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OPERATION AND MAINTENANCE OF CANALS

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1. INTRODUCTION

A canal is defined as an artificial channel constructed to convey appreciable quantities of water. Canals are used for purposes of irrigation, navigation, bulk transfer of water, the present topic is for the canals which are used for bulk transfer of water as in the case of the link canals in Punjab and for irrigation. The irrigation canals off-take from headworks such as barrages or intake structures of dams. They bifurcate into branches and distributaries, which may be further divided into minors to convey water to the irrigation fields through masonery outlets.

Pakistan like other developing countries, is faced with a major challenges how to increase agriculture production to feed the growing population (at an annual rate of about 3 percent) rather to produce surplus crops for export which has been a foreign exchange earner for the country for many years. Agricultural production can be increased by either expanding the irrigated cropped area or by raising the crop yields. Yet another reliable and economical way to increase irrigated cropped area and yield of crops is to avoid wastages and generate some additional water supplies by better management, and efficient operation and maintenance (O&M) of irrigation canals. Hence, the purpose of this paper which deals with different aspects of operation and maintenance of the canal systems.

2. BACKGROUND

The canal systems in the Indus Basin are the life-line of Pakistan's agriculture in which alongwith Barani areas more than 70% of the population is involved. Without the water supplied by the irrigation canals, most crops would not be grown in sufficient quantities because of low annual precipitation (less than 150 mm) and high evaporation (1250 mm to 2800 mm) over much of the Indus plains.

Pakistan has a gigantic irrigation system covering more than 36,500 miles of canals in Pakistan serving a culturable command area of 34.5 million acres. For this about 101 million acre feet of water are diverted at Barrages and Headworks out of total annual inflow of 152 million acre feet in the Indus Plain. The major concentration of irrigated land is in parts of the Provinces of Sind and Punjab but there are also significant areas in Baluchistan and the Northwest Frontier. The division of water between provinces and between the 43 individual canal systems within the Indus Basin is based on annual and seasonal allocations and substantiated by water

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measurement. There are three dams (reservoirs) situated in the basin to store wet season flows for use in the dry season. There are 19 barrages located on the Indus River and its main tributries with 12 link canals that control the individual canal systems. Travel time of water destined for the extremes of the basin can take weeks from the time it is released from the reservoirs until it finally reaches the individual farmer. The rainy season extends primarily from mid-April to mid-October. Excess run-off is stored in Tarbela and Mangla Dams until they are filled. Therefore, flows in the Indus River and its tributories generally do not exceed the normal irrigation demands except in a 3 month period, July to October.

Gross commanded area in Punjab alone is nearly 24 million acres. The canals are perennial that is they run through-out the year except for short periods of closure for two to four weeks during low demand. low supply period that is December to January.. Such closures are required also to carry out repairs to structures etc that cannot be done when the canals are flowing.

During the summer season called Kharif supply the canals convey more water (even double) than during the winter season called Rabi supply. The total culturable commanded area in Punjab is 21 million acres out of which about 13 million acres get perennial supply. Some of the canals are non-perennial that is they flow during summer only when the rivers are in high flow. They serve a culturable commanded area of about 8 million acres. The total designed discharge capacity of canals is over 150,000 cubic feet per second. The total length of canals in the system is about 23000 miles. This indicates the vastness and complicity of the system and the effort required to maintain this old and intricate network.

There has been a continuous increase in the reported irrigated area over the years. For example in Punjab, irrigated acreages increased form 10.30 million acres in 1947 to 24.4 million acres in 1986. Canals are operated with minimum freeboard so it is difficult to increase their capacities still further during the Kharif season.

3. IRRIGATION WATER SUPPLY OBJECTIVES

Irrigation supply objectives can be examined from different perspectives : the farmer, the authority responsible for system operation and the country,s economy.

The farmer's first concern is to produce enough food for subsistence or to maximize his income. The ideal mode of water delivery from his view point is delivery as per his requirement with time, quantity and quality.

The objectives of the authority responsible for the system operation may be in conflict with the individual farmer's interest. These may includes equitable water allocation and distribution rules, simplicity of operation and efficient distribution where and when water is scarce. When water resources are limited, the authority must restrain individuals from competing for their own self-interest which may require the enforcement of regulations governing water distribution.

