4. DIFFICULTIES AND PROBLEMS OF TAUNSA BARRAGE

4.1. Damages on the Gate Structure

(1) Abrasion and damage of shoes at groove

The shoes at grooves of the barrage gates (weir bay, undersluice bay and upstream navigation lock) have been considerably abraided and deformed, and interfere the function of gate operation. The abrasion of the shoes at grooves is considered to be inappropriate of the selection of the quality of materials (roller of high-tension stainless steel, track plate of regular steel, rocker assembly of high-tension steel not harder than roller). The abrasion of the track plate which is difficult to replace is heavily and partially damaged at 13 mm in average and 16 mm is maximum. The rollers receive unequal hydraulic pressure caused by the uneven abrasion of the track plates. The roller axis and the fitting member (key plate and bolt) which are not designed to receive such an unequal load have been deformed and fallen off together with the influence of the corrosion of the fitting member.

Because of the abrasion of the track plate and falling off of the roller, contact of the frame of roller train with groove, deformation of roller train and increase of hoisting load have been incurred. Besides the above mentioned reasons, increase of the hoisting load is enhanced by the sticking up of obstacles into roller guard caused by the over flow above the gate due to irregular gate operation. A Stoney type gate can reduce its hoisting load to a great extent, but is easy to jam obstacles into a roller train, and the control of the jamming phenomenonis a serious problem.

The rocker assembly is a monolithic structure with the end girder, and partial wearing out of roller contact face, uneven wearing out of lower portion and growth of crack at the weld zone were observed. The rocker assembly is fixed with multi-support, low stiffness, easy to jam with foreign obstacle, growing the axis corrosion and losing the revolving function. Lower portion of many roller guards have been damaged and fallen down due to excessive load caused by the jamming of obstacles. Many suspension ropes for roller train also have been damaged due to the excessive heavy load.

(2) Damage of end girders of down side undersluice gate

The undersluice gates have many problems due to the type of two storyed double leaf gates, which are prone to open the space between the gates. When the opening becomes wide, hoisting of down side gate is difficult due to the hydraulic load from the top. The water flow between the gates brings much obstacles into the roller guard and induces jamming between

roller train and rocker assembly, and creates gate operation troubles. These problems are originated from an inevitable structural essential defect of two storied stoney gate.

Seven down side undersluice gate leaves and 12 rocker assemblies among all 12 undersluice bays were repaired, and four end girders have been cracked due to the poor repair works.

(3) Damages of seals and gate leaf bottoms

Seals and bottom portion of the gate leaves at the barrage (undersliuce bay, weir bay and navigation lock) have been damaged with falling seal metals, and furious leakage was observed. At the bottom portion of the all gate leaves, the corrosion has been on going and 1 to 2 mm roughs on the surface have been made. The bottom of the weir gate leaves has been deformed 3° bending in average and 13.1° bending at maximum caused by the losing of the function of rocker assembly. Upstream portions of gate guide surfaces have been shaved by the contact of existing seal metals to about 5 mm. The top side flanges of the sill I-shaped beams have been eroded and the second stage concrete has been heavily scored.

(4) Damages of hoisting devices

The hoisting devices of the barrage gates have been affected by the heavy hoisting load, and contact of the drams to the flame by shifting on the shaft, loosing of the bolts and crack at the bearing fitting base, and ill-gearing were observed. Driving chains have been loosed and some times the chains slip on the sprocket wheel, and are in dangerous conditions. The winding position of the suspension rope on the dram has been slipped out and some gates have operational troubles due to the piling of suspension rope at the gate position of full open and full close.

Beside above mentioned damages, some structural defects were observed. No gallery to the drams and interim gears and the covers for them disturbs maintenance work, and much rust and stain have been taken place due to the lack of maintenance such as cleaning and lubrication. The covers for gear portion have been accelerating remarkable corrosion at about half number of interim gear flames. Some of them have passed through holes at the member under this structural defects problems.

(5) Ill operational function of hoisting device

The hoisting load is increasing and various damages on function have been created by the defect of hoisting device and damage at gate leaf shoe together with the shortage of the counter balance weight. Due to the operational difficulty of the undersluice gate, less flushing of silt pocket is causing excessive sedimentation problem in the D.G. Khan canal. Higher hoisting of the barrage gates requires long hour manual operation and makes operators to be tired. The

braking method for all gates operation except T.P. link gates is clutch pedal off system. The hoisting load is too heavy and several human accidents have been taken place caused by the miss operation of the break pedal and sudden gate dropping.

(6) Deterioration of walkway deck

The wooden walkway deck at the top of superstructure is considerably deteriorated. There are some missing boards and holes at the deck, and serious deficits on safe.

(7) Insufficiency of checking gallery

No checking gallery is provided to hoisting dram and interim gear, and difficult to approach them, and giving considerable obstacles for the maintenance of hoisting dram and interim gear. No ladder is provided to approach the bay glasis and floor, and it is inconvenient for checking and maintenance of the barrage gates.

(8) Corrosion of superstructure

No remarkable damages and structural defects on superstructure were observed. Some rust were observed because of no repainting work since the construction of barrage.

(9) Shortage of annual closure period

Maintenance and repairing of the barrage gates are conducted in annual closure period of about 3 weeks in January, but the sufficient maintenance work of surface preparation, repairing of shoe areas, etc. are difficult due to the shortage of the closure period. No temporary closure facilities are provided at the barrage pier and no gate full open is allowed except the annual closure period because of perennial irrigation, the maintenance and repairing of the gates, which require open condition, are difficult.

(10) Problems of head regulator gates

The bottom portion of D.G. Khan canal and Muzaffargarh canal head regulator gates have more corroded compared with that of barrage gate, but not so heavy corrosion to affect to the gate leaf strength. Some 3 to 5 mm abrasions at the shoe areas were observed, but no problem for regular gate operation. Some damage on sealing metals such as falling of upper sealing metals is considered to be not serious because the position of the upper sealing metals i.e., RL 446.60 ft is higher than the design pond level. The leakage water at the time of high flood would be not so serious to the canal system. Damages of dram bearing and looseness of driving chain have taken place. Some damaged suspension ropes of roller train are possible to be adjusted or replaced by routine maintenance or repairing.

Although some adjustment of counter balance is required, the hoisting load of the head regulator gates is small and possible to be operated by one human power. The operational function of the hoisting device was observed in good condition.

There is no requirement of rehabilitation on gate leaf, shoe plate and hoisting device. Some adjustment or small repairing for hoisting device, replace of walkway deck and repainting of superstructure are required. Also some access passage from the walkway deck to the hoisting dram is required for proper maintenance.

(11) Problems of the downstream navigation lock

The downstream navigation lock gate is in good condition without any serious rust, since the gate is seldom operated and usually suspended above water. The abrasion at the shoe area seems to be no problem because of infrequent operation. The seal metal, whose sealing function may be going down, also seemed to be no problem, because the gate is not on full-time pond purpose. The hoisting device needs adjusting of gearing and resetting of the position of dram to avoid the contact with member frames. The device should be improved for a smooth operation, from the viewpoints of the large lifting height and long waiting time for navigation.

Thus, the gate and gate guide of downstream lock needs no rehabilitation, but its hoisting device requires some adjustment, repair and improvement; such as electrification, setting of maintenance facilities for hoisting dram under walkway deck, replace of the deck board and repainting of superstructure.

(12) Subjects on remaining physical life of gates

To estimate remaining physical life of the gate in terms of stress, some gate members were investigated by ultra sonic thickness gauge. According to the results, every weir gates retain more than 100 years physical life. The remaining physical life of the T.P. link canal head regulator gates are estimated at about 9 years when the stress will reach to the yield point because of extreme deterioration at the lower position of the gate leaf. In case of D.G. Khan canal head regulator gates, the remaining physical life of the most corroded member at the lower gate leaf is estimated at 43 years when the allowable stress is set as one half of yield point. There is some difference of designing conditions between D.G. Khan canal and T.P. link canal head regulator gates. Maximum generated stress of D.G. Khan, was designed low as 11.710 psi, and T.P. link was high as 21.292 psi. Due to the difference of the quality of the gate materials, T.P. link canal head regulator gate is considered to the rapidly corroded. Based on the results of the remaining physical life estimation, T.P. link canal head regulator

gates will face the time of replacement in near future, even though the life will be prolonged by careful repainting and maintenance.

4.2. Problems on Hydraulic Structure

4.2.1. Hydraulic Structure

Hydraulic structures of the Taunsa barrage and its related regulators were investigated in detail by each bay as follows.

Table 4.2.1 General Features of Damages on Hydraulic Structures

Facilities	Damages
U/S Loose Stone	While some pits and mounds were observed, no significant damages were identified.
U/S C.C. Block	No damages were observed.
U/S Concrete Floor	No significant damages were observed.
U/S Glacis	No significant damages were observed.
D/S Glacis	Surface of skin-concrete has been abraded severely in every bay, exposing the braces and reinforcing iron bars.
D/S Concrete Floor	Excoriation and partly rolled down in skin-concrete and iron bars bent up correlating to damages of friction blocks were observed. Sub-surface flow between skin-concrete and mass concrete was recognized in some bays.
Friction Blocks	Missing and rolling over of friction blocks were observed mostly in half number of bays.
D/S C.C. Block	No damages were observed.
D/S Loose Stone	Considerable depressions and mounds correlating to the progress of retrogression were observed.
Piers	In relation with deterioration of gate grooves, groove contact in the piers were scoured by leaking jet flow through roller guard.

Remark: Detail description on this aspect is presented in Annex B, B.2.

Through the observation on hydraulic structures, damages of downstream glacis and friction blocks consisting of trapezoidal blocks and cubic blocks need careful attention. In 32 bays out of a total of 65 bays of the river gates, serious damages of friction block were identified. Especially for the friction block destruction, it has been troubled with uplift problem on account of sub-surface flow between skin concrete and mass concrete. Downstream glacis erosion and extended expansion joint of floor concrete should be repaired carefully so as not to suffer from block destruction by uplift pressure.

Retrogression of levels is a process triggered by construction of pickup weirs or humps across natural streams in alluvial and permeable foundation environments, and results in degradation of stream bed with subsequent lowering of water levels on the downstream of the weir. The retrogressed may undermine the stability of a work by an increase in the exit gradient beyond the safe limits. It will increase the destructive action of the hydraulic jump as with the increase fall and decrease depth of downstream water due to the lowering of the water levels at that end, and jump will tend to travel down to the C.C. blocks and loose stone protection area.

At Taunsa barrage, the conditions have not varied in the usual/normal course. The barrage is experiencing tail water levels that are substantially lower than even the minimum designed retrogressed levels, although 40 years have elapsed since its commissioning. The lowering of tail water levels below the designed minimum levels causes reduction in tail water depths. This naturally results in depths less than the conjugate depths required for formation of a good hydraulic jump at the proper place and level for effective energy dissipation. The difference in actual and designed levels, results in the formation of an unstable jump, much below the required safe levels with a secondary jump at the end of the impervious floor and on the block apron, which causes heavy scour and negative pressures in the block area and loose stone apron and consequently lifting and washing away of the apron stone and settlement of the PCC settling blocks.

Comparison between the designed minimum retrogressed tail water levels and recent actual retrogression is shown in the following table, which indicates retrogression greater than 7.0 ft lowering of downstream river water levels.

Table 4.2.2 Actual Conditions of Retrogression in 1997

Discharge in cusec	Designed Minimum Rated Tail Water Level	Designed Minimum Retrogressed Tail Water Level	Designed Magnitude of Retrogression Provided	Actual Tail Water Level from Min. Envelope for 1997	Actual Retrogression at Present
40,000	432.00	428.35	3.65	422.20	9.80
80,000	434.40	431.30	3.10	424.85	9.55
100,000	435.15	432.15	3.00	425.65	9.50
200,000	437.50	435.00	2.50	428.30	9.20
300,000	438.90	436.70	2.20	429.80	9.10
400,000	439.90	438.00	1.90	430.90	9.00
500,000	440.70	439.00	1.70	431.70	9.00
600,000	441.30	439.70	1.60	432.50	8.80
700,000	441.80	440.30	1.50	433.00	8.80
800,000	442.30	440.90	1.40	433.55	8.75
900,000	442.70	441.40	1.30	434.00	8.70
1,000,000	443.00	441.80	1.20	434.40	8.60

Detail description on this aspect is presented in Annex B, B.2.

The minimum levels required for formation of stable hydraulic jump indicate the present barrage capacity which comes to 500,000 cusec for stable jump situation ensuring barrage safety. This capacity is very much below the design discharge of 1,000,000 cusec (only 50 %).

Since construction of the Taunsa barrage, some deterioration occurred as shown in the following table. Almost troubles had been repaired by 1963, and no substantial damages was reported until 1987. Damages brought out after 1987, are deferred those repairs mentioned in the following table.

Besides execution of the Study on Taunsa Barrage, PID has conducted an investigation on Evaluation of Safety of Hydraulic Structure on existing 14 intake barrages in Punjab Province including the Taunsa Barrage. The investigation is an examination in general aiming at safety evaluation for hydraulic structures of all concerned barrages in common view at a same point of time, in contrast with this Study which is a feasibility study on a specified barrage. As final report of the investigation will be complied in August 1998, it is expected to unveil situation in safety of all barrages in Punjab complementing by the results of this Study.

Table 4.2.3 Major Damages and Repairs on Hydraulic Structures since Construction

Year of event	Damages
First year of operation (1958):	Un-tightened anchor bolts, skin concrete of navigation bay (Bay 8) was damaged.
Until the end of 1960 flood:	Bays 56 to 65, trapezoidal blocks uprooted and skin concrete rolled down as a similar type of work to that in 1962-63 was done.
Until the end of 1961 flood:	Bays 54 to 65, D/S glacis were eroded.
1959-1961 floods:	Bays 1, 21, 23 & 24, trapezoidal blocks damaged.
1962 flood:	Bay 49, all trapezoidal blocks uprooted and entire skin rolled down.
1962 flood:	Bay 50, three trapezoidal block uprooted and rolled down.
1962 flood:	Bay 52, skin concrete, trapezoidal blocks and cubicle blocks lifted more than half a feet.
Until the end of 1962 flood:	Loosed anchor bolts fixing trapezoidal blocks to the mass concrete, as CE Bahawalpur inspected and instructed anchor bolts should be fixed as much as possible.
1987 flood:	Bays 41-42, entire skin concrete rolled up in bay 41 and 50 % of skin concrete rolled up in bay 42, 15 nos. of trapezoidal blocks and 11 nos. of friction blocks up-rooted.
As of December 1997	Cubicle blocks missing in Bay 10/2 nos., Bay 28/1 no., Bay 36/1 no., Bay 41/7 nos., Bay 47/1 no., Bay 48/4 nos., Bay 65/2 nos., Trapezoidal blocks missing in Bay 28/1 no., Bay 34/2 nos., Trapezoidal blocks severely damaged in Bay 4/1 no., Bay 5/6 nos., Bay 6/5 nos., Bay 7/2 nos., Bay 9/5 no., Bay 10/4 nos., Bay 11/7 nos., Bay 12/11 nos., Bay 13/11 no., Bay 14/9 no., Bay 15/10 nos., Bay 16/7 no., Bay 17/9 nos., Bay 18/8 nos., Bay 19/11 nos., Bay 20/10 nos., Bay 22/7 nos., Bay 50/9 nos., Bay 51/8 nos., Bay 53/13 nos., Bay 54/12 nos., Bay 55/10 nos., Bay 56/8 no., Bay 62/13 nos.

4.2.2. Barrage Foundation

(1) Geological features of foundation ground

The Indus river has about 13 km wide high-flood channel and 2 to 3 km wide low-flood channel with its bed slope of 1/5,000 to 1/10,000 in the Taunsa barrage area. It is assumed that the mean annual maximum flood is 466,000 cusec that is regarded to form the bed slope at equilibrium at recurrence interval of 2 to 3 years. The river has been meandering and sand bars have been formed and eroded repeatedly.

As the density of the sand layer and the arrangement of particles in it are subjected to the variation of depositing condition, the river morphological process and the physical channel condition and the flow condition fulfill the depositing circumstance of fine sand at the site.

Therefore, the foundation could be treated as uniform sand layers geologically with its changes of density varied with depth.

Subsoil conditions were explored by drilling of bore holes around the barrage. Eight bore holes were drilled by rotary wash method. Depth of each hole was 40 m. Bearing capacity of the foundation was determined by standard penetration test (SPT) and the soil samples taken by the SPT were used for particle size distribution test.

