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Improving Soil Diversion Bunds

Spate Irrigation Network pakistan

Practical Notes Spate Irrigation

1. Introduction

Spate irrigation - a system that supplies agricultural fields with channelled floodwater - has a history of centuries in Pakistan. From generation to generation, knowledge and information about spate irrigation have been passed on, creating a unique resource management system. Nowhere else in the world a larger surface is being developed under spate irrigation.

In spate irrigated areas, flash floods are - partly - diverted to supply land with water, to fill drinking ponds, and to water rangelands and forest ranges. Traditionally this water comes from free intakes in the foothill zones. Further down in the plains it is being diverted by means of soil bunds that are constructed across ephemeral rivers - i.e. streams only containing water for limited periods of time.

A number of substantial soil bunds have been built in farmer-managed schemes in Pakistan. Table 1 gives an impression of some selected diversion bunds in the DI Khan area and their dimensions. The soil bunds are not unique to Pakistan, but the technology is nowhere else implemented at this scale[1].

This note describes the current practice and the scope for improvements and is prepared to both identify meaningful programmes in Pakistan and elsewhere - particularly in countries where the scope to newly develop large lowland spate irrigation systems is large. The note describes the construction of soil bunds and possible improve support systems. Improving these traditional structures in many cases is the most effective way of supporting spate irrigation.

Figure 1. Downstream section of Vehoa river

2. Current practice

Traditional diversion and guide bunds (ghandhs) have been developed over long time periods, at some locations even over centuries. They have been adjusted to local wadi (i.e. ephemeral river) characteristics by the farmers and their ancestors. This has enabled irrigation to be sustainable by using only local materials and indigenous skills.

Both the location and the height of soil bunds are determined by the lay of the land. They should be chosen in such a way that no unwanted flooding of areas is provoked. In case a diversion bund across a river would only have a single off-take, the bund should be constructed at a certain angle with the river or in the shape of an arc, in order to dissipate the force of the flood water. If a cross bund were to have off-takes at both river banks, it would need to be built in a straight line. Depending on the height of the bund and the slope of the land, the cross bund might serve several off-takes. Also the distance between bunds should be kept in mind.

Soil bunds are constructed preferably with loamy

Table 1. Dimensions of some diversion bunds in DI Khan (Pakistan)

Location	Length (m)	Height (m)	Width (m)
Sad Swad	351	3.2	10.4
Sad Rabnawaz	754	7.0	12.0
Sad Dinga	330	1.9	15.1
Gandi Abdullah	178	8.0	14.0
Gandi Booki	1350	3.0	8.0
Gandi Mullawali	87	1.9	4.5

Source: Jamal Khan et al. (2004)

1) Soil diversion and guide bunds are also used in other lowland spate irrigation systems, especially in Yemen and Sudan. In the Tokar system for instance in Sudan long diversion and guide bunds are in use - the most important one being the Tomosay diversion bund and the Tomosay embankment. The soil bund of this embankment runs for some 50 kilometres along the western limit of the scheme. The embankment was set up to contain flood-flows within the Middle Delta, which is the most suitable land for irrigation.

soil. Gravel and saline soil are to be avoided, the latter would lead to cracking of the soil bund. The bunds need to be developed layer by layer, each layer being one to one-and-a-half meter thick. Compaction is done by bulldozer, by animal traction or by hand. Once constructed, animals should be prevented to trespass and trample the soil bunds, as this could weaken their structure. Reinforcement of soil bunds is being done by mixing vegetation into them, by laying brush wood along the lower toe or by stone pitching. Sometimes, as has been the case in the Las Bela area, short wooden poles have been driven into the most vulnerable parts of the bunds to make them stronger. In some improved systems, gabions are used, as well as internal lining with polyethylene sheets. The latter method has been successfully experimented with by the Water Resources Research Institute in Pakistan. In Hadramawt in Yemen, traditional conical so-called algama structures have been utilized to reinforce earthen bunds.

