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RESTORING DESIGN CAPACITY OF MARALA RAVI LINK CANAL

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RESTORING DESIGN CAPACITY OF MARALA RAVI LINK CANAL: A CASE STUDY

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ABSTRACT

Marala Ravi Link Canal is one of the three link canals constructed before the Indus Water Treaty for providing water to those canal systems having their headworks in the Indian Territory. MR Link Canal off-takes from Marala Barrage on the River Chenab and was commissioned in July 1957. MR Link experienced heavy siltation in the initial years of its operation leading to significant reduction in its discharge carrying capacity.

This paper reviews the major hydraulic problems in the MR Link, their possible causes and the previous improvement measures and their effects. The proposed plan for restoration and improvement of MR Link system has been critically examined. Various design approaches have been evaluated in the context of their applicability to the irrigation canals in general and MR Link in particular. Different alternatives for evolving cost effective restoration plans are presented.

The paper concludes that sediment intake into MR Link has improved after the construction of new Marala Barrage. Deferred maintenance and lack of monitoring have been identified as the major factors for the continuation of the problems in MR Link. This study suggests that construction costs for restoration of MR Link can be reduced significantly using low cost techniques and local resources without compromising on the quality of work. The increasing influences of the Funding Agencies on water sector projects and policies require careful consideration. The paper strongly recommends to evolve a policy for safe-guarding vital national interest with prime focus on self reliance.

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A. INTRODUCTION

Marala Ravi Link Canal (MR Link) is one of the three link canals[4] constructed by Pakistan before the signing of Indus Waters Treaty. The main purpose of these link canals was to provide alternative source of water to those canal systems, which were truncated at the time of creation of Pakistan and their Head-Works were left on the Indian side. Irrigation supplies in these channels were cut off by India soon after independence in 1947. Planning, design and construction of MR Link and other two link canals was carried out by the Pakistani Engineers using local resources.

MR Link canal system off-taking from Marala Barrage on the Chenab River, is essential for providing water to the canals commanded by the Eastern Rivers (Ravi, Sutlej and its tributaries) during the critical periods of shortage. This requirement will increase in future as the natural flows in the eastern rivers will diminish due to construction of dams by India; the entire eastern rivers flows having been earmarked to India under the Indus Waters Treaty. The MR Link Canal System is mainly intended to irrigate the area between the Ravi and Sutlej Rivers, as well as, the area on the left bank of the Sutlej. MR Link Canal and Bambanwala-Ravi-Bedian-Depalpur (B.R.B.D.) Link Canal are the two main components of the system. This paper discusses the issues related to MR Link Canal with particular reference to the proposed project for restoration and improvement of the MR Link System.

The MR Link was designed to transfer 22,000 cusecs from the Chenab River to Ravi River during Kharif Season for supplementing flows in Lower Bari Doab Canal (L.B.D.C) and for onward transmission to Sutlej River via the Balloki - Sulemanki (B.S) Link Canal. The MR Link Canal can also be used to supply up to 5000 cusecs to B.R.B.D. Link via the sub-link that takes-off near the tail out-fall of MR Link. MR Link is a non-perennial canal and mainly draws from excess Chenab supplies at Marala during Summer high flow season, as Marala has not been integrated with the Western storages.

MR Link is an unlined canal and has a length of 317,000 ft. It outfalls into the river Ravi some distance upstream of the Ravi Syphon. The head regulator for MR Link was originally constructed just upstream of the Upper Chenab Canal (UCC) head regulator in the left pocket of the old Marala weir. After construction of new Marala Barrage in 1968, this arrangement was shifted to the new site downstream. The canal has 92 structures like bridges, cross drainage works, syphons, supper-passages and falls, etc.

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[4] The other two link Canals were Balloki-Sulemanki (BS) Link and Bambanwala - Ravi - Bedian - Depalpur (B.R.B.D) Link.

B. OBJECTIVES OF THE STUDY

The objectives of the study include:

--- identification of the major hydraulic problems of MR link and the possible causes thereof;

--- review of the previous studies and improvement measures in order to have a better appreciation of the perspective of the issues;

--- suggesting design approaches for restoring the capacity of MR Link Canal. The main emphasis would be on solving the sedimentation problems of the main / link canals in general and MR link in particular.

--- bringing out alternative planning measures for evolving cost-effective restoration proposals; and

--- discuss the role of the funding agencies influencing the Water Sector Projects and Policies.

C. HYDRAULIC PROBLEMS OF MR LINK CANAL

MR Link was commissioned in July 1957. The head regulator of the Link was located 300 ft. on the upstream of the UCC head regulator in a retarded position. The length of divide wall of old Marala weir being only 328 ft., the head regulator of MR Link was completely outside the pocket area. The location of the old regulator in a retarded position and absence of pocket/still pond effect in front of it caused the river water to flow almost directly into the link thereby causing heavy deposition of silt (about 4.5 feet depth) in the head reach by end of summer season 1958. By the end of summer season 1959, the depth of silt had risen to about 8.2 feet. The situation kept on aggravating with the passage of time. The silt carrying capacity, presumed at 0.7 grams per liter at full supply, was made at times to exceed far more than the designed limit even at low discharges to avoid repeated closure of the link so as to meet the pressing demand of Sutlej Valley Canals. The relaxation of silt entry criteria continued till the situation eased out after construction of the other links envisaged in the Indus Basin Plan to connect river Sutlej.

The silt depositions in the link canal rendered the old regulator non-modular and thus encroached upon its discharging capacity. The excessive sediment intake no doubt caused the channel to adopt steeper slopes, but the reduced depth of flow on that account resulted in erosion of berms and banks causing

abnormal widening of the channel section. The higher elevation of flowing water in the link submerged a few of the bridges in the head reach. Partial running of the link aggravated the channel condition, and the canal started meandering thereby causing scour on the outer curves and damage to the banks. The abnormal channel widening in the head reaches of the link can be seen from fig.1.

Full supply level at head of MR Link in the year 1959-60 had risen to about RL 807.50 ft. with only 15,000 Cusecs discharge, against the original designed level of 803.8 ft. for 22,000 Cusecs. The situation continued aggravating till the construction of new Marala Barrage in 1968. With the construction of new Marala Barrage, the silt intake into MR link considerably improved. The sediment previously deposited in the canal bed has, however, not been excavated / removed. This has resulted in reduction of the capacity of MR link to around 15,000 cusecs. Despite considerable scouring of silt deposits and consequent lowering of the water levels since 1988, the discharge run in MR Link has not exceeded 15000 cusecs. One of the reasons for this is the weak banks and vulnerable points like overflow/breach sites, inadequate freeboard & bank widths, and excessive side erosion in some of the canal stretches that act as major constraints in the way of increasing the discharge capacity of the link. A typical problem reach between RD 207+000 and 209+000 is shown in fig. 2.

Yet another factor to be considered in the operation of MR Link canal is the existence of a number of high level off-takes which provide irrigation facilities to the adjoining lands. In order to feed these channels, heading up of the supplies has to be resorted to in the MR Link at the regulation points, particularly the regulator at RD 237+230. The effect of heading up extends upstream, which apart from encroaching upon the freeboard, affects the behaviour of the channel in the upper reach. In addition, inadequate cross drainage capacity has been reflecting on the operation of the Link during high rainfall events. During these periods, the canal banks either get breached by the flood waters of flashy streams or the local inhabitants cut the banks to get relief from the inundation.

The main problems in MR Link can thus be categorized as :

- Sedimentation of channel section, causing:
  - Rise of Full Supply Levels; and
  - Loss of Channel Capacity.
- Lateral instability due to excessive bank erosion.
- Weak and vulnerable canal embankments in some reaches having inadequate freeboard and restricted bank widths.
- Inadequate cross drainage facilities.

The possible causes of the problems in MR Link may include the followings:

i) Excessive and un-controlled sediment entry into MR Link during initial years of its operation, which resulted in heavy siltation in the head reaches. The silt deposits were never removed, so the channel had to operate in a deteriorated condition with deformed bed configuration.

ii) Steeper energy gradient in the head reaches of the link canal, particularly up to Aik Nullah crossing at R.D. 90+190. The water surface slope in this reach observed during 1985 was 0.17 per thousand against the last designed slope of 0.12 per thousand. The existing water surface slope in this reach is around 0.16 per thousand. The steeper energy gradient results in higher flow velocities, which may be responsible for excessive bank erosion.

iii) Over-loading of the channels can cause changes in the channel plan forms. There is a significant evidence both from field and flume data that excessive sediment can generate instability leading to meandering of the channels (Shakir, 1992). The lateral instability / excessive bank erosion in the head reach of MR Link needs to be viewed in this perspective, especially in the context of seasonal variation of sediment inflows.

iv) Lack of adequate control points on MR Link in the head and middle reaches appears to be a constraining factor. In the entire length of about 72 KM from head to RD 237+230, there is no control point (cross regulator, fall, etc.) on the link. This restricts the ability to exercise control over water levels and energy gradients in the critical head reach.

v) The external interferences with the channel regime, like unplanned and uncontrolled sand mining from the bed of the MR Link. This has been depicted in fig. 3, which clearly shows the abnormal bank erosion in the canal reaches where excessive sand mining had been done in the previous closure.

vi) Running the MR Link with partial supplies has reflected on channel regime and aggravated the problem of lateral instability.

vii) Deferred maintenance and inadequate monitoring and evaluation are also visualized to be the factors responsible for the present deteriorated channel condition.

D. GENERAL REVIEW OF REMEDIAL MEASURES AND IMPROVEMENT PROPOSALS

A detailed review of the various remedial measures and proposals for improvement and restoration of MR Link is presented below in the chronological order.

Early Remedial Measures.

In order to solve the problems and to improve the working of the MR Link Canal, the following measures were taken during 1960-64 :

-- Replacement / modification of the shutters of Marala weir so as to maintain a pond level of RL 809.5 ft (originally RL 808 ft);

-- Extension of the divide wall from 328 ft to 640 ft. In the new situation the divide wall covered about one third of the regulator of MR Link;

-- Construction of training works along the left marginal Bund so as to shift the confluence point of Jammu Tawi and Chenab away from the pocket;

-- Construction of earthen spurs with stone pitched noses and sides in the head reach of MR Link on both sides of the canal so as to tighten the bed width up to design; and

-- Lowering of the crest of the regulating bridge-cum-fall at RD 237+230 by 4.34 ft in order to induce retrogressive erosion in MR Link.

Construction of New Barrage.

The problems concerning sedimentation and bank erosion could not be solved by the actions mentioned above. Therefore it was decided to construct a new barrage at Marala with new regulators for the two canals (MR Link and Upper Chenab Canal (UCC)).

The new barrage was constructed 1,100 ft downstream of the old weir and became operational in 1968. The pond level in the pocket was raised from RL 808 / 809.5 ft to RL 812 ft in Kharif season. The left pocket is 867 feet wide and 1,080 feet long. The divide wall ends at a small distance from the upstream abutment of the MR Link regulator.

The construction of the new Barrage considerably reduced the sediment intake into MR Link. The problems in MR Link, however, continued because restoration of MR Link was not undertaken concurrently and the channel had to operate in the deteriorated condition with silted and deformed bed configuration and excessive widening.

Chohan Proposal.

Chohan (1986) carried out a comprehensive review of the problems in MR Link, with particular reference to the causes of the problem and proposed measures for improving the situation. The improvement measures were identified separately for Marala Barrage and MR Link Canal. The measures included:

Marala Barrage.

* Extension of the divide wall to increase the length of the pocket by about 400 feet;
* Construction of silt excluder;
* Compartmentation of the pocket into three zones so as to permit partial flushing operations;
* Paving of the pocket floor to increase the efficiency of flushing operations;
* Removing the crest of the old weir to avoid silt depositions upstream of the pocket and to improve silt control; and
* Raising of the regulator crest of MR Link so as to decrease the sediment intake into the link.

MR Link Canal.

* Re-grading of MR Link with higher slope of 0.18 per 1000 in the head reach up to RD 90+190 to enable the redesigned channel to respond better to the prevailing conditions of sediment grade and charge. The modified FSL at the head of link was proposed as RL 810.8 ft.

* Staged desilting of the link canal in accordance with the above redesign.

* Construction of bank protection measures with stone pitched profile walls 100 ft. long at every 1000 ft, with longitudinal killa bushing.

* Strengthening of the banks to withstand the rise of full supply level in the canal combined with raising of decking of three submerged bridges.

Model Test Results.

The proposed improvement measures for Marala barrage were investigated in a scale model by the Irrigation Research Institute (IRI, 1988). The test results showed that :

* The construction of raised crest in combination with a raised pond reduces the sediment entry into MR Link by 50%, but the silt entry may increase due to river bed accretion. Yet, the long-term reduction in silt entry into MR Link would be about 40%.

* Extension of the divide wall does not reduce the sediment entry into MR Link;

* A silt excluder can be effective in reducing the silt entry into MR Link by about 80% without affecting the sediment withdrawal by UCC;

* The compartmentation of the pocket deteriorates the present situation due to increased turbulence;

* The dismantling of the old weir does not have an advantageous effect on the sediment flushing or the sediment entry into MR Link but will be helpful to lower the flood levels upstream of the barrage.

Present Status of MR Link Canal.

Since 1988, the situation in MR Link is showing signs of improvement. The silt deposits in the bed of the link are being scoured, resulting in a decrease of silt depth from 9 to 5 ft. This improved situation can be attributed to the following factors:

* shifting of the confluence of Jammu Tawi and Chenab rivers in the upstream direction. The present confluence is considered to be very favourable and is holding. This has improved the river approach towards the pocket thereby reducing silt entry into the off-taking channels.

* the construction of Salal Dam in India which might temporarily have reduced the sediment load in the Chenab River;

* the exceptional high flood of 1988 causing the flushing of deposits in the pocket and further upstream of the barrage. This has generated a sand trap capacity upstream of the barrage;

* Sand Mining in MR Link during closure.

Feasibility Study for Restoration of MR Link System.

A feasibility study for improvement and restoration of MR Link Canal System was carried out under Asian Development Bank (ADB) Technical Assistance (TA No.1582-PAK) during 1992-94 by a group of Consultants at a cost of Rs 32.0 million. The study was conducted in a broader perspective for restoration and improvement of the MR Link system, i.e. MR Link and BRBD Link Canals. The

investigations relating to MR Link Canal mainly focussed on assessment of water resources to determine the needed capacity, design approach for restoration of the link canal, and Scale Model Studies for reducing silt entry into MR Link.

In order to restore the capacity of MR Link Canal, the feasibility study recommended the following improvement measures :

* River Training Works upstream of Marala Barrage;
* Sediment Exclusion works at Marala Barrage; and
* Restoration/desilting of MR Link Canal.

For optimizing measures to control silt entry into the link, model studies were carried out in Irrigation Research Station Nandipur. The proposed interventions were studied on the overall model and the detailed model. The model studies concluded that construction of a tunnel excluder in the left pocket of Marala Barrage will provide the best performance for reducing sediment entry into MR Link. In addition to the above, the Consultants recommended to construct river training works (extension of spur JT-1 and remodelling of the spur head) on Jammu Tawi river to prevent the confluence of Chenab and Jammu Tawi shifting downstream. The proposed restoration works for MR Link canal involves excavation to remove sediment deposits from bed of the canal. The restoration designs have been evolved based on Lacey's approach and checked using a physical method. The last designed bed levels of the canal at the head regulator have been retained in both the above designs.

Detailed Engineering Designs for the Proposed Restoration Project.

As the next step and follow on to the Feasibility Study, preparation of detailed engineering designs for the Project has been launched. A PC-II for this stage, costing Rs 125.44 million, was prepared by Punjab Irrigation Department (PID, Punjab) in September, 1994. The objective of this PC-II is to develop detailed designs of the Project enabling construction activities to proceed. The engineering designs will include site investigations ; surveys ; model studies ; detailed designs ; tender documents ; and project preparation activities such as PC-I finalization. Total required input include 58 man-months of the foreign Consultants and 122 man-months of local technical experts and 110 man-months of the support staff. Eighty two percent cost of detailed engineering stage studies is to be financed by the Asian Development Bank (ADB) loan, while the remaining 18% cost will be borne by the Punjab Government.

The present status is that seven groups of Consulting Firms have been pre-qualified for the detailed engineering design stage of the Project. All the pre-qualified groups have foreign firms in the lead role. These groups are currently preparing their technical and financial proposals.

E. SUGGESTED APPROACH FOR RESTORING CAPACITY OF M.R.LINK.

Design Approach.

There has been quite a debate on the design approach to be followed for restoration of MR Link Canal. The Feasibility Study Consultants favoured the use of physical methods based on sediment transport and flow resistance. The Irrigation Department supported conventional Lacey's regime approach for channel design. The Consultants and the Asian Bank consider Lacey's approach as old with restricted application for extrapolated discharges. The department viewed the new approach as inadequate being untested in the actual field conditions. The issue could not be resolved at the feasibility stage and has been passed on to the Detailed Engineering Design stage for more in-depth studies.

Leaving aside the controversy over the basic design approach, the geometric parameters of the channel predicted by the above approaches are compared in table 1. It may be observed that while the bed width in both the approaches is virtually the same, the physical method design results in 15% increase of F.S. depth. The resulting velocities predicted by physical methods are about 20% lower than the Lacey's design velocities.

TABLE-1

Geometric Parameter of M.R. Link using alternative Design Approaches.

Channel Parameters (in the head reach)	Using Lacey's Approach	Using Physical Method
Discharge	22,000 Cusecs	22,000 Cusecs
Bed Width	345.00 ft.	344.00 ft.
F.S.Depth	14.30 ft.	16.47 ft.
Slope	1 : 8333	1 : 9520
Side Slope	1 : 1.5	1 : 2.5
Velocity	4.34 ft./sec.	3.46 ft./sec.

In order to study the effect of sediment concentration and grade on the geometric parameters of the channel, Shakir's method (1992) has been used during this study. This method was basically developed by HR Wallingford using the Ackers White sediment theory and White et al approach for flow resistance with optimization of sediment transporting capacity of the channel. Shakir (1992) tested this method experimentally as well as using the extensive field data including Pakistani canals and rivers. As a result of these investigations, he proposed a modified method for the design of stable straight channels. The geometric parameters predicted by Shakir's method for various sediment conditions are given in table 2. This presents an interesting comparison of the impact of the changes in sediment size and concentration on the channel geometry. The results seem to explain the general widening trend of M.R. Link. The results however show that the method is sensitive to changes in the sediment load, particularly slope predictions are very sensitive to these changes. Irrigation channels in Pakistan operate under widely fluctuating inputs of sediment loads, especially during the high river flow season. The use of a physical method as a basic design approach, therefore, need to be reviewed critically.

TABLE-2

Predicted Geometric Parameters Using Shakir's Method Under Various Sediment Input Conditions.

Channel Parameters	d_{35} = 0.2 mm			d_{35} = 0.3 mm		
	200 ppm	300 ppm	400 ppm	200 ppm	300 ppm	400 ppm
A. Discharge 22,000 Cusecs.						
Bed Width (ft)	390	380	370	419	408	397
F.S.Depth (ft)	17.4	16.7	16.2	14.8	14.1	13.4
Slope	1:12980	1:10504	1:8818	1:6614	1:5030	1:4058
B. Discharge 15,000 Cusecs.						
Bed Width (ft)	321	312	304	346	338	329
F.S.Depth (ft)	15.0	14.5	14.0	12.7	12.2	11.6
Slope	1:11800	1:9520	1:8025	1:6184	1:4714	1:3810

In view of the foregoing discussion, there is a need to carry out a detailed analysis of various empirical and physical methods using the prototype field data of Punjab Canals. The results of these investigations should then be tested against actual field conditions in the stable reaches of the MR Link Canal for validation and optimization. Highlighting the importance of this approach, Shahid (1990) has concluded that there is no substitute for basing canal design on the observed characteristics of stable canals in the same general location using the same water source. Another important consideration in designing the geometric parameters is the upper limit of velocity for the design of stable silt canals. Shahid (1990) recommended range of 3.5-3.7 ft/sec as the upper limit of the velocity for silt stable channels in the Indus Basin. For higher discharges, this may require review of the Lacey's approach for design of geometric parameters of the regime canals.

Analysis of Sediment Transport Capacity.

The difference between sediment intake and sediment transport capacity particularly during the initial years of operation, has been the single most important reason for extensive siltation and consequent reduced discharge capacity of MR Link Canal. The feasibility Consultants predicted the sediment carrying capacity of MR Link in the range of 126-141 ppm using the Ackers White modified formula for designed discharge of 22,000 Cusecs. In order to validate these predictions, the average actual sediment entry during the period 1985 to 1993 was analyzed and the over-all average sediment intake was found to be 274 ppm. With sediment deposits being scoured during this period, at less than design discharge in MR Link, the transporting capacity of MR Link should clearly be more than the above average sediment entry.

