

traditional form of irrigation was highlighted. This exposed a range of constraints to spate irrigation improvement, which may be summarized as follows:

- a lack of sufficient data on spate hydrology to allow detailed analyses;
- the technical problems of dealing with destructive floods and high sediment loads;
- the high cost of permanent diversion weirs and flood protection works, which often cannot be justified by the tangible benefits;
- a general lack of knowledge of appropriate development concepts and the specific characteristics of spate irrigation and traditional water rights on the part of governments, donors and consultants;
- the lack of adequate provision for operation and maintenance after completion of wadi improvement works.

45. Government, for its part, is seriously constrained in its efforts to address the problems faced by spate irrigation farmers: the Soil Conservation and Irrigation Division of the MOA has a well trained and experienced group of technicians and engineers, but they are insufficient in numbers for the present needs of the country and lack exposure to recent developments in spate irrigation engineering.

IV. OPTIONS FOR FURTHER DEVELOPMENT

A. Dams or Spate Breakers

46. As mentioned, the major problems faced by farmers in traditional spate irrigation systems are those of control over the spate flows at the head of the system, the most obvious apparent solution to which is to provide storage. This would permit regulation of flows to the irrigable area to manageable levels, reducing the risk of expensive damage to diversion structures and headworks, and apparently permitting more efficient use of the available water resources, since little of the flow would be allowed to by-pass the irrigation scheme.

47. If this concept was accepted, one would then be left to decide whether a dam with storage reservoir should be constructed, with either a long main canal or diversion structures, or alternatively a spate breaker^{2/} with a series of diversion structures.

48. The construction of a storage reservoir on the wadi would provide a technically attractive means of regulating the highly variable spate flows, which typically are of short duration with very sharp peaks, into an almost perennial irrigation supply. However, the heavy sediment load carried by the

^{2/} A spate breaker is a dam of low storage capacity, compared with mean annual inflow, which provides temporary retention and attenuation of peak flows.

floods would cause a rapid loss of reservoir storage which, depending on the storage ratio^{8/} of the dam, would result in loss of its useful life in only a few years.

49. For example, studies in Yemen have shown that mean sediment concentrations in wadi flows can be of the order of 1.5% to 3% of mean annual inflow, by volume. At these rates of sedimentation a reservoir of capacity 10 Mm³ on Wadi Laba, which would require a major dam because of the steep slope of the wadi, would lose its entire storage capacity after only 6 to 13 years. Once the reservoir was silted up the wadi irrigation system would then revert to traditional methods of spate diversion.

50. Although a dam could initially command a larger irrigable area than that possible utilizing run-of-river spate flows, it would involve high capital investment costs per hectare, which, from experience elsewhere, would be difficult to justify in terms of the benefits to be gained, particularly in view of its very short economic life. Although spate breakers are generally less costly than major storage reservoirs, they have an even shorter life because of their characteristically low storage ratios, and are similarly difficult to justify.

51. A perennial or near perennial irrigation scheme would also require a new distribution network, since that developed for spate irrigation would be inappropriate because of the high bed losses involved. Such a system would be alien to the farmers' experience, and its operation and maintenance would require a complete change in traditional irrigation and agricultural practices. It could also lead to intensive rather than extensive use of land, when in fact water not land is the limiting resource.

52. It is therefore concluded that neither dams nor spate breakers are viable options for further development of spate irrigation in the project areas.

B. Groundwater Development

53. There is little or no groundwater abstraction in the project areas, other than that from a few scattered wells, used for drinking water. This contrasts sharply with wadis of the Saudi and Yemeni Tihama, where groundwater is widely developed for irrigation, albeit generally in small pockets, mainly for vegetable production by the private sector. Why there have not been similar developments in the project areas is not known: there is likely to be significant recharge to groundwater, as it is thought that little of the annual wadi flow actually reaches the sea. It may simply be that the private sector has not yet reached the stage, following so many years of conflict in the area, of considering investments in such ventures^{9/}, or it may be that the markets have not yet been developed.

^{8/} The storage ratio is the ratio of storage capacity to mean annual inflow. Thus a dam of capacity 1 Mm³ with mean annual inflow of 10 Mm³ would have a storage ratio of 0.10.

^{9/} One farmer interviewed at Sheeb declared an interest in irrigation from groundwater, for the production of dates, and was hoping for Government assistance in drilling a borehole.