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LINED CHANNELS – A REVIEW WITH PARTICULAR REFERENCE TO THEIR APPLICATION IN PAKISTAN

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Lining is simply a protective covering of impermeable material mainly used to prevent the seepage but in some cases it is also used to improve the command by flattening the bed slopes of a channel in flat country or to cut down the cost of excavation through hard strata in uneven country. By lining a canal, its discharge capacity can be almost doubled as the coefficient of friction is reduced, or conversely, the cross-section of a lined channel can be only half as large as that of unlined canal. Since the section is considerably reduced there is a saving in land acquisition also. Lining also lowers the maintenance cost, stops pilfering of water and prevents water absorbing salts where passing-through Kalarish tracts. In hilly areas, the linings may permit full utilization of the available slopes reducing the sections further and avoiding the cost on the provisions of the falls required in the unlined channels. For controlling water logging and salinity also, the lining should receive careful consideration.

An ideal canal lining would be watertight, be moderate in cost, prevent the growth of weeds, resist the attack of burrowing animals, be strong and durable, be adaptable to the construction of a shape and finish providing maximum hydraulic efficiency, and have a reasonable amount of flexibility. No canal lining material, now in use, possesses all of these characteristics, but each possesses most of them to a greater or lesser degree. The need for lining canals is now generally recognized and interest in lining is developing rapidly.

Seepage Losses. In unlined canals, the loss due to absorption (or seepage) through the bed and sides is much more than that due to evaporation from water surface. In alluvial soils, these combined losses are allowed for at the rate of 8–10 cusecs/10^5 ft^2 of the wetted surface area. In clayey canals, the losses may be of the order of 5 cusecs/ 10^5 ft^2. Lining reduces these losses to less than 1/10 cusec. Seepage accounts for the greater portion of conveyance losses in canals, except in a few cases where water is abundant and operation waste is high. Conveyance losses are primarily from seepage, headgate losses and operation wastes. Losses vary widely, but on the average canal they range from a third to a half of all the water diverted for irrigation purposes. Some recent research indicates that losses in water course alone may be as high as 40%. Extensive experimentation is in progress and at present about 25% of the water entering unlined canals and laterals is assumed to be the seepage loss before it reaches the farmer's field.

The amount and character of seepage losses are governed largely by the character of the subgrade material. The conveyance or transit loss due to seepage in various soils are reported in Table 1. Seepage losses can be reduced to some extent by proper alignment, design, construction and maintenance of the channels. Canals excavated through material containing fractured rock and broken shale strata or through material which is underlain with fractured material are subject to high conveyance losses. Under certain conditions, heavy losses take place through clay material left by decaying roots. Storage reservoirs's and irrigation systems must have thus greater capacities, and consequently cost more, to provide for the water lost. In the Handbook of Applied Hydraulics by Davis, it has been reported that the cement-concrete-lined canal costs nearly three times as much as the unlined canal on the basis of construction alone but the value of the seepage lost reverses the ratio. Unlined canals thus in porous soils are seldom economically justified.

While some of the water that seeps from a canal may be recaptured by canals and ditches that are lower in elevation, nearly all of it is usually lost to the irrigator. Also, the seeped water frequently collects in lower lands, making them unproductive or necessitating expensive drainage systems. A carefully laid concrete lining 3-in thick or more reduces the loss/ft^2/day to perhaps 0.04 ft^3. Some mortar

Table 1. Conveyance or transit loss (ft^3/ft^2) of the wetted perimeter) in 24 hr for canal not affected by the rise of ground water.

Classification of soil	Seepage loss (ft^3/ft^2) of the wetted surface) in 24 hr r
Impervious clay loam	0.25 – 0.35
Ordinary clay loam	0.50 – 0.75
Sandy loam	1.00 – 1.50
Loose sandy soils	1.50 – 1.75
Gravelly sandy soils	2.00 – 2.50
Porous gravelly soils	2.50 – 3.00
Very gravelly soils	3.00 – 6.00

Table 2. Permissible velocities (ft/sec) after aging of canals.

