JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
WATER AND POWER DEVELOPMENT AUTHORITY (WAPDA)
ISLAMIC REPUBLIC OF PAKISTAN

FEASIBILITY STUDY ON THE DEVELOPMENT OF MUNDA DAM MULTIPURPOSE PROJECT IN ISLAMIC REPUBLIC OF PAKISTAN

FINAL REPORT

VOLUME I
MAIN REPORT

MARCH 2000

NIPPON KOEI CO., LTD.
NIPPON GIKEN INC.

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	HY	Hydrological Investigation

The cost estimate is based on the price level and exchange rate of September 1999. The exchange rate is:

US$1.00 = PRs.50.0

PREFACE

In response to a request from the Government of the Islamic Republic of Pakistan, the Government of Japan decided to conduct the Feasibility Study on the Development of Munda Dam Multipurpose Project in the Islamic Republic of Pakistan and entrusted the study to Japan International Cooperation Agency (JICA).

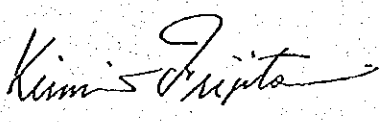
JICA sent a study team, led by Mr. Tetsu Nonaka of Nippon Koei Co., Ltd. and organized by Nippon Koei Co., Ltd. and Nippon Giken Inc. to the Islamic Republic of Pakistan six times from May 1998 to January 2000.

The team held discussions with the officials concerned of the Government of the Islamic Republic of Pakistan and conducted related field surveys. After returning to Japan, the team conducted further studies and compiled the final results in this report.

I hope this report will contribute to the promotion of the plan and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation throughout the study.

March 2000



Kimio Fujita
President
Japan International Cooperation Agency

March 2000

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

Letter of Transmittal

We are pleased to submit to you herewith the Final Report of Feasibility Study on the Development of Munda Dam Multipurpose Project in the Islamic Republic of Pakistan.

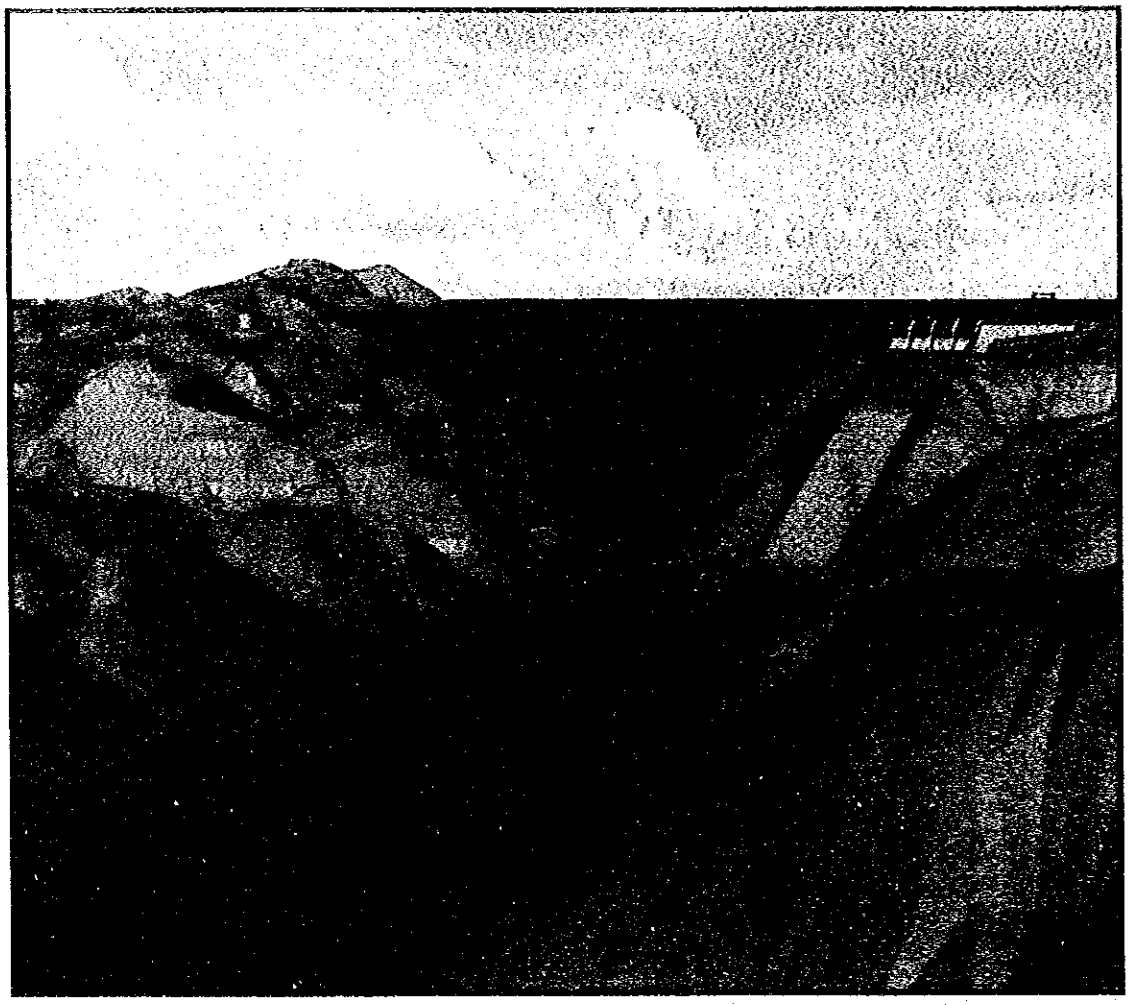
This Report deals with the formulation of the development plan for the Munda Dam Multipurpose Project which is planned to be built on the Swat River about 37 km north of Peshawar. In the Feasibility Study, it was proposed that by constructing 213 m high Munda multipurpose dam the Project generate 740 MW peak power, supply irrigation water to the new cultivable command area of 6,110 ha as well as the existing system, and store flood discharge of 100 million m^3 for mitigating the damages.

The Report consists of four (4) Volumes, Main Report, Executive Summary, Supporting Report, and Data Book. The Main Report covers all the investigation and study results including field investigation activities, sector studies, plan formulation, cost estimates, EIA and project evaluation. The Executive Summary presents main outputs of the Study. The Supporting Report gives additional and supporting information and data to the Main Report. The Data Book consists of geological and hydrological data.

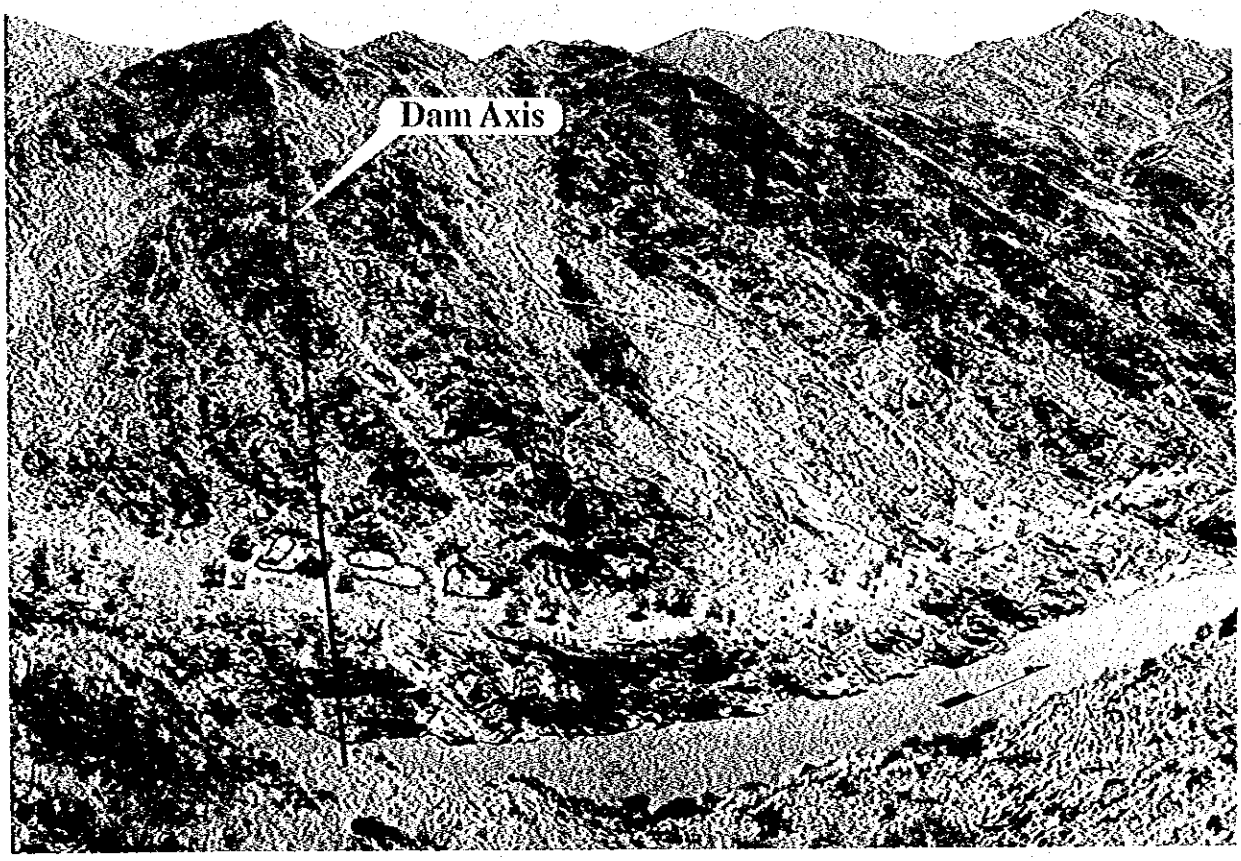
We would like to express our grateful acknowledgement to the personnel of your Agency, your Branch Office in Islamabad, and the Embassy of Japan in Islamabad, and also to officials and individuals of the Government of the Islamic Republic of Pakistan and the Government of NWFP for their assistance and advice extended to the Study Team. We sincerely hope that the results of this Study would contribute to the national and regional development of the country.

Yours sincerely,

Tetsu Nonaka
Team Leader
Feasibility Study on
the Development of
Munda Dam Multipurpose Project



Perspective of Munda Dam



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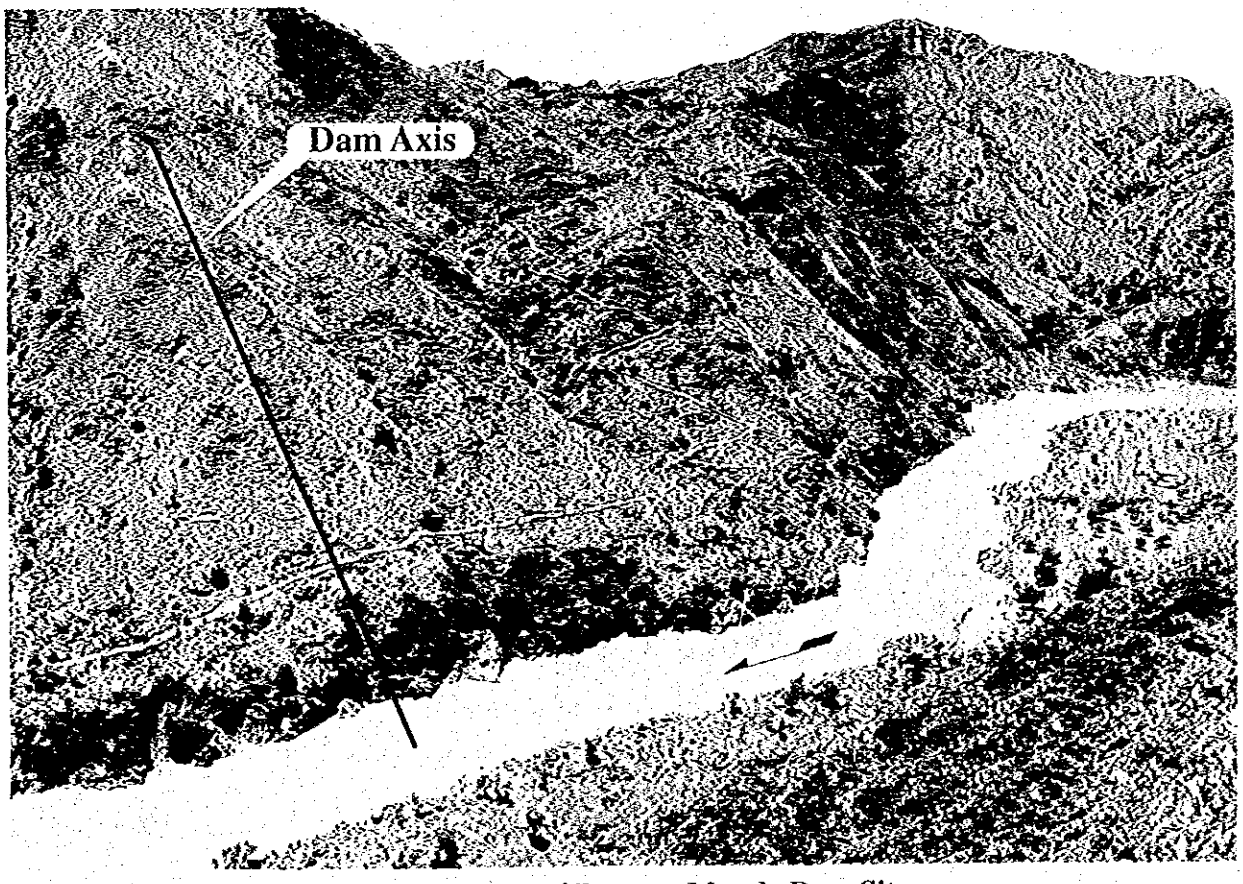

