Changes in River Regime as a Result of Link Canals

By

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Introduction.

The essential function of a link canal is to transfer water from one source where an adequate supply is available to another where additional supplies are desired.

In order to maintain control of the quantity and quality of the waters so transferred, it is usual to provide head and tail regulators on the link canal and a controlling river structure, whether it be an open weir or a barrage, across the source of supply immediately downstream of the head regulator.

Thus, whereas the link canal in itself has little effect on the regime of the rivers at the head or tail of the link, the controlling structures may have far reaching effects.

General.

Before commenting further on these effects, the looseness with which certain terms are sometimes used may warrant a few definitions as they are to be used in this contribution.

REGIME is used as an overall term combining the effects of such factors as discharge, velocity, breadth, depth, silt factor, etc., of a river or canal.

The term IN REGIME infers that the aggregate effects of the various factors in a river, or a given stretch of river, have balanced themselves out and no material change is evident. This definition refers, of course, to rivers flowing through alluvial plains, such as are found in Pakistan and not to river courses having virtually unerodible sides and bed.

A WEIR maintains a pond level by means of a permanent crest, with or without shutters, and provides no control of the river during low flood. A BARRAGE is a gated weir having a lower crest and provides control during all stages of flood.

A weir or barrage is normally best sited in a stretch of the river which is in regime and with such location and orientation that the river in flood passes through with an even intensity throughout the width of the structure, i.e., with the minimum of concentration.

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It follows from the above definitions that if an obstruction, natural or artificial, occurs in a river in regime, the regime conditions are unbalanced and changes may be expected in the conditions of approach and discharge.

Accretion.

The creation of a pond, or ariificial lake, causes a delta to be formed at the head of the pond consisting of the coarser particles of sediment load, the tail of the delta will eventually extend to the weir until the bed slope conforms to the revised regime conditions of the river.

The slope of the river is flattened during the process of accretion but in due course the river will revert to its original slope but with a higher bed level.

The effects of accretion will vary with the suspended load, but will involve a greater danger of flooding, or raising of protective bunds where these exist.

A barrage with its lower crest and greater control of discharge has obvious advantages over a weir and offers a grerter prospect of the accre ted material being flushed downstream, of the barrage during flood periods.

Applying these comments to the Indus Basin Projects it is probbale that during periods of high flood, head regulators will be closed and the flood waters containing the highest silt content will be passed downstream of the barrage.

When the new link canals are in operation they will be passing as silt-free water as is practicable, thus where a link discharges into a river upstream of a barrage, *e.g.* at Qadirabad and Sidhnai, the combined link and river water in the pool will have a much lower silt content than would otherwise enter the pool ; this point is emphasized when it is realised that during the greater part of the year there will be little or no discharge from the river entering the pool. Thus accretion problems in the pool may not be as serious in the case of the new I.B.P. barrages as they have been in the past when undiluted river discharges only have deposited their sediment load in the pool.

These conditions will not apply to the Marala-Ravi and other silt carrying links where conditions will be unchanged.

Retrogression

A direct effect of accretion upstream is the discharge of comparatively silt-free water through the barrage and this, combined with a reduced discharge, causes retrogression of the bed downstream of the barrage.

This process successively lowers the downstream bed level during the early years of operation of the barrage and, unless adequate precautions are taken in design, may endanger the downstream floor not only by undermining, but by increasing the exit gradient to dangerous limits. River structures such as bridges, culverts, etc., within range of the retrogression may also be endangered.

As stated under the subject of Accretion the upstream bed slope will gradually revert to its original value and as this stage approaches the sediment load passing through the barrage increases, in fact due to silt exclusion from the off taking canal, the sediment load may easily increase and this coupled with the decreased discharge, causes a recovery in the downstream bed levels. The period of recovery is normally greater than the period of retrogression but as in the case of Khanki on the Chenab, the eventual downstream bed level may be higher than it was originally.

The period of recovery will vary with the intensity of the suspended load in the same way as the recovery of the upstream bed slope varied with the same factor. The effects of retrogression can however. only be regarded as a passing phase and whilst precautions must be taken against the dangers involved, no advantage should be taken of such factors as the lowering of flood levels or of the water table.

Meandering

For a river to adapt a straight course is, to say the least, not natural, and every channel except those with stable banks such as at Sidhnai, will adopt a winding course which will vary as conditions in the river itself change. These conditions may include almost anything from a varying sediment load to the growth of a shrub in one of the banks.

Eminent hydrologists have, from time to time, presented their conclusions from collected data and empirical formulae have been derived to establish the relationship between the velocity, width and bed load of rivers with the meander breadth and length. Further research is necessary and for the purposes of this short commentary, general relationships only are considered.

The flatter the slope greater will be the tendency to meander. Thus, with the formation of a pond, there will be a tendency to increase the meander width and should the length of the pond be great in proportion to the distance to the next control point upstream the boundaries of the flood plain, or khadir, may be attacked, thus increasing the danger of flooding or attack on protective bunds.

It is a common practice to either divert the river during the period of construction; or to build "in the dry" and later divert the river to pass through the structure. The period of construction usually includes three or more flood seasons and this may be sufficient to cause a diversion which in turn causes a different meander pattern upstream and affect the condition of approach to the completed structure.

The flood width of a river is taken as the width of the river when flowing in regime at maximum discharge and for all practical purposes may be taken as Lacey's $P=2.67\ Q^{\frac{1}{2}}$. The minimum meander width may be taken as 4P (for a spilling river) but for obvious practical and financial reasons the width of a barrage would only be designed equal to one flood width, with or without a looseness factor. Hence to prevent outflanking, spurs or other means, must be adopted to destroy the meander pattern at a distance less than half the meander length upstream. Inglis advocated a value of 0.4 M_2 , which may be taken as 3 to 4 flood widths, upstream of the barrage.

Most barrages today incorporate guide bunds as an essential part of the design. Guide bunds generally extend not less than one flood width upstream and though their main function is to provide a uniform approach, they also fulfil the function of preventing a meander developing which would attack the approaches to the barrage.

A notable feature of the barrages being provided under the I.B.P. is that during the greater part of the year they divert practically the entire approach flow into link canals off-taking from one side of the barrage only. This is particularly evident at Sidhnai when the off-taking head regulators on the left bank extend well over one half, and nearly three quarters, of the length of the barrage. This is the most unnatural state of affairs and in spite of the fact that the canals take off from a pond, there will be a tendency for erosion to take place on the right bank upstream of the barrage unless adequate precautions are taken.

There will also be a bela formed on the right side of the river immediately upstream of the barrage which would, if not catered for, mask the right side of the barrage and reduce the discharge during periods of flood. Such conditions are taken into account during the design stage of the barrage.

Design

These comments are confined to the effects of controlling structures on river regime, but it will be evident from previous comments that design criteria can, and must, affect the resultant regime of the river.

Pond Level.

The creation of a pond, regardless of any other consideration, entails accretion upstream, but the creation of a pond whose level is higher than the high flood level introduces conditions whereby the accreted material will tend to form a berm, or berms, which will not be removed by intermittent floods or freshets and special consideration, must be given where such a condition is unavoidable.

Afflux.

It is a general practice in the Punjab to restrict afflux to 3 feet. This restriction is primarily to reduce scour but other, equally important, factors are involved. A low afflux involves a wider and more expensive barrage with a proportionately greater tendency to shoaling upstream. A higher afflux reduces the width (but increases the height) of the barrage and constricts the approach channel thus assisting in retaining an open channel during dominent discharges, reducing the effects of shoaling and minimising the tendency to meander during periods of low discharges.

Afflux and intensity are closely related and in broad terms the optimum afflux in alluvial plains may be considered as that which will not create a greater intensity than approximately 300 cusecs per foot of width between abutments.

Model Studies.

Considerable advances have been made in river engineering during recent years but it cannot yet be claimed that the science has advanced much beyond the empirical stage.

Experience, and occasionally, a natural instinct, on river works remains the prime consideration in design.

Perhaps the greatest advance in any single branch of the design of river works has been that in the preparation and interpretation of model studies Nowadays no major river work is carried out without extensive model studies to determine the effect of such works on the regime of the river.

Such studies, carried out by skilled technicians, can do more than anything else to determine the resultant effect of interfering with the natural flow of a river but again, the results of such studies need to be interpreted by an engineer experienced in comparing the results of model studies with the prototypes if the full value of the studies are to be obtained.

Conclusions.

The foregoing brief notes apply in general to the effect of link canals on river regime. In the Indus Basin Project there are, however, two rivers which may be affected much more acutely, and dangerously and are likely to present serious problems in years to come.

The Rivers Ravi and Sutlej in normal circumstances and in the foreseeable future, will be entirely cut off before entering Pakistan territory and for all practical purposes will cease to exist. Long reaches will, apart from local rainwater and storms, remain dry throughout the year whilst others will carry link canal discharges only. The 150 odd mile stretch of River Sutlej, for instance, between Suleimanke and Panjnad, where the maximum historic discharge is recorded as 427,000 cusecs, will remain dry except for local rainwater.

It is most difficult, at this stage, to assess the combined effect of retrogression and accretion, but it is not difficult to realise that the existing river channels are going to deteriorate to such an extent that they will be quite incapable of discharging their present quantities.

The discharge from the link canals, with a certain amount of manual assistance, may form their own regime channels occupying a small portion of the present river channel, but in this event will the cultivators not develope the remainder of the river bed for the production of crops ?

It is quite probable, therefore, that the river channels as existing today will cease to exist when the existing and proposed projects in Pakistan and India are complete.

Next must be considered the controlling river structures inside India.

In the event of, for instance, the Bakhra reservoir being full during the period of a flood or as a result of any other emergency, the Indian Authorities would be capable and to the best of my knowledge entitled, to pass the entire flood downstream of the dam.

Some of this flood water would be consumed in Indian territory but the bulk would follow the Sutlej depression and enter Pakistan where flood courses have ceased to exist and cause unprecendented flood damage.

The potential dangers on the Ravi may be even greater than on the Sutlej, and we must seriously consider—is there an economically feasible solution to this problem ? Perhaps Members of this Congress will suggest possible solutions for future consideration.