In view of the above discrepancies, the sediment transport capacity has been analyzed in more detail, using a number of sediment predictors. The sediment transport capacity has been calculated under various operating scenarios for different sediment sizes, and has been presented in table 3. These results indicate wide variations in sediment transport capacity using different sediment transport approaches. These approaches are particularly sensitive to the changes in slope and variations in sediment size.

The choice of sediment transport formula to be used in design of a channel with physical method needs to be reviewed critically. This would only be possible after a detailed analysis of different sediment theories based on Punjab Canal data. The overall approach for design of irrigation channels in Pakistan

Table 3

Sediment Transport Capacity Under Various Operating Conditions For Different Sediment Sizes (Discharge : 22000 cusecs)

Representative Sediment Size (mm)	Sediment Transport Capacity (ppm)											
	Ackers–White Approach			Ackers–White (Revised) Approach			Engelund Hansen Approach			Mushtaq's Approach		
	1:5000	1:8000	1:10000	1:5000	1:8000	1:10000	1:5000	1:8000	1:10000	1:5000	1:8000	1:10000
0.15	1117	609	451	666	394	303	829	324	207	1746	787	528
0.20	463	295	236	370	246	201	593	232	148	1268	559	369
0.25	287	200	167	267	190	160	451	176	113	971	418	271
0.30	213	157	135	215	160	138	358	140	90	772	325	206
0.35	172	133	116	184	141	124	293	115	73	630	258	161
0.40	148	117	104	162	128	113	246	96	61	524	210	128

needs to be evolved after objective evaluation of the empirical and physical methods.

Post-Improvement Monitoring of the Channel.

Effective and efficient monitoring would be central to the success and sustainability of the MR Link restoration. Lack of adequate channel monitoring has already been identified as one of the major causes responsible for hydraulic problems in MR Link. The location of head regulator of MR Link close to the foothills and at the confluence of three rivers poses serious problems in controlling the sediment intake into the Link Canal. This emphasizes the need to implement a well-conceived and a well-planned monitoring system after completion of MR Link restoration, otherwise the huge investments may prove ineffective or even futile. The proposed system should closely monitor river behavior and confluence point, sediment depth in the left pocket, sediment entry (both concentration and size distribution) into MR Link, and operational patterns, as well as, changes in bed and water levels of the MR Link. The monitoring system has to be supported by an efficient evaluation capability in order to enable the operation staff to anticipate the emerging problems and for taking timely remedial actions, whenever needed.

F. DISCUSSION

Extent of Siltation Problems.

The average annual silt entry into M.R. Link since its commissioning is presented in Fig.4. It is clear from this figure that average silt entry into M.R. Link was extremely high in the initial years of operation, when the channel used to take-off from the old Marala Weir. The sediment intake during the year 1960 and 1961 was as high as 1250 and 1400 ppm respectively. Since the construction of new Marala Barrage, the silt in-take into link has improved considerably and fairly stabilized. The average value is around 300 ppm, although the silt in-take ranged between 200 to 400 ppm. This trend continues and average silt entry into the MR Link during 1993 was 280 ppm.

The field observations indicate significant scouring of sediment deposits after 1988; the depth of sediment deposits reducing to around 5 ft. in 1993 from about 9 ft. in 1985. The trend of scouring appears to be continuing.

Restoration Options.

In the feasibility report for restoration of M.R. Link Canal, the Consultants proposed the following measures:-

	Component	Estimated Cost (M.Rs.)	Implementation Arrangements
-	River Training Works upstream of Marala Barrage;	77.502	ICB / LCB
-	Sediment Exclusion works at Marala Barrage; and	196.761	ICB / LCB
-	Restoration/desilting of MR Link Canal and Sub-Link.	1196.430	ICB
-	Plus physical and price contingencies.		

Optimizing full supply level at head of MR Link. The proposed desilting of M.R. Link involves huge expenditure. Therefore, there is a need to investigate various alternatives to economize the restoration works. The important consideration in this regard is the F.S.L. to be adopted at the head of the Link. The feasibility Consultants have proposed to adopt the following levels for restoration of MR Link.