Original material excavated for canal	Canals carrying water		
	Clear	With colloidal silts	With non-colloidal silts, sands, gravels or rock fragments
Fine sand (noncolloidal)	1.50	2.50	1.50
Sandy loam (noncolloidal)	1.75	2.50	2.00
Silt loam (noncolloidal)	2.00	3.00	2.00
Alluvial silts (noncolloidal)	2.00	3.50	2.00
Volcanic ash	2.50	3.50	2.00
Ordinary firm loam	2.50	3.50	2.25
Fine gravel	2.50	5.00	3.75
Stiff clay (very colloidal)	3.75	5.00	3.00
Alluvial silts (colloidal)	3.75	5.00	3.00
Coarse gravel (noncolloidal)	4.00	6.00	6.50
Shingles	5.00	5.50	6.50
Shales	6.00	6.00	5.00

linings in small canals have served for more than 60 years. Cement mortar 1-in thick lining, carefully laid, reduces the seepage loss to about 0.20 ft^3/ft^2 of the wetted perimeter in 24 hr. In a deep and narrow channel, the deposit of silt will be heavy but at the same time the absorption losses will be greater in porous soils.

The Indus Basin is irrigated by a network of 48 principal perennial and nonperennial canal systems, delivering about 94 MAF of water at the canal heads (excluding about 9.3 MAF of Terbela water), and commands nearly 34.5 MA of culturable area. The irrigated plains of Indus Basin are underalin by an extensive ground-water aquifer. The total recharge to the aquifer has been estimated between 40–60 MAF from rivers, irrigation and rain water. Obviously, the contribution of seepage is significant.

Erosion. Erosion an unlined channel can be avoided by

Table 3. The effect of hydraulic mean radius and bed material on the scouring velocities of a channel.

Material of channel bed	There is no scour until a mean velocity is reached of	
	R(ft) (hydraulic mean radius)	Velocity (ft/sec)
Fine silt	1.00	0.40
	2.50	0.70
	5.00	0.90
	10.00	1.50
Heavy silt and fine sand	1.00	0.90
	2.50	1.50
	5.00	1.75
	10.00	2.25
Coarse sand	1.00	1.75
	2.50	2.25
	5.00	3.00
	10.00	3.50
Small pebbles	1.00	2.25
	2.50	3.00
	5.00	3.50
	10.00	4.50
Large pebbles and coarse sand	1.00	5.00
	2.50	6.00
	5.00	7.00
	10.00	9.00
Large stones	1.00	15.00
	10.00	23.00

having low velocities which require costly large sections encouraging the growth of aquatic plants. In addition, this increases seepage, evaporation and silt clearing expense. Deposit of silt increases resistance to erosion. The erosion is also decreased by the silt in suspension. Thus a canal that will scour at one season may silt at another. Table 2 gives the permissible velocities in canals carrying water clear, with colloidal silts and with noncolloidal silts, sands, gravels or rock fragments.For safe design,maximum velocity should be taken from this table and Kennedy's formula adopted for calculating the minimum velocity in the channels.

The combined effect of the bed material and the hydraulic mean radius has been given in Table 3. Velocities above 40 ft/sec for clear water in concrete channels have been found to do no harm. In the waters with abrasive materials, unless bad in this respect, velocities up to10–12/ ft/sec should not prove injurious to wood or first class concrete. Galvanizing may be damaged by coarse sand or gravel at less than 6–8 ft/sec. Table 4 indicates the relation between the mean velocities which will not erode and the material of channel bed after aging in shallow ditches and

Table 4. Mean velocities which will not erode after aging of the channels. (Am. Soc. Eng., (1926)

Material of channel bed	Velocities (ft/sec)	
	shallow ditch	deep canal
Fine sand or silt	0.50–1.50	1.50–2.50
Clayey loam or sandy clay	1.50–2.00	2.25–3.50
Well graded gravel	2.25–3.50	4.00–6.00
Stone masonry	7.50–15.00	- -
Concrete or solid rock	15.00–25.00	- -

deep canals.

Deep narrow sections are more efficient but may require lining to prevent erosion. It is considered advisable to maintain a constant velocity throughout the length of an irrigation channel so that the suspended silts may be carried to the fields. For a nonsilting channel, critical velocity ratio (i.e. mean velocity/critical velocity) should be 1 or a little more at the head or head reach, and about 0.8 towards the tail. In case of a power channel, suspended matter should be removed, as far as possible, to prevent injurious abrasive effects on the turbines.

