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 II
EXECUTIVE SUMMARY

MARCH 2000

NIPPON KOEI CO., LTD.
NIPPON GIKEN INC.

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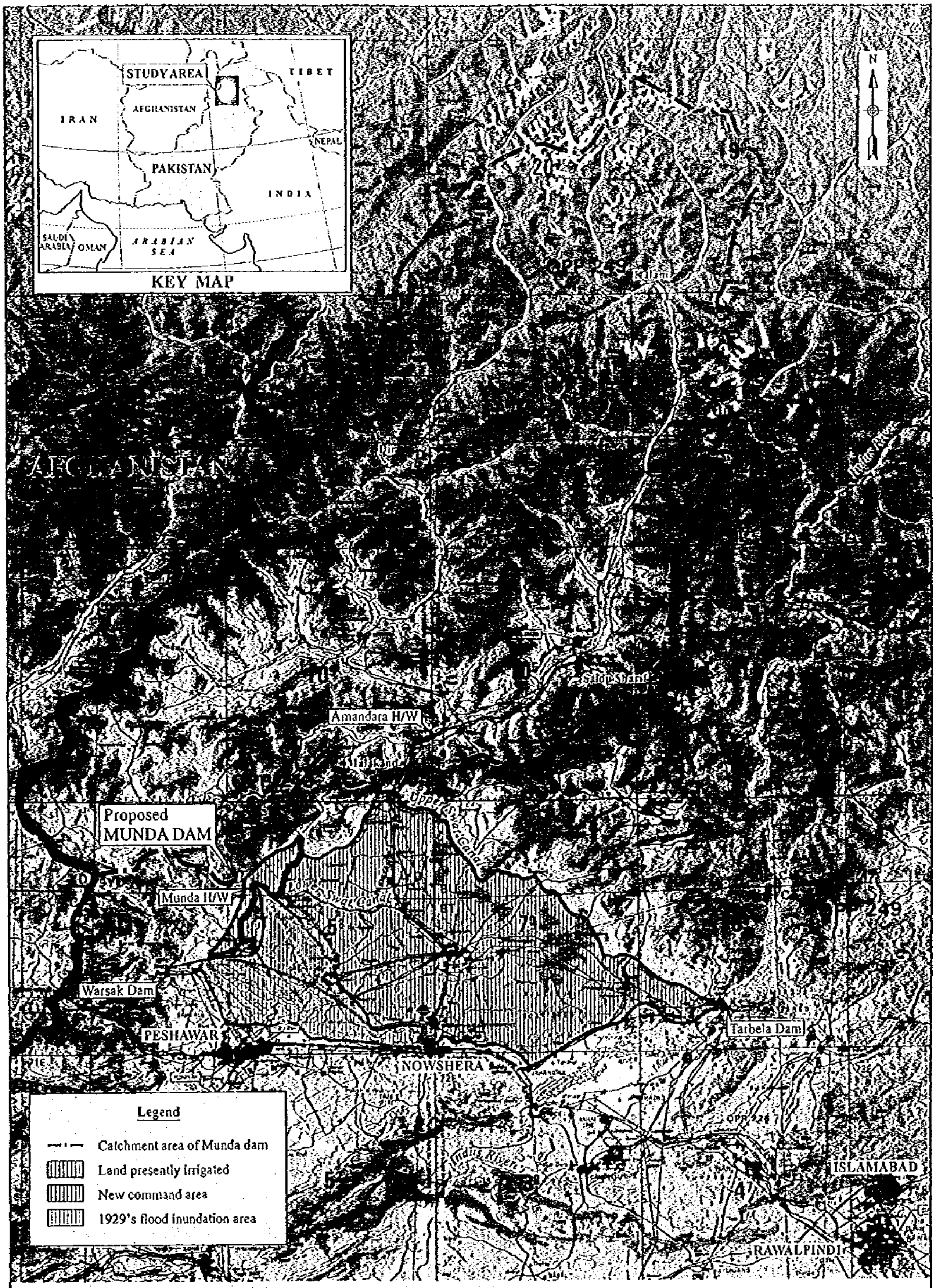
LIST OF VOLUMES

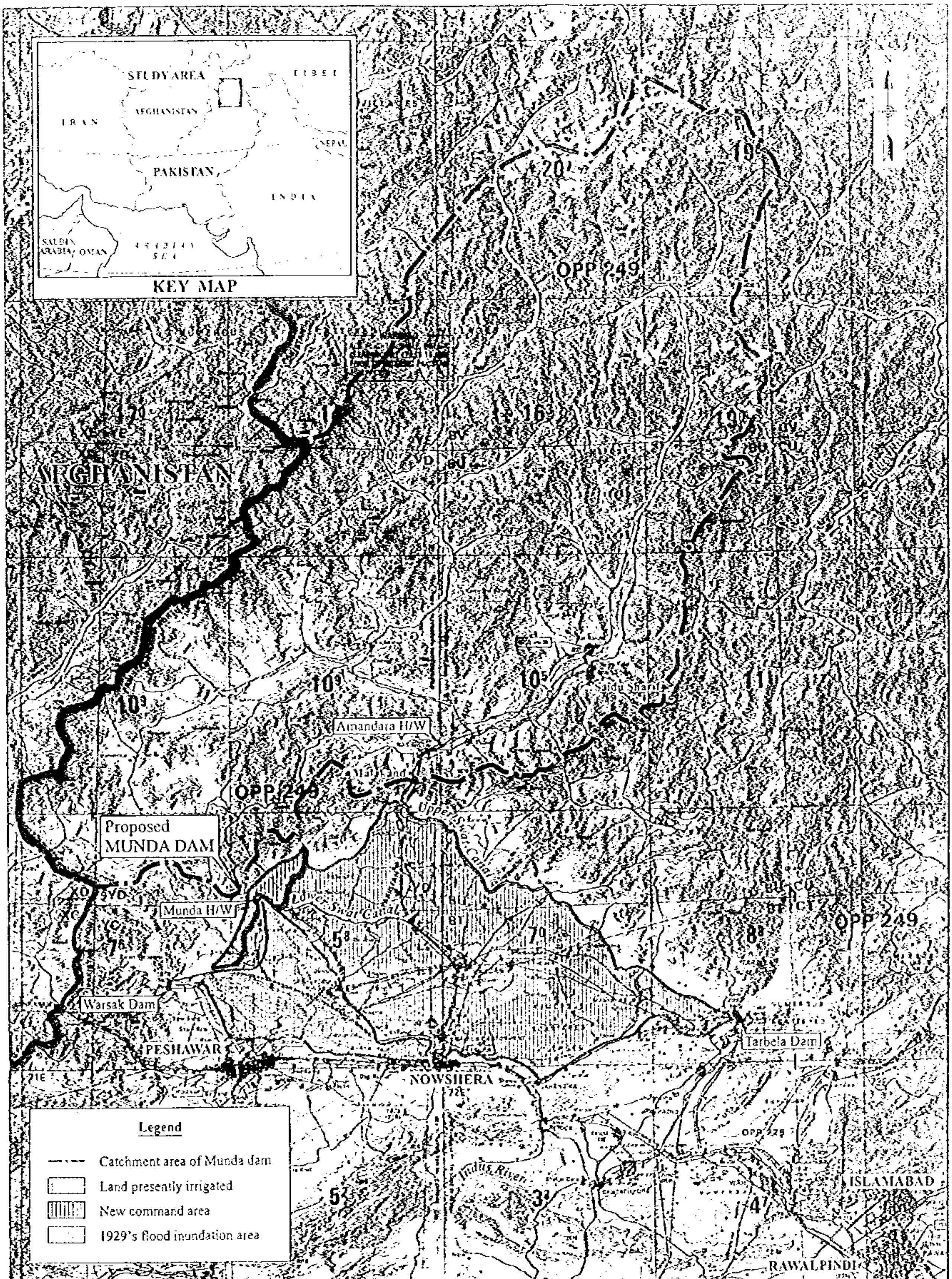
The cost estimate is based on the price level and exchange rate of September 1999. The exchange rate is:

US$1.00 = PRs.50.0

Perspective of Munda Dam



Location Map of Study Area



Location Map of Study Area

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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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

EXECUTIVE SUMMARY

I. THE STUDY

Background of the Study

1 The Munda Dam Multipurpose Project dates back to 1963 when the Water and Power Development Authority (WAPDA) initiated a preliminary geological investigation of the dam site. In this study, the construction of a 210 m high rockfill dam with a surface power plant of installed capacity of 400 MW was proposed.

Since then, WAPDA conducted a Pre-Feasibility Study and issued its report in November 1992 where it was proposed, by constructing a 180 m high rockfill dam upstream of the existing Munda Headworks, to generate hydropower (600 MW at peak), irrigate land of some12,000 ha, and provide flood control during the rainy season with use of a reservoir created by the dam, of which a gross storage volume is 623 million m^3.

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

In response to the request, the Government of Japan dispatched missions in March 1996 and September 1996. The two parties reached an agreement as to the contents and scope of the Study, subsequently the minutes of meeting having been signed on March 5, 1997.

Upon inter-governmental approval in Pakistan and selection of the Consultant on the Japan side, the Feasibility Study was initiated in March 1998.

Objectives of the Study

2 The main objectives of the Feasibility Study are to formulate an optimum development program of the Munda Dam Multipurpose Project taking into account effective water usage in a comprehensive manner including hydropower, irrigation and flood control, 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 implementation of

the Project. One of the main objectives is also to transfer technology and train the counterpart personnel of the Pakistan side during the course of the Study.

The Study Area covers the Munda Dam site 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.

Structure of Final Report

3 The Study was conducted in three stages, namely, Preliminary Investigation Stage, Detailed Investigation Stage, and Basic Design Stage, with phases of a home office preparatory work, six field investigations and three home office works for a duration of 24 months from mid-March 1998 to mid-March 2000. 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

II. SOCIOECONOMIC STATUS

Geographic Features

4 Munda Dam site and its surrounding area in the Swat River basin is located about 5 km upstream of the existing Munda Headworks at Abazai near the town of Shabqadar Deri, in North-West Frontier Province (NWFP), 37 km north of Peshawar. The reservoir area of the dam extends upstream to Mohmand and Bajaur Agencies, in the Federal Administered Tribal Areas (FATA) and Malakand Agency in the Provincial Administered Tribal Areas (PATA). The total length of the reservoir is about 56 km in the rocky gorge of the Swat River. The area is formed by barren and rugged hills and basins. The Swat River flows through deep gorges, so not much cultivable land is found along its banks. However, various places along the riverbanks are pierced by deep *nullahs* /streams. Patches of alluvial fans are found at such confluences of the basin.

Administration Situation

5 There are 21 districts in the province including the key districts of Peshawar and Charsadda close to the Munda Dam site. In FATA, the tribal areas are comprised of mountainous territory approximately 650 km long which borders with

Baluchistan in the south. The FATA population is estimated to be over 3 million. The command area likely to be affected by the Project is spread across three administrative units, namely, Mohmand Agency at the right bank, Malakand Agency at the left bank, and one *Tehsil* (Subdistrict), Tangi of District Charsadda as shown in Figure S1.

6 In irrigation sector reform, the National Drainage Program (NDP) assisted by the World Bank and other international donors, the North-West Frontier Province Irrigation Drainage Authority (NWFPIDA) was formed in 1997, as an autonomous provincial water authority responsible for coordinating all planning and development of water resources within the provinces and handling distribution of irrigation water to financially autonomous independent public utilities at the canal command level. The structure of NWFPIDA and process of implementation is to be established following the recommendations by the Institutional Reform Consultants assigned in 1999.

Population

7 The total population of Pakistan is 130.6 million according to the 1998 census, with an average annual growth rate of 2.6%. Population in NWFP is 17.5 million, with an average annual growth rate of 2.8%. Population in FATA area is 3.1 million with a slower growth rate of 2.1%. Eighty three (83) percent of the population in NWFP reside in the rural area. The total population of the command area is 141,530, with 53% males and 47% females according to the field survey in 1999. The entire population is ethnically *Pakhtoon* and strictly adheres to Sunni Islam. Socially the area is backward and traditional, following the *Pakhtoon* code/s.

The male literacy rate is 19% and the female rate is 11% in the command area. The overall literacy rate is low compared to national or provincial averages, while the male literacy rate is about twice that of females. The government schools in the command area consist of 118 primary, 24 middle, and 9 high schools.

According to the Labor Force Surveys in 1999, the unemployment rate is estimated at 6.1% for 1999 in the country but the most recent figure for unemployment in NWFP is not available. Farming is the main economic activity in the command area. And most of the labor in the command area is unskilled or semi-skilled. All such workers are male and work for daily wages. Animal husbandry is an integral part of the economy. Domestic animals are included in almost every household as they contribute in important ways to its running, from providing food to being a source of income. Their meat and milk is consumed at home as well as being sold in the larger settlements and/or neighboring towns and cities.

Economic Profile

8 GDP for the fiscal year 1998-99 in Pakistan was US$ 64 billion equivalent, and GDP per capita was US$490 below target due to sanctions and disappointing cotton and wheat yield. GDP grew by 3.1%. Inflation in 1998-99 period was at 6.1%. The trade deficit was US$1.4 billion in 1998-99 and is expected to improve to US$ 800 million.

In the command area, the main sources of income are agriculture, labor, remittances of migrant workers, animal husbandry, government jobs, small businesses, mining, and small cottage industry. Farming is the main economic activity but the arable land resource base is extremely small, roughly about 5-8% of the total land in the command area. Lack of irrigation is a major hurdle and much of the agricultural activity is subsistence. About 50% of people in the command area do not own any land. Of those who do have land, about half have holdings of only up to two hectares (5 acres).

Per capita electricity consumption of 266 kWh in NWFP for 1998 is lower than the national average at 317 kWh, but per capita consumption in FATA area is much higher than the national average, 567 kWh, reflecting the subsidized rate the region has enjoyed. Road network density and per capita gas consumption all reflect the lower development level in NWFP.

In the command area, all of the 70 villages are electrified. Traditionally, consumers would pay a flat rate regardless of their actual consumption. Recently the government has been attempting to rationalize electricity billing in tribal areas and the situation is in flux. Most of the villages in the command area are accessible by roads. About half of households have television sets. The main mode of obtaining potable water is through public wells. Half of the villages have natural springs while 15% of the villages have water supply schemes. But the number of households having water supply scheme connections are some 30%.

National Development Plan

9 GOP has launched a long term agenda for growth and stabilization, the Pakistan 2010 Program. The program calls for the real GDP to grow at an average rate of 7.4% per annum. Population would grow at an annual average of 2.1% thereby doubling the per capita income by the year 2010. Saving rate must average 23% of GDP, investment must average 26% of GDP, with foreign investment and

lending covering the difference. Export-to-GDP ratio must increase from the current level of 17.5% to about 25%, implying an annual growth rate of 9%.

Regional Development Plan

10 NWFP lags behind in the national development indicators. According to the NWFP Development Strategies, NWFP remains a food deficient province. Out of a total of 1,742,000 hectares of cultivated land, only 792,000 hectares are irrigated. The target is to add 433,468 hectares to the existing irrigated land. On water resources development, several dams, including the Munda Dam, have been proposed.

With abundance in hydro potential, NWFP could be a national hydropower base. It has 16 projects with an estimated total capacity of 1,204 MW that are under various stages of study for private investment and the total cost is estimated at $ 1,203 million.

III. SITE CONDITIONS

Location and Topography

11 The proposed Munda Dam is located on the Swat River, a major tributary of the Kabul River. The dam site is situated approximately at coordinates, 34°21' N and 71°32' E.

The total catchment area of the Swat River basin is 13,650 km^2 at the proposed dam site, lying between latitudes 34°20' N to 35°56' N and longitudes 71°20' E to 72°50' E, and is about 137 km long and 110 km wide. The proposed Munda reservoir is extended from south to north in a steep gorge of the Swat River. The Munda Dam site is situated at the downstream end of the mountainous area of the Swat basin, from which the valley widens forming a fan configuration.

Geology

12 Bedrock of the Munda Dam site is composed mainly of crystalline schist, partly associated with thin limestone layers and doleritic rock, of Permian Duma Formation that strikes across the river nearly at a right angle and dips more than 40° downstream as shown in Figure S2. The dam will found mainly on the hard siliceous to psammitic schist on the left bank and the green schist on the right bank. The bedrock in fresh and intact condition is hard or moderately hard. River gravel deposit has thickness of approximately 8 m. The drilling at the middle part of the riverbed on the dam axis and inclined borehole did not indicate existence of any fractured zone of substantial size under the riverbed.

13 Soil cover is very limited and the bedrock, apparently not seriously weathered, is widely exposed. The rock in the surface zone, however, is slacked and show high water permeability in borehole water tests. The foundation has a general condition that the seepage potential from 25 Lugeon unit up to higher values over 100 prevails in the zone from zero to 15 m of depth and the medium seepage not exceeding 25 Lugeon unit in the zone from 15 m to 35 m. Deeper than 35 m, the Lugeon values are not more than 5. In the upper part of the slope for the dam abutment, the slacking of the bedrock deepens, and the topographic and geologic conditions are poor and less stable in the higher part above elevation 560 m. The thin limestone layers intercalated in the schist near the dam site, which strike at nearly right angle to the river channel and are not deeply karstified, will not cause visible underseepage.

The reservoir area stretches to the area of Permian to Cretaceous metamorphic rocks with variety of crystalline schists and granite or granitic gneiss. Limestone is also included in those strata with signs of karst solution at places. The karstification or the formation of cavities in the limestone is limited within the depth of several tens of meters as was seen in the drilling of the Sappare limestone, or within a reach of underground circulation of the rain water with carbon dioxide. As seepage water would have to travel far, there is no possibility of substantial water loss occurs from the reservoir. Slopes are generally stable and no large land slide is envisaged.

Seismicity

14 The Project area is located in a highly tectonic zone of the Himalayan foothills and between two major thrust faults. The seismic risk was estimated from the earthquake record of 2,259 events obtained from an international earthquake data of USGS. For dam design, a design earthquake acceleration of 0.15g is proposed.

Construction Materials

15 The earth core material is available from several areas downstream of the Munda Headworks. A borrow area proposed in a plain to the west of the village of Sadar Garhi is most advantageous for its shortest haul distance and the least environmental interference with cultivated or inhabited land. The rock material is to be taken from two quarry sites of Sappare and Todobo Banda, nearest to the dam site, one for massive blocks of hard limestone and the other for smaller pieces of siliceous schist to meet the required quantity of over 16,000,000 m^3. Good gravel for coarse concrete aggregate can be taken from the river bed deposit of the Swat River downstream of the Munda Headwork. Sand on the Swat

riverbed, however, is too fine for the fine aggregate and the filter zone material for the rockfill dam. Sand will have to be produced by crushing the gravel.

Hydrology

Hydro-meteorological Data

16 The Swat River originates from snow-covered Swat Kohistan with an average elevation of 4,500 m. The climate of the Swat River basin is classified as sub-humid tropical continental high lands. Rain falls within two seasons, monsoon (July to September) and spring (February to May). The monsoon rains bring 30% of annual rainfall in the basin and prevail with moisture brought by winds from Arabian Sea and the Bay of Bengal. In the upper region, monsoon rains bring 15% of annual rainfall and the rest is due to snowmelt that takes effect during summer. The Swat River consequently carries perennial flow, which is generated from snowmelt and rainfall. On average, the rainfall over the catchment varies from 500 mm to 1,500 mm.