Link Parameters	Last Designed	Proposed Design
Pond level	R.L. 808/809.5	R.L.812.0
Full supply level	R.L.804.2 ft	R.L.805.6 ft
Full supply Depth	14.2 ft.	15.6 ft.
Bed level	R.L. 790.0	R.L. 790.0
Bed width	345 ft.	344 ft.

The proposed design would require large quantities of silt removal thereby exposing foundations of a number of structures along the channel. The existing pond level at Marala Barrage at R.L.812 ft.

indicates the possibility of raising the F.S.L. of MR Link at its head, consistent with the technical requirements of the working head and environmental concentrations. Previous records show that MR Link has been running with higher water levels than proposed for restoration works. For example, in the recent past, the link has been running with water levels higher than R.L. 808.00 ft at its head. Preliminary calculations indicate that full supply level at the head of M.R Link can be safely increased to R.L. 808.00 ft. This alternative design would substantially reduce the quantity of silt to be removed and need for protecting the structure foundations. This higher F.S.L. may necessitate raising and strengthening of canal banks and raising the decks of a few bridges in the head reach. These costs would, however, be comparatively much lower.

Implement measures for lateral stability: defer desilting. In view of the gradually reducing silt deposits in MR Link under the present favourable silt in-take conditions, yet another alternative design scenario is to defer channel desilting for the time being. The measures for restoring lateral stability may be implemented, especially in the head reach of the canal. With the formation of berms and tightening of channel section, the remaining silt deposits are expected to be picked up from the channel bed and need for desilting may be minimized. The measures for lateral stability need not be very expensive and may be planned according to actual field requirements. The existing channel conditions indicate that some reaches of MR Link are comparatively stable. In these reaches low-cost techniques for berm formations may to be employed. These techniques may include phased development of berms, as well as, use of pilchi spurs and bamboo bushing depending upon the site-specific requirements. In the worst affected reaches, stone protection by means of stone studs, short lengths of stone profiles at regular intervals, or even stone pitching at canal curves may be considered. The final choice of the techniques would depend on the specific site conditions and economic considerations. The comparative costs of these measures are presented below.

Lateral Control Technique	Cost (Million Rs per 1000 Rft)
Stone pitching	4.00
Stone Profiles	1.30
Killa Bushing	0.55
Pilchi spurs	0.35

As indicated above pilchi spurs offer the most economical solution. Technical adequacy of pilchi spurs is also quite well proved. On UCC, pilchi spurs have been employed for controlling excessive side erosion in different reaches and have proved to be effective, as depicted in fig.5. Pilchi spurs may therefore be tried on pilot basis for restoring lateral stability of MR Link.

Optimizing silt exclusion measures. The need for providing tunnel type silt excluder, as recommended by the Feasibility Study, requires to be carefully evaluated in view of the improved and fairly stable sediment in-take into MR Link. Apart from the cost consideration, construction difficulties at site and vulnerability to blockage are possible concerns of the proposed measure. Yet another and probably the most important limitation of the silt excluder is its inability to meet the twin objectives of reducing silt in-take into MR Link while conserving silt entry into UCC. Upper Chenab Canal already being in considerable scour, any further reductions in the sediment in-take may aggravate the situation. In view thereof, it may be advisable to investigate alternative measures for silt control. These may include raising crest of head regulator of MR Link, provision of a skimming platform in front of MR Link head regulator and improved regulation patterns for barrage gate operation. Timely flushing of silt deposits from the left pocket and efficient monitoring of silt intake into MR Link can also prove to be quite helpful in this regard.

River training works. The condition of the river approach in the past few years has remained fairly stable and the confluence of Jammu Tawi and the river chenab is holding. The recent trends, however, suggest that the river chenab has become active as a result of changes in the sediment load and character after the construction of Salal Dam. This may be indicative of possible changes in the river approach which needs to be closely watched. The suggested River Training Works should be re-examined on physical scale models in the light of the changing river behaviour.

Operation & Maintenance.

Need for proper operation and maintenance cannot be over-emphasized. Inadequate monitoring and lack of proper maintenance are considered to be the major reasons for the gradual worsening and deterioration of MR Link. Preventive maintenance, if properly carried out, can play a vital role in reducing the problems and subsequent maintenance needs. If adequate attention had been given to this aspect, the

deterioration had not reached to this extent. Lack of adequate funds for proper maintenance and declining discipline act as the main constraints in achieving the desired standards of maintenance. The present condition of the channel in some reaches suggests that considerable improvements can be affected by proper maintenance without resorting to expensive restoration works.