From the point of view of country's economic objectives, an irrigation system may be intended to increase food and fiber production to generate employment and/or foreign exchange and/or to help alleviate rural poverty. These objectives are achieved by adopting a policy of extensive irrigation by spreading water to benefit as many farmers as possible, as opposed to intensive irrigation. Adoption of extensive irrigation puts considerable impact on the rules of water distribution and system designs as well. Apart from the economic objectives, it is also important to sustain long term irrigation performance without negative environmental effects such as salinistion, water logging or water related diseases.

All of these objectives are rarely compatible. Thus local conditions and comparative preferences are the controlling factors of irrigation supply, performance and operation of facilities.

4. FACTORS EFFECTING THE IRRIGATION SUPPLY SYSTEM

The Irrigation supply objective and the subsequent operation depends on a variety of factors. Not all of these factors are of equal importance in the process some have more impact in the field application of irrigation water and others in the design and operation of the conveyance and distribution system. Main physical and other factors are discussed below :

(i) Physical Factors

The first and most critical factor is the water availability. If the water supply to the system is variable and unpredictable, the only practical objective to set could be equitable distribution. This is the case of run-of-river system especially those using headwaters where run-off closely follows rainfall variations. On the other hand, in the case of systems with fully regulated supply, all the desirable objectives of irrigation equity, reliability, timeliness, efficiency and flexibility can be considered.

A second physical factor to consider is climate and rainfall pattern. The variability and unpredictability of rainfall require flexibility in system operation to achieve efficiency.

Soil-plant-water relationship is another factor. The water and variety of soils may influence decisions of irrigation supply and operation. The crops, their stage of growth and climatic factors besides soils together with other requirements for farming practices and economic considerations determine which method of irrigation to use.

Topography is also factor which effects the design and operational choices of irrigation canals. The quality of water and especially silt content is another important factor in canal system design and operation. Heavy silt content may increase maintenance costs considerably if canals are operated under variable flow conditions.

This aspect is one of the crucial decision factors in selecting the "On-Off" operating mode for run-of-river system.

(ii) **Non-Physical Factors**

An important consideration for the operating authority and ultimately for the farmers, is the cost of operation of irrigation facilities. Number of staff required, good transmission and/or communication net-work and transportation equipments, etc. to operate efficiently and equitably and irrigation system varies with its characteristics.

Another factor is the quality and capability of organization responsible for operation and maintenance of irrigation system. The ability/skills of the ploicy-setting bodies and operating personnel, together with methods for accomplishing their responsibilities as well as their tenures of offices effect the operational efficiencies of any irrigation system. Other factors include the socio-political aspects which effect the operational performance of an irrigation system.

5. IMPORTANCE OF OPERATION AND MAINTENANCE OF SYSTEM.

No matter how well constructed, an irrigation system fulfills its intended function only when properly operated and maintained. Effective maintenance is an essential element of good operation.

Once an irrigation system is working, its operation and maintenance play a critical role in determining the growth of agriculture. Inefficient O&M develops negative consequences of poor performance of irrigation system which include :

(i) Below capacity working and/or erratic water supplies which in turn lower the area cultivated and depress yields.

(ii) A tendency to grow lower value crops.

(iii) Lower investment in yield-enhancing inputs such as fertilizer.

(iv) Reduced on-farm investments.

(v) Wastage and losses of water which may result in salinisation/water logging.

(vi) Higher rehabilitation investments and shifting of capital from other important sectors of country's economy.

Operation and maintenance include the management of water supplies and up-keep of system facilities from the water source to the farmers fields. Operation means the allocation and delivery of water supplies often over long distances and handling the drainage run-off. The organization/staff necessary to accomplish the work and its responsibility, operating practices and procedures for the handling, movements,

disposal of water, and the value of keeping accurate records and communications in these operations. Maintenance is the up-keep of irrigation structures, channel banks, outlets and the removal of silt and vegetation from canals.

The operation of an irrigation system normally requires detailed knowledge of crop water requirements bacause water is usually delivered to meet peak irrigation demands. In Pakistan this is not generally the case; the canals are required todeliver a fixed supply of water, varying with seasons, to each distributary and minor canal. The design of each system was based on an equitable suply to be delivered to each watercourse; this meant a uniform cropping intensity with a fixed water duty rate. The intensities vary considerably between systems but all were well below 100 percent. Over a period of time enhanced requirements of agricultural produce has allowed the intensities increase to/but lax operations have allowed such increases towards the head end of the canals. The average inflow to a system has also been increased in many cases over the period of time since the project was first implemented. Thus changes have been made since the first projects were constructed about 140 years ago.

The systems were designed to be operated with minimum of water control, a limited communication and transportation net-work, case of operation and low construction cost. It operates on contiguous flow system with uncontrolled outlets but having precise dimensions and cill levels to provide equitable (proportional) delivery through-out the canal systems. The concept equitable distribution' was evolved at the vary outset of irrigation canal designs and execution around the middle of last century when the first canals in the region were constructed.

6. CANAL IRRIGATION PERFORMANCE IN PAKISTAN

As already mentioned that canal irrigation developed in Pakistan under specific social, economic, climatic and unreliable and limited surfacr water resources. Run-off-river basis operation of canals to command large tracts with limited designed cropping intensities restrained the system to operate on equitable distribution of available water. With construcation of Chashma, Mangla and Tarbela reservoirs along with link canal, now the system is the largest contiguous gravity irrigation system in the World. It is beyond doubt that the system fulfilled the primary objectives of its functions. But with the concept of ideal (On-demand) delivery system, it can be said that our system failed to provide water to crops at the right time, and in sufficient quantities. Further inefficient utilization of available water and overall scarcity of water are other elements of system deficiency. Thus it can be said that the performance of the Pakistan irrigation system remained lacking behind with respect to operational efficiencies. Inefficient O&M is main cause of low efficiancies and high distributional inequities. Thus many of the negative consequences of in-efficient O&M are already in evidence. The ability to carry out meintenance is inhibited. to a major degree, by financial constraints. Thus the continuous deferred manitenance is rapidly deteriorating the irrigation infrastructure. Technical issues of O&M activities are also important to attain better O&M efficiencies. Traditional operation and

maintenance practice is another factor of low efficiencies of the system. With facilities available to the system the maximum achieveable overall efficiencies of the system can be 40% as per modern standards against present about 30%. Thus 10% improvement in overall efficiency is possible with better O&M, provided improvement in technical capability and financial resources are ensured.

7. OPERATIONAL AND MAINTENANCE DEFICIENCIES OF PAKISTAN CANAL SYSTEMS

The short comings in the O&M activities of canal system can be listed as under :

(i) The primary problem in alluvial canal systems in Pakistan is that the sanctioned flow does not reach the tailend outlets of distributaries and minors. Some of the reasons why water does not reach the tailend water courses are :-

a. Over drawal of outlets upstream.
b. Inaccurate seepage loss estimates.
c. Inaccurate inflow estimates.
d. Sedimentation and resulting change in water surface levels.
e. Improperly set outlets/or faulty design of outlets.
f. System changes since what was designed or constructed.
g. Limited desilting.
h. Un-coordinated re-establishment of equitable distribution.
i. In-efficient management.
j. Sociopolitical pressures.

(ii) Absence of sufficient standared water measurement devices to ensure accurate distribution of water as planned.

(iii) Scheduling and delivering water in canals in isolation of crop demands which tends to wastage, excessive losses, over-irrigation or under-irrigation. These result in low crop yields, salinization and water logging besides wastage of water.

(iv) Inefficiency of management results in unreliable and inequitable distribution fo water among distributaries and outlets. Further operation of canals either excess of designed discharge or below capacity resulting creation of problems in geometary of canal sections.

(v) Poor communication and Transportation systems which can totally fail during emergency (storms, rainfalls etc).

(vi) Handling the system specially operation & regulation by illiterate or semi-skilled persons.

(vii) Minimal participation of the farmers or their viewpoint in all operation activities of canal systems.

(viii) Inadequate performance and maintenance standards.

(ix) Frequent breaches of canals and interruptions in water supply, particularly at distributaries and minors levels due to inadequate maintenance, or by farmers.

(x) Insufficient or not-well defined procedures of monitoring, evaluation and accountability at all level of management.

(xi) Administration is lacking in preparation of operational and maintenance plans and their implimentation.

8. IMPROVED CANAL OPERATIONS

Operational standards must be established and adhered to so as to ensure continued operation of the individual canal systems in their as-built conditions.

The main characteristics of well operated canal system can be enumerated in their order of importance :

* Reliability (arrival of water according to schedule).
* Timely supply (meets irrigation requirements).
* Equitable distribution (among canals, distributaries and outlets along a distributory), as applied in Pakistan.
* Efficient supply (minimization of canal losses and wastage in regulation).
* Accountability, discipline and enforcement.
* Maintain canal standards (adequate budget and professioal staff).
* Minimum involvement of system administration combined with maximum coordination with farmers.

A well operated irrigation system should aim at the achievement of most, if not all, of these characteristics within the constraints imposed on the system by Government policies, topography and the physical facilities provided during initial construction. Improvements/betterments are made to alleviate or eliminate physical constraints but without funds allocation constraints.

a. Improved Canal Operation

Improved canal operation include development and practices of improved mangement practices, programmes, controls and monitoring/evaluation systems that will allow the various irrigation canals and sub-systems to meet their primary objectives. Operations consisted of what are considered today the six basic management

procedures namely :

(i) **Scheduling.** Scheduling is a synonym for planning. It involves the determination of how much, when and where water should be delivered. As such, it involves the determination of crop water requirements and then irrigation demands, sehedules the irrigation demands on a weekly basis for ease in rotation forecasts water availability, prepares alternative options and re-examines and adjusts the schedule periodically.

(ii) **Delivery.** Delivery involves the physcial distribution of water to each watercourse in the system. It is the hour-to-hour and day-to-day movement of water through out the conveyance system. The scheduled demand must be balanced against the actual flow available. The available water is then allocated according to predetermined criteria. This process is repeated downstream at all cross regulators or divisions of flow. Various delivery strategies are used to allocate and move the water through the system.

(iii) **Monitoring.** Monitoring is essentially record keeping and the processing of collected information or data into a form that the canal officers can use to evaluate the operation of the system. Discharge and water surface elevations are the two main mearsurements recorded. Discharge records are used to determine and show accountablility hence equity. Water surfacr elevations are also used to determine equitablity as well as changes in system operation, primarily sedimentation.

(iv) **Accountability.** Accountability is providing both management and the farmers with the knowledge of how well the water is being distributed and who is getting what; i.e. making or keeping a water balance. The posting of delivery records, calibration records, the Patwaris field measurements, informing people of what is happening. Accountability is vital to safeguard farmer's rights.

(v) **Evaulation.** Evaluation is the comparison of records over a long period of time to detect changing conditions. The actual records accountability. The results of system performance are compared with the objectives, Changes and improvements are difined and recommended.

(vi) **Adjustment.** Adjustment is making the recommended chages in the operating procedures as well as adding improvement to the system. Converting stoplog control to gate control or resetting outlets are forms of improvements. Desilting would be the most common change. Small changes in allocations to meet measured seepage losses is one change that would concern delivery based on evaluation of records. Improvements or chage must be made to meet the ever changing needs of the farmers.

In Pakistan Irrigation System,scheduling was essentially, built into the design capacity when-ever possible during the Kharif season 15 April to 15 October. The Rabi season demand was fied at some percentage of the Kharif demand while the nonperennial canals were left dry.

Since there were no storage dams of consequence, all barrages operated on a run-of-river basis according to the distribution percentage assigned. Run-of river operation was and still is under the ancient adage; use it or lose it. Today the two major reservoirs Tarbela and Mangla have greatly altered flow conditions. Even now there are times the old adage can still be applied even though reservoir releases are controlled, allowing the flow in the Indus and Jhelum Rivers to be controlled for roughly 9 months each year. Diversion at the barrage divides the available flow on a relatively equitable basis. Outside pressures are often exerted but still their influence is not damaging on the division of water at the control structures. The final test of any irrigation system is at the tail cluster. If the watercourses located at the tailends of a system receive their allocated/sanctioned flow the system is well operated.

Monitoring, accountability, evaluation and adjustment represent procedures such as water measurement, H-Registers, control point monitoring, discharge records, current meter calibrations and occasional structural changfes or additions. These procedures were not always defined in detail in the existing irrigation manuals but they are all there and the canal officers have to operate and maintain. These procedures must be developed for establishing a water balance in a canal of system. Fruther accurate water measurements methods should be adopted at all canals, distributaries and minors headworks. Stage-discharge relations established all regulation points of canal needs timely adjustments. Accurate data observation and preparation of reports should be based on factual position and supervisory personnel must review all reports and data being forwarded from an office.

