Diversion structures and flood protection works in the PDRY

by Habib Hasan Abbas
Chief Engineer, Yemeni-Soviet Projects, PDRY

1. Introduction

Irrigation areas in the PDRY are usually located along the main wadis. The alluvial soils mostly consist of loamy sands, sandy loams and silty loams. The depth of the soils increases in the direction of wadi flow coming from the mountains. In their upper reaches wadis are rather narrow with steep gradients while near the coastal plains they grow wider and the gradients become flatter.

In the PDRY surface water runoff is diverted for irrigation by means of diversion weirs of the overflow type and by small traditional diversion works (oqmas). The construction cost of these works is not very high and they give rather quick returns in terms of increased agricultural output,. allowing suspended material to be transported to the irrigation areas which increases the soil fertility.

Since only 0.7 percent of the total area of the PDRY is arable, much attention has been given to flood protection and wadi training works under long term wadi development programmes in order to preserve such limited land resources and to rationalize the utilization of spate water.

2. Nature of spate irrigation systems

Irrigation systems in the area dating back from the earliest times were characterized by numerous small diversion works on the wadis and unlined distribution canals of low efficiency. The specific nature of the floods, which are mostly formed in the northern part of the country, together with the soil and terrain conditions of the wadis in the middle and lower reaches and the low efficiency of water distribution networks, are the factors which created the existing traditional irrigation pattern of small fields stretching along wadi slopes. The introduction of the public sector in agriculture and state ownership of land offered a real opportunity of improving the existing irrigation systems and further development. of land resources by building solid diversion structures: large canals protected against seepage and erosion.

In the past 17 years a considerable amount of work has been done on construction and reconstruction of existing traditional irrigation systems and the improvement of irrigation water supply. The Wadi Tuban spate irrigation system is a good example.

Within the long-term development programme the Yemini-Soviet Projects have constructed and reconstructed a series of seven diversion weirs and other small diversion works to irrigate the whole delta (figure 1). Feasibility studies carried out by Yemini-Soviet Projects have recommended full improvement and levelling of lands in the upper delta and improvement of existing systems in the downstream areas. Reconstruction of the two remaining diversion weirs, one of which is in the Wadi Kabir (Al Wahst) and another one in the Wadi Saghir (Al-Kunasira), will be undertaken in the current five-year-plan period of 1986-1990.

Accumulation of water by means of storage reservoirs or basins on the wadis of the PDRY for further distribution on the irrigation fields is impracticable at present because of technical difficulties. High intensity and short duration of the floods passing along the wadis, heavy bed load and suspended materials carried by the stream reaching 50 to 70 kg/m^3 sometimes make it very difficult to find a proper engineering solution for the problem of accumulation of spate water in the storage basins and reservoirs. Furthermore such basins require careful and extensive maintenance work due to heavy sediment deposition. These structures are subject to considerable water losses due to seepage and surface evaporation in the dry and hot climatic conditions of this country.

Construction of storage basins without consideration of the irrigation pattern in the delta as a whole may produce undesirable effects on the groundwater basin, as the spates are the main source of natural groundwater recharge. Groundwater from deep and shallow wells is widely used in this country for the purpose of irrigation and cultivation of many crops. Thus the storage basins proposed for construction in future should be treated as a constituent element of water resource balance.

3. Diversion structures

3.1 Hydrological observations

Recently much attention has been paid to improving hydrological observations on wadis. Work is under way to create a complete observation and monitoring system under the Water Resources Section of the Department of Irrigation, and on the Wadis Tuban, Bana, Hajr and some others hydrological stations have been set up. However there are not enough data so far to make a correct hydrological series which is necessary for an adequate flow discharge curve with regard to any flood event of a given probability.

Diversion structures built in the 1970s demonstrate the

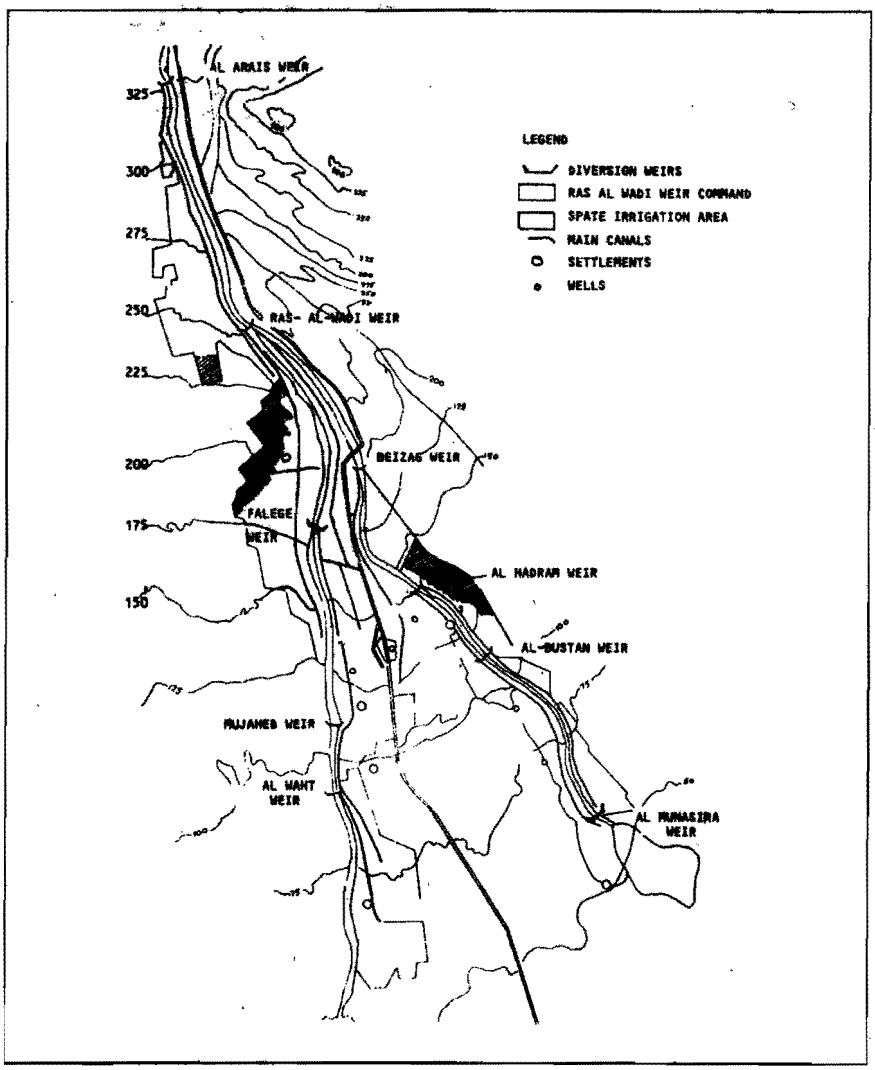

Figure 1 Layout of diversion weirs on Wadi Tuban

shortcomings of the hydrological data collection system before that period. They were capable of handling only one peak flood in a ten-to-fifteen year return period. Many weirs were destroyed in the disastrous 1982 flood. That event prompted the need to upgrade the diversion structures to withstand safely one-in-a-hundred-year probability floods.

During the past few years 13 major diversion weirs have been designed, reconstructed and constructed on Wadis Tuban, Rabwa, Ahwar and Bana with capacities in the range of 1000 to 6600 m^3/s.

3.2 Design and construction of diversion weirs (solid structures)

The design of the weirs is determined by several factors, including high values of instantaneous flow discharge, unexpected arrival of the spate water, short duration of flood events, heavy bed and suspended load and large amounts of floating trash carried by the first wave. The weirs are mostly frontal type in plan and have a long spillway which provides for discharge of the excess water and floating material to the downstream side.

The intake part is a regulator which divides the stream into two layers, one passing through the higher level intake part of the regulator, the other into the lower level discharging part. This design allows better control of bed load deposition. On some weirs load transfer to the downstream side is enhanced by an artificially curved approach channel in the upstream side of the weir and the angle shaped sill of the regulator (figure 2).

The regulator has a system of gates for control of water intake to the main canal depending on availability of water in the wadi. Scour protection of the structure is ensured by proper bafflement on the spillway apron of the weir. The length of the stilling basin, depth of the downstream cutoff and the shape of the downstream floor are determined by specific discharge per one running metre of the weir crest length. Spillway apron underscouring of the downstream cutoff is prevented by arranging gabion matress or flexible reinforced concrete blocks with stone rip-rap. Such protection structures settle and go deep into the ground in case cut-off begins and prevent further degradation of weir. Considerable dissipation of the stream energy is achieved in the stilling basin by the use of an hydraulic cushion. All these measures provide for normal operation of the diversion structure and help to preserve natural stream conditions in the upstream and downstream areas of the wadi (figure 2).

Experience gained in the course of reconstruction. and development projects suggested some very effective de-

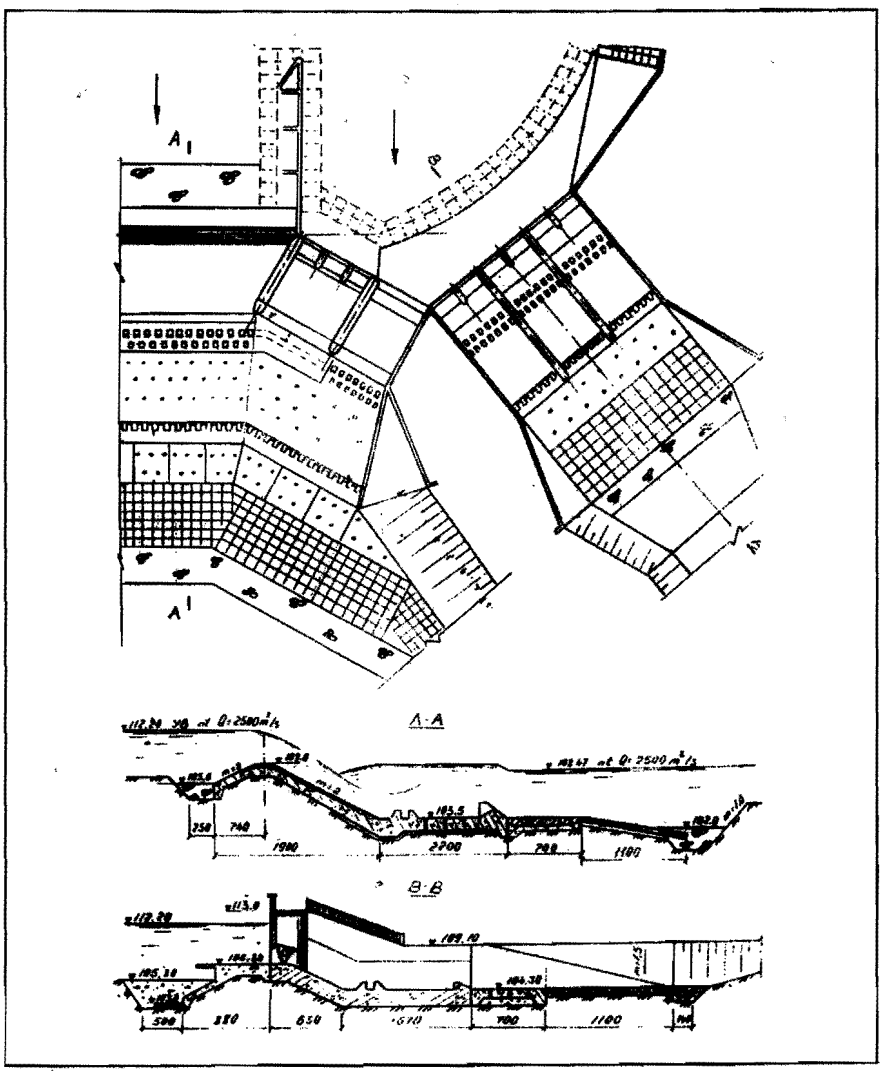

Figure 2 Batais weir on Wadi Bana

signs and new methods of erection suitable for local conditions. A good example is the Bateis weir on the Wadi Bana where the site chosen, designed and constructed in accordance with the terrain and geological conditions of the area. This diversion structure, capable of passing floods of 2 500 m^3/s, required less concrete and reinforced concrete material to build thus reducing the time and cost of construction. The design allows for flood discharges greater than 2500 m^3/s to overflow the crest of the earth embankment and breach it. The repair of such a breach is relatively quick and cheap.

Downstream of the Bateis weir on Wadi Bana where the wadi channel is wider, another kind of design has been adopted for a new Haija weir. Its spillway, directed obliquely relative to the stream from the beginning of its crest to the water intake, follows the slope of the wadi. Near the water intake where specific discharge per one running metre is 14.5 m^3/s a length of 170 metres of the weir is constructed of reinforced concrete. The remaining 312 metres of the weir is built of gabion work, for a specific discharge of 9.5 m^3/s.

The oblique spillway which follows the slope of the wadi improves the hydraulic parameters of the diversion structure. In a period of low discharge the whole of the stream is diverted to the intake. During floods with increasing discharge more and more excess water overflows the spillway crest. At the maximum discharge of 5000 m/s (flood event of 1 percent) excess water will overflow the whole length of the crest.

The design adopted here, together with bank protecting training spurs in the upstream and downstream channels, helps to keep the wadi in a stable course and directs the stream towards the lower spillway portion.

3.3 Weirless diversion works (improved ogmas)

Diversion structures without weirs can also be built to provide additional supplies of irrigation water to the fields during floods of high intensity/discharge. On the Wadi Rabwa, below Saba, a weirless diversion structure diverts flood water to the nearby areas; seven more similar structures are planned. They are low in cost and quick to build, particularly suitable for hilly terrain. The design incorporates reliable gates for water intake control and simple flushing devices such as applied for the Al Thalab intake structure under construction on Wadi Tuban.

4. Flood protection works

Severe wadi bank scour and stream bed degradation are often caused by high intensity floods. In the lower, wider flood plain the stream may change its course frequently,

leading to erosion of the banks and sometimes endangering neighbouring settlements. To prevent this training walls and protective spurs are built to channel the water. The length and number of such constructions are determined by each individual stream's regime. Such walls and spurs may be built of gabions with a concrete lining. A lining of reinforced concrete slabs with flexible joints is highly efficient.

Wadi bed degradation and bank scour is often worsened because bed. material. has been borrowed for construction. purposes elsewhere. Borrow pits in the wadi channel lower the bed elevations and affect the stability of the stream course along a considerable length of the wadi, necessitating the construction of protection and training works on a much larger scale.

Solid diversion structures also help to stabilize the wadi channels to a certain degree as well as to protect the banks against scouring. When they are built in conjunction with short protection spurs the damage caused by severe floods is reduced to a minimum. Wadi development projects therefore envisage the construction of protection and training works alongside solid diversion structures in an integrated system.

A distinguished wadi development project can be seen near Bateis village on the Wadi Bana where the construction of a diversion weir was carried out together with a considerable amount of work on bank protection near the village. Scour protection of the left side bank was ensured by using a reinforced concrete slab lining. with. flexible joints between. slabs. Major bank protection works have been undertaken on the Wadis Bana, Ahwar, Tuban, Rabwa and Beihan. However the total amount of bank erosion and wadi bed degradation protection works is not sufficient so far and greater effort will be needed in future to solve this problem on all the wadis of the PDRY.

Summary and conclusion

The country is irrigated by spate water covering about 70 percent of the cultivated area. So far there are no effective methods for collecting spate water in reservoirs or dams for irrigation. The diversion weirs and oqmas are the main structures for the diversion of flood water either through improved and properly constructed main canals or using existing traditional networks. Thirteen diversion weirs have been constructed and reconstructed on major wadis involving the construction of main canals. and irrigation networks and land levelling. These diversion weirs still need some improvement in their sediment control systems.

However, in most of the wadis, there are insufficient hydrological data to make a correct hydrological series and an adequate flow discharge curve for a given probability flood event. Recently much attention has been paid to improving hydrological observations.

In view of the shortage of land and water resources in the country much attention has been given in the long term wadi development programme to designing and constructing flood protection and river training works for the prevention of agricultural land erosion and to enhancing hydrological structures and good water management.

References

1. *Yemeni-Soviet study on Tuban - Rabwa - Ahwar*, 1983
2. *Design of Ahwar, Haija weirs*, Yemeni-Soviet Projects.