Role of Funding Agencies in Water Sector Projects.

The Funding Agencies play a pivotal role in the design of development projects and final decision making in the developing countries like Pakistan. The requirements and priorities of the Funding Agencies are normally not consistent with the local needs. The Agencies generally prefer involvement of international consultants and contractors for carrying out feasibility stage investigations, detailed designs and implementation of the project works. This results in manifold increase in project costs, deprivation to the national consultants and professionals from the experience and benefits of large size projects and constrained opportunities for development of the local construction industry. Apart from the above drawbacks, the expatriates do not have the grass root knowledge about the local conditions and problems. This limits the usefulness of the project proposals and also restricts the envisaged benefits. Since the developing countries have resource constraints, therefore, the financiers get a chance to impose terms and conditions suitable to them and manipulate overwhelming control over decision-making.

The MR Link restoration project is no exception to the above conditions. The feasibility study was conducted by a group of consultants led by an international firm at a cost of over Rs. 30 million. Similarly for the detailed engineering designs, the seven Consulting Groups pre-qualified, do not include even a single local consulting firm in the lead role. The detailed engineering designs are estimated to cost over Rs. 125 million. The feasibility stage estimates for implementation of the project, predominantly through international competitive bidding, cost over Rs. 5000 million for the entire project and around Rs. 2200 million for restoration of MR Link alone. The cost estimates indicate excessive rates for the works to be carried out through the international contractors, which appear to be at least twice the highest prevailing rates for similar items of work. There is strong evidence on the basis of preliminary analysis to believe that, if properly planned and efficiently implemented by the local institutions, restoration of MR Link can be substantially completed just with the amount proposed to be spent on the detailed engineering designs.

G. COMMENTS AND RECOMMENDATIONS

The following conclusions can be drawn from this investigation.

1. The main problem of M-R link is the significant reduction in its discharge carrying capacity due to excessive and uncontrolled sediment entry during the early years of operation.

2. The sediment intake has improved and stabilized since the construction of new Marala Barrage in 1968. The previous sediment deposits, however, were not excavated and the channel continued to operate with deformed bed configuration.

3. Deferred maintenance, lack of monitoring and inadequate banks in some vulnerable reaches are identified as the major factors responsible for continuation of the problems in MR link Canal.

4. Since 1988, the condition of MR Link is gradually improving. As a result of favorable river approach and consequent reduction in silt entry into MR Link, sediment deposits in the channel are being scoured.

5. There is a need to carefully analyze the situation in the light of past experiences and prevailing conditions. The proposals for restoring capacity of MR link should be evolved in this context. Considerable improvement may be possible if steps for proper maintenance and monitoring are implemented. State of the Art technology may be used to validate conventional design and to optimize benefits from the investments.

6. Alternative planning proposals need to be carefully evaluated in order to identify and evolve a cost effective restoration plan. Efforts should be made to economize the construction costs by using the low cost techniques. It may be worth while to test the promising alternatives on pilot basis through Action Research before finalizing the improvement strategy.

7. Efforts should be made to utilize the national resources to the maximum possible extent. The use of local experts and construction industry will significantly reduce the Project Costs, without compromising on quality.

8. There is an increasing trend that the Funding Agencies are influencing Water Sector Projects and policies. These influences emerge from the priorities and policies of the donors, which are normally not consistent with the national interests. There is thus over-whelming need to evolve a national policy on the subject with prime focus on self reliance.

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FIG.4. AVERAGE ANNUAL SEDIMENT ENTRY INTO MR-LINK CANAL

PHOTOGRAPHS OF FALL R.D.64357 MUZAFFARGARH CANAL



Fig.1. Abnormal Channel Widening in the Head Reach of MR Link Canal.



Fig.2. A Typical Vulnerable Point Between RD 207 and 209. Site of Previous Overflow/Breach, Which is Closed By a Ring Bund: Constraint in Increasing Discharge Capacity.



Fig.3. Abnormal Bank Erosion Due to Unplanned Sand Mining.



Fig.5. General view of berm formation using pilchi spurs in UCC.