CHAPTER 5

STUDY ON REHABILITATION AND ENHANCEMENT

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5.1 Turbine

5.1.1 Study on Rehabilitation of Turbine

The Survey Team's comments on the recommendations related to the turbines in the F/S report are described in Tables 3-9 to 3-12 of Chapter 3.

The result of the study for rehabilitation of the turbines in the Project is shown below.

(1) Units 1 to 4

1) Inlet Valve

The water leakage from the inlet valve when fully closed is so excessive that it is difficult to reduce by simple maintenance works. When any maintenance work inside the turbine is required, the intake gate is closed, which results to the stoppage of the two units. Without closing intake gate, it is very difficult to do any work inside the turbine due to excessive leakage water from fully closed inlet valve. A bi-plane type inlet valve is recommended to minimize water leakage for doing any work inside turbine without closing intake gate but closing inlet valve. By replacing inlet valve to bi-plane type one, head loss would be reduced is effective for high efficiency power generation together with only one unit stopping for one unit turbine inside work.

In consideration of the above, the Survey Team recommended ~~to~~ replacing the existing butterfly inlet valve by a bi-plane type, although the F/S report recommended that the existing butterfly inlet valve be repaired only for utilization in the future.

The bi-plane type inlet valve is designed such that there will be no requirement for greasing, which is better from the viewpoint of ecology.

In addition, it is recommended that the by-pass valve and its piping be replaced through the Project.

2) Spiral Casing

Overhaul of the spiral casing with partial replacement and repair is recommended. Measuring instruments, including the turbine water flow detector, shall be replaced to match the new design monitoring system. Almost all the measuring signals shall be transferred to new control system. It is difficult to add the signal transfer unit to existing measuring instrument due to out-of-date instrument.

3) Turbine Runner

The turbine runner shall be replaced with a new designed runner.

4) Guide Vane

Guide vanes shall be replaced with the latest design.

New design guide vane is not required feeding lubricant grease.

5) Guide Vane Operating Mechanism

Overhaul of the guide vane operating mechanism is required for replacement of some parts except gate operating ring which shall be reused.

6) Head Cover

The head cover shall be replaced in order to adopt the new design of the turbine shaft and shaft seal.

As recommended below item (8), shaft seal is recommended to replace, in this case, head cover shall also be replaced for mounting the new shaft seal equipment.

7) Turbine Shaft

Inspection and spare preparation of the turbine shaft is requested, however, there is no need for a spare shaft as suggested in the F/S report. Because there is almost no possibility using spare shaft forever.

8) Shaft Seal

The shaft seals shall be replaced with new designs for improving their performance.

9) Discharge Ring and Draft Tube

Inspection of the discharge ring and draft tube liner, and treatment with blasting and re-coating are required.

10) Turbine Guide Bearing

The guide bearing shall be replaced with new one.

11) Governor

The governors shall be replaced with the latest design, which is of digital type and requires a speed signal generator (SSG) with speed detector.

The existing speed detector shall be taken out.

The mechanical-type position detector for the guide vane shall be replaced with an electrical-type position detector. Communication between governor system and control system is required. For providing sufficient communications with new control system, all of the electrical component of governor shall be replaced.

12) Governor Pressure Oil System

The governor pressure oil system shall be replaced with a new design for long life operation of the system. Almost all the component of governor oil pressure system is no more manufacturing, therefore getting spares in the market is impossible. So, all of the pressure oil system shall be replaced.

(2) Units 5 and 6

Units 5 and 6 rehabilitation is the same as Units 1 to 4, except for the following equipment:

1) Guide vane operating mechanism

The guide vane operating mechanism shall be replaced with a new one.

2) Turbine shaft

The turbine shaft shall be replaced with a new one.

(3) Units 7 to 10

Although overhaul of Units 7 to 10 is also required with the replacement of some equipment, the operation period of these units is not so long as compared to Units 1 to 6. Periodical maintenance shall be required.

An output power limitation control is required after raising the reservoir level in order to prevent damage due to the limitation of the capacity of the generator, including IPB and the main transformer.

5.1.2 Study on Rehabilitation of Auxiliary Equipment for Turbine

(1) Cooling Water System

The cooling water supply system is normally connected by the same interconnected piping. It is tapped from the upstream side of the turbine inlet valve on all units except for Units 5 and 6, which are supplied downstream of the valves.

Units 1 to 4 have stand-by cooling pumps each. These pumps have been working ever since their commissioning, therefore, they should be replaced with new ones through the Project.

The cooling water system is currently functional without any major fault, but piping and valve replacement are required for continuous reliable operation for another 40years.

(2) Compressed Air Systems for Generator Brakes

No replacement is required.

(3) Oil-lifting Equipment

No replacement is required.

(4) Overhead Traveling Crane and Lifting Beam for Generator rotor

According to the information of a senior mechanical engineer in Mangla Power Station, the conditions of both cranes are satisfactory. Therefore, no replacement of the parts is required. In addition, the lifting beam for tandem operation of both cranes and the lifting device for the rotor is safely stored in the erection bay.

5.1.3 Study on Enhancement of Turbine

The turbine characteristics for both cases of just rehabilitation and enhancement are completely the same, because both cases are required to correspond to the raising of the water level of Mangla Dam.

(1) Units 1 to 4

The scope of the works for enhancement of turbine and unit mechanical equipment is same as that for rehabilitation as mentioned in Sub-clause 5.1.1.

(2) Units 5 and 6

The scope of the works for enhancement of the turbine and unit mechanical equipment is the same as that for rehabilitation as mentioned in Sub-clause 5.1.1.

(3) Units 7 to 10

The scope of the works for Units 7 to 10 is recommended to be just rehabilitation as mentioned in Sub-clause 5.1.1. The output water limitation shall be considered for limiting the generator output due to the limitation of electrical equipment such as generator, IPB, and main transformer.

5.1.4 Study on Enhancement of Auxiliary Equipment for Turbine

(1) Cooling Water System

Cooling water supply system is normally connected by the same interconnected piping. It is tapped from the upstream side of the turbine inlet valves on all units except for Units 5 and 6, which are supplied with water from downstream of the valves.

Units 1 to 4 have separate individual stand-by cooling pumps. These pumps have been working ever since their commissioning, and therefore, should be replaced with new ones.

The cooling water system is currently functional, but piping and valve replacement is necessary for continuous reliable operation for another 40 years.

(2) Compressed Air Systems for Generator Brakes

If more capacity is necessary from the existing capacity, replacement should be considered.

(3) Oil Lifting Equipment

If the existing capacity is not adequate, then replacement of the lifting equipment should be considered.

5.2 Generator

5.2.1 Study on Rehabilitation of Generator

The following study for generators was undertaken by using the data given in Section 4.2:

(1) Study of Generator Stator Coil

Estimation of remaining life for generator stator coil

From the data of "number of start/stop" and "operating hours", the remaining life of the stator winding is estimated by N-Y Map method which is presented in the report of the "Institute of Electrical Engineers of Japan".

1) Operating hours

The total operating hours after commissioning of each unit is as follows;

Table 5-1 Total Operating Hours

Unit Number	Total Operating Hours	Commissioning Date	Unit Number	Total Operating Hours	Commissioning Date
Unit 1	361,373 hrs	03/07/1967	Unit 6	263,583 hrs	11/03/1974
Unit 2	360,017 hrs	14/07/1967	Unit 7	203,276 hrs	19/06/1981
Unit 3	301,809 hrs	07/03/1968	Unit 8	190,092 hrs	22/08/1981
Unit 4	297,087 hrs	17/06/1969	Unit 9	100,223 hrs	24/09/1993
Unit 5	268,864 hrs	29/12/1973	Unit 10	90,364 hrs	06/07/1994

Source: WAPDA (Mangla Hydropower Station)

2) Number of start/stop

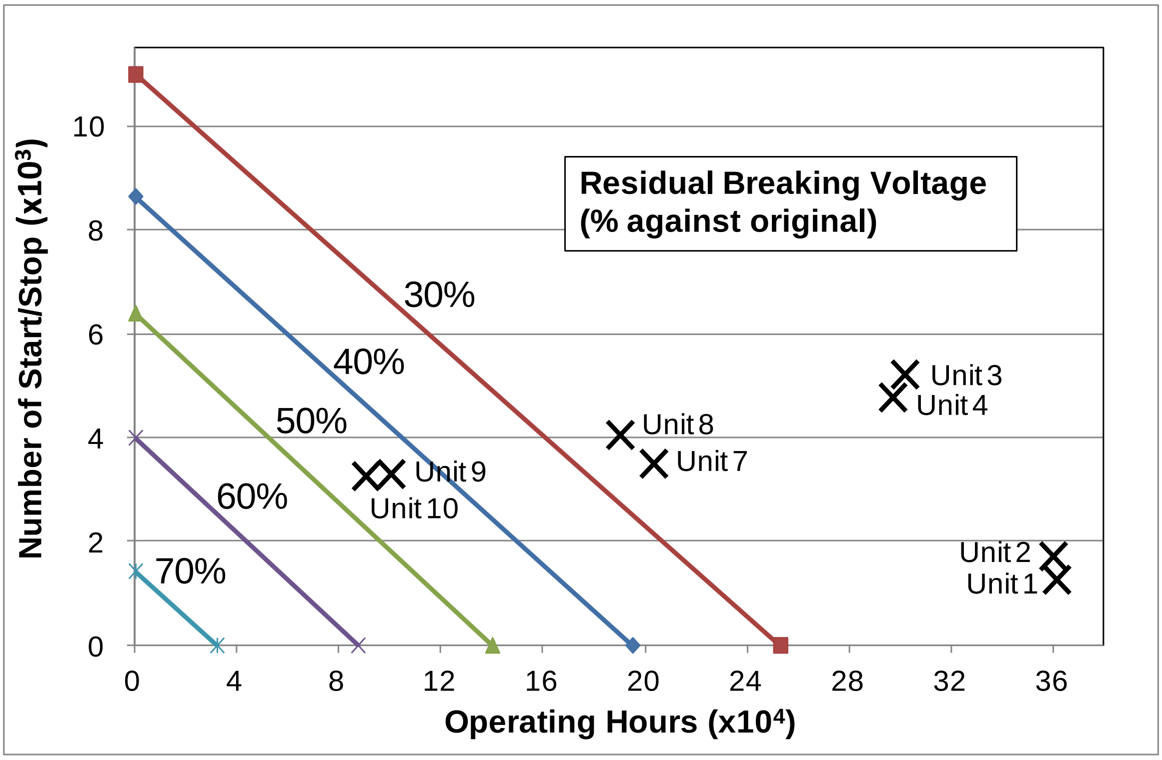
The number of start/stop of each unit is mentioned in Section 4.2, and the total numbers after commissioning are as follows;

Table 5-2 Number of Start/Stop

-	U-1	U-2	U-3	U-4	U-5	U-6	U-7	U-8	U-9	U-10
Total Number of Start/Stop	1,265	1,716	5,219	4,777	2,040	2,142	3,501	4,054	3,301	3,260

Source: WAPDA (Mangla Hydropower Station)

3) Estimation of residual life



From the above data, residual life of the stator winding is estimated as follows. This estimation used the graph of N-Y Map.

Source: Institute of Electrical Engineers of Japan, Modified by the Survey Team

Figure 5-1 N-Y Map

The N-Y map is taken from the report of the “Institute of Electrical Engineers of Japan”. However, since this map seems to be too severe, it will be used only as reference if the data is near the border of the limit line.

This N-Y map shows the percentage of residual breaking voltage against the original breaking voltage. Original breaking voltage, which should be confirmed from the original manufacturer, is usually 4-5 times of the rated voltage.

Lower limit of the breaking voltage, which is the life limit, is 1000 V plus 2 times of the rated voltage (so called 2E + 1000).

The rated voltage of Mangla is 13,200 V, therefore the lower limit (voltage of life limit) is

27,400 V. On the other hand, when the original breaking voltage is assumed as 5 times of rated voltage, this original figure is calculated as 66,000 V. Then 27,400V of “2E + 1000” is 41% of original breaking voltage. This means that the 41% line is the border of life limit.

i. Unit 1

Operating hours since the commissioning up to the end of 2011: 361,373 hours

Number of start/stop: 1265

Taking into account the above two parameters in the N-Y map, the residual breaking voltage showed less than 30%; this means the stator winding of Unit 1 generator is already beyond the typical life of expectancy. Therefore, the stator coils for this unit need to be replaced.

ii. Unit 2

Operating hours since the commissioning up to the end of 2011: 360,017 hours

Number of start/stop: 1716

Taking into account the above two parameters in N-Y map, the residual breaking voltage showed less than 30%, this means the stator winding of Unit 2 generator is already beyond the typical life expectancy. Therefore, stator coils for this unit need to be replaced.

iii. Unit 3

Operating hours since the commissioning up to the end of 2011: 301,809 hours

Number of start/stop: 5219

Taking into account the above two parameters in N-Y map, the residual breaking voltage showed less than 30%, which means that the stator winding of Unit 3 generator is already beyond its typical life expectancy. Therefore, stator coils for this unit need to be replaced.

iv. Unit 4

Operating hours since the commissioning up to the end of 2011: 297,087 hours

Number of start/stop: 4777

Taking into account the above two parameters in the N-Y map, the residual breaking voltage showed less than 30%, which means that the stator winding of Unit 4 generator is already beyond its typical life expectancy. Therefore, the stator coils for this unit need to be replaced.

v. Unit 5

Operating hours since the commissioning up to the end of 2011: 268,864 hours

Number of start/stop: 2040

Stator coils were rewound in 1991 and repaired in 2010.This unit is now operating at reduced load. However, the replaced coils are not from the original manufacturer, thus, the stator coils are recommended to be replaced.

vi. Unit 6

Operating hours since the commissioning up to the end of 2011: 263,583 hours

Number of start/stop: 2142

As the design of the generator of this unit is the same as Unit 5, the same trouble as Unit 5 is expected. Therefore, stator coils are recommended to be replaced.

vii. Unit 7

Operating hours since the commissioning up to the end of 2011: 203,276 hours

Number of start/stop: 3501

From the N-Y map, the stator coil of this unit is also in its last stage of life, but only 30 years have passed since the commissioning and the result of the insulation resistance test showed they are operating safely. Taking these into consideration and to assure reliable operation for the next 40 years, the stator coil is better to be replaced.

viii. Unit 8

Operating hours since the commissioning up to the end of 2011: 190,092 hours

Number of start/stop: 4054

From the N-Y map, the stator coil of this unit is also in its last stage of life, but only 30 years have passed since the commissioning and the result of the insulation resistance test showed the coils are operating safely. Taking these matters into consideration and to assure reliable operation for the next 40 years, the stator coil is better to be replaced.

ix. Unit 9

Operating hours since the commissioning up to the end of 2011: 100,223 hours

Number of start/stop: 3301

Stator coils for this unit are quite new, thus, replacement is not required.

x. Unit 10

Operating hours since the commissioning up to the end of 2011: 90,364 hours

Number of start/stop: 3260

Stator coils for this unit are quite new, thus replacement is not required.

From the above, stator winding (coil) of Units 1 to 4 are required to be replaced with new coils, regardless of the grade of rehabilitation (with enhancement or without enhancement).

For Units 5 and 6, although the stator coils were replaced in 1991, a major short circuit to the ground happened and rewinding was made as mentioned in Section 4.6. Therefore, replacement of the coils is recommended.

(2) Study of Other Parts of Generators (Other than Stator Coil)

Other parts were also studied whether rehabilitation/replacement is necessary or not.

The summary table is given on the following page of Section 3.2.4 and recommended parts to be replaced are as follows.

1) Units 1 to 4

i. Stator

Winding: By the reasons mentioned above, winding should be replaced.

Core: As these are beyond their typical life, the core should be replaced.

Frame: All frames should be replaced.

Necessary action:

Stator foundation should be inspected. There are some small cracks on the concrete below the stator.

Foundation bolts should also be inspected.

ii. Rotor

Field poles and field windings should be replaced, although the F/S report mentioned they can be reused. The reason is that they are beyond their typical life.

The following parts should also be replaced;

Top and bottom insulation collars, pole keys, pole leads, and damper connectors.

Other small parts will be decided after inspection at the detailed design stage such as non-destructive examination.

It is necessary to inspect rim plates and shrink keys at the detailed design stage and decide whether re-stacking is needed or not.

iii. Thrust and Guide Bearing

The thrust and guide bearing are in good condition.

iv. Brakes and Jacks

Brake and jack are required to be replaced newly.

v. Generator Cooling System

The following parts should be replaced:

Air coolers, all RTDs, and piping material inside of air housing.

vi. Generator Brush Assembly and Collector Rings

The static excitation system is recommended instead of the existing rotating excitation system, the generator brush and collector rings should be replaced with new ones, including the upper shaft.

In case these parts will remain in their existing positions to keep the generator flywheel effect, the collector ring and brush holder should be replaced.

vii. Generator Main Leads

Most of the parts can be used with some rehabilitation such as re-insulation or improvement of contact conditions. Flexible connectors should be replaced.

viii. Excitation System

As the existing system is rather obsolete system, this should be replaced with static digital excitation system.

ix. Generator Main Bus (Isolated Phase Bus)

Some tests such as insulation resistance measurement and bus resistance measurement, or other systemic tests, are necessary but they seem to be reused.

2) Units 5 and 6

Although the F/S report mentioned another idea, all parts for these units, except the main-bus (IPB), are recommended to be replaced, with the reasons mentioned above in Section 3.2.3 and with the reasons such as;

- Major short circuit happened and design of upper guide bearing need to be changed.
- Unit 5 is operating with only limited output.
- Both coils for Units 5 and 6 were damaged and replaced with non-original manufacturer's coil.

3) Units 7 and 8

Most of the comments for these units are the same as the F/S report.

i. Stator

Winding : As this will soon reach the typical life expectancy, windings should be replaced. But priority is not so high.

Core : Core should be replaced due to the same reason as mentioned above.

Frame : All frames should be replaced.

ii. Rotor

Field poles and field windings are still in good condition, so they can be reused after re-insulation.

It is possible to reuse most of the other parts.

iii. Thrust and Guide Bearings

Thrust and guide bearings are in good condition.

iv. Brakes and Jacks

Brake and jack are required to be replaced newly

v. Generator Cooling System

The following parts should be replaced:

Air coolers, all RTDs, and piping material inside of air housing.

vi. Generator Brush Assembly and Collector Rings

Brush holder, although apparently in good condition, are old finger-type brush holders and should be replaced with new ones.

Most of other parts can be used with some rehabilitation.

vii. Generator Main Leads

Most of the parts can be used with some rehabilitation such as re-insulation or improvement of contact conditions.

Flexible connectors should be inspected and replaced, if necessary.

viii. Excitation System

It may be possible to reuse, but for highest reliability the voltage regulator should be the digital type to eliminate analog component drift.

ix. Generator Main Bus (Isolated Phase Bus)

Some tests such as insulation resistance measurement, bus resistance measurement, or other systemic tests, are necessary but they seem to be reused.

4) Units 9 and 10

Most of the comments for these units are same as the F/S report.

i. Stator

To assure reliable operation for the next 40 years, the stator winding needs to be replaced in next 10 to 15 years.

ii. Rotor

Most of the parts are possible to reuse.

iii. Thrust and Guide Bearing

The thrust and guide bearing are in good condition.

iv. Brakes and jacks

Brake and jack are required to be replaced newly.

v. Generator Cooling System

For every cooler, one RTD for measuring the inlet air temperature and one RTD to measure the exhaust air temperature should be installed.

The following parts should be replaced;

Air coolers and piping material inside of air housing.

vi. Generator Brush Assembly and Collector Rings

All the parts can be reused.

vii. Generator Main Leads

The generator main leads are suitable to reuse.

viii. Excitation System

According to the Mangla operation staff, as mentioned in Sub-clause 4.2;

AVRs of Units 9 and 10 are more sensitive and any variation in this system trips the units, e.g., whenever load demand decreased, there is an option to shut down any unit, Units 9 and 10 are preferred to be shut down first. Due to problematic AVRs these units were started for peaking and shut down afterwards. Therefore, the number of start/stop for these units is rather high than any other units.

Therefore, this system is recommended to be replaced.

ix. Generator Main Bus (Isolated Phase Bus)

The generator main bus is suitable for reuse.

5.2.2 Study on Enhancement of Generator

(1) Units 1 to 4

The replacement of stator coils is recommended as mentioned above in Section 5.1 whether enhancement is considered or not. Aside from the stator coil, other parts required to be replaced are given below. More parts other than just rehabilitation are added here, which are required to be replaced due to increase in weight of the generator.

i. Stator

All parts such as winding (coil) and core should be replaced.

Necessary action

Stator foundation should be inspected. There are some small cracks on the concrete below the stator.

Foundation bolts should also be inspected.

If the load in the vertical and horizontal directions is increased by around 30% after enhancement, it seems to be fine because the original foundation design has more than 50% margin.

ii. Rotor

Only the rotor spider and rim plates can be used and other parts such as poles and field winding should be replaced due to the increase in current.

The deterioration of field winding are expected as same conditions as the stator winding. Therefore these parts are recommended to be replaced, as stator winding is judged to be replaced.

iii. Brakes and Jacks

Brake and jack are required to be replaced newly.

iv. Generator Cooling System

The following parts should be replaced: air coolers, all RTDs, and piping material inside of air housing.

v. Generator Brush Assembly and Collector Rings

According to the capacity increase, the excitation system will also be upgraded, and static excitation system is recommended. Furthermore, a new upper shaft with collector rings should be provided.

In case the existing DC exciter will remain in its position to keep the generator flywheel effect, the collector ring and brush holder should be replaced.

vi. Generator Main Leads

According to the capacity increase, the main leads must also be upgraded, therefore replacement is necessary.

vii. Excitation System

According to the capacity increase, the excitation system must be upgraded, and static excitation system is recommended. Furthermore, a new upper shaft with collector rings should be provided.

viii. Generator Main Bus (Isolated Phase Bus)

According to the capacity increase, the current rating must be increased, therefore this should be replaced with upgraded IPB.

ix. Guide and Thrust Bearing

According to the weight increase, the guide bearing, thrust bearing, and thrust runner (which is mounted on the rotor) should be replaced.

Thrust bearings were not replaced these more than 40 years from the commissioning of these units, and then they must be deteriorated. Thrust bearing is the most important mechanical parts, which support the rotating parts of not only generator rotating parts but also turbine rotating parts. If these parts will be damaged, a serious accident of turbine/generator will be expected. This accident may extend another parts damage and cause very long term unit stoppage for repair. This is the reason that these bearings are recommended to be replaced.

(2) Units 5 and 6

The Survey Team recommended the replacement of all parts for Units 5 and 6 due to the reasons mentioned above in Sub-section 3.2.3 and the following:

- Major short circuit happened and design of the upper guide bearing needs to be changed.
- Unit 5 is operating with only limited output.
- Both coils for Units 5 and 6 were damaged and replaced with non-original manufacturer's coil.

It is further recommended that design of the guide bearing should be changed to reduce oil splashes.

(3) Units 7 and 8

Same as Units 1 to 4, when these units are required to be upgraded.

(4) Units 9 and 10

Same as Units 5 and 6, when these units are required to be upgraded.

5.2.3 Study on Enhancement of Auxiliary Equipment for Generator

According to the enhancement of the generator output, the IPB and generator transformer should be checked as below:

(1) IPB

The current rating of each IPB is 6,287A for Units 1 to 6, 6000 A for Units 7 and 8, 6300 A for Units 9 and 10. On the other hand, the current rating, after enhancement up to 180 MVA of generator capacity, should be 7873 A. Therefore, the existing IPBs of the object units of enhancement do not have enough current rating, and they need to be replaced.

(2) Generator Transformer

The rated capacity of existing generator transformers are 138 MVA for Units 1, 2 and 4 to 6, and 144 MVA for Units 3 and 7 to 10. Therefore, after enhancement to 180 MVA of generator capacity, all the transformers of object units of enhancement need to be replaced.

5.3 Control and Protection

5.3.1 General

(1) The facilities aimed for rehabilitation and enhancement through the Project include:

i. Control and protection system for upgrading units; and

ii. Control systems significantly requiring improvement.

(2) Selection criteria of aimed facilities

i. Upgrading of units will replace the governors, automatic voltage regulator (AVRs), and associated auxiliary equipment with turbines, generators, and step-up transformers. New control, protection, and interface circuits among them should be installed.

ii. The following modifications shall improve the operation performance and stabilities for the

Mangla Power Station:

- Units 3 and 4 will be connected to 132 kV bus for reduction of overloading of interconnection transformers (132/220 KV).
- Modification of 11 kV station service circuit for station service restoration.

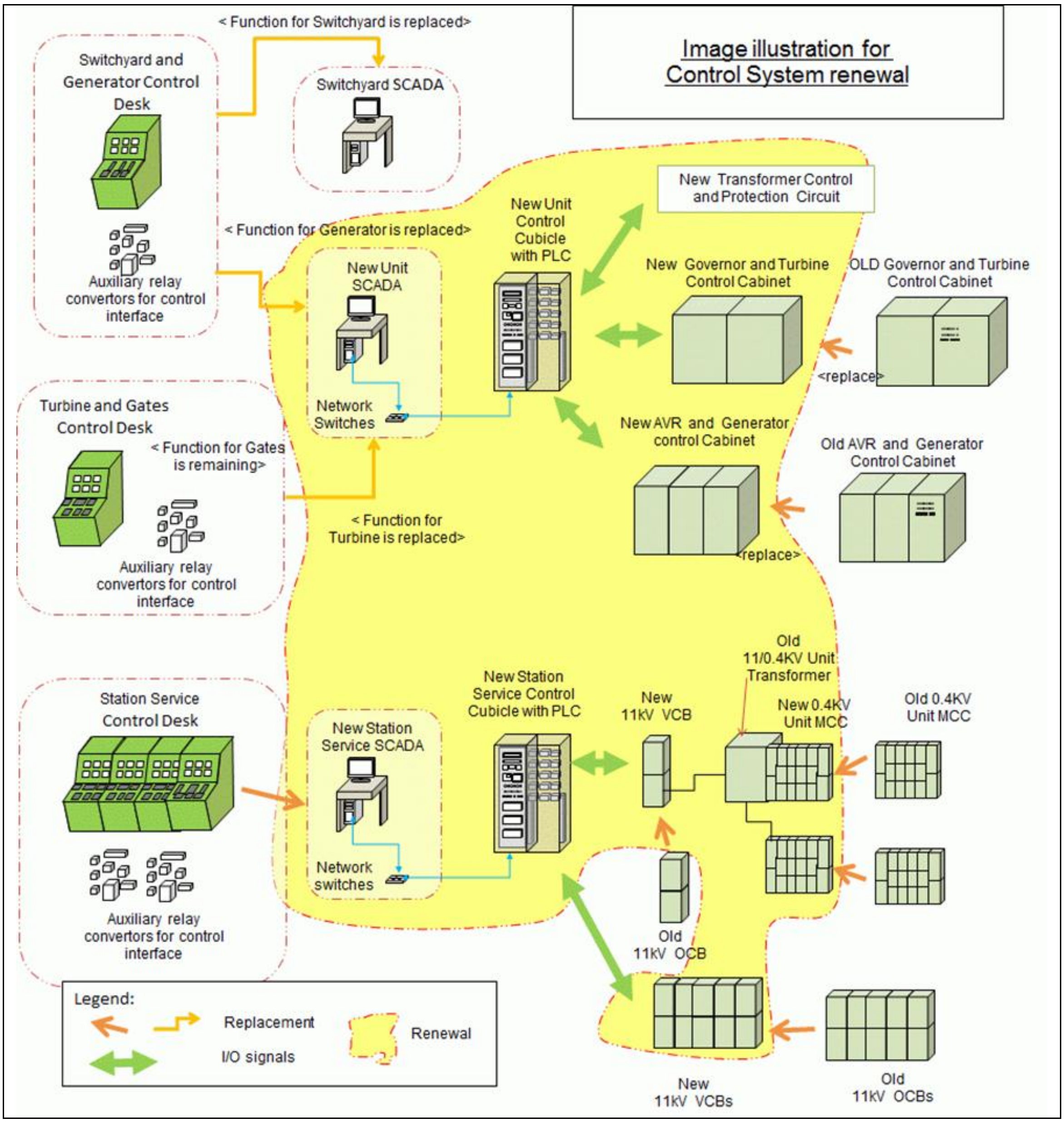
(3) Countermeasure against aged facilities

Not only units for upgrading but also almost all facilities in the power station are aged.

Remaining facilities will be subjected to replacement or rehabilitation works, but such works require long-time unit stoppages, which affect the power conveyance under the power shortage.

However, through good maintenance of the power station, such facilities can be kept in operating condition for the time being. Therefore, it is preferable that the control and protection system rehabilitation will be done parallel with the main units programmed for repair or overhaul by other projects.

Illustration of the replacement or modification of the control system is shown in Figure 5-2.



Source: Prepared by the Survey Team

Figure 5-2 Image Illustration for Control System Renewal

5.3.2 Control and Protection for Generation Units

(1) Components of Control System

The Survey Team recommended that the control system will be replaced from the conventional wired logic circuit with programmable logic controller (PLC) and supervisory control and data accusation system (SCADA), which is the same option as in the F/S. The system will be configured by the following components. A sample of the four generation units control system is shown in Figure 5-3.

1) Unit Local Control Panel (Cubicle)

The PLCs will be equipped in the unit local control panels. This panel performs to control the turbines and generators automatically through the governor /turbine control cabinets, and AVR/generators cabinets. The PLCs are linked to SCADA in the control room for remote control. All of the field data are collected to the PLCs, then the PLCs will send the collected data to SCADA through a network.

2) Programmable Logic Controller (PLC)

The PLC performs the functions instead of the conventional wired logic sequence control circuit, and additionally, will implement the automatic units control functions.

3) Touch Panel

Local control panels will have touch panels, which perform the human machine interfaces instead of conventional indicators and switches. The touch panel will show the status of units and measurement values on the LCD.

The PLC is an electronic device; normally capacities of the voltage or breaking current for field devices are not enough to control directly, and some of field sensors' signals also cannot match PLCs' input. Therefore, some of interface circuits will be installed between the PLCs and such field equipment. Such interfacing circuit is called an interposing circuit in this report. This circuit will be equipped in specified panels beside the PLCs, which are called in this report as interposing relay panels.

4) Units SCADA (Supervisory Control and Data Accusation system)

This SCADA consists of PLC SCADA servers (data server), human machine interface (HMIs), engineering work station, and network switches. It is not a SCADA system for grid system control. It controls and supervises the turbine and generator from the control room instead of actual conventional turbine control desks, and generator and switchyard control desks. The SCADA system is based on the PCs (personal computers).

5) HMI

This is a human interface device between the operator and SCADA control system. The HMIs' screen (LCD) shows the status and condition of turbines, generators, step-up transformers, and such associated auxiliary equipment. The HMI receives the operator's control command for the turbine and generator via a keyboard or a mouse. It is prepared for each generation unit.

6) PLC SCADA Server (PC)

This is a data server between the HMIs and PLCs. The operator's commands are written in the database, and this database is read by the PLC. Collected status and measured value by the PLC is transferred to the PLC SCADA server, written in the database, and read by the HMIs.

7) Historical Event Recorder Function

This function chronologically arranges and shows the occurring events and troubles on the screens (LCD) or printers.

8) Periodical Data Report Function

This function performs to arrange and print the measured data such as energy production, water discharge, voltage, and current per day, week, or month.

9) Engineering Work Station (PC)

This computer is used for SCADA system maintenance. A system administrator can change the system parameters and troubles are analyzed through this computer.

10) Automatic Synchronizer

Actually, two sets of automatic synchronizer are used for ten units. These synchronizers are also old, and the VT signal selection circuit is complicated.

Automatic synchronizer for upgrading units will have an independent automatic synchronizer for each two units. (e.g., Units 1 and 2, Units 3 and 4)

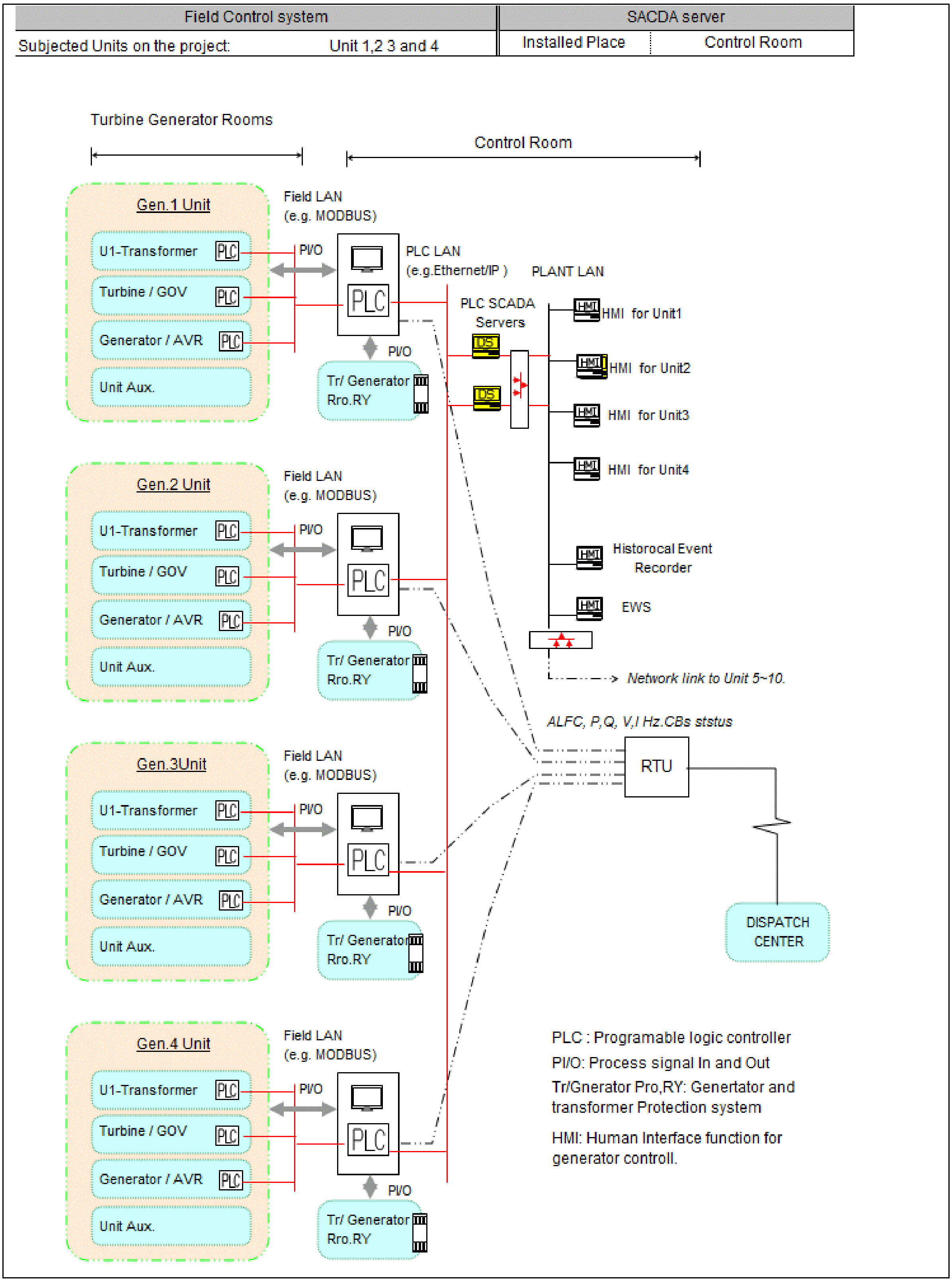
i) This modification can be able to revise and adjust the synchronizing circuits without interruption of the synchronization of another unit.
ii) Circuit breaker closing and generator voltage and speed adjustment parameters can be adjusted per each two units.
iii) The cost of an automatic synchronizer is actually not high.

(2) Protection Relay System

The Survey Team recommended replacing the conventional protection relays with digital relays, which is the same option as in the F/S.

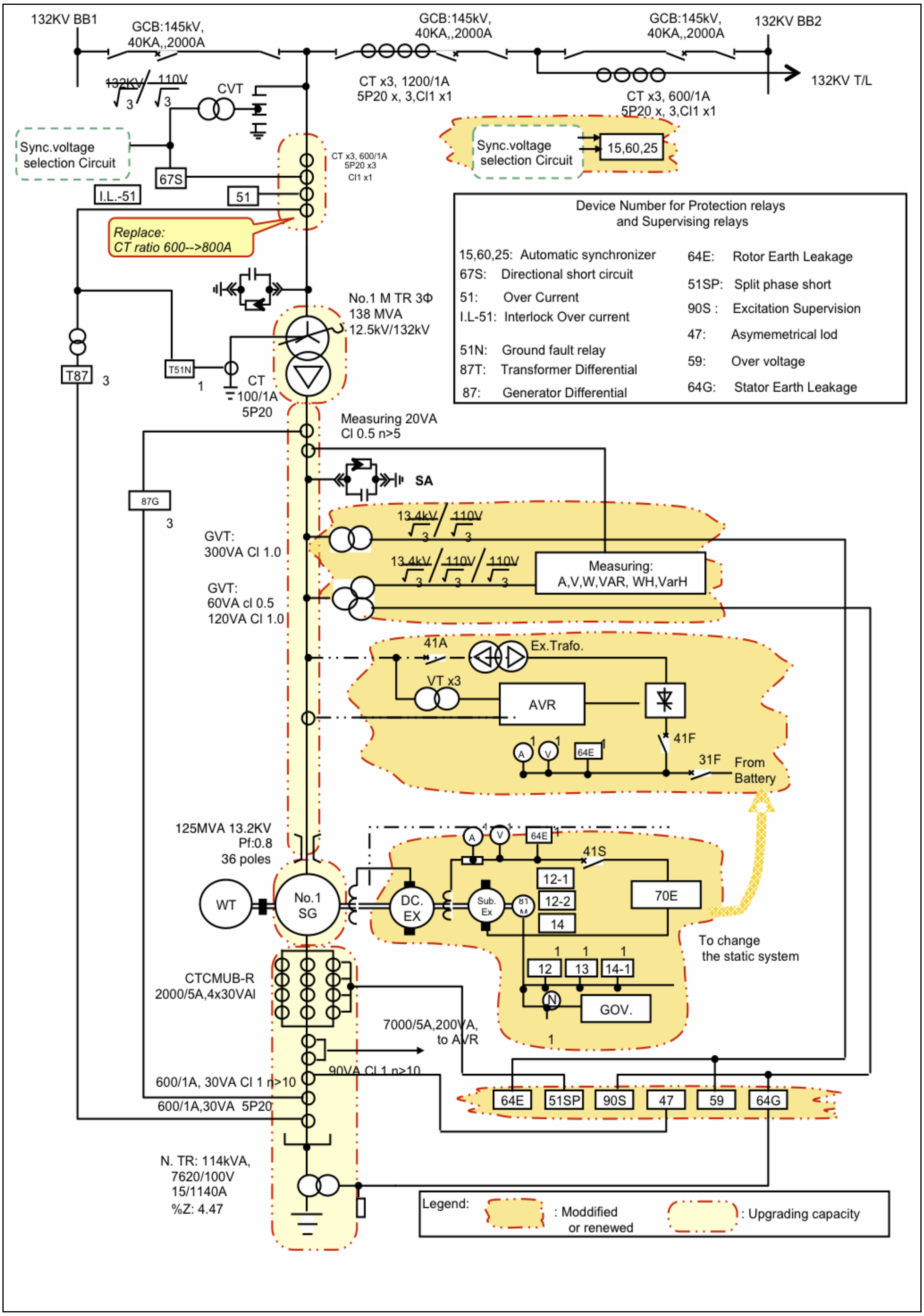
The attached single line diagram, Figure 5-4, shows the modification places and protection relay elements.

The protection relay elements are almost the same as actual system. Some of the additional elements will be added as VT failures.



Source: Prepared by the Survey Team

Figure 5-3 Sample of Four Generation Units Control System with SC



Source: Prepared by the Survey Team

Figure 5-4 Single Line Diagram for Generation Unit with Modification Places

5.3.3 Control and Protection for Switchyard

(1) Opinion of the Survey Team about the Switchyard Control and Protection

The control and protection of transmission lines should be designed with unified philosophy between both ends of stations. Therefore, planning should be a concern of the NTDC/NPCC and opposite side stations. Due to such situation, the Project will modify the related facilities for generation upgrading. The modification of the transmission line protection and control system can almost be done separately from generation unit modification work.

(2) Control

Mainly, the control and protection system consists of conventional wired logic sequence circuits. The indicators, auxiliary relays, and wires are still used from the original installed condition.

The circuit control function will be maintained as the original. The F/S report recommended to replace entirely with a new system, but the Project will not replace to modern circuit as PLC due to reason (1) above.

Intended scope of the Project is shown in Table 5-3.

Table 5-3 Switchyard Control System Work

Circuit	Scope of Refurbish Work
Control and Monitoring for Transmission Lines	Not part of the scope
Control and Monitoring for Generator Feeders	Automatic synchronization for circuit breaker is part of the scope; others are not part of scope. *1
Control and Monitoring for 220 kV/132 kV Interconnection Transformers	Not part of the scope
132 kV/11 kV Station Service Transformers	Not part of the scope, but some circuits will be modified by the Project.

Source: Prepared by the Survey Team

Note *1: Synchronizing relays will be installed per unit for simplification of VT selection circuit.

(3) Protection

Actually, generator feeder line protections are installed with the same protection panels of transmission lines, which are connected with the same bays of feeder lines. The function of the feeder protection (over current and unit differential relays) will be implemented in the new generator unit protection systems. Related circuits of bus protection and breaker failures protections will be exempted from the scope because they are deeply related to other transmission lines and circuits.

Some transmission line protection relays were replaced already with digital protection relays.

Table 5-4 Switchyard Protection System Work

Circuit	Scope of Refurbish Work
Protection for Transmission Lines	Not part of the scope
Protection for Generator Feeders	Not part of the scope, but some circuits will be modified by the Project.
Protection for 220/132 kV Interconnection Transformers	Not part of the scope
132 kV/11 kV Station Service Transformers	Not part of the scope, but some parts will be modified by the Poject.

Source: Prepared by the Survey Team

(4) Resetting Parameters for Actual Protection Relays

The set values and parameters of protections relays as bus protection, CB failures, feeder line protections will be required to change.

The protection relays will not be changed by the Project. The modified circuits and cable relocation are required, which are consequences of the generator feeders' relocation. These will be implemented by the Project.

(5) Relocation of Generator Feeders

The control and protection circuit modification for the generator feeder lines will be required in the generator upgrade. Table 5-5 shows the modification bays. These protection and control systems for the bays are the targets of modification work.

Table 5-5 Modified Bay Comparison

Bay No.	Original Circuit	Feeder CT Ratio	Circuit CBs Rate	New Circuit	Remarks
E1	T/L Spare	-	-	GEN1. Feeder	Remove
E2	GEN1. Feeder	600/1 A	-	GEN2. Feeder	-
E4	STR TR. No.2	-	-	GEN3. Feeder	-
E5	GEN2. Feeder	-	-	GEN4. Feeder	Remove and Standby
D8	GEN3. Feeder	-	-	ICT TR No.3	-
D9	GEN4. Feeder	-	-	STR TR No.3	220/11 kV
D15	ICT TR No.3	-	-	Spare	-

Source: Prepared by the Survey Team

Note: T/L (Transmission Line), GEN (Generator), ICT TR (Inter Connection Transformer), STR TR (Station Service Transformer)

(6) Summary Table of Transmission Line Equipment

In the case of the upgraded generator is 150 MW (PF=0.8), its step-up transformer's capacity will be more than 187 MV control and protection system. The rated current is around 820 ampere (A) at 132 kV circuit, and 410 (A) at 220 kV circuit.

Current transformer (CT) ratios for the system should also be changed.

Consideration for interruptible short circuit currents of the circuit breakers should also be studied against the generator upgrading.

Tables 5-6 and 5-7 below show present facilities for each circuit for reference in the study.

Table 5-6 Summary of 132 kV Transmission Line Circuits

BAY		Circuit Name	CB TYPE	CT Ratio	Main Protection Relay
-E3	1*	ICT No.3	*GCB4	1600-800-400/1 A	
	C*		*GCB4	1600-800-400/1 A	
	2*	No facilities			
-E1	1	DADAYAL	*GCB5	800/1 A	(DZ) GE,SHPM101
	C		*GCB5	800/1 A	
	2	KALLAR SYEDAN	*GCB5	800/1 A	(DZ) GE:SHPM101
-E2	1	DADYAL FUTURE		1600-800-400/1 A	
	C			1600-800-400/1 A	
	2	OLD RATAWA FUTURE		1600-800-400/1 A	
E0	1	CATTAR PARI / MIR PUR	*ACB3	600-300/1 A	(DZ) ABB:REL670
	C		*ACB3	1200/1 A	
	2	KUTHIALAIN SHEKHIAN	*ACB3	600-300/1 A	(DZ),BBC:L3 wyS
E1	1	MANGLA RIGHT BANK	*GCB2	600-300/1 A	(DZ),BBC:L3 wyS
	C		*GCB2	1200/1 A	
	2	RAJAL	*GCB2	600-300/1 A	(DZ),BBC:L3 wyS
E2	1	GEN. No.1	*ACB1 -> *GCB2	600/1 A	
	C		*GCB2	1200/1 A	
	2	G KHAN	*ACB1 -> *GCB2	600-300/1 A	(DZ),BBC:L3 wyS
E3	1	STN TR No.1	*ACB1	50/1 A, 300/1 A	
	C		*GCB2	1200/1 A	
	2	N RAWAT	*GCB2	600-300/1 A	(DZ),BBC:L3 wyS
E4	1	STN TR No.2	*ACB1-> *GCB2	50/1A, 300/1 A	
	C		*ACB3	1200/1 A	
	2	DINGA	*ACB3	600-300/1 A	(DZ),BBC:L3 wyS
E5	1	GEN. No.2	*ACB1 -> *GCB2	600/1 A	
	C		*GCB2	1200/1 A	
	2	KHN 2	*ACB1 -> *GCB2	600-300/1 A	(DZ) ABB:REL670
E6	1	ICT TR No.1	*GCB2	600/1 A	
	C		*GCB2	1200/1 A	
	2	KHN 3	*GCB2	600-300/1 A	(DZ) ABB:REL670

Source: Prepared by the Survey Team

Note 1: BUS-I side circuit, 2: BUS-II side circuit, C: Middle circuit

Table 5-7 Summary of 220 kV Transmission Line Circuits

BAY		Circuit Name	CB TYPE	CT Ratio	Main Protection Relay
D7	1*	ICT TR No.1	*GCB3	400/1 A	
	C*		*GCB3	1500/1 A	
	2*	MANGLA NEW RAWATA 1	*GCB3	1000-500/1 A	(DZ) BBC:LZ31-20
D8	1	GEN. No. 3	*GCB3	400/1 A	
	C		*GCB3	1500/1 A	
	2	MANGLA NEW RAWATA 2	*GCB3	1000-500/1 A	(DZ) BBC:LZ31-20
D9	1	GEN. No. 4	*GCB3	400/1 A	
	C		*GCB3	1500/1 A	
	2	KSK 2	*GCB3	1000-500/1 A	(DZ) SIE:7SA 5131
D10	1	GEN. No. 5	*ACB3	400/1 A	
	C		*ACB3	1500/1 A	
	2	KSK 1	*ACB3	1000-500/1 A	(DZ) SIE:7SA 5131
D11	1	GEN. No. 6	*ACB3	400/1 A	
	C		*ACB3	1500/1 A	
	2	KSK 3	*ACB3	1000-500/1 A	(DZ) BBC: LZ32
D12	1	GEN. No. 7	*GCB1	400/1 A	
	C		*GCB1	1500/1 A	
	2	GHK 1	*GCB1	1000-500/1 A	(DZ) BBC: LZ32
D13	1	GEN. No. 8	*GCB1	400/1 A	
	C		*GCB1	1500/1 A	
	2	N. GHK	*GCB1	1000-500/1 A	(DZ) BBC: LZ32
D14 ß	1	GEN. No. 9	*GCB1	400/1 A	
	C		*GCB1	1500/1 A	
	2	GEN. No. 10	*GCB1	400/1 A	
D15	1	ICT No.3	*GCB7	2400-1200-600/1 A	
	C		*GCB6	2400-1200-600/1 A	
	2	GHK 2	*GCB6	2400-1200-600/1 A	(DZ) GE: SHNB102

Source: Prepared by the Survey Team

Note: 1: BUS-I side circuit, 2: BUS-II side circuit, C: Middle circuit

Abbreviation:		
SIE: SIEMENSE	BBC: BROWN BOVERI	GE: GENERAL ELECTRIC
(DZ) : Distance relay	GEN: Generator Feeder Line	
ACB: Air blast Circuit Breaker	GCB: Gas Circuit Breaker	
*ACB1: BBC, DHVF-170 nc4d, 145 kV-21.9 kA	*ACB2: ABB, DLF-145 nc2d, 145 kV-30.6 kA	
*ACB3: ABB, DLF-245 nc4, 245 kV-31.5 kA	*GCB1: ABB, HPL245/25B1, 245 kV- 40 kA	
*GCB2: SIEMENSE, 3AP FG, 145 kV-40 kA	*GCB3: SIEMENSE, 3AP F1, 245 kV-50 kA	
*GCB4: ABB, LTB 145 D1/B, 145 kV-40 kA	* GCB5: ABB, HPL 145/2501,145 kV-50 kA	
*GCB6: SPRENCHER ENERGY, HGF-114/1 A, 245 kV-40 kA	*GCB7: NUOVS MAGRINI GALILEO, 245 kV-50 kA	
ACB -> GCB: There is a plan to replace from ACB to GCB.		

(7) Requirement of Modification for Switchyard SCADA

The program or parameter of SCADA should be modified to adapt to the relocated generator feeders and station service transformers' locations. The generator feeders CTs ratios will be changed, and the measuring program will also require modification.

For more effective supervision of the power station, data exchange via LAN will be requested for this SCADA and generating unit SCADAs.

5.3.4 Protection and Control System for Station Service

(1) Circuit Configuration Plan by the Survey Team

Figures 5-5 and 5-6 show the idea of the Survey Team. This plan totally considers the modification generator feeder replacement and station service circuit. It is designed more simply to avoid the complicated interlock and operation procedure of switchgears, in which the increase of components in the circuits will correspondingly increase trouble and complexity.

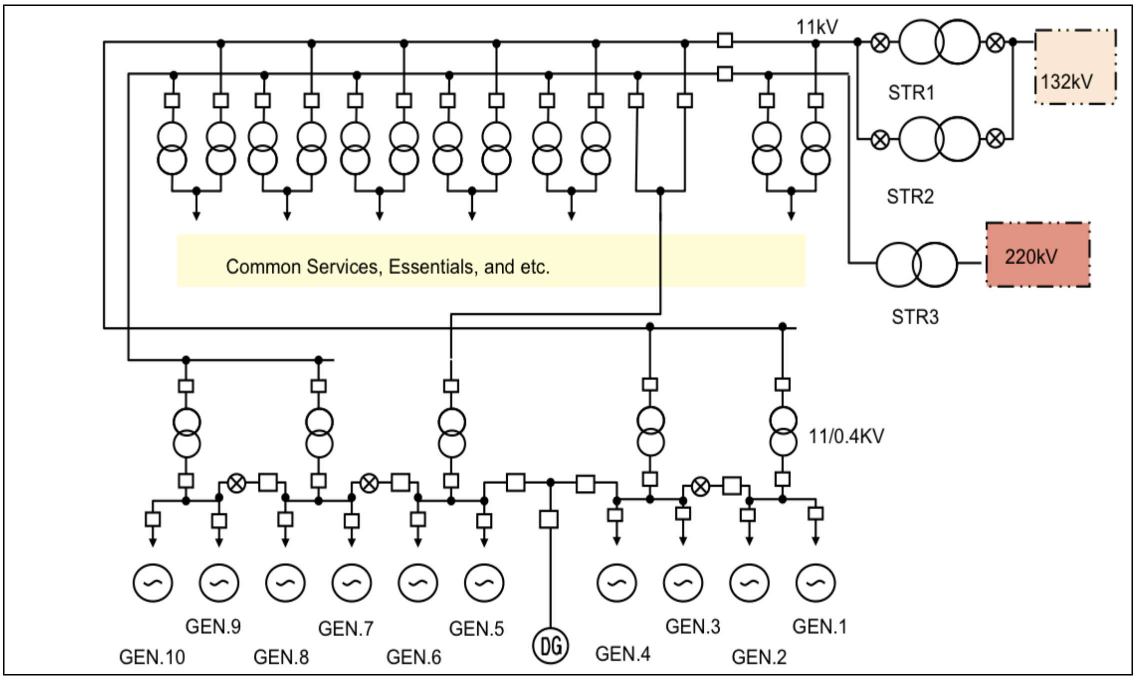
Overall modification requires station service stoppage for a long time. This means prolonged unit stops, thus it is not a realistic solution for the Mangla Power Station. The station service modification work requires unit stoppage for as short time as possible. The Survey Team's concept considers this matter.

Figure 5-7 shows the circuit transition through the modification work.

- Redundancy of power supply:

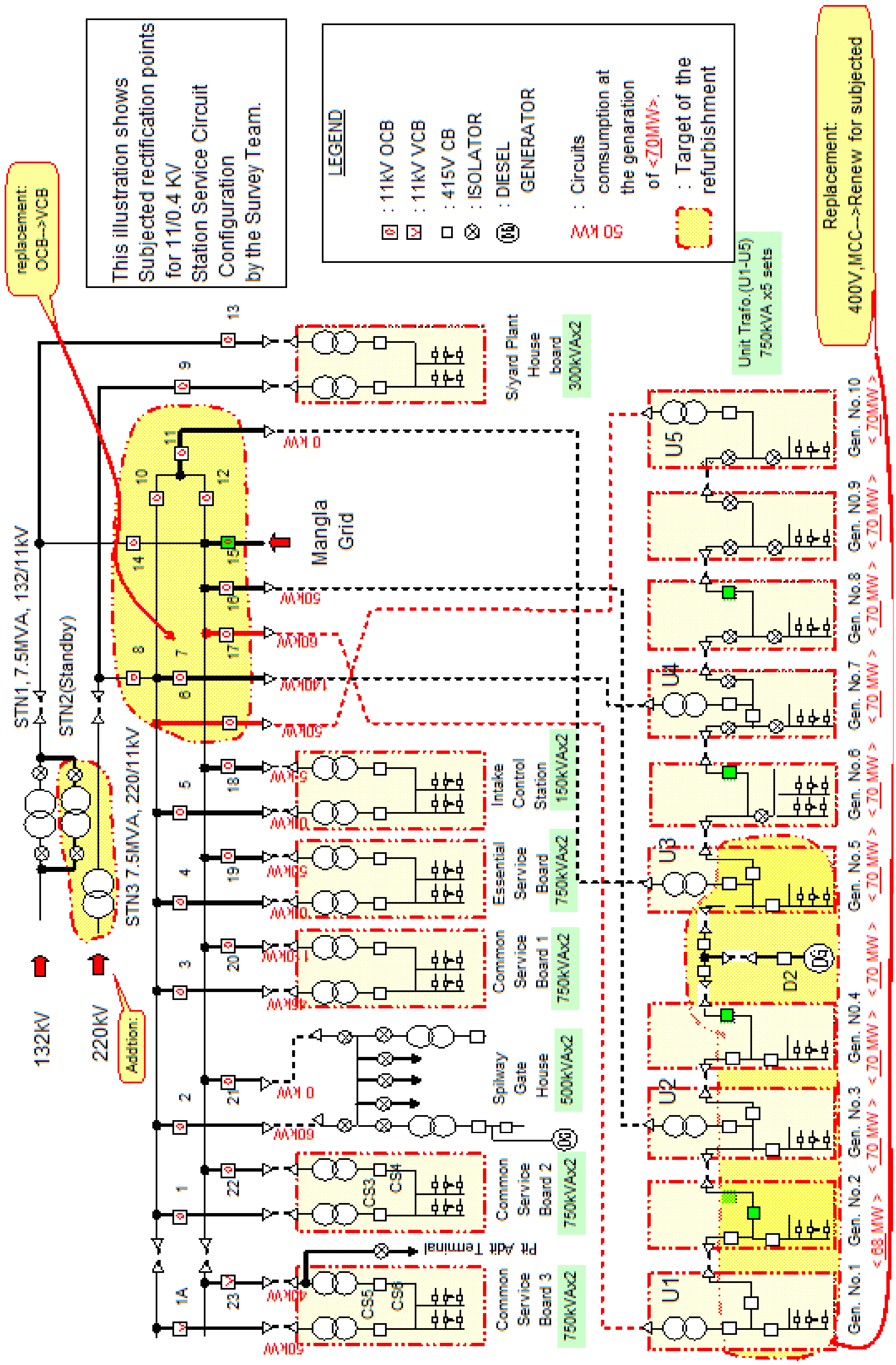
Station service power transformers are connected with 132 kV bus and 220 kV bus. The 220 kV transformer is an additional, while one of the existing 132 kV transformers can be used as standby transformer.

The Survey Team suggest further study on modification of station service power supply circuit at the detailed design (D/D) stage.



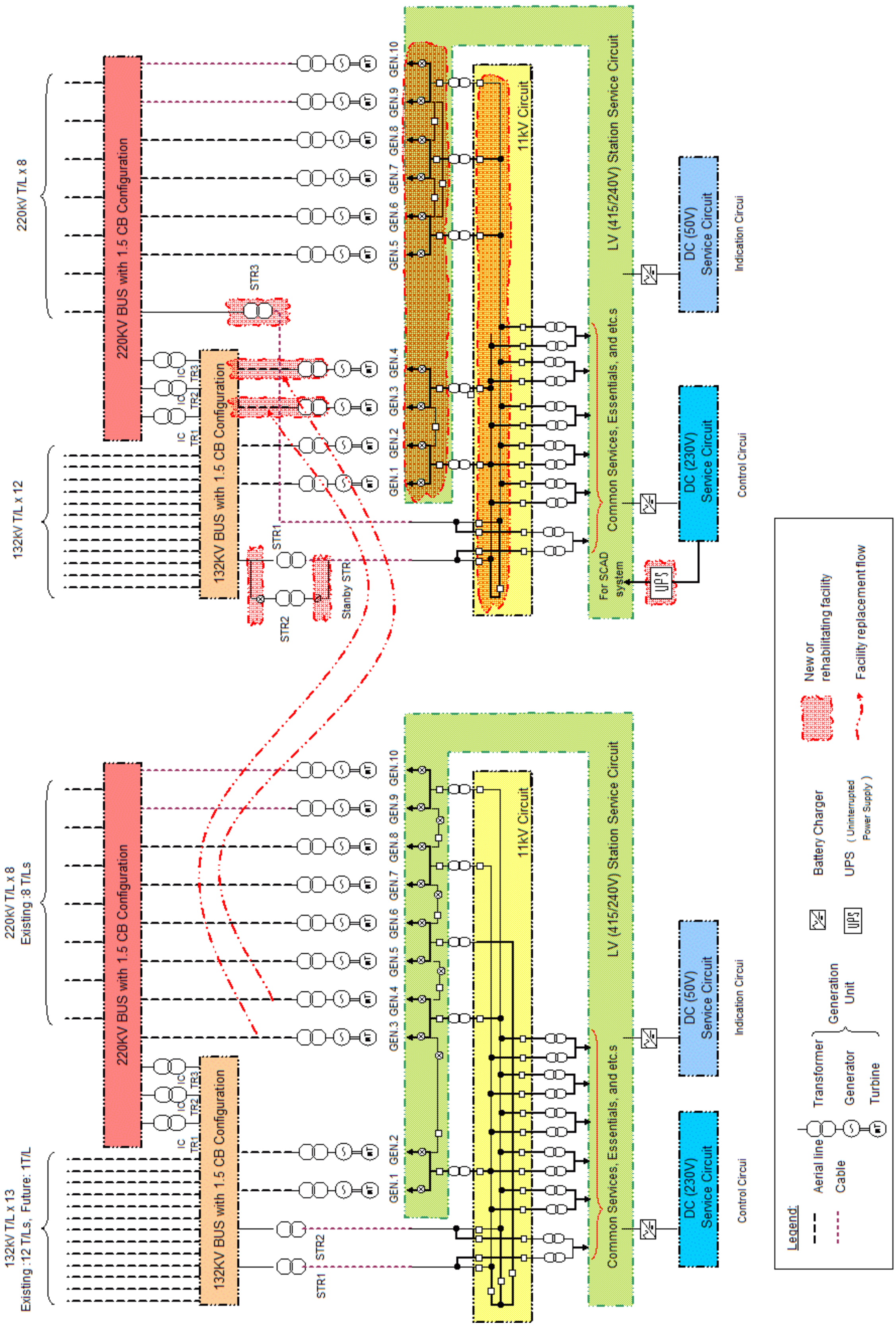
Source: Prepared by the Survey Team

Figure 5-5 Station Service Configuration by the Survey Team



Source : Prepared by the Survey Team

Figure 5-6 Suggested Station Service Circuit by the Survey Team



Source : Prepared by the Survey Team

Figure 5-7 Station Service circuit Transition

(2) Necessity of Low Voltage (415 V) Circuit Modification

The F/S report's alternative plans also required low voltage-side modification.

Particularly for options 3, 4, and 5, it seems that the effective result cannot be obtained without low voltage circuit modification as described in Sub-section 3.2.4.

Low voltage circuit modification requires further study of actual circuits. For example, the connected loads will be classified into the following categories in the table below to adapt each operation scenario such as blackout start, normal start and run.

Table 5-8 Categories of Low Voltage Circuit

Class-A	Equipment must operate before units start.	Condition of blackout start
Class-B	Equipment should operate during unit operation	Condition of unit operation
Class-C	Equipment can allow stoppage of operation in a few hours.	Availability of operation after unit synchronizing

Source: Prepared by the Survey Team

(3) Appurtenant Work

The replacement of low-voltage circuit cables and mold circuit breakers which are installed and connected to "the motor control center cabinets for turbine and generator auxiliary equipment" are also required with the upgrading of such facilities.

(4) Service Circuit Breakers of 11kV Station

Actually, there are a total 26 sets of 11 kV circuits; 24 sets of oil circuit breaker (OCBs) and two sets of vacuum circuit breakers (VCBs) were installed recently. The OCBs are almost outdated, and are recommended to be replaced with VCBs. It is the same recommendation in the F/S.

5.3.5 Control and Protection for 11KV Generator Circuit Breaker

The F/S report recommended the modification plan for the station service circuit as option-5 as described in Sub-section 3.2.4. This plan requires generator circuit breakers installation between the transformer and the generator. Unit supply of 11/0.4 kV transformer branches from the 11 kV side of step-up transformer with the station service 11 kV circuit breaker.

Power supply for generator and turbine auxiliaries is fed from the unit supply transformer after excitation. The Survey Team is against this plan:

Some of auxiliaries such as the cooling water system should be operated before unit starts.

Station drainage system should be continually operated without turbine operation condition.

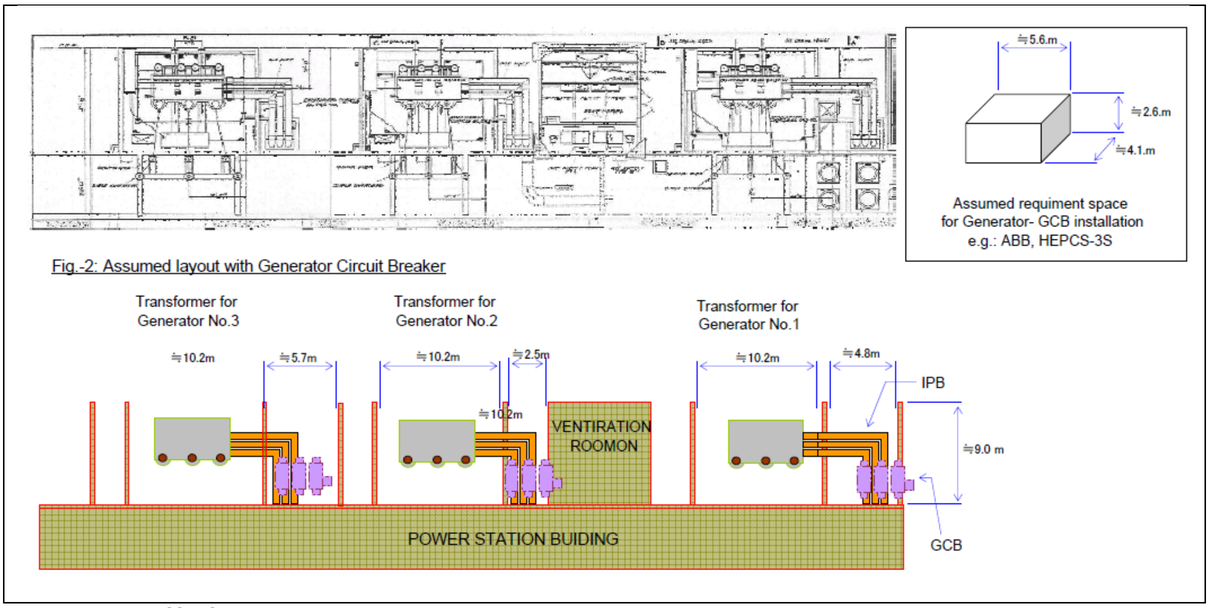
For the installation of generator CB, it requires high cost and large-scale building and IPB modification.

The 11 kV side generator current is around 8000 amperes. The price of generator circuit breaker is very high and there are not so many suppliers in the market.

Finally, some of the essential or common services still require power supply before the start and stoppage of the unit like the cooling water system and drainage system. Other power sources are still required for them. Therefore, such modification cost performance is not as high as anticipated in the F/S report. And it is still remain as the requirement of common and essential power supply.

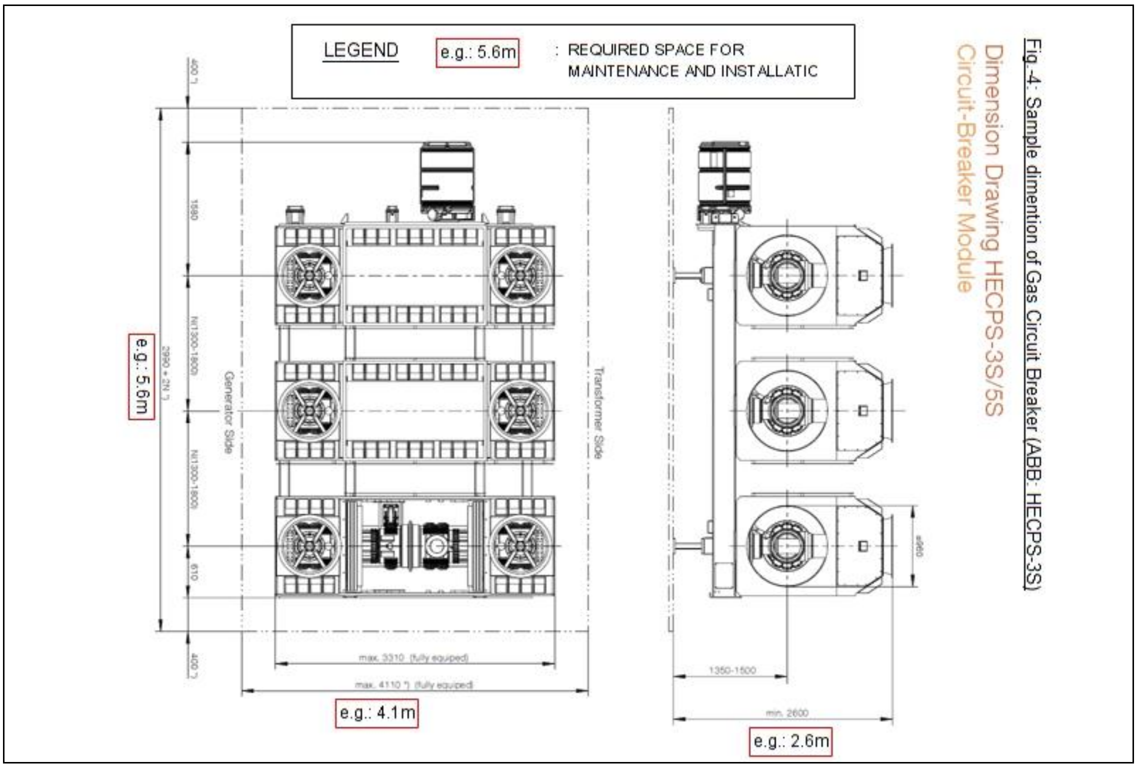
Figures 5-8 and 5-9 show an example of 11 kV generator circuit breaker installation and a sample of circuit breaker size.

The Survey Team suggest further study on modification of 11 kV generator circuit breaker at the detailed design (D/D) stage.



Source: Prepared by the Survey Team

Figure 5-8 Sample Layout for GCB Setting



Source: Prepared by the Survey Team

Figure 5-9 Sample Dimension of GCB

5.4 Switchyard

5.4.1 Study on Rehabilitation and Enhancement of Switchyard

To lessen the power flow from 220 kV to 132 kV in the switchyard, the generators' connections to 132 kV and 220 kV are required to be modified.

In the rehabilitation and enhancement project, the step-up transformers for the subject units shall be replaced by new ones to meet the enhanced capacity of 180 MVA, which is now 138 MVA for Units 1 to 4 and 144 MVA for Units 6 to 10.

Taking the opportunity, the generators connecting to 132 kV are increased to four units from two units at present, namely Gen.1 to Gen. 4 to be connected to 132 kV and the remaining six units remain to be connected to 220 kV. The modification of the step-up transformers is shown in Table 5-9.

The Survey Team recommends conducting the simulation for verifying the stability of new power system in switchyard based on the their recommendation on the above at the detailed design (D/D) stage.

Table 5-9 Proposed Modification of Generator Connection to Switchyard

Existing Capacities are 138 MVA or 144 MVA		
Generator	Step Up Tr.	SWS Bus
Unit 1	12.5/132 kV	132 kV
Unit 2	12.5/132 kV	132 kV
Unit 3	12.5/220 kV	220 kV
Unit 4	↑	↑
Unit 5		
Unit 6		
Unit 7		
Unit 8		
Unit 9	↓	↓
Unit 10	12.5/220 kV	220 kV

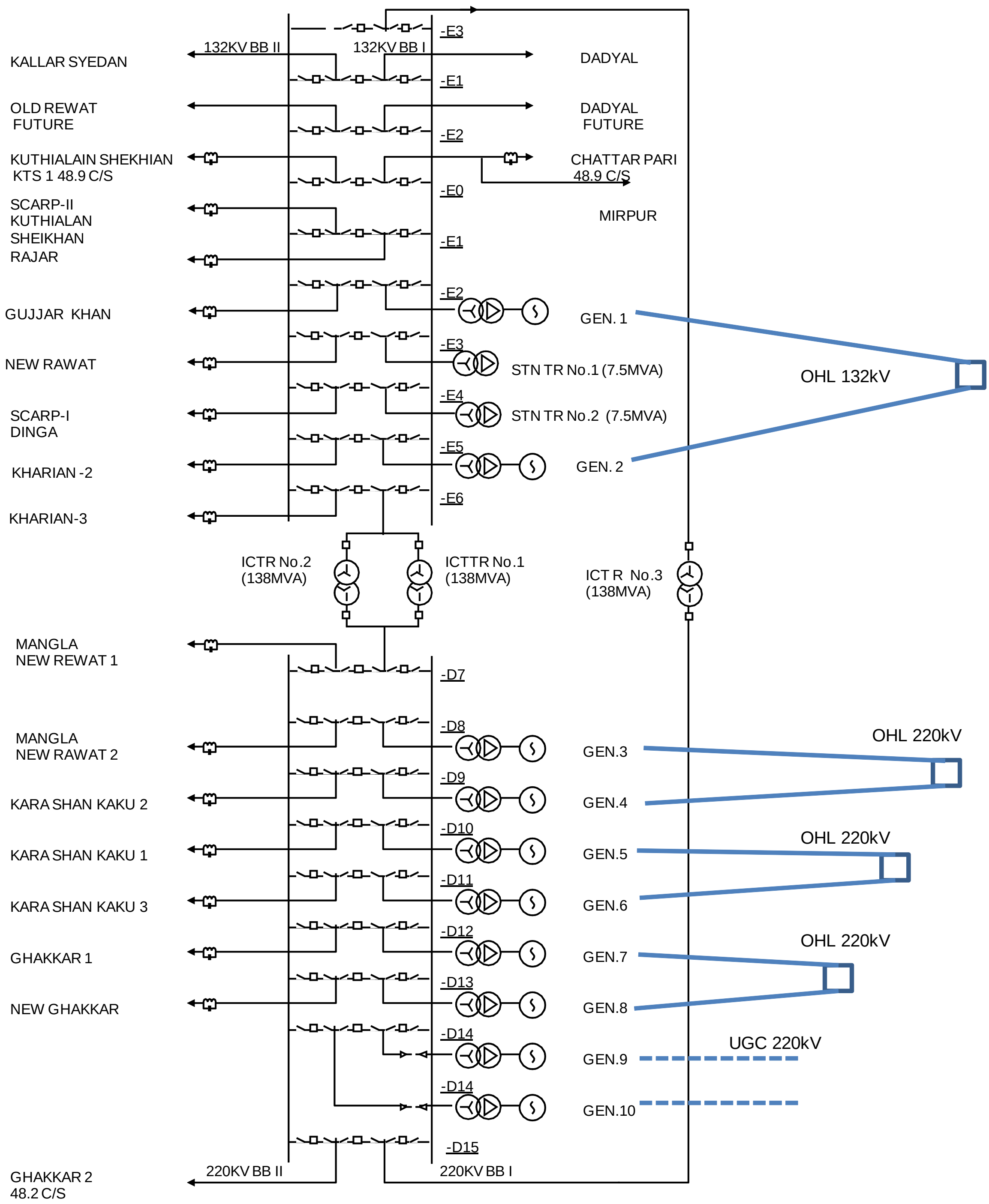
Modified Capacity: 180 MVA		
Generator	Step Up Tr.	SWS Bus
Unit 1	12.5/132 kV	132 kV
Unit 2	12.5/132 kV	132 kV
Unit 3	12.5/132 kV	132 kV
Unit 4	12.5/132 kV	132 kV
Unit 5	12.5/220 kV	220 kV
Unit 6	↑	↑
Unit 7		
Unit 8		
Unit 9	↓	↓
Unit 10	12.5/220 kV	220 kV

Source: Prepared by the Survey Team

Remarks: Rated voltage of generators output is 13.2 kV

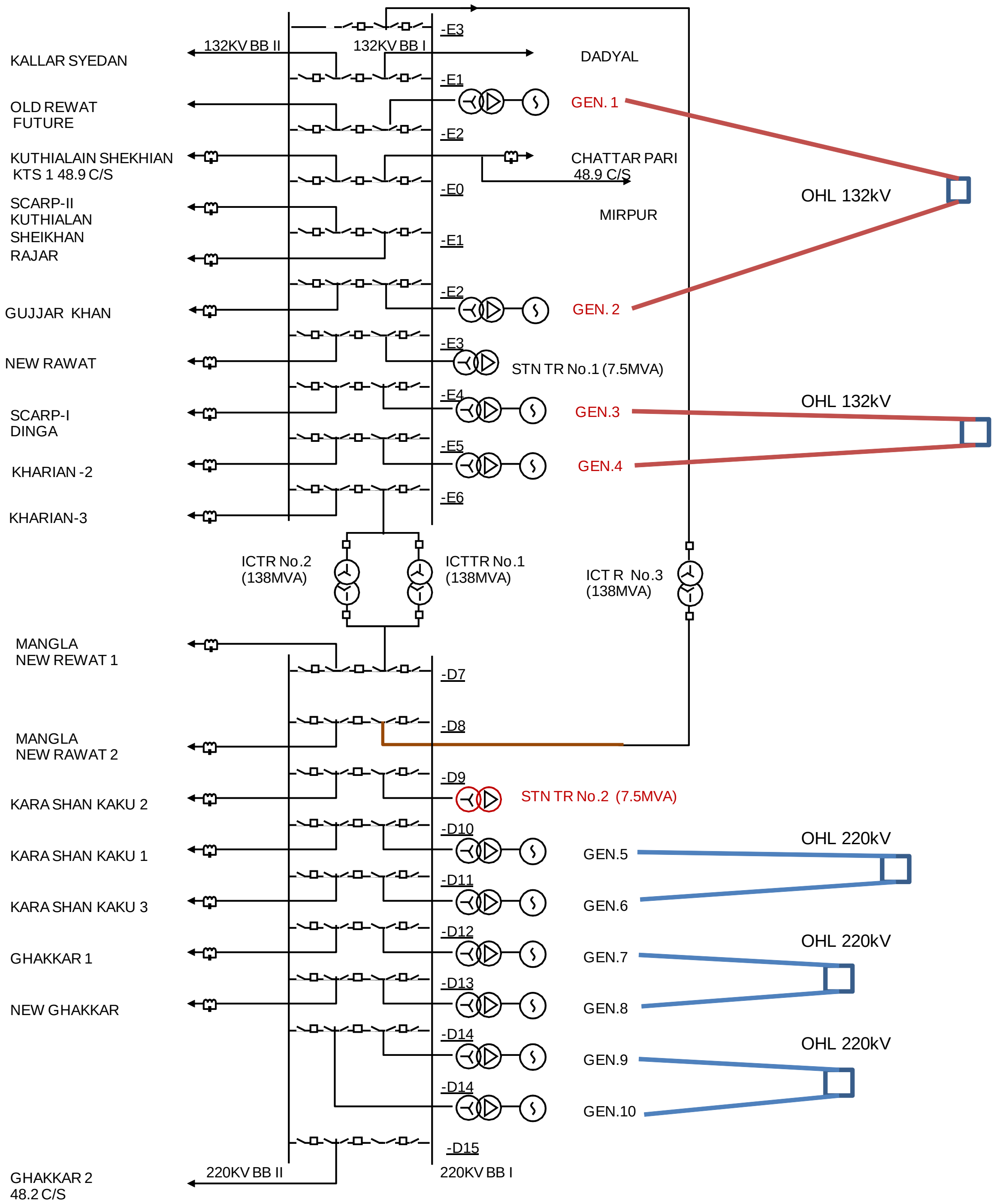
(1) Connection Diagrams for Before and After

The existing and proposed modification of generators' connection to the switchyard is shown in Figures 5-10 and 5-11, respectively.



Source: Prepared by the Survey Team

Figure 5-10 Existing Generator Connection to Switchyard



Source: Prepared by the Survey Team

Figure 5-11 Modified Generator Connection to Switchyard

(2) Procedure

The procedures of modification are as follows:

1) Underground cable connection of Units 9 and 10 generators to switchyard is modified to connect by 220 kV overhead line, which is done by NTDC

2) Rehabilitation and enhancement of Units 5 and 6:
No change in connection

3) Rehabilitation and enhancement of Units 1 and 2
No change in connection

4) Rehabilitation and enhancement of Units 3 and 4:
   - Change the step-up transformers for Units 3 and 4 to the voltage ratio of the 12.5/132 kV from 12.5/220 kV.
   - Connections of transmission lines for Units 1 and 2 are shifted to bay-E1 & E2 from E2 & E5, respectively.
   - Dismount station transformer No.2 7.5 MVA from bay E4
   - Shift the transmission lines for Units 3 and 4 to bay 132 kV E4 & E5 from 220 kV D8 & D9, respectively.
   - Connect a new station transformer No.2 220/11 kV 2.7 MVA to the bay of 220 kV D9
   - Shift the interconnecting transformer No.3 to bay D8 from the bay D15

5) Rehabilitation and enhancement of Units 7 and 8
No change in connection

6) Rehabilitation and enhancement of Units 9 and 10
No change in connection

5.5 Civil Works

5.5.1 Structure Reinforcement and Improvement

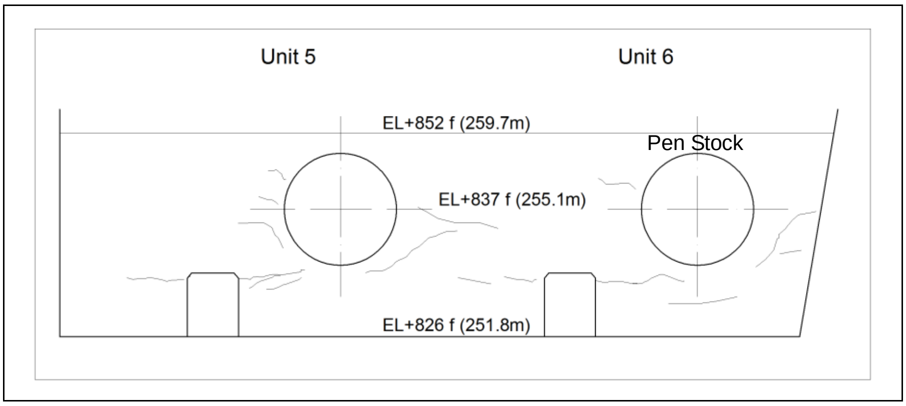
For the turbine and generator foundation, the diagnosis test for concrete strength by Schmidt Hummer was carried out on 27 February 2012 and the result is shown in Table 5-10. In general, a crack with less than 0.3 mm is a hair crack and not harmful to the structure even without any countermeasure.

Table 5-10 Cracks in Power House

Foundation	Average Strength (N/mm^2)	Crack		Countermeasures
		Location	Size	
No.1	48.2	-	0.3 mm >	Epoxy Injection
No.2	50.3	-	0.3 mm >	Epoxy Injection
No.3	44.0	-	0.3 mm >	Epoxy Injection
No.4	48.5	-	0.3 mm >	Epoxy Injection
No.5	51.6	Around Pen Stock	> 5 mm	Epoxy Injection +Carbon Fiber
No.6	52.4	Around Pen Stock	> 5 mm	Epoxy Injection + Carbon Fiber
No.7	50.2	-	0.3 mm >	Epoxy Injection
No.8	51.6	Gallery	0.3 mm >	Epoxy Injection
No.9	48.3	-	0.3 mm >	Epoxy Injection
No.10	50.2	-	0.3 mm >	Epoxy Injection
-	55.4	Crane wall (Up）	0.3 mm >	Epoxy Injection
-	40.4	Crane wall (Down）	0.3 mm >	Epoxy Injection

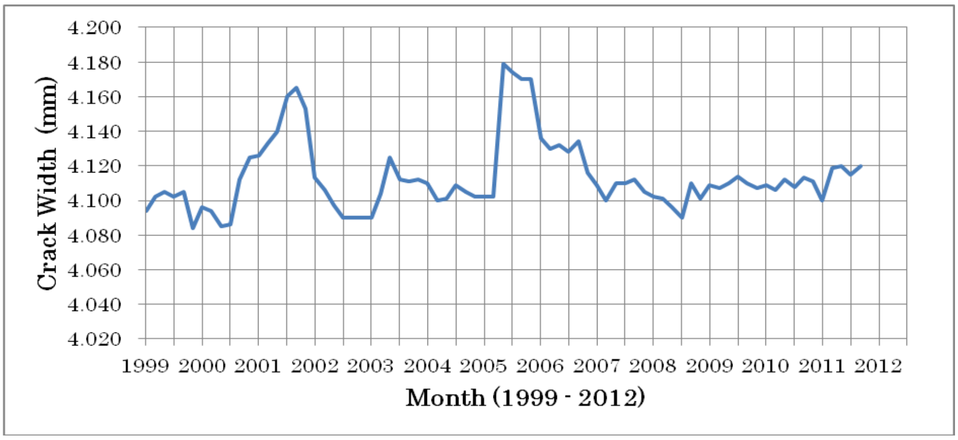
Source: Prepared by the Survey Team

The result of investigation revealed that a crack has occurred around the penstock (see Figure 5-11) with more than 5 mm width slanted at Units 5 and 6, which is necessary for urgently repair with epoxy injection and carbon fiber sheet. Figure 5-12 shows the movement of the crack width at the Unit 5 foundation from 1999 up to 2012. The cracks have not expanded width between 4.08 mm to 4.18 mm. Other cracks are also observed and these are just bigger than hair cracks, which also need epoxy injection to prevent water penetration. WAPDA is consistently observing the crack in order to confirm the movement such as enlargement or slip, however, some observation data are available at the power station but not in all facilities. Actually, the foundation needs to be replaced by new high-strength concrete up to the portion of the crack. Replacement is not possible because there are adjacent equipment such as the turbine and generator. Therefore, reinforcement using epoxy injection and carbon fiber sheet shall be recommended.



Source: Prepared by the Survey Team

Figure 5-12 Cracking Around Units 5 and 6



Source: WAPDA Hydrological Section of Mangla Dam

Figure 5-13 Crack Width at Unit 5 Foundation

In case of improvement and optimization of the generator, the reinforcement/new foundation must consider effects occurring through the acting force in the opposite direction of the generator at the foundation, when it is at emergency stop. Secondly, due to the upgrading of the generating units for optimization, the foundation and oil pit may be changed in size and shape, which the F/S report did not mention.

Accordingly, the reinforcement and improvement works must be considered in order to cater to the aforementioned matters and these need to be incorporated into the cost estimation and implementation schedule.

The Survey Team recommends introducing a three-dimensional (3-D) measurement for grasping the present conditions and analyzing the transition of the existing cracks. These data can be utilized to map out the appropriate countermeasures against the existing cracks and large-sized earthquake in the future.

5.6 Rehabilitation and Enhancement Scenarios

5.6.1 Review of Maximum Output of Turbine and Generator

In the review of the scenarios for rehabilitation and enhancement through the Project, the Survey Team has calculated the maximum turbine output in consideration of the raising of Mangla Dam, as follows:

(1) Reservoir water level after dam raising : EL 1,242 ft (378.8 m)
Tailrace water level : EL 836 ft (255.0 m)

Gross head at maximum output : 123.8 m

(2) Each unit maximum allowable discharge capacity : 4,900 cfs (138.7 m^3/s)

(3) 1) Head loss at intake tunnel for 9,800 cfs : 10.3 ft (3.14 m)

2) Head loss at trashracks for 9,800 cfs : 2.0 ft (0.61 m)

3) Head loss at bi-plane type inlet valve for 4,900 cfs : 1.83 ft (0.56 m)

Note: Head loss in case of butterfly-type inlet valve is 2.76 ft (0.84 m)

(4) Effective head at maximum output

= Gross head – Head losses

= 123.8 m – (3.14+0.61+0.56) m = 119.5 m

The turbine maximum output will be calculated as follows;

P max = 9.8 * Q at P max * H at P max * η T KW

Where Q at P max = 138.7 m^3/s

H at P max = 119.5 m

η T = 93.0% (Estimated turbine efficiency at P max)

<u>Therefore P max = 151.1 MW</u>

Based on the above maximum turbine output, the Survey Team recommended the rehabilitation and enhancement concept of the Project as follows:

(1) Main recommendation by the Survey Team is:

1) Generator's Capacity: Enhancement up to 180 MVA/unit from the existing 125 MVA/unit

2) Output: Enhancement up to 144 MW/unit with 0.8 power factor

(2) Main difference compared with the F/S report is that the Survey Team's idea does not include modification of the existing concrete foundation of turbines and generators.

The basic feature of the turbine and generator (generator output is 144 MW/unit at rated power factor) as existing and after enhancement is shown in Table-5-11.

Table 5-11 Basic Features of Turbines and Generators (generator's output: 144 MW/unit)

-	Rates	Existing A	After Enhancement B	Ratio B/A
Turbine	**Rated output**	**138 kBHP=103MW**	**172.7 kBHP=126.6MW**	**122.9%**
	Rated discharge	4,550cfs=128.8 m^3/s	4,900cfs=138.7m^3/s	107.7%
	Effective head	295f=89.9m	334f=101.9m	113.3%
	Maximum output	198 kBHP=**147.7MW**	**151.1MW**	**102.3%**
	Discharge at maximum output	4,936cfs=139.7m^3/s	138.7 m^3/s	99.3%
	Effective head at maximum output	380f=115.8m	119.5m	103.2%
	Rated speed	166.7 min^{-1}	166.7 min^{-1}	-
Generator	Rated capacity	125MVA	180MVA	144.0%
	Rated power factor	0.80	0.80	-
	Output at rated power factor	**100MW**	**144MW**	144.0%
	Rated voltage	13.2kV	13.2kV	-
	Rated speed	166.7 min^{-1}	166.7 min^{-1}	-
	Overload (Continuous opearation)	115% (**115MW**)	No overload capacity (**144MW**)	**125.2%**

Source: Prepared by the Survey Team

5.6.2 Priority of Rehabilitation and Enhancement

(1) Priority of Turbine Rehabilitation

Considering the duration of the unit operation and numbers of repair for the turbine runner and associated equipment present conditions, the replacement or rehabilitation is recommended as shown in the following Table 5-12.

i Units 1 to 4

The operating duration is more than 45 years. The life of a turbine is 40 to 45 years in accordance with the Japan Electrical Association's recommendation. Repair welding is limited to three times as advised in the same recommendation. Considering these limits, major parts of turbines shall be replaced with new ones, except embedded parts. Rehabilitation of embedded parts shall also be done together with replacement of rotating parts.

ii Units 5 and 6

Although the operating duration after replacement of turbine runner is not so long, the design of the turbine may be not adequate for further long time operation. Therefore, replacement of major parts of the turbine to new technology design runner is recommended.

iii Units 7 and 8

While the numbers of the repair welding are more than three times, it is less than 1/2 times of Units 1 to 4. Thus, other long duration operation might be possible same as Units 1 to 4. However, continuous careful repair of the runner is required until the end of the turbine life.

iv Units 9 and 10

Same as above Units 7 and 8.

Table 5-12 Priority of Rehabilitation of Turbine

Unit	Inlet Valve	Runner	Governor	Other Equipment
1 to 4	Leakage water from valve packing to turbine is extremely high and leakage water at pipe connection is also very high. Prior to rehabilitation of turbine, rehabilitation or replacement of inlet valve shall be done.	Repair welding of each runner is done every 2 or 3 years after starting operation. The repair welding in Japan is limited for 3 times to prevent breakage. Total number of re-welding is more than 10 times and preferable to replace to a new runner.	Mechanical type governor is operating and the manufacturing of this type had been suspended long time ago. Therefore, spare parts supply is not available together with maintenance engineers. So, replacement of the governor system is required.	The wired damages and rust shall be repaired and overhaul of the irrigation valve is required for further long time operation. Measuring instrument and electrical wiring shall be replaced for getting maintenance data in the new control system.
5 and 6	Same as above	For getting good characteristics turbine, replacement of turbine major parts is required.	Same as left	Same as above
7 and 8	Still good condition	Still good condition	Still good condition	Still good condition
9 and 10	Still good condition	Still good condition	Still good condition	Still good condition

Source: Prepared by the Survey Team

From the above table, rehabilitation or replacement of inlet valve, runner, governor, and irrigation valve for Units 1 to 6 is urgently required.

(2) Priority of Generator Rehabilitation

The following Table 5-13 is the summary of the generator's current condition from the study of rehabilitation in Sub-section 5.2.1, and shows the priority of rehabilitation.

Table 5-13 Priority of Rehabilitation of Generator

Unit No.	Analysis by N-Y Map	Analysis by Insulation Resistance Measurement	Analysis by Past Fault/Incident	Judgment
1 to 4	Stator winding is already beyond the typical life expectancy	Still Good	-	Urgent rehabilitation is necessary
5 and 6	Fault/incident of the winding occurred some times (As some windings have been replaced, analysis by N-Y map cannot be conducted)	Still Good	Fault/incident occurred frequently in the past.	Urgent rehabilitation is necessary
7 and 8	Stator winding is in the last stage of life, but priority is not so high	Still Good	-	Rehabilitation is necessary, but priority is not so high
9 and 10	Stator winding is quite new, as compared to other units	Still Good	-	Rehabilitation is necessary, but priority is not so high

Source: Prepared by the Survey Team

From the above table, rehabilitation for Units 1 to 6 is urgently required. For Units 7 and 8, rehabilitation is also required although it is of second priority, and Units 9 and 10 is of last priority.

5.6.3 Rehabilitation and Enhancement Scenarios Recommended by the Survey Team

In consideration of Tables 5-12 and 5-13, the Survey Team recommended the following two scenarios for rehabilitation and enhancement of generators to increase their capability up to 144 MW per unit at PF 0.8 (rated capacity is 180 MVA).

Scenario A: Rehabilitation and Enhancement for Units 1 to 4

Scenario B: Rehabilitation and Enhancement for Units 1 to 6

The comparison table of the above scenarios are shown in Table 5-14.

Table 5-14 Rehabilitation and Enhancement Scenarios (144MW/unit)

Scenarios	Against Rated Capacity			Against Overload Capacity		
	Existing	After Enhancement	Incremental Generating Power	Existing	After Enhancement	Incremental Generating Power
A	1,000MW in total	Enhancement to 1,176 MW in total Units 1-4: 144MW Units 5-10: 100MW (no change)	176MW (+17.6%)	1,150MW in total	Enhancement to 1,266 MW in total Units 1-4: 144MW Units 5-10: 115MW (no change)	116MW (+10.1%)
B		Enhancement to 1,264 MW in total Units 1-6: 144MW Units 7-10: 100MW (no change)	264MW (+26.4%)		Enhancement to 1,324 MW in total Units 1-6: 144MW Units 7-10: 115MW (no change)	174MW (+15.1%)

Source: Prepared by the Survey Team

5.6.4 Expected Increased Amount of Power Generation

The Survey Team has calculated the annual power generation which is expected to be increased by the implementation of the Project.

(1) Future Forecast of Water Balance at Mangla Dam

The future forecast of water balance at Mangla dam in the period from the year of 2012 to 2053 for 42 years was calculated as shown in Table 5-15 based on the past hydrology data of Mangla dam including inflow, outflow and sedimentation etc. from the year of 1968.

Table 5-15 Future Forecast of Water Balance

Year	Inflow (MAF)	Outflow (MAF)	Spillage (MAF)	Year	Inflow (MAF)	Outflow (MAF)	Spillage (MAF)
2012	25.26	23.30	0.98	2035	31.94	25.03	7.22
2017	28.20	25.29	3.34	2036	31.43	24.83	5.75
2019	23.92	20.99	0.08	2037	24.10	22.85	2.44
2020	25.56	22.58	2.84	2038	24.86	22.96	1.32
2022	24.60	22.45	1.60	2039	26.83	23.74	3.27
2024	22.68	21.93	0.10	2040	31.05	24.42	6.12
2025	23.40	22.98	1.14	2042	23.96	23.21	2.31
2027	27.64	24.11	3.27	2047	27.17	22.84	3.32
2030	27.12	22.20	1.33	2049	31.02	24.99	5.75
2031	28.02	23.41	4.65	2050	26.65	24.05	1.44
2032	24.75	22.57	3.23	2051	23.73	23.17	2.39
2033	21.78	21.05	0.91	2053	24.28	23.55	1.26
2034	25.98	22.99	2.78	**Average**	**22.74**	**21.05**	**1.64**

Source: Prepared by the Survey Team

(2) Annual Power Generation of the Existing Power Plant

The annual power generation of the existing power plant in Mangla Power Station in the period from 2001 to 2010 for the past ten (10) years is shown in the following table. The average annual power generation for the pat 10 years is calculated to be 5,000.1 [GWh].

Table 5-16 Annual Power Generation of Existing Power Plant

Year	Annual Power Generation [GWh]
2001	3,398.9
2002	5,363.2
2003	5,058.9
2004	4,218.5
2005	5,445.9
2006	6,150.9
2007	4,687.3
2008	4,797.4
2009	4,772.4
2010	6,107.6
Average Annual Power Generation	**5,000.1**
Average Plant Factor [%]	**49.6**

Source: Prepared by the Survey Team

(3) Annual Power Generation for Scenario A (for 4 units)

The annual power generation after the implementation of Scenario A, which will be enhanced up to 1,266 MW in total from the existing 1,150 MW, in the period from 2012 to 2053 for 42 years is shown in the following table. The average annual power generation is calculated to be 6,585.9 GWh which is added 1,585.8 GWh from 5,000.1 GWh of the existing plant. The said incremental energy is expected to cover about 892,000 households in accordance with the calculation using the figure of the average electricity consumption of domestic in Table 9-18, Chapter 9.

Table 5-17 Annual Power Generation after Implementation of Scenario A (144MW/unit)

Year	Annual Power Generation [GWh]	Year	Annual Power Generation [GWh]	Year	Annual Power Generation [GWh]
2012	5,548.2	2026	6,241.9	2040	7,691.5
2013	7,389.8	2027	7,629.9	2041	6,330.6
2014	5,203.0	2028	5,980.8	2042	7,224.3
2015	3,943.3	2029	4,722.3	2043	4,894.5
2016	6,436.5	2030	6,767.4	2044	3,283.8
2017	8,118.5	2031	7,646.8	2045	3,482.5
2018	5,960.0	2032	7,347.3	2046	5,150.3
2019	5,981.1	2033	6,729.3	2047	7,152.0
2020	7,402.9	2034	7,333.6	2048	6,370.5
2021	6,038.5	2035	7,976.5	2049	7,827.6
2022	7,241.5	2036	7,915.5	2050	7,656.9
2023	6,719.5	2037	7167.3	2051	7,316.6
2024	7,148.7	2038	7,024.1	2052	6,552.9
2025	7,374.8	2039	7,447.1	2053	7,237.3
Average Annual Power Generation					**6,585.9**
Average Plant Factor [%]					**59.4**

Source: Prepared by the Survey Team

(4) Annual Power Generation for Scenario B (for 6 units)

The annual power generation after the implementation of Scenario B, which will be enhanced up to 1,324 MW in total from the existing 1,150 MW, in the period from 2012 to 2053 for 42 years is shown in the following table. The average annual power generation is calculated to be 6,660.8 GWh which is added 1,660.7 GWh from the existing plant. The said incremental energy is expected to cover about 934,000 households which is calculated in the same manner as the above (3).

Table 5-18 Annual Power Generation after Implementation of Scenario B (144MW/unit)

Year	Annual Power Generation [GWh]	Year	Annual Power Generation [GWh]	Year	Annual Power Generation [GWh]
2012	5,548.2	2026	6,255.6	2040	7,845.5
2013	7,439.3	2027	7,798.3	2041	6,388.5
2014	5,203.0	2028	5,994.7	2042	7,360.8
2015	3,943.3	2029	4,722.3	2043	4,894.5
2016	6,436.5	2030	6,873.2	2044	3,283.8
2017	8,297.7	2031	7,800.4	2045	3,482.5
2018	5,960.0	2032	7,497.6	2046	5,150.3
2019	6,037.8	2033	6,771.5	2047	7,289.9
2020	7,502.3	2034	7,457.6	2048	6,243.5
2021	6,038.5	2035	8,142.3	2049	8,001.0
2022	7,325.7	2036	8,120.7	2050	7,826.6
2023	6,747.0	2037	7,303.7	2051	7,465.3
2024	7,222.2	2038	7,106.5	2052	6,558.9
2025	7,515.1	2039	7,566.3	2053	7,370.3
Average Annual Power Generation					**6,660.8**
Average Plant Factor [%]					**57.4**

Source: Prepared by the Survey Team

5.6.5 Recommendation in the F/S Report

As described in the previous clauses in this chapter, the Survey Team has proposed the rehabilitation and enhancement of generators to increase their capability up to 144 MW per unit at PF 0.8 (rated capacity is 180 MVA), instead of the existing one which has a capability of 115 MW (rated capacity is 125 MVA), on the condition that the existing concrete foundations are to be used without rehabilitation. Meanwhile, in the F/S report, it is recommended to rehabilitate and enhance the generator for upgrade up to 135 MW per unit at PF 0.8 (rated capacity is 169 MVA).

The Survey Team has reviewed the recommended idea in the F/S report, in particular, from the technical aspects as below.

(1) Annual Power Generation for Scenario A (for 4 units)

The annual power generation after the implementation of Scenario A, which will be enhanced up to 1,230 MW in total (enhancement of 4 generators up to 135 MW) from the existing 1,150 MW, in the period from 2012 to 2053 for 42 years is shown in the following table. The average annual power generation is calculated to be 6,532.6 GWh which is added 1,532.5 GWh from 5,000.1 GWh of the existing plant. The said incremental energy is expected to cover about 862,000 households.

Table 5-19 Annual Power Generation after Implementation of Scenario A (135MW/unit)

Year	Annual Power Generation [GWh]	Year	Annual Power Generation [GWh]	Year	Annual Power Generation [GWh]
2012	5,548.2	2026	6,233.4	2040	7,569.4
2013	7,325.9	2027	7,511.2	2041	6,314.0
2014	5,203.0	2028	5,972.4	2042	7,132.9
2015	3,943.3	2029	4,722.3	2043	4,894.5
2016	6,392.0	2030	6,724.3	2044	3,283.8
2017	7,978.5	2031	7,552.5	2045	3,482.5
2018	5,960.0	2032	7,253.0	2046	5,150.3
2019	5,946.0	2033	6,697.2	2047	7,060.6
2020	7,332.6	2034	7,265.7	2048	6,356.1
2021	6,038.5	2035	7,874.4	2049	7,746.9
2022	7,187.8	2036	7,787.7	2050	7,542.8
2023	6,705.3	2037	7,082.1	2051	7,226.9
2024	7,085.2	2038	6,964.1	2052	6,537.6
2025	7,263.1	2039	7,373.0	2053	7,147.2
Average Annual Power Generation					**6,532.6**
Average Plant Factor [%]					**60.6**

Source: Prepared by the Survey Team

(2) Annual Power Generation for Scenario B (for 6 units)

The annual power generation after the implementation of Scenario B, which will be enhanced up to 1,270 MW (enhancement of 6 generators up to 135 MW) in total from the existing 1,150

MW, in the period from 2012 to 2053 for 42 years is shown in the following table. The average annual power generation is calculated to be 6,588.4 GWh which is added 1,588.3 GWh from the existing plant. The said incremental energy is expected to cover about 894,000 households.

Table 5-20 Annual Power Generation after Implementation of Scenario B (135MW/unit)

Year	Annual Power Generation [GWh]	Year	Annual Power Generation [GWh]	Year	Annual Power Generation [GWh]
2012	5,548.2	2026	6,242.9	2040	7,689.7
2013	7,352.0	2027	7,642.9	2041	6,361.7
2014	5,203.0	2028	5,982.0	2042	7,232.3
2015	3,943.3	2029	4,722.3	2043	4,894.5
2016	6,417.1	2030	6,772.6	2044	3,283.8
2017	8,140.5	2031	7,658.1	2045	3,482.5
2018	5,960.0	2032	7,358.6	2046	5,150.3
2019	5,985.2	2033	6,735.8	2047	7,161.2
2020	7,410.0	2034	7,364.1	2048	6,243.5
2021	6,038.5	2035	7,988.8	2049	8,001.0
2022	7,247.5	2036	7,931.3	2050	7,839.6
2023	6,734.8	2037	7,177.9	2051	7,326.2
2024	7,154.7	2038	7,028.8	2052	6,558.9
2025	7,376.4	2039	7,458.0	2053	7,247.2
Average Annual Power Generation					**6,588.4**
Average Plant Factor [%]					**59.2**

Source: Prepared by the Survey Team

5.6.6 Conclusion of Recommendation of Rehabilitation and Enhancement Scenarios

As the result of calculation in Tables 5-17 to 5-20, it reveals that the generator's output of 144MW per unit is more advantageous than 135MW at the average annual power generation. However, in case of 144 MW, the expected number of days which would be reached the maximum output of 1,266MW (4 units enhancement) and 1,324MW (6 units enhancement) is limited to 65 days and 54 days respectively due to the restriction of water resources which are stored to Mangla Dam. Thereby, the average plant factor of 144MW, which is defined as the ratio of the average power load of a power plant to its rated capacity, is lower than 135MW. (The average plant factor of 144MW at Scenario A and B is 59.4% and 57.4%, while one of 135MW is 60.6% and 59.2% respectively)

It means that the operation of generator's output with 135 MW is more efficient in terms of the level of plant factor.

Therefore, the Survey Team also can recommend the rehabilitation and enhancement concept with generator's output of 135 MW per unit with 0.8 power factor in accordance with the recommendation in the F/S report, and the subsequent review of this chapter is carried out based on it.

Incidentally, the Survey Team has judged that there is no any change on the result of technical reviews mentioned in the preceding clauses by adopting the generator's output 135 MW per unit instead of 144 MW, except the capacity of main transformer which is changed to 169 MW instead of 180 MVA which is described in Sub-clause 5.4.1.

The basic feature of the turbine and generator (generator output is 135 MW/unit at rated power factor) as existing and after enhancement is shown in Table-5-21.

Table 5-21 Basic Features of Turbines and Generators (generator's output: 135 MW/unit)

-	Rates	Existing A	After Enhancement B	Ratio B/A
Turbine	**Rated output**	**138 kBHP=103MW**	**172.7 kBHP=126.6MW**	**122.9%**
	Rated discharge	4,550cfs=128.8 m^3/s	4,900cfs=138.7m^3/s	107.7%
	Effective head	295f=89.9m	334f=101.9m	113.3%
	Maximum output	198 kBHP=**147.7MW**	**138.0MW**	**93.4%**
	Discharge at maximum output	4,936cfs=139.7m^3/s	138.7 m^3/s	99.3%
	Effective head at maximum output	380f=115.8m	109.92m	94.9%
	Rated speed	166.7 min^{-1}	166.7 min^{-1}	-
Generator	Rated capacity	125MVA	168.75MVA	135.0%
	Rated power factor	0.80	0.80	-
	Output at rated power factor	**100MW**	**135MW**	135.0%
	Rated voltage	13.2kV	13.2kV	-
	Rated speed	166.7 min^{-1}	166.7 min^{-1}	-
	Overload (Continuous opearation)	115% (**115MW**)	No overload capacity (**135MW**)	**117.4%**

Source: Prepared by the Survey Team

As the conclusion, the Survey Team recommended the following two scenarios for rehabilitation and enhancement of the generator for upgrade up to 135 MW per unit at PF 0.8 (rated capacity is 169 MVA).

Scenario A: Rehabilitation and Enhancement for Units 1 to 4

Scenario B: Rehabilitation and Enhancement for Units 1 to 6

The comparison table of the above scenarios are shown in Table 5-22.

Table 5-22 Rehabilitation and Enhancement Scenarios (135MW/unit)

Scenarios	Against Rated Capacity			Against Overload Capacity		
	Existing	After Enhancement	Incremental Generating Power	Existing	After Enhancement	Incremental Generating Power
A	1,000MW in total	Enhancement to 1,140 MW in total Units 1-4: 135MW Units 5-10: 100MW (no change)	140MW (+14.0%)	1,150MW in total	Enhancement to 1,230 MW in total Units 1-4: 135MW Units 5-10: 115MW (no change)	80MW (+7.0%)
B		Enhancement to 1,210 MW in total Units 1-6: 135MW Units 7-10: 100MW (no change)	210MW (+21.0%)		Enhancement to 1,270 MW in total Units 1-6: 135MW Units 7-10: 115MW (no change)	120MW (+10.4%)

Source: Prepared by the Survey Team

5.6.7 Study on Superiority of Japanese Technology

The Survey Team reviewed the superiority of water turbine generator products manufactured by Japanese manufacturing firms compared to those of other overseas manufacturers in order to formulate the Project as a STEP Yen loan.

However, it is considered that there is no broad distinction between Japanese and the overseas manufacturers in terms of technical capability to meet the requirement of rehabilitation and enhancement proposed in this study.

Therefore, the superiority of Japanese manufacturers is explained from the viewpoint of "reliability of equipment” based on past operating records at Mangla Power Station, which were provided by WAPDA through this preliminary survey.

(1) Annual Power Generation and Operating Ratio

Based on the actual data of annual power generation and operating hours of each unit of water turbine generator from the commissioning date up to December 31, 2011, the average annual power generation and operating ratio were calculated as shown in Table 5-23.

As indicated in the above table, the average annual power generation of each unit is calculated below:

- Units 1 to 4 (both turbine and generator are Japanese products): 581 [GWh/year]
- Units 7 & 8 (turbine is an overseas product and generator is Japanese product): 492 [GWh/year]
- Units 5 & 6, 9 & 10 (both turbine and generator are overseas products): 436 [GWh/year]

The operating ratio of each unit is also calculated below:

- Units 1 to 4: 81.3 [%]
- Units 7 & 8: 68.2 [%]
- Units 5 & 6, 9 & 10: 69.7 [%]

Table 5-23 Past Operating Record at Mangla Power Station

Unit No.	Manufacturer		Commissioning Date	Power Generation [GWh]	Operating Hour [hour]	Total Days from Commissioning Date*1	Total Hours from Commissioning Date*2 [hour]	Average Annual Power Generation [GWh]		Operating Ratio [%]	
	Turbine	Generator		(A)	(B)	(C)	(D)=(C)x24	(E)=(A/C)x365	%	(F)=(B/D)*100	%
1	Mitsubishi	Hitachi	03-Jul-67	29,307	340,770	16,252	390,048	658	-	87.4	-
2			14-Jul-67	28,017	339,577	16,241	389,784	630	-	87.1	-
3			07-Mar-68	23,015	286,155	16,004	384,096	525	-	74.5	-
4			17-Jun-69	21,815	282,725	15,537	372,888	512	-	75.8	-
5	CKD Blansco	CKD Blansco	29-Dec-73	19,203	256,400	13,881	333,144	505	-	77.0	-
6			11-Mar-74	18,903	258,391	13,809	331,416	500	-	78.0	-
7	Escherwyse	Hitachi	25-May-81	15,439	188,648	11,177	268,248	504	-	70.3	-
8			22-Jul-81	14,618	176,528	11,119	266,856	480	-	66.2	-
9	CKD Blansco	CKD Blansco	24-Sep-93	6,913	87,956	6,672	160,128	378	-	54.9	-
10			06-Jul-94	6,321	79,054	6,387	153,288	361	-	51.6	-
Total				**183,551**	**2,296,204**	**127,079**	**3,049,896**	**5,053**	**-**	**75.29**	**-**
Units 1 through 4				102,154	1,249,227	64,034	1,536,816	581	100.0	81.3	100.0
Units 7 & 8				30,057	365,176	22,296	535,104	492	84.7	68.2	84.0
Units 5 & 6, 9 & 10				51,340	681,801	40,749	977,976	436	75.0	69.7	85.8

Source: Prepared by the Survey Team

Note: *1 Total number of days from the commissioning date to December 31, 2011
*2 Total number of hours from the commissioning date to December 31, 2011

(2) Fault Record

Regarding Units 1 to 4, 7 and 8, the Survey Team confirmed that any failure or trouble affecting the generating capability or functions of the water turbine generator has not occurred from the commissioning date up to present.

On the other hand, for Units 5 and 6, the damages of the stator winding, stator core and field winding of generator has been occurring frequently. Since the first failure occurred in 1990, similar failures have occurred six times with stoppage of a generator for a total of 20 months. Unit 6 has had five times failures with stoppage of generator for a total of 12 months since the first failure occurred in 1985.

In addition, despite the short operating period which is less than 20 years, Units 9 and 10 recorded the lowest operating ratio in all units. Unit 9 was 54.93% and Unit 10 was 51.57%, due to the fault of AVR (automatic voltage regulator) of the exciter causing frequent irregular trips.

(3) Conclusion

As described above, it is judged that Japanese products of water turbine generator have superiority from the viewpoint of "reliability of equipment” backed by the past operating records at Mangla Power Station.

However, as for annual power generation and operating ratio, these figures are influenced by the operating pattern. The Survey Team confirmed from WAPDA that Units 1 and 2 are connected to 132 kV system and Units 3 through 10 are connected to 220 kV system. There are thirteen 132 kV transmission lines emanating from 132 kV bays of switchyard in Mangla Power Station. To meet the growing load demand of 132 kV transmission lines, (3) interconnection auto transformers (132 kV/220 kV) have been installed. For system stability and also to avoid overloading of interconnecting auto transformers, Unit 1 and Unit 2 were normally run at base load and these were the last units to stop with. That is the reason that the number of operating hours of Unit 1 and 2 are more and the number of start / stop is much less as compared to the other units.

5.6.8 Study on Possibility of Formulating the Project as STEP Loan

The Japanese products of water turbine generator have superiority from the viewpoint of "Reliability of Equipment”, however, there is no remarkable distinction of technical aspects between the Japanese manufacturers and the overseas ones. Therefore, it seems have a low potential for the formulating the Project as STEP loan.

In case the Project is implemented by general untied Japanese ODA loans instead of STEP loan, the Survey Team recommends the following measures in order to maintain the high quality and performance of the Project which is envisaged in this study:

(1) The Tenderer shall meet the following requirements as the qualification of Tenderer.

1) experience of rehabilitation project of hydropower station on same scale of Mangla Power Station and except for own country
2) experience of rehabilitation project of hydropower station with other company's products
3) actual performance for safety operation more than 5 years after rehabilitation project
4) experience of project funded by JICA, JBIC, World Bank and ADB

(2) Burden of Expense on Reverse Engineering

The cost for the reverse engineering shall be born by the Contractor including the electrical tariff to compensate the stoppage of water turbine generator for the reverse engineering by the Contractor. The said cost shall be evaluated at the cost evaluation stage.

(3) Life Cycle Cost (LCC)

A life style cost (LCC) consists of certain portion, which is operation cost and fuel cost, and uncertain portion such as replacement cost of equipment, or expenses for replacement with spare parts.

The comprehensive evaluation at the cost evaluation stage shall be considered the LCC, which consists of maintenance cost (equipment cost, installation cost, personnel expenses, etc.) and stoppage duration of water turbine generator required for maintenance, for 10 years operation after commissioning.

The Tenderers shall calculate the maintenance cost required for 35 years operation including overhaul works of turbines and generators which will be carried once a decade.

In addition, the Tenderers shall calculate a monetary loss caused by unscheduled shutdown due to any failure or damage of the equipment based on past actual performance owned by each Tenderer. As for the Tenderers who could not prove their past performance for 35 years operation, the Tender Documents shall stipulate the calculation methods for such Tenderers, for example, the determined sum of the cost shall be added in their tender price.

CHAPTER 6

ENVIRONMENT AND SOCIAL CONSIDERATIONS

CHAPTER 6 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

6.1 Environmental and Social Considerations

6.1.1 Necessity of an IEE or EIA

(1) Pakistan Regulations on EIA

The legal basis for the necessity and scheme of an Environmental Impact Assessment (EIA) is given by the following two regulations in Pakistan.

- Pakistan Environmental Protection Act (PEPA), 1997 (Act No. XXXIV OF 1997)
- Pakistan Environmental Protection Agency Review of Initial Environmental Examination and Environmental Impact Assessment Regulations, 2000 (S.R.O. 339 (1)/2001)

The PEPA 1997 is an act provided for the protection, conservation, rehabilitation and improvement of the environment, for the prevention and control of pollution, and promotion of sustainable development; namely the basic act for the environmental administration in Pakistan. Article 12 of the act stipulates on the IEE or EIA requirements as follows:

> 12. Initial environmental examination and environmental impact assessment.
>
> —(1) No proponent of a project shall commence construction or operation unless he has filed with the Government Agency designated by Federal Environmental Protection Agency or Provincial Environmental Protection Agencies, as the case may be, or, where the project is likely to cause adverse environmental effects, an environmental impact assessment, and has obtained an approval from the Government Agency in respect thereof.

Source: Basic Act for the Environmental Administration in Pakistan

Pakistan EPA (Review of IEE and EIA) Regulations, 2000, defines project types that require or does not require an IEE or EIA.

> Schedule I in the regulation, as specified in the ‘‘Rule 3 Projects requiring an IEE’’, lists types of projects that require an IEE.
>
> - ‘Hydroelectric power generation less than 50 MW’ is in the list.

Schedule II in the regulation, as specified in the ''Rule 4 Projects requiring an EIA'', lists types of projects that require an EIA. ● 'Hydroelectric power generation over 50 MW' is in the list.
Article 5. "Projects not requiring an IEE or EIA'' prescribes that; (1) A proponent of a project not falling in any category listed in Schedules I and II shall not be required to file an IEE or EIA: Provided that the proponent shall file – (a) an EIA, if the project is likely to cause an adverse environmental effect; (b) for projects not listed in Schedules I and II in respect of the Federal Agency issued guidelines for construction and operation, an application for approval accompanied by an undertaking and an affidavit that the aforesaid guidelines shall be fully complied with. (2) Notwithstanding anything contained in Sub-regulation (1), the Federal Agency may direct the proponent of the project, whether or not listed in Schedule I or II, to file an IEE or EIA, for reasons to be recorded in such direction: Provided that no such direction shall be issued without the recommendation in writing of the Environmental Assessment Advisory Committee constituted under Regulation 23. (3) The provisions of Section 12 shall apply to a project in respect of which an IEE or EIA is filed under Sub-regulation (1) or (2).

Source: Pakistan EPA Regulations, 2000

(2) Project Necessity of an IEE or EIA

Interpreted with the advice of the Environment Cell of WAPDA and international standard context as well as Japanese concerned regulations, Article 12 of PEPA, 1997 requires application of EIA for new project where new installation of facility or physical structure are commenced, as well as for the one that is likely to cause an adverse environmental effects.

The concerned Project does not fall in the category of new project, but project of rehabilitation (as refurbishment) and enhancement (as up-gradation) of existing facility inside Mangla Power Station. Therefore, neither IEE nor EIA are supposed to be applied to this Project.

However, Schedule I and II in Pakistan EPA (Review of IEE and EIA) Regulations, 2000 does not specify the project type clear and distinct enough to distinguish between new and rehabilitation project, in respect where Japanese corresponding regulations distinctively define those. If only project size is counted, the concerned Project would fall under Schedule II which means that EIA is required since the Project will enhance the capacity of generation by 116 MW to 174 MW. Further, Article 5 of the above Regulation 2000 gives the Federal Agency, namely Pakistan Environmental Protection Agency (Pak-EPA), the authority of judging IEE/EIA requirement.

Considering these, WAPDA should consult with Pak-EPA and prepare the necessary filing to follow their instruction as required, before the next step of the study.

6.1.2 Environmental Evaluation

(1) Concerned Regulations

The following are the primary regulations of environmental protection and environmental impact assessment system in Pakistan and AJK (Azad Jammu & Kashmir) governments, concerning the proposed Project.

- Pakistan National Conservation Strategy (NCS), 1992;

  It outlines the country's primary approach toward encouraging sustainable development, conserving natural resources, and improving management and efficiency in the use of resources.

  It has 14 core areas in which policy intervention is considered crucial for the preservation of Pakistan's natural and physical environment. The core areas that are relevant in the context of the Project are pollution prevention and increasing energy efficiency.

- Pakistan Environmental Protection Act, 1997

  Two organizations are given authority to administer the provisions of the Act, namely, Pakistan Environmental Protection Council (PEPC) and Pakistan Environmental Protection Agency (Pak-EPA). The PEPC, members of which include representatives of the government, industry, other professionals, and NGOs, supervises the functions of Pak-EPA. The Pak-EPA is responsible for ensuring enforcement of National Environmental Quality Standards (NEQS) and authorized to delegate powers to its provincial counterparts and provincial EPAs /EPD (environmental protection agencies and department). One of the functions delegated by Pak-EPA to the provincial EPAs/ EPD is the review and approval of EIA reports for projects undertaken in their corresponding jurisdictions.

- National Environmental Policy, 2005

  The policy, while recognizing the goals and objectives of the National Conservation Strategy and other existing environment-related national policies, strategies and action plans, provides broad guidelines to the federal and local governments for addressing environmental concerns and ensuring effective management of their environmental resources.

- National Environmental Quality Standards
  - The S.R.O. 549(1)/2000 contains two national standards: one for municipal and liquid industrial effluents, and the other for industrial gaseous emission.
  - The S.R.O. 528(1)/2001 regulates specific requirements on self-monitoring and reporting by industries.
  - The S.R.O. 1062(1)/2010 stipulates ambient air quality standards.
  - The S.R.O. 1063(1)/2010 stipulates drinking water quality standards.
  - The S.R.O. 1064(1)/2010 stipulates noise standards.
- Hazardous Substance Rules 2003

  The regulation set the rules to deal with hazardous substances and gave a list of these substances.
- AJK Environmental Protection Act 2000

  The Act with registration No. 696-702/LD/Leg/2000 describes the establishment, powers, and functions of the Environmental Protection Council and Agency in AJK.

(2) Possible Impacts and Mitigation

The project components only extend to the repair and replacement of existing turbines, generators, and their peripherals inside the power station. Any permanent physical transformation will not occur to the environment, external to and surrounding the power station.

In this section, possible environmental and social impacts regarding the project activities of overhaul, repair and replacement are briefly identified[1]. Accordingly, corresponding mitigation measures are also examined where and when required. Examinations here are based on the JICA Guidelines for Environmental and Social Considerations (April 2010), the discussions with the Environmental Cell of WAPDA, the survey at Mangla Power Station, the environmental review of the FS report for Mangla Refurbishment Project by WAPDA (hereinafter referred to as the FS report) and other legal review of Pakistan EPA (Environmental Protection Agency).

The following are the impacts and mitigation measures examined:

[1] This project falls into category C under the JICA guidelines for environmental and social guidelines , since JICA's financing component, repair and replacement of facilities, is not likely to have a minimal adverse impact on the environment. This chapter is not a requirement of JICA, but recommendation to the project proponent.

1) Water use for other purpose

Impacts

Impacts on water uses other than power generation were examined whether they would possibly occur with the operation rule of the existing reservoir water, although the issue is not discussed in the FS report.

There will be no change of water flow downstream due to the rehabilitation project. Irrigation water is secured on first priority regardless of the project, by the given rules with AJK-Government, according to both Environmental Cell and Mangla Power Station Office of WAPDA. Also, since water flow downstream will not change at all, there will be no impacts on local water use for local water supply, local industries, fishing, local recreation, water transportation, and other activities.

Mitigation

No mitigation measures are required for this purpose since no impacts are expected.

2) Water quality

Impacts

At the current stage, procurement procedure is not clearly designed yet.

If construction camp is set up during procurement work, the FS report assumes 70 to 80% of consumed 15 l/capita/day-water will become sewage with 50 to 75 persons presumed working. However, the construction camp will not necessarily be set up due to the prospective scale and method of works necessary for replacing turbines and generators and other equipment on scheme of JICA project.

During procurement as well as operation, spilling and leakage of lubricants, oils and other petroleum products may occur.

Mitigation

Monitoring of effluent water quality discharged from the sewage system of the power station should be conducted on quarterly basis or more if necessary. It may be recommended on key parameters of oil and grease content as well as on the standard parameter of BOD, TDS, coli-form groups, and chlorine for both wastewater discharge and its receiving water upstream and downstream discharge outlet.

In case of a construction camp being set up, domestic and chemical effluent waters from the camp should be treated before the discharge into the environment, with on-site sanitation systems, namely septic tanks along with soakage pits. In addition, proper monitoring to check the compliance with the National Environmental Quality Standards (NEQS) should be carried out periodically.

To avoid pollution of ground and surface water by spilling and leakage of lubricants, oils, and other petroleum products, the following measures are recommended:

- Standard Operation Procedures (SOPs) for procurement and operation to be prepared and followed to minimize any oil spills and leakage.
- Proper design of storage places and facilities with encasement
- Employment of good engineering practices, such as collection and recycling of lubricant oils.
- Introduction of new design of replacement equipment or its parts that require no or less lubricant oils, such as for turbine inlet valves.

3) Noise, vibration, and dust emission during construction works for replacement.

Impacts

There will be no environmental significant impacts of noise, vibration, and dust through the rehabilitation and replacement works since the existing power station is sufficiently distant from the inhabited area and a good network of paved access road from the trunk road to the project site already exists. Only the risks of on-site workers may be considered during dismantling of existing units (generators, turbines and their peripherals) and they should be taken care of with protective measures for working labor's health and safety.

Mitigation

- No mitigation for noise, vibration, and dust is necessary for residential quarters since the project site (power station) is at least a few kilometers away from the nearest inhabited area.
- SOPs for guarding labor health and safety to be prepared and followed to minimize the workers risk during rehabilitation and replacement work.
- Noise and vibration should be controlled by distance and barrier of noise-absorbing material. It should be controlled below 80 dBA (from 1 meter at the source) according to the FS report.
- Ear muffs and other personal protective equipment should be provided to workers during work activities.
- A proper system of monitoring noise and air pollution may be developed by the Contractor duly approved by the Consultant.

4) Solid Waste

Impacts

An amount of solid waste will be generated from dismantled units that will consist of hazardous and non-hazardous waste. Inappropriate disposal of hazardous and non-hazardous waste may cause significant adverse impact on the local environment.

Mitigation

Hazardous and non-hazardous waste should be handled separately in disposal.

- Those separately treated solid waste should be safely disposed only in demarcated waste disposal sites.
- Precautionary planning of solid waste management prior to implementation of dismantling work is recommended.
- For collection of waste, supply of fiber-glass-waste-bins throughout project site, that of separate bins for recyclable material, avoidance of using polyethylene bags, and keeping the practice of tight sealing waste-collection-containers at all times are required.
- For final disposal of waste, non-hazardous waste should be disposed according to the locally ordinary practice properly chosen from incineration, composting or sanitary landfill, while hazardous waste should be managed separately.

5) Other impacts during construction (rehabilitation and replacement).

Impacts

i) Movement of heavy machine and equipment for installation
Hauling and movement of heavy machine and equipment may cause some risks to pedestrian, livestock, animal, other traffic, local utility network, or do hindrance and jam to local traffic.

ii) Construction camp and worker-related issues
If construction camp is set up during construction works for rehabilitation and replacement, it might cause impacts on flora and fauna resulting to soil erosion for site clearance, interference with agriculture and grazing area, disease transmission and soil contamination by solid waste and air pollution with generators of electricity for labor camp, besides the sewage issue stated above in ‘’2) Water quality’’.

iii) Workers exposure to hazardous materials and other safety risks during dismantling stage of old equipment
This is also related to labor health issue during construction. Project workers may be exposed to wastes containing hazardous material e.g., asbestos, PCBs and paint

materials. They may be also exposed to safety risks, such as falling from height, injury of accidents, and hit by collapsing material.

Mitigation

i) Movement of heavy machine and equipment for installation

Precautionary planning for traffic routes and transport of equipment before travelling is recommended, with consideration to visibility during transport, placing signs-signals-marks in compliance with local authority, scheduling allowing safety speed, preventive measures for spill, and falling load from vehicles and safe parking with standard procedure.

ii) Construction camp and worker-related issues

The best mitigation measures should be not setting up any construction camp. If it cannot be avoided, the following measures need to be taken.

- The construction camp should reuse an old site that was used for Mangla Dam Raising Project.
- Stock of stripped top soil for later re-vegetation and use of proper drainage system for avoiding soil erosion.
- Proper waste water treatment as stated in ''2) Water quality''.
- Proper solid waste management as stated in ''4) Solid waste''.
- Though the whole area around the reservoir of Mangla Power Station is owned by WAPDA, a comprehensive tree plantation plan is recommended along the construction camp.
- Mini-stack and silencer should be installed for generator on-site. Periodical maintenance and monitoring of emission gases to check compliance with NEQS are the duties of the Contractor.

iii) Workers exposure to hazardous materials and other safety risks

- For prevention from exposure to asbestos, PCBs and hazardous paint materials, prepare SOPs to treat unknown materials that might be in contact with, and give standard instruction to workers in the initial stage of works during dismantling of old units.
- Preparation of plan, equipment and reporting for accidental spill clean-up, and removal of hazardous materials.
- Workers be required to wear personal protective equipment (PPEs) such as helmet, gloves, overalls, goggles, safety shoes, and inner protection wears to avoid exposure to hazardous materials or to avoid injury of collapse, fall and others.
- Provision of medicine, emergency kits and vehicle on-site for emergency rescue as a duty of the Contractor.
- Provision of a space for protected storage of hazardous materials and paints.

- To avoid collapse hazard, supporting arrangement for structures under dismantling, removal, and replacement.

6.1.3 Environmental Management

(1) Water Quality Management

In order to prevent contamination of the environment, for water with oily discharge, treatment facilities should be installed in the power station. The treatment system, through which all the discharge is treated, includes a drainage system to collect surface water runoff and treatment facility for oily water before discharge into the sewer. To ensure that, leveling drains, operator training, and monitoring of effluent and discharged water will be needed. The cleaned water recycle in power station may be recommended. At least, effluent of power station should be discharged through sewage system or through infiltration facility into surface water.

The power station have not conducted water quality monitoring on water of reservoir and discharged water from dam so far. In order to ensure the effects of water treatment in compliance with NEQS, periodical monitoring is recommended for oily content as well as standard parameter of BOD, TDS, coli-form groups, and chlorine.

(2) Treatment or Management of Hazardous Waste Oil and Material

In the operation stage of power station, the solid waste management system should be established in handling and disposing sludge and other solid waste. Solid waste including hazardous waste, oily rags, used fuel, and lubricant oil filters are to be collected in leak-proof and fire-proof containers and transported for proper and legitimate disposal site/facility.

According to the Mangla Power Station Office, waste oil are routinely packed in drum-can and transferred to Cante Area (Army Area), 5 km from the power station. In order to strengthen the current management activities on solid and hazardous waste, rechecking the inventory of those materials and wastes in the power station, reviewing the SOPs for management of those materials and wastes, and the preparation of comprehensive solid waste management plan are recommended.

6.2 Project Impact on GHG Emission Reduction

The project intends to directly contribute to GHG emission reduction through hydropower plants rehabilitation and enhancement aiming to generate renewable energy, which does not emit GHG at generation, with the use of hydropower.

This section made an estimation for project impact on GHG emission reduction, with available data of WAPDA and calculation with JICA Climate Finance Impact Tool (Mitigation) Draft Ver.

1.0, June 2011, on mitigation-17-hydro sector.

6.2.1 Methodology on Emission Reduction

The GHG emission reduction through hydropower is determined as the difference between baseline emissions (GHG emissions with the power generation of fossil fuel that will be replaced by enhanced hydropower of the Project) and project emissions after project activity of hydropower plants enhancement. The formula is as follows.

$$ERy = BEy - PEy \ (t\text{-}CO2/y)$$

- ***ERy***: GHG emissions reduction in year y achieved by the project (t-CO2/y)
- ***BEy***: GHG emissions at fossil fired power plants in year y (t-CO2/y) (Baseline emission)
- ***PEy***: GHG emissions after running hydro pow

6.2.2 Scenarios of Rehabilitation and Enhancement

Project impacts on GHG emission reduction are calculated for the following two scenarios that are proposed in Chapter 5 as well as for the individual unit.

Table 6-1 Scenarios of Rehabilitation and Enhancement

Scenarios	Unit
Scenario-A	Unit 1,2,3, & 4
Scenario-B	Unit 1,2,3,4,5, & 6

6.2.3 Quantity of Electricity to be Increased after Project Implementation

For each unit, the capacity of generation will be enhanced from 115 MW to 135 MW. Then, the quantity of electricity to be increased after project implementation (EGpj,y) is the following, with respect to each scenario.

Scenario-A: With 4 units enhanced, the total increase of generation will be 80 MW and 1,532.5 GWh annually.

Scenario-B: With 6 units enhanced, the total increase of generation will be 120 MW and 1,588.3 GWh annually.

6.2.4 Calculation of Baseline Emission

If hydropower plants are enhanced, the corresponding electric power supply can be replaced from the fossil fired power into hydropower. Amount of GHG emission from electric power supply is reduced through the replacement of conventional fossil fired power with hydropower generation. When the existing hydropower plants decrease in performance by deterioration, plant improvement increases the power generation efficiency and reduces the electric power supply from the existing power plants. Thus, GHG emission should be equal to that from suppressed fuel combustion. The formula is as follows:

$$\mathbf{BEy} = \Sigma FCi \times NCVi \times COEFi$$

Type	Items	Description
Output	**BEy**	Baseline emission: GHG emissions of fuel consumption replaced by the hydropower (t-CO2/y)
Input	FCi,y	Suppressed amount of fuel i (kL,m3,t/y)
	NCVi	Net Calorific Value of each fuel type (GJ/ kL, m3, t)
	COEFi	CO2 emission factor of each fuel type (t-CO2/TJ)

Source: Prepared by the Survey Team

(1) Evaluation of FCi,y

When hydropower plants connect to the grid, the existing power plants in the grid should be replaced in a decreasing order of unit fuel cost. Reducing fuel type and its priority should be determined on such view.

a) Electric power supply in each fuel type of grid power under WAPDA
Type of fuels and its electric power supply (GWh/y) and consumption (kL,m3,t/y) in each fuel type comprised the grid power of WAPDA.

Table 6-2 Power Supply in Each Fuel Type of Grid Power under WAPDA

Fuel type	Quantity of Generated Electricity (GWh/y)	Fuel Consumption (converted to crude oil)	
		Consumed Volume	Unit
Crude oil	22,738	6,742	ktoe
Gas	27,085	8,493	ktoe
Coal	136	73	ktoe

Source: Answers of WAPDA Environment Cell to the Questionnaire of the Study Team, May 2012, with reference to Pakistan Energy Year Book 2009, Table1.6 and Table 5.3.

Note: The concerned values above are the same for both Scenario-A and Scenario-B.

b) Priority of target fuel for reducing
Since the unit fuel cost has not been available from WAPDA in the study, fuel unit costs were set in the order of petroleum, gas, and coal for evaluation.

c) Essential amount of fuels
In Pakistan, because of energy source diversification promotion, multiple fuel types (petroleum, gas, coal) can be used within the grid. Therefore, fuels at some level of amount should be set aside for minimum operation of plants for each fuel type. In conclusion, 5% of the total electric power supply is set aside as essential amount of fuels.

d) Reducible fuel type and electric power supply
Excluding the essential amount of fuels computed in c), the reducible amount of fuels is identified in priority order of target fuel for reducing, and the reducible fuel type and electric power supply are computed as shown in Table 6-3.

Table 6-3 Suppressible Quantities of Power Generation by Fuel Type

	Suppression Priority	Quantity of Generated Electricity	Quantity Unable to Suppress	Suppressible Quantity
		MWh/y	MWh/y	MWh/y
Petroleum	1	22,737,700	2,498	22,735,202
Gas	2	27,084,740	2,498	27,082,242
Coal	3	136,400	2,498	133,902

Source: Values calculated with JICA Climate-FIT(Mitigation) Draft Ver. 1.0, June 2011, on hydro sector

(2) Net Calorific Value (NCVi) and CO2 Emission Factor (COEFi) of Each Fuel Type

Based on the reducible amount of fuels in d), GHG emissions of electric power generation with fossil fuels should be replaced with hydropower supply of the Project (EGpj,y), Tables 6-4, 6-5 and 6-6 show the calculation.

Table 6-4 Net Calorific Value and CO2 Emission Factor of Each Fuel Type

Fuel Type	Net Calorific Value (unit)		CO2 Emission Factor (unit)	
Crude oil	43.0	Gj/t	77.4	t-CO2/TJ
Gas	0.0365	GJ/m3	56.1	t-CO2/TJ
Coal	19.8	GJ/t	94.6	t-CO2/TJ

Source: Answer of WAPDA Environment Cell to the Questionnaire of the Study Team, May 2012, with reference to Pakistan Energy Year Book 2009, Appendix 7.4 and unit conversion by JICA Study Team

Table 6-5 CO2 Emissions of Thermal Power to be Replaced after the Project for Scenario-A

Fuel Type	Quantity Unable to Suppress	Suppressible Quantity	Suppressed Quantity	Heat Efficiency	Caloric CO2 Emission Factor	Fuel Suppressed Quantity	CO2 Emission Reduced Quantity
	MWh/y	MWh/y	MWh/y	%	t-CO2/TJ	ktoe/y	t-CO2/y
Petroleum	2,498	22,735,202	1,532,500	29.0%	77.4	454.4	1,472,452
Gas	2,498	27,082,242	0	27.4%	56.1	0.0	0
Coal	2,498	133,902	0	16.2%	94.6	0.0	0
Total			1,532,500			454.4	1,472,452

Source: Values calculated with JICA Climate-FIT(Mitigation) Draft Ver. 1.0, June 2011, on hydro sector

Table 6-6 CO2 Emissions of Thermal Power to be Replaced after the Project for Scenario-B

Fuel Type	Quantity Unable to Suppress	Suppressible Quantity	Suppressed Quantity	Heat Efficiency	Caloric CO2 Emission Factor	Fuel Suppressed Quantity	CO2 Emission Reduced Quantity
	MWh/y	MWh/y	MWh/y	%	t-CO2/TJ	ktoe/y	t-CO2/y
Petroleum	2,498	22,735,202	1,588,300	29.0%	77.4	470.9	1,526,065
Gas	2,498	27,082,242	0	27.4%	56.1	0.0	0
Coal	2,498	133,902	0	16.2%	94.6	0.0	0
Total			1,588,300			470.9	1,526,065

Source: Values calculated with JICA Climate-FIT(Mitigation) Draft Ver. 1.0, June 2011, on hydro sector

6.2.5 Calculation of Project Emission

The GHG emissions from hydropower supply after the Project starts will be "0".

$$\boldsymbol{PEy} = 0$$

However, if the hydropower plant has reservoir, methane will be generated from the reservoir. Actually, the concerned hydropower plant of the Project, Mangra Hydropower Station, has its reservoir. Then, the formula below shall be applied. When methane is less than 1% of baseline emission, it can be ignored.

$$\boldsymbol{PEy} = (EF_{RES} \times EGpj,y)/1000$$

- EFRes：Default GHG emission factor from reservoir
  (Default value at 23rd CDM conference: 90 kg-CO2/MWh)
- EGPJ,y：Amount of power supply from hydropower plants in year y (MWh/y)
- 1000：Net conversion factor(1t-CO2=1000 kg-CO2)

Table 6-7 Project Emission from Reservoir for Scenario-A

-	Emission Factor	Quantity of Electricity	Quantity of Emission
GHG	0.09 t-CO2/MWh	1,532,500 MWh	137,925 t-CO2

Source: GHG emission factor values specified in 23rd CDM committee meeting

Table 6-8 Project Emission from Reservoir for Scenario-B

-	Emission Factor	Quantity of Electricity	Quantity of Emission
GHG	0.09 t-CO2/MWh	1,588,300 MWh	142,947 t-CO2

Source: GHG emission factor values specified in 23rd CDM committee meeting

6.2.6 GHG Emission Reduction after Project Activity

The following are the results of the calculation for GHG emission reduction after the Mangla Power Station Rehabilitation and Enhancement Project.

(1) Scenario-A (With 4 units enhanced)

1) Scenario-A: Baseline emission

BEy = ΣFCi × conversion factor (41.868：TJ/ktoe) × COEFi

BE_y	Baseline emission: GHG emission associated with fuel consumption which is assumed to be replaced by hydropower generation	1,472,452	t-CO_2/y
FC_i	Reduction of fuel type I consumption in scope of reduction	-	ktoe/y
	Crude oil	454	ktoe/y
	Gas	0	ktoe/y
	Coal	0	ktoe/y
	Others	0	ktoe/y
$COEF_i$	CO_2 emission factor per net calorific value of fuel type i	-	t-CO_2/TJ
	Crude oil	77.4	t-CO_2/TJ
	Gas	56.1	t-CO_2/TJ
	Coal	94.6	t-CO_2/TJ
	Others	0	t-CO_2/TJ

Source : Prepared by the Survey Team

2) Scenario-A: Project emission **PEy**

PE_y	Project emission: GHG emission after project activity	137,925	t-CO_2/y
PE_{res}	Emission from reservoirs	137,925	t-CO_2/y

Source : Prepared by the Survey Team

3) Scenario-A : GHG emission reduction after project activity **ERy** ＝**BEy** － **PEy** [t-CO2/y]

ER_y	GHG emission reduction after project activity	1,334,527	t-CO_2/y
BE_y	Baseline emission: GHG emission reduction associated with fuel consumption which is assumed to be replaced by hydropower generation	1,472,452	t-CO_2/y
PE_y	Project emission: GHG emission after project activity	137,925	t-CO_2/y

Source : Prepared by the Survey Team

GHG Emission Reduction for Scenario-A = 1,334,527 [t-CO2/y]

(2) Scenario-B (With 6 units enhanced)

1) Scenario-B: Baseline emission **BEy**

BE_y	Baseline emission: GHG emission associated with fuel consumption which is assumed to be replaced by hydropower generation	1,526,065	t-CO_2/y
FC_i	Reduction of fuel type I consumption in scope of reduction	-	ktoe/y
	Crude Oil	471	ktoe/y
	Gas	0	ktoe/y
	Coal	0	ktoe/y
	Others	0	ktoe/y
$COEF_i$	CO_2 emission factor per net calorific value of fuel type i	-	t-CO_2/y
	Crude oil	77.4	t-CO_2/y
	Gas	56.1	t-CO_2/y
	Coal	94.6	t-CO_2/y
	Others	0	t-CO_2/y

Source : Prepared by the Survey Team

2) Scenario-B: Project emission **PEy**

PE_y	Project emission: GHG emission after project activity	142,947	t-CO_2/y
PE_{res}	Emission from reservoirs	142,947	t-CO_2/y

Source : Prepared by the Survey Team

3) Scenario-B: GHG emission reduction after project activity **ERy** ＝**BEy** － **PEy** [t-CO2/y]

ER_y	GHG emission reduction after project activity	1,383,118	t-CO_2/y
BE_y	Baseline emission: GHG emission reduction associated with fuel consumption which is assumed to be replaced by hydropower generation	1,526,065	t-CO_2/y
PE_y	Project emission: GHG emission after project activity	142,947	t-CO_2/y

Source : Prepared by the Survey Team

GHG Emission Reduction for Scenario-B = 1,383,118 [t-CO2/y]

CHAPTER 7

PROJECT IMPLEMENTATION PLAN

CHAPTER 7 PROJECT IMPLEMENTATION PLAN

7.1 Implementation Policy

7.1.1 General Procedure for Obtaining Approval of the Project

(1) Normally, a Planning Commission Form-2 (PC-II) is first prepared and accomplished by the executing agency responsible for the implementation of the project. This form is important to obtain the approval of the Planning Commission for the allocation of funds for the conduct of the F/S of the project.

(2) Then, the feasibility study will be prepared by the implementation agency by hiring a cconsultant. The implementation agency through the Ministry of Water and Power (MoWP) and Economic Affairs Division (EAD) will approach different donor agencies for arrangement of loan agreement (foreign exchange component) to execute the project.

(3) The Planning Commission Form-I (PC-I) is then prepared by the concerned department. PC-I is a document prescribed by the Planning Commission for processing of development projects. It contains the details of project objectives, justification, implementation, construction schedule, location, salient features, cost estimates, financing schedule, cost-benefit ratio and its economic rate of return (EIRR).

(4) The concerned department submits the prepared PC-I to the MoWP for evaluation and onward submission to the Planning Commission of Pakistan.

(5) Planning Commission examines the proposed project in depth by circulating it to all the stakeholders, provincial governments (if involved) and the Ministry of Finance for their comments/reservations (if any).

(6) After getting the comments of all the stakeholders, a working paper is prepared by the Planning Commission of Pakistan.

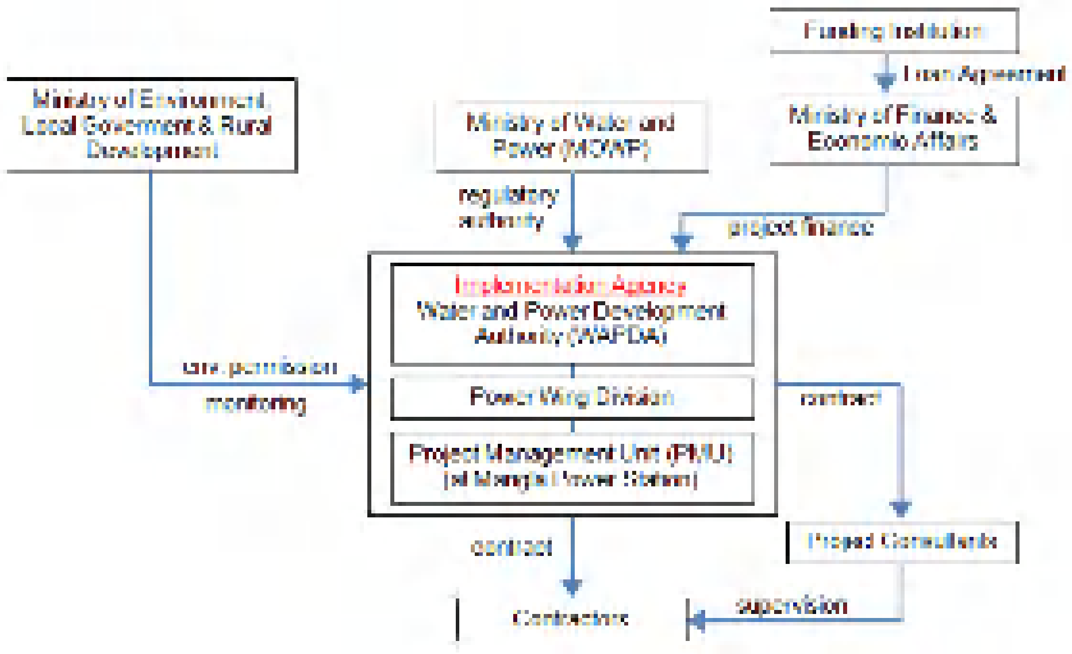
(7) In light of that working paper and keeping in view the overall cost of the project, the case is elevated to the Central Development Working Party (CDWP) if the cost of the project is up to PRs 1,000 million. The meeting is chaired by the deputy chairman of the Planning Commission, and attended by all stakeholders, i.e., EAD, Ministry of Finance, provincial government, MoWP and the implementation department/agency.

(8) If the value of the project is more than PRs 1,000 million, then it is elevated to the Executive Committee of National Economic Council (ECNEC) for approval. The ECNEC is headed by the finance minister and constituted by EAD, Planning Commission of Pakistan, provincial governments, MoWP and the implementation department/agency.

(9) After the approval of the project, the case will be transmitted by the Planning Commission of Pakistan to the Finance Division for the release of funds as per the schedule given in PC-I.

7.1.2 Implementation Process of the Project

A draft implementation process of the Project is shown in Figure 7-1:



Source: Prepared by the Survey Team

Figure 7-1 Project Implementation Process

The following are the envisioned undertakings of the implementation agency (WAPDA), consultants, and contractors of the Project:

(1) Implementation Agency

The implementation agency for the Project will be WAPDA under the supervision of the Energy Division of MOWP. It was assessed that WAPDA has enough technical capabilities to implement the Project with its abundant experiences as implementation agency for hydropower projects such as Warsak Hydropower Station, Tarbera Dam, Mangla Dam, Chashma Hydropower Station and Ghazi Barotha Hydropower station etc. In addition, WAPDA has established the structure for the development of human resources such as the Hydel Training Center Mangla as described in Chapter 2.5.4.

The WAPDA will be responsible for the implementation of the Project as listed below:

1) The manpower of the project management unit (PMU) for the Project is shown in Table 7-1. The PMU will consist of staff coming from the Power Wing Division in WAPDA Headquarter. The PMU office will be located in Mangla Power Station. As for other specialists such as environmental specialists and land officer, they will be assigned from the other divisions in WAPDA Headquarter, when needed.

Table 7-1 Manpower of the Project Management Unit (PMU)

No.	Position	BPS	Required Number of Staff
1	Project Manager	19	1
2	Senior Engineer (Mechanical)	18	1
3	Senior Engineer (Electrical)	18	1
4	Senior Engineer (Civil)	18	1
5	Junior Engineer (Mechanical)	17	1
6	Junior Engineer (Electrical)	17	1
7	Junior Engineer (Civil)	17	1
8	B & A.O	17	1
9	Foreman (Mechanical)	16	1
10	Foreman (Electrical)	16	1
11	Asst. B & A.O	16	1
12	Stenographer	15	1
13	Office Assistant	14	1
14	Sub-Engineer (Mechanical)	11	2
15	Sub-Engineer (Electrical)	11	2
16	Sub-Engineer (Civil)	11	1
17	A/cs Assistant	11	2
18	Others (non-technical)	-	26
Total			46

Source: Prepared by the Survey Team

The roles and responsibilities of key officers in the PMU are the following:

Project Engineer

i) He will act as the superintending engineer (electrical/mechanical) having sufficient experience in the field of construction, rehabilitation, and operation of hydropower plants.

ii) He will have the overall responsibility for the project.

iii) He will be responsible for the execution of the project from its initial stage up to the completion stage.

iv) He will perform as a liaison between departments, consultants, contractors, and the loan agency.

v) He will be in charge of the administration, accounts, and security of the project.

vi) He will be responsible for the overall administration management for the implementation of the project through WAPDA staff, consultants, and contractors.

vii) He will maintain the project accounts to get the proposed budget estimates and cash flow requirements including maintenance of expenditure accounts through project accounts officers.

viii) He will look after the security of the equipment, the consultants and the contractors working in the project.

ix) He will maintain copies of the progress of the project as per time schedule submitted by the contractors monthly/yearly, and provide completion report to all stakeholders.

Senior Engineer (Mechanical)

i) He has sufficient experience in the mechanical portion of the Project.

ii) He will be responsible for the mechanical parts inspection, installation, and testing as per schedule of the Project.

iii) He will prepare the daily progress report, monthly progress report, and completion report relating to the mechanical portion.

iv) He will assist the project engineer in the execution of his duties.

Senior Engineer (Electrical)

i) He has sufficient experience in the electrical portion of the Project.

ii) He will be responsible for the electrical parts inspection, installation, and testing as per schedule of the Project.

iii) He will prepare the daily progress report, monthly progress report, and completion report relating to the electrical portion.

iv) He will assist the project engineer in the execution of his duties.

Senior Engineer (Civil)

i) He has sufficient experience on the civil side of the hydropower construction and rehabilitation.

ii) He will be responsible for the inspection and execution of civil works by the contractor as per WAPDA specifications.

iii) He will prepare the daily, monthly, and completion reports relating to the civil portion.

iv) He will assist the project engineer in all civil engineering works.

Junior Engineer (Mechanical)

i) He is an engineering graduate in mechanical discipline having an experience in the construction and rehabilitation projects of hydropower project.

ii) He will assist the senior engineer (mechanical) in the execution of his duties.

Junior Engineer (Electrical)

i) He is a engineering graduate in electrical discipline having an experience in the construction and rehabilitation of hydropower project.

ii) He will assist the senior engineer (electrical) in the execution of his duties.

Junior Engineer (Civil)

i) He is a civil engineering graduate having an experience in the construction and rehabilitation of hydropower project.

ii) He will assist the senior engineer (civil) in the execution of his duties.

Foremen (Mechanical & Electrical)

i) They are diploma holders in their respective field (mechanical and electrical) having sufficient experience in the construction, rehabilitation and maintenance works of hydropower plant.

ii) They will coordinate among the related departments and provincial authorities for the smooth implementation of the Project.

iii) They will perform coordination among concerned agencies prior to securing the environmental certificate of the Project from the Ministry of Environment, Local Government and Rural Development.

iv) They will assist and cooperate with the project consultants.

v) They will perform close communication with institution(s) of the project fund during tendering, contracts, procurement, project progress and the other information related to the Project.

vi) They will monitor tender announcement, tender closing, evaluation and contract.

vii) They will assist the contractor for custom clearance of import/re-export equipment and materials, and special tools for the Project.

viii) They will assist in the issuance of payment certificates.

ix) They will provide assignment of operators and maintenance staffs for new facilities.

x) They will provide commissioning of facilities, operation and maintenance.

WAPDA has to secure budget and staffs to execute the above duties.

(2) Competent Authority (MoWP)

The competent authority for the Project is MoWP. The MoWP will be responsible for the following:

1) Oversee the performance of WAPDA in the implementation and O&M of the projects in light of the government instructions/directives.
2) Monitor the overall performance of WAPDA and watch the progress and status of projects under implementation or maintained by the attached departments.
3) In case of any bottlenecks where other ministries are involved, MoWP will approach the other ministries for the removal of these bottlenecks for the smooth implementation and O&M of the Project.

(3) Consultant

The consultant will be responsible for the activities below. Items in parentheses are the corresponding output of each activity.

1) Conduct detailed design and preparation of tender documents. (Tender Documents)
2) Prepare cost estimate and time schedule. (Cost Estimate and Schedule)
3) Conduct site visit and assist the employer in the conduct of tendering process. (Addendum)
4) Prepare pre-qualification documents. (P/Q Documents)
5) Conduct tender evaluation. (Evaluation Report)
6) Assist employer to carry out contract negotiation. (Contract Agreement and Minutes)
7) Review drawings for approval of equipment, materials, and construction method. (Comment Letters)
8) Witness shop inspection. (Inspection Report)
9) Witness site inspection. (Inspection Report)
10) Monitor progress and issue interim payment certificate. (Progress/Payment Certificate)
11) Prepare monthly progress report. (Monthly Reports)
12) Assist employer to issue taking-over certificate. (Taking-over Certificate)
13) Prepare completion report. (Completion Report)
14) Review as-built drawings and compile. (Compiled As-built Drawings)
15) General works regarding supervision during construction:
    - To assist employer to supervise whole project activities including supervision of contractor and environmental impact assessment;
    - To arrange interface between employer and JICA; and
    - To provide employer's engineers with technical assistance regarding construction, operation, and maintenance.

(4) Contractor

The contract of the contractor for the Project will be made on a turnkey basis. Therefore, the contractors will be responsible for the following:

1) Engineering and procurement of equipment and materials related to the Project including site survey and design.
2) Shop test, packing, shipping, customs clearance and delivery to site.
3) Pre-commissioning and commissioning tests.
4) Training of WAPDA engineers at the manufacturer's factory.
5) On-the-job training for the WAPDA engineers in the project site.
6) Maintenance of facilities during defects liability period.

7.1.3 Selection of Consultant

Projects are normally identified first by the respective department such as WAPDA through a reconnaissance survey and broad features/location of the projects as defined in the survey report. The consultancy firms/JVs are hired by the implementation agency for carrying out the feasibility study, detailed design study or construction supervision of the project until its completion. Then, the terms of reference (TOR) for further studies, as defined above are prepared. The Project is then advertised to hire the services of consultancy firms/JVs for its implementation. The following steps are undertaken according to the guidelines prepared by the Pakistan Engineering Council (PEC) keeping in view the World Bank/Asian Development Bank or other donor agencies criterion. However, for a specific project, if any donor agency has shown interest in funding, the procedures/criteria for hiring of consultants are shared with the agency and finalized in light of the donors' requirements.

The following steps are followed in the selection of consultant:

Step-1

The expression of interest (EOI) is an invitation of the implementation agency to eligible firms/JVs published in the national press. The consultancy firms registered with the PEC are provided with the EOI document. The firms/JVs are then asked to submit qualifications as well as experience of their permanent staff, overall experience of the firm, and experience of projects of similar nature. The time given for submission of the EOI documents is generally about a month.

Step-2

The evaluation of EOI documents of each firm/JV is done by a committee designated by the implementation agency. The evaluation is based on the qualification/experience of similar nature of the firm/JV as well as proposed key personnel. Based on the overall/similar experience, suitable firms are pre-qualified. This process takes about a month and a half.

Step-3

The pre-qualified firms/JVs are issued a Request for Proposal (RFP) documents and they are asked to submit their technical and financial proposals under two separate envelops within the stipulated time, which is generally about 45 days. However, the time can be adjusted depending on the size of the assignment.

Step-4

The technical proposals are first opened and evaluated by a committee designated by the implementation agency as per PEC guidelines on quality-based selection (QBS), or quality- and cost-based selection (QCBS) with the following criteria:

i) Qualification of the Firm/JV

ii) Approach and Methodology

iii) Key Personnel (Qualifications & Experience)

This evaluation is to be done for about a month and a half.

Step-5

The evaluation report of the Standing Committee is submitted to the implementation agency for approval. This takes 20 to 30 days.

i) In case of QBS, the financial proposals of the firms whose technical proposals met the minimum qualifying mark are opened. The firm/JV who obtained the highest score on the Technical Proposal plus the Financial Proposal will be declared as winner and the consultancy services contract agreement will be signed with the winning firm/JV.

ii) In QCBS, 80% weightage is given to the technical proposal and 20% to the financial proposal of each firm or JV.

Step-6

The evaluation report is also sent to the donor agency for their vetting/concurrence. After receipt of concurrence from the donor agency, the evaluation report is submitted to the implementation agency for contract negotiations with the firm/JV which takes 30 to 45 days.

Step-7

After negotiations and preparation of the final draft of consultancy services contract agreement, the implementation agency's final approval is sought and contract signing is done within 20 to 30 days.

7.1.4 Procurement of Goods and Services

(1) Mode of Procurement

The Project shall be carried out as one package under an International Competitive Bidding (ICB) mode. Tender documents shall be released to tenderers that will pass the pre-qualification criteria.

(2) Origin for Procurement

Origin of the equipment and materials for the Project will not be specified due to the principle of the ICB; however, the successful tenderer shall have experience in similar projects, be financially stable, employ capable engineers to manage the Project, and the tender shall propose first class equipment and materials. Tender documents shall therefore clearly mention the tenderer's qualification and experience, equipment quality, function and technical guarantees, etc., and their evaluation criteria to prevent lowering the quality of the Project.

(3) Guarantee Period

It will be specified in the contract documents that the plant shall be guaranteed for a certain period after taking over. It is proposed that a 24-month guarantee period be specified in the tender documents. If plant has defects, poor quality, improperly installed, etc., an accident may arise in a few months after energizing.

Besides, it is preferably mentioned in the tender documents that the contractor has the duty to train WAPDA's operators and maintenance staff during construction and defects liability period.

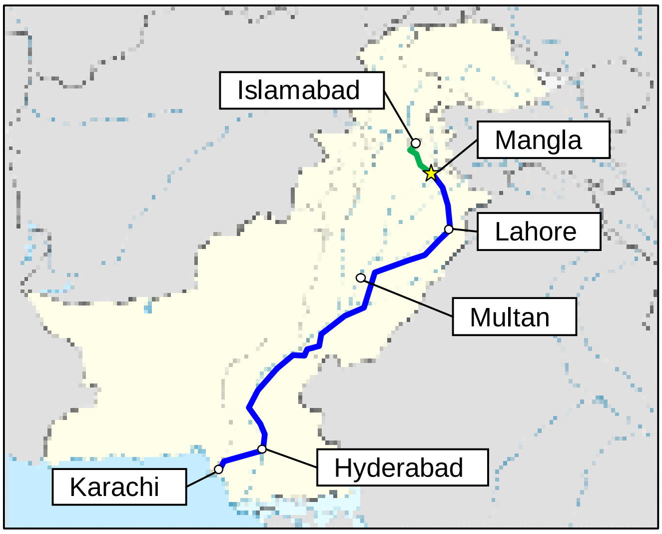
7.1.5 Transportation

There are two transportation routes used in Pakistan. One is shipping to Karachi by ship and inland transportation by truck. Another one is flying to Islamabad by air cargo, and then inland transportation to Mangla by truck. A comparison table on the distances of the different landing ports is shown in Table 7-2 and transportation route map is shown in Figure 7-2. In the past project, the route from Karachi is generally used, however, the Survey Team recommends that the route from Karachi will be used for general cargoes and the route from Islamabad will be used for smaller items and during emergency cases.

Table 7-2 Transportation Route

Port	Conveyance	Distance to Power Station	Via
Karachi	By ship and truck	1,500 km	Hyderabad, Multan, Lahore
Islamabad	By air and truck	200 km	-

Source: Prepared by the Survey Team



Source: Prepared by the Survey Team

Figure 7-2 Route Map of Transportation

The condition of the roads used for inland transportation to the site is good and the maximum loading condition of any bridge along the route is limited to 40 tons. Trailer trucks could access the temporary storage yard in the site directly.

7.2 Implementation Schedule (Nondisclosure)

7.3 Quality Control Plan

(1) Quality Control of Equipment and Materials to be Supplied

The consultant will check the quality control manuals submitted by the contractor to determine if manufacturing products meet the quality standard or followed the needed procedures. The consultant will either instruct or reject the contractor to take over the materials. The consultant and WAPDA engineers will witness shop tests for major equipment to be procured under the Project.

(2) Quality Control during Construction

1) Contractor’s Documents
The contractor shall submit the construction schedule, shop drawings, design calculations, test procedures, test reports, O&M manuals, quality control plans and safety plans for approval of WAPDA and/or consultant.

2) Control of Site Works
During the construction works, the consultant and WAPDA inspectors will check damages on equipment and materials, and order the repair or replacement of the damaged equipment and materials. Prior to the issuance of payment certificates to the contractors, the consultant and/or WAPDA inspectors will inspect not only the progress but also the quality of all facilities claimed by the contractors in their application for payment.

3) Commissioning Tests
The consultant and WAPDA representative will check the test report, and function and performance of substation equipment before the energizing.

7.4 Operation and Maintenance Plan

1) The WAPDA, being a semi-autonomous body, is controlled by the GOP through MoWP. The WAPDA, being an independent authority, is responsible for the O&M of the projects/power houses in light of government instructions/directives.
2) The WAPDA arranges budget (both foreign and local) for O&M of the projects through MoWP and the Ministry of Finance or utilizes its own resources as much as possible.[1]
3) The WAPDA has its own staff for the operation and maintenance of the power houses/projects.
4) Operation of the hydropower stations is carried out according to the intent of water

[1] WAPDA has covered the O&M cost of Mangla Power Station entirely by use of its own financial resources since its commissioning in 1967.
However, WAPDA has never carried out overhaul of turbines & generators in consideration of the next reasons: 1) prolonged power crisis across the country, and 2) saving the many steps and a lot of time required for obtaining the approval from the Government of Pakistan.

releases issued by IRSA who put their consolidated demand on the leases as per requirement of irrigation departments of the provinces.

5) The WAPDA is also responsible for arranging spare parts and other materials required for the smooth running of the projects.
6) The MoWP oversees the performance of WAPDA during the implementation and O&M in light of the government instructions/directives.
7) The WAPDA is also responsible for the security of all hydropower stations/installation and performs this activity through a dedicated security staff.

7.5 Payment Procedure to the Contractor

The payment to the contractor shall be made in Foreign Currency (F/C) and Local Currency (L/C).

And, an advance payment shall be paid to the contractor for mobilization and design, when the contractor submits a guarantee in accordance with the contract agreement.

7.5.1 Civil Works

The basic payment procedure for the civil works to the contractor is described below:

1. The contractor shall submit eight copies of the application for payment signed by the representative of the contractor to the project manager of the PMU of WAPDA at the end of each month.
2. After preliminary review by the project manager, the application for payment will be sent to the consultants for review and certification.
3. Within 7 to 28 days (or as mentioned in the contract agreement) of receipt of the application for payment, the consultant shall determine the amount of payment and issue a certificate herein called “interim payment certificate” (IPC) to WAPDA and the contractor.
4. The project manager of the PMU, after thorough evaluation, will approve the IPC and place a demand of approved amount of payment to the general manager (finance) of the Power Wing of WAPDA.
5. The general manager (finance) of the Power Wing will release the approved amount of payment to the project manager of the PMU and transfer the funds into his official bank account.
6. The project manager of the PMU will issue a cheque to the contractor on receipt of funds from the general manager (finance) of Power Wing.

7. The maximum period within which the payment is to be made to the contractor is 30 to 60 days (or as agreed in the contract agreement), from the first submission of application for payment to the project manager of the PMU.

7.5.2 Electrical and Mechanical Works

The basic payment procedure for the electrical and mechanical works to the contractor is described below:

1. The contractor shall submit eight copies of the application for payment signed by the representative of the contractor to WAPDA at the end of each month.
2. The application for payment on the delivery of any plant and erection equipment shall also be accompanied by the following:
    - Copies of the contractor’s invoice showing plant description, quantity, unit price, total price;
    - Copies of packing list identifying contents of each package;
    - Contractor’s guaranty certificate;
    - Inspection certificate issued by the consultant and the manufacturer’s factory inspection report;
    - Clean on board, bill of lading or air waybill;
    - Certificate that the plant complies with specification;
    - Certificate of origin, issued by the contractor;
    - Marine insurance policies;
    - Consultant’s permission to deliver; and
    - Any other documents as considered necessary by the consultant.
3. Within 14 days (or as prescribed in the contract agreement) of receipt of the monthly statement, the consultant shall determine the amount of payment to the contractor and issue to WAPDA and the contractor a certificate of payment.
4. The amount of payment to the contractor under any payment certificate issued by the consultant shall be paid by WAPDA to the contractor within 58 days (foreign component) and within 49 days (local component) after the contractor’s monthly statement has been submitted to the consultant for certification. (These periods can vary as per contract agreement.)

7.6 Security Regulation in the Project Site

The Ministry of Interior (MOI) stipulates the security regulation for government-sponsored project. Their security is the main responsibility of the government. The sponsoring ministry or department must be made responsible to coordinate and ensure the safety and security of their foreign guests in collaboration with the law enforcing agencies (LEAs). The sponsor must deputize an officer to look after the security aspects and the whole blame and responsibility must not be thrown to the LEAs alone.

The security regulation in the project site and camp site stipulated by the MOI is described below:

Security in the Project Site

1) Responsibility of security rests with the sponsoring department, ministry, or private firm.
2) All security arrangements must be coordinated with the Foreigner's Security Cell (FSC), MOI.
3) Sponsors should submit the security plan to FSC, MOI and get its approval prior to the arrival of foreigners.
4) Only one agency should be made responsible for security. All other security agencies must function under its command.
5) Project site should be isolated from local habitation.
6) Project site must be well cordoned possibly with only one entry and exit point.
7) Nobody should be allowed to enter the project area without a security pass or valid permission issued by an appropriate, responsible, and competent authority.
8) Security arrangements should be directly proportional to the level of threat being anticipated.
9) Required number of security towers should be built on the perimeter of the project site.
10) Good and reliable communication within the project site and with the outside agency, such as sponsor and LEAs, should be ensured.
11) Sufficient security staff should be hired or assigned to the project site.
12) Security must remain active round the clock.
13) Security staff must work in three shifts for this purpose.
14) Security staff must get proper rest after their duty.
15) Security staff must not be overworked. Overwork can hamper their efficiency.
16) Efficiency and state of mind of security staff should be given due consideration.
17) Security staff should be cleared security-wise from intelligence agencies before assigning security duty with the foreigners.

18) All local labor must be cleared security-wise before employing them to the Project.

Security in the Camp Site

In addition to the abovementioned points, the following should be considered:

1) All-out efforts should be made to keep the camp within the parameters of the project site so that an integrated security arrangement will work.

2) If it is not possible, then the camp should be kept as close to the project site as possible.

3) In this case, a separate security plan should be made and submitted to FSC, MOI for approval prior to the arrival of foreigners.

4) Foreigners must stay within the camp site and should not be allowed to move out freely for security reasons.

5) They must be provided all facilities and items of daily use inside the camp site.

6) If camp site is not within the project site, then a separate commander should be made responsible for the security of the camp site.

7.7 Required Permission for Foreigner to Enter the Project Site

The following procedures are stipulated by MOI in acquiring permission of foreigner to enter the project site in Mangla. The said permission is named as non-objection certificate (NOC).

1) The consultant or the contractor will apply to WAPDA for an issuance of NOC.

2) WAPDA requests to MOI for issuance of NOC for the consultant or the contractor.

3) MOI instructs the Administration of AJ&K, Inspected General Police (IGP) for arrangement of the security for the consultant or the contractor during their transfer to the project site in Mangla and their stay at the site.

4) MOI issues the NOC to WAPDA, and WAPDA informs the consultant and the contractor.

CHAPTER 8

PROJECT COST ESTIMATION

CHAPTER 8 PROJECT COST ESTIMATION (Non DISCLOSURE)

CHAPTER 9

FINANCIAL AND ECONOMIC ANALYSES

CHAPTER 9 FINANCIAL AND ECONOMIC ANALYSES (Non DISCLOSURE)

CHAPTER 10

CONCLUSION AND RECOMMENDATIONS

CHAPTER 10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions (Disclosure)

10.2 Recommendations Prior to Implementation

As previously stated, after the conclusion of the L/A, it will take at least 30 months to secure a contract with a contractor for the rehabilitation and enhancement works. The recommendations for maintenance are to be done by the implementation agency prior to the implementation of the Project as stated below:

- To clean up erection bays;
- To confirm the operating conditions of the lifting beam, lifting device, and wire;
- To confirm the operating conditions of overhead traveling crane with inching operation; and
- To clean up the inside of water pits and generator rooms.

10.3 Recommendations for Monitoring System Using Japanese Technology

10.3.1 Hydraulic Consideration

According to the result of the field survey in this study, the monitoring systems for sedimentation in the reservoir, water level of the reservoir, movement of the power house and seepage model analysis data since 1968 are manually operated. These systems are not reliable and precise. Consequently, the improvement of the existing monitoring systems is strongly recommended by the use of GIS technology.

The upgrading monitoring systems recommended by the Survey Team are as follows:

1) Rehabilitation of sedimentation monitoring system at the dam;
2) Rehabilitation of water level monitoring system at the dam;
3) Rehabilitation of seepage monitoring system at the power house;
4) Rehabilitation of movement monitoring system at the power house;
5) Rehabilitation of crack observation at the power house;
6) Rehabilitation of existing meteorological and river observation stations for tributaries; and
7) Centralized control panel monitoring system.

10.3.2 Monitoring System for Sedimentation Using Japanese Technology

The sedimentation of Mangla Dam is being surveyed every three to five years since the 1970's and its volume is shown in Table 4-25. The annual average sedimentation is 36.13 million m^3. If the situation of sedimentation and its volume are observed in an earlier time, the appropriate counter measures against sedimentation may be considered and implemented for each river properly. Therefore, the reservoir will be effectively used for irrigation/hydraulic power after preventing sedimentation. In the past, the survey of sedimentation took more than two months. If the survey is conducted using GPS and multi-beam sonar sounding system by Japanese technology, the period of survey would be shortened and accurate sedimentation volume would be obtained.

On the other hand, the movement monitoring system is being conducted at the power house but the existing equipment are old model and manually operated. The updated model shall be recommended for installation to obtain accurate monitoring. The updated equipment is very accurate and the data is transmitted by wireless to the centralized monitor station, which is useful during emergency period. Using the updated monitoring system, the movement of the dam body and power station and pore-water pressure shall be observed at the centralized monitor station in real time to prevent accidents.

Presently, the model systems of the meteorological stations upstream of the dam are also old. The stations are still manually operated and there is no real time monitoring. The stations must also be updated by using data logger and transmitter for sending data automatically to the centralized monitor station on time via 3G system. The meteorological and river data shall be accurately observed thru the internet in real time so that the dam shall be managed and observed properly.

Table 10-7 shows the number of equipment to be installed, the specification of equipment, and estimated cost for rehabilitation of the existing measurement and observation systems.

Table 10-7 Cost Estimate for Equipment and System (Disclosure)

The tentative implementation schedule is shown in Table 10-8.

Table 10-8 Implementation Schedule

Monitoring System	Work Item	Month				
		1	2	3	4	5
Sedimentation of Dam	Measurement	—	—			
	Arc-GIS			—	—	
	Training	—	—	—	—	
Movement of Power House	Installation		—			
	Training			—		

Seepage at Power House	Installation		━━			
	Training			━━		
Crack Displacement	Installation			━━		
	Training				━━	
Water Level of Dam	Installation		━━			
	Training			━━		
Meteorological and River Stations	Installation	━━	━━			
	Training			━━		
Centralized Control Panel	Installation			━━	━━	
	Training				━━	
-	Reinforcement of Cracks	━━	━━			

Source: Prepared by the Survey Team

10.4 Time Based Action Plan

The works to be done by WAPDA prior to the conclusion of L/A is summarised as the Time Based Action Plan in the table below:

Table 10-9 Time Based Action Plan

No.	Work Items	Time Frame	Responsible Department of WAPDA
1	Preparation of PC-I by WAPDA/Consultant and its submission to Minister of Water and Power (MoWP)	1.0 month	General Manager (Hydel) Development
2	Minister of Water and Power (MoWP) examines PC-I and submit it to Planning Commission for obtaining their approval.	1.0 month	MoWP
3	Planning Commission examines the proposed project in depth by circulating it to all the stakeholders, the Provincial Governments (if involved) and Ministry of Finance for their comments / reservations (if any)	1.0 month	Planning Commission
4	After getting the comments of all the stakeholders a working paper would be prepared by the Planning Commission of Pakistan.	0.5 month	Planning Commission
5	As the value of the project is more than Rs 1,000 million, it is to be put up in Executive Committee of National Economic Council (ECNEC) for approval. ECNEC is headed by MOF and attended by EAD, Planning Commission of Pakistan, provincial governments, MoWP and WAPDA through its Chairman / Member Power and General Manager (Hydel) Development.	1.0 month	Planning Commission , Chairman WAPDA, Member (P) and G.M. (Hydel) Development
6	Establishment of the Project Management Unit (PMU) of WAPDA at the project site to execute the project.	1.0 month	General Manager (Hydel) Development would obtain the approval of the WAPDA Authority.