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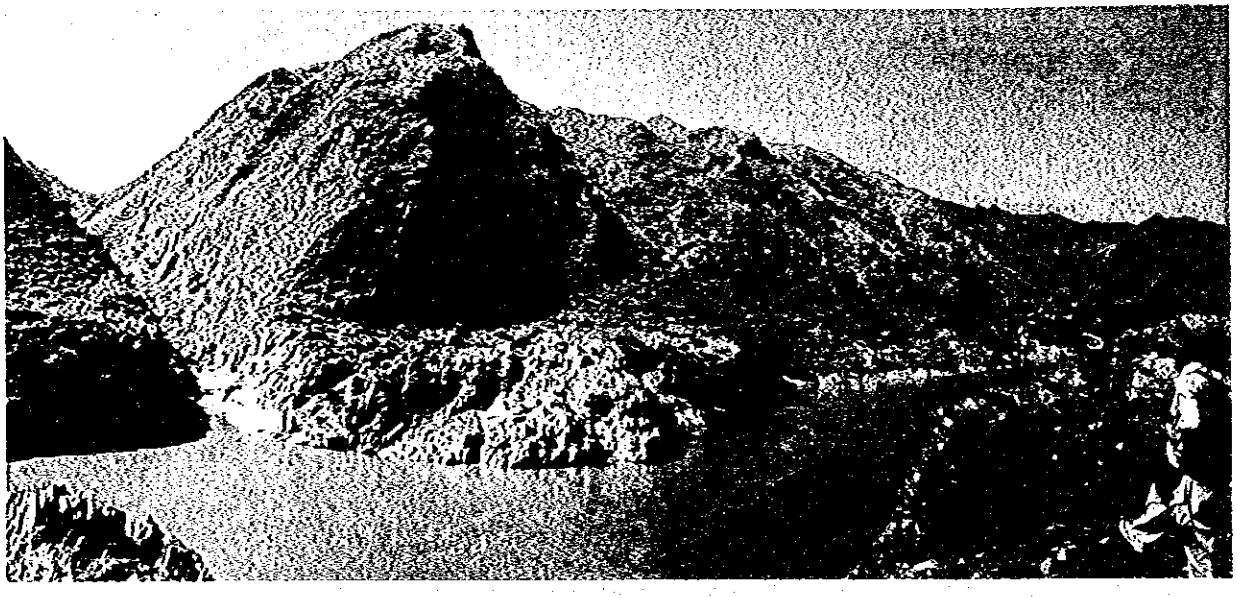
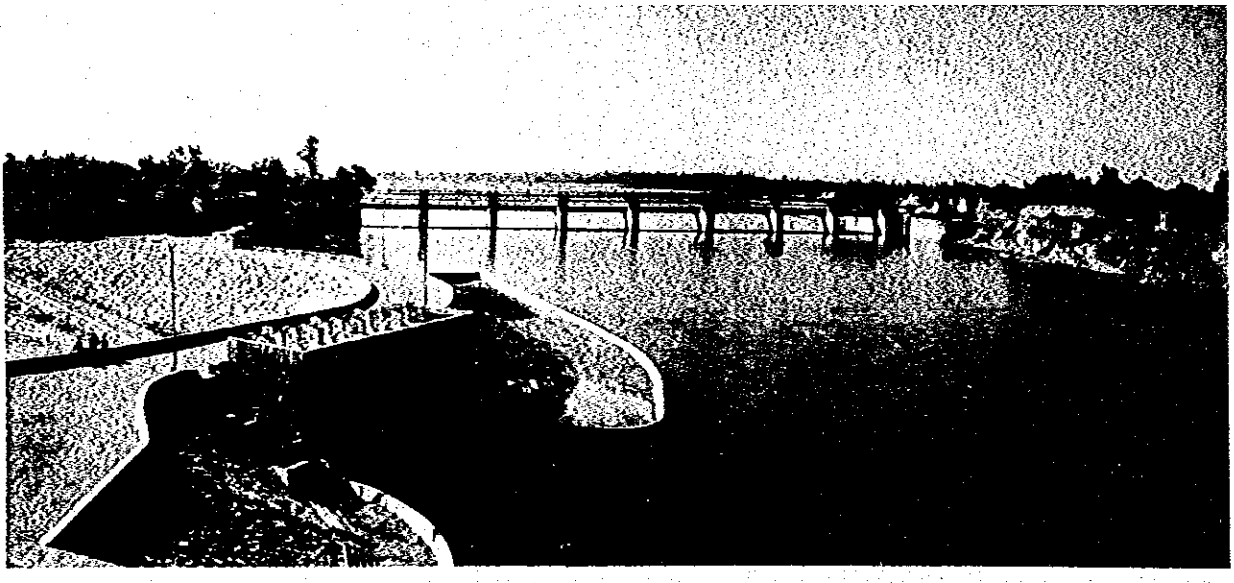
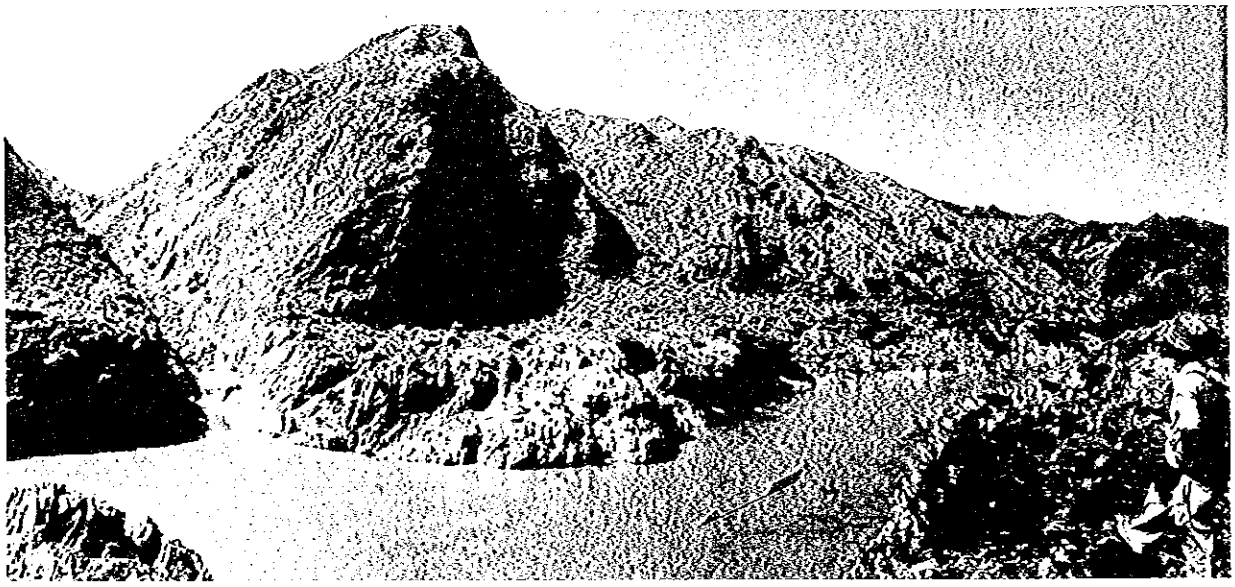