N-values increases with depth showing more than 50 at the depth between RL 338 and 374 varied with the location. From the ground surface down to about 15 ft, N-values are lower than 15. Down to the depth of RL 338 to 374, N-values range between 15 and 50. In most of the location, N-values are from 20 to 30 at the elevation of RL 380 ft to 394 ft equivalent to that of the bottom of the foundation wells and it was categorized "dense" ground. Particle size distributes almost same over whole drilling holes, 3 to 16 % of total particle weight is over #50 sieve (0.3 mm), 84 to 92 % between #100 and #50 sieve (0.15 to 0.3 mm) and 1 to 10 % smaller than #100 sieve (0.15 mm). Permeability is estimated at (1 to 2) x 10^{-2} cm/sec.

(2) Foundation structure

Barrage foundations comprise well foundation and sheet piles, the former is located under the piers and right and left training banks for supporting and the latter is provided to seepage under barrage and both training banks. Each pier of has 5 foundation wells of varied dimensions in their depth and length of which elevation is between RL 384 and 390 in undersluice section and between RL 387 and 394 in weir. Three rows of steel sheet piles are provided under the floor concrete. The upstream sheet piles are 15 ft long reached RL 405 in the weir section and RL 402 in the undersluice section while those of center and downstream are 20 ft long reached RL 395 in the weir section and RL 394 in the undersluice section. Floor concrete is 3 ft thick upstream of the gate, 9.75 ft thick at the maximum in the weir section and it varies from 5 to 8 ft thick depending on uplift downstream of the gate.

(3) Evaluating barrage safety

Safety of the foundation is examined by bearing capacity, undermining and uplift.

1) Bearing capacity

Safety of foundation ground for wells has examined by ultimate equilibrium method. Ultimate bearing capacity q_d of the ground composed of cohesionless material is computed 165 psi as N-value of 20 in the foundation ground and allowable bearing capacity q_a is estimated at 58 psi. On the other hand, normal stress p to the ground is about 23 psi. The foundation

ground has judged having sufficient bearing capacity *qa* of 58 psi against active normal stress *p* of 23 psi.

2) Undermining

Failure by undermining depends on specific geological details, such as the position, sequence and continuity of the individual layers in the foundation. It develops with the passage of time and called progressive failure. Usually undermining start from unconfined portion downstream making springs and extends to the foundation of the structure.

Safety to piping failure was examined by Lane' s creep formula and Khosla' s theory in the study. By Lane' s creep formula, existing structure shows creep coefficient *c* of 7.7 or hydraulic gradient of 0.13 under designed head across of 30 feet. It means existing structure is safe to piping failure. On the contrary, the computed exit gradient by Khosla' s theory shows 0.185 for weir section and 0.189 for under-sluice section, which fall unsafer side than recommended exit gradient for fine sand of 0.14 to 0.17. This examination shows that the structure has kept a narrow safety.

There are depressions and cracks in the pavement in the parking area on the left bank of the Taunsa barrage. The biggest depression is located at the surface of back-filled material along the retaining wall. The depressions supposed to have been developed as following stages. The depression was initiated by settlement of back-fill material. At first, back-filled material behind the concrete blocks settled in the transition, then contact surface between the concrete blocks was opened. The wave action or fluctuation of the water level sucked material behind the blocks out through the openings which had accelerated settling of concrete blocks and developed concentration of sub-surface flow to the openings. Finally undermining or backward piping has grown and back-filled material moved through the channels. Since back-filled sand was cohisionless material which could not keep the channels in the ground, sand particles on the channels fell down and washed away then sand layer on the channels loosened and finally loosened zone reached the ground and the depression has appeared.

The structure of floor concrete consists of lower mass concrete and upper 1 ft skin concrete. Detailed inspection was done in the bay 42 removing deposited sand. The skin concrete was tore off in the middle of the bay and there were springs. The joints treatment seems not suitable for hydraulic structure because limited joints are provided water-stop and most of the joints is covered with bitumen. The joint treatment is same to skin concrete. It is expected that the joints might be opened during placing concrete and existence of open gaps through which water can pass. There is a possibility of voids or channels under the floor concrete created by suction of sand particles. Undermining seems to be developing under the barrage caused by suction of sand grains and it is indicated a possible piping by the facts, such as

composition of foundation material, creep ratio in the foundation ground, exit gradient, depressions on the left abutment, springs from the joints of the floor concrete.

3) Uplift

Uplift is acting force to any part of impervious concrete floor from seepage water. Foundation of the Taunsa barrage consisted of even fine sand can be treated as uniform pervious foundation. Using Khosla's formula, uplift is computed. On the other hand, actual uplift can be monitored by pressure pipes on each pier. In original design of the barrage, 579 pressure pipes are distributed, but only 20 numbers of pressure pipes are in order at present, which can measure pressure upstream of the gate and no pressure pipes is showing pressure downstream of the gate. Unfortunately computed uplift cannot compare with actual pressure under the barrage consequently.

Inspection for the bay 42 of the barrage revealed existing springs on the floor concrete which could create piping under the mass concrete. If floor concrete is watertight, confined sub-surface flow acts to the floor concrete as uplift. The spring, however, releasing seepage pressure. Therefore, the springs through the floor concrete must contribute to improve safety to uplift if sand grains will not be carried with water.

4.3. Problems on Sediment

Sediment in D.G. Khan canal as rising canal bed of more than 7 ft is a great obstacle on canal system function. The sediment problem in D.G. Khan canal is one of highlighted aspect in the Study.

Silt observation data evidences that the sediment problem has been caused by not deposit of suspended load, but river bed load entry through right pocket. Result of grain size distribution analysis conducted in the Study also stands by its conclusion (see Annex C).

According to the analysis on sediment balance concerning right pocket, allowable intensity of sediment transport of D.G. Khan canal is estimated at 23.9 kg/sec on condition of full canal discharge and without sediment on the canal bed. However, it is reduced to 12.8 kg/sec in actual situation due to decreasing trac f tive force by sediment. Against the capable intensity of sediment transport of D.G. Khan canal, silt entry of 41.1 kg/sec from right pocket to D.G. Khan canal under full sediment in right pocket and normal river water condition, is estimated. The difference between both figures shall deposit on the canal bed.

The sediment problem is caused by dysfunction of undersluices in right pocket. Due to deterioration of undersluice gates, flushing of silt in right pocket could not be done properly. River approach to the barrage further aggravated the situation resulting into heavy silt entry into D.G. Khan canal. The sediment could be ejected through vortextube type silt ejector provided at RD 7,500 (former at RD 20,800) of the D.G. Khan canal. The silt ejector was not functioning properly at times due to excessive silt entry and improper hydraulic conditions. Restoration of function of undersluices in right pocket is desired earnestly as early as possible.

4.4. Problems on Canal System

Due to the inadequacy of the maintenance works, deterioration of the canal systems has been accelerated, and some of them have fallen down to unrepairble condition. The following structures heavily deteriorated are required urgent rehabilitation works.

Feeder facilities:

- heavy sediment in D.G. Khan canal especially upper reaches
- dysfunction of silt ejector

Diversion facilities:

- deteriorated head regulators
- low flexibility of regulators' operation

Safety facilities:

- deterioration and dysfunction of canal escapes
- choking up of hill torrent crossings

Sediment in D.G. Khan canal hinders satisfactory water flow as decreasing canal sectional area of 40 to 45 %. The sediment problem is an aspect in the field of canal system as well as Taunsa barrage system. While essential remedy against the sediment problem in D.G. Khan canal is to control sediment entry to the canal, entered silt into canal shall be dealt with as a part of canal system. Maintaining performance of existing silt ejector is mostly required.

Conceptual difference between D.G. Khan canal and Muzaffargarh canal is recognized in facility designing as well as a difference in natural condition. Muzaffargarh canal system seems to be steadily designed rather than another, having adequate number of head regulator which enable to deliver water flexibly. On the contrary, D.G. Khan canal system was stiffly designed having limited number of head regulator on the assumption of water delivering with always full discharge. This stiffen design of D.G. Khan canal makes flexible water delivering correlating to fluctuated feeding impossible.

The investigated 50 major canal facilities were not in satisfactory conditions only except four facilities. However, repair works for those damages will not be included in the rehabilitation work because it will be regained by ordinary operation and maintenance activities or training regulation belders in operation. Nevertheless, dysfunction of escapes by inoperative gates with bending spindles, corrosion of gate leaves, erosion of guide wall etc. should not go unheeded by reason of its importance over whole system's safety.

D.G. Khan canal is crossed with hill torrents running from foot of Sulaiman mountain range. There are 20 super passage crossings at the intersections. At some crossings, back water was observed due to sediment deposit. Timely maintenance for the sediment at the hill torrent crossings is highly required for sustaining canal system safety.

4.5. Problems on Water Use Management

Water use management in the Indus river system has been conducted without possible hindrance on a large scale as being one of the greatest system in the world. Excessive number of personnel are involved in the water use management activities, but there is a room to improve the system so that function effectively. Precious record of daily water level and discharge etc. is dealing by hand writing, and transporting such data by word of mouth with wireless. Indents used to be collected, transported and confirmed by manual, it should be modernized.

At the time when Taunsa barrage was in function in 1959, irrigation water supply had commenced temporarily without supplying water to Dajal extension area. After the inauguration of the project, all water uses concerning the Taunsa barrage except Dajal extension were authorized and approved those water right on the Indus Water Treaty in 1991. The water right of the Dajal extension was still not authorized and no prospect for its approval. This Dajal extension issue is not affected to present water uses of existing areas, but having great deal with canal operation of D.G. Khan canal. Though provisional discharge of 8,301 cusec is provided to D.G. Khan canal, canal section had been constructed with full capacity of 14,200 cusec. Silt deposition in D.G. Khan canal are accelerated due to small velocity caused by these reasons. This water right issue is looking forward to settle as earlier as possible.

4.6. Problems on Operation and Maintenance

4.6.1. Operation and Maintenance of Irrigation System

The operation and maintenance organizations described in Section 3.3, is performing O&M of the Taunsa barrage and appurtenant canal systems. Their great practical experiences and their efforts on O&M under severe circumstances are appreciated very much.

Present O&M by IPD does not seem effectively, since IPD is operating under an organizational structure and administrative rules. The general tendency on irrigation is to invest in poorly planned civil works packages. Institutional and policy recommendations are often ignored. The investment program is mainly driven from supply side, with little regard for implementation requirements and sectorial priorities. By and large each project is revised time and again in terms of cost, schedule and benefits which disturb the investment plan and adversely affect policies and targets. In addition, public spending on irrigation has been declining by about 4 % per year in real terms since the mid-1980's. These have delayed completion of ongoing investments and the launching of new ones.

There is little market-type interaction in revenue collection and delivery of water. Revenue collection and implementation of O&M are done by different agencies. Revenue collected from water charges does not go directly to IPD. Funds allocated to IPD by the provincial government are insufficient for proper O&M of the irrigation and drainage systems. This shortfall is caused by low water rates and inadequate assessment and collection of water charges. Presently, one of the major reasons for shortage of development funds is failure to recover capital costs from users benefiting directly from the project. Technical performance on O&M of IPD is declining by lack of proper training of the engineers and technicians along with shortfall of funds.

Deterioration of irrigation facilities, primarily due to inadequate maintenance, is a major source of poor system performance. Inadequate O&M is largely the result of inadequate institutional capability and lack of funding. Importance of irrigation is emphasized to the economy of Pakistan. GOP and GOPunjab are recommended to allocate proper funds for irrigation on demand.

4.6.2. Workshops

IPD Punjab has workshops for O&M of barrages. Among them, Taunsa barrage workshop takes charge of minor repair at the barrage, Multan workshop takes charge of manufacturing

spare parts required barrages and canal systems in the region, and Bhalwar workshop manufactures major parts of gates for all the barrages belonging to IPD Punjab.

Emergent repair works along with regular maintenance are charge of the Taunsa barrage workshop to which about 50 personnel of engineers and mechanics belong. This workshop, however, does not operate most of the year except during a closure period and personnel and aged facilities are idle mostly. While, personnel of private firms work together with government employees in the 3 to 4 weeks closure period, since maintenance works for the gates concentrate only in this period.

Multan workshop established for maintenance and repair of earth machines and electric motors and pumps for SCARP. About 50 personnel belong to the workshop with well-equipped facilities, that is able to manufacture gates for the canals and spare parts for barrage gates. Taunsa, Trimmu, Panjnad and Islam barrages with their irrigation systems are located in the region centered Multan. Accordingly there are considerable amount of works not only for barrage gates but also gates for canals.

Bhalwar workshop where the gates of Taunsa barrage were manufactured is central workshop of IPD Punjab. About 50 engineers and 300 mechanics belong to the workshop which is equipped substantial facilities for making large scale product like gates for barrages and small and medium dams. IPD Punjab performs O&M of 14 barrages and over 10 small and medium dams in Punjab, while number of dams is increasing. Accordingly, it is expected future increase of rehabilitation works. Considering capability and capacity of the workshops, their O&M plans shall be established by each level of workshop, such as those attached to the barrage, those to be regional center and those covering whole Punjab.

5. IMPROVEMENT CONCEPT FOR THE TAUNSA BARRAGE IRRIGATION SYSTEM REHABILITATION

5.1. Present Status of Taunsa Barrage Irrigation System Rehabilitation and Improvement Concept

5.1.1. Present Status of Taunsa Irrigation System

Taunsa Barrage Irrigation System consists of sub-systems such as Taunsa barrage as a principal, canal system, distribution system, irrigation management system and so on. The investigation on damages and deterioration for the concerned systems was undertaken during the field survey and drew a result as summarized below.

Table 5.1.1 Damages and Deterioration on Structure

Structure		Damages and Deterioration
Gate Structure	Gate Leaf	- Undersluices are in severely deteriorated condition as being difficult for operation. - Odd gate leaf structure of undersluices having two plates causes difficulties in operation. Abrasion was observed in lower gate leafs of undersluices. - Large bending by buckling and large breaks at joints of end girders of undersluices were observed. - Deformation of flanges at bottom portion of weir gates were observed.
	Shoe at Grooves	- Sever abrasion was observed in every track plates of whole gates. - Some rollers are missing, and rubbing with groove due to deformation of roller train. - Every rocker assemblies of all gates were adhered due to its corrosion and deformation. - Drawbacks such as lost, or fall out were observed for roller guard.
	Gate Seal	- Every seal metals were missing. - Abrasion of sill beams as reducing of its width, and cut of the flange, were observed.
	Hoist Structure	- In the reduction gears, many mal-adjustment, broken bearing and chattering were commonly found. - Covers for drum and interim gear were disturbing the lubrication and accelerating the corrosion of the frame. - the cog fitting was considerably bad and slipping out of position and shallow fittings were frequently observed. - Odd design of hoist structure is hindered adequate operation and maintenance. - Inconvenience and delay of operation was recognized because of manual gate opening.
	Hoist Deck	- Wooden deck was deteriorated, and caused luck of pay load capacity and safety.
	Maintenance Gallery	- Odd design of maintenance gallery is much hindered adequate operation and maintenance.
	Glacis	- Heavy erosion of skin concrete and exposed reinforcing iron bars were observed in D/S glacis of all bays. - Remarkable pitting was recognized in sill beam of all gates.

	Structure	Damages and Deterioration
Hydraulic Structure	D/S Concrete Floor	- Falling out of skin concrete was observed. - Significant exfoliation of skin concrete from mass concrete was identified, in which sub-surface flow was occurred. - Spouting water was observed at some points along the joints.
	Friction Blocks	- Falling down and deformation of some blocks were observed. - Destruction of skin concrete with which blocks were contacted were observed. Reinforcing bars of skin concrete were exposed and bent up.
	Protection Stone	- Lost, deformation and rolling of loose stone were observed.
Barrage Foundation	Barrage Foundation	- Spouting water was found at some points along the joints. - Sub-surface problem which compel to restrict taking head across more than 22 ft, was broken out.
	Barrage Abutment	- Ground sink because of sub-surface flow.
Canal System	Canal	- Severe silt deposition was observed in D.G. Khan canal. - Remarkable erosion was observed downstream of canal regulators.
	Canal Structure	- Some deterioration on concrete structure and gates were observed. - Insufficient canal escape function was given, due to deterioration of existing escape structure and inadequate design of structures.

Taking above deteriorated condition into consideration, Taunsa barrage is a prominent system to be rehabilitated immediately among whole concerned sub-systems.

5.1.2. Anticipated Scenario for Barrage Collapse

Damages for gate structure are converged around the shoe at grooves, in rocker assembly, roller train etc. Those damages and abrasion are giving rise to a phenomena of difficulty or hardness of gate operation, requiring much force power for operation. Multiplying dysfunction by other defects of hoist system, "soundness and adequacy of gate operating function" as an essential role of barrage is being hampered.

The deterioration is coming into view as the hardness of gate operation. Such inconvenience could not be mitigated by ordinary activities of operation and maintenance, because such deterioration is a progressive damage unable to stop the retrogression unless resolve essential problem. If those damages will be left as it is, the difficulty and hardness of gate operation must be worsen exponentially, being still more accelerated by forcible gate operation. At present, about 41 kgm torque on an average as equivalent of eight to twelve parsons manpower is required for gate lifting, as compared with design value of 29 kgm as functioned as it was. In the near future, gate lifting may become on impossibility due to either difficulty of force

power supply by manpower corresponding to increase of operational power need, or broking some portion of gate by excessive force.

Following figure gives a forecast of increase of gate operation force by each bay, on the bases of measured value of required force as of 1997, year of 39 years passing since Taunsa barrage constructed. Providing that 87 kgm as equivalent to twelve manpower force is a limit of gate operation as being under present manual operation, an inoperative gate will appear in 2001 in the beginning. Then other gates will follow swit with continuity.

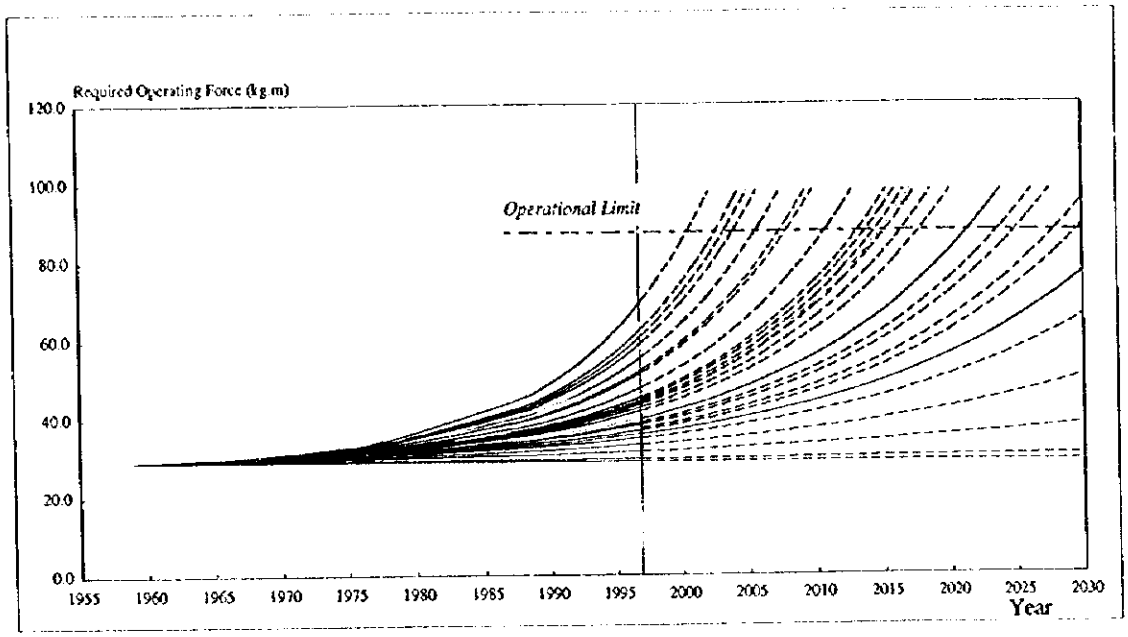

Fig. 5.1.1 Estimated Deterioration Curve of Taunsa Barrage Weir Gates

Furthermore, other rehabilitation work components proposed within the rehabilitation plan such as change of gate leaf in some bays, repair of hydraulic structure, countermeasures against siltation etc. are necessary elements to be urgently improved by certain intensive project because it is impossible to stop its deterioration through ordinary activities in operation and maintenance. If such default leaves as it is, that shall also multiply a deterioration which may threaten the barrage itself. Though above mentioned deterioration is mormal for barrage function, above all damage of side support of gate leaf shall be apt to appear earlier. Therefore, "anticipated scenario for barrage collapse" is that collapse will begin with dysfunction of gate shoe area at groove.

5.1.3. Concept of Taunsa Barrage System Rehabilitation

It is concluded that urgent rehabilitation is required in Taunsa barrage system in consideration with present damaged status. The rehabilitation project envisages elimination of ills and damages as a top priority, and improvement to uplife and modify its function shall be taken additionally. The objectives of Taunsa barrage rehabilitation is described below.

1) Rehabilitation work should be taken at the earliest possible.

2) Rehabilitation scale and method should be selected in a manner to meet with resource availability and capacity of implementation organization.

3) Present stoney gate type shall be followed within the rehabilitation project.

4) Bulkhead gates are proposed to be utilized for gate rehabilitation work.

5) Some faults in present design for hoist system and superstructure may also be improved in necessary and sufficient conditions.

6) Minimal remodeling required in hydraulic structure corresponding with hydraulic condition change such as progress of retrogression shall be considered.

7) Head across is limited to less than 22 ft provisionally, due to danger in uplift risk. Head across of more than 22 ft is not required in Rabi because feeding water giving high head across over 22 ft is not allowed in order to secure water right of water user in downstream province. However, rehabilitation will target to allow taking original head across in view point of barrage safety.

8) Gate rehabilitation should be implemented prior to hydraulic structure rehabilitation. The hydraulic structure rehabilitation shall be done bay by bay after completion of water sealing process by gate rehabilitation.

9) Principal benefit of this rehabilitation project is the growth of agricultural produce through assurance of irrigation water supply.

10) Railway structure is put outside of the rehabilitation project, due to operation being with another agency.

11) Taunsa barrage road bridge is proposed to be rehabilitated in another phase of the Project.

Irrigation in the command area under the Taunsa barrage system has been based on non-perennial water supply. It is not recommendable to alter present non-perennial to perennial irrigation, even though higher cropping intensity can be expected if perennial irrigation were adopted. Non-perennial irrigation was applied so as not to extend waterlogging and saline hazard in the command area, not simply for the reason of scarce available river water in Rabi. For these reasons, alternation to perennial irrigation should not be done unless effective countermeasures against such waterlogging problem are taken. Therefore, it is recommended to follow present non-perennial irrigation for the rehabilitation project of the Taunsa barrage irrigation system.

In the field of irrigation water management, some inconvenience in water use arising from long extention of canal system were identified during the field survey. Due to a few day's time lag from off-taking point to tail of main canal, difficulties to adjust between water demand and supply are inevitable in the canal system. Buffer function for the adjustment by means of regulation ponds can not be supported. Only remedy for escaping excess water in canal to farm lands is used to be taken in order to secure canal system. Due to inflexible application of *Warabandi*, farmer on turn has to take water even if water is not required. Water dividing into facilities having fixed water dividing ratio, and small number of adequate water measures cause shortage of water in downstream areas even if upper areas are inundated by abundant irrigation water. These inconveniences are to be addressed. However, remodeling of irrigation system is not needed.

5.2. Trend of Water Supply Need for Taunsa Barrage Irrigation System

Supposing that amendment of water use is needed for reasons of change of water consumption structure corresponding to the social development since construction of the barrage, water supply standard on the Taunsa Barrage Irrigation System may have to be renovated so as to meet present requirement at the moment. Authorized water apportionment of concerned canals in the Indus Treaty are as follows:

Table 5.2.1 Water Right of Canals Concerned

Canal	CCA (ha)	Kharif (million m3)	Rabi (million m3)	Whole Year (million m3)
D.G. Khan	385,000	2586.7	926.0	3,512.7
Muzaffargarh	314,000	2,581.7	924.2	3,505.9
Sub-Total	699,000	5,168.4	1,850.2	7,018.6
*T.P. Link**	*597,000*	*4,193.9*	*1,874.9*	*6,068.8*

*: Water right of T.P. Link Canal is not specified in water volume but determined by discharges in several terms. Above tables of T.P.Link Canal are converted into water volume in each season.

Above irrigation water is equivalent to the water depth of 1,004 mm par area, that is much advantageous figure in compulsion with national average of the same of 810 mm. Undoubtedly, complete equalized water distribution is not realized in the irrigation system as causing water-logging and salinity hazards in some areas. However, such inconvenient in water use is come out from not insufficient of water, but from inadequate water management. It could be improved through development on water management. As to water uses except for

irrigation purpose, no substantial water uses required much increasing water supply are not programmed for the concerned area. Taking these circumstances in water use into consideration, no change on water supply standard is recommended in the Rehabilitation Project.

5.3. Rehabilitation Target of the Project

The Taunsa barrage irrigation system consists of the sub-systems, namely Indus river system, Taunsa barrage system, canal system, canal management system, irrigators associations, water distribution system, irrigation management system, and agriculture system.

These sub-systems do not function independently, but these work comprehensively as a Taunsa barrage irrigation system functioning related to each other. These are also balanced with each other. When there is a sub-system facilitated surpassingly rather than others, the most of its advantage is not effective at all. On the contrary, if there is a substandard sub-system rather than others, entire workability of the Taunsa barrage irrigation system is oppressed by its lowered level. Unbalanced improvement of each sub-system might be of no use, and not effective.

On these understandings, almost sub-systems of the Taunsa barrage irrigation system excepting barrage system are satisfied in initial developed stage even though there are some inconveniences. Only the barrage system should be lifted its substandard situation so as to rank among other sub-systems as shown in Fig. 5.3.1. This rehabilitation project will be concentrated upon Taunsa barrage improvement by this reason. After realizing this rehabilitation project on the Taunsa barrage, other ultimate development project of the Taunsa barrage irrigation system seeking entirely stage up may be launched.

It is revealed that problems facing on Taunsa barrage system are related each other in reality as shown in Fig. 5.3.2. Rehabilitation plan on the Taunsa barrage system shall be formulated in consideration with those relations. Faithful performance on operation and maintenance for the Taunsa barrage was observed during field survey, though no improvement, using old equipment, and few opportunity to introduce modern technique were recognized in their duties. Operation regulation of the gate is respectful for which precious experiences on historical river training activities for the huge Indus river are reflected. And also observed data of river discharge, sedimentation and so on, are recognized to be much useful. These data are recommended to avail widely more, computerizing if anything.

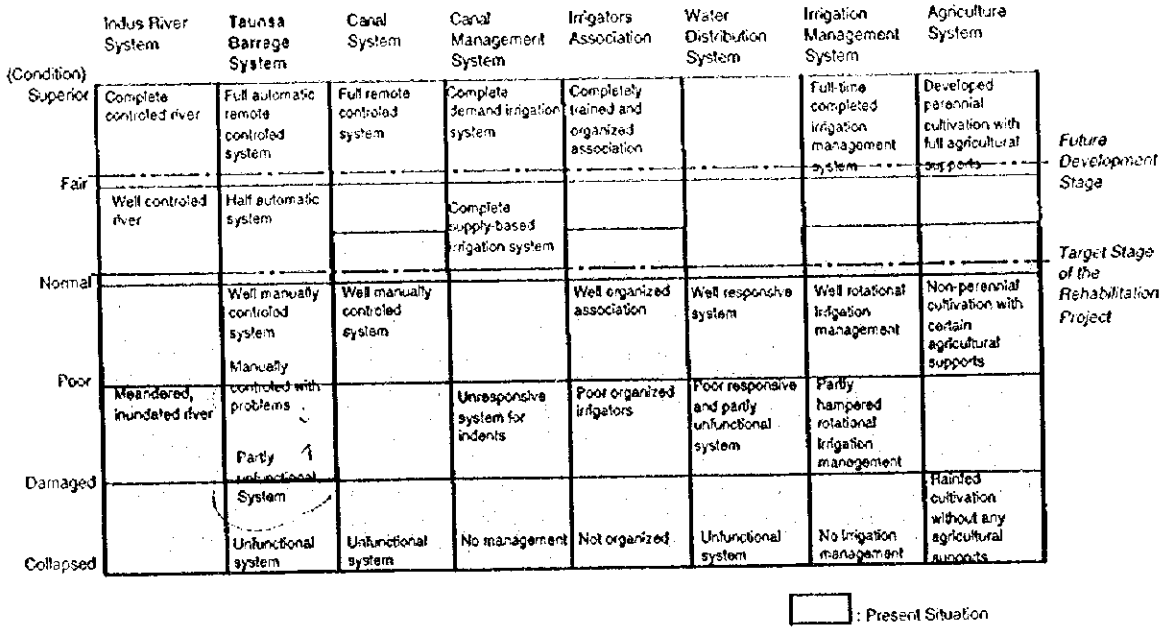

Fig. 5.3.1 General Concept of Rehabilitation of Taunsa Barrage Irrigation System

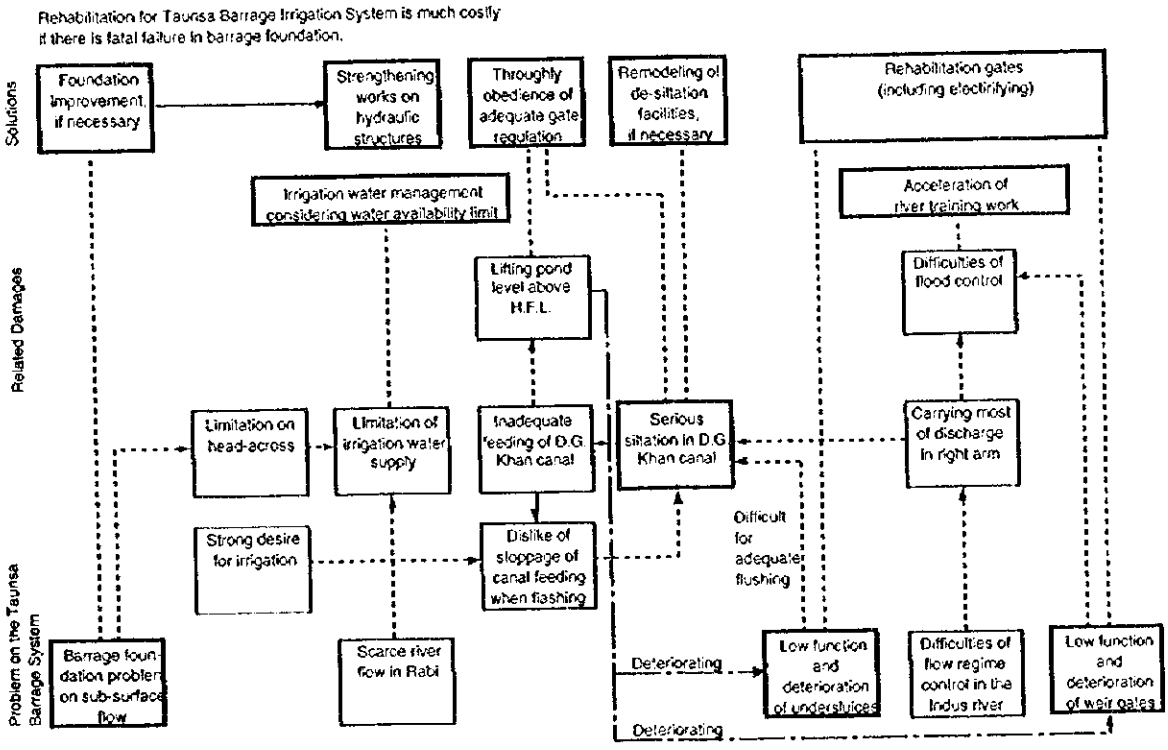

Fig. 5.3.2 Problems and General Solution on Taunsa Barrage System

5.4. Alternative Study on Optimization of the Rehabilitation Project

Prior to formulation of the rehabilitation plan, basic frame of the plan such as project scale and project period has to be set. As there are any options on determination of the frame, alternative study was done as follows.

(1) Study on Optimum Project Scale

On the basis of the present status of Taunsa Barrage Irrigation System rehabilitation and improvement concept, candidates of project component such as gate facility rehabilitation work, hydraulic structure rehabilitation work and so on, are supposed. Candidates for the project component seem to be categorized into two characteristics of "repair work" and "improvement work". As to the repair work, no alternatives can be thought about because of having unmistakable target and no any variation of methods for realizing its purpose. On the contrary, some alternatives can be contemplated for the improvement work because there is a room for trading investment off its benefit. In order to set optimum project scale, alternatives composed of some improvement works and repair works shall be compared.

For instance, there are any options for the gate leaf improvement. Undersluices shall be replaced to one plate gate taking present inconvenient into consideration, however, improvement plan on the other gates vary depend upon targeted system reliability. Four alternatives seeking different reliability which are composed of every component met to the target reliability are considered and compared as follows:

Alternative I: All undersluice and weir gates will be newly replaced to fixed wheel gate, and related hoist and gate shoe shall be remodeled. All gates except canal regulator gates will be electrified in gate operation. Hydraulic structure shall be repaired in its damaged portion. Piers shall be remodeled corresponding to the gate type change.

Alternative II: All undersluice and weir gates will be newly replaced following present stoney gate type, and related hoist and gate shoe shall be improved. All gates except canal regulator gates will be electrified in gate operation. Hydraulic structure shall be repaired in its damaged portion.

Alternative III: All undersluice gates will be newly replaced with one leaf gate following present Stoney gate type. Weir gates will be repaired continuously using present gate leaf. Related hoist and side support devices in all bays shall be improved. All gates except canal regulator gates will be electrified in gate operation. Hydraulic structure shall be repaired in its damaged portion.

Alternative IV: All undersluice and weir gates will be repaired continuously using present gate leaf. Related hoist and gate shoe in all bays shall be improved. All gates are operated manually as following present system. Hydraulic structure shall be repaired in its damaged portion.

Table 5.4.1 Comparison of Alternative Plans

Item	Alternative I	Alternative II	Alternative III	Alternative IV
Gate Structure				
Gate Leaf: Undersluice Gate	All undersluice gates will newly replaced to fixed wheel gate, remodeled to one plate gate.	All undersluice gates will newly replaced following Stoney gate type, remodeled to one plate gate.	All undersluice gates will newly replaced following Stoney gate type, remodeled to one plate gate.	Existing gate leafs will continuous utilized through repairing damages. Gates of Bay 2, 6, 64 will be replaced.
Gate Leaf: Weir Gate	All weir gates will newly replaced to fixed wheel gate.	All weir gates will newly replaced following Stoney gate.	Existing gate leafs will continuously using through repairing damages of bottom lip.	Existing gate leafs will continuously using through repairing damages of bottom lip.
Gate Leaf: Regulator Gate	T.P. link regulator gates will be replaced.	T.P. link regulator gates will be replaced.	T.P. link regulator gates will be replaced.	T.P. link regulator gates will be replaced.
Gate Shoe	Totally repaired	Totally repaired	Totally repaired	Totally repaired
Gate Sill	-	-	Water stop rubber will be attached at the leaf bottom.	Water stop rubber will be attached at the leaf bottom.
Hoist Device	Replaced (for fixed wheel gate type)	Replaced (for Stoney gate type)	Repaired and adjusted damages and hindrances	Repaired and adjusted damages and hindrances
Hoist Deck	Changed to grating	Changed to grating	Changed to grating	Changed to grating
Superstructure	Strengthen corresponding to gate type change *			
Inspection Passage	Improved corresponding to the superstructure change.	Installed new passage for middle gear inspection.	Installed new passage for middle gear inspection.	Installed new passage for middle gear inspection.
Electrification of Gate Operation	Electrified for all gates except regulators, by remote control	Electrified for all gates except regulators, by site control	Electrified for all gates except regulators, by site control	Manual gate operation
Hydraulic Structure				
D/S Glacis	Repair of skin concrete	Repair of skin concrete	Repair of skin concrete	Repair of skin concrete
D/S Concrete Floor				
Friction Block	Repair of all blocks	Repair of all blocks	Repair of all blocks	Repair of all blocks
Protection Work	Enlargement of C.C. blocks	Enlargement of C.C. blocks	Enlargement of C.C. blocks	Enlargement of C.C. blocks
Pier	Remodel corresponding to gate type change *			
Barrage Foundation	Grout injection	Grout injection	Grout injection	Grout injection
Barrage Abutment	Improvement work	Improvement work	Improvement work	Improvement work
Pressure Pipe Repair	Installation of piezo meters	Installation of piezo meters	Installation of piezo meters	Installation of piezo meters

Item	Alternative I	Alternative II	Alternative III	Alternative IV
Others				
Security Facility, O&M Facility, Monitoring Facility, & Other Related Facility	Equipment procurement	Equipment procurement	Equipment procurement	Equipment procurement
Canal facilities				
D.G. Khan Canal	Silt excavation	Silt excavation	Silt excavation	Silt excavation
Canal Structure	Improvement of canal escape gates	Improvement of canal escape gates	Improvement of canal escape gates	Improvement of canal escape gates
Economy				
Project Life	60 years	60 years	50 years	30 years
Construction Cost	Rs. 2,773.86 million	Rs. 2,505.49 million	Rs. 1,963.98 million	Rs. 1,805.08 million
Gate Leaf Replace	Rs. 812.23 million	Rs. 732.84 million	Rs. 438.00 million	Rs. 375.75 million
Hoist Improve.	Rs. 496.09 million	Rs. 327.22 million	Rs. 80.54 million	Rs. 80.54 million
Deck Improve.	Rs. 256.33 million	Rs. 246.33 million	Rs. 246.33 million	Rs. 149.69 million
Bulkhead Gate	Rs. 268.26 million	Rs. 268.26 million	Rs. 268.26 million	Rs. 268.26 million
Hydraulic Struct.	Rs. 464.94 million	Rs. 454.82 million	Rs. 454.82 million	Rs. 454.22 million
Other Works	Rs. 476.02 million	Rs. 476.02 million	Rs. 476.02 million	Rs. 476.02 million
Annual O&M Cost	Rs. 25.42 million	Rs. 26.81 million	Rs. 28.81 million	Rs. 36.50 million
Replacement Cost (every 10 years)	Rs. 22.18 million	Rs. 22.18 million	Rs. 22.18 million	Rs. 11.30 million
Net Present Value (12 % discount rate)	Rs. 26,320 million	Rs. 26,450 million	Rs. 26,680 million	Rs. 25,880 million
Judgment	Not optimal (Technically difficulty in remodeling of pier, superstructure, etc., & Higher initial investment)	Not optimal (Higher initial investment)	Best	Better (Shorter project life, & Smaller NPV)

*: It will raise some difficulties in technical because piers should be decreased in its thickness accompanied with gate groove remodeling, which could not be allowed without special measures.
- Above study was conducted under the assumption of 6.5 years construction period.
- Replacement cost is on the bases of 10 years expenditure.
- Agricultural benefit is applied the result presented in Chapter 9.

Trough above alternative study on optimum project scale, it is concluded that the Alternative III is the most optimum, and to be selected as a favorite rehabilitation frame.

(2) Available Working Days for the Rehabilitation Work

Probable number of days in a year of which discharge does not exceed low flow (250,000 cusec) is assumed at 313 days. It is applicable for the study on available working days, however, unknown probability shall be considered.

As to gates structure rehabilitation works, additional safety factor should be considered because of working into and around water. And also weir gates should be kept in functional condition

during flood period against flood mitigation. Taking these factors into consideration, available working days for gates structure rehabilitation works is decided 9 months from September to May, in which discharge is expected lower than 200,000 cusec.

As to hydraulic structure rehabilitation works, special attention should be paid for temporary dry work. It is mentioned that construction work is difficult and uneconomic under the condition having more than 100,000 cusec discharge. Taking these factors into consideration, available working days for hydraulic structure rehabilitation works is decided 7 months from October to April, in which discharge is expected lower than 100,000 cusec.

(3) Alternative Study on Optimum Construction Period and Number of Bulkhead Gate

Determination of construction period influences greatly investment scale and project economy. And procured number of bulkhead gate utilizing gate structure rehabilitation work is also same important factor. Assuming decided available working days for the rehabilitation work, alternative study on optimum construction period and number of bulkhead gate is conducted. On the alternative study, some combinations as follows can be considered.

Table 5.4.2 Alternative Construction Plans

Case	A	B	C	D	E	F	G	H	I
Number of Maintenance Gate	4	4	4	6	6	6	8	8	8
Number of bays to be done civil work par year	12	11	10	17	13	11	17	13	11
Required years for Gate Work	5.7	5.7	5.7	3.5	3.5	3.5	2.5	2.5	2.5
Required years for Civil Work	5.5	6.0	6.5	4.0	5.0	6.0	4.0	5.0	6.0
Total years for Construction	7.0	7.5	8.0	5.5	6.5	7.5	5.5	6.5	7.5

For the considered alternatives, construction cost and benefit are estimated as follows, converting to those percentage against figures of the Case E.

Table 5.4.3 Comparative Study Results on Construction Period

Case	Construct. Cost	Benefit	EIRR	Remarks
A	1.011	0.991	0.980	
B	1.011	0.983	0.972	
C	1.019	0.976	0.957	
D	--	1.018	-	About 1,500 manpower is impossibly required at peak period.
E	**1.000**	**1.000**	**1.000**	
F	1.007	0.983	0.976	
G	--	1.018	-	About 1,500 manpower is continuously using required at peak period.
H	1.015	1.000	0.985	
I	1.020	0.983	0.963	

Construction cost is estimated on the basis of direct construction cost.
Benefit is calculated as NPV of agricultural benefit with 12 % discount rate.

Through above alternative study, Case E, 6.5 years of actual construction period by using six bulkhead gate, is selected as the most feasible scheme.

(4) Electrification of Gate Operation

Present manual gate operation is hampered adequate performance of the barrage. Electrification of gate operation is recommended to be introduced for convenience of gate operation, and effectiveness of gate manipulation. However, disadvantage for the electrification such as increase of maintenance expenditure and reliability of electricity supply have to be considered. Method of the electrification and measures in emergency should be thought out.

Though electricity charge may also pressure O&M finance, it was already confirmed its feasibility in the alternative study on optimum project scale. Therefore, most important factor is a reliability of electricity supply for ordinary gate operation. Multi-attachment not only electric device but also manual or portable engine hoist is proposed for the emergency measures.

Frequency of gate operation is; 0.23 times/day for weir gate, 0.09 times/day for undersluice, and 0.22 times/day for canal regulator gate. Low frequency of operation of undersluice seems to be due to not low necessity of operation but difficulty of operation by deterioration. Anyhow, some frequency of operation can be recognized in every gate of the Taunsa barrage. However, electrification of canal regulator is not necessary because of easiness of gate lifting. Electrification with providing multi-attachable device is proposed for undersluice gate and weir gate.

(5) Adequate Project Life Year

Project life of this rehabilitation project is set as 50 years. There is a opinion standing at much safety side, 20 to 30 years project life as gate life. However, barrage structure including gates is surely alive keeping good function more than 50 years. Below table is showing ages of functional barrage existing in Punjab province.

Table 5.4.4 Running Term of Barrages in Punjab

Barrage	River	Completed Year	Running Term
Rasul	Jhelum	1901	97
Marala	Chenab	1912	86
Kanki	Chenab	1892	106
Trimmu	Chenab	1939	59
Balloki	Ravi	1913	85
Suleimanke	Sutlej	1927	71
Islam	Sutlej	1928	70
Panjnad	Panjnad	1929	69
Indus	Jinnah	1947	51
Chashma	Indus	1971	27
Taunsa	Indus	1958	40

According to the above data, about 100 years operation is normally possible providing adequate ordinary cares on operation and maintenance. Fifty years project life can be regarded as normal.

6. Improvement Plan

6.1. Improvement Plan of Taunsa Barrage

6.1.1. Improvement of Gate

Rehabilitation plan of the gates installed in the Taunsa barrage is formulated based on the studies of the problem, solution and optimization.

(1) Repair of shoe at grooves

- Quality of the material of truck plates and rocker assemblies shall be altered to high-tension stainless steel considering the difficulty of the replacement by routine O&M.
- Quality of the material of gate rollers shall be altered to standard cast steel so as to mitigate wearing of track plates and rocker assemblies, because the roller replacement is easy by routine O&M.
- Worn track plates shall be shaved by machine by 15 mm at the upper portion and 5 mm at the upper portion from roller treading original surface. Additional track plate shall be fixed on the existing track plate by stainless bolts.
- Type of the shoes of the rocker assembly shall be altered from multiple points support and replaced together with end girder to T-shaped cross section one and fit on the replaced new girder.
- Angles joining end girders with main beans shall be cut off, and replace new ones and join again the both members by high-tension bolts.
- Roller guard shall be taken off with proper countermeasures, because many roller guards have falten by the biting of obstacles, and roller guards requires some major repairs of pier so as to firmly fix on the gate guide. Self guard structure will be adapted attaching a brim on roller train flame so as to protect the roller train when the gate up and down. The suspension rope for the roller train shall be replaced.

(2) Rehabilitation of downside undersluice gate

Downside undersluice gates which have vertical crack at the end girders shall be urgently rehabilitated. The direct cause of the incident of the crack is poor repairing work of rocker assemblies. Originally, the requirement of the improvement of rocker assembly due to

jamming of obstacles and peculiar design type of two stories Stoney gate. Mono-leaf type undersluice gate is proposed aiming at the radical solution of the problems.

The proposed mono-leaf gate is girder type. The gate leaf will be manufactured as nine divisible one to be 8 ton maximum weight for transport and election. Site assembling will be weeding structure. According to the modification to the mono-lief gate, hoisting devices for upper side gate will be no necessary, so the driving device will be dismantled and the interim gear, counter shaft dram and counter balance will be connected to the proposed gate so as to share the gate operation load. Hanging position of the proposed gate, and existing suspension rope will be used again. The gate and the rope socket will be connected with metalware similar to existing manor. The counter balance applied from existing upper side undersluice gate will be adjusted to the proposed gate weight.

(3) Repair of seal portion

L-shaped rubber seal will be installed to the gate both side vertical end girders. The track plate sealing faces on the grooves will be smoothly finished from uneven one. The corroded rip at the gate bottom will be replaced to stainless steel rip by welding procedure, and flat shape rubber seal will be attached to the replaced rip. The sill beam on the bay crest will be excavated from the skin concrete and replaced to I-shaped steal beam with plating of stainless steel on the top. The replaced I-shaped beam will be set in the excavated concrete and fixed by chemical anchor bolts. The concrete excavated area will be filled with second stage concrete after the I-beam placement.

(4) Repair of hoisting device

Most hoisting devices are under the conditions of partial movement, loosening or ill-gearing and repairable to the originally designed conditions, because of no serious damages on the major parts. Therefore, repairing measure will be as follows.

- Drams shifted on the dram shaft will be settled at proper position by new fixing bolts.
- Ill-gearing will be adjusted with repairing of gear cogs.
- Damaged shaft will be replaced and loosened bolt will be tightened.
- Corroded interim gear flame will be cut off and new flame will be placed.
- Dram and interim gear will be cleaned, oiled and rust will be eliminated.
- Winding position of suspension rope will be adjusted to make full opening and full closing possible and to eliminate imbalance of gate hanging.

(5) Improvement of hoisting function

Electrification and portable hoisting machine are effective for the improvement of hoisting functions. The portable hoisting machines of two sets for emergency have been arranged in December 1997, accordingly electrification of hoisting device is proposed as following improvement.

- Existing driving parts of the barrage gate hoisting device located above the timber walkway will be changed to electrified driving parts consist of electric motor, helical reducer, bearing and sprocket.
- Helical reducer will be compatible to manual operation handle or portable hoisting machine.
- Electrified driving parts will equip dial type position indicator.
- Electrified driving parts will be connected with interim gear under timber walkway by chain.
- Existing on-off mechanism will be remained to proposed system
- Weight of the counter balance will be adjusted to the gate leaf adding with scrapped steel from disposal gate.
- Electrified simultaneous operation load will be limited within ten gates.
- Electrified hoisting device will be operated by the site push-button.

(6) Replace of walkway deck

Deteriorated timber walkway on the top of superstructure of the barrage including head regulator gate will be replaced with galvanized grating.

(7) Installation of passage for O&M

Passage will be installed for routine O&M as follows.

- Passage with about 500 mm width at the dram and interim gear under walkway deck along barrage axis will be made.
- Galvanized gratin will be laid at the floor of the passage, and connected by ladder to walkway deck for up and down movement.

- Vertical ladder along the groove at the downstream side will be installed to the bay crest for gate maintenance.

(8) Repainting of superstructure

However the superstructure has been never repainted since the construction in 1958, it is almost sound. Touch up painting (after surface preparation, once anticorrosive painting and once top coating) for peeled off coating portion and once finishing painting for entire area are proposed.

(9) Preparation of bulkhead gate

Bulkhead gates are provided for maintenance, urgent repair or rehabilitation of the barrage gates. However a stop log type or a floating bulk head type is considered as the maintenance gate, Taunsa barrage will adopt a floating bulk head type using upstream pond water, because the setting of the stop log using crane machine is difficult due to the obstacles of railway and high-tension power line.

This maintenance gate is possible to utilize for other almost barrages in Pakistan. The bay span of almost barrages is 60 ft just the same to Taunsa. The maintenance gate will be divided six blocks, two partitions in vertical and three partitions in horizontal, with upper limit of 30 ton weight considering the traffic ability.

Among six bulkhead gates to be used in the rehabilitation work, two of them will be continuously used at Taunsa barrage site in O&M into rehabilitation and maintenance work for other barrages after completion of the Project. The bulkhead gates for such rounds use can be moored in existing workshop when it is in a pause for engagement.

(10) Set up of storage yard for maintenance gate

Storage yard of about 8,000 sq.m will be set up at the left bank upstream side close to T.P. link head regulator gate for storage of six units maintenance gate. In the storage yard, rope winch, railway, incline facilities including carrying bogies, rest stands for the maintenance gate, tugboat for traction of maintenance gate will be provided.

The storage yard also will share parking areas for truck and truck crane necessary for the loading of air compressor, connecting pipe and mooring tool, and moorage to poutoons for crane and carriage. The storage yard will be fenced and wharf will equip moorings and fender beam.

(11) Rehabilitation of the gate leaf of T.P. link head regulator

Because of the remaining physical life of the gate leaf of T.P. link head regulator is very short and estimated to cease during the proposed rehabilitation project, the following works are proposed.

- Existing gate leaf will be replaced to new one of which structure is roller gate with girder beam.
- P-shaped rubber seal will be adopted to ceiling and both vertical ends, and flat rubber seal adopted bottom sill.
- After the replacement to the new gate, existing counter balance will be connected and adjusted so as to reduce operational load.
- Existing hoisting device will be used for proposed gate system.

6.1.2. Improvement of Hydraulic Structures

As indicated in the section of the present problems, extraordinary high velocity in flow caused by degradation/retrogression of riverbed and uplift acting under the skin concrete from subsurface flow damage friction blocks and skin concrete in the weir downstream severely.

Riverbed degradation, one of the most harmful influence on stability of the structure, has exceeded the estimated amount in the original design, and it suggested that other factors also have varied from the original design conditions. In the Study, then, they are reviewed and present conditions have checked whether they coincide with the circumstance. The results are shown in the following table.

Table 6.1.1 Summary of Evaluation of Present Parameters

Item	Required parameter	Present parameter	Determination
Design flood (100 year probability)	823,000 cs	1,000,000 cs	+++
Weir length (by Lacey's)	799.4 m	1,321.3 m	+++
U/S scour depth			
Weir	> 11.9 m	11.0 m	-
Undersluice	> 14.1 m	11.6 m	- -
D/S scour depth			
Weir	> 11.9 m	14.6 m	++
Undersluice	> 14.1 m	14.9 m	+
Total length of concrete floor (GE: 1/5.5)			
Weir	> 72.1 m	71.0 m	-
Under sluice	> 77.4 m	72.5 m	- -
Length of D/S concrete floor			
Weir	> 35.2 m	24.1 m	- - -
Undersluice	> 36.8 m	26.8 m	- - -
Length of C.C. block apron			
Weir	> 17.9 m	17.3 m	-
Undersluice	> 21.1 m	17.3 m	- -
Length of D/S loose stone apron			
Weir	> 23.8 m	24.6 m	++
Undersluice	> 28.1 m	27.4 m	-

Remark: Detailed description on this aspect is presented in Annex B, B2.

Length of the downstream floor concrete in the above table is obviously short as a measure for dissipation of energy through hydraulic jump. It is recommended to improve present condition as a strengthening stilling basin.

The remedial measures directed towards eliminating the effects of retrogression mainly aim at improving the tail water levels. The following options can be considered:

1) Remodeling the stilling basin by introduction of devices that could raise the water levels required for improvement in energy dissipation,

2) A subsidiary weir placed at the end of loose stone apron,

3) A pair of spurs anchored one each to right and left bank to construct the water-way,

4) A low Ogee shape weir crest on piles, and

5) A rock weir constructed with stone gabion as the end of impervious floor.

Item 3) formed a part of recommendations made in the late sixties but this dose not serve the purpose because the heading up caused by the spurs will generate severe scour at the spur-head and also in the bed, and the maintenance cost will be too high. Item 4) is not recommended

because the construction would pose substantial problems due to the location. And, item 5) is not recommended also because difficulties in maintenance of the rock weir. Therefore, among above measures, 1) remodeling the stilling basin and 2) provision of subsidiary weir, are most practicable solutions.

In view of economy and difficulties on construction, as 1) is preferable rather than another, remodeling the stilling basin is proposed in the Study. However, 2) is not thrown out of count until confirming the performance of those functions and applicability through model studies to be conducted in further stage. Tail scouring problem on the downstream of the proposed subsidiary weir itself caused probably instead of the same in the existing stilling basin, should be resolved.

Based on above discussion taking other remarkable damages into consideration, improvement of hydraulic structure including repair works are recommended as follows:

1) Reconstruction of skin-concrete in downstream glacis,

2) Reconstruction of skin-concrete in downstream floor,

3) Grouting foundation ground under mass-concrete and drain along the joints,

4) Improvement of stilling basin with repairing friction blocks anchored to the mass-concrete,

5) Extension of downstream bed protection concrete blocks, and

6) Replacing of loose stone apron.

Provisionally head across of Taunsa barrage is restricted below 22 ft due to an anxiety about piping. In actual situation, head-across of more than 22 ft is not required in Rabi because feeding water giving high head across than 22 ft is not allowed in order to secure water right of water users in downstream province. However, recover of allowable head across from 22 ft to 30 ft is targeted in this Project in view point of barrage safety. Measure for this purpose is proposed to spread geo-textile filter under C.C. blocks in order to stop movement of sand. Spreading of the geo-textile filter shall be done with width of longer than the length of required concrete floor length for giving design head across. By this measure, head across of Taunsa barrage could be expected to recover to the value of original design.

Besides these, monitoring on distribution of uplift is impossible since almost pressure pipes are out of order at present. Measurement of uplift by the pressure pipes is the heart to maintain the barrage safe, therefore, existing pressure pipes shall be replaced to an improved measuring system in the Project.

Moreover, present guide wall of right pocket is not always proper against oblique approach to river flow upstream of Taunsa barrage. In order to improve such bothersome approach causing desiment problem in D.G. Khan canal, extension of length of the guide wall might be effective.

6.1.3. Others

Railway bridge put on the Taunsa barrage is not required to rehabilitate immediately without damages and faults. Since operation of the railway bridge is also out of control of IPD done by PR, it may be not concerned with the Project. However, good arrangement with the PR on scheduling the work should be taken so as not to influence to railway service significantly.

Some deterioration of road bridge such as suspected-nutralization of concrete, exposure of reinforced iron bars, cracks in hinged bearing portion of suspended spans were observed. While it is not worried about its destruction for the time being, rehabilitation will be required in future taking increase of traffic into consideration. It is recommended to implement barrage bridge rehabilitation as a separate project phase from this rehabilitation project watching through progress of its deterioration.

6.2. Improvement of Canal System

6.2.1. Dredging in the Upper Reaches of D.G. Khan Canal

D.G. Khan canal had designed as a regime channel, however it cannot be free from siltation to enormous inflow of depositing material. Present heavy sediment in the upper reaches of the D.G. Khan canal might be resulted by much silt entry far beyond the designed condition. Besides, it is questionable whether the present hydraulic condition does meet with an regime channel criteria.

Taking account of the fact that the undersluice gates are not properly operated and huge amount of silt flows into the canal, capacity of silt entry in the upper reaches of the canal is also improper. Present flow section especially in the upper reaches of the canal between RD 0 to RD 40,000 does not meet with the requirement. Present width fulfills final discharge of existing requirement and the Dajal extension, however present discharge defined provisionally is lower than that of the final, then low velocity has decreased tractive force in the channel. At present, excess inflow of silt addition to the low tractive force makes huge sediment on the channel bed surface.

There is little possibility to carry the final discharge of 11,400 cusec including Dajal extension in the canal by solving water rights conflicts immediately, then temporary discharge of 8,301 cusec would be carried in the canal for a period of time. As a remedial measure for the close of canal section by sediment, excavation to the full existing width is not appropriate. According to the study on the sediment transport, when the canal excavated to full existing width, the friction velocity on the channel surface would decrease to 85 % of the requirement and sediment transport would reduce less than half (from 0.00484 to 0.00212 cu.m/sec). It means full width excavation reproduce heavy siltation in the canal again, and lining of the channel as another solution will not solve the problem since necessary measure is to keep design velocity in the channel but full width lining would not make required velocity. Effective measure is to excavate canal bed by decreased channel width until the realization of the Dajal extension.

The study on the sediment transport in the undersluice revealed that velocity in existing canal is sufficient to carry sediment when inflow of bed load and high concentration suspended load would be decreased by suitable operation of undersluice gates. It is recommended that velocity in the canal must be kept at the requirement by retaining inflow at the discharge of higher limit as much as possible. When flow section would be decreased, canal must be excavated to keep temporary canal width of 180 ft.

6.2.2. Improvement of Other Canal Structures

As previously mentioned in the present problems, other structures such as head regulators, canal regulators and canal escapes have been damaged. They are, however, in use even damaged situation and they are mostly minor failures. Then they should be repaired and maintained in a routine maintenance.

Canal escape needs good maintenance as a structure against emergency, since malfunction of the escape causes spilling over the canal not only resulting serious damages to the houses and farming lands by flooding but also requiring possible expensive repair works by collapse of canal embankment. The canal escape at RD 88,500 on the left bank of the D.G. Khan canal is not working and the one at RD 246,000 on the right bank of the Muzaffargarh canal has damaged seriously, then rehabilitation of these escapes are included in the Project.

6.3. Improvement of Irrigation Facilities

In Kharif season, flow in the Indus river is abundant and design off-taking discharge is easily drawn to the canals. On the contrary, during Rabi season, river flow is scarce and uneven distribution of irrigation creates problems occasionally especially in the D.G. Khan canal. Solving this, the D.G. Khan canal circle office requests to feed full discharge in short duration to the canal in several times in Rabi season, instead of current distribution of small discharge in a long period, still it is not satisfied because of water right.

The D.G. Khan canal circle has applied rotational water distribution (Canal Warabandi) to designated canal sections temporarily to the existing status. Though it is allowed in such a time delayed water distribution acceptable by farmers, it creates serious conflict between irrigators in the D.G. Khan canal in a sowing period when every farmer need water simultaneously. In the Muzaffargarh canal, limitation for intake is same, however the conflict has not always created because distribution is adjustable by head regulator gates.

Basic requirement to solve the problem is provision of buffers for water distribution. The Taunsa barrage cannot be provided buffer function, but regulating ponds may be constructed along the canals. Present irrigation water supply system has fulfilled fundamental requirement as mentioned in the section 5.3, and settlement of uneven water distribution might be categorized into higher level development. An improving plan including construction of buffer ponds contains many complicated problems to be solved in future, therefore its further discussion will be expected beyond this Study.

6.4. Improvement on Water Distribution

The Water Regulation Division of Punjab determines basic water distribution plan by 10-day basis for each canal based on the apportionment of the Indus Water Treaty consulting to the Indus River System Authority prior to the beginning of the every water year. Then canal divisions request water distribution by indents to the barrage division as the farmers' water demand arise. Considering availability of water, the barrage division makes operational plan based on the basic water distribution plan.

There is no problem on its planning and operation of the basic water distribution plan at present. On the contrary, though shortage of water supply demanded by farmers is solved immediately, excess discharge in canal is liable to be neglected and water spills over flooding crop lands. It is reducing discharge allocated other farms and resulting uneven water distribution since total quantity of water is limited. Gate operation, however, is in good condition without any problem.

This fact indicates overall management is necessary covering total canal system with monitoring and checking. This system shall check operation in each canal section from overall system management and adjust the gate operation by the barrage division. The Study has revealed that little hardware or physical improvement is required, however institutional improvement is recommended such as establishment of comprehensive checking system with responsibility or stationing a person in charge.

6.5. Institutional Improvement on Operation and Maintenance

6.5.1. Institution for Operation and Management

Difficulties in operation and maintenance are as follows:

- Improper stationing of personnel, including total number and unbalanced work quantity and stationed personnel,
- Short of mechanics,
- Inefficient work,
- Un-mechanized maintenance work, and
- Lack of finance for operation and maintenance.

There are 151 personnel working in the Taunsa barrage division, including personnel assigned to the direct operation duties of the barrage and indirect supporting services such as operation of the offices and guest houses. The proposed plan will be to reduce the number of necessary personnel to 1/3 of existing number by introducing electric gate operation. It is necessary to review the existing assignment since some personnel remain in needless assignment, on the other hand personnel having mechanical knowledge and experience concerning maintenance of gate need more number in an exiting organization.

Operation and maintenance is seemed to be inappropriate in some case, regular technical training shall be given to the personnel assigned to operation and management not only of the Taunsa barrage but also of other barrages in Punjab. Besides, equipment and tools for operation and maintenance and for monitoring are insufficient and early introduction of computers is necessary for quick data analysis of the barrage safety and its record keeping.

Addition to this, funds for operation and maintenance are insufficient. It needs to allocate adequate funds necessary to its operation and maintenance considering important irrigation system and high efficiency of the project. The proposed institutional improvement is determined to meet the financial requirement in which future operation and maintenance cost

will be below existing funds, since future financial status in operation and maintenance of the barrage is quite uncertain.

6.5.2. Operation of Taunsa Barrage

Existing operation of the barrage have complied with the rules and regulations of the Taunsa barrage (L.B. No. 112, 1965). Since it includes detailed operation on the gate of undersluice, weir and lock, control on the pond level, maintenance procedures of the gates, etc., future operation is recommended to be complied with the rules after completion of the rehabilitation. The gates in the barrage can be operated in three ways, which are electric motor drive, engine drive and manual operation. Electric operation can choose three status, which are UP, DOWN and STOP. Switches are placed on the upper deck and gate stops after 1 ft travel in UP and DOWN status. Therefore, future operation will need watch-person who gives order to the gate operator and use same signal or signs of communication between the watch-person and operator.

6.6. Improvement of Workshop

Workshops in Punjab are facilitated properly and assigned suitable personnel. Mostly the workshops have minimum works to repair canal gates and manufacturing parts for barrage gates. Since facilities of workshops conform to new construction or large rehabilitation works, usual minor works for maintenance are too little for the facilities and leaves them idle.

It is recommended to shrink the capacity and to enhance efficiency of the workshops in future. Taunsa barrage workshop shall be operated only for ordinary maintenance, such as daily inspection, greasing, etc. Since Multan workshop can be placed as a regional center and Bhalwar workshop can be placed as a provincial center, they will handle not only Taunsa barrage but also other dams, barrages and canal systems. Their works must be limited in the extent which can be done by existing personnel and facilities and the workshops will not enhance the capacity. Extension of the capacity of private firms are requested for commissioning them ordinary repair works or accumulated seasonal works in a closure period. In the Project, large scale manufacturing will be done in Bhalwar workshop and mass production and particular processing will be done by private firms.

7. PROJECT COMPONENT AND COST ESTIMATE

7.1. Rehabilitation of Gates of Taunsa Barrage

The proposed rehabilitation works on the gate structures are as follows.

Table 7.1.1 Rehabilitation Works on Barrage Gates

(Unit: ton)

Item	Undersluice gates (11 gates)		Weir gates (53 gates)		U/S Lock gates (1 gate)	
	Unit weight	Total weight	Unit weight	Total weight	Unit weight	Total weight
Repair of truck plate and rocker assembly	4.148	45.628	3.561	188.733	4.148	4.148
Replacement of gate leaf	45.986	505.846	-	-	14.978	14.978
Improvement of water tight	1.609	17.699	1.599	84.747	0.601	0.601
Renewal of hoisting device	4.317	47.487	1.516	80.348	1.516	1.516
Electrification of hoisting device	1.286	14.146	1.286	68.158	1.286	1.286
Improvement of deck on superstructure	1.431	15.741	1.431	75.843	0.610	0.610
Installation of inspection passage	2.000	22.000	2.000	106.000	1.509	1.509
Repaint on superstructure	-	375.440	-	332.180	-	-
Preparatory work using bulkhead	3.746	41.206	2.206	119.780	-	-

Table 7.1.2 Rehabilitation Works on Head Regulator Gates

(Unit: ton)

Item	TP Link Gate (7 gates)		DGK Gate (7 gates)		MGH Gate (5 gates)	
	Unit weight	Total weight	Unit weight	Total weight	Unit weight	Total weight
Repair of truck plate and rocker assembly	-	-	-	-	-	-
Replacement of gate leaf	8.2000	57.400	-	-	-	-
Improvement of water tight	-	-	-	-	-	-
Renewal of hoisting device	-	-	-	-	-	-
Electrification of hoisting device	-	-	-	-	-	-
Improvement of deck on superstructure	0.498	3.486	0.498	3.486	0.498	2.490
Installation of inspection passage	1.273	8.911	1.273	9.911	1.273	6.365
Repaint on superstructure		200.000	-	200.000	-	-
Preparatory work using bulkhead	-	-	-	-	-	-

Table 7.1.3 Preparation on Bulkhead

(Unit: ton)

Item	Unit weight	Total weight	Remarks
Fabrication of Bulkheal	110.559	663.359	One Bulkhead will be separate six pieces. Most heavy piece has 30 ton
Jetty and stockyard	100.000	600.000	

7.2. Rehabilitation Works of Hydraulic Structure

The proposed rehabilitation works on the hydraulic structures are as follows.