9. IMPROVED CANAL MAINTENANCE

Maintenance activity begins the day the system is placed in operation. Canal maintenance signifies the upkeep and surveillance with the objectives of keeping the system in a top operating condition at the lowest possible maintenance cost and aim at its longest life and greatest use. It should also take care of the increased wear and tear especially in those canals which are part of very old systems. According to the Canal Act, canal includes the channels conveying water, banks, inspection roads, spoil banks, outlets, headworks, head regulators, cross-regulators, syphons and all structures as well as railway sidings and plantation in the lands that are earmarked for the canals and are in possesion in the department concerned. Canal failures are usually due to inadequate operation or maintenance procedures. The principle causes of failure are :-

Inadequate freeboard, or freeboard deterioration due to other causes including animal tresspass.

- Improper operation of water control facilities.
- Farmers tempering with cutlets (unauthorized closures).
- Failure to maintain canal capacity (siltation).
- Actions of borrowing animals (Rodent holes).
- Inadequate inspection and follow up supervision.
- Lack of timely repairs and preventive maintenance.
- Piping and/or inadequate coverage of phreatic surface (hydraulic gradient).

The general measures that must be considered in canal and embankment maintenance are :

- Trash removal and weed control.
- Inspection and monitoring.
- Canal safety (freeboard and embankment section).
- Hydraulic characteristics (Capacity and water surface elevation).
- Patrol road and miscellaneous items.

a. Maintenance Standards

For efficient maintenance different parameters must be standarized which should represent minimum works required to be carried out periodically.

The following maintenance standards will ensure the safe operation of canal :

The canal system facilities requiring annual maintenance are the channel embankments, bed levels and structures. The work items required are repair of the inspection road on the embankment crest. Maintenance of channel bed levels requires removal of deposited sediment and maintenance of structures requires painting of metal surfaces and repair of upstream banks and downstream stilling basins. The maintenance standard as recently updated and recommended are as

follows :-

Facility	Maintenance Standard
Embankment Inspection Road	1. Replace 5 inches of material along 20% of total length each year.
	2. Grade road surface 6 times per year.
	3. Prohibit public access to non paved inspection roads (the Highway Department must provide alternate roads or take over maintenance).
Embankment Slope, Outside (includes 4 feet of road shoulders).	1. Replace 5 inches of material along 20% of total length.
	2. Repair 400 rain cuts per mile on main or branch canals and 200 per mile on distributaries and minors.
	3. Remove all trees and brush, establish turfing where feasible and control weed growth to facilitate inspection of seepage on outside slopes.
Embankment Slope, Inside.	1. Provide 50 feet of killa bushing per mile per year to correct and prevent erosion where necessary for canals above 200 cfs.
	2. Maintain existing turf on inside slopes above water surface.
	3. Cut weeds as necessry to allow visual inspection of canal prism.
	4. Remove all trees and brush.
Bed Level Control	1. Remove an average of 6 inches of silt annually from 30% of the lenght of distributries and minors with dischages up to 200 cfs.
	2. Establish monitoring stations at downstream locations to ensure cross-section and sediment concentrations remain within Limits.
	3. Initally the sediment removed directly from the canal will be placed along the toe of the canal. An evaluation of the potential problems of purchasing sediment storage areas will be made when more exact amounts and locations are determined.

Structures	1. Inspect alll gates, gate hosts and steel accessories annually and repaint, repair or replace as needed during the canal closure period. A miscellaneous cost is included for this work. 2. Provide 50 feet of killa bushing and 25 feet of brick pitching in stilling basins downstream of water structures.
Lined Canals	1. Replace 1% of total area each year.

b. **Performance Standards**

Performance standards refer to thresholds of performance cosidered acceptable, tolerable, or unacceptable. The following performance stadards of various parameters are suggested :

(i) **Freeboard.** The freeboard (FB) is never allowed to erode or be worn off more than 5 inches. The freeboard must be replaced as soon as the minimum freehoard is reached at any point on the canal embankment.

(ii) **Capacity.** The canal capacity must never be allowed to become less than the design capacity.

(iii) **Maximum.** The maximum discharge allowed in the canal is 1.2 times the design discharge at full supply level (FSL). The duration of a dischage greater than the design discharge cannot exceed two weeks under any circumstances.

(iv) **Maximum Water Level.** The maximum water level can never be allowed to exceed one half the design freeboard under any circumstances. This standard fixes the siltation standard.

(v) **Siltation :** Silt accumulation in a distributary or minor is not allowed to exceed 9 inches. When 6 inches of sediment is observed or measured above the design bed level of the canal desilting must be programed for the next closure period.

