	5.0
PELTON	2 units 3 jets each 5.0 m^3/s	3 units 3 jets each 5.0 m^3/s	4 units 3 jets each 5.0 m^3/s	2 units 2 jets each 2.5 m^3/s	2 units 3 jets each 5.0 m^3/s
FRANCIS				2 units each 12.5 m^3/s	2 units each 12.5 m^3/s
Gross Head m	310	311	312	329	330

Gravel spill and sand trap was common for all options. A lateral intake on the right bank of Daral Khwar was also common to all options. Design flood of 860 m^3/s was assumed to all options. Selection of turbines was governed by the fact that the scheme was to be on "run of river" type with a minimum discharge of about 0.5 m^3/s. Two Pelton machines had to be added in any case. The minimum water releases for environmental purposes was taken to be 100 l/s. The cost estimates of the above mentioned options are summarised below:

HYDROPOWER PROJECT DARAL KHWAR/BAHAIN
COMPLICATION OF PRELIMINARY COST ASSESSMENT

POWERHOUSE AT RIGHT BANK OF SWAT RIVER

Alternative	Q design (m^3/s)	Grosshead (m)	Losses (m)	Nethead (m)	Capacity (kW)	Total Cost 1000 US$	Spec. Cost US$/kW
DAR10R	10	310	11.08	298.92	24879	29700	1194
DAR15R	15	311	11.54	299.46	37973	37875	1011
DAR20R	20	312	11.53	300.47	50134	48270	963
DAR30R	30	329	12.15	316.85	77760	55153	711
DAR35R	35	330	12.15	317.85	90911	65709	688

POWERHOUSE AT LEFT BANK OF SWAT RIVER

Alternative	Q design (m^3/s)	Max Gross head (m)	Losses (m)	Max. Nethead (m)	Capacity (kW)	Total Cost 1000 US$	Spec. Cost US$/kW
DAR10L	10	310	12.00	298.00	24802	31277	1261
DAR15L	15	311	12.11	298.89	37235	38054	1022
DAR20L	20	312	12.42	299.58	49984	50797	1016
DAR30L	30	329	13.08	315.92	77889	58046	749
DAR35L	35	330	13.09	316.91	80911	65709	723

The best design discharge (10 m^3/s) with an output of 25 MW was determined on economic parameters. Benefits were quantified on the basis of LRMC of capacity and energy. The results of this analysis were:-

- Powerhouse on the left bank was ruled out due to higher costs.
- No final decision about sizing could be taken as results were very sensitive to relatively small changes in: cost; tariff; discount rate; and hydrology.

The decision was to keep pending the selection of optimal size until more precise information were obtained. Subsequent data collection and analysis (presented in Appendix 7.3 Interim Report No. 1a) established that :-

Best design discharge was the 15 m^3/s option for alternative on right bank powerhouse with an output of approx. 35 MW.

Sensitivity analysis carried out indicated the decision to be robust and stable to variations of cost, tariff, discount rate and discharge.

7.1.3 Data Review and Plant Dimensioning

The Data Review (presented in Appendix 7.2 Interim Report No. 2) reviewed the findings of Interim Report No. 1 and the new documents then available, namely:

- Report on Engineering Geology, May 1996, Consolidated Engineering Services, CES (PVT) LTD.
- Draft Environmental Assessment, June 1996, Designmen Consulting Engineers (PVT) LTD. Islamabad.
- Report on Geophysical Prospection, August 1996, IGH Consulting Engineers, Dr. Muñoz, Guatemala.

Because no final Hydrological and Geological Reports were available at that time only a Preliminary Plant Dimensioning, based on the following general layout data, was carried out:

Headrace water level	Approx.	1723	m.a.s.l
Max tailrace level	Approx.	1413	m.a.s.l
Gross head	Approx.	310	m
Setting	Approx.	2	m
Losses	Approx.	9	m
Net head	Approx.	299	m
Design discharge		11	m^3/s
Design capacity	Approx.	28	MW

The plant Dimensioning main structure are:

- Weir with Lateral Intake
- Connection Tunnel with Gravel Spilling Systems
- Sand trap (2 chambers)
- Headrace canal (rectangular section)
- Headrace tunnel and access tunnel
- Surge Tank
- Penstock Tunnel and Valve Chamber
- Embedded Penstock
- Powerhouse with three Pelton turbine
- Tailrace structure

Finally it has to be mentioned that during the Data Review and Plant Dimensioning phase again no final decision about sizing could be taken. The 11 m^m/s design discharge adopted for the Plant Dimensioning was only a preliminary one.

7.2 FINAL SELECTION OF PLANT LAYOUT

Reference: Interim Report No. 1a (Appendix 7.3, December 1996)

For better understanding a brief description of the procedure concerning the Final Selection of Plant Layout is given.

In the very first study of Daral Khwar[1] (identification study) a design discharge of 10 m^3/s was selected to give comparable data with other schemes within Swat Valley. In the stage of interim Report No. 1 (Appendix 7.1, May 95) a design discharges between 10 m^3/s and 35 m^3/s and an alternative location of the powerhouse on the left bank of Swat River were investigated. The result of this Interim Report No. 1 was, that the best design discharge was 10 m^3/s. However, a sensitive analysis showed, that this result was quite unstable and no final decision could be made. The range between 10 m^3/s and 25 m^3/s had to be kept in mind in the meanwhile. The location of the powerhouse site could be fixed on the right side of Swat River in this stage.

Following the results of Interim Report No. 1 in a next step a preliminary plant dimensioning was done, to give all the participants an idea of the dimensioning and the design of the power plant. 10 m^3/s and a net-head of about 300 m required a layout with 3 horizontal Pelton-turbines. As 3-Pelton-turbines with the same revolution (375 rpm) can operate with 11 m^3/s (in total) within Interim Report No.2 11 m^3/s was selected as design discharge, keeping in mind, that this could be changed later.

Due to the fact that it was not possible to define the optimum design discharge in the Interim Report No. 1 – May 1995 an update of this report became necessary.

The Interim Report No. 1a therefore presents the final selection of the design discharge, made upon the basis of rough layouts for the defined alternatives. The optimisation with impact of economic evaluation parameters, updated hydrological data of Daral Khwar, updated cost estimation on the basis of geological investigations and environmental aspects was the basis for working out the Feasibility Study for final determination of main project features.

A compilation of the results of the cost estimate for the defined alternatives is shown below:

**HYDROPOWER PROJECT DARAL KHWAR/BAHRAIN
COMPILATION OF COST ASSESSMENT
FOR FINAL SELECTION OF PLANT LAYOUT**

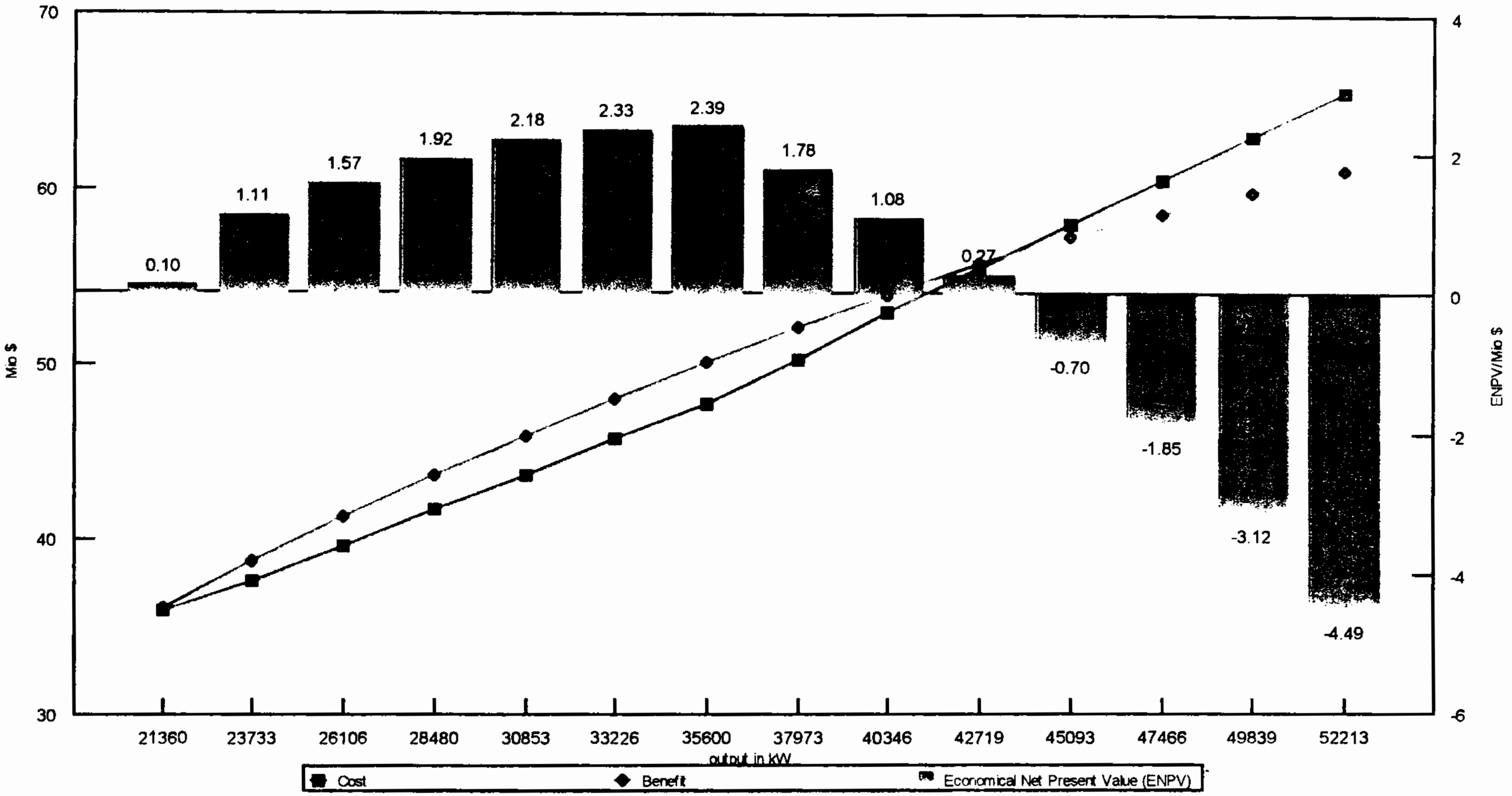
Alternative	Q design (m^3/s)	Grosshead (m)	Losses (m)	Nethead (m)	Capacity (kW)	Total cost 1000 US$	Spec. Cost (US$/kW)
DAR10R	10	310	11.08	298.92	24879	32455	1305
DAR15R	15	311	11.54	299.46	37973	40850	1076
DAR20R	20	312	11.53	300.47	50134	50941	1016

To find out the optimum size of the plant layout, the same method was used, which was used for Interim Report No. 1, May 1995.

The result of the Interim Report No. 1a was, that the best final layout of Daral Khwar Hydropower Scheme is a design discharge of 15 m^3/s with an output of approx. 35 MW.

[1] *Identification of Hydropower Development Potential in Swat Valley. GTZ/SHYDO*

OUTPUT OPTIMISATION



7.3 COMPILATION OF SALIENT LAYOUT AND DESIGN FEATURES

7.3.1 Compilation of Main Structures

River	Daral Khwar		
	Catchment area at weir site	250	km^2
	Mean annual discharge	10.76	m^3/s
	Total annual flow	340.9	Mio m^3

Details of Main Structures

Weir Structure	Type	Fixed sill	
	Height above riverbed	2.5	m
	Depth below river bed approx.	6.5	m
	4 overflow sections each	8	m wide
	1 flushing section	4	m wide
	Length of weir structure	17	m
	Width of weir structure	48	m
	Design flood (100y - flood)	640	m^3/s
Intake	Type	Lateral	Intake
	4 sections each	2.6	m wide
	Stoplog pockets		
	Coarse rack		
	Spilling section with gate		
	Intake gate		
Connection Tunnel	Height	5.00	m
	Width	4.00	m
	Cross Section	17.13	m^2
	Length without Gravel Sp. approx.	28	m
Gravel Spill	Height	6.00	m
	Width	4.00	m
	Cross Section	19.25	m^2
	Length	30	m
	Flushing Gate		
Sandtrap	No of chambers	2	
	effective height each	6.25	m
	clear width per chamber	5.00	m
	total width of sandtrap	13.40	m
	effective length	40	m
	total length approx.	90	m
	overflow section		
	inlet gates		
	flushing gates		
	fine rack		
	outlet gates		
	spilling canal		
Headrace Canal	Height, internal	3.40	m
	Width, internal	2.50	m
	Cross Section	8.50	m^2
	Length approx.	41	m
Headrace Tunnel	Type of Cross Section	Horse Shoe	
	Height	3.30	m
	Width	3.00	m
	Cross Section	8.34	m^2
	Length from portal to Surge Tank	3,044	m
	Slope	0.5	%
	Storage Volume	26,000	m^3

Surge Tank	Type	Shaft	
	Internal diameter	12.00	m
	Cross Section	113.10	m^2
	Height	30	m
Penstock Tunnel	Height 3.05		m
	Width	4.40	m
	Cross Section	15.02	m^2
	Length	50	m
	Penstock Pipe diameter	2.00	m
Valve Chamber	Width	13	m
	Length	11	m
	Height (above ground)	8	m
	Depth (below ground)	6	m
	Emergency Valve dia	2	m
	Maintenance Valve dia	2	m
	Crane - Capacity	100	kN
Embedded Penstock	Diameter	2.00	m
	Length	840	m
Road Crossing Structure	Width approx.	5.2	m
	Length approx.	9.6	m
	Height approx.	13.4	m
Powerhouse	Type External		
	Depth below machine hall floor	10.7	m
	Machine hall: Length	30.4	m
	Width	16.5	m
	Height above machine hall floor	15.7	m
	Total length of Powerhouse	34.4	m
	Total width of Powerhouse	29.6	m
	Total height of Powerhouse	26.4	m
Tailrace	Cascade type, No of units	3	No
	Width (Francis/Pelton)	3.25/1.40	m
	Height approx.	8	m
	Length	15.9	m
Hydro Mechanical Equipment	Francis Turbines vertical shaft	2	Units
	Speed	1000	rpm
	Net head	293.3	m
	Discharge per unit	6.25	m^3/s
	Pelton Turbine horizontal shaft	1	Unit
	speed	500	rpm
	Net head	290.7	m
	Discharge per unit	2.5	m^3/s
	Total turbine discharge	15	m^3/s
Electrical Equipment	Generators for Francis turbines (No. of units)	2	
	Speed	1000	rpm
	Capacity	18	MVA
	Generator for Pelton turbine (No. of unit)	1	
	Speed	500	rpm
	Capacity	7,5	MVA
	2 Main Transformers	11/132	kVA
	Switchgear	132	kV

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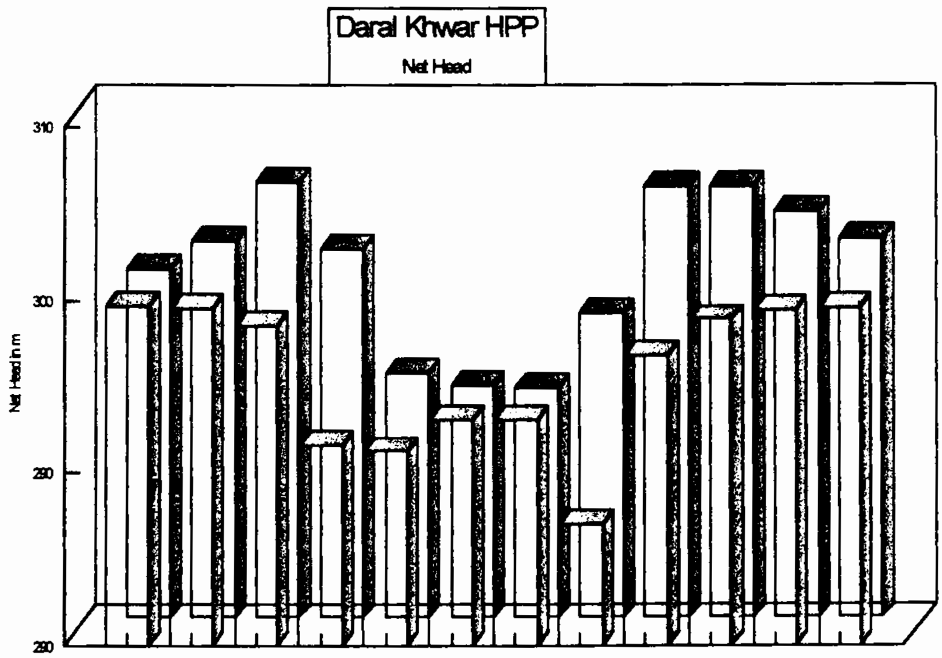
7.3.2 Power and Energy

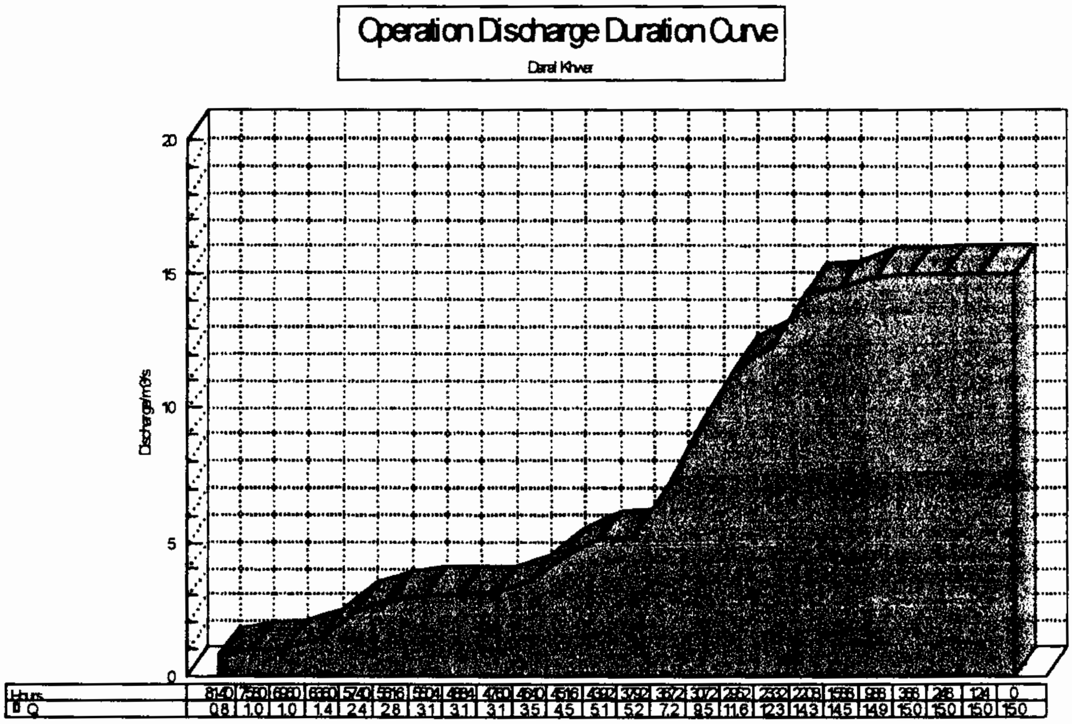
Design Discharge	2 Francis (6.25 m^3/s each)	12.5	m^3/s
	1 Pelton	2.5	m^3/s
	Total	15.0	m^3/s
Operation Guideline	Stop of generation, flushing section open during periods Q> 50 m^3/s: approx.	1	%
	Minimum rest water	200	l/s
	%age of spilling water when Q> 10 m^3/s:	10	%
	Annual Turbine run-off	222	Mio.m^3
Head	Headrace water level	1,723.0	m asl
	Mean tailrace water level	1,405.0	m asl
	Gross head	318	m
Losses	(at Q_{design} = 15 m^3/s)	14.14	m
Lost head	Francis Units	10.28	m
	Pelton Unit	12.86	m
Net head	Francis Units	293.27	m
	Pelton Unit	290.69	m
Energy output	Francis Units	29.2	MW
	Pelton Unit	5.8	MW
	Power Factor	0.48	
	Mean annual energy	148	GWh

7.3.2.1 Graphic Net Head per Month



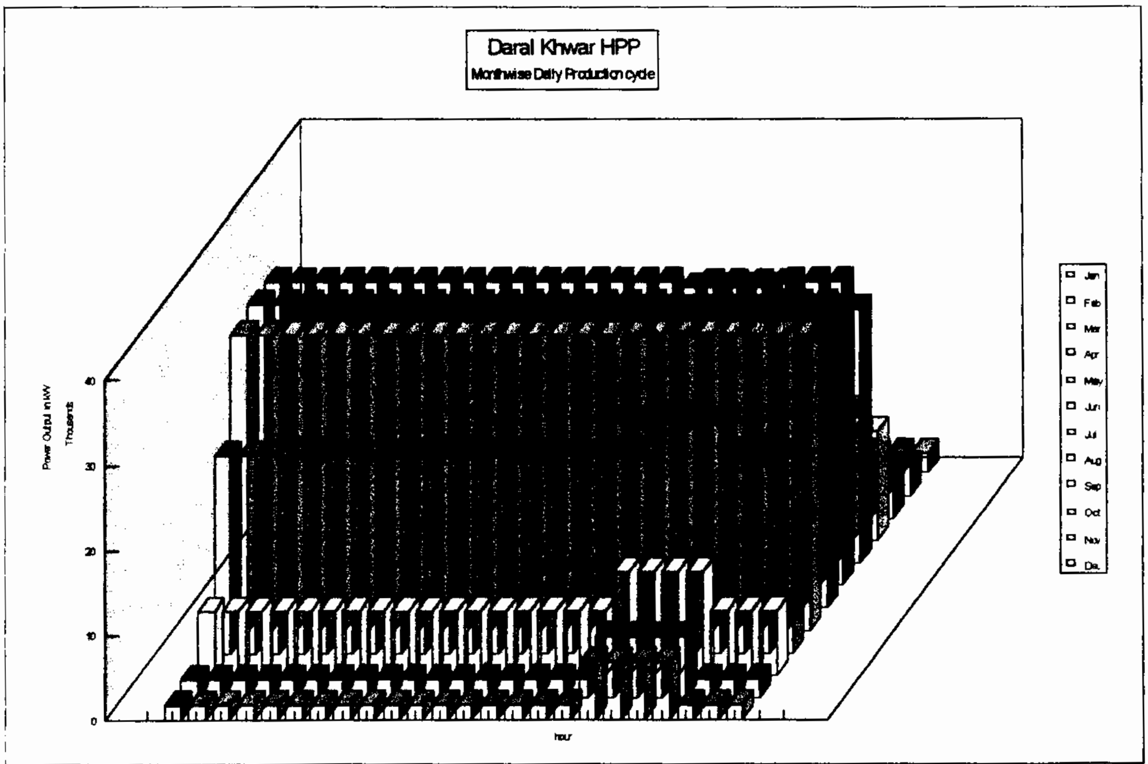
Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Peaking operation	300	300	299	292	291	293	293	287	297	299	299	300
Offpeak operation	300	302	305	301	294	293	293	298	305	305	303	302

7.3.2.2 Graphic Operation Discharge Duration Curve

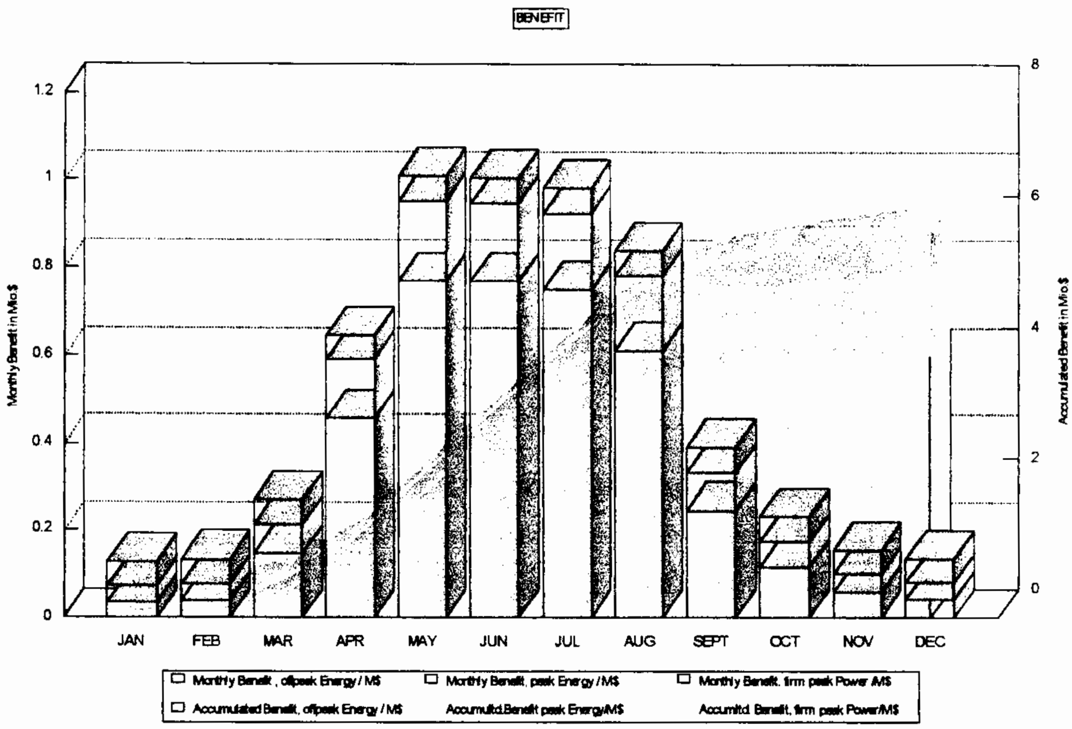


Hours	8140	7580	6960	6360	5740	5616	5504	4884	4760	4640	4516	4392	3792	3672	3072	2952	2332	2208	1588	988	368	248	124	0
Q	0.8	1.0	1.0	1.4	2.4	2.8	3.1	3.1	3.1	3.5	4.5	5.1	5.2	7.2	9.5	11.6	12.3	14.3	14.5	14.9	15.0	15.0	15.0	15.0

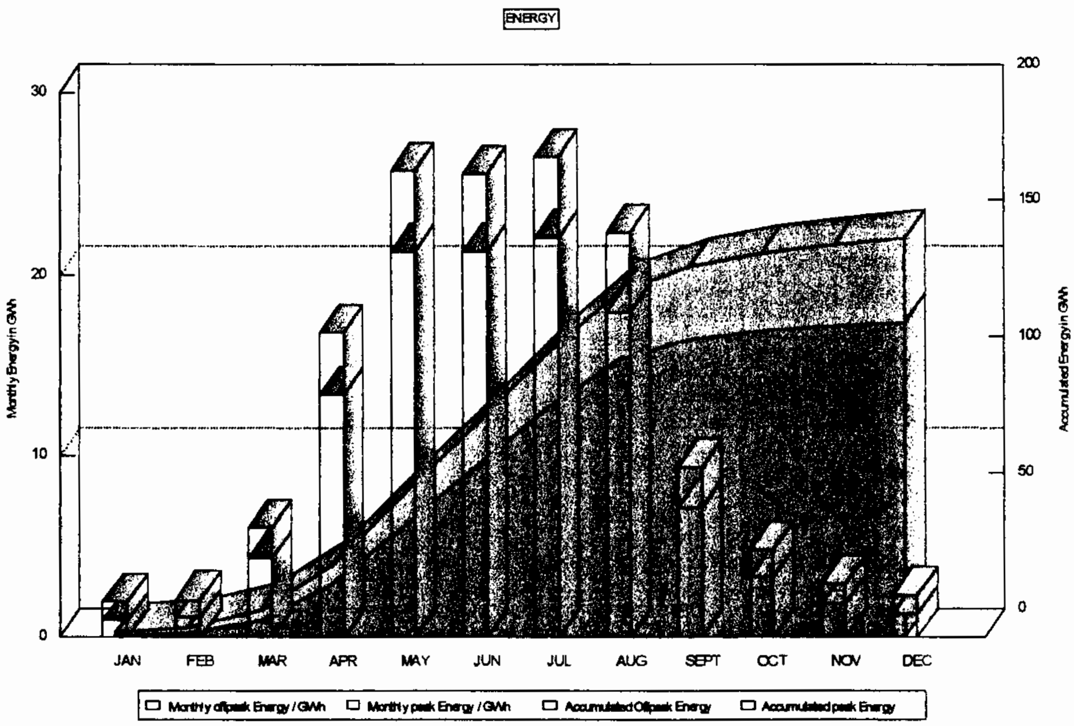
7.3.2.3 Graphic Daily Productive Cycle, Month wise



7.3.2.4 Graphic Energy per Month and Accumulated



7.3.2.5 Graphic Economic Benefit Monthly and Accumulated



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8.0 HYDROPOWER DESIGN

The engineering design of the project covers the following main sections:

- Civil Works Design
- Hydraulic Steel Structures
- Hydromechanical Equipment
- Electrical Equipment
- Construction

8.1 CIVIL WORKS DESIGN

References: Appendix 8, Hydraulic and Static Pre-calculations.
Main Report Volume 2, Drawings

Based on the results of previous studies, which have been discussed under Chapter 7, the alternative for design discharge of 15 m^3/s and the Powerhouse on the right bank of Swat River has been adopted for the Feasibility Design.

Since the basic solution of the hydropower project is now defined, design of the main structures is subjected to comparative evaluation in terms of economy, engineering and geology.

The civil design comprises the power plant components grouped as follows:

- Weir
- Conduit System
- Powerhouse

8.1.1 Weir

The valley of Daral Khwar is comparatively narrow and it was not considered practicable to design a reservoir, which can be used for storage purposes.

During operation the maximum depth of water at the weir upstream side will be 2.3 m.

The access road from BAHRAIN town to the weir site is under construction. The energy supply for the area is intended to be provided by an 11 kV transmission line from BAHRAIN town. The transformer 11 kV/0.4 kV is accommodated in the operation building at the downstream end of the sandtrap.

8.1.1.1 Location

The most suitable location for siting the weir in the gorge has been fixed near the village ARIN just upstream of an existing footbridge.

The width of the original riverbed in this area varies from 6 m (at the abutments of the footbridge) to 30 m (some 50 m upstream).

The natural descent of Daral Khwar near Arin is approx. 6.5 %.

8.1.1.2 Study of Alternative Weir Types

As part of the study, several different weir types, needed to give an operation water level of 1723.3 m a.s.l, were compared namely:

- Tyrolean
- Weir with gates
- Fixed sill

The evaluation method for comparison considered the following criteria:

- Topography
- Geology
- Flood control

Apart from foundation aspects, an important factor to be considered is the flushing requirement for the retained water to avoid silting up or blocking of the area in front of the intake structure.

For using of a Tyrolean weir the design discharge is to high. A weir with gates creates problems with the blocked sediment transport. The higher storage level will mean more water losses through the high permeable soil. Gates might cause safety problems in case of high floods because opening of the gates needs energy and must be done in a proper way. With the fixed sill type one can avoid or at least decrease the problems caused with the other weir types.

The fixed sill weir type therefore was recommended as the basis for the Feasibility Design.

8.1.1.3 Engineering Geological Aspects

Most of the valley slopes around Arin village are steep and strewn with boulders, although some sections of Daral Khwar itself are wider and flat, and filled with alluvial deposits. The weir site proper was chosen in the vicinity of an existing wooden bridge, where a steep norite outcrop on the right bank forms a narrow gap; the Daral water partly undercuts the cliff, on top of which some houses are located. Directly opposite the huge boulder-like cliff, slope deposits covering the bedrock, belong to the "Bahrain Pyroxene Granulite", and are exposed for some dekameter higher up along the left slope.

The bedrock outcrop is evident within 20 m of the river extending some distance upstream; for this reason the weir axis has been defined to run diagonal to the river course in the initial stages of the investigation. The left bank upstream section appears to have much less gravel cover, as Borehole DW3 reached bedrock at 20.10 m only, while DW1 encountered rock at 26.50 m.

The left abutment of the 48 m long weir, also that of the access bridge downstream of this line will meet less favourable conditions where excavation and foundations are concerned. It may be that the weir at the left abutment will have to be lengthened towards the slope so as to found the structure in bedrock; this applies particularly to the downstream part of it in the area of the sharp turn of the access road.

The flushing section as well as the long overflow sections of the weir have to be founded on river deposits, consisting of fine to coarse gravels. Excavation of a few metres depth should be possible without blasting. Heavy blocks may need special treatment, but pop-shooting should be avoided so as not to increase the already unfavourable permeability conditions. Beneath the main concrete structure of the weir, bridge piers and stilling basin, a level regulating lean concrete slab may become necessary. Upstream of the river deposits, a long percolation path of seeping water will be established by means of a foil blanket.

Downstream of the weir (overflow section), a heavy riprap will be installed which may be embedded in mortar or concrete. At the downstream end of the stilling basin structure a concrete sill across the valley will stabilize the construction, and prevent scour.

8.1.1.4 Weir Design

After selection of the fixed sill type as weir structure, the design criteria for the following are discussed

- River diversion
- Flood control

A hydraulic model test for the weir structure demonstrating performance under flood conditions, during flushing and characteristics of intake are recommended before the final design is completed.

- **River diversion during construction**

  During construction of the weir the possibility of a 10 year flood (395 m^3/s) has to be accommodated. Flood values have been determined in the Hydrological Report/December 1996.

  It is considered that the erection of the weir, intake structure and by-pass tunnel will have to be done in at least three stages.

  In the first stage two (of the four) overflow sections at the left bank are constructed (without the crest of the weir, which will be done later). The excavation has to be protected by cofferdams consisting of steel sheet piles braced by steel beams connected by steel bar. The short earthfill cofferdams will be covered by pitching and extend to the slopes of the valley.

  The remaining river-cross section will be used for flood relief.

During the second stage, the flushing section, intake structure and by-pass tunnel at the right bank will be constructed. The exposed foundations will need to be protected in the same way as the described for the first stage.

The remaining central section between the two cofferdam should be sufficient to accommodate any flood during this period in foreseen flood relief.

In the third step, the longitudinal sheet pile walls are removed and the central two overflow sections excavated and concreted. Upstream the excavation will be protected by a steel-sheet-pile cofferdam, and downstream by a steel-sheet-pile cofferdam combined with an earthfill cofferdam. Any flood will be passed through the overflow sections on the left bank and via the by-pass tunnel on the right bank.

Finally the crest section of the overflow structure at the left bank will be completed. This can take place during a low flow - period or protected by steel sheet piles.

- **Flood control**

For this task there are no gates nor sluices required, because the structure will simply act like a sill of 2.5 m height in the Khwar.

The overflow part of the weir consists of four sections each 8 m wide. For flood control the 4.0 m wide flushing section is assumed to be not available (blocked gate).

The inclination of the upstream wall is selected at 1.5:1 in order to guarantee sediment transport during high floods. The height of the weir above the riverbed is 2.5 m, giving a top of sill elevation of 1723.5 m asl.

The shape of the weir crest is parabolic in order to avoid underpressure. Assuming a velocity of 6.4 m/s the resulting equation is:

$Yi = 0.12 \times Xi^2$ where x and y are the dimensions in the horizontal and vertical directions.

At times of high flood the flow is super-critical, the weir becomes submerged and there in no stilling basin is required.

- **Excavation and foundations**

The required valley width for placement of the weir structure will need extensive excavation on both flanks of Daral Khwar. The final inclinations are proposed to be a maximum of 2:1, a masonry retaining wall will be necessary to protect the slopes against erosion particularly downstream.

Excavation for the central section of weir structure will be in alluvium and not reach bedrock. However both abutments will reach or at least be near to the bedrock with their foundation.

At the upstream part a 2 m wide by 3 m high (1714.5 m asl) concrete beam is designed, acting as a cut-off wall.

- **Concrete placement**

All parts of the structure will be placed as reinforced concrete.

The crest of the overflow sections and the flushing section will be equipped with steel protection. The lower, downstream part of the overflow sections will be covered by stone pavement.

The concrete will be produced in a local concrete factory. The aggregates will consist of prepared material obtained from the excavations or from tunneling.

Laboratory tests are necessary to determine the specifications for aggregates, cement, cement content, water content etc. as required for an easily workable and watertight concrete BN 25.

During concrete production and placement, concrete testing and cement qualification tests in a site laboratory will be necessary.

- **Upstream blanket**

  An upstream blanket will be necessary to ensure a long percolation path. Its exact length will depend on the permeability of the river deposits, but may be at least 30 m. The final length of the blanket has to be decided during construction, when the exact values for permeability has been determined by soil investigation and soil tests.

  A geoplastic foil will be placed on a sandbed and covered by a geotextile membrane, covered by sand and gravel bedding layers and finally the blanket will be protected by riprap, bedded in mortar.

- **Downstream protection**

  Approximately 45 m downstream of the weir, a concrete endsill is foreseen. Between this and the weir heavy riprap with a minimum diameter of 1.4 m, connected with heavy reinforcement bars and fixed to the weir/endsill is required.

  Downstream of the endsill a further 10 m of riprap is necessary to prevent scour and possible regression.

- **Weir bridge**

  The access road from Bahrain will be on the left bank of the Khwar. It is therefore proposed to erect a bridge over the Khwar to reach the Intake, Gravel Spill, Sandtrap etc on the right bank.

  The bridge will comprise of steel beam sub-structure, with timber decking 3.5 m wide.

- **Auxiliary equipment**

  The required auxiliary equipment comprises the following:

  * Flushing gate, 2 sections each 2.5 m high by 4 m wide, - hydraulic operation
  * Stop log pockets in front of the flushing gate
  * Electrical equipment
    - power supply
    - hydraulic pumps
    - lighting
    - hydrograph of the river water level fluctuations at the intake
    - telecom equipment

8.1.2 Conduit System

The conduit system of Daral Khwar Hydropower Project, from weir to powerhouse consists of the following structures:

- Intake
- Connection Tunnel including Gravel Spill Structure
- Sandtrap
- Headrace Canal
- Headrace Tunnel and Access Tunnel
- Surge Tank
- Penstock Tunnel
- Valve Chamber
- Embedded Penstock and Road Crossing Structure

8.1.2.1 Intake

The lateral intake is located directly beside the flushing section of the weir with an inclination of 4 %. It forms an integral part of the combined concrete structure.

In order to prevent inflow of bedload into the conduit system, an intake sill will be 1 m above of the inclined underside of the flushing section. The sill will thus be stepped.

The intake opening is divided into two by means of a concrete dividing wall, thereby reducing the spans for the concrete structures. These sections are then further split into two halves in order to reduce the span of the stop logs. The intake therefore has four sections, each 2.6 m wide.

The height of the opening varies between 1.1 and 2.0 m.

Each opening is equipped with a trash-rack. The combined area of all sections is 16 m^2. Stoplog pockets are provided in front of the trashracks to facilitate maintenance and repair.

An additional spilling section is proposed directly beyond the intake front wall in the form of a groove 1 m wide by 1 m deep. This leads to a canal, about 2 m high and then heads into the weir-flushing section. It is equipped with a spilling gate 1 m wide and 2 m high hand-driven. This gate will also be used for passing the rest water of 200 l/s to the Khwar.

The intake chamber is some 14.3 m long, its end equipped with the intake gate 4 m wide by 3.25 m high, hydraulic operated.

In front of the spilling gate and in front of the intake gate there are manholes with chequered plate covers provided. Immediately downstream of the intake gate there is a manhole placed with grating cover for ventilation purpose.

Access to the intake will be via the weir bridge.

The intake is designed to be closed in times of high flow in Daral Khwar in order to avoid excessive sediment inflow. This will also avoid damage to the conduit system and protect the hydromechanical equipment. The limit of 50 m^3/s for operation will be checked by the model test, but ultimately, monitoring during subsequent years of operation will indicate the level more precisely.

8.1.2.2 Connection Tunnel

- **Engineering Geological Aspects**

  The 58 m long free-flow tunnel between weir/intake and sandtrap will serve also as a gravel spill system. The tunnel will be excavated using drilling and blasting technique due to its small length and differing cross sections. Rock condition is good, and no unusual difficulty is assumed. Borehole DT1A showed no groundwater, so drainage will not be necessary in this short tunnel.

  Stability is expected to be favourable; rock class according to LAUFFER, are anticipated, ranging between A and C. The inlet and outlet portals have been pre-fixed in a range of 10 m, within which the portals proper can be located and decided by the Engineer on site. Sliding can be excluded, safety measures will be minimal, ie typical of tunnels in sound rock.

- **Longitudinal Section**

  The tunnel has an inclination of 3 %, the upstream part (28 m long) serves as a by-pass whilst the downstream section, 30 m long, will also be used as the gravel spill structure.

- **Cross-section**

  Both parts are of horse-shoe type. The upstream part will have a height of 5 m by 4 m wide, with an internal cross-section of 17.1 m^2. For the downstream part, respective figures are:

6 m high by 4 m wide, 19.3 m^2 cross-section. The whole tunnel will be concrete lined minimum 20 cm thick.

- **Gravel Spill Section**

The downstream part of the tunnel will be equipped with a flushing gate, 1 m wide by 2 m high.

Upstream of the gate a manhole with chequered plate cover will enable access. Beyond it, the 10 m long flushing canal leads to the Khwar. Bottom level of the flushing opening is 1717.5 m asl. Main opening at the end of the tunnel has an invert level of 1720.7 m asl leading to the sandtrap.

8.1.2.3 Sandtrap

- **Engineering Geological Aspects**

The 2-chamber sandtrap will have an active length each of 40 m, a total length of 90 m including the gravel flushing gates and operation building. They are founded on river and slope deposits respectively. Being located at the very foot of the slope, excavation will be in loose gravel from sand through to boulder size. During summer, which is the wet season, high water levels are possible associated with the Daral Khwar. Small seepage quantities may occur at the hill side, requiring some drainage measures along the slope side chamber wall. The need for drainage culverts will be decided during construction. Heavy protection measures (riprap) on the river side is mandatory to protect against high floods. Safety measures along the slope will depend on the excavation depth at the foot of the slope. For stabilisation, gabions can be used if necessary.

- **Layout**

The sandtrap is designed for removal of all grains larger than 0.3 mm during periods of full discharge. The calculation results in the following necessary values for a two chamber type:

width for each chamber	5.00 m
effective depth	6.25 m
effective length	40.00 m

- **Longitudinal Section**

In the first part the width is increased from 4 m, at the end of the Gravel Spill to 11 m (internal) at the beginning of the chambers. In this part the access road to the operation building is crossing the structure. The 23 m long section houses the overflow section comprising 3 openings each 3.5 m long and 0.9 m high.

The overflow section slopes down to the Khwar and should be protected in this area by stone-pitching.

The second section is the 9 m long ramp inclined down 1:1.8 necessary to meet the required depth of the sandtrap. This part should be equipped with a stilling rack or similar energy reducing device.

The third section comprises the 40 m long trapping section itself. The invert in this part has an longitudinal inclination of 4 % and the edges should be chamfered. The total height of the structure ranges between 10 and 12 m, while the width of the structure here is 13.4 m.

Finally a 17 m long section houses the two flushing gates, each 1 m wide by 1.8 m high, and the fine racks. It is possible to install a Rack Cleaning Machine if it transpires after several years operation that there is a need. The bottom level of the fine racks is 1720 m asl and in this part the internal width is decreasing from 11 m to 2.5 m at the beginning of the Headrace Canal. At the very end of the structure there is a large manhole for maintenance works in the conduit system. This manhole will be covered by grating for ventilation purposes.

At the downstream end of the trapping section a combined flushing canal 1 m wide, 1.8 m high concrete structure followed by an open flushing canal, 2 m wide with stone pitching, leads to the Khwar.

- **Auxiliary equipment**

The required auxiliary equipment for the sandtrap is listed as follows:

* 2 Inlet gates, 5 m wide, 2.8 m high - hydraulic
* 2 Fine Racks, 5 m wide, 2.6 m high, 70° inclined
* 2 Outlet gates, 4m wide, 3.2 m high - hydraulic
* 2 Flushing gates, 1 m wide, 1.8 m high - hand driven
* Optional: rack cleaning machine
* Electrical equipment comprising:
  - power supply
  - emergency diesel generator
  - hydraulic pump
  - lighting
  - telecom equipment
  - transformer 11 kV/0.4 kV

The electrical equipment as well as the flushing and outlet gates and the fine racks (including optional RCM) will be housed by the operating building. This will be some 16 m by 12 m long, and 10 m high. It will also be used as storage facility in the area.

8.1.2.4 Headrace Canal

- **Engineering Geological Aspects**

The headrace canal between sandtrap and tunnel portal will be a concrete culvert structure, backfill with gravel material. No particular difficulty concerning excavation and foundation is anticipated. During the construction period, some temporary safety measures along the slope side are recommended to safeguard against sliding, particularly towards the portal area with its higher and steeper slopes.

- **Structural Design**

A 41 m long headrace canal is necessary to bridge the gap between the sandtrap and the portal of the headrace tunnel. The concrete structure has been designed with a width of 2.5 m a hight of 3.4 m, inclined at 0.5 % and covered by 1.8 m backfill. The last few metres take the form of a venture pipe in order to meet the horseshoe shaped cross section of the headrace tunnel.

8.1.2.5 Headrace Tunnel from Intake Area to Surge tank

- **Alignment - Longitudinal Profile**

The alignment of the headrace tunnel from the Intake area at Daral Khwar to the surge tank in Swat Valley is a traverse running from Daral Khwar in a general north west - south east direction to the surge structure.

The total length of the headrace tunnel from the portal at the intake area to the surge shaft axis is 3043.7 m.

According to the elevation 1716.8 m at the upstream portal and 1701.8 at the surge tank the gradient of the tunnel is approximately 0.5 percent. This inclination was selected in accordance with operation conditions for using the tunnel volume as a short time storage.

The maximum cover of the headrace tunnel was determined from the map 1: 10,000 to be approximately 600 m. Due to the poor quality of the available map this value is not reliable and might easily be some 200 m more.

A 115 m long access tunnel will connect the headrace tunnel with the access road, from the main road Madyan - Bahrain, partly via an existing forest road. The clearance for the conventional driving will be the same as for the headrace tunnel itself (without inner lining). For the TBM heading option, the clearance should be much wider (4.5 m high and 4.6 m wide), dictated by transport requirements (transport of the TBM equipment). The access tunnel itself will most likely be by conventional driving.

The access gallery and some 200 m of the headrace tunnel should be driven relatively early so that the geological parameters for the final location and design of the surge tank and penstock tunnel can be determined.

The access tunnel will serve as an exploration adit at the same time. A new road of approximately 1.5 km length will have to be constructed from the existing forest road to Kulban, which itself will need to be improved. The beginning of this forest road is at the main road Madyan - Bahrain. The maximum gradient of the new road should be less than 10 percent.

Excavating the road, steep and partly rocky slopes, with smaller talus cones and screes will have to be crossed, resulting in some difficult excavation, and calling for retaining walls and other stabilising measures.

- **Cross section (Internal Diameter)**

Several optimization analyses were carried out to determine the most economical tunnel cross-section. The annual cost of energy losses in the power tunnel corresponding to different diameters was compared with the annual cost of the tunnel evaluated with a capital recovery factor. The storage aspect of the tunnel was also considered. The tunnel diameter is seen to be most economical where the sum total of the annual cost of the tunnel plus the cost of the energy losses is smallest. This results in an optimal internal tunnel diameter of 3.25 m, giving a rated discharge of 15 m^3/s for the 3 turbines.

The discharge section is 8.43 m^2 (horse shoe profile) and the resulting flow velocity of approximately 1.8 m/s at full load (15 m^3/s) is within the range allowed for concrete lined tunnels. In case a TBM is to be used, the excavation diameter is fixed at 3.9 m and the internal diameter will depend finally on the support requirements. This results in internal diameters ranging between 3.20 and 3.40 (66 % will be 3.4 m).

- **General Engineering Geological Aspects**

No rock mechanical investigation results are available on which a decision can be made, whether to head the tunnel with a TBM or conventionally. According to the general geological conditions concerning structure, age, and petrography, it seems to be quite possible to use a TBM for heading works. At least this question should be left open until results from rock mechanic investigations in connection with the surge tank area are available.

The **rock classification** applied for the headrace tunnel was chosen according to LAUFFER. The basic criterion for these rock classes are the "bridging time", i.e. the time which elapses before the tunnel starts to deform, and the width of the span; the wider the cavity of course, the shorter the bridging time. Six rock classes have been defined for the main (upstream) part of the headrace tunnel, the seventh ("G") will not be applied. Sediments such as talus cone, scree, alluvial or terrace materials will not occur in this section of tunnel alignment. It is self-evident that the condition of the rock mass and its "bridging time" influences also the type and quality of the heading works, particularly in the case of conventional heading. In addition the petrological conditions and the structural behaviour of the rock mass will also cause a certain difference.

Summarising, the following figures below were assumed for the 2869.2 m long upstream part of the tunnel from the inlet portal to the area below borehole No DT 4.

For the 174.5 m long part between DT4 and the axis of the surge structure, the following rock classes have been assumed, assuming the likelihood of worse rock conditions in connection with the so-called main "sheared zone" and the minor fault zones in this area.

Rock Classess	Upstream Part		Downstream Part		Total	
	%	M	%	m	%	m
A/B	70	2008.4	0	0	66.0	2008.4
C	20	573.8	10	17.5	19.4	591.3
D	6	172.2	60	104.7	9.1	276.9
E	3	86.0	20	34.9	4.0	120.9
F	1	28.7	10	17.5	1.5	46.5
Total	100	2869.2	100	174.5	100.0	3043.7

As the whole headrace tunnel has to be lined, the "inner shell" support consists of minimum 20 cm thick concrete lining irrespective of the rock class and differing strengths of the "outer shell".

Finally, the PRIMARY ROCK STRESSES should be mentioned, the effect of which can be both positive and negative, according to the thickness of the overlying rock mass, and according to the tectonic history of the mountain. In the case of Daral Khwar, only relatively minor primary stresses are expected, due to the seismic activities in the past, together with the narrow mountain ridge, where most stresses should have been released already by the long geological history (seismicity, exposure of narrow mountain ridge, erosion). Moreover, only 700 m of maximum rock cover are expected.

- **Heading method**

The dimensions, length of headrace tunnel and the petrographical conditions render possible both the conventional type of heading and TBM-techniques.

The application of TBM is not likely for a gallery of this diameter and length in this region, but the tender documents should allow the Contractor the option of using either method.

A final decision can only be made after technical and cost comparisons on the basis of various offers are received, with additional consideration of the Contractors' own experiences. Both methods are described in the following items.

Typical cross-sections for different rock classes are based on using the TBM as well as conventional heading. For other drawings (layout drawings, sections, etc.) mainly the conventional heading was assumed. In case of TBM application these drawings might need slight adaptations. The general design will not change.

- **Conventional Heading Method**

In the following, most of the discussions concerning engineering geology apply to the conventional method, but will also be relevant for TBM driving.

The main concept of modem tunnelling (New Austrian Tunnelling Method - NATM) is to activate a zone of the rock mass surrounding the excavated cavity, considering it as a "bearing ring" thereby becoming part of the construction system rock and lining. In doing so, four important principles should be observed:

* consideration of the geological rock mass behaviour;
* evidence of unfavourable status of stress and strain by applying appropriate support measures in due time;
* optimisation of the support resistance in relation to tolerable deformations;
* control /checking by measurements of deformations.

The heading of a tunnel, therefore, has to be understood as a composite construction consisting of rock mass on the one hand and support elements on the other. The relaxation of the rock necessarily results in an increasing convergence of the tunnel, i.e. movements towards the cavity. This deformation process needs time to develop, the length of which depends on the rock quality ("bridging time" according to LAUFFER).

Support measures have to be carried out in direct relationship to the actual rock properties and in such a way that they become active, before any critical movements take place. Support measures must be carried out in due time and in consideration of the relaxation behaviour of the rock.

Heading will be done in accordance with the fundamental principles of shotcrete methods. thus maintaining the natural rock bearing capacity as far as possible. To avoid excessive loosening, and reduce the damage of the surrounding rock mass, badly needed as part of the "bearing ring", and to minimise overbreak, the excavation should be carried out by parallel borehole drilling and milli-second blasting. A larger hole in the centre of 10 to 15 m length in advance would create both a cut for blasting and provide advance information of the geological conditions eg petrography, faults, and presence of water, etc. The "smooth" excavation method proposed has many parameters concerning length of rounds, pre-splitting, number and pattern of boreholes, muck size, abrasion of core bits, and overbreak. All of them depend on the rock type and its stability, ie the classification of the actual rock; standard cross sections will be discussed in connection with the supports. In other words, the type of heading is directly dependent on the rock class.

For calculation purposes, it is assumed that necessary support measures are applied immediately after excavation corresponding to the rock class. The explosives correspond in type and quality to meet the demands of careful rock mass excavation. As driving method and lining measures depend on the type of rock and on the rock classification respectively, both may have to be changed every now and then.

After mucking-out with loader and dumper, the tunnel floor should be levelled; possible water - ingress has to be drained and ventilation installed, if necessary. The floor concrete can be placed weekly in order not to interrupt the heading works more than necessary, sufficiently frequently anyway prevent the floor from being damaged.

During heading, the rock mass has to be classified in order to define the quality of heading and the quantity of supports.

Although large quantities of water are not expected, drainage measures should not be excluded. While drilling, water always has to be drained, natural groundwater, pouring in through joints, is expected only in the vicinity of the portals, where the rock cover is relatively limited - to some dekametres.

Theoretically, water pockets and local inflows are always possible, particularly in the neighbourhood of fault zones (impermeable layers) or in sections with small rock cover. Independently from its source, the water must be collected as near to its occurrence as possible to avoid softening of the rock, especially in the tunnel floor. The collected water is drained by a ditch along the bench, if heading is done from bottom to top. In case of falling heading, dewatering requires pump sumps and pumping by means of sludge pumps, regulated by the water level automatically.

Low inflows or dropping water can be sealed by shotcrete layers of 3 to 5 cm only (grain size up to 4 mm, 400 to 500 kg/m^3 of cement, 5 to 10 % accelerator agent). Static water pressure behind shotcrete layers can be avoided by installing water tubes and/or drain holes; the latter ones allow an exact and restricted drainage whatever the distance from the portal. In case of large water inflow, forepoling drillholes are essential. To stop longterm large influx, cement grouting will be necessary, the type and quantity of which cannot be defined yet, as it depends so much on local conditions.

Where the chemical properties of the water are concerned, it is expected that no harmful effect will occur to the structures by solution; water analyses will be carried out in the design stage.

The immediate **"outer-shell-support"** is strictly based on the NATM and consists of shotcrete, steel wire mesh, rock bolts and - in extreme case only - steel arches. During heading through very unstable rock masses, lances, grouted pipe bolts, and forepoling plates may become necessary. In the worst case special heading techniques have to be applied.

The main support of the excavated opening will comprise shotcrete in combination with steel wire mesh and rock bolts. The thickness of the shotcrete, number of rock bolts, and the number of mesh layers may be altered and combined in such a way that at least five rock classes A to E may be covered by this system. The rock mechanical function of the shotcrete can be seen in the limitation of rock loosening, ie a relatively high strength gain of the shotcrete can be quickly achieved. Moreover, the shotcrete seals the rock surface and simply prevents it from weathering. The shotcrete can be reinforced by steel wire mesh in less stable tunnel sections. A second steel wire mesh and a third shotcrete layer may be installed in the case of Rock Class D or E. In the case of less unstable conditions, for instance Rock Class C, "chicken wire" can be used which is much weaker, easier to fix onto the rock wall, and much cheaper.

Rock bolts maintain a bearing ring, built-in systematically in the tunnel roof and walls; by this the surrounding rock changes its load function into that of a support one. Additionally, anchoring prevents the rock mass from loosening, as unfavourable shear planes (joints, bedding, faults) may be crossed by rock bolts. The number of rock bolts will vary from nil to a systematic anchoring of 12 or more of different lengths.

Steel arches provide a heavy support, are difficult to handle and expensive; their installation also needs a lot of time. Therefore they should be generally avoided, but if at all necessary, they should be foreseen only in tunnel sections where the outer lining (rock bolts, shotcrete, wire mesh) seem to be insufficient (i.e. in fault zones or in portal areas).

Steel arches increase the bearing capacity of the outer lining leading to a steady force distribution. The arches must be embedded into the applied shotcrete. Steel arches will facilitate the exact excavation up to the payline in various cross sections.

In fault zones, thick mylonite layers may occur, in which forepoling is necessary (Rock Class F). In this case, lances, grouted anchors, and/or forepoling plates may have to be used. The floor of the tunnel may have to be arched in these sections.

- **TBM-Driving Method**

A tunnel boring machine excavates the required cross section without the use of explosives. Compared to conventional drill and blast tunnels, a tunnel boring machine has the following main advantages:

* The tunnel will have a smooth contour, which is of advantage for the unique lining thickness
* Problems due to blast vibration are eliminated, allowing a more advantageous rock classification
* Excavation time will be normally reduced due to a higher advance rate.

The excavation diameter for the TBM-machine was selected to be 3.90 m to achieve a net diameter between 3.20 to 3.40 m (66 % 3.40 m), depending on support thickness and a minimum concrete lining of 20 cm.

ROCK CLASSIFICATION ACCORDING TO LAUFFER

ROCK CLASS A/B (approximately 66 % of the total length)	Stable to slightly friable
Rock mass behaviour:	No, or single, overbreak in the TBM area. Bridging time more than 3 weeks (A). Bridging time 4 days to 3 weeks (B)
Location of the support measures:	At any distance behind TBM
Support measures:	Shotcrete local (A) and on the roof (B) and single rock bolts to seal joints or support single rock wedges if required
Influence on tunnel driving:	No influence
ROCK CLASS C (approximately 20 % of the total length)	Fractured, friable
Rock mass behaviour:	Overbreak within and behind the TBM area. Bridging time approximately 10 hours to 4 days
Location of the support measures:	Some support (shotcrete and local rockbolts) is required in the TBM-area. Main support can be completed from the tail.
Support measures:	5 to 7,5 circumferential reinforced shotcrete, rock bolts with a length of 1.8 - 2,0 m mainly in the roof-section.
Influence on tunnel driving:	Occasional hindrance
ROCK CLASS D (approximately 9 % of the total length)	badly fractured, intense friable
Rock mass behaviour:	Intense overbreak within the TBM-area. Bridging time 2 to 10 hours
Location of the support measures:	Initial support in the TBM-area with steel arches on the roof, shotcrete and rock bolts. Finalization of the support system from the tail.
Support measures:	7,5 to 10 cm circumferential reinforced shotcrete. Steel arches on the roof. Rock bolts with a length of 2,0 - 2,5 m.
Influence on tunnel driving:	Hindrance of advance caused by support works.
ROCK CLASS E (approximately 4 % of the total length)	Totally fractured, faulted, unstable
Rock mass behaviour:	Possible swelling behaviour of the unstable rock mass. Bridging time 10 hours to 2 days.
Location of the support measures:	Immediate support behind the cutterhead with steel arches, shotcrete and rock bolts. Systematic completion of the support from the tail.
Support measures:	Steel arches, 10 – 15 cm reinforced shotcrete and rock bolts 2.5 – 3.0 m.
Influence on tunnel driving:	Frequent standstill caused by the support works.
ROCK CLASS F (approximately 1.5 % of the total length)	Mylonitic zones, faults, squeezing
Rock mass behaviour:	Possible strong swelling and squeezing behaviour of the rock mass. Bridging time 2 to 5 hours.
Location of the support measures:	Immediate support in the cutter head area with steel arches, shotcrete and circumferential bolting. Completion of the support from the tail.
Support measures:	Steel arches, minimum 15 cm (2 layers) reinforced shotcrete & bolting system with rock bolts 2.5–3.5 m.
Influence on tunnel driving:	Frequent standstill caused by the support works.

* Support

  The initial lining must maintain the inherent strength of the rock mass, acting as a thin membrane inseparable from the surrounding material to prevent its loss of strength which, if permitted to occur, would require additional support installation. Once installed to a closed ring the initial lining must maintain the stability of the whole structure without further assistance of supplementary supports. The detailed quantity of support elements is dictated by the rock class.

* Monitoring

  Five different characteristics of the ground/lining response to the excavation and load redistribution must be observed by use of special monitoring devices. These are:

  - deformation of the initial lining
  - deformation of the surrounding rock mass
  - axial stresses acting within the initial lining
  - radial stresses acting as a "ground load" upon the initial lining
  - stress acting on the rock bolt system

* Water Pressure Measurements

  The design of the inner lining should take account of the measured quantity and pressure of the ground water increase. In order to avoid misleading results caused by the dewatering influence of the tunnel driving pressures should be monitored at a distance of about 15 m from the excavation line, using either a standpipe piezometer or electrical pressure measuring device. Where an electric device is used care should be taken to ensure that the plug-in-contacts are properly protected against damp and water and that no water seepage is possible while it is plugged in.

* Probe Drilling

  Due to the fact that a continuous investigation of the entire tunnel alignment is not normally undertaken and the complex geological and tectonic conditions do not allow an accurate prediction of the ground conditions which are likely to be met during tunnel driving, the use of continuous probe drilling must be seriously considered. Such pre-drilling would normally extend approximately 20 m ahead the excavation and have an overlap of at least 4 m in order to avoid misleading results due to deviation.

* Installation of TBM Equipment

  In the initial stage, heading of the access tunnel to the surge structure will be necessary by conventional method.

  Geotechnical investigations are recommended in this part as a pre-check for the final location and design of the surgeshaft. TBM equipment will be first installed in the access tunnel.

* Mucking

  The excavated material will be transported by rail to the tunnel portal and further by trucks to a stockpiling area, either to be used as construction material or remain permanent in this area which has to be recultivated.

- **Lining Alternatives**

The maximum internal dynamic pressure in the headrace tunnel will occur near the surge tank, approximately 3 bar.

In headrace pressure tunnels various types of lining are used, which are described in the following paragraphs:

* Unlined pressure tunnels:

  Pressure tunnels can be left unlined where the rock is stable, nearly impervious and primary stress is adequate.

  A lining is not essential where the rock is stable but permeable as long as the groundwater level is higher than the operating water level (pressure line). so that no leakage occurs.

In Pakistan's Karakhorum mountains unlined power tunnels will be rare for two reasons:

- there are no areas in the complex tectonics that offer unfolded and impermeable rock positions,
- an unlined tunnel has to be excavated with an approximately 30 to 40 percent larger diameter to compensate for the higher friction losses caused by the rough rock.

Even with smooth excavation, techniques using the TBM, lining of the tunnel will be required in sections with tectonic influenced rock.

* Concrete linings

Concrete linings are common for pressure tunnels.

The load cases for dimensioning the thickness of the lining are:

- external water pressure against the empty tunnel
- maximum internal water pressure assuming no external water pressure.

- **External Water Pressure**

In many cases the external water pressure is the load case for pre-dimensioning the lining thickness.

It is usual to do this using a relatively low safety factor due to:

* As measured, the external water pressure is normally lower around the tunnel than it should be theoretically.
The reason for this phenomena may be the long term latent drainage effect around the consolidated zone of the tunnel.

* The load case is a special load case during emptying of the tunnel. Particularly for long tunnels with a big water volume it takes a long time to drain the tunnel and the load increases very gradually.

* Normally the external water pressure is reduced by the internal water pressure.

* The geometry of TBM driven tunnels is very accurate which ensures a central pressure of the lining created by the external water pressure.

In the case of very high external water pressures, the installation of vents may be provided to keep the thickness of the lining within limits. The vents should reduce the external pressure to the internal pressure. The disadvantage of such vent installation is the necessity of its maintenance.

Due to the narrow mountain ridge between the Daral Khwar Valley and Swat River, the maximal external water pressure was assumed with 300 m=30 bar above the headrace tunnel. The required lining thickness in the case of on internal diameter of 3.40 m was estimated to be 15 cm. For additional security, the lining thickness was selected to be 20 cm.

- **Internal water pressure**

The formulae of KASTNER for the stress calculations (tensile stresses in the lining) are recommended because results are confirmed by measurements in a high number of pressure tunnels.

For the headrace tunnel, the maximal internal pressure is proportional to the maximum level in the surge tank in case of an emergency stop of the turbines - approximately 31 m (3.1 bar).

The circumferential tensile stresses are lower than the limited value.

In the weaker rock classes D, E and F, circumferential consolidation grouting is required to improve the rock mass around the tunnel.

- **Other lining systems**

  Prestressed concrete linings, concrete lining with plastic sheeting, prestressed concrete lining with seal or steeled joints lining are not necessary for the main part of the headrace tunnel. However, for the area near the surge tank, special sealing measures may become necessary e.g. plastic sheeting, like for the surge tank itself.

8.1.2.6 Surge tank

Modem peak storage schemes are expected to operate flexibly throughout the whole power range, this is only possible if the surge tank is designed appropriately.

Different systems are possible to meet the demand for full flexibility of operation.

- **Typical surge tank systems**

Type of surge tank	Border conditions
Surge shaft without chambers	• Simple Structure • Less connecting parts • No chambers • No operation restrictions • Useable for most discharges • Conventional type
Surge shaft with lower chamber	• Lower chamber is advantageous for regulated start-up of turbines • Closing at full load will require a larger diameter of shaft or lead to higher oscillations
Two chamber surge tank	• Type of surge tank without operational restrictions • Reasonable volumes of the chambers
Two chamber surge tank with a reserve flow control throttle	• Reduced space requirement for the surge chambers • Difficult system of the reserve flow control throttle • Advantageous for high discharge rates

For the Feasibility Design the conventional type of a surge shaft without chambers was selected due to its simplicity.

- **Engineering Geological Aspects**

  According to common understanding, the surge tank will be excavated within the tectonically strained section between Boreholes DP4 and DT3. The excavation will take place in a material of "blocky" character, huge rock mass bodies with cohesionless contact to each other. Permeability is high, groundwater during most of the year absent. From the rock class point of view, it must be relatively unstable, however, very hard where drilling and blasting is concemed.

  Sinking of the surge tank may need special construction methods, such as grouting up before excavation, pile walls or drop shaft foundations. Therefore, a rock classification is hardly relevant; pre-stabilisation before conventional excavation is needed. Final lining should be strong according to the unfavourable rock conditions; for dimensioning, the bearing capacity of the rock will not be taken into consideration.

  The question still exists, whether a shifting of the surge tank into the mountain of say 200 m may be a better solution. A two chamber surge structure with access tunnel to the upper chamber would have the advantage for all main structures to be located in relatively undisturbed, unfaulted bedrock. This is particularly valid for the concrete plugs at the very end of the headrace tunnel towards the penstock and access tunnels, where "sound rock" is needed. Only the minor penstock tunnel would then enter the faulted section. This question can definitely be answered by a pilot tunnel reaching beyond the "minor fault zone", i.e. approximately 250 m of adit length. Rock-mechanical investigations, combined with insitu engineering geological measures, will have to be taken into consideration.

- **Structural Design**

The Surge structure has been designed in connection with the hydraulic analysis as follows:

A vertical shafts of 12 m diameter will be located directly above the headrace tunnel. The bottom level of the tunnel here is 1701.08 m asl. Up until 1705.5 m asl the cross section is 3m wide. Between 1705.5 m asl and 1710 m asl the sections will widen to meet the required diameter of 12m. From 1710 m asl to 1735 m asl the intemal diameter stays constant.

The top of the shaft is covered by a concrete plate, with an opening foreseen for ventilation. This in turn will be covered by a small building with windows equipped with ventilation louvers.

The connection of the surge tank to the penstock tunnel is planned with an inclination of 45°. This allows to use the headrace tunnel as a storage tunnel. The main point is to avoid air to be sucked in the penstock and therefore the elevation of the penstock tunnel is 10.4 m lower than the elevation of the headrace tunnel.

- **Hydraulic calculation**

The assumptions of plant operation guidelines for the hydraulic design of the surge tunnel have been defined as follows:

* Start up time for all turbines: 30 seconds (full discharge : 15m³/s)
* Closing time for all turbines: 10 seconds (full discharge : 15m³/s)

These parameters will cover all future demands conceming safety of the surge structure.

It is not unusual for relative small discharge plants to start up all units at the same time, whilst simultaneous breakdown of all units is unlikely but has to be considered in the hydraulic dimensioning.

In the computer hydraulic calculations the most unfavorable frequency of turbine-operation as a basis for determination of the maximum and minimum possible surge levels in the shaft is considered as follows:

* Start up in 30 seconds
* Breakdown at maximum flow velocity in the headrace tunnel 198 seconds after start up.
* Second start up at minimum flow velocity in the headrace tunnel 7 minutes after first start up.
* Breakdown at maximum flow velocity in the headrace tunnel 614 seconds after first start up.
* Third start up at minimum flow velocity in the headrace tunnel 838 seconds after first start up.
* 7Breakdown at maximum flow velocity in the headrace tunnel 1032 seconds (approximately 17 minutes) after first start up.

Contamination of start up and break down cases will not change the maximum and minimum surge levels and their respectively higher and lower values.

The calculation results conceming the extreme surge levels are:

* Maximum surge level: 1731.60 m asl
* Minimum surge level: 1710.04 m asl

The safety factor, according to Thoma, for the system stability is calculated to be quite sufficient.

The final dimensioning of the surge structure will need the basic detail requirements of the manufacturers for the hydromechanical equipment.

- **Excavation and Support**

  Construction methods for the shaft is proposed as follows:

  * Construction of an approximately 430 m long access road from elevation 1698 m asl (working platform for headrace tunnel) to the upper level of the structure at 1735 m asl.
  * Preparation of a working platform with a minimum diameter of 18 m at 1735 m asl.
  * Conventional excavation of a strip approximately 3 m wide along the outer line of the structure, with a gradient from say 15 % in the form of a spiral.
  * Bracing the walls against the remaining inner cone.
  * Preparation of the primary lining consisting of heavy systematic rock bolts 100 - 300 kN up to 9 m long and 20 - 30 m reinforced shotcrete in 2 - 3 layers.

- **Inner Lining**

  Sealing measures will be necessary to avoid seepage.

  At the shotcrete of the primary lining, a protection layer (thin smooth shotcrete layer and/or geotextile fleece) will be placed. A 2-3 mm polyvinylchloride or polyethylene sheeting is then fastened to the shotcrete with a backing of polypropylene fibre prior to the inner concrete lining being placed.

  This concrete lining will be 30-60 m thick and need heavy reinforcement. On the hill side, thrust reinforcement will be required in order to meet the demand of the pressure shock and the earth force. No rock bearing capacity can be assumed in this area.

8.1.2.7 Penstock and Access Tunnels

- **Engineering Geological Aspects**

  Downstream of the concrete plug, which will be heavily anchored in pre-grouted and consolidated rock, the 50 m long penstock tunnel will be driven through highly jointed, slightly faulted rock and rocky overburden. The same applies to the 115 m long access tunnel which, according to the strike of the main "sheared zone", will remain for most of the section within this heavily faulted area.

  The assumed rock classification are:

	Penstock Tunnel		Access Tunnel	
• Rock Class A/B	0 %	0 m	0 %	0 m
• Rock Class C	0 %	0 m	0 %	0 m
• Rock Class D	50 %	25 m	50 %	58 m
• Rock Class E	30 %	15 m	40 %	46 m
• Rock Class F	20 %	10 m	10 %	11 m
•	100 %	50 m	100 %	115 m

  Whether even the Rock Class G occurs, must be left open, as handling of cohesionless blocks of varying size can be judged upon quite differently.

  Excavation of both tunnels may need pre-consolidations by grouting. The horseshoe-shaped tunnels will generally need more protection measures than that normally expected in the corresponding rock classes.

  The access tunnel of nearly 18 m² (for TBM) net cross section leads to the open access road along the penstock slope. To keep the TBM-alternative for offers of construction companies open, the access road must be constructed accordingly, i.e. as a truckable road. By excavating the road, some steep rock walls and scree fields have to be crossed, resulting in extensive protection and stabilisation measures.

- **Alignments**

  The Penstock Tunnel connects the surge tank with the valve chamber and houses the supported penstock pipe. It is approximately 50 m long and will have a gradient from minimum 0.5 % downhill.

  The approximately 115 m long access tunnel branches off the headrace tunnel at an angle of approximately 35° and is the connection to the working platform at 1698 m asl.

- **Cross sections**

  The Penstock Tunnel will be 3.95 m high by 4.4 m wide, resulting in an internal cross section area of 15 m² for the horse-shoe profile. The 2 m diameter steel penstock pipe is arranged near the southern wall, while in the northern part there is space remaining for maintenance purposes. In the concrete floor two grooves are provided, one for drainage the other for a steel covered cable canal.

  An additional layer of shotcrete is proposed to get an smoother inner surface.

  The cross section of the Access Tunnel for the conventional driven headrace tunnel can be the same as for the headrace tunnel itself. However, an inner lining for the access tunnel is not necessary.

- **Heading**

  Both tunnels will be conventionally driven (means by drilling on blasting). Due to the weak rock classes the support measures have to be comparatively heavy. Reinforced shotcrete from 7.5 to 15 cm or more will be needed. Steel arches on the roof always, and at the walls often, will be required. 12 or more rock bolts, 2.0 - 4.0 m long will be necessary.

- **Tunnel plugs**

  At the upstream ends of both tunnels, plugs are necessary to transfer the water pressure into the surrounding rock. Around the massive concrete structures long anchors and a grouting curtain to avoid seepage are required. The plug for the access tunnel is equipped with tunnel door (1.8 by 1.8 m is proposed) the penstock tunnel plug is fitted with a bent funnel-like steel pipe (diameter from 3 m to 2 m, bend 45°).

8.1.2.8 Valve Chamber

The valve chamber is located at the downstream end of the penstock tunnel. Access is possible via a road from the working platform for the headrace tunnel at 1698 m asl. In front of the building another working platform is needed, with the entrance at an elevation of 1694 m asl.

- **Structural Design**

  The reinforced concrete building is 13 m wide and 11 m long, the superstructure being some 8 m high. The underground structure, where the penstock pipe passes through, is approximately 6m deep and 7.4 m wide. The building is a slope-type one and, integrated in the concrete structure, is an anchor block for the bend at the upstream end of the embedded part of the penstock pipe.

- **Auxiliary Equipment**

  The required auxiliary equipment is preliminary listed as follows:

  * 1 maintenance valve, diameter 2 m, - hydraulicly operated
  * 1 emergency valve, diameter 2 m, - hydraulicly operated
  * Equipment for draining and ventilation of the pipe
  * Entrance gate 4.4 by 3.5 m
  * Several windows
  * 1 crane, capacity 10 tonne.

Electrical equipment

* Power supply
* Hydraulic pump
* Control systems
* Lighting
* Telecom equipment

8.1.2.9 Embedded Penstock

- **Engineering Geological Aspects**

The 2 m diameter penstock starts at the plug in 50 m inside the penstock tunnel, where the pipe is supported. In the portal area, the valve chamber houses the upper anchor block. Due to the rock conditions beneath a loose overburden of some 5 m, the blocks and strongly fissured norite will need pre-consolidation measures in the form of grouting down to between 15 and 25 m. Anchors will have their bond sections at the appropriate depths.

From the anchor block, the 850 m long penstock pipe will be embedded such that at least 1 m of cover can be provided, with the backfill material. The whole penstock slope is covered with loose overburden except a small rock outcrop downslope of Borehole DP3. In the upper part of the penstock slope, the excavation is made more difficult due to the many large boulders to be dealt with.

In the area adjacent to borehole No DP3, the material is generally finer-grained slope deposits which can be more easily excavated and backfilled. Same applies to the lower part of the slope upstream of the main Swat valley road from Madyan to Bahrain. The overburden can be handled relatively easily, although several big blocks may have to be boulder blasted. Just downstream of borehole DP3, strongly weathered and highly jointed rock outcrops are evident which may need careful blasting. Backfill will be possible with little further treatment, although due to the irregular surface of the foundation in the penstock trench, a level regulating course of sand will have to be laid.

The penstock pipe will cross the main road, requiring a concrete structure, on top of which the new road can be diverted. Then, not far from the crossing, the second anchor block just in front of the powerhouse has to be constructed, being integrated into the powerhouse foundation together with the manifold. This block will need to be anchored quite deep into the slope deposits and special measures adopted to consolidate the loose ground. The bedrock exists some 30 m below ground level.

- **Alignment**

The alignment of the penstock from the valve chamber to the powerhouse runs in a general northwest - southeast direction. Toward the powerhouse the direction changes, going eastwards, crossing the contour lines and the main Madyan - Bahrain road perpendicularly. The axis is shifted up to 50 m to the southwest, compared with a previous design in which a more or less straight line was foreseen. This new design calls for two horizontal bends each with a radius of some 150 m. The crossing point on the main Madyan-Bahrain road will be by means of a concrete bridge like structure. At the powerhouse the penstock ends in a manifold, covered by a heavy anchor block which again will be formed integral with the concrete structure of the powerhouse.

- **Longitudinal Section**

Starting with a bend of radius R=10 m at the valve chamber the pipe runs parallel to the slope surface with an average inclination of 20° for some 270 m. The inclination then reduces to 6° for approximately 70 m, before increasing to 25° for another some 240 m in an area of farmland on terraces. Above the main road, the inclination increases even more to 37°, then crossing the road the pipe reaches the manifold after some 75 m. Any bend will have a minimum radius of 150 m in order to avoid losses and possible uplift forces in the pipe.

At regular intervals the trench for the penstock is interrupted by a small earth bunds to avoid erosion by water flow during rainy periods, in the worst case a torrent may form causing landslides in the surrounding areas. Small drainage ditches should be dug tanning out at the bunds, to allow drainage of the construction trench.

The small earth bunds should be impermeable and may remain after the construction stage to reduce the wash-out effect on the finer backfilling material.

- **Cross Section and Protection Measures**

To find out the best internal diameter of the steel pipe an optimisation was carried out.

The wall thickness of the 2 m diameter penstock will vary between 12 and 28 mm, for steel quality ST 52-3 according to DIN 17100 (German standard). All welded joints should be X-rayed. The thickness and steel quality may be further optimised at a later stage (e.g. during preparation of the tender documents).

The following measures are proposed for protection against corrosion:

Internal protection:	- Surface preparation: Sandblasting according to Swedish Standard Sa3
Primary Coat:	- Two pack zinc powder epoxy-resin based paint
Finishing coat:	- Two pack coal-tar asphaltum, epoxy resin compound paint.
External Protection:	- Corrosion protection tapes of artificial material e.g. PE foil.

In order to protect the PE foil the pipe must be bedded on a 30 cm thick layer of fine sand not exceeding 2 mm. Also a minimum 20 cm thick cover of the same material should protect the penstock periphery.

Backfill of the excavation may be with the excavated material, after screening coarse material is general unsuitable for backfilling, any boulders or cobbles present should be removed and deposited elsewhere.

The minimum cover of the penstock should be 1 m. The backfilling material must be brought up in 30 cm layers and well compacted.

The transport braces should remain in position, and maybe additional braces placed before and/or during the backfill procedure in order to keep the deformations within reasonable limits. Any deformations must be closely monitored during backfilling.

On completion, the backfilling material should be covered by a minimum 10 cm thick layer of topsoil. Re-naturalisation and planting of grass or meadow plants in the penstock construction area should take place as soon as possible to create additional stability for the slope and avoid surface water erosion.

- **Road Crossing Structure**

A road crossing structure has to be constructed for traversing the main Madyan - Bahrain Road. It is recommended to form the structure adjacent to the river side of the existing road, which should be sheltered by a wall of steel sheet piles braced by steel beams and anchored in to the slope by means of rock bolts.

On completion, the steel-sheet piles will be extracted and the new road can then be constructed over the bridge. The penstock pipe can then be placed in this area without any impediment to public road traffic.

The structure will be some 9.6 long by 5.2 m wide. Due to the relatively steep slope, the height varies between 7 m and 14 m.

On the downhill side, wingwalls will be constructed 2.5 m long. The embankment slope of the new road will have an inclination of 2:1 and should be covered by natural stone masonry (typical local type). After construction of the new road the cutting of the old road should be backfilled with excavated material, the slope being stepped to form new terraces.

8.1.3 Powerhouse

Previous studies conducted for the Feasibility Design have shown a clear preference for powerhouse located at the right bank of Swat River, 1 km downstream of Bahrain Town.

The choice of location was primarily governed by the favourable topography and the satisfactory results of geotechnical investigations. The short access from the main Madyan - Bahrain Road is another advantage.

The powerstation area comprises the following parts:

- A sub-structure housing mainly the Francis turbines and generators, with some auxiliary rooms and the pit for the Pelton turbine
- Superstructure, above ground, comprising the machine hall and operating facilities
- Open switchgear area
- Residential buildings

8.1.3.1 Engineering Geological Aspects

The right Swat River bank is covered by terrace and slope deposits, interfingering each other in the area between the main Swat road and powerhouse area. The bedrock surface proper could not be defined, neither by boreholes (technical incapabilities, breakdowns) nor by geophysical investigations (refraction seismic). The results of several investigation attempts differ in the order of magnitude of some dekametres.

At the same time, the purely noritic bedrock out crops on the Swat River left bank, offering excellent foundation conditions. The possibility of a powerhouse located on the left bank was introduced and compared by cost estimation with the right bank alternative. The former turned out to be significantly more expensive mostly due to the pipe bridge crossing the River Swat. Excavation in sound bedrock and respective safety measures at the rear of the powerhouse also meant additional complications. Thus, the decision was taken to locate the powerhouse on the right bank, as identified initially, designing the foundations assuming alluvial conditions prevail for some depth.

Excavation of the loose terrace deposits, consisting mostly of alluvium - gravel, sand, little silt and some big boulders between, is not envisaged to create undue difficulty. No groundwater is evident above El 1403 m which is slightly below the deepest foundation level of the powerhouse. Safety measures during the construction time, where the side slope of the excavation are concerned, will consist of shotcrete with weir mesh, rock bolts, and maybe deep anchors.

The slope-type **powerhouse** will be founded on terrace deposits, the parameters of which concerning settlement will need to be investigated in detail after excavation. Compaction measures and/or ground consolidation may be necessary. While the slope side of the powerhouse will be partly backfilled, the river bank along the buildings will have to be protected against high floods by heavy riprap or pitching.

The tailrace structure comprises 3 canals - 1 for each turbine forming cascades. It will also be founded on river deposits and appropriate safety measures at the end of the tailrace canals against erosion have to be taken into consideration, e.g. riprap embedded in concrete.

8.1.3.2 Structural Design

A short access road has to be constructed to reach the powerhouse area from the main Madyan - Bahrain road.

The mean water level of Swat River is assumed to be at an elevation of 1405 m asl. The highest flood level according to a 10,000 year flood discharge of 3348 m^3/s is calculated to be at an elevation of maximum 1415.4 m asl.

Thus the powerhouse floor at the entrance, where the Pelton turbine is placed, is designed at an elevation of 1417 m asl, well safe against high floods. The floor level above the Frances Turbines will be 2 m higher.

The powerhouse has been designed to resist backfill load and the side slope up to a level of 1424 m a.s.l.

On the eastern side a road is planned, crossing the tailrace canals to provide access to the rooms in this part of the structure and to allow a possible future access to the area south of the powerhouse.

North of the building, where the main gate and the door to the office part is foreseen, there is a plain area provided which can be used for maintenance and assembly purposes when the areas in the machine hall have insufficient space. Along this area at the hill side there is a 7 m high retaining wall required, which can be constructed as a stone masonry wall or even boulders compacted by an excavator.

The manifold at the western side of the building is embedded in concrete. This end anchor block for the penstock pipe around the manifold will be integrated into the powerhouse foundation.

The powerhouse is a reinforced concrete structure. The excavation slopes need support of anchors, rock bolts, shotcrete and wire mesh during the construction time, and where the slopes will not be backfilled permanently. The construction pit has to be protected towards the river with adequate measures (e.g. steel sheet pile cofferdam, concrete pile wall) to be save against at least a 5-years flood.

- **Underground Structures**

  This part of the building can be divided in two parts:

  The southern part for the Francis Turbines where the foundation is deepest reaches down to El 1406 m and comprises three floors. The northern part, where the Pelton Turbine is situated is less deep, at an elevation of 1411.5 m a.s.l, with the bottom level of the foundation and housing just one floor.

  Beneath the deepest floor level a sump will be placed for collecting leakage water and emptying the turbines. The pit has to be equipped with pumps. The final layout of the pit concerning levels, dimensions and placement will be left for the final design since it depends on the layout of the turbines and pumps.

  The three structural floors are furnished with the following functional equipment:

  * Valve Floor at elevation 1408.4 m
    Valve shafts for Francis Turbines
    Spiral Tubes for " "
    Draft Tubes for " "
    Staircase
  * Turbine Floor at elevation 1411.6 m
    Hydraulic equipment
    Compressed air based
    Bearing coolers
    Several facilities for regulation of the Francis Turbines
    Staircases
  * Generator Floor
    - Francis Part at elevation 1415.6 m
      Generators
      Generator Cells
      Bus Bar Corridor
      Staircases

- Pelton Part at elevation 1412.5 m
  Valve Shaft
  Turbine Pit
  Generator Pit
  Generator Cells
  Bearing Cooler
  Battery Assembling
  Rectifier
  Battery Room
  Diesel Generator
  Diesel Tank
  Corridor
  Staircase

- **Superstructure**
  - Machine Hall

  The machine hall is 30.4 m long by 16.5 m wide and maximum 15.8 m high. The height is determined by the hoisting requirements of the 35 tonne crane.

  Near the main gate at the northern wall and east of the Francis Turbines assembly places are provided

  - Operation Building

  The operation structure consists of two parts: one in front of the building at the river side is 34.4 m long by 5.1 m wide, comprising several rooms and reaching over two floors. The second is located at the back of the machine hall at the slope side, 18.6 m long by 4 m wide, and housing the 11 kV plant. This part of the structure is foreseen as a simple storey.

  The building comprises the following functional equipment and installations:

  - Ground Floor at elevations 1417.0 and 1418.4 m
    Auxiliary Transformers
    Low Voltage
    Relays
    Spare Parts Stores
    Workshop
    11 kV Room
    Toilets and washroom
    Staircases
    Entrance Hall
  - First Floor at elevation 1421.6 m
    Control Room
    Office
    Tea kitchen
    Toilets and washroom
    Corridor
    Staircase

  The arrangement of the operation building may change slightly in the course of the detailed planning of the equipment.

- **Tailrace**

  For each turbine a separate tailrace canal in foreseen, those for the Francis Turbine are 3.25 m wide, while the Pelton canal is 1.4 m wide.

  The 17 m long structures forms cascades by means of 4 sills and stilling basins. The foundation is also stepped according to the level of the sills, reaching at the deepest part an elevation of 1701.5 m.

  Near the powerhouse a minimum 3.5 m wide road crosses the tailrace structures.

- **Open Switchyard area**

  A flat area 18 m wide and 50 m long will be provided for part of the switchyard, west of the machine hall at the slope side of the building.

  At the western part an access road is designed coming from the powerhouse access road.

  Transformers are located at both ends of the area together with their oil seperators and between them a part of the switchgear facilities are placed.

  The roof of the machine hall has been designed to cater for the remaining switchyard installation.

- **Residential buildings and main store**

  The following buildings are recommended to be constructed near Bahrain Town:

  * Resthouse
  * Resident Engineers
  * Operators
  * Chowkidars
  * Store (main spare parts, oil tank, diesel tank etc.)
  * Car park

8.2 HYDRAULIC STEEL WORKS

8.2.1 Weir

- **Flushing Gate**

  No. of units: 1, with 2 sections horizontally split, each: Width: 4m, Height: 2.5m, Bottom pressure 0.45 and 0.8 bar respectively.

  The Gates shall be oil hydraulically operated. Two servo-motors at both sides of the gates have to be provided. All areas in contact with sealing should be of stainless steel or stainless steel plated. The parts to be embedded in concrete as well as the oil pressure system belong to the supply volume. The oil pressure system shall be large enough to supply simultaneously pressure oil for the flushing gates and the intake gates installed in the same weir/intake structure. Two electric motor driven oil pump sets shall be furnished for regular and stand-by service with an automatic alternator to change the operation. A failure of one pump set shall initiate the stand-by set(s) to operate. Local and remote control of all gates should be enabled.

- **Stoplog**

  No. of units: 1, Width: 4m, Height: 5m, Bottom pressure 0.8 bar.

  All stoplogs should be designed for a lifting by hand.

8.2.2 Intake

- **Intake Trashrack**

  No. of units: 4, Width: 2.6m, Height: 1.1 - 2m, Clear between bars: 0.100m, Area: 16m^2

  The trashrack panels should be fixed by stainless steel bolts. The trashrack manually cleaned.

- **Stoplog**

  No. of units: 4, Width: 2.6m, Height: 2.00m.

  The design of the stoplog should allow maintenance of the trashrack with the stoplogs in closed position.

  The lifting of the stoplogs should be provided by hand.

- **Spilling Gate**

  No. of units: 1, Width: 1m, Height: 2m, Bottom pressure 0.9 bar.

  The gate should be manually operated. Embedded parts with strips in the area of sealing of stainless steel or stainless plated steel.

- **Intake Gate**

  No. of units: 1, Width: 4.0m, Height: 3.25m, Bottom pressure 0.7 bar.

  In emergency cases the intake gate should be designed to close against full discharge. For the first filling of the tunnel the gate will be partially opened and must operate without inadmissible vibrations during the filling procedure.

  The gate should be of roller type, hydraulically operated by oil pressure. The gate have shall a total of 8 wheel with self lubricating bushing. The bottom seals shall be made from flat rubber, the lateral seals will be of music note type. If necessary, the gate should be filled in the lower part with concrete as ballast to assure the self-closing tendency without additional pressure on the top side of the servo-motor. The gate shall be guided between the downstream lateral guide rails and the upstream counter guide, where the machined seal sliding strips of stainless steel are welded on.

The gate will be operated by one oil hydraulic servomotor, mounted on a bridge allowing the hoisting of the complete gate above the upper tunnel level. The hydraulic pressure system must be equipped with two electric motor driven pumps for regular and stand-by service and shall be supplied with all necessary connection pipes, valves and instruments for remote supervision and operation. The auxiliary devices for the maintenance of the gate are part of the delivery.

8.2.3 Gravel Spill Structure

- **Flushing Gate**

  No. of units: 1, Width: 1m, Height: 2m, Bottom pressure 0.7 bar.

  The gate should be manually operated. Embedded parts with strips in the area of sealing of stainless steel or stainless plated steel.

8.2.4 Sand Trap

- **Inlet Gate**

  No. of units: 2, Width: 5.00m, Height: 2.8m, Bottom pressure 0.3 bar.

  Each desander chamber will be equipped with one gate at the inlet side which shall be closed in case of maintenance. It should be designed as roller gate and shall be hydraulically operated. The oil pressure shall be supplied by a common oil pressure system for both units.

- **Fine Trashrack**

  No. of units: 2, Width: 5m, Height: 2.6m, Clear between bars: 0.02m, Area: 13m2

  The trashrack panels should be fixed by stainless steel bolts.

- **Outlet Gate**

  No. of units: 2, Width: 4.00m, Height: 3.2m, Bottom pressure 0.3 bar.

  In cases of maintenance of the desander the opening of each chamber can be closed by a oil pressure operated gate. It should be designed as roller gate and shall be hydraulically operated. The oil pressure shall be supplied by a common oil pressure system for both units.

- **Flushing Gate**

  No. of units: 2, Width: 1m, Height: 1.8m, Bottom pressure 1 bar.

  The gate should be manually operated. Embedded parts with strips in the area of sealing of stainless steel or stainless plated steel.

8.2.5 Valve Chamber

- **Maintenance Valve**

  No. of units: 1, Diameter. 2m, Pressure 5 bar, Type Butterfly Valve

  In cases of maintenance of the opening of the Penstock can be closed by a oil pressure operated valve. The oil pressure shall be supplied by a common oil pressure system with the Emergency Valve.

- **Emergency Valve**

  No. of units: 1, Diameter. 2m, Pressure 5 bar, Type Butterfly Valve

  In cases of emergency (pipe burst) the Penstock can be closed by a weight operated valve.. The oil pressure for the opening shall be supplied by a common oil pressure system with the Maintenance Valve.

- **Drainage and Ventilation Valve**

  Valves for Drainage and ventilation of the pipe will be installed in the valve chamber.

- **Crane**

  No. of units: 1, Width:9.5m, Height: 5.5m, Capacity. 10 tonne

  A crane will be installed in the valve chamber to facilitate the pertinent maintenance works.

8.2.6 Access Tunnel

- **Tunnel Door**

  No. of units: 1, Width: 1.8m, Height: 1.8m, Pressure 5 bar.

  The access of the tunnel is equipped with a tunnel door for inspection and maintenance purposes.

8.2.7 Penstock

From the tunnel outlet, the water will be conveyed to the powerhouse by a completely buried steel penstock. On an appropriate slope, burying has several advantages over a free spanning erection on plinths as:

- protection of scenic beauty of the landscape;
- reduced cost;
- avoiding of expansion joints.

The penstock will have two horizontal bends with a radius of 150m. In vertical section starting with a bend of radium R=10m at the valve chamber the pipe runs parallel to the slope surface with an average inclination of 20° for Somme 270m. The inclination then reduces to 6° for approximately 70m, before steepening to 25° for another some 240m in an area of farmland on terraces. Above the main road, the inclination steepens even more to 37°, then crossing the road the pipe reaches the manifold after some 75m. Any bend will have a minimum radius of 150m in order to avoid losses and possible uplift forces in the pipe.

At the powerhouse the penstock ends in a manifold, covered by a heavy anchor block, which again will be formed integral with the concrete structure of the powerhouse.

The penstock will be made completely out of X 52 steel (St 52-3 DIN 17100). An optimization of the diameter (see annex B 2/2 of Appendix 8 Hydraulic and static Pre-calculations) to led the following layout.

Section	Length (m)	Dia (m)	Thickness (mm)	Weight (tonne)
1	63	2	10	31
2	210	2	12	123
3	230	2	15	169
4	230	2	22	248
5	180	2	28	247
Total	913	2	10—28	787

The penstock has been designed to support a 30% dynamic over-pressure which may be produced by the speed governing system. A static calculation is presented in annex B 3/3 of the Conceptual Design Study.

The penstock can be assembled at site out of factory made 6m to 8m long spiral welded pipes.

The following measures are proposed for protection against corrosion:

Internal protection:	- Surface preparation: Sandblasting according to Swedish Standard Sa3
Primary Coat:	- Two pack zinc powder epoxy-resin based paint
Finishing coat:	- Two pack coal-tar asphaltum, epoxy resin compound paint.
External Protection:	- Corrosion protection tapes of artificial material e.g. PE foil.

In order to protect the PE foil the pipe must be bedded on a 30 cm thick layer of fine sand not exceeding 2 mm. Also a minimum 20 cm thick cover of the same material should protect the penstock periphery.

Backfill of the excavation may be with the excavated material, after screening coarse material is general unsuitable for backfilling, any boulders or cobbles present should be removed and deposited elsewhere.

The minimum cover of the penstock should be 1 m. The backfilling material must be brought up in 30 cm layers and well compacted.

The transport braces should remain in position, and maybe additional braces placed before and/or during the backfill procedure in order to keep the deformations within reasonable limits. Any deformations must be closely monitored during backfilling.

On completion, the backfilling material should be covered by a minimum 10 cm thick layer of topsoil. Re-naturalisation and planting of grass or meadow plants in the penstock construction area should take place as soon as possible to create additional stability for the slope and avoid surface water erosion.

8.2.8 Manifold

The manifold allows the bifurcation of the penstock to the three turbines. It would be built in parts which can be transported. The parts would be welded at site, allowing only circumferencial seams.

	Length (m)	Dia (m)	Thickness (mm)	Weight (tonne)
Main Pipe	8	2	28	11.0
Bifurcation 1	17	0.7	28	8.2
Bifurcation 2	19	1.1	28	14.4
Bifurcation 3	12	1.1	28	9.1
Total	-	-	-	42.7

The manifold is located at the western end of the powerhouse building, completely embedded in concrete, thus forming the end anchor block of the penstock which will be integrated into the powerhouse foundation.

8.3 HYDRO-MECHANICAL EQUIPMENT

8.3.1 Design Parameters

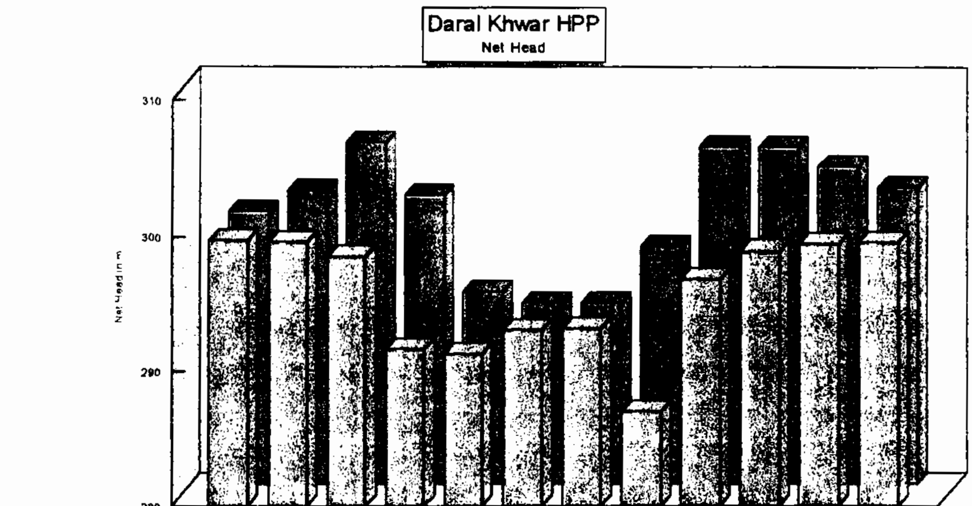
- **Design Discharge**

  Based on an economical evaluation of alternative design discharges the optimum rated discharge for the main hydro-mechanical equipment was found to be 15 m^3/s.

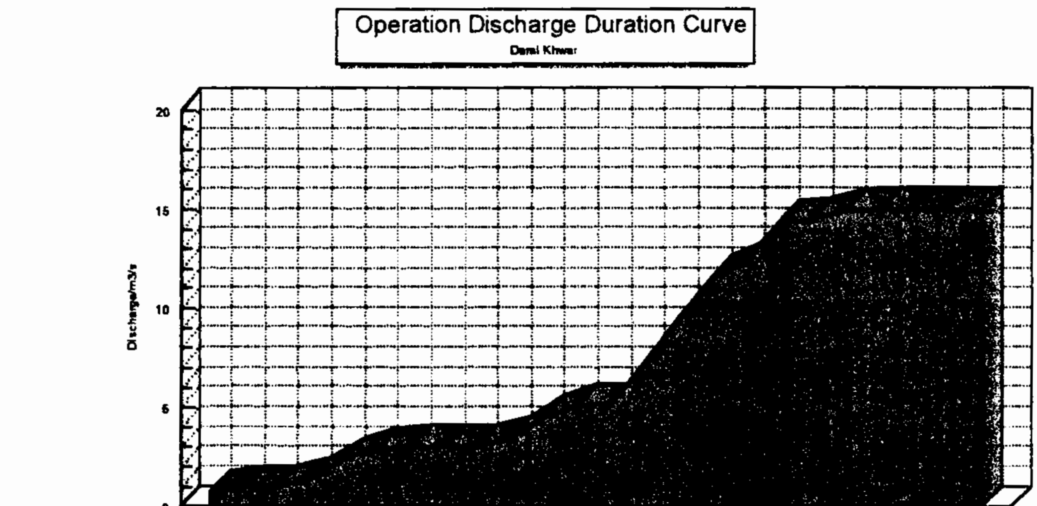
  The 32,300 m^3 net volume of the (tunnel) reservoir will facilitate the storage of low flows to allow turbine operation with increased discharge during peak demand in low flow periods.

- **Head Conditions**

  The available net head is depending on (tunnel) reservoir water level and losses in the waterway e.g. tunnel and penstock, which depend on the turbined discharge. The net head has been calculated as a monthly average for peak and off-peak operation. As a result, the net head varies between 283 m and 305 m. Details are presented below and in the Tabular and graphical presentations in an **Annex** after this Chapter.



Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Peaking operation	300	300	299	292	291	293	293	287	297	299	299	300
Offpeak operation	300	903	305	301	294	293	293	298	305	905	303	302



Hours	8140	7680	6960	6360	5740	5616	5504	4884	4780	4640	4516	4392	3792	3672	3072	2952	2332	2208	1588	968	368	248	124	0
Q	0.8	1.0	1.0	1.4	2.4	2.8	3.1	3.1	3.1	3.5	4.5	5.1	5.2	7.2	9.5	11.6	12.3	14.3	14.5	14.9	15.0	15.0	15.0	15.0

8.3.2 Type and Number of Units

8.3.2.1 Selection of Turbines

With the net head ranging from 287 m to 293 m at full discharge of 15 m^3/s, Pelton, Francis and Turgo turbines are suitable for power generation. A list of suitable turbine configurations is given below:

- **Power station data:**

Discharge (m^3)/s	*Head (m)*	Operating Days			
12.50-15.0	283-298	96	Maximum total net head (m)	=	305
6.25-12.5	298-301	61	Minimum total net head (m)	=	283
2.50-6.25	298-305	81	Elevation above sea level (m.a.s.l)	=	1415
0.80-2.50	300-303	104	Discharge (m^3/s)	=	0.8-15

- **Selected layout data:**

Out of the numerous suitable turbine constellations the following alternatives have been investigated:

Alt.	No. of Units	Type	Discharge m^3/sec	Speed rpm	Unit Power-MW	Setting m
1	3	Francis	5.00	1000	12.57	-2.71
2	3	Pelton	5.00	333	12.94	+3.37
3	4	Turgo	3.75	1000	9.66	+2.55
4	2	Francis	6.25	1000	15.71	-4.99
	1	Pelton	2.50	500	6.4	+2.34

- **Francis Turbines (Alt 1)**

The operation of Francis turbines is limited to a minimum of approx. 30 % of the rated discharge. Daral Khwar hydropower project is designed to be used for four hour daily peak operation, limited only by the reduced storage capacity in the tunnel.

The design discharge of 15 m^3/s leads to the optimum arrangement of 3 vertical Francis units, each with a rated flow of 5 m^3/s and a turbine speed of 1000 rpm.

The setting of the Francis turbine in the case of Daral Khwar must be chosen above groundwater level, thus fixing the tail water level to 1415.3 m.a.s.l, independent of the water level situation in the Swat River.

One Francis unit can operate in the range of 5 m^3/s to a minimum of approx. 2 m^3/s. As there are more than 100 operation days with discharges below 2 m^3/sec, the "3 Francis" alternative has to be ruled out.

- **Pelton Turbines (Alt 2)**

This type of turbine has a slightly lower optimum efficiency than the Francis turbine but can operate over a larger range of flow. The design discharge 15 m^3/s will find the most suitable arrangement in three horizontal 2-jet units, each with a rated flow of 5 m^3/s. The turbine speed will be 333 rpm.

The Pelton turbines can operate at almost any water flow of Daral Khwar, but the low speed requires an expensive generator in case of direct coupling. The adaptation of low speed by a gearbox is not recommended.

The flood level of Swat River will require the setting of the units at an elevation higher than 1418.2 m a.s.l.(shaft).

- **Turgo Turbines (Alt 3)**

  Turgo Impulse Turbines are similar to Pelton Turbines in installation and operational behaviour. Their advantage lies in a higher water discharge relative to the runner diameter, leading to higher specific speed.

  The range of this type of turbine is limited to about 300 m of head and 10 MW turbine output.

  The design discharge of 15 m^3/s will find the most suitable arrangement in four horizontal, 2-jet units, each with a rated flow of 3.75 m^3/s. The turbine speed will be 1000 rpm.

  Turgo turbines can operate at almost any water flow of Daral Khwar.

  The flood level of Swat River will require these units to be set at an elevation higher than 1418.2 m a.s.l. (shaft).

  Consultations with the most experienced Turgo Manufacturer (Gilkes) revealed that turbines of this head and output have never been fabricated. After intense investigation with the design department, it was found that the material would be stressed to its limit.

  It was therefore decided to drop this option.

8.3.2.2 Turbine Selection as a Basis for the Feasibility Study

As a result of the findings described above a combination of Francis and Pelton Turbine has been found to match best the requirement of Daral Khwar HPP. Discharges up to 2.5 m^3/s will be used by a Pelton Turbine, discharges above by two Francis Turbines.

The turbines will have the following characteristics:

Type: Pelton (Alt. 4)			Type: Francis (alt. 4)		
Number of Jets	=	2	*Number of units*	=	2
Number of units	=	1	speed (rpm)	=	1000.0
speed (rpm)	=	500.0	runaway speed (rpm)	=	1610.1
runaway speed (rpm)	=	900.0	Runner dia (m)	=	.83
Runner dia (m)	=	1.31	Inlet diameter (m)	=	1.09
Nozzle dia (m)	=	0.148	Height of gate (m)	=	.166
Bucket size (m)	=	0.458	Unit Discharge (m^3/s)	=	6.25
Unit Discharge (m^3/s)	=	2.50	Min. Unit Discharge (m^3/s)	=	2.5
Min. Unit Discharge (m^3/s)	=	0.31	Rated Net head (m)	=	286.7
Rated Net head (m)	=	283.80	Rated Output (MW)	=	15.71
Rated Output (MW)	=	6.40	Approx. Eturb. (GWh)	=	124
Approx. Eturb. (GWh)	=	23	Setting min (m)	=	-4.99
Setting min (m)	=	2.34			

A very similar arrangement has been installed in an Austrian HPP with good results.

8.3.3 Design of the Selected Francis Turbine

8.3.3.1 Turbine Main Data

Type of Turbine	Vertical Francis
Number of units	2
Rated turbine flow	6.25 m^3/s
Rated turbine power	max. 16 MW each
Turbine speed	1000 rpm
Runaway speed	1610 rpm
Runner diameter	830 mm

8.3.3.2 Design Criteria

- **Turbine Setting**

  The required setting is known to vary from one manufacturer to another. Due to the expected sand abrasion problems, the turbine setting should be chosen conservatively, to avoid accelerated cavitation.

  The setting of the Francis units was determined at elevation 1410 m a.s.l., some 5 m below tail water level.

- **Design Heads**

  The net head will vary from 305 m at maximum of tunnel reservoir and minimum operation discharge at 2.5 m^3/sec to 287 m at minimum reservoir and maximum operation discharge of 15 m^3/sec.

  Tail water level will be constant at 1415.3 m.

  The design net head at full discharge will be 293 m because of the operational characteristics of the power plant.

  Values lower than 293 m result from lower reservoir levels at the end of the four hour peaking operation.

- **Efficiency**

  The peak efficiency point should be defined according to the mode of operation and the flow duration curve.

  Normally the peak efficiency point is located at around 80 % of the rated turbine flow. Efficiency of Francis units is proposed to be 93 % at the optimum point.

- **Turbine structures**
  * The runner will be cast construction of chrome-nickel steel.
  * The steel structures of the spiral casing, covers, stay-ring, draft tube etc. should be made from fine grained carbon steel.
  * Stainless steel will be used for guide vanes, renewable sealing rings and also for bolts, auxiliary piping, etc.
  * A sufficient stock of spare parts should be kept for maintenance.

- **Inlet valves**

  A spherical valve will be installed. The valve diameter will be equal to the inlet diameter of the spiral casing (approx. 1100 mm).

  The valves will be provided with a bypass and a double acting servo-motor for opening and closing, both being operated by oil pressure from the turbine governors.

  Two moveable sealing rings will be provided in order to avoid a dewatering of the pressure tunnel in emergency cases. The upstream situated sealing ring will be closed in standstill position of the turbine to enable the exchange of the downstream sealing.

- **Governors**

  Each governor will be able to control the unit as well in parallel operation with the network as in isolated network.

  The governor will be equipped with a digital electronic governor head to be installed in the main turbine control board. The oil pressure system including the control valves for the oil supply to the servomotors of the turbine as well to the servomotors of the spherical valve will be installed on the turbine floor. A local manual control for start and stop of the unit will be provided.

The governors will be equipped with all necessary control devices for remote control and water level control.

8.3.4 Design of the Selected Pelton Turbine

8.3.4.1 Turbine Main Data

Type	Horizontal Pelton
Number of Jets	2
Speed	500 rpm
Runaway Speed	900 rpm
Runner diameter	1.31 m
Nozzle diameter	148 mm
Unit Discharge	2.5 m^3/s
Minimum Unit Discharge	0.31 m^3/s
Rated Net Head	283.8 m
Rated Output	6.4 MW
Setting min	2.34 m

- For direct coupling to a synchronous generator.
- Casing of cast steel or double walled plate steel with noise damping filling.
- Runner cast of stainless steel.
- Turbine shaft of forged steel with flange.
- Two nozzles regulated by oil servo-motor.
- Nozzles and spear tip made of stainless steel.
- Deflectors hydraulically controlled by the speed governor. Deflector plate will be made of stainless steel.

8.3.4.2 Design Criteria

- **Turbine Setting**

  The setting has been determined at an elevation of 1418.2 m.a.s.l, 1.2 m above powerhouse floor and 2.9 m above tail water level.

- **Design Head**

  The net head will vary from 301.8 m at maximum level of tunnel reservoir and minimum operation discharge of 0.4 m^3/sec. to 283.8 m at minimum reservoir level and maximum operation discharge of 15 m^3/sec.

- **Efficiency**

  Peak efficiency of the pelton unit will be approximately 88%.

- **Inlet Valve**

  This will be a spherical valve with:

  * 700 mm inner diameter for automatic closing by a weight loaded lever,
  * Flanges at both sides,
  * Disassembling flange at the downstream end,
  * Bypass with two hand operated spherical valves and dewatering pipe leading to the tailrace canal,
  * Control equipment for remote operation of the releasing devices,
  * Oil pressure operated servo-motor for the opening of the valve and the damping in closing direction.

- **Bifurcation Pipe**

  Inlet diameter Dia. = 0.70 m with flanges.

- **Governor**

  With hydraulic pressure supply system,
  Remote control and indication for the installation in the control room of the main turbines

- **Flywheel**

  A flywheel for coupling between flanges of turbine and generator shaft should be considered it the finally needed inertia cannot be provided by the generator rotor.

8.3.5 Dewatering System

The dewatering system is considered necessary to drain the conduit system and the lowest part of the powerhouse shaft.

Dewatering of the conduit system is possible through the turbine units to tail water corresponding to the actual water level of Swat River.

The remaining water from the pressure tunnel, draft tubes and tailrace tunnel will be drained by gravity into the tailrace. Pumps are installed for drainage during flood.

The drain water of the turbine shaft will be collected in a drainage pit located at lowest elevation of the turbine draft tube to be pumped into the tailrace.

8.3.6 Cooling Ventilation and Heating

- **Main Cooling System**

  The main cooling system is required for cooling of generator coolers, thrust and guide bearings, turbine guide bearing, block transformers, etc.

  The total cooling water demand has been estimated at approx. 80 l/s.

  The water must be free from organic material and sediments. In order to reduce maintenance works to a minimum, permanent water treatment needed for fresh water cooling has been ruled out. It is proposed to install a closed water circuit system with re-cooling through an easily maintained pipe system in the tailrace channel.

  Cooling water will be collected in 2 tanks, capacity 3 m^3 each, in a room at generator floor level. The water will be distributed from either chamber by a pipe system to the generator coolers, turbine guide bearings, thrust and guide bearings, shaft seal etc. and block transformers.

  The maximum inlet temperature should not exceed 30°C.

  The heated water will be collected by a main pipe leading into the tailrace tunnel.

  Heat back-cooling be realised will over a ring-pipe system, dimensioned for a minimal back-cooling temperature of 30°C at 20°C tailrace water temperature.

  The pipe system includes manual and automatic shut-off valves, thermometers, flow meters and flow relays.

- **Ventilation**

  The power station is mainly above ground level and has sufficient openings in the exterior walls to allow natural ventilation.

  The Control room will have a separate ventilation system with equipment controlling the air temperature and humidity.

8.3.7 Auxiliary Equipment

- **Powerhouse Crane**

The powerhouse crane will be a bridge crane with a main hoist which can serve all normal requirements for lifting and moving of heavy components during installation, maintenance work and operation. The generator rotors are generally the heaviest components; lifting height is determined by the generators. Additionally, the crane shall be provided with an auxiliary hoist travelling under the main crane girder and away from the entrance gate. This will increase the crane operating area and offer quicker service for the smaller components.

The main crane hook shall be capable of lifting the tallest component off the transport vehicle and both the main and auxiliary hooks should be capable of reaching sufficiently low to serve the turbine floor.

Main data:

Main hoist capacity, expected	35	tonne
Auxiliary hoist capacity	5	tonne
Bridge span, distance between rails	16	m
Crane travel	30	m
Hoisting height	9	m

Additional auxiliary cranes are necessary at the turbine floor, in workshops, etc.

- **Workshop Equipment**

The workshop equipment should be sufficient to perform the following functions:

* Dismantling and erection of all turbine parts, as well as most other components related to the power plant.
* Allow the repair or renewal of components which do not need specialized skill or experience. This includes welding, drilling, turning, grinding, etc., and the repair of the power plant trucks and cars.

- **Oil Handling Equipment**

A centralised oil handling system is not foreseen. Spare oil, as well as used oil, will be stored in ordinary oil drums. The scope of supply should include equipment for taking oil samples, manual and electrical transfer pumps with pipes/hoses and filters, as well as a mobile, high grade filtering unit with oil separator. The latter can be coupled in parallel into all oil systems, including the transformers, during ordinary operation.

- **Fire Fighting Equipment**

In general, 6 kg hand held and 25 kg mobile fire extinguishers shall be placed at central locations in both the power station and at the intake. In addition, the power station will be provided with several taps for fire hoses on each floor. The water for the fire fighting system shall be taken directly from the bifurcation pipe. With special fog-spray nozzles, the equipment can even be used for putting out oil fires as well as being operated close to the electrical equipment.

Daral Khwar with limited Tunnel Storage

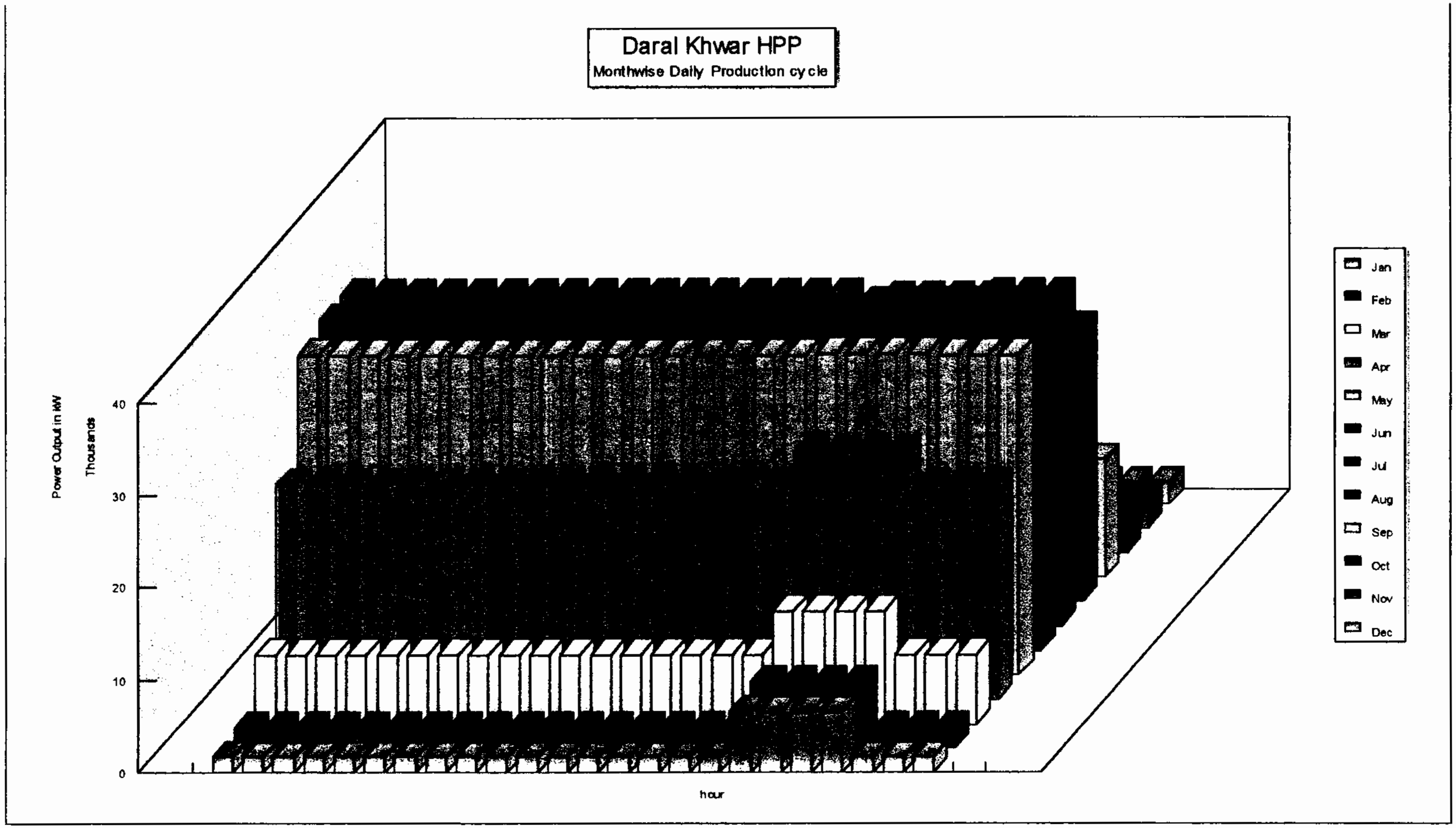
Evaluation of Capacity, Energy and Benefit

Loss function	Peak time /h	4	Fix loss /kW	100
factors q^2	Off peak time /h	20	eta Trafo	0.99
	Alt. Max. / m	1723	eta Generator	0.96
0.0642	Alt. Min. /m	1708	eta Turbine 4	0.84
			eta Turbine 20	0.86

		Qtot	Qturb4	Qturb20	alt.Swat	altintake 4	altintake 20	h 4	h20	h4 net	h20 net	eta4	eta20	Ppeak	Pfpeak	Poffpeak	E/peak	E/offpeak	E/tot	Lossduration	V/peak	V/offpeak	P/fpeak	B/peak	B/Firmcap	B/offpeak	B/tot	days	M3
	15.0	m^3/sec	m^3/sec	m^3/sec	m	m	m	m	m	m	m			kW	kW	KW	GWh	GWh	GWh	h	$/kWh	$/kWh	$/kW firm cap.	Mio$	Mio$	Mio$	Mio$		
1.11	JAN	1.1	2.8	0.8	1415	1716	1716	300	300	300	300	0.81	0.83	6727	6727	1782	0.834	1	2	6	0.039	0.034	7.08	0.033	0.048	0.038	0.118	31	2981385
1.32	FEB	1.3	3.1	1.0	1415	1716	1717	300	302	300	302	0.81	0.83	7220	6727	2302	0.809	1	2	7	0.039	0.034	7.08	0.032	0.048	0.044	0.123	28	3192786
3.41	MAR	3.4	5.1	3.1	1415	1716	1721	300	306	299	305	0.81	0.83	12173	6727	7543	1.510	5	6	44	0.039	0.034	7.08	0.060	0.048	0.159	0.266	31	9123855
9.82	APR	9.8	11.6	9.5	1415	1716	1722	300	307	292	301	0.81	0.83	26848	6727	23270	3.222	14	17	335	0.039	0.034	7.08	0.127	0.048	0.476	0.650	30	25457627
14.55	MAY	14.5	15.0	14.5	1415	1721	1723	306	308	291	294	0.81	0.83	34835	6727	34712	4.320	22	26	730	0.042	0.036	7.08	0.181	0.048	0.777	1.006	31	38962698
14.95	JUN	14.9	15.0	14.9	1415	1723	1723	308	308	293	293	0.81	0.83	35044	6727	35775	4.205	21	26	745	0.042	0.036	7.08	0.176	0.048	0.775	0.999	30	38749574
14.97	JUL	15.0	15.0	15.0	1415	1723	1723	308	308	293	293	0.81	0.83	35054	6727	35828	4.347	22	27	772	0.039	0.034	7.08	0.171	0.048	0.757	0.976	31	40095411
12.60	AUG	12.6	14.3	12.3	1415	1716	1723	300	307	287	298	0.81	0.83	32806	6727	29758	4.068	18	23	555	0.039	0.034	7.08	0.160	0.048	0.628	0.836	31	33759454
5.50	SEP	5.5	7.2	5.2	1415	1716	1722	300	307	297	305	0.81	0.83	17077	6727	12763	2.049	8	10	108	0.039	0.034	7.08	0.081	0.048	0.261	0.389	30	14259439
2.75	OCT	2.8	4.5	2.4	1415	1716	1721	300	305	299	305	0.81	0.83	10629	6727	5906	1.318	4	5	29	0.039	0.034	7.08	0.052	0.048	0.125	0.224	31	7374073
1.75	NOV	1.7	3.5	1.4	1415	1716	1719	300	304	299	303	0.81	0.83	8242	6727	3381	0.989	2	3	12	0.036	0.031	7.08	0.036	0.048	0.064	0.147	30	4531720
1.35	DEC	1.3	3.1	1.0	1415	1716	1717	300	302	300	302	0.81	0.83	7281	6727	2366	0.903	1	2	8	0.036	0.031	7.08	0.033	0.048	0.046	0.127	31	3603087
										h min	h max			**P max**	**P firm**				**E total**										
	TOTAL									287	305			**35054**	**6727**		29	119	**148**	3352				1.142	0.572	4.148	5.862	365	222
																			0.48	0.38									

Legend

Qtot	m^3/sec	Total discharge available for turbining	Pfpeak	kW	Firm peak capacity (avaiable 4hours per day all over the year with 95% probability)
Qturb4	m^3/sec	Discharge avaiable for 4 hour peaking	Poffpeak	kW	Average capacity during off peak production
Qturb20	m^3/sec	Discharge available for 20 hor offpeak production	E/peak	GWh	Peak energy
alt.Indus	m	Waterlevel of Swat River	E/offpeak	GWh	Off peak Energy
altintake 4	m	Average Waterlevel of headpond for peaking	E/tot	GWh	Total energy
altintake 20	m	Average Waterlevel of headpond for offpak production	V/peak	$/kWh	Value per kWh of peak energy
h 4	m	Gross head available for 4 hour peaking	V/offpeak	$/kWh	Value per kWh of off peak energy
h20	m	Gross head available for 20 hour offpeak production	P/fpeak	$/kWfirmcap	Value per kW of firm capacity
h4 net	m	Net head available for 4 hour peaking	B/peak	Mio$	Benefit of peak energy
h20 net	m	Net head available for 20 hour offpeak production	B/Firmcap	Mio$	Benefit of firm capacity
eta4		Total efficiency during peaking	B/offpeak	Mio$	Benefit of off peak energy
eta20		Total efficiency during offpeak production	B/totfirm	Mio$	Total benefit
Ppeak	kW	Peak capacity			


Daral Khwar HPP
Monthwise Daily Production cycle
Power Output in kW
Thousands
40
30
20
10
0
hour
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

8.4 ELECTRICAL EQUIPMENT

This chapter summarises the feasibility design considerations for the electrical installations of the powerhouse. These layouts form the basis of the cost estimates and will serve also as a basis for the future final design.

The electrical equipment consists mainly of:-

- two vertical shaft generators of 18 MVA and one horizontal shaft generator of 7.5 MVA connected via 11 kV cables to a 11 kV switch board.
- auxiliary supply for all power needs of the powerhouse and intake area designed to give a maximum level of reliability.
- control and protection devices for all functions of the plant including the 132 kV switchyard.

8.4.1 Border Conditions

8.4.1.1 Codes and Standards

All electrical equipment shall comply with the IEC (International Electro-technical Commission) standards. In case of non-existence of relevant IEC standards, BS or VDE/DW standards shall apply. Where available relevant Pakistani standards and codes shall be respected.

8.4.1.2 Site Conditions

- **Altitudes**

Powerhouse	1417 m.a.s.l.
Weir	1723 m.a.s.l.

- **Humidity**

Max.	91%
Min.	8%
Mean	68%

- **Temperature**

Air max.	33°C
Air min.	0°C
Air Average	16°C
Water max. (Daral Khwar)	20°C
Water min. (Daral Khwar)	4°C

8.4.1.3 System Requirements

- **Insulation Co-ordination**

  WAPDA standards require an Impulse Withstand Voltage of 650 kV for the 132 kV system. This value corresponds to the higher alternative of IEC standard No.71 which offers two options, namely 550 kV and 650 kV. Thus, a high lightning intensity has been taken into consideration.

  For the 11 and 33 kV system, values 95 kV and 170 kV respectively have been taken for the Impulse Withstand Voltage.

- **Short Circuit Withstand**

  A power system analysis has been undertaken, considering all projects planned to be undertaken up to the year 2015.

  As a result a short circuit level of 1400 MVA has to be established at 132 kV level in Daral Khwar. According to WAPDA's standards, the minimum short circuit on the 132 kV system is a current of 20 kA. The corresponding values are 12.5 kA for 11 kV and 16 kA for 33 kV equipment.

8.4.2 Generator of Francis Turbines (18 MVA)

8.4.2.1 Design

The design of the generator is mainly determined by the layout of the turbine.

The rated output of 18 MVA corresponds to a nominal turbine power of about 15.3 MW and a power factor of 0.85, is considered sufficient to satisfy the reactive power demand of the system.

The voltage was chosen to be 11 kV, appropriate for this size and standard in WAPDA system.

ELECTRICAL LAYOUT
DARAL KHWAR HPP.

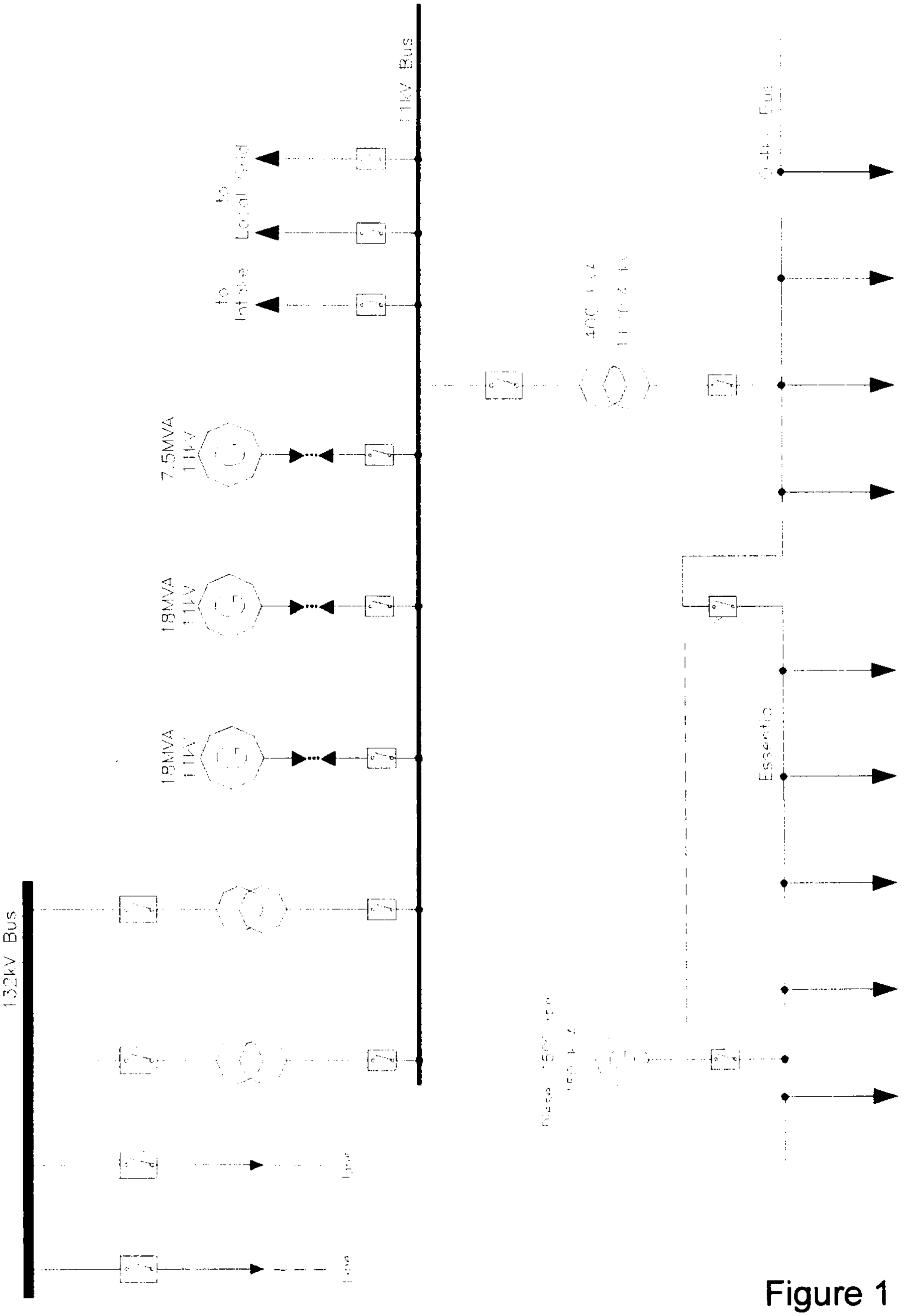


Figure 1

8.4.2.2 Rotor

The rotor dimensions area function of the speed n in sec-1, the capacity S_n in MVA, the desired GD2 (WR2) in tm2 and constructive factors.

$$D = \sqrt{\frac{GD^2}{Sn} x \frac{0.0055 x n}{k}} = \sqrt{\frac{35 x 0.0055 x 1000}{18 x 2.7}} = 1.99 \, Say \, 2m$$

$$L = \frac{Sn}{D^2 x 0.0055 x n} = \frac{18}{2^2 x 0.0055 x 1000} = 0.82 \, m \, Say \, 0.85 \, m$$

For this bore diameter, the most appropriate is a design of solid forging with thick steel plates welded together to a solid body.

The poles shall be laminated and be provided with a damper winding for the required operational stability.

8.4.2.3 Stator

The stator shall be framed by welded steel rings on both sides which will transmit all dynamic and static forces through supporting feet to the base plates into the foundations. For proper and effective cooling, the generator core shall be divided by radial air gaps for air flow through the generator core. The winding shall be designed so that a generated wave form is as close to sine wave as possible.

The stator winding shall be made of bar or coil winding system, with an insulation of continuous tape impregnated with synthetic resin in vacuum and subsequently cured. The coils must be provided with a necessary anti corona protection at the end of the slot sections. The generator shall be able to run at 10% overload without exceeding the temperature limits.

8.4.2.4 Bearings

The generator will be of conventional design with an upper combined thrust and guide bearing and a lower guide bearing. The thrust bearing should therefore be designed to carry the combined weight of the generator rotor, shaft and turbine runner, as well as the hydraulic thrust during operation. To allow the unit to be operated with intermittent start/stop, the thrust bearing will be equipped with a high pressure lubrication system. This will provide the initial oil film at start-up and running out and virtually eliminates the breakaway torque.

8.4.2.5 Cooling

The generator shall be air cooled and self-ventilated by axial or radial ventilation through the rotor, itself acting as a fan. The air will be re-cooled by air/water heat exchangers situated outside the stator housing. With this design a closed air loop system inside the generator pit is formed thus avoiding pollution through atmospheric impurities.

8.4.2.6 Excitation System

Two types of excitation system have been considered for generator excitation:

a) Static excitation
b) Rotary excitation

Static excitation has the advantage of being quick response, can deliver fully reversible excitation voltage and as the static system can be inserted in the control panels, it reduces the height of the generator pit.

Rotary excitation consists of an AC exciter machine together with a converter bridge mounted on the shaft. This system does not require slip rings and carbon brushes and maintenance is considerably reduced. Field flashing to initiate voltage build-up is also eliminated, thus considerably reducing the size of the station battery.

As the disadvantage of slow regulation speed has no significance on a 1000 rpm speed generator, the advantages of the Rotary excitation system are obviously convincing. It is therefore proposed to install in Daral Khwar a thyristor controlled rotating exciter system which constitutes a fast, maintenance free system with well defined frequency characteristics.

8.4.2.7 Voltage Regulation

The voltage regulator forms part of the excitation system its primary task being to maintain the voltage of the power system and the transient stability in the network. An additional task is to protect the generator against thermal strain in winding and iron.

The regulator shall have the following functions:

- Voltage regulation
- Field current regulation
- Field current limiter
- Reaction compensation
- Supervision and Logic Circuits
- Following of Line voltage during synchronising
- Under excitation limiter
- Stator current limiter
- Power system stabiliser
- Power factor regulator
- Active compensation

The equipment will be powered from the 110 V DC station battery via a DC/AC converter if needed.

8.4.2.8 Generator Summary

• Number	2	• Weight of Rotor	31 tonne
• Capacity	18 MVA	• Weight of Stator	17 tonne
• Speed	1000 rpm	• Total weight	56 tonne
• Runaway speed	1500 rpm	• Moment of Inertia (WD^2)	35 tm^2
• Voltage	11 kV ± 5%	• Winding Insulation	Class F
• Power factor	0.85	• Utilisation	Class B
• Efficiency	98%	• Cooling	Air/Water
• Bore	2 m	• Excitation	Rotary
• Length of Rotor	0.85 m		

8.4.2.9 Generator of Pelton Turbine (7.5 MVA)

The Pelton turbine will drive a 7.5 MVA synchronous generator with the following main data:

• Nominal capacity	7500 kVA
• Nominal Speed	500 rpm
• Runway speed	900 rpm
• Nominal Voltage	11kV/50hz
• Power Factor	0.8
• Type	IM 7201 (D9)
• Bore	2.75 m
• Length of Rotor	0.35 m
• Moment of Inertia (GD^2	56 tm^2
• Protection Class	IP44, (IP23 / for the exiter)
• Insulation Class	F
• Temperature rise acc. to class	B
• Cooling	Air/Water
• Weight	36 tonnes (Rotor 20 tonne, Stator 14 tonne)
• Excitation	Brushless with Rotary diodes with the following functions: * Voltage regulation (PI) * Power factor regulation * Field current regulator * Stator current limiter * Field current limiter * Start-up exiting through remanence * Reaction compensation * Supervision and Logic circuits

8.4.3 Transformers

There are 2 main step up Transformers, and 2 auxiliary Transformers installed.

8.4.3.1 Main Transformers

The 11 kV busbar is coupled to the 2 main transformers to step up the generating voltage of 11 kV to the transmission voltage of 132 kV. The Transformers are installed in an open air switchyard adjacent the powerhouse and linked by cable to the 11 kV busbar.

- **Design**

  The transformers shall comply with the system requirements and be built for solidly earthed neutral on 132 kV side. Cooling shall be performed by natural flow up to 20 MVA and forced by fans from 20 MVA to 26 MVA. (ONAN/ONAF)

  The delta connected winding on the medium voltage side will provide a closed circuit for possible third harmonics originated by the generator. The high voltage winding is Y connected with the neutral taken out on a separate terminal for connection to earth.

- **Rating and Data**

Capacity	20/26 MVA
Voltage primary	11 kV
Voltage secondary	132 kV ± 5% ± 10%
Frequency	50 Hz
Temperature rise	55 °C
Power factor	0.8
Vector group	YN d11
Impedance	12%
Cooling	ONAN/ONAF
On load tap charger	Yes

- **Weight**

Total	25 tonne
Transport	14 tonne
Oil	7 tonne

- **Dimensions**

Dimensions	Install	Transport
Height	5.2 m	2.7 m
Width	3.4 m	2 m
Length	5.6 m	3.5 m

8.4.3.2 Auxiliary Transformers

Auxiliary transformers will be installed for the powerhouse auxiliary supply and the intake area. The transformer, for powerhouse and intake area, will be outdoor installed and consequently a conventional oil immersed hermetically sealed distribution transformer can be used.

The transformers have the following ratings

	Power House Transformer	Intake Transformer
Number	1	1
Capacity	400 kVA	100 kVA
Voltage		
Primary	11 ± 2.5/5%	11 ± 2.5/5%
Secondary	0.4 kV	0.4kV
BIL	75 kV	75 kV
Frequency	50 Hz	50 Hz
Vector group	Dyn 11	Dyn 11
Type	Oil	Oil
Cooling	ONAN	ONAN
Impedance	6%	6%
Dimension		
Length	1470 mm	1030 mm
Width	990 mm	780 mm
Height	1700 mm	1600 mm
Weight	1460 kg	660 kg

8.4.4 132 kV Switchgear

8.4.4.1 Selection of Switchgear Arrangement

For Daral Khwar Powerhouse, designed as an external type structure and with no lack of space, an outdoor switchyard is the most cost effective design.

There exists a variety of different designs such as:

single bus-bar, double bus-bar, single circuit breaker system, bypass system, double breaker system and so on.

The variants differ basically in cost and reliability. Main power plants whose loss will seriously affect the main grid, or have high production capabilities for long periods of time, will usually go for high reliability designs even at possibly disproportional high costs.

At Daral Khwar full production is calculated to occur for about 4 months in a year, the three units will allow a sufficiently high operational flexibility and there are two lines connecting to the grid.

The increased cost for the different multi circuit and breaker systems must be weighted against the benefits of higher flexibility and availability in operation and maintenance.

In particular such benefits will occur, where for example in the case of circuit breaker failure the risk of a subsequent complete shut down of one of the units is larger than with a more complex, circuit breaker system. The risk of a circuit breaker failure is however difficult to predict. It depends not only on the statistical failure rate of the breaker itself, but also on the mode of operation of the plant and the quality and intervals of maintenance. Life expectancy for the equipment is very high under rated conditions.

Based on the above considerations, the best alternative is a:

Single Bus-bar with a
Single Circuit Breaker System.

Maintenance of the breakers can be done during the winter months with one machine only running and/or connecting the plant to one of the outgoing feeders only.

To avoid longer production interruptions, i.e. in the case of an unexpected failure, a set of sufficient spare parts should be available at the plant.

8.4.4.2 Design

The switchgear was assumed to be the conventional outdoor type with modern SF6 circuit breakers. The design consists of six bays: two for the main transformers, two for the outgoing line one for the grid station transformer and one for bus-bar voltage transformers and earthing switch. There is also space for one extra bay.

The following design criteria would apply:

Installation of equipment	:	Outdoor
Highest Voltage for Equipment	:	145 kV
Rated short circuit current (1s)	:	23 kA
Rated impulse withstand voltage (1.2/50µs peak value)	:	650 kV (to earth)

IEC 815/85 recommends creepage distance values ranging from 16 mm/kV (r.m.s. phase to earth voltage) to 31 mm/kV. In Pakistan, a very long dry season is often followed by a sudden sometimes violent and strong start of the winter season. These conditions could cause a considerable buildup of dust on the insulators and hence the creepage distance should not be under-estimated. It is proposed that a minimum distance of 3620 mm corresponding to 25 mm/kV should be adopted. The IEC characterises this distance as being suitable to cover conditions in industrial areas with relatively severe pollution. Since the dust is probably not very polluted, it will maintain a comparatively loose consistency and should anyway be washed away by the first showers.

LOCATION OF 132 Kv SWITCHYARD
DDARAL KHWAR HPP

Figure 2

The size of the bus conductors will be 600 mm^2 ACSR cable, mounted between steel structures at a distance of 36 meters.

The distance between different phases should be 3.5 m as generally adopted in WAPDA switchyards. In case of a short circuit, the bus cables are attracted, but because of the short distance of 48 m between the steel structures, the displacement is negligible. The minimum distance for 145 kV systems should be 115 cm, as VDE 0101, for outdoor installations. The insulation of the bus will be done by a double insulator chain of 12 discs each, type 146/254 mm or similar.

8.4.4.3 Circuit Breakers

Each transformer feeder will require for 132 kV switchgear a power circuit breaker with a nominal rating of 1.250 A and 145 kV. The interrupting capacity should be above 5,000 MVA, which corresponds to an impulse current of 31.5 kA asymmetrically.

It is recommended to use SF6 gas breakers.

The proposed three phase breakers will allow fast reclosure operation at line fault. A motor driven spring charging mechanism is proposed, as it requires less maintenance than a hydraulic mechanism.

The basic dimensions as the followings:

- basic size 0.65 x 0.65 m
- height about 3.6 m
- distance between centre lines 1.8 - 2.0 m

The three poles should be mounted together on a common base. The auxiliary energy will be supplied by 400 V ac from the station service generator of the power plant.

8.4.4.4 Disconnecting Switches (Isolators)

The disconnecting switches will be electrically group operated. This way they will withstand more than 310 kV between open contacts and a short circuit impulse current of at least 31.5 kA when closed. The nominal rating in closed position will be 800 A and 145 kV.

The dimensions are approximately:

- total height 1.90 m
- total length 1.85 m
- length of moving arm 0.85 m

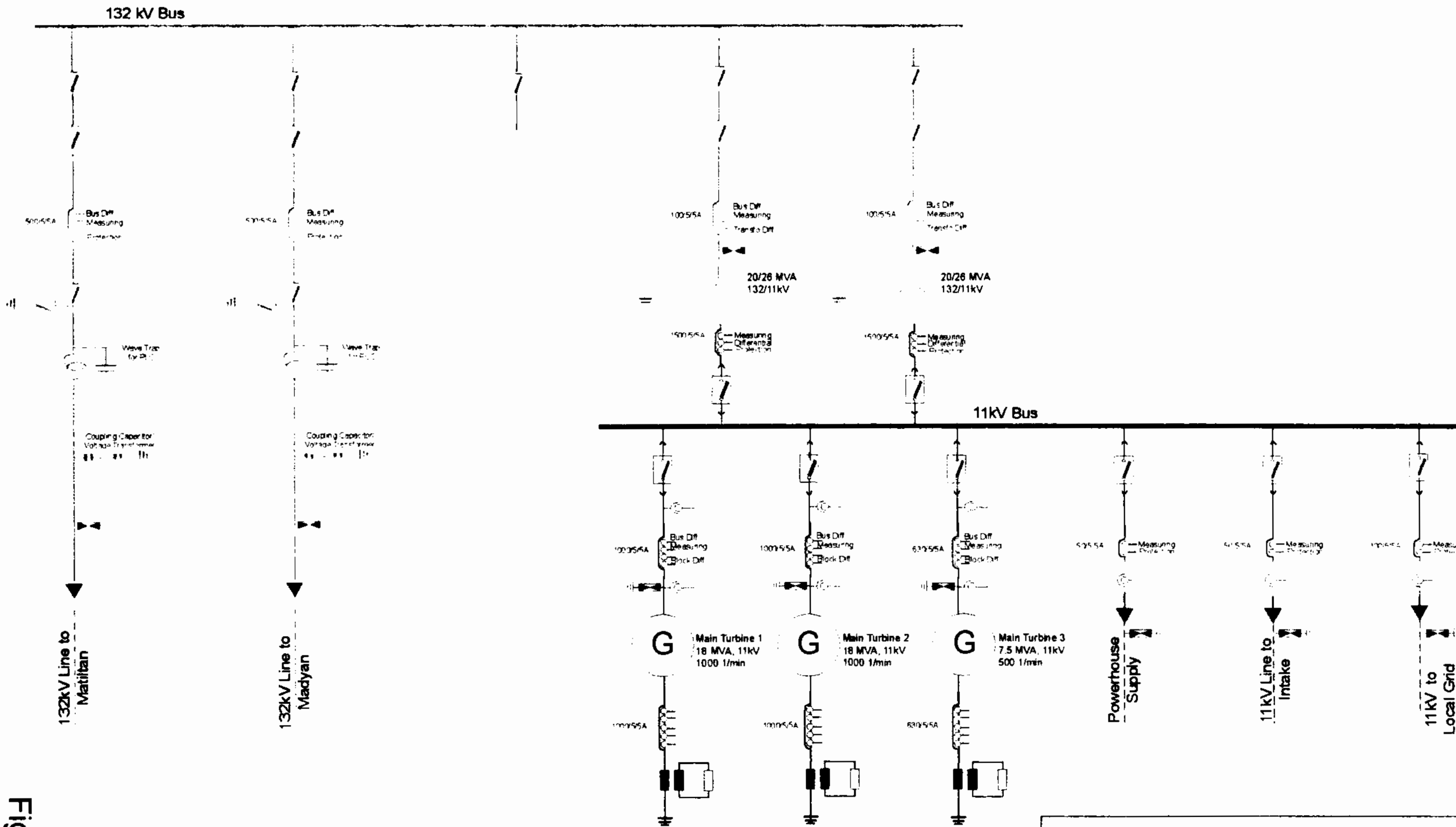
All disconnecting switches will be mounted on steel structures to reach the necessary height of terminals for electrical connections. The distance will be 3.0 m between the centrelines of disconnecting switches.

For the outgoing lines, an additional earthing switch will be required. It consists of a blade mounted on the base, at the bottom of the column, that is orientated to the line side. The specifications will be as per IEC for short circuit conditions.

8.4.4.5 Measuring Equipment

Each unit will be equipped with current and a voltage transformers between the main transformer and the main circuit breaker. As there will be sufficient space available, there is no need for bushing CT. It is proposed to install independent current transformers which give a higher flexibility.

On the outgoing lines, combinations of current and potential transformers are required for metering and synchronising. An area of 60 cm x 60 cm is needed for mounting one transformer in each phase. It is proposed to install a capacitive voltage transformer on one phase for the purpose of Power Line Carrier (PLC) connections and for eventual synchronisation needs.



Daral Khwar Hydropower Plant
37MW / 44MVA
Main Single Line Diagram

Figure 3

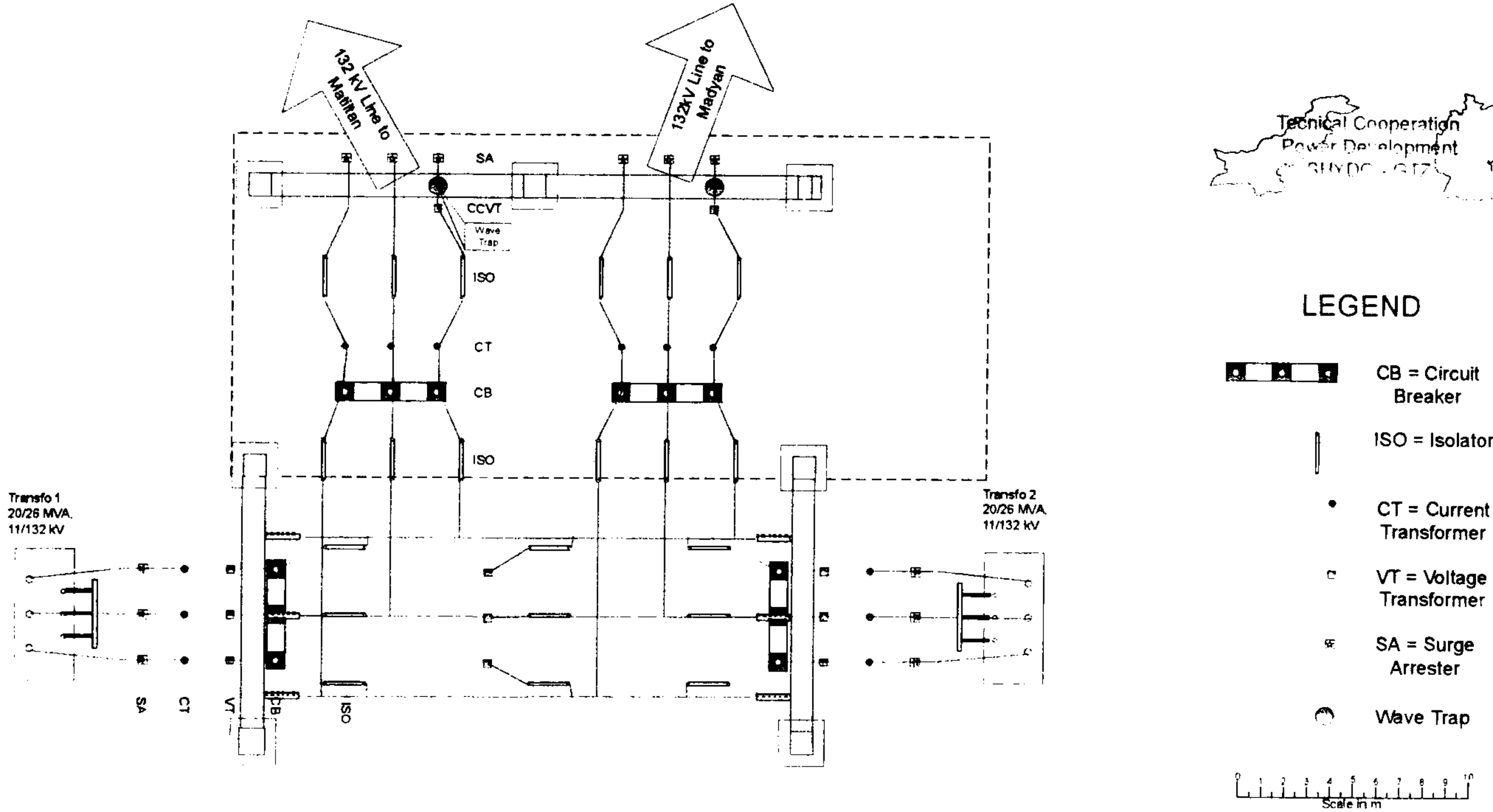
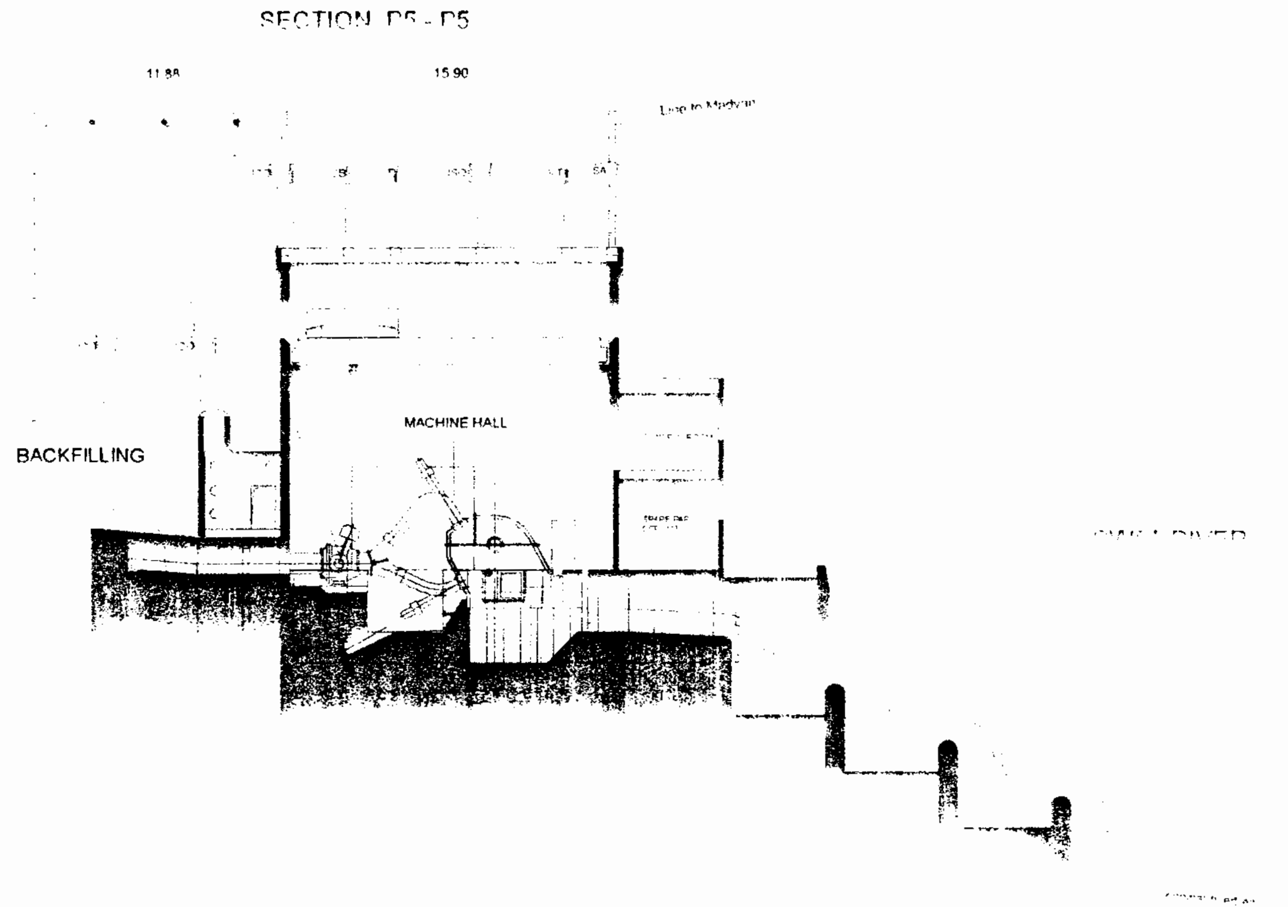


Figure 4

DaralKhwar HPP
132kV Swichyard

132kV SWITCHYARD SECTION
DARAL KHWAR H.P.P.



Figure

All measuring transformers are assumed to be in the accuracy class 0.5 ±, in accordance with normal practice. During the detail design, accurate ratings for the current and voltage transformers should be derived.

8.4.4.6 Surge Arresters

On the incoming lines Surge Arrester (SA) should be connected to each phase. Additionally, one group of three SAS will a be included on each transformer bushing as shown in the general layout of the switchyard.

Gapless metal-oxide arresters are proposed. The magnitude and duration of temporary power frequency over voltages are important design criteria and, accordingly, they must be defined during the detail design phase by the successful bidder .

8.4.5 Medium and Low Voltage Installations

- **Powerhouse**

  The medium and low voltage installations are designed to guarantee a reliable power supply for all functions of the hydropower station.

  The 11 kV main bus-bar is fed by Turbines or by the the 132/11 kV main transformers.

  One 400 kVA transformer will feed the 0.4 kV station service bus-bar which is divided in an essential and a non-essential section. The essential section can be fed by a 250 kW emergency diesel set.

  This arrangement guarantees enough reliability to secure all essential power needs for security, protection and a black start-up.

- **Intake/Weir Area**

  Two options were considered for establishing a power supply to the intake area:

  * by a tunnel cable;
  * by the planned 11 kV overhead line for rural electrification of Daral Khwar valley.

  Due to its simpler technology and the considerably lower price, preference was given to the overhead line solution. The line will pass alongside the embedded penstock to the valve chamber/surge tank and then following the 1900 m contour line until the crossing with a forest road. The line will then follow the road for some 1000 m and then from an altitude of 2000 go steadily down to 1900 m for another 1000 m. From there just above the intake the line will descend to 1800 m to the intake/weir. The length of the line is about 5 km. A communication cable will be mounted on the same poles.

8.4.5.1 Medium Voltage

The primary purpose of the 11 kV switchgear is to supply auxiliary power for the power plant.

The switchgear will be located in a separate room in the powerhouse.

For the auxiliary supply and the generator circuit breakers, these systems shall be equipped with modem fuse disconnect switches and circuit breakers of SF6 or vacuum type enclosed in cubicles thus providing high personnel safety.

Design criteria:	12 kV
Type of cubicles:	Metal-clad Cubicles on trucks
Rated short circuit current (1s)	30 kA
Rated lightning impulse withstand voltage (earth to earth):	75 kV
Fuse disconnector switches:	The failure of a fuse shall open the disconnector switch automatically.

Intake Area One Line Diagram
Daral Khwar H.P.P.

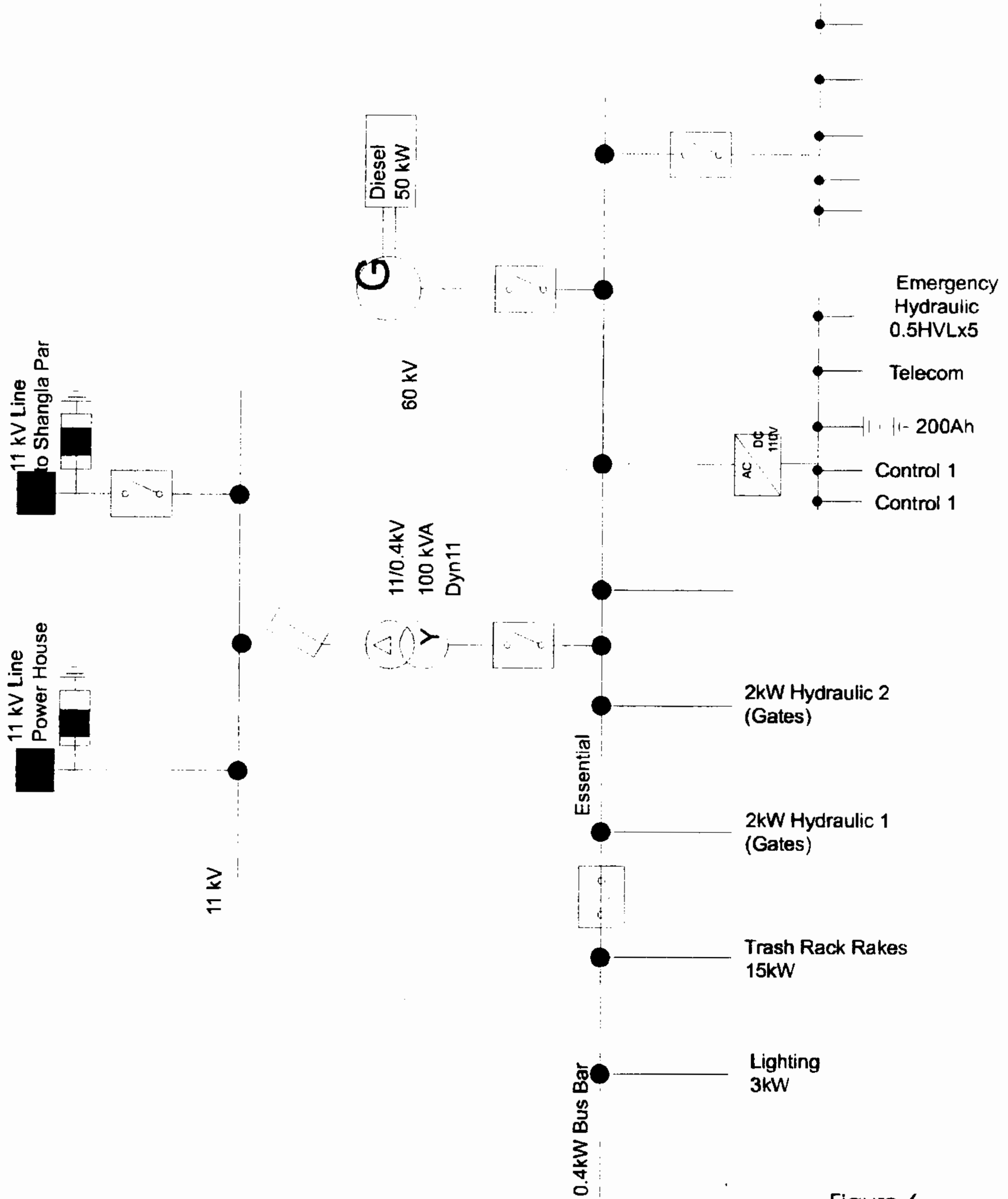
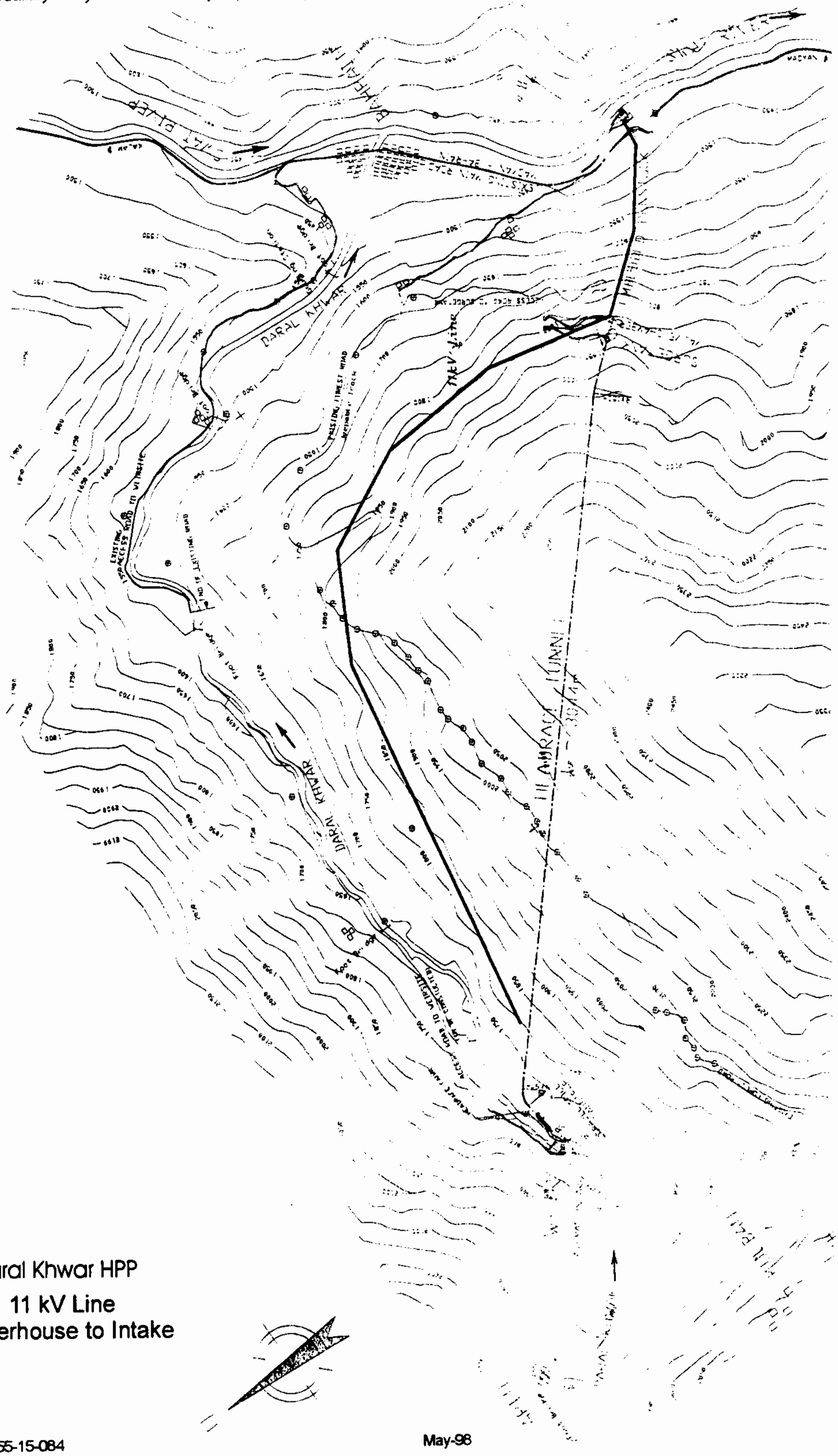


Figure 6



Daral Khwar HPP
11 kV Line
Powerhouse to Intake

The connections between the generators and the 11 kV bus-bar and the main transformers will be made using 12 kV single phase cables. For the rating of 950 A or 1150 A respectively this design will offer the most economic solution. Their characteristics are:

- Type: XPE, 240 mm2 Copper, Single Core
- Length: 60 m
- Disposition: 2 cables per phase laid in 2 bundles of 3 cables installed in cable ducts

8.4.5.2 Low Voltage

The low voltage A.C. distribution system will be designed as a 400 V, 3 phase four wire plus protective (earth) conductor system.

Normally the station service bus will be supplied by the station supply transformer connected to the 11 kV grid bus.

If this supply is not available (which is extremely unlikely), a standby diesel generating set shall start automatically and provide power for supply to essential equipment.

The intake and powerhouse distribution systems should be designed with a normal main switch-gear and an essential load switchgear interlocked with bus-breaker for automatic separation in failure situations. If a black-out occurs in the main system, the feeder connected to the essential load bus-bar will feed all essential loads from the standby diesel generator.

During normal operation, the AC switchgear with double bus-bars will be operated with closed bus-breaker, in other words, the essential load distribution system will be continuously energised during normal operation to ensure the system availability. The distribution system will supply low voltage power to all plant service systems, lighting and battery chargers, including all power cables, local control cabinets with necessary motor starters and sub-distribution panels. From the battery banks d.c./a.c. power converters will provide uninterrupted power to essential control functions.

All motors shall be powered and controlled through motor starter units assembled in motor control centres (MCCs). The starters are assumed to be of the withdrawable design where each unit may consist of more than one starter. The number of MCCs would be determined by their lengths and availability to the localisation motors.

8.4.5.3 DC Supply

- **Design**

  The purpose of the battery system is to provide a safe and reliable supply of power and control voltage to all primary functions. The system is independent of all other power systems and ensures reliable execution of the control functions, both for normal operation and during possible fault conditions.

  For the powerhouse the recommended direct current supply is based on a duplicated supply design. The two independent 110V battery systems, each with a separate main distribution switch-gear, will both feed each of the local DC distribution bus-bars.

  The double battery system will mainly provide power to the complete Plant Control System, the Local Control System, the control voltage for the hardwired part of this system and DC equipment such as motors for black-start procedures.

  Some instrument protection devices or computer interfaces will need 24V or 48V DC supply. In this case AC/DC converters should be used. The use of separate 24V or 48V batteries should be made available.

  The battery system for the intake will provide power mainly to the intake Local Control System and the control voltage for the hardwired part of this system. Particular functions which must be performed in the intake area are water level monitoring and gate control.

- **Dimensioning**

The powerhouse battery shall guarantee the function of all vital elements to bridge a timely limited power failure and to shut down and restart the plant safely. The capacity will be established as follows:

Use Emergency Lighting	Power W	Duration h	Capacity kWh
5 spots on 5 floors 25x40w =	1000	6	60
Plant Control System (PCS)	1000	24	24
Unit Control System (UCS) 6x200w =	1200	24	28.8
Protection System	2000	1	2
Auxiliary Power 11 kV	1000	0.5	0.5
Auxiliary Power 132 kV	1000	1	1
Lubrication pumps	100	0.6	0.06
Hydraulic pumps gates + valves			4
Hydraulic pumps governors			1
Telecom/Telecontrol/others			10
Say 80 kWh			77.9

Voltage = 110 V

Capacity $\frac{80,000}{110}$ = 727 Ah

Efficiency and aging factor = 0.7

Battery capacity 727 Ah / 0.7 = 1038 Ah

Say = 1100 Ah

The batteries will be installed in a separate, specially ventilated battery room on racks. The net space requirement will be 3 m^2 if arranged in 4 levels.

The battery charger will be dimensioned to recharge the batteries in 10 hours time according to voltage current (V-J) characteristics. In order to assure proper gass free charging, its capacity will be

$$\frac{1100\,Ah \times 110\,V}{10\,h \times 0.8} = 15\,kW$$

At the intake another emergency battery pack will be installed with the following capacity:

Use	Power W	Duration (h)	Capacity (kWh)
Lighting	200	6	1.2
Control	150	48	7.2
Telecom	50	48	2.4
Hydraulic			2
Others			1
			13.8 kWh Say: 14 kWh

Voltage : 110 V Capacity : $\frac{14,000}{110 \times 0.7}$ $181\,Ah$ say: $200Ah$

The battery charger will have a capacity of:

$$\frac{200\ Ah \times 110\ V}{10\ h \times 0.8} = 2.8\ kW$$

The space requirement of the complete set (battery and charger) will be 1 m^2 if arranged on racks with at least 4 levels.

8.4.6 Control and Alarm System

The plant will be equipped with a state of the art computerised control system. The main advantage of this type of control over the traditional hardwired type is the replacement of the big number of cables and wires for communication between the different points of control of the plant by a single fibre optical wire. All switching, alarm and control conditions are fixed in a computer programme which is easier to install, diagnostic and to maintain. The risk of faulty connections is reduced considerably, the installation provides more clarity thus facilitating a fast and simple error diagnostic, future modifications can easily be introduced without disturbing the operation of the plant.

The system consists of the following elements:

- 1 No. Plant Control System with
- 6 No. Unit Control System
- 1 No. Data Communication System

8.4.6.1 Plant Control System (PCS)

This will be installed in the control room which will be equipped with:

- an elevated floor for cable distribution
- air conditioning
- a galvanic isolated power supply, equipped with overvoltage devices

The Plant Control System will allow an overall control and monitoring of the plant. The operation of the whole system is carried out from the Plant Control System.

Process control, like command procedures, interlocking routines, etc., are handled by the Unit Control Systems, so that no failure in the PCS will disturb the operation of the plant.

The Control System Software shall include all state of the art functions. Basically three modes of operation of the power plant will be needed:

- Load controlled operation with time-dependent function; used for standard operation of ponding and peaking
- Water level controlled operation, aiming to keep the water level in the intake reservoir constant at a defined level
- Operation on an isolated grid; used in case of interruption to the national grid.

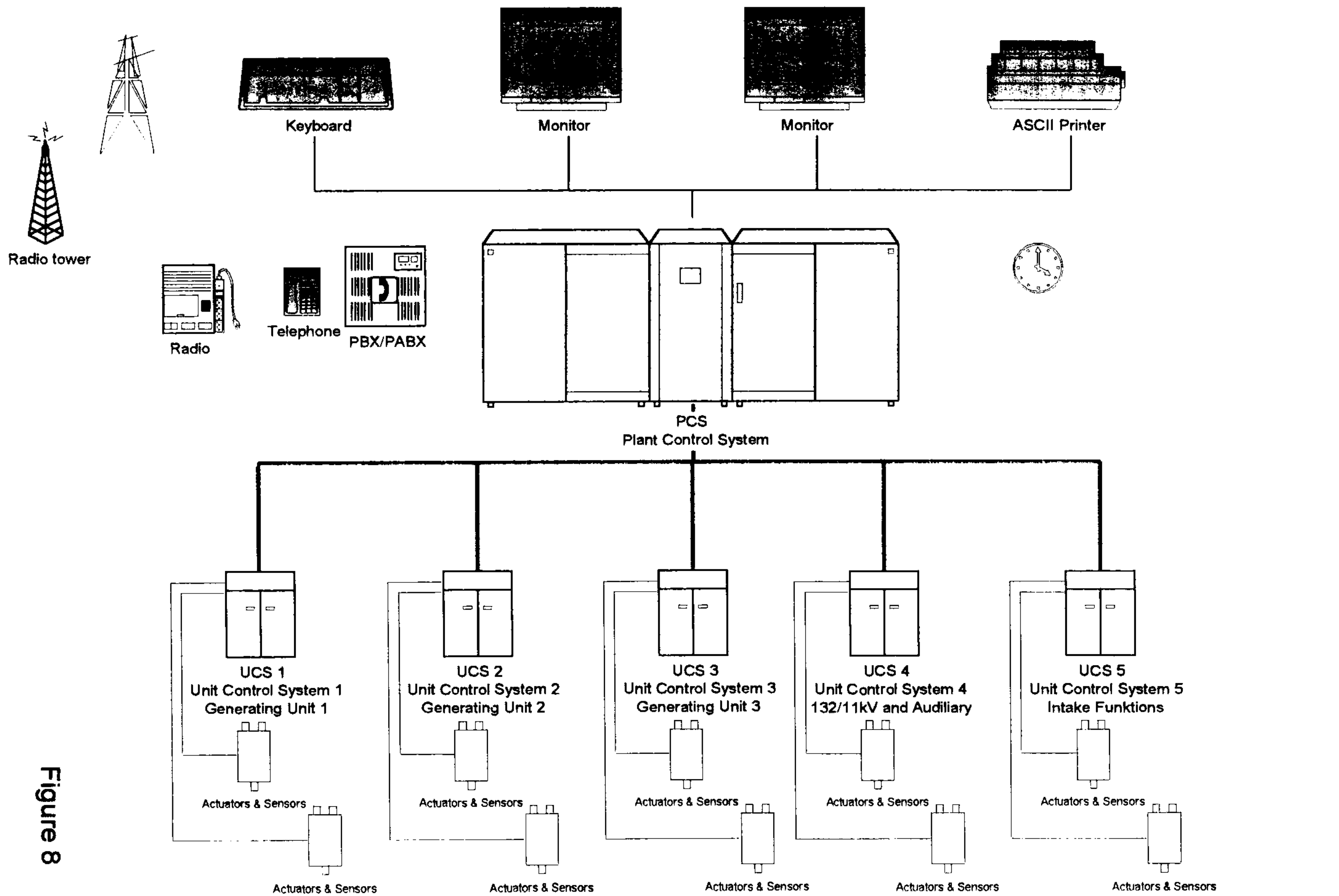
Combinations of the control modes will be useful.

In any case the Plant Control System will distribute the load between the units to maintain optimum power production or to meet other specified criteria.

8.4.6.2 The Unit Control Systems

Will be employed for process control of the following units

UCS1	Generating Unit 1
UCS2	Generating Unit 2
UCS3	Generating Unit 3
UCS4	Auxiliary System
UCS5	132/11 kV Switchyard
UCS6	Intake Functions



DARAL KHWAR
Plant Control System
lahore hess 19/09/98 drawing1

Figure 8

The UCSs shall co-ordinate and perform the operational tasks commanded by the PCS.

- The UCSs shall comprise programmable controllers (PLC) based on micro-processor technology, and shall perform all functions for accessing, analysing and acting on the information from the process equipment.

- The UCSs will be connected by optical fibres and an interface with the plant control (PCS).

- In the "Local Control" mode, the manual control panel of the UCS is to be in operation. Operation of the devices connected to the UCS must then be performed directly.

- Unit Control System for the Generating Units (UCS1, UCS2 and UCS3).
  The UCS for the generating units will be programmed for fully automatic start and stop procedures for the units, including synchronisation. However, the operation and functions of the voltage regulators and the turbine governors will be independent. The initiated procedure would carry out sequentially all command actions and the sequence of operations together with the immediate status would be transferred to the PCS.

- Unit Control System for the Power station auxiliary supply (UCS4).
  The UCS supervises the plant auxiliary power supply system and provides automatic switching to the available power sources according to an agreed priority schedule. In addition to the auxiliary power supply, including the medium voltage equipment, UCS4 supervises the drainage pumps, ventilation system, the cooling water pumps, the chilled water system, light and small power etc. (The fire fighting system will have an independent conventional control system).

- Unit control system for the HV/MV switchyard (UCS5)
  This and the protection relays will be located in the powerhouse control room. The UCS is interconnected with the local control panels for the 132 kV and 11 kV switchgear and the relay protection panels which will actuate independently from the UCS.

- Unit control system for the Intake (UCS6)
  This UCS is located in the intake gate house and will supervise the standby diesel generating unit, the power supply and the gates as well as signals from the intake to the powerhouse and the water level controller.

  For security reasons the flushing gates will be manually operated at site but signals for "open/closed" will be recorded in the PCS.

8.4.6.3 Communication between the PCS and the UCS

This will consist of a fibre-optical cable system. The communication layout can either be a bus system, a loop system or a star system.

8.4.6.4 In "Manual Control" mode

In this mode the UCSs are put out of automatic operation; each operation is performed locally on each device.

In addition, manual operation can be performed directly on the equipment, i.e. on the generating units, switchgear panels, motor control cubicles (MCC) etc., and all monitoring and control must then be done locally from the UCS mimic panel. The design of the local control panels must include equipment for indicating status and control of major parts such as generator, turbine, breakers, switches, control of alarm, level set-points, etc.

Start, stop and other control of the generating units must be possible by manual operation. The monitoring and operation are done by means of the control panels for the automatic voltage regulator (AVR) and the turbine governor as well as by manual operation of valves, switches etc. for manual operation together with local instruments. Also, an independent **emergency stop** function for the generating units must be installed for use in the event of a severe fault, e.g. fire or flooding. The emergency stop function is initiated by the emergency buttons which are to be installed at selected locations.

8.4.7 Protection Equipment

Separate relay protection cubicles comprising modern electronic relays will be installed. All relays shall preferably be of the same make (manufacture) to build a uniform modular system.

The functioning of the protection relays shall not depend on the control system. The relays are to be organised in two groups so that one group provides back-up protection for the other group.

Auxiliary power shall be taken from the 110 V D.C. system only. Separate circuits shall serve the two groups of relays in order to obtain maximum reliability. The relays shall be capable of operating properly with voltage variations of -20% to +10%.

- **Generation Protection**

  The generator is linked to the primary winding of the transformer by underground cables. To avoid the build-up of dangerous over-voltages in the event of an arcing earth fault, possible due to the relatively high capacitance of the system, the generator neutral point must be earthed through an impedance which will limit the earth fault current to a suitable value.

  It is modem practice to use a distribution transformer in the range of about 5 - 20 kVA. The secondary winding, which is designed for a voltage of 100 - 500 V, is loaded with a resistor of a value which, when referred through the transformer ratio, will pass a suitable fault current. The resistor is therefore of low ohms value and can be of rugged construction while still presenting a high equivalent value in the generator circuit.

  As a basis of design, the resistive component of fault current should be one to five times the residual capacitive current (that is 3 x Ico). It is proposed to install the earth fault relay in the secondary circuit of the earthing/distribution transformer.

- **The 18 MVA (Francis) generator protection shall consist of:**

  * Over-/under voltage relay.
  * Over/under frequency relay.
  * Over current/short circuit relay.
  * Reverse power relay.
  * Negative sequence current relay.
  * Loss of excitation relay (Minimum reactance relay).
  * Shaft current relay.
  * Rotor (field winding) earth fault relay.
  * Three phase generator differential current relay.
  * Stator earth fault relay.
  * Vibration and shaft movement supervision relay.
  * Winding thermal relay.

- **The 7.5 MVA (Pelton) generator will be protected by:**

  * Over/Under Voltage relay
  * Over/Under Frequency relay
  * Over current/Short circuit (voltage depended) relay
  * Differential relay
  * Reverse Power relay
  * Synchro-check relay

- **The 132 kV transformer protection will include:**

  * • Oil temperature and level control.
  * • Buchholz relay.
  * • Three phase over current relay as backup device.
  * • Three phase unit block differential current relay.
  * • Neutral point earth fault current relay (common for all units).

PROTECTION SCHEME
DARAL KHWAR H.P.P.

LEGEND

49	WINDING THERMAL RELAY
SV	VIBRATION SHAFT MOVEMENT RELAY
SC	SHAFT CURRENT RELAY
81	UNDER/OVER FREQUENCY RELAY
32	REVERSE POWER RELAY
40	LOSS OF EXCITATION
46	NEGATIVE SEQUENCE
51V	OVER CURRENT RELAY (Voltage restraint)
59	UNDER VOLTAGE RELAY
27	OVER VOLTAGE RELAY
64	ROTOR/STATOR GROUND FAULT RELAY
87	DIFFERENTIAL PROTECTION

LIGHTING ARRESTOR

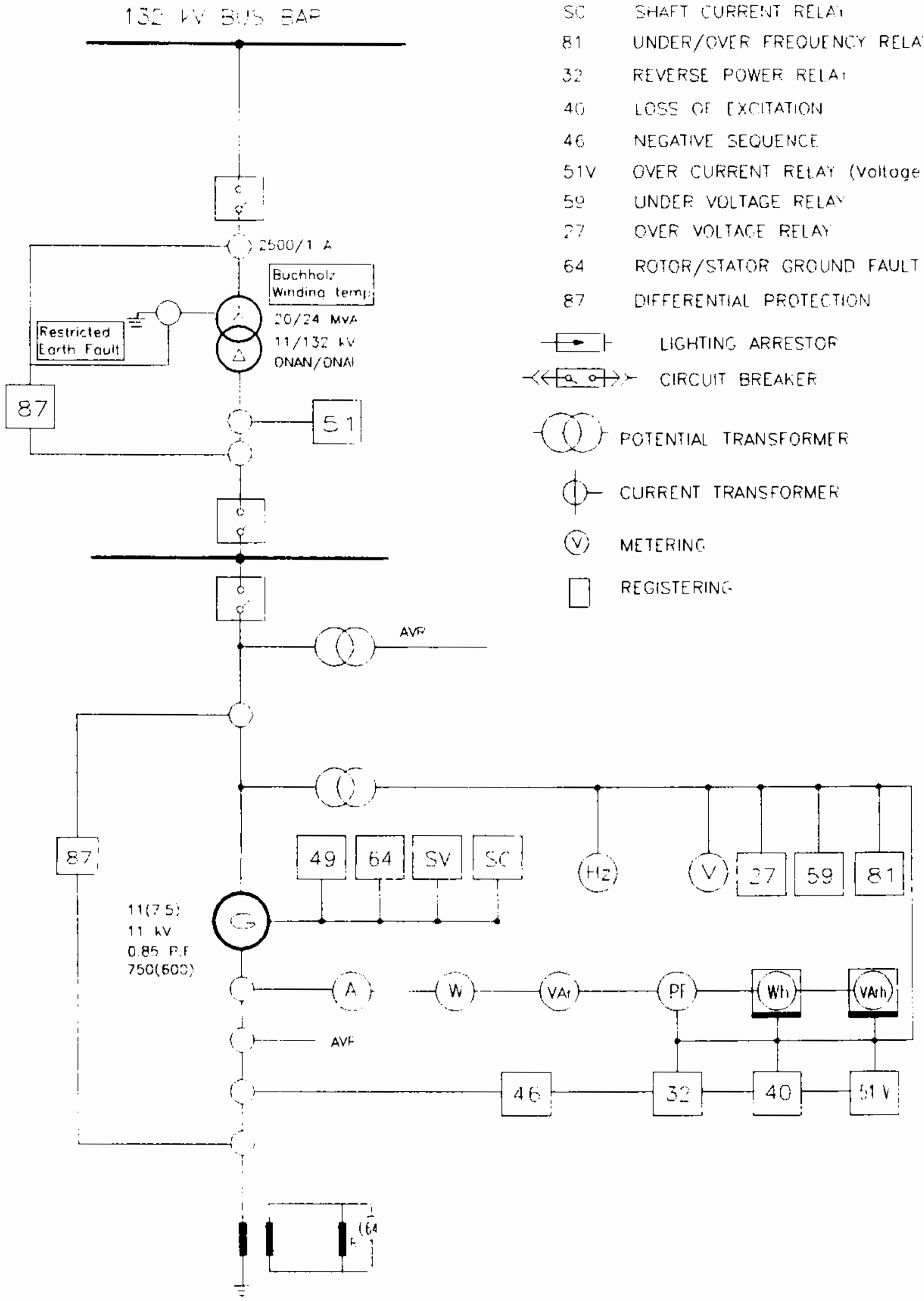
CIRCUIT BREAKER

POTENTIAL TRANSFORMER

CURRENT TRANSFORMER

METERING

REGISTERING



- **The 132 kV transmission line protection comprises:**
  - Three-phase minimum impedance relay with fault location facility.
  - Three phase over current relay.
  - Earth fault relay.
  - Synchro-check relay.

- **The 11 kV/0.4 kV auxiliary transformer protection consists of :**
  - Oil temperature.
  - Buchholz relay.
  - Three phase over current relay (as backup).

- **11 kV Distribution Line Protection comprises:**
  - Three phase over current relay.
  - Three-phase re-closure relay.
  - Earth fault relay.

8.4.8 Telecommunication and Watches

8.4.8.1 Powerhouse Communication

Within and outside the area of the powerhouse an appropriate communication system is needed. This will make it possible to communicate the operational instructions to concerned sections.

A digital telephone network is to be installed in the powerhouse to cover the entire plant - powerhouse, intake and the residential camp.

Each generating unit will include at least one telephone per floor. All cranes should be connected to this communication system, as well as the working and lay down areas. The central exchange will be connected to the station battery so that there will be no outage in the case of a complete shutdown of the plant.

The system will include 5 loudspeakers and 20 telephone sets.

8.4.8.2 Powerhouse Intake Communication

To link the powerhouse with the intake area, several alternatives are considered:

- Power Line Carrier on 11 kV or 132 kV System (Expensive End Stations).
- Fibre Optical Conductor in Headrace Tunnel (Expensive Design of Cable).
- Fibre Optical Conductor on 11 kV Overhead Power Line.
- Conventional Communication Cable on 11 kV Overhead Power Line.
- Radio Link (needs expensive maintenance, and requires a transmitter station as a high mountain separates the two head stations).

As the distance between the two stations is short (about 5 km) and within the reach of a conventional communication cable without intermediate signal amplifier, a copper cable, clamped onto the 11 kV Power Overhead Line would be the cheapest alternative.

Alternatively, an optical fibre cable also clamped to the 11 kV Power Overhead Line has advantages in reliability, quantity of information which can be transmitted and, most important, no problems with electro-magnetic interference which for outweighs its higher price. It is therefore recommended to adopt the optical fibre cable clamped to the 11 kV Power Line.

8.4.8.3 External Communication

WAPDA uses for its communication between powerhouse and load dispatch centre a system of power line carrier. The coupling is done between one phase and earth which makes it necessary to install for each communication line one line trap and one coupling capacitor at each terminal.

It is planned to integrate Daral Khwar HPP via Matiltan into the system, these:

- These line traps and capacitive voltage transformers will be installed.
- The location of the equipment will be partially in the switchyard, and partially in the area of the control room. The 48 V supply will be made by DC/DC Converters fed by the 110 V main battery.
- This system will give the possibility for voice and signal transmission on the 132 kV line between the powerhouse and the remote load dispatch centre.
- The control room is additionally connected to the public telephone system to guarantee the communication with the power plant in case of a failure of the power line carrier system. Radio communication should be added for additional reliability.

8.4.8.4 Watches

An independent system of watches which can be synchronised with outside systems, if necessary, will be installed for control purposes. Each generating unit will have a digital time indication. The master clock will be installed in the control room.

8.4.9 Lighting and Small Power

An adequate indoor and outdoor lighting with illumination levels in accordance with recognised standards will be provided. Inside the powerhouse, an emergency lighting system powered from the station battery must be installed; the system will operate the instant normal power supply fails.

AC lighting and small power socket outlets, for 240 V, shall be single-phase, connected between phase and neutral of the 400 V system.

Fluorescent lighting fittings are preferred everywhere indoors where it is feasible. For outdoor lighting, sodium floodlights with built-in gear for high pressure sodium lamps are recommended. In order to reduce the number of equipment types and sizes which have to be stocked as spares, there must be standardisation of both lamps and fittings. This will result in relatively few varieties.

Under normal conditions, both the emergency and normal lighting will be in operation. These two systems will have totally separate circuits with power supply as follows:

- **Emergency lighting:**

  In normal operation, it is directly powered from the 415 V essential switchgear. At plant supply failure the following occurs:

  The first 60 seconds supply comes from the main batteries through a DC/AC converter.

  After 60 seconds, the supply is obtained from the standby diesel generating unit (essential load switch-gear separated from normal supply).

  Both systems have as a main concept, common distributed "on/off" switches. Emergency lighting will therefore not come on automatically in vacant rooms where the light is off. However, special consideration must be paid to areas containing "escape routes".

- **Normal lighting:**

  Always powered from normal switch-gear

  It is recommended that the normal lighting system should be designed according to the following design criteria:

Type of area	Illumination level	
Outdoor:		
Areas with common staff traffic	50	lux
Other areas, as dam intake area	20	lux
Indoor:		
Offices, control rooms, switchgear rooms	400	lux
Storage rooms, corridors, etc	100	lux
Tunnels	50	lux
Equipment rooms	50	lux
Machine hall, etc.	100	lux

The illumination requirement for the emergency lighting shall be at least 1 lux over all the related areas.

The portable battery hand sets shall be available for additional DC lighting during maintenance works, etc., in case of AC failure. They shall be placed at various places in the powerhouse.

Exit lights shall be installed above doors, staircases, etc.; during blackouts these shall be powered from their internal batteries for a minimum of 15 minutes.

The following outdoor areas have to be illuminated:

- **Intake Area**

  Access road
  Intake gate and trash rack
  Dam crest
  Gates
  Reservoir surface upstream using reflectors
  River surface downstream using reflectors

- **Powerhouse area**

  Access road
  Switchyard
  Tailrace Area
  River surface using reflectors

Indoor lighting will be installed in all rooms, such as transformer boxes, low voltage switch-gear, regulator area, ventilation equipment, relay racks, office, workshop, sanitary facilities.

The machine hall will show on both long walls a chain of fluorescent lamps which are used for orientation only. During maintenance and repair jobs on a unit, portable illumination will be used where necessary. The control room will have intensity controlled illumination, so that it might be adopted to special situations. Special attention shall be paid to avoid reflexes on monitor screens.

8.4.10 Emergency Diesel Set

In case of a breakdown of the WAPDA system simultaneously with a failure or standstill of all Hydro Generators, a Diesel Generator must take over the supply of a certain group of equipment to ensure and facilitate a safe shutdown or block start up on repair of the plant.

Two Diesel Generators, one in the Powerhouse and one in the Intake area will be installed.

8.4.10.1 Powerhouse Diesel Generator Set

The set will be able to supply the complete station service as well as the two unit services.

Station service	180	kW
Unit Service 1	34	kW
Unit Service 2	34	kW
Total	**248**	**kW**

x	Simultaneous factor	=	0.8	198	kW
	Divided by ageing factor	=	0.8	248	kW
x	Power factor	=	0.75	333	kVA

The Emergency diesel set will have the following characteristics:

Nominal capacity 250 kW/ 333kVA
Nominal speed 1500 rpm
Nominal voltage 440 V/50 Hz

The biggest motor being only 20 kW, a brushless exciting system with rotating diodes can be applied.

The space required for the installation of this unit, including an automatic transfer, will be 6 x 4.5 m. The room should be high enough to lead the hot exhaust gases through the silencer to the outside atmosphere. Besides the automatic control system, there will be an independent start-up battery of 24 V with its charger. A diesel oil tank with a capacity of 5,000 liters will be provided.

An automatic fuel pump keeps the day tank of 1000 ltr capacity filled.

The cooling air of this room will be moved by the fan of the motor. The warm air is expelled and fresh air drawn through wall openings from outdoors.

8.4.10.2 Intake Area Diesel Generator Set

The set will supply sufficient power to operate the gates and to insure emergency lighting, control and communication. The set will have the following characteristics:

Nominal capacity	40 kW/50 kVA
Nominal speed	1500 rpm
Nominal voltage	400V/50 Hz

will be automatic in case of power failure. An independent 24 V start-up battery with charger and a 1000 l oil tank are foreseen.

8.4.10.3 Earthing System

WAPDA operates its 132 kV system with the neutral solidly grounded. This means that in case of any line to ground fault close to the switchyard a fault current will pass through the neutral connection of each transformer in service. This fault current shall not produce voltages harmful to men and equipment.

To avoid those voltages it is recommended to:

- Connect all grounding systems together (High Voltage, Medium Voltage and Low Voltage Service and Protection earth).
- Lower the grounding resistance to a value low enough to limit the earthing voltage to a manageable level by connecting all ground systems together
  - HV switchyard earthing mesh
  - Powerhouse foundation ground
  - Shield wire of outgoing lines
  - Installation of additional grounding rods
  - burying of counterpoise of an appropriate length under the outgoing lines
- Control step and contact voltages by an appropriate arrangement of earthing conductors.

In case of a one-phase to ground fault the current will not exceed the 3 phase short circuit fault current which has been calculated to be 6400 A at 132 kV at Daral Khwar.

To meet the above mentioned conditions and respect a

- step voltage 90 V
- contact voltage 75 V
- earthing voltage 1000 V (limited by the insulation of LV Equipment)

An earthing resistance of less than:

$$R = \frac{U}{I} = \frac{1000V}{6400} = 0.16\,\Omega \text{ is required.}$$

To meet this condition the following measures are proposed:

Earth resistivity	=	50 ... 10 Ω
Area switchyard	=	1000 m^2
Area powerhouse	=	700 m^2
Chain resistance of shield wire	=	1.6 W
Length of counterpoise	=	0.5 km per line
Number of transmission lines	=	2

- **Earthing mesh resistance switchyard:**

  Area, A = 1000 m^2

  Diameter of equivalent circular area:

$$D = \sqrt{\frac{A \times 4}{\Pi}} = \sqrt{\frac{1000\,m^2 \times 4}{\Pi}} = 36m$$

$$\underline{Rm} = \frac{r}{2D} = \frac{50\,\Omega\,m}{2 \times 36m} = 0.69\Omega$$

- **Powerhouse foundations:**

  Area A = 700 m^2

  Diameter of equivalent circular area

$$D = \sqrt{\frac{700\,m^2 \times 4}{\Pi}} = 30\,m$$

  Earthing resistance

$$\underline{R_F} = \frac{30\,\Omega\,m}{2 \times 30\,m} = 0.5\Omega$$

- **Rods:**

  Length L = 2.5 m

$$R_r = \frac{\rho}{2 \times \Pi \times L} \times l_m \frac{4 \times L}{d}$$

$$= 3.18 \times 6.21 = 20\,\Omega \text{ per rod}$$

  for 40 rods

  $R^n = 0.5\Omega$

- **Shield Wire:**

$$R_{sw} \quad \frac{1.6}{2}\,\Omega$$

- **Total Ground Resistance:**

$$\frac{1}{R_{tot}} = \frac{1}{R_M} + \frac{1}{R_F} + \frac{1}{R_R} + \frac{1}{R_{SW}}$$

$$\frac{\Omega}{R_{tot}} = \frac{1}{1.04} + \frac{1}{0.83} + \frac{1}{0.5} + \frac{2}{1.6} = 6.69$$

R = 0.15 Ω

which is lower than the required maximum resistance of 0.16 Ω.

The exact material, diameter, jointing and position of the earth conductors, rods and electrodes will be determined in the final design.

8.5 CONSTRUCTION

8.5.1 Temporary Site Installation Plants for Construction

- **Weir Area**

Due to the narrow valley at the weir site, a temporary site installation plant for construction is required on the left slope downstream the weir structure in an area of 5000 m² where the valley is wider, for aggregate storage, crushing plants, concrete mixing plants, cement storage and workshops etc.

A second temporary site installation plant is possible at the left terrace downstream the weir for site offices and additional workshops.

For access during construction of the weir and connection tunnel, Daral Khwar will be crossed via a temporary bridge or it will be waded across by vehicles there where the riverbed is wider. For construction of other structures in the weir area, Daral Khwar will be crossed via the weir bridge.

- **Powerhouse Area**

The temporary site installation plant during the construction period of the powerhouse and the conduit system is proposed in the 5000 m^2 area near the powerhouse site between the right Swat river bank and the road to Bahrain.

The site installation is required for aggregate storage, crushing and concrete mixing plants, the cement storage and workshops.

After completion of the main structures (approx. 3 years), the site area at weir and powerhouse area etc. will have to be restored to the original condition.

8.5.2 Stock Piling and Disposal of Surplus Material

Excavated material at all structures (Weir/Conduit System/Powerhouse)	160100	m^3
Suitable material for concrete aggregate (Norites and selected boulders/cobbles along Daral Khwar)	31600	m^3
Suitable material for riprap, pitching, stone works	17400	m^3
Backfill volume of all structures	54000	m^3
Deposit requirements for surplus material	57100	m^3

The disposal of surplus excavated material is feasible in treeless area near the excavation sites within a distance of up to 5 km and will require a total area of approx. 2 hectare. Cultivation is possible with native soil and humus layer material from the excavated terraces in the powerhouse area.

8.5.3 Construction Material

The most important construction material for all structure is concrete.

The following quantities of concrete would be required:

Weir and intake	7510	m^3
Conduit system	18040	m^3
Powerhouse and tailrace	7550	m^3
Total:	33100	m^3

8.5.3.1 Concrete Aggregate

Laboratory tests on the proposed concrete aggregates are necessary to determine their suitability.

- **Concrete for the Weir and Appurtenant Structures**

  The excavations at weir site, sandtrap, headrace canal and the mucking material from the diversion tunnels and the upstream part of the headrace tunnel with rock type Norite are favourable to be used for concrete aggregate.

  Selected boulders and cobbles, readily available along the course of Daral Khwar as well as on its banks in form of young terraces can be crushed to a specific size. The crushed material can be used as aggregate for concrete of the weir and appurtenant structures.

  In case of a deficit of aggregates for concrete at the weir site, it can be supplied from a quarry at Swat River.

- **Concrete for the Powerhouse and Conduit System**

  Part of the excavated material from the powerhouse and the mucking material from the downstream part of the headrace tunnel and from the surge structures as well from the access and penstock tunnels with rock type Norite are suitable for concrete aggregates. For the conduit system and the powerhouse structures approx. 25600 m^3 aggregate are necessary.

  Good quality of sand is neither available along the course of Daral nor in close vicinity of the proposed powerhouse. It has to be procured from Swat Valley.

8.5.3.2 Crushing Plants

Crushing plants are proposed at the site installation plant near the weir area as well as near the powerhouse area.

The capacity of the crushing plants will be governed by the rate of concrete placement and by the size of the intermediate stockpiles.

For crushing of 33,000 m^3 aggregate in a period of 1 to 2 years, the capacity of the crushing plants would be sufficient within 40-50 m^3/day each.

Adequate arrangements will have to be incorporated in the crushing and screening plants in order to produce aggregates to meet the requirements of the grading curves.

8.5.3.3 Mixing Plants

Concrete mixing batching plants will be installed at both site installations.

The processed aggregates will be hauled from the aggregate stockpile to the sites of the mixing plants. A capacity of up to 250 m^3/day each would be required for the mixing plants at the weir and powerhouse areas.

8.5.3.4 Concrete Quality

The requirements of concrete strength vary according to different structural uses.

Preliminary investigation consisting of laboratory tests with crushed aggregates obtained from the proposed quarry sites for determination of their suitability are required.

The normal concrete strength class will be B25 according to DIN 1045 with a mean cement content 300 kg/m^3. Concrete with special properties will have to be used for tunnel lining.

8.5.3.5 Concrete Placement

The concrete for surface structures will have be transported from the mixing plants by vehicle to platforms at the sites.

The method of concrete conveyance (e.g. by crane, with transit mixtures, conveyor belt or pumping) shall have be determined so as to prevent segregation. Concrete lining of underground structures will need transport to the site and final mixing and placement by pumping.

8.5.4 Tentative Construction Time Schedule

See Main Report Volume 2 of 2

Estimations on time schedule are based on experiences of modem construction methods with up-to-date equipment.

It is estimated that the construction period for the Hydropower Project will take three years (five year including preliminary works, test operation and commissioning)

Year 0 Some engineering and preparatory works

- Land Acquisition
- Design and Tender Document
- Tendering/Bidding
- Evaluation and Award of Contracts
- Access roads.

Year 1--3 Construction period (3 years)

Year 4 Test Operation, Commissioning and Contractual maintenance period of the hydropower project would be within 1 year of completion of construction.

Construction works are divided into separate time schedules for the main works and structures:

* Preparatory Work
* Weir and Intake
* Conduit System
* Powerhouse
* Additional Works

8.5.4.1 Preparatory Works

The preparatory works comprises the following activities:

Construction of access roads to the weir site, to the working platform for head race tunnel, to the surge tank, to the powerhouse, reconstruction of bridges, site installation and camps in the powerhouse area and in the weir site.

Construction of access roads are independent activities and can be executed in parallel and completed within one year. For a total length of approx. 6 km, progress rates of 250-500 m/month or 10-20 m/day are needed, however, the branch of road to the surge tank will be constructed only after the actual geological conditions, as a result of the excavation of the access tunnel and initial part of the of the head race tunnel, are known and a final decision is taken for the surge tank location.

Site installation of plants and camps in the powerhouse area and in the weir site implies about 10000 m^3 of excavation each, the works will require three months at each site with rates of 130-260 m^3/day, the execution of those activities are in relation to the access roads progress. In the end of the construction period, the excavated sites will be back filled.

8.5.4.2 Weir and intake

To accommodate the river water flow during construction the weir will be executed in three stages for that purpose construction of temporary cofferdams and sheet pile walls will be required.

Excavation works of about 32000 m^3 will be completed in 6 months or 200-400 m^3/day.

Some 7500 m^3 of concrete for the weir and intake will be placed in six months or 50-100 m^3/day.

Upstream weir blanket, downstream river bed and river sides slopes protection will need some 9200 m^3 of heavy rip-rap, stone pitching ,etc. over 9 months or 40-80 m^3/day.

All civil works for the weir and intake will be completed in two years, mechanical and electrical works will be completed six months later.

8.5.4.3 Conduit System

The main independent sequence of activities is the access tunnel excavation and support in three months, the first part of the head race tunnel excavation and support in three months, the second part of the head race tunnel excavation and support in nine months, the head race tunnel concrete lining in one year.

For the 3044 m length headrace tunnel, the total excavation will be about 36000 m^3 with average rates of excavation of 3700 m^3/month or150 m^3/day or 13m/day. The tunnel lining will be about 7700 m^3 of concrete with average progress rates of 650 m^3/month or 26 m^3/day or 11 m/day

The cross-sectional area and the length of the headrace tunnel as well as the geological conditions render possible both conventional type of heading and TBM-techniques. A final decision can be made after technical and cost comparison on the basis of various offers with additional considerations of the contractors experience.

In case TBM-driving (only in one direction from the downstream portal) a mean daily progress of 13 m is reasonable

In case of conventional method, heading may start additionally from the upstream portal.

After completion of the head race tunnel excavation the penstock tunnel excavation and support will be executed in three months and then in parallel the surge tank and the valve chamber each in six months.

Excavation of 45 m height surge tank in parallel with the valve chamber implies about 7500 m^3 or 2500 m^3/month or 100-200 m^3/day. About 2400 m^3 of reinforced concrete for both structures will be placed with rates of 800 m^3/month or 30-60 m^3/day

Construction of the sand trap will be initiated after completion of the weir bridge and it is foreseen to take nine months and then in parallel the mechanical and electrical works for the sand trap within six months and the head race canal construction in three months.

The sand trap construction involves about 7200 m^3 of excavation with rates of 2400 m^3/month or 100-200 m^3/day. About 3100 m^3 of filling with excavated material will be done at a rate of 100-150 m^3/day.

Some 5100 m^3 of reinforced concrete will be placed with rates of 1700 m^3/month or 70-140 m^3/day. Works like gabions, stone pavement, stone masonry with a total volume of 3600 m^3 will be executed with rates of 1200 m^3/month or 50-75 m^3/day.

A second sequence of activities is given by the road crossing structure in three months and the construction of the embedded penstock in one year. For the 841 m embedded penstock about 20000 m^3 of excavation and 20000 m^3 of back filling are foreseen with rates of progress each 3400 m^3/month or 140-210 m^3/day. For the penstock itself, an average rate of progress of 6 m/day is considered.

All civil works for the conduit system will be completed in two and half years, mechanical and electrical works will be completed three months later.

8.5.4.4 Powerhouse

For the powerhouse main civil works activities and estimated progress rates are as follow:

The excavation and back filling in the powerhouse and switchyard areas each will require three months, the concrete woks for the substructure of the powerhouse and anchor block of the penstock will require one year and it will start after the excavation in the powerhouse area is completed, also the concrete works will be in co-ordination with the timely delivery of hydro-mechanical equipment parts to be fitted and embedded in reinforced concrete.

Excavation works in the powerhouse area is about 47000 m^3 it will demand progress rates of 16000 m^3/month or 650-1000 m^3/day, about 8000 m^3 of back filling with excavated material means 2700 m^3/month or 110-200 m^3/day

About 5400 m^3 of concrete for the powerhouse substructure from elevation 1406.30 m.a.s.l. to elevation 1417 m.a.s.l. and for the penstock anchor block will demand an average progress rate of 1100 m^3/month or 40-80 m^3/day.

The tail race concrete structure involves six months, the powerhouse concrete superstructure needs one year, the miscellaneous finishing works requires nine months and these will be completed six months after the superstructure.

Some 2200 m^3 of concrete for the powerhouse superstructure from elevation 1417 m.a.s.l. to 1432.70 m.a.s.l. and tail race structure demands rates of 370 m^3/month or 15-30 m^3/day

The above given progress rates for the power house concrete also consider the required time for some 11000 m^2 of formwork and 465 tonne of reinforcing steel bar.

Also some 3700 m^3 of heavy riprap, pitching and stone masonry will be executed in the powerhouse area.

In parallel to the civil works the turbines, generators, transformers, auxiliary equipment, and switchyard will need three years to fabricate, deliver, assemble, etc.

To manufacture and deliver of the draft tube and spiral case of the Francis turbines and the steel lining for the Pelton turbine pit, to be fitted and embedded in concrete of the powerhouse substructure, will involve one year. To fabricate and transport the Francis turbines and generators, inclusive the Pelton set, will require the first and second year. The third year is to assemble the turbines, generators, transformers, auxiliary equipment, and switchyard

The transmission system will need one year and will be completed six months earlier than the assemblage of transformers, auxiliary equipment and switchyard

All civil works in the powerhouse area will be completed in 33 months , mechanical and electrical works will be completed three months later. Overall, powerhouse work needs three years

Additional civil works like residential buildings, stores, workshop etc. are not in the critical path of the time schedule. All of them can be completed in two years.

Start up and test operation will be possible three years after beginning of construction works and along with the commissioning period six months will be needed.

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9 TRANSPORT AND ACCESS FACILITIES

The transportation of heavy construction and permanent equipment to and within the project area needs careful attention. Based on the feasibility design, the heaviest pieces of equipment are the rotors of the generators and the three phases transformers with a maximum weight of up to 30 tonne. Tractors with dozer blades start form about 6.7 tonne (D3B Caterpillar) to about 88 tonne (D10 Caterpillar).

9.1 TRANSPORT OF EQUIPMENT FROM KARACHI TO BAHRAIN

It is fairly certain that the heaviest pieces of equipment will start their journey northwards beginning from the docks at Karachi.

9.1.1 Exceptional Loads to be Carried

For the 2 Francis turbine-generator units and the Pelton turbine-generator unit envisaged, there will be some parts whose weights and dimensions to transport will be unavoidably substantial. They are as follows:

	Item	Weight (T)	Dia (m)	Length (m)
1.	Rotor	30	1.55	1.3
2.	Stator	17	---	---
3.	Transformer	14	2m x 3.5m x 2.7m high	

There are two general possibilities for the route, which must be taken to get the equipment to the project area:

- Entirely by road;
- By rail up to Dargai and then by road.

Out of these options, the second one seems to be more favourable basically because this will reduce road traffic hold ups and inconvenience for other road users. The time for transport of the equipment would also be shorter.

9.1.2 Transport by Railway

The main broad gauge line from Karachi to Dargai has, as one of its design criteria, a 22,86 tonne axle load. The main free width is 4.1 m and the free height 5.8 m the transportation of the equipment by rail will therefore cause no problem. It is anticipated that suitable railway wagons will be available

9.1.3 Unloading at Dargai

The equipment will have to be unloaded at Dargai and loaded on trucks or trailers. With regard to the transformers they might be moved side-ways from the railway wagon over to the trailer without lifting, provided suitable wagons are used.

For all other equipment the contractor will provide a mobile crane for lifting the parts. Appropriate cranes are easily available in Pakistan.

9.1.4 Road Transport from Dargai to Bahrain

Transportation by road will be done over a distance of 128 km from Dargai to the project area. The loading capacities of the structures that lie between Dargai and Project area have been possible to evaluate.

The route has been surveyed; every corner and steep slope, culvert and bridge structure inspected and any difficulties for transportation analysed.

Since all roads are reputed to be designed to European standards, there should, in the normal way, be no problem in transporting loads of 50 tonne. It is also common knowledge that the Army require bridges to have a carrying capacity of exceptional loads, like tanks, which weigh up to 75 tonne.

However, the C & W Department - responsible for all roads in the Province - states that the maximum capacity of all crossing points is 10 tonnes per vehicle. Anyway, from a practical point of view, it would be realistic to consider this to be equivalent to an axle load of 5 tonnes, acceptable on all but spans longer than, say 12m.

Concerning inclination, the slopes have been measured and are generally 1:10 for long hauls, but some short inclines do have gradients of 1:8.

Sharp bends are ubiquitous in hilly areas, but generally appear limited to a minimum radius of at least 20m.

The bridges and road survey from Dargai to Bahrain is presented in the following table:

9.1.4.1 Transporter

The following is seen as a pre-requisite:

i) A special trailer with multiple axles, each axle limited to a weight of 5 tonnes or less.

ii) A special trailer with steering wheels - front and back - to negotiate tight bends.

iii) A powerful tractor unit to pull heavy loads up the steeper slopes.

WAPDA have such a piece of equipment, at least the trailer part, it being used for transport of heavy equipment to Tarbela some 25 years ago. Failing this there is a Karachi based company that specialises in heavy lifting and transportation of heavy loads on multi-wheeled trailers. However they have little experience in the northern mountainous areas and were reluctant to quote prices at this stage.

9.1.4.2 Longer Bridges

The Bailey bridge at Madyan poses special problems for crossing the Swat River. Apart from being too narrow for exceptional loads, it is an old bridge, and even in its prime would probably only have be incapable of carrying a maximum 20 tonne load.

There are no alternative routes or crossings of the Swat River in this area so other means of getting to the other side have to be considered. The three most likely are:

i) a temporary cable crane,
ii) a pontoon or
iii) a barge (or raft),

The last method is seen as perhaps the most feasible. Numerous small tracks do exist leading down to the water edge, however they will not be passable by heavy trailers until some substantial improvement - the minimum being to normalise the gradient, widen, and possibly lay a running surface. Even though the river flows quite strongly, a system of cables will suffice to hold the barge in position, and while it is being winched across the river.

Bridges and Road Survey from Dargai to Bahrain

S.No	Location	RD (Km)	Type	Structure	Length (m)	Width (m)	Thickness (m)	Picture No	Remarks
	Dargai	0.00							
1		22.0	Pre- stressed	R.C.C	48.0	8.0	-	1	2 Spans, strong, designed for total load of 70 tonnes*
2		36.9	Arch Bridge	SM	6.50	6.0	1.5	-	Built during Ex- State Govt. (1960' s), but still sound
3		37.9	Arch Bridge	SM	35.8	5.6	1.2	-	2 Spans, stone masonry, condition good
4		41.7	Arch culvert	SM	3.00	5.2	0.9	-	Small Culvert & seems to be OK
5		44.1	Curve					2	Sharp, lengthy and steep "S" bend
6		45.0	Arch Bridge	SM	28.6	5.5	1.2	-	2 Spans, Old and sound
7		45.5	Pre- stressed	R.C.C	52.0	8.5	-	-	2 Spans, strong, designed for total load of 70 tonnes
8		49.5	Slab Bridge	SB	11.0	5.4	0.3	-	2 spans bridge with 7 No steel I- section beams, condition good
9		54.1	Arch Culvert	SM	11.0	7.5	1.10	-	Its condition is OK
10		59.0	Arch Culvert	SM	9.50	9.2	0.90	-	Good condition
11		60.0	Pre-stressed	R.C.C	91.0	7.0	-	-	4 Spans, 4 I - beams, Newly built and is OK
12		67.0	Slab culvert	R.C.C	4.20	11	0.28	-	Structure is OK
13		72.9	Arch Culvert	SM	9.00	6.2	0.90	-	Old and in good condition
14		74.2	Arch Culvert	SM	11.0	5.7	0.90	-	Old and its left abutment has a minor crack
15		75.3	Pre-stressed	R.C.C	25.0	7.2	-	3	Single Spans, 3 I - beams, Newly built and is OK
16		78.2	Arch Culvert	SM	8.00	6.2	0.90	-	Good condition
17		78.6	Arch Bridge	SM	17.0	8.2	1.20	4	Condition good
18		79.8	Arch Bridge	SM	11.0	6.4	0.90	-	Built of sound Stone masonry and in good condition
19		81.6	Arch Culvert	SM	4.00	6.2	0.60	-	The thickness of SM is less, seems to be OK
20		82.0	Arch Culvert	SM	4.00	6.8	0.60	-	The thickness of SM is less, seems to be OK
21		83.8	Arch Culvert	SM	5.40	6.7	0.90	-	Old but sound
22		84.8	Slab culvert	SM	5.80	6.2	0.30	-	The slab concrete is very old but has no cracks
23		84.8	Slab culvert	SM	5.80	6.2	0.30	-	The slab concrete is very old but has no cracks
24		86.2	Arch Culvert	SM	3.00	6.1	0.90	-	Good condition

Cont'd........

* As advised by Frontier Works Organization

Bridges and Road Survey from Dargai to Bahrain

S.No	Location	RD (Km)	Type	Structure	Length (m)	Width (m)	Thickness (m)	Picture No	Remarks
25		86.6	Slab culvert	SM	5.20	6.3	0.30	-	8 No I - Steel beams, Single span, a little vibration is noted when heavy truck is passing over
26		90.8	Arch Culvert	SM	4.00	6.5	0.90	-	Built during Ex- State Govt. (1960' s), but still sound
	Khwazakhela	92.6							Khwazakhela is at 92.6 Km from Dargai
27		92.60	Arch + Slab	SM + R.C.C	70.00	7.2	-	5	Originally it was an Arch Bridge but now widened by R.C.C beams on both sides, condition good
28		93.80	Slab culvert	SM	3.00	6.1	0.30	-	Small culvert and is in good condition
29		95.00	Arch bridge	SM	12.70	5.8	1.20	6	Picture shows a little sag, however seems to be OK
30		96.30	Arch bridge	SM	14.00	4.3	1.20	7	Abutments are slightly eroded
31		99.20	Arch Culvert	SM	4.50	5.6	0.90	-	Condition good
32		102.9	Arch Bridge	SM	8.50	5.2	0.9	8	Old but sound
33		104.5	Arch culvert	SM	3.50	5.6	0.6	-	Small culvert, good condition
34		105.8	Arch culvert	SM	4.50	6.2	0.6	-	Small culvert, good condition
35		108.9	Arch Bridge	SM	15.0	6.2	1.2	9	Masonry is thick and strong
36		112.5	Arch culvert	SM	3.00	4.8	0.9	-	Its condition is OK
37		114.1	Arch Bridge	SM	9.00	6	1.2	10	Abutments are slightly cracked
38	**Madayan**	118.9	Arch Bridge	SM	36.4	3	1.2	11	2 Spans, good condition, over Madayan Khwar
39		119.4	Bailey bridge	SB	41.8	3.2	-	12, 13	Can carry ~ 20 T (C & W, says)
40		122.6	Arch Bridge	SM	10.0	2.6	4	14	Masonry is thick (4m) and strong
41		123.7	Pre-stressed	R.C.C	23.0	7	-	15	5 Rectangular beams and in good condition
42		125.2	Arch culvert	SM	6.70	2.8	4	-	Built of 4m thick stone masonry and seems strong
43		127.5	Arch Bridge	SM	23.5	3.2	1.2	16	Condition good
	Bahrain	128.0							End point of survey

SM = Stone Masonry, R.C.C = Reinforced Cement Concrete, SB = Steel Beams

9.1.4.3 Estimated Cost

The estimated additional cost of transporting heavy loads from Dargai to the project area near Bahrain is calculated as follows:

i)	Hire of special trailer and tractor unit @ $ 500/day for 30 days	15,000 US$
ii)	Hire of heavy craneage for loading/unloading @ $ 500/day for 20 days	10,000 US$
iii)	Fabrication of barge unit c/w cables	70,000 US$
	transporting and setting up	20,000 US$
iv)	Improvement of temporary access roads	20,000 US$
v)	Strengthening of old masonry structures and culverts or subsequent repair if necessary	20,000 US$
	Total:	155,000 US$

The cost of transportation itself and various additional charges of handling the equipment at port of landing etc. to be considered in **Chapter 11** Cost Estimate are summarised as follows:

i) Dockside unloading - bome by ship owners

ii) Transport to warehouse, and storage (demurrage) is equivalent to 2.5% of landed cost

iii) Customs duties on equipment and machinery for Hydel under current legislation

iv) Octroi - KMC (in Karachi) charged at 2% of landed cost

v) Transportation by rail, Karachi to Dargai (or by road) including levies, octroi, etc. and insurance.

vi) Transportation by road from Dargai to the project site (Bahrain).

9.2 ACCESS AND TRANSPORT IN THE PROJECT AREA

9.2.1 Access Road to the Power House

A short access road of approx. 0.4 km length has to be constructed form the main Madyan-Bahrain road, downhill to the elevation 1420 m asl, to reach the Power House and Switchyard areas.

9.2.2 Access Road to the Access Tunnel, Valve Chamber and Surge Tank

A new road of approx. 1.5 km length will have to be constructed starting at chainage 970 m of the existing forest road to Kulban, which itself will need to be improved, to the Access Tunnel and Valve Chamber working platforms. The maximum gradient of this improved road should be less than 10 percent. Retaining walls and other stabilizing measures will be required to bring the rood to acceptable standard.

In case that a TBM is chosen for the headrace tunnel excavation, it will be necessary to serve the working site by a truckable road.

The access to the Surge Tank branches off from the working platform of the Access Tunnel and is approx. 500 m length

9.2.3 Access Road to the Weir Area

The access road from Bahrain to the Weir site will be approx. 4.8 km length, about 1.2 km has already been constructed. However, the existing road is typically 4-5 m wide, widening of the existing road to achieve the minimum 6 m width is required. The remaining road length to be constructed is about 3.6 km.

The access road from Bahrain to the Weir area will be on the left bank of the Khwar. It is therefore proposed to erect a bridge over the weir to reach the Intake, Gravel Spill, Sand trap etc. on the right bank. The bridge will compose of steel beam substructure, with timber decking.

9.2.4 Road Crossing Structure

A road crossing structure has to be constructed for traversing the main Madyan-Bahrain road with the embedded penstock. It is recommended to form the structure adjacent to the river side of the existing road.

9.3 PHOTOGRAPHS OF VARIOUS ROAD STRUCTURES FROM DARGAI TO BAHRAIN

The pictures referred in Table "Bridges and Road Survey from Dargai to Bahrain" under section 9.1.4 are presented as APPENDIX 9.

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10.1 INTRODUCTION

Daral Khwar Hydropower Plant (HPP) is located in the Swat River Valley about 2 km down stream of the centre of Bahrain village. It is one of a series of HPPs which will be developed in the northern part of Pakistan. **Annex 10.1.1** (next page) gives an overview of location, capacity, year of commissioning and distances.

It is obvious that all these HPPs will have a decisive impact on the existing and planned transmission system. The transmission system to be planned for Daral Khwar cannot be developed in an appropriate manner without knowing the layout of the system which will be needed to satisfy the production and demand load of the next 20 to 30 years. The development of the above mentioned HPP has recently reached a point of concreteness which allows its integration in the National Power Plan of Pakistan (NPP), in spite of the fact that no attempt has been made so far to define the transmission system in a sufficient detail which is needed for a feasibility study. And effort has been made in this study to set the parameters for the future transmission planning of northern Pakistan in close co-operation with WAPDA Power Planning. Appendix 10 presents a GTZ sponsored study that defines the transmission and grid system expansion programme for the area where the High Head Power Plants are located. The study defines the economic and systematic expansion of the system in relation to expansion of the Hydropower generating facilities and extension of the national and regional grids.

In a second step the successive implementation of the system up to year 2010 will be defined and finally costs will be allocated to the different HPP and especially Daral Khwar HPP.

The detailed study "Transmission Interconnection of New High Head Hydropower Plants with WAPDA Transmission System" presented in Appendix 10, provides details about load flow, short circuit conditions and dynamic stability considerations. As this study has been finalised after the elaboration of this report, small and insignificant difference may have occurred. This difference does not change the results of this study.

A specific Transient Stability analysis should be undertaken once more in the final design phase in conjunction with the final determination of turbine, governor and generator data.

10.2 LAYOUT CONSIDERATIONS

The layout of a transmission system (routing, voltage, system, conductor) follows a series of technical and economical considerations. The best solution can only be found when technical and economical parameters are clearly defined.

10.2.1 Optimal Transmission System

The optimal transmission system is defined as the one which meets all technical requirements which are

- system stability
- voltage drop considerations
- power flow conditions
- thermal capacity of elements

and is the least cost solution considering given economic parameters which include

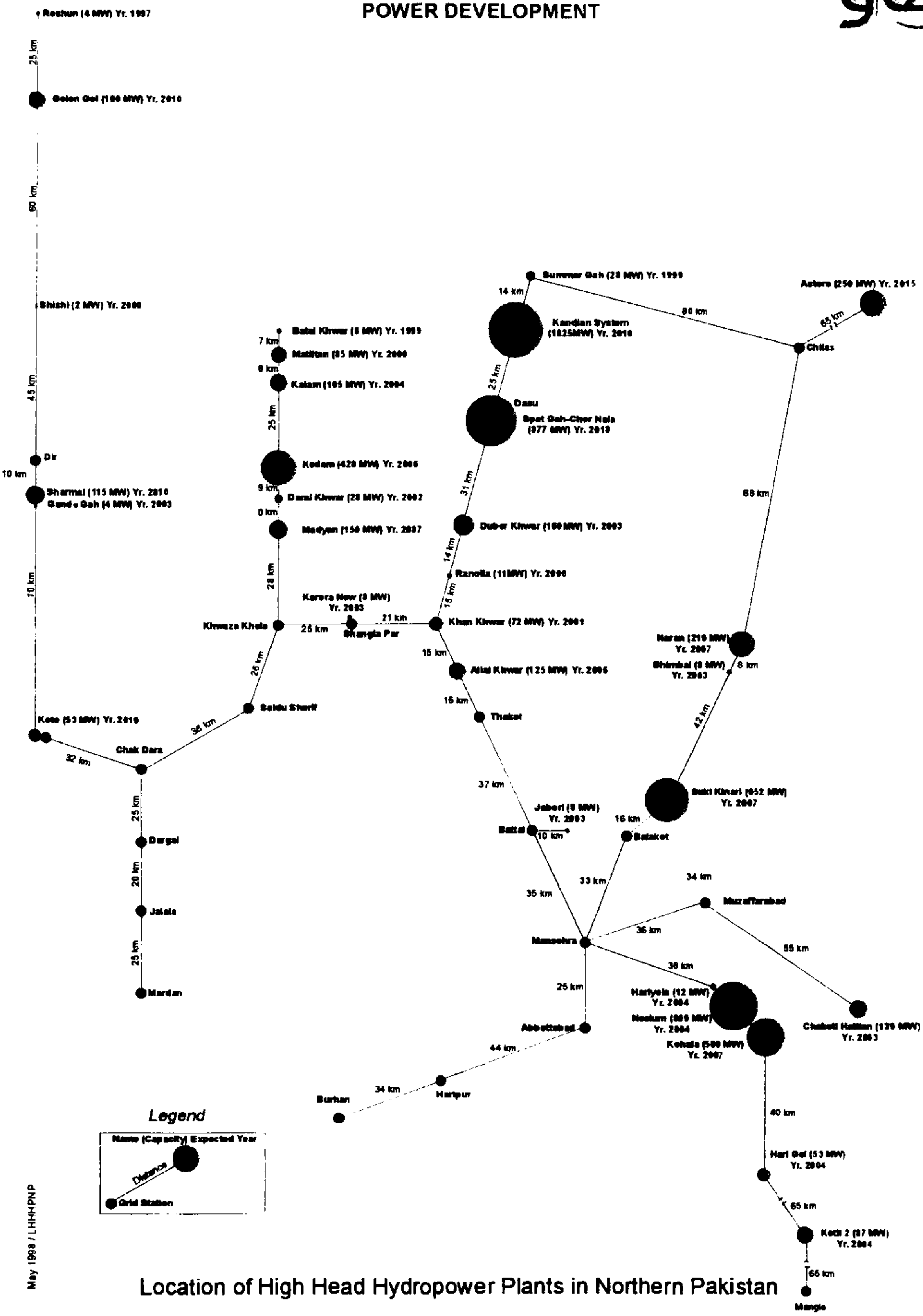
- capital cost
- cost of losses
- discount rates.

The economic choice of Voltage System and Conductor for mountainous areas is presented in **Annex 10.2.1.**

The parameters needed to elaborate the graph Economic Choice of Voltage System and Conductor have been taken as follows:

Annex 10.1.1

PAKISTAN GERMAN TECHNICAL COOPERATION
POWER DEVELOPMENT



Location of High Head Hydropower Plants in Northern Pakistan

Annex 10.2.1

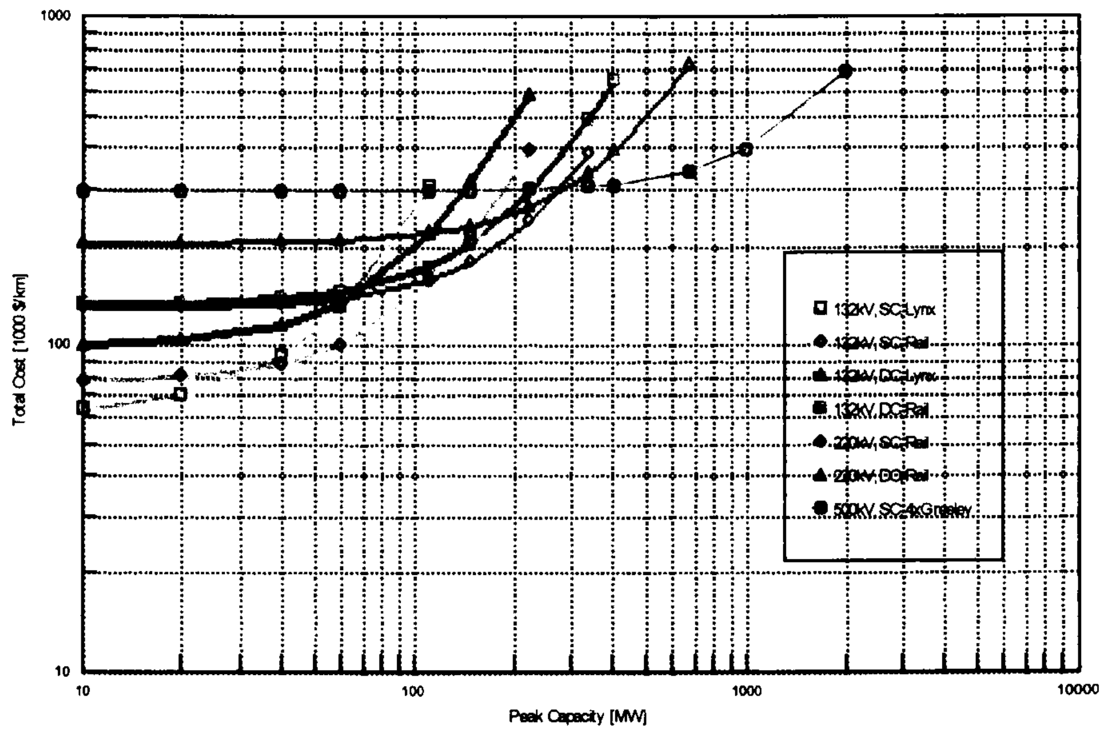
CHOICE OF VOLTAGE, SYSTEM & CONDUCTOR SIZE FOR 132 kV, 220 kV & 500kV

Voltage Level		132 kV				220 kV		500 kV
System		sc		dc		sc	dc	sc
Conductor		lynx	rail	lynx	rail	rail	rail	4xgreely
Investment cost (Mountenous area)	*Ci [k$/km]*	*62.234*	*77.754*	*99.607*	*133.889*	*130.835*	*207.695*	*292.858*
Energy cost	ce [$/kWh)	0.038	0.038	0.038	0.038	0.038	0.038	0.038
Loss duration	Dl [h]	3150	3150	3150	3150	3150	3150	3150
Conductor Resistance	rc [Ohm/km]	0.19	0.062	0.095	0.031	0.062	0.031	0.01395
Max Power Capacity	Pm [MW]	3000	3000	3000	3000	3000	3000	3000
Powerfactor	pf	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Line Voltage	Ul [kV]	132	132	132	132	220	220	500
Discount rate	i [%]	10	10	10	10	10	10	10
Loss cost	*Cl [k$/km]*	*173034*	*56464*	*86517*	*28232*	*20327*	*10163*	*885*
Total cost	Ct [k$/km]	173096	56542	86617	28366	20458	10371	1178

Function: Ct = Ci + (ce x Dl x rc x Pm^2 / (pf x U)^2) x ((1 + i)^n - 1)/(i x (1+i)^n))

Max.Power to Transmit in MW \	TOTAL COST in 1000 US$						
0	62	78	100	134	131	208	293
10	64	78	101	134	131	208	293
20	70	80	103	135	132	208	293
40	93	88	115	139	134	210	293
60	131	100	134	145	139	212	293
112	303	156	220	173	159	222	294
150		219	316	204	182	233	295
224		393	582	291	244	264	298
337				490	387	336	304
404				646		392	309
674						721	338
1000							391
2000							686
3000							

Economic Choice of Line: Voltage, System & Conductor



Investment Cost

WAPDA is using standardized Transmission Line Layouts for 33, 66, 132, 220 and 500 kV Lines. The standards include

Voltage	Towers	Circuit	Insulators	Conductor arrangement	Conductor
33 kV	Steel Lattice	Single	Pin	Horizontal in Line	Dog
66 kV	Steel Lattice	Single	Disc	Christmas Tree	Dog
132 kV	Steel Lattice	Single	"	Christmas Tree	Lynx/Rail
	and Tubular	& Double	"	Vertical in Line	"
220 kV	Steel Lattice	Single	"	Christmas Tree	Rail
		& Double		Vertical in Line	"
500 kV	Steel Lattice	Single	"	Horizontal in Line	Greeley (bundle)

A detailed cost estimate with underlying technical layout considerations is given in **Annexes 10.2.2-1 to 10.2.2-3** with the following results:

- **Cost of HV Transmission Lines**

Voltage	Conductor	Single circuit	Double circuit	Double circuit one equipped
66kV*				
Plain Area	1 x dog	$ 34,402.47		
Mountainous Area		$ 49,948.19		
132kV				
Plain Area	1 x lynx	$ 43,550.28	$ 68,990.22	$ 55,749.00
Mountainous Area		$ 63,214.89	$ 101,430.65	$ 87,013.00
132kV				
Plain Area	1 x rail	$ 55,308.86		
Mountainous Area		$ 77,754.31		
220kV				
Plain Area	1 x rail	$ 92,706.94	$ 147,153.87	
Mountainous Area		$130,707.56	$ 207,472.31	

As the project region is situated in mountainous areas where no important lines have been built upto now, the estimate has been split into plain area and mountainous area by adopting the technically different parameters.

The result of this analytical estimate is confirmed by the average prices of transmission lines published in WAPDA statistics.

- **Energy Cost**

  Economic costs have been taken into consideration and brought to an average on the bases of the Integrated Operations and Tariff Study for WAPDA and KESC prepared by Cooper and Lybrand Deloitte, April 1991.

- **Loss Duration**

  The loss duration in hours has been calculated under consideration of the typical production cycle of Daral Khwar HPP. This production cycle will be very common in High Head Hydropower Plants with daily 4 hour peaking capacity to be constructed in the mountainous areas of northern Pakistan.

  The production cycle and the calculation of the loss duration is presented in **Annexes 10.2.3** and the graph Daral Khwar daily production cycle month wise below.

  As a result 3,112 hours loss duration have been calculated.

* *US$ / km*

Cost of HV Transmission Lines

as of 1996

-------------------66kV--------------

US$/km	single circuit
Plain area	$34,095
Mountainous area	$49,593

----------------------------------Cost Details 66 kV--------------------------------

Cost of 66kV, S/C Line in plain areas

Designation	unitprice/$	Qty/km	total/$/km	%
tower,66kV,s/c,plain,(2.6 to)	2860	3.50	10000	23.4
land & right of way	380	3.50	1329	3.1
foundation,s/c,(6.1m3)	1342	3.50	4692	11.0
hardware,66kV,s/c	240	3.50	839	2.0
insulators,66kV,s/c,plain	304	3.50	1062	2.5
earthwire,9mm	400	1.05	420	1.0
conductor,dog	900	3.15	2835	6.6
subtotal 1			21177	49.6
contingencies,15%			3177	7.4
subtotal 2			24354	57.1
erection, 40%			9741	22.8
total			34095	79.9

Cost of 66kV, S/C Line in mountainous areas

Designation	unitprice/$	Qty/km	total/$/km	%
tower,66kV,s/c,mountain,(3.3to)	3630	3.70	13444	21.6
land & right of way	380	3.70	1407	2.3
foundation,s/c,(6.1m3)	1342	3.70	4970	8.0
hardware,66kV,s/c	240	3.70	889	1.4
insulators,66kV,s/c,mountain	378	3.70	1401	2.3
earthwire,9mm	400	1.05	420	0.7
conductor,dog	900	3.15	2835	4.6
subtotal 1			25367	40.8
contingencies,15%			3805	6.1
subtotal 2			29172	46.9
erection, 70%			20421	32.8
total			49593	79.7

unit cost in US$ of 1996	66kV	
tower,66kV,s/c,mountain	3630	unit
tower,66kV,s/c,plain	2860	unit
land & right of way	380	per tower
foundation,s/c,(6.1m3)	1342	per tower
hardware,66kV,s/c	240	per tower
insulators,66kV,s/c,mountain	378	per tower
insulators,66kV,s/c,plain	304	per tower
earthwire,9mm	400	per km
conductor,dog	900	per km

base prices		
foundation	220	$/m3
steelstructures	1100	$/ton
insulator	13	$/disc

layout considerations -------------66kV---------------

towers		plain	mountain
tangent	0-8grd	60%	55%
angle	8-30grd	12%	30%
acute angle	30-60grd	8%	15%
average weight s/c		2.6	3.3 ton/tower

foundation
s/c 6.1 m3

insulator strings	discs/tower	plain	disc/tower	mountain	disc/tower
suspension	18	60%	14.4	55%	9.9
single tension	32	12%	3.84	30%	9.6
doble tension	64	8%	5.12	15%	9.6
average s/c			23.36		29.10

span	plain	mountain
average s/c & d/c	286	270 m
average quantity	3.50	3.70 tower/km

Cost of HV Transmission Lines

as of 1998

------------------132kV--------------

US$/km	single circuit	doble circuit	doble circuit one circuit equipped
Plain area	$42,671	$87,338	$64,889
Mountainous area	$62,234	$99,807	$86,883

----------------------------------Cost Details 132 kV----------------------------------

Cost of 132kV, S/C Line in plain areas

Designation	unitprice/$	Qty/km	total/$/km	%
tower,132kV,s/c,plain,(3.2 to)	3575	3.50	12500	29.3
land & right of way	390	3.50	1364	3.2
foundation,s/c,(6.1m3)	1220	3.50	4266	10.0
hardware,132kV,s/c	250	3.50	874	2.0
insulators,132kV,s/c,plain	583	3.50	2040	4.8
earthwire,9mm	400	1.05	420	1.0
conductor,lynx	1600	3.15	5040	11.8
subtotal 1			26503	62.1
contingencies,15%			3976	9.3
subtotal 2			30479	71.4
erection, 40%			12192	28.6
total			42671	100.0

Cost of 132kV, S/C Line in mountainous areas

Designation	unitprice/$	Qty/km	total/$/km	%
tower,132kV,s/c,mountain,(4 to)	4510	3.70	16704	26.8
land & right of way	390	3.70	1444	2.3
foundation,s/c,(6.1m3)	1220	3.70	4519	7.3
hardware,132kV,s/c	250	3.70	926	1.5
insulators,132kV,s/c,mountain	751	3.70	2781	4.5
earthwire,9mm	400	1.05	420	0.7
conductor,lynx	1600	3.15	5040	8.1
subtotal 1			31833	51.2
contingencies,15%			4775	7.7
subtotal 2			36608	58.8
erection, 70%			25626	41.2
total			62234	100.0

Cost of 132kV, D/C Line in plain areas

Designation	unitprice/$	Qty/km	total/$/km	%
tower,132kV,d/c,plain,(5to)	5522	3.50	19308	28.7
land & right of way	390	3.50	1364	2.0
foundation,d/c,(7.2m3)	1440	3.50	5035	7.5
hardware,132kV,s/c	440	3.50	1538	2.3
insulators,132kV,d/c,plain	1167	3.50	4080	6.1
earthwire,9mm	400	1.05	420	0.6
conductor,lynx	1600	6.3	10080	15.0
subtotal 1			41825	62.1
contingencies,15%			6274	9.3
subtotal 2			48098	71.4
erection, 40%			19239	28.6
total			67338	100.0

Cost of 132kV, D/C Line in mountainous areas

Designation	unitprice/$	Qty/km	total/$/km	%
tower,132kV,d/c,mountain,(8.3to)	7150	3.70	26481	26.6
land & right of way	390	3.70	1444	1.5
foundation,d/c,(7.2m3)	1440	3.70	5333	5.4
hardware,132kV,s/c	440	3.70	1630	1.6
insulators,132kV,d/c,mountain	1502	3.70	5561	5.6
earthwire,9mm	400	1.05	420	0.4
conductor,lynx	1600	6.3	10080	10.1
subtotal 1			50950	51.2
contingencies,15%			7643	7.7
subtotal 2			58593	58.8
erection, 70%			41015	41.2
total			99807	100.0

unit cost in US$ of 1998	132kV	
tower,132kV,s/c,mountain,(4 to)	4510	unit
tower,132kV,s/c,plain,(3,2 to)	3575	unit
tower,132kV,d/c,mountain,(6,3 to)	7150	unit
tower,132kV,d/c,plain,(5 to)	5522	unit
land & right of way	390	per tower
foundation,s/c,(6.1m3)	1220	per tower
foundation,d/c,(7.2m3)	1440	per tower
hardware,132kV,s/c	250	per tower
hardware,132kV,d/c	440	per tower
insulators,132kV,s/c,mountain	751	per tower
insulators,132kV,s/c,plain	583	per tower
insulators,132kV,d/c,mountain	1502	per tower
insulators,132kV,d/c,plain	1167	per tower
earthwire,9mm	400	per km
conductor,lynx	1600	per km

base prices		
foundation	200	$/m3
steelstructures	1100	$/ton
insulator	13	$/disc

layout considerations ------------132kV---------------

towers		plain	mountain	
tangent	0-8grd	80%	55%	
angle	8-30grd	12%	30%	
acute angle	30-60grd	8%	15%	
average weight s/c		3.25	4.1	ton/tower
average weight d/c		5.02	6.5	ton/tower

foundation		
s/c	6.1	m3
d/c	7.2	m3

insulator strings	discs/tower	plain	disc/tower	mountain	disc/tower
suspension	33	80%	28.4	55%	18.15
single tension	66	12%	7.92	30%	19.8
doble tension	132	8%	10.56	15%	19.8
average s/c			44.88		57.75
average d/c			89.76		115.5

span	plain	mountain	
average s/c & d/c	286	270	m
average quantity	3.50	3.70	tower/km

Annex 10.2.2 - 2

Cost of HV Transmission Lines

as of 1996

---------------------220kV----------------

US$/km	single circuit (Estd. 63% of D/C)	doble circuit
Plain area	$93,008	$147,632
Mountainous area	$130,836	$207,675

-----------------------------------Cost Details 220 kV---

Cost of 220kV, D/C Line in plain areas

Designation	unitprice/$	Qty/km	total/$/km	%
tower,d/c,plain	16500	2.6	43421	29.4
land & right of way	420	2.6	1105	0.7
foundation,d/c	4708	2.8	12389	8.4
hardware,s/c	870	2.6	2289	1.6
insulators,d/c,plain	2970	2.8	7816	5.3
earthwire,9mm	400	1.05	420	0.3
conductor	3850	6.3	24255	16.4
subtotal 1			91697	62.1
contingencies,15%			13755	9.3
subtotal 2			105451	71.4
erection, 40%			42180	28.6
total			147632	100.0

Cost of 220kV, D/C Line in mountainous areas

Designation	unitprice/$	Qty/km	total/$/km	%
tower,d/c,mountain	21450	2.8	59583	28.7
land & right of way	420	2.8	1167	0.6
foundation,d/c,(7.2m3)	4708	2.8	13078	6.3
hardware,s/c	870	2.8	2417	1.2
insulators,d/c,mountain	1911	2.8	5308	2.6
earthwire,9mm	400	1.05	420	0.2
conductor	3850	6.3	24255	11.7
subtotal 1			106228	51.2
contingencies,15%			15934	7.7
subtotal 2			122162	58.8
erection, 70%			85513	41.2
total			207675	100.0

unit cost in US$ of 1996	220kV	
tower,s/c,mountain	0	unit
tower,s/c,plain,	0	unit
tower,d/c,mountain	21450	unit
tower,d/c,plain	16500	unit
land & right of way	420	per tower
foundation,s/c	0	per tower
foundation,d/c	4708	per tower
hardware,220kV,s/c	0	per tower
hardware,220kV,d/c	870	per tower
insulators,220kV,s/c,mountain	1911	per tower
insulators,220kV,s/c,plain	1485	per tower
insulators,220kV,d/c,mountain	3822	per tower
insulators,220kV,d/c,plain	2970	per tower
earthwire,9mm	400	per km
conductor,rail,(220kV)	3850	per km

base prices		
foundation	220	$/m3
steelstructures	1100	$/ton
insulator	13	$/disc

layout considerations -------------220kV---------------

towers		plain	mountain
tangent	0-8grd	80%	55%
angle	8-30grd	12%	30%
acute angle	30-60grd	8%	15%
average weight s/c		0	0 ton/tower
average weight d/c		15	19.5 ton/tower

foundation	
s/c	0 m3
d/c	21.4 m3

insulator strings	discs/tower	plain	disc/tower	mountain	disc/tower
suspension	84	80%	67.2	55%	46.2
single tension	168	12%	20.16	30%	50.4
doble tension	336	8%	26.88	15%	50.4
average s/c			114.24		147
average d/c			228.48		294

span	plain	mountain
average s/c & d/c	380	360 m
average quantity	2.63	2.78 tower/km

Daral Khwar with limited Tunnel Storage

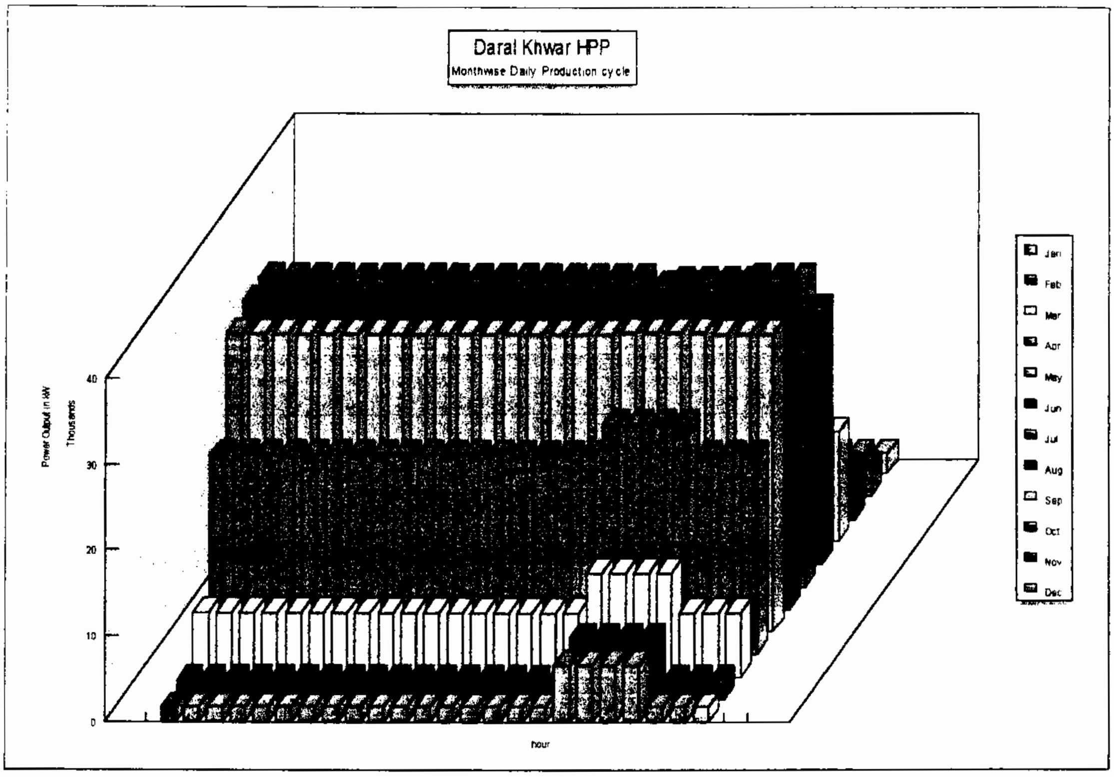
Evaluation of Capacity, Energy and Benefit

Loss function		Peak time /h	4	Fix loss /kW	100
factors q^2		Off peak time /h	20	eta Trafo	0.99
		Alt. Max. / m	1723	eta Generator	0.98
0.0642		Alt. Min. /m	1708	eta Turbine 4	0.84
				eta Turbine 20	0.86

		Qtot	Qturb4	Qturb20	alt.Swat	altintake 4	altintake 20	h 4	h20	h4 net	h20 net	eta4	eta20	Ppeak	Pfpeak	Poffpeak	E/peak	E/offpeak	E/tot	Lossduration	V/peak	V/offpeak	P/fpeak	B/peak	B/Firmcap	B/offpeak	B/tot	days	M3
	15.0	m^3/ sec	m^3/ sec	m^3/ sec	m	m	m	m	m	m	m			kW	kW	kW	GWh	GWh	GWh	h	$/ kWh	$/ kWh	$/kW firm cap.	Mio$	Mio$	Mio$	Mio$		
1.11	JAN	1.1	2.8	0.8	1415	1716	1716	300	300	300	300	0.81	0.83	6727	6727	1782	0.834	1	2	6	0.039	0.034	7.08	0.033	0.048	0.038	0.118	31	2981385
1.32	FEB	1.3	3.1	1.0	1415	1716	1717	300	302	300	302	0.81	0.83	7220	6727	2302	0.809	1	2	7	0.039	0.034	7.08	0.032	0.048	0.044	0.123	28	3192786
3.41	MAR	3.4	5.1	3.1	1415	1716	1721	300	306	299	305	0.81	0.83	12173	6727	7543	1.510	5	6	44	0.039	0.034	7.08	0.060	0.048	0.159	0.266	31	9123855
9.82	APR	9.8	11.6	9.5	1415	1716	1722	300	307	292	301	0.81	0.83	26848	6727	23270	3.222	14	17	335	0.039	0.034	7.08	0.127	0.048	0.476	0.650	30	25457627
14.55	MAY	14.5	15.0	14.5	1415	1721	1723	306	308	291	294	0.81	0.83	34835	6727	34712	4.320	22	26	730	0.042	0.036	7.08	0.181	0.048	0.777	1.006	31	38962698
14.95	JUN	14.9	15.0	14.9	1415	1723	1723	308	308	293	293	0.81	0.83	35044	6727	35775	4.205	21	26	745	0.042	0.036	7.08	0.176	0.048	0.775	0.999	30	38749574
14.97	JUL	15.0	15.0	15.0	1415	1723	1723	308	308	293	293	0.81	0.83	35054	6727	35828	4.347	22	27	772	0.039	0.034	7.08	0.171	0.048	0.757	0.976	31	40095411
12.60	AUG	12.6	14.3	12.3	1415	1718	1723	300	307	287	298	0.81	0.83	32806	6727	29758	4.068	18	23	555	0.039	0.034	7.08	0.160	0.048	0.628	0.836	31	33759454
5.50	SEP	5.5	7.2	5.2	1415	1716	1722	300	307	297	305	0.81	0.83	17077	6727	12763	2.049	8	10	108	0.039	0.034	7.08	0.081	0.048	0.261	0.389	30	14259439
2.75	OCT	2.8	4.5	2.4	1415	1716	1721	300	305	299	305	0.81	0.83	10629	6727	5906	1.318	4	5	29	0.039	0.034	7.08	0.052	0.048	0.125	0.224	31	7374073
1.75	NOV	1.7	3.5	1.4	1415	1716	1719	300	304	299	303	0.81	0.83	8242	6727	3381	0.989	2	3	12	0.036	0.031	7.08	0.036	0.048	0.064	0.147	30	4531720
1.35	DEC	1.3	3.1	1.0	1415	1716	1717	300	302	300	302	0.81	0.83	7281	6727	2366	0.903	1	2	8	0.036	0.031	7.08	0.033	0.048	0.046	0.127	31	3603087
										h min	h max			P max	P firm				E total										
		TOTAL								287	305			35054	6727		29	119	148	3352				1.142	0.572	4.148	5.862	365	222
																			0.48	0.38									

Legend

Qtot	m^3/sec	Total discharge available for turbining	Pfpeak	kW	Firm peak capacity (available 4hours per day all over the year with 95% probability)
Qturb4	m^3/sec	Discharge available for 4 hour peaking	Poffpeak	kW	Average capacity during off peak production
Qturb20	m^3/sec	Discharge available for 20 hour offpeak production	E/peak	GWh	Peak energy
alt.Indus	m	Waterlevel of Swat River	E/offpeak	GWh	Off peak Energy
altintake 4	m	Average Waterlevel of headpond for peaking	E/tot	GWh	Total energy
altintake 20	m	Average Waterlevel of headpond for offpak production	V/peak	$/kWh	Value per kWh of peak energy
h 4	m	Gross head available for 4 hour peaking	V/offpeak	$/kWh	Value per kWh of off peak energy
h20	m	Gross head available for 20 hour offpeak production	P/fpeak	$/kWfirmcap	Value per kW of firm capacity
h4 net	m	Net head available for 4 hour peaking	B/peak	Mio$	Benefit of peak energy
h20 net	m	Net head available for 20 hour offpeak production	B/Firmcap	Mio$	Benefit of firm capacity
eta4		Total efficiency during peaking	B/offpeak	Mio$	Benefit of off peak energy
eta20		Total efficiency during offpeak production	B/totfirm	Mio$	Total benefit
Ppeak	kW	Peak capacity			



- **Discount Rate**

  An economical discount rate of 10% has been taken.

- **Economic Life Time**

  30 years of economic life has been taken.

10.2.2 Redundancy Criterion

In case of the outage of one line, the remaining system must be able to take over the power flow from the concerned HPP in order to avoid instability of the system. In the case of smaller HPP whose loss will not be crucial to the system, a second circuit can be omitted.

Technically speaking, this means that in cases where this n-1 criterion is applied, the remaining system can be loaded upto its technical limit which is determined by the thermal loading limits of conductors. In accordance with WAPDA standard an ambient temperature of 35°C and a Conductor temperature of 75°C have been taken as border conditions.

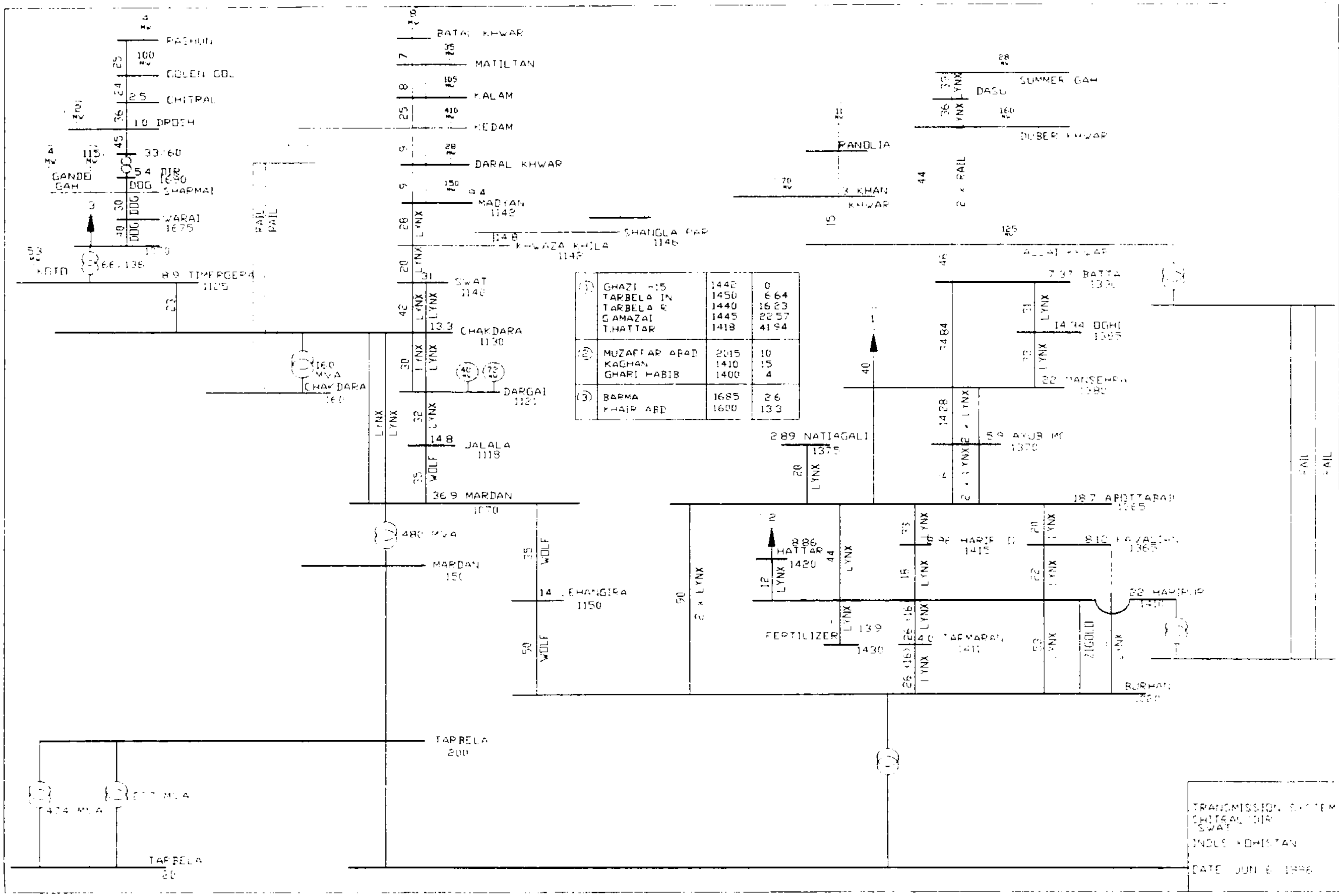
The following thermal loading limits have been established in accordance with WAPDA practice:

	Nominal	Thermal Loading Limit / MVA				
Conductor	Diameter mm	33 kV	66 kV	132 kV	220 kV	500 kV
Dog	14.15	20	39	77	-	-
Lynx	519.63	-	56	112	-	-
Rail	28.48	-	-	202	337	766
Greeley	27.09			184	307	2094 (3 bundle)

10.2.3 Existing System

The existing transmission system in the region has been designed to transfer the energy from the national grid to the consumer centers in the valleys. It is basically composed of 132 kV Single Circuit (SC) Lynx Conductor lines. A layout of the existing system is presented in **Annex 10.2.4.** Whenever possible, this system, should be integrated.

Annex 10.2.4


BATAL KHWAR
MATILTAN
KALAM
KEDAM
DARAL KHWAR
MADYAN 1142
KHWAZA KHELA
SHANGLA PAR
SWAT
CHAKDARA 1130
DARGAI
JALALA 1119
369 MARDAN 1070
480 MVA
MARDAN
JEHANGIRA 1150
TARBELA 200
TARBELA
CHITRAL
GOLEN GOL
DIR 1690
TIMERGERA 1105
CHAKDARA
GHAZI 415 | 1440 | 0
TARBELA IN | 1450 | 664
TARBELA R | 1440 | 1623
GAMAZAI | 1445 | 2257
T.HATTAR | 1418 | 4194
MUZAFFAR ABAD | 2015 | 10
KAGHAN | 1410 | 15
GHARI HABIB | 1400 | 4
BARMA | 1685 | 26
KHAIR ABD | 1600 | 133
SUMMER GAH
DASU
DUBER KHWAR
PANDLIA
ALLAI KHWAR
BATTA
OGHI
MANSEHRA
NATIAGALI 1375
AYUB MC
ABOTTABAD
HATTAR 1420
HARIPUR
FERTILIZER 1430
TARNAVAL
BURHAN
TRANSMISSION SYSTEM
CHITRAL DIR
SWAT
INDUS KOHISTAN
DATE JUN 6 1996

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10.3 THE TRANSMISSION SYSTEM

10.3.1 Routing

Given the topography and the location of the Hydropower Plant presented in **Chapter 10.1, Annex 10.1.1** above, the power/energy produced in the northem valleys of NWFP will have to be transmitted over basically 4 Influx-Channels into the System

1. Chitral Valley / Panjkoora Valley via Chakdara to Mardan
2. Swat Valley via Chakdara to Mardan
3. Indus Valley via Mansehra to Islamabad
4. Kaghan Valley via Mansehra to Islamabad or to Mangla.

10.3.2 Voltage

Due to the size of the HPP to be interconnected, two types of systems have to be designed, a 220/500 kV system and a 132/220 kV System.

Both systems are necessary independent of each other and the layout of one system does not influence significantly the layout of the other one in a way, that both systems can be planned and implemented independently.

Precautions must be taken only in the choice of the routing giving priority to the right of way of the line with the higher voltage level.

10.3.2.1 220/500 kV System

The 220/500 kV system in for larger sites ranging from 400 MW upto 1000 MW. This transmission system mostly on 500 kV level will reach further into the grid system and being of supra-regional importance will have to be planned individually within the NPP-system expansion planning on a national basis.

10.3.2.2 132/500 kV System

The 132/220 kV voltage system for medium sites upto approx. 400 MW and on a more regional basis within the northem periphery of the grid system. The power from this system will be partly absorbed in the area itself and partly be transmitted to the area bordered by the line Peshawar-Mardan-Tarbela-Burhan-Islamabad.

The status of preparation of the concemed HPP presently identified to the tune of approximately 1500 MW will allow a successive implementation of these projects upto the year 2010. Daral Khwar HPP will form a part of this system.

10.3.2.3 Layout and Development of the 132/200 kV System

Based on the above considerations a transmission system has been designed which will allow to satisfy the local and regional demand and which will integrate the proposed HPP as follows:

Chitral / Panjkoora		Swat		Indus	
Name	Capacity	Name	Capacity	Name	Capacity
Reshun	4 MW	Batal Khwar	8 MW	Summar Gah	28 MW
Shishi	2 MW	Matiltan	82 MW	Duber Khwar	160 MW
Golen Gol	100 MW	Kalam	100 MW	Ranolia	11 MW
Sharnai	115 MW	Kedam	410 MW	Khan Khwar	72 MW
Koto	53 MW	Daral	28 MW	Allai Khwar	125 MW
		Madyan	140 MW		
Total:	274 MW		968 MW		396 MW
			Grand Total:		1638 MW

The basic system is presented in **Annex 10.3.9**. The 132/220 kV transmission system will be built up step by step synchronous to the development of the concerned HPP and the local power demand.

Demand Forecast for WAPDA Grid Stations in Northern Pakistan

	Existing Grid Station										New Grid Stations					
Year of Forecast	Timergara	Chakdara	Khwaza Khela	Mardan	Swat	Shangla Par	Battal	Mansehra	Abottabad	Haripur	Besham	Dir	Drosh	Chitral	Madyan	Matiltan
1996	25	13	5	31	45	3	15	48	25	89	11	7	4	2	4	3
1997	27	14	5	33	48	3	16	51	27	94	12	7	5	2	4	3
1998	28	15	6	35	51	3	17	54	28	100	12	8	5	2	4	3
1999	30	15	6	37	54	4	18	57	30	106	13	9	5	3	4	3
[redacted]																
2005	42	22	8	52	76	5	25	81	42	150	18	13	8	4	6	5
[redacted]																
2008	50	26	10	62	91	6	30	97	50	179	20	15	9	4	7	6
2009	53	28	11	66	96	6	32	102	53	190	21	16	9	5	7	6
[redacted]																
[redacted]																

All figures in MW
Average Groth rate = 6% per Year for existing stations

The demand forecast is presented in the table above. It has been elaborated for the existing WAPDA Grid Stations by increasing the 1996 peak load with an annual 6% growth rate. In some cases the demand of several S/S have been summed up in another S/S in order to simplify the presentation.

For the future Grid Stations, the intermediate demand forecast of the relevant regional electrification studies prepared by SHYDO/GTZ have been taken.

The development of the system in steps coinciding with the commissioning of new HPP has been elaborated for the years:

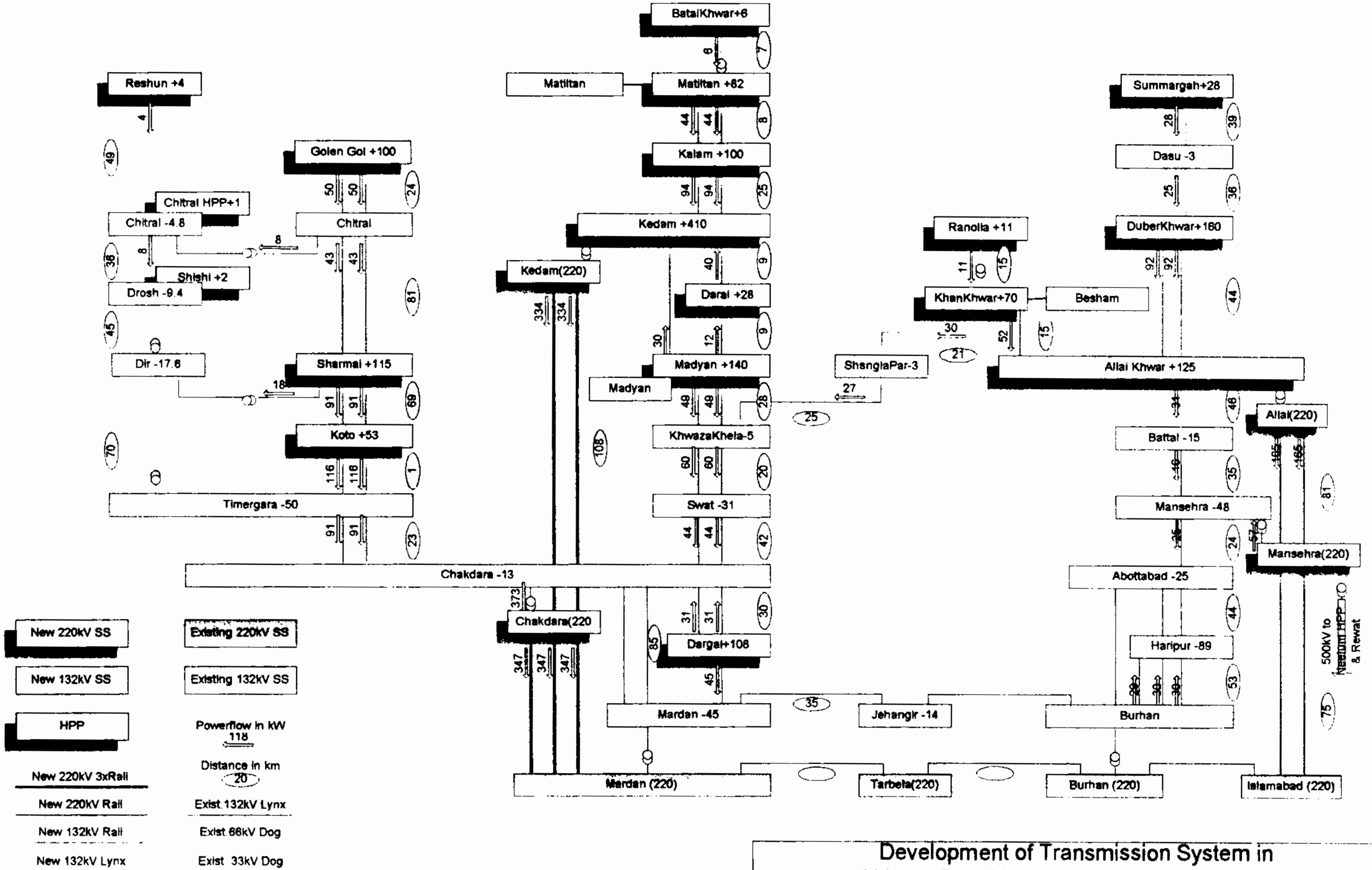
1996-2000-2001-2002-2003-2004-2006-2007-2010 and 2020.

The results are presented in **Annexes 10.3.1** to **10.3.11.**

As shown in the annexed graphics Daral Khwar will be connected to the system by two 132 kV transmission lines in order to meet the n-1 redundancy criterion.

It is expected that Matiltan and Batal Hydropower plants will be build before the under discussion Daral Khwar HPP. Batal Khwar will be connected to Matiltan HPP by means of a 33 kV interconnection. Matiltan will be connected to the system at proposed Madyan grid station by means of 132 kV Lines. Daral HPP will be connected to Madyan Grid Station by in out of one of the two circuits from Matiltan to Madyan, this effectively will provide for two interconnections to the grid, one line to Madayan and the other through Matiltan. The in out at Daral Khwar power plant is by means of 1-km transmission line on lynx. The double circuit Matiltan to Madyan will possibly be on Rail Conductor (51 km long). The Madyan to Khawaza Khela and Swat existing interconnection will also need to be made a double circuit interconnection to centre for the three power plants under discussion.

Annex 10.2.4



Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2010

Version 3. 24/07/98 Printed on 24/07/98 drawing1

10.4 COST

The cost of the 132 kV system has been elaborated and economic cost allocated to the specific HPP.

10.4.1 Cost Estimation

Cost estimation for the element of the system has been carried out based on the detailed analysis described in chapter 10.2.1 and **Annexes 10.2.2.**

The investment cost for the whole system is shown in in the same Annexes divided in sub-systems as follows:

System 1	Indus Valley	34.8 Mio. $
System 2	Swat Valley	41.1 Mio. $
System 3	Chitral/Panjkoora Valley	32.8 Mio. $

The economic cost has been elaborated by discounting investment cost and HPP capacity to 1996 (see **Annex 10.2.1**).

The benefit due to distribution tasks taken over by the system has been considered by elaboration of a distribution orientated transmission system without inclusion of HPP. The discounted investment cost of this system has been deducted from the base case transmission system which includes all proposed HPPs.

The results are as follows:

Summary Allocation of Transmission Cost
Chitral/Panchoora-, Swat-, Indus-Valley

Name of HPP	Capacity	Transmission Cost			Transmission discounted 1996	
		Direct	System	Total		
	MW	Mio $	Mio $	Mio $	Mio $	MW
Battal Khwar	8	0.3	0.2	0.6	0.4	6
Ranolia	11	0.3	0.3	0.7	0.6	8.3
Summar Gah	28	1.3	0.8	2.1	2.4	21.0
Darai Khwar	28	0.8	0.8	1.6	1.0	17
Koto	53	1.2	1.6	2.8	1.6	15.4
Khan Khwar	70	1.9	2.1	4.0	3.6	47.8
Matiltan	85	3.3	2.6	5.8	4.2	64
Kalam	100	3.6	3.0	6.6	4.6	51
Golen Gol	100	3.7	3.0	6.7	4.7	29.0
Sharmai	115	3.2	3.5	6.7	4.1	33.3
Allai Khwar	124	3.1	3.8	6.8	5.7	52.6
Madyan	150	3.7	4.5	8.2	4.7	58
Duber Khwar	160	5.3	4.8	10.2	9.9	90.3
Kedam	410	12.0	12.4	24.4	15.3	174
System Expansion				22.0		
Total Systems	**1442**	**44**	**44**	**109**	**63**	**668**

Specific Transmission Cost

Discounted Transmission cost with HPP		62.7 Mio $
Discounted Transmission cost without HPP		22.3 Mio $
Discounted net Transmission Cost		40.4 Mio $
Discounted added Capacity		667.9 MW
Specific Transmission Cost		60.6 $/kW
Allocation of Cost		
	-Direct 50%	30.3 $/kW
	-System 50%	30.3 $/kW
Distribution of direct cost		by Load Moment

The result of 60,6 $/kW specific transmission cost is similar to the specific transmission cost of 70 $/kW elaborated on national level in the Cooper and Leybrands Study but including S/Station cost. In the present case, station costs have been included in the cost of the relevant HPP.

10.4.2 Allocation of Cost

The transmission costs have been allocated to the different HPP by allocating 50% of the cost or 30,3 $/kW to system cost and 50% to Direct or Connection Cost.

The distribution of the Direct Cost has been done by Load Moment (Capacity x Distance to Load Centre) in order to capture benefits of closer location to load centre and punish long transmission lines to remote HPP.

The result is presented in the above table, details can be seen in **Annex 10.4.1**.

Daral Khwar HPP bears an economic transmission cost of

Direct cost	0.8 Mio. US$
System cost	0.8 Mio. US$
Total cost	1.6 Mio. US$

This value is higher than the investment cost of 0.8 Mio. US$ for connecting Daral Khwar to the system (see Chapter 11 "Cost").

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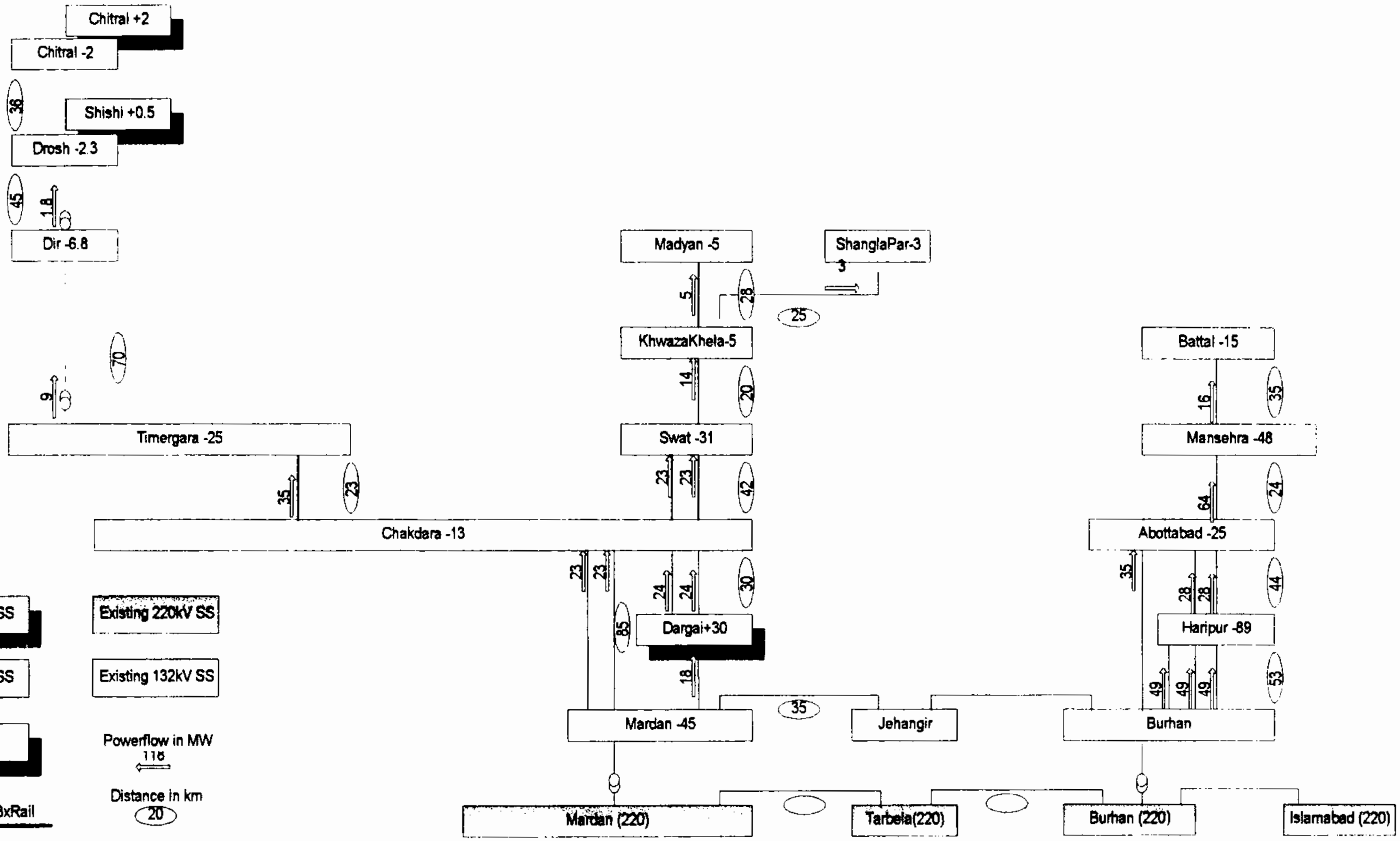

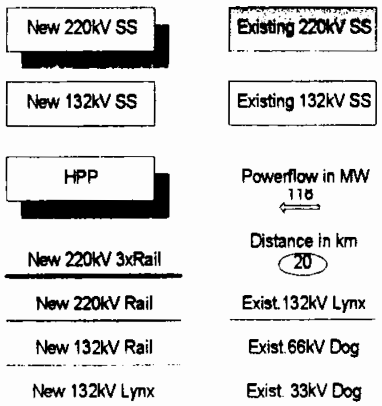

Development of Transmission System in Chitral-, Panchkora-, Swat- and Indus Valley Year 1996

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Annex 10.3.1

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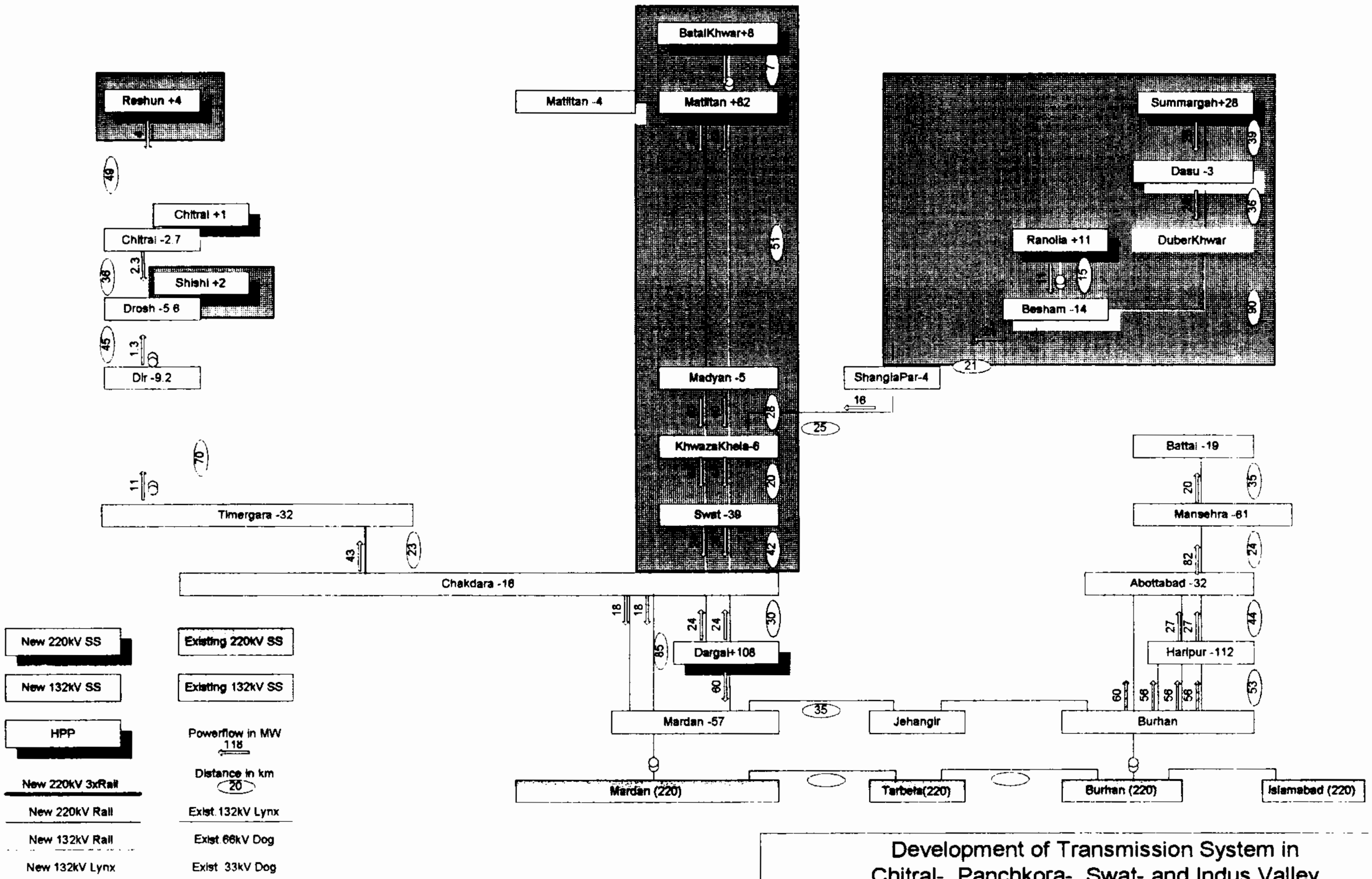

Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2000

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Annex 10.3.2

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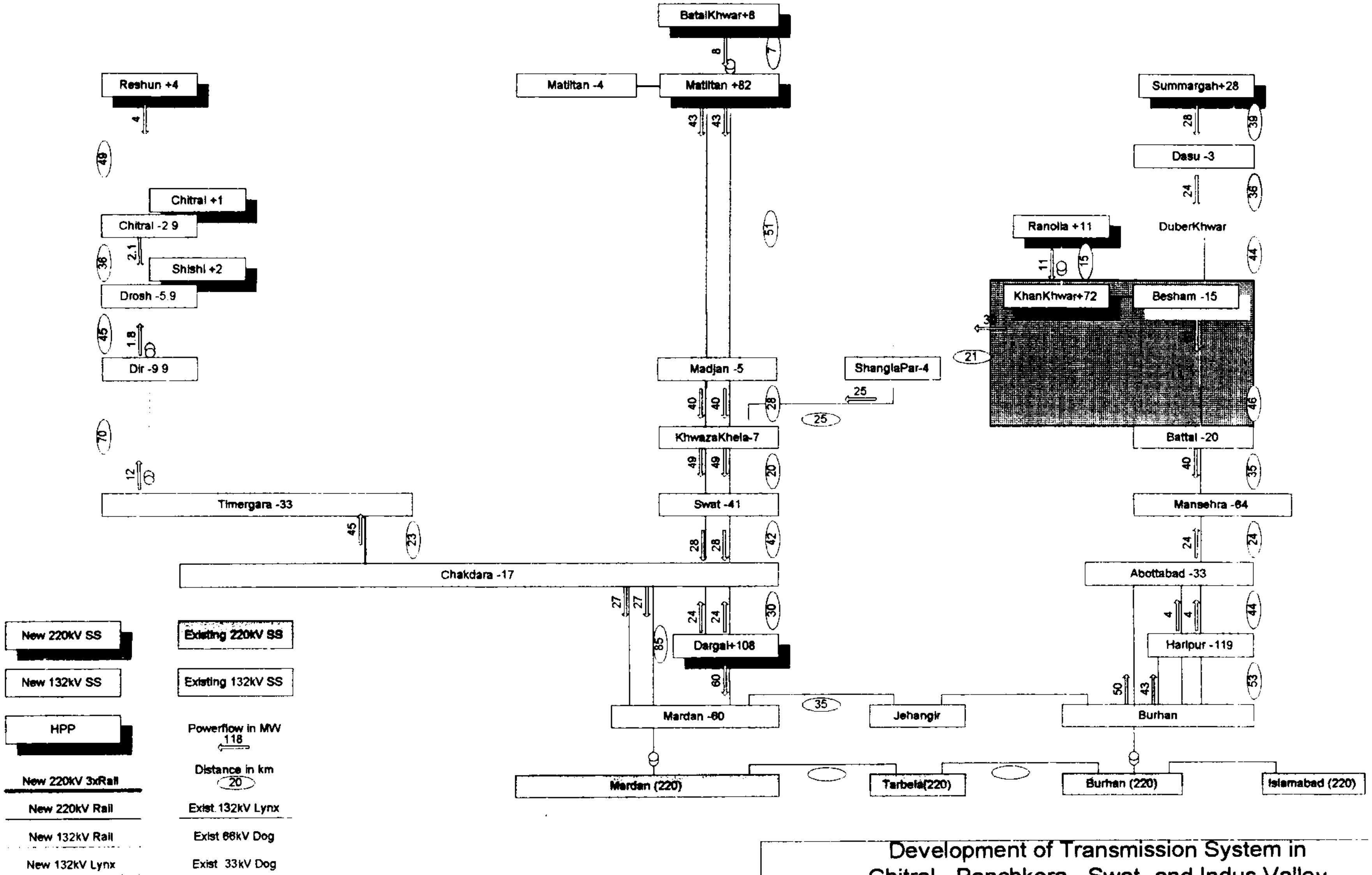
Annex 10.3.3



Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2001

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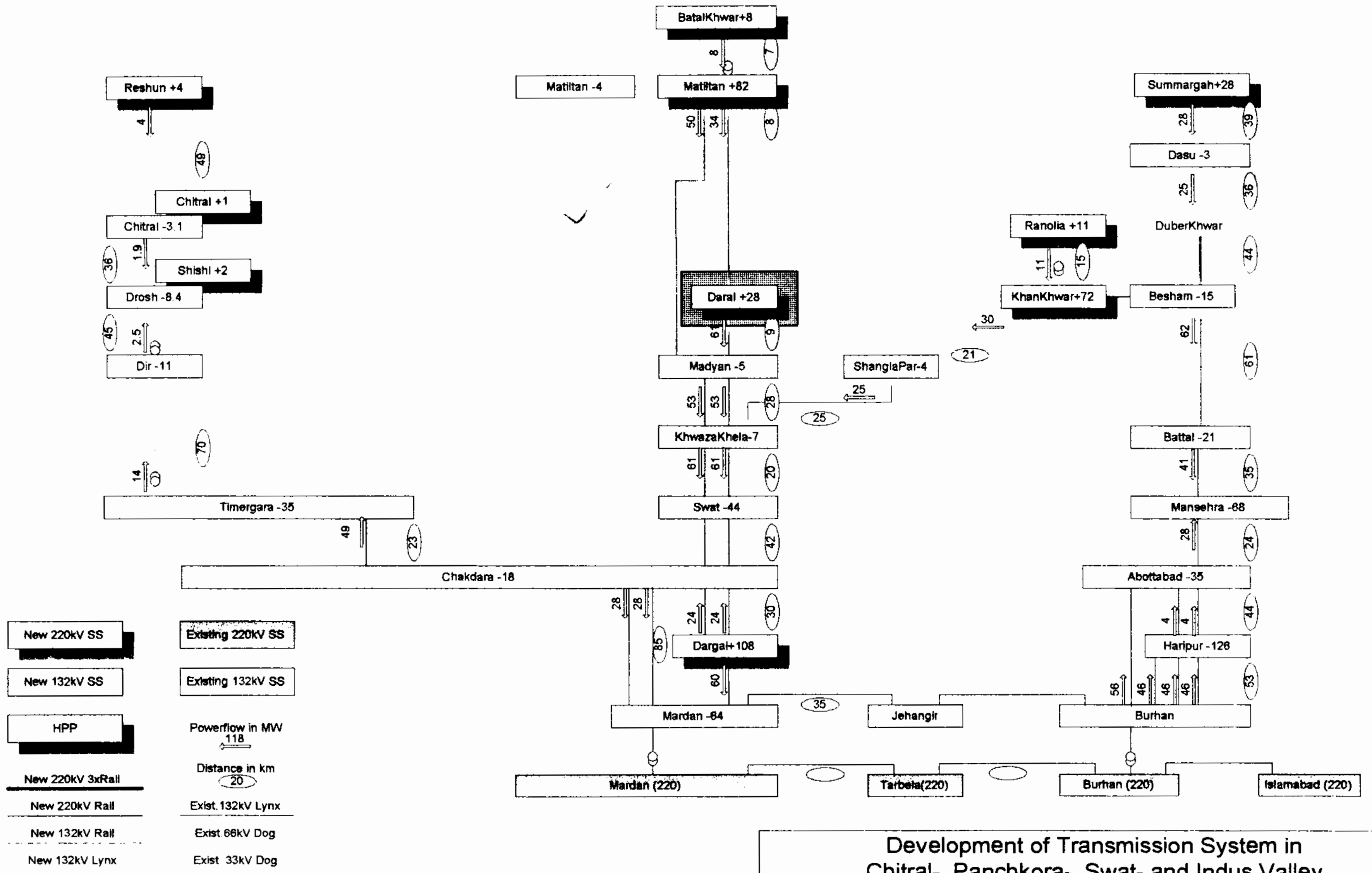

Development of Transmission System in Chitral-, Panchkora-, Swat- and Indus Valley Year 2002

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Annex 10.3.4

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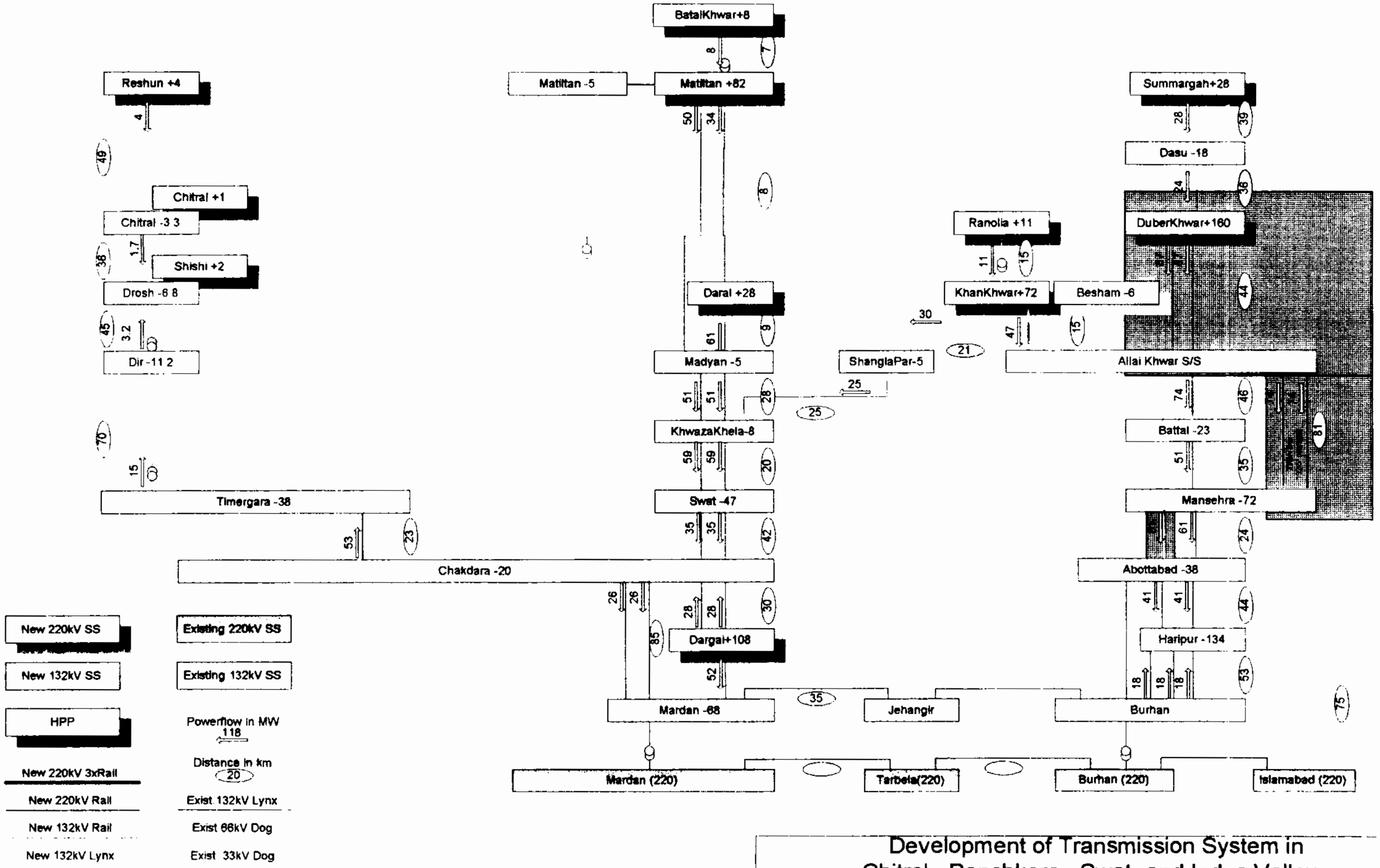
Annex 10.3.5



Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2003

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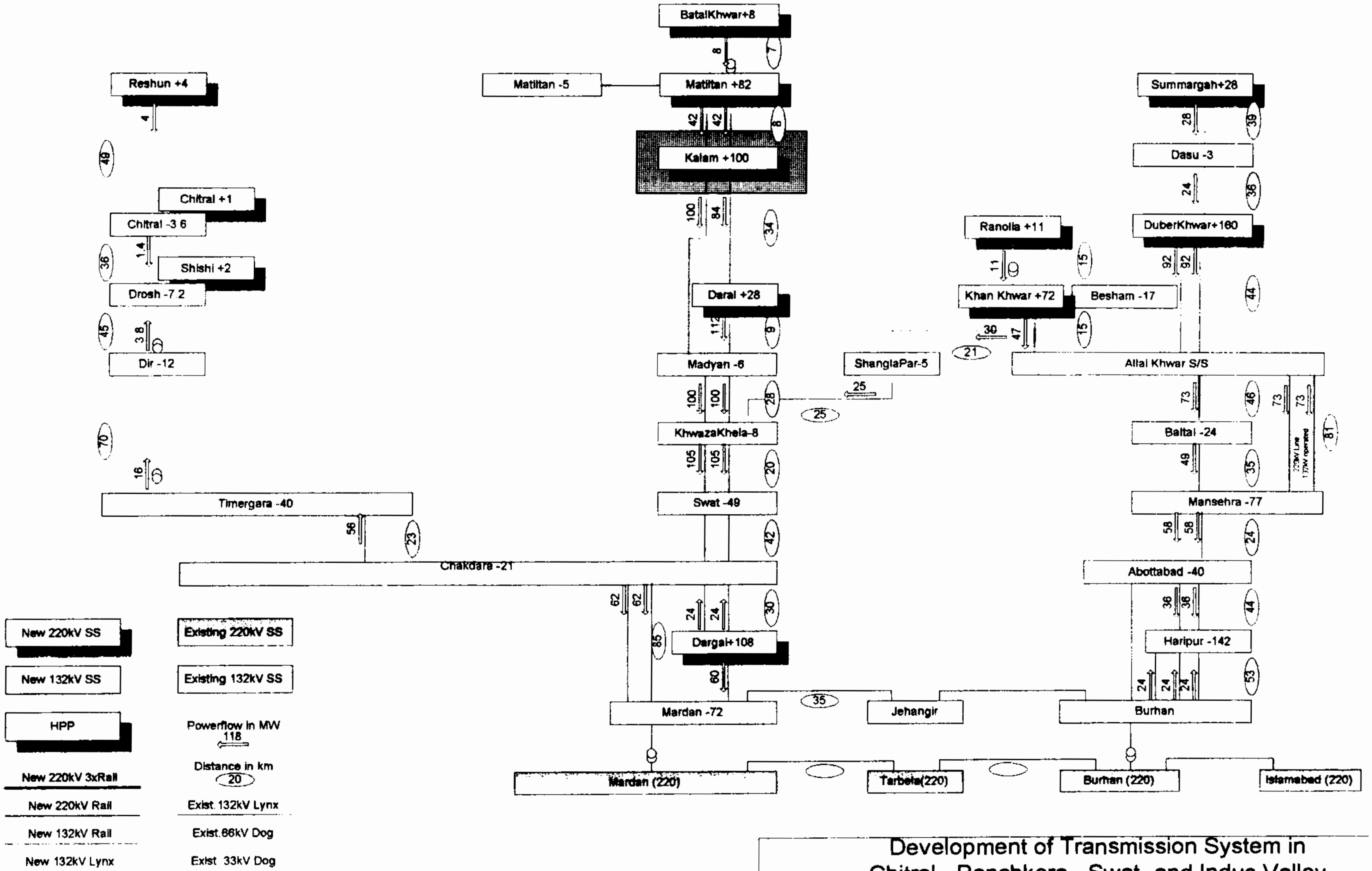

Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2004

Version3 25/07/96. Printed on 25/07/96. drawing3

Annex 10.3.6

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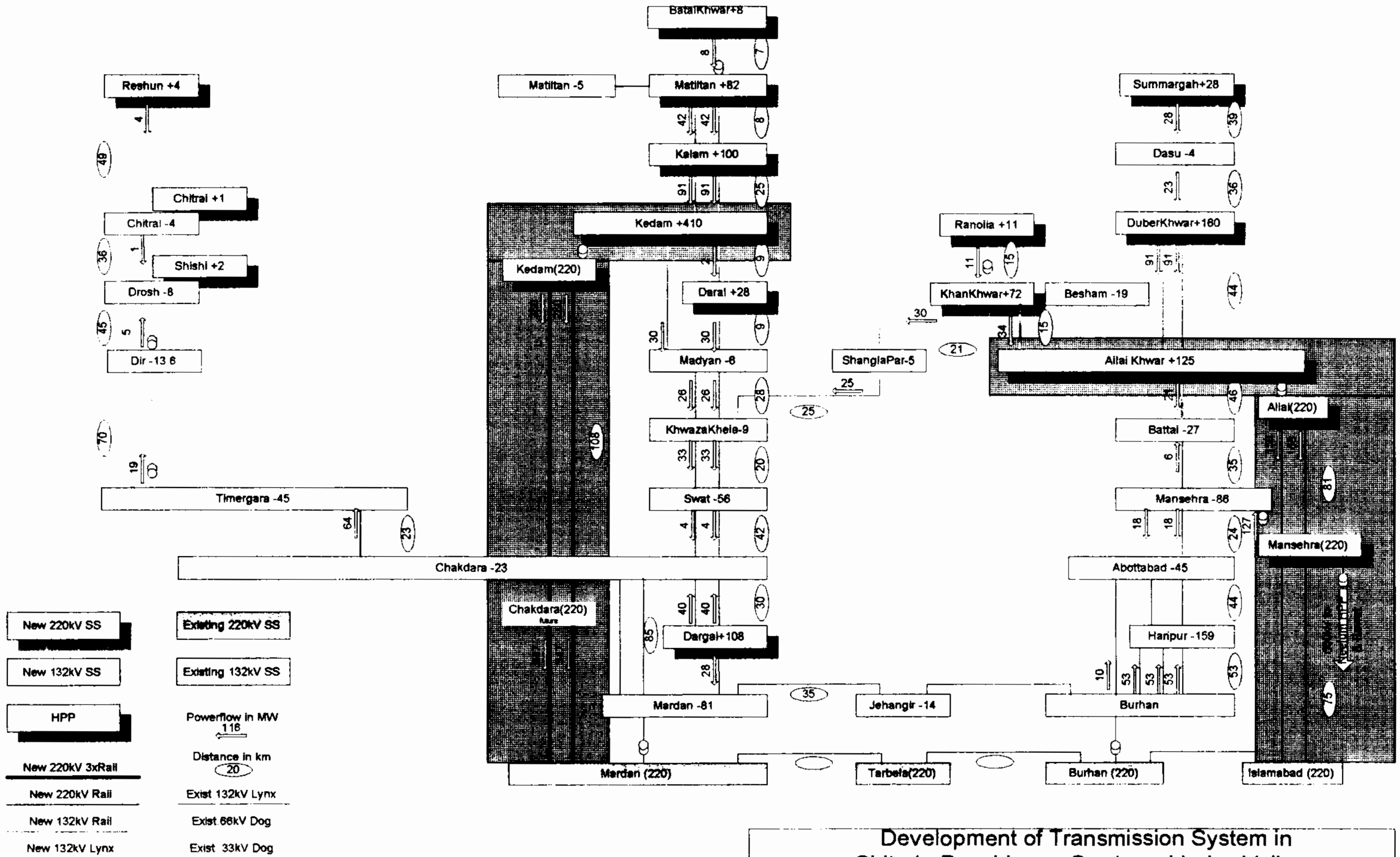

Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2006

Version3. 25/07/96. Printed on 25/07/96. drawing4

Annex 10.3.7

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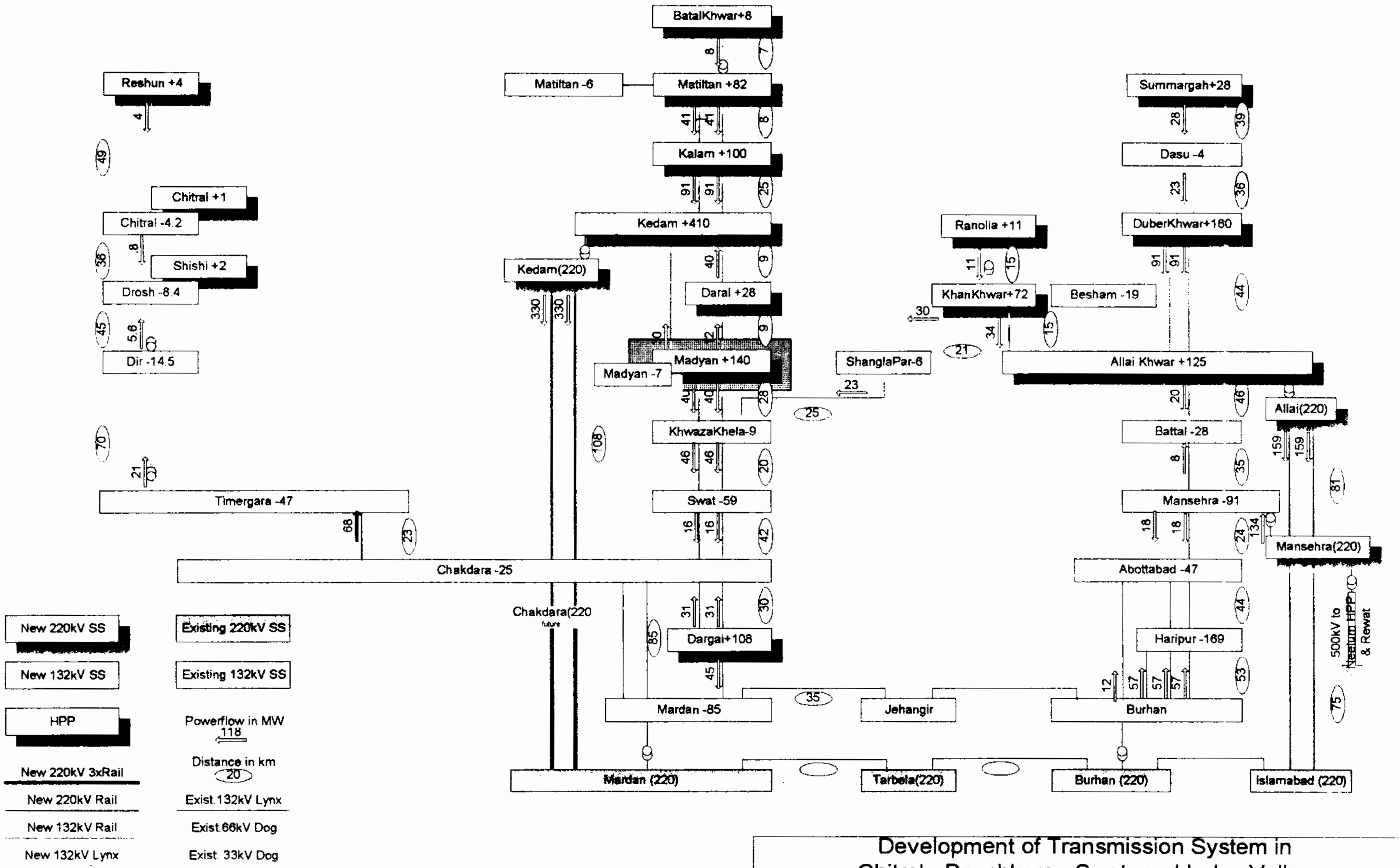

Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2007

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Annex 10.3.8

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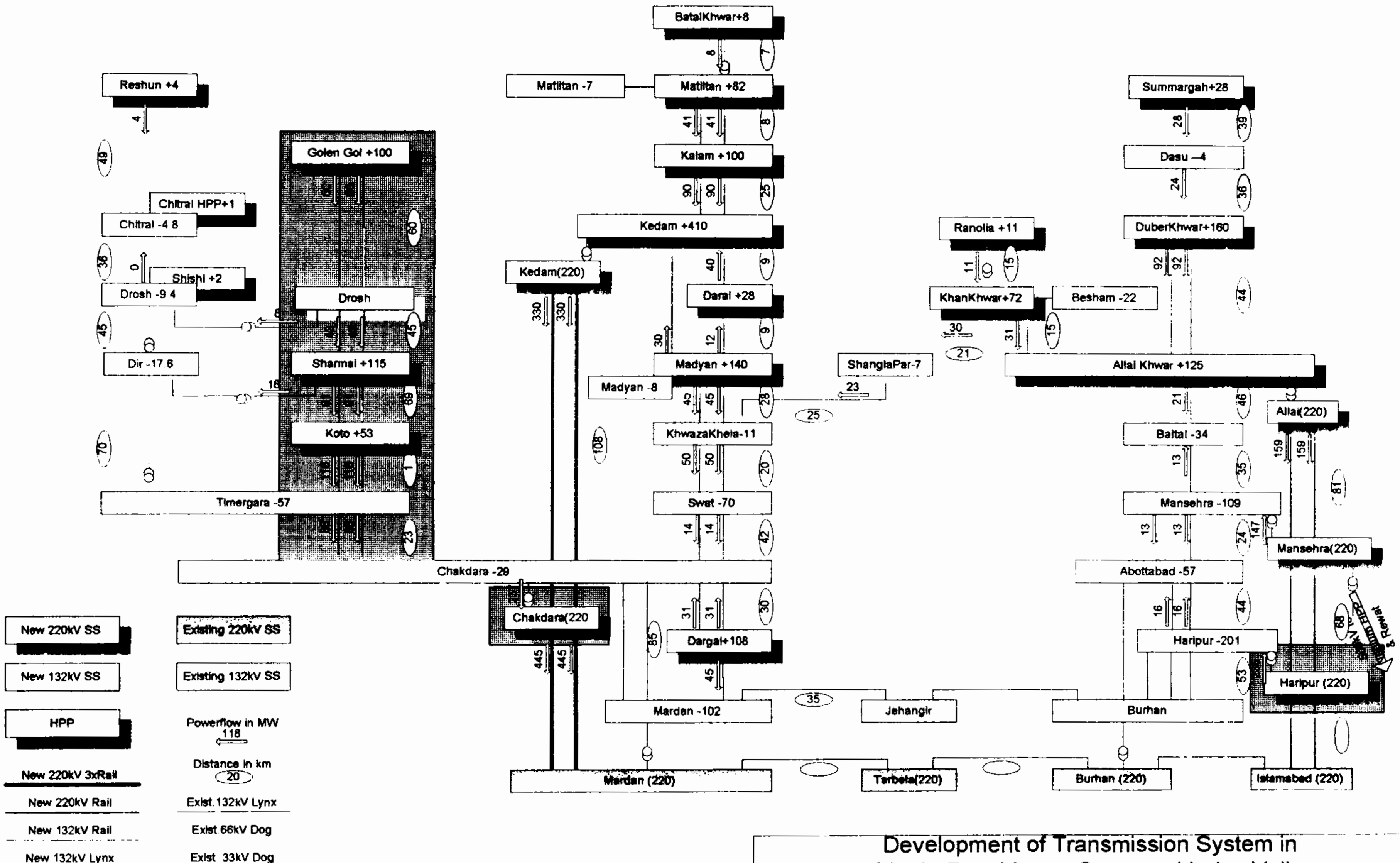

Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2010

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Annex 10.3.9

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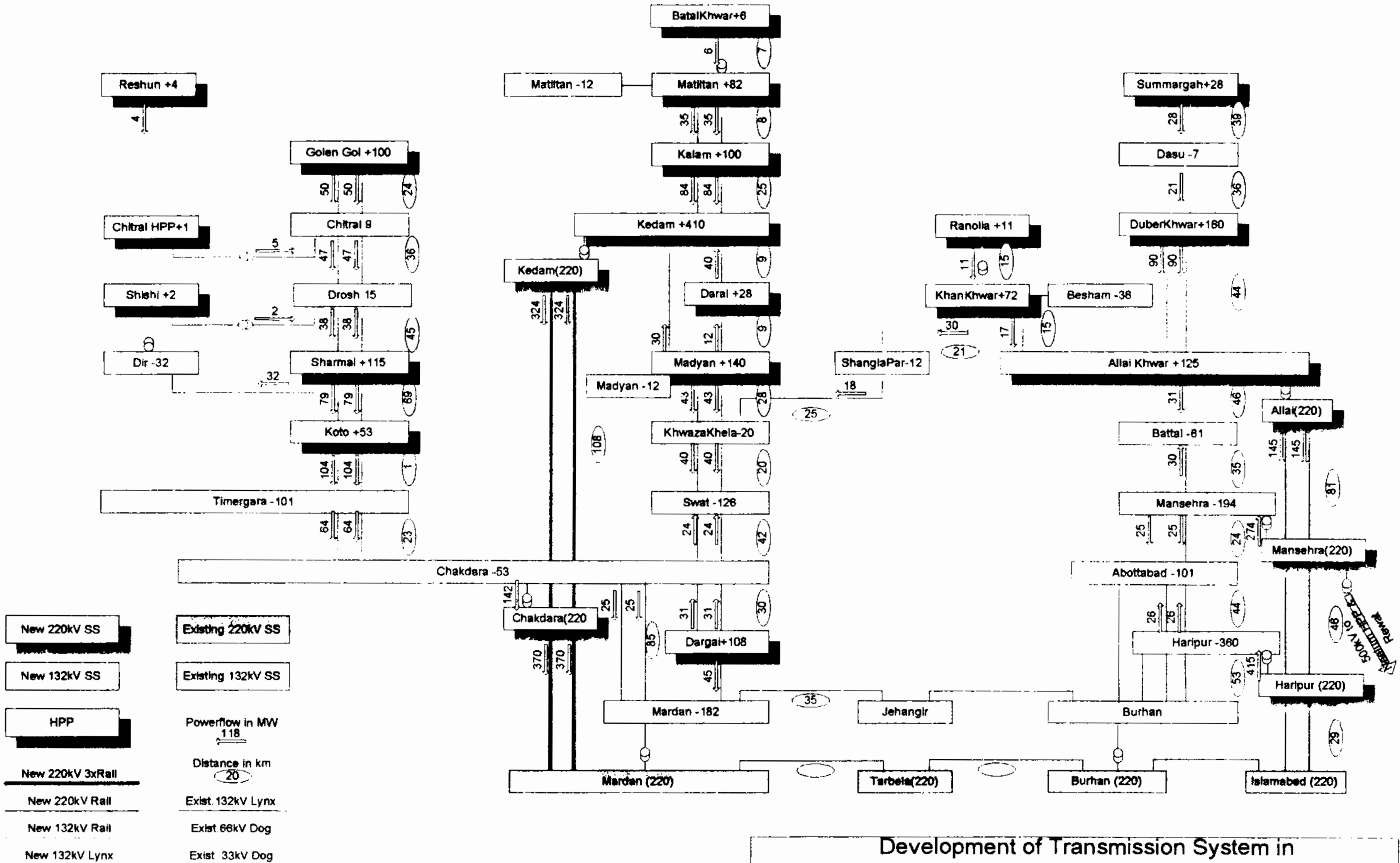
Annex 10.3.10



Development of Transmission System in
Chitral-, Panchkora-, Swat- and Indus Valley
Year 2020

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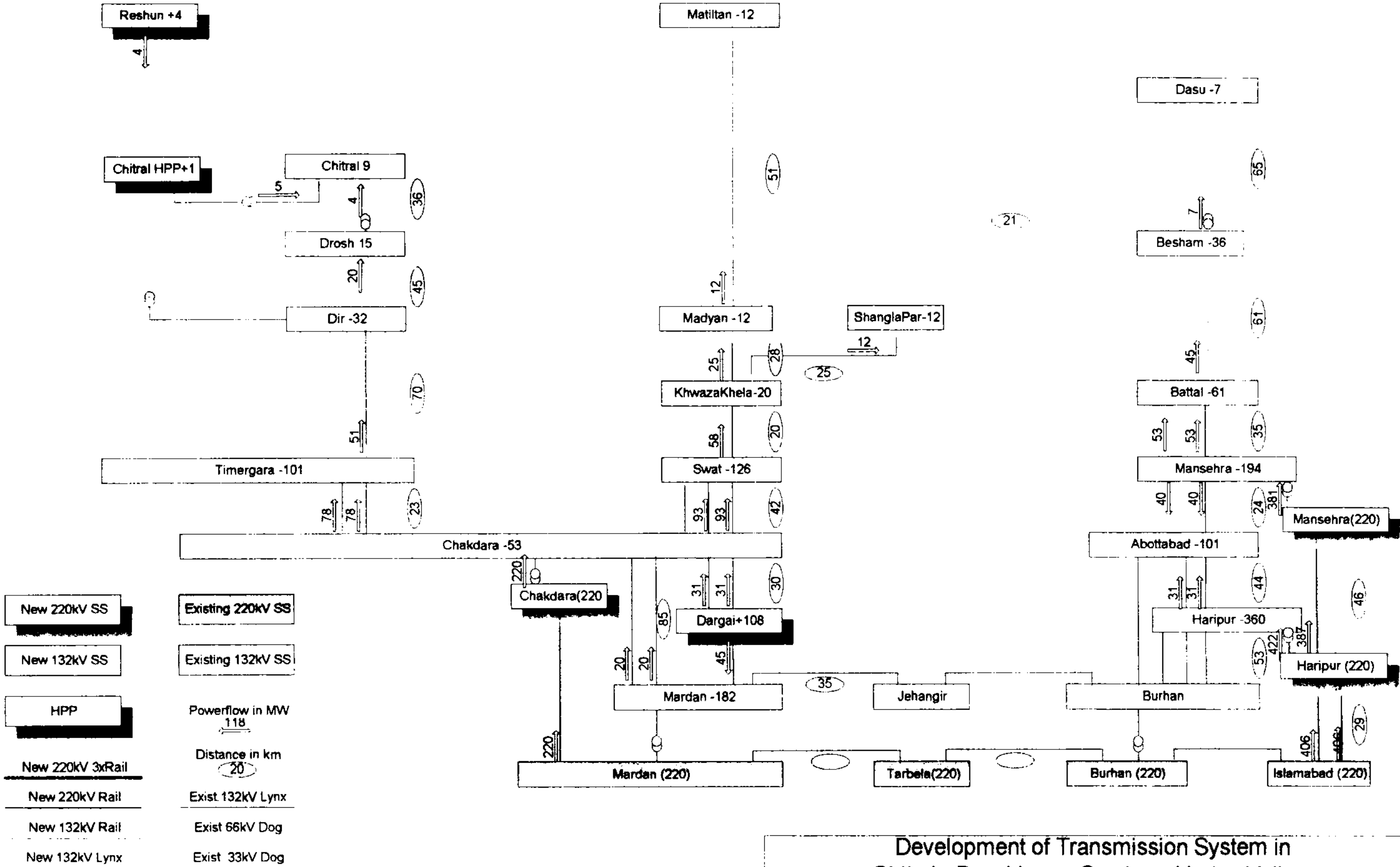
Annex 10.3.11



Development of Transmission System in Chitral-, Panchkora-, Swat- and Indus Valley Year 2020 without Hydropower Plants

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Annex 10.4.1

Evaluation and Repartition of Transmission Cost for Hydropower Plants in NWFP

System 1 — **Indus Valley**

Cost of System

from HPP	to HPP	length km	type	voltage KV	Specific cost km/k$	Investment cost k$	Discounted cost 1996 k$	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Summar Gah	Duber Khwar	75	SC Lynx	132	62	4650	3494				4650										
Duber Khwar	Allai Khwar	44	DC Rail	132	132	5808	3860				2323	1162		2323							
Allai Khwar	Battal	46	SC Rail	132	77	3542	2419					3542									
Khan Khwar	Allai Khwar	15	SC Rail	132	77	1155	789					1155									
Khan Khwar	Shangla Par	21	SC Lynx	132	62	1302	978				1302										
Mansehra	Abottabad	24	SC Lynx	133	63	1512	863							1512							
Allai Khwar	Mansehra	81	DC Rail	220	208	16848	9510							16848							
Ranolia	Khan Khwar	15	DC Dog	33	22	330	248				330										
					TOTAL	34817	22142														

Repartition of Cost

Name of HPP	Capacity MW	Distance km	Loadmoment km x MW	%	Direct Cost k$	System Cost k$	Total k$	Disc.Cost k$
Summar Gah	28	237	6636	10.79	1287	848	2135	2389
Duber Khwar	160	171	27360	44.49	5308	4844	10152	9861
Allai Khwar	125	127	15875	25.82	3080	3785	6864	5716
Khan Khwar	70	142	9940	16.16	1928	2119	4048	3679
Ranolia	11	153	1683	2.74	326	333	660	606
	394	SUM	61494	100	11929	11929	23858	22142

System 2 — **Swat Valley**

Cost of System

from HPP	to HPP	length km	type	voltage KV	Specific cost km/k$	Investment cost k$	Discounted cost 1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Battal Khwar	Matiltan	7	SC Dog	33	12	84	63				84										
Matiltan	Chakdara	141	DC Rail	132	132	18612	13963				18612										
Kedam	Chakdara	108	DC Rail	220	207	22356	9481										22356				
Chakdara	Mardan	85	DC 3xRail	221	263	15649	6636										15649				
					TOTAL	41062	30164														

Repartition of Cost

Name of HPP	Free Capacity MW	Distance km	Loadmoment km x MW	%	Direct Cost k$	System Cost k$	Total k$	Disc.Cost k$
Matiltan	85	141	11985	13.77	3257	2874	6830	4184
Kalam	100	133	13300	15.28	3614	3028	6642	4610
Kedam	410	108	44280	50.88	12032	12414	24446	15349
Daral Khwar	28	99	2772	3.19	753	848	1601	981
Madyan	150	90	13500	15.51	3668	4542	8210	4680
Battal Khwar	8	148	1184	1.36	322	242	564	410
	781	SUM	87021	100	23646	23646	47293	30164

System 3 — **Chitral & Panchkora Valley**

Cost of System

from HPP	to HPP	length km	type	voltage KV	Specific cost km/k$	Investment cost k$	Discounted cost 1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Golen Gol	Chakdara	198	DC Rail	132	132	26136	7571														26136
Chacdara	Mardan	85	DC 3xRail	221	263	6707	2844										6707				
					TOTAL	32843	10415														

Repartition of Cost

Name of HPP	FreeCapacity MW	Distance km	Loadmoment km x MW	%	Direct Cost k$	System Cost k$	Total k$	Disc.Cost k$
Golen Gol	100	321	32100	45.15	3664	3028	6691	4702
Shermal	115	246	28290	39.79	3229	3482	6711	4144
Koto	53	202	10706	15.06	1222	1605	2827	1568
	268	SUM	71096	100	8114	8114	16229	10415

Evaluation of Transmission Cost without HPP

System 1 **Indus Valley**

Cost of System

from S/S	to S/S	length km	type	voltage kV	Specific cost km/k$	Investment cost k$	Discounted cost1996 k$	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Mansehra	Battal	35	SC Lynx	132	62	2170	629														2170
Mansehra	Abottabad	24	SC Lynx	132	63	1512	1136				1512										
Mansehra	Haripur	75	SC Rail	220	90	6750	4191						6750								
Haripur	Islamabad	29	DC Rail	220	150	4350	2701						4350								
Besham	Dasu	65	SC Dog	66	50	3250	2442				3250										
Battal	Besham	61	SC Lynx	132	63	3843	2887				3843										
Battal	Mansehra	35	SC Lynx	133	64	2240	1045									2240					
					TOTAL	21875	15031														

System 2 **Swat Valley**

Cost of System

from S/S	to S/S	length km	type	voltage kV	Specific cost km/k$	Investment cost k$	Discounted cost k$	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Madyan	Matiltan	51	SC Lynx	132	62	3162	2376				3162										
Matiltan	Battal Khwar	7	SC Dog	33	12	84	63				84										
Swat	Chakdara	42	SC Rail	132	90	3780	1095														3780
Chakdara	Mardan	85	DC 3xRail	221	263	22355															
					TOTAL	7026	3534														

System 3 **Chitral & Panchkora Valley**

Cost of System

from S/S	to S/S	length km	type	voltage kV	Specific cost km/k$	Investment cost k$	Discounted cost k$	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Timergara	Chakdara	23	SC Rail	132	90	2070	600														2070
Timergara	Dir	70	SC Lynx	132	62	4340	1841										4340				
Dir	Drosh	45	SC Dog	66	50	2250	1270							2250							
					TOTAL	2070	3710														

Summary

		Investment cost k$	Discounted cost k$
System 1		21875	15031
System 2		7026	3534
System 3		2070	3710
	TOTAL	**30971**	**22274.8**

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11.1 BASIS OF ESTIMATES

The cost estimates have been established on the basis of the Feasibility Design of Daral Khwar Hydropower Project.

The basic construction cost of the hydropower scheme is divided into main groups as

- Preliminary Works
- Civil Works
- Hydraulic Steel Works
- Hydro-mechanical Equipment
- Electrical Equipment
- Transmission System
- Engineering and Administration
- Other Costs

The basic construction cost estimate contains all work and supply items included in the construction of permanent project works, investigation and planning costs, engineering and administration services and the cost of all preliminary works.

A contingency allowance is included as a separate item in the estimate for each project component. The purpose of this allowance is to cover minor differences between actual and estimated quantities, unforeseen items of work, possible minor changes and other contingencies.

Finally, as foreign investment would be needed, the cost estimate was split into foreign and local components, which vary with the individual items.

11.1.1 Preliminary Works Cost

See **Table A** Cost Estimate of Preliminary Works.

Preliminary works comprise of the following:

a) Environment Impact Mitigation Cost

- Compensation for trees and houses.
- Disposal of excavated material with landscaping and plantation
- Rehabilitation of quarry with landscaping and plantation
- Improvement of water supply system and sewerage system of Bahrain town
- Providing sewerage disposal for the houses downstream of the weir
- Providing power transmission lines to the two water mills, providing electric motors couplings and other items for conversion
- Monitoring of quality of water supply over the plant life
- Land acquisition

The environmental impact mitigation cost has been derived from the Environmental Impact Assessment report (**Appendix 6** of the Feasibility Study)

Total Cost <u>622,000 US $</u>

b) Cost of the Access Roads to the Main Work Sites

- Access Roads to the Weir Area

A new permanent access road to the weir area with a length of approximately 3,600 m is recommended for construction and maintenance purposes only.

Total Cost: <u>500,000 US $</u>

Table A
Preliminary Works Cost

Price Level 1997 42.00 Rs/US$

ITEM	STRUCTURE	Cost in 1000 US$		
		Local	Foreign	Total
A1	**INITIAL AND ANNUAL ENVIRONMENTAL MITIGATION COST**	**622.00**	**0.00**	**622.00**
A11	Compensation of trees	5.00	0.00	5.00
A12	Disposal of excavated material with landscaping and plantation	30.00	0.00	30.00
A13	Rehabilitation of quarry with landscaping and plantation	8.00	0.00	8.00
A14	Improving water supply system and sewerage system of Bahrain town	240.00	0.00	240.00
A15	Providing sewerage disposal for the houses downstream of the weir	24.00	0.00	24.00
A16	Cost of providing power transmission lines to the two water mills, providing electric motors, couplings and other items for conversion	5.00	0.00	5.00
A17	Monitoring of quality of water supply over the plant life	30.00	0.00	30.00
A18	Land acquisition	280.00	0.00	280.00
A2	**ACCESS ROADS TO THE MAIN WORKS SITES**	**1005.00**	**0.00**	**1005.00**
A21	New access road to the weir site, 3.6 km	500.00	0.00	500.00
A22	New access road to the access tunnel, penstock tunnel, surge tank area, 2 km	280.00	0.00	280.00
A23	New access road to the powerhouse down to elevation 1420 masl, 0.4 km	70.00	0.00	70.00
A24	Improvement of existing roads to project sites, 2.2 km	155.00	0.00	155.00
A3	**COST OF TRANSPORTING HEAVY LOADS, DARGAI-BAHRAIN**	**155.00**	**0.00**	**155.00**
A31	Hire of special trailer and tractor unit	15.00	0.00	15.00
A32	Hire of heavy cranage for loading/unloading	10.00	0.00	10.00
A33	Fabrication of barge unit c/w cables, transporting and setting up	90.00	0.00	90.00
A34	Improvement of temporary access roads to Swat river water edges at Madyan	20.00	0.00	20.00
A35	Strengthening of old masonry bridges and culverts / subsequent repair if necessary	20.00	0.00	20.00
A4	**CAMPS AND HOUSING DURING CONSTRUCTION**	**270.00**	**0.00**	**270.00**
A41	Camps and housing for the construction and supervisory staff	270.00	0.00	270.00
	SUBTOTAL	2052.00	0.00	2052.00
	10 % CONTINGENCIES	205.20	0.00	205.20
	TOTAL COST OF PRELIMINARY WORKS	**2257.20**	**0.00**	**2257.20**

Price escalation and interest during construction are not included

- Access Roads to the Access Tunnel and Penstock Tunnel Platforms, and Surge Tank

A new permanent access road to the access tunnel and penstock tunnel working platforms and a road branch to the surge tank area with a combined length of approx. 2,000-m is recommended for construction and maintenance purposes.

Total Cost: 280,000 US $

- Access Road to the Powerhouse Site

A new permanent access road to the powerhouse area with a length of approx. 400 m is recommended for construction and maintenance purposes.

Total Cost: 70,000 US $

- Improvement of Exiting Roads to the Project Sites

Improvement of the alignment and widening of the route of the exiting roads to the weir area and towards the access tunnel platform of the headrace tunnel with a length of approx. 1,200 m and 1,000 m respectively is required to facilitate the traffic during construction

Total Cost: 155,000 US $

c) Cost of Transporting Heavy Loads from Dargai to Bahrain

- Hire of special tractor and tractor unit
- Hire of heavy cranage for loading / unloading
- Fabrication of barge unit c/w cables, transporting and setting up
- Improvement of temporary access roads to Swat river shores at Madyan
- Strengthening of old masonry bridges and culverts and subsequent repair if necessary

The cost of transporting heavy loads from Dargai to Bahrain has been derived from **Chapter 9** of this study "Transport and Access Facilities"

Total Cost 155,000 US $

d) Camps and Housing for the Construction and Supervisory Staff

Based on the experience gathered from other similar hydropower projects, the cost of camps and housing for the construction and supervisory staff is estimated as follows:

The required area is about 2,700 m^2., and the

Total Cost: 270,000 US $

e) Total Cost of Preliminary Works

Sub Total from a) to d)	2,052,000 US$
10% Contingency	205,200 US$
Total Cost of Preliminary Works	**2,257,200 US$**

Preliminary works are considered to be 100% local currency.

11.1.2 Civil Works Cost

See: **Appendix 11** Cost Estimate Civil Works,

Table B Compilation of Cost Estimates for Civil Works

Based on the engineering design of the project, the quantities have been calculated for the individual work items.

Table B
Compilation of Cost Estimates for Civil Works

Price Level 1997 42.00 Rs/US$

ITEM	STRUCTURE	Cost in 1000 US$		
		Local	Foreign	Total
	WEIR AND INTAKE	**1005.41**	**782.68**	**1788.09**
B11	Site installation and river diversion	87.54	200.39	287.93
B12	Weir	852.48	531.83	1384.31
B13	Lateral intake	65.38	50.46	115.85
	CONDUIT SYSTEM	**3606.22**	**7016.80**	**10623.02**
B21	Connection tunnel and gravel spill	61.69	127.54	189.23
B31	Sandtrap	797.78	338.30	1136.08
B32	Headrace canal	62.68	56.10	118.78
B41	Headrace tunnel	1997.17	5172.65	7169.81
B42	Access tunnel	142.19	340.43	482.62
B43	Working platform of the access tunnel	7.94	51.00	58.95
B51	Surge tank	293.90	523.53	817.42
B52	Penstock tunnel	58.61	137.87	196.48
B53	Valve chamber and penstock anchor block	82.27	61.53	143.80
B54	Working platform penstock tunnel and valve chamber	6.10	32.44	38.53
B61	Penstock excavation works	95.89	175.42	271.31
	POWERHOUSE AND TAILRACE STRUCTURES	**1141.42**	**1097.34**	**2238.75**
B71	Site installation, excavation and protection work	162.75	612.48	775.24
B71	Concrete works	782.93	387.88	1170.81
B72	Finishing / internal works	195.73	96.97	292.70
	ADDITIONAL WORKS	**373.50**	**0.00**	**373.50**
B81	Permanent residential buildings / stores /workshops	373.50	0.00	373.50
	SUBTOTAL	6126.55	8896.82	15023.37
	15 % CONTINGENCIES	918.98	1334.52	2253.50
	TOTAL COST CIVIL WORKS	**7045.53**	**10231.34**	**17276.87**

Price escalation and interest during construction are not included

The computed unit prices include the cost of labour, material and equipment, with due consideration for the local conditions. Each item has been calculated for local and foreign currency. The main structures have been subdivided as follows:

- Weir and Intake
- Conduit System
- Powerhouse
- Other Works

This has been done as there would be different contracting companies which would be interested in different aspects of the project.

Contingencies for the civil works were taken as 15% of the basic cost which reflects uncertainties of conditions and minor changes of work.

Total Cost of Civil Works	**17,276,871 US$**	(100%)
Local Components	7,045,530 US$	(41%)
Foreign Components	10,231,341 US$	(59%)

Compilation of cost estimates for civil works is enclosed in this chapter as **Table B.**

Some examples of estimated unit rates (price level 1997) for civil works of main structures are listed as follows:

(Contingencies of 15% as considered for civil works are not included in these unit rates).

- **River Diversion, Weir Structure**

Cofferdams	8	US$/m^3
Rock excavation	11	US$/m^3
Provision and placing of concrete	80-90	US$/m^3
Provision and placing for formwork	18-22	US$/m^2
Provision and bending of steel bar	650	US$/tonne

- **Sandtrap**

Sandtrap total length	90	m
Effective cross-sectional area	62.50	m^2
Excavation, reinforced concrete, protection works	12,623	US$/m

- **Headrace tunnel**

Tunnel length	3044	M
Cross-sectional area	8.34	m^2
Excavation, support and concrete lining	2,356	US$/m

- **Surge tank**

Vertical chamber height	35	m
Cross-sectional area	113.1	m^2
Excavation, support and concrete lining	23,355	US$/m

- **Penstock**

Length	900	m
Diameter	2.00	m^2
Excavation, steel pipe, support, cradle and cover	3,635	US$/m

- **Powerhouse and tailrace**

Excavation powerhouse pit including support	13	US$/m^3
Provision and placing of concrete powerhouse	90	US$/m^3
Provision and placing formwork powerhouse	18-22	US$/m^2
Provision and bending of steel bar	650	US$/tonne

11.1.3 Cost of Hydraulic Steel Works

See **Table C**

Based on the engineering design and the hydraulic steel works - layout presented in **Chapter 8.2** of this study, a cost estimation of the complete hydraulic steel structures has been undertaken.

Weights and prices of the hydraulic steel structures have been estimated on the basis of carefully analysed supplier-tenders and available characteristic indices from the European market for similar equipment.

Taking account of the international market situation and the local site condition of the Daral Khwar Project, particularly the cost proportion of transport and assembly works have been increased.

It is assumed, that some smaller components of particular items can be delivered by local companies. The corresponding figures are listed in table C.

The cost estimate has been subdivided in the main structures as follows:

- **Weir** Total cost 136,080 US$
  * Flushing gate with two sections horizontally split.(1 unit)
  * Stop logs (1 set)
  * Gantry crane for placing and lifting of the stop logs (1 unit)
  * Steel lining, armour protection for the weir overflow section, intake and flushing gate sections

- **Intake and Gravel Spilling Structure** Total cost 83,633 US$
  * Trash racks (4 sets)
  * Stop logs (4 units)
  * Spilling gate of the intake gate (1 unit)
  * intake gate (1 unit)
  * Flushing gate of the gravel spilling structure (1 unit)

- **Sand trap** Total cost 154,508 US$
  * Inlet gate (2 units)
  * Fine trash rack (2 units)
  * Outlet gate (2 units)
  * Flushing gate (2 unit)

- **Valve Chamber** Total cost 151,200 US$
  * Maintenance valve (1 unit)
  * Emergency valve (1 unit)
  * Drainage and ventilation valves
  * Crane of 10 tonne and 9.5 m width (1 unit)

- **Access Tunnel** Total cost 12,600 US$
  * Tunnel door 1.8 m x 1.8 m (1 unit)

- **Penstock** Total cost 3,150,000 US$
  * Steel penstock 913 m length , 2 diameter
  * Manifold

- **Powerhouse** Total cost 151,200 US$
  * Crane 30 tonne, m (1 unit)

Table C
Hydraulic Steel Works Cost

ITEM	STRUCTURE	Cost in 1000 US$		
		Local	Foreign	Total
C10	**WEIR, INTAKE**	**125.00**	**30.00**	**155.00**
C101	Flushing gate 4m x 2.5m x 2	25.00	15.00	40.00
C102	Stop logs 4m x 5m x 1	16.00	0.00	16.00
C103	Trash rack 2.6m x 1.1m-2m x 4	10.00	0.00	10.00
C104	Stop logs 2.6m x 2m x 4	16.00	0.00	16.00
C105	Spilling gate 1m x 2m x 1	4.00	0.00	4.00
C106	Intake gate 4m x 3.25m x 4	10.00	15.00	25.00
C107	Flushing gate 1m x 2m x 1	4.00	0.00	4.00
C108	Steel lining 18 tonne	40.00	0.00	40.00
C20	**SANDTRAP**	**89.00**	**20.00**	**109.00**
A201	Inlet gate 5m x 2.8m x 2	37.00	13.00	50.00
A202	Fine rack 5m x 2.6m x 2	26.00	0.00	26.00
A203	Outlet gate 4m x 3.2m x 2	18.00	7.00	25.00
A204	Flushing gate 1m x 1.8m x 2	8.00	0.00	8.00
C21	**VALVE CHAMBER**	**20.00**	**110.00**	**130.00**
A211	Maintenance butterfly valve Di=2m, 5bar	0.00	40.00	40.00
A212	Emergency butterfly valve Di=2m, 5 bar	0.00	40.00	40.00
A213	Drainage and ventilation valves	0.00	10.00	10.00
A214	Tunnel door 1.8m x 1.8m	10.00	0.00	10.00
A215	Crane 10 tonne, 9.5 m	10.00	20.00	30.00
C22	**PENSTOCK**	**2350.00**	**150.00**	**2500.00**
A221	Penstock pipe Di=2m, m	2200.00	100.00	2300.00
A222	Distribution pipe	150.00	50.00	200.00
C30	**POWER HOUSE**	**40.00**	**80.00**	**120.00**
C301	Crane 30 tonne, m	40.00	80.00	120.00
	SUBTOTAL 1	2624.00	390.00	3014.00
	TRANSPORT COST 5% OF SUBTOTAL 1	131.20	19.50	150.70
	ERECTION COST 15% OF C21, C22, C30	372.50	40.00	412.50
	ERECTION COST 30% OF C10, C20	70.20	9.00	79.20
	SUBTOTAL 2	3197.90	458.50	3656.40
	CONTINGENCIES 5% OF SUBTOTAL 2	159.90	22.93	182.82
	TOTAL COST OF HYDRAULIC STEEL WORKS	**3357.80**	**481.43**	**3839.22**

11.1.4 Hydro-mechanical Equipment Cost

Based on the hydro-mechanical layout of the project and the description in **Chapter 8.3** of this study, the hydro-mechanical equipment comprises 2 Francis turbines including bifurcation, inlet valves, draft tubes, govemors, auxiliary mechanical equipment and additional 1 Pelton turbine.

A cost estimation of the complete hydro-mechanical equipment has been undertaken.

It is known that mechanical equipment such as hydraulic turbines, valves and governors are quoted by the suppliers at rates which vary by 100% depending on the market situation.

In the case of this Daral Khwar the prices have been estimated after careful analysis and on base prices mainly taken from recent tenders on the European market.

Because of no existing own production recourses in Pakistan, a 100 % foreign delivery of the complete hydro-mechanical equipment has been assumed.

- **Francis turbines**, 2 units, 6.25 m^3/s each Total cost 2,739,240 US$
  - Bifurcation, asymmetric, 2.0 m inlet diameter, approx. 1.1 m outlet diameter
  - Inlet valves, 1.1 m nominal diameter, spherical valves with double acting servo-motors operated by oil pressure, bypass pipe included
  - Spiral casing with fixed stay vanes, adjustable guide vane mechanism for flow regulation moved by hydraulic servo-motors
  - Shaft, turbine runner, guide bearings - vertical support by thrust bearings in the generators
  - Draft tube
  - Govemor, 2 electro-hydraulic control units with hydraulic oil pressure supply system
  - Auxiliary mechanical equipment
    dewatering-, cooling- and ventilation systems, workshop-, oil handling- and fire fighting equipment.

- **Pelton turbine**, 1 unit, 2.5 m^3/s Total cost 650,160 US$
  including casing, runner, turbine shaft, fly wheel, nozzles, bifurcation pipe, inlet valve and govemor.

Table D
Hydro Mechanical Equipment Cost

ITEM	STRUCTURE	Cost in 1000 US$		
		Local	Foreign	Total
D100	**FRANCIS TURBINE, 2 UNITS, 6.25 m^3/s each**	**0.00**	**2174.00**	**2174.00**
D101	Bifurcation	0.00	97.00	97.00
D102	Inlet valve	0.00	219.00	219.00
D103	Spiral case	0.00	410.00	410.00
D104	Guide-vane mechanism	0.00	1033.00	1033.00
D105	Shaft	0.00	24.00	24.00
D106	Runner	0.00	120.00	120.00
D107	Bearing	0.00	37.00	37.00
D108	Sealing	0.00	12.00	12.00
D109	Draft tube (bend)	0.00	42.00	42.00
D110	Governor	0.00	153.00	153.00
D111	Auxiliary mechanical equipment	0.00	27.00	27.00
D200	**PELTON TURBINE, 1 UNIT, 2.5 m^3/s**	**0.00**	**516.00**	**516.00**
D201	Turbine complete with governor	0.00	451.00	451.00
D202	Inlet valve	0.00	65.00	65.00
	SUBTOTAL 1	0.00	2690.00	2690.00
	Transport Cost 5% of Subtotal 1	120.00	14.50	134.50
	Erection Cost 15% of Subtotal 1	120.00	283.50	403.50
	SUBTOTAL 2	240.00	2988.00	3228.00
	Contingencies 5% of Subtotal 2	12.00	149.40	161.40
	TOTAL COST OF HYDROMECHANICAL EQUIPMENT	**252.00**	**3137.40**	**3389.40**

11.1.5 Electrical Equipment Cost

See **Table E**

Based on the electrical layout presented in **Chapter 8.4** of this study, a cost estimation of the complete electrical equipment has been undertaken.

It is known that equipment such as Generators, Transformers and Switchgear are quoted by the suppliers at rates, which vary by 200% depending on the market situation. In countries without an own production of the equipment in question, as it is the case in Pakistan, prices are usually at the lower end of the scale.

In the cost estimate of Daral Khwar the prices have been elaborated after careful analysis and on base prices mainly taken from recent tenders of WAPDA for equal or very similar equipment.

If must be understood, that restriction upon access to the international markets may increase cost of the concerned items significantly (up to 3 times).

The estimate has be structured in the generic items of:

- Generators — Total cost 2.08 Mio. US$
  Including the two generators of 18 MVA each and one generator of 7.5 MVA
- Transformers — Total cost 0.368 Mio. US$
  Including two Transformers of 26 MVA each, and two auxiliary transformers.
- 132 kV Switchgear — Total cost 0.395 Mio. US$
  Including all equipment for the 132 kV switchyard as specified and presented in the drawings
- 11 kV Switchgear — Total cost 0.479 Mio. US$
  Including all 11 kV equipment needed in the powerhouse and intake area with cubicles, cables and accessories as specified and presented in the drawings.
- Low Voltage and DC supply — Total cost 0.551 Mio. US$
  Including the whole lot of 0,4 kV AC and 110 V DC equipment needed in the powerhouse and intake.
- Control, Alarm, Protection Telecommunication and Watches — Total cost 1.884 Mio. US$
  Including all relevant equipment to ensure the safe operation of the plant
- Lighting and Small Power and Emergency Diesel — Total cost 0.378 Mio. US$
  Including all items according to the specifications laid down in the description and drawings.
- Various — Total cost 0.935 Mio. US$
  This item sums up all other equipment needed for a proper operation of the plant such as Fire Alarm and Fighting Equipment, Earthing system Main cooling system of the main Generators, Transformers and Powerhouse Climatization, Cables, Rocks, Spare parts and other small items not specifically considered.

The cost of the electrical equipment sums up to 7.070 Mio. US$

Contingencies of 5% (including price and physical contingencies)have to be added.

The total cost, inclusive of contingencies,
of the electrical equipment has been estimated as: **7.424 Mio. US$**

out of which 18% correspond to local cost and 82% correspond to foreign cost.

Table E
Electrical Equipment Cost

Price Level 1997 42.00 Rs./US$

No.	Structure and Pay Items	Cost in 1000 US$ Local	Foreign	Total
E1000	**E1 - Generator**	**130**	**1950**	**2080**
E1100	Delivery of Generators 18 MVA each	0	1200	1200
E1101	Transport to site	60	60	120
E1102	Erection	40	200	240
E1103	Commissioning	15	60	75
E1200	Delivery of generator 7.5 MVA	0	400	400
E1201	Transport	5	10	15
E1202	Erection & Commissioning	10	20	30
E2000	**E2 - Transformers**	**65**	**03**	**368**
E2100	2 Block Transformers, 26 MVA each	40	300	340
E2101	Delivery of transformers	0	260	260
E2102	Transport to site	30	30	60
E2103	Erection & commissioning	10	10	20
E2200	Auxiliary Transformers	25	3	28
E2210	Delivery of Powerhouse Transformers	10	0	10
E2220	Delivery of intake Transformers	5	0	5
E2201	Transport to site	0	1	1
E2202	Erection & Commissioning	10	2	12
E3000	**E3 - 132 kV Switchgear**	**65**	**330**	**395**
E3010	Delivery Circuit Breakers	0	140	140
E3020	Delivery Isolator	0	35	35
E3030	Delivery Voltage Transformer	0	36	36
E3040	Delivery Current Transformer	0	48	48
E3050	Delivery Surge arrester	0	36	36
E3060	Delivery Gantry	15	0	85
E3070	Delivery other	15	15	30
E3080	Civil Works	15	0	15
E3001	Erection & Commissioning	20	20	40
E4000	**E4 - 11 kV Switchgear**	**237**	**242**	**479**
E4110	Delivery Powerhouse panels	100	170	270
E4120	Delivery Intake panels	30	50	80
E4200	Delivery cables	25	5	30
E4201	Transport cables	1	0	1
E4300	Accessories	1	1	2
E4001	Erection and commissioning	20	4	24
E4400	11kV line powerhouse intake	60	12	72

Contin'd......

Table E
Electrical Equipment Cost

Price Level 1997 42.00 Rs./US$

No.	Structure and Pay Items	Cost in 1000 US$		
		Local	Foreign	Total
E5000	**E5 - Low Voltage & DC Supply**	**111**	**440**	**551**
E5110	Delivery 0.4 kV Panels	0	352	352
E5120	Delivery 0.4 kV Cables & Accessories	20	5	25
E5101	Erection & commissioning	40	12	52
E5210	Delivery 110 V, 1100 Ah DC Supply	40	60	100
E5220	Delivery 110 V, 250 Ah DC Supply	6	10	16
E5201	Erection & Commissioning	5	1	6
E6000	**E6 - Control, alarm, protection, telecommunication &**	**164**	**1720**	**1884**
	watches			
E6100		100	1400	1500
E6201	Supply, Erection & Commissioning of control and alarm system	7	150	157
E6202	Delivery to site of protection	20	20	40
	Erection & Commissioning			
E6310		0	60	60
E6320	Delivery power line carrier	5	0	5
E6330	Delivery public exchange	5	5	10
E6340	Delivery radio	5	60	65
E6350	Delivery fiber optic link to intake	2	5	7
E6301	Delivery watches	20	20	40
	Erection & Commissioning			
E7000		**194**	**184**	**378**
	E7 - Lightning & small power and emergency diesel			
E7101		65	40	105
E7102	Delivery Lighting & Small Power	100	10	110
	Erection & Commissioning			
E7211		10	100	110
E7212	Delivery to site 250 kW Diesel Set	15	8	23
E7231	Erection & Commissioning	2	25	27
E7232	Delivery to Site 40 kW Diesel Set	2	1	3
	Erection & Commissioning			
E8000		**330**	**605**	**935**
	E8 - Various			
E8100		10	60	70
E8200	Fire Alarm System	10	50	60
E8300	Fire Fighting Equipment	25	25	50
E8400	Earthing System	20	80	100
E8500	Main Cooling System	--	--	--
E8600		--	--	--
E8700		40	40	80
E8800	Cables &racks	25	200	225
E8900	Spare parts	200	150	350
	Other			
		1296	5774	7070
	Subtotal for E electrical equipment			
		65	289	354
	5 % contingency			
		1361	**6063**	**7424**
	Total cost for electrical equipment			

11.1.6 Transmission System

See **Table F**

With reference to chapter 10 of this study the investment cost for all works needed to interconnect Daral Khwar HPP to the national grid have been estimated.

On the commissioning date of Daral Khwar the lines to Matiltan will exist as Matiltan HPP will have been commissioned as proposed in 2000. Only the cost of opening one circuit and connecting of two line ends to Daral Khwar HPPP have to be considered.

The 132 kV switchgear for the outgoing feeders in Daral Khwar have been considered in Table E. Electrical Equipment. Prices are based on WAPDA contacts brought to 1997 price level.

- Interconnection with Matiltan HPP and Madyan Grid Station: 0.100 Mio. US$
- **Total investment cost** **0.100 Mio. US$**

It is important to point out once more that the cost figures given above and in Table F represent the investment needed to connect Daral Khwar HPP to the System. The Economic cost of interconnection of Daral Khwar ascending to 1.60 Mio. US$ have been elaborated and explained in Chapter 10 of this study.

11.1.7 Engineering and Administration Costs

Engineering and Administration was taken to include the requirements of foreign and local consultants to do further site investigations, the detailed design, the preparation of tender and contract documents and supervision of the construction works. The cost of these activities was taken as 6% of the engineering works, excluding the preliminary works. Engineering costs for the preliminary works were assumed to be included in the costs of these works.

Engineering and Administration costs as 6% of items B to F for local and foreign components are:

Local component	0.727	Mio.US$
Foreign component	1.195	Mio.US$
Total	**1.922**	**Mio.US$**

Table F
Transmission System Cost

Sr. No.	Structure and Pay Item	Cost in 1000 US$ Local	Foreign	Total
F1000	F1 – Transmission line	95		95
	Contingency 5%	5		5
	Total cost for transmission system	**100**		**100**

11.1.8 Other Costs

Other costs which the private investor would have to meet include:

- Bank clearance charges and local insurance, this was taken as 1% of the engineering works and Engineering and Administration, excluding preliminary works.

This cost is taken as a local component and amounts to:

Local component **0.340 Mio.US$**

- Customs duty of 2% on imported equipment, machinery and plant cost according to the "Policy Framework and Package of Incentives for Private Sector Hydel Power Generation Projects". May 1995.

Customs duty of 2% on: 50% of Civil Foreign Component plus 100% of Foreign component for Hydraulic Steel Works, Hydro-mechanical Equipment, Electrical Equipment, Transmission System, and Engineering and Administration.

This cost is taken as a local component and amounts to:

Local component **0.320 Mio.US$**

- Income tax of 4% on payments to the contractors according to the earlier cited policy.

Income tax of 4% on: 50% of Civil Foreign Component plus 100% of Local Component for Civil Works, Hydraulic Steel Works, Hydro-mechanical Equipment, Electrical Equipment, Transmission System, and Engineering and Administration.

This cost is taken as local component and amounts to:

Local component **0.718 Mio.US$**

11.1.9 Summary of Project Cost

See **Table S** Project Cost Summary

The detailed cost estimates of civil works are given in Appendix 11, while the detailed costs for other main works are given in the relevant chapters. A summary of the project costs is given in Table S. The breakdown of foreign and local costs are also shown in this table.

The total construction cost, including engineering and administration, bank clearance and insurance charges, and duties and taxes but excluding price escalation and interest during construction is about US$ 37.6 million at 1997 price levels. The resulting capacity cost is US$ 1080 /kW which is not unfavourable.

A breakdown of the construction cost reflects the following as a percentage of the total costs excluding escalation and interest during construction.

	Mio. US$	%
• Preliminary works	2.257	6.0
• Civil works	17.277	46.0
• Hydraulic steel works	3.839	10.2
• Hydro-mechanical equipment	3.389	9.0
• Electrical equipment	7.424	19.8
• Transmission system	0.100	0.3
• Engineering and Administration	1.922	5.1
• Other costs	1.378	3.7

US$ 37.586 million

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11.2 CASHFLOW SCHEDULE OF INVESTMENT

The cashflow schedule is based on the proposed construction schedules according to **Appendix 8A.**

All costs without price escalation and interest during construction have been distributed quarterly over the period of disbursement of individual works for the local and foreign components.

Following table provides a compact version of the expenditures.

Year	Quarter	Cash flow in thousand US$					
		Local		Foreign		Total	
0	1	0		0		0	
	2	0		0		0	
	3	550		0		550	
	4	317	867	0	0	317	867
1	1	401		747		1148	
	2	788		1634		2423	
	3	638		908		1546	
	4	1821	3647	1214	4504	3034	8151
2	1	1723		1782		3504	
	2	1598		1955		3552	
	3	1694		2116		3810	
	4	1839	6853	1813	7665	3652	14518
3	1	1816		3172		4988	
	2	1761		2732		4493	
	3	907		1850		2757	
	4	627	5110	1184	8939	1811	14049
Total		16478		21108		37586	
		37%		63%		100%	

As can be seen from the above table, the call on foreign and local capital is highest in years 2 and 3 with the peak occurring in year 2. The local investment is about 44% of the total of investment while the foreign investment is about 56%.

The full schedule of expenditures without price escalation and interest during construction is given in **Tables 1,2,3** and **Figure 11.2.**

11.3 OPERATION, MAINTENANCE AND REPLACEMENT COST

11.3.1 Cost of Operation and Maintenance

Due to the great variety of types and characteristics of HPP's, due to the big difference, in geology and geography in HPP's of similar capacity and due to the big differences in magnitude of civil works and dams it is quite difficult to establish cost functions to determinate O&M costs of HPP's. Generally spoken the best result can be obtained from a similar plant, in similar conditions.

The most similar plant in Pakistan, situated in NWFP as Daral Khwar HPP is Warsak HPP. Warsak has an installed capacity of 240 MW at a yearly plant factor of around 50%.

For the estimation of O&M cost of Daral Khwar three methods can be applied

- **Estimate by a percentage of investment cost.**

It is generally accepted that HPP's have O&M cost usually between 0.8 % to 2 % of the investment cost. In the case of Daral Khwar this will come to

37 Mio. US$ x 0.08	=	300,000 US$
37 Mio. US$ x 0.02	=	740,000 US$

As Daral Khwar is a maintenance friendly project, without big reservoir and an expected low wear of turbine runners an estimate of 450,000 US$/year would appear appropriate.

- **Cost estimate by generic cost function where the O&M cost is presented as a function of the installed capacity.**

According to a study published by Harza in 1980 elaborated for the Government of Venezuela, brought to 1997 price level the O&M cost for a 36 MW HPP would be:

Capacity O&M cost	10.96 US$/kW
Energy O&M cost at 47 % plant factor	3.62 US$/kW
Total O&M cost	14.58 US$/kW

36,000 x 14.58 = 524,880 US$/year

- **Cost estimate by comparison with a similar plant.**

Warsak HPP had an O&M cost of 2,5 Mio. $ in 1993/94 - 1994/95 which comes to 10 $/kW installed capacity. Warsak is a problematic plant, basically due to erosion problems caused by the silted up reservoir. On the other hand Daral Khwar is of significantly smaller size so that a cost of 13.5 US$/kW seems to be appropriate. O&M cost for Daral Khwar would work out to be 486,000 US$/year.

By all methods the O&M costs come out to be very close around 500,000 US$ per year.

500,000 US$ per year

as Operation and Maintenance cost for Daral Khwar will be adapted for further studies.

Sources:
NPP Issue 1996
Power system statistics WAPDA 1992
Harza, Manual de costos de obsras de Aprovechamiento Hdraulico
Venezuela Julio 1980.

11.3.2 Replacement Cost

Various equipments have to be replaced during the life time of the project. The relevant costs are assumed as follows:

Item	Percentage	Period	Replacement Cost in Mio. US$
Civil works	10 %	after 30 years	17x0.1=1.7
Steel works	20 %	after 20 years	3.8x0.2=0.8
Hydro-mechanical Equipment	10 %	after 5 years	3.4x0.1=0.3
Electrical Equipment	20 %	after 15 years	7.4x0.2=1.5

Distribution of Replacement Cost in Mio. US$

Element Year	5	10	15	20	25	30	35	40	45
Hydro-mechanical	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Electrical	--	--	1.5	--	--	1.5	--	--	1.5
Steel	--	--	--	0.8	--	--	--	0.8	--
Civil	--	--	--	--	--	1.7	--	--	--
Sum	0.3	0.3	1.8	1.1	0.3	3.5	0.3	1.3	1.8

Table S
Daral Khwar Hydropower Project 35 MW, Project Cost Summary

Price Level 1997 (42 Rs/US$) *Price escalation and interest during construction are not included*

ITEM	STRUCTURE	COST IN 1000 US$		
		LOCAL	FOREIGN	TOTAL
A	**PRELIMINARY WORKS**	**2257.20**	**0.00**	**2257.20**
A1	ENVIRONMENTAL MITIGATION COST & LAND ACQUISITION	684.20	0.00	684.20
A2	ACCESS ROADS TO THE MAIN WORKS SITES	1105.50	0.00	1105.50
A3	COST OF TRANSPORTING HEAVY LOADS, DARGAI-BAHRAIN	170.50	0.00	170.50
A4	CAMPS AND HOUSING DURING CONSTRUCTION	297.00	0.00	297.00
B	**CIVIL WORKS**	**7045.53**	**10231.34**	**17276.87**
	WEIR AND INTAKE	1156.22	900.09	2056.30
B11	SITE INSTALLATION & RIVER DIVERSION	100.67	230.45	331.12
B12	WEIR	980.36	611.60	1591.96
B13	LATERAL INTAKE	75.19	58.03	133.22
	CONDUIT SYSTEM	4147.16	8069.32	12216.48
B21	CONNECTION TUNNEL AND GRAVEL SPILL	70.95	146.67	217.62
B31	SANDTRAP	917.45	389.04	1306.49
B32	HEADRACE CANAL	72.08	64.51	136.59
B41	HEADRACE TUNNEL	2296.74	5948.55	8245.29
B42	ACCESS TUNNEL	163.52	391.50	555.01
B43	WORKING PLATFORM OF THE ACCESS TUNNEL	9.14	58.65	67.79
B51	SURGE TANK	337.98	602.05	940.04
B52	PENSTOCK TUNNEL	67.40	158.55	225.95
B53	VALVE CHAMBER AND PENSTOCK ANCHOR BLOCK	94.61	70.76	165.37
B54	WORKING PLATFORM PENSTOCK TUNNEL AND VALVE CHAMBER	7.01	37.30	44.32
B61	PENSTOCK CIVIL WORKS AND ROAD CROSSING STRUCTURE	110.28	201.73	312.01
	POWERHOUSE	1312.63	1261.94	2574.56
B71	SITE INSTALLATION, EXCAVATION AND PROTECTION WORKS	187.17	704.36	891.52
B72	CONCRETE WORKS	900.37	446.06	1346.43
B73	FINISHING / INTERNAL WORKS	225.09	111.52	336.61
B81	ADDITIONAL WORKS (Permanent Residential Buildings/Stores/Workshops)	429.53	0.00	429.53
C	**HYDRAULIC STEEL WORKS**	**3357.80**	**481.43**	**3839.22**
C10	WEIR, INTAKE	131.25	31.50	162.75
C20	SANDTRAP	93.45	21.00	114.45
C21	VALVE CHAMBER	21.00	115.50	136.50
C22	PENSTOCK	2467.50	157.50	2625.00
C30	POWER HOUSE	42.00	84.00	126.00
C40	TRANSPORT	137.76	20.48	158.24
C50	ERECTION	464.84	51.45	516.29
D	**HYDROMECHANICAL EQUIPMENT**	**252.00**	**3137.40**	**3389.40**
D100	FRANCIS TURBINE, 2 UNITS, 6.25 m3/s EACH	0.00	2282.70	2282.70
D200	PELTON TURBINE, 1 UNITS, 2.5 m3/s	0.00	541.80	541.80
D300	TRANSPORT	126.00	15.23	141.23
D400	ERECTION	126.00	297.68	423.68
E	**ELECTRICAL EQUIPMENT**	**1360.80**	**6062.70**	**7423.50**
E1	GENERATORS	136.50	2047.50	2184.00
E11	*TWO GENERATORS 18 MVA EACH*	*120.75*	*1596.00*	*1716.75*
E12	*ONE GENERATOR 7.5 MVA*	*15.75*	*451.50*	*467.25*
E2	TRANSFORMERS	68.25	318.15	386.40
E21	*TWO BLOCK TRANSFORMERS, 26 MWA EACH*	*42.00*	*315.00*	*357.00*
E22	*AUXILIARY TRANSFORMERS*	*26.25*	*3.15*	*29.40*
E3	132 kV SWITCHGEAR	68.25	346.50	414.75
E4	11 kV SWITCHGEAR AND 11 kV LINE POWERHOUSE INTAKE	248.85	254.10	502.95
E5	0.4 kV AC LOW VOLTAGE & 110 V DC SUPPLY	116.55	462.00	578.55
E6	CONTROL, ALARM, PROTECTION, TELECOMMUNICATION & WATCHES	172.20	1806.00	1978.20
E7	LIGHTING & SMALL POWER AND EMERGENCY DIESEL	203.70	193.20	396.90
E8	VARIOUS	346.50	635.25	981.75
F	**TRANSMISSION SYSTEM** (Transmission Line)	**100.00**	**0.00**	**100.00**
G	**ENGINEERING AND ADMINISTRATION** (6% of B to F)	**726.97**	**1194.77**	**1921.74**
H	**OTHER COST**	**1377.70**	**0.00**	**1377.70**
H1	BANK CLEARANCE AND LOCAL INSURANCE @ 1% OF B TO G	339.51	0.00	339.51
H2	CUSTOMS DUTY @ 2% OF EQUIPMENT, MACHINERY AND PLANT COST OF B TO G	319.84	0.00	319.84
H3	INCOME TAX @ 4% ON PAYMENTS TO THE CONTRACTORS OF B TO G	718.35	0.00	718.35
TOTAL PROJECT COST		**16477.99**	**21107.64**	**37585.63**

Table 1: Daral Khwar HPP Cash Flow Schedule (Local and Foreign Components)

Item	Structure	Cost in 1000 US$			Year 0				Year 1				Year 2				Year 3			
		Local	Foreign	Total	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
A	**Preliminary Works**	**2257**	**0**	**2257**	**0**	**0**	**550**	**317**	**312**	**428**	**132**	**75**	**17**	**58**	**113**	**113**	**17**	**41**	**41**	**41**
A1	Environmental Mitigation Cost & Land Acquisition	684	0	684			274	41		41	41	41		41	41	41		41	41	41
A2	Access Roads To the Main Works Sites	1106	0	1106			276	276	221	221					55	55				
A3	Cost of Transporting Heavy Loads, Dargai-Bahrain	171	0	171					17	17	17	34	17	17	17	17	17			
A4	Camps and Housing During Construction	297	0	297					74	149	74									
B	**Civil Works**	**7046**	**10231**	**17277**	**0**	**0**	**0**	**0**	**79**	**910**	**999**	**1088**	**2622**	**2291**	**2265**	**1874**	**2178**	**2199**	**661**	**112**
	Weir and Intake	1156	900	2056	0	0	0	0	0	26	175	375	455	388	318	159	80	80	0	0
B11	Site Installation & River Diversion	101	230	331						26	96	70	70	70						
B12	Weir	980	612	1592							80	239	318	318	318	159	80	80		
B13	Lateral intake	75	58	133								67	67							
	Conduit System	4147	8069	12216	0	0	0	0	0	115	602	490	1945	1680	1725	1442	1900	1769	549	0
B21	Connection Tunnel and Gravel Spill	71	147	218									218							
B31	Sandtrap	917	389	1306												392	523	392		
B32	Headrace Canal	72	65	137															137	
B41	Headrace Tunnel	2297	5949	8245								412	1649	1649	1649	825	825	825	412	
B42	Access Tunnel	164	391	555							555									
B43	Working Platform of the Access Tunnel	9	59	68						68										
B51	Surge Tank	338	602	940													470	470		
B52	Penstock Tunnel	67	159	226												226				
B53	Valve Chamber and Penstock Anchor Block	95	71	165													83	83		
B54	Working Platform Penstock Tunnel and Valve Chamber	7	37	44											44					
B61	Penstock Civil Works and Road Crossing Structure	110	202	312						47	47	78	78	31	31					
	Powerhouse	1313	1262	2575	0	0	0	0	26	716	168	168	168	168	168	218	198	351	112	112
B71	Site Installation, Excavation and Protection Works	187	704	892					26	716						50	30	70		
B72	Concrete Works	900	446	1346							168	168	168	168	168	168	168	168		
B73	Finishing / Internal Works	225	112	337														112	112	112
B81	Permanent Residential Buildings / Stores / Workshops	430	0	430					54	54	54	54	54	54	54	54				
C	**Hydraulic Steel Works**	**3358**	**481**	**3839**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1050**	**529**	**495**	**495**	**662**	**176**	**176**	**165**	**91**
C10	Weir, Intake	131	32	163												41	41	41	41	
C20	Sandtrap	93	21	114															57	57
C21	Valve Chamber	21	116	137													68	68		
C22	Penstock	2468	158	2625								1050	394	394	394	394				
C30	Power House	42	84	126												126				
C40	Transport	138	20	158									32	24	24	24	16	16	16	8
C50	Erection	465	51	516									103	77	77	77	52	52	52	26

Cont'd.....

Table 1: Daral Khwar HPP Cash Flow Schedule (Local and Foreign Components)

Item	Structure	Cost in 1000 US$			Year 0				Year 1				Year 2				Year 3			
		Local	Foreign	Total	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
D	**Hydro-mechanical Equipment**	**252**	**3137**	**3389**	**0**	**0**	**0**	**0**	**685**	**391**	**282**	**54**	**0**	**282**	**282**	**353**	**918**	**141**	**0**	**0**
D100	Francis Turbine, 2 Units, 6.25 m^3/s each	0	2283	2283					685	228	228			228	228	228	457			
D200	Pelton Turbine, 1 Unit, 2.5 m^3/s	0	542	542						163	54	54		54	54	54	108			
D300	Transport	126	15	141												71	71			
D400	Erection	126	298	424													282	141		
E	**Electrical Equipment**	**1361**	**6063**	**7424**	**0**	**0**	**0**	**0**	**0**	**515**	**0**	**484**	**0**	**93**	**279**	**290**	**1216**	**1496**	**1643**	**1408**
	Generators	137	2048	2184	0	0	0	0	0	515	0	484	0	93	172	218	47	218	437	0
E11	Two Generators 18 MVA each	121	1596	1717						515		343			172	172		172	343	
E12	One Generator 7.5 MVA	16	452	467								140		93		47	47	47	93	
	Transformers	68	318	386	0	0	0	0	0	0	0	0	0	0	107	71	9	77	6	116
E21	Two Block Transformers, 26 MVA each	42	315	357											107	71		71		107
E22	Auxiliary Transformers	26	3	29													9	6	6	9
E3	132 kV Switchgear	68	347	415													124	83	83	124
E4	11 kV Switchgear and 11 kV Line Powerhouse Intake	249	254	503													151	101	101	151
E5	0.4 kV AC Low Voltage & 110 V DC Supply	117	462	579													145	145	145	145
E6	Control, Alarm, Protection, Telecommunication & Watches	172	1806	1978													495	495	495	495
E7	Lighting & Small Power and Emergency Diesel	204	193	397														132	132	132
E8	Various	347	635	982													245	245	245	245
F	**Transmission System (Line)**	**100**	**0**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**25**	**25**	**25**	**25**	**0**	**0**
G	**Engineering and Administration** (6% of B to F)	**727**	**1195**	**1922**	**0**	**0**	**0**	**0**	**46**	**109**	**77**	**161**	**189**	**190**	**201**	**192**	**271**	**242**	**148**	**97**
H	**Other Cost**	**1378**	**0**	**1378**	**0**	**0**	**0**	**0**	**26**	**70**	**55**	**123**	**148**	**143**	**149**	**144**	**188**	**172**	**98**	**62**
H1	Bank Clearance and Local Insurance @ 1% of B To G	340	0	340	0	0	0	0	8	19	14	28	33	34	35	34	48	43	26	17
H2	Customs Duty @ 2% of Equipment, Machinery and Plant Cost of B To G	320	0	320	0	0	0	0	15	26	12	19	19	25	28	26	51	42	33	23
H3	Income Tax @ 4% On Payments To the Contractors of B To G	718	0	718	0	0	0	0	3	25	29	76	95	85	86	84	88	86	39	22
	Total Project Cost	**16478**	**21108**	**37586**	**0**	**0**	**550**	**317**	**1148**	**2423**	**1546**	**3034**	**3504**	**3552**	**3810**	**3652**	**4988**	**4493**	**2757**	**1811**

Price Level 1997 (42 Rs/US$),
Price escalation and interest during construction are not included

Table 2: Daral Khwar HPP Cash Flow Schedule (Local Components)

Item	Structure	Cost in 1000 US$			Year 0				Year 1				Year 2				Year 3			
		Local	Foreign	Total	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
A	**Preliminary Works**	**2257**		**2257**	**0**	**0**	**550**	**317**	**312**	**428**	**132**	**75**	**17**	**58**	**113**	**113**	**17**	**41**	**41**	**41**
A1	Environmental Mitigation Cost & Land Acquisition	684		684			274	41		41	41	41		41	41	41		41	41	41
A2	Access Roads To the Main Works Sites	1106		1106			276	276	221	221					55	55				
A3	Cost of Transporting Heavy Loads, Dargai-Bahrain	171		171					17	17	17	34	17	17	17	17	17			
A4	Camps and Housing During Construction	297		297					74	149	74									
B	**Civil Works**	**7046**		**7046**	**0**	**0**	**0**	**0**	**60**	**237**	**424**	**515**	**979**	**854**	**840**	**847**	**981**	**973**	**262**	**75**
	Weir and Intake	1156		1156	0	0	0	0	0	8	78	206	255	217	196	98	49	49	0	0
B11	Site Installation & River Diversion	101		101						8	29	21	21	21						
B12	Weir	980		980							49	147	196	196	196	98	49	49		
B13	Lateral Intake	75		75								38	38							
	Conduit System	4147		4147	0	0	0	0	0	26	180	142	558	470	477	572	813	721	187	0
B21	Connection Tunnel and Gravel Spill	71		71									71							
B31	Sandtrap	917		917												275	367	275		
B32	Headrace Canal	72		72															72	
B41	Headrace Tunnel	2297		2297								115	459	459	459	230	230	230	115	
B42	Access Tunnel	164		164							164									
B43	Working Platform of the Access Tunnel	9		9						9										
B51	Surge Tank	338		338													169	169		
B52	Penstock Tunnel	67		67												67				
B53	Valve Chamber and Penstock Anchor Block	95		95													47	47		
B54	Working Platform Penstock Tunnel and Valve Chamber	7		7											7					
B61	Penstock Civil Works and Road Crossing Structure	110		110						17	17	28	28	11	11					
	Powerhouse	1313		1313	0	0	0	0	5	150	113	113	113	113	113	123	119	202	75	75
B71	Site Installation, Excavation and Protection Works	187		187					5	150						11	6	15		
B72	Concrete Works	900		900							113	113	113	113	113	113	113	113		
B73	Finishing / Internal Works	225		225														75	75	75
B81	Permanent Residential Buildings / Stores / Workshops	430		430					54	54	54	54	54	54	54	54				
C	**Hydraulic Steel Works**	**3358**		**3358**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**987**	**491**	**461**	**461**	**535**	**104**	**104**	**140**	**77**
C10	Weir, intake	131		131												33	33	33	33	
C20	Sandtrap	93		93															47	47
C21	Valve Chamber	21		21													11	11		
C22	Penstock	2468		2468								987	370	370	370	370				
C30	Power House	42		42												42				
C40	Transport	138		138									28	21	21	21	14	14	14	7
C50	Erection	465		465									93	70	70	70	46	46	46	23

Cont'd.....

Table 2: Daral Khwar HPP Cash Flow Schedule (Local Components)

Item	Structure	Cost in 1000 US$			Year 0				Year 1				Year 2				Year 3			
		Local	Foreign	Total	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
D	**Hydro-mechanical Equipment**	**252**		**252**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**63**	**147**	**42**	**0**	**0**
D100	Francis Turbine, 2 Units, 6.25 m^3/s each	0		0					0	0	0			0	0	0	0			
D200	Pelton Turbine, 1 Unit, 2.5 m^3/s	0		0						0	0	0		0	0	0	0			
D300	Transport	126		126												63	63			
D400	Erection	126		126													84	42		
E	**Electrical Equipment**	**1361**		**1361**	**0**	**0**	**0**	**0**	**0**	**36**	**0**	**29**	**0**	**3**	**25**	**22**	**263**	**317**	**323**	**342**
	Generators	137		137	0	0	0	0	0	36	0	29	0	3	12	14	2	14	27	0
E11	Two Generators 18 MVA each	121		121						36		24			12	12		12	24	
E12	One Generator 7.5 MVA	16		16								5		3		2	2	2	3	
	Transformers	68		68	0	0	0	0	0	0	0	0	0	0	13	8	9	14	5	20
E21	Two Block Transformers, 26 MVA each	42		42											13	8		8		13
E22	Auxiliary Transformers	26		29													9	6	6	9
E3	132 kV Switchgear	68		68													20	14	14	20
E4	11 kV Switchgear and 11 kV Line Powerhouse Intake	249		249													75	50	50	75
E5	0.4 kV AC Low Voltage & 110 V DC Supply	117		117													29	29	29	29
E6	Control, Alarm, Protection, Telecommunication & Watches	172		172													43	43	43	43
E7	Lighting & Small Power and Emergency Diesel	204		204														68	68	68
E8	Various	347		347													87	87	87	87
F	**Transmission System (Line)**	**100**		**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**25**	**25**	**25**	**25**	**0**	**0**
G	**Engineering and Administration (6% of B to F)**	**727**		**727**	**0**	**0**	**0**	**0**	**4**	**16**	**25**	**92**	**88**	**79**	**81**	**90**	**91**	**88**	**43**	**30**
H	**Other Cost**	**1378**		**1378**	**0**	**0**	**0**	**0**	**26**	**70**	**55**	**123**	**148**	**143**	**149**	**144**	**188**	**172**	**98**	**62**
H1	Bank Clearance and Local Insurance @ 1% of B To G	340		340	0	0	0	0	8	19	14	28	33	34	35	34	48	43	26	17
H2	Customs Duty @ 2% of Equipment, Machinery and Plant Cost of B To G	320		320	0	0	0	0	15	26	12	19	19	25	28	26	51	42	33	23
H3	Income Tax @ 4% On Payments To the Contractors of B To G	718		718	0	0	0	0	3	25	29	76	95	85	86	84	88	86	39	22
	Total Project Cost	**16478**		**16478**	**0**	**0**	**560**	**317**	**401**	**788**	**639**	**1821**	**1723**	**1598**	**1694**	**1839**	**1816**	**1761**	**907**	**627**

Price Level 1997 (42 Rs/US$),
Price escalation and interest during construction are not included

Table 3: Daral Khwar HPP Cash Flow Schedule (Foreign Components)

Item	Structure	Cost in 1000 US$			Year 0				Year 1				Year 2				Year 3			
		Local	Foreign	Total	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
A	**Preliminary Works**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A1	Environmental Mitigation Cost & Land Acquisition		0	0			0	0		0	0	0		0	0	0		0	0	0
A2	Access Roads To the Main Works Sites		0	0			0	0	0	0					0	0				
A3	Cost of Transporting Heavy Loads, Dargai-Bahrain		0	0					0	0	0	0	0	0	0	0	0			
A4	Camps and Housing During Construction		0	0					0	0	0									
B	**Civil Works**		**10231**	**10231**	**0**	**0**	**0**	**0**	**20**	**672**	**575**	**573**	**1643**	**1437**	**1425**	**1027**	**1197**	**1227**	**399**	**37**
	Weir and Intake		900	900	0	0	0	0	0	18	97	170	200	171	122	61	31	31	0	0
B11	Site Installation & River Diversion		230	230						18	66	49	49	49						
B12	Weir		612	612							31	92	122	122	122	61	31	31		
B13	Lateral Intake		58	58								29	29							
	Conduit System		8069	8069	0	0	0	0	0	89	422	348	1387	1210	1247	870	1087	1048	362	0
B21	Connection Tunnel and Gravel Spill		147	147									147							
B31	Sandtrap		389	389												117	156	117		
B32	Headrace Canal		65	65															65	
B41	Headrace Tunnel		5949	5949								297	1190	1190	1190	595	595	595	595	297
B42	Access Tunnel		391	391							391									
B43	Working Platform of the Access Tunnel		59	59						59										
B51	Surge Tank		602	602													301	301		
B52	Penstock Tunnel		159	159												159				
B53	Valve Chamber and Penstock Anchor Block		71	71													35	35		
B54	Working Platform Penstock Tunnel and Valve Chamber		37	37											37					
B61	Penstock Civil Works and Road Crossing Structure		202	202						30	30	50	50	20	20					
	Powerhouse		1262	1262	0	0	0	0	20	566	56	56	56	56	56	95	79	148	37	37
B71	Site Installation, Excavation and Protection Works		704	704					20	566						40	24	55		
B72	Concrete Works		446	446							56	56	56	56	56	56	56	56		
B73	Finishing / Internal Works		112	112														37	37	37
B81	Permanent Residential Buildings / Stores / Workshops		0	0					0	0	0	0	0	0	0	0				
C	**Hydraulic Steel Works**		**481**	**481**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**63**	**38**	**34**	**34**	**126**	**73**	**73**	**26**	**14**
C10	Weir, Intake		32	32												8	8	8	8	
C20	Sandtrap		21	21															11	11
C21	Valve Chamber		116	116													58	58		
C22	Penstock		158	158								63	24	24	24	24				
C30	Power House		84	84												84				
C40	Transport		20	20									4	3	3	3	2	2	2	1
C50	Erection		51	51									10	8	8	8	5	5	5	3

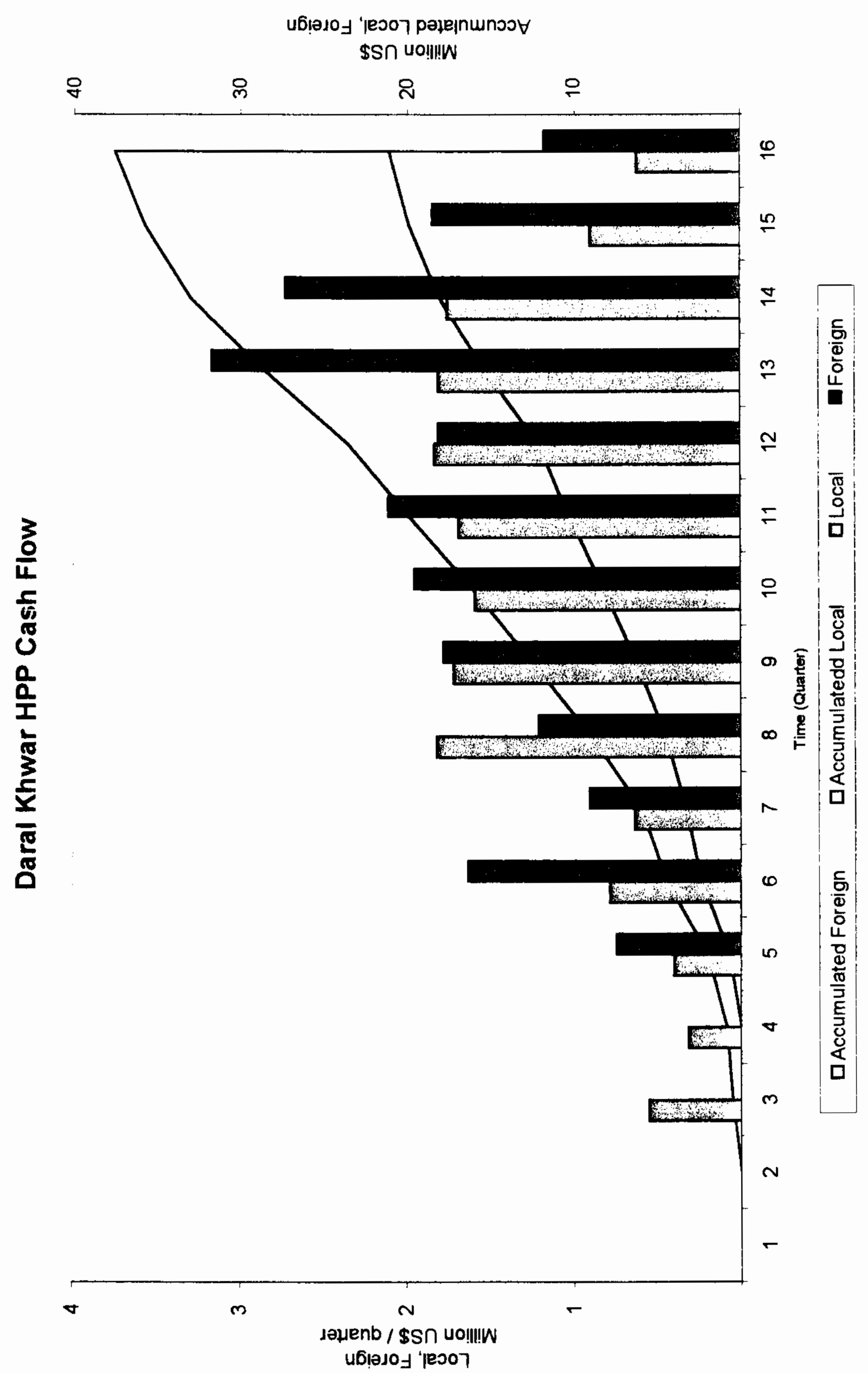
Cont'd.....

Table 3: Daral Khwar HPP Cash Flow Schedule (Foreign Components)

Item	Structure	Cost in 1000 US$			Year 0				Year 1				Year 2				Year 3			
		Local	Foreign	Total	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
D	**Hydro-mechanical Equipment**		**3137**	**3137**	**0**	**0**	**0**	**0**	**685**	**391**	**282**	**54**	**0**	**282**	**282**	**290**	**771**	**99**	**0**	**0**
D100	Francis Turbine, 2 Units, 6.25 m^3/s each		2283	2283					685	228	228			228	228	228	457			
D200	Pelton Turbine, 1 Unit, 2.5 m^3/s		542	542						163	54	54		54	54	54	108			
D300	Transport		15	15												8	8			
D400	Erection		298	298													198	99		
E	**Electrical Equipment**		**6063**	**6063**	**0**	**0**	**0**	**0**	**0**	**479**	**0**	**455**	**0**	**90**	**254**	**268**	**952**	**1179**	**1320**	**1066**
	Generators		2048	2048	0	0	0	0	0	479	0	455	0	90	160	205	45	205	410	0
E11	Two Generators 18 MVA each		1596	1596						479		319			160	160		160	319	
E12	One Generator 7.5 MVA		452	452								135		90		45	45	45	90	
	Transformers		318	318	0	0	0	0	0	0	0	0	0	0	95	63	1	64	1	95
E21	Two Block Transformers, 26 MVA each		315	315											95	63		63		95
E22	Auxiliary Transformers		3	3													1	1	1	1
E3	132 kV Switchgear		347	347													104	69	69	104
E4	11 kV Switchgear and 11 kV Line Powerhouse Intake		254	254													76	51	51	76
E5	0.4 kV AC Low Voltage & 110 V DC Supply		462	462													116	116	116	116
E6	Control, Alarm, Protection, Telecommunication & Watches		1806	1806													452	452	452	452
E7	Lighting & Small Power and Emergency Diesel		193	193														64	64	64
E8	Various		635	635													159	159	159	159
F	**Transmission System (Line)**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
G	**Engineering and Administration (6% of B to F)**		**1195**	**1195**	**0**	**0**	**0**	**0**	**42**	**93**	**51**	**69**	**101**	**111**	**120**	**103**	**180**	**155**	**105**	**67**
H	**Other Cost**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
H1	Bank Clearance and Local Insurance @ 1% of B To G																			
H2	Customs Duty @ 2% of Equipment, Machinery and Plant Cost of B To G																			
H3	Income Tax @ 4% On Payments To the Contractors of B To G																			
	Total Project Cost		**21108**	**21108**	**0**	**0**	**0**	**0**	**747**	**1634**	**908**	**1214**	**1782**	**1955**	**2116**	**1813**	**3172**	**2732**	**1850**	**1185**

Price Level 1997 (42 Rs/US$),
Price escalation and interest during construction are not included

Figure 11.2



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12.1 BACK GROUND

The Regional Power Development Study - Swat Valley (Volumes I to III, Chapters 1 to 6) presents the long term power system expansion plan for the planning region Swat Valley. The power system expansion plan mentioned above is aimed at satisfying rural electricity demand by means of small High Head hydro-electric power generating stations.

The methodology in the above mentioned chapter 6 was to determine the least cost hydel solution towards meeting rural demand in Swat Valley Planning Region. The fact that the planning region under consideration was partially electrified and interconnected to the WAPDA national grid system suggested a revision of strategy. Grid interconnection provided possibilities of building hydropower plants for higher outputs than required for rural demand in isolated systems (available 365 days/year). The focus therefore shifted from one of identifying least cost hydel solution to meet rural demand to development of hydropower potential to cater to the requirements of the WAPDA grid system (inclusive of rural and regional demand of planning area under discussion). The high head hydel power generation potential in the Districts Swat (portion draining into river Swat north of Madyan). This also included sites identified for purposes of meeting rural demand but now upgraded (from 365 days availability to about 90 days availability). It is these upgraded sites that are the focus of attention in this feasibility study.

The upgraded hydropower generating potential identified was meant to supply the requirements of the national grid and meeting rural and regional demand. These hydropower generating schemes are meant to form candidate additions to the WAPDA Generating Expansion Plan. The hydropower generating potentials which appear to be economic are presented as follows:

Ranking	Scheme	Installed * Capacity kW	Energy * Output Gwh/a	Total * Investment M. Rs.	Irr%
1.	12/2 : Arin Bahrain	25000	128.13	466.36	19.08
2.	10 : Kedam	6900	39.80	198.76	14.97
3.	7/1 : Matiltan	9150	51.92	306.69	11.47
4.	7/2 : Matiltan	35000	178.80	869.22	14.22
5.	11 : Gamai	9000	46.13	263.58	13.53
6.	9 : Mankial	10500	56.06	345.55	11.13
7.	4 : Utror	6700	35.77	242.09	10.08

** Preliminary cost estimate and sizing.*

The regional power development study recommended the preparation of feasibility studies for the hydropower potential identified in the planning region. The projects were ranked as above. This study is a step towards realization of the recommendations of the Regional Power Development Plan Study. This present feasibility study represents the initial part of the recommended power expansion plan for the Regions Swat Valley.

12.2 OPTIMIZATION OF UPGRADING OF DARAL KHWAR

The optimization of proposed Daral Khwar was evaluated based upon the criteria that the size of the hydro power plant would be one when incremental benefits equal incremental costs. The output of the plant was valued at the Long Run Marginal Cost (LRMC). Estimates are derived from the Asian Development Bank sponsored "Integrated Operations and Tariff study for WAPDA and KESC" June 1991 by Coopers & Lybrand Deloitte. Optimization process is described in Chapter 7 of this study. The optimized size of plant to be built to be as follows: Installed Capacity - 35 MW; Annual Energy - 148 GWh/a; Plant Factor - 48%.

12.3 COST ESTIMATES

The financial cost estimate (1997 price level) of the various project components is presented in Chapter 11. Economic cost estimate for project components summarized as below:

Economic[1] Cost Estimate: Daral Khwar Hydel Plants

	1997 Price Level	000 US$	
	Foreign	Local	Total
Year 0	0	867	867
Year 1	4612	3534	8146
Year 2	7642	6877	14519
Year 3	8854	16478	37536
Total	21108	16478	37586

Vertical & Horizontal totals may not agree due to rounding. Does not include interest during construction, financing costs and price escalation.

O&M cost for the project has been estimated at 0.5 M.US$/a replacement costs are discussed in detail in **Chapter 11.**

12.4 PARAMETERS

12.4.1 Shadow Prices

The standard conversion factor (SCF) is used to determine the shadow prices for non-tradable items for which enough data or information is not available. Based on 1993-94 data the SCF is about 0.86. Tradeables are valued at border prices.

Shadow prices for the project are summarized as below:-

Imported items	:	1.0 x Border price	Wage Rate		
Cement	:	0.66 x Local price	* Unskilled labor	:	0.61 x market wages
Steel	:	0.81 x Local price	* Skilled labor	:	1.06 x market wages

Other items are shadow priced at a SCF of 0.86

12.4.2 Discount Rate

The shadow discount rate is one which closely approximates the governments objectives. This discount rate should not be one prevalent in the local market but should be one which the government would like to be prevalent. The selection of a discount rate for economic optimization exercise is an important decision and much more extensive analysis needs to be undertaken before settling upon a discount rate. The economic discount rate to be used for long rage optimization exercise should not be more than 6% -8% and should in any case not be above 10%. Detailed discussion is presented in Annexure 12 of this study.

12.5 METHODOLOGY

The project economic feasibility is assessed in two parts: The first determines that the proposed project would form a part of the least cost system expansion solution; The second determines that the project would be feasible in comparison to avoided investments in other sectors of the economy;

1 *The economic costs are derived as follows: CIF border prices for foreign inputs plus a margin for inland transportation are taken as economic prices; Foreign costs are taken to be economic prices; Local costs are shadow priced using 0.86 SCF. Environmental costs are taken at financial estimates.*

12.5.1 Economic Feasibility - LRMC and Thermal Equivalence Basis

12.5.1.1 Systems Aspects

Conventional project appraisal methodology uses avoided cost concepts or treats the entire output of a generation project operating at the maximum feasible load factor as an addition to supplies valued at the governing tariffs.

The above approach does not fully simulate the entire effect the proposed addition will have on the power system. A new generating station may contribute energy at its maximum possible. However, it may shift existing base load stations to intermediate or peaking duty. The utilization of these stations will fall and the net increase of output will be less than the gross generation from the project. The net increase of supply is to be valued at the governing tariff whereas the rest of the output should be valued in terms of savings in operating costs in the existing stations.

Hydel power generation is generally evaluated in terms of primary energy valued at the governing tariff whereas secondary energy is valued in terms of fuel cost savings. This approach ignores the fact that power projects are part of an interlinked system and the impact of the project on other components in the system needs to be taken into account.

12.5.1.2 Economic Valuation Methodology for Northern Pakistan

The medium and small output upgraded high head hydel generating schemes, located in northern Pakistan, are meant for interconnection to the national grid but would also serve the local rural demand. The methodology can be described as follows:

Each hydel generating site is evaluated on the base of equivalent thermal which it would replace. High head hydel generating sites with reservoir can be considered as follows: A firm full output for peaking purposes available throughout the year, for say 4 hours a day. This output would result in avoided peaking capacity and operating cost; A variable output with output levels varying from 4 hours a day at full output to 24 hours a day full output. This output will not result in avoided base or intermediate load capacity cost and will in fact result in only avoided operating costs for secondary energy supplied. This component of energy will also impose a cost on the system due to the reduced utilization of thermal base load station.

The above can be modelled by means of with and without conditions. These are described as follows: **Without conditions** - The without conditions can be simulated by two generating stations. Addition of an equivalent output (corrected for forced outage rates) gas turbine and an equivalent output base load coal or oil fired generating station; **With conditions** - The gas turbine is replaced by the firm portion of the hydel addition output. Whereas the base load thermal generating station is operated at a reduced output level. The thermal station is operated to ensure firm energy equivalent to that achieved by the without option. The output from such an analysis is compared by comparison of the net present value of both options described above to serve the same demand and energy.

12.5.1.3 Economic Analysis Feasibility - Benefits at LRMC

Marginal cost of power supply is defined as the change in total cost of service resulting from small change in demand. This cost may change according to the place and time of use. Long run marginal costs signify economic efficiency. Long run marginal cost (LRMC) can be defined as the cost of serving additional or incremental demand in the long run, when investments can be made to minimize total costs. The main components of the LRMC structure are: Marginal Energy Costs (peak & off peak); Marginal Capacity Cost of Generation; Marginal Transmission and Distribution Capacity Costs. The LRMC provides the best set of indicators to evaluate system changes at the margin.

The benefits of serving local rural demand can be captured as follows: Use of LRMC at the appropriate level (say 66 kV at applicable load factor) to capture the benefits of serving rural loads. The hydel generating stations under analysis are located in mountainous northern areas of Pakistan, in some of these areas the grid system is already existing and is serving both urban and rural loads. The impact of adding hydel generation upon transmission annual costs should also be included as a cost or a benefit, as the case may be. The LRMC cost estimates for capacity and energy at different voltage levels can be used as a proxy for capturing the geographic location impact of adding generation to the power system.

12.6 QUANTIFICATION OF BENEFITS

12.6.1 Long Run Marginal Cost (LRMC)

The benefits attributable to the project are proposed to be valued by the Long Run Marginal Cost (LRMC) of capacity, peak and off peak energy at different voltage levels. LRMC estimates have been derived and presented in the "Integrated Operations and Tariff Study for WAPDA and KESC" Lybrand, Cooper, 1994).

12.6.2 Consumer Surplus

Measurable benefits are valued in terms of the incremental demand that can be served under the proposed investment compared to the lower level of demand that can be served if no new supply capacity were added to the power system.

Costs are also defined as the difference between power supply costs for meeting the demand forecast with the proposed investment and system costs without any investments in the new supply capacity and related services.

Residential Customers - Total benefits of new residential users is divided into: Substitution of existing methods of lighting i.e. kerosine by electricity; Consumer's surplus derived from the additional quantity of electricity above the substituted level caused by the large drop in the price of energy that results from a switch from kerosine to electricity for lighting purposes. Gross benefits for residential customers work out to be Rs. 4.85/kWh.

Industrial and Agricultural Customers - For industrial, agricultural and other customers the basis for valuation of the benefits is their avoided costs. That is the cost that these users would pay if they had to meet their electricity needs by installing and operating diesel based generators or tubewells instead of taking electricity from the national grid. The gross benefits for small and medium/large customers is Rs. 5.69/kWh and Rs. 4.79/kWh respectively. For agricultural customers it is Rs. 4.64/kWh.

Other Customers - For the other customers including commercial, bulk, public lighting and traction and public lighting the avoided cost is the average between small industry residential and agricultural. This has been calculated to be Rs. 4.72/kWh.

12.6.2.1 Quantification of Costs

Costs are defined as the difference between power supply costs for meeting the demand slice under discussion with the proposed investment and system costs without any investments in new supply capacity and related services.

The total cost of the proposed Daral Khwar HPP has been estimated to be M.Rs. 1579.0. This includes the direct transmission costs. Administrative overheads at 25% of the total cost of the plant are to be added to the above cost estimate. Indirect transmission costs (these include change of conductor on transmission lines in some segments, increase in transformer capacity in existing and new grid stations to serve additional demand etc.) is estimated to be Rs. 3025.00/kW (based upon marginal capacity cost of 132 kV as estimated in "Integrated Operations and Tariff Study for WAPDA and KESC - Coopery & Lybrand Deloitte, April 1991). The capital investment in primary and secondary distribution is estimated to be Rs. 9166.00/kW (from above document). The O&M estimates are 2.5% for transmission indirect investment and 10% for primary and secondary distribution (inclusive of commercial and billing charges).

This incremental cost analysis does not attempt to quantity the higher system losses in the secondary transmission and primary and secondary distribution circuits if proposed investment have not to be made.

12.7 PROJECT ECONOMIC FEASIBILITY

12.7.1 Least Economy Cost Planning

The least cost solution is determined by means of: the WASP runs, and benefits valued of LRMC.

12.7.1.1 WASP Runs

The system generation expansion planning is optimized by use of the WASP III model. The WASP III runs are annually updated. The WASP III runs are also arranged by WAPDA (and GOP) before taking expansion investment decesions. The last few WASP runs are discussed as follows:-

- **National Power Plan (NPP) - November 1993**

The CIDA funded and assisted NPP project aimed at enhancement of WAPDA's power system planning capabilities. The program also included the development of the least cost system generation expansion plan for the country. This was finalized in 1994:

The results of the modelling are summarized as follows:-

The additions were:

*	Combined cycle plants	18%
*	Oil-fired steam plants	47%
*	Combustion turbine plants	15%
*	Hydro electric projects	19%

The capacity mix of the system would change as follows:

		Weight (in %)		
		FY1995	FY2010	FY2018
*	Hydro electric	41	30	25
*	Thermal			
	- Oil-fired	16	23	43
	- Coal-fired	1	< 1	< 1
	- Gas-fired	42	26	32
	- Nuclear	0	1	< 1

Source: NPP-18, Draft Report, Nov. 1993

The NPP plan was made available for comments. The short comings of the WAPDA-NPP least cost solution were: The NPP base case was a overtly thermal friendly expansion plan. The "Bias" included: a high discount rate of 12% (various other studies indicated economic discount rate to be between 4.7% - 8%); fuel costs below economic levels; improper shadow pricing; and improper application of environmental consideration; The NPP base case did not consider considerable high head hydel potential identified in Azad Jummu and Kashmir (AJ&K) and northern mountainous NWFP; The plan was thermal driven.

- **SHYDO/HEPO (WAPDA) GTZ Updating (April 1994)**

The NPP plan was thermal dominated. The plan did not consider significant high hydel potential identified in NWFP and AJ&K (over 8000 MW). It would seem that significant amount of hydel capacity could economically replace the thermal identified by the plan. Such an effort to indicate possibility of inducting economic hydel was carried out under the HEPO-WAPDA/SHYDO/GTZ joint effort.

The SHYDO/HEPO (WAPDA)/GTZ team took up the development of an alternative base case. This updating was made on parameters utilized in the NPP base case with the exception that high head hydels were also included as candidate plants.

The new least cost solution differs from the NPP version as follows:-

	TOTAL ADDITIONS (MW)	
	WAPDA NPP	HEPO(WAPDA)/GTZ SHYDO VARIANT
- Gas Turbines	6800	2500
Steam/Combined Cycle	29282	31302
Hydel	8645	13343

The revised plan results in much fewer gas turbines as the hydels take up most of the peaking loads, base load thermal are increased to make up for seasonality of hydels. Both plans end up with almost the same NPV.

- **WAPDA Update (May 1995)**

  The NPP in the annual update took note of the above results and an option included the high head potential. The result of this scenario was that most of the high head hydel power plants were a part of the least cost expansion plan.

- **WAPDA update (May 1996)**

  The latest update of the NPP and the least cost system generation expansion plan considered almost all of the identified high head hydel potential candidate plants.

  The optimized least cost system expansion plan is summarized as follows:-

Sequence of Generation Additions - Base Case

	Thermal Projects				Hydroelectric Projects			Cumulative	
Fiscal year	Combustion Turbine 200 MW	Combined Cycle 630 MW	Steam COAL 600 MW	Thermal Capacity MW	Name of Project	MW	Hydel Capacity MW	Capacity Additions (MW)	LOLP %
1995/96								0	2.2
2002/03					Duber Khwar	170	294	294	0.7
					Allai-IV	124			
2003/04				0	Khan Khwar	73	446	740	1.0
					Matiltan	84			
					Chakothi	139			
					Kotli	97			
					Harighel	53			
2004/05	1			200	Swat - A1	105	105	1045	1.0
2005/06	3	1		1230	Swat - B1	429	429	2704	0.9
2006/07					Kalabagh 1-4	1200	1917	4621	0.6
					Sehra	65			
					Suki Kinari	652			
2007/08					Kalabagh 5-8	1200	1654	6275	0.9
					Karrang	454			
2008/09	2			400	Neelum- Jhelum	930	930	7605	0.8
2009/10	1	2		1460	Tarbela 4th Ext.	960	1811	10876	0.6
					Spat Gah	851			
2010/11	1	2		1460			0	12336	0.7
2011/12	1	1		830	Basha 1-3	840	840	14006	0.8
2012/13		2		1260	Basha 4-6	840	840	16106	0.9
2013/14	1	3	3	3890	Basha 7-9	840	840	20836	0.7
2014/15	7	1	3	3830	Basha 10-12	840	840	25506	0.8
2015/16	1		4	2600				28106	0.8
2016/17	1		3	2000	Kohala	1000	1000	31106	0.9
2017/18	1		4	2600	Munda	600	600	34306	0.9
Total	20	12	17	21760			12546	34306	0.9

12.7.1.2 Role of High Head Hydropower in National Power Mix

Hydropower in general and High head Hydel Plants in particular are ideally suited to serve peak demand. The most economic method of meeting demand in a thermal hydel solution would be to supplement base load by hydels and intermediate class thermal and peaking thermals by High Head Hydel facilities. The existing power mix, in Pakistan, is a thermal hydel mix. The lest cost solution to meet future demand is discussed in elsewhere. The expansion plan can be summarized as follows:

	Thermal Capacity Added upto YR-2018 MW
* Combustion Turbines	6800
* Private Sector	1293
* Combined Cycle	8190
* Steam (LSFO)	19800

The least cost solution developed by HEPO/SHYDO/GTZ was developed to indicate the impact of considering the high head hydel schemes identified in northern NWFP and AJK as candidates. This resulted in a slight lowering of the NPV and the thermal part of the energy mix changed as follows:

	Year 2018		
	Base Case	Modified Case	Diff.
* Combustion Turbines	6800	2500	-4300
* Private Sector	1293	1293	0
* Combined Cycle	8190	8190	0
* Steam (LSFO)	19800	19800	0

The least cost solution which considered high head hydels as candidates resulted in 4300 MW less combustion turbine capacity. The high head hydel therefore resulted in:

- Avoided gas fired turbine capacity (peaking turbines)
- Avoided fuel and operation costs of thermal power plants.

The least cost solution therefore in itself, high lights the role of high head hydel plants. The role is:

TO PROVIDE PEAK CAPACITY
TO MEET DAILY SYSTEM PEAKS

Besides contributing towards capacity at peak demand periods the high head hydels also contribute off-peak energy during the hydrologically wet periods of the year and result in avoided fuel and operational costs of thermal power plants (there is a cost associated with this as it result in lower plant factors of thermal plants. This can partially be offset by means of adding intermediate class thermal plants instead of base load thermal facilities).

12.8 FEASIBILITY ON LRMC AND THERMAL EQUIVALENCE BASIS

The economic feasibility on the basis of LRMC and thermal equivalence is summarized as follows:

ECONOMIC EVALUATION OF HIGH HEAD HYDRO POWER
SUMMARY OF RESULTS

THERMAL EQUIVALENCE			
COST OF GENERATION : THERMAL EQUIVALENT (BASE CASE)			
GAS TURBINE	=	5.19	Rs./kWh
COAL FIRED STEAM	=	1.77	Rs./kWh
TOTAL	=	1.90	Rs./kWh
NPV AT 10%	=	3494	M.Rs.
HYDEL THERMAL OPTION			
COST OF GENERATION : HYDEL THERMAL ALTERNATIVE			
HYDEL STATION	=	1.33	Rs./kWh
COAL FIRED STEAM	=	2.50	Rs./kWh
TOTAL	=	1.83	Rs./kWh
NPV AT 10%	=	3360	M.Rs.
ECONOMIC FEASIBILITY : THERMAL EQUIVALENCE			
NET PRESENT VALUE AT 10 %	=	135	M.Rs.
INTERNAL RATE OF RETURN	=	11.15	%

ECONOMIC FEASIBILITY USING MARGINAL COSTS			
NET PRESENT VALUE AT 10 %	=	543	M.Rs.
INTERNAL RATE OF RETURN	=	14.57	%

ECONOMIC FEASIBILITY USING MARGINAL COSTS			
AND CONSIDERING LOCAL DEMAND			
NET PRESENT VALUE AT 10 %	=	555	M.Rs.
INTERNAL RATE OF RETURN	=	14.68	%
BENEFIT TO COST RATIO	=	1.40	

12.9 FEASIBILITY ON CONSUMER SURPLUS BASIS

The second step in the economic evaluation of the power plant is to establish that the least cost solution is indeed also economic. This is determined by means of justifying the proposed investment in comparison to avoided investments in other sections of the economy.

Benefits and costs to be used for this section are presented in section 12.6. The analysis is presented as follows:

Economic Feasibility - Consumer Surplus Basis

Year	Capital Cost Hydel Including Transmission M.Rs.	Capital Cost Indirect Transmission M.Rs.	Distribution M.Rs.	Operation & Maintenance M.Rs.	Total Costs M.Rs.	Energy Delivered GWh	Energy Value GWh	Total Benefit M.Rs.	Net Benefit M.Rs.
-2	4.55				432.22			0.00	-432.22
-1	427.67				1403.78			0.00	-1403.78
0	762.25	52.94	160.93		1978.06			0.00	-1978.06
1	737.78	52.94	160.93	50.29	1052.23	133.20	644.16	644.16	-408.08
2				50.29	50.29	133.20	644.16	644.16	593.86
3				50.29	50.29	133.20	644.16	644.16	593.86
4				50.29	50.29	133.20	644.16	644.16	593.86
5	14.49			50.29	64.78	133.20	644.16	644.16	579.37
6				50.29	50.29	133.20	644.16	644.16	593.86
7				50.29	50.29	133.20	644.16	644.16	593.86
8				50.29	50.29	133.20	644.16	644.16	593.86
9				50.29	50.29	133.20	644.16	644.16	593.86
10	14.49			50.29	64.78	133.20	644.16	644.16	579.37
11				50.29	50.29	133.20	644.16	644.16	593.86
12				50.29	50.29	133.20	644.16	644.16	593.86
13				50.29	50.29	133.20	644.16	644.16	593.86
14				50.29	50.29	133.20	644.16	644.16	593.86
15	86.94			50.29	137.23	133.20	644.16	644.16	506.92
16				50.29	50.29	133.20	644.16	644.16	593.86
17				50.29	50.29	133.20	644.16	644.16	593.86
18				50.29	50.29	133.20	644.16	644.16	593.86
19				50.29	50.29	133.20	644.16	644.16	593.86
20	53.13			50.29	103.42	133.20	644.16	644.16	540.73
21				50.29	50.29	133.20	644.16	644.16	593.86
22				50.29	50.29	133.20	644.16	644.16	593.86
23				50.29	50.29	133.20	644.16	644.16	593.86
24				50.29	50.29	133.20	644.16	644.16	593.86
25	14.49			50.29	64.78	133.20	644.16	644.16	579.37
26				50.29	50.29	133.20	644.16	644.16	593.86
27				50.29	50.29	133.20	644.16	644.16	593.86
28				50.29	50.29	133.20	644.16	644.16	593.86
29				50.29	50.29	133.20	644.16	644.16	593.86
30	169.05			50.29	219.34	133.20	644.16	644.16	424.81
						EIRR	=	11.3	%
						NPV @ 10	=	441.73	M.Rs.

12.10 CONCLUSION

The economic analysis was based on the steps summarized as follows:

- The hydel solution (proposed hydropower plant) is determined to be the economic choice when compared to alternative means of serving demand.
- The least cost solution (hydel power plant) results in benefits which are larger than costs.

The result of the economic analysis is summarized below:

	Economic Feasibility	
	NPV M.US$	IRR %
Consumer Surplus Basis		
- At 100% consumer surplus	10.52	11.36
Sensitivity		
* At 50% consumer surplus	5.14	10.67
* At 50% higher projects costs	2.88	10.35
LRMC Basis		
* Without local demand	12.93	14.57
* With local demand	13.21	14.68
Thermal Equivalence Basis	3.21	11.15

Based upon analysis presented above the proposed Daral Khwar Hydel Generating Power Plant is economic at the stated parameters.

The project should therefore be taken up for construction.

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	1	Part I. Bidding Procedures
	2	Part II. Conditions of Contract and Standard Forms
	3	Part III. Employer's Requirements
Volume 2		**FEASIBILITY STUDY REVIEW REPORT 2008**
	4	Feasibility Study Review Report 2008
Volume 3		**FEASIBILITY STUDY REPORT 2005**
	5	1. Volume 1.1 of 4: Technical Report - Main Report & Annexes
	6	2. Volume 1.2 of 4: Main Report and Appendices
	7	3. Volume 2 of 4: Economic and Financial Analyses
	8	4. Volume 3 of 4: Environmental Assesment
	9	5. Volume 4 of 4: Resettlement Plan
Volume 4		**FEASIBILITY STUDY 1998**
	10	1. Main Report Vol 1 of 2
	11	2. Main Report Vol 2 of 2
	12	3. Appendix-2 (The Power Market) - February 17, 1998
	13	4. Appendix-3 (Topography) - March, 1998 -Report and Summary of Results -Stations Description
	14	5. Appendix-3 (Topography) - March, 1998 -Level Spread Sheets
	15	6. Appendix-3 (Topography) - March, 1998 -Road Alignment
	16	7. Appendix-4 (Hydrological Report) - April, 1998

List of Documents For Handing Over To Bidders

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	18	9. Appendix-5.2 (Geology) - April, 1997 -Geophysical Prospecting -Field Control of Geological Mapping -Engineering Geology (Volume 1 & 2)
	19	10. Appendix-6 (Environmental Impact Assessment) - April, 1998
	20	11. Appendix-7 (Selection of Plant Layout) Interim Report No. 1, 1a & 2
	21	12. Appendix-8 (Hydraulic and Static Pre-Calculations) - May, 1998
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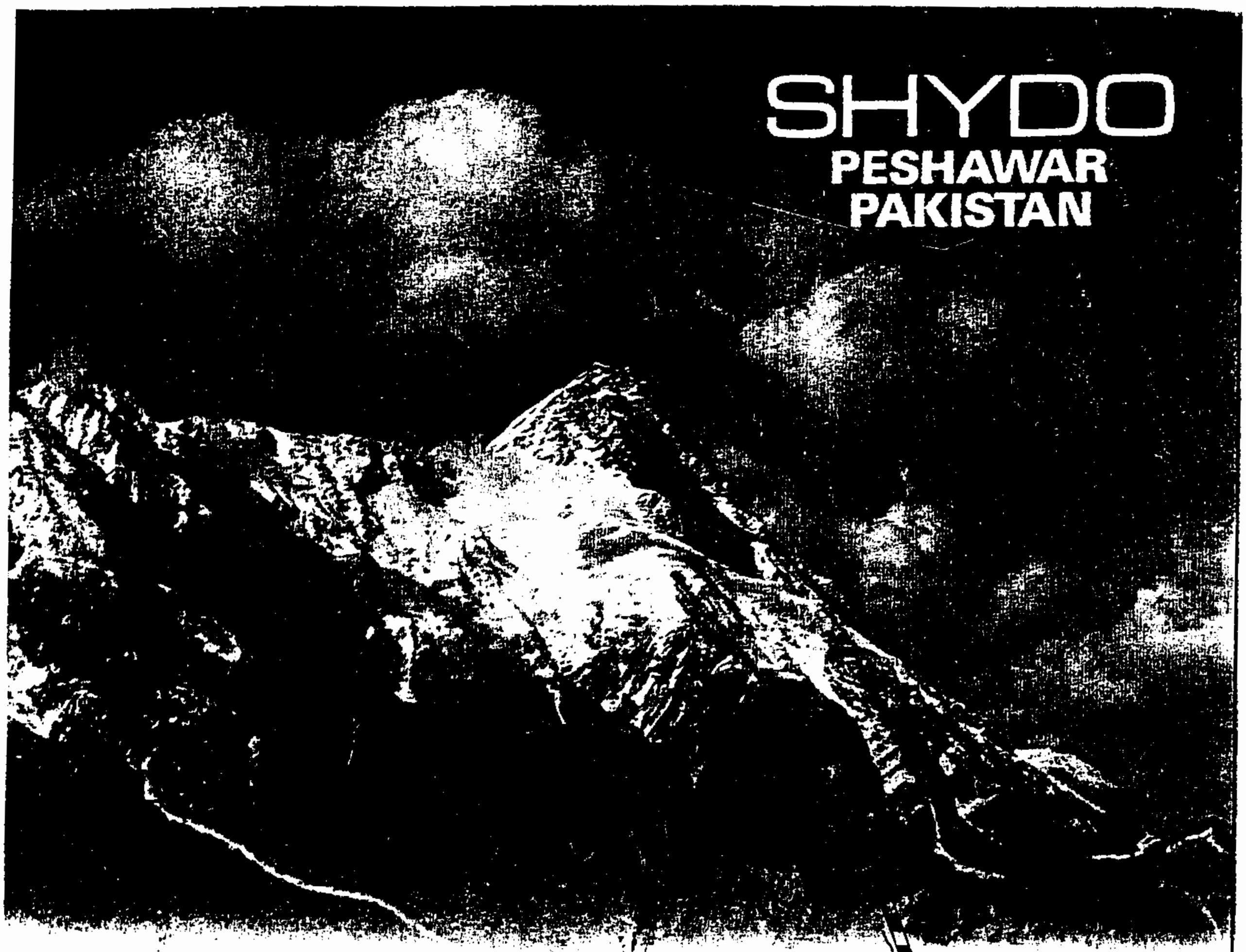
HYDROPOWER DEVELOPMENT IN IOUNTAINOUS AREAS OF N. W. F. P.



FEASIBILITY STUDY

DARAL KHWAR

HYDROPOWER PROJECT

MAIN REPORT

Vol. 2 of 2

May 1998

PAKISTAN GERMAN TECHNICAL COOPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

Main Report

 Vol 2 of 2

DARAL KHWAR HYDROPOWER PROJECT

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CONDUIT SYSTEM ... CONTINUATION

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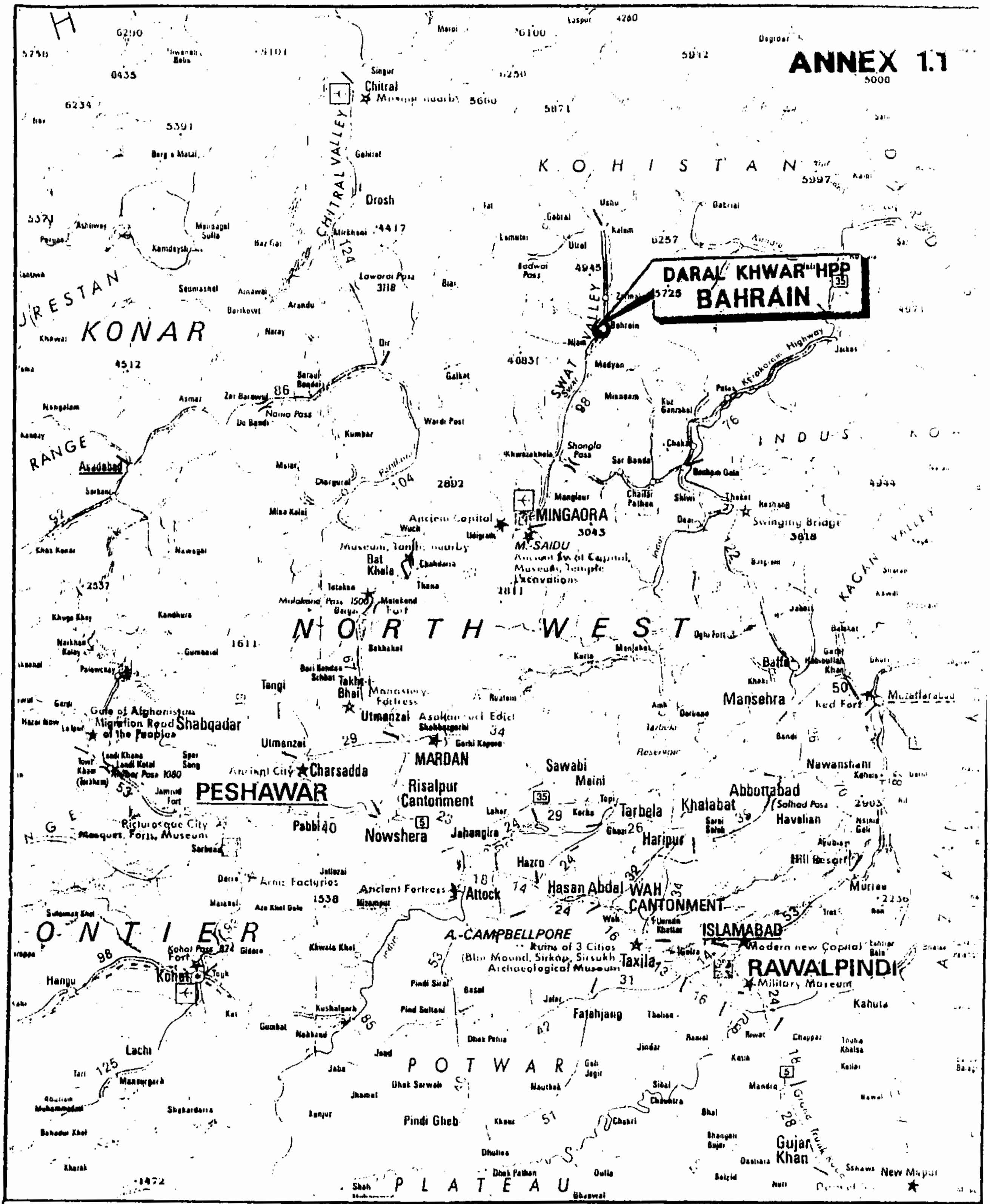
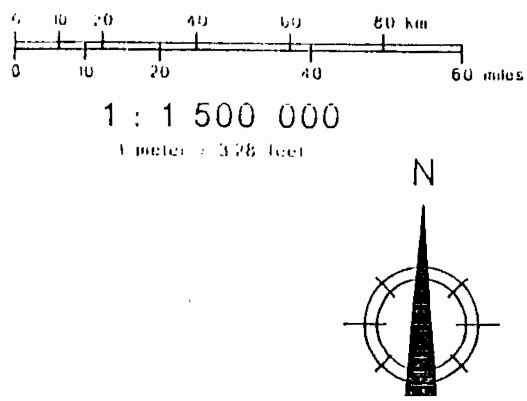




GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL COOPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

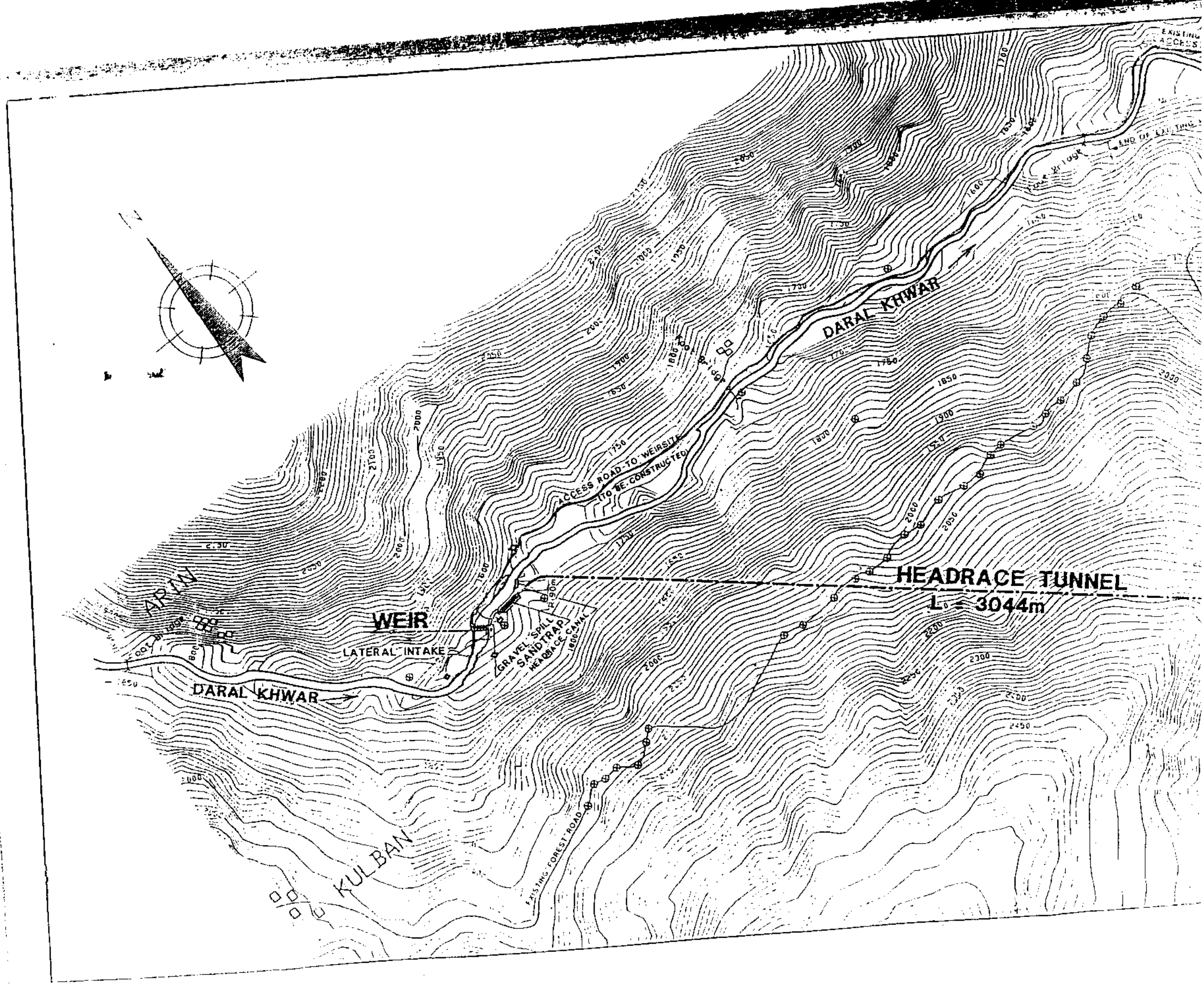
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

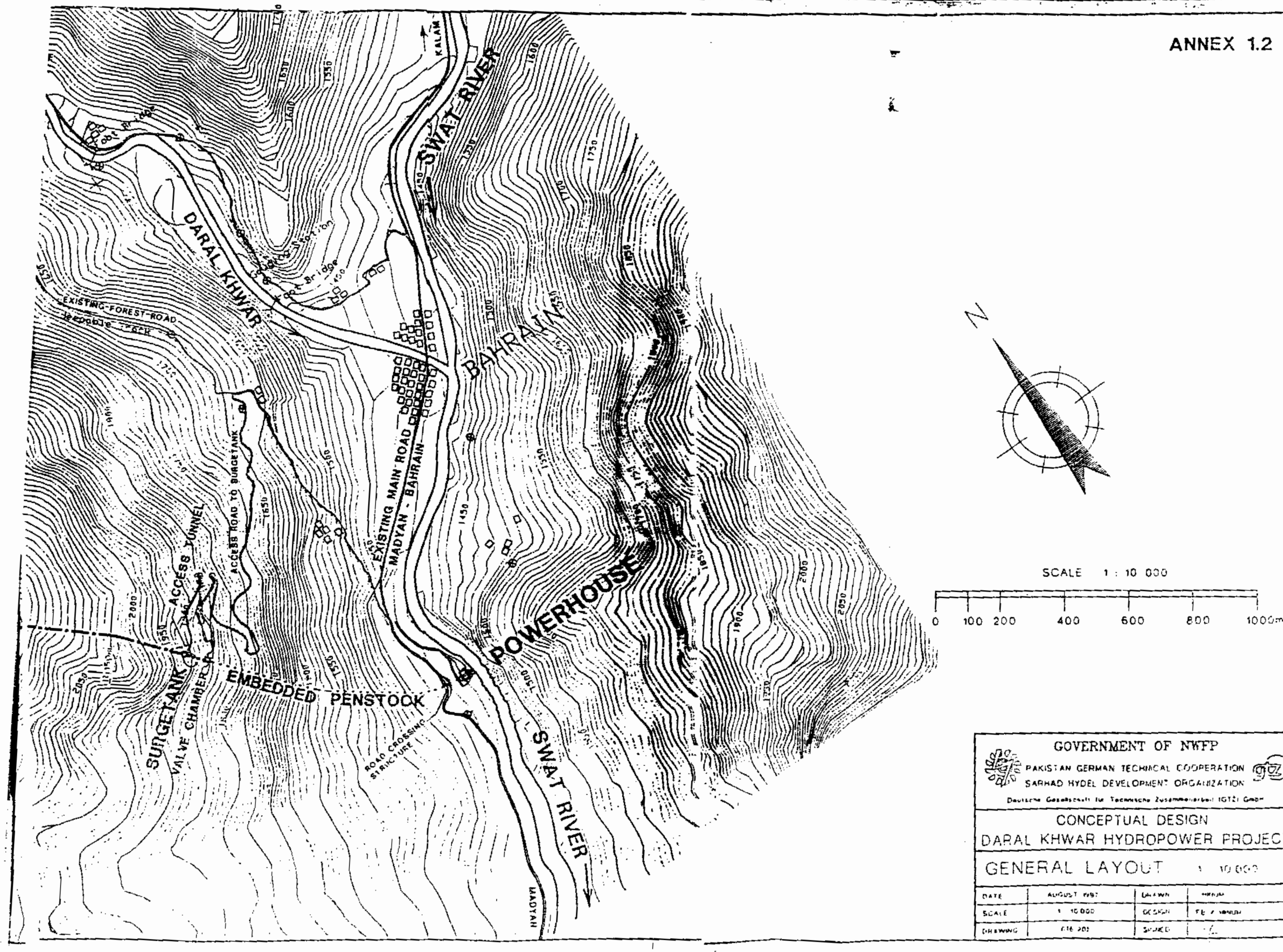
LOCATION OF THE PROJECT AREA

DATE	JUNE 1997	DRAWN	HINUM
SCALE	1 : 1.5 Mio.	DESIGN	FR / [illegible]



HEADRACE TUNNEL
L = 3044m
WEIR
LATERAL INTAKE
GRAVEL SPILL
SANDTRAP
HEADRACE CANAL
DARAL KHWAR
DARAL KHWAR
ACCESS ROAD TO WEIRSITE
(TO BE CONSTRUCTED)
EXISTING FOREST ROAD
KULBAN
ARIN

ANNEX 1.2



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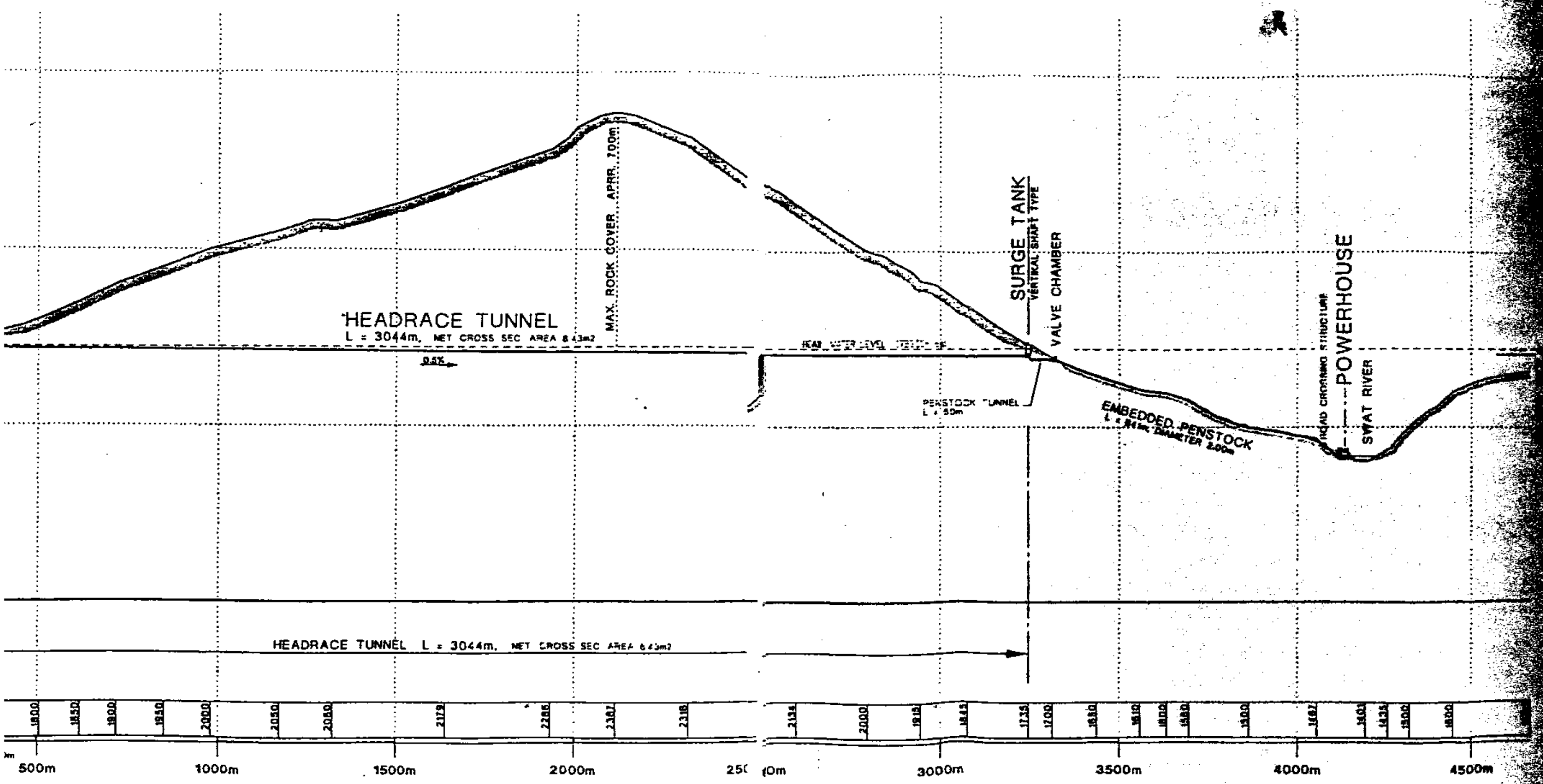
PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

GENERAL LAYOUT

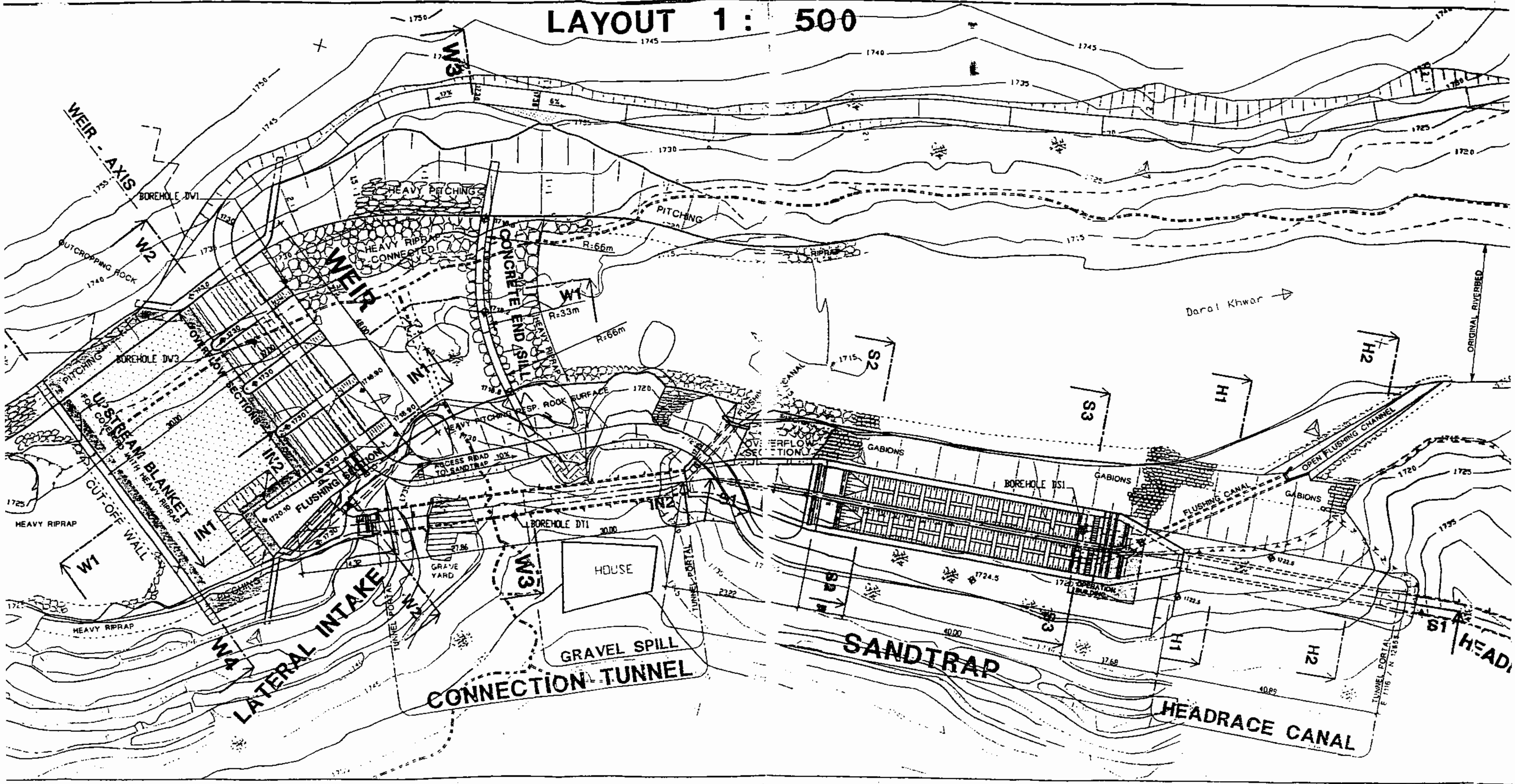
DATE	AUGUST 1997	DRAWN	
SCALE	1 : 10 000	DESIGN	
DRAWING		SIGNED	

GENERAL LONGITUDINAL SECTION 1 : 10,000

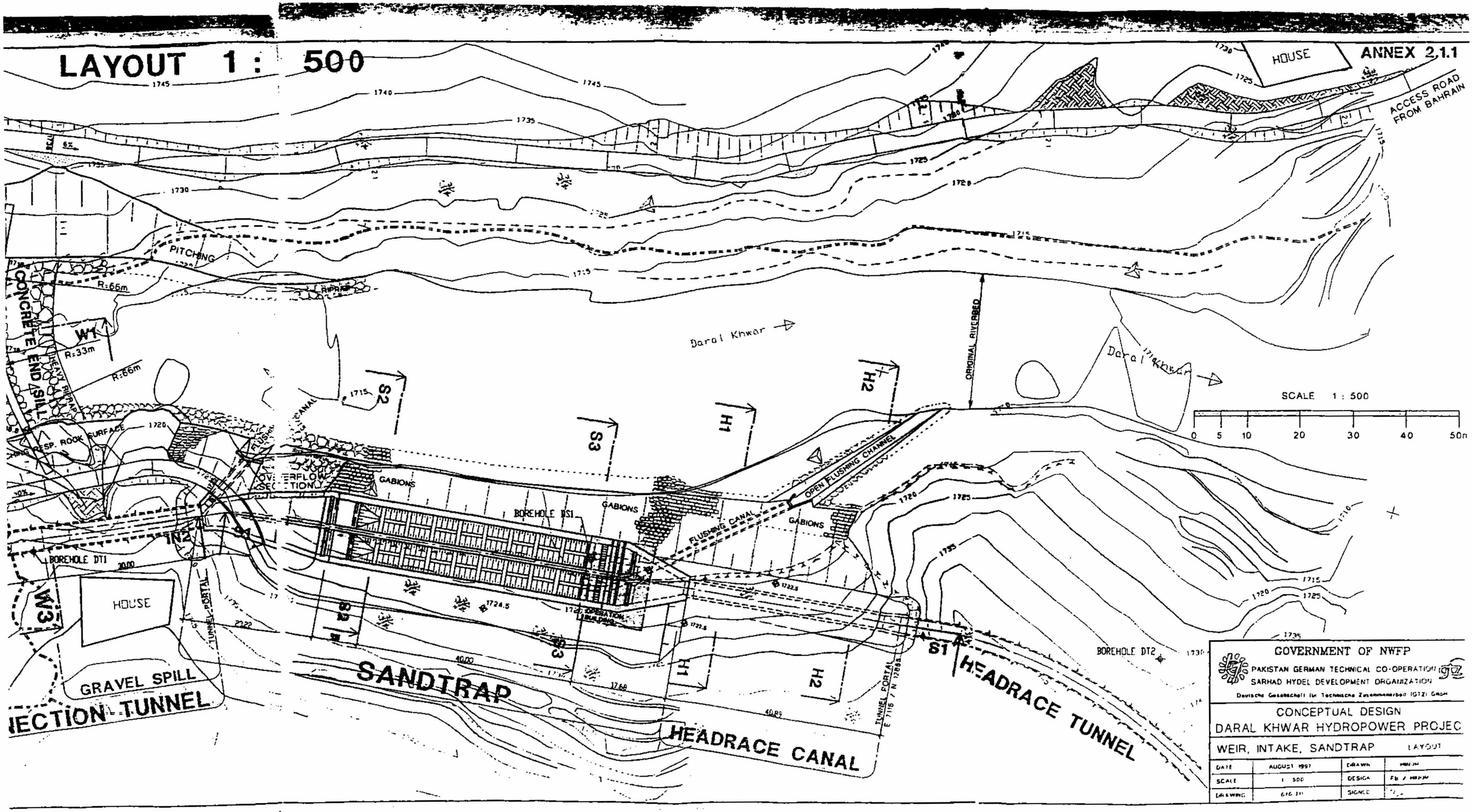


ROCK CLASSIFICATION (ACCORDING LAUFFER)	TOTAL	A/B	C	D	E	F
	IN m	2008	591	277	121	47
	IN %	66	19	9	4	2

LAYOUT 1 : 500

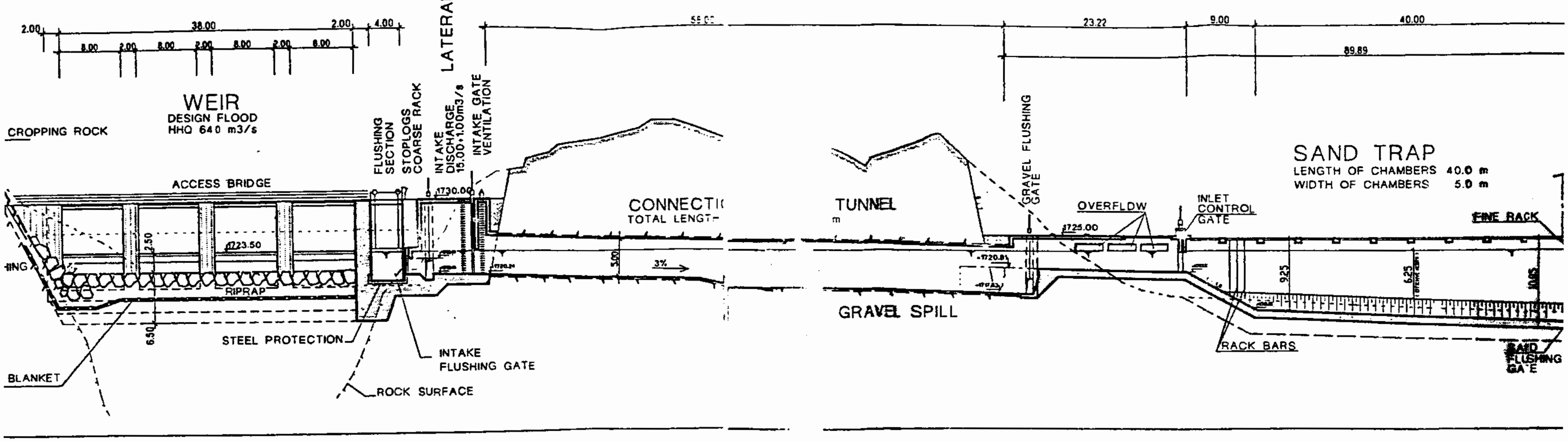


WEIR - AXIS
BOREHOLE DW1
OUTCROPPING ROCK
W2
W3
W1
W4
WEIR
HEAVY PITCHING
HEAVY RIPRAP CONNECTED
CONCRETE END SILL
HEAVY RIPRAP
PITCHING
RIPRAP
R=66m
R=33m
BOREHOLE DW3
OVERFLOW SECTIONS
U/STREAM BLANKET
CUT-OFF WALL
HEAVY RIPRAP
FLUSHING SECTION
IN1
IN2
ACCESS ROAD TO SANDTRAP
BOREHOLE DT1
HOUSE
GRAVE YARD
TUNNEL PORTAL
LATERAL INTAKE
GRAVEL SPILL
CONNECTION TUNNEL
Daral Khwar
ORIGINAL RIVERBED
S1
S2
S3
H1
H2
OVERFLOW SECTION
GABIONS
BOREHOLE DS1
FLUSHING CANAL
OPEN FLUSHING CHANNEL
OPERATION BUILDING
SANDTRAP
HEADRACE CANAL

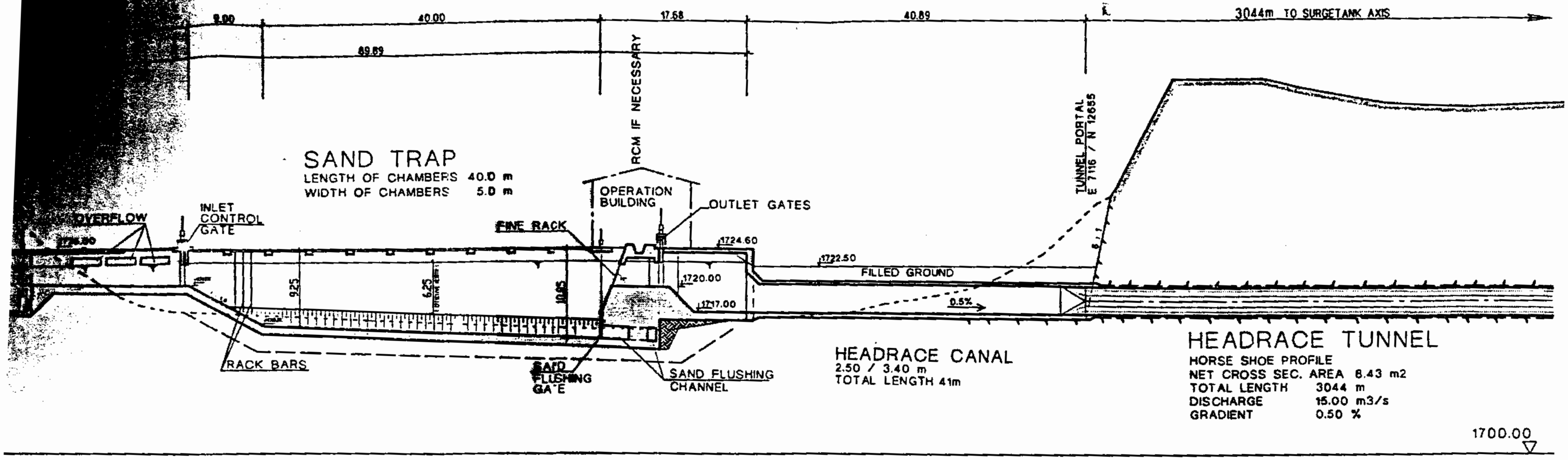


LAYOUT 1 : 500
ANNEX 2.1.1
HOUSE
ACCESS ROAD FROM BAHRAIN
PITCHING
RIPRAP
R=66m
R=33m
R=66m
W1
CONCRETE END SILL
HEAVY RIPRAP
RESP. ROCK SURFACE
Daral Khwar
Daral Khwar
ORIGINAL RIVERBED
SCALE 1 : 500
0 5 10 20 30 40 50m
S2
S3
H1
H2
OVERFLOW SECTION
GABIONS
GABIONS
GABIONS
BOREHOLE DS1
FLUSHING CANAL
OPEN FLUSHING CHANNEL
OPERATION BUILDING
IN2
BOREHOLE DT1
W3
HOUSE
TUNNEL PORTAL
GRAVEL SPILL
ECTION TUNNEL
SANDTRAP
HEADRACE CANAL
TUNNEL PORTAL
S1
HEADRACE TUNNEL
BOREHOLE DT2
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJEC
WEIR, INTAKE, SANDTRAP LAYOUT
DATE AUGUST 1997
SCALE 1 : 500

LONGITUDINAL SECTION 1 : 500



...CTION 1 : 500



SCALE 1 : 500

0 5 10 20 30 40 50m

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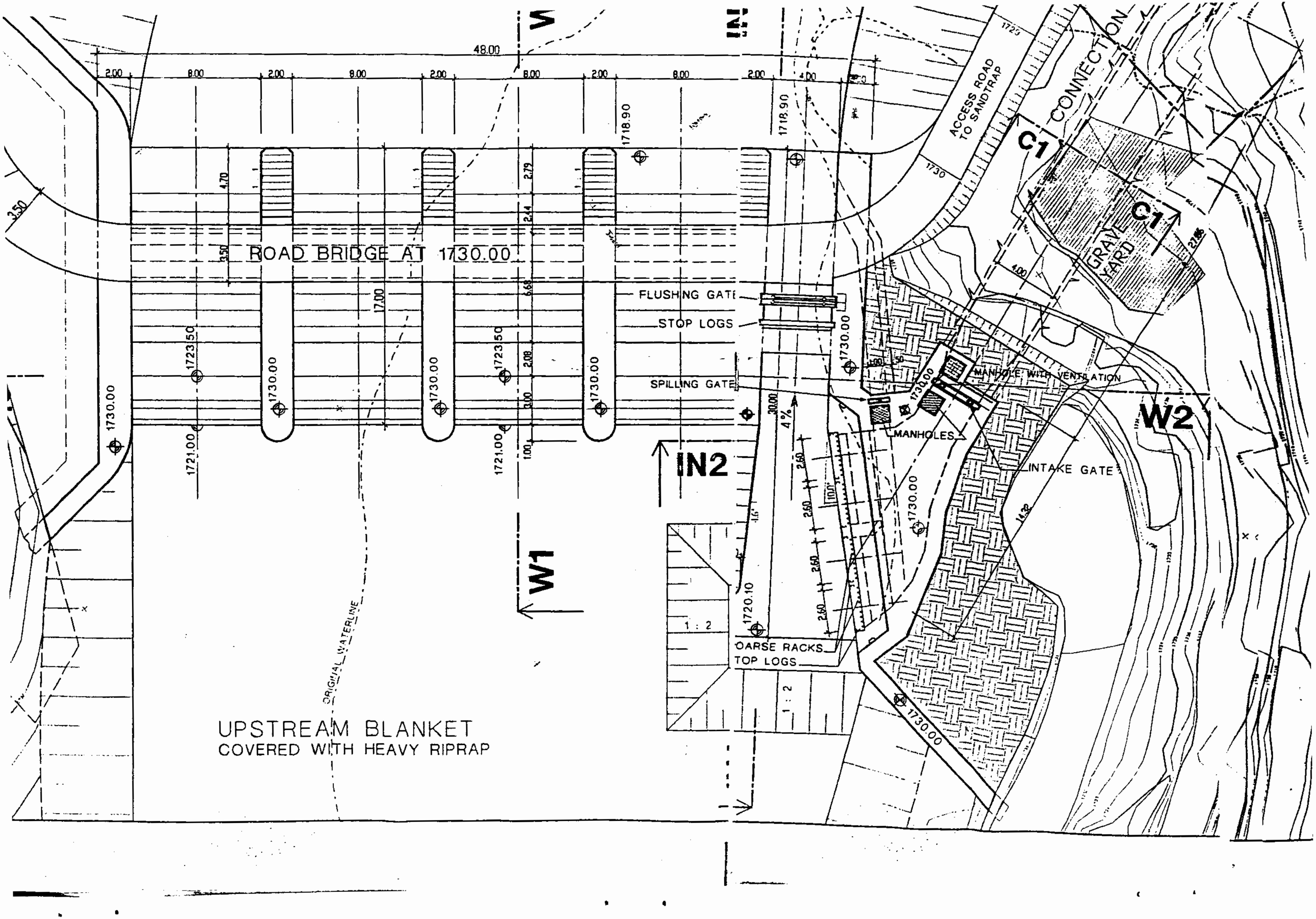
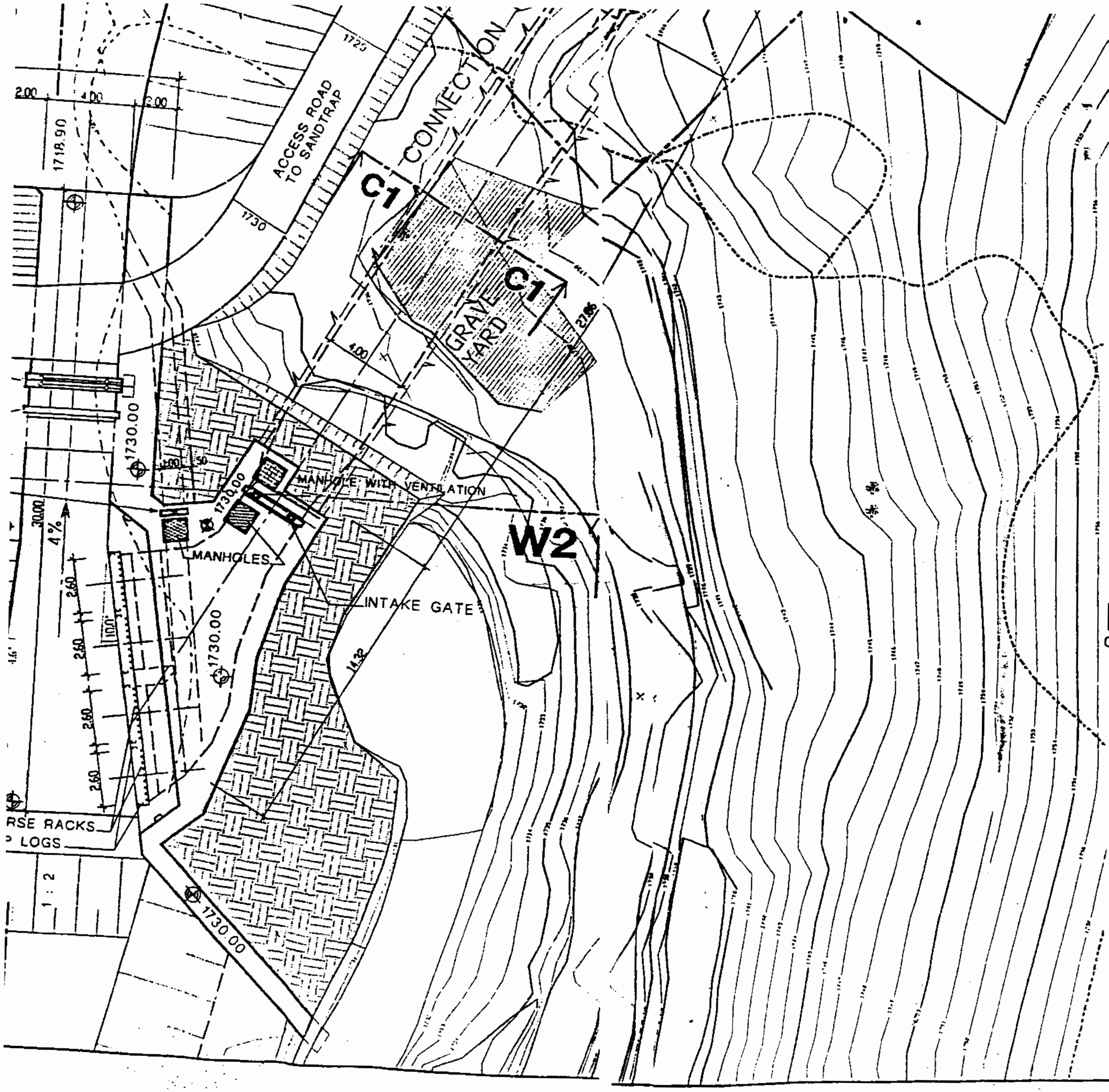
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH			
CONCEPTUAL DESIGN			
DARAL KHWAR HYDROPOWER PROJECT			
WEIR, INTAKE, SANDTRAP GENERAL LONGITUDINAL SECTION			
DATE	AUGUST 1997	DRAWN	HINUM
SCALE	1 : 500	DESIGN	FB / HINUM
DRAWING	676 212	SIGNED	



48.00
2.00
8.00
2.00
8.00
2.00
8.00
2.00
8.00
2.00
4.00
ROAD BRIDGE AT 1730.00
FLUSHING GATE
STOP LOGS
SPILLING GATE
MANHOLE WITH VENTILATION
MANHOLES
INTAKE GATE
ACCESS ROAD TO SANDTRAP
CONNECTION
GRAVE YARD
C1
C1
W1
W2
IN2
1730.00
1723.50
1721.00
1718.90
1720.10
4%
OARSE RACKS
TOP LOGS
ORIGINAL WATERLINE
1 : 2
UPSTREAM BLANKET
COVERED WITH HEAVY RIPRAP



SCALE 1 : 200

0 2 4 8 12 16 20m

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PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

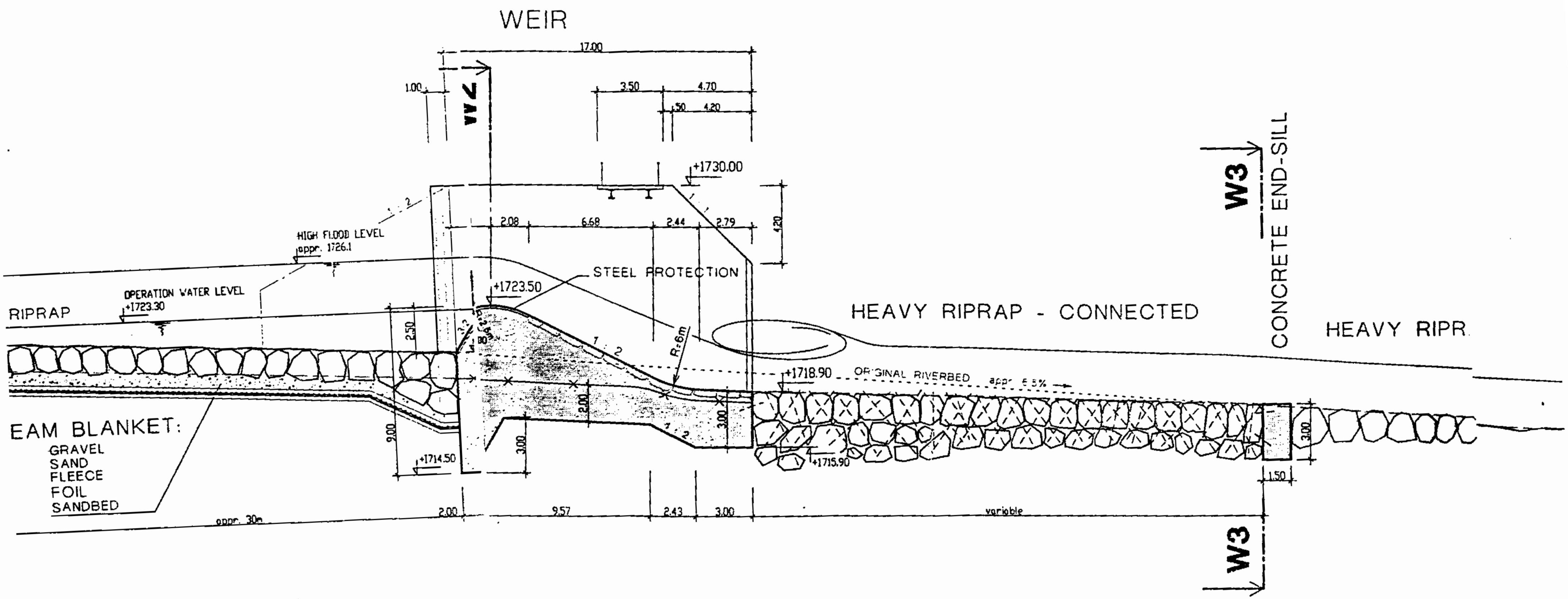
CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

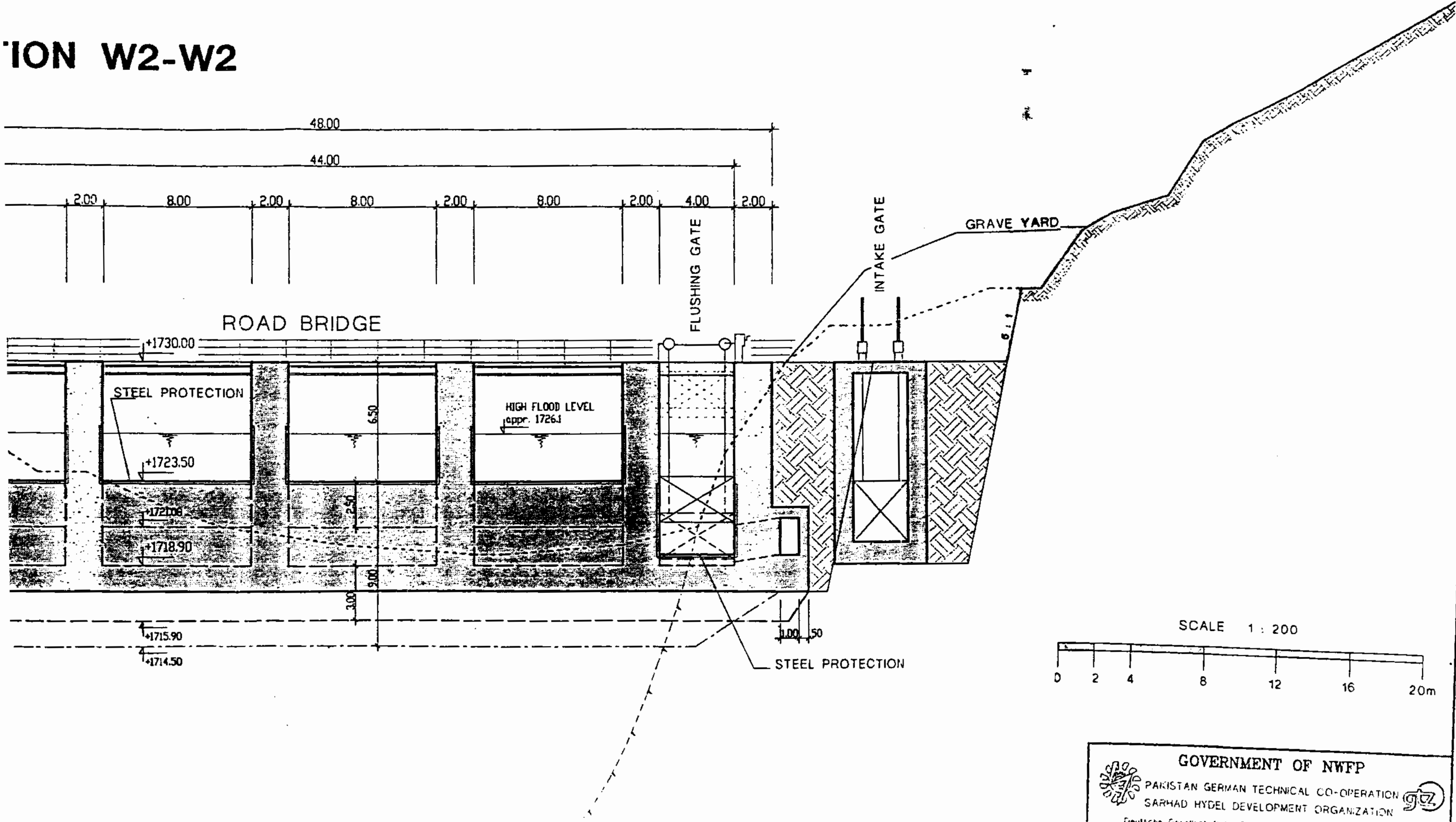
WEIR AND INTAKE LAYOUT

DATE	AUGUST 1997	DRAWN	HINUM
SCALE	1 : 200	DESIGN	FB / HINUM
DRAWING	676-213	SIGNED	

SECTION W1-W1

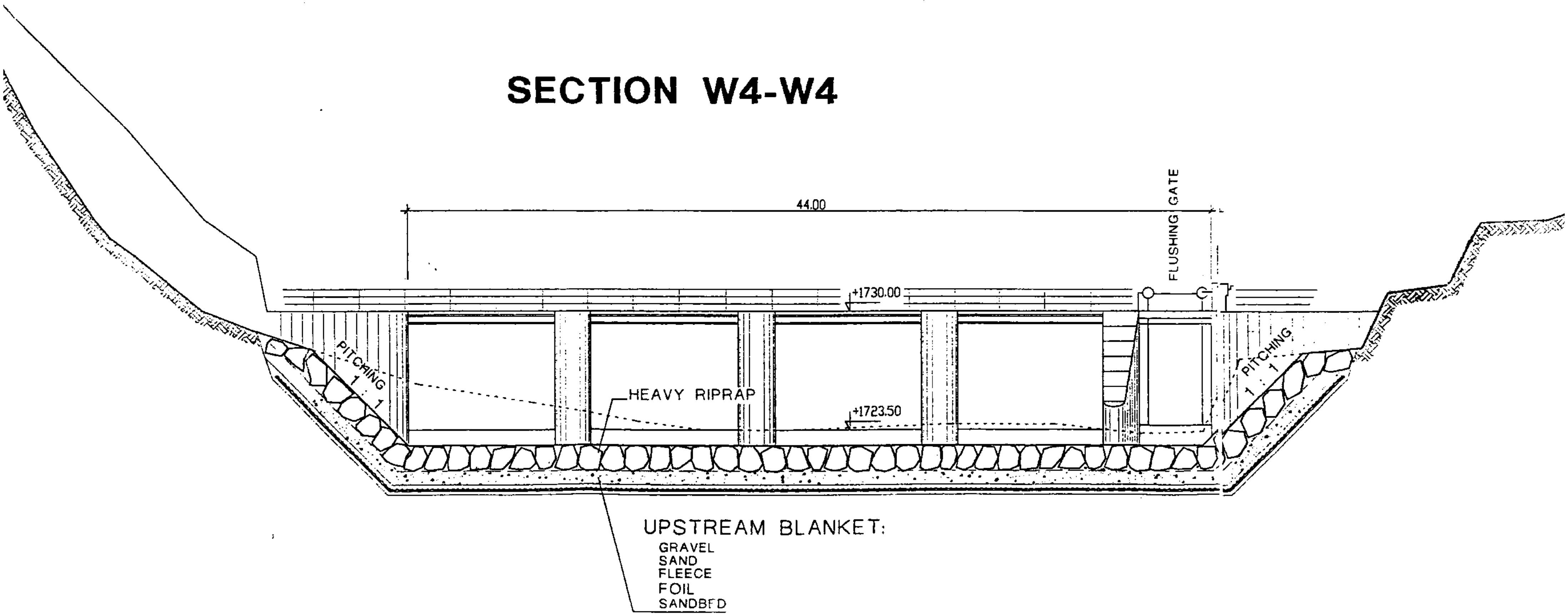


'ION W2-W2

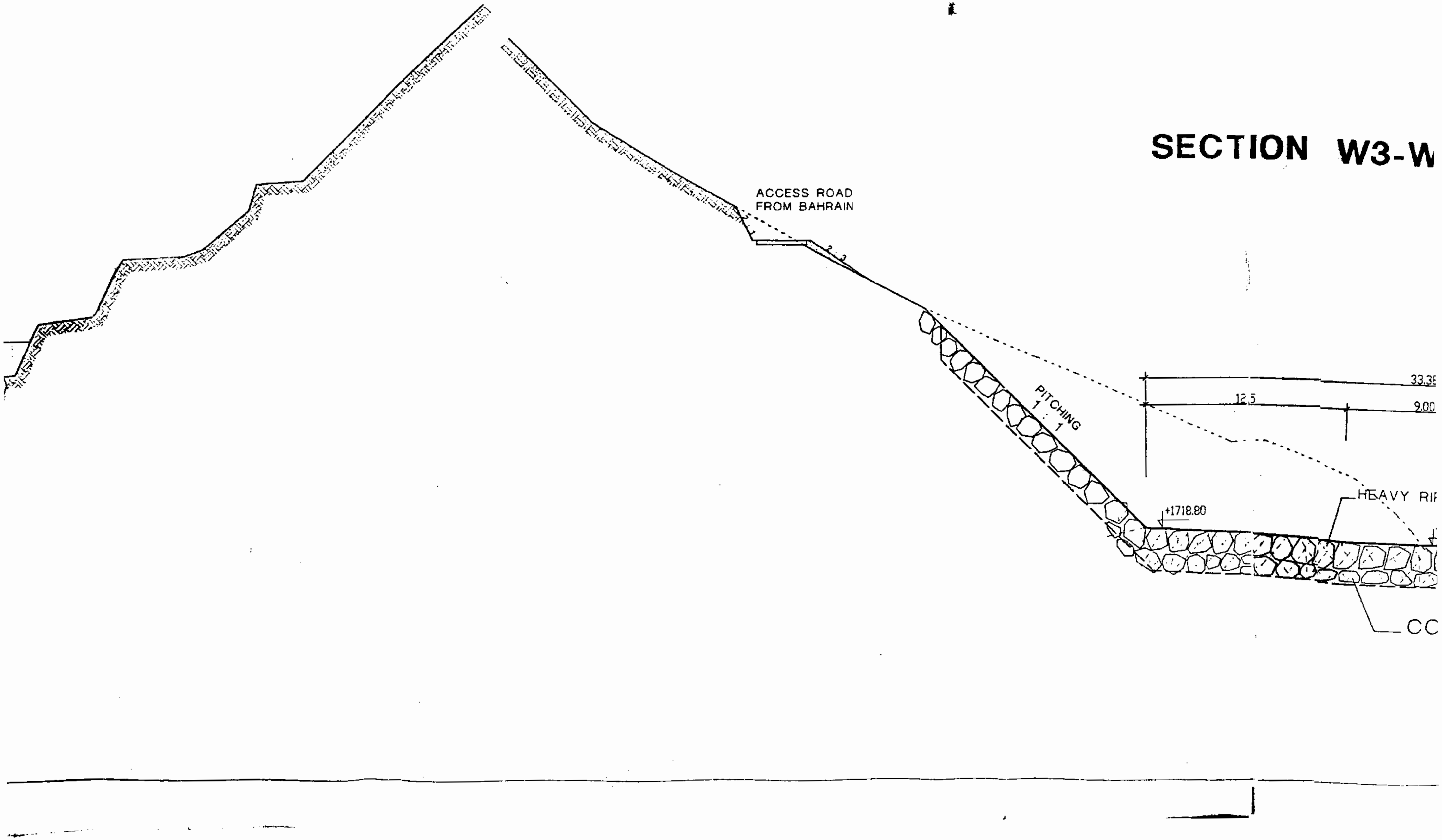


GOVERNMENT OF NWFP			
PAKISTAN GERMAN TECHNICAL CO-OPERATION SARHAD HYDEL DEVELOPMENT ORGANIZATION Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH			
CONCEPTUAL DESIGN DARAL KHWAR HYDROPOWER PROJECT			
WEIR SECTIONS (PART 1)			
DATE	AUGUST 199?	DRAWN	HINJM
SCALE	1 : 200	DESIGN	FB - HINJM
DRAWING	676-214	SIGNED	

SECTION W4-W4

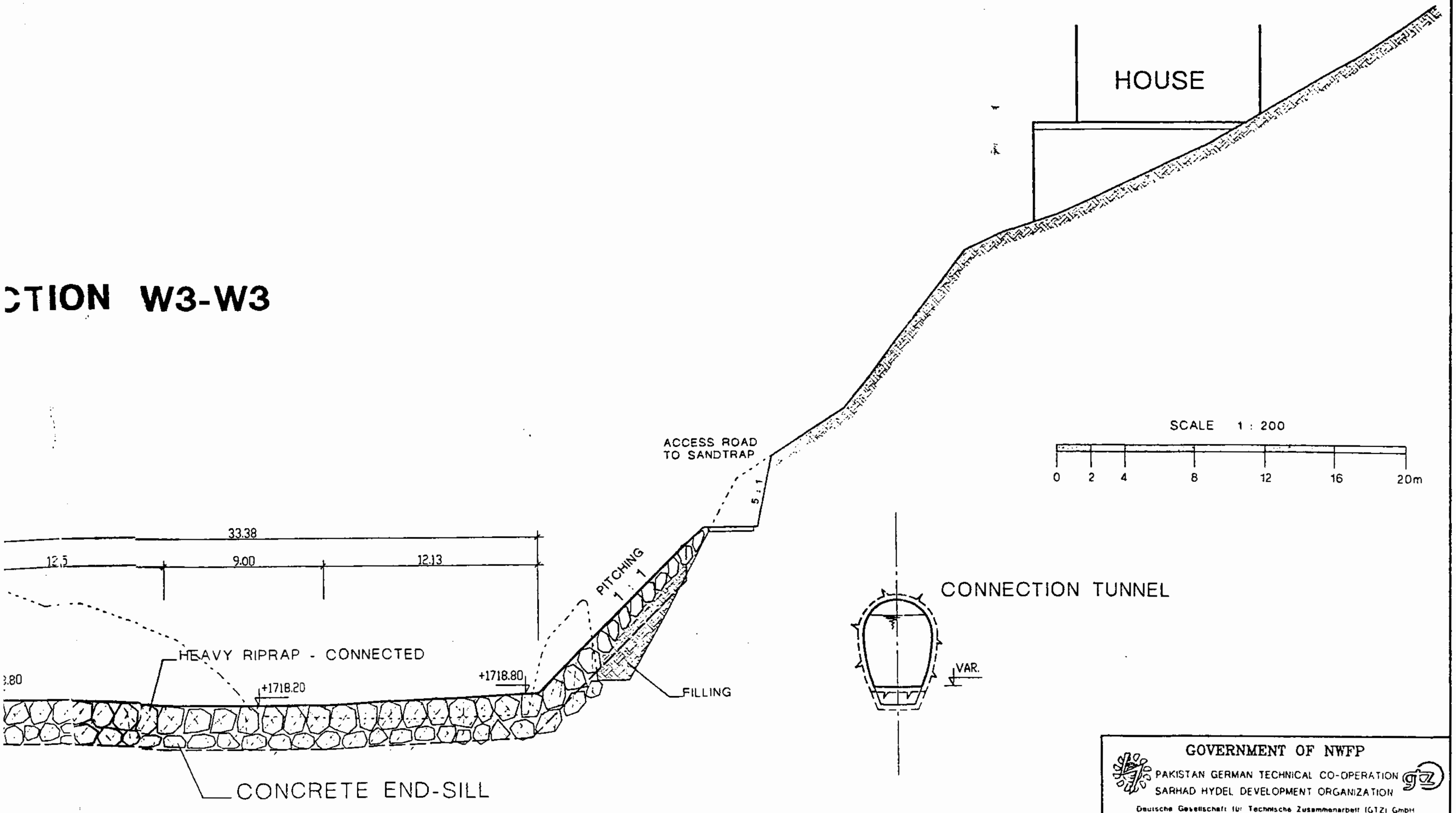


SECTION W3-W



ACCESS ROAD
FROM BAHRAIN
PITCHING
1 : 1
33.38
12.5
9.00
+1718.80
HEAVY RI
CC

ANNEX 4.2.3



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CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

WEIR — SECTIONS (PART 2)

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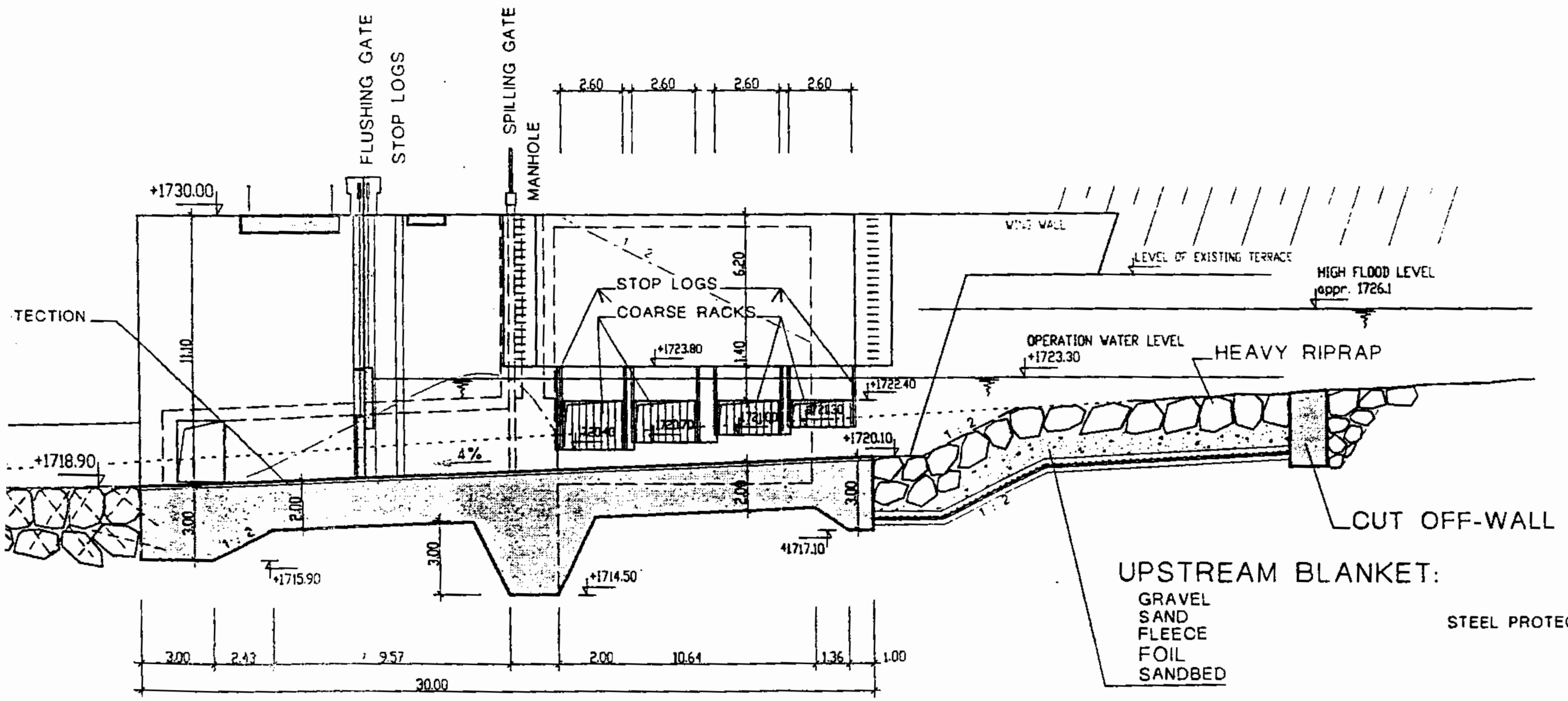
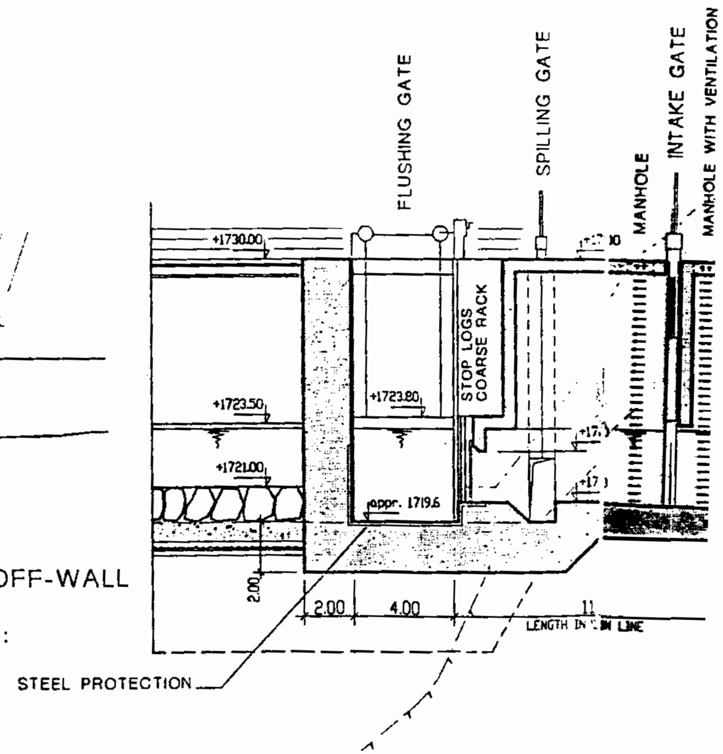
SCALE	1 : 200	DESIGN	FB / HINUM
DRAWING	670-215	SIGNED	

SECTION IN1-IN1

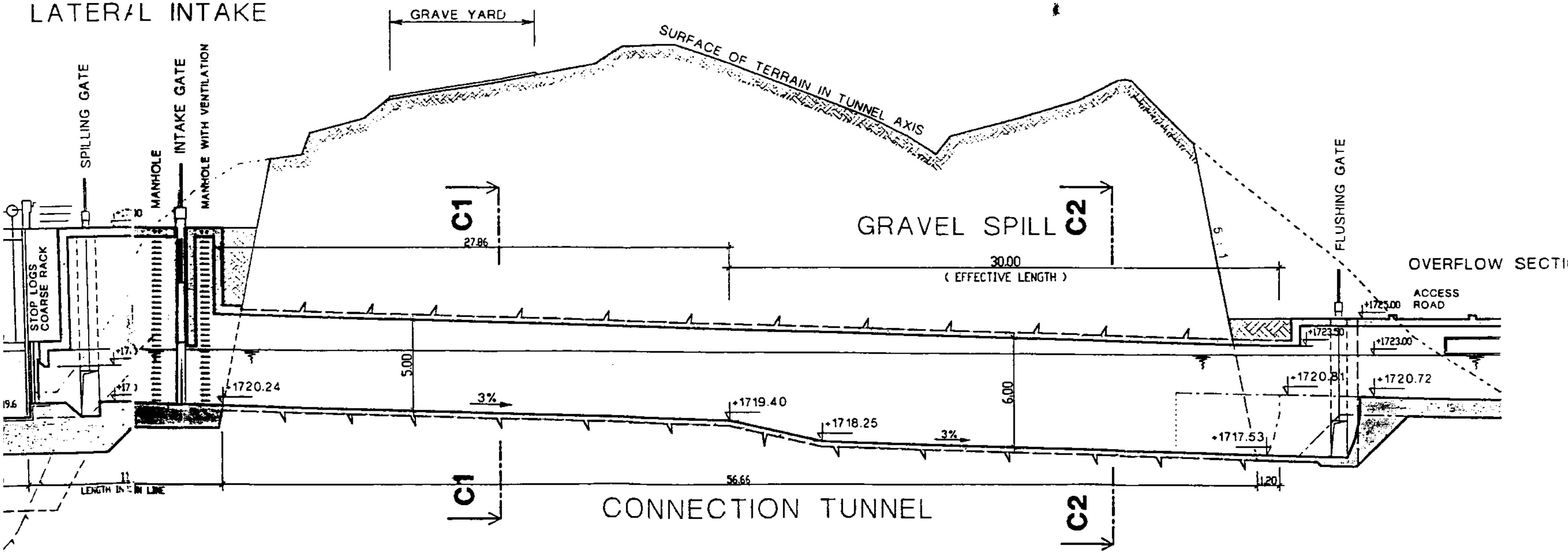


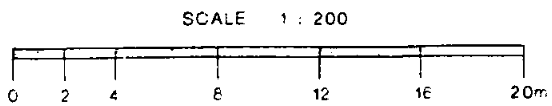
SECTION IN2

LATERAL INT



ECTION IN2-IN2





GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJEC

INTAKE — SECTIONS

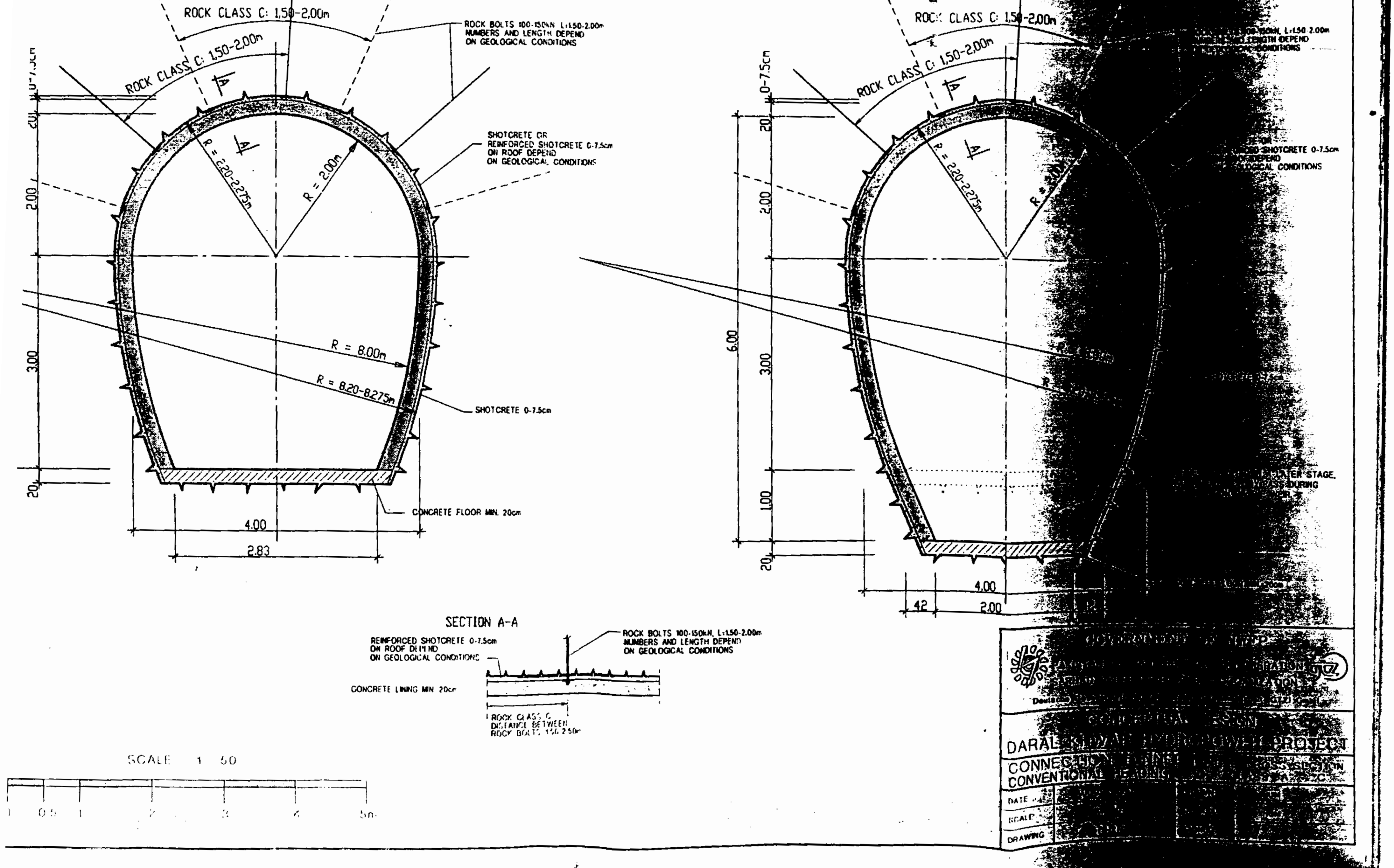
DATE	AUGUST 1997	DRAWN	
SCALE	1 : 200	DESIGN	FB /
DRAWING	676 216	SIGNED	

SECTION C - C

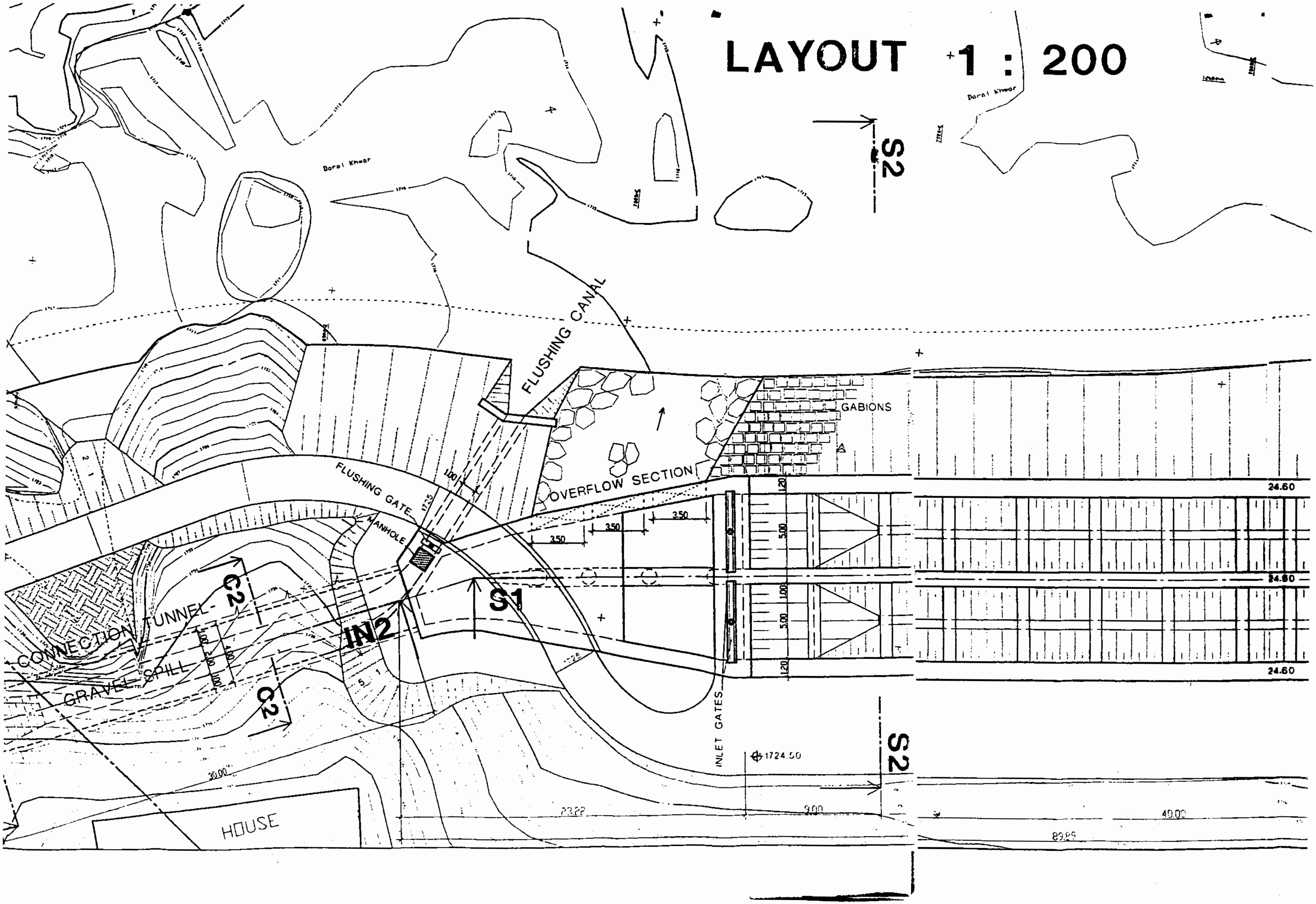
CONNECTION TUNNEL WITHOUT GRAVEL SPILL FEATURE

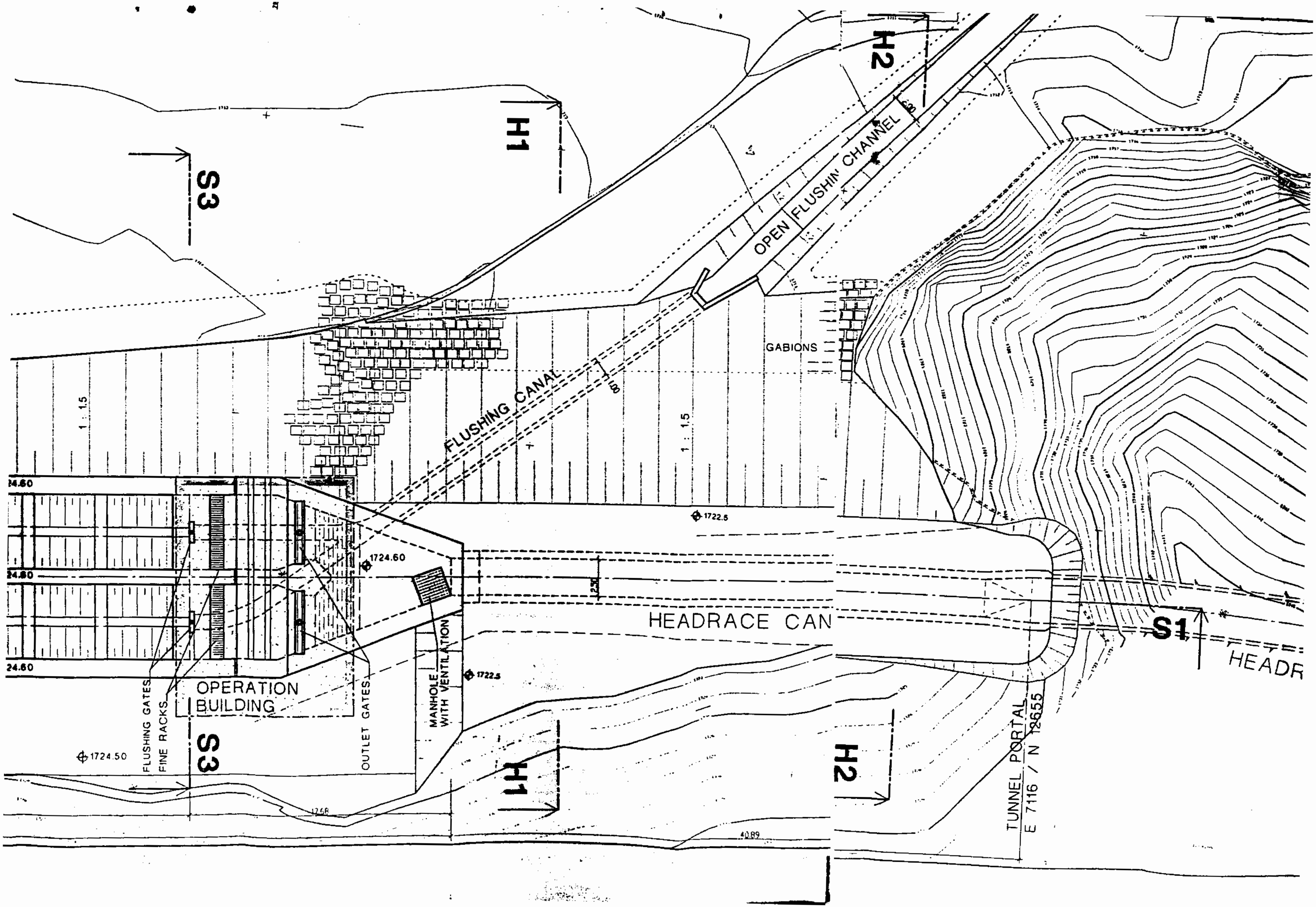
ROCK CLASS A-C
STABLE - FRIABLE
(ACCORDING TO LAUFFER)

CONNECTION TUNNEL WITH GRAVEL SPILL FEATURE



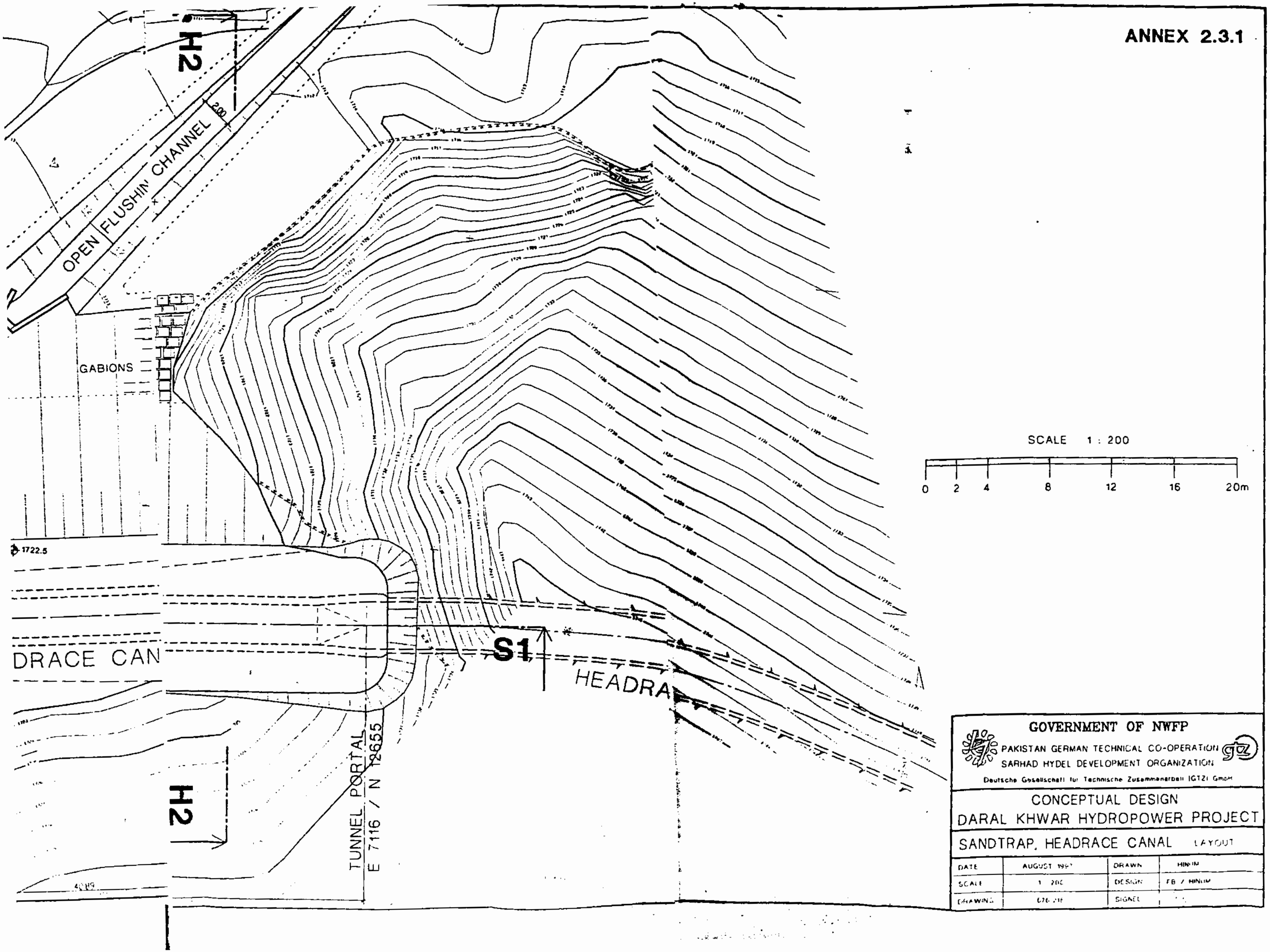
LAYOUT 1 : 200


S2
Doral Khwar
FLUSHING CANAL
GABIONS
OVERFLOW SECTION
FLUSHING GATE
MANHOLE
1.00
1725
3.50
3.50
3.50
24.60
24.60
24.60
1.20
5.00
1.00
5.00
1.20
C2
C2
S1
IN2
CONNECTION TUNNEL
GRAVEL SPILL
1.00
2.00
4.00
1.00
INLET GATES
1724.50
S2
30.00
HOUSE
23.22
9.00
40.00
89.95



H1
S3
H2
OPEN FLUSHIN CHANNEL
GABIONS
FLUSHING CANAL
1 : 1.5
1 : 1.5
24.60
24.60
24.60
1722.5
1724.60
2.50
HEADRACE CAN
HEADR
S1
MANHOLE WITH VENTILATION
1722.5
OPERATION BUILDING
FLUSHING GATES
FINE RACKS
OUTLET GATES
1724.50
S3
H1
H2
TUNNEL PORTAL
E 7116 / N 12655
40.89

ANNEX 2.3.1



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

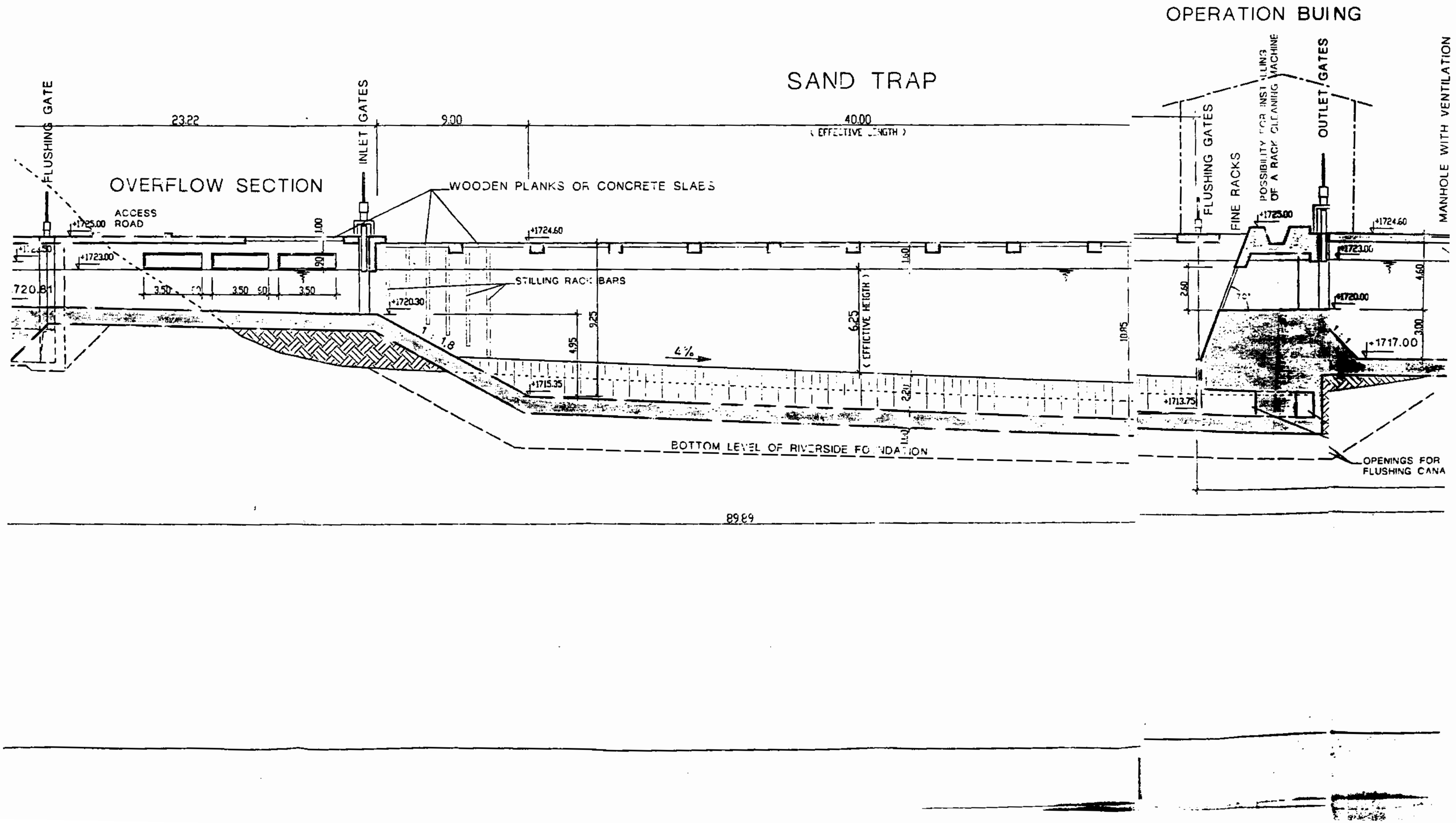
CONCEPTUAL DESIGN

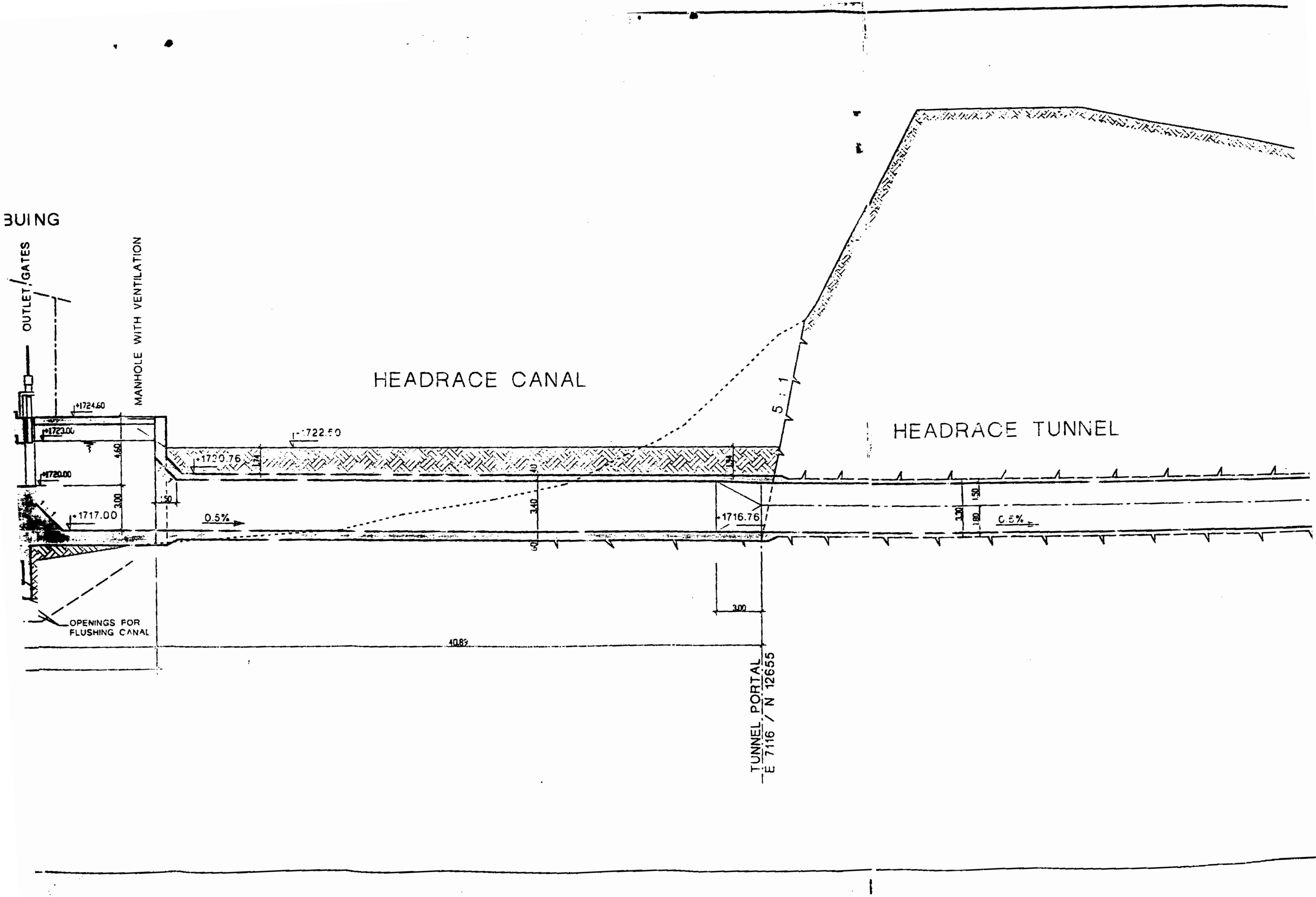
DARAL KHWAR HYDROPOWER PROJECT

SANDTRAP, HEADRACE CANAL LAYOUT

DATE	AUGUST 1997	DRAWN	HINUM
SCALE	1 : 200	DESIGN	FB / HINUM
DRAWING	076 218	SIGNED	

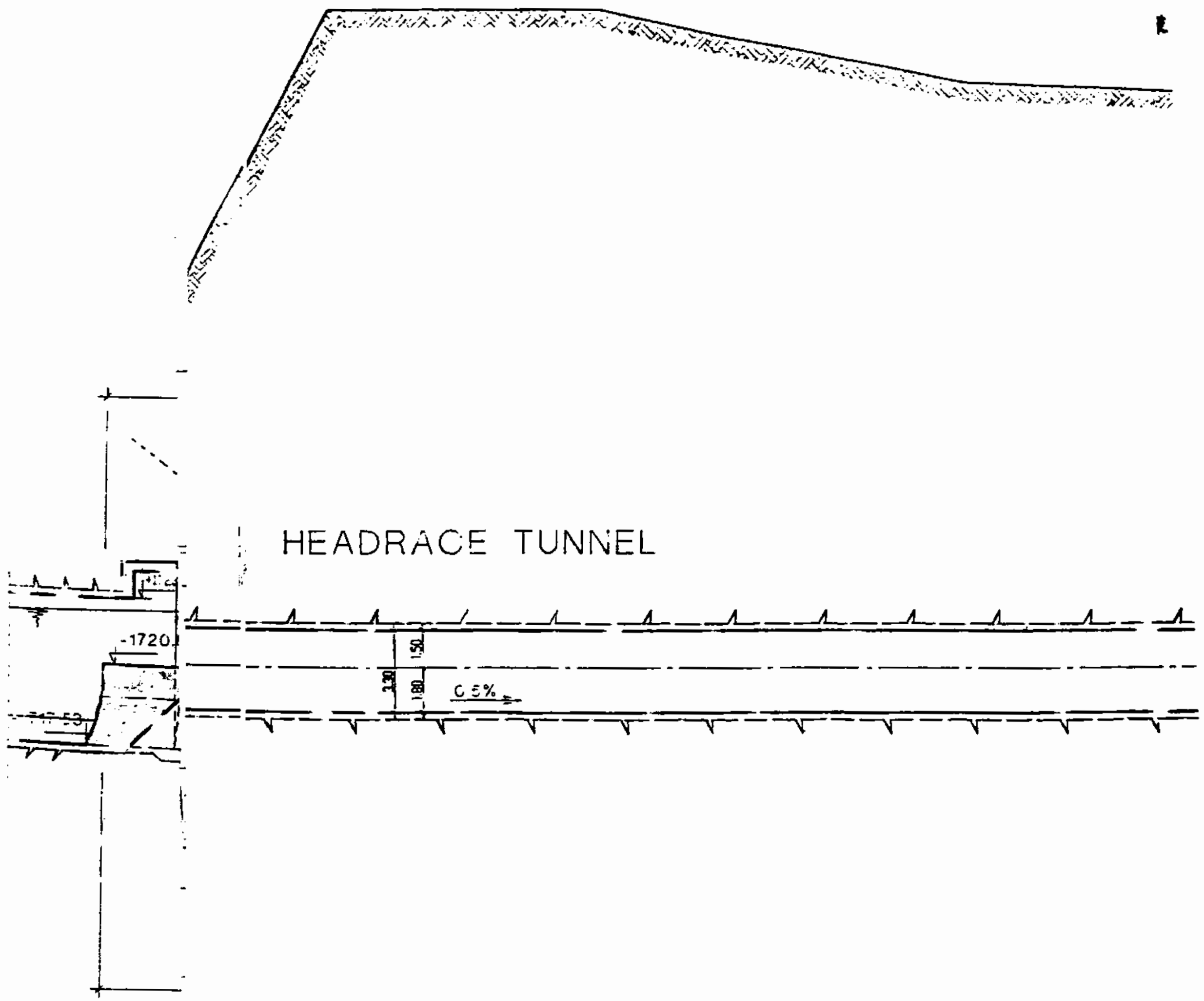
SECTION S1-S1





BUING
OUTLET GATES
MANHOLE WITH VENTILATION
HEADRACE CANAL
HEADRACE TUNNEL
+1724.60
+1723.00
+1720.00
+1717.00
4.60
3.00
.50
1722.50
+1720.76
1.74
.40
3.40
.60
0.5%
5 : 1
+1716.76
3.00
1.50
3.30
1.80
0.5%
OPENINGS FOR
FLUSHING CANAL
40.89
TUNNEL PORTAL
E 7116 / N 12655

ANNEX 2.3.2



SCALE 1 : 200

0 2 4 8 12 16 20m

GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

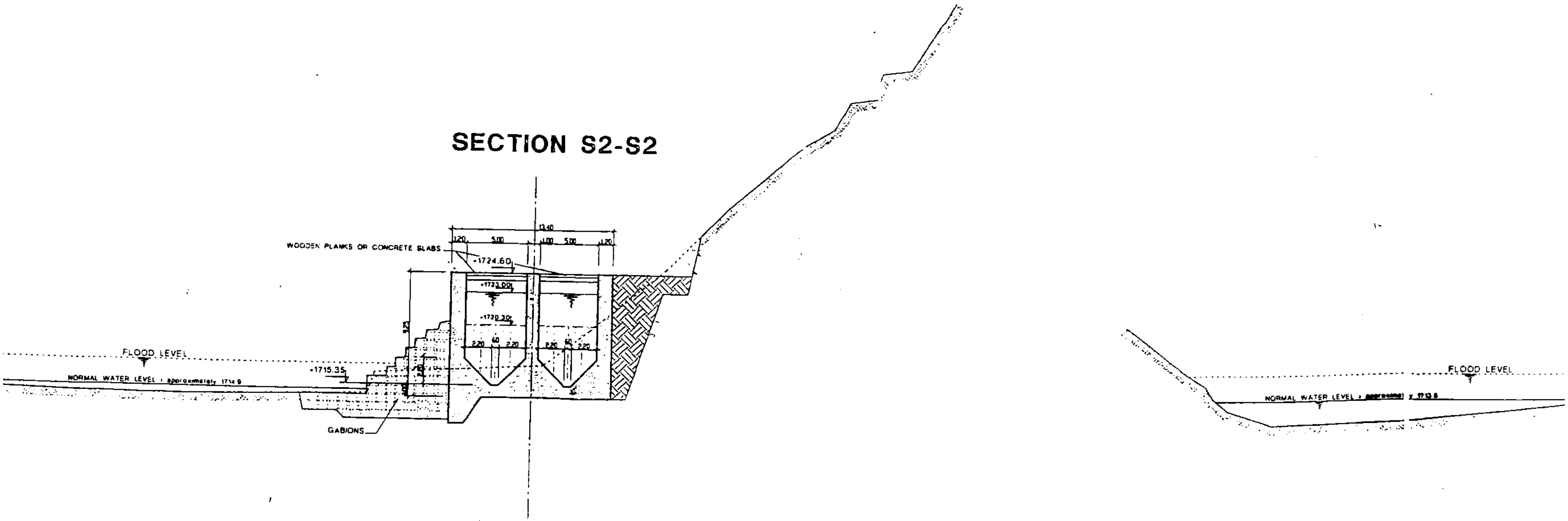
CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

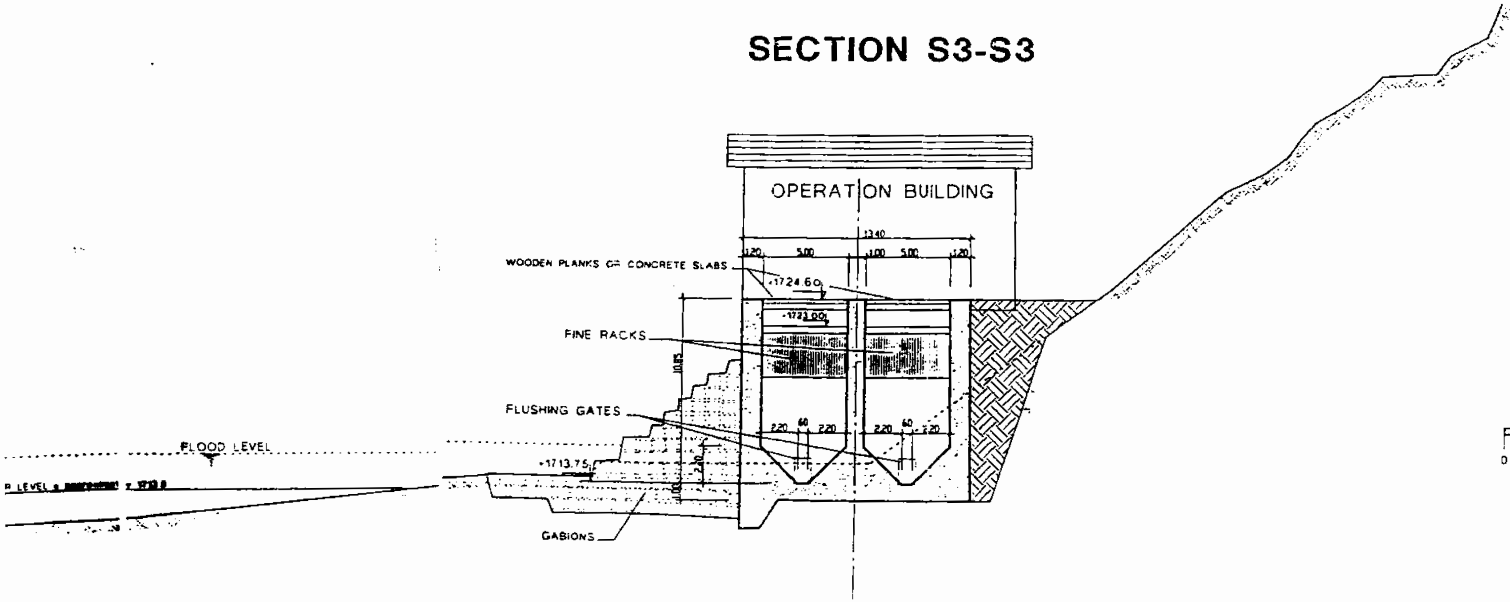
SANDTRAP, HEADRACE CANAL LONGITUDINAL SECTION

DATE	AUGUST 1992	DRAWN	
SCALE	1 : 200	DESIGN	
DRAWG.		SIGNED	

SECTION S2-S2



SECTION S3-S3



SCALE 1 : 200

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GOVERNMENT OF NWFP

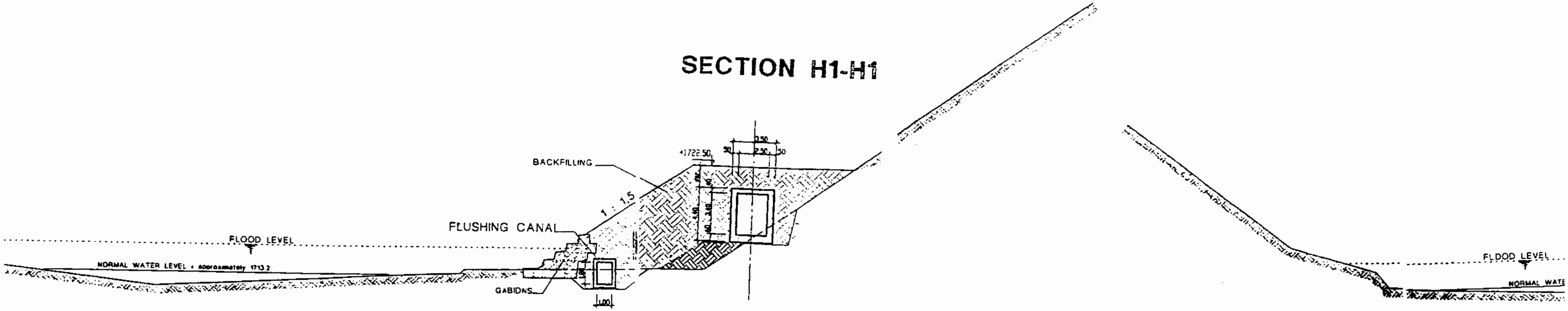
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

SANDTRAP CROSS SECTIONS

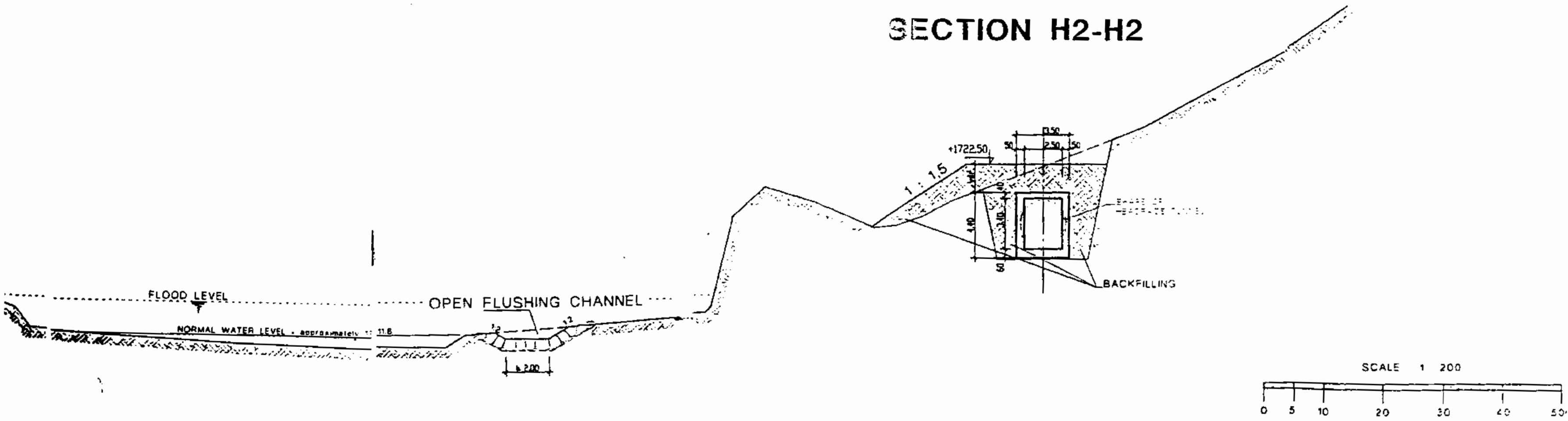
DATE	AUGUST 1997	DRAWN	
SCALE	1 : 200	DESIGN	
DRAWING		CHECK	

SECTION H1-H1



ANNEX 2.3.4

SECTION H2-H2

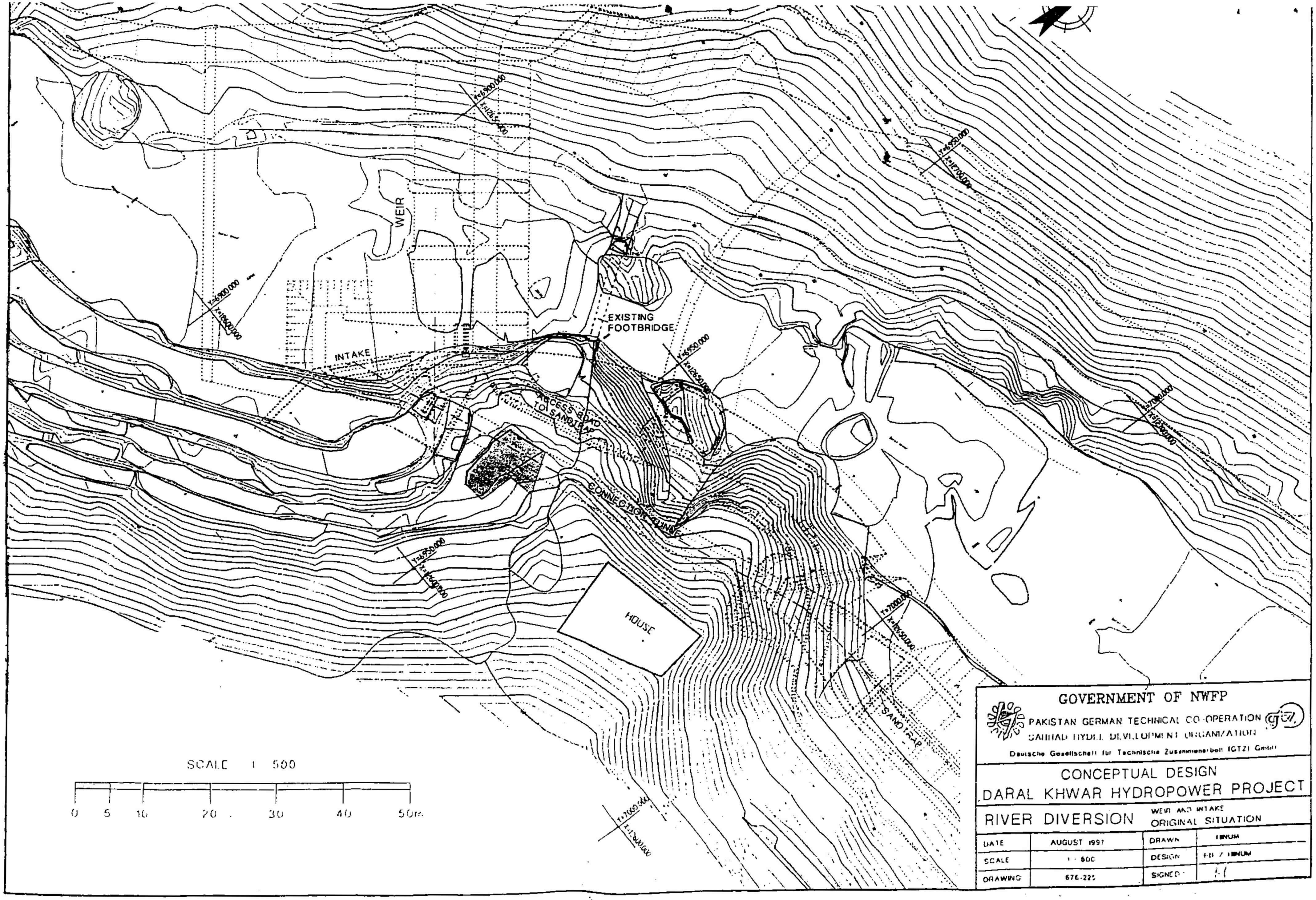


GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJE

HEADRACE CANAL



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

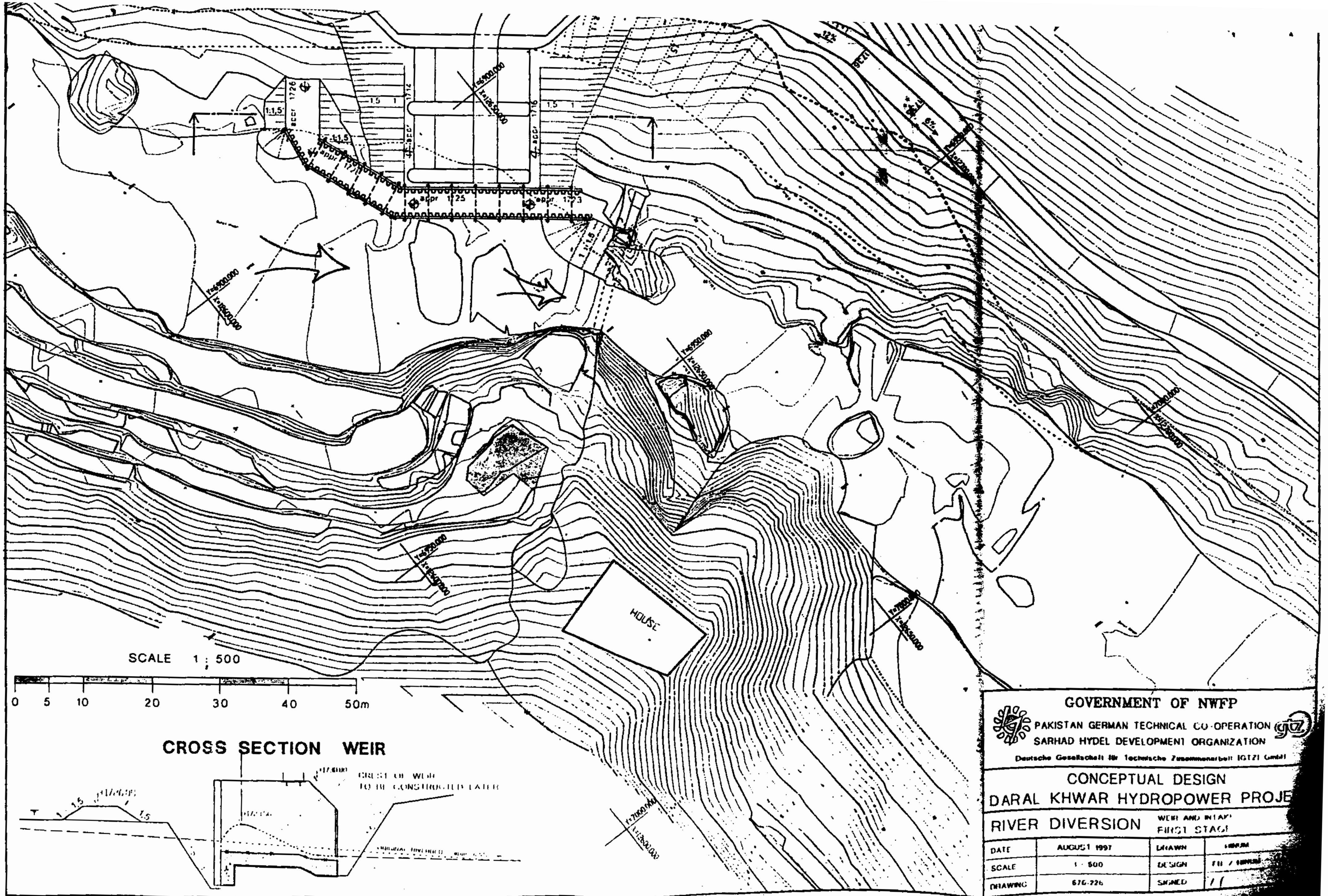
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

RIVER DIVERSION — WEIR AND INTAKE ORIGINAL SITUATION

DATE	AUGUST 1997	DRAWN	HINUM
SCALE	1 : 500	DESIGN	FH / HINUM
DRAWING	676-225	SIGNED	



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

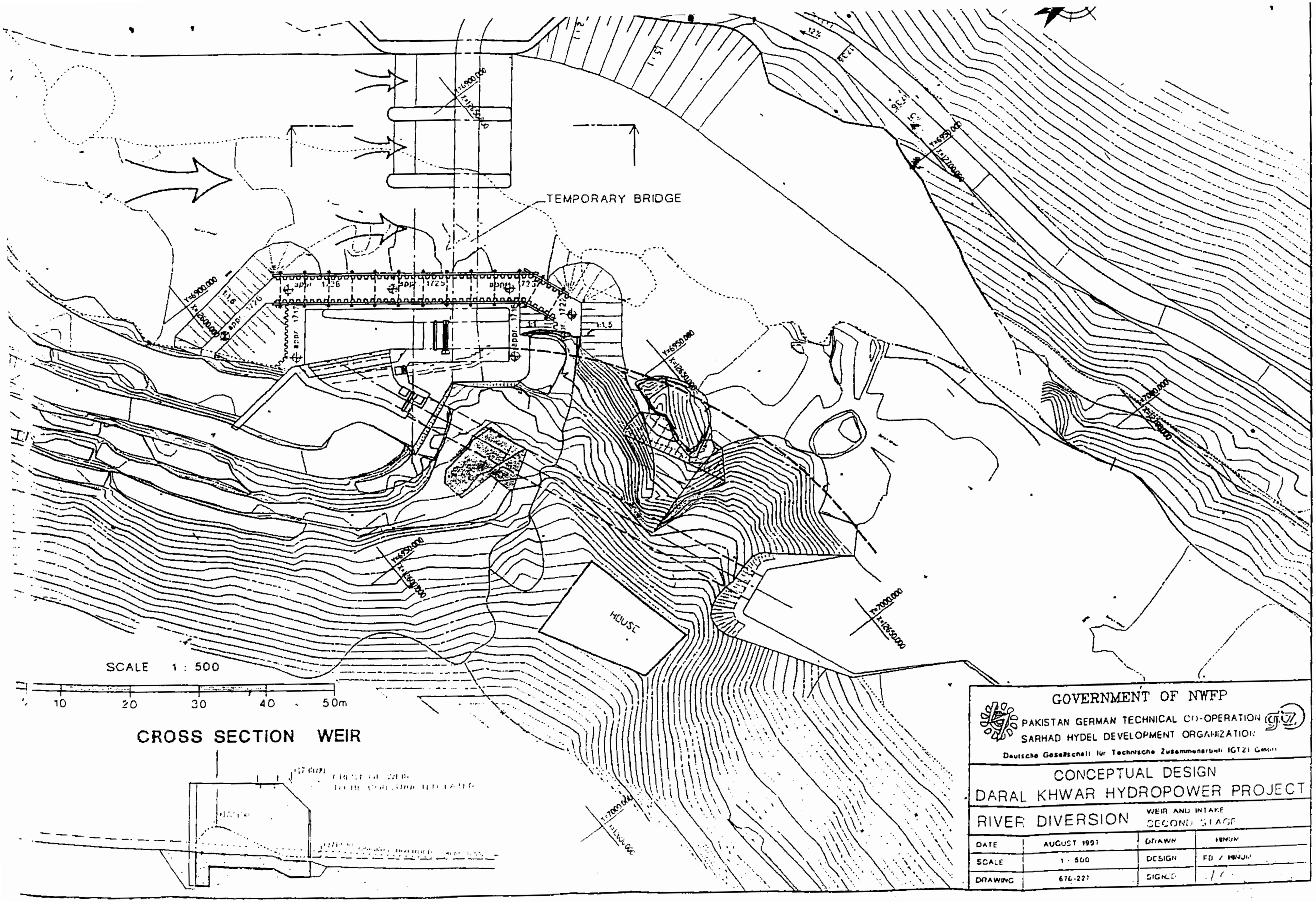
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

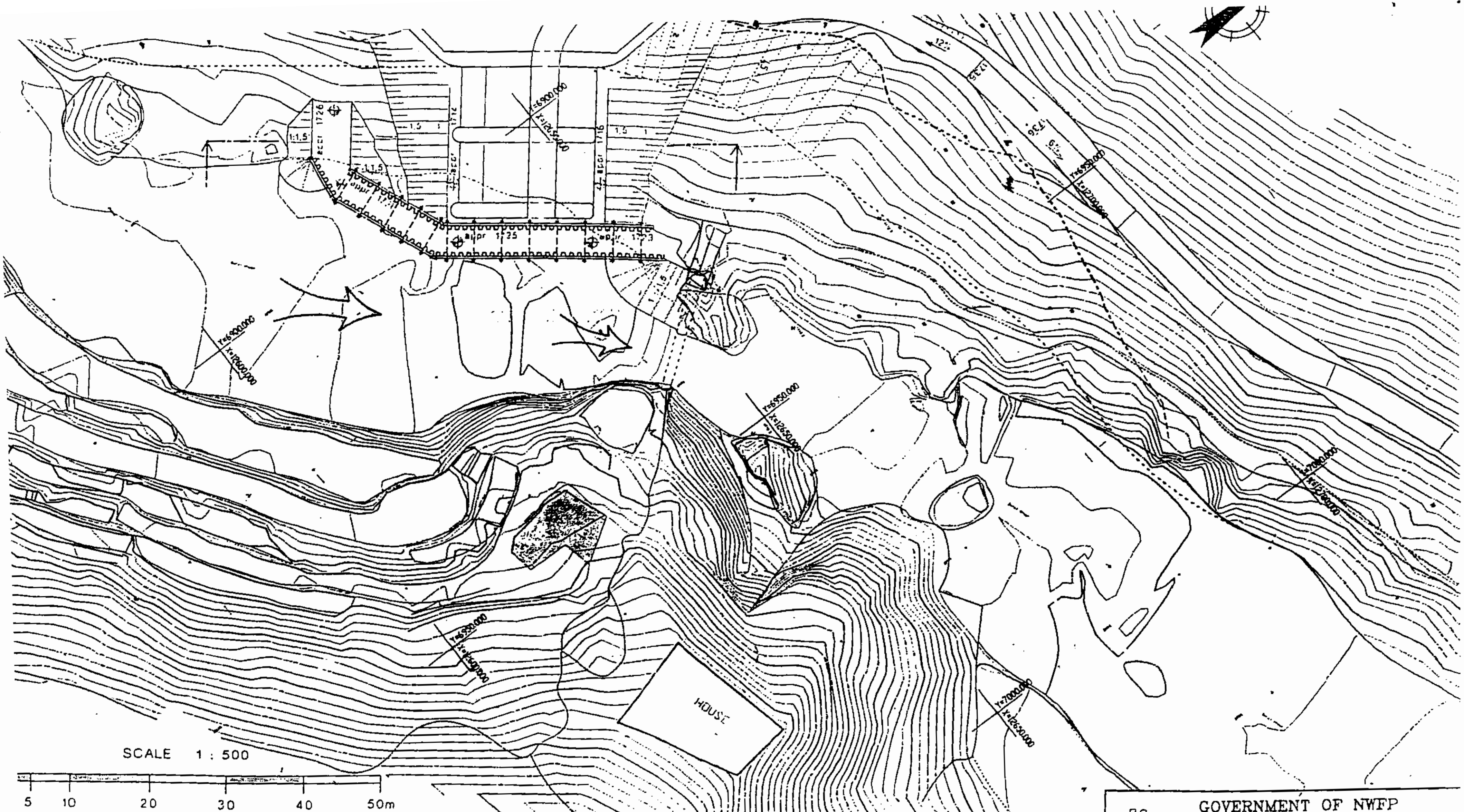
CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJE

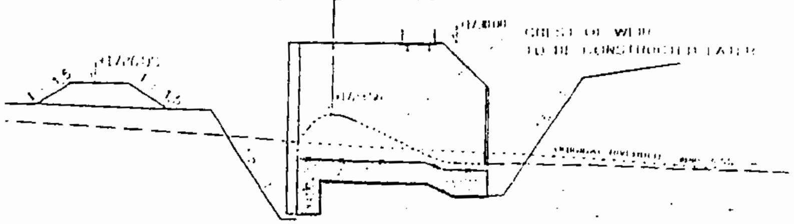
RIVER DIVERSION — WEIR AND INTAKE FIRST STAGE

DATE	AUGUST 1997	DRAWN	[illegible]
SCALE	1 : 500	DESIGN	[illegible]
DRAWING	676-226	SIGNED	[illegible]


TEMPORARY BRIDGE
HOUSE
Y=6900.000
Y=6950.000
Y=7000.000
X=12650.000
appr. 1726
appr. 1725
appr. 1723
12%
1:5
1:1,5
SCALE 1 : 500
10 20 30 40 50m
CROSS SECTION WEIR
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT
RIVER DIVERSION
WEIR AND INTAKE
SECOND STAGE
DATE
AUGUST 1997
DRAWN
HINUM
SCALE
1 : 500
DESIGN
FB / HINUM
DRAWING
676-227
SIGNED



CROSS SECTION WEIR



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

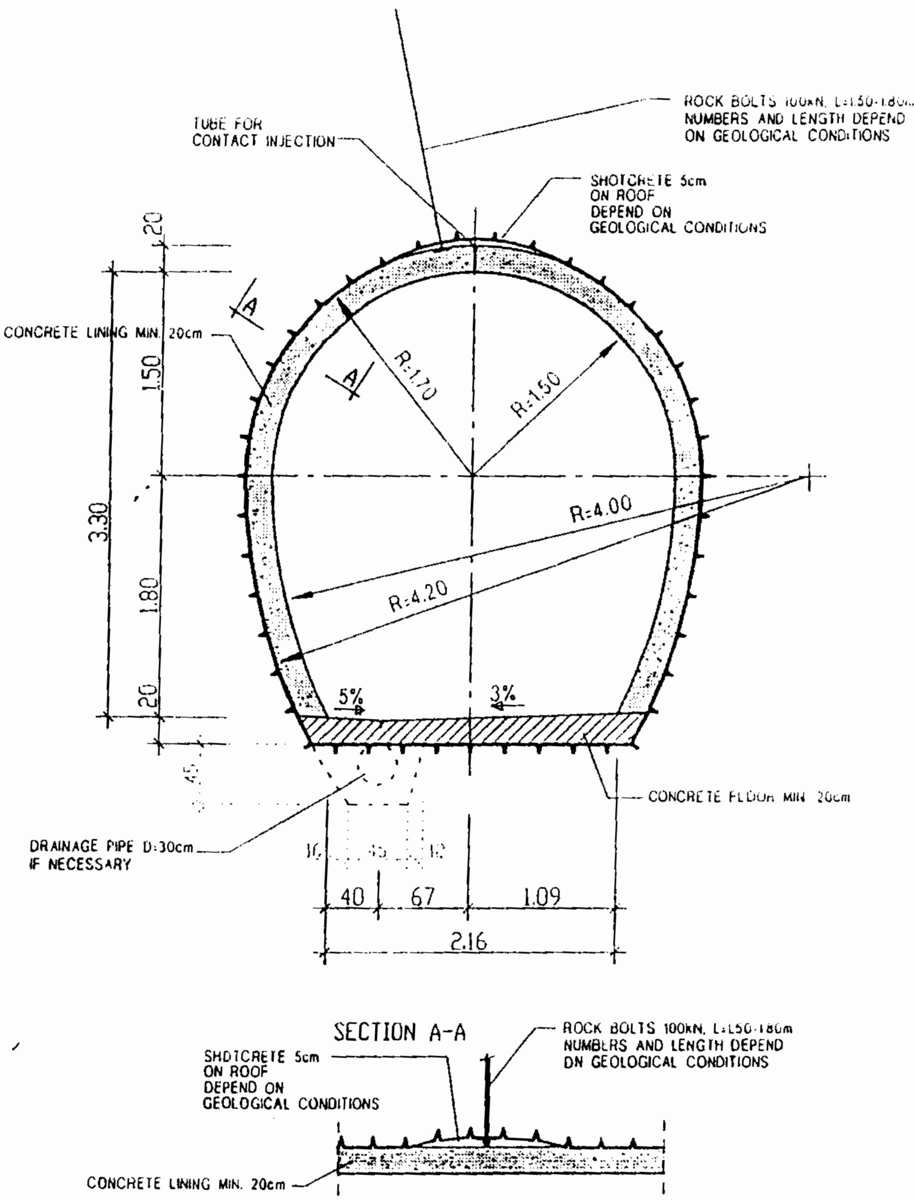
DARAL KHWAR HYDROPOWER PROJE

RIVER DIVERSION — WEIR AND INTAKE FIRST STAGE

DATE	AUGUST 1997	DRAWN	
SCALE	1 : 500	DESIGN	
DRAWING	676-22	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS A
STABLE, SOUND
(ACCORDING TO LAUFFER)

ANNEX 3.1.1



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

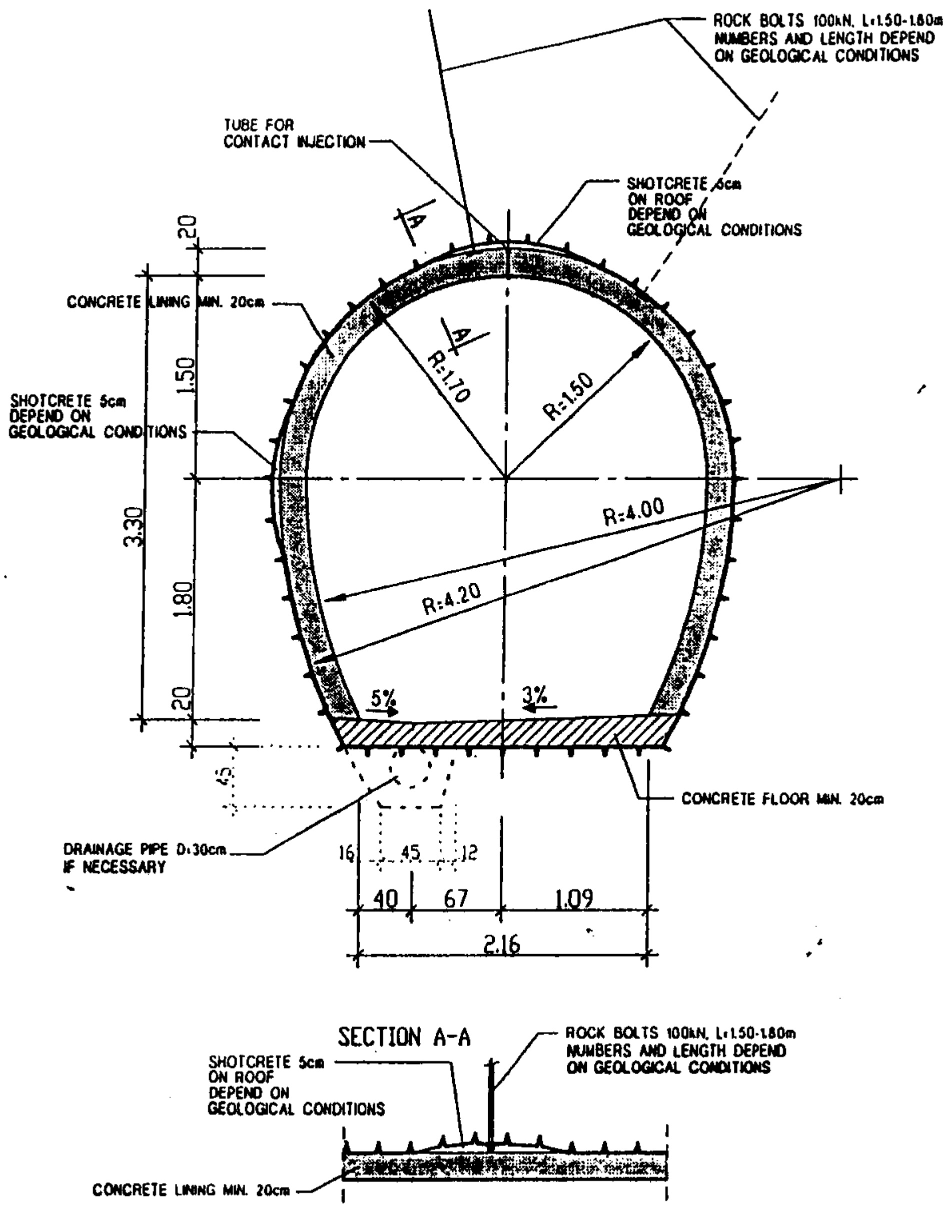
DARAL KHWAR HYDROPOWER PROJECT

HEADRACE TUNNEL CONVENTIONAL HEADING	TYPICAL CROSS SECTION ROCK CLASS "A"

DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-230	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS B
SLIGHTLY FRIABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.2



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

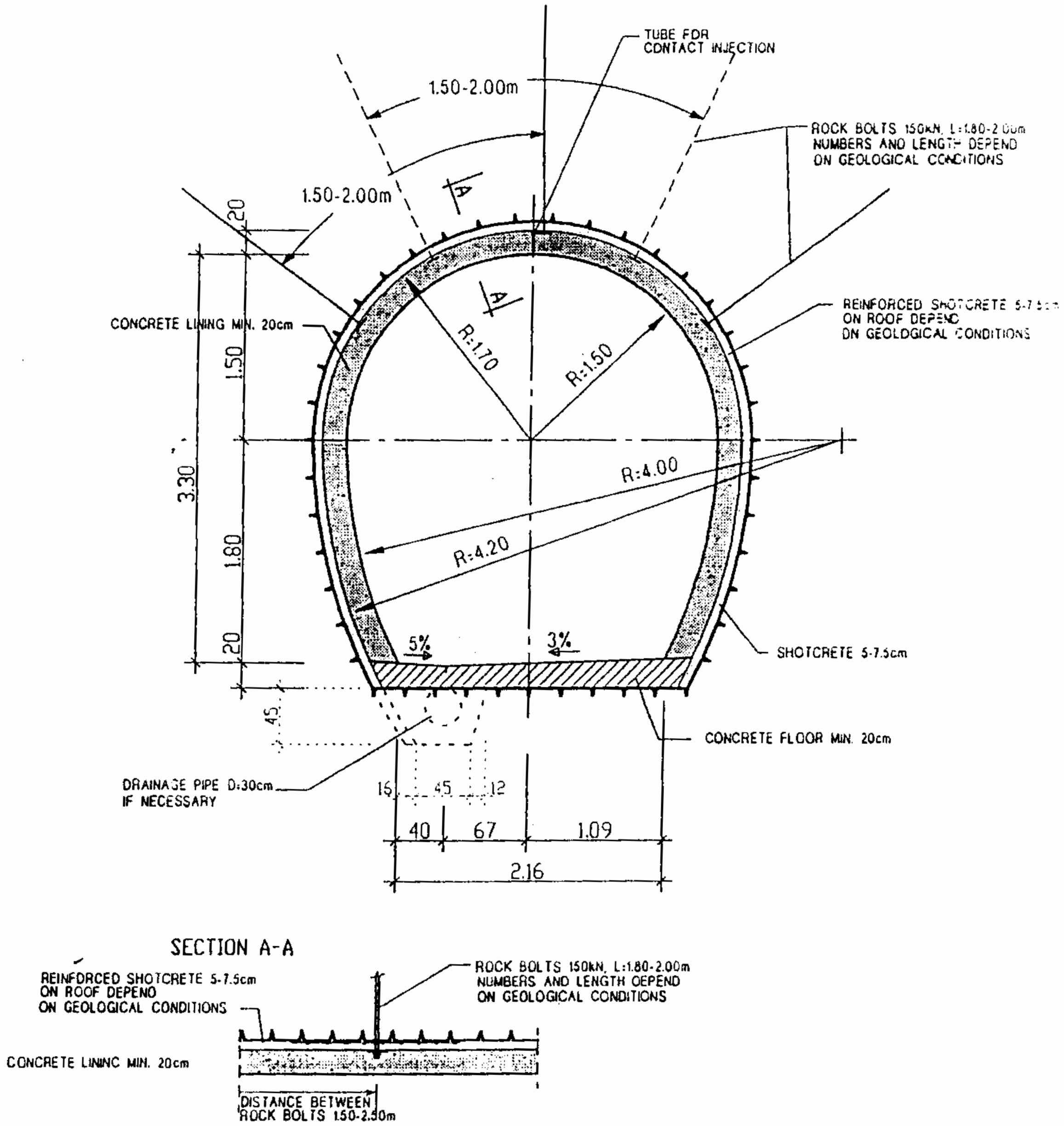
HEADRACE TUNNEL
CONVENTIONAL HEADING

TYPICAL CROSS SECTION
ROCK CLASS "B"

DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-231	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS C
FRACTURED, FRIABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.3



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

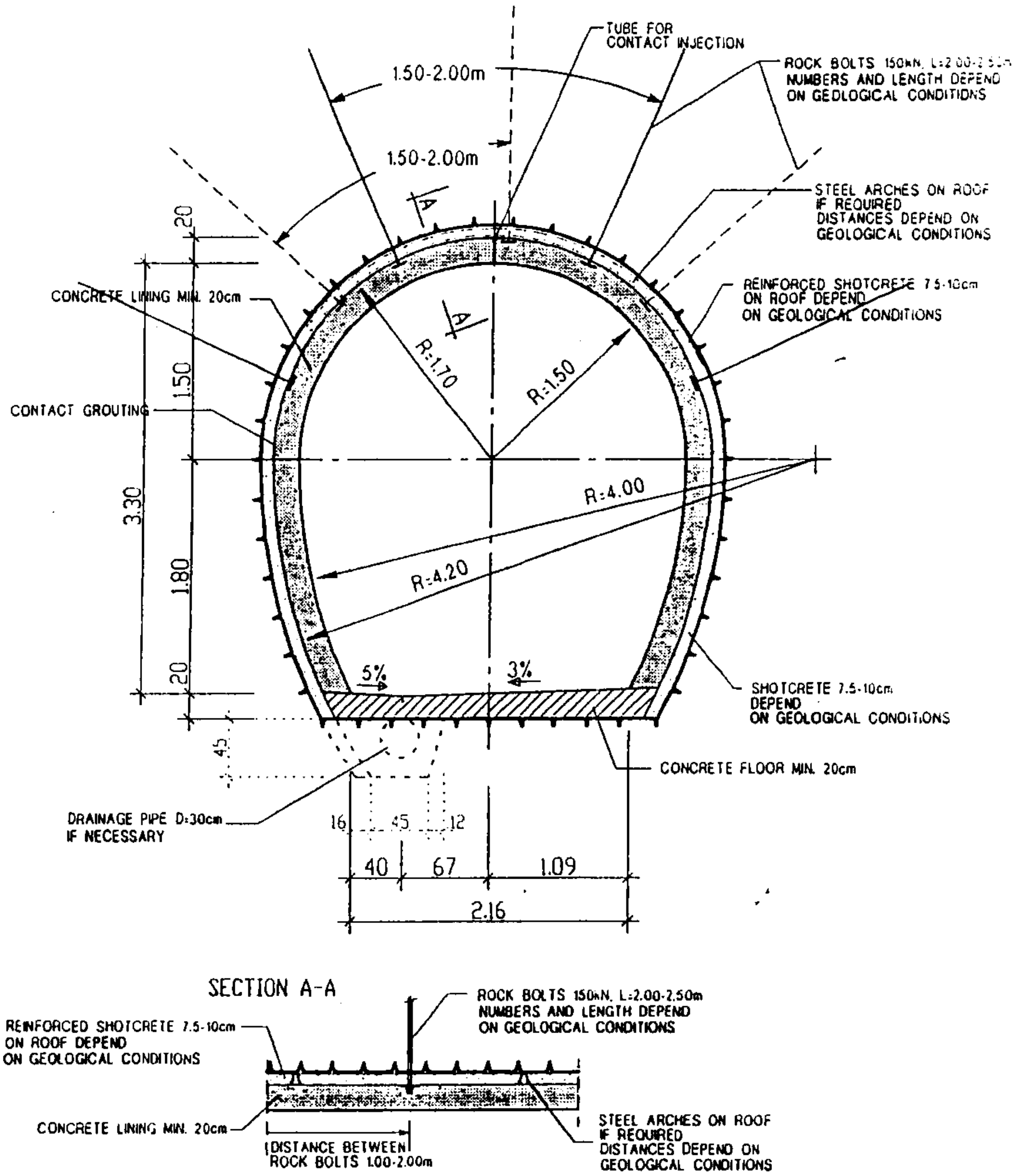
DARAL KHWAR HYDROPOWER PROJECT

HEADRACE TUNNEL CONVENTIONAL HEADING — TYPICAL CROSS SECTION ROCK CLASS "C"

DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINZM
DRAWING	676-232	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS D
BADLY FRACTURED, INTENSE FRIABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.4



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

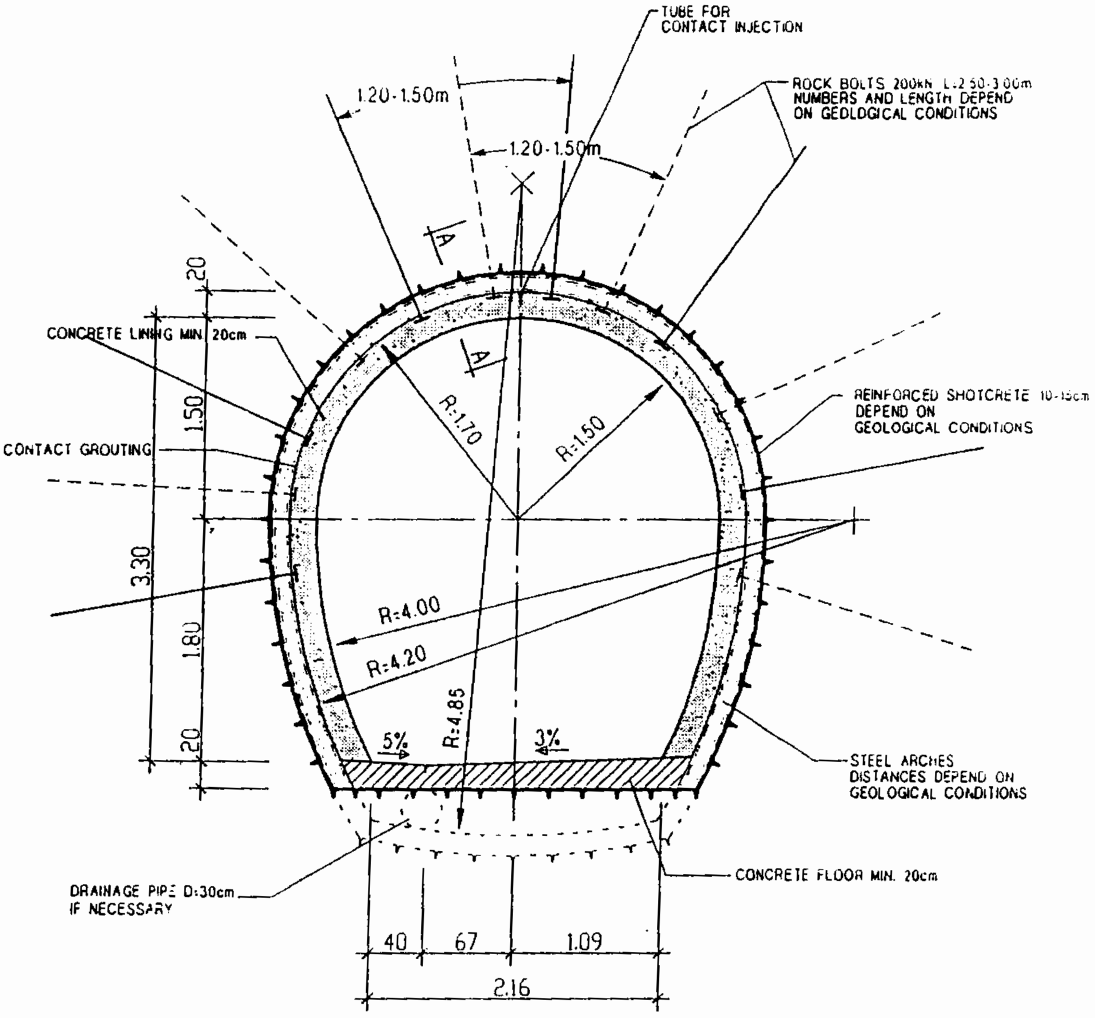
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

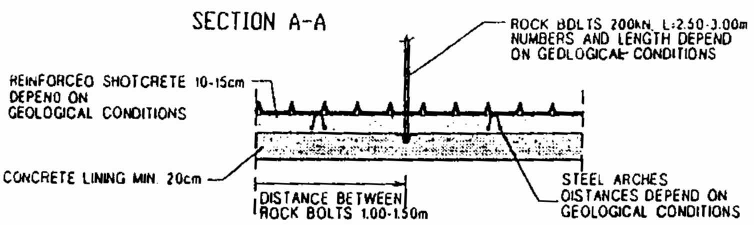
HEADRACE TUNNEL CONVENTIONAL HEADING — TYPICAL CROSS SECTION ROCK CLASS "D"

DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-233	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS E
TOTALLY FRACTURED, FAULTED, UNSTABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.5





GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

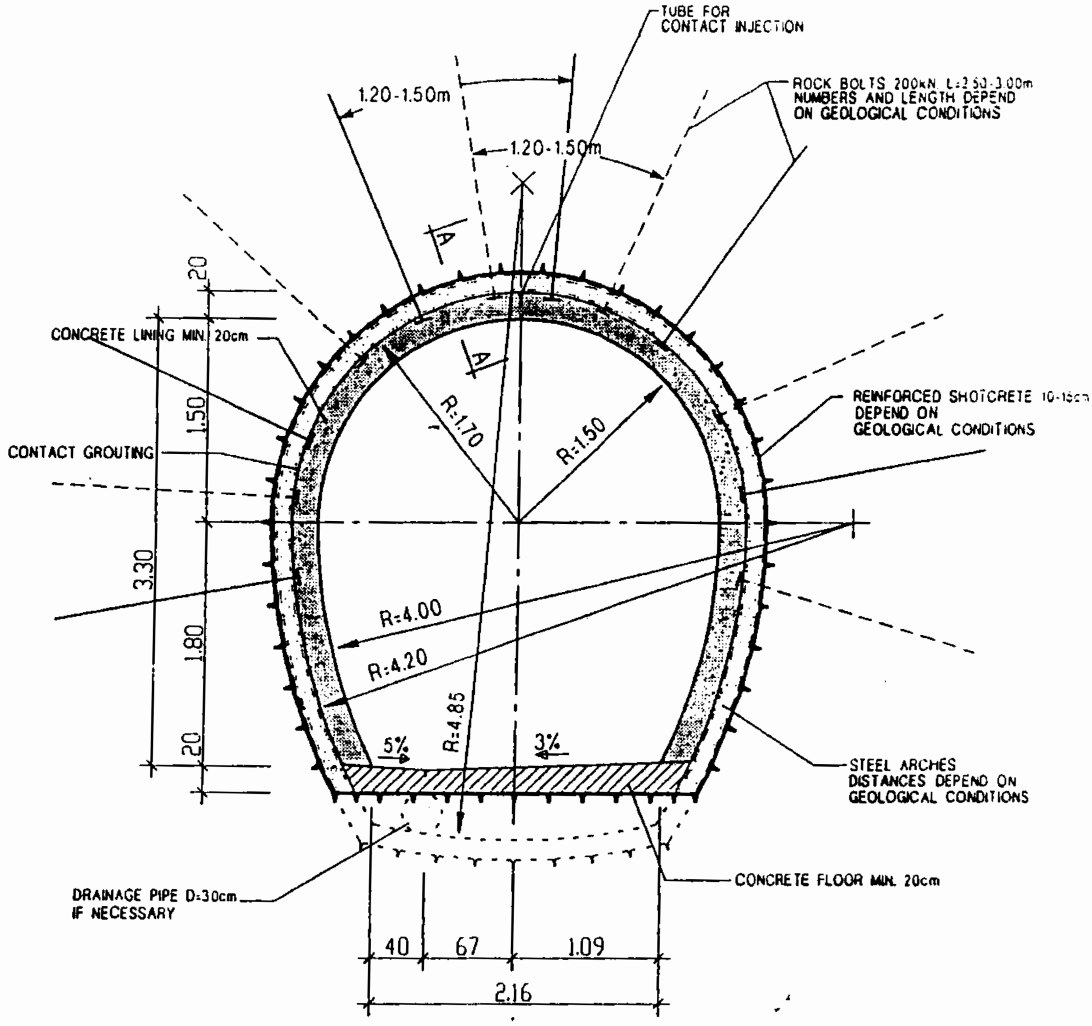
HEADRACE TUNNEL
CONVENTIONAL HEADING

TYPICAL CROSS SECTION
ROCK CLASS "E"

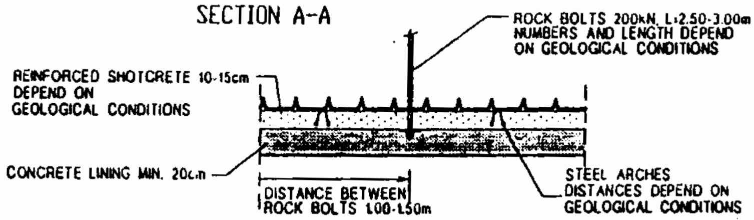
DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-234	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS E
TOTALLY FRACTURED, FAULTED, UNSTABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.5



SECTION A-A



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

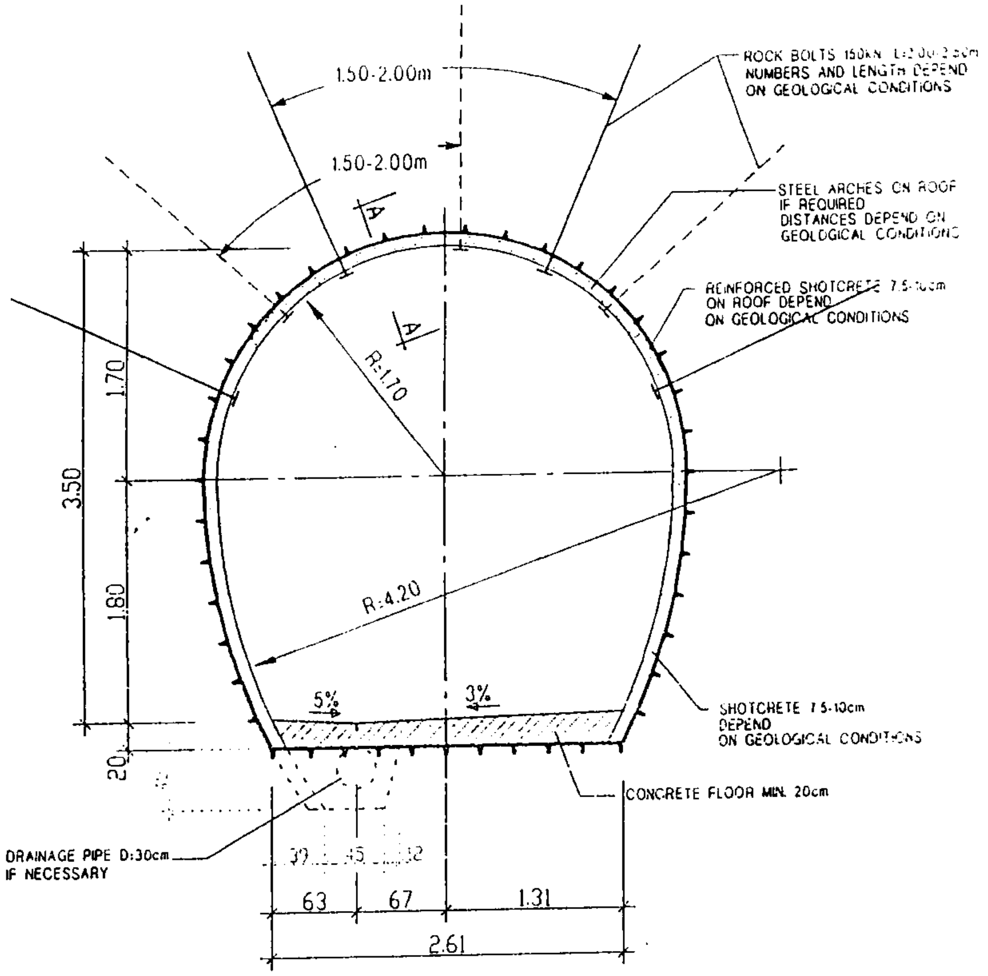
HEADRACE TUNNEL
CONVENTIONAL HEADING

TYPICAL CROSS SECTION
ROCK CLASS "E"

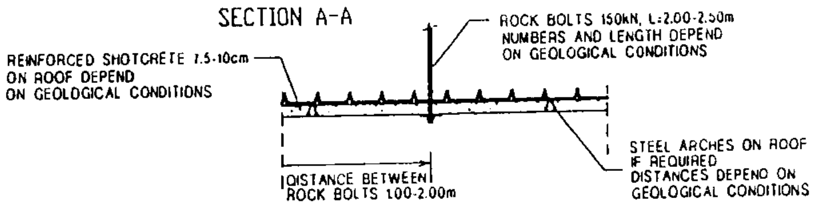
DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-234	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS D
BADLY FRACTURED, INTENSE FRIABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.7



SECTION A-A



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

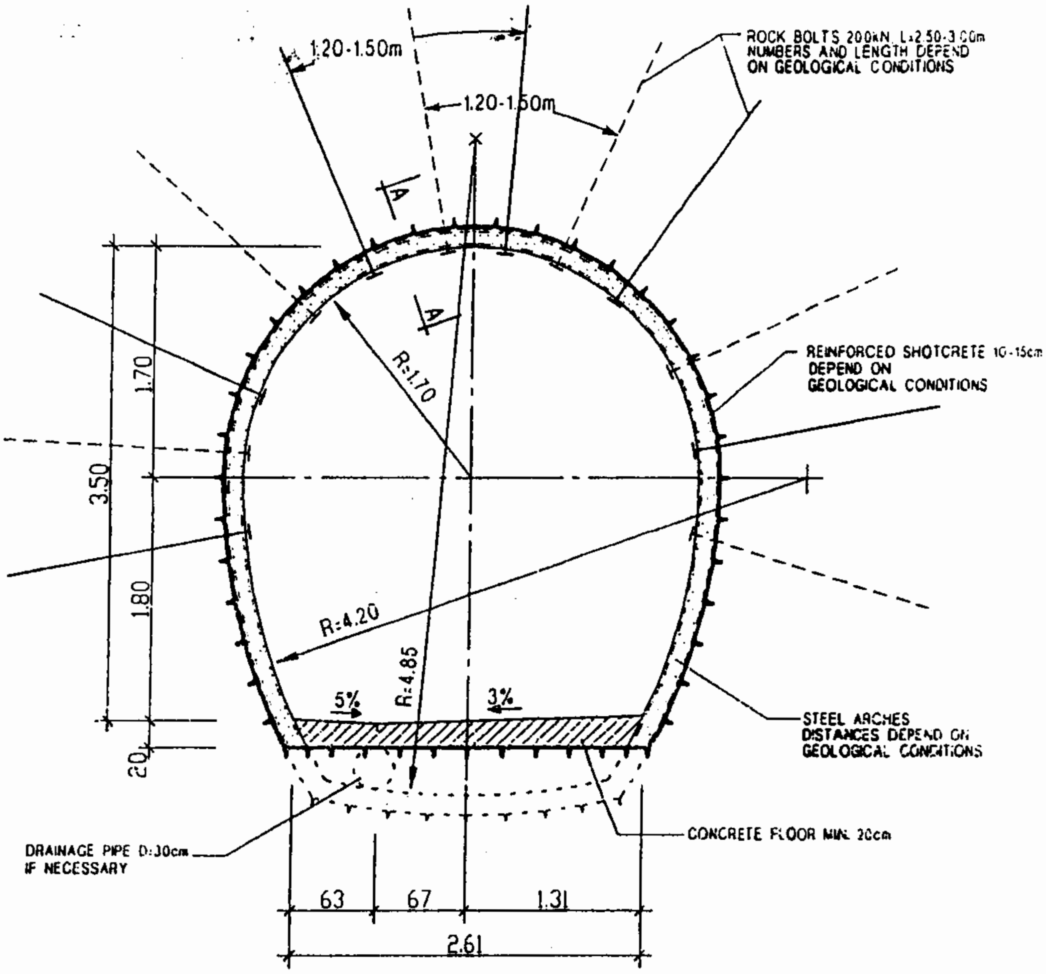
ACCESS TUNNEL
TO HEADR. TUNNEL -CONV. HEADING