Water Logging and Salinity. In the Indus Valley, water logging and salinity became noticeable as early as 1892 in Rachna Doab within a few years of commissioning lower Chenab Canal. During the period from 1945 to 1963 [1], the average annual rate of reclamation did not go beyond 30,000 acres as against an annual loss of land of the order of about one lac acres. Severe damage has been reported to be increasing at a rate from 0.2 to 0.4% of the irrigated area per year due to water logging and salinity. The Revelle Report states that the area of canal irrigated and cultivated land already damaged seriously by these is close to 5 MA in the Indus Plain. The latest survey reveals that nealy 12.8 MA of land is strongly saline and the survey of 1975 indicates that about 17 MA are underlain by the water-table within 10 ft. depth. To maintain the water-table between 10–15 ft depth, the Fifth Plan envisages the addition of about 40,500 tubewells in the private sector which shall provide an increase of about 5.87 MAF also. Similarly about 6,100 tubewells would be added during this period in public sector providing an increase of 3.58 MAF. The Plan also specifies the following major issues relating to the ground water development schemes: (a) During 1970–76, the installation of new tubewells slowed down from 9000 to 6000/annum, though replacement was also about 6000/annum. The subsidy scheme has made some progress and would be continued. (b) For small farmers, suitable credit arrangements would also be necessary. Cooperative water associations should be encouraged. (c) Since electrification cannot be expanded, the encouragement to diesel tubewells should continue. (d) The installation of tubewells needs to be restricted in the areas where water table has dropped much faster than anticipated. (e) It would be necessary either to develop capability for manufacturing flexible tubewell pipes or to encourage fractional tubewells operated by transportable pumping units to meet the conditions in the reverain areas.

In addition, the following areas [2] have also been pointed out for improvement: (i) Despite the corrosive nature of the aquifer, the mild steel pipe strainers were imported. Later, shift to fibre-glass strainers was also not properly planned. (ii) The frequent electrical and mechanical breakdowns, long delays in carrying out major repairs, late replacement of damaged wells, power shut-downs and behaviour of tubewell operators. (iii) The farmers fought for the levy of the enhanced water rates in court. More and more farmers are now opting to discontinue the use of public tubewells. Already about 250 deep wells have been closed and more will have to be closed down soon. (iv) Shallow tubewells pump comparatively good quality water and are more efficient in financial and economic terms. (v) For about 50% of the tubewells installed in the saline areas, insufficient canal supplies were available for proper mixing; and in the remaining areas, arrangements were completely inadequate. Water, having a salt concentration from 1500 to 4000 ppm, was proposed to be used in conjunction with the canal supplies. (vi) Most of the deep tubewells were meant to serve hundreds small farmers necessitating the construction and maintenance of long link water courses. (vii) The proximity of the seepage drains induced accelerated seepage from the canals. (viii) Unless the adequate drainage of excess unused water is made good, the application of additional reclamation supplies, to leach down salt from the root zones, leads to aggravating the situation. (ix) The provision of horizontal drains, to export salt, was dropped during its actual execution. This was a serious omission.

Some Problems in the Hilly Areas. Side-hill canals often require lining for safety, particularly if the ground is liable to slippage when saturated. Mud flows (where soaking into an upland areas of deep soil has built up a high water-content in the soil) may displace buildings etc. before coming to rest at a lower level. Frost-heaving occurs when the freezing of the soil results in layers. Where the drainage is inadequate, even the heaviest lining may be lifted by frost. Well-drained coarse grained soils may thaw from 4 to 6 ft. The thawing means the release of water which cannot be drained away through the frozen ground below. The surface soil then can flow readily down the slopes (3^{o}

or less even) and is known as active layer. If the overall cost of a drainage system to alleviate or prevent damage from seepage exceeds the cost of lining, the lining is economically justified.

In hilly areas,the streams generally carry water during winter and thus the seepage loss in unlined channels is much more than the loss on this account during summer season whien streams carry colloidal silts with water. The available discharge for running the hydel stations is also much less during winter though the demand for electricity is maxi-mum at that time, particularly for heating purposes due to fuel shortage in those areas, Due to limited water supply, the lining of power channels is well-justified in all types of soils. It may also be possible to reduce the length of a channel by lining it in such areas.

Design of Channels

The channels are generally designed by the following Manning's formula:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

When V, velocity of water in ft/sec. n, coefficient of roughness (rugosity coefficient). R, Hydraulic mean radius or HMD.

$$= \frac{\text{Cross-sectional area of the liquid (in ft)}}{\text{Wetted perimeter}}$$

$$\text{and} \quad S = \frac{\text{Vertical fall}}{\text{Length of the channel}} \quad \text{(Sine of slope)}$$

Table 5 gives the velocities in the open channels calculated by this formula. The rugosity coefficient increases to about 0.050 – 0.060 when the canals are 2/3rd choked with vegetation and is only about 0.010 when the canals are cement plastered. Velocities in the tile drains of clay or concrete, flowing full, are calculated by $V = 138 R^{2/3} S^{1/2}$. The coefficient of rugosity is taken as 0.045 when a canal has rough rocky bed and sides.