The first significant water resources development on the Swat River took place in 1885 when the Lower Swat Canal (LSC) was opened at the left bank with construction of the Munda Headworks. During 1915-19 the Doaba Canal was constructed to be fed from the right-bank of the Headworks. In 1914, the Upper Swat Canal (USC) was completed to take off from the Amandara Headworks. For this reason, many agencies were historically involved in the meteorological and hydrological observations in the Swat River basin as indicated in Figure S3. However, there are scarce observatories in the reach of the Munda Dam site. The discharge measurement data at the existing Munda Headworks were found to be unreliable due to its location being effected by back water of the Munda weir in the high flow season, etc. As a result of verifying the existing upstream observatories, data taken by the Surface Water Hydrology Project of WAPDA (SWHP) were found to be the most reliable.

Stream Flow

17 The long term monthly flow data at the Munda Dam was estimated based on flow-catchment area relationships using flow records at the four stations of Kalam, Chakdara, Nowshera, and Warsak. As a result, the average natural synthesized flow at the Munda Dam site was calculated at 281.2 m^3/s. This corresponds to 228.6 m^3/s, reflecting the water diverted to USC at present and various existing irrigation schemes. Further, taking into account the future diversions of water for USC and other water uses as shown in Figure S4, the average flow was calculated at 206.2 m^3/s, of which the monthly series was applied for optimization study of

the Munda Dam since the future extension of USC is expected to be implemented soon.

Floods

18 In view of the large scale of the Project (both financial and physical), it was decided to adopt a probable maximum flood (PMF) based on probable maximum precipitation (PMP) for the dam and spillway design. Estimation of PMP was made based on the largest historical storm of August 26 – 29, 1929 and applying methodology as documented in the report of World Meteorological Organization (WMO), consequently it having concluded that the estimated Munda PMF peak is 19,390 m^3/sec as shown as Case 2 in Figure S5. On the other hand, probable floods for different return periods are to be considered for the design of powerhouse, downstream structures of spillway and the diversion facilities. As there exists no reliable flood records, probable flood calculations was made based on rainfall frequency values converting the results to equivalent flood values using rainfall-runoff relationship. The frequency curve and estimated values for different return periods obtained are shown in Figure S5, where, for example, a 200 year return flood is 5,720 m^3/s.

Sedimentation

19 The suspended sediment records at the Munda Headworks could not be utilized in this Study because of its unreliability. Accordingly, it was estimated by applying the regional analysis based on the available sediment records at the four gauging stations of Kalam, Chakdara, Warsak, and Nowshera. The total sediment yield estimated as the sum of suspended load and the bed load is 373 ton/km^2 which corresponds to an annual total sediment of 373 ton/km^2 considering geological factors. Further, taking account of compact sediment density, bed load density, and trap efficiency, the sediment accumulation after 100 years was estimated at 373 million m^3.

IV. POWER DEVELOPMENT SURVEY

Power Sector Organization

20 The power sector of Pakistan is under control of the Ministry of Water and Power (MOWP). Under MOWP, the two power supply utilities, Water and Power Development Authority (WAPDA) and the Karachi Electricity Supply Corporation (KESC) are responsible for operation of the integrated power systems that includes generation, transmission, and distribution. WAPDA's system covers

the whole country except the Karachi area, and KESC is responsible for the Karachi area. The energy sector organization of GOP is shown in Figure S7.

The current power supplying functions of WAPDA and KESC are going to be re-organized as the first step toward future corporatization and privatization of the power sector. As is shown in Figure S8, huge organization of WAPDA will be dissolved to WAPDA itself in charge of hydroelectric generation, Pakistan Electric Power Company (PEPCO), a managing company, and 12 companies, comprising 3 Thermal Generation Companies, one National Transmission and Dispatch Company and 8 Distribution Companies, under PEPCO's control. The National Electric Power Regulatory Authority (NEPRA) was established for overall control of the power sector with active involvement of the private sector..

There are three organizations responsible for hydropower development and rural power supply in NWFP: (1) Hydro Electric Planning Organization (HEPO), a supporting organization of WAPDA, (2) provincial government of NWFP, and (3) Sarhad Hydel Development Organization (SHYDO) under the NWFP provincial government. HEPO is a nation-wide organization, and is in charge of relatively large projects in the NWFP area. While, SHYDO studies mainly medium to large run-of-river projects to be implemented under the private sector. The Provincial Government of NWFP is to promote IPP activities in the territory.

Historical Power Demand and Future Forecast

21 The historical power generation and sales records of the country (WAPDA and KESC combined), for the period of 1984 to 1998 are shown in Table S1. The annual growth rate of sold energy of the country was 6.2% in average in the last 10 years, which is declining in recent years. Major particulars of the 1997-98 demand of the country are summarized below:

Generated energy	60,018	GWh
Peak demand at generator terminal	10,081	MW
Sold energy	44,078	GWh
Per capita consumption	326	KWh
Annual load factor	68.0	%
T&D loss factor	24.0	%

22 The load dispatching center (LDC) records for typical daily load curves of the WAPDA system are available for through the year. The 1997-98 load curves of Summer (July), Winter (January) and Intermediate season (April) are compared in Figure S9.

These load curves show that (1) the daily peak load appears in the evening, around 7 to 8 o'clock according to season, (2) the peak duration is about 4 hours throughout the year, and (3) the peak demand is largest in July, and daily load factor is also highest in this month.

The calculated daily load factors of the above 3 load curves are very high, 76 to 86%, highest in July. The suppression of peak demand is conspicuous due to insufficiency in power system capacities, and this makes load factor high.

23 In the Revised 9th 5-Year Plan of May 1999, the government forecasted two scenarios of power demand, Normal and Low based on economic growth of 6% and 5%, for the period of 1997 to 2018. This low scenario forecast is quite similar to the forecast recommended by the World Bank as tabulated in Table S2. The 3 forecasts, normal and low scenarios of the government and World Bank, are compared in Figure S10.

The above forecasts were reviewed by the JICA Study Team by analyzing the historical growth of sold energy with reference to the growth of GDP for the period of 1982-83 to 1997-98. As a result, it was judged that the revised load forecast of GOP is in a reasonable range.

Existing Power System

24 The total installed capacity of the existing hydroelectric power stations is 4,826 MW, of which 98% is occupied by the three major reservoir type power stations, i.e. Tarbela (3,478 MW), Mangla (1,000 MW), and Warsak (240 MW). In Pakistan, the first priority of water use of a multipurpose reservoir is for irrigation water supply. Therefore, a reservoir is to be operated based on irrigation requirement.