Proposed Powerhouse Site



Existing Munda Headworks



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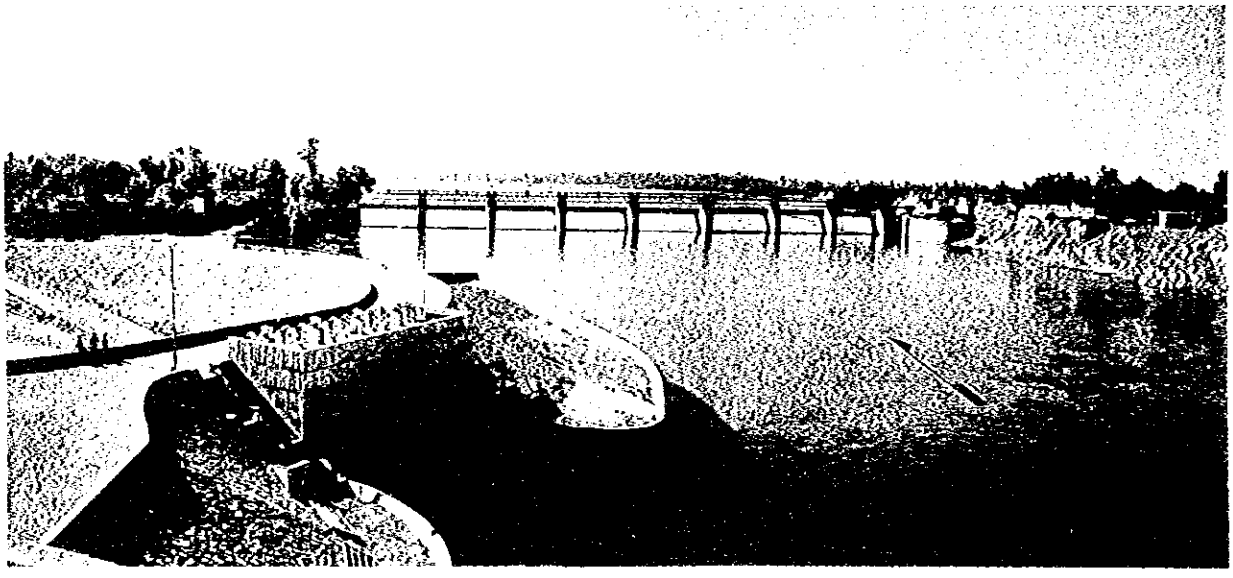