(vi) **Canal Width** : The average width of a canal will be allowed to vary between the design width and 1.1 times the design width without concern. No canal will be allowed to become narrower than the design width. A canal will not be allowed to widen beyond 1.2 times the design width. The bottom width is the critical dimension. The average top width is used to judge the condition of the canal. Minor scalloping due to animal ingress and egress, is not considered in evaluating the canal width as it does not effect hydraulic performance.

10. CANAL STRUCTURES MAINTENANCE

Maintenance of canal structures are very important for safe operation of canal and distribution/regulation of flow in the system. These strucutres includes head Regulators of canals, cross regulators, bridges, falls, outlets and tail clusters etc. Canal structures seldom fail except for piping failures or miss operations of cross regulators is sometime the cause of failure. The level of maintenance on canal structures decreases from the main head and cross regulators in the downstream direction. Additional emphasis is required on preventive maintenance of the water control structures within the system on the smaller canals.

The maintenance programme for canal strucutres are primarily carried out annually during closure ofcanals, although some work may be accomplished on a seasonal or periodic basis; particularly bridges and non-water control structures.

The perofrmance standard for structural maintenance may includes the following :-

1. All water control structures must meet the conditions specified on the as-built drawings and/or as modified by subsequent authorized change orders and marked appropriately on the drawings. Design drawings can be substituted for as-built drawings but should be field verified and all important deviations so marked.

2. All structures must be maintained in good condition with no loose or missing brick/rocks, open cracks or other defects. Deferred repairs cannot exceed one year.

3. All gates must be fully operational throughout normal range of operation. Gates will be exercised annually.

4. All cross regulators are required to have a full set of stoplogs at the site at all times.

5. All mechanical equipment and miscellaneous metal work must be protected against corrsion.

6. All mecahnical equipment must be lubricated in accordance with manufacturer's instructions or as otherwise specified.

7. All safety devices must be in place and in proper working condition. Bridge railings are a safety device.

8. Gate seals must be in place and complete. Leakage around seals should be minimal and not through the seal.

9. Downsteam areas of all water control structures and bridges must be protected from scour; both bank erosion and bed scour by eccepted maintenance procedures. Riprap being the most convenient.

10. All structures and facilities used for water measurement must have available on file the complete calibration establishing the stage-discharge relation. In addition, the annual re-calibration check should be made to verify the stability of the stage-discharge relation and filed.

11. The staff guages located at each water measuring station or facility must be in a readable condition at all times.

12. Structures must be kept free of floating trash.

13. Canal freeboard standards must be maintained at all structures.

11. HYDRAULIC SECTION IMPROVEMENT

Operation and maintenance of the canals is related to the performance of hydraulic section of the canal, as sedimentation or scouring of the canal is the main hinderance in its performance. Sometimes this factor becomes crucial in equitable delivery of water in a canal, specially in tail reaches of the distributaries and in minors. The improved operation and maintenance aspects discussed in section 8 and 9 depend upon the hydraulic behaviour of canal. Thus if the canals are lined upto distributary level at least the performance of the O&M of the channels will greatly improve. The permanent section of the canal will remove a number of O&M constratints specially unreliability and inequity of supplies.

The lining of canals will provide the following benefits :-

(i) Command to outlets will be improved.
(ii) Irrigation supplies to farmers will be assured.
(iii) Conveyance losses will be considerably reduced.
(iv) In-equalities in irrigation supplies to farmers will be eliminated specially at tail outlets.
(v) Intensity of irrigation will be increased by utilizing the saving of canal water.
(vi) Yield of the crops will be increased by reliable supply.
(vii) Operation and maintenance of distributaries will be reduced and efficeincy of the department will considerably improve.

The above mentioned benefits have already been experienced by the Department from the performance of a few lined canals below 30 cusecs discharge in Command Water Management Project which are under implementation. The total length of all type of canals in Punjab is about 22809 miles. Over half of this constitute distributaries and minors. The distribution system of a canal system in Pakistan,

consists of distributaries and minors which off-take from main canal and branch canals. Due to major capital costs involved, this task can be carried out over long term and taken up in phases, starting from tail reaches of distributaries of under 30 cusecs discharge and minor canals. After completion of all the canals under 30 cusecs, the next phase of canals above 30 cusecs and below 50 cusecs can be taken up. The third phase shall then be for canals form 50 cusecs to 80 cusecs and the fourth phase from 80 cusecs to 100 cusecs. Although the benefits shall accrue only after completion of lining, the phased development is proposed keeping in view the enormity of the task and the high capital costs.