Table 7.2.1 Rehabilitation Works on Hydraulic Structure

Item	Number	Unit Volume (cu.m)	Total Volume (cu.m)	Remarks
Repair of skin concrete	-	-	10,400	Removal and reconstruction
Repair of friction blocks				
Trapezoidal block	832 blocks	1.19	990	Reconstruction
Cubical block	896 blocks	2.75	2,464	Reconstruction
Repair of C.C. blocks	14,160 blocks	1.73	24,470	Spreading geo-textile filter
Installation of C.C. blocks	8,220 blocks	1.73	14,220	Spreading geo-textile filter
Installation of end sill	-	-	5,760	To prevent washing out
Extension of apron	-	-	19,600	Extension
Repair of flared out wall				
Earth work	-	8,880	17,760	Both side abutment
Concrete work	-	600	1,200	Both side abutment

Further, pressure pipes will be installed at 13 piers or 20 % of the all piers. Twelve pressure pipes will be positioned at one pier. Those pipes will be managed by remote control at boot on superstructure.

7.3. Strengthening of Foundation

Grouting is employed to strengthen the barrage foundation. At the downstream sites of each bay, 400 kg of cement mortar will be injected using ten grout holes with a diameter of 45 mm.

7.4. Measure against Sedimentation in D.G. Khan Canal

Dredging works will be carried out to remove heaped sediment at the portion between RD 000 and RD 40,000 of D.G. Khan canal. The distance and width of the dredging is 12.192 km and 180 ft (54.86 m), respectively. Thus, the dredging volume is estimated at 1.27 million cu.m.

7.5. Repair Work in Canals

Inlet of escape of D.G. Khan canal, position at RD 88,500 and Muzaffargarh canal, positioned at RD 246,000. Item and quantity of repairing work in each canal are shown in the following table.

Table 7.5.1 Rehabilitation Works on Head Regulator Gates

Item	Escape in D.G. Khan Canal		Escape in Muzaffargarh Canal	
	ton/gate	Total	ton/gate	Total
Mechanical work (ton)				
Truck plate and rocker assembly, repair	0.50	3.50	-	-
Gate leaf, replace	2.10	14.70	-	-
Water tight, repair	0.10	0.70	-	-
Hoisting device, improvement	0.22	1.54	-	-
Superstructure, improvement	1.20	8.40	-	-
Civil work (m3)				
Dredging	-	2,000	-	2,500
Slope pitching	-	150	-	700

7.6. Procurement of Equipment

In the rehabilitation project, O&M and monitoring equipment will be procured to assure the irrigation function and stability of the Taunsa barrage irrigation system. The list of the equipment is shown in the following table.

Table 7.6.1 Procurement of Equipment

Item	Specification	Qty	
1) Water recorder	With floating system	Unit	7
2) Rain recorder	Tipping bucket type	Unit	1
3) Current meter	For high velocity	Unit	1
4) Current meter	For low/middle velocity	Unit	1
5) Silt sampler	For sampling bed load	Unit	1
6) Silt sampler	For sampling suspended load	Unit	1
7) Grain-size analyzer		Unit	1
8) Boat	23 feet	Unit	1
9) Handie-talkie	For short/middle distance	Set	2
10) Computer	Analysis and record data	Set	3
11) Truck	2 ton, long body	Unit	2
12) Wheel loader	Bucket capacity: 1.5 to 2.0 m3	Unit	2

7.7. Temporary Work

(1) Gate work

On rehabilitation of gate work, floating bulkhead gate will be used for stopping water. This bulkhead will be fabricated and supplied at ground before starting all works. Procedure of execution is as follows:

- Fabrication of floating bulkheads,
- Rehabilitation of undersluice gates and 16 weir gates at right side,
- Rehabilitation of undersluice gates at left side, and
- Continuous rehabilitation of gates form left side.

Floating bulkhead will be set at upstream point of piers. Elevation of top of bulkhead will be as same as top of existing gates. Guide rail and bearing plate will be fixed to piers in order to disperse hydrostatic pressure load to pier. In setting bulkhead on pier at stream side and guide wall such as bay 1, 9, 61, 62 and 65, guide rail and bearing plate fixed on wall with chemical anchor. Bearing pressure girder across the Bulkhead will be possible to change girder for normal pier into at stream side and guide wall with flange. Water tight will be formed from water stop plate with flat robber seal that pressed on the wall. In stopping water on crest, weight of bulkhead will form water tight on the crest portion. The bulkheads will have six air-tight tanks in that water will be pour and drainage with drain pipe and air pipe. Bulkhead will sank in or float on water by controlling water in the tank.

In execution of rehabilitation work of undersluice gates, new gate leaf will be replaced after existing lief with shear hulk from upstream. Counter weight is hugged temporarily over the gate in execution. Small members required to rehabilitation will be installed with truck crane on the bridge.

In execution of rehabilitation work of weir gates, existing gates will be temporarily hugged up to height place and side girder will be replaced with truck crane on the bridge. Bottom girder will be replaced continuously.

In execution of rehabilitation work of the upstream lock gate, gate girder will be renewed during the closure period. Side girder of the gate will be replaced with truck crane on the bridge with downstream lock gate closed. Bottom girder will be restored on hanging scaffolding.

Of rehabilitation working day, undersluice gate will need 71 days, and weir gates need 50 days. Renewal of hoisting device, deck and inspection passage will be done for the year except emergency, because these works will not produce influences of flood condition.

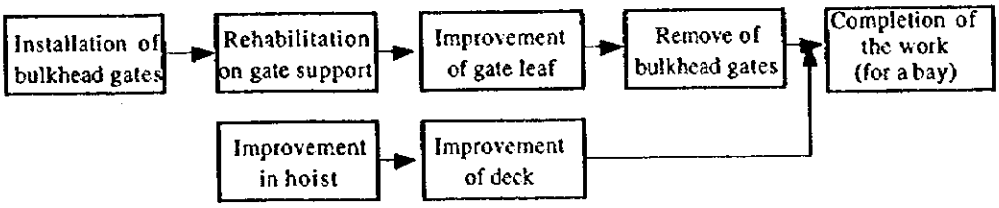

Fig. 7.7.1 Rehabilitation Works in Gate Structure

(2) Hydraulic structure

The civil work regarding rehabilitation of hydraulic structure will be executed after gate rehabilitation work finished. In starting work, cofferdam made by steel cage unit (4 m * 6 m * 4 m) will be set on river bed with floating crane and jute bags will be put in the cage. Rehabilitation of hydraulic structure will be done under dry condition with cofferdam completed. Procedure of execution is; 1) remove existing skin concrete and friction blocks, expending geo-textile on concrete joints, assemble bars, reconstructing friction concrete and skin concrete, 2) remove existing C.C. concrete, spreading geo-textile, reconstructing C.C blocks, 3) remove a port of existing lunching apron, constructing new C.C. blocks extended. After these works will complete, cofferdam will be removed. Finally lunching apron will be constricted. All these jobs will be executed for a period time from October to April.

Flared out wall will be improved in executing rehabilitation of bay under the wall. Executing procedure is as flowing: 1) remove existing concrete blocks composed wall, 2) construct buttressed-retaining wall, 3) expand geo-textile as same as backfiring. A lower part of wall will be completed by May.

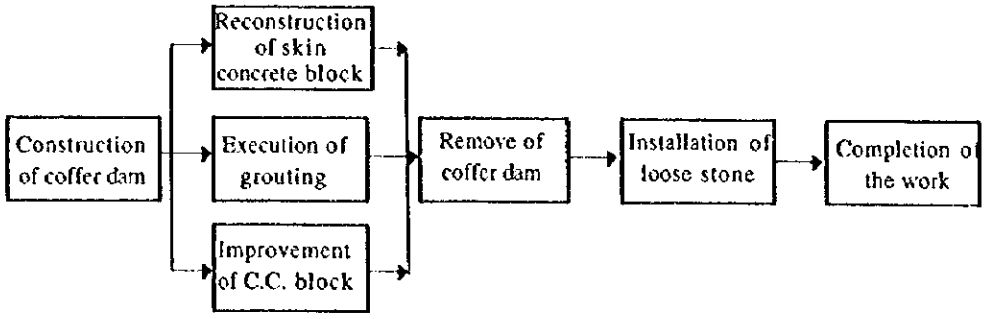

Fig. 7.7.2 Rehabilitation Works in Hydraulic Structure

(3) Others

Prior to the rehabilitation at site, the stockyard and jetty for bulkheads and construction material should be constructed on a ground of about 1 ha. Proposed stockyard will be constructed at protected lowland of left guide bank where is do reclamation. This area will not have hydrological influence on flow and will be able to be access to the gates by bulkhead. Proposed temporary stockyard for civil work will use park at riverside.

7.8. Project Cost

7.8.1. Construction Cost

The construction cost is composed by; 1) direct construction cost, 2) indirect construction cost, 3) physical contingencies, 4) price contingencies, and 5) interest and service charges. The direct construction cost amounts to Rs. 1,964.0 million, and the total basic construction cost which includes the items 1) to 3) is estimated at Rs. 2,610 million. This cost consists of Rs. 1,489 million (57 %) of local currency portion and Rs. 1,121 million (43 %) of foreign currency portion.

Price contingencies are estimated over a period of the project implementation of 11 years in local and foreing currency portion, at 11.4 % and 4.4 % a year, respectively. And Interest and service charges are estimated at 3 % as a whole.

In such manner, The Project Cost of the Project is estimated as shown in Table 7.8.1.

Table 7.8.1 Construction Cost

(Rs.'000)

Project Cost Component	Local Currency	Foreign Currency	Total
I. Direct Construction Cost	**1,108,601**	**855,375**	**1,963,976**
1 Rehabilitation of Gates	338,611	426,260	764,871
a) Weir gates	227,794	274,593	502,387
b) Undersluice gates	87,901	118,701	206,602
c) Upstream lock gate	4,051	5,129	9,180
d) Downstream lock gate	1,837	2,369	4,206
e) D.G. Khan & Muzaffargarh canal regulator gate	9,468	14,604	24,072
f) T.P. link canal regulator gate	7,560	10,864	18,424
2 Floating Bulkhead	130,706	137,553	268,259
a) Fabricate and transportation	70,693	86,154	156,847
b) Construct jetty and stockyard	60,013	51,399	111,412
3 Rehabilitation of Hydraulic Structure	375,612	76,431	452,043
a) Rehabilitation of skin concrete	61,492	16,521	78,013
b) Reconstruction of friction block	21,478	6,367	27,845
c) Reconstruction of C.C. concrete	160,266	30,555	190,821
d) Extension of C.C. concrete	60,533	17,737	78,271
e) Construction of toe wall	23,422	1,141	24,563
f) Extension of loose stone	30,184	431	30,615
g) Reconstruction of flared out wall at left bank	7,445	1,834	9,279
h) Reconstruction of flared out wall at right bank	7,445	1,834	9,279
i) Grouting	3,346	11	3,357
4 Extension of Right Guide Wall	5,191	5,788	10,979
5 Measure against Sedimentation in D.G. Khan Canal	33,666	1,204	34,870
6 Repair of Canal System	4,093	2,527	6,620
a) Escape gate at D.G. Khan canal	3,055	2,514	5,569
- Rehabilitation of gate	2,821	2,510	5,331
- Dredging	11	1	12
- Slope protection	222	3	226
b) Escape gate at Muzaffargarh canal	1,038	13	1,051
- Slope protection	1,038	13	1,051
7 Installation of Pressure Pipe	3,670	21,580	25,250
8 Procurement of Material & Equipment	142	1,423	1,565
9 Temporary Work	88,250	13,250	101,500
a) Cofferdam made by steel cage and jute bags	80,000	10,500	90,500
b) Cofferdam made by jute bags	8,250	2,750	11,000
10 Site Expense	56,133	113,400	169,533
11 Preliminary and General Items (7% to sum of 1 to 9)	72,526	55,959	128,485
II. Indirect Construction Cost	**114,349**	**180,248**	**294,597**
a) Consultancy service (10% to Direct Cost)	58,919	137,479	196,398
b) Implementation cost (5% to Direct Cost)	55,430	42,769	98,199
III. Duty and Taxes	**155,424**	**0**	**155,424**
IV. Physical Contingency	**110,860**	**85,538**	**196,398**
Total Base Construction Cost	**1,489,234**	**1,121,161**	**2,610,395**
V. Price Contingency (Local 11.4%/year, Foreign 4.4% year)	**1,635,026**	**348,785**	**1,983,811**
VI. Interest and Service Charge	**44,677**	**33,635**	**78,312**
a) Interest during construction period			
b) Bank service charge (3%)	44,677	33,635	78,312
GRAND TOTAL COST	**3,168,937**	**1,503,581**	**4,672,518**

7.8.2. Replacement Cost

After the completion of the rehabilitation works, some equipment and parts, whose life span is shorter than the project life, should be replaced at the proper period. The following table shows the items to be replaced during the project life and the cost.

Table 7.8.2 Replacement Cost

Item	Replacement period	Quantity	Replaced cost (Rs.)
Rubber seal	every 10 years	All gates	8,700,000
Panel board	every 20 years	Weir gates	21,750,000
Lighting implement	every 10 years	L.S.	1,200,000
O&M equipment	every 10 years	L.S.	1,400,000

7.8.3. O&M Cost

The operation and maintenance works of the TBO will be improved by restructuring of the organization and by the new O&M equipment procured. Future O&M cost is estimated at Rs. 28.81 million a year as shown below.

Table 7.8.3 Annual O&M Cost

O&M works	O&M cost (Rs)	Remarks
Gate operation	950,000	10 operators
Painting, gate	800,000	
Repair, machinery	4,000,000	
Repair, hydraulic structure	400,000	
River training work	5,000,000	
Cleaning	400,000	
Monitoring	1,610,000	
Protection, dredging	6,000,000	
Administration cost	760,000	
General expense	8,000,000	
Electric charge	400,000	including consumable cost
Miscellaneous	390,000	
Total	28,810,000	

8. PROJECT IMPLEMENTATION PLAN

8.1. Constraints on Implementation of Project

The project implementation plan was formulated in consideration with several constraints, as explained below.

1) Gate operation during the construction;
As for the gate operation, the discharge in the canals should be kept functioning as much as possible during construction period, because the canal water is essential to the farming and human life in the command area. The river flow of the Indus should not be disturbed especially in flood season.

2) Structural difficulty in the repair;
The attached structure such as road, railway, telephone line and electric wire will limit material supply, available construction machinery, and working space and time.

3) Right of land and water use around the site;
The location and area of the stockyard has been planned in consideration with present right of property. The jetty for the proposed floating bulkheads is to be constructed apart from the existing guide bank.

4) Limitation on transportation;
In execution of this project, the route of the inner transportation for heavy construction equipment and materials will be limited due to width and load capacity.

5) Availability of labor and materials;
Availability of he material and labor is limited in terms of quantity and quality. For the electric power supply, temporary generating system will be need.

6) Law and regulation;
The project should be implemented under the law and regulation of Pakistan.

7) Consideration to environment;
The precious environment around the barrage should not be affected by the rehabilitation works.

8.2. Implementation Schedule

8.2.1. Executing Agency of the Project

Executing agency of the project is Irrigation and Power Department of the Punjab. The IPD will organize Taunsa Barrage Irrigation System Rehabilitation Project Office at the site. The fully furnished office should deal with planing, supervision of design and construction, land acquisition, coordination of related organizations, contract supervision, accounting, etc.

Present staff of the Taunsa barrage office will be concurrently main staff of the proposed project office. In addition, some specialists of gate mechanical and civil work will be staffed with this project office on contract basis. The proposed staff structure of the project office is shown in the following table.

Table 8.2.1 Proposed Staff Structure of the Project Office

Job Classification	Class	Concurrence Terms	Contract
Executive Engineer	BPS-18	1	
Assistant Executive Engineer	BPS-17	1	1
Assistant Engineer	BPS-11	2	1
Divisional Head Draftsman	BPS-13	2	4
Draftsman	BPS-10		1
Tracer	BPS-5		1
Head Accounts Clerk	BPS-13		1
Accounts Clerk	BPS-7		1
Senior Clerk	BPS-11		1
Junior Clerk	BPS-6	4	2
Sub-Clerk	BPS-5	4	2
Naib Qasid	BPS-1	3	3
Carrier Staff			9
Contract Administrator			3
Assistant Engineer			9
Sub Engineer			9
Survey Engineer			2
Rodman			10

8.2.2. Implementation Schedule

The project is expected to be implemented under financial and technical assistance from international organizations. Prior to the rehabilitation works, therefore, the necessary processes of financial arrangement, contract arrangement, and detailed design will take about 3.5 years. The most optimum construction work period at site is 6.5 years by fully using 6

sets of bulkheads, which needs 1.5 years for fabrication. Thus, the overall implementation period is 11.5 years.

The overall implementation schedule and construction schedules are shown in Fig. 8.2.1 and Fig. 8.2.2, respectively.

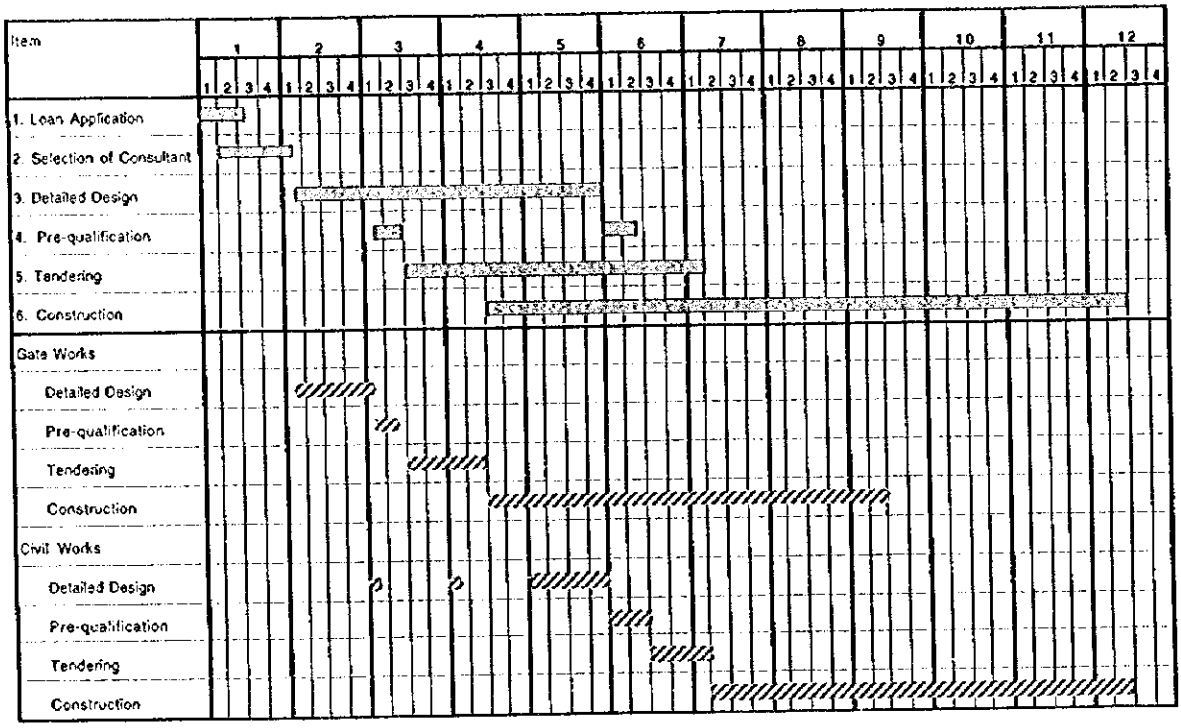

Fig. 8.2.1 Project Implementation Schedule

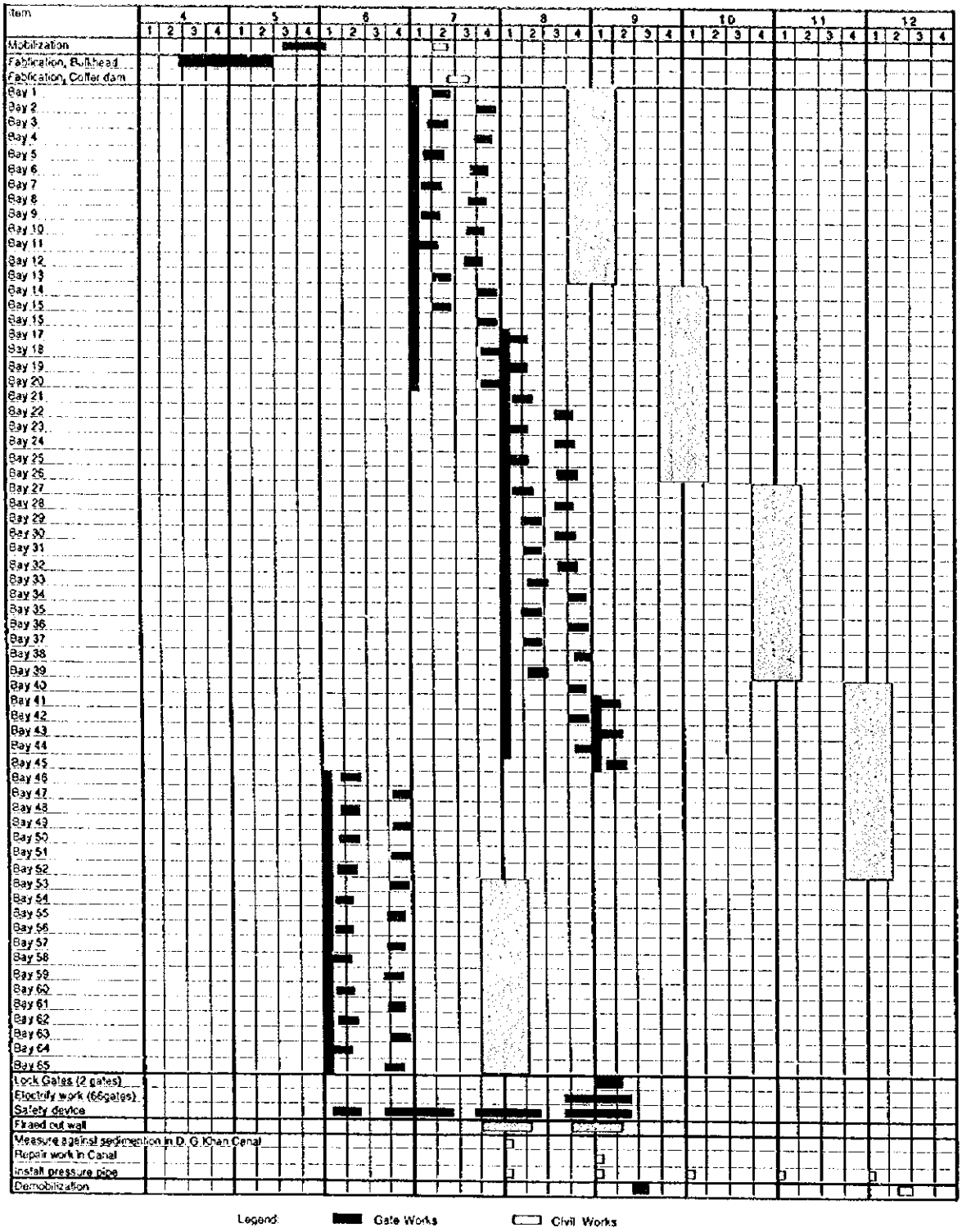

Fig. 8.2.2 Construction Work Plan

8.3. Operation and Maintenance Plan

After implementation of the Project, the barrage system shall continuously be maintained and operated by Taunsa Barrage Office (TBO). The TBO will be re-structured for new adequate operation. The proposed organization of TBO is shown in the following table.

Table 8.3.1 Proposed Staffs for O&M

Section	Present nos	Proposed nos	Remarks
O&M Responsible	4	4	
Gate Operation	36	10	by electrifying for operation
Gate Painting	1	1	
Mechanic	1	1	
Mechanical Engineer	0	1	for the necessity of gate maintenance
Monitoring	17	17	
O&M Administrative	92	74	rationalization of existing system
Total	151	108	

Ordinary monitoring works within barrage operation such as measurement of water levels, proving on hydraulic structures, sounding sedimentation, observation on pressure pipes etc. are essential to provide necessary information for barrage operation, to watch harmful symptom for barrage safety, to collect useful data necessary for devising measures for every problems. The activities on ordinary monitoring achieving at present is suggested to be improved inconveniences in operation. It was observed a fact that adequate observation and analysis is not always conducted due to luck of capable equipment. Within the Project, the ordinary monitoring will be encouraged through procuring necessary equipment.

8.4. Contract of Project Implementation

The contract for the Project is divided into 6 categories as follows:

Table 8.4.1 Proposed Contract Works

Contract Category	Tender Type	Works
Detailed design	International Tender	Designing in detailed level on whole components composed in the Project
Gate and its related structure	International Tender	Covering all rehabilitation works concerning gate structure
Bulkhead gate procurement	International Tender	Procurement of bulkhead gate, and preparing its jetty
Civil Work	International Tender	Implementation of all civil works concerning rehabilitation on hydraulic structure
Equipment procurement	International Tender	Procurement of O&M and monitoring equipment
Office building construction	Domestic Tender	Construction of offices and building for project implementation

Every contract will be conducted taking close coordination as shown in Fig. 8.4.1. Those contracts are applied open tendering procedure, as pre-qualification, tendering, client approval etc., which should be followed the rule and regulation of IPD.

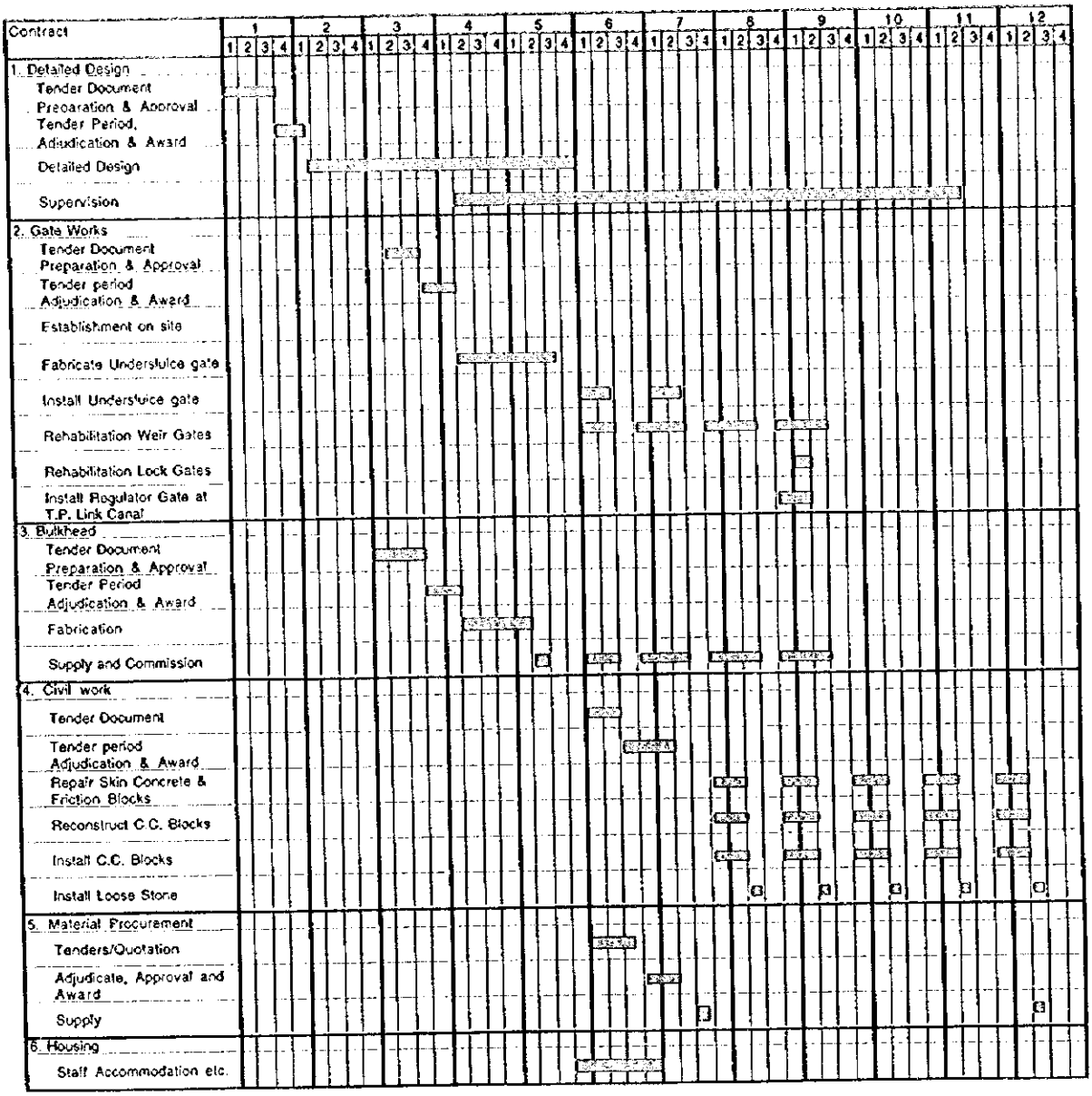

Fig. 8.4.1 Overall Program for Each Contract

8.5. Monitoring Plan of the Project

After entering service of the implemented project, adequate O&M is required to be fulfilled during and even after the project live. However, monitoring for the Project effectiveness is also important in order to feedback to the Project itself and to reflect other rehabilitation project. It is recommended to monitor the Project result periodically.

The monitoring shall be conducted during annual closure period by special survey group composed of specialists selected by IPD. The result obtained through the monitoring shall be transported any agencies concerned including TBO.

9. PROJECT EVALUATION

9.1. Outline

The objective of the Taunsa Barrage Irrigation System Rehabilitation Project is to recover or secure the irrigation service by means of rehabilitation and/or remodeling of the existing barrage. The main project components derived from the comparative studies are; 1) restoration of the gate structures, 2) rehabilitation of the hydraulic structure, 3) strengthening of foundation, 4) improvement of sediment control, 5) rehabilitation of canal facilities, 6) O&M equipment, and 7) temporary works. Some works aim enlonging their useful life or reducing O&M cost by the rehabilitation project.

The objective of the Project is to maintain the designed irrigation service in the command area continuously and certainly. If the Project will not be implemented, the diversion function of the barrage will be reduced.

9.2. Economic Evaluation

(1) Basic Assumption

The basic assumptions for the economic evaluation of the Project are summarized as follows.

- The economic useful value of the Project is 50 years.
- All prices are expressed at January 1998 prices in Pakistani rupee.
- The currency exchange rate is at US$ 1.00 = Rs. 44.00 = Yen 132.00 as of January, 1998.
- The transfer cost elements such as tax, duty, subsidy and interest are excluded for the estimation of the economic values.
- The standard conversion factor (SCF) of 0.87 is applied to domestic cost elements for the estimation of the economic values.
- The unskilled labor cost is converted to the economic value applying the conversion factor of 0.75.
- The foreign currency portion of the cost is the same as the financial price.
- The economic prices of the tradable agricultural commodities are estimated on the basis of IBRD projection of world market prices terms.

(2) Project Cost in Economic Terms

The project cost in the evaluation consists of the construction cost, O&M cost and replacement cost. The economic costs of the Project are estimated for the economic evaluation, applying the basic assumption mentioned above. The economic cost of the Project is summarized in the following table.

Table 9.2.1 Summary of Financial and Economic Costs of the Project

(Unit: Rs. million)

Item	Financial Cost	Economic Cost
I Construction Cost	2,455.0	2,150.5
1) Direct Cost	1,964.0	1,711.3
2) Engineering/Administration	294.6	258.0
3) Physical Contingency	196.4	171.1
II Annual O&M Cost*	-3.2	-2.8
III Replacement Cost		
Rubber parts (every 10 years)	8.7	7.6
Electric facilities (every 20 years)	21.8	18.9
Light, etc. (every 10 years)	1.2	1.0
O&M equipment (every 10 years)	1.4	1.2

Note: * The difference of the O&M cost between under With and Without Project conditions, Rs. 28.81 million and Rs. 32.00 million.

Source: JICA Study Team

(3) Project Benefit in Economic Terms

The benefit born by the Project is evaluated by the difference of the agricultural production between With and Without Project condition.

Table 9.2.2 Unit Net Return of Main Crops in Economic Prices

(Unit: Rs./acre)

Crop	Gross Return	Production Cost	Net Return
Cotton (Irrigated)	23,509	5,623	17,886
Rice (Irrigated)	2,253	2,190	64
Kharif Fodder (Irrigated)	4,118	1,518	2,600
Kharif Fodder (Un-Irrigated)	2,882	1,405	1,477
Wheat (Irrigated)	8,686	3,683	5,002
Wheat (Un-Irrigated)	4,570	3,683	887
Oilseeds (Irrigated)	4,916	1,825	3,091
Oilseeds (Un-Irrigated)	2,624	1,882	743
Rabi Fodder (Irrigated)	5,982	2,887	3,095
Rabi Fodder (Un-Irrigated)	4,187	2,660	1,527
Sugarcane (Irrigated)	40,425	28,648	11,779
Orchard (Irrigated)	28,298	26,797	1,500

Notes:

Source: JICA Study Team

The direct beneficial areas of the Project are the command areas of the D.G. Khan canal, Muzaffargarh canal and lower part of the Rangpur canal. The original function of the T.P. link canal, to divert water into Panjnad command area, is taken as a indirect benefit of the Project. The Dajal extension project is not counted for the direct benefit area due to its uncertainty in realization.

The cropping pattern in the area is assumed to be continued in case of With Project condition. Under Without Project condition, the intake discharge as well as irrigated area will diminish due to failure of weir gate operation. On the abandoned farm land some rainfed cultivation of crops except rice, cotton and sugarcane. During the construction works, the irrigated area is assumed to be decreased at 50 % both in Kharif and Rabi season.

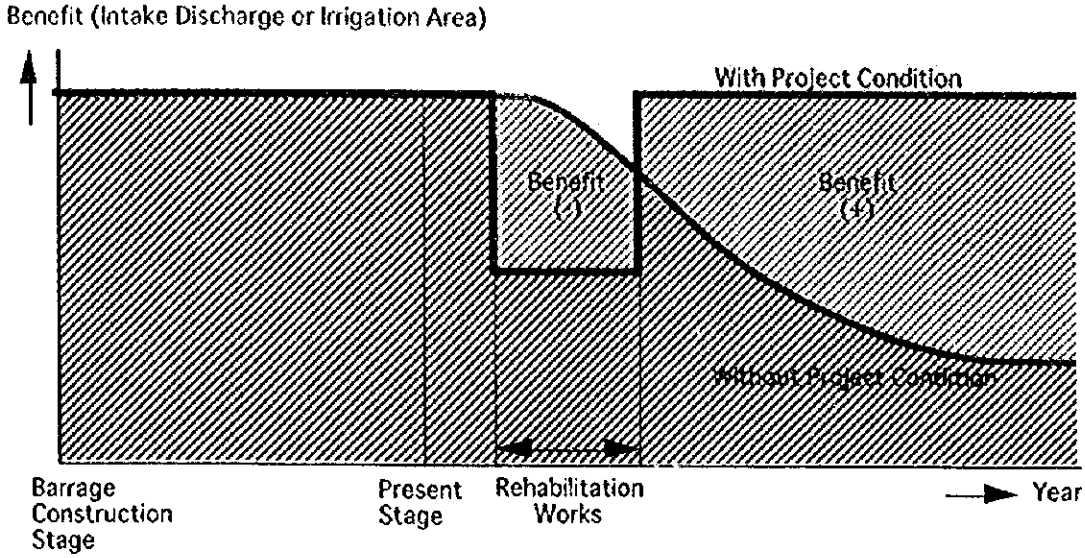

Fig. 9.2.1 Concept on Occurrence of Project Benefit

Table 9.2.3 Benefit of the Project in Economic Prices

Crop	Unit Return (Rs./acre)	With Project Area ('000 acre)	With Project Return (Rs.million)	Without Project Area ('000 acre)	Without Project Return (Rs.million)
Cotton (Irrigated)	17,886	646	11,574	148	2,656
Rice (Irrigated)	64	85	5	20	1
Kharif Fodder (Irrigated)	2,600	218	568	50	131
Kharif Fodder (Un-Irrigated)	1,477	0	0	749	1,106
Wheat (Irrigated)	5,002	623	3,118	0	0
Wheat (Un-Irrigated)	887	0	0	623	553
Oilseeds (Irrigated)	3,091	23	70	0	0
Oilseeds (Un-Irrigated)	743	0	0	23	17
Rabi Fodder (Irrigated)	3,095	130	401	0	0
Rabi Fodder (Un-Irrigated)	1,527	0	0	130	198
Sugarcane (Irrigated)	4,934	23	115	5	26
Orchard (Irrigated)	11,779	129	1,517	30	349
Orchard (Un-Irrigated)	1,500	0	0	99	149
Total		1,877	17,341	1,877	5,186
Increment				0	12,156

Notes: The figures under Without Project condition shows the lowest intake situation (23 % of original discharge).

Source: JICA Study Team

(4) Economic Evaluation

The indicators of Net Present Value (NPV), Benefit Cost Ratio (B/C) and Economic Internal Rate of Return (EIRR) is calculated assuming a discount rate as 12 %. The cash flow of the Project is shown in the following table.

Table 9.2.4 Cash Flow of the Project

(Unit: Rs. million)

Year		Cost				Benefit			B-C
		Const.	O&M	Replace.	Total	With	Without	W-WO	
1	2000	44			44	17,341	17,341	0	-44
2	2001	22			22	13,550	13,550	0	-22
3	2002	99			99	13,550	13,550	0	-99
4	2003	306			306	11,732	11,732	0	-306
5	2004	278			278	11,004	11,004	0	-278
6	2005	324			324	9,869	11,004	-1,135	-1,459
7	2006	413			413	9,869	9,792	77	-336
8	2007	239			239	9,869	9,792	77	-162
9	2008	149			149	9,869	8,095	1,774	1,625
10	2009	155			155	9,869	8,095	1,774	1,620
11	2010	121			121	9,869	8,095	1,774	1,653
12	2011		-3		-3	17,341	7,731	9,610	9,613
13	2012		-3		-3	17,341	7,731	9,610	9,613
14	2013		-3		-3	17,341	7,489	9,852	9,855
15	2014		-3		-3	17,341	6,155	11,186	11,189
16	2015		-3		-3	17,341	5,913	11,428	11,431
17	2016		-3		-3	17,341	5,792	11,550	11,552
18	2017		-3	9	6	17,341	5,792	11,550	11,544
19-20	2018		-3		-3	17,341	5,671	11,671	11,674
21	2020		-3	1	-2	17,341	5,671	11,671	11,672
22-24	2021		-3		-3	17,341	5,549	11,792	11,795
25-27	2024		-3		-3	17,341	5,428	11,913	11,916
28	2027		-3	28	25	17,341	5,428	11,913	11,888
29-30	2028		-3		-3	17,341	5,343	11,998	12,001
31	2030		-3	1	-2	17,341	5,343	11,998	12,000
32-37	2031		-3		-3	17,341	5,343	11,998	12,001
38	2037		-3	9	6	17,341	5,343	11,998	11,992
39-40	2038		-3		-3	17,341	5,186	12,156	12,158
41	2040		-3	1	-2	17,341	5,186	12,156	12,157
42-47	2041		-3		-3	17,341	5,186	12,156	12,158
48	2047		-3	28	25	17,341	5,186	12,156	12,131
49-50	2048		-3		-3	17,341	5,186	12,156	12,158
51	2050		-3	1	-2	17,341	5,186	12,156	12,157
52-57	2051		-3		-3	17,341	5,186	12,156	12,158
58	2057		-3	9	6	17,341	5,186	12,156	12,150
59-61	2058		-3		-3	17,341	5,186	12,156	12,158

Source: JICA Study Team

The cash flow table provides the economic indicators of NPV as Rs. 26,681 million, B/C as 26.1, and EIRR as 50.2 %. As the annual benefit derived from irrigated agriculture is significantly large compared with the Project cost, these economic indicators are extremely high. As a conclusion, the Taunsa barrage irrigation system rehabilitation project is judged as a economically feasible project.

Table 9.2.5 NPV, B/C and EIRR of the Project

	Indicator	Result
1	Net Present Value (NPV, 12 % discount rate)	Rs. 26,681 million
2	Benefit Cost Ration (B/C, 12 % discount rate)	26.1
3	Economic Internal Rate of Return (EIRR)	50.2 %

Source: JICA Study Team

(5) Sensitivity Analysis

The sensitivity analysis of the Project was done for expectation of some risky conditions. Three cases is assumed in this analysis; 1) 20 % increase in the initial investment, 2) 20 % decrease in agricultural benefit, and 3) 1 year delay in the project implementation. The EIRR under the any cases is estimated as high as 47 %, as shown in the following table.

Table 9.2.6 Sensitivity Analysis of the Project

	Case	NPV Rs. million	B/C	EIRR %
1	20 % increase in initial investment	26,468	21.8	47.8
2	20 % decrease in agricultural benefit	21,133	20.9	47.2
3	1-year delay in project implementation	22,110	24.3	46.9

Source: JICA Study Team

9.3. Financial Evaluation

This Project will not force the farmers to pay for the cost. The farmers will pay their regular irrigation water fee to the IPD under present institutions. The annual farm income under the standard cropping pattern and practices is estimated at Rs. 7,528 per acre in financial terms, while the water fee applying the unit rates of canal water by crops is only Rs. 53 per acre or 0.7 % of the farm income. Under Without Project condition, the farm income may decreases at Rs. 5,672 per acre and the water fee become Rs. 33 per acre due to change in cropping pattern. The present canal water fee is very little compared with the return.

Table 9.3.1 Farm Income and Irrigation Water Fee

(Unit: Rs./acre)

	Condition	Farm Income	Water Fee
1	With Project condition	7,518	53 (0.7 %)
2	Without Project condition	5,672	33 (0.6 %)
3	Increment	1,846	

Note: All figures are expressed in market prices.
Source: JICA Study Team

When the PIDA is established, water fee could increase and reliability of water supply could go up. From the viewpoint of the beneficial farmers, the advantage of the expected irrigation practice seems to be much stronger than the disadvantage of the increased water fee.

9.4. Social Impacts of the Project

(1) Panjnad Barrage Irrigation System

The main function of the T.P. link canal is a supplemental water supply to the Panjnad barrage located at the downstream of the confluence of the Chenab and Sutlej rivers. Panjnad and Abbasia canals originated form the Panjnad barrage irrigate 615,000 ha of GCA. After rehabilitation of the Taunsa barrage, therefore, the preferable diversion from the Indus and more stable irrigation in the Panjnad barrage irrigation system area is expected.

(2) Mitigation of Flood Damage

The flood damage occurs frequently in these year because the some deteriorated barrage gates can not open during the high water season. The flood damage is anticipated to become more frequently and significantly if the rehabilitation is not carried out. As this rehabilitation project will make the gate operation more certainly even in a flood season, the magnitude of the flood damage around the barrage will be mitigated considerably.

(3) Improvement of Farm Economic Condition by Stable Water Supply

The stable water supply accomplished by the proper gate operation is expected to contribute to improvement of farmers' economic condition. The most farmers use tubewells for the purpose of supplemental water supply when they can not get expected amount of canal water on their farms even in Kharif season. If the Taunsa barrage irrigation system can be operated more certainly, the pump operation time can be minimized. Thus, the pump operation cost or payment to water market can be saved.

(4) Dajal Branch Canal Extension Plan

The Dajal branch extension plan to irrigate 132,000 ha of GCA at the tail of D.G. Khan canal is still pending. The long-history plan since the Taunsa barrage construction period is difficult to be realized soon because of no water right from the Indus. However, the plan is possible to run when some desirable allocation of water is arranged. To keep the Taunsa barrage in good condition secures the possibility of the future project implementation.

(5) Assurance of Non-Irrigation Functions

The Taunsa barrage serves several non-irrigation functions, such as non-irrigation water use, road transportation, railway transportation, oil pipeline, and telephone line crossing. Such associate functions will be automatically assured by means of the implementation of the Taunsa barrage rehabilitation project.

9.5. Environmental Consideration

Since the proposed rehabilitation work of the Taunsa barrage is the preventive measure for the existing irrigation system and it does not include the expansion of the irrigation area, the impact of this rehabilitation on the environment of the Study area is expected to be minimal. However, the impact on the wildlife sanctuary during the construction should be taken into account in order to avoid any negative effects on the precious inhabitants. Among the conceivable impacts during the construction period, the most important point is to avoid any water pollution not to give any detrimental impact on the water life around the barrage and in the lower stream including Indus dolphin, water birds and fisheries.

10. PRELIMINARY STUDY ON TAUNSA ROAD BRIDGE REHABILITATION

10.1. Present Condition of Taunsa Road Bridge

The Taunsa road bridge has serviced for O&M works on the barrage as well as public traffic since 1959. The bridge is designed as a reinforced concrete cantilever girder bridge with a 24 feet width roadway and both sidewalks, and a class AAA army loading of 70 ton design load. The 40-year-old bridge has been worn out and missing concrete at the bottom of the girder with distortion and clacking. The joint survey done by the IPD and C&W Department in December 1995 suggested that 1) strengthening the monitoring, 2) implementing appropriate maintenance and repair, and 3) introducing a traffic ban on over 40 ton 10 wheel truck, over 65 ton 14 wheel trailer and over 65 ton 22 wheel trailer, though sign of urgent collapse is not observed yet.

The passing of the road bridge charges Rs. 3 to cars and tractors, Rs. 5 to wagons, Rs. 15 to buses and trucks and Rs. 100 to trailers. The IPD has a responsibility of the charging through a contractor. The provincial government commits a contractor to collect the traffic charge, and contractor pays the collected charge deducing the cost as a government revenue. The annual traffic charge amounts to Rs. 8 to 10 million and more than a half of that goes to the government.

10.2. Necessity of Rehabilitation

The present traffic volume is estimated at 1,348 vehicles a day, which consists 437 cars, 508 trucks, 149 wagons, 137 trailers and 119 tractors. It has become triple times in these three years. As the Ghazi Ghat bridge, another road bridge at 80 km downstream from Taunsa, can not allow over 20 ton heavy vehicle to go across the Indus river, the importance of the Taunsa road bridge is increasing. In addition, when the Indus highway will be start the service within these 5 years, the traffic volume on the Taunsa bridge, which is nearest access to the highway, is expected to increase significantly.

The anticipated future of the road bridge is, thus the condition of slab and beam is going down and demand of common and heavy vehicles is going up. Therefore, the early rehabilitation works on the road bridge is recommended before the degradation reaches to serious condition.

10.3. Rehabilitation Plan of Taunsa Road Bridge

The large-scale rehabilitation is more suitable for the Taunsa road bridge than a partly repair because the observed deterioration is spread on the all length of the bridge. The original construction was done easily on the embankment foundation, but the rehabilitation works on the water will be accompanied with much difficulty.

The necessary rehabilitation works are removal of slabs and beams and placement of a new PC grillage girder bridge.

10.4. Rehabilitation Works and Costs

(1) Rehabilitation Method

The rehabilitation works of the barrage bridge shall be commenced to demolish suspended span, then proceeded to anchor girder from both river bank sides. In every rehabilitation works, one way traffic will be secured taking construction works from. For the construction work of suspended span, suspended timbering will be applied due to difficulty of supporting by ground.

(2) Construction Cost

The total construction cost on replacement the worn cantilever girder bridge to the new PC grillage girder bridge is estimated at about Rs. 2,407 million. The required prestressing steel is planned to be imported because such item is not available in domestic market.

10.5. Project Evaluation and Project Implementation Plan

(1) Economic Evaluation

The benefits of the bridge rehabilitation will appear as saving of vehicle operation cost (VOC), and saving of O&M cost on the barrage. The VOC saving benefit is calculated as additionally required detour cost including fuel, depreciation cost and labor cost. If the Taunsa road bridge is fallen down, the vehicle must pass the Ghazi Ghat bridge (80 km downstream) or Chashma bridge (280 km upstream) to cross the Indus river. Assumed the daily traffic volume on the Taunsa is 1,300 as present, the VOC saving benefit is estimated at Rs. 1,281 million a year in economic terms. The O&M cost of the Taunsa barrage is saved by using the road bridge, compared with by using boats. The O&M cost saving is estimated at Rs. 0.34

million a year. Total annual benefit of the road bridge rehabilitation is expected at Rs. 1,281.34 million.

The rehabilitation cost is estimated at Rs. 2,407 million of which foreign currency portion is Rs. 626 million and local portion is Rs. 1,781 million. To keep the bridge safe and clean, the annual O&M cost of the new bridge would be Rs. 0.13 million per annum.

As a result of economic evaluation assuming the project life as 50 years and social discount rate as 12 %, EIRR is 25.5 %, NPV is Rs. 3,680 million, and B/C is 3.19. The project, therefore, is very feasible and to be set a high priority for implementation.

(2) Financial Evaluation

In financial terms, the income of the assumed autonomous body is an annual traffic charge estimated at 8 to 10 million, and the expenditure is an O&M cost at Rs. 0.13 million. Considering that the bridge over the Indus is the highly important public works, the most of the capital cost should be paid by the government. The project during O&M stage, therefore, is financially justified.

(3) Project Implementation Plan

The project may commences after completion of the Taunsa barrage irrigation system rehabilitation project, and the work period will be 2 years.