Table 6 indicates the side slopes for cuts and banks in the open channels. For greater than 10 ft, the slopes may be made slightly flatter. Also, if the bank work is in contact with water (as in the case of channel fully in bank or partly in cutting and partly in bank), the slopes may be made flatter. In ordinary soils, the actually constructed side slopes may be 1:1 but these are taken as ½:1 for design purposes. This practice is followed because, after the channel comes into operation, the side slopes get silted.

The top of lining is not usually extended for the full height of the bank free board and may range from 6 in to 2 ft above the water surface. It is questionable that whether the bank heights can be reduced in the lined canals. The lower limit for the free board in an earth canals is usually 1 ft and 4 ft is a usual upper limit. Between these limits, it is usually adopted approximately 1 ft + 25% of the depth.

Floods and the Desert Lands. The desert arable lands, approximately 27.0 million acres, are lying waste in Pakistan for lack of water. We know that with even a slight rainfall of about 1–2 in most of the desert becomes green and provides enough feed to the grazing cattle. At present, there is no arrangement to utilize the extra flood water for beneficial purposes. The only arrangement that exists is for protection of land from floods by erecting flood protection bunds. The devastating floods in Pakistan are of short duration and carry heavy loads of fertile silt. The irrigation channels are closed during floods for fear of choking up as these are designed to maintain their regime with light silt loads. By lining the earthen canals with concrete, the

Table 5. Velocity of water (ft/sec) based on Manning's formula (R=1.2 ft).

n \ S	001	002	004	010	Remarks
0.014	3.79	5.36	7.58	11.99	Ordinary concrete lined channel.
0.025	2.12	3.00	4.25	6.71	Earthen channels in poor order (with neglected maintenance); a good value for small channels serving a couple of farms.
0.030	1.77	2.50	3.54	5.59	Earthen channels in very bad order banks irregular bed badly pitted by erosion.
0.040	1.33	1.88	2.65	4.20	Rough rubble; with rough bottoms and much vegetation (badly choked with heavy growth).

Table 6. Side slopes for cuts and banks in the open channels.

Silt/rock	Side slopes (X horizontal in/vertical). in cutting up to 10 ft depth	Bank work up to 10 ft height
Solid rock	1/8 : 1	5/4 : 1
Soft firm rock	1/4 : 1	5/4 : 1
Fissured (more or less disintegrated) rock.	1/2 : 1	5/4 : 1
Cemented gravel	3/4 : 1	5/4 : 1
Stiff clay	3/4 : 1	1½ : 1 (when properly compacted)
Firm, gravelly and clay soil	1 : 1	1½ : 1
Average loam or gravelly loam	1½ : 1	1½ : 1
Loose sandy loam	1 : 1	2 : 1
Very sandy soil	3 : 1	2 : 1

existing channels can function as the flood channels also to carry the extra flood water with heavy silt loads into the desert lands. These channels will then serve to break the peak of the floods also.

It is well known that the ground water beneath the desert is saline and the depth [3] of the water table is 40 ft below the natural surface. The flood water will reduce the salinity level and raise the ground water table also in the deserts. The presence of sand gives us yet another indication that saline and brackish water can be utilized on such soils to raise some sort of salt tolerant crops. At present, the disposal of the flood water is not satisfactory and is increasing the danger of waterlogging. It is believed that with the increased vegetation in the desert lands, the climate of the deserts will change appreciably in due course of time.

Types of lining. Lining may be of:

(i) In low velocities, clay is spread in 3–6 in thick layers and puddled into place. 3½ in thick layer of the puddled clay gives very beneficial effects but it is not suitable in perennial flows. The usual way to stop excessive percolation is to excavate the channel of a section greater than the required one and then get it artificially silted with light and fine silt to the required section.

(ii) Soil-cement linings, properly constructed, are resistant to weed growth and burrowing animals. The surface of soil-cement lining developes a network of fine hair cracks. Soils for this purpose should not contain greater than 35% of silt and clay. Cement content required varied from 15 to 20% by volume.