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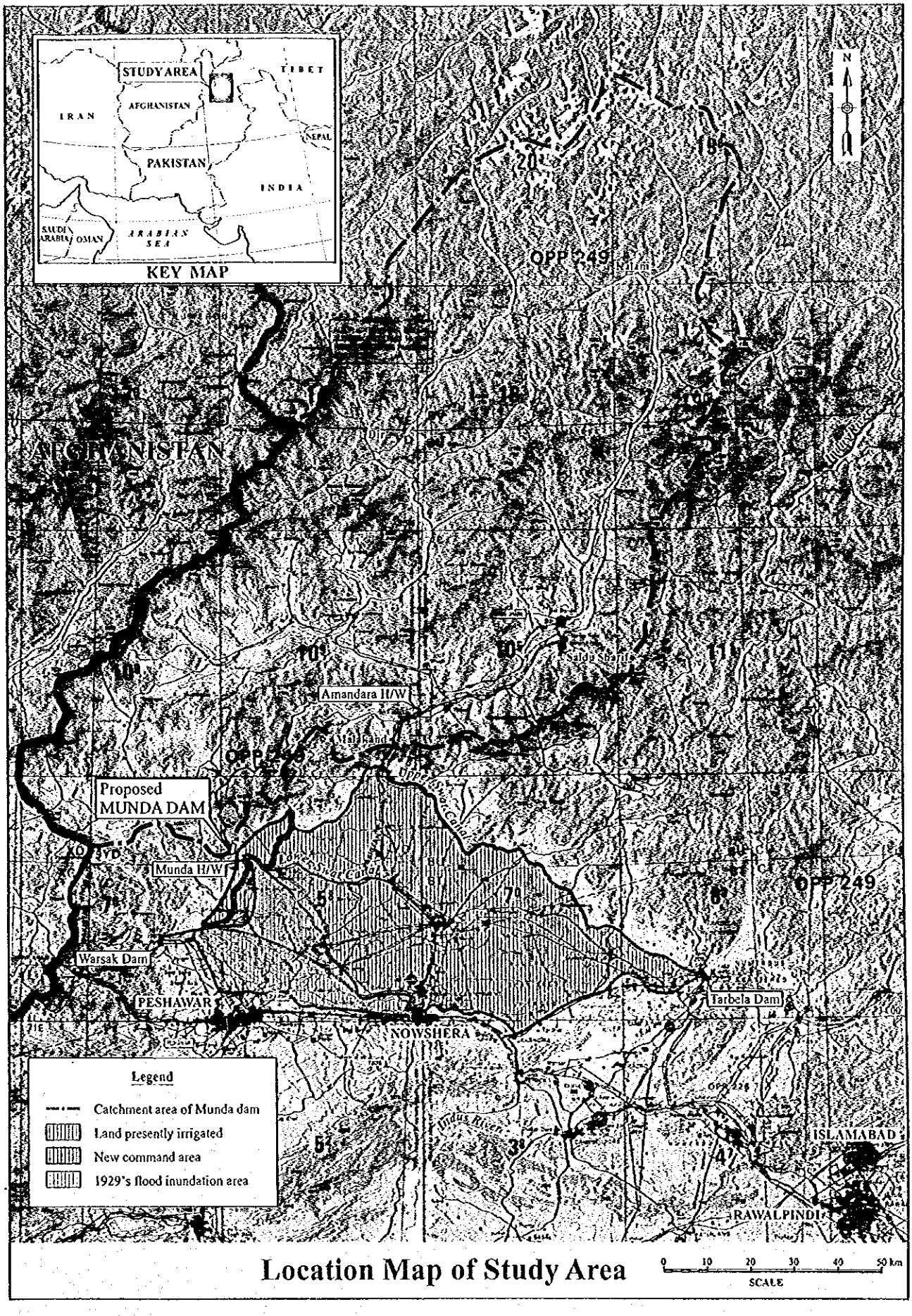
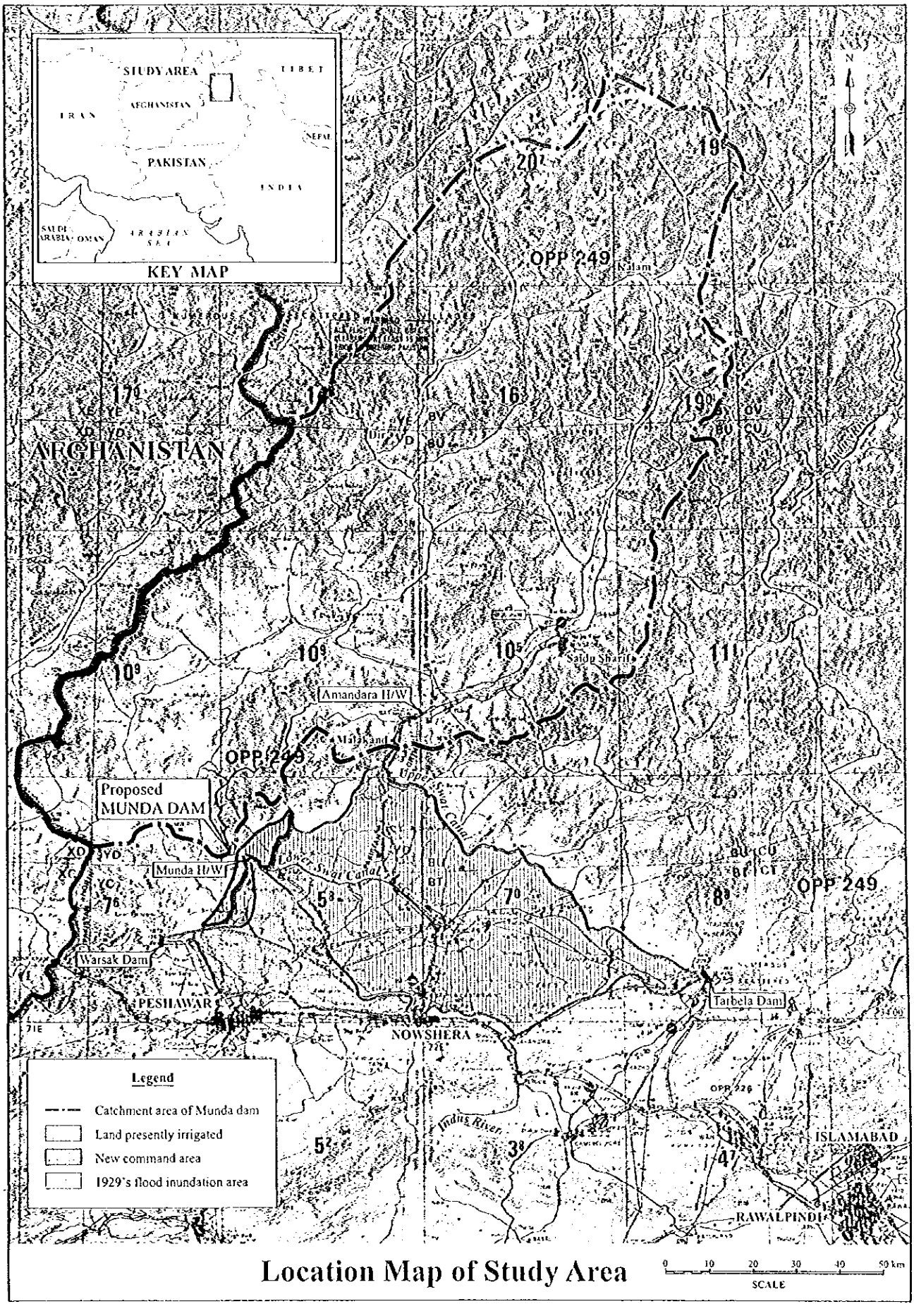


Location Map of Study Area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NOWSHERA
Tarbela Dam
Indus River
ISLAMABAD
RAWALPINDI
Legend
Catchment area of Munda dam
Land presently irrigated
New command area
1929's flood inundation area
Location Map of Study Area
0 10 20 30 40 50 km
SCALE

FEATURES OF MUNDA DAM MULTIPURPOSE PROJECT

1. Dam and Reservoir

1.1 Hydrology and Reservoir

• Catchment area	:	13,650 km^2
• Annual mean discharge	:	206 m^3/s
• Reservoir area	:	24.0 km^2
• Design flood water level (PMF)	:	EL.561.8 m
• Surcharge water level	:	EL.559.4 m
• Full supply level (FSL)	:	EL.555.0 m
• Minimum operation level (MOL)	:	EL.510.0 m
• Assumed sediment level	:	EL.474.0 m
• Gross storage volume	:	1,594 million m^3
• Effective storage volume	:	834 million m^3
• Flood control space above FSL	:	100 million m^3
• Dead storage volume	:	387 million m^3
• Sediment storage volume	:	373 million m^3

1.2 Munda Dam

• Type	:	Concrete Face Rockfill Dam (CFRD)
• Dam height	:	213 m
• Crest level	:	EL.563 m
• Plinth base level	:	EL.350 m
• Crest length	:	760 m
• Crest width	:	12 m
• Embankment slope	:	1:1.40 for upstream and 1:1.50 for downstream
• Total embankment volume	:	16.5 million m^3

1.3 Spillway

• Type	:	Gated spillway and non-gated weir
• Gated weir	:	Crest EL. 541.5 m, 74 m wide
• Non-gated weir	:	Crest EL.555.0 m, 80 m wide
• Design flood inflow for spillway (PMF)	:	19,390 m^3/s
• Design flood for chute way	:	3,800 m^3/s (1,000 year probable flood outflow)
• Design flood for plunge pool	:	1,900 m^3/s (100 year probable flood outflow)
• Spillway gate	:	Radial gate, 15.5 m wide x 18.4 m high x 4 nos.
• Chute way	:	EL.555.0 m – EL.400.0 m, 60 m wide
• Energy dissipation	:	Flip bucket type
• Plunge pool		Bottom EL.354.0 m, 60 m wide x 175 m long

1.4 River Diversion & River Outlet

• Main cofferdam	:	Integrated type, crest EL.410.0 m
• Design flood	:	3,630 m^3/s (25 year probable flood)
• Diversion tunnel (left)	:	12.0 m diameter x 940 m long

•	Diversion tunnel (right) / River outlet tunnel	:	12.0 m diameter x 950 m long
•	Intake of river outlet	:	Morning glory type at EL.480.0 m
•	River outlet shaft	:	4.5 m diameter x 100 m deep
•	Closure gate	:	6.0 m wide x 12.0 m high x 2 sets
•	River outlet gate	:	High-pressure slide gate, 3.0 m wide x 3.1 m high x 4 sets

2. Hydropower Generation Facilities

2.1 General

•	Installed capacity	:	740 MW
•	Maximum plant discharge	:	505.0 m^3/s
•	Tail water level at plant discharge	:	EL.369.0 m
•	Tail water level at one unit operation	:	EL.367.0 m
•	Tail water level at no flow	:	EL.364.0 m
•	Maximum gross head	:	186.0 m
•	Minimum gross head	:	141.0 m
•	Rated effective head	:	162.5 m

2.2 Power Waterway

•	Intake	:	8.0 m wide x 23.4 m high x 3 bays
•	Intake gate	:	6 m wide x 12.0 m high x 2 sets
•	Headrace tunnel	:	12.0 m diameter x 490 m long x 1 no.
•	Surge tank	:	Restricted orifice type, 15.0 m and 25.0 m diameter for shaft and tower, respectively, 70 m high in total
•	Penstock	:	7.4 m diameter, 540 m long, 2 lanes
•	Powerhouse	:	Open-air type, 110.0 m wide x 49.0 m long

2.3 Generating Equipment

•	Turbine	:	Vertical-shaft Francis type, 189 MW x 4, turbine speed 187.5 rpm
•	Generator	:	220 MVA x 4 units, 50 Hz, AC3-phase synchronous, semi-umbrella type
•	Main Transformer	:	220 MVA, 3 single-phase for outdoor
•	Switchyard	:	220 kV outdoor switchyard, 7 circuits
•	Overhead travelling crane	:	225 ton x 2 nos.

2.4 Transmission Line and Substation

•	Transmission line	:	220 kV x 30 km long
•	Substation	:	Receiving at New Shahibagh substation

3. New Irrigation Facilities

•	Gross command area (left bank)	:	4,540 ha
•	Gross command area (right bank)	:	2,310 ha
•	Gross command area (total)	:	6,850 ha
•	Cultivable command area (left bank)	:	4,070 ha
•	Cultivable command area (right bank)	:	2,040 ha
•	Cultivable command area (total)	:	6,110 ha
•	Maximum discharge (left bank)	:	4.4 m^3/s

- Maximum discharge (right bank) : 2.2 m^3/s
- Feeder system (left bank) : Non-pressure tunnel, 2.2 m diameter, 5.0 km long
- Feeder system (right bank) : Vertical shaft mixed flow pump, 18.88 m head
- Canal length (left bank) : 14.0 km (main) and 22.6 km (distributaries)
- Canal length (right bank) : 12.9 km (main) and 7.5 km (distributaries)

4. Construction Period

- Detailed design/tender : 3 years
- Construction period for diversion tunnels : 2 years
- Main construction period : 6.5 years
- Total construction period : 9 years

5. Project Cost

- Base cost : Foreign currency component: US$ 474 million
  Local currency component: US$ 414 million equivalent
  Total: US$ 888 million equivalent
- Total project cost including contingencies : Foreign currency component: US$ 612 million
  Local currency component: US$ 537 million equivalent
  Total: US$ 1,149 million equivalent

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ON
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FINAL REPORT
VOLUME I
MAIN REPORT

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Abbreviations

Abbreviations	Meanings
ADA	Agricultural Development Authority
ADB	Asian Development Bank
AEB	Area Electricity Boards
AJ&K	Azad Jam and Kashmir
AUP	Agriculture University Peshawar
BOO	Build, Own, and Operate
BOOT	Build, Own, Operate, and Transfer
CA	Command Area/ Catchment Area
CAD	Command Area Development
CCA	Cultivable Command Area
(GCA)	Gross Command Area
(GIA)	Gross Irrigable Area
CFRD	Concrete Face Rockfill Dam
CMTL	Central Material Testing Laboratory
C&W	Communication and Works Department
DSM	Demand Side Management
EAD	Economic Affairs Division
ECNEC	Executive Committee of National Economic Council
ECRD	Earth Core Rockfill Dam
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FAS	Fuel Adjustment Surcharge
FATA	Federally Administrative Tribal Area
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
GDP	Gross Domestic Product
GIS	Geographic Information System
GOJ	Government of Japan
GOP	Government of Pakistan
GTZ	Deutsche Gesellschaft für Techniche Zusammenarbeit
HEPO	Hydro Electric Planning Organization
IBRD	International Bank for Reconstruction and Development
ID	Irrigation Department
IEE	Initial Environmental Examination
IFIC	Institution for International Cooperation
IPP	Independent Power Producer
IRSA	Indus River System Authority
ISRIP	International Sedimentation Research Institute of Pakistan
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
KESC	Karachi Electricity Supply Corporation
LOS	Letter of Support
LSC	Lower Swat Canal
MAF	Million Acre Feet
MBT	Main Boundary Thrust
MCE	Maximum Credible Earthquake
M/M	Minutes of the Meeting
MMT	Main Mantle Thrust
M/P	Master Plan
msp	million short ton