12. CONCLUDING REMARKS

The main issues of operation are that while water is supplied at the right time according to equitable or on-demand basis distribution to every nook and corner of the irrigated area, there are no breaches or mishaps due to over-suply and also that wastages of water are minimized. This also includes handling of drainage run-off. The first step of the operation of the system is the regulation of flows into main canals from the rivers/supply sources. This is carried out on a central basis from the headquarters based on the damand of various canal divisions and sub-dividion on the canal and link systems in the area. The local distribution of water and the operation of regulators and bifurcation structures as well as any ascapages is done by the dividional and other staff on pre-determined requirements. The requirments are determined on accepted usages keeping in view the maximum capacity of the canals, the minimum dischages on which a system can work efficiently from a hydraulic point of view as well as the physical condition of the canals such as any breaches or carrying out of emergency works. Appreciable rainfall in the area also effects the requirements and the indent for the supply of a particular dischage has to be adjusted by the local officers. It is evident therefore that each regulator and its gates, vertical needles or karris arrangements has to be checked twice a day and adjustments made where necessary.

The Irrigation Department's work is therefor labour intensive and of high responsibilities. In advanced countries canal operations including regulation and distribution of water have been modernized so that the entire work is done through computers which are used in seriding messages to the regulation points (gated structures) by other cable or radio. The systems on which computer has been introduced so far are however compact and smaller in areas. For example while Punjab irrigates 20.56 million acres through a single entity, in Califorina State of U.S.A water is delivered to less than half the area i.e 9.39 million acres through decentralized network comprising of 244 water districts. Computerizing the entire system will therefore be complicated and have not been thought of in the Punjab irrigation system. It will also be highly expensive especially because the individual canal systems in Punjab are compact but long and comparatively narrow in width due to nature of Doabas. For example main canals like Pakpattan and L.B.D.C. are each over 125 miles long. It is also not felt necessry to computerize it because the operation including all aspects of regulation and distribution are looked after by the

same engineering staff who are responsible for maintenance, repairs and construction, administration and revenue asessment etc. For this purpose one engineer supported by appropriate staff is responsible for a commanded area of about 26000 acrea in Punjab. This is thus an efficient and economical system of operation as compared to anywhere in the World.

Further although due to the large size of the system and farflung areas the difficulties of operation are many and constant vigilance and devotion is required by the officerrs/staff employed on the job, the equitable distribution is still more workable from an opoerational point of view then the on demand system.

Keeping maintenance work current on all facialities in a system is the keystone of any successful irrigation system. Routine and preventive maintenance not only pays dividends in the form of economical operation and a smooth working system, but also means on uninterrupted delivery of water. Deferred maintenance may serve in the beginning when things are new and working well, but the deterioration curve tends to be geometric which means that as time goes on into the future the problems multiply very rapidly to the point where massive amount of repairs are required. Due to deferred maintenance of irrigation canals, operational efficiencey can decrease to such level that it can be difficult even to sustanin current agriculture rather to improve it. thus the government of Pakistan has attempted to improve the performance of the irrigation system by implementing a series of irrigation development programmes. Hoewever, the system is still confronted with the twin problems of low operational efficiencies and high distributional inequities.

The importance of lining of distribution system i.e. distributaries and minor canals has already been deiscussed. Besides improvement in Operatin & Maintenance, over all benefit to agriculture production due to reliable supply further support to idea to 'line' the distribution system. However, due to high initial capital investment, the lining of small canals and tail reaches has been proposed as first step.

Besides technical aspect of O&M, financial constraints remain the dominent factor of deferred maintenance for sometime in past. Over the years the maintenance cost have increased many fold and very often the department does not have enough annual funds to maintain the systems according to specifications and requirements.

The constant increasing demand for irrigation water, underscores the need to reform such economic policies that tend to result in alocation of less funds for O&M activities. However since O&M of large irrigation system, is an expensive activity, it is important to ascertain the social productivity of such investments.

For efficient O&M of irrigation system, increased O&M investments are important. Increased O&M spending in canals would result in less frequent canal breaches, savings of water losses and capability to pass enhanced discharges whereever and whenever prequred. The net result will be the availability of higher and more reliable supplies resulting in increase of agricultural production.

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