TYPICAL CROSS SECTION
ROCK CLASS "D"

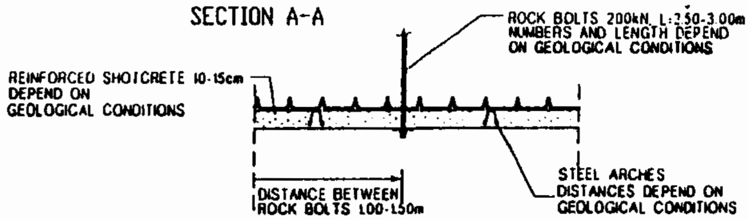
DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-236	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS E
TOTALLY FRACTURED, FAULTED, UNSTABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.8



SECTION A-A



GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

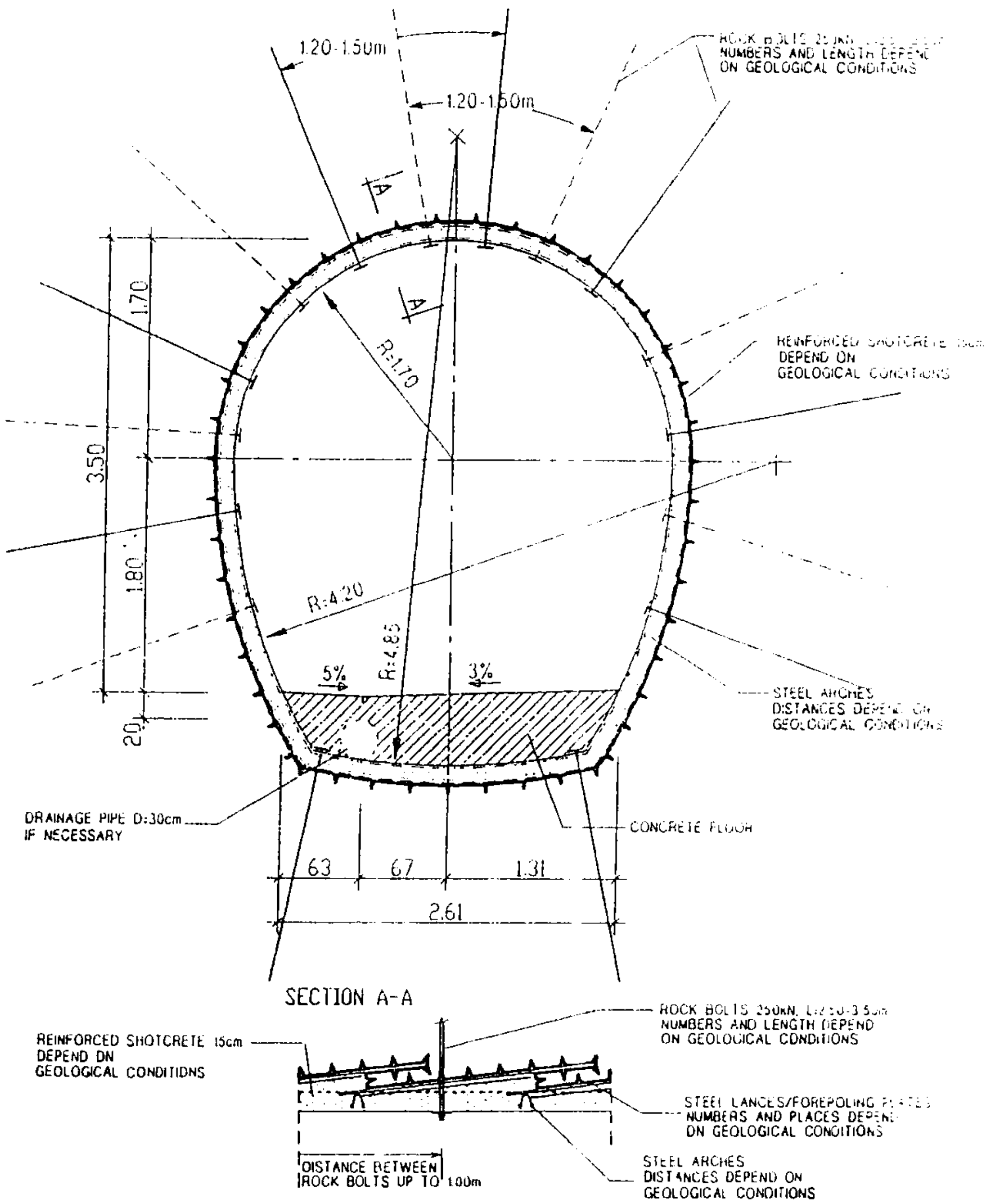
ACCESS TUNNEL
TO HEADR. TUNNEL -CONV. HEADING

TYPICAL CROSS SECTION
ROCK CLASS "E"

DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-237	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS F
MYLONITIC ZONES, FAULTS, SQUEEZING
(ACCORDING TO LAUFFER)

ANNEX 3.1.9



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

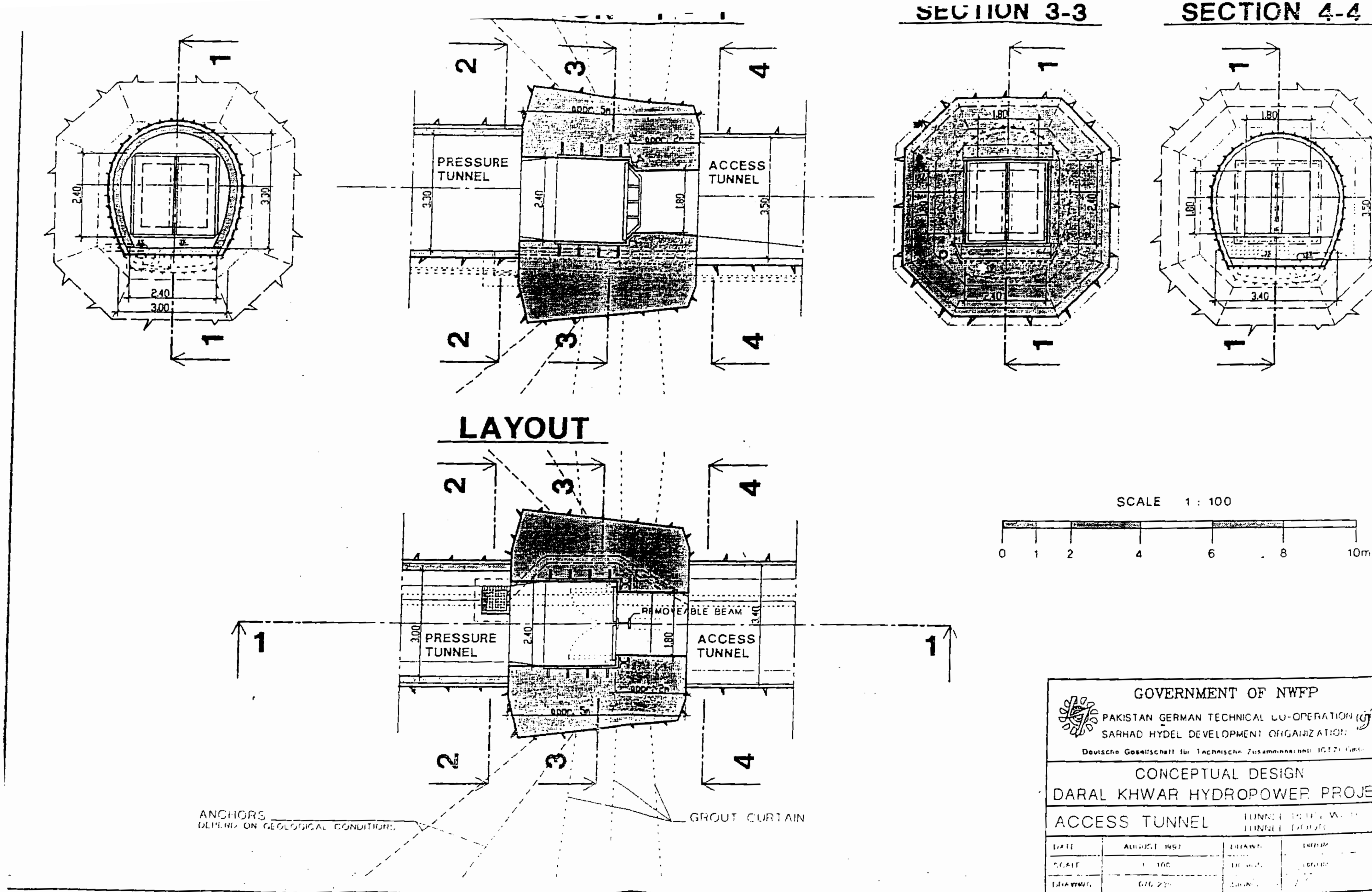
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

ACCESS TUNNEL TO HEADR. TUNNEL -CONV HEADING — TYPICAL CROSS SECTION ROCK CLASS "F"

DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-238	SIGNED	



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

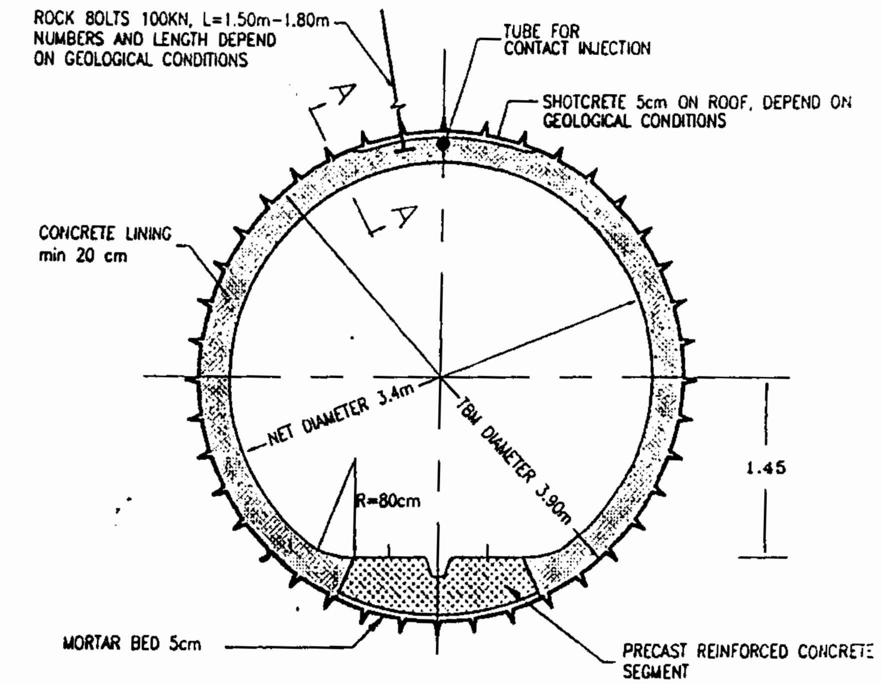
DARAL KHWAR HYDROPOWER PROJEC

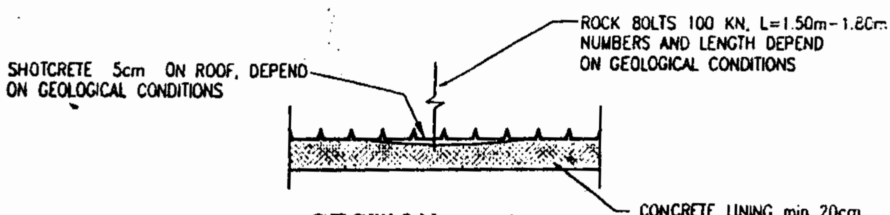
ACCESS TUNNEL

DATE	AUGUST 1997	DRAWN	
SCALE	1 : 100	DESIGN	
DRAWING		SHOWN	

TBM - DRIVING
ROCK CLASS A
STABLE, SOUND
(ACCORDING TO LAUFFER)

ANNEX 3.1.11





SECTION A-A

GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

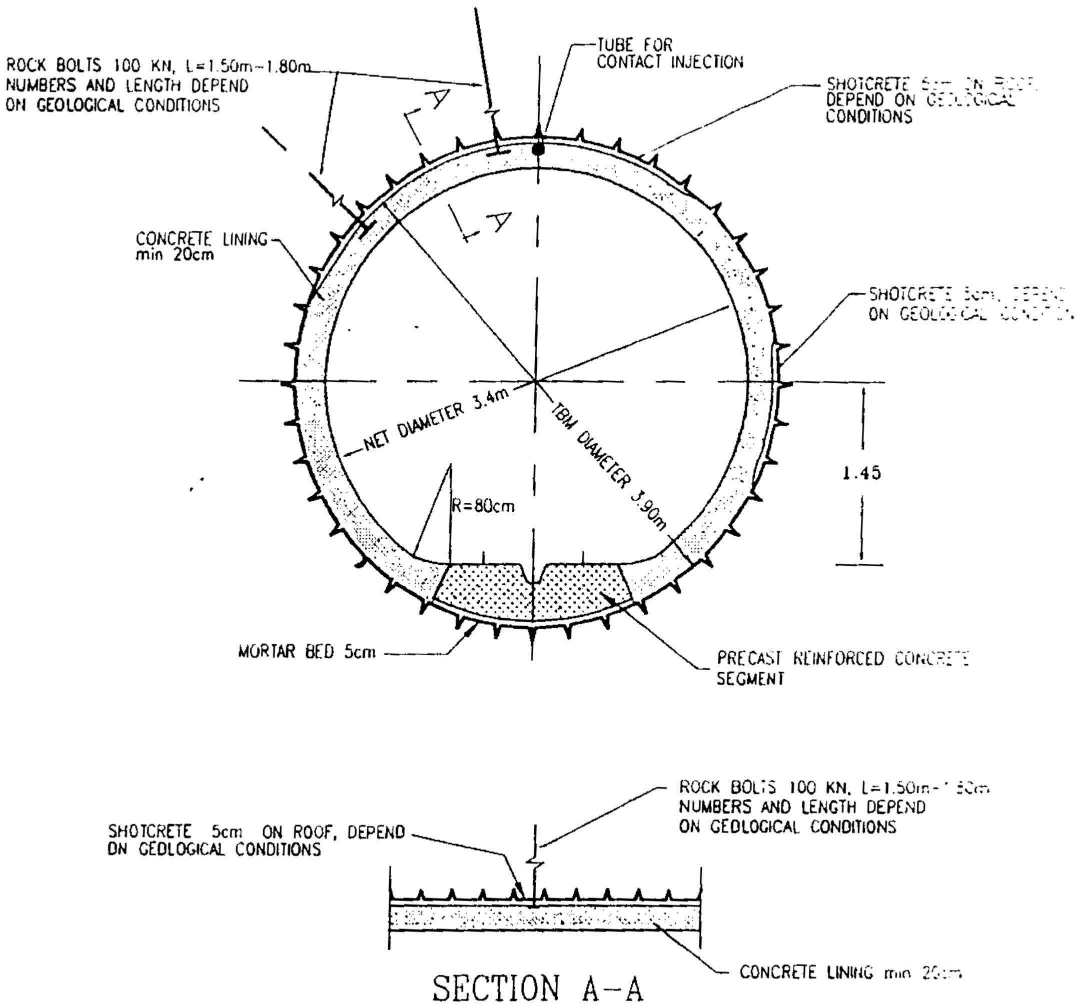
HEADRACE TUNNEL
TBM-DRIVING

TYPICAL CROSS SECTION
ROCK CLASS "A"

DATE	AUGUST 1997	DRAWN	NIAMAT KHAN
SCALE	1 : 50	DESIGNED	HINUM
DRAWING	676-290	SIGNED	

TBM - DRIVING
ROCK CLASS B
SLIGHTLY FRIABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.12



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

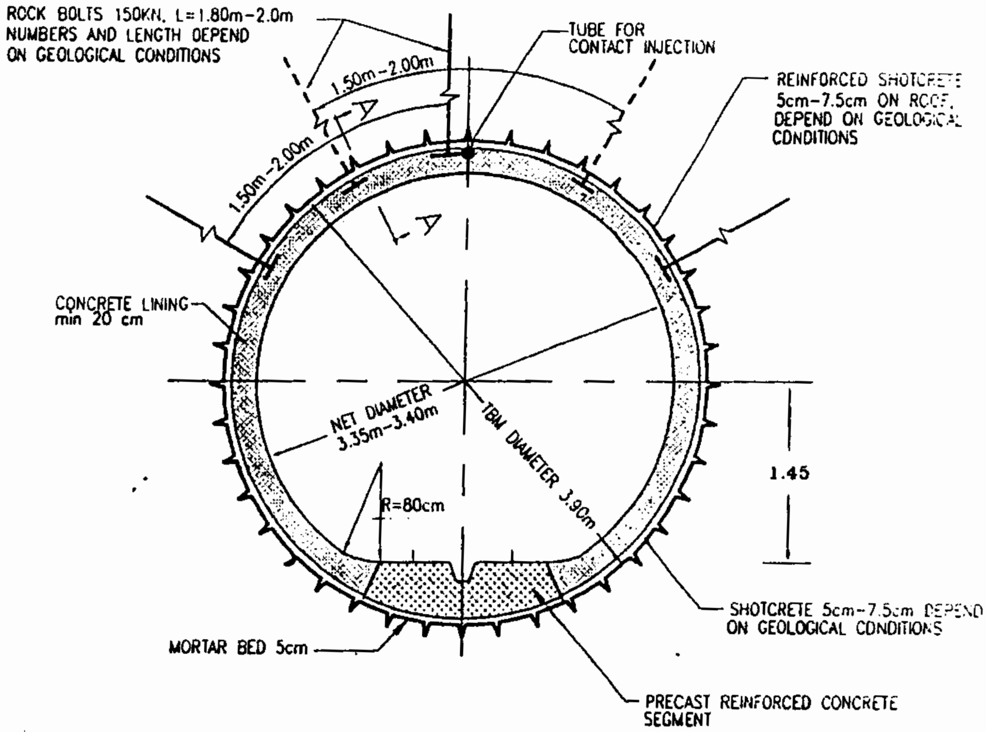
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

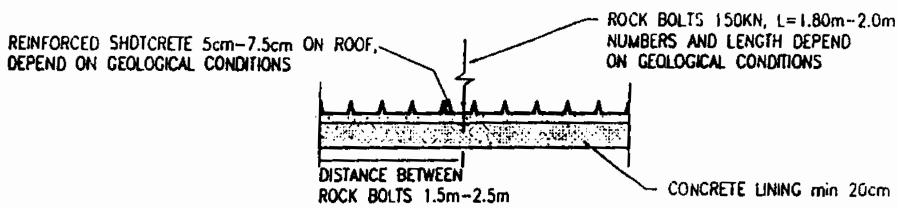
HEADRACE TUNNEL TBM-DRIVING — TYPICAL CROSS SECTION ROCK CLASS "B"

DATE	AUGUST 1997	DRAWN	NIAMAT KHAN
SCALE	1 : 50	DESIGNED	HIN.M
DRAWING	676-291	SIGNED	

TBM - DRIVING
ROCK CLASS C
FRACTURED, FRIABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.13





SECTION A-A

GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

HEADRACE TUNNEL
TBM-DRIVING

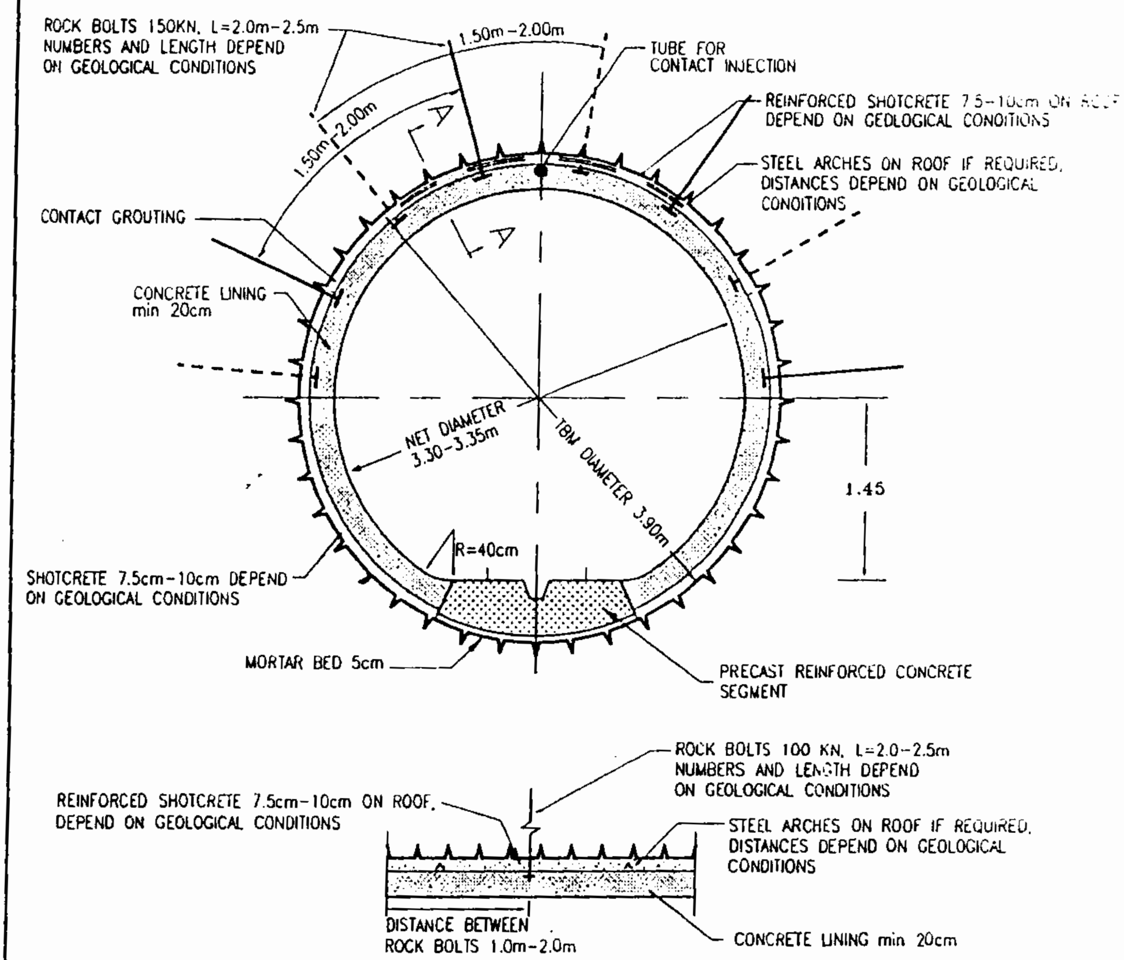
TYPICAL CROSS SECTION
ROCK CLASS "C"

DATE	AUGUST 1997	DRAWN	NIAMAT KHAN
SCALE	1 : 50	DESIGNED	HINUM
DRAWING	676-292	SIGNED	

TBM - DRIVING

ANNEX 3.1.14

ROCK CLASS D
BADLY FRACTURED, INTENSE FRIABLE
(ACCORDING TO LAUFFER)



SECTION A-A

GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

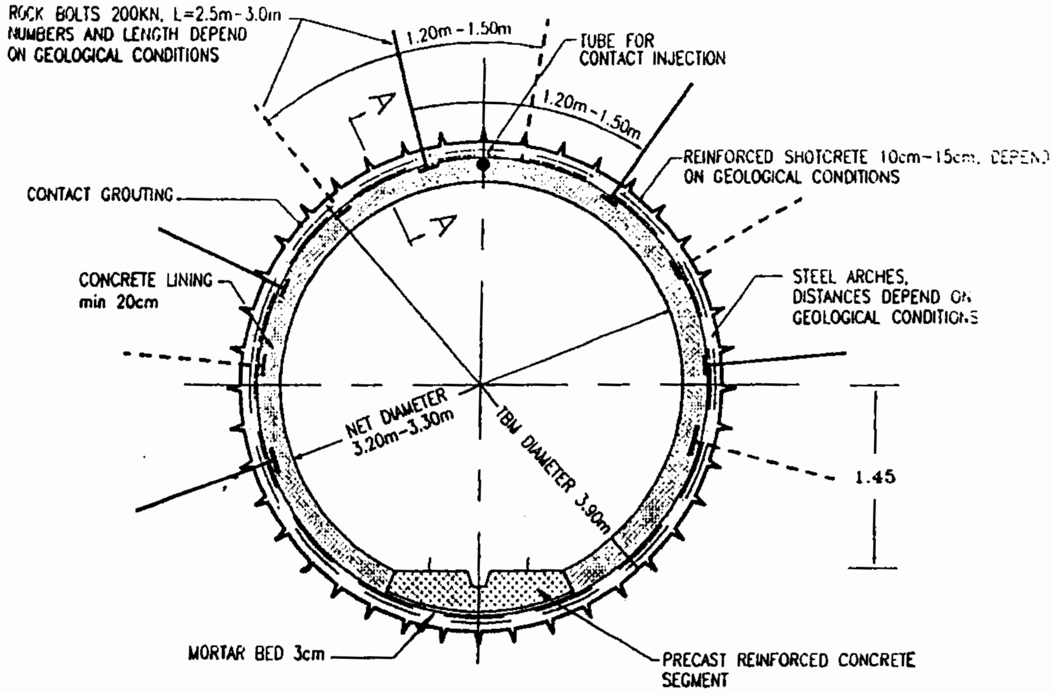
HEADRACE TUNNEL TBM-DRIVING — TYPICAL CROSS SECTION ROCK CLASS "D"

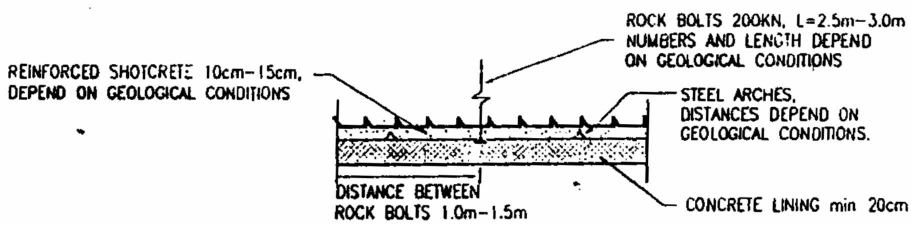
DATE	AUGUST 1997	DRAWN	NIAMAT KHAN
SCALE	1 : 50	DESIGNED	HINUM
DRAWING	676-293	SIGNED	

TBM - DRIVING

ANNEX 3.1.15

ROCK CLASS E
TOTALLY FRACTURED, FAULTED, UNSTABLE
(ACCORDING TO LAUFFER)





SECTION A-A

GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

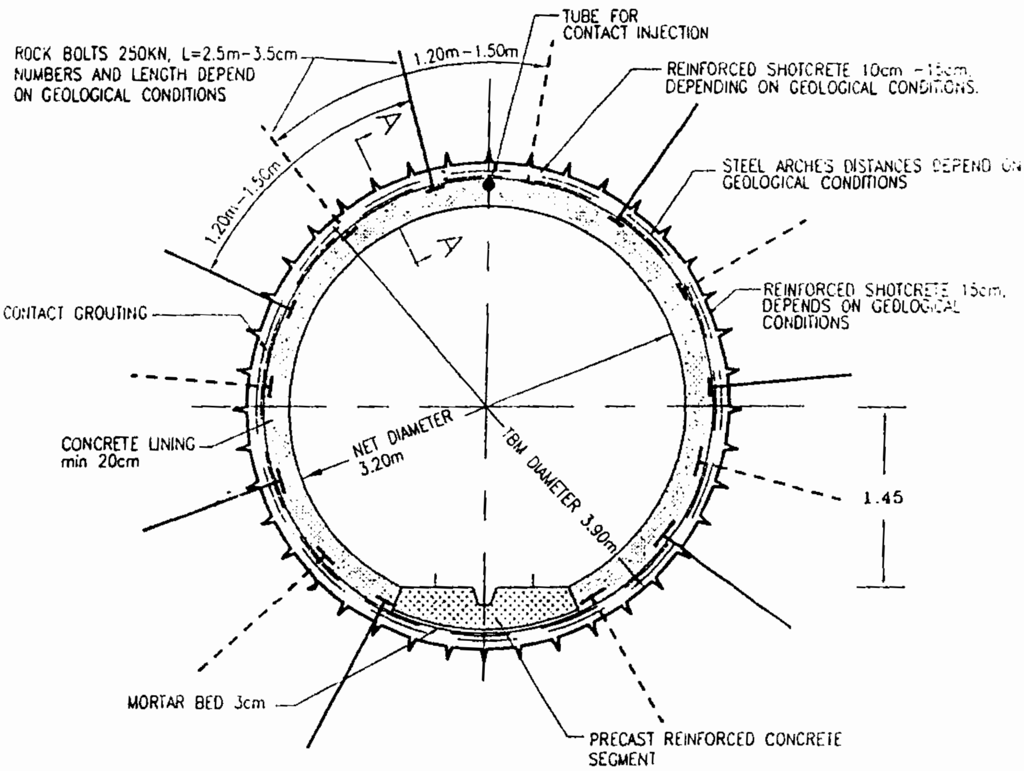
HEADRACE TUNNEL TBM-DRIVING — TYPICAL CROSS SECTION ROCK CLASS "E"

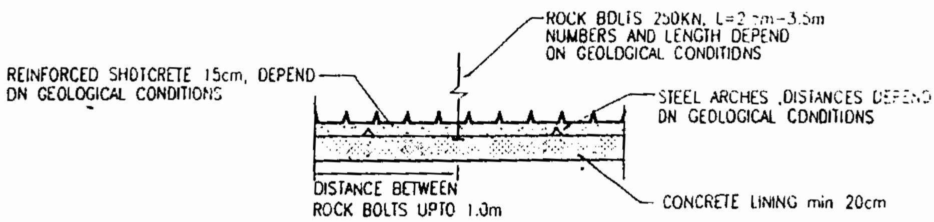
DATE	AUGUST 1997	DRAWN	NIAMAT KHAN
SCALE	1 : 50	DESIGNED	HINLM
DRAWING	616-294	SIGNED	

TBM - DRIVING

ANNEX 3.1.16

ROCK CLASS F
MYLONITIC ZONES, FAULTS, SQUEEZING
(ACCORDING TO LAUFFER)





SECTION A-A

GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION (GTZ)
SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

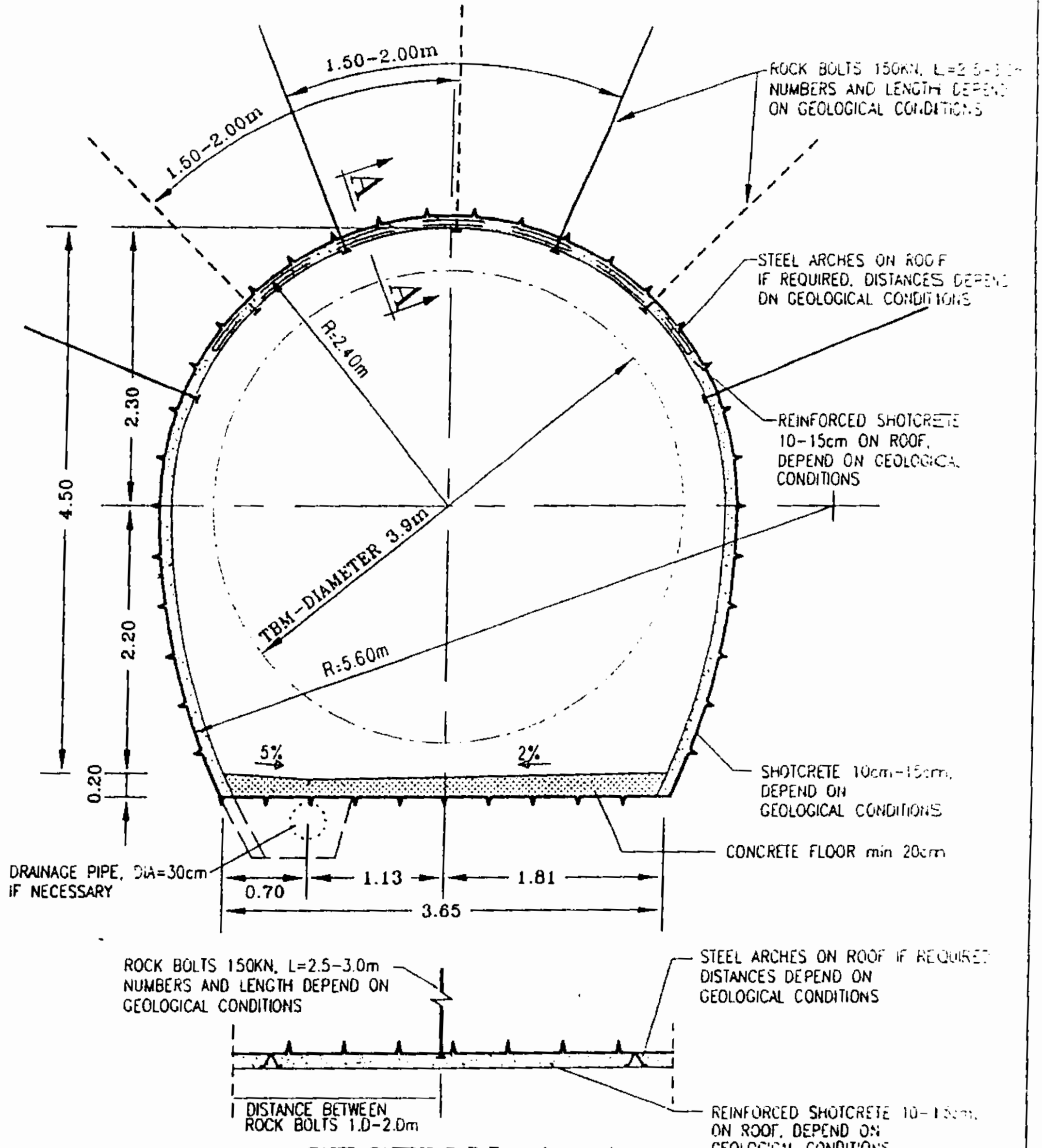
HEADRACE TUNNEL
TBM-DRIVING

TYPICAL CROSS SECTION
ROCK CLASS "F"

DATE	AUGUST 1997	DRAWN	NIAMAT KHAN
SCALE	1 : 50	DESIGNED	HINUM
DRAWING	676-295	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS D
BADLY FRACTURED, INTENSE FRIABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.17

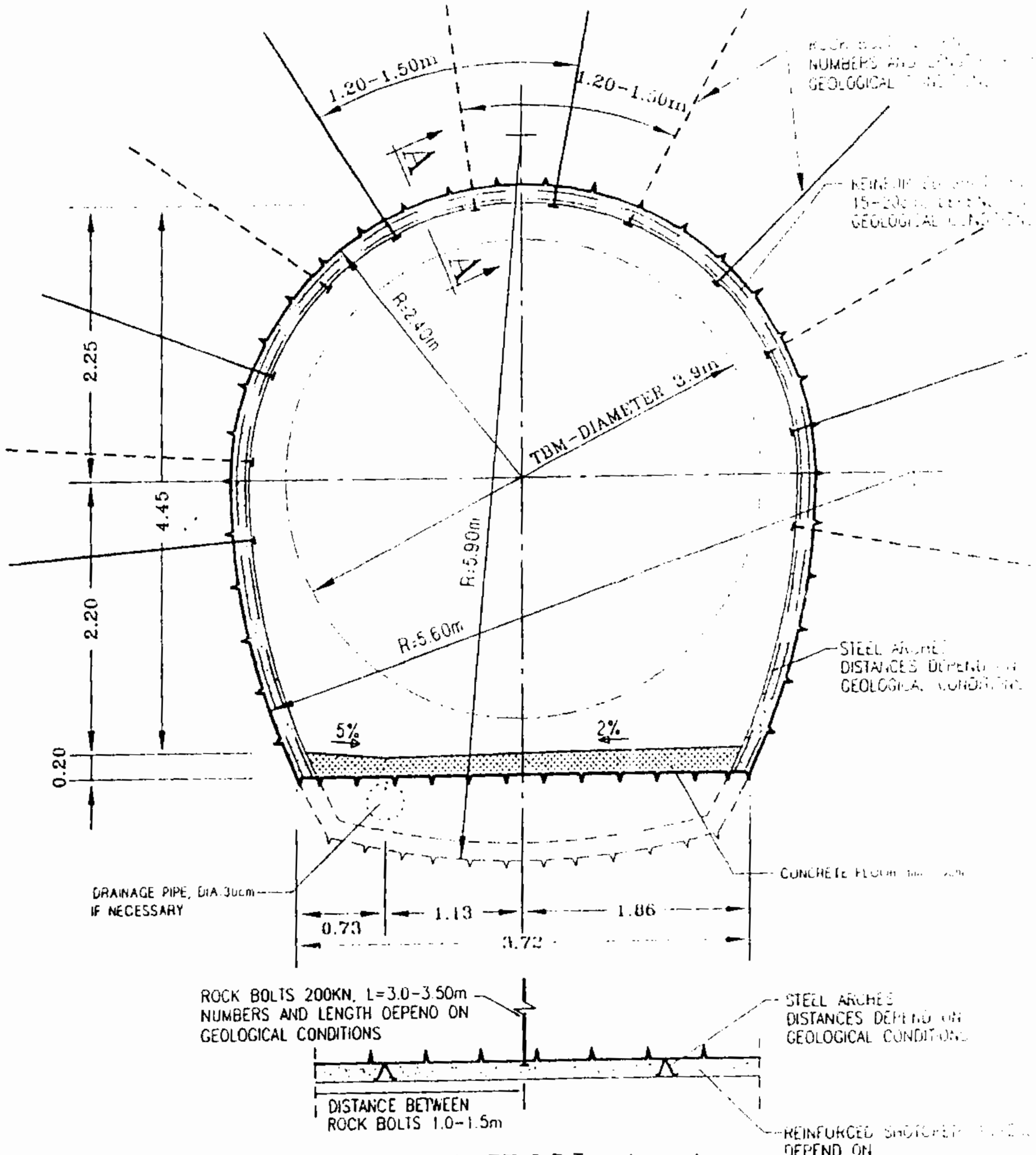


SECTION A–A

GOVERNMENT OF NWFP PAKISTAN GERMAN TECHNICAL CO-OPERATION SARHAD HYDEL DEVELOPMENT ORGANIZATION Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH			
CONCEPTUAL DESIGN DARAL KHWAR HYDROPOWER PROJECT			
ACCESS TUNNEL TO HEADR TUNNEL -TBM-DRIVING		TYPICAL CROSS SECTION ROCK CLASS "D"	
DATED	AUGUST 1997	DRAWN	NIAMAT KHAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-296	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS E
TOTALLY FRACTURED, FAULTED, UNSTABLE
(ACCORDING TO LAUFFER)

ANNEX 3.1.18



SECTION A-A

GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

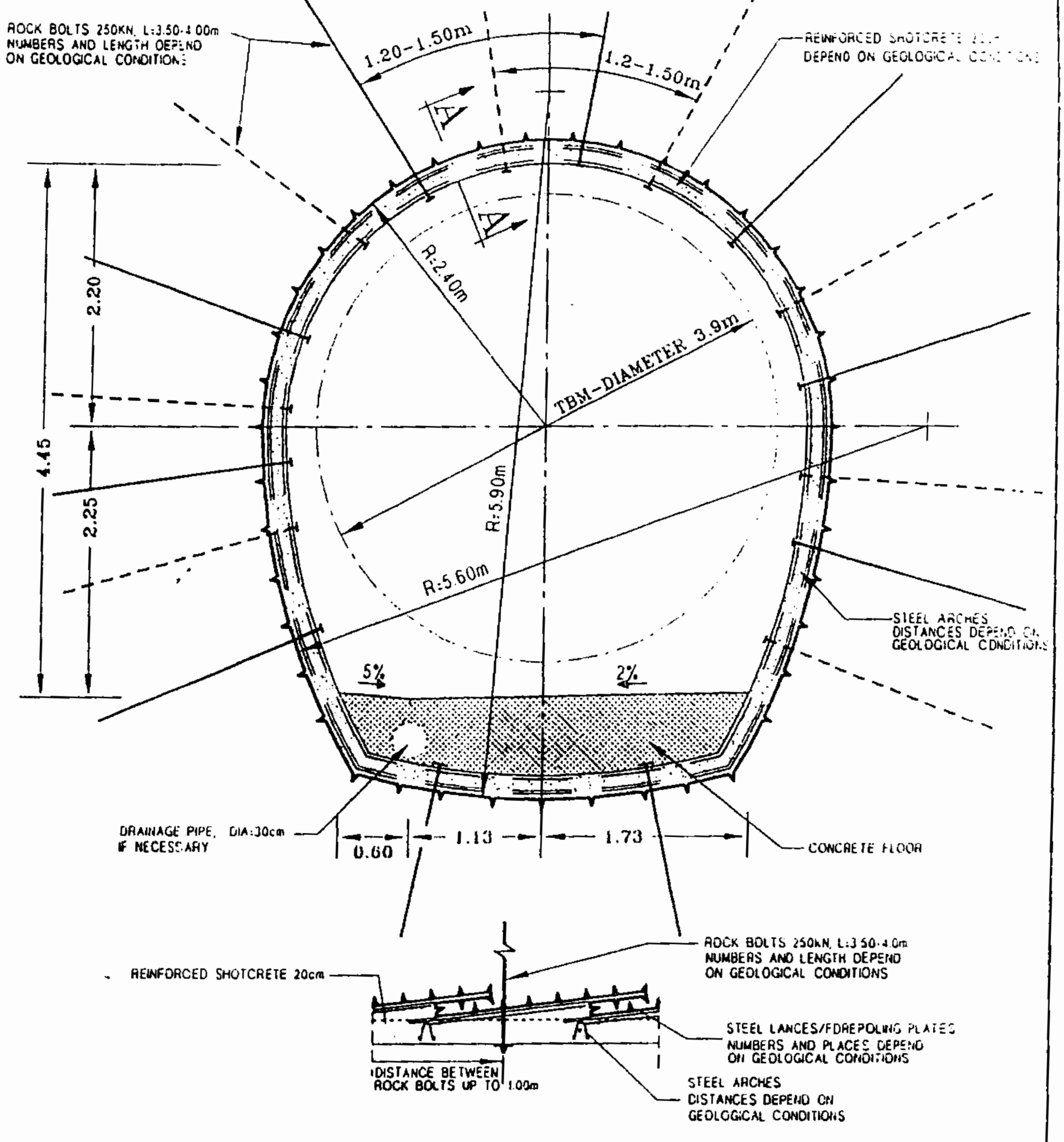
ACCESS TUNNEL
TO HEADR. TUNNEL -TBM-DRIVING

TYPICAL CROSS SECTION
ROCK CLASS E

DATED	AUGUST 1997	DRAWN	[illegible]
SCALE	1 : 50	DESIGN	[illegible]
DRAWING	[illegible]	SIGNED	

CONVENTIONAL HEADING ROCK CLASS F MYLONITIC ZONES, FAULTS, SQUEEZING (ACCORDING TO LAUFFER)

ANNEX 3.1.19



SECTION A–A

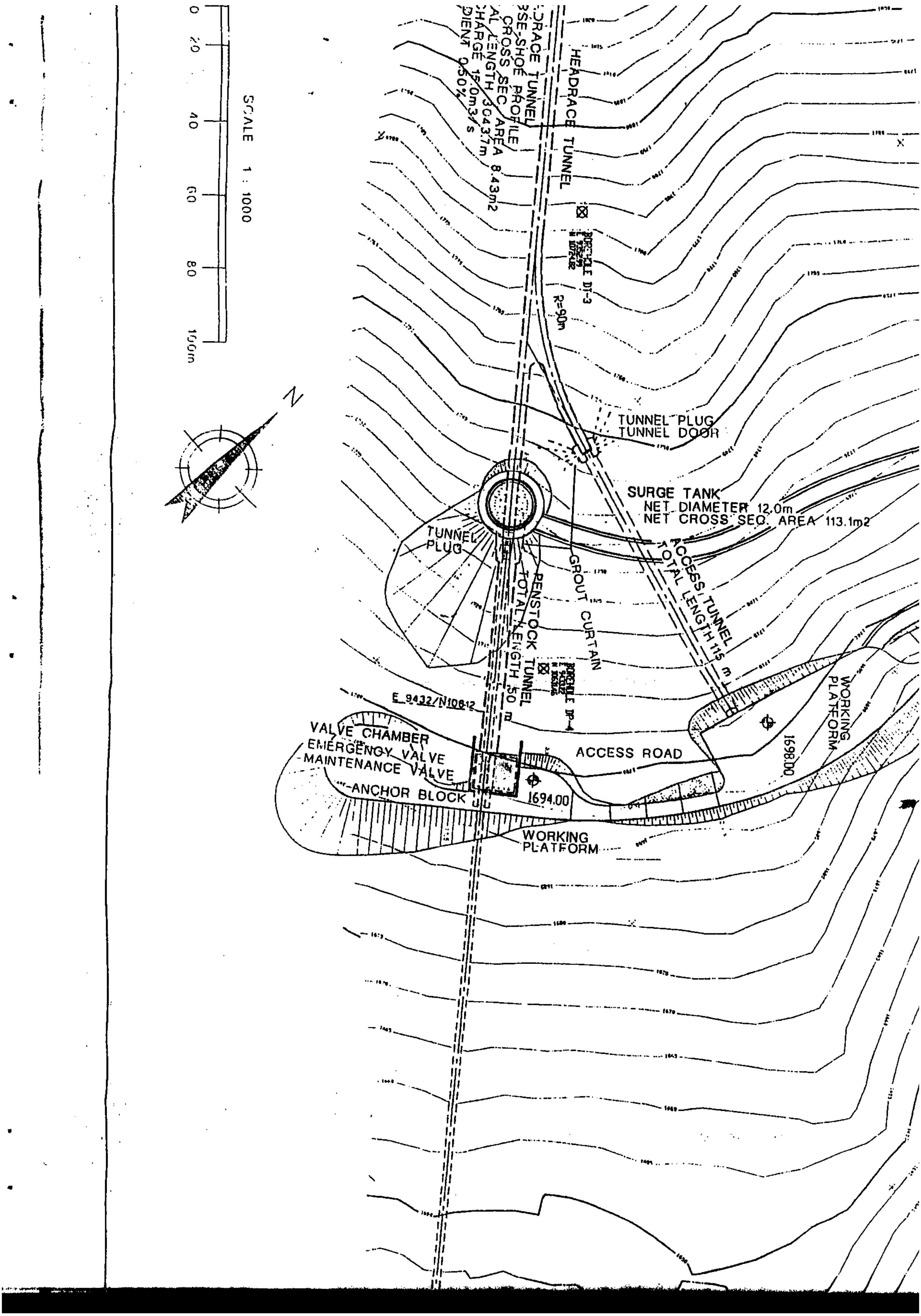
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

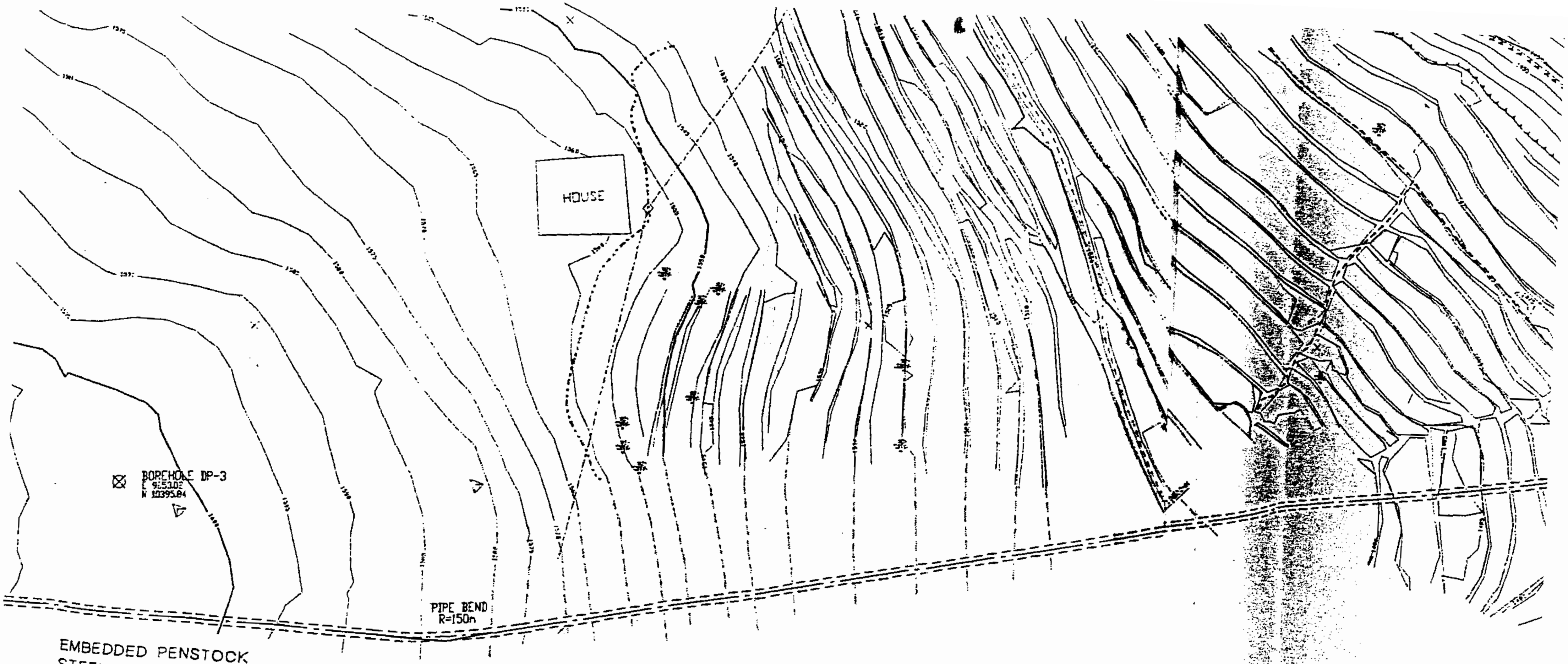
ACCESS TUNNEL
TO HEADR. TUNNEL -TBM-DRIVING

TYPICAL CROSS SECTION
ROCK CLASS "E"

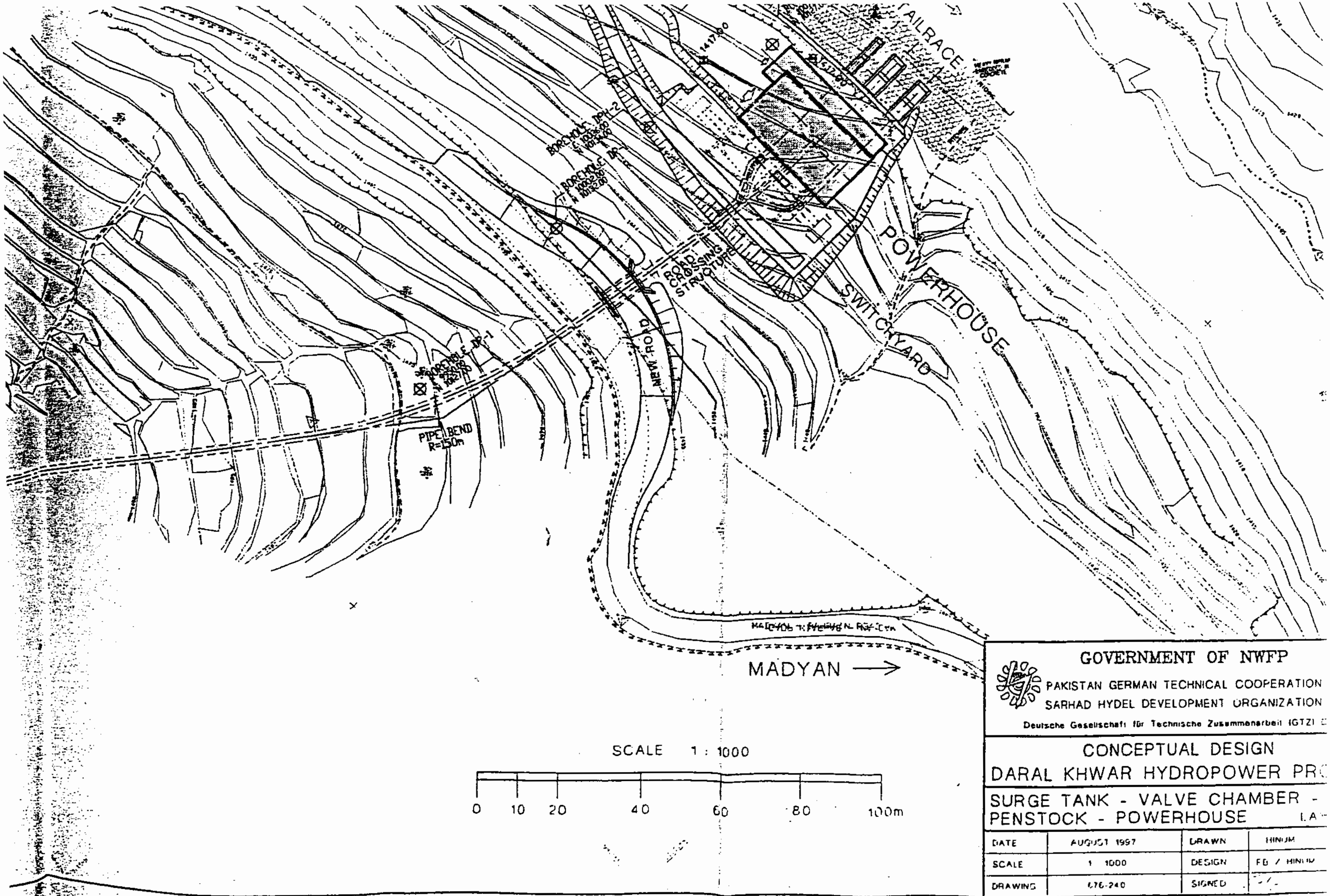
DATED	AUGUST 1997	DRAWN	NIAMAT KHAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-298	SIGNED	



SCALE 1 : 1000
0 20 40 60 80 100m
N
HEADRACE TUNNEL
DRACE TUNNEL
RSE-SHOE PROFILE
CROSS SEC. AREA 8.43m2
AL LENGTH 3643.7m
CHARGE 15.0m3/s
DIENT 0.50%
R=90m
TUNNEL PLUG
TUNNEL DOOR
SURGE TANK
NET DIAMETER 12.0m
NET CROSS SEC. AREA 113.1m2
TUNNEL PLUG
GROUT CURTAIN
ACCESS TUNNEL
TOTAL LENGTH 115 m
PENSTOCK TUNNEL
TOTAL LENGTH 50 m
E 9432/N10612
VALVE CHAMBER
EMERGENCY VALVE
MAINTENANCE VALVE
ANCHOR BLOCK
1694.00
ACCESS ROAD
WORKING PLATFORM
1698.00
WORKING PLATFORM



EMBEDDED PENSTOCK
STEEL PIPE
NET DIAMETER 2.00m
NET CROSS SEC. AREA 3.14m2
TOTAL LENGTH 841m
DISCHARGE 15.00m3/s



GOVERNMENT OF NWFP

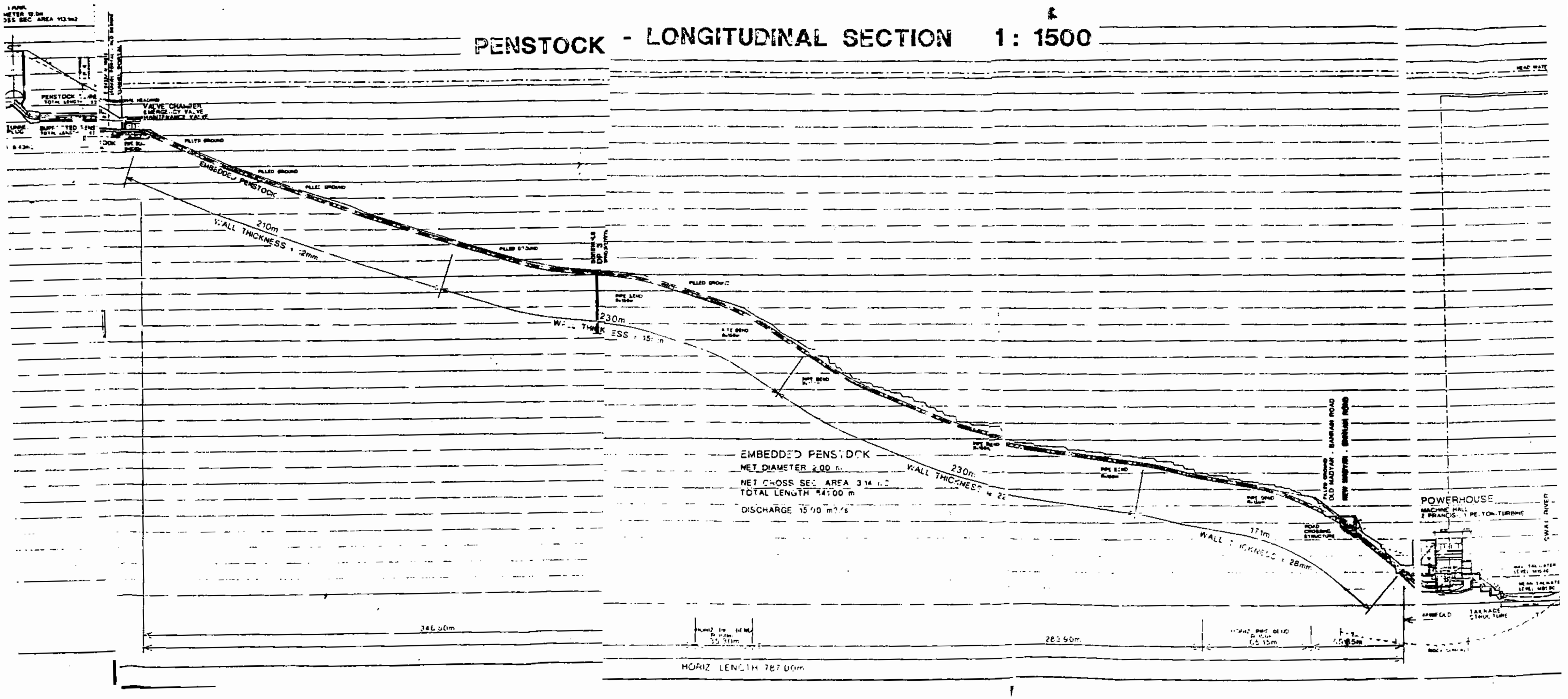
PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)

CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PR

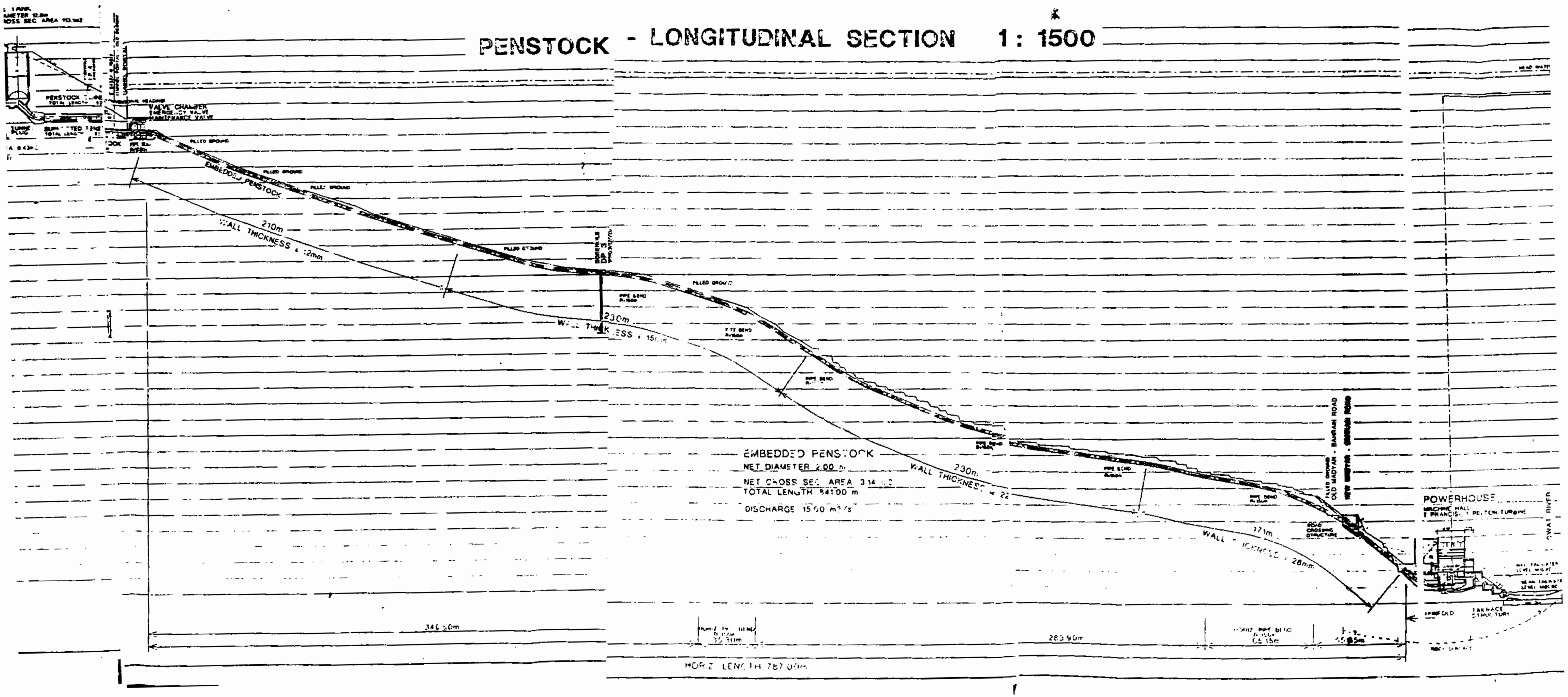
SURGE TANK - VALVE CHAMBER -
PENSTOCK - POWERHOUSE LA

DATE	AUGUST 1997	DRAWN	HINUM
SCALE	1 : 1000	DESIGN	FB / HINUM
DRAWING	476-240	SIGNED	

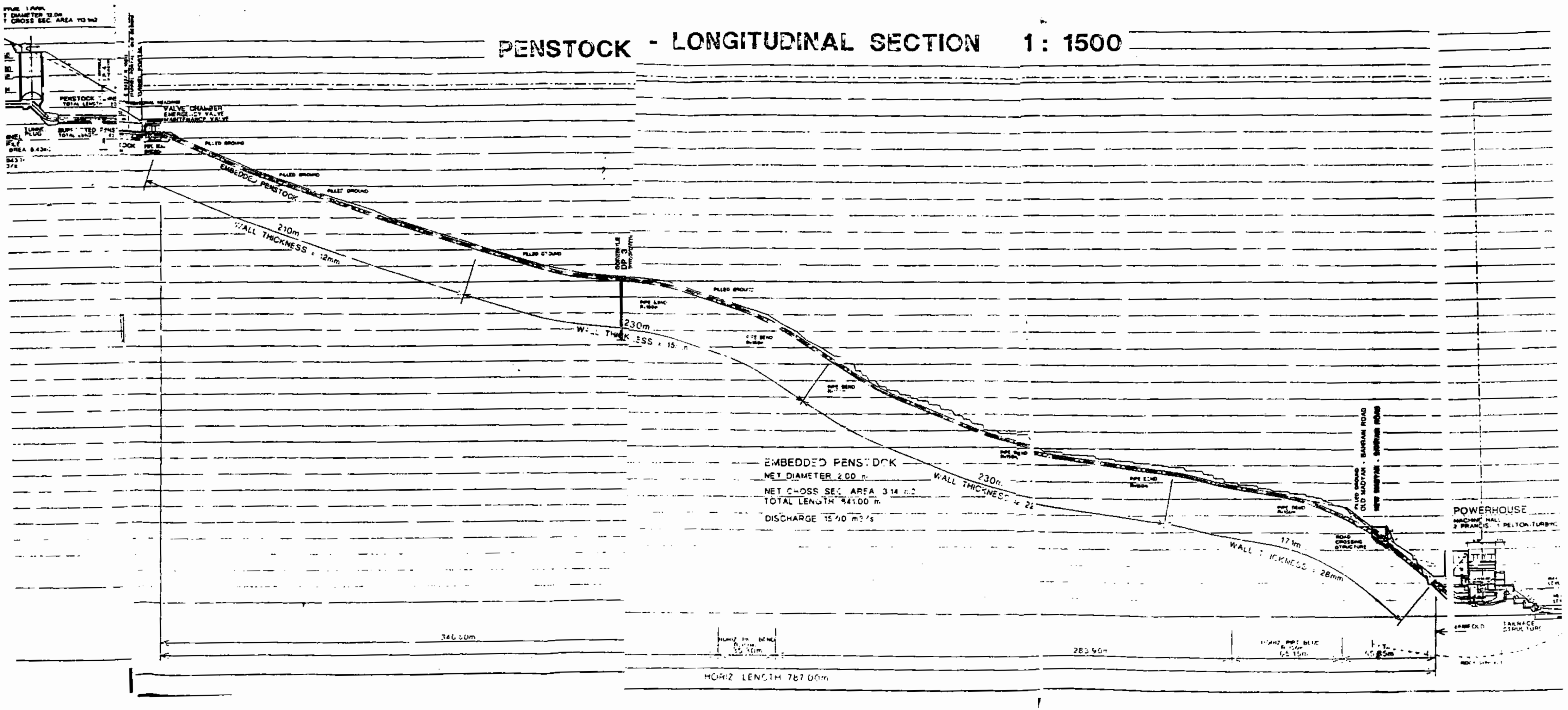
PENSTOCK - LONGITUDINAL SECTION 1: 1500



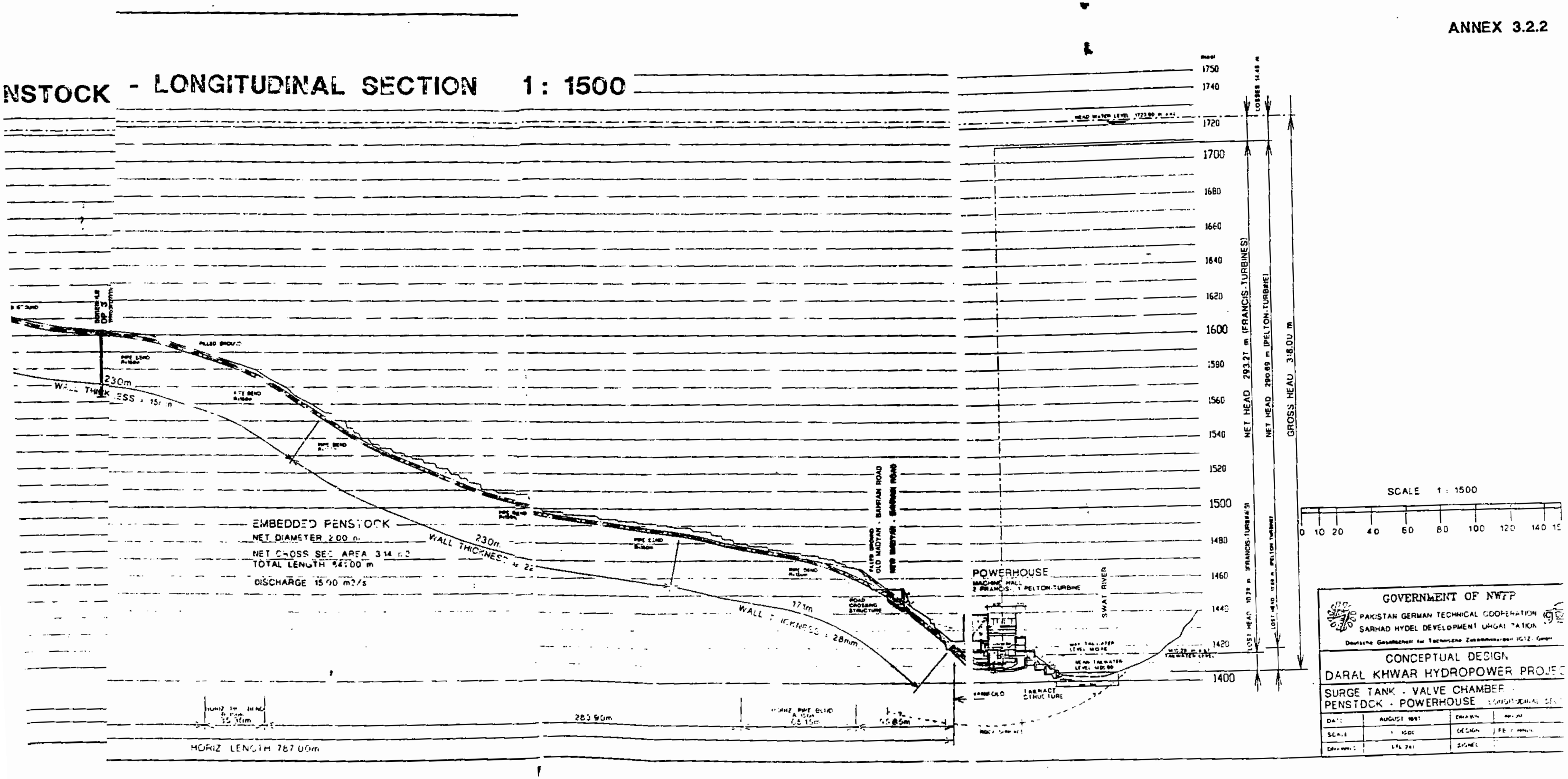
PENSTOCK - LONGITUDINAL SECTION 1: 1500



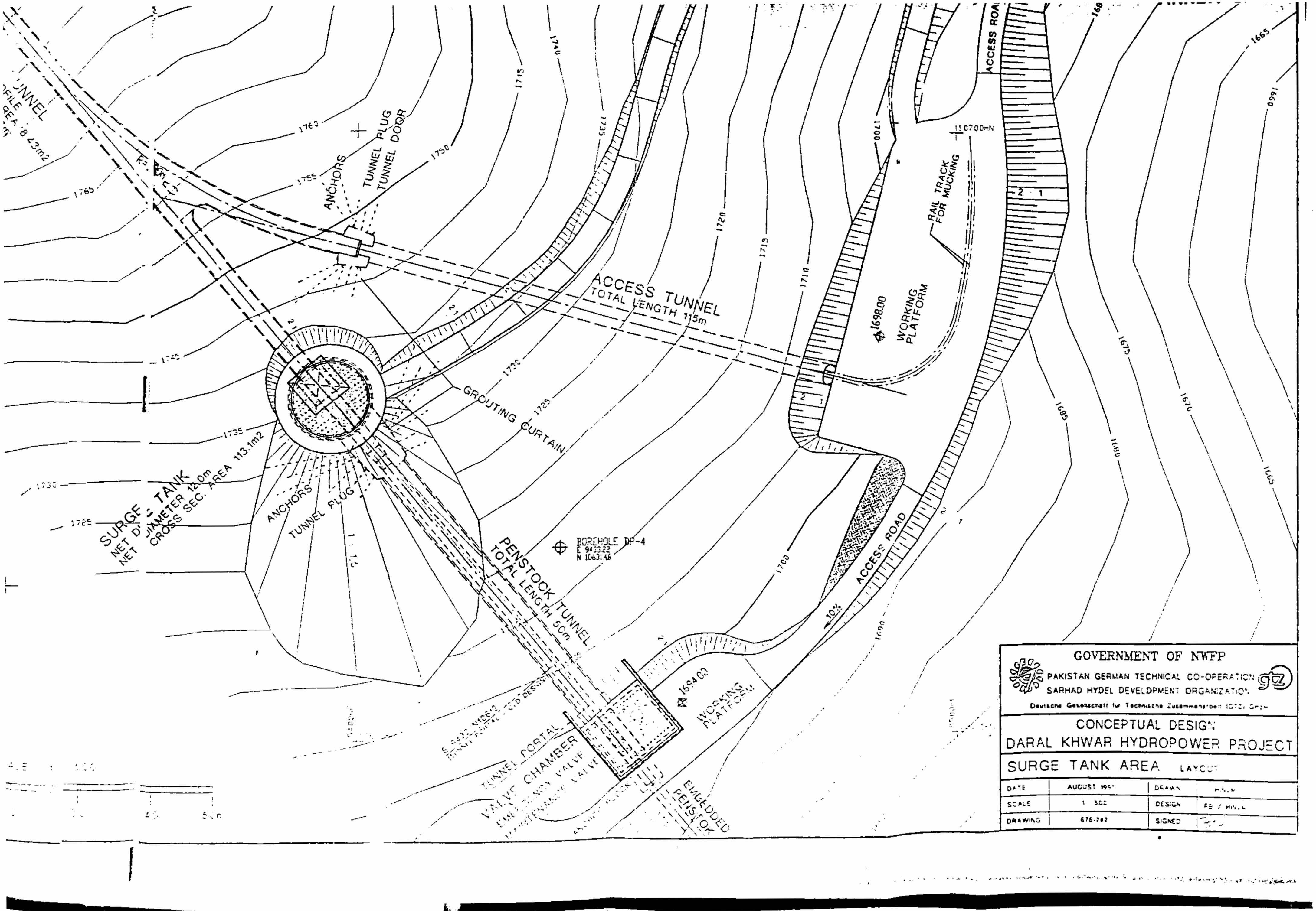
PENSTOCK - LONGITUDINAL SECTION 1: 1500



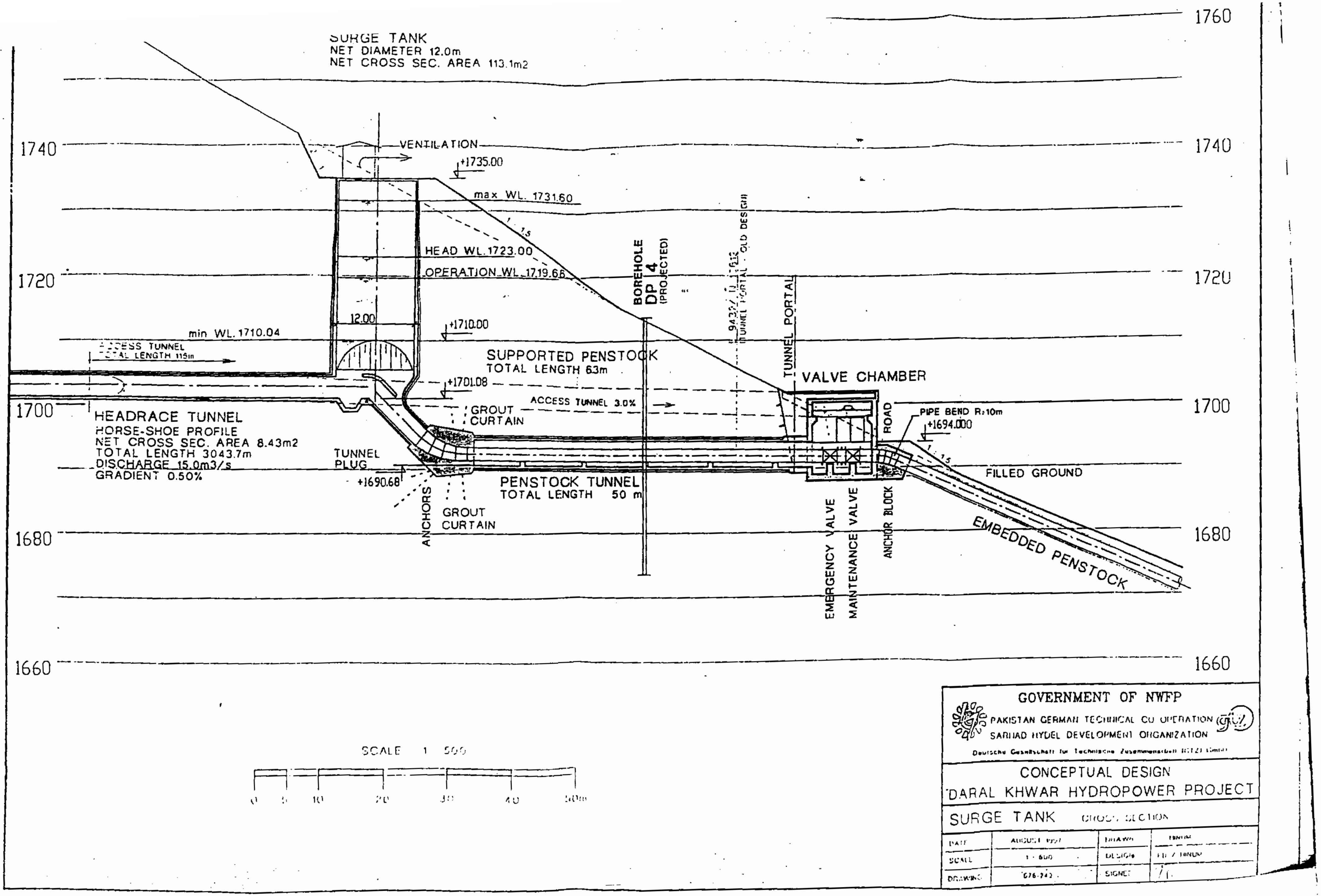
ANNEX 3.2.2



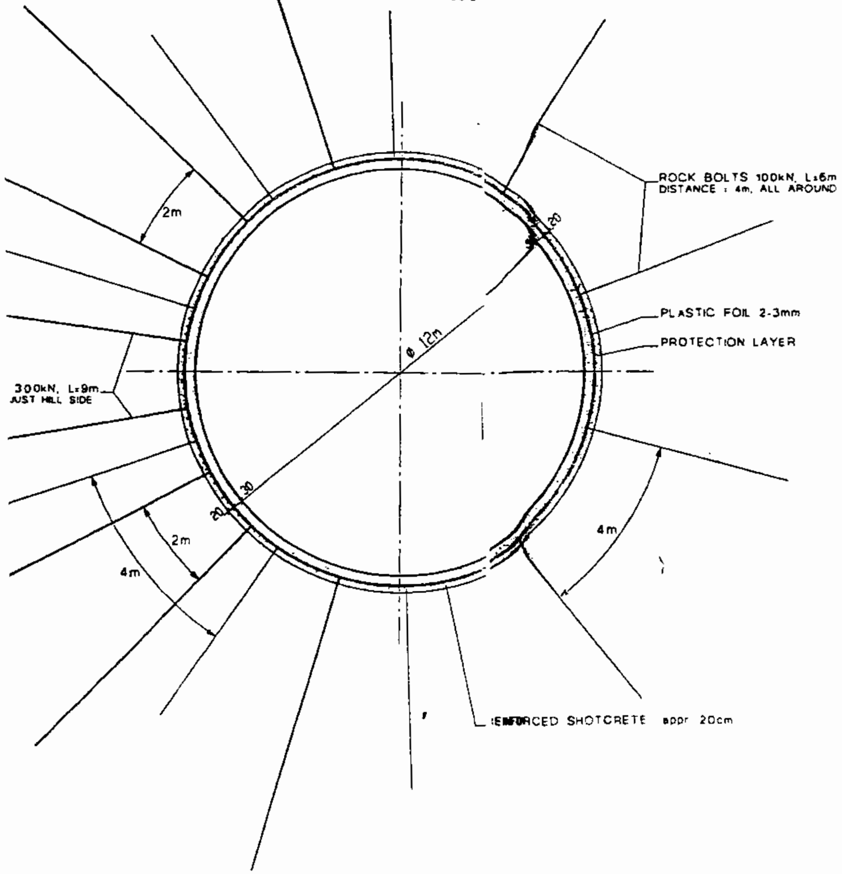
NSTOCK - LONGITUDINAL SECTION 1: 1500
1750
1740
1720
1700
1680
1660
1640
1620
1600
1580
1560
1540
1520
1500
1480
1460
1440
1420
1400
NET HEAD 293.27 m (FRANCIS-TURBINES)
NET HEAD 290.69 m (PELTON-TURBINE)
GROSS HEAD 318.00 m
230m
230m
171m
EMBEDDED PENSTOCK
NET DIAMETER 2.00 m
TOTAL LENGTH
DISCHARGE
POWERHOUSE
SWAT RIVER
283.90m
HORIZ LENGTH 767.00m
SCALE 1 : 1500
0 10 20 40 60 80 100 120 140
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANISATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJE
SURGE TANK - VALVE CHAMBER -
PENSTOCK - POWERHOUSE



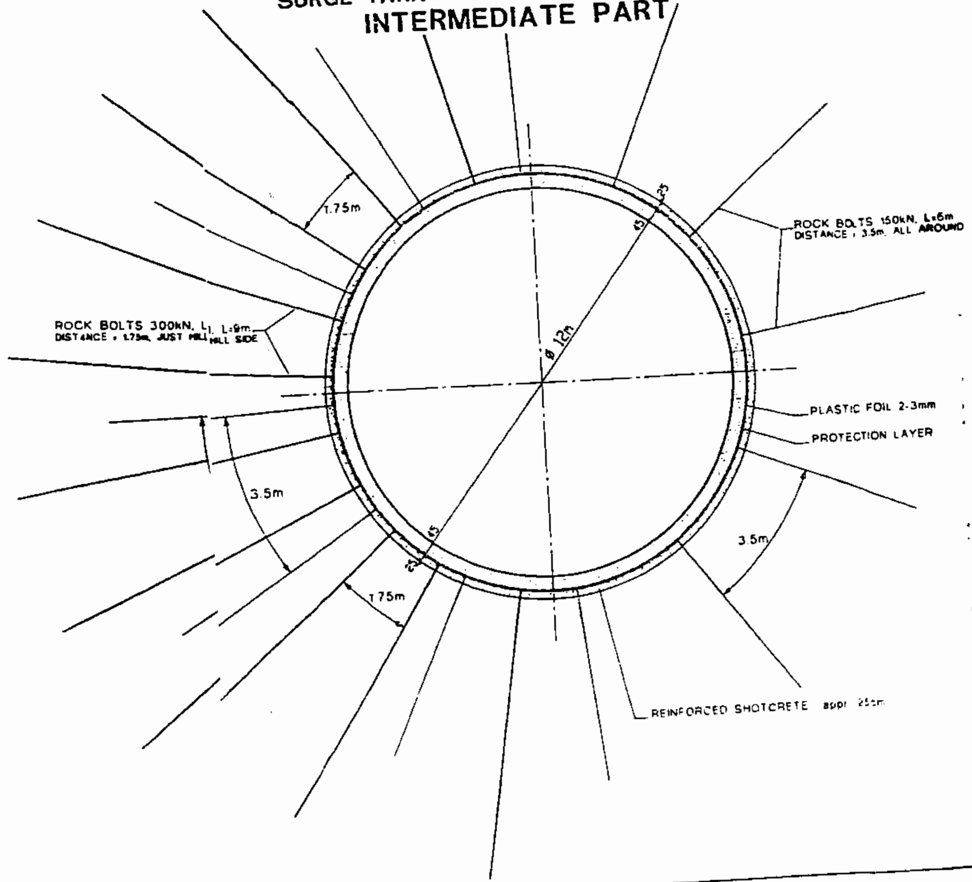
ACCESS TUNNEL
TOTAL LENGTH 115m
TUNNEL PLUG
TUNNEL DOOR
ANCHORS
GROUTING CURTAIN
SURGE TANK
NET DIAMETER 12.0m
NET CROSS SEC. AREA 113.1m2
ANCHORS
TUNNEL PLUG
PENSTOCK TUNNEL
TOTAL LENGTH 50m
BOREHOLE DP-4
WORKING PLATFORM
1698.00
RAIL TRACK FOR MUCKING
ACCESS ROAD
ACCESS ROAD
10%
1694.00
WORKING PLATFORM
TUNNEL PORTAL
VALVE CHAMBER
EMBEDDED PENSTOCK
1765
1760
1755
1750
1745
1740
1735
1730
1725
1720
1715
1710
1700
1695
1690
1685
1680
1675
1670
1665
1660
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT
SURGE TANK AREA LAYOUT
DATE
SCALE
DRAWING
DRAWN
DESIGN
SIGNED
1 : 500
676-242

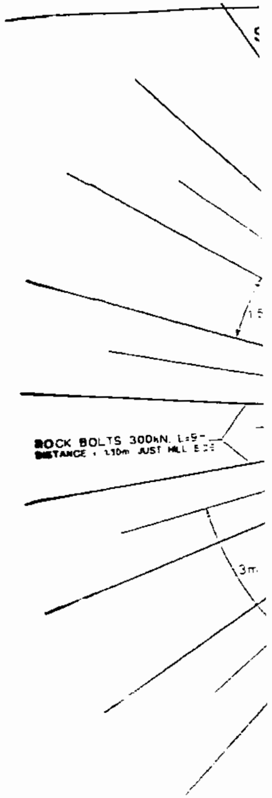

SURGE TANK
NET DIAMETER 12.0m
NET CROSS SEC. AREA 113.1m2
1760
1740
1720
1700
1680
1660
VENTILATION
+1735.00
max WL. 1731.60
HEAD WL.1723.00
OPERATION WL. 1719.66
BOREHOLE
DP 4
(PROJECTED)
TUNNEL PORTAL
min WL. 1710.04
12.00
+1710.00
SUPPORTED PENSTOCK
TOTAL LENGTH 63m
VALVE CHAMBER
+1701.08
ACCESS TUNNEL 3.0%
GROUT
CURTAIN
ROAD
PIPE BEND R:10m
+1694.000
HEADRACE TUNNEL
HORSE-SHOE PROFILE
NET CROSS SEC. AREA 8.43m2
TOTAL LENGTH 3043.7m
DISCHARGE 15.0m3/s
GRADIENT 0.50%
TUNNEL
PLUG
+1690.68
PENSTOCK TUNNEL
TOTAL LENGTH 50 m
FILLED GROUND
ANCHORS
GROUT
CURTAIN
EMERGENCY VALVE
MAINTENANCE VALVE
ANCHOR BLOCK
EMBEDDED PENSTOCK
SCALE 1 : 500
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT
SURGE TANK
DATE
SCALE
DRAWING
DRAWN
DESIGN
SIGNED

SURGE TANK - TYPICAL CROSS SECTION
UPPER PART

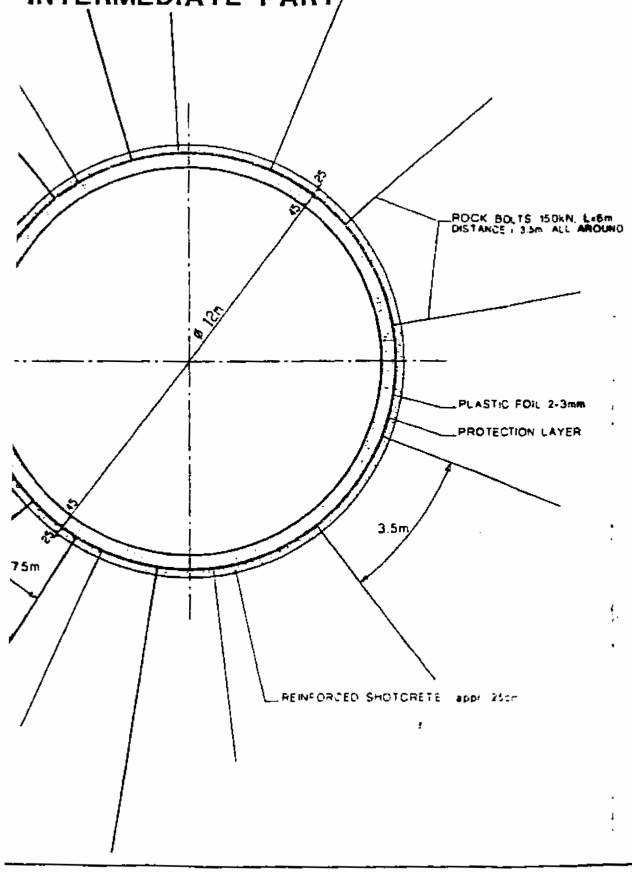


SURGE TANK - TYPICAL CROSS SECTION
INTERMEDIATE PART



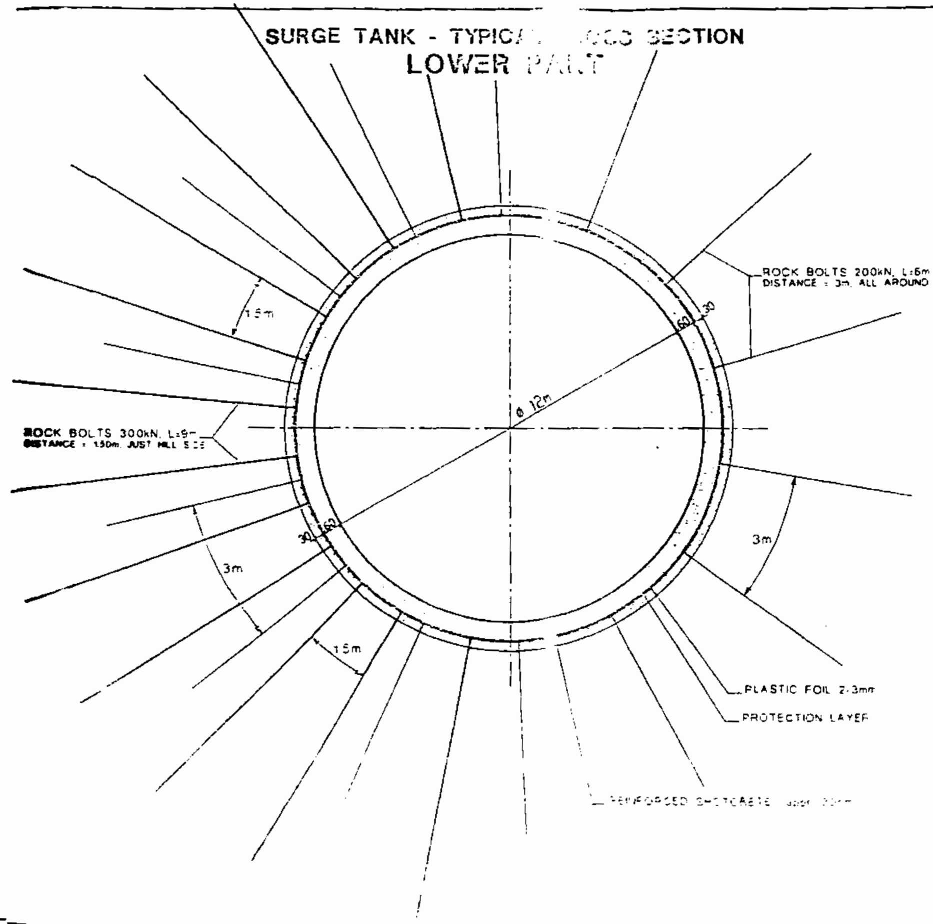


TANK - TYPICAL CROSS SECTION
INTERMEDIATE PART



SURGE TANK - TYPICAL CROSS SECTION
LOWER PART

ANNEX 3.2.5



SCALE 1 : 100

0 1 2 4 6 8 10m

GOVERNMENT OF NWFP

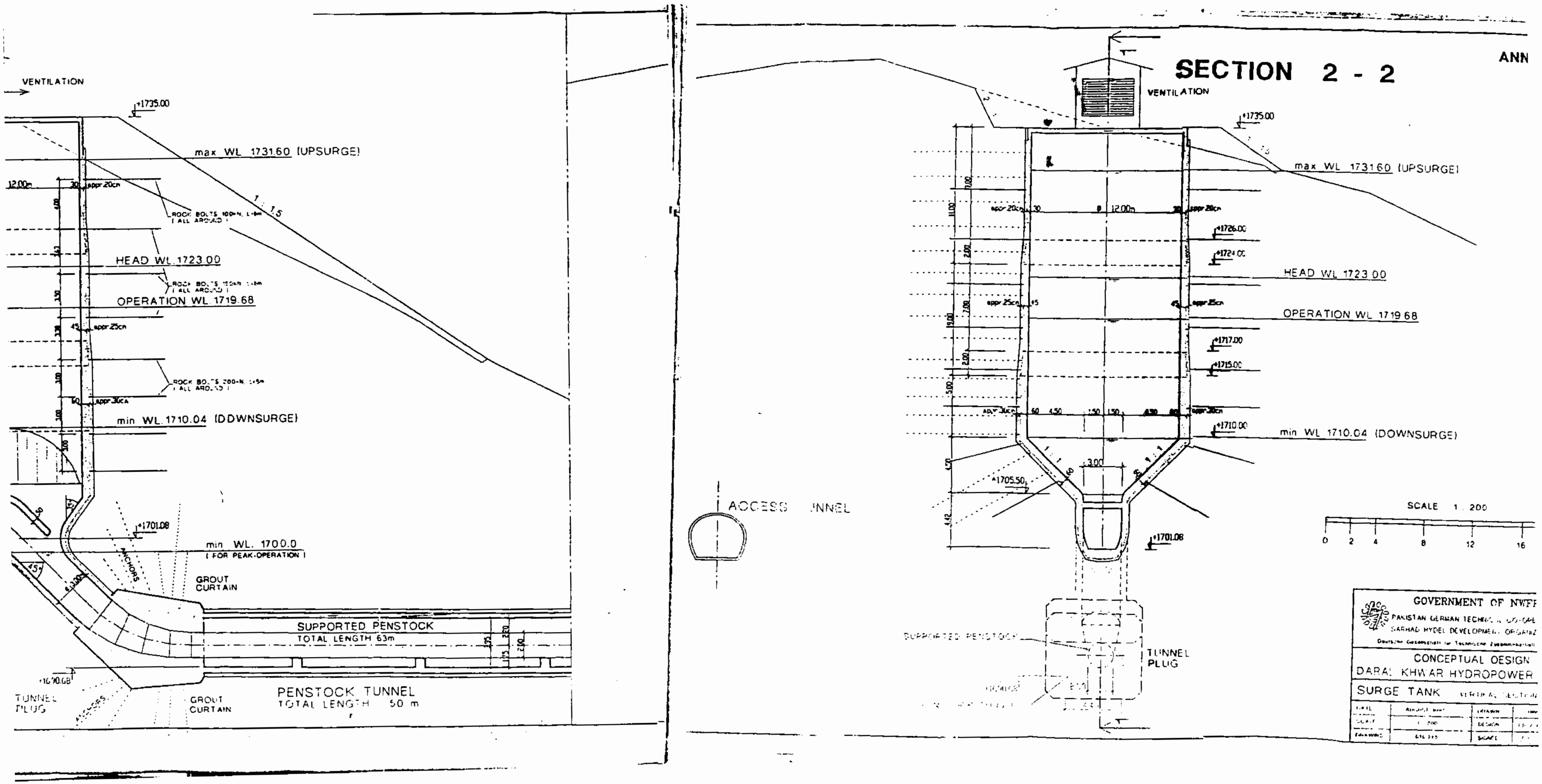
PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

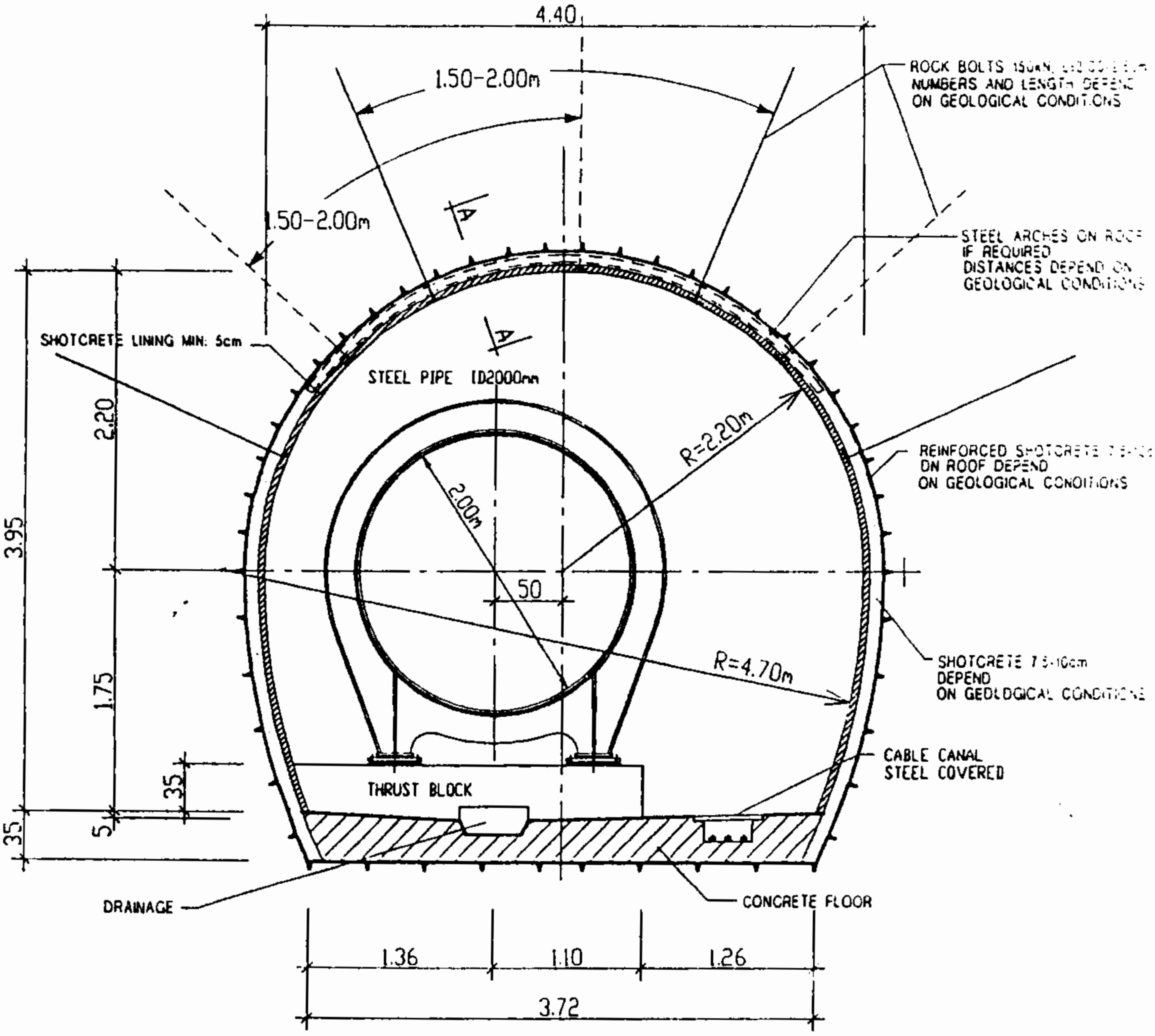
SURGE TANK TYPICAL CROSS SECTIONS

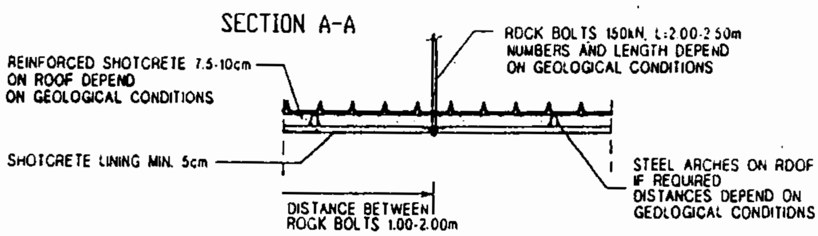


GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER
SURGE TANK VERTICAL SECTION

CONVENTIONAL HEADING
ROCK CLASS D
BADLY FRACTURED, INTENSE FRIABLE
(ACCORDING TO LAUFFER)

ANNEX 3.3.1





GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

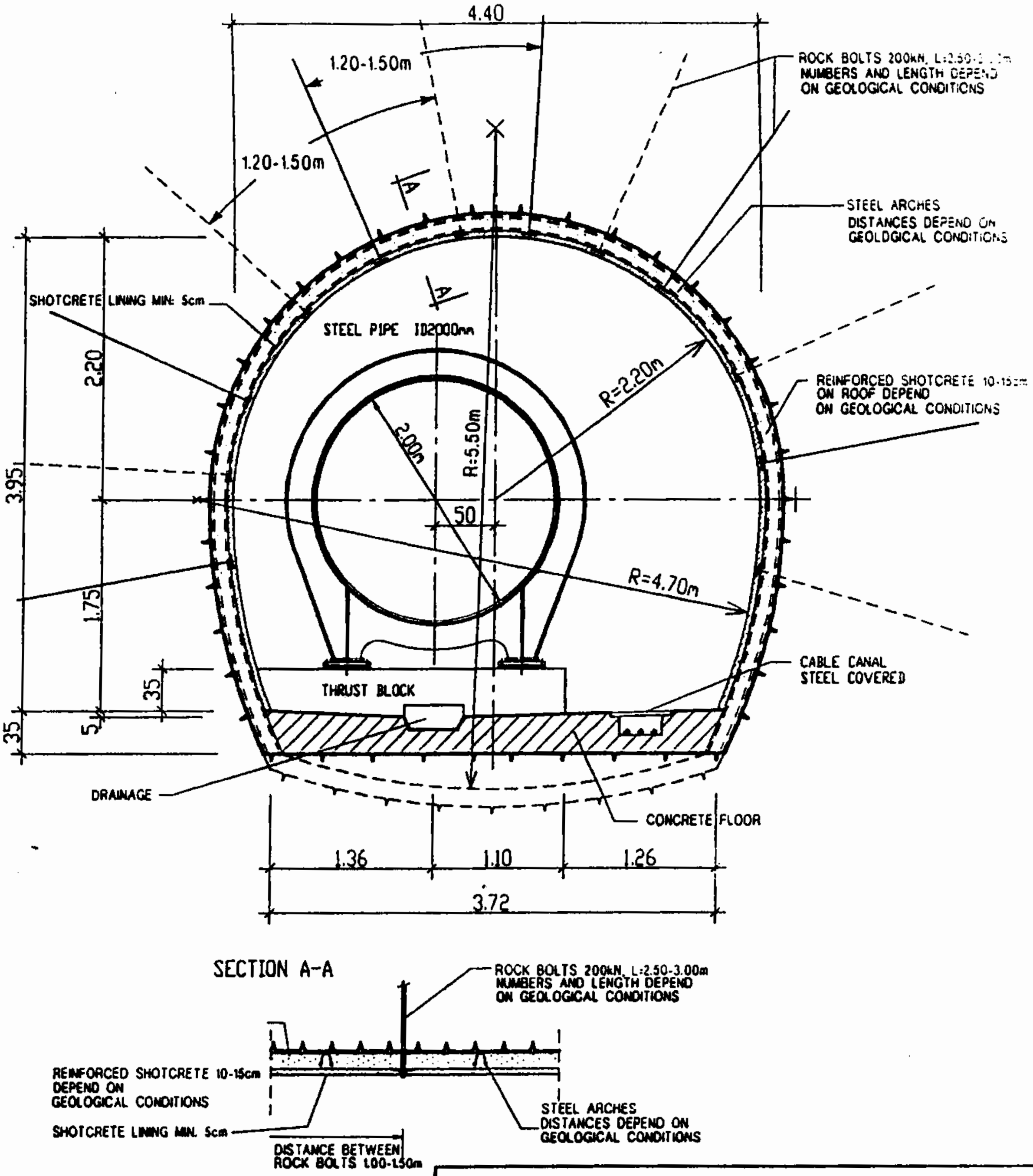
PENSTOCK TUNNEL (CONVENTIONAL HEADING)

TYPICAL CROSS SECTION ROCK CLASS "D"

DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-250	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS E
TOTALLY FRACTURED, FAULTED, UNSTABLE
(ACCORDING TO LAUFFER)

ANNEX 3.3.2



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

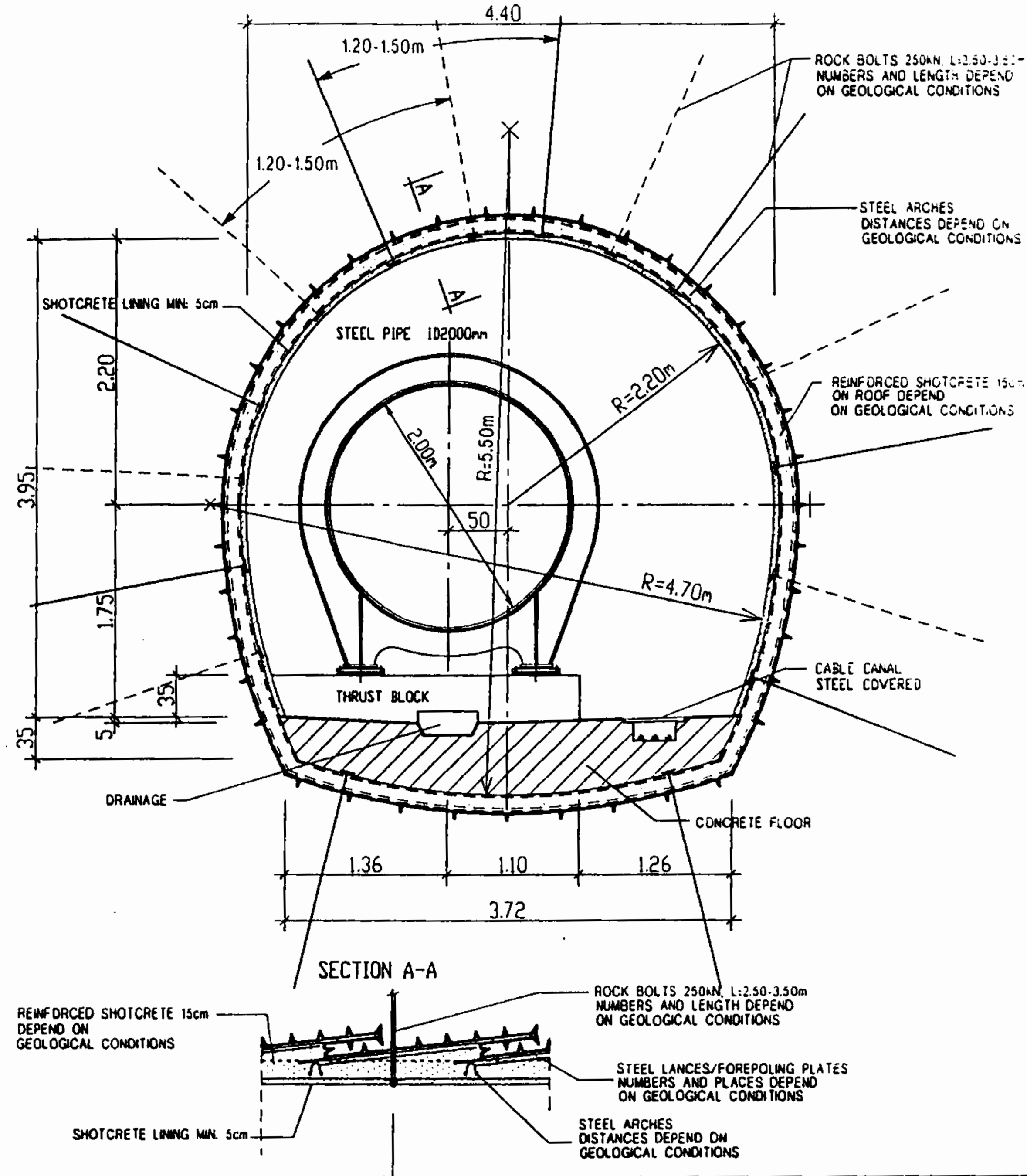
PENSTOCK TUNNEL (CONVENTIONAL HEADING)

TYPICAL CROSS SECTION ROCK CLASS "E"

DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-251	SIGNED	

CONVENTIONAL HEADING
ROCK CLASS F
MYLONITIC ZONES, FAULTS, SQUEEZING
(ACCORDING TO LAUFFER)

ANNEX 3.3.3



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

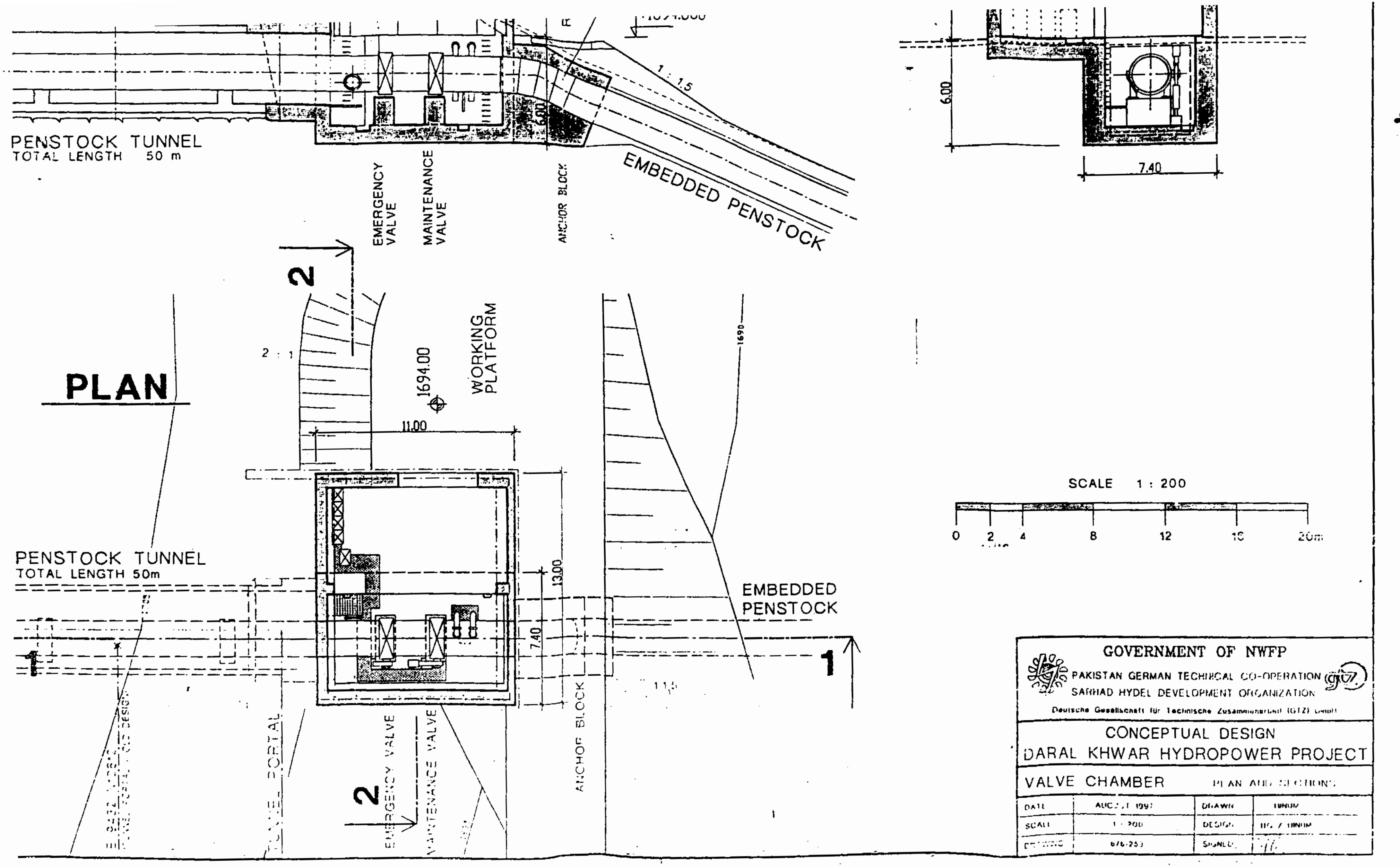
SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJECT

PENSTOCK TUNNEL (CONVENTIONAL HEADING)		TYPICAL CROSS SECTION ROCK CLASS "F"	
DATE	AUGUST 1997	DRAWN	BELTRAN
SCALE	1 : 50	DESIGN	HINUM
DRAWING	676-252	SIGNED	



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION (gtz)
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

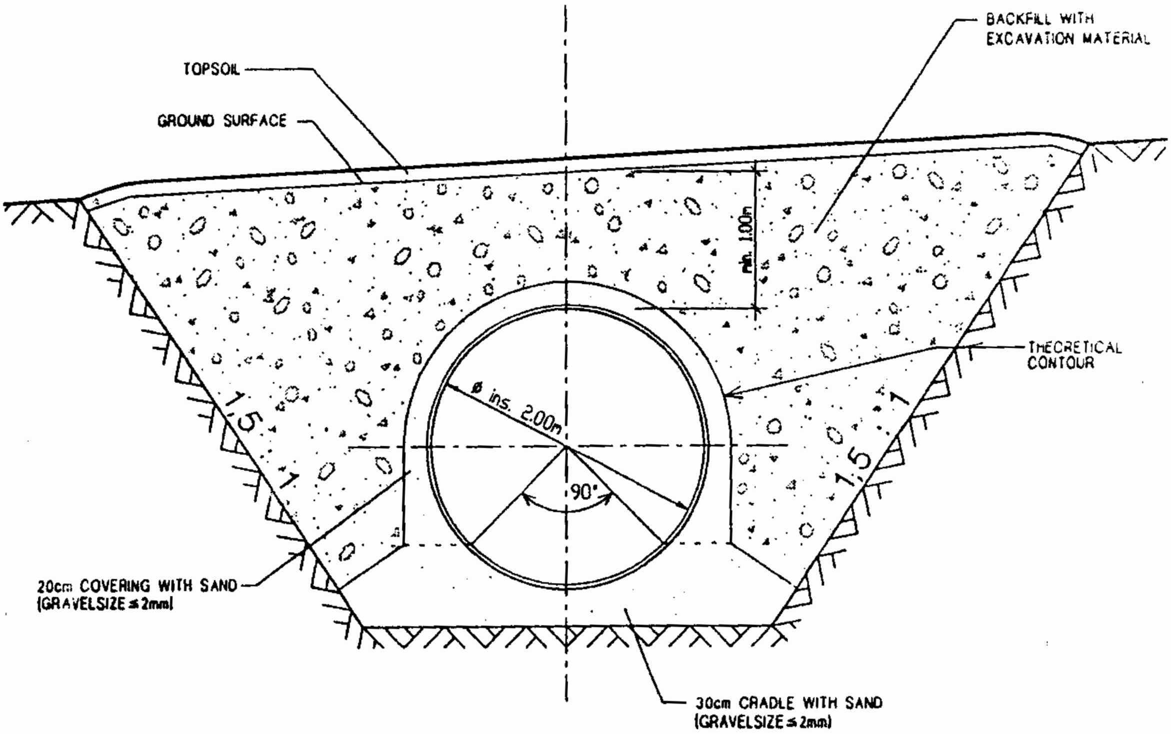
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

VALVE CHAMBER PLAN AND SECTIONS

DATE	AUG[illegible] 199[illegible]	DRAWN	[illegible]
SCALE	1 : 200	DESIGN	[illegible]
DRAWING	676-253	SIGNED	[illegible]

ANNEX 3.3.5

PENSTOCK
TYPICAL CROSS SECTION
OPTIMAL TERRAIN



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

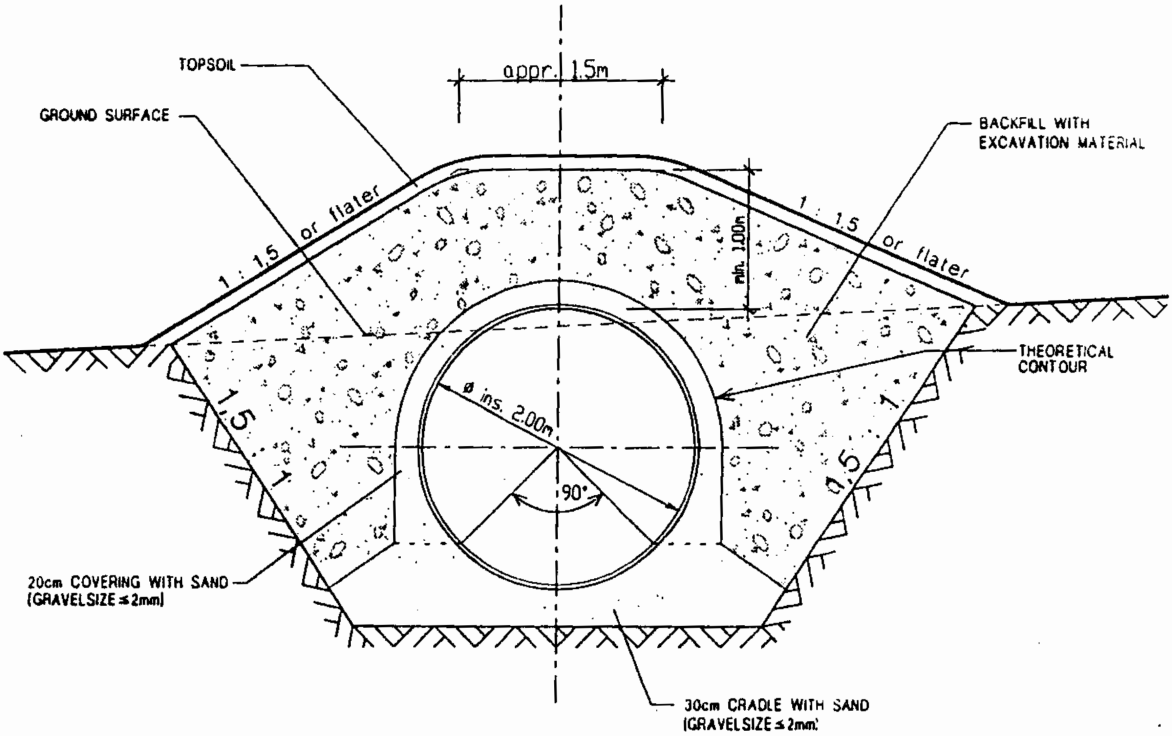
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT

EMBEDDED PENSTOCK — TYPICAL CROSS SECTION OPTIMAL TERRAIN

DATE	AUGUST 1997	DRAWN	HINUM
SCALE	1 : 50	DESIGN	FB / HINUM
DRAWING	676-254	SIGNED	

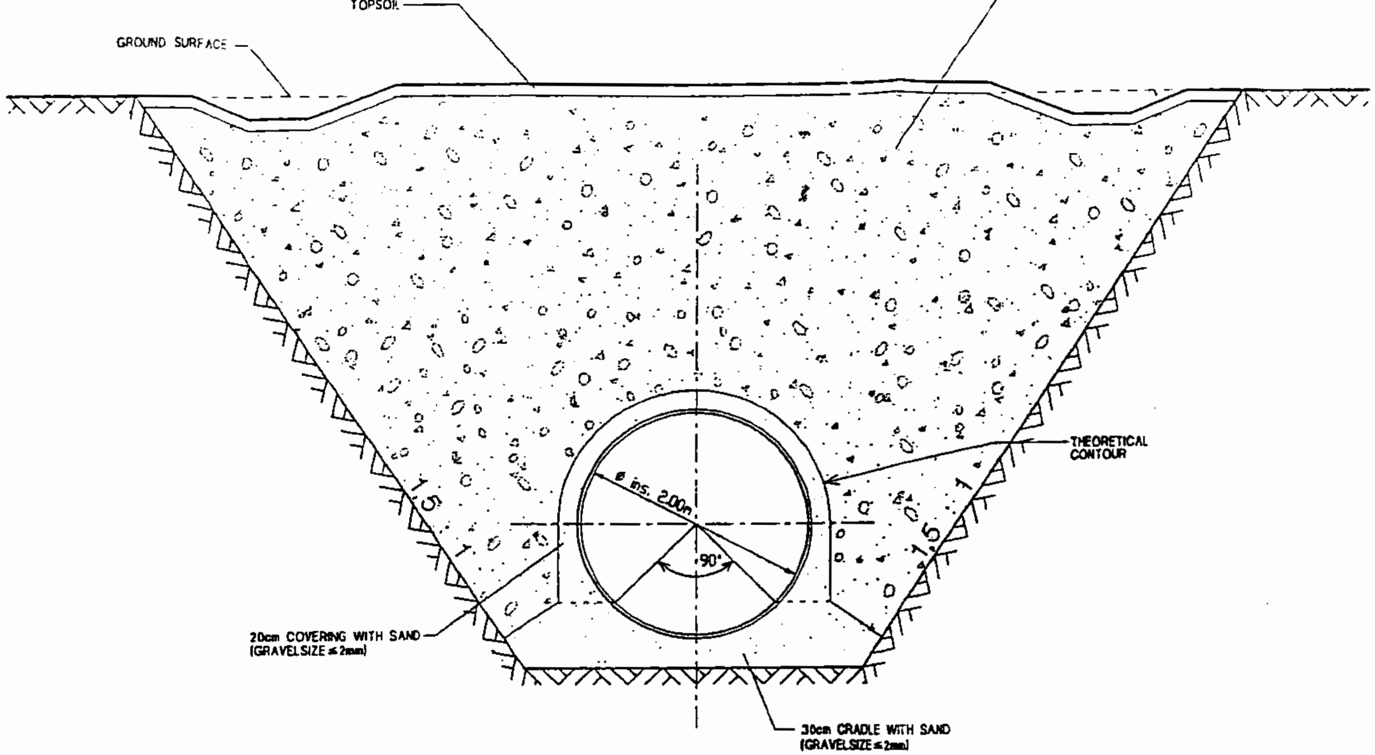
ANNEX 3.3.6

PENSTOCK
TYPICAL CROSS SECTION
FILLED GROUND



GOVERNMENT OF NWFP			
PAKISTAN GERMAN TECHNICAL CO-OPERATION SARHAD HYDEL DEVELOPMENT ORGANIZATION Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH			
CONCEPTUAL DESIGN DARAL KHWAR HYDROPOWER PROJECT			
EMBEDDED PENSTOCK		TYPICAL CROSS SECTION FILLED GROUND	
DATE	AUGUST 1997	DRAWN	HINUM
SCALE	1 : 50	DESIGN	FB / HINUM
DRAWING	676-255	SIGNED	

TYPICAL CROSS SECTION
DEEP CUTTING



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL CO-OPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

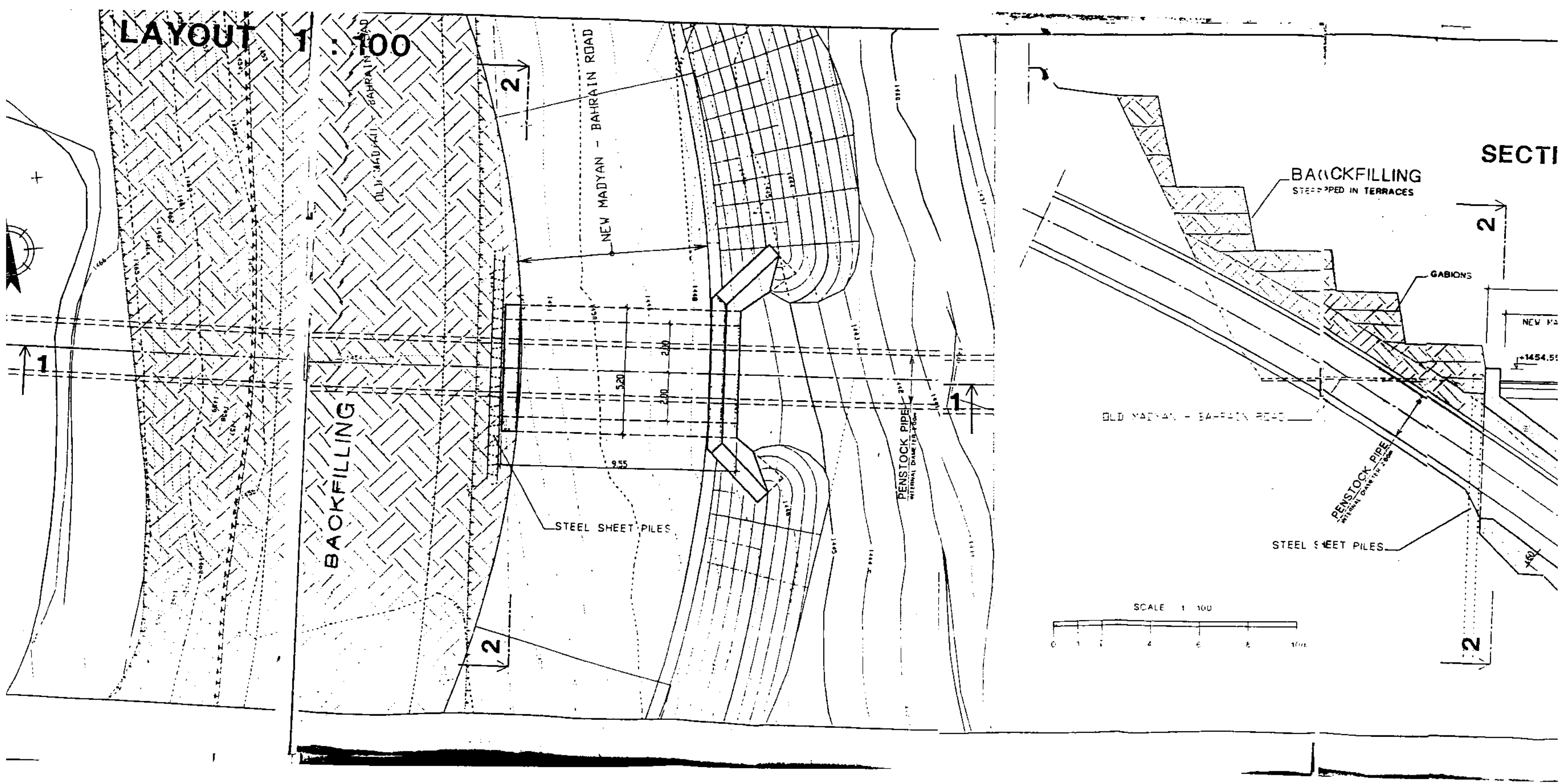
Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH

CONCEPTUAL DESIGN

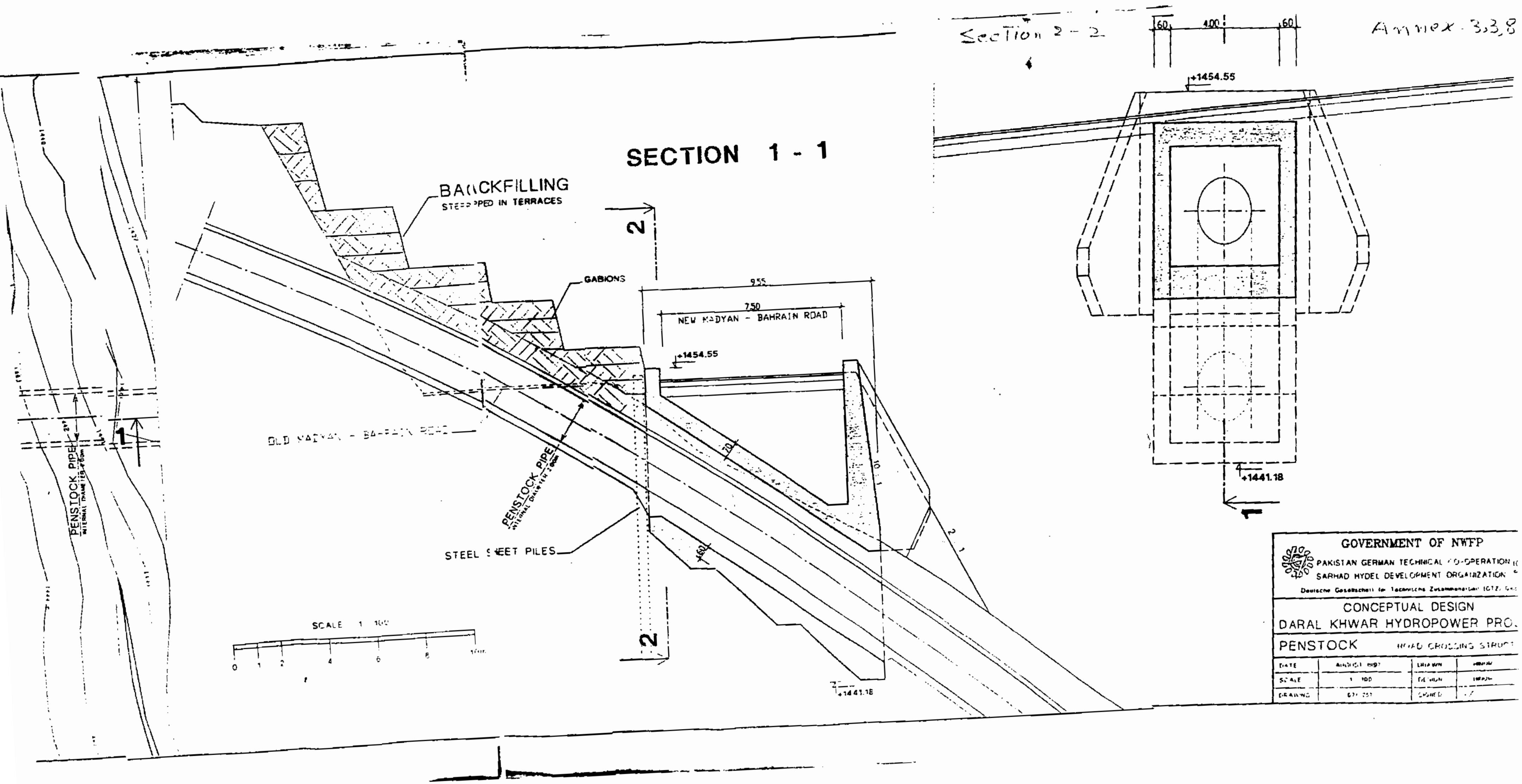
DARAL KHWAR HYDROPOWER PROJECT

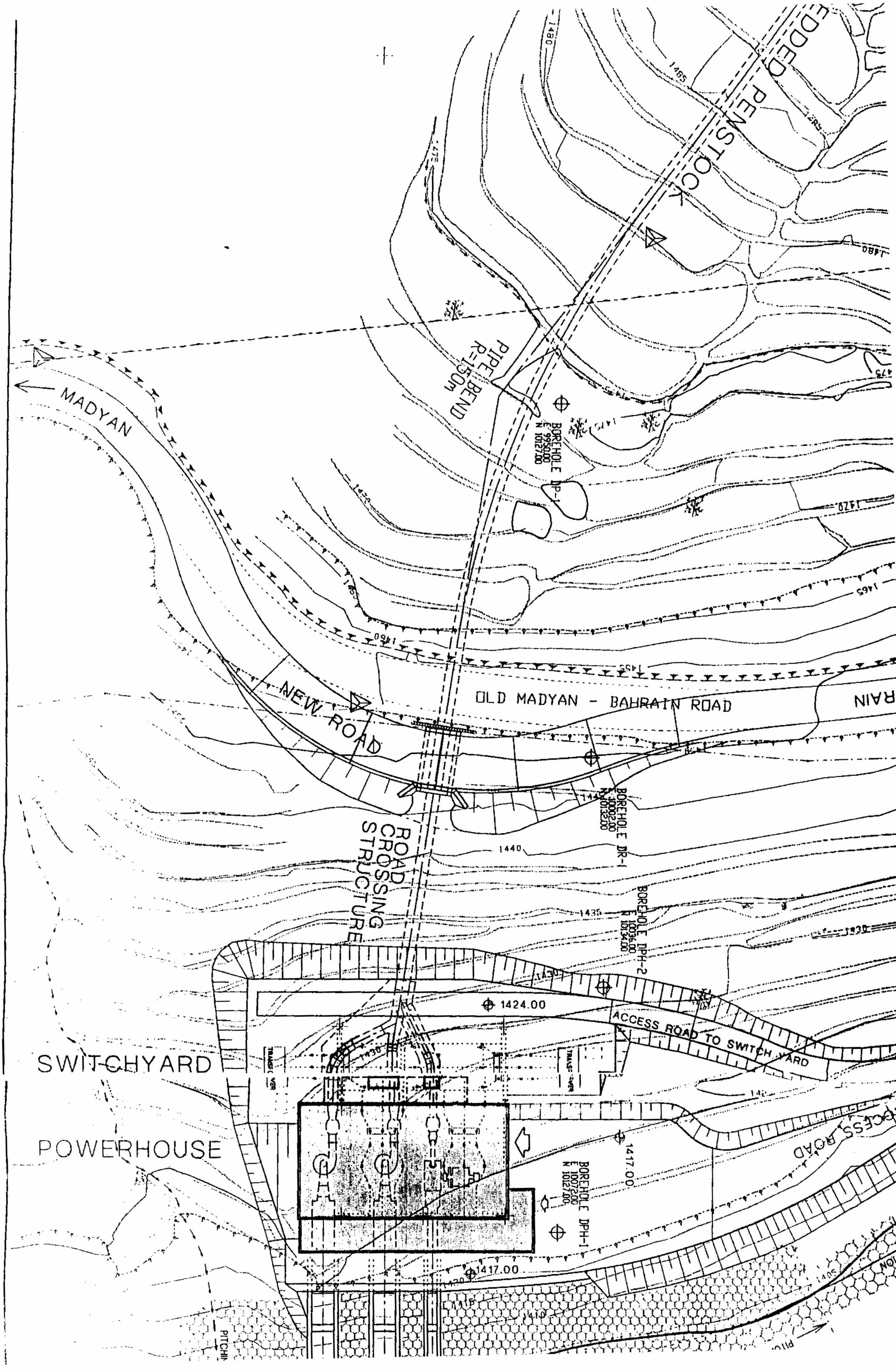
EMBEDDED PENSTOCK TYPICAL CROSS SECTION DEEP CUTTING

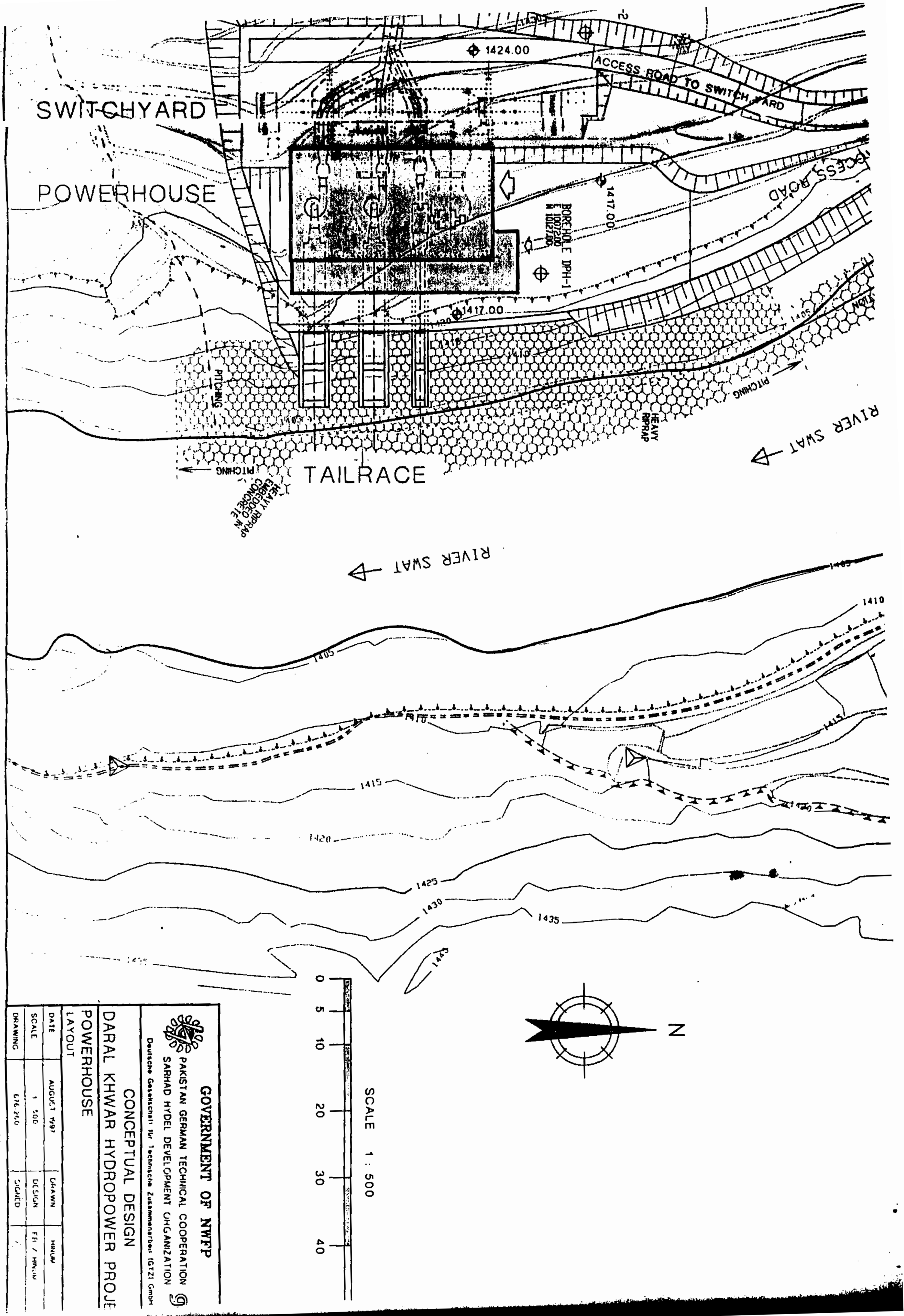
DATE	AUGUST 1997	DRAWN	[illegible]
SCALE	1 : 50	DESIGN	[illegible]
DRAWING	676-250	SIGNED	[illegible]


LAYOUT 1 : 100
BACKFILLING
OLD MADYAN - BAHRAIN ROAD
NEW MADYAN - BAHRAIN ROAD
STEEL SHEET PILES
5.20
2.00
2.00
9.55
PENSTOCK PIPE
1
1
2
2
SECTI
BACKFILLING
STEPPED IN TERRACES
GABIONS
OLD MADYAN - BAHRAIN ROAD
PENSTOCK PIPE
STEEL SHEET PILES
+1454.55
SCALE 1 : 100
0
1
2
4
6
8
10m
2
2

Annex 3.3.8


SECTION 1 - 1
BACKFILLING
STEPPED IN TERRACES
GABIONS
9.55
7.50
NEW MADYAN - BAHRAIN ROAD
+1454.55
OLD MADYAN - BAHRAIN ROAD
PENSTOCK PIPE
STEEL SHEET PILES
+1441.18
SCALE 1:100
Section 2 - 2
60
400
60
+1454.55
+1441.18
PENSTOCK PIPE
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PRO.
PENSTOCK
ROAD CROSSING STRUCT


PENSTOCK
PIPE BEND
R=150m
MADYAN
BOREHOLE DP-1
NEW ROAD
OLD MADYAN - BAHRAIN ROAD
BOREHOLE DR-1
ROAD CROSSING STRUCTURE
BOREHOLE DPH-2
1424.00
ACCESS ROAD TO SWITCH YARD
SWITCHYARD
POWERHOUSE
ACCESS ROAD
1417.00
BOREHOLE DPH-1
1417.00



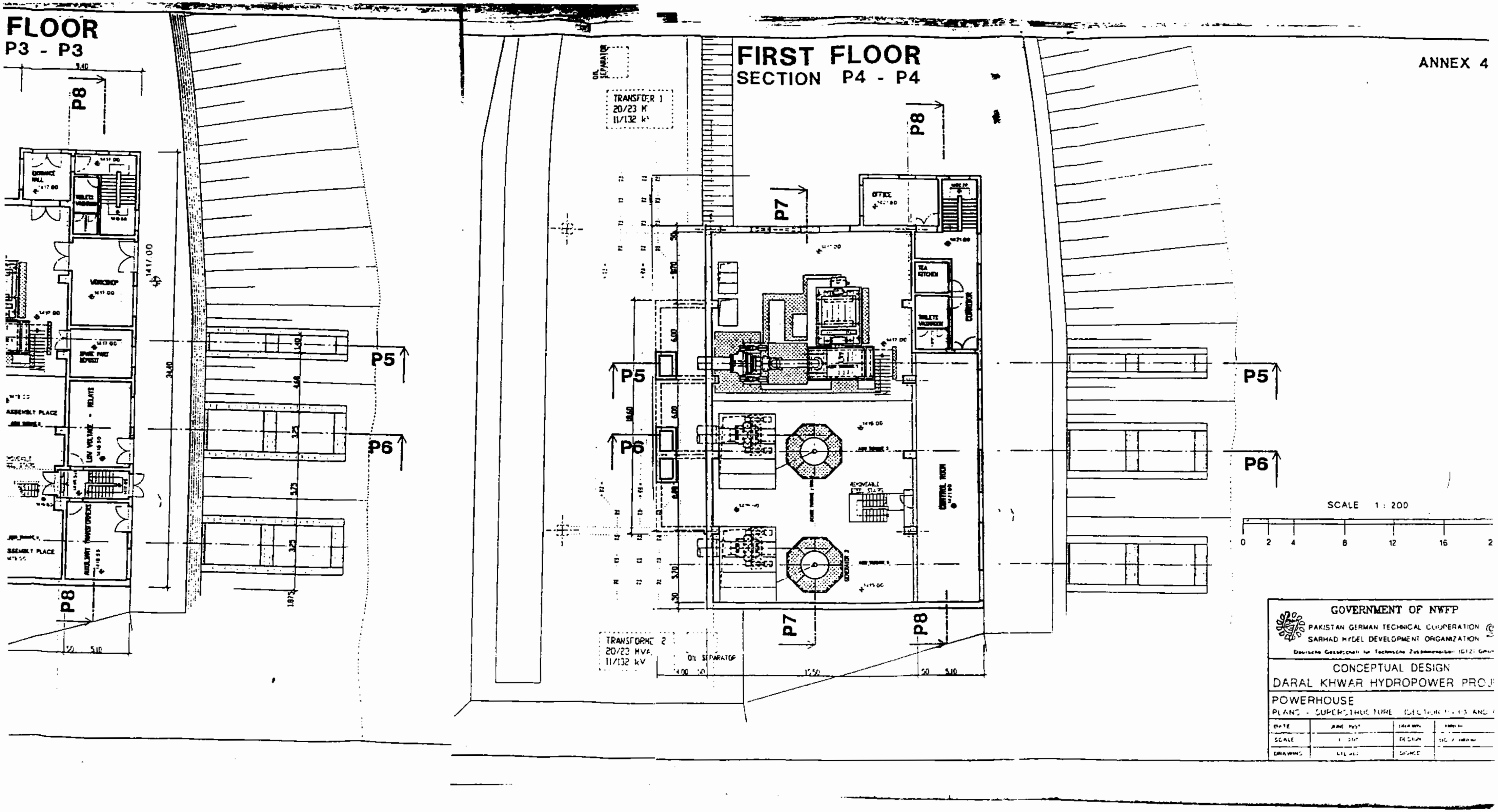
GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

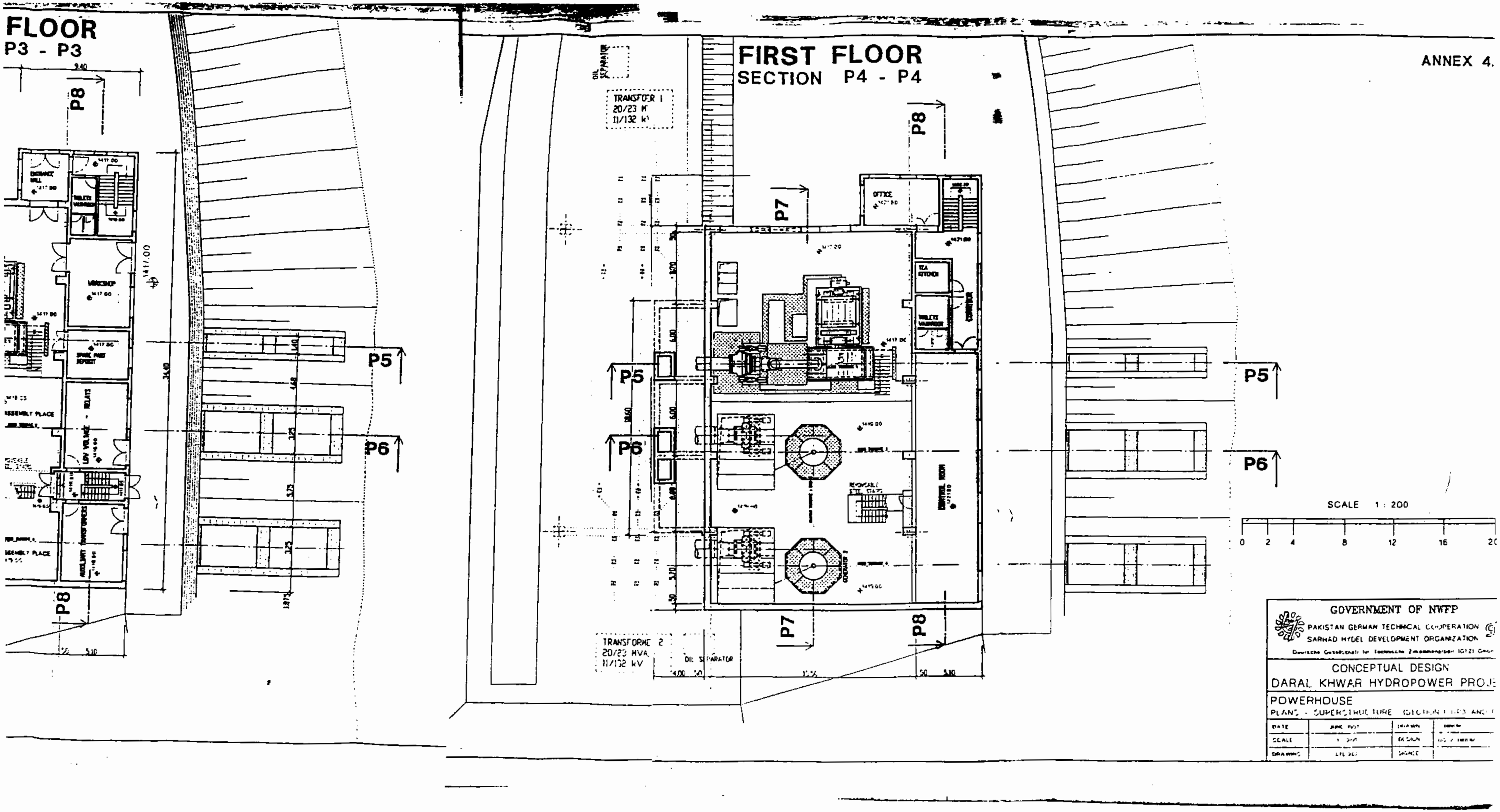
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJE
POWERHOUSE
LAYOUT

DATE	AUGUST 1997	DRAWN	HRUM
SCALE	1 : 500	DESIGN	FB / HRUM
DRAWING	676-260	SIGNED	

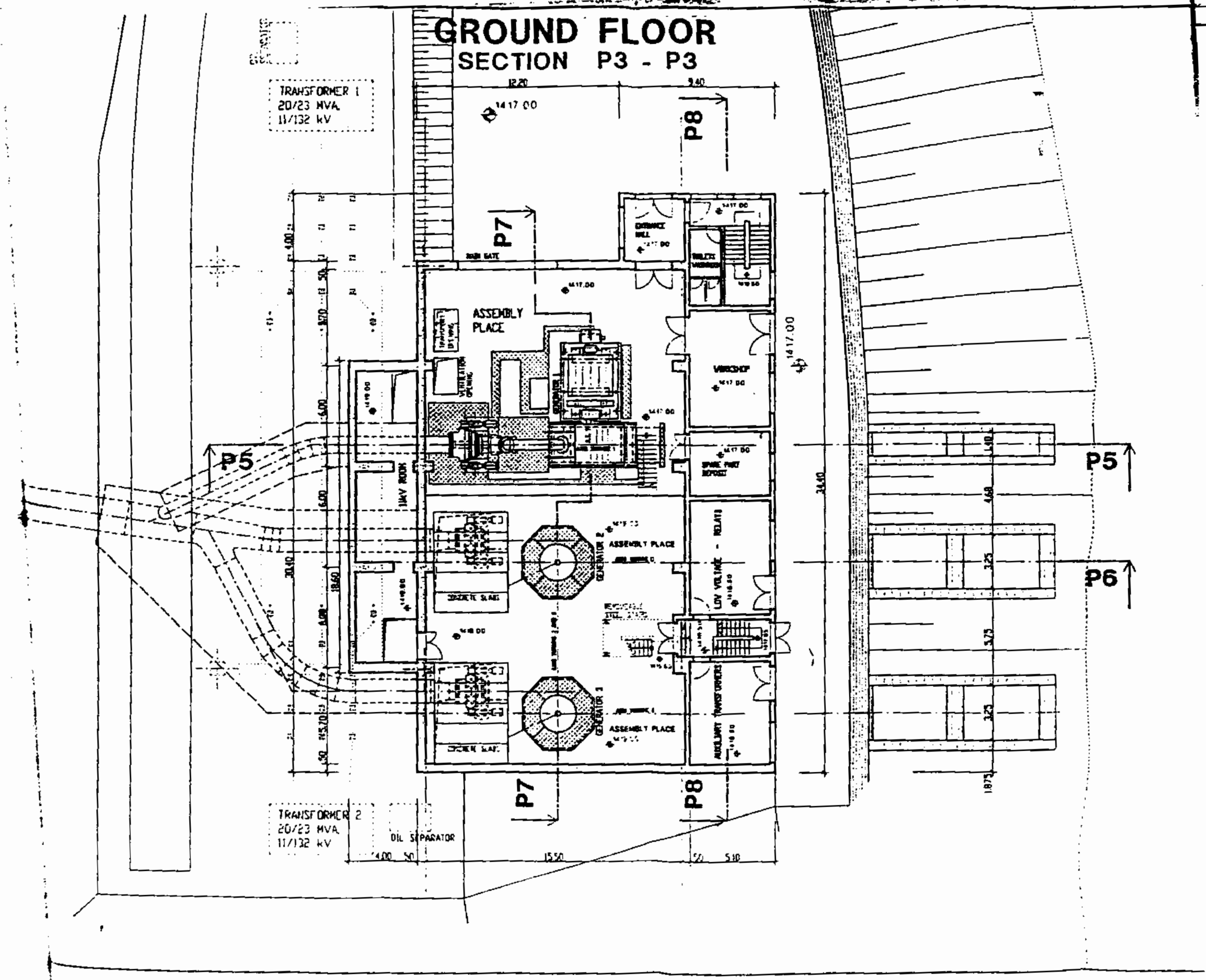
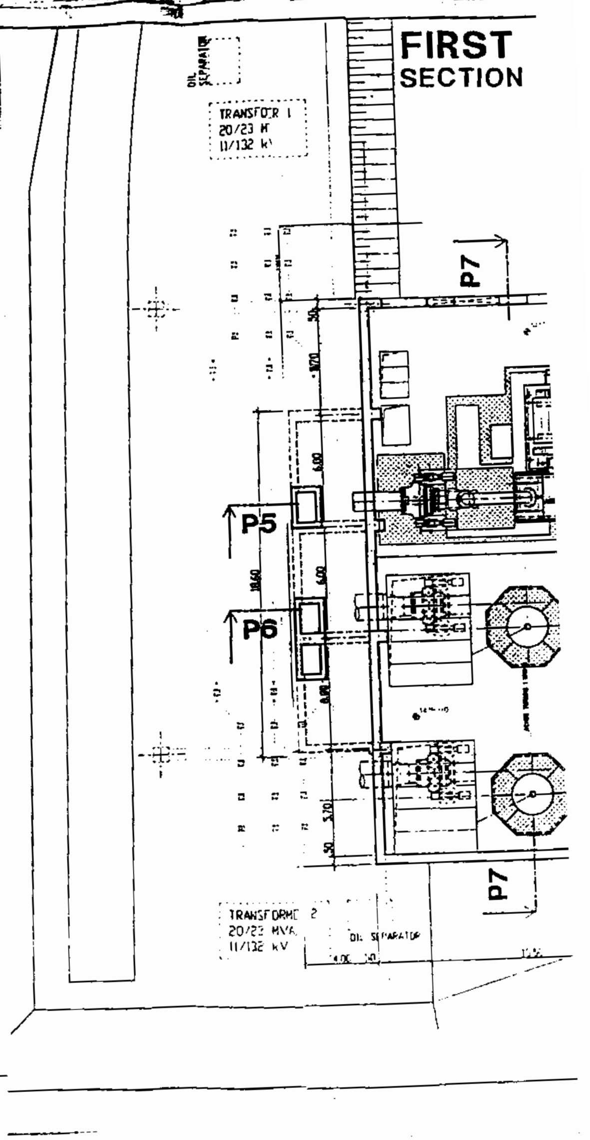
ANNEX 4



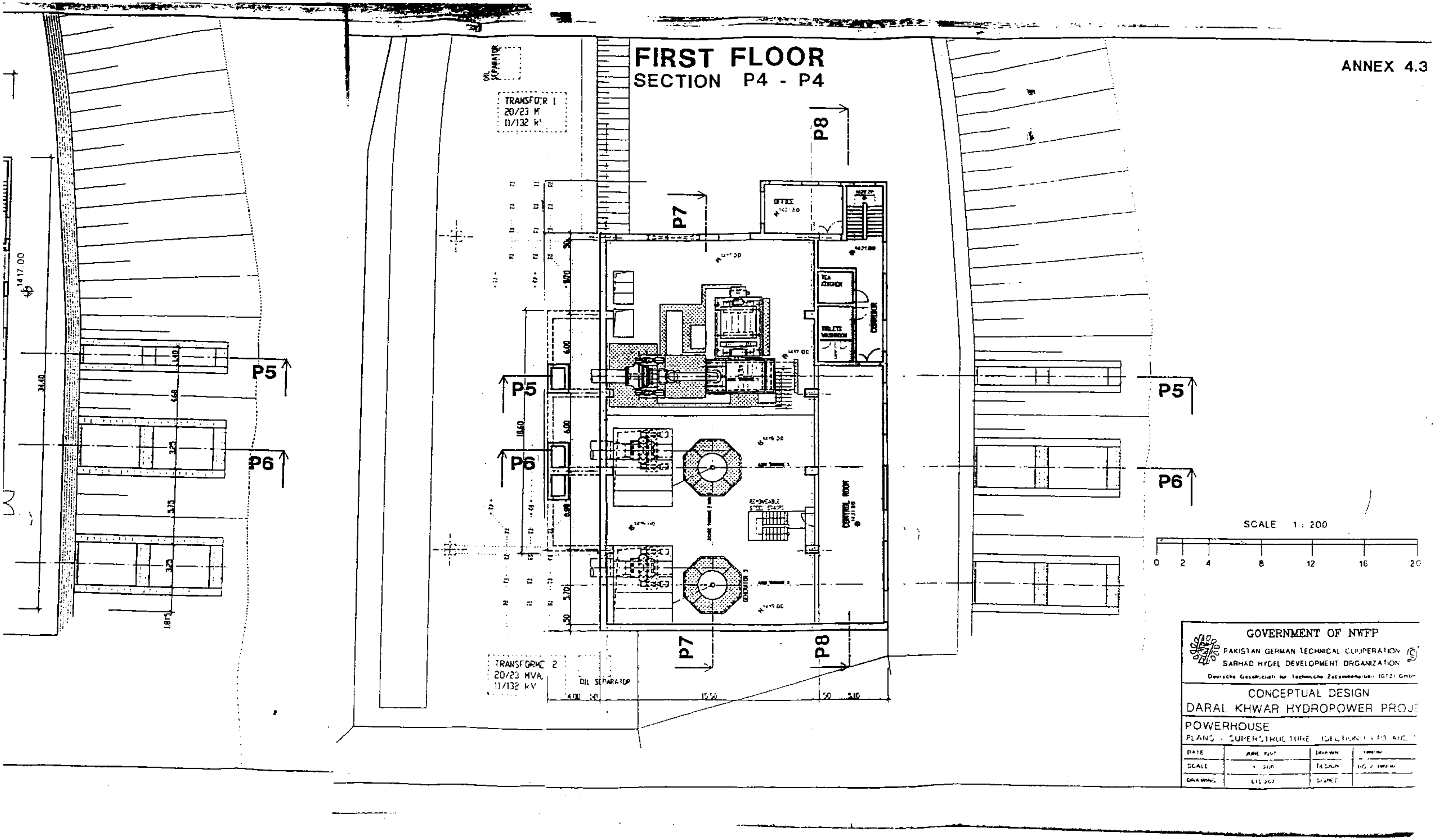
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJ
POWERHOUSE



FLOOR
P3 - P3
FIRST FLOOR
SECTION P4 - P4
ANNEX 4.
P5
P6
P7
P8
TRANSFORMER 1
TRANSFORMER 2
20/23 MVA
11/132 kV
OIL SEPARATOR
SCALE 1 : 200
0 2 4 8 12 16 20
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJE
POWERHOUSE
DATE
SCALE
DRAWING
DESIGN

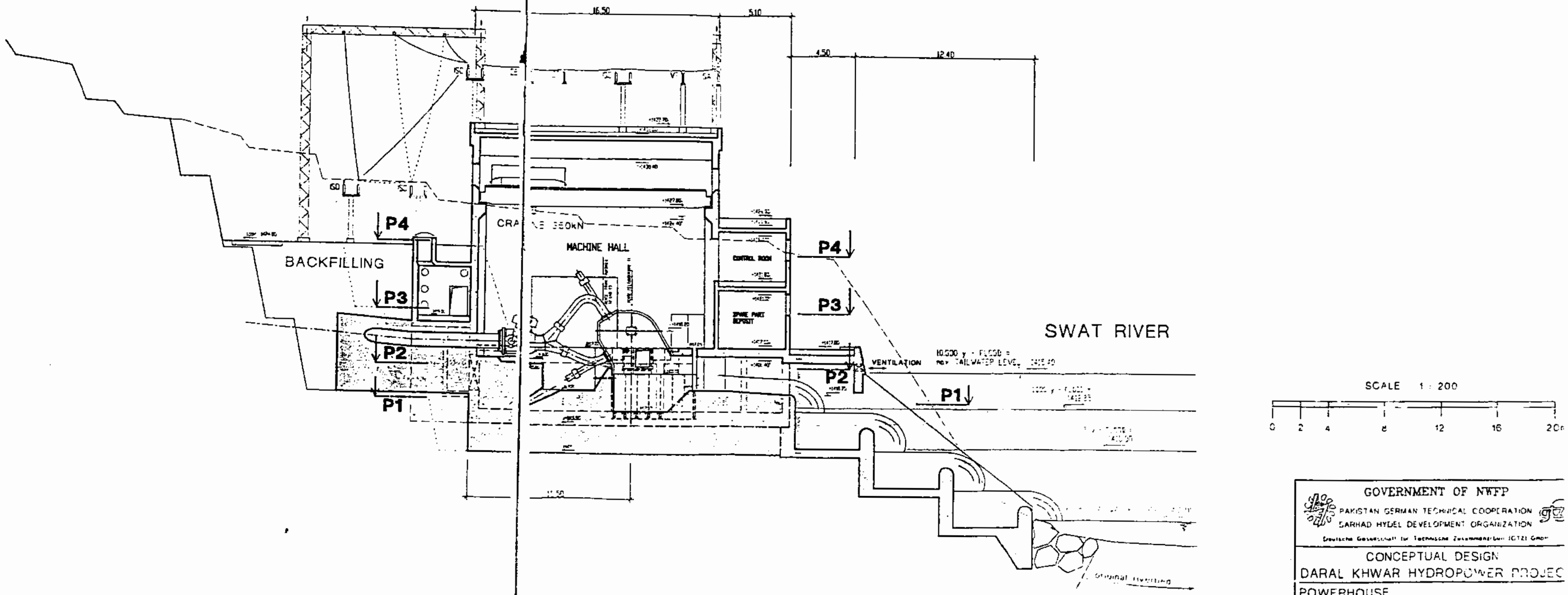

GROUND FLOOR
SECTION P3 - P3
TRANSFORMER 1
20/23 MVA
11/132 kV
TRANSFORMER 2
20/23 MVA
11/132 kV
OIL SEPARATOR
ASSEMBLY PLACE
11kV ROOM
WORKSHOP
SPARE PART DEPOSIT
LOW VOLTAGE - RELAYS
AUXILIARY TRANSFORMERS
ENTRANCE HALL
CONCRETE SLAB
GENERATOR 2
GENERATOR 3
1417.00
P5
P6
P7
P8
30.40
18.60
34.40
15.50
6.00
4.00
1.875
3.25
5.75
4.68
1.40

FIRST
SECTION
OIL SEPARATOR
P5
P6
P7
18.60
6.00
5.70

ANNEX 4.3


FIRST FLOOR
SECTION P4 - P4
TRANSFORMER 1
20/23 M
11/132 kV
OIL SEPARATOR
TRANSFORMER 2
20/23 MVA
11/132 kV
OIL SEPARATOR
OFFICE
TEA KITCHEN
TOILETS WASHROOM
CORRIDOR
CONTROL ROOM
REMOVABLE STEEL STAIRS
GENERATOR 2
P5
P6
P7
P8
SCALE 1 : 200
0 2 4 8 12 16 20
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJE
POWERHOUSE
DATE
SCALE
DRAWING
DRAWN
DESIGN
SIGNED

ANNEX 4.4

SECTION P5 - P5



GOVERNMENT OF NWFP

PAKISTAN GERMAN TECHNICAL COOPERATION

SARHAD HYDEL DEVELOPMENT ORGANIZATION

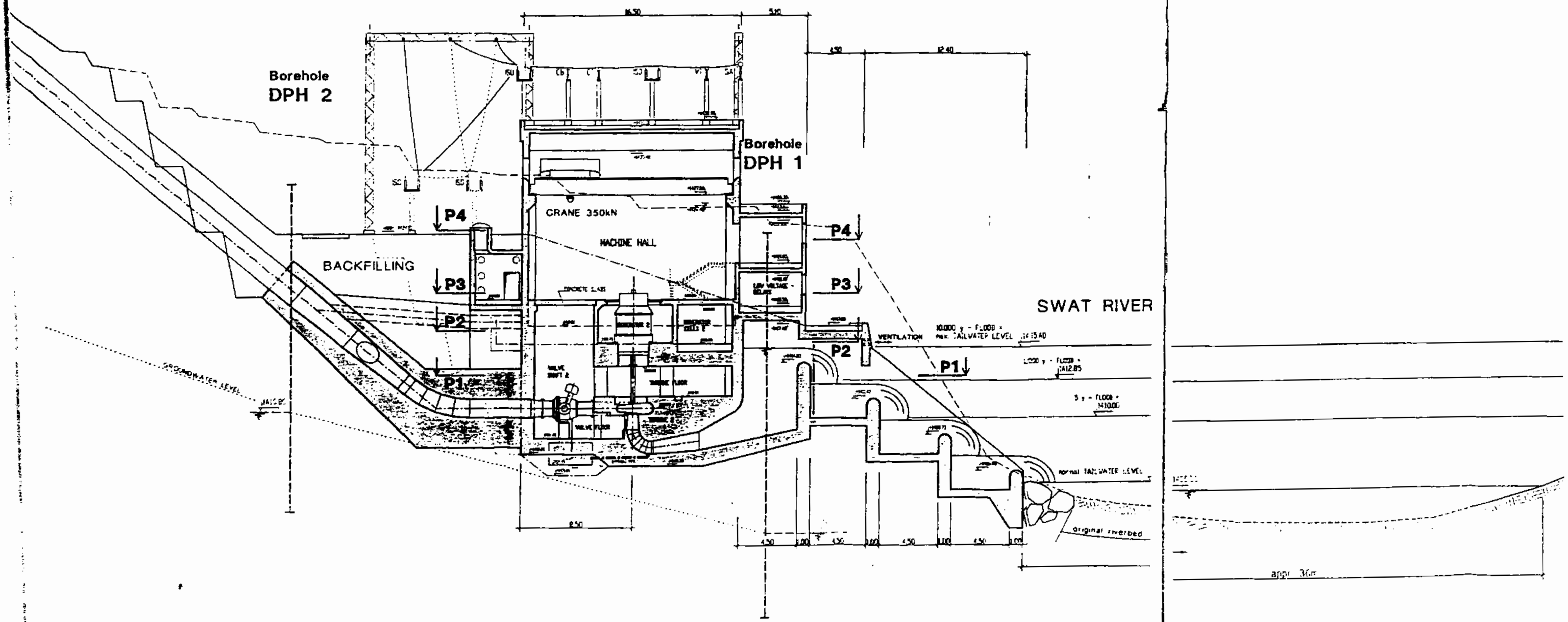
CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PROJEC

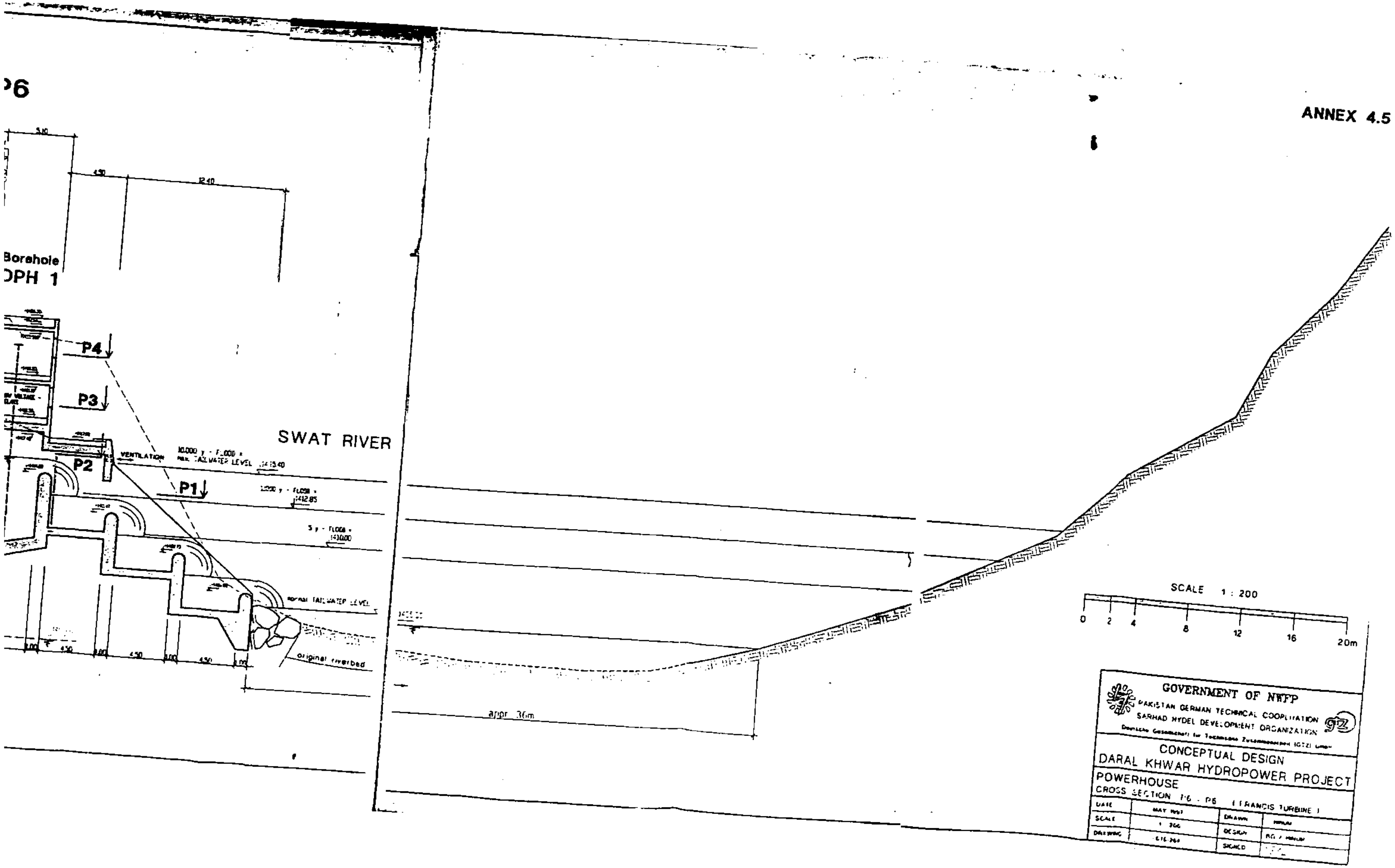
POWERHOUSE

DATE	[illegible]	DRAWN	[illegible]
SCALE	[illegible]	DESIGN	[illegible]
DRAWING	[illegible]	SIGNED	

SECTION P6 - P6

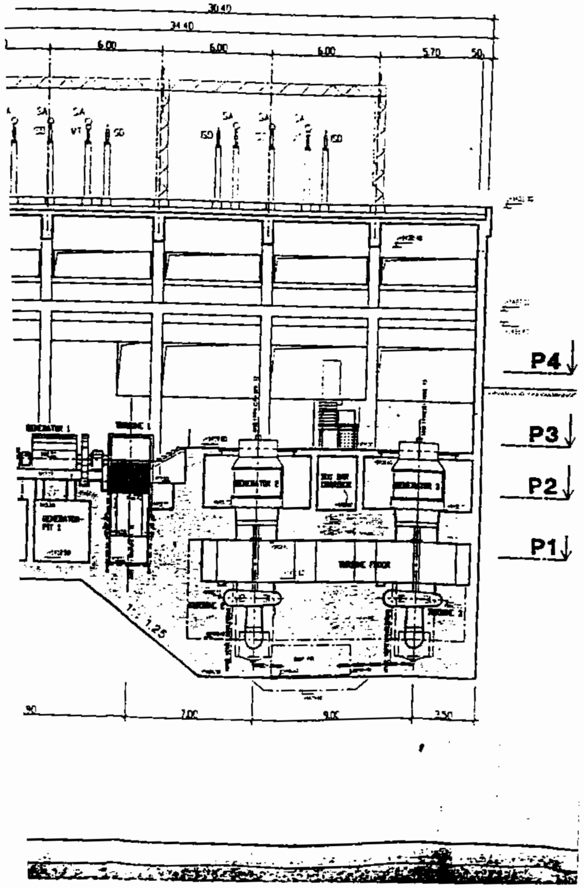


ANNEX 4.5

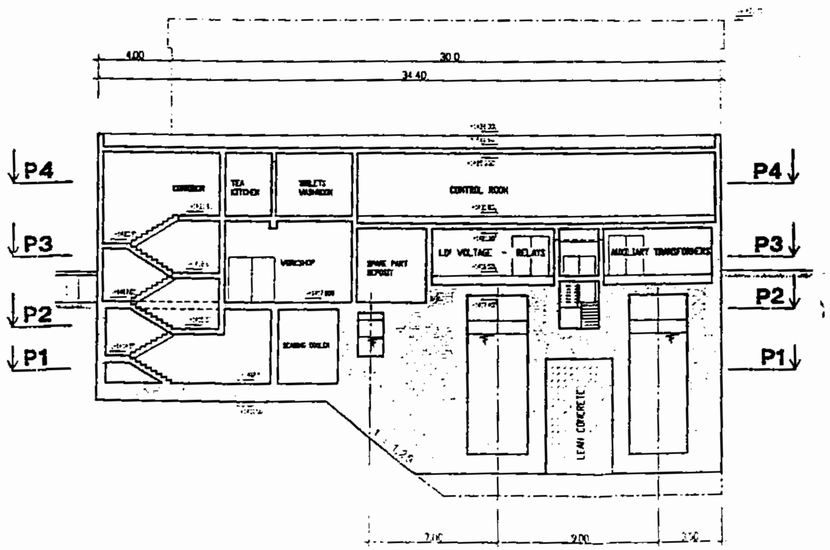

P6
Borehole
DPH 1
P4
P3
P2
P1
VENTILATION
SWAT RIVER
max. TAILWATER LEVEL
normal TAILWATER LEVEL
original riverbed
appr. 36m
SCALE 1 : 200
0
2
4
8
12
16
20m
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER PROJECT
POWERHOUSE
CROSS SECTION
FRANCIS TURBINE
DATE
SCALE
DRAWING
DRAWN
DESIGN
SIGNED

ANNEX
4·6

ΊTION P7 - P7



SECTION P8 - P8



SCALE 1 : 200

0 2 4 8 12 16 20m

GOVERNMENT OF NWFP

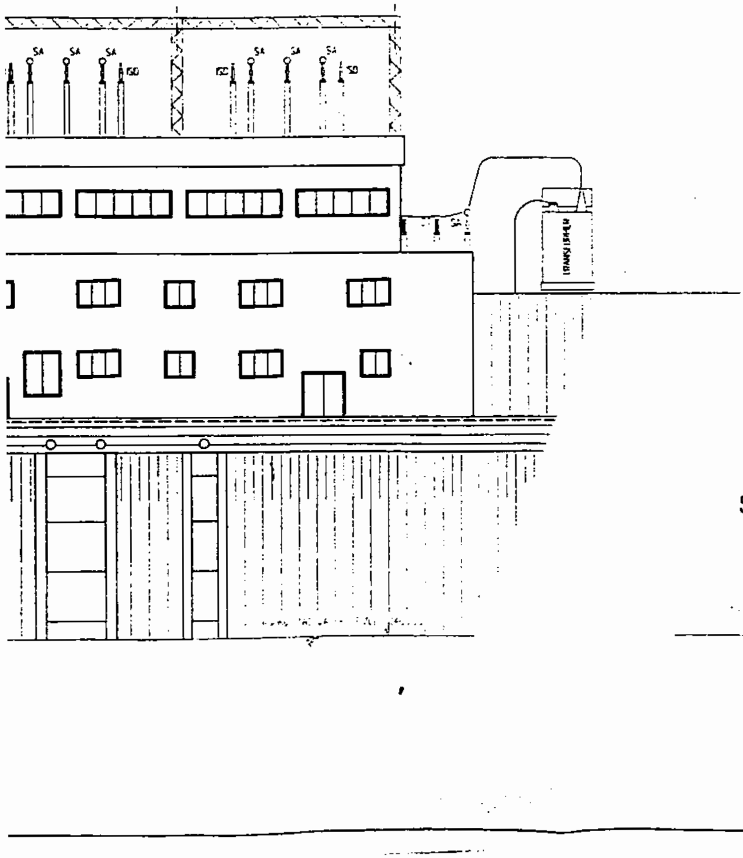
PAKISTAN GERMAN TECHNICAL COOPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION

CONCEPTUAL DESIGN

DARAL KHWAR HYDROPOWER PR

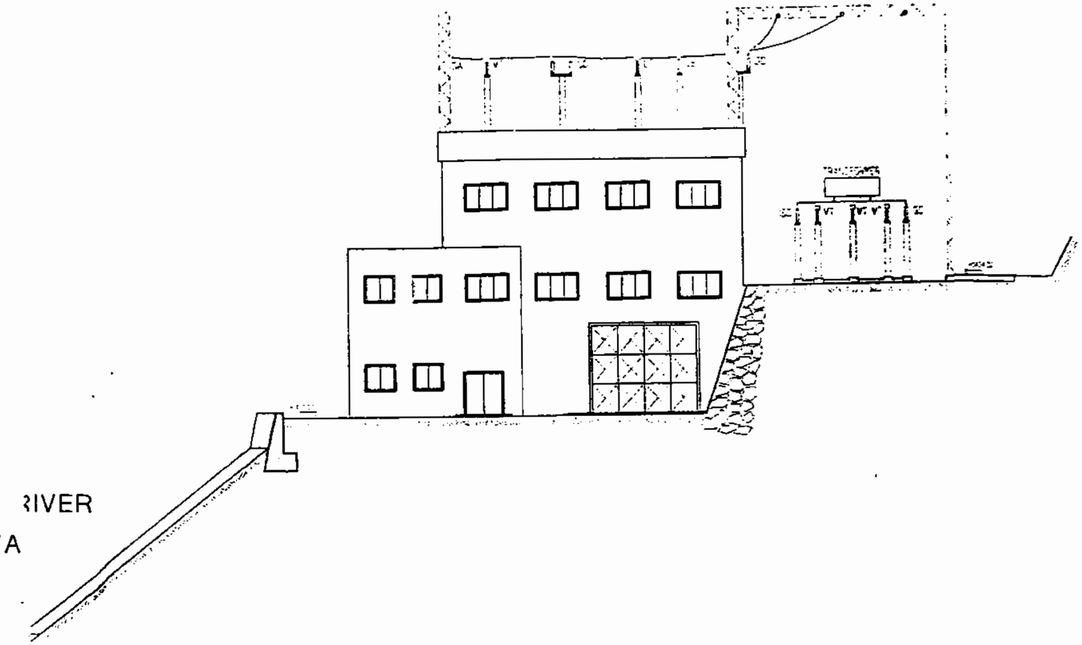
POWERHOUSE

FROM EASTSIDE



RIVER
SWA

VIEW FROM NORTHSIDE



SCALE 1 : 200

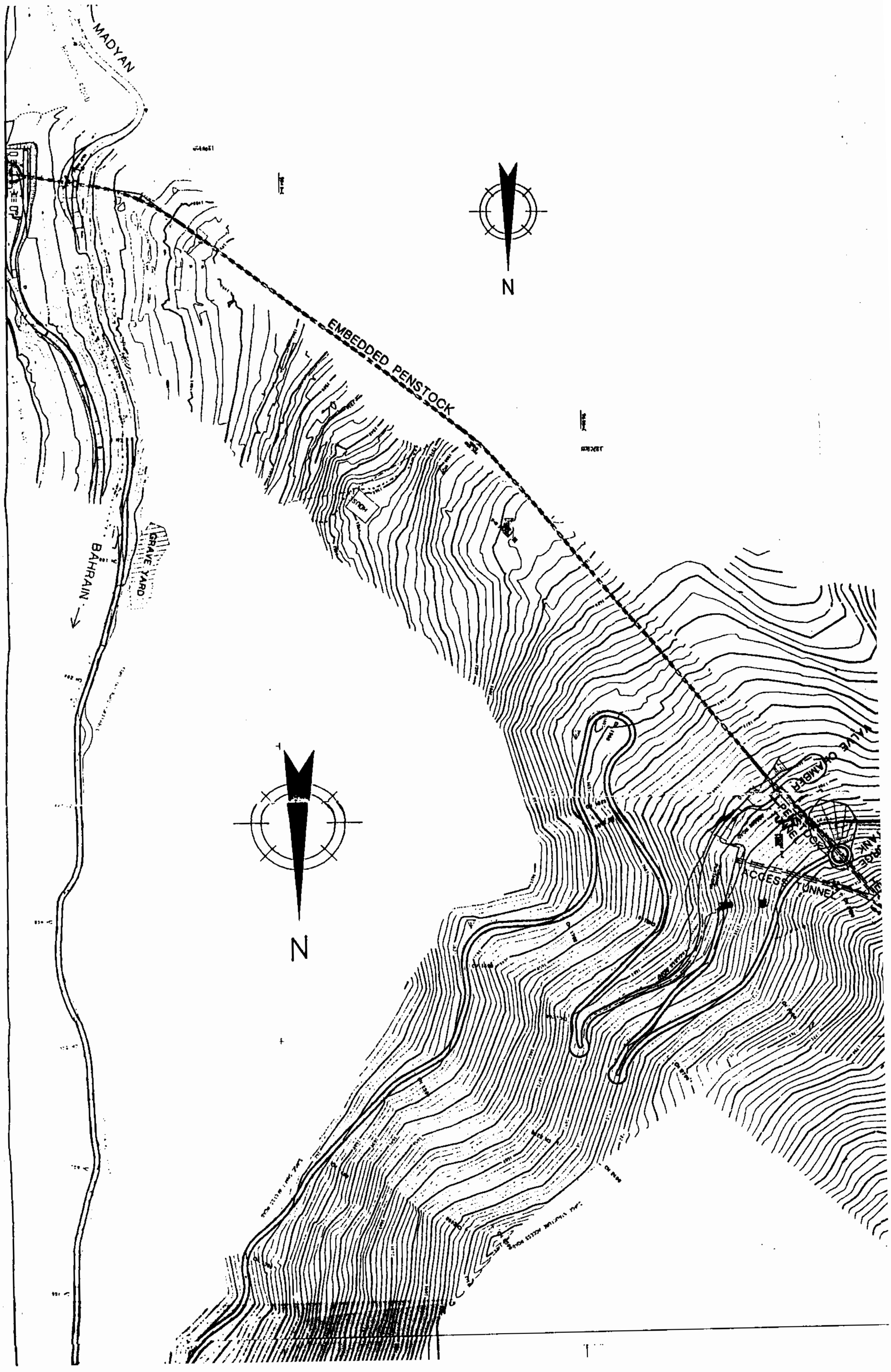
0 2 4 8 12 16

GOVERNMENT OF

PAKISTAN GERMAN TECHNICAL C
SARHAD HYDEL DEVELOPMENT OR

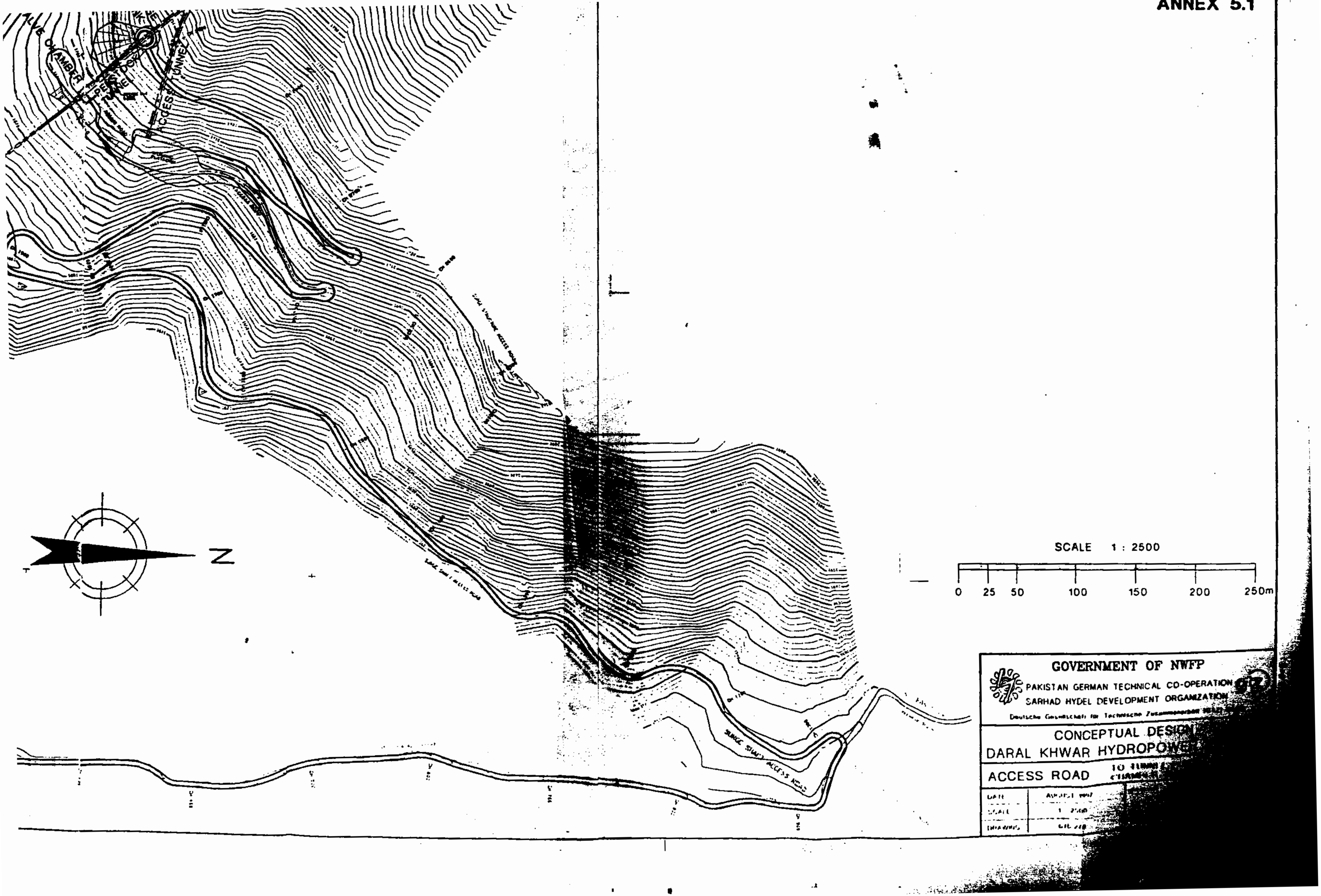
CONCEPTUAL DES
DARAL KHWAR HYDROPOV

POWERHOUSE



MADYAN
EMBEDDED PENSTOCK
N
N
HOUSE
GRAVE YARD
BAHRAIN
VALVE CHAMBER
ACCESS TUNNEL

ANNEX 5.1



CHAMBER
ACCESS TUNNEL
SURGE SHAFT ACCESS ROAD
N
SCALE 1 : 2500
0 25 50 100 150 200 250m
GOVERNMENT OF NWFP
PAKISTAN GERMAN TECHNICAL CO-OPERATION
SARHAD HYDEL DEVELOPMENT ORGANIZATION
CONCEPTUAL DESIGN
DARAL KHWAR HYDROPOWER
ACCESS ROAD