25 The total installed capacity of existing thermal power plants in the WAPDA system consists of 4,281 MW of WAPDA plants and private facilities of 3,044 MW. The WAPDA system comprises comparable capacity of steam plants and combined cycle plants. Recently, IPP plants are generating 30% of the energy of the country.

26 The transmission network of Pakistan has 500 kV transmission spine lines in 2 to 3 circuits from the Tarbela power station in the north to the Hub power station facing to the Arabian sea, 1,500 km in total length. These transmission lines interconnect all major facilities in the country through 500/220 kV substations and 220/132 kV networks in the country.

In NWFP, the 500 kV system was recently extended from Tarbela to Peshawar, and only two 220 kV transmission lines from Tarbela to Mardan and from Peshawar 500 kV to Daud Khel are in operation at present.

Power System Development Plan

27 The government wishes to utilize indigenous sources of energy as far as possible for power generation to reduce reliance on imported oil. Based on this policy, the first priority of power development is to accelerate hydroelectric developments. The utilization of fuels of indigenous sources, coal and natural gas, is aimed for thermal power development. Development of oil thermal plants is not allowed any more, and the existing plants will be phased out.

The generation development during the 9th Plan period is shown in Table S3. The total capacity addition of 4,733 MW comprises public sector addition of 1,959 MW (hydroelectric and nuclear plants) and private sector addition of 2,774 MW (thermal plants). The largest addition of the public sector is the 1,450 MW Ghazi Barotha hydroelectric plant, a run-of-river project on the Indus main stream just downstream of the Tarbela power station. The private sector thermal power plants are relatively small in capacity and based on fuel oil and gas.

28 In 1995, GOP announced the Policy to promote Private Sector Hydel Power Generation Projects either of run-of-river type or with nominal pondages. In the 1998 Policy for New Private Independent Power Projects, a competition process was introduced in setting power tariffs to move towards the creation of a competitive power market in Pakistan.

29 The Kalabagh Multipurpose Dam Project (2,400 MW at first stage, 3,600 MW at final) is at present recognized as the most important project for early development. This project is on the Indus main stream, 192 km downstream from the existing Tarbela power station. Feasibility study of this project was already made in the 1980s, and detailed design is finished and bidding documents are ready. Thus, implementation of this project can be commenced any time if the environmental problems are settled and construction fund becomes available.

30 For hydroelectric development succeeding to the 10th Plan period, 41 proposals were received from private parties. In 1998, the following four projects were selected for implementation by IPPs on the basis of 1995 Policy:

Name of Project	Output	Location	Studied by
Malakand III	81 MW	Malakand on Upper Swat canal	WAPDA/SWABI/ SCARP
Jinnah	96 MW	Jinnah Barrage on Indus river	WAPDA/ GTZ
Matiltan	84 MW	Ushu on Swat river	SHYDO
New Bong Escape	45 MW	Mangla on Jhelum river	WAPDA/ HARZA

As the next step, the following 6 projects have been selected in 1999 on the basis of the 1998 Policy as IPP projects for implementation:

Name of Project	Capacity	Location	Studied by
Neelum Jhelum	963 MW	Muzaffarabad on Jhelum river	WAPDA/ Norconsult
Khan Khwar	72 MW	Khan Khwar on Swat river	SHYDO
Golen Gol	106 MW	Chitral/ Mastuj on Golen river	HEPO/ WAPDA
Daral Khwar	36 MW	Panjkura on Swat river	SHYDO
Allai Khwar	163 MW	Allai on Indus river	SHYDO
Summer Gah	28 MW	Summer on Swat river	SHYDO

31 According to the Generation Program of NPP, thermal plants using indigenous coal and natural gas are required after 2005 based on the normal growth scenario or after 2007 based on the low growth scenario. In the Program, development scales of coal thermal plants and gas combined cycle plants are almost equal.

32 The WAPDA's extension plans of 500 kV and 220 kV transmission systems in the northern area up to 2003 are shown in Figure S11.

In the NWFP areas also, the 220 kV and 132 kV transmission system needs to be extended with development of hydroelectric plants such as Munda, Swat B1, Malakand III, Matiltan, etc., and for promotion of electrification of remote communities. The Munda power station is located about 37 km north of Peshawar.

33 It is not possible to transfer all the Munda power of 740 MW through one existing substation due to insufficiency in equipment capacity. In the surrounding area of the Munda power station, there are two large 220 kV system plans at Shahibagh and Charsadda. These substations are 25 to 30 km from the Munda power station and can be designed taking into account transfer of power from the Munda power station. Of these two substations, the New Shahibagh Substation was selected as the most appropriate substation to receive the Munda power.

V. WATER SUPPLY DEVELOPMENT STUDY

34 Water supply purposes of the Munda Dam Multipurpose Project were studied considering hydropower generation, irrigation water supply for *barani* area, supplemental irrigation water supply for existing systems, and water supply for domestic and industrial uses based on those optimized in the Pre-Feasibility Study. The surface irrigation method which is traditionally and widely spread in the Study Area is applied as it is easy for the farmers to adopt. Native farmers are considered as basis for the planning in the Project without resettlement of new farmers from other areas.

New Irrigation Development Plan

35 Target area of new irrigation scheme of the Project is major rainfed farmlands extending in both banks of the Swat River and extended in the left bank area of 8,210 ha (20,280 acres) and right bank of 3,680 ha (9,100 acres) in Cultivable Command Area (CCA) when it was identified in the Pre-Feasibility Study. During the field investigation, it was revealed that some portions of the new command area might be eliminated because farm lands are not fully arable and some overlap with the other existing irrigation plan and system. As the results of adjustment with the GONWFP, the area was reduced by almost half and the adjusted new command area is summarized as follows:

Unit: ha (acre)

	(GCA)	(CCA)
Left Bank Area	4,539 (11,220)	4,066 (10,050)
Right Bank Area	2,314 (5,720)	2,043 (5,050)
Total	6,853 (16,940)	6,109 (15,100)

As shown in Figure S12, the left bank area of the new irrigation scheme extends up to the Jindai Khwar and includes arable lands located in the west side of the Jindai Khwar and the existing Tangi irrigation scheme area (715 ha). The right bank area stretches it out over the Subhan Khwar embodying a part of the Warsak Canal command area.