In a different way, soil containing 5% cement was compacted to a 3-in thick layer and topped with ¼–½ in cement-sand plaster. Satisfactory results were obtained with the soils having 8–15% clay, 12–25% silt and 60–80% sand by weight.

(iii) The synthetic rubbers, such as butyl-coated membranes show high resistance to deterioration from weathering and biological activity. Unlike the asphaltic membrane, these will not be penetrated by plant roots. Although the tensile strength is good, it is not sufficient to withstand the traffic of livestock. In view of this, these should be the buried membranes.. Natural rubber while water-tight and flexible, deteriorates rapidly. Prefabricated burried asphalt, oiled paper and bentonite membranes have also been used in lining the canals. Buried asphalt membrane has been found very economical and practical for the control of seepage in operating systems where an eroded, oversized, unlined section makes the cost of a hard-surface lining prohibitive. It has been reported by U.S. Bureau of Reclamation that at the close of 1949, a 3450-ft stretch of Heart Mountain canal was lined with this membrane. The water table dropped immediately and the next season no water appeared in 8 foot-deep-observation wells. The fields, which had previously been too wet to farm, produced outstanding crops during the 1950 season.

Certain disadvantages are inherent in all buried membrane linings; the velocity must be restricted and the capacity of canals on the same grade with the same cross-sectional area is smaller because of the greater roughness of the cover material. Likewise, maintenance is extremely difficult The surface roughness obviously does not affect the capacity of reservoirs and, therefore, the surface areas lined would be about the same regardlass of the lining employed.

(iv) Asphaltic concrete has the disadvantage that it permits certain types of weed growth and requires the use of a soil sterilizing agent on the subgrade. Normally, the asphaltic content is about 8%.

(v) It has been reported that 90% reduction in seepage was achieved in a leaky-sandy clay lining having small calcium by filling the lake with salt water.

(vi) Alternate coats of alum (2 oz in 1 gallon of hot water) and soap (12 oz in 1 gallon of water) solutions were well-worked into the surface a number of times until the pores were filled with insoluble aluminium soap.

(vii) One of the most promising plastic composition is polyethylene but successful use of plastic sheet for lining will depend upon developing a suitable cover to hold it in place. Nothing will bond permanently to it, and earth or gravel covers require very flat slopes. Black film is used in preference to that of other colours or to clear film because such films deteriorate in sunlight. For most conditions, a 4-mil thick film will provide satisfactory control for three years.Where nutgrass is a serious problem,8 mil film is recommended. Films thinner than 4 mil will not ordinarily last more than one year.

(viii) In a ft^3 of water, 6.6 lb sodium carbonate or soda ash was dissolved and this solution was sprayed on 200 ft^2. After the first layer of 2 in thick was treated, another 2 in layer was spread and treated in a similar way. After that 8 in silt, dug from the channel, was spread and rolled with hand rollers. The best results are obtained with this treatment when soil contains at least 10% clay.

(ix) In the past, the standard concrete lining was 3–4 in thickness, reinforced with 3/8 in steel bars on 1 ft centres. The use of reinforcement is not considered justified now except where failure would endanger canal or other property. The tendency in recent years also is to reduce the thickness to 2–3 in. It is impractical to design concrete lining sufficiently strong to withstand pressure exerted by frost action or expansive forces of soils. The best practice is to design a slab which will maintain itself against the forces of weathering. In order to meet this requirement, concrete should be designed to have a compressive strength of approximately 4000 lb/in^2.. Precast concrete slabs are also used for this purpose. Fillets along the bottoms of the sides provide some improvement in efficiency. Linings steeper than 3/4 : 1 should be designed as retaining walls. Concrete linings are sometimes slightly roughened by moss, algae, or insect deposits. They require a minimum amount of maintenance and have a long service life.

(x) Lininga may be made waterproof by the additon of 10% K. oil in 1:3 Portland cement mortar or 1:2:4 P. cement concrete. Concrete requires twice mixing and sets in twice as much time as usual. K.oil retards greatly the disintegration of cement concrete due to alkalies.

(xi) Precast blocks lining is easy to install and practically no experience is required. Its greatest advantages lie in its practicability for use in repairing small sections, or for use by farmers in lining their ditches. Prevalling high labour costs in the U.S.A. make it uneconomical for large scale lining jobs.

(xii) Fair-sized ditches, with water depths of 3 or 4 ft, have been sucessfully lined with cement mortar ½ in or even less thick plaster. Layers up to 2 in thick of cement mortar have been used for lining. Cement mortars have been applied by the compressed air also. Shotcrete is especially useful for repairing hard-surface linings.

(xiii) Brick linings, which do not produce expansion or contraction cracks, have been laid with the following specification: (a) ½ in layer of 1:5 cement mortar is laid on the consolidated and damped soil in 1:3 cement mortar. (b) ½ in plaster 1:3 is sandwiched in between the two layers of bricks or brick tiles. (c) The lining may be plastered or pointed on the face and may also be reinforced.

Recommendations

Keeping the importance of lining the existing and new canals in view, the following types of hard-surface linings are recommended for adoption in Pakistan:

(i) In the far-flung areas of the northern region, Portland cement costs about Rs.100–150 per bag. Due to improper cartage, the quality of cement also deteriorates. Better solution, in those areas, will be to use (locally manufactured) lime which possesses nearly half the density of Portland cement. The lime sets slowly and, therefore, it will be proper if the lime-concrete blocks, made earlier, are laid in lime mortar and then pointed with P.cement and hydrated lime mortar. For improving the hydraulic efficiency of the lining, the exposed surface of the blocks may be rubbed or grinded before use. It has been observed that the construction with lime behaves better in earthquakes as the Portland cement, being rigid, generally cracks. The resistance to erosion can be further increased by coating the lining with sodium silicate solution.

(ii) The manufacture of hydraulic lime or natural cement may also prove economical in those areas. Hydraulic lime is made by burning siliceous or argillaceous lime stones, containing clay from 5 to 30%. It contains so much free lime that the mass of clinker will slake on the addition of water. Hydraulic lime possesses hydraulic properties and sets under water within 7–30 days. Natural cements are produced by burning at a temperature usually little, if any, above that of an ordinary lime kiln (900°) a natural clayey lime stone containing 15–40% of $SiO_2.Al_2O_3$ and Fe_2O_3 without preliminary grinding and mixing. After burning the mass will not slake, if water be poured on it. It is necessary, therefore, to grind it quite fine. It will thus be possible to make an appropriate use of the resources available.

(iii) Stone masonry lining may be laid in lime mortar, where economical, and pointed with cement-lime mortar of a suitable ratio.

(iv) For other areas in Pakistan, precast block lining would have been better but we are short of Portland cement at present. It is, therefore, suggested that the autoclaved sand-lime bricks or tiles, developed by PCSIR, may be used for lining the canals. It is expected that the seepage loss will be much less in this type of lining.

As a first task, all the water courses in the disaster zones, particularly where the soil is porous and ground water is saline, should be lined; to be followed later by canals where necessary. In all above alternatives, labour intensive methods have been suggested recognizing that in such construction, a large fraction of the total cost is spent productively within the country and specially on the employment and betterment of the local population. Using the prefabricated technology, the quality can be achieved at a uniformly, acceptable standard by the locally available labour and at the same time it is easy to adjust the time factor also required for the completion of assignment. Hard surface linings may also provide the increased capacity of the existing unlined canals, at less cost than would be involved in enlarging the sections, by providing the increased hydraulic efficiency and lesseningg of the seepage loss.

The Fifth Five-Year Plan provides an increase of about 11.15 MAF (12.2%) in the water availability at the farmgate. The envisaged large scale tubewell development will require more investment than the capital required for lining the canals besides the recurring expenditure on pumping. A comparative cost study, including an evaluation of the merits and liabilities of pumping ground water and lining the existing canals should be worked out to determine the more economical method for the proposed increase in the water availability at the farmgate. As mentioned earlier, buried asphalt membrane may prove much more economical and practical for the purpose, controlling water-logging and salinity also. It is suggested that the PCSIR may be given the task of developing a low cost lining immediately for achieving the desired results. They may also examine the possibility of applying the emulsion-type sealants for the purpose while the canals are in service. Determination of the relative efficiencies and cost economics of tubewells or horizontal drains versus canal lining also appears to be necessary in checking water-logging and salinity.

Due to earth's rotation, the moving bodies have the acceleration to the right of their motion in the northern hemisphere. Consequently the right banks of the rivers are eroded and the rivers bypass the obstacles to the right. The deviation is maximum at poles and zero at equator in horizontal plane when in vertical plane it is maximum at equator and zero at poles. It appears useful tc study this effect on seepage, erosion, floods, waterlogging and salinity for the finding out the correct and economical solution of these problems.

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