Source: Prepared by the Survey Team

APPENDICES

APPENDIX 1

CONTRAST TABLE OF THE TOR AND THE REPORT

Appendix 1 Contrast Table of the ToR and the Reports (1/6)

ToR in the Inception Report	Draft Final Report
【F1-2】 Basic Study and Review of Project Scope (1) Analysis of present condition and issues the power sector currently facing	
1) The Survey Team shall review the existing reports and documents such as "Policy for Power Generation Projects Year 2002", "Medium Term Development Framework (MTDF)", "Approach Paper for 10th Five Year Plan for 2010-15", and "Energy Sector Task Force". In addition, the Survey Team shall review the law, regulations, policy and future planning etc. related to the development of power sector planned by the central government, and shall discuss with the relevant parties, if any.	- Chapter 2 Basic Data and Information
2) The Survey Team shall review the development program of domestic generation and future prospect of the supply condition of domestic and import energy. The Survey Team shall also review the future construction plan of the power generating plant.	- Chapter 2 Basic Data and Information / Clause 2.2 National Power System Expansion Plan, Clause 2.3 Generation Planning
3) The Survey Team shall grasp the present activities of other donors in the power sector, and extract the appropriate information to be used for the Project effectively, such as agenda between donors and objected sectors, the scope of the assistance program, and procurement information etc.	- Chapter 2 Basic Data and Information / Clause 2.4.6 Present Activities/Status of Projects Supported by Other Donors
(2) Understanding the present situation of Mangla Hydro Power Station	
1) The Survey Team shall review the design reports, drawings, technical specifications of equipment and past operation records of Mangla Hydro Power Station based on the data and information collected at the F/S conducted by WAPDA.	- Chapter 3 Review of the F/S Report
2) The Survey Team shall investigate the construction condition at the project site of Mangla Hydro Power Station and special requirement for safety management during the construction of the Project. In addition, the Survey Team shall study the administrative procedure required for access the project site after commencement of the Project.	- Chapter 7 Project Implementation Plan / Clause 7.6 Security Regulation in the Project Site, Clause 7.7 Required Permission for Foreigner to Enter the Project Site
(3) Review of necessity of the Project The Survey Team shall confirm the needs of rehabilitation and enhancement of the water turbines, generators, other equipment and concrete foundations, and shall review the	- Chapter 4 Findings in the Plant Survey

Appendix 1　Contrast Table of the ToR and the Reports (2/6)

ToR in the Inception Report	Draft Final Report
necessity of the Project through the reviewing the present conditions and issues currently facing at the power sector, the past fault records and repair records of equipment, and F/S report prepared by WAPDA.	
【D2-1】Basic Study and Review of Project Scope (Continuance) (1) Review of Necessity of Project The Survey Team shall review the necessity of the Project through analyzing the data and information collected during 1st Field Survey.	- Chapter 4 Findings in the Plant Survey
(2) Review of Project Scope	
1) The Survey Team shall review the validity of the scope and construction method of the Project considering the WAPDA's management skill on operation and maintenance.	- Chapter 1 Introduction / Clause 1.3 Basic Concept
2) The Survey Team shall review the required condition for forming the project as STEP project, focusing on the procurement ratio of product manufactured in Japan, the contract condition and the contract package. And, the Survey Team shall confirm the tender method discussing with WAPDA	- Chapter 1 Introduction / Clause 1.3 Basic Concept
3) The Survey Team shall plan the term of reference and man-months required for the procurement of consultant for project implementation.	- Chapter 7 Project Implementation Plan / Clause 7.1 Implementation Policy
4) The Survey Team shall formulate soft component required for capacity buildings enabling improvement of O&M capability of WAPDA, and include them in the scope of the Project	- Chapter 2 Basic Data and Information / Clause 2.5.4 Mangla Hydro Power Station - Chapter 4 Findings in the Plant Survey / Clause 4.3 Maintenance Management
5) The Survey Team shall review the further utilization of Japanese latest technology which can contribute to increase effectiveness of the Project.	- Chapter 10 Conclusions and Recommendations / Clause 10.3 Recommendations for Monitoring System Using Japanese Technology
【F2-3】Review of Implementation Schedule (1) The Survey Team shall confirm the relevant administrative procedures for obtaining the approval of the Project regulated by the Government of Pakistan, and review the appropriate procedure for smooth implementation of the Project.	- Chapter 7 Project Implementation Plan / Clause 7.1 Implementation Policy

Appendix 1　Contrast Table of the ToR and the Reports (3/6)

ToR in the Inception Report	Draft Final Report
(2) The Survey Team shall review the planning, procurement method, implementation and operation and maintenance (O & M) management for the Project.	- Chapter 7 Project Implementation Plan
(3) The Survey Team shall study on the procurement of the Consultant, such as selection of the consultant, proposal evaluation, process of the contract, and required period for of contract.	- Chapter 7 Project Implementation Plan / Clause 7.1 Implementation Policy
(4) The Survey Team shall prepare the bar chart implementation schedule of the Project in which each step of the implementation such as detailed design stage, tender, procurement, and erection works is shown.[	- Chapter 7 Project Implementation Plan / Clause 7.2 Implementation Schedule
(5) The Survey Team shall list the key items for the implementation of the Project and prepare the Time-bound Action Plan including the implementation agency and department, period of execution of the Project etc.	- Chapter 10 Conclusions and Recommendations / Clause 10.4　Time Based Action Plan
【F2-4】Review of Project Implementation and Structure of Operation and Maintenance (1) Project Implementation Structure The Survey Team shall confirm and examine the following items of the executing agencies, then recommend an optimum implementation organization for the Project. 1) Executing agency such as project management units (PMU) 2) Scope of work, organization and human resources of the executing agency 3) Financial status of the executing agency 4) Technical capability of the executing agency 5) Experience of the executing agency for similar projects	- Chapter 2 Basic Data and Information / Clause 2.5 Mangla Hydro Power Station - Chapter 7 Project Implementation Plan / Clause 7.1 Implementation Policy
(2) Operation and Maintenance Structure The Survey Team shall confirm and examine the following items of the operation and maintenance (O&M) organization and recommend the optimum organization. 1) Existing O&M division 2) Scope of works, manpower, and organization structures 3) Allocated budget for the O&M division	- Chapter 2 Basic Data and Information / Clause 2.5 Mangla Hydro Power Station - Chapter 7 Project Implementation Plan / Clause 7.1 Implementation Policy

Appendix 1 Contrast Table of the ToR and the Reports (4/6)

ToR in the Inception Report	Draft Final Report
4) Technical level of the O&M division	
【F2-5】Project Cost Estimation The Survey Team shall estimate the project costs consisting of the following items, in accordance with the JICA's guideline. 1) Main project cost consists of the costs for procurement of equipment and materials, transportation, construction and erection including civil works, commissioning. As for the civil works, the cost of man power, materials, rental fee of construction equipment, etc. shall be estimated. 2) Price escalation for the main project cost 3) Physical contingency 4) Interest during construction 5) Commitment charge for the bank 6) Consultant fee including price escalation and contingency 7) Administration cost 8) Tax charge (Value-added tax and custom duty)	- Chapter 8 Project Cost Estimation
【F2-6】Environmental and Social Considerations (1) Based on the first survey in the country and the Interim Report, the scope, the quantity and the methods of work of the Project shall be identified.	- Chapter 6 Environment and Social Considerations
(2) Regarding those scope, quantity and methods of work, the Survey Team shall identify adverse environmental and social impacts that would possibly be caused by the Project, by means of the environmental checklist on the sector concerned.	- Chapter 6 Environment and Social Considerations
(3) Referring to the JICA Guidelines for Environmental and Social Considerations, Version of April 2010, the environmental and social impacts shall be examined if the results of previous evaluation, in which the adverse impacts by the Project would be minimal, is still valid or not.	- Chapter 6 Environment and Social Considerations

Appendix 1 Contrast Table of the ToR and the Reports (5/6)

ToR in the Inception Report	Draft Final Report
(4) The Survey Team shall review the environmental and social considerations reported by WAPDA for the Project, and check whether the Project components are complying with the environmental regulations of the Government of Pakistan, including the environmental impact assessment scheme.	- Chapter 6 Environment and Social Considerations
(5) Based on the examination above, the Survey Team shall study necessary measures to be taken for the potential environmental and social impacts. Especially, the possibilities of incidence shall be examined and appropriate mitigation measures are planned for the following; - Possible change of water use arrangement among users that might be caused by the rehabilitation work of the Project - Impacts of the rehabilitation work on irrigation water and the surrounding water related. - Water pollution by the work - Noise, vibration and dust to be generated by the work, and - Others, if necessary	- Chapter 6 Environment and Social Considerations
【F2-7】Analysis of Impact on GHG Emission Reduction The Project's impact on GHG emission reduction shall be estimated with the methodology of Clean Development Mechanism (CDM). First, the study shall conduct data identification and collection for the data, such as electricity (GWh) generated and GHG (t-CO_2) emitted by thermal power generation with the fossil fuels which would be replaced by the Project. Then, based on the calculation with those data, the impact on GHG emission reduction shall be estimated. In particular, the analysis shall refer to the method defined in JICA Climate Finance Impact Tool for Mitigation, 'JICA Climate-FIT (Mitigation), Draft Ver. 1.0, June 2011', which set a base on Intergovernmental Panel on Climate Change (IPCC) Guidelines.	- Chapter 6 Environment and Social Considerations
【F2-8】Analysis of Impact of the Project (1) Operation and impact indicators shall be selected and baseline and target value shall be determined with reference to the past loan projects. The indicators for evaluating the quantitative and qualitative impact of the Project and the target of indicators in three years after the completion of the Project shall be proposed to Pakistan side.	- Chapter 9 Financial and Economic Analyses / Clause 9.7 Operation and Effect Indicators

Appendix 1 Contrast Table of the ToR and the Reports (6/6)

ToR in the Inception Report	Draft Final Report
(2) Appropriate qualitative impact shall be clarified as it is important to make the qualitative impact clear in order to examine the validity of the Project.	- Chapter 9 Financial and Economic Analyses / Clause 9.7 Operation and Effect Indicators
(3) The financial and economic validity of the Project shall be checked based on the calculation of financial internal rate of return (FIRR) and economic internal rate of return (EIRR), after clarifying the assumptions on cost, benefit, project life, and discount rate based on the feasibility study, which is being conducted by WAPDA and discussion with relevant organizations.	- Chapter 9 Financial and Economic Analyses
(4) The assumptions on cost, benefit and other conditions shall be made and IRR is calculated in line with the feasibility study of WAPDA and the similar types of projects in the past. Financial benefit shall be calculated based on incremental electricity sales from the increase of the electricity generation. Economic benefit shall be decided based on the review of the alternative goods such as coal and diesel oil. Sensitivity analysis shall be conducted based on the changes of conditions such as cost increase, benefit reduction, and delay in construction.	- Chapter 9 Financial and Economic Analyses - Chapter 10 Conclusions and Recommendations

APPENDIX 2

COMMENTS ON THE MINUTES OF MEETING

Appendix 2 WAPDA's Comments on the Minutes of Meting and JICA's Survey Team's Replies (1/2)

WAPDA's Comments	JICA Survey Team's Replies	Draft Final Report
Subjected Report: Inception Report **Meeting Date: February 23, 2012**		
1. WAPDA suggested JICA Survey Team (JST) to review the hydrological analysis after raising the dam, which was not presented in the methodology of the survey".	JST replied that since they had planned to refer the results of hydrological analysis after raising the dam done by WAPDA, the review of hydrological analysis is not in the scope of their work in the contract between JICA and the JST at present.	The result of review of the hydrological analysis described in the F/S report is incorporated into Clause 3.2.5 and Clause 4.9 of Draft Final Report.
2. WAPDA asked JST the subjected scope of the rehabilitation units of the survey.	JST replied that under the contract between JICA and the JST, the subjected units of the survey are mainly No.1 to No.4. However, upon discussion between WAPDA and JST during 1st Field Survey, the subjected units of the survey possibly can be changed for including all units of the power station.	JST has carried out the plant survey for all the existing units of Mangla Hydro Power Station as described in Chapter 4 of Draft Final Report.
3. WAPDA suggested JST to change the title of the project to "Up-gradation and Refurbishment of Generating Units of Mangla Power Station" as the project was named on the F/S commenced in middle of last year.	JST explained that as the title is decided by JICA, it is may be difficult to change. Anyhow JST will forward WAPDA's request to JICA, and reply the results on their response.	The project title in this preparatory survey is no changed from that proposed by JICA.
Subjected Report: Interim Report **Meeting Date: May 21, 2012**		
4. WAPDA suggested JST to calculate the benefits by reducing head loss of Inlet Valve, and incorporate in the Draft Final Report.	JST proposed to replace the Inlet Valve with By-plane type valve which can reduce the head loss and enhance the generation capacity, on the other hand, there would be cost implications. JST explained that this replacement is also necessary to address the water leakage problem.	The calculation of the head loss in case of butterfly-type inlet valve is described in Clause 5.6.1 of Draft Final Report.
5. WAPDA commented that the efficiency of turbines installed in Ghazi Barotha HPP is almost 94%, which is manufactured by Voith Hydro, therefore WAPDA suggested JST should review the turbine efficiency.	JST assumed the turbine efficiency as 91.2% at maximum head and discharge after replacement.	The estimated turbine efficiency at turbine maximum output is 93.0 % as described in Clause 5.6.1 of Draft Final Report.
6. WAPDA commented that financial analysis is required to be carried out by JST on the incremental energy generated by 144MW proposed by JST against 135MW proposed in the	JST conducted the financial analysis for both of 144MW and 135MW per unit.	Already incorporated into Chapter 9 and Chapter 10.

Appendix 2 WAPDA's Comments on the Minutes of Meting and JICA's Survey Team's Replies (2/2)

WAPDA's Comments	JICA Survey Team's Replies	Draft Final Report
F/S Report.		
7. WAPDA suggested that incremental annual energy generated (GWh) expected by the recommended 174 MW incremental capacity [(144 MW - 115 MW) x 6 units] is required to be stated in the Draft Final Report.	JST conducted the calculation of incremental annual energy generated (GWh).	The result of calculation is attached in Annexes 10 & 11.
8. WAPDA suggested that two scenarios of implementation schedule, namely one unit at a time, and two units simultaneously, are required to be studied, considering maximum demand in July to September each year.	JST made a preparation of 2 cases of implementation schedules, one with condition of single unit stoppage, the other is one with two stoppage simultaneously.	The both schedules are attached in Clause 7.2 of Draft Final Report.
9. WAPDA desired that the degree of deterioration for all turbines be assessed in the Draft Final Report.	JST described the degree of deterioration for all turbines.	Already incorporated into Chapter 4 and Chapter 5.
Subjected Report: Draft Final Report Meeting Date: August 28, 2012		
10. Regarding the proposal of Enhanced capacity of generators to 144MW, WAPDA suggested JST to review their proposal keeping in view the capacity of 135MW recommended by MWH & NESPAK in their F/S, as generators of larger capacity are not beneficial due to hydraulic constraints.	JST reviewed the 135 MW recommended by MWH & NESPAK in their F/S from the viewpoints of technical, economical and financial etc.	Already incorporated into Chapter 10 and Appendixes 12 to 15.
11. WAPDA also suggested JST to compare the costs of 144 MW generators and 135 MW generators and re-calculate the EIRR and FIRR keeping in view their respective incremental benefit.	JST reviewed the 135 MW recommended by MWH & NESPAK in their F/S from the viewpoints of technical, economical and financial etc.	Already incorporated into Chapter 10 and Appendixes 12 to 15.
12. WAPDA also suggested JST to review their proposal of replacement of equipment of turbines and generators as compared with the recommendations of the F/S report.	JST made a comparison tables listed the recommendations in F/S report and JST's comments.	Already incorporated into Tables 3-9 to 3-17 of Chapter 3 in Draft Final Report.

APPENDIX 3

GENERAL JICA PROCUREMENT PROCEDURE FLOW CHART

FINAL REPORT
for
The Preparatory Survey for Mangla Hydro Power Station Rehabilitation and Enhancement Project in Pakistan

CONTENTS

Chapter 1 INTRODUCTION

Chapter 2 BASIC DATA AND INFORMATION

APPENDIX 4

MANGLA DAM RESERVOIR WATER ACCOUNT

Mangla Dam Resrervoir Water Account

Year	Resrervoir Water Account				
	Inflow (MCM)	Outflow (MCM)	Pwer Use (MCM)	Flood Relief (MCM)	Storage Releases (MCM)
1968	29,338	28,122	27,609	513	5,348
1969	26,651	27,664	24,237	3,428	6,438
1970	29,858	31,132	26,753	4,379	6,546
1971	18,943	19,077	18,823	254	6,016
1972	16,720	15,713	15,661	52	4,621
1973	30,793	29,977	29,919	58	5,821
1974	32,543	34,325	31,996	2,329	7,234
1975	20,112	19,568	19,403	165	4,336
1976	31,298	30,694	25,487	5,207	5,685
1977	30,472	31,439	28,257	3,182	6,473
1978	24,214	22,101	20,804	1,298	5,452
1979	30,373	30,203	18,084	12,119	4,855
1980	25,543	26,938	20,049	6,889	5,696
1981	28,897	27,264	24,249	3,015	5,168
1982	27,910	29,532	20,477	9,055	6,524
1983	26,331	26,484	23,053	3,432	5,947
1984	32,350	33,399	21,555	11,844	6,540
1985	23,030	23,298	21,220	2,080	6,684
1986	21,772	20,241	20,241	0	5,681
1987	34,335	34,245	26,248	7,998	5,721
1988	34,325	34,364	25,019	9,347	5,969
1989	29,578	30,314	25,455	4,857	6,149
1990	30,478	29,242	27,124	2,120	6,038
1991	33,747	31,583	29,253	2,330	4,819
1992	38,374	40,343	24,374	15,971	5,768
1993	39,476	40,537	25,829	14,709	5,215
1994	28,015	28,881	23,563	5,319	6,091
1995	32,675	31,470	29,320	7,084	6,513
1996	34,635	33,510	30,106	3,261	5,171
1997	35,836	37,923	29,499	8,425	5,547
1998	29,626	28,641	26,490	2,152	5,357
1999	26,785	27,752	27,752	0	6,530
2000	17,783	17,821	17,821	0	5,116
2001	15,469	15,299	15,299	0	5,097
2002	14,666	14,375	14,375	0	4,431
2003	21,448	21,289	20,590	699	6,758
2004	27,968	28,527	28,122	405	6,454
2005	22,768	21,807	21,807	0	4,914
2006	28,606	28,974	27,010	1,965	167
2007	28,617	26,182	24,634	1,548	4,897
2008	21,839	24,513	22,977	333	3,519
2009	22,510	22,812	22,737	154	6,351
2010	25,957	26,771	26,414	358	6,847
2011	31,737	27,626	25,463	5,741	7,244
Averrage	**27,600**	**27,545**	**23,981**	**3,729**	**5,631**

APPENDIX 5

MANGLA DAM RAINFALL DATA

Mangla Dam Rainfall Data

Station	Month	2010		2009		2008		2007		2006		2005		2004		2003		2002		2001		Averrage	
		Total	Max	Total	Max	Total	Max	Total	Max	Total	Max	Total	Max	Total	Max	Total	Max	Total	Max	Total	Max	Ave.	Max
DOMEL Lat. 34 22 04 Lon. 73 28 08 Elev. 686 ft masl	1	33.4	25.4	4.7	1.2	243.3	49.5	6.4	2.3	224.6	72.4	201	70.1	168.6	47.8	31.2	23.9	83.9	53.1	1.3	1.3	99.8	72.4
	2	314.5	73.7	7.1	2	89.9	29.2	137.7	26.4	127.5	45.5	291.8	38.1	87.1	22.9	391.7	140.7	116.5	65	12.7	3.5	157.7	140.7
	3	76.8	25.6	2.9	1.1	12.4	5.3	242.8	73.7	128.5	36.1	169.4	35.1	11.2	7.1	196.7	70.1	100	32.3	95.6	42.2	103.6	73.7
	4	70.8	16.5	8	2.3	164.6	34.8	52.8	26.7	82.1	43.2	78.9	43.2	112	38.6	153.9	42.7	67.6	17.8	72.5	17.8	86.3	43.2
	5	83.1	26.7	2.1	0.7	141.7	32.8	71.9	21.6	46.3	30.5	94.3	43.2	65.6	26.2	121.5	41.9	51.8	24.1	90.6	33.5	76.9	43.2
	6	110.9	28.4	2.8	0.8	275.3	87.6	184.4	33	189.1	41.9			155.9	49.8	98.5	21.6	192.1	82.6	106.7	21.1	146.2	87.6
	7	569.8	98.3	11.2	2.1	276.4	59.4	173.7	34.3	514	142.7	292.6	155.4	287.1	79.8	236.9	36.1	122	43.2	250.3	53.8	273.4	155.4
	8	219.6	71.1	5.9	2.7	225.3	49.5	124.2	30.5	411	159.3	221	41.9	221.6	42.7	90.6	29.7	183.6	41.7	125.3	31.5	182.8	159.3
	9	99.4	63	3.5	1.5	104.6	68.1	78	21.1	64.2	14.7	123.7	55.6	133.6	81.3	115	43.7	93.8	28.4	77.8	36.6	89.4	81.3
	10	27.9	24.1	0.6	0.5	51.3	22.9	0	0	44.3	27.7	68.3	30.5	118.3	61	13.5	13.5	42.6	34.5	10.4	7.4	37.7	61
	11	1.3	1.3	1	0.6	57.7	34.8	17.8	17.8	112.6	44.7	25.1	12.2	38.6	38.1	66.5	37.8	1.3	1.3	69.9	11.9	39.2	44.7
	12			1.2	0.8	152.4	80	42	14.7	242.7	100.6	0	0	74.3	41.6	91.4	45.2	31.4	15.7	12.9	11.9	72.0	100.6
Total		1607.5	98.3	51	2.7	1794.9	87.6	1131.7	73.7	2186.9	159.3	1566.1	155.4	1473.9	81.3	1607.4	140.7	1086.6	82.6	926	53.8	1365.0	159.3
PALANDRI Lat. 33 43 10 Lon. 73 41 06 Elev. 1,402 ft masl	1	25.4	17.5	101.6	39.1	222.3	66	0	0	136.5	44.5	126.4	45.2	177	52.1	37.3	20.8	102.3	44.4	4.3	3.3	93.3	66
	2	212.6	132.1	128.5	54.6	72.9	29.2	148.6	48.3	68.3	36.8	324.4	67.4	56.8	19.1	537.5	177.8	57.1	39.4	4.8	3	161.2	177.8
	3	71.9	22.4	93	33.8	2.5	1.3	282.4	68.6	37.7	19.1	136.5	36.8	0	0	104.4	54.6	73.4	29	71.7	37.3	87.4	68.6
	4	25.9	18.3	163.8	86.4	158.2	57.2	17.8	12.7	53	24.1	22.9	21.6	80.6	30.5	27.5	10.2	11.5	6.6	53.1	11.7	61.4	86.4
	5	0	0	12.2	6.4	53.8	21.6	62.7	24.1	26.4	14	39.4	12.7	80.9	58.4	22.6	17.8	18	8.6	103.2	43.7	41.9	58.4
	6	83.8	34	86.4	24.9	283.5	58.7	95.3	24.6	68.7	22.9			87.8	25.4	71.3	33	124.2	35.6	234.6	56.6	126.2	58.7
	7	628.1	194.3	208.5	67.3	151.4	80	276.9	59.7	162.9	35.6			159.3	43.2	254.5	53.3	103	21.3	368.6	101.6	257.0	194.3
	8	159.3	36.1	162.8	45.7	110	21.6	87.4	39.9	282.1	124.5			128.7	30	158.6	66	239.3	55.9	176.8	88.6	167.2	124.5
	9	33	12.7	89.7	47	26.7	10.2	81.3	16.5	20.9	8.1			54.7	29.2	125.8	51.3	108.6	31.8	88	32.6	69.9	51.3
	10	67.3	63.5	31.8	25.4	71.4	39.4	0	0	36.1	30.5			116.8	51.6	3.8	3.8	21.5	15.2	11.7	8.1	40.0	63.5
	11	7.6	5.1	0	0	1.5	1.5	20.3	20.3	59.6	36.8			50.8	50.8	43.9	28.7	3.6	3.6	43.2	21.6	25.6	50.8
	12	3.8	3.8	14.2	11.4	129.3	54.6	8.6	5.1	160.2	67.8			63	34.3	45.2	23.6	18.5	11.2	19.6	14.5	51.4	67.8
Total		1318.7	194.3	1092.5	86.4	1283.5	80	1081.3	68.6	1112.4	124.5	649.6	67.4	1056.4	58.4	1432.4	177.8	881	55.9	1179.6	101.6	1182.5	194.3
KOTLI Lat. 33 29 05 Lon. 73 52 52 Elev. 610 ft masl	1	21.6	11.4	62.2	30	156.7	65	1.3	1.3	91.9	42.2	98.1	29.5	137.8	47.8	13.7	11.7	46.8	22.4			70.0	65
	2	122.2	79.5	97.8	45.2	60.2	19.1	160.3	43.7	50.5	36.8	151.7	27.9	23.2	14	279.3	125.2	58.4	31.8			111.5	125.2
	3	69.6	36.8	52.6	20.3	10.7	7.6	247.7	64.8	67.1	18.3	96.8	37.1	5.6	5.6	85.1	41.9	56.6	27.4			76.9	64.8
	4	15.2	10.2	46	19.3	120.7	35.1	21.1	16.5	17.8	12.7	3.8	3.8	78.5	39.6	26.6	11.4	15.2	7.6			38.3	39.6
	5	65.8	29.2	5.8	4.6	55.6	26.7	47.2	25.9	63.4	20.3	18.1	5.1	75.2	71.4	18.5	11.4	32.5	23.6			42.5	71.4
	6	65.3	20.1	34.5	9.4	244.9	49.5	100.8	34.8	139.5	36.8	21.1	11.7	67.4	17	104.3	55.9	78.5	39.9			95.1	55.9
	7	304.5	67.3	132.3	34.3	265.2	67.3	161.3	51.1	381	72.4	193.5	32	165.3	53.3	178.8	36.6	101.4	46.2			209.3	72.4
	8	182.1	36.3	142	25.4	134.4	54.6	188.2	73.7	308.3	58.3	89.9	27.2	197.5	58.4	149.2	45.7	266.6	57.2			184.2	73.7
	9	53.1	14	9.7	5.6	76.7	31.8	64.3	30.5	72.6	19.8	51.7	34	23.4	8.4	99.8	29.5	115.6	35.6			63.0	35.6
	10	55.1	49.5	2.8	1.5	68.8	35.6	0	0	32.8	21.6	15.8	6.4	38.9	19.1	7.1	7.1	29.2	27.9			27.8	49.5
	11	4.3	3	33.5	19.1	2.5	1.3	7.1	7.1	57.3	21.6	2	2	24.9	24.9	26.9	26.9	3.8	3.8			18.0	26.9
	12	18.3	13.2	5.6	3.8	101.6	38.1	4.1	4.1	128.7	65	0	0	43.7	40.6	26.9	15.2	12.5	6.9			37.9	65
Total		977.1	79.5	624.8	45.2	1298	67.3	1003.4	73.7	1410.9	72.4	742.5	37.1	881.4	71.4	1016.2	125.2	817.1	57.2	0	0	974.6	125.2
KALLAR Lat. 33 25 00 Lon. 73 22 00 Elev. 518 ft masl	1	21.6	21.6	40.6	30.5	74.2	42.7	0	0	180.2	69.9	64.3	20.1	67	16.8	12.7	11.4	37.3	34.3	0	0	49.8	69.9
	2	87.7	47.8	44.5	27.9	41.7	17.5	18	5.6	218.9	62.2	140.4	34.3	117.3	58.4	214.6	95.5	17.3	6.9	0	0	90.0	95.5
	3	64.3	35.6	53.3	27.9	13.7	13.7	50.8	8.9	81.5	30.5	77.1	33.5	81.2	31.8	91.4	38.1	32.3	14	32	21.6	57.8	38.1
	4	2.5	2.5	68.6	43.7	108.2	38.4	8.1	7.6	109.2	50.8	8.9	5.1	170.2	34.3	7.1	5.1	8.8	4.3	23.6	14.7	51.5	50.8
	5	50.8	25.4	27.2	23.4	20.3	7.6	20.1	10.7	35.6	8.9	13.2	8.9	47.3	17.8	5.1	5.1	21.4	19.1	45.2	27.4	28.6	27.4
	6	67.3	29.2	17.8	11.4	190.5	82.6	6.3	3.8	21	7.1			19.4	13	34.7	19.1	168.2	48.3	155.7	43.2	75.7	82.6
	7	523.1	273.1	129	78.7	352.6	107.4	10.1	2.5	36.5	11.4			28.7	10.2	264.4	71.1	135.5	34.3	265	74.2	193.9	273.1
	8	143.5	40.6	112.3	98.3	95	45.5	0	0	53.4	16.8	126.5	29.2	25.8	7.6	166.2	47	213.1	79	124	42.4	106.0	98.3
	9	15.2	7.6	61	22.9	61	20.3	10.2	10.2	23	10.2			29.3	19.1	169.7	106.7	200.2	67.3	32.2	22.1	66.9	106.7
	10	24.1	24.4	0	0	10.2	6.4	0	0	2.3	1.3	26.2	17.8	211.3	80	0	0	8.6	4.8	44.1	33.5	32.7	80
	11	0	0	11.4	11.4	2.5	2.5	0	0	168	50.8			45.7	33.5	29.3	22.9	0	0	11.9	11.9	29.9	50.8
	12	26.7	26.7	1.3	1.3	86.4	33	21.1	8.1	169.4	39.4			117.9	35.3	30.5	16.5	15	12.7	0.5	0.5	52.1	39.4
Total		1026.8	273.1	567	98.3	1056.3	107.4	144.7	10.7	1099	69.9	456.6	34.3	961.1	80	1025.7	106.7	857.7	79	734.2	74.2	834.7	273.1
MANGLA DAM Lat. 33 07 28 Lon. 73 38 00 Elev. 282 ft masl	1	7.9	7.1	57.9	32.5	73.4	1.3	0	0	43.5	21.1			86.8	27.4	17.8	16.3	12.9	4.1	2.5	2.5	33.6	32.5
	2	80.5	69.9	6	25.4	20.8	10.9	147.9	43.2	29.2	20.3			28.4	17.8	159.6	68.6	10.4	6.4	0	0	53.6	69.9
	3	51.4	24.6	22.9	14.5	1.3	1.3	181.4	41.9	41.1	26.7			0	0	39.6	30.5	23.4	11.4	29.5	11.4	43.4	41.9
	4	8.1	8.1	24.6	16.5	112.3	50.8	0	0	7.7	6.4			44	27.7	8.6	3.8	9.9	6.1	19.3	5.1	26.1	50.8
	5	47.2	21.6	13.2	10.7	32.3	24.1	51.3	28.7	27.1	15.2			60.2	55.9	4.3	3.8	16	14	16.4	7.6	29.8	55.9
	6	48.3	17.8	29.7	8.9	175	40.6	128.8	40.9	60.5	25.4			89.2	48.3	53.9	16.5	78.6	21.3	148.3	45.7	90.3	48.3
	7	284.5	106.7	116.1	58.4	199.4	37.8	173.5	40.9	367	132.6			205.8	44.5	225.4	87.6	53	16.5	209.4	52.1	203.8	132.6
	8	231.6	42.2	193	64.8	166.9	48.8	224.3	51.6	197.7	72.4			242.9	45.7	184	45.7	135.1	30.5	118.4	55.9	188.2	72.4
	9	14.7	6.1	33.3	26.7	23.1	10.9	37.3	7.6	77	26.4			13.5	7.1	145.7	58.9	178.4	50.8	17.2	4.6	60.0	58.9
	10	32.5	25.4	1.5	1.5	22.9	14.5	0	0	30.5	25.4			30	11.4	10.7	10.7	3.8	3.8	10.5	10.2	15.8	25.4
	11	0	0	29	21.8	2	2	3.8	3.8	40.8	18.5			9.4	9.4	19.8	19.8	0	0	1.3	1.3	11.8	21.8
	12	18	17	0	0	49.8	20.3	0	0	127	82.6			14.8	13.5	14.5	13.2	12	10.2	0	0	26.2	82.6
Total		824.7	106.7	527.2	64.8	879.2	50.8	948.3	51.6	1049.1	132.6	0	0	825	55.9	883.9	87.6	533.5	50.8	572.8	55.9	782.6	132.6