Proposed Cropping Pattern

36 Cropping pattern and intensity for the command area of the new irrigation scheme of the Project was framed so as to match with irrigation water availability, land adoptability, climate conditions, and socioeconomical possibility of the command area, in due consideration of the cropping patterns experienced in the Tangi Lift Irrigation Scheme and averages of Charsadda district. Furthermore, good economic soundness was pursued through comparative study by alternatives. The following cropping pattern and intensity that holds sound profitability and practicability are proposed:

Crops	Intensity(%)	Crops	Intensity(%)
Kharif		*Rabi*	
Maize	27	Wheat	30
Vegetables	8	Oilseeds	2
Pulses	4	Onion	6
Fodder	3	Vegetables	7
Tobacco	6	Fodder	3
Sugarcane	30	Sugarcane	(30)
Orchards	8	Orchards	(8)
Subtotal	86	Subtotal	48
Total			134

Supplemental Water Supply to LSC

37 While the Upper Swat Canal (USC) will be a complete irrigation system with its shortage of facilities' capacity improved by remodeling of the Swabi SCARP Project, the Lower Swat Canal (LSC) is not always in full water supply circumstance especially in *Rabi* season, because additional water source development was not attained. Some deficits of irrigation water supply in LSC were found to occur. The deficits occurred should be supplemented from a new water source. The proposed Munda Project could be an option to supply water to meet the water demand.

Supplemental Water Supply to Civil Canals

38 Civil canals located along the Khiali and Abazai Rivers, the Swat River downstream from the Munda Headworks have functioned as other water supply systems concerning the Study Area. The civil canal is an earth canal that directly introduces water from the Swat River without a permanent intake structure. These civil canals were constructed in the 1800s, and maintained and operated by farmers themselves. At present, 14 civil canals have been working having total discharge of about 5.70 m^3/s (200 cusecs). These canals face difficulty feeding water at all during *Rabi* due to no river flow in the Swat River. The proposed Munda Project could help to supply water to meet the water demand by civil canals. Further, by adding 2.85 m^3/s (100 cusecs) as proposed in the Pre-Feasibility Study, civil canal water feeding could be improved to 8.49 m^3/s (300 cusecs). Considering quantity of water to meet requirements and extra release as standing water in river for convenient water taking, it was considered reasonable.

VI. FLOOD CONTROL STUDY

Flood Control Benefit Estimate

39 The assessment of the flood benefits focussed on the reach from the dam site, virtually the Munda Headworks in the Khiali River to Nowshera in the Kabul River. Additional benefits may be expected in the reach downstream of Attock in the Indus River but quantification of such benefits is extremely uncertain due to the cumulative impacts of flows from other tributaries which join the Indus River.

The field investigation including interviews with local people about flood damage was carried out at 60 points over the Swat/Kabul River flood plain area downstream of the Munda Headworks and between Warsak Dam and Nowshera.

40 With use of the flood discharge - damage relationships, damage values for the floods of respective return periods were computed for both without and with the Munda Dam. The flood control benefits are attained as the reduction of average annual flood damages expressed as difference of annual average damages between with and without the Project.

41 Figure S13 shows the relationship between the flood control benefits and control spaces. According to Figure S13, optimum flood control space may fall within a range between 75 million and 100 million m^3. Increment of the benefit is marginal even if the control space is set at more than 100 million m^3 and hence it was concluded that a flood control space of 100 million m^3 be taken.

Since the dam is designed on the basis of the normal reservoir water level (in this case, FSL) against the Probable Maximum Flood, it is considered appropriate to allocate the flood control space above FSL.

VII. PLAN FORMULATION

42 The development concept of the Project is of multipurpose, consisting of peak power generation, irrigation water supply to the new irrigation scheme with CCA of 6,110 ha as well as the existing system, and flood control providing a control space of 100 million m^3 in the reservoir.

Taking this into account, the optimum development scale of the Project was formulated at the Munda Dam site on condition that the possible maximum reservoir full supply level (FSL) is EL. 580 m from environmental viewpoint, which does not cause wide submergence of the settled area in the upstream end of the reservoir area, as well as topographic limit at the Munda Dam site. The reservoir area, general layout and general plan of the selected development scheme are shown in DWG. S1, S2 and S3.

In the development scale alternatives, 16 dam heights, where FSL ranges from EL. 505 m to EL. 580 m with an interval of 5 m, were considered in combination with several minimum operating levels (MOL). The reservoir operation of each alternative was simulated using the simulation model and annual energy production and economic power benefits were estimated. In addition, the economic agricultural benefit and flood control benefit were taken into account for totaling overall economic benefits. All the construction costs were estimated for each alternative based on the developed basic design.

43 The alternative study revealed that the values of EIRR are almost identical for FSLs between 540 m and 565 m while those of NPV vary from 142 to 184 million

US$ with the highest NPV given at FSL 565 m as shown in Figure S14. However, further consideration was given to the realistic crest level of the Munda Dam from the viewpoints of topography and geology of the dam site with sedimentation expected at the upstream end of the reservoir. The consideration concluded that FSL 555 m with MOL 510 m, which corresponds to the dam crest level of EL. 563 m, is the practical and most economical alternative.

The effective storage volume of the selected alternative is 834 million m^3 between FSL and MOL. The installed capacity is 740 MW with a plant factor of 37%. The annual energy production is 2,407 GWh, in which the firm energy (peak generation) is 847 GWh and secondary energy (off-peak generation) is 1,560 GWh. The simulation results of reservoir operation is presented in Figure S15 for the selected scheme.

The Electric Generation Expansion Analysis System (EGEAS) was used for finding the optimum installation timing of the Munda power station. The result of the EGEAS computation revealed that the Munda Project has an optimum installation timing of year 2010 as illustrated in Figure S16.

VIII. FEASIBILITY DESIGN

Main Dam

44 Concrete Face Rockfill Dam (CFRD) was selected as the most appropriate dam type through examination of it and comparison with other dam types such as earth core rockfill dam and roller compacted concrete dam from the viewpoints of topography and geology of the dam site, availability of the construction material, and technical and economical advantages. The dam optimized is 213 m high and the total embankment volume is around 16.5 million m^3 with the upstream and downstream slopes of 1:1.4 and 1:1.5, respectively. Rock materials to be used for the dam embankment are limestone, quartzite, and siliceous schist. DWG S4 and S5 show plan, front elevation, and section of the main dam.

River Diversion and River Outlet

45 The tunnel type river diversion was designed considering the topography with steep abutments. At least two river diversion tunnels are required so that the river outlet facilities can be installed in one of the tunnels while the other tunnel continues to divert the river flow. The applied diversion design flood is 3,630 m^3/s of peak discharge, a 25-year probable flood. The diversion tunnels are 12 m in diameter, and 975 m and 964 m long, respectively, both being laid out on the

left bank. A 60 m high cofferdam, which is later integrated with the main dam, was laid out.

The river outlet facilities constructed in the left diversion tunnel will function to release river water downstream for meeting irrigation and other water requirement during reservoir impounding as well as to release reservoir water to draw down the water level in an emergency case. The river outlet has a morning glory type intake, a shaft of 4.5 m in diameter and 100 m long, and 2 sets of gates.