The long-established bund structures have some features that are definitely advantageous: they are flexible, they are appropriate and they are able to function at low cost. Moreover they are working relatively efficiently and they limit the diversion of high flows and high sediment loads:

- The flexibility of the traditional way of diverting water for irrigation is shown in its power to adapt to different circumstances. The riverbed topography, the long section and the alignment of low-flow channels may shift during medium or heavy flooding, but the location and lay-out of intakes can easily be adjusted to the wadi bed conditions. Diversion spurs can be extended or diversion bunds moved upstream if required by the level of sedimentation on the fields or in the irrigation channels.
- The traditional water intakes operate appropriately and at low cost as they are made of local materials using indigenous skills. Thus the intakes can be maintained for an unlimited period by farmers without help from outside.
- The fact that a series of intakes can be used along riverbeds makes the diversion network potentially highly efficient. Large floods may destroy intakes at the heads of spate schemes, but - as the floodwater runs along the riverbed - significant flows can be diverted through other intakes downstream. A substantial part of the yearly run-off occurs in small to medium-sized flood-flows. These may vary in duration and volume, but they can still be effectively diverted by traditional intakes without irreparable damage.
- The intakes limit the diversion of high flows and high sediment loads. The wash out of deflecting spurs, diversion bunds and breach sections during very high floods abruptly lowers the water level at that point of entry. Consequently, the discharges to be diverted to the command area are being reduced, and high flood damage and sediment deposition to downstream canal and field system is prevented.

Traditional soil diversion structures, on the other hand, are also associated with a couple of major disadvantages. The most important one is the vast quantity of labour and materials needed to regularly repair the earthen diversion structures that have been damaged or washed away by large floods. There is often a shortage of suitable material (i.e. good soil) around the diversion sites once they need to be fixed. Farmers want to rebuild bunds that have been affected as soon as possible, but high flood-flows often prohibit access to the necessary riverbed material.

A second disadvantage of traditional diversions is that the floodwater cannot always be diverted to where it is needed, despite the relatively high efficiency that can be achieved with multiple water intakes. When a large flood destroys intakes upstream, water from floods still to come cannot be diverted until repair works are completed. On the contrary, small floods will either be completely diverted at higher intakes, or lost because of seepage into the riverbed before the flows reach diversion sites downstream. Some estimates is that losses in river beds are in the order of 2 to 3 percent of floodwater per kilometre.

On the other hand over time, sedimentation from diversion bunds (if never breached) raises the upstream riverbed and the floodwater levels. If bunds do not to break in time, huge flows may be diverted into the first reaches of canals. Upper reaches of a canal can thus become a new bed for the river. In even worse cases, the entire canal could form a new permanent course through the irrigated area. This obviously creates

Figure 2. Broken bund

Box 1: Maintaining earthen structures in spate irrigation systems

Repairing intakes and rebuilding bunds are time and energy consuming tasks in spate irrigation. They are part of a whole range of duties that farmers have to manage and execute to make this system work. In Pakistan, the individual farmer using spate irrigation does his ploughing in April and May when he has no crops. If needed he mends or raises the laths (side dykes) surrounding his field, using his own soil due to property rights. This earthwork leads to some depressions ('combails') in the field. In case of fewer rains, these combails accumulate the water and yield animal fodder and maybe some grain. After good floods, the total field is being cultivated, producing green and dry fodder and food grains. In this case the combails also serve as stilling basins from which water is spread over the fields.

If two adjacent fields have equal levels, both neighbours will work the side dykes. Otherwise the farmer with the highest field will take care of them. The laths are trapezium-shaped and usually 3 to 4 feet high. At the water inlet ('moanah'), two heaps of soil are collected to close the opening again after the field has been filled with water. Gradually, concrete inlets and overflows - already common features in canal irrigation - are replacing some of the traditional earthwork in spate irrigated areas.

After the earthwork on the field and the lath, the efforts of the individual farmer will move to the wakra (dyke) in the kass (channel for irrigation water). The wakra - generally trapezoidal as well - is about as high as the lath, but it rises some 6 to 8 feet at an angle of 90 degrees above the kass bed. The kass is a joint property, but after it has been dug initially it is not being maintained. Its undergrowth is sometimes even encouraged, because it helps to break the water current and supplies firewood for the families. Usually a farmer breaks the wakra himself, after his field is full of floodwater.

When all this has been done, the entire community participates to raise the bund or main dyke, the ghandh. All farmers benefiting from the kass share the burden. In the past, raising the main dyke demanded a lot of physical effort from the farmers and their relatives. Nowadays their contribution has changed to a financial one according to plot sizes, to rent bulldozers and tractors that have replaced manual and animal labour for this job. Ghandhs are 2 to 3 feet higher than the kass, and up to 15 feet higher than its bed. Soil from this irrigation channel is used to make the bund higher.

A bund (ghandh) will only be breached by the farmers if all fields have been filled with water. In some cases, downstream farmers have been found breaking the bund to get water to their plots. This has led to animosity between (groups of) farmers.

There are examples in which a bund is used with multiple kass systems, involving more than one community preparing and protecting the ghandh. In such situations the local government may come in - not only assisting with the work to be done on the bund, but also organizing irrigation rights of farmers.

Figure 3. Farming according to moisture, field depression (combail) in forefront

enormous damage to the spate and field systems, resulting in significant loss of land as well as losing command to secondary and other canals. Alternatively due to the belated breaking of the bunds, the existing river bed may scour out too deeply. This results in the need for farmers to build bigger bunds in order to divert the same quantity of irrigation water.

To prevent such problems, farmers often breach bunds deliberately. In general farmers take care and try to manage the sedimentation process in the river beds - through the location of the bunds (avoiding bunds being built too closely and the river bed becomes too high) or in severely degraded rivers by making bunds that cause sedimentation and force the river to come up. The bunds along the Korakan river in Balochistan, for example, were washed out very frequently because the river bed was deeply incised and high floods had no natural way to escape. By blocking of the river with a strong soil bund the river bed was forced to come up.

A related issue is the silting of flood channels, for instance caused by lack of maintenance. As a consequence, pressure starts to build up on the cross-bunds in the river because the water cannot get out. This may lead to the early collapse of the bunds.

3. Improving the system

The centuries old practice of spate irrigation in Pakistan deserves a serious update to improve its efficiency. The need for frequent rebuilding of diversion bunds is often a major challenge - and

Box 2: The importance of earthmoving equipment

In Pakistan the transition from animal power to earthwork machinery is almost complete in spate irrigated areas. Oxen and bulls are rarely seen doing earthwork. Following large equipment grants, for instance from the Japanese Government, from the eighties onwards, farmers have come accustomed to hiring bulldozers at heavily subsidized rates. Similarly the use of tractors relies upon rentals. Apart from the cost of hiring earthwork equipment, farmers also have to feed and entertain the machine operators in addition to paying for getting the bulldozers repaired and operational, if broken down. Many bulldozers have now by far outlasted their economic life and their services become more and more scarce, affecting the viability of spate irrigation. The availability of bulldozers and tractors is getting increasingly certain, often depending on the political connections of the farmers.

Time is often of paramount importance. The rains last for about a month each year, but their intensity, duration and timing are unpredictable. Once the wet season starts, the bulldozers and tractors should be ready to roll at critical spots in the area. Doing so, their operators can make immediate use of the available rainwater, necessary to moisten the sand that has to be moved to form impregnable soil bunds. If the bulldozers and tractors are brought in with delays, the sand may have become dry again, unable to stand on its own.

Figure 4. Guide bund along flood channel, Daraban Zam, DG Khan

in some spate system can make up more than 75% of all the work. In some cases, peak floods can occur more than once within a few days due to persistent storms. The reconstruction of bunds requires the cooperation of large numbers of farmers, as well as the availability of equipment and replacement. Yet, vital floods could still be missed for irrigation.

The major change in the system has been the shift from manual and animal labour to the use of bulldozer and tractors in the previous decades (see box 2). This has been a welcome development making it possible to reconstruct bunds timely. At the same time it has made farmers dependent on the facilities which is becoming more and more of a problem - as the number of working bulldozers (see box 2) - is going down and no new earthmoving equipment is made available for subsidized rental.

There are three strategies that should be considered to improve the functioning of the systems of soil bunds for spate irrigation:

- Increase availability of earth moving equipment
- Better services through trained bull dozer operators
- Overall investments in durability of the soil bund systems

(1) Increase availability of earth moving equipment

Over the years the stock of subsidized earthmoving equipment has gone down and there is nothing to replace it. The use of bulldozer and tractors has become indispensable for the farmers in spate irrigated areas, but at the same time this equipment is getting scarce and running the broken down equipment is putting a huge financial burden on their shoulders. It is strongly recommended that the stock of equipment is replenished but that at the same time better management systems are put in place that guarantee replacement and repair. Government could rent the machinery to the farmers at subsidized rates. As an alternative the farmers can form a collective, such as a society or a cooperative, to acquire bulldozers or tractors and share the use of them among the members. This construction could also involve the maintenance of the equipment and the training of its operators. A third option is to develop with a strong local private service sector. There is limited experience of this in other countries, which suggest that with adequate support all these options are possible.

(2) Better services through trained bull dozer operators

Another important aspect is the training of the people working with the machinery. The bulldozer operators are normally trained in road projects, based on cut-and-fill techniques. However, spate irrigation earthwork requires totally different skills which until now are learnt only through practice, not in appropriate training programmes. The operators of bulldozers and tractors should undergo applicable training to understand the working and the purpose of spate irrigation and the mechanics of water, especially under flood conditions. Also these workmen need to be trained to suit the local soil conditions, and to know how to make best use of available resources like brush wood. Mixing soil with properly moist or wet sand can help to raise the dykes and make them impregnable once they have dried and hardened.

Figure 5. Working on soil bunds, DG Khan

The construction of ghandhs (bunds or main dykes) and wakras (minor dykes in the flood channels) should be done layer by layer, in a way that the soil gets compact and can withstand water pressure. For well compacted soils the water flowing over the bund does not mean immediate breaching. Dykes constructed this way take much longer to break through, and thus enough overflow can enter a kass (irrigation channel) - to the benefit of the majority of the famers in the area.

(3) Overall improve the durability of the soil bund systems

The never-ending process of maintaining and repairing soil bunds (ghandhs or main dykes), kass (irrigation channels) and wakras (dykes) should be studied as part of a larger picture. In many systems the ghandh is the weakest link in the system but the problem is caused by the insufficient capacity of the flood channel systems. Because the main channel contains more water than the kass can handle, water ponds up and the ghandh is often breached before all fields are irrigated. In seasons with extra-ordinary rains it is not unusual that the already impoverished farmers have to repair their ghandh three times. With the high demand for machinery, the monsoon rains may be over by the time the ghandh is finally ready - leaving the fields dry. In these circumstances it is important to deploy earth moving equipment on the channels as well as on the diversion bunds. Individual farmers can be taught to keep their kass (irrigation channel) clear of all undergrowth vegetation. Then the spate water can flow freely, reducing the pressure on the ghandh (main dyke) considerably. This way the ghandh has better chances to survive, and more water can be led to the fields. To compensate the loss of vegetation (often used as firewood), the farmers can be asked to plant fruit trees on the edges of their fields. These trees - or plants - can also produce leaves for their animals, as well as firewood.

There are also several ways to strengthen the soil bunds. Some techniques are already in vogue and maybe outscaled: the use of limited stone pitching, wooden poles or plastic screens to avoid seepage and piping.

To strengthen the bunds, the use of gabions should also be considered in more situations. If the bund (ghandh) consists of two sections, the one facing the kass should have a gabion filled with stones, material that is abundantly present in the main channel. The empty spaces between the stones in the gabion will release the water pressure, and the flow in the kass will be guaranteed. The section of the ghandh away from the kass should be made of earthwork, it can easily be breached again once the need for water has been met. If the bund has three portions, the outer two should have stone-filled gabions. The earthwork portion in the middle could act as fuse. In case of silting the gabion could be extracted or readjusted.

When enough funds are available, the concept of improved intakes should be considered. It means that guide bunds along the sides would be reinforced to keep the main channel between defined limits. Currently this is not the case, and thus erosion and loss of fields are quite common: waste lands along both sides of main channels are reported to be at least three times as wide as the channels themselves.

Figure 6. Kass - spate channel

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This note was prepared by Allah Nawaz Qaisrani, Frank van Steenbergen, Karim Nawaz and Joost Ten Horn.
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