Abbreviations	Meanings
MWP	Ministry of Water and Power
NDP	National Drainage Program
NEPRA	National Electric Power Regulatory Authority
NGO	Non-Governmental Organization
NPCC	National Power Control Center
NPP	National Power Plan
NWFP	North-West Frontier Province
O&M	Operation and Maintenance
OECD	Organization for Economic Cooperation and Development
OECF	Overseas Economic Corporation Fund
PARC	Pakistan Agricultural Research Council
PASSCO	Pakistan Agricultural Storage and Services Corporation
PD	Project Description
PE&D	Planning Environment and Development Department
PEPCO	Pakistan Electric Power Company
PHED	Public Health Engineering Department
PHLC	Pehur High Level Canal
PMF	Probable Maximum Flood
PMS	Pakistan Meteorological Service
PPC	Private Power Cell
PPIB	Private Power and Infrastructure Board
PLC	Power Line Carrier
Q/N	Questionnaire
RCC	Roller Compacted Concrete, Regional Control Center
SCADA	Supervisory Control And Data Acquisition
SCARP	Salinity Control and Reclamation Project
SCF	Standard Conversion Factor
SDA	Sarhad Development Authority
SHYDO	Sarhad Hydel Development Organization
SIDB	Small Industries Development Board
S/W	Scope of Work
SWHP	Surface Water Hydrology Project
SWR	Shadow Wage Rate
UNEP	United Nations Environment Program
USC	Upper Swat Canal
UTM	Universal Terrain Model
WAPDA	Water and Power Development Authority
WASP	Wien Automatic System Planning Package
WB	World Bank
WEC	WAPDA Environmental Cell
WMO	World Meteorological Organization
WPPO	WAPDA Power Privatization Organization

Conversion Factors

Length (1)

m	cm	yard	ft	inch
1	100	1.09361	3.28084	39.370
0.01	1	0.010936	0.032803	0.39370
0.91440	91.4400	1	3	36
0.30480	30.480	0.33333	1	12
0.02540	2.54000	0.02778	0.08333	1

Length (2)

km	nautical mile (nm)	yard	mile
1	0.5400	1093.61	0.62137
1.852	1	2026.67	1.1515
0.000914	–	1	–
1.60934	0.869	1760	1

Area (1)

m^2	cm^2	ft^2	in^2
1	10000	10.764	1550
0.09290	929.0	1	144.0
0.0001	1	0.001076	0.1550
0.0006452	6.4516	0.006944	1

Area (2)

ha	km^2	acre	$mile^2$
1	0.0100	2.471	0.00386
100	1	247.10	0.3861
0.4047	0.004047	1	0.001563
259	2.590	640	1

Volume

in^3	U.S. gallon	Imperial gallon	ft^3	m^3	acre-ft
1	0.00433	0.00361	5.79×10^{-4}	1.64×10^{-5}	1.33×10^{-8}
231	1	0.833	0.134	0.00379	3.07×10^{-6}
277	1.20	1	0.161	0.00455	3.68×10^{-6}
1728	7.48	6.23	1	0.0283	2.30×10^{-5}
61,000	264	220	35.3	1	8.11×10^{-4}
7.53×10^7	3.26×10^5	2.71×10^5	43,560	1230	1

Discharge

U.S. gallon /day (gpd)	ft^3/day	U.S. gal/min	Imperial gpm	acre-ft/day	ft^3/sec (cfs)	m^3/sec
1	0.134	6.94×10^{-4}	5.78×10^{-4}	3.07×10^{-6}	1.55×10^{-6}	4.38×10^{-8}
7.48	1	5.19×10^{-3}	4.33×10^{-3}	2.30×10^{-5}	1.16×10^{-5}	3.28×10^{-7}
1440	193	1	0.833	4.42×10^{-3}	2.23×10^{-3}	6.31×10^{-5}
1728	231	1.20	1	5.31×10^{-3}	2.67×10^{-3}	7.57×10^{-5}
3.26×10^5	43,560	226	188	1	0.504	0.0143
6.46×10^5	86,400	449	374	1.98	1	0.0283
2.28×10^7	3.05×10^6	15,800	13,200	70.0	35.3	1

Weight

kg	t	oz	lb	short ton	long ton
1	0.001	35.27	2.204 6	0.00110	9.8420×10^{-4}
1000	1	3.527×10^{4}	2204.6	1.1023	0.984
0.02835	2.835×10^{-5}	1	0.06250	3.125×10^{-5}	2.790×10^{-5}
0.4536	4.536×10^{-3}	16	1	0.0005	4.464×10^{-4}
907.2	0.9072	32.000×10^{3}	2.000×10^{3}	1	0.8529
1016	1.016	3.584×10^{4}	2.240×10^{3}	1.12	1

Velocity

m/sec	km/hr	ft/sec	mile/hr	Kn
1	3.600	3.2808	2.237	1.9438
0.2778	1	0.9113	0.6214	0.5400
0.3048	1.0973	1	0.6818	0.5925
0.4470	1.6093	1.4667	1	0.8690
0.5144	1.8520	1.6878	1.1508	1

Density (c.g.s.Unit)

gr/cc	kg/m^3=(gr/l)	gr/m^3	lb/ft^3	oz/ft^3
1	1×10^{3}	1×10^{6}	62.43	998.8
0.001	1	1×10^{3}	0.06243	0.9988
1×10^{-6}	1×10^{-3}	1	6.243×10^{-5}	9.988×10^{-4}
0.016018	16.018	1.6018×10^{4}	1	16
0.0010012	1.0012	1.0012×10^{3}	0.0625	1

Pressure

M Pa =(N/mm^2)	Pa =(N/m^2)	bar	kgf/cm^2	atm	mmH_2O	mmHg
1	1×10^{6}	10	10.197	9.869 2	1.0197×10^{5}	7500.617
1×10^{-6}	1	1×10^{-5}	1.0197×10^{-5}	9.8692×10^{-6}	0.101 971 6	7.5006×10^{-3}
0.1	1×10^{5}	1	1.019 716	0.986 923 3	1.0197×10^{4}	750.0617
0.098 0665	98 066.5	0.980 665	1	0.967 841 1	1×10^{4}	735.559 3
0.101325	101 325	1.01325	1.03323	1	1.0332×10^{4}	760
9.8067×10^{-6}	9.806 65	9.806×10^{-5}	1×10^{-4}	9.6784×10^{-5}	1	7.3555×10^{-2}
1.3332×10^{-4}	133.322 4	1.3332×10^{-3}	1.3595×10^{-3}	1.3158×10^{-3}	13.595 10	1

CHAPTER 1 INTRODUCTION

1.1 Background of Study

Pakistan has an area of about 800,000 km^2 and a population of approximately 130,000,000. Half of the total labor population is engaged in agriculture. From 1985 to 1998, the economy grew annually by about 5.5% on average, except from 1996 to 1997 when the economic growth lowered to about 3%. Gross Domestic Product (GDP) per capita in 1997 was US $ 490.

Total installed capacity of electric power plants as of January 1, 1996 was 12,800 MW. It is forecasted that if the same economic growth rate as experienced in the past is maintained, the power demand will increase to 18,000 MW in 2003, 25,700 MW in 2008, 34,800 MW in 2013, and 46,700 MW in 2018. Power supply is predicted to cover such demand growth until 2002 or 2003 by implementing Chashma hydropower project (184 MW), Ghazi Barotha hydropower project (1,450 MW), and other thermal power plants developed by the private sector. However, the power demand is foreseen to grow at a rate of about 7% per annum. Therefore, it is necessary for Pakistan to continue providing a stable power supply that meets this demand.

On the other hand, socioeconomic development of the regional society of the Swat River Basin, located in the northwestern part of North-West Frontier Province, the objective area of the Study, depends upon optimum development and management of water resources available in the region due to its dry nature.

Thus, a development scheme of hydropower, flood control and water supply for agricultural development and the others within the basin, by constructing a multipurpose dam at the Munda area where the Swat River flows out from the mountain to the alluvial plain in Charsadda is expected to be implemented.

The Water and Power Development Authority (WAPDA) initiated a preliminary geological investigation at the dam site in 1963. In its 1969 report, it proposed that a 210 m high rockfill dam be constructed creating a reservoir with a gross storage capacity of 2.4 billion m^3, with a gated spillway having a design capacity of 15,100 m^3/sec and a surface power plant with installed capacity of 400 MW.

Since then, a local consulting firm entrusted by WAPDA conducted a Pre-Feasibility Study on the Munda Multipurpose Dam Project and issued its report in November 1992. According to their report, the Munda Multipurpose Dam Project is to be located 4.8 km upstream of the existing Munda Headworks and will generate hydropower (600 MW), irrigate land of some 12,000 ha, and

provide flood control during the rainy season, by creation of a reservoir with a gross storage volume of 623 million m^3 by a 180 m high rockfill dam. The construction cost would be approximately 120 to 150 billion Japanese Yen, equivalent to the amount expected to be financed, besides its own funds, through international monetary agencies such as the World Bank.

In July 1995, the Government of Pakistan made an official request to the Government of Japan to conduct a Feasibility Study of the project in respect to the supplemental field investigation, environmental impact assessment, detailed design of the structures, financial analysis and reservoir operation including review of the Pre-Feasibility Study.

In response to the request, the Government of Japan dispatched a project formulation mission in March 1996 and confirmed the contents of the request. Furthermore, in September 1996, the Government of Japan sent a preliminary mission, for discussing about and concluding the scope of the study with the Government of Pakistan except for the detailed design of the structures.

The two parties reached an agreement as to the contents and scope of the Study but because of a political issue as to the future cost to be shared between the Federal Government and the Provincial Government of the North-West Frontier, the Pakistan side reserved signing of the agreement.

Through the change of administration of the Federal Government of Pakistan and resolution of the issue at the side of Pakistan, this agreement was concluded on March 5, 1997 and became effective in September 1997 after inter-governmental approval procedures in Pakistan, thereby enabling the initiation of the Study.

1.2 Purpose of Study

The main objectives of the Feasibility Study are to formulate an optimum development program of the Munda Multipurpose Dam Project considering comprehensive effective water usage including hydropower, flood control, and irrigation, mainly through the review of the existing Pre-Feasibility Study and supplemental field investigation, then to assess feasibility of the Project and prepare a report acceptable to the international monetary agencies, by forecasting the possible arrangement of funds required for implementing the project. One of the main objectives is also to transfer technology and train the counterpart personnel of the Pakistan side through and during the course of the Study.

The Study area covers the Munda and its surrounding area in the Swat River basin located in the North-West Frontier Province as shown in the Location Map of the Project Area.

1.3 The Study Procedure and Schedule

The Study was conducted in three stages, namely, Preliminary Investigation Stage, Detailed Investigation Stage, and Basic Design Stage, with phases of home preparatory work, six field investigations and three home works during the period of 24 months from mid-March 1998 to mid-March 2000. The overall work schedule is summarized below.

Study Stages and Reports

Study Stage	Work Period	Report Submitted
Home preparatory work	March 1998	Inception report
First field investigation	May – June 1998	
First home work	July – August 1998	
Second field investigation	September – December 1998	Progress report 1
Third field investigation	January – March 1999	
Fourth field investigation	May – July 1999	Progress report 2
Second home work	July – September 1999	
Fifth field investigation	October 1999	Interim report
Third home work	November – December 1999	
Sixth field investigation	January 2000	Draft final report Final report

1.4 Structure of Final Report

This Final Report presents the results of all the investigations and studies carried out by the Study Team from March 1998 to February 2000 comprising the following four volumes:

Volume I : Main Report
Volume II : Executive Summary
Volume III : Supporting Report
Volume IV : Data Book

Volume I deals with full details of the study results covering from the project history and baseline conditions to feasibility design and project evaluation, being supplemented by Volume III as well as Volume IV. Chapter 1 presents background, purpose and outline of the Feasibility Study. Chapter 2 shows general status of national and regional socioeconomic conditions. Chapter 3 describes natural conditions of the study area such as topography, geology and hydrology. Chapter 4, 5 and 6 state results of surveys and studies in the fields

of the power development, water supply and flood control, respectively. Chapter 7 explains the plan formulation executed for the multipurpose dam. Chapter 8 gives the result of the feasibility design for the civil structures, electrical equipment and irrigation facilities. Chapter 9 discusses construction plan and cost estimate of the project. Chapter 10 proposes some ideas on operation systems of the Munda Dam. Chapter 11 gives the results of the environmental assessment and management plans. Chapter 12 details economic and financial analyses. Chapter 13 recommends investigations and surveys required for the detailed design stage of the Munda Project.

1.5 Acknowledgement

For implementing the Study, the Study Team has appreciatively been supported by the WAPDA personnel and officials of the Government of NWFP with a lot of helpful assistance and advice. The Study Team wishes to express grateful acknowledgement to all the concerned personnel from WAPDA and the Government of NWFP. Besides, the Study Team received a lot of cooperation in the fields of data collection and information presentation through the public entities and agencies in the Government of Pakistan, technical cooperation agencies of donor countries and international organizations. The Study Team sincerely expresses many thanks to the officials and individuals of these groups.