Spillway

46 The combined type spillway consisting of gated spillway and non-gated weir was laid out on the left abutment to suit the topography. The designed spillway has 4 sets of gates, each being 15.5 m wide and 18.4 m high, with a 80 m long non-gated overflow weir accompanied with a 60m wide chuteway, a flip bucket, and a plunge pool. PMF was applied for discharge capacity estimate. The design discharges for the chute and plunge pool are 3,800 m^3/s (1,000-year probable flood outflow) and 1,900 m^3/s (100-year probable flood outflow). DWG. S6 shows plan, profile, and sections of the spillway.

Waterway and Power House

47 A power intake, an intake gate shaft, a headrace tunnel, a surge tank, penstock tunnels, open penstock, a surface type powerhouse, and an open switchyard were laid out on the right abutment. An open-air type and a underground type powerhouse were compared and the waterway with the open-air type powerhouse was selected as it is the most economical. The powerhouse will be of conventional surface type, and constructed on the right bank of the narrow gorge of Swat River.

The headrace tunnel diameter was set at 12 m and penstock diameter at 7.4 m based on the optimization study. The restricted orifice type surge tank was designed, of which the upper and lower chamber diameters are 25 m and 15 m, respectively. Plan and profile of the waterway and powerhouse and powerhouse are presented in DWG. S7 and S8.

Re-regulation Weir

48 The function of the re-regulation weir is to store water released from the power station during the peak generation for 4 hours a day, and to regulate the river flow releasing the stored water constantly downstream of the weir. Through comparison of three alternative sites of the weir, which are located 3.5 km, 4.3 km, and 5.0 km (existing Munda Headworks site) downstream from the proposed

Munda Dam axis, the 3.5 km site was selected to be the most appropriate for its economical and environmental advantages.

The maximum water level in the normal condition and flood water level were estimated to be EL. 381.8 m and EL. 372.2 m, respectively. The curtain wall type weir with 7 radial gates was selected.

Power Station Facilities

49 The Munda power station was planned as a peaking station with daily peak duration of 4 hours. The total available output of the power station from the operating water head (162.5 m) and discharge (505 m^3/sec) is 740 MW. The power station will be provided with four 185 MW units of water turbine generators. The water turbines will be 189 MW vertical shaft Francis turbines operated directly coupled with 220 MVA AC synchronous generators.

The generated power will be stepped up to the transmission voltage of 220 kV with main transformers at the back of the powerhouse, and transferred to an open outdoor switchyard with a double bus system on a hilltop.

Transmission System

50 A 220 kV double-circuit transmission line, about 30 km long with 2-bundled Rail conductors (954 MCM) will be required between the outdoor switchyard and the planned New Shahibagh substation (main substation for supply to Peshawar) to connect with the 220 kV network in the area. The New Shahibagh substation needs to be designed taking into account the receiving of 740 MW Munda power. The two circuit extensions of 220 kV bus are required to connect with the 220 kV line from the Munda power station.

The selected plan will be the least cost plan satisfying the technical requirements. There are many examples to send more than 740 MW power with a 220 kV class transmission line in southeast Asian countries. The 500 kV transmission is suitable for long distance transmission of large power, but will result in much higher cost (at least 2.4 times the proposed 220 kV plan) for the small transmission of the Munda power.

Irrigation Facilities

51 Irrigation facilities for the New Irrigation Scheme of the Project was designed as an newly established system. The irrigation system is to be designed as being functional to apply demand base irrigation, on the assumption that the proposed irrigation development plan can be realized. Layout of the irrigation system would be taken into consideration deployment of beneficial farm lands and

location of rivers and water courses so as to apply proposed on-farm development system.

As studied and concluded in the development layout optimization of irrigation facilities, a tunnel system at the left bank area and a lifting system with pump at the right bank area are selected for the feeder system. Dimensions of proposed feeder system are as follows:

	Left Bank Irrigation System	Right Bank Irrigation System
Feeder Type	Tunnel Type: Circular shaped cross section non-pressure tunnel	Pump Type: Vertical Shaft Mixed Flow Pump
Detail Dimensions	Excavated Dia.: 2.40 m Finished Dia.: 2.20 m Length : 5,000 m Longit. Slope: 1/2,000 Discharge: 4.391m³/s Design Water Depth: 1.836 m Discharge Level: EL 466.0 m Intake Level: EL 470.0 m	Actual Head: 14.0 m Total Head: 18.88 m Low Sanction Level: EL 366.0 m Pump Number: 4 nos. Discharge: 2.204m³/s Bore: 500 mm Pump output: 200 kW

52 Main canal and distributaries are of concrete-lined open channel. Route alignment was optimized for construction cost and locations of farm lands based on water supply by gravity. Many related structures of the main canal such as river crossings, bridges, and turnouts are required. Salient features of main canals of the Project including numbers of several related structures are as follows:

Left Bank Irrigation System		Right Bank Irrigation System	
Maximum discharge:	4.391 m^3/sec	Maximum discharge:	2.204 m^3/sec
Length:	13,950 m	Length:	12,900 m
Bed slope:	1/4,000	Bed slope:	1/4,000
Side slope:	1: 1.5	Side slope:	1: 1.5
(Related structures)		(Related structures)	
Super passage:	4 nos.	Super passage:	3 nos.
Nala culvert:	34 nos.	Nala culvert:	36 nos.
Canal escape	3 nos.	Canal escape	4 nos.
Bridge:	26 nos.	Bridge:	25 nos.
Offtake:	4 nos.	Offtake:	5 nos.
Mogha:	2 nos.	*Mogha*:	0 no.

IX. CONSTRUCTION PLAN AND COST ESTIMATE

Construction Method

53 Among the works to be executed under the Project, the construction of CFRD with embankment volume of 16,500,000 m^3 is the most significant work for the project implementation. Temporary river diversion for the dam works is planned to be achieved applying the diversion tunnel method and designed for a 25-year probable flood of 3,630 m^3/s. Two diversion tunnels of 12 m diameter will be provided in the left bank of the dam site. In order to minimize the overall

construction schedule, the tunnel construction is planned to be advanced prior to the main civil work contract where overall schedule is so arranged that the river diversion for riverbed excavation can be commenced in the beginning of the dry season when the first diversion tunnel is completed. Under the program, the second tunnel should be completed by the end of the dry season. Integrated cofferdam scheme (by partial facing of slab concrete of the main dam) was adopted in this Study, as it minimizes the construction cost of the Project.

54 The dam body is comprised of nine embankment zones and all the fill materials can be obtained in the vicinity of the dam site within 8 km hauling distance. With average embankment speed of 500,000 m^3/month, about 3 years will be required for the dam embankment work.

The face slab concrete work is planned to be carried out in 3 stages in consideration of the following advantages:

1) To provide the main dam with cofferdam function with 1st stage slab concrete in early stage of the construction.
2) To enable concurrent work of embankment and concrete works, thus shortening total dam construction period.
3) To avoid segregation of concrete mix during conveyance of concrete in long sloping chute.

The reservoir impounding will be achieved during dry season in 2009, releasing part of river water through a river outlet gate provided in No.1 diversion tunnel (left) to maintain irrigation water required in the downstream area.

Construction Schedule

55 The construction of main works will be commenced from middle of 2002 after financial arrangement, detailed design, and procurement process of contractors. The first unit of the generating set will be commissioned in the middle of 2009 and all the generating sets will be put into commercial operation at the end of 2009 after 8 years construction period as indicated in Figure S17.

The following activities will constitute the critical path in the overall time schedule.

1) Preparation of PC-I (Implementation Program)
2) Financial arrangement
3) Selection of consultant
4) Detailed design and bid document preparation
5) Procurement procedures
6) Access road construction

7) Diversion tunnel construction
8) River diversion (end September 2004)
9) Dam construction
10) Reservoir impounding (from December 2008)
11) Wet test of generating equipment
12) Commissioning of power plant No.1 (end June 2009)
13) Commissioning of all the power plant (end December 2009)

Cost Estimate

56 The project cost was estimated basically using unit prices, taking account of existing site conditions, prevailing market prices of various construction resources, proposed construction method, and work quantities derived from feasibility design.

The total project cost is estimated at US$ 1,148.9 x 10^6, comprising foreign currency component of US$ 611.8 x 10^6 and local currency component of US$ 537.1 x 10^6 as summarized below and detailed in Table S4.

Unit: million US$

Description	F.C.	L.C.	Total
I. Base Cost	474.0	414.0	898.0
Construction Cost	440.0	257.7	697.7
Engineering Service	34.0	11.3	45.3
Administration	-	17.4	17.4
Land compensation	-	2.5	2.5
Environmental mitigation	-	5.0	5.0
Tax	-	121.0	120.1
II. Contingency	137.8	123.1	260.9
Price contingency	91.5	77.6	169.1
Physical contingency	46.3	45.5	91.8
Total Project Cost	611.8	537.1	1,148.9

X. DAM OPERATION SYSTEM

57 Present portfolio of WAPDA covers operation and maintenance of (a) generation, transmission, and distribution of power; (b) irrigation, water supply, and drainage; (c) prevention of water logging and reclamation of waterlogged and saline land; (d) flood control; and (e) internal navigation in the country but future one seems intransparent subject to the next phase of the forthcoming organizational restructuring. On the other hand, the North-West Frontier Province Irrigation Drainage Authority (NWFPIDA) was established in 1997 with focus to take over all the irrigation and drainage functions covered by the Irrigation Department of GONWFP. It is therefore necessary to demarcate among the agencies concerned

clearly the responsible area before its implementation, preferably before commencement of the detailed design.

58 Power generation provides the majority of benefit earnings in the Project. There is no doubt at present that power plant operation will be done by WAPDA. Flood fighting and maintenance flow operation falls also in one of portfolio of the operation team. Depending on future restructuring, there may be a possibility to operate the power plant indirectly by employing or hiring a power operation company which may be constituted at the time of completion of the Project. Flood fighting, however, should be included in the scope of work for such company.

59 The established NWFPIDA is an autonomous body for irrigation management, though the structure of its organization and process of implementation are yet to be formulated subject to recommendation by the Institutional Reform Consultants for which the procedure to appoint consultants was initiated in June 1999. It is certain that NWFPIDA would be concerned with operation and maintenance of the irrigation component of the Project and the outcome of the deliberations on the Farmers Organization would be applicable to the new command area of the Project. Further activities of the Area Water Board on the Swat Canal Command would be influential to the new command area of the Project.

60 Until and unless setting-up of NWFPIDA is on a stream and functions well, WAPDA will be the only possible operating body under which the Project is implemented but irrigation component of the Project may be covered by NWFPIDA when it becomes operational.

XI. ENVIRONMENTAL ASSESSMENT

61 The Environmental Assessment was carried out driving mitigation measures, of which the objective is to maximize the benefits and to minimize the undesirable impacts on the environment and the surrounding local community. As a whole, it was concluded that overall the Project is not going to have any major negative environmental impacts.

Fishery and Aquatic Biodiversity

62 In fishery and aquatic biodiversity, field studies and analysis found 16 species of fish in and around the Munda Dam reservoir area, although there will be a reduction in their population during the construction period. The EA devised mitigatory measures to make the fishery more productive, so there will be great opportunities for enhanced fish production in the reservoir. Periodic stocking of

fish will be carried out throughout the Project life from construction to operation period.

Archeological and Cultural Heritage

63 For the archeological and cultural heritage issues, attempt was made to evaluate all the sites in the Munda Dam area. Apart from one small grave/shrine downstream of the dam on the left side, no other cultural sites will be adversely affected by Munda Dam and reservoir.

Ecological Conditions

64 The ecological conditions will not be harmed, and there will be no significant loss of any rare or precious flora caused by the construction of the Munda Dam. This will be an opportunity to organize the grazing land in a scientific manner where areas are periodically rotated for replenishment. The sediment load will be 90% less passing the dam site. A 2.8 m^3/s compensation discharge downstream of the Munda Headworks will maintain the biological minimum flow.

People Affected

65 For the people affected, the Project will displace in total 118 people. All of these people would be easily resettled in nearby areas in Mohmand Agency. The EA has in consultation with WAPDA provided adequate compensation, details are provided in the breakdown of costs.

Infrastructures Lost

66 The only serious loss to any infrastructure will be five wire and rope bridges.

Employment of Local People for Construction

67 The procurement documents of the Project shall include a provision that during construction the Contractor should give preference to hiring labor from within the above people so as to maintain good working relations between the Munda Dam Multipurpose Project and the local people who are economically not much above poverty level.

Cost of Environmental Mitigation and Cost of Resettlement Compensation and Land Acquisition

68 The cost of environmental mitigation was estimated at US$ 5 million (Rs. 250 million) and those for land compensation and people affected were estimated by WAPDA to be US$ 2.5 million (Rs. 123 million). The cost for resettlement compensation and land acquisition is one of the major line items of the cost. The costs derived here could change during the negotiations for the purchase of the land, which may be protracted.