APPENDIX 6

MANGLA DAM TEMPERATURE DATA

Mangla Dam Temperature Data

Station	Month	2010		2009		2008		2007		2006		2005		2004		2003		2002		2001		2000		Averrage (F)		Averrage C°	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
DOMEL Lat. 34 22 04 Lon. 73 28 08 Elev. 686 ft masl	1	69	39			54	35	65	35	59	38	57	38	59	40	66	37	62	35	64	35	60	38	62	35	16	2
	2	62	42			62	38	62	42	68	43	55	40	69	42	62	41	60	40	77	40	63	40	64	38	18	3
	3	84	54			81	52	70	47	72	49	70	49	84	53	70	49	73	50	76	49	73	47	75	47	24	8
	4	87	61			78	56	91	59	85	56	82	55	86	59	82	57	79	57	79	59	89	59	84	55	29	13
	5	91	66			92	64	93	65	98	67	85	61	93	64	87	60	95	65	94	67	93	65	92	60	33	16
	6	94	68			93	73	96	70	94	75			95	70	99	71	98	70	93	73	99	71	96	68	35	20
	7	93	71			94	75	92	73	96	68	92	74	95	72	94	74	98	73	91	75	92	74	94	68	34	20
	8	91	72			94	74	95	75	89	74	94	73			93	73	91	74	91	74	90	73	92	72	33	22
	9	91	69			92	67	90	67	91	66	94	69	93	68	90	69	89	63	92	65	87	67	91	63	33	17
	10	87	59			88	59	90	53	85	58	86	56	79	56	88	55	87	57	80	57	84	56	85	53	30	12
	11	78	50			77	49	77	44	71	48	74	44	75	46	73	45	80	48	74	45	73	47	75	44	24	7
	12	67	37			67	44	60	39	61	40	66	36	62	42	63	40	65	42	66	41	65	40	64	36	18	2
PALANDRI Lat. 33 43 10 Lon. 73 41 06 Elev. 1,402 ft masl	1	64	40			50	33	59	37	56	37	53	35	54	38	60	39	58	37	63	38	54	34	57	33	14	1
	2	57	40			58	38	58	40	64	45	51	37	61	41	56	39	60	41	69	40	57	35	59	35	15	2
	3	74	51			75	51	63	44	65	47	64	47	77	53	64	46	68	48	75	44	68	42	69	42	21	6
	4	81	58			73	53	81	58	78	55	74	53	79	58	76	56	78	59	78	52	85	57	78	52	26	11
	5	86	63			84	61	84	61	88	65	79	58	85	62	82	59	90	64	90	65	91	66	86	58	30	14
	6	88	64			82	66	87	67	86	64	84	62	85	65	91	68	86	66	86	65	91	65	87	62	30	17
	7	83	67			82	68	82	67	82	68	81	67	85	67	82	67	88	66	83	67	81	66	83	66	28	19
	8	80	68			81	66	83	68	80	67	83	67	80	66	81	67	80	67	81	67	81	66	81	66	27	19
	9	81	62			81	60	80	62	80	61	81	64	82	63	79	63	78	58	80	60	81	62	80	58	27	14
	10	78	54			78	54	79	52	76	54	74	52	72	52	77	54	78	54	75	53	84	57	77	52	25	11
	11	69	44			72	47	72	47	69	50	71	48	68	47	67	45	70	48	70	48	70	47	70	44	21	7
	12	60	37			65	41	58	38	58	39	66	39	61	43	59	41	60	42	65	43	61	41	61	37	16	3
KOTLI Lat. 33 29 05 Lon. 73 52 52 Elev. 610 ft masl	1	70	36			58	38	65	40	62	42	60	41	61	44	66	41	68	39	68	36	64	39	64	36	18	2
	2	67	44			62	43	62	45	72	50	59	46	69	46	65	46	70	43	75	42	65	47	67	42	19	6
	3	82	54			82	52	71	51	75	54	73	56	85	55	74	54	81	51	83	52	77	49	78	49	26	9
	4	92	62			83	57	91	64	88	61	84	59	91	62	86	64	92	62	88	62	94	63	89	57	32	14
	5	95	69			94	68	94	71	100	74	90	68	96	70	94	70	103	71	101	73	102	74	97	68	36	20
	6	99	73			91	71	97	77	97	75	101	77	96	76	100	77	102	74	97	74	98	75	98	71	37	22
	7	92	74			89	73	90	77	90	75	90	77	94	77	91	78	102	75	93	76	91	76	92	73	33	23
	8	88	74			89	73	90	78	88	76	91	76	89	75	90	77	94	74	94	75	91	74	90	73	32	23
	9	88	68			87	65	88	71	88	70	91	74	91	72	87	73	89	65	93	67	89	70	89	65	32	18
	10	86	59			84	58	86	56	84	63	86	60	81	59	85	59	88	59	88	60	90	59	86	56	30	13
	11	78	46			77	52	78	53	72	54	77	49	77	49	74	49	79	50	81	48	79	50	77	46	25	8
	12	67	36			67	42	65	41	63	44	70	37	65	46	67	45	67	44	72	42	72	40	68	36	20	2
KALLAR Lat. 33 25 00 Lon. 73 22 00 Elev. 518 ft masl	1	71	42			61	39	68	42	64	43	62	42			68	41	69	71	68	40	65	44	66	39	19	4
	2	67	43			67	45	67	48	74	52	62	46			67	47	70	46	75	47	67	44	68	43	20	6
	3	85	55			84	60	73	53	76	55	78	56	85	60	76	55	81	56	84	56	78	54	80	53	27	12
	4	94	60			82	64	93	67	92	67	86	62	89	66	89	65	90	68	88	66	93	64	90	60	32	16
	5	97	69			96	73	97	73	101	78	92	69	93	69	97	70	102	76	101	76	101	78	98	69	37	21
	6	100	73			94	76	99	77	100	77	102	81	97	75	103	77	100	76	96	76	99	78	99	73	37	23
	7	95	73			91	75	93	75	93	78			96	78	94	77	101	77	93	76	92	76	94	73	35	23
	8	88	75			91	76	93	76	91	77	95	76	92	75	92	77	93	76	94	76	91	74	92	74	33	23
	9	90	72			90	70	91	72	91	73	92	74	91	72	89	75	90	67	94	71	90	70	91	67	33	19
	10	88	63			87	63	86	61	89	66	87	64	83	62	86	62			86	64	90	64	87	61	30	16
	11	81	51			79	51	80	54	75	55	78	52	76	54	76	53	81	53	83	53	80	54	79	51	26	11
	12	70	40			69	44	66	46			71	44	68	49	70	46	70	46	73	46	73	45	70	40	21	4
MANGLA DAM Lat. 33 07 28 Lon. 73 38 00 Elev. 282 ft masl	1	67	41			63	40	69	41	67	43	64	42	65	44	62	40	68	41	64	39	64	43	65	39	19	4
	2	71	49			69	45	69	50	78	50	63	48	73	49	70	49	72	47	75	47	67	46	71	45	22	7
	3	87	61			87	60	77	55	79	55	78	55	89	60	79	58	84	77	84	56	78	55	82	55	28	13
	4	99	72			88	65	95	69	94	66	89	64	95	70	92	67	95	69	90	67	97	69	93	64	34	18
	5	101	75			100	75	99	75	103	79	95	72	100	74	99	73	136	79	103	78	103	78	104	72	40	22
	6	104	79			96	76	100	78	102	79	107	81	99	78	105	79	102	78	97	77	100	79	101	76	38	24
	7	95	77			94	77	95	78	94	79	95	78	97	77	95	78	104	81	94	78	92	78	96	77	35	25
	8	91	77			94	77	93	78	93	79	96	78	92	75	93	78	95	79	94	79	91	76	93	75	34	24
	9	94	74			94	73	93	74	92	73	95	76	94	74	92	75	90	71	95	72	89	73	93	71	34	22
	10	91	67			92	67	91	60	90	67	91	63	85	62	87	61	89	65	88	66	90	64	89	60	32	16
	11	84	52			82	52	81	52	78	56	81	50	81	52	78	50	82	53	83	52	79	53	81	50	27	10
	12	72	41			73	48	70	44	67	47	73	40	70	46	71	45	72	46	73	46	72	44	71	40	22	4

APPENDIX 7

MANGLA DAM SEDIMENT DEPOSIT IN RESERVOIR (1967-2010)

Sediment Deposits in Reservoir (1967-2010)

Year	Uppr Jhelum MCM	Lower Jhelum MCM	Kanshi MCM	Poonch MCM	Main MCM	Khud & Jari MCM	Total MCM	Reservoir Capacity MCM
1967	16.10	3.76	2.28	11.10	4.56	-	37.81	7,062
1968	16.10	3.76	2.28	11.10	4.56	-	37.81	
1969	16.10	3.76	2.28	11.10	4.56	-	37.81	
1970	16.10	3.76	2.28	11.10	4.56	-	37.81	6,956
1971	26.93	3.18	1.27	10.43	2.76	-	44.58	99%
1972	26.93	3.18	1.27	10.43	2.76	-	44.58	
1973	26.93	3.18	1.27	10.43	2.76	-	44.58	6,864
1974	13.72	6.82	4.48	13.62	1.69	18.53	58.86	97%
1975	13.72	6.82	4.48	13.62	1.69	18.53	58.86	
1976	13.72	6.82	4.48	13.62	1.69	18.53	58.86	
1977	13.72	6.82	4.48	13.62	1.69	18.53	58.86	
1978	13.72	6.82	4.48	13.62	1.69	18.53	58.86	6,586
1979	5.48	7.00	1.55	3.98	3.54	5.78	27.33	93%
1980	5.48	7.00	1.55	3.98	3.54	5.78	27.33	
1981	5.48	7.00	1.55	3.98	3.54	5.78	27.33	
1982	5.48	7.00	1.55	3.98	3.54	5.78	27.33	
1983	5.48	7.00	1.55	3.98	3.54	5.78	27.33	6,480
1984	3.92	10.04	1.77	6.94	6.82	3.36	32.86	92%
1985	3.92	10.04	1.77	6.94	6.82	3.36	32.86	
1986	3.92	10.04	1.77	6.94	6.82	3.36	32.86	
1987	3.92	10.04	1.77	6.94	6.82	3.36	32.86	
1988	3.92	10.04	1.77	6.94	6.82	3.36	32.86	6,374
1989	12.73	10.29	2.15	6.01	17.77	2.90	51.85	90%
1990	12.73	10.29	2.15	6.01	17.77	2.90	51.85	
1991	12.73	10.29	2.15	6.01	17.77	2.90	51.85	
1992	12.73	10.29	2.15	6.01	17.77	2.90	51.85	
1993	12.73	10.29	2.15	6.01	17.77	2.90	51.85	6,189
1994	-2.42	-0.84	0.54	9.08	36.55	-1.09	41.83	88%
1995	-2.42	-0.84	0.54	9.08	36.55	-1.09	41.83	
1996	-2.42	-0.84	0.54	9.08	36.55	-1.09	41.83	
1997	-2.42	-0.84	0.54	9.08	36.55	-1.09	41.83	6,136
1998	-2.99	-0.36	1.04	7.04	22.98	-0.32	27.38	87%
1999	-2.99	-0.36	1.04	7.04	22.98	-0.32	27.38	
2000	-2.99	-0.36	1.04	7.04	22.98	-0.32	27.38	6,110
2001	-7.78	-7.30	14.25	13.20	12.47	3.00	27.83	87%
2002	-7.78	-7.30	14.25	13.20	12.47	3.00	27.83	6,068
2003	-2.57	0.88	0.42	-2.21	16.43	2.25	15.19	86%
2004	-2.57	0.88	0.42	-2.21	16.43	2.25	15.19	
2005	-2.57	0.88	0.42	-2.21	16.43	2.25	15.19	6,004
2006	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90	85%
2007	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90	
2008	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90	
2009	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90	
2010	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90	5,943
Total	328.05	179.93	100.60	304.33	521.55	155.19	1,589.65	84%
Ratio	21%	11%	6%	19%	33%	10%	100%	

APPENDIX 8

DETAIL OF AVERAGE 10-DAILY IRSA INDENTS

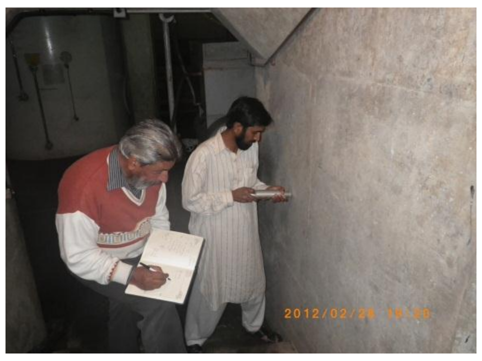
Detail of Average 10-daily IRSA Indents

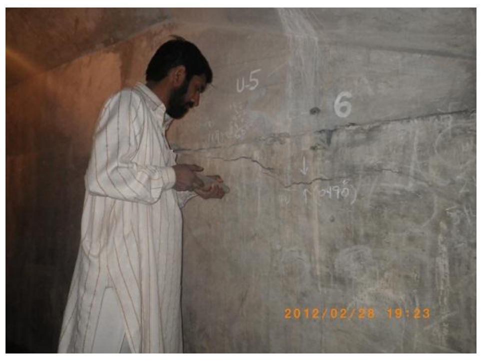
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Ave. Cs	Ave. m3/s
Jan	1	8,000	12,700	8,800	16,800	5,000	7,900	21,050	8,000	5,000	5,000	10,000	9,841	278
	2	7,000	5,100	3,722	10,000	5,000	16,000	24,300	5,700	1,000	0	10,000	7,984	226
	3	9,636	5,455	5,455	9,636	4,091	27,000	16,273	6,818	909	6,636	15,727	9,785	277
Feb	1	14,400	13,200	16,200	14,000	10,000	42,500	22,600	19,800	27,500	15,600	20,900	19,700	558
	2	26,700	20,800	14,324	36,000	13,000	49,700	17,600	24,900	41,100	27,000	27,200	27,120	768
	3	28,000	28,000	6,250	40,000	31,250	32,500	18,000	30,333	44,000	27,875	33,000	29,019	821
Mar	1	7,932	26,800	37,800	26,000	48,100	40,000	29,100	28,100	39,000	27,850	27,000	30,698	869
	2	8,300	20,000	60,000	21,700	56,300	28,900	23,100	23,800	22,600	30,000	38,500	30,291	857
	3	5,300	20,000	39,091	28,909	78,182	19,091	18,000	26,909	10,000	28,000	37,273	28,250	799
Apr	1	7,000	20,000	35,500	25,600	41,000	27,600	31,500	24,600	28,000	26,200	41,000	28,000	792
	2	12,400	22,800	33,800	27,800	34,000	32,500	38,609	33,100	29,500	26,000	40,000	30,046	850
	3	11,000	30,600	32,100	32,400	49,200	39,000	45,606	40,000	40,300	32,600	46,500	36,301	1,027
May	1	32,300	30,800	39,000	34,800	60,000	47,500	45,424	37,500	51,600	42,500	46,000	42,493	1,203
	2	29,500	25,700	72,000	43,000	54,934	55,000	42,616	38,500	48,600	38,000	52,500	45,486	1,287
	3	27,634	30,000	65,500	38,182	52,510	31,818	37,884	44,000	46,000	43,091	44,091	41,883	1,185
Jun	1	11,450	30,500	50,000	45,600	28,500	33,000	38,500	38,100	43,100	46,000	46,000	37,341	1,057
	2	10,000	15,500	52,200	28,000	21,700	26,500	41,000	27,000	57,700	53,500	35,500	33,509	948
	3	10,000	20,000	43,356	17,500	21,000	27,400	26,339	24,500	56,500	40,000	19,000	27,781	786
Jul	1	10,000	15,000	49,500	19,600	40,400	16,500	27,800	19,000	40,000	32,000	17,500	26,118	739
	2	10,000	12,900	27,500	12,000	56,000	16,500	35,000	15,100	27,300	19,300	15,000	22,418	634
	3	10,000	16,636	36,239	21,909	98,182	15,545	26,000	15,000	19,091	15,000	15,000	26,237	742
Aug	1	10,000	17,500	19,200	16,000	20,000	22,000	15,800	12,900	15,000	15,000	15,000	16,218	459
	2	10,000	10,000	18,200	12,300	20,000	21,200	20,100	10,300	27,300	15,000	13,800	16,200	458
	3	9,545	15,000	18,182	12,000	15,000	20,000	22,180	11,091	23,364	17,525	11,000	15,899	450
Sep	1	12,500	17,600	18,200	27,500	14,200	20,000	17,900	24,000	30,000	37,572	10,300	20,888	591
	2	28,000	28,000	26,989	20,500	16,700	20,000	31,800	37,000	43,000	26,190	10,000	26,198	741
	3	27,600	37,400	27,900	20,600	27,200	27,500	34,500	39,800	45,000	27,200	15,700	30,036	850
Oct	1	18,000	34,800	25,000	8,000	30,000	30,000	31,000	34,400	38,000	35,000	27,000	28,291	801
	2	13,600	14,100	27,400	5,300	7,500	24,000	28,700	24,800	18,000	35,000	24,800	20,291	574
	3	5,455	8,455	16,909	15,818	13,909	16,818	11,818	19,364	20,273	24,909	21,545	15,934	451
Nov	1	12,200	27,400	35,500	27,600	26,100	22,100	28,500	40,600	28,500	30,800	30,200	28,136	796
	2	22,000	36,300	38,700	30,000	29,600	29,400	28,000	42,000	31,100	33,500	32,000	32,055	907
	3	23,000	35,300	34,200	31,100	30,000	25,900	29,000	2,570	30,300	26,600	33,000	27,361	774
Dec	1	20,800	35,400	31,900	31,000	30,000	45,000	30,500	27,000	30,000	27,300	32,800	31,064	879
	2	22,500	32,700	31,300	22,000	30,000	41,000	26,500	23,400	28,500	28,000	30,000	28,718	813
	3	13,091	19,455	27,273	9,727	16,091	20,455	14,545	10,455	12,182	18,182	17,277	16,248	460

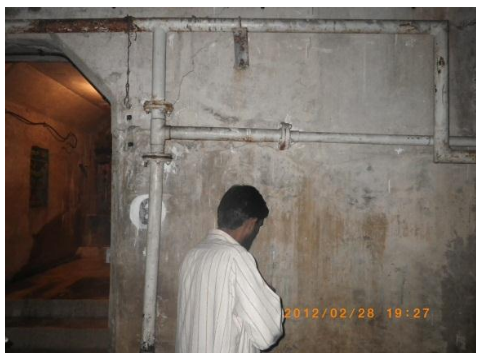
APPENDIX 9

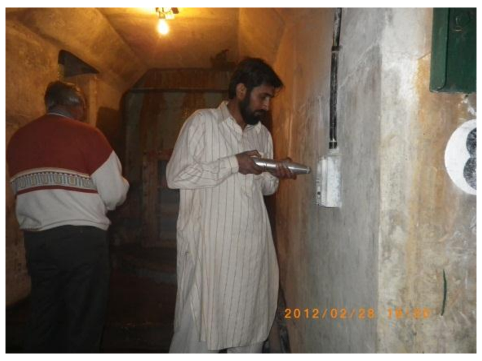
SCHMIDT HUMMER TEST

Schmidt Hummer Test

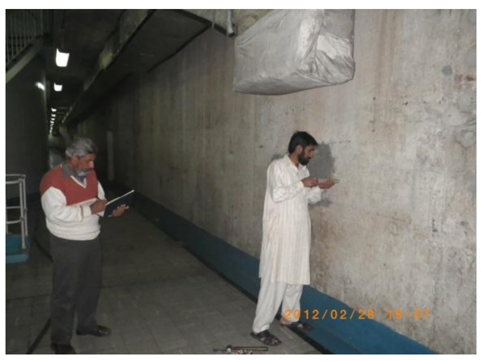
Turbine Foundation (#.3)		Ro	Photo	Testing	Comments
Test No. 1	44	37.9			Hair Cracking (less than 3.0mm)
Test No. 2	45	39.2			
Test No. 3	50	45.5			
Test No. 4	55	51.9			
Test No. 5	50	45.5			
Averrage		44.0			

Turbine Foundation (#.5)		Ro	Photo	Testing	Comments
Test No. 1	52	48.0			Hair Cracking (less than 3.0mm)
Test No. 2	50	45.5			
Test No. 3	56	53.1			
Test No. 4	56	53.1			
Test No. 5	60	58.2			
Averrage		51.6			

Turbine Foundation (#.6)	Ro	F(N/mm2)	Photo	Testing	Comments
Test No. 1	53	49.3			Slanting Cracking around Pen Stock (Approx. 5.0mm)
Test No. 2	56	53.1			
Test No. 3	54	50.6			
Test No. 4	62	60.7			
Test No. 5	52	48.0			
Averrage		52.4			

Turbine Foundation (#.8)	Ro	F(N/mm2)	Photo	Testing	Comments
Test No. 1	56	53.1			Horizontal Cracking around Gallery (Approx. 5.0mm)
Test No. 2	58	55.7			
Test No. 3	56	53.1			
Test No. 4	48	43.0			
Test No. 5	56	53.1			
Averrage		51.6			

Crane Wall (Right)		Ro	Photo	Testing	Comments
Test No. 1	56	53.1			Hair Cracking (less than 3.0mm)
Test No. 2	58	55.7			
Test No. 3	60	58.2			
Test No. 4	60	58.2			
Test No. 5	55	51.9			
Averrage		55.4			

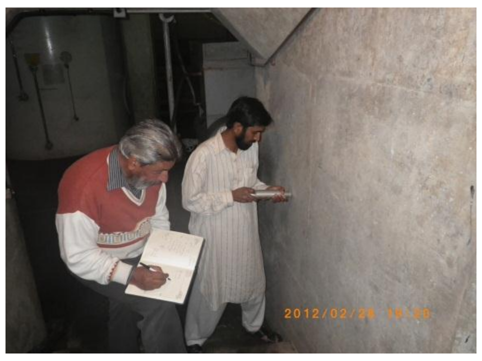
Crane Wall (Left)	Ro	F(N/mm2)	Photo	Testing	Comments
Test No. 1	48	43.0			Hair Cracking (less than 3.0mm)
Test No. 2	50	45.5			
Test No. 3	46	40.4			
Test No. 4	42	35.3			
Test No. 5	44	37.9			
Averrage		40.4			

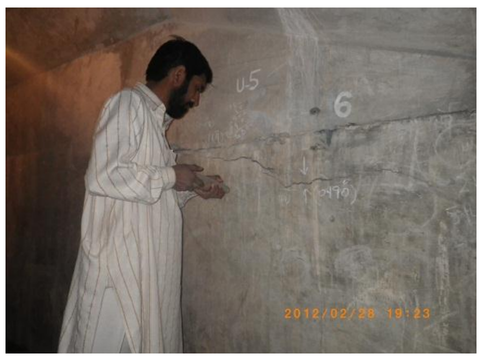
Notes: F (N/mm2) = -18.0 + 1.27 x Ro (Test Result)

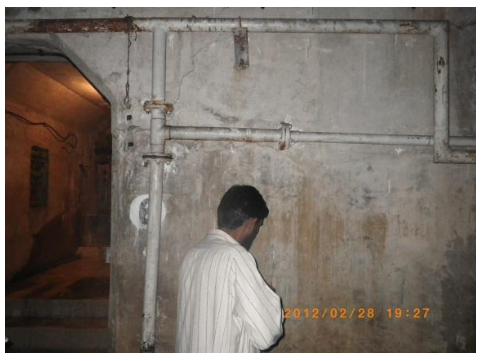
APPENDIX 9

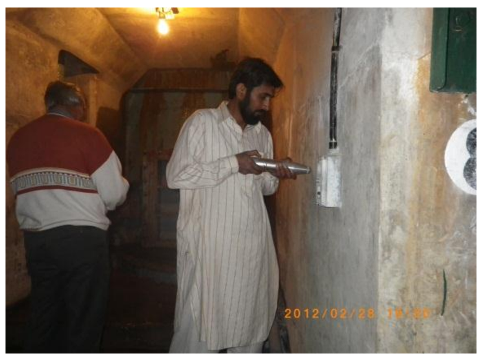
SCHMIDT HUMMER TEST

Schmidt Hummer Test

Turbine Foundation (#.3)		Ro	Photo	Testing	Comments
Test No. 1	44	37.9			Hair Cracking (less than 3.0mm)
Test No. 2	45	39.2			
Test No. 3	50	45.5			
Test No. 4	55	51.9			
Test No. 5	50	45.5			
Averrage		44.0			

Turbine Foundation (#.5)		Ro	Photo	Testing	Comments
Test No. 1	52	48.0			Hair Cracking (less than 3.0mm)
Test No. 2	50	45.5			
Test No. 3	56	53.1			
Test No. 4	56	53.1			
Test No. 5	60	58.2			
Averrage		51.6			

Turbine Foundation (#.6)	Ro	F(N/mm2)	Photo	Testing	Comments
Test No. 1	53	49.3			Slanting Cracking around Pen Stock (Approx. 5.0mm)
Test No. 2	56	53.1			
Test No. 3	54	50.6			
Test No. 4	62	60.7			
Test No. 5	52	48.0			
Averrage		52.4			

Turbine Foundation (#.8)	Ro	F(N/mm2)	Photo	Testing	Comments
Test No. 1	56	53.1			Horizontal Cracking around Gallery (Approx. 5.0mm)
Test No. 2	58	55.7			
Test No. 3	56	53.1			
Test No. 4	48	43.0			
Test No. 5	56	53.1			
Averrage		51.6			

Crane Wall (Right)		Ro	Photo	Testing	Comments
Test No. 1	56	53.1			Hair Cracking (less than 3.0mm)
Test No. 2	58	55.7			
Test No. 3	60	58.2			
Test No. 4	60	58.2			
Test No. 5	55	51.9			
Averrage		55.4			

Crane Wall (Left)	Ro	F(N/mm2)	Photo	Testing	Comments
Test No. 1	48	43.0			Hair Cracking (less than 3.0mm)
Test No. 2	50	45.5			
Test No. 3	46	40.4			
Test No. 4	42	35.3			
Test No. 5	44	37.9			
Averrage		40.4			

Notes: F (N/mm2) = -18.0 + 1.27 x Ro (Test Result)