Alternative Concepts of Water Storage in Spate Areas of Pakistan

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Spate Irrigation Network

Consultation paper Spate Irrigation

Introduction

Pakistan's Agricultural Economy and Integrated Land Use Systems

Agriculture sector currently contributes 21% to the Gross Domestic Product (GDP) of Pakistan and provides employment to over 40% of the labour force (GOP 2012a). About 60% of country's exports are directly or indirectly based on agricultural commodities and products. The country's geographical area is divided into 10 broad agro-ecological regions considering physiography as criteria of classification (PARC 1980). These regions are (Figure 1):

- Indus delta
- Southern irrigated plain
- Sandy deserts
- Northern irrigated plain
- Barani lands
- Wet mountains
- Northern dry mountains
- Western dry mountains
- Dry western plateau
- Sulaiman piedmont

Main limitation for development of agriculture is water, which is much more capital intensive than any other development. The sedimentation in multi-purpose storage reservoirs on the Indus Main, rivers and channels, erosion of soil, waterlogging, salinity, desertification and over-grazing are examples of unsustainable agricultural systems.

Pakistan's agricultural production system is complex because it consists of a mix of crops, fruit/forest plants, fodders, forages, livestock

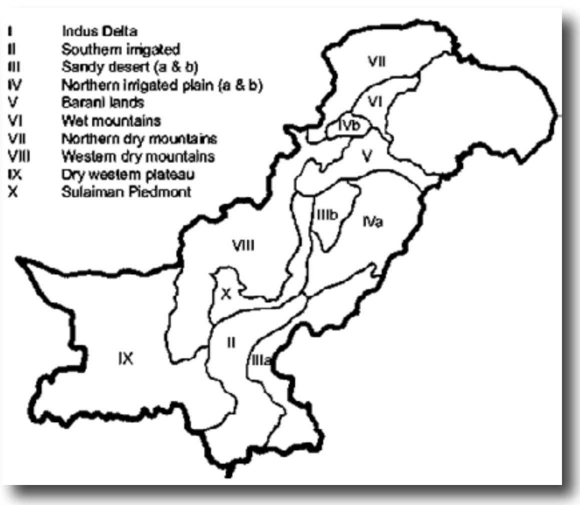


Figure 1. Broad agro-ecological regions of Pakistan (Source: PARC, Islamabad, Pakistan)

and freshwater fisheries – an integrated farming system. However, since last few decades there have been some changes in land use where focus has been largely on crops, fruits and vegetables. Four major cropping patterns are in practice, which include: rice-wheat, cotton-wheat, sugarcane-wheat and maize-wheat.

The cultivated area is classified as canal commands, tubewell commands, spate irrigation (Sailaba in Balochistan and Rod-Kohi in other provinces) and Barani (rainfed). Total culturable area is 23.57 million hectares (mha), whereas, 11.82 mha are under forage and forests. This makes 35.39 mha suitable for agriculture and forestry (GOP 2012b). Salinity is one of the major problems in the Indus basin irrigation system (IBIS). WAPDA (1981) surveys indicated that 26 and 39% area was affected by surface and profile salinity, respectively. Salinity refers to both soluble salts and sodium. However, if the presence of sodium exceeds the permissible limits, the soil is characterized either as sodic or as saline-sodic. Waterlogging is another problem affecting irrigated agriculture.

Within 100 years of the development of the IBIS, water table has risen from 40 m to within 3 m on about 42% of basin area. The situation was worst in Sindh where water table was within range of 3 m on about 57% of irrigated area. The high water table creates problem of oxygen deficiency, salt build-up in the soil profile and poor workability with soil (WAPDA 1986). The situation has improved after the persistent droughts and increase in groundwater abstraction since 1986. High water table in fresh groundwater zone provides facility for sub-irrigation. It also provides a source of water for irrigation through pumping. High water table is a problem in areas where groundwater is of poor quality (Ahmad 1982; Ahmad et al 1987; Ahmad 1991).

The IBIS can be regarded as the world's largest freshwater aquifer created due to inefficient irrigation system and practices and one can characterized it as a man-supported aquifer. This provides an adequate information and knowledge to develop man-supported aquifers in spate irrigated areas of Pakistan: a) Northern dry mountains; b) Sulaiman piedmont; c) Western dry mountains; and d) Dry western plateau.

Potential spate irrigation area is 2 million ha based but in reality it is much more as potential areas of 7 tribal agencies (FATA), frontier regions, AJK, ICT and GB are not included. Even the nonreported areas of the four provinces are also not included. Further, if water conveyance and application efficiency is improved and off-stream storage reservoirs are added for reliability, the current spate potential area can be doubled. Spate irrigation will be the future potential area for creating new livelihoods, and supporting the cause of addressing the issue of terrorism which is largely an effect of the lack of livelihood for the youth. The haphazard development of water and agriculture in the traditional context will not compete with earnings from smuggling and poppy cultivation in tribal areas and frontier regions.

Dams Outside the IBIS of Pakistan

Dams located outside the IBIS, especially constructed in the Barani and the spate irrigation farming systems to store floodwater are the focus of this study. Out of the total dams constructed in the country, only few dams are constructed off-stream to avoid sedimentation in the reservoir. The best examples are the Tanda Headworks and dam constructed in Khyber Pakhtunkhwa (KPK) and the Shabo Headworks and Water Tanks constructed in Balochistan's spate irrigation area.

Dams Classification as per ICOLD Criteria

According to the International Commission on Large Dams (ICOLD), total dams and reservoirs in Pakistan higher than 15 m (49 ft) height are 143 as per classification made by the Pakistan's Chapter of the ICOLD (ICOLD 2012a). Mirani Dam is the largest dam in the world in terms of volume for flood protection with a flood stock of 58.869 million m^3 constructed in the spate irrigation area, while Sabakzai Dam is 7th largest in the world with a flood stock of 2.364 million m^3 (ICOLD 2012b). According to ICOLD, dams with height above the foundation of greater than 15 m (49 ft) are known as large dams (ICOLD 2012c,d). Out of these 143, Mangla and Tarbela are the major dams as defined by ICOLD of dams having height of over 100 m. Thus 141 are large dams as classified by ICOLD but locally these are regarded as small and medium dams.

The distribution of large dams as per ICOLD between the heights of 15 to 100 m is presented for various provinces. There are four dams in Azad Jammu and Kashmir, 67 dams in Balochistan, nine dams in KPK and 50 dams in Punjab (GOP 2012c; Annexure-I).

In addition to these constructed dams, 32 small/ medium dams (over 15 m height) are either under construction or in the planning phase. WAPDA and provincial Irrigation Departments are responsible for constructing dams of over 15 m.

Objectives and TORs of the Study

This study was supported by the MetaMeta and the objectives are:

"Develop and promote alternative concepts for dam development on ephemeral rivers using innovative ideas of managing floodwater and sediments to maintain hydrological equilibrium".

At present several dam projects are under consideration on ephemeral rivers from the Suleiman and Khirther ranges – including the Nai Gauge Dam and several other small dams in all the four provinces. The development of these dams is undertaken without a longer term perspective and without looking at the value and potential of spate irrigation systems. The activities proposed for the study are:

- Review of several proposed projects – taking a medium- and long term perspectives – looking among others at long term sedimentation management, effect on groundwater, effect of flood management and changes to local river morphology, present and potential benefits of current uses (agriculture, livestock, others).
- Make a joint steering team with main organizations in dam development. Overview of on-going activities, compare with international practices (Yemen) and national best practices (i.e. Shabo Headworks in Balochistan; Tanda Headworks and dam in Kohat district of KPK, etc.), and propose cost-effective alternatives.
- The innovative options of underground geo-synthetic barriers will be investigated in a cascade system to enhance recharge and reduce peak and prolong duration of the flood.
- Conduct or review available case studies for the small dams constructed during last two decades and based on the SWOT analysis a strategy will be developed for integrated watershed management, reservoir operation, command area development and spate irrigation.

Situational Analysis and Key Issues

Selection of Site

In Pakistan most of the sites are initially selected either by the Small Dams Organizations in the provinces or WAPDA or by the local political leaders. The selected sites which are finally agreed are normally supported by the local political leaders and notables. There is no Master Plan for the development of small, medium and large dams (outside the IBIS) therefore scattered selection of sites affects the stream morphology and water rights of lower riparian. Further, scattered and isolated selection of site for these dams without considering traditional water rights of spate irrigation and/or other multiple uses of water affect current water users and their livelihood. This normally ends up with conflicts between water users of command area who are the direct beneficiaries and the upper and lower riparian.

Planning the Dam and the Command Area

The planning for the selected site is done largely by the Consultants without conducting adequate and precise consultations with the water users of the proposed command area, upper riparian and lower riparian. Usually quick and dirty appraisals are conducted normally using structured questionnaires, and indigenous knowledge and demands are hardly grafted with the baseline and socio-economic surveys.

The dams and canals are planned in the way this country use to construct irrigation system during the 19th century. The stored water provides an opportunity for planning irrigated agriculture on demand basis but small and medium dams are still designed for surface irrigation without developing the command area. The irrigation system is largely designed for deficit irrigation, as the designed cropping intensity is kept low to justify the cost per unit of command area.

Plans ones prepared are hardly shared with rural communities. So whatever the plans are made these are never agreed by the water users and thus result in conflicts once the construction of the dam is over. As stored water is also used for domestic and stockwater and these two functions are normally undertaken by women and their participation is almost non-existent. In addition, women also used canal water for washing clothes and kids used it for bathing, this aspect is also never integrated in the planning process.

Design of the Dam, Irrigation Network and the Command Area

The small and medium dams are normally designed for irrigation purposes and hydropower is produced only on streams having perennial flows like the Satpara dam in Skardu. The dams in the spate irrigation areas are designed for providing water for deficit irrigation with an objective to increase the command area so that the per unit cost of the construction of dam is justified.

How this is done, is very interesting. Let us take the example of the Gomal Zam dam which is being constructed on the Gomal Zam to provide perennial and non-perennial irrigation to the currently spate irrigated lands. Three levels of cropping intensity are taken as designed cropping intensity and the water requirement are estimated based on design cropping intensities. Three levels of cropping intensity used for the designing of the dam are 60, 100 and 120% per annum. This means that only 30, 50 and 60% of the command area under the three designed sub-commands will be irrigated in a year.

Command area in these dams does not mean anything as water provided to crop the area ranges from 30-60%. The average cropped area is 37% per annum for the Gomal Zam command. This means that in reality the actual command area is almost one-third of the designed command area. This is the trick used while justifying the cost.

The irrigation network is designed considering the designed cropping intensity and field irrigation efficiency of leveled fields. Assumption is taken that farmers will form their lands and they are also responsible for constructing earthen watercourses to transport water from the canals to the farms and the fields. This also created lot of problems as no technical knowledge and support is provided for designing earthen watercourses and field channels or designing farm layout for efficient surface irrigation. Resultantly, efficiency of field irrigation and watercourse conveyance is extremely poor.

The Small Dam's Organizations normally considers the cropping intensity as an indicator of the command area developed but in fact it is almost half of the cropping intensity. Cropping intensity by definition covers both the crop seasons and potentially it is 200% for two crops.

There is a need to reconsider the whole planning process if irrigated agriculture has to be developed cost-effectively and water productivity has to be enhanced.

Lack of Watershed Management

Watershed management is not an integral part of the projects related to small to large dams constructed outside the IBIS. The degraded watersheds contribute to the inflow of sediments to the reservoir. There are many factors which contribute to the sediment inflows to the reservoir but the experiences in Punjab indicated that there are dams which are still functional even after 50 years of the construction and most of these dams are medium dams and watersheds are located in medium to high rainfall zones i.e. the Rawal dam in Rawalpindi. In low rainfall regions, some of the dams after 20 years have lost their major part of the live storage capacity.

The basic reason why watershed management is not included in the dam's project is primarily due to the cost. But the impacts are very serious. If watershed management interventions are linked with income generation i.e. production of fuelwood, arid fruit plants and pastures then the investments in watershed management can be justified.

In-adequate Utilization of Storage Water for Aquatic Food Resources

In Punjab, the Department of Fisheries is responsible for auctioning the production of fish in the reservoirs and the contractors do not invest in the reservoirs' fisheries for higher productivity because their contract is only for three years. Longer terms contracts will motivate the contractors to invest in fish stocking and maintaining higher productivity. Aquatic food resources include only fish production and other options are never tried. Farmers around the periphery of the reservoir is not allowed or not motivated to introduce cage fish therefore the farmers who have lost their land in the reservoir or located in the watershed (upper riparian) have no opportunity for livelihood.

Planning for aquatic food resources is hardly done at the planning stage and after the commissioning of the dam the fish production assignment is handed over to the Fisheries Department.

Lack of Integration of Small Dams with Spate Irrigation

The small dams are not integrated with the existing spate irrigation system. For example, in the Mirani dam, before the construction of the dam large area was irrigated under spate irrigation i.e. over 100,000 acres. The dam is designed for a command area of 33,000 acres but in reality only 7,000 acres are currently being commanded due to lack of development of the command area.

Spate farmers outside the command area of the Mirani dam feel that they have been deprived because nothing has been done for them. The water stored in the reservoir and released for the command area use to be available to the spate farmers. Now the left-over spate farmers will get the water which will flow over the spillway during the flood period and will be available to the left-over spate farmers. Similarly, the Gomal Zam dam project has not included any intervention for the spate farmers, even though it was possible to provide them water during the flood period in especially designed spate water channels instead allowing water to flow into the river. Just an intervention of providing floodwater in a sustainable way to the left-over spate farmers would have resulted in increasing the area irrigated by spate flows.

The intervention is basically conceived as an alternate system of spate farming and thus a new class of command area farmers is emerged. The left-over spate farmers represent the deprived communities.

Slow Development from Barani and Spate Farming to Perennial Irrigated Agriculture – A Case Study of Punjab and KPK

The development from Barani or spate irrigated farming to dam's canal irrigated agriculture in the command area of non-major dams is slow in the provinces of Punjab, KPK and Balochistan, as the average cropping intensity is around 54% in Punjab (ranging from 20-99% for the seven dams) and 57% (23-132% for the six dams) in the KPK against an average designed cropping intensity of 120 and 100%, respectively. The wide variability in the cropping intensity needs an in-depth study to identify the reasons contributing to this huge variability, which might provide sustainable options for achieving higher intensity in the forthcoming projects.

The annual cropping intensity in seven dams of Punjab was 50, 54 and 59% during 2002-03, 2003-04 and 2004-05, respectively, indicating the minor temporal variability[1].

The reasons for slow development of irrigated agriculture in the small dams of Punjab and KPK are:

- strategy for design of small dams and irrigation networks was aimed to provide irrigation water for a cropping intensity of 70% in Rabi and 50% in Kharif (Punjab) with an objective to distribute water to a larger segment of the community[2]
- watercourse development below the Mogha (outlet) was left on the discretion of farmers against the provision of Sarkari Khal (public watercourse) provided in the Canal and Drainage Acts of Punjab and KPK
- farmers' field channels were also left to be constructed by the farmers
- some of the farmers' fields are higher than the water level in the canal coupled with undulating topography further restricted farmers for forming their lands for irrigation because it is difficult to dispose of the additional earth[3]
- the loss of top soil during land forming resulted in loss of soil productivity
- the current strategy does not consider enhancing water productivity as criteria for the design of irrigation network
- inadequate institutional and agricultural support services (input availability and disposal of the produce).

Other major reason for slow development of irrigated agriculture in small dams is further reduction in availability of water to farmers due to huge operational losses in the canal network, as result of deferred maintenance. This has adversely affected the water users especially at the tail-end reaches. The alternative design options for designing the irrigation network are hardly considered in the conduct of the Feasibility of Small Dams i.e. geo-synthetic lining of the canal and/or the pipe-flow irrigation system[4].

Another reason for slow development of irrigated agriculture in small dams is that farmers are not practicing the formal Warabandi in canals of small dams and in most of the cases they have evolved a schedule, which works and meet their requirement. The Warabandi institution is hardly utilized to organize formal Farmers' Organizations (FOs). The time available for water duration to small farmers, is so short (6-10 minutes per acre in the Jabbi dam under a rotation of 7 or 10 days), that they can't irrigate their fields on

1) *The cropping intensity was estimated for seven dams of the Islamabad Circle of the Punjab province (Qibla Bandi, Mirwal, Jabbi, Shahpur, Dhok Sanday Mar, Chhanni Bor, and Ratti Kassi) with a design command area of 10,503 acres (actual design area of Shahpur dam is used) having 31, 31 and 36% cropping intensity for the Rabi season and 19, 23 and 23% for the Kharif season during the years 2002-03, 2003-04 and 2004-05, respectively. The canal networks of these dams were designed to provide water under an irrigation strategy based on designed cropping intensity of 70% in the Rabi and 50% in the Kharif seasons.*

2) *The Small Dams Organization is not aware of the reasons of selecting the strategy for commanding 50-60% of the farm area. The farmers are also not aware of the irrigation strategy used for the design of the dam and the canal network. Thus, complete conversion from Barani to irrigated farming is not possible under the current strategy of commanding half-of-the-farm area. The information regarding economic models for alternative irrigation strategies for the small dams is not available in the Feasibility Reports. The only logical explanation is that the purpose is to keep the unit cost low to justify the economic benefits because the command area does not mean anything when the design cropping intensity is 100-120%.*

3) *The canal network currently in place is not effective in delivering water to the command area as the fields are either at higher elevation or there are conflicts among the water users served by a particular Mogha (Outlet) of the canal i.e. the Jabbi dam in the Attock district (Punjab) and the Tanda dam in the Kohat district (KPK). In the Tanda dam of the KPK, around 1500 acres are not commanded due to higher elevation of fields, which constitute around 5% of the designed command area.*

4) *The canal operational losses are around 50% of the designed discharge of the canal having direct impact on the availability of water to increase the cropping intensity or to meet crop water needs. In the Tanda dam of Kohat district, around 3000 acres are not getting water at the tail-end reaches of the Minor canals. In the Mirwal and Shahpur dams of the Attock district of Punjab, the canal operational losses are very high in the lined canals and tail-end reaches are receiving hardly 30% of the allocated discharge (Field Study of IWMI and WRRI-NARC 1995). Weed infestation and rodents are very common in the lined canals (open channels) of dams constructed in the last 20 years, primarily due to the deferred maintenance of the canal by the water users or by the department. The pipe-flow water delivery system is not tried in any of the dams already constructed or planned both in Punjab and KPK. The KPK is planning to provide pipe-flow irrigation system in the catchment areas for drip irrigation to raise plantations including fruit orchards – linking income generation with watershed management.*

a given turn. The alternative rotations of 14 or 21 or 28 days are never practiced to find a viable option for developing the formal Warabandi[5].

Low Productivity of Water/Non-remunerative Agriculture – A Case Study of Punjab and KPK

The low water productivity of canal command area is primarily due to inefficient application and use of water and low crop yields because of inappropriate production technology and imbalanced use of inputs (fertilizers, etc.)[6]. Farmers are mainly growing food grains and fodders – wheat, maize, sorghum, berseem, etc. The border/basin irrigation is practiced predominantly on un-levelled fields. Farmers are not practicing furrow irrigation and planting on beds, which can save up to 30% of water.

There is hardly any strategy formulated by the provincial governments to link water with productivity. Formal interdepartmental/agency cooperation is completely missing in linking water storage development with increased productivity. The OFWM and Agriculture Extension Services are hardly involved in the small dam's projects. The formal farmers' institutions do not exist.

Farmers are using pumps in the command area and around the periphery of the dam for domestic and irrigation purposes in Shahpur, Mirwal and Jabbi dams in Attock district of Punjab and having over 330 dugwells and tubewells in the Tanda dam in Kohat district. In these dams, the conjunctive use of water was possible due to the significant impacts of small dams in recharging the groundwater (Shahpur, Jabbi and Khai dams of Punjab and Tanda dam in KPK). But no one has tried to use sprinkler or drip irrigation even in certain dams' considerable pressure heads are available.

There is clear evidence in the small dams of Punjab and KPK, that groundwater recharge is an intangible benefit of the dam and it adds reliability in availability of water and improves water productivity, as farmers can operate their wells on demand. This has also led to sustainable production of high value vegetables and fruits in the command area i.e. off-season vegetables[7] and guava in the Tanda dam and citrus and vegetables in the Mirwal and Bhugtal dams. Tanda dam is now famous in KPK as garlic and guava ecology primarily due to the contribution of groundwater. The canal water availability from the dam is not reliable to encourage farmers to shift to high value vegetables and fruits. Thus water reliability of small dams is a serious concern and must be included in the criteria for designing of water allowance, cropping intensity and command area.

Forgone Benefits from Multiple Uses of Water – Freshwater Fisheries – A Case Study of Punjab and KPK

The Fisheries Department is responsible for raising fish in the reservoirs. Department assigns contracts for fish production and catch in the reservoir through open bidding for a period of three years. Contractor is responsible for adding fries into the pond and also for feeding the fish.

Contractors are of the opinion that three-years contract is not sufficient to have investment in fisheries. Punjab Fisheries Department is now thinking for extending the contract to seven years. The contractors also feel that it might be better if fisheries are responsibility of small dams or Water Users' Associations, as they are not getting any support from the Fisheries Department. They feel that they are better supported by the dam staff and the water users. This is an important aspect raised by the contractor that there are benefits of coordinated and a comprehensive strategy.

5) *There is hardly any formal Warabandi for canals of small dams and farmers are trying to practice some sort of arrangement, which help them to irrigate their lands. Water conflicts are common in the Punjab province compared to the KPK. The huge canal operational losses coupled with lack of formal Warabandi resulted in severe shortage of water at the tail-end reaches. Why farmers are hesitant to follow a formal Warabandi is that majority of the small-holders can't get benefit of the water turn, because the time allocated to them is inadequate to irrigate their land, therefore, they adjust their water turn with their fellow farmers. Thus small farmers might have water turn after two or three weeks.*

6) *The yields of wheat and maize are 2-3 and 1.5-2 tons/ha, respectively, whereas there is a potential to increase the wheat yield to 6 tons/ha and maize hybrid to at least 9 tons/ha.*

7) *The farmers in the command area of the Tanda dam have started growing early and off-season vegetables using the low-height plastic tunnels, where they are growing early Kharif vegetable seedlings by increasing the temperature and control of frost. During the spring season, they transplant these seedlings in the fields, when temperature is favourable for growth and there is no frost incidence. The vegetables commonly grown are cucumber, squashes, chillies, tomatoes, etc.*

The productivity of reservoir fisheries is extremely low primarily due to lack of competition among the contractors in the bidding process. The period of contract of three years was also a major reason for the contractor to practice low-input fisheries, as they are not confident that they will get return of their investment in short term contracts. There are no formal linkages between the Fisheries Department, farmers of the command area and the Small Dams Organization, which contributed in lack of competition among the contractors during the bidding process[8]. The role of the Fisheries Department is limited in the production of fish, as they are largely involved in assigning the contract to the contractors. The FOs or WUAs are not functional, and even they exist, they are not involved for the award of fisheries contracts to the contractors and no income is provided to the FOs/WUAs for the O&M of the irrigation network and watershed management in the catchment area[9].

The income from reservoir fisheries can be increased to a maximum of 10 times through awarding contracts by the FOs and through extension of community support to the contractors to raise and catch the fish and to provide favourable and secured environment to the contractors.

Farmers are not aware of freshwater fish culture and they are not utilizing the periphery of the dam for fish production, which is of high value intervention for the dams. Although, most of the farmers complain that water in the reservoir is not sufficient for irrigation purposes, therefore, they did not try traditional fish production technology because it is a water-intensive intervention. The cage fish production will consume negligible amount of water as cages can be put around the periphery of the reservoir and these cages can float with the inflow of water into the dam. Thus benefits of stored water can be expanded through the introduction of cage fisheries and farmers of the catchment area can be included as partners in distributing the benefits to farmers who have been excluded from the benefits of the command area.

The owners of mini dams (<15 m height) in Punjab were very successful in raising freshwater fisheries, where some of the dams have around 50 fish ponds. This is largely due to single ownership of the dam in relatively high rainfall areas.

Limited Operation and Maintenance Budget

The O&M budget is an issue as a whole in the public-sector institutions and thus Small Dams Organization is not an exception. The fluctuations in annual budget are considerable[10]. The O&M budget is hardly sufficient for any emergent repairs thus in reality routine O&M is deferred. The increase in O&M budget is not possible in the near future, therefore, alternate options have to be evaluated. One of the alternate options is to transfer the O&M of the canal network and watershed management to the FOs. The FOs rules and regulations under the PIDA and KIDA Acts authorize the FOs to collect the Abiana and to keep 40% of the Abiana and deposit 60% of the Abiana to the Area Water Board (AWB). In case of small dams, the Small Dams Organization can be restructured as an AWB, if there is a demand for reforms.

The active involvement of FOs is essential to have sustainable O&M of the canal network. For sustainability purposes, there is a need to have diversification in sources of revenues. The diversification is possible by extending the role of FOs in awarding contracts for reservoir fisheries and for entering into watershed management through the introduction of plantation economy (forest/fruit plantations). FOs may be allowed to collect and manage revenues from various sources as per laid rules and regulations of the FOs. However, there is a need to include revenues from various sources – Abiana, income from fisheries contracts and income from watershed plantations.

FOs have not only to be organized but they also have to be trained to improve their capacity for collection of Abiana, award of contracts for fisheries, organizing and managing plantations in the catchment area, book keeping, accounts and

8) *In the Qibla Bandi dam of the Attock district of Punjab, the contract for fishing was awarded at Rs. 250,000 per annum, whereas the net income by the contractor over a period of three years was around Rs. 4.5 million. The contract of fisheries in the Tanda dam is around Rs. 350,000 per annum and contractor is allowed to fish for two years and then one year as a rest period.*

9) *The FOs Rules and Regulations under the PIDA and KIDA Acts can be used to allow FOs to keep 40% of the revenues and deposit 60% of the revenues to the Small Dams Organization.*

10) *For the Tanda Dam of Kohat district of KPK, the annual O&M budget of the financial year of 2005-06 was around Rs. 1.0 million, which sometime even reduce to Rs. 0.5 million. The dam was constructed during 1967 with a cost of Rs. 564 million (US$ 118 million). The current price of the asset would be around Rs. 11.0 billion. Thus 0.1% cost for the O&M comes to Rs. 11.0 million.*

administration. After building capacity of FOs, O&M of canal network, fisheries contracts and management of watershed plantations can be transferred to FOs.

Non-conventional approaches have to be adopted, where representative of FOs and farmers have to be taken to locations where FOs are managing revenues in water and agriculture[11], so that they can personally interact with their fellow farmers and observe the success stories.

Need for Alternative and Innovative Approaches

Water Scarcity and Need for Storage

One-third of the developing world might face severe water shortages in the 21st century even though large amounts of water will continue to flow to the sea from the water-scarce regions (Figure 2). The problem is that the sporadic, spatial and temporal distribution of precipitation rarely coincides with the demand. Whether the demand is for natural processes or human needs, the only way water supply can match demand is through storage (Keller et al. 2000).

There are three common ways of storing water in: a) soil profile; b) aquifers; and c) reservoirs. Storage in the soil profile is extremely important for crop production, but it is relatively a short-term storage (Keller et al. 2000), but very much attractive to the Barani farmers as in-situ water storage is the only option for them. Similarly, the spate farmers also store water in the soil profile applying a deeper depth of water i.e. 1 to 1.5 m depth of water and one-irrigation before planting for seedbed preparation and 1-2 irrigations during crop production period can provide wheat yields of up to 4 tons/ha. It is also due to the nutrient-rich sediments flowing with floodwater which brought adequate nutrients and farmers hardly use any chemical fertilizers. Therefore, the IWMI recommendation of not storing water in soil is valid only where it can be stored in reservoir and in aquifer. IWMI basically recommended only two options of storing water in reservoirs or in aquifers. IWMI compared these two technologies from the hydrological, operational, and economic standpoints. Some of the environmental aspects of these options are also mentioned by IWMI, but these aspects are very location specific and complex.

Two principle conclusions of the IWMI analysis are: a) aquifers and reservoirs all serve an indispensable role in water storage, and each

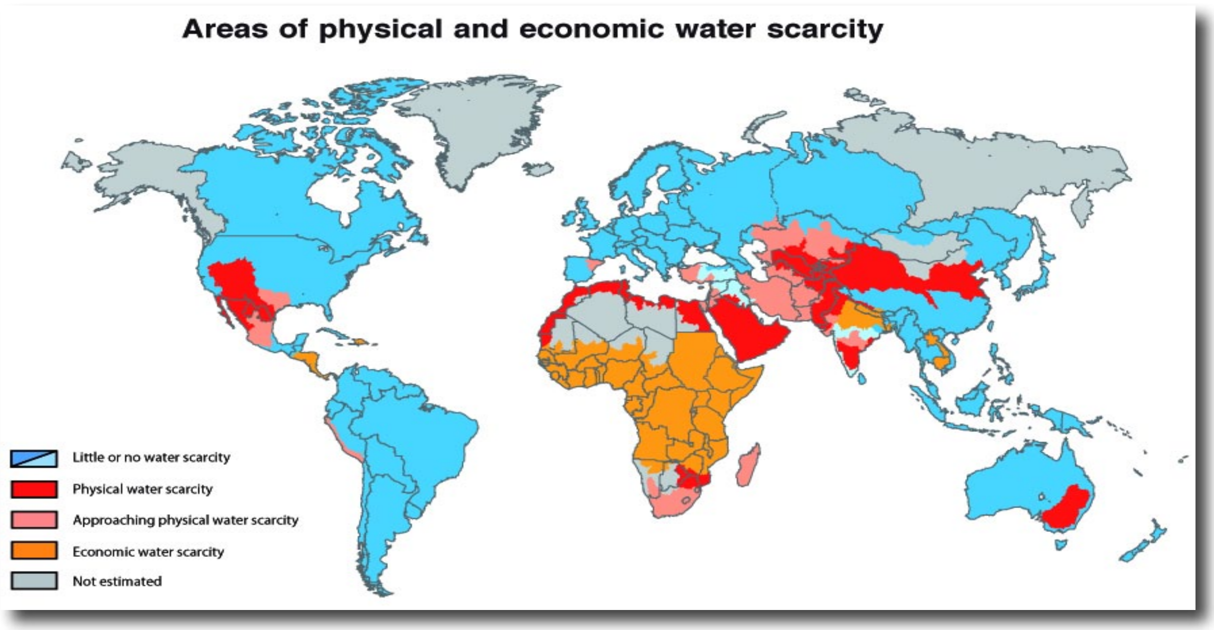


Figure 2. Areas of global physical and economic water scarcity (Source: Insights from the comprehensive assessement of water management in agriculture 2006)

11) *The Hakra 4-R distributary in Bahawalnagar, Potato and Vegetables Growers Association, Okara, and Malakand Fruit Growers Association, Swat are the examples of success, where farmers are managing the O&M of the projects and maintaining the accounts of the revenues successfully. Some of these initiatives were taken by the farmers without any involvement of the public-sector institutions – the Potato and Vegetables Growers Association of Okara in Punjab is one of the best example of an indigenous initiative without driven by donors' financed project. Their membership is extended to 100s of farmers and now the Association provide the potato and vegetables seeds, cold storage services, etc.*

technology has strong comparative advantages under specific conditions of time and place; and b) where it is possible to do so, substantial gains can be achieved by combining the two storage technologies in an integrated fashion (Keller et al. 2000).

IWMI further illustrated that all but the most optimistic scenarios, there is a dearth of freshwater storage. If climate change as a result of global warming manifests, the need for freshwater storage will become even more acute. Increasing storage through a combination of groundwater and reservoirs is critical to meet water requirement of the 21st century. This is especially so in monsoonal Asia and the developing countries in the tropics and semi-tropics (Keller et al. 2000).

The Challenge

There are two schools of thought. First School of Thought which supports the storage of water to address the issue of water scarcity and then taking the advantage of climate change over-emphasize that storages are required both in reservoirs and in aquifers. Second School of Thought is promoting indigenous water harvesting systems like spate irrigation, rainfed farming and runoff farming, in addition to groundwater recharge. Groundwater recharge is common to both. The first promotes it as an outcome of the inefficient irrigation – the school of thought brought the definition of global water efficiency. Second School of Thought promotes groundwater as a designed intervention and not as an effect of any cause – inefficiency leading to waterlogging and taken it as recharge.

The analysis of small and medium dams in Pakistan indicated that the economic returns were much lower than the expected and the benefits were foregone due to lack of full development of the command area and inflow of heavy sediments into the reservoirs. Furthermore, there were many conflicts among upper and lower riparian on water rights and allocations.

There is a need to develop an alternative and innovative approach for water storage and management so that "Productive and Water Secure spate and Barani Farming Systems" can be developed and sustained with an objective to have environmental water management on one hand, and to enhance existing and to create new livelihoods on the other hand, as unemployment and poverty are the major challenges being faced by the country. The benefits of investments should be equitably distributed to all the water users having water rights. Furthermore, planning has to be made considering all sources of water (precipitation, surface water and groundwater) and all sub-sectors of water use (agricultural, domestic, stockwater, etc.). The livelihood options should be based on an integrated land use covering aspects of:

- Landscaping watershed area for production of fuelwood, pastures, arid fruits, etc.
- Aquaculture in reservoir including reservoir fisheries, cage fish production on the periphery of the reservoir, aquatic food and flower plants, etc.
- High value and high efficiency irrigated agriculture in the command area
- Provision of floodwater to the left-over spate farmers whose lands will not fall in the command area, such developments have to be an integral part of the construction of the small dams
- Farmers' cooperatives and involvement of corporate sector in provision of services related to high-efficiency and high-value agriculture and aquaculture.

Alternative Concepts for Augmenting and Managing Water

Off-Stream Dams for Augmenting Water

Case Study of Shabo Headworks, Balochistan, Pakistan

The Shabo Headworks and Storage Tanks is the only scheme in Balochistan for spate irrigation, where off-stream storage tanks were constructed to minimize tank's sedimentation. The Shabo Headworks is located in the Pishin District at Longitude of 33018'N and Latitude of 30007'E. The scheme was constructed by the British Government in undivided India during 1888. The elevation of the location is 1587 m from mean sea level. Currently, the scheme is being operated by the Balochistan Irrigation Department and they are responsible for the routine O&M of the headworks, main canal, and storage tanks. Farmers are responsible for the secondary level irrigation system and field operations at the farm level.

The designed command area was 6,512 acres in 1888, out of which currently 2,171 acres are now under cultivation as tanks are silted and one is not functional. The cost of construction of this scheme was Rs. 104/ha or Rs. 42/acre at the price level of 1888. Length of the Main Canal is 38 km with design capacity of 7 m^3/sec (247 cusecs). Four storage tanks were constructed to store floodwater so that it is available for irrigation for longer duration.

The average cropping intensity of the scheme is 50 and 80% in Rabi and Kharif seasons, respectively, with an annual cropping intensity of 130%, which is reasonably high. Wheat, water melons, cumin and barley are grown. There are no reported conflicts between the water users as they can resolve their conflicts in a cooperative manner. There is no formal FO at the scheme level and the Department never tried to form such organizations. Farmers are managing secondary level system on their own.

The major findings of the Case Study of the Shabo Headworks are:

- Alternative concept of water storage, management and sustainable farming systems is available in Balochistan since the last 124 years and performed well in this period. But all the developments after that were largely done in a limited concept of developing the on-stream storage dams without planning and constructing these schemes in an integrated fashion.
- Reduction in command area was mainly due to the reason of deferred maintenance where tanks were not cleaned and water conveyance system was not managed adequately. There is no other example of weir-controlled gated water diversion system in the country which sustained so long on the ephemeral rivers. Even today 33% of the command area is still cultivated. This reduction is not only due to the deferred maintenance of the system because smuggling is now one of the major businesses of local people and agriculture has been neglected.
- Department of Agriculture could not introduce best practices for high efficiency and high value agriculture in the command area and next generation is involved in other ways of livelihood.
- The concept of managing sediments through off-stream diversion and storage worked well over a century and it can be tried in future projects especially in the regions where land is available for storage. Arid and semi-arid lands are most suitable for such type of systems.
- In future, such schemes can be designed in a comprehensive manner where water productivity should be the focus instead of the cropping intensity and/or the command area. The system can be operated in a semi-perennial mode and thus development of command area is essential so that light irrigations can be applied using furrow irrigation. For fruit orchards, drip irrigation can be introduced with additional sand filters to eliminate the sediments of the stored water.
- The ecology is suitable for fruits and vegetables and more area can be brought under semi-perennial irrigation system. However, cereals can be grown using floodwater, which can't be stored in the tanks. There is a need for conjunctive water use, where floodwater, stored water and shallow groundwater can all be used effectively.

Case Study of Tanda Dam Off-Stream Storage

Tanda dam is located in the district of Kohat in the KPK at longitude of 33°34'28"N and latitude of 71°23'11"E and was completed in 1967 as an off-stream dam. The live storage capacity is 99,000 acre-feet with culturable command area of 32,000 acres. The cost per acre at the time of construction was Rs. 17,640. It was built on Kohat's Toi River towards the Hangu district. In order to fill this dam, a 300 meters tunnel was built in the hills. It is a medium sized dam, aimed to generate electricity for the region and provide irrigation to a large command area.

Figures 3 and 4. Gated and un-gated weir controlled off-stream water diversion to water tanks

Tanda Dam serves as a main source of water for irrigation to the adjacent areas. It irrigates agricultural lands up to Dohda Sharif and Dharma to grow wheat, sugarcane and vegetables. Guava is one of the most famous fruit in the area and fetch premium price in the markets of Northern Pakistan. Tanda Dam is acclaimed for its landscape and its ecology. It has also been allocated as a Wetland site by the RAMSAR Convention. The dam is used for irrigation, fisheries and tourism. The major findings of the Case Study of the Tanda dam are:

- The off-stream storage helped in managing inflow of sediment load in water of the Tanda dam. One can see the blue colour of water, which is a clear indication of low level of suspended sediments. The dam has successfully worked for over 45 years and provides an excellent example of advantages of off-stream dams in arid and semi-arid regions.
- The cropping intensity is much more than the designed cropping intensity and some of the farmers are getting cropping intensity of over 200%. The higher cropping intensity is due to the use of groundwater, as the tail-end farmers are facing shortage of canal water.
- Fisheries production is relatively good and Department auction the contracts for fisheries. Fish of Tanda dam fetch higher price largely due to the freshwater fish of large size. Commercial varieties of fish are being produced in the reservoir.
- Tanda dam is a multi-purpose dam as it provides water for irrigation, hydropower, fisheries, and recharge to groundwater. Farmers of the command area have installed hundreds of dugwells or tubewells to meet their deficit in irrigation.
- Farmers work in a cooperative manner and they tried their level best to resolve conflicts but there is a lack of formal FO. Farmers are not getting any support from line departments for enhancing their water productivity or adoption of high-efficiency and high-value agriculture.

Sand Dams for Augmenting Groundwater and Creating New Aquifers – A Case Study of Sand Dams in Kenya

Sandy dams are basically designed to augment groundwater and at the same time these can be used for creating new aquifers especially in areas where water table is deep and these dams can provide shallow localized aquifers, which can be abstracted cost-effectively. These can be built at places having seasonal rivers with sandy sediments. Such conditions are found across the world's arid lands practicing spate or rainfed farming. However, currently around 150 sand dams per annum are being built worldwide, mainly in Kenya (Excellent 2012).

Conclusions of Case Studies

Two Case Studies concluded that both of these are examples of Innovative Options already available in the country. The Shabo Headworks in arid environment of the Pishin district, Balochistan and the Tanda dam in semi-arid and sub-humid environment of Kohat, KPK provide excellent options for off-stream storages to avoid sedimentation in the reservoir, groundwater recharge, fisheries and tourism. The Shabo headworks provide an opportunity for developing off-stream water reservoirs in the Spate ecologies of the country. These two sites can be used for the conduct of the training courses for the development of integrated and innovative concepts of off-stream water storage and multiple uses of stored water. The Government of Pakistan and the provincial governments may look into this option of making these two sites as Model schemes and training platform for the future.

Figure 5. Meeting with Spate farmers

Figure 6. Tanda dam and command area




Figures 7 to 10. Left to right: reservoir; spillway; and at bottom two view of irrigation canal of the Tanda dam, Kohat district of KPK.

The Messer Excellent Development, who is the pioneer of constructing sand dams in Africa, has the Mission to change this scenario and introduce this technology all around the world.

There are references to sand dams (or similar structures) in the Mediterranean region around 500 AD. They were also present in the 19th century in Mexico and USA and in the mid-20th century in India and Namibia. Isolated examples can be found in Yemen, Jordan, Japan, Turkey, Zambia, Burkino Faso, Ghana, Ethiopia, Somalia and Zimbabwe. The First Kenyan sand dam was built in 1950's. Afterward a significant increase in the number of sand dams built in Kenya was found between 1980 and 2010. Today around150 dams are being built per annum, of which 100 are in Kenya. The sand dams have recently been introduced into Mozambique, Ethiopia and Sudan. Sand dams are the world's lowest cost method of capturing runoff and floodwater in arid regions. Some of the basic characteristics are:

- Transform Barani and spate irrigation farming systems where sustainable livelihood is a challenge and farmers are facing difficulty in production of crops, livestock, fodders, etc.
- Provide year round water supply of relatively safe quality - something like a miracle.
- Provide: a) year-round water supply; b) time and money for schooling, agriculture and nutrition; and c) self-sufficiency for rural communities.

What is a sand dam?

Sand dam structure is basically masonry or reinforced concrete wall built in seasonal riverbeds to capture and store water beneath the sand, which will help in both filtering and protecting stored water. It is advisable to raise the dam in phases so that only sand is deposited upstream, otherwise high dams would allow deposition of silt along with sand. A small sand dam holds 2-10 million litres of water and is the lowest-cost runoff or floodwater harvesting solution based on the size of the dam and storage capacity (Figures 11 and 12).

How does a sand dam works?

Seasonal rains quickly fill the reservoir with water and sediments.

- The sediments based on texture are characterised as clay, silt, sand and gravel.
- The gravel and heavier sand sinks behind the dam, whilst the lighter silt washes downstream and clay particles take longer time to settle – this is a common phenomenon in the upstream areas where coarse materials deposit first and fines deposit later in the downstream having low gradient.

The gravel and sand particles accumulate until the reservoir is completely full of gravel and sand up to the spillway.

Figures 11 and 12. Stone masonry structure in the dry river bed for the sand dam

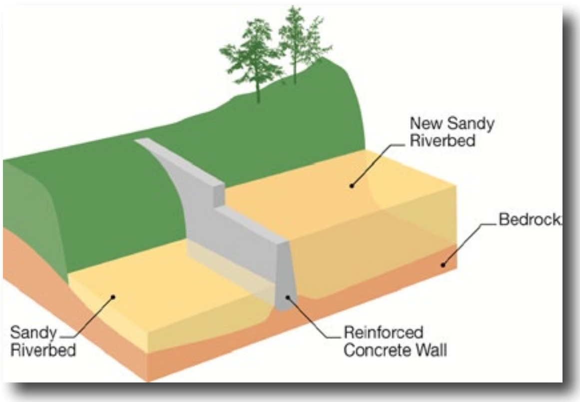
- Water is stored within the sand making up 25-40% of the total volume of the reservoir based on the porosity of the fill material.
- The studies conducted in Kenya indicated that small sand dams store less than 10 million litres of water depending on the particle size of sand and size of the reservoir. In reality, the storage capacity of the reservoir would depend on the site-specific conditions, area and height of the dam.

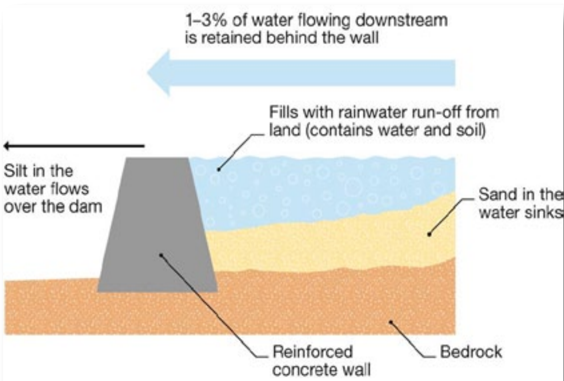
Getting Water from Sand Dams

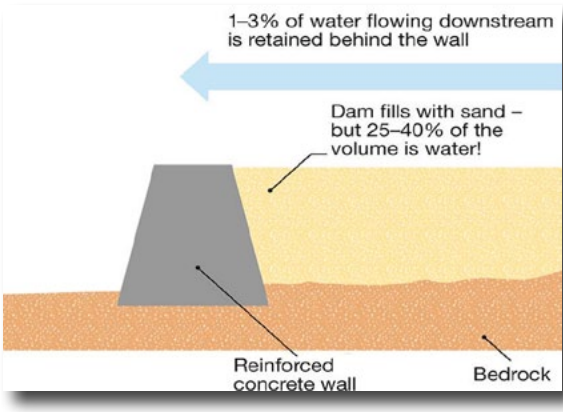
There are three ways to abstract water from the sand dams. The community decides on the most appropriate option for them.

The benefits of sand dams are:

- Surface evaporation is reduced to a bare minimum when water is stored in the pore spaces of gravel and sand matrix.
- The mix of gravel and sand also filters the water clean and protects it from parasite carriers such as mosquitoes and snails. Furthermore, there is no growth of aquatic weeds which are common in shallow reservoirs and ponds in spate irrigation areas of Pakistan.
- Storage of water in sand fill material reduces considerably the incidence of diseases in children of less than 5 years of age - malaria and diarrhoea.
-







Figures 13 to 16. Process of sand accumulation and water storage in the sand dam

Figure 17 to 20. Methods of acquiring water: scoop holes, pipe filtration and shallow dugwells

Sand dams improve water supplies

- A small sand dam creates a local, reliable, clean water supply system adequate for provision of water up to 1,000 people over a span of 50 years based on the Kenyan experience but it will vary from location to location and demand of the community for multiple uses.
- A small sand dam stores less than 10 million litres of water each season and recharges naturally based on Kenyan experience but it is site-specific and based on the demand.
- Held below the sand, water is prevented from evaporation.
- A sand dam provides enough water for people to drink, water their animals, and irrigate their high value vegetables and fruits.

Figures 21. Stored water use for vegetables

A sand dam provides 1 person with clean water for life, for just US$ 15, based on the typical sand dam in Kenya costing US$ 15,000 and providing water for 1,000 people (Excellent Development 2012).

Sand dams enable food production

- Sand dams save farmers 2-12 hours every day in Kenya. In Pakistan as women is involved in domestic water, stockwater and washing clothes so their time will be saved and drudgery is reduced from their daily life.
- Time saved can be used for activities to initiate income generation activities.

Sand dams benefit health & incomes

- Mosquitoes cannot breed in water stored in the sand, thus reducing the incidence of malaria. Moreover, water can be stored under relatively better hygienic conditions in the sand matrix so it will also reduce the incidence of diarrhoea.
- Snails carrying the bilharzias virus cannot survive – dramatically reducing the risk of diarrhoea.
- Animals cannot contaminate water, which is a serious issue in surface ponds, where human and livestock drink from same pond and women wash clothes on the banks of these ponds and effluents are disposed back to the

Figure 22. Marketing agri-products

pond. This situation prevails in spate irrigation areas of Pakistan and thus sand dam is one of the most suitable and cost-effective options where surface water is used for drinking purposes.
- Income generated from the marketing of vegetables and other commodities and products.

Impacts of reliable and clean supply of water
- Diets improve as farmers have time to improve productivity and production; and diversify crops, especially input of vegetables in their diets add vitamins and minerals.
- Incomes improve as people have time to spend on livelihoods.

The UN estimates that every US$1 invested in water supply in developing countries delivers US$6 in increased incomes, health and education benefits (Asia Waterwatch 2005).

Sand dams transform the environment
- Sand dams raise water table both in the upstream and downstream of the dam thus provides sustainable adaptation for drought if cascade is built.
- Biodiversity improves, as trees and indigenous species are able to thrive.
- Very little amount of water flowing downstream is captured by the sand dams meaning water is not diverted away from downstream users.
- Sand dams reduce flood risks by reducing the flood peak and spread the duration of the flood. It increases downstream baseflow during the dry seasons – creating added benefit for downstream users.

Sand dams offer excellent value for money
- Sand dams are the world's lowest-cost method of capturing floodwater in arid and semi-arid lands and for rural communities.
- Sand dams recharge naturally every season Rabi or Kharif or with any rain storm contribute to runoff or floodwater, storing water year round in small sand dams.
- Sand dams are built to last over 50 years with no operational costs and require little or no maintenance.

Technology and cost per 1,000 litres as experienced in Kenya by Excellent Development presented in Table 1.

Figure 23. Downstream view of a sand dam in the Ilikoni Valley, Kenya.

Technology	Costs (USD/1,000 l)
Sand and subsurface dams	0.6 - 1.2
Runoff open reservoirs	2.7 - 4.5
Underground tanks	3.6 - 21.0
Above ground tanks	27 - 96.0

Table 1. Technology and cost of water

Table 1 shows that the cost of both the sand and sub-surface dams is the lowest among other interventions compared in Kenya. In addition, the cost of environmental improvement and reduction in the cost of treating water for drinking purposes is much less or non-existent for the sand and sub-surface dams. This is one of the major concerns in Pakistan, where in spate ecologies rural communities are still using water of surface ponds for multiple uses.

The potential for sand dams

Potentials of sand dams, in general terms, are:

- 40% of the world's land is classified as arid having no facility for irrigated agriculture or sometime named as drylands;
- 2.3 billion people live in the drylands;
- 80% of the world's poor rely on dryland resources'
- 44% of the world's food is produced in drylands (UNDP 2012)
- Sand dams can be built anywhere where there are seasonal rivers with sandy sediment, conditions that are found across the world's 'drylands'. In Pakistan these areas are located in all the four provinces, FATA, AJK, ICT, GB, etc.
- However currently around 150 sand dams are being built per year worldwide, mainly in Kenya. Excellent Development is committed to change this situation and interested to introduce this technology all around the world especially in the arid and semi-arid regions where water is at premium.

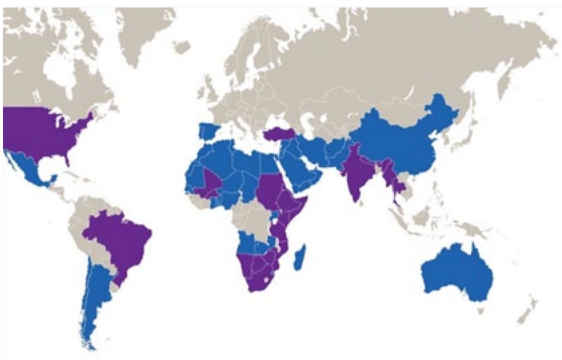


Figure 24. Mauve colour represents countries having sand dams already being constructed. Blue colour represents countries with regions suited to sand dams.

The spatial distribution of the global situation, where sand dams are being built and the locations suited for the construction of sand dams in future are presented in Figure 24. Pakistan is characterised as an area by the Excellent 2012 which is suitable for the construction of sand dams or similar structures. Even the concept can be used to suit Pakistan's specific requirement.

How to build a sand dam

The methodology presented by Excellent Development is reproduced:

a. Community identifies 3 or more potential sites that meet their needs
b. Optimum site selected, design completed and materials quantified
c. Community collects rocks, sand and water and land above dam site terraced
d. Legal agreements with adjacent land owners signed
e. Excavation of river sediment to bedrock for building foundation of sand dam
f. Weathered rock removed and fissures sealed with mortar
g. Infiltration gallery constructed upstream of dam connected to piped outlet or pump
h. Timber formwork erected
i. Vertical steel reinforcement bars drilled into bedrock
j. Stone masonry (rocks bonded by sand and cement mortar placed in the formwork)
k. Horizontal lines of barbed wire every 30 cm binds the steel bars and rocks
l. Formwork removed after one day and dam watered morning and evening for 30 days to cure the cement

The major findings of the Case Study of sand dams are:

- Technology of sand dams is environment-friendly, cost-effective and healthy for storing and utilization of clean and relatively safe water, because sand reservoir will work as a natural filter and water can be harnessed through dugwell, infiltration galleries or pumps which can be protected from pollution. Small pumping systems can be installed using multi-filter technology, where filters will be placed horizontally to harvest the thin layer of water under drought conditions. Deep filters can be designed to harness all the stored water using sand and gravel.

- System life will be longer and water can be used for multiple purposes. For domestic, stockwater and industrial uses, dugwells and small multi-filter pumps can be used, whereas infiltration galleries would be required for harvesting water for agricultural purposes.
- As dugwell, low-discharge multi-filter pumping systems and infiltration galleries are essential part of sand dam systems, therefore innovative options for the three water harnessing technologies have to be evaluated and described fully. This is done in the subsequent sections.
- The surface water reservoirs and ponds which are now used in the spate irrigated areas and in other arid regions of Pakistan, it is very difficult to avoid infestation of aquatic weeds due to shallow depth of water in the reservoirs. Evaporation also becomes significant in shallow water depth ponds or reservoirs. These ponds provide water for a period of 4-5 months and then communities have to travel longer distances in search of water. Maintaining quality and keeping animals away from these ponds is an impossible task i.e. ponds in Barkhan, Musa Khel and D. I. Khan. Sand dams provide an opportunity to maintain the quality of stored water and to avoid any sort of aquatic weeds. As animals can't see water on the surface so there is hardly any chance for entering urine and faeces of animals in to the water reservoirs.
- Technology can be adapted to all sorts of physiographic, topographic and hydrological conditions.
- There is no or very insignificant O&M cost of sand dams and the rural communities or their organizations can easily managed these systems and no institutional support is needed from the public-sector except regulating these systems so that everyone is benefitted from these investments.
- Sand dams perform perfectly where there is bed rock at a depth of 5-10 m. If there is no complete barrier to seepage, the seepage losses will help to recharge the groundwater. The base flow even in the dry season will contribute to recharge the sand dam or recharge the natural aquifer. However, in situations where underground hard-rock barriers are not available a Cascade of sand dams would be more effective in recharging the groundwater.
- Even it is possible to develop new shallow aquifers by recharging the area and supported development of new aquifers. The benefits are larger to create shallow aquifers because water from shallow aquifers can be pumped cost-effectively. Furthermore, the new aquifers will bring wastelands under cultivation and will provide new livelihood sources which are rather a high priority development objective to provide livelihood to un-employed youth.

Sub-surface Dams for Augmenting Groundwater

What are Sub-surface Dams?
Sub-surface dams are structures that intercept or obstruct the natural flow of groundwater and provide storage of groundwater. They have been used in several parts of the world, notably India, Africa and Brazil. They are used in areas where flows of groundwater vary considerably during the course of the year, from very high flows following rain to negligible flows during the dry season. Groundwater dams can be divided in two types: subsurface dams and sand storage dams.

A sub-surface dam intercepts or obstructs the flow of an aquifer and reduces the variation of the level of the groundwater table upstream of the dam. It is built entirely under the ground (Figure 25). However, the PE or PP plastic liners are now available to use as underground barriers instead of constructing high-cost concrete or masonry structures – that is an option for Pakistan.

A sand storage dam is constructed above the ground surface. Gravel and sand particles transported during periods of high flow are allowed to deposit in front of the dam, and water is stored in these deposits (Figure 26).

The sand storage dam is constructed in layers to allow sand to be deposited and finer materials be washed downstream. Further this will phase out the cost of construction and structure will get stable once it is formed in layers.

A groundwater dam can also be a combination of these two types. When constructing a sub-surface dam in a river bed, one can increase the storage volume by letting the dam wall rise over the surface, thus causing additional accumulation of sediments. Similarly, when a sand storage dam is constructed it is necessary to excavate a trench in the sand bed in order to reach bedrock, which can be used to create a sub-surface dam too (Figure 27).

Groundwater dams are built across streams or valleys. A trench is dug across the valley or stream, reaching to the bedrock or other stable layer like clay.

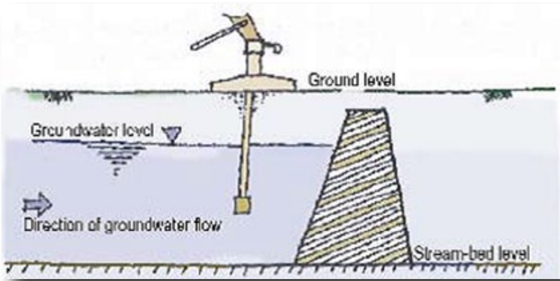


Figure 25. Sub-surface dam for new aquifer

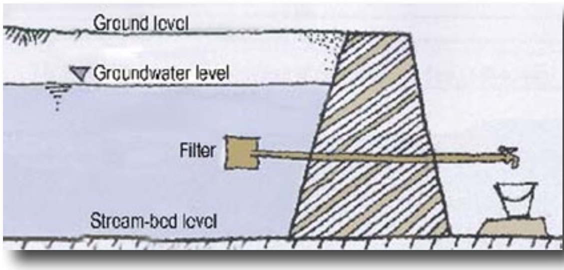


Figure 26. Sand dam to develop new aquifer

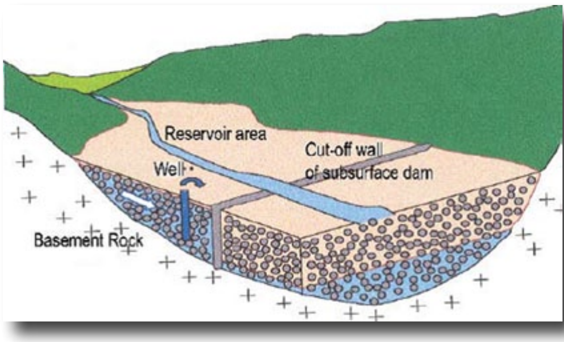


Figure 27. Schematic conceptual view of the sub-surface dam

An impervious wall is constructed in the trench, which is then refilled with the excavated material.

A sub-surface dam is constructed below ground level and arrests the flow in a natural aquifer. The best sites for construction of groundwater dams are those where the soil consists of sands and gravel, with rock or an impermeable layer at a few metres' depth. Ideally, the dam should be built there where rainwater from a large catchment area flows through a narrow passage.

The optimum zone for constructing a sand-storage dam is generally found on gentle slopes in the transition zone between hills and plains. Finding suitable places to build the dam is harder when the river is wider. In view of an efficient reservoir it is important that it is based upon impermeable beds or bedrock is underlying the reservoir. In general the topographical gradient of the construction sites is between 0.2-4 %, but in extreme cases slopes of 10-16 % have been used (Nilsson 1988). Thus there is large range of slopes which can be utilized. The only adjustment needed is to build cascade system for lands with steep slopes.

Underground reservoirs in sand-rivers are principally recharged by flash floods, which originate in catchment areas with higher elevation. A single and short-lived flash flood may fully recharge a reservoir with water. Upon full saturation of the reservoir, the remaining flash floods will pass over the dam without further infiltration, replenishing aquifers downstream. For the wider rivers, costly structures can be avoided and PP or PE liners can be used for underground barriers because water is not only needed in the mountains but it is also needed in the plains. Rather a cascade of such plastic liner barriers can have larger impacts in restricting the base flow or groundwater flows.

A few hours after the passing of a flash flood, the surface of the sand-river may look dry again, but the water which in the meantime has been stored in the reservoir can be drawn for many months. In subsurface dams water may be obtained from the underground reservoir from a well upstream of the dam. The subsurface dam technology is designed to block underground water flow at shallow depth, so that traditional watering points will be lasting longer and new watering points will be created to develop unused grazing areas.

Advantages and Dis-advantages of Sub-surface Dams

The basic principle of the groundwater dam is that instead of storing the water in surface reservoirs, water is stored underground. It is composed of a cut-off wall by which the groundwater flow is dammed (or intrusion of the seawater is prevented), and facilities (like wells, intake shaft and pumps) that draw up the stored groundwater.

Advantages

- Water storage in groundwater dams offers as a major advantage that evaporation losses are much less for water stored underground. Since the subsurface dam suffers virtually no loss of stored water from evaporation, it is more advantageous than the surface dam in dry regions.
- Evaporation is confined to the upper layer of a sand reservoir. As the water sinks, the evaporation reduces and even completely stops, when the water level sinks to about 60 cm below the sand surface.
- Risk of contamination of the stored water from the surface is reduced because parasites cannot breed in underground water.

Contamination of water by insects and animals cannot take place because water is not visible at the sand's surface. Health hazards such as mosquito breeding are avoided.

- The problem of submergence of land, which is normally associated with surface dams, is not present with subsurface dams. There is no danger of breaching disasters. The surface area can be used in the same way before and after the construction of the subsurface dams. Normally, with no submergence of the reservoir area involved, subsurface dam development does not interfere with current land use.
- It has only minimal social impact (for example, it does not entail the relocation of residents) and its impact on the ecosystem is minimal as well.
- Silting is not a problem for groundwater dams, in contrast to surface dams, which would silt up quickly. Unlike the surface dam, it does not suffer from a reduction of storage space due to accumulation of sediments.
- The absence of surface structures does not obstruct the flow of water and materials. It also allows migration and interaction of living creatures. Since the cut-off wall, buried underground, is not likely to corrode or deteriorate, the function of the subsurface dam is almost permanently maintained.
- Technology is preferred by the community for several reasons: it increases the capacity of traditional wells, it is simple and less expensive to construct, replicable and easily maintainable by the community.
- Further it causes less contamination of water and a temporary availability of water avoids attracting permanent human settlement. Maintenance is simple. Construction costs are relatively low, especially after the development of geo-synthetic liners, which are cost-effective and easy to install.

Disadvantages

- Since the utilization of stored groundwater in a sub-surface dam requires pumping, operating costs are higher than those of a surface dam. The size of the voids between the solids of sand determines the capacity of the basin. When the particle size is small, only 5% of the water can be extracted. But the surface dams may require pumping of water as in certain cases command area is at higher elevation.

- Survey, design and construction processes require trained persons to avoid possible failures. Strict control of subsurface dam water is difficult because water can easily been stolen, simply by digging a well. To prevent such practices, agreements must be made on land use and economic activities in the sub-surface dam reservoir area, and concerned parties must develop morals to protect water resource but it is also true in the surface dam. Therefore, it is not a serious disadvantage.

Difference between Sub-surface and Sand dams

The general principles of sand storage dams and sub-surface dams are similar. In general, sand storage dams are used when the topographical gradient is high and subsurface dams are used when the topographical gradient is low. Therefore a combination of these two systems would provide appropriate option of cascade of dams for the stream emerging from highlands and feeding to the plains.

If the impervious layer lies near the surface, the storage capacity of the basin will be low. A sand storage dam will enlarge the storage, while a subsurface dam only uses the storage capacity under the surface. When the river is narrow and has high embankments, the storage capacity of a sand storage dam can easily be enlarged.

The embankments give a good anchoring possibility. An advantage of sub-surface dams over sand storage dams is their simple design. Water does not flow through the dam and no spillway is needed. Unlike a sand storage dam, a subsurface dam is not exposed to forces of flowing water. It is clear that different circumstances ask for different solutions or combination of two technologies.

Figure 28. Dam under construction

Dugwells for Abstracting Water from Sand or Sub-surface Dams

Traditional and most common method of harnessing water from groundwater in rural areas of the developing world is by dugwells (Water Aid 2008). In contrast to surface water, groundwater is usually of higher quality. Although technical equipment could support the construction of a dugwell, excavation is mostly done manually as many rural regions offer cheap labour and lack adequate technical resources.

The basic principle is rather straightforward: with the prior knowledge that groundwater is present and not too deep, a hole is dug until the groundwater level is reached. Inflowing groundwater is collected and can be extracted with the help of pump. Depths of dugwell range from shallow (about 5 m in depth) to deep dugwells (over 20 m in depth). An excavation of about 1.5 m in diameter provides adequate working space for the diggers and will allow a final internal diameter of about 1.2 m after the well has been lined (Water Aid 2008). Dugwells of more than 15 m in diameter are used in areas having limited well yield due to reduced hydraulic conductivity. One may check the availability of pre-cast rings diameter before finalizing the digging diameter of the well.

The performance of the well in terms of quantity is largely determined by the aquifer characteristics (i.e. the porosity), by the diameter and depth of the well. Wells with a large diameter and depth expose a greater area for infiltration, and therefore provide fast recharge, e.g. an aquifer of 2 m in depth and a well with 1.3 m diameter will expose 8.2 m^2 for infiltration of water, while a 150 mm diameter drilled hole only exposes 1 m^2 (Collins 2000).

Initial Assessment of Design
Before starting to design a dugwell, an initial assessment should be conducted to effectively and efficiently develop and manage the dugwells.

Figure 29. Construction of dugwell

This assessment includes analysis of water demand and availability of groundwater based on aquifer characteristics. Eventually, this assessment can lead to cost-effective development of dugwells considering the utilization for multiple purposes.

Pre-requisites of Design
Before constructing a dugwell, geological suitability of the area, acceptance within the community and the capability of O&M of the system have to be assessed.

A thorough investigation of the area should be conducted to determine:

- Existence of an aquifer or alternatively, dry riverbeds may provide a water source during dry-season (Nissen-Petersen 1997; Nissen-Petersen 2006).
- The information related to depth to water level and depth of water column is needed to meet the requirement of water required in volumetric terms.
- The quantity of available water and possibility of future recharge potential
- The quality of shallow groundwater because in areas where sewage is disposed through septic tank system quality of shallow groundwater is not safe for drinking
- The range of technically feasible options for the construction (Collins 2000) for a complete list of criteria.

Villagers and members of the neighbouring communities who have already installed the dugwells can be a good source of information on the presence of shallow groundwater by collecting data of depth to water level. Also, certain types of vegetation can indicate presence of groundwater (Collins 2000). Often, existing wells in close proximity indicate the presence of groundwater. If technical equipment for installing hand pump is available, test borings can give detailed information on the groundwater level.

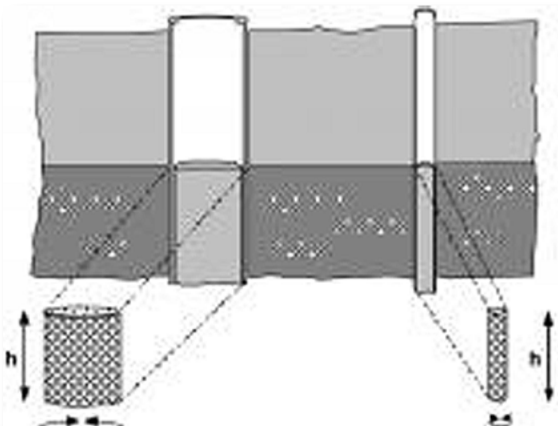


Figure 30. Exposed area to stored water

Furthermore, in Pakistan water diviners performs quite reasonably about the availability of groundwater and they can identify a point where water is relatively in easy access and quantity. The author tried this technique with the electrical resistivity and the report of water diviner was correct. Water diviner was of the view that water is shallow whereas the electrical resistivity indicated depth to water level of around 140 feet. In fact during construction water was found at the depth of 20 feet and in reasonable quantity.

Elements of a Dug Well
A dugwell consists of three major components (Collins 2000; Smet and Wijk 2002):

- Well head: Part of the well, which is visible from the ground surface. It protects the well from contamination and generally consists of a well cover or apron, a concrete seal, a manhole (for access), a drainage channel and a pump.
- Well shaft: Section of the well between the head and the intake. It is made out of a strong, durable material, which can easily be kept clean.
- Intake: Walls of the intake are constructed in such a way as to allow water to pass from the aquifer into the well, thus creating a storage area, which can be accessed by pump. Currently pre-cast concrete rings are cost-effective and easy to install. The brick or stone masonry is difficult as skilled labour is hard to find.

Construction
Skilled workers, who are solely involved in the digging profession, are required for construction purposes. During or after excavation, a permanent lining needs to be installed unless the well is constructed in rock formations. The lining serves several purposes: a) during construction, it provides protection against caving and collapse; and b) prevents crumbling ground from filling up the dug hole.

After completion of the well it retains the walls (Smet and Wijk 2002). Although a wide range of construction methods and materials can be used, mostly it is recommended to use circular precast concrete “rings”. In very soft formations, the rings are sunk starting from the surface: a) digging from the inside of the ring; b) removing the material with a bucket and adding new rings as required. In harder, semi-consolidated formations, the rings can also be inlaid after having excavated the hole completely until the groundwater level (UNICEF 1999).

Regardless of the method that has been used to excavate the well to the water table, excavation below this level should never be attempted until the sides of the excavation have received the support of a permanent lining. Excavation below the water table should be carried out within precast concrete caisson rings of a smaller diameter than the rest of the well (Water Aid 2008). In most cases, a pump is required for dewatering to allow excavation below the water table (UNICEF 1999).

The section of the well penetrating the aquifer requires a lining with openings or perforations enabling the groundwater to flow into the well (Smet and Wijk 2002). In formations with fine sand or silt particles, a filter at the bottom of the finished well is often necessary to prevent particles to enter and clog the well. Usually, the filter is made out of a layer of gravel and coarse sand or a porous concrete plug (UNICEF 1999). The important points to be considered during construction are: a) in the impervious formation there is a need to put the concrete lining; and b)

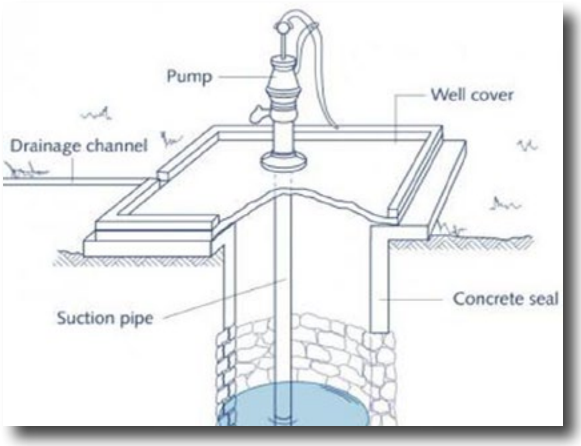


Figure 31. Elements of dugwell

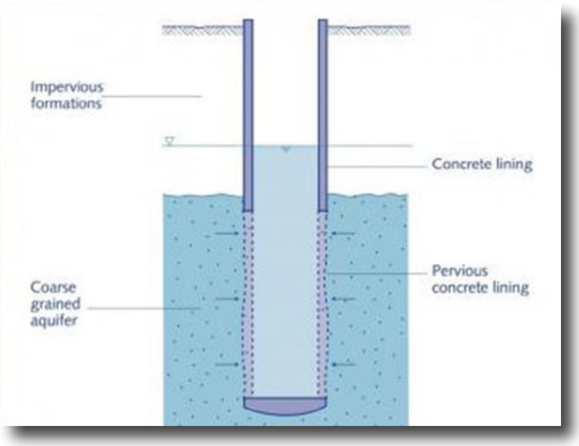


Figure 32. Dugwell in coarse granular material (Smet and Wijk 2002)

in the coarse grained aquifer there is a need to have pervious concrete lining so that well yield is reasonable.

Safety Issues

Depending on the strata, excavation can be very dangerous. Safety regulations must be strictly followed. Wells safely dug during the dry season may become unstable when the water level rises in the wet season and therefore must be lined in time to prevent a collapse (Water Aid 2008).

Disinfection: During the construction phase, the well will become contaminated due to labourers standing inside and debris and organic material falling inside. Upon completion of the well, but before any water is collected and used, a disinfection of the well (e.g. with chlorine) must be carried out (Collins 2000).

Protection: Most dugwells are highly exposed to contamination, making protection of the groundwater source vital. Protection involves the protection from runoff water, and the protection from objects, animals or particles falling inside the well (Groenwall 2010). Open dugwells (i.e. without a sealing or apron), particularly those with very large diameters (>2 m), are very likely to get contaminated and hence should not be constructed.

Improving the Well Yield

When the yield of an existing dugwell declines, or even ceases, there are number of options for improving the well yield. The particular option will depend on whether the problem of the reduced yield is a consequence of a lowering of the water table or a decrease in the yield of the aquifer. In the former case, the intake of the well must be extended to a greater depth, while in the latter case; the exposed area of the aquifer must be increased in a horizontal direction (Collins 2000). Further, artificial recharge could be an option to increase the yield of a groundwater source.

Figure 33. Protected dugwell in Uganda

Health Aspects

Since groundwater gets physically and biologically filtered as it flows through the soil, water drawn from dugwells is usually of higher quality than surface water and most often safe to drink if not contaminated with geo-genic pollution (e.g. arsenic) or cross contamination (e.g. leaching pathogens from unsealed pit-latrines). In order to maintain this quality, solid construction, protection measures and adequate maintenance must be ensured. In this regard, wells should be protected from any contaminants entering the system by installing a sealing apron and a drainage system. Protection of the surrounding area is equally important. Correspondingly, water users need to know and understand operational rules and regulations. Common practices and attitudes could be a threat to any new system, and so to dugwell. Capacity building and awareness raising should therefore be key aspects of any water management project (Collins 2000). Although, dugwells are common in Pakistan, but even then health aspects are important because these are hardly enforced by the communities.

Advantages and Disadvantages of Dugwells

Advantages

- High degree of involvement of the local community during the whole process of dugwell planning and construction
- Under supervision, not highly skilled workers are required because dugwell labour is already available and their rates are much higher than ordinary labour, as they charge per feet depth of digging in dry and aquifer zones, separately. The rates are also different if hard rock is there then they normally work on labour charge rates.
- Simple equipment sufficient for both construction and maintenance
- Low cost of O&M
- Involvement of local well diggers
- Use of locally available materials
- Yield can be increased by increasing the diameter and the depth of water column

Disadvantages

- Long construction phase – time consuming effort because of labour intensive technology
- Danger of excavation where there are chances of well collapse and gases
- Pump are often required to lower the water table during the construction phase
- Application restricted to regions with rather soft geological formation and relatively high groundwater levels or dry riverbeds
- Alteration of water level can adversely affect the surrounding environment

- Weight of lining rings (concrete) up to 900 kg – difficult to handle under certain situations
- Dependence on water table fluctuations, shallow aquifers are susceptible to pollutants infiltrating from the surface (e.g. leachate from pit latrines)
- Contamination in open dugwells likely to occur: mud, vegetation, animals, waste & use of buckets/ropes. There is a need for careful O&M. People (i.e. children) can fall into the well if it is uncovered. After completion of the well it retains the walls (Smet and Wijk 2002).
- Cost of digging is now much higher than drilling as the skilled labour rates are much higher for digging in water and for hard rock formations. In Pakistan, now there is shortage of skilled manpower for digging of wells especially digging in difficult situations.

Infiltration Galleries for Abstracting Storm Water

Infiltration Practices

The purpose of infiltration practices is to infiltrate floodwater from impervious surfaces with no direct discharge to surface waters. The infiltration systems are applicable for treating runoff from any impervious surface that has been pre-treated to meet the effluent limits for discharges to infiltration. While soils in the bed of the ephemeral rivers are usually highly permeable, permeability tests should be performed to ensure infiltration rates are adequate for treatment. Infiltration structures should not be installed in areas with a high water table where untreated storm water may affect groundwater quality. A minimum four feet separation from invert of the structure to seasonally high groundwater is required.

The advantages of the infiltration practices are: a) properly installed and maintained, infiltration structures can prevent discharge of runoff from impervious surfaces; b) infiltration practices also recharge local groundwater supplies and help maintain vegetation; and c) on-site infiltration is particularly effective for phosphorus removal (ICHE 2000).

The disadvantages of the infiltration practices are: a) infiltration systems convey surface water to groundwater regardless of quality if not treated storm water flows may negatively affect groundwater. In particular, infiltration practices are not effective for nitrogen removal; b) infiltration methods are generally ineffective in areas with a high groundwater table; and c) in other areas, infiltration systems may alter natural groundwater flows by dewatering some areas and saturating others. Heavy sediment loads and organic particulates from leaves and needles may reduce infiltration capacity; infiltration structures must be carefully monitored to ensure such clogging does not hinder effective treatment. Soils can also become saturated with pollutants, reducing treatment capacity.

Infiltration can be a very effective method for storm water treatment, especially when coupled with native vegetation. Effective removal of dissolved constituents is highly dependent on soil type. Loamy soils are particularly suited for removal of dissolved nutrients and fine particulates; coarse soils are generally less effective. Beyond pollutant removal, infiltration practices help restore the natural hydraulic balance of developed areas by returning storm water flows to the soil and attenuating storm water peak flows. Such attenuation serves to prevent channel erosion and protect downstream. Common infiltration systems are: a) infiltration trench; b) infiltration gallery; and c) dry well (Goldman 1986; Maryland 2000; TRPA 1988).

Infiltration Trench

An infiltration trench is a shallow trench back-filled with gravel to allow for enhanced runoff infiltration. Runoff is diverted into the trenches, from which it percolates into the subsoil. Vegetated conveyance swales may also serve as infiltration trenches.

Infiltration trenches are most common along the drip line of elevated impervious surfaces, such as rooftops. Trenches used to drain large, heavily used paved areas, such as parking lots or other impervious surfaces should include pre-treatment to remove heavy sediments and hydrocarbons. The sizing of infiltration trenches is dependent on the design storm, soil type, and the total area of impervious surface.

According to a study performed for TRPA in 1996, the standard design 18-inch wide by 8-inch deep trench infiltrates approximately 1.6 inches per hours per 20 square feet of the contributing area. West Yost and Associates also estimated the annual load reductions per foot of infiltration trench based on seven rainfall storm events in the Lake Tahoe Basin, as listed in Table 2 (TRPA 2001).

The State of Idaho's Catalog of Storm Water Best Management Practices for Idaho Cities and

Pollutants	Annual Load Reduction
NO_3-N (Nitrate	0.061 g
TKN (Total Kjeldhal Nitrogen)	0.16 g
SRP (Soluble Reactive Phosphorous)	0.0043 g
TP (Total Phosphorous)	0.031 g

Table 2. Estimated annual load reductions per foot of infiltration trench (TRPA 2001).

Counties indicates that the expected pollutant removal effectiveness of infiltration trenches is 75% for sediment, 55% for phosphorus, and greater than 70% for trace metals, bacteria, and petroleum hydrocarbons (IDEQ 1997). The tips for the installation of the infiltration trenches are:

- Excavate a trench of the required size along roof drip line or adjacent to impervious surface. Over size, if space permits.
- Add filter cloth (optional) and gravel to fill the trench.
- Infiltration trenches installed on steep slopes benefit from wood borders with cross-slope stops to prevent gravel from moving down slope.

Infiltration trenches require extensive maintenance to ensure effectiveness. In most circumstances their life expectancy is 10 to 20 years. Accumulated debris must be periodically cleaned from the surface to allow flows to infiltrate. If trenches become ineffective, they should be replaced or reworked immediately. Rock or gravel should be removed and washed of accumulated sediment or replaced with clean rock.

Infiltration trenches are best suited to treat rooftop runoff. They may also be used for treating runoff from small impervious surfaces with light sediment loads and minimal oil and grease build-up. Use pre-treatment structures or source control methods to prevent clogging in areas where sediment loads are high and prevent soil contamination where oil and grease concentrations are high.

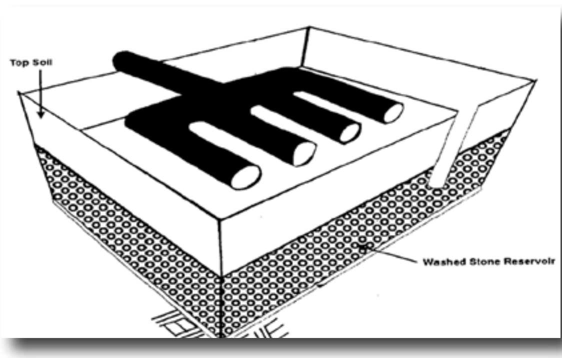
Infiltration trenches are inappropriate for treating large impervious areas where high pollutant loads will likely overwhelm infiltration capacities.

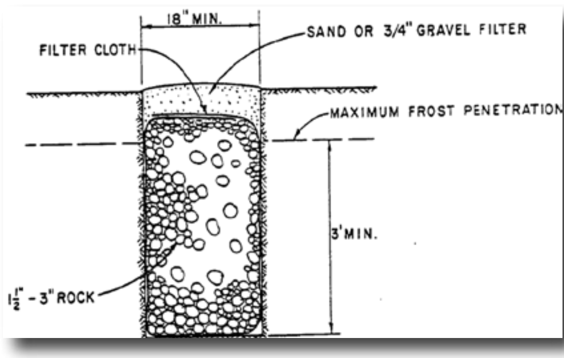
The use of geotextile fabrics in infiltration trenches to prevent soil intrusion into the gravel fill may significantly reduce infiltration capacity.

Infiltration Gallery
Infiltration structures designed to deliver captured runoff to the subsoil through sub-surface reservoirs usually composed of rock or gravel.

Below grade infiltration structures can provide innovative storm water treatment in areas where space is limited. As with other infiltration practices, percolation tests should be performed to ensure adequate infiltration rates. It is important to consider possible pollutant loads and include pre-treatment devices to help minimize maintenance cost. High flow bypasses should also be included in the design. Infiltration galleries are most appropriate as secondary treatment for runoff from impervious surfaces such as parking lots that have pre-treatment structures in place. Be aware runoff discharged to groundwater is subject to the maximum pollutant loads. It is also important to consider potential impacts of structural subgrade materials and the possibility of surface instability caused by soil piping and/or slope destabilization.

Consult a qualified agricultural engineer to determine if soil conditions are appropriate for infiltration. Since infiltration galleries are below grade, they are extremely difficult to maintain. Inlets should be inspected regularly for plants materials (i.e. pine needles in Murree hills) and other debris that may clog the system. If infiltration rates have visibly diminished, the system must be dug up and rehabilitated.





Figures 34 and 35. Typical infiltration galleries (MWCG 1987)

Infiltration galleries are appropriate for treating runoff from small impervious areas where space is limited. However, avoid installation in larger areas with high sediment loads, high oil and grease accumulation, and in soils with limited permeability. Like other infiltration methods, galleries should not be used in areas with high groundwater or shallow depth to an impervious layer.

Washoe County installed a 4 foot by 48 inch underground basin as part of a water quality improvement project. Pine needles and other debris frequently plug the inlet causing system bypass. Maintaining the underground basin is extremely time consuming. Infiltration facilities installed under roadways as part of California Tahoe Conservancy funded projects at Black Bart Avenue and Apache Street have not shown any apparent damage to roadway sections after several years of operation (MWCG 1987).

Hydrologic Landscape

The spate irrigation has to be undertaken in the context of a watershed covering the catchment, water bodies and the command area. The watershed landscape is important while considering the hydrologic landscape. There is a need to integrate the concept of landscape with the hydrologic landscape. The vegetation in the form of grasses, shrubs and trees of local indigenous species must be given due consideration in designing the landscape so that system is sustained on longer-term basis.
The watershed is the area which contributes to spate flows and it is also a source of providing water for other multiple uses. Therefore landscape will certainly help to avoid the environmental pollution and degradation. The water coming from the watershed landscape is channelled into reservoirs of the small and large dams or conveyed directly for spate irrigation.

Due to degraded watershed conditions the water flow is like a mud flow. The natural landscape is built on foundations of arid to semi-arid mountains devoid of adequate vegetation. The watershed landscape has also to be protected to help the wildlife flourish and ecosystem is sustained on longer term basis.

As part of the watershed landscape development, a researched guidebook and companion travellers maps featuring routes have to be developed to help local communities, district administration and visitors including students and faculty to explore and understand different parts of the watershed.

Remote and yet accessible - that is one of many contradictions of the watershed landscape. These landscapes can be seen by thousands of people travelling on the roads linking the Sulaiman and Khirther ranges with the national highways and motorways and millions of people who live in the surrounding towns and cities have never visited these areas.

The watershed landscape should be easy to reach and has good public transport connections. Many of the villages and towns allow direct access to some of these watersheds landscapes. Even for those who cannot physically reach the uplands, the future projects should provide plenty of opportunities to be inspired by learn more about and be involved in caring for these unique places.

One of the key elements of the future projects should be to provide and improve access to the upland landscape to help new and existing audiences explore these unique areas. There are a number of key strands that will improve both the physical access through footpath, car park and signage improvements and intellectual access through improved interpretation on and off-site, new trail leaflets, downloadable learning resources, and new opportunities to get involved in activities. Working with a whole network of partners also allows us to bring the landscape to new audiences through exhibitions, displays, family activities, volunteering opportunities, community events and academic research by students and faculty.

Over the past centuries writers and artists have found the unique sense of place that is generated by the Sulaiman and Khirther ranges to be a rich source of inspiration. Millions of people live in or around the Sulaiman and Khirther ranges yet they feel remote, wild and exhilarating and have inspired artists and writers over generations.

The watershed landscape future activities or projects can host a series of residencies and working with a new generation of artists and writers to celebrate this long tradition and help bring the wealth of creativity associated with this landscape to our attention once more. Events and activities linked to the residencies can take place across the project area. New work created by the artists and writers can be celebrated in museum, gallery and community venues across the region. The Universities located in spate ecologies i.e. Gomal University, D. I. Khan, Baha-ud-din Zikaria University, Bahawalpur, Agriculture College of D. G. Khan, University of Sindh Jamshoro, Mehran University of Engineering and Technology, Hyderabad and many others can take spate irrigation as their special area of interest and participate in hydrologic landscape of spate area.

The watershed landscape is a distinctive landscape rich in biodiversity and playing host to a variety of habitat types from remote summits to scrub forests, rangelands and rural settlements. Some of the uplands can be designated as a Special Protection Area or hot spots and may be nationally or internationally important for its populations of endangered breeding birds.

As well as providing the perfect habitat for wildlife, the ecosystems of the Sulaiman ranges offer us important opportunities for recreation, learning, reflection and aesthetic experiences but also benefit us more directly through the provision of resources and services; for example fresh water through the natural water cycle, clean air, and the generation of fuel and food. The landscape is a delicate balance between the living organisms and their physical environment and the reliance that humans have had on this landscape for many thousands of years continues to change this balance. Threats to upland species include loss of habitat due to fire, erosion, development as well as climate change. Increasing pressure from the modern world means that these ecosystems need our care if they are to continue to withstand these demands.

The watershed landscape activities can help to support some of the key landowners and stakeholders in the uplands to care for this area and ensure that the rich biodiversity is protected through a series of activities such as re-vegetation of the local habitats, tree planting, restoration of dry stone walls and implementing sensitive access solutions.

How the Sulaiman and Khirther ranges landscape came to look the way it does, is a complex story of human exploitation and environmental change. It is a landscape in which countless generations of hunter/gatherers, and early farmers worked and lived out their lives. Gradually, and over a period of thousands of years, their activities lead to the uplands becoming cleared of trees, and the soils becoming poorer, eventually forcing people to abandon it.

Although no longer a place in which to live, the uplands continued to play a vital role in all that we see around us today. It was the wool from the sheep that grazed its surface and the high energy streams that flowed down to power the waterwheels of the mills. Later it was the seams of coal and good quality building stone from beneath its surface that enabled industry to expand, and people to build the urban landscapes for an ever increasing population. Maintaining such large industrial populations also required a good supply of water which was again provided by the uplands through an elaborate system of water management.

So much about where we live, what we do, and how we go about our daily lives has been determined by our relationship with the uplands. This in turn has left its mark on the landscape.

There are some special towns within the spate ecology. For example the Fort Manro is the only place in the Punjab part of Sulaiman ranges having cool weather in summer and excellent resort for the tourists. The watershed landscape around Fort Manro is an excellent opportunity to develop for spate eco-tourism in Punjab. Similar locations are available in Balochistan and Sindh. The Fort Sandaiman (new name Zoab) and areas of Loralai, Killa Saifulla and Ziarat are excellent places for highlands spate irrigation. Equally good landscape is available in plains of Sibi, D. I. Khan and D. G. Khan. The question to ponder is that why the spate communities along the roadside and remote are provided opportunity to participate in watershed landscape and spate eco-tourism so that they and their children feel that they are also living in a better ecology. This will also bring new livelihoods and also brought to the attention of media regarding this traditional system of livelihood in the country.

Landscape of Fort Manro

Fort Munro is part of the Sulaiman Mountain range. The range is located in central Pakistan, extending southward about 280 miles (450 km) from the Gumal Pass to just north of Jacobabad, separating the North-West Frontier Province and Punjab from Balochistan. Its heights gradually decrease toward the south, with summits averaging 6,000–7,000 feet, the highest being the twin peaks (30 miles from the Gumal Pass) called Takht-i Sulaiman, or Solomon's Throne, which legend connects with King Solomon's visit to sub-continent; the higher of the peaks, at 18,481 feet (5,633 m), is the site of a Muslim Ziyarat (shrine) visited annually by many pilgrims. The range's eastern face dips steeply to the Indus River, but on the west the range declines more gradually. Juniper and edible pines abound in the north and olives in the centre, but vegetation is scarce in the south. The Ghat, Zao, Chuhar Khel Dhana, and Sakhi Sarwar are the principal passes in the north. In the south, west of Dera Ghazi Khan, lies the hill station of Fort Munro.

Figures 36 to 39. Landscape of Fort Manro – a summer resort in Spate ecology

Integrated Land

The integrated land use is very common in the mountainous and sub-mountainous regions of Pakistan where farmers are integrating crops, fruit/forest plants, fodders, livestock and rural poultry. Fisheries are now being introduced in the sub-mountainous regions where rainfall is over 500 mm.

In small dams command area the integrated land use system covering crops, forest plants, fruit plants, vegetables and livestock is being practiced in a traditional manner and there is an ample potential to make further improvement. In the recent past the crops have taken over the other land uses and mostly these areas are now dominated by crops and livestock.

Why an integrated land use framework is needed for small dams' projects? It is a real issue to be addressed? There are four components of any water storage constructed in the Barani lands, spate irrigation areas and arid regions: a) watershed area; b) reservoir; c) command area; and d) spate irrigation area, as a left-over area and not part of the command area (Figure 40). The reasons for having integrated land use for the four components of the storage dams are:

- **The First Component** of the water storage system is the watershed area contributing runoff to the reservoir. The farmers of the watershed area are not beneficiaries of the traditional small dams' projects in Pakistan. The topography in most of the cases provides an excellent opportunity for integrated land use including forest plants, shrubs, grasses and fruit plants which can provide livelihood to the farmers and reduce the incoming flow of sediments. Crops must be avoided because any tillage operations in the watershed areas always enhance the process of soil erosion and sediments inflow to the reservoir. Livestock is also part of the integrated land use system because livestock provides a cash support to the farmers where they can sell their animals at the time when they are in need of money. So it serves as a bank to the farmers.
- **The Second Component** is the reservoir. The farmers who have lost their land in the reservoir have no stake in the command area or watershed, as they have lost their source of livelihood. The one time compensation of land paid to them is not a substitute for the livelihood. Some of them are facing misery due to the loss of livelihood. These farmers should be allowed to have Cage Fish production along the periphery of the lake so that they can earn some livelihood

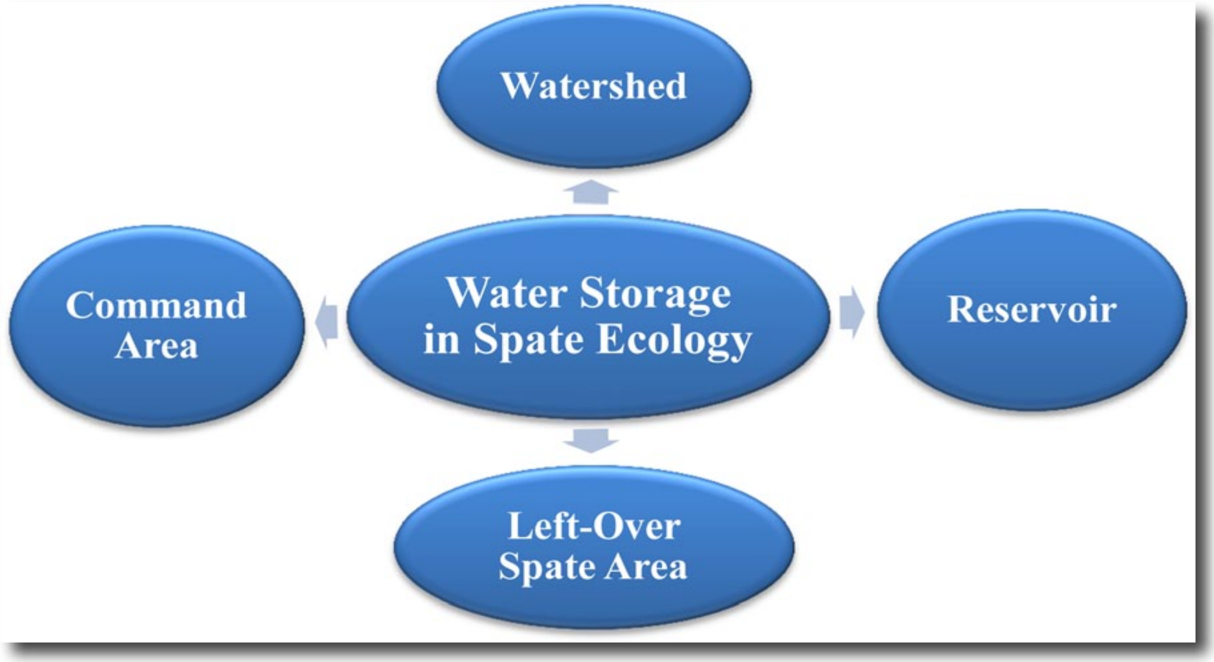


Figure 40. Four major components of water storage in Spate ecology of Pakistan

without using any water or land. Further reservoir fisheries is also an integral part of the land use system and it should be given highest priority because fish raised on natural food fetch higher price in the market. The incorporation of supplemental feeding would further improve the productivity.

- **The Third Component** is the command area, where farmers can integrate fruits, vegetables, crops and fodders. Livestock is an essential part of the integrated land use. Fisheries can be added at the tail-end farms because there is always tail-water which can be stored at the end of each watercourse to raise fish in the storage pond. This will add extra income to the farmers and tail water can be managed better. Further drainage effluent from the pond water can be used by the downstream farmers in the un-commanded area to grow vegetables or fruit plants. The drainage water from fish pond is always nutritious.
- **The Fourth Component** is the left-over spate area which was not benefitted from the irrigation network of the small dam. This group is a deprived community and deserve some consideration. The way traditionally the dams are built this group get only the water which flows over the spillway to manage the excess inflows. No change in water entitlements is made after the construction of the dam. Rather concept of spate irrigation is not integrated with the small dam. If the water entitlements of these farmers are kept intact then some interventions of channelizing floodwater for spate irrigation and farmers have better control over the floodwater so that they are not deprived from their historic right of water use. The land use for the spate areas has to be designed differently where low water requirement crops like barley, chickpea, sorghum, millets and pulses (mashbeans, mungbeans and mothbeans) can be tried. They can have forest trees and shrubs to manage drought years so that they have some livelihood during these years.

The integrated land use system of small dams in Pakistan is presented in Figure 41. The integrated land use plans for the four components indicates that high value crops are recommended for the command area, grains and food legumes for spate area, plantations in watershed and fisheries in the reservoir. Thus there is wide variation in the suggested land use systems considering the comparative advantage of each of the component.

Strategy

The strategy for developing alternative system of water storage in spate ecology would depend on the comprehensive, holistic and integrated approach. The strategic goal must be to have “Productive and Sustainable spate Irrigation and Water Storage System for Enhanced Livelihoods” covering all the major components: a) watershed area feeding the inflows to the reservoir; b) reservoir for supplying water to the command area and other multiple uses to have “right for everyone on water”; c) command area; and d) the left-over farmers of spate irrigation system.

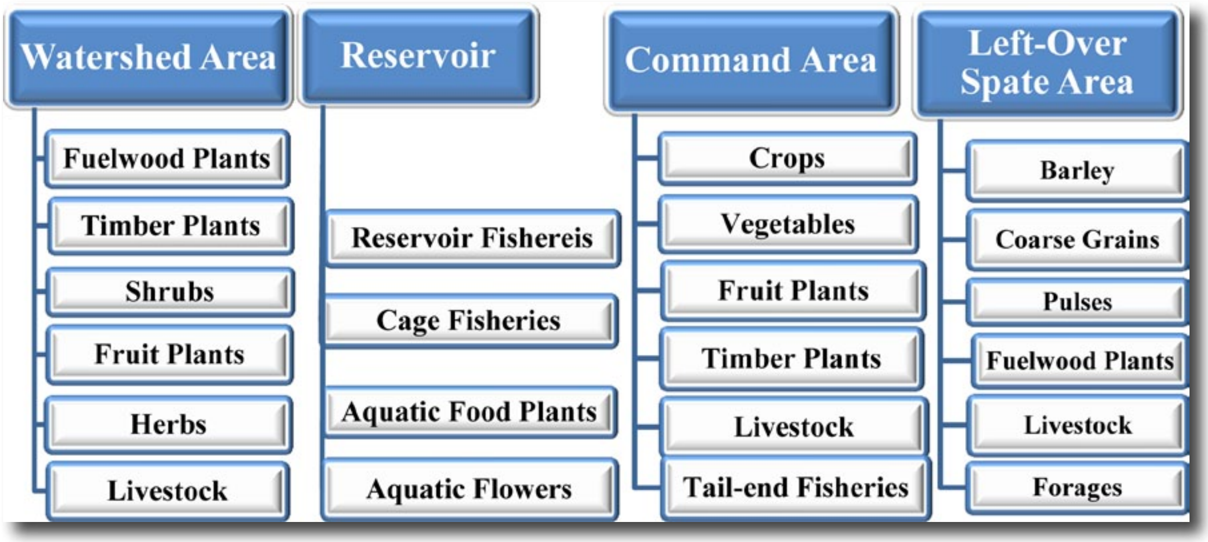


Figure 41. Integrated Land Use for Small Dams considering an integrated approach

The concept of "Justice to All" has to be accepted for providing "Fair Deal to all the Users" from four different components of the spate irrigation and Water Storage facility. Until everyone in the local community has rights on water and livelihood the investments made in the water storage reservoirs will not provide targeted benefits.

The important point worth considering is that any new development without the rights to everyone and justice for all would not be sustainable as conflicts on water and loss of livelihood would be further deepen and it will be difficult to harvest the benefits of investment. We have to note that with the independent media and easy access to information, the water users in the future will be more informed and disciplined to fight for their rights and they have to be listened and provided justice.

The elements of the Strategy for "Productive and Sustainable spate Irrigation and Water Storage System for Enhanced Livelihoods" are:

- Any type of water storage in the spate irrigation system should not be considered as an alternate to the spate irrigation rather it has to be used as a complimentary intervention to bring reliability and sustainability in spate irrigation system. The approach of "either-or" will not work as most of the small dams have very short life of around 20-25 years, whereas spate irrigation has been there since many thousands of years. The concept of water storage has to be integrated with the spate irrigation system and then any intervention be introduced. There is a need to review that what will happen when the reservoir will be fully silted up. If it takes 25 years, does it mean that skills of spate irrigation will be there at the time of reverting back to spate irrigation. Further question is that whether it is possible to revert after 25 years.
- The problems associated with the in-stream water storage in terms of sustainability of the storage reservoir due to heavy load of inflow of sediments, slow development of the command area, foregone benefits due to slow development of the command area and reservoir's fisheries, water conflicts among the water users and O&M problems can be avoided by changing the concept of small or large in-stream dams with much shorter life in the spate areas to off-stream dams, sub-surface dams and sand storage dams. The sub-surface and sand storage dams can help to generate now aquifers and to bring sustainability to the spate irrigation environments. The integrated options are not only sustainable, but are also cost-effective and do not require much engineering feasibilities and technical support.
- The sub-surface and sand storage dams can contribute to develop new aquifers which can help to provide sustainability for spate farming and multiple uses of water in spate ecologies as groundwater can be assessed on demand basis. A cascade of groundwater storage dams can help to create much more sustainable river basins in spate areas and generate new livelihoods for the coming generations who are not interested to take spate farming as a livelihood due to the drudgery and uncertainty associated with it.
- The groundwater in spate irrigation areas is deep and is normally of marginal to brackish in quality. The groundwater dams would help to create shallow aquifers of freshwater and provide healthy source of water for domestic,

stockwater and agricultural purposes. The creation of artificial aquifers is very important in arid and semiarid lands by constructing various types of dams across temporary waterways. The improvement of water quality is also most important in areas with marginal to brackish quality groundwater.

- The integrated approach is essential. The small dams have four components: a) watershed area feeding inflows to the reservoir; b) reservoir; c) command area of the small dam; and d) left-over farmers of spate irrigation lost their water rights in the dry season and get water only when water flows from the spillway. These four components have to be considered while planning construction of dams and water entitlements of all the farmers belonging to the four components must be continued considering the historic rights of all the farmers, landless, women and children and livestock.
- The integrated land use covering crops, fruit/forest plants, shrubs, grasses, fisheries and livestock would increase the livelihood and adapt to the extreme events of droughts and floods which will be more severe due to the future expected climate change. The forest plants, shrubs and grasses can survive in droughts and provide fuelwood and pastures to the local inhabitants. Roots of forest plants and forage can extract water from deeper depths and can survive persistent droughts and still provide some livelihood to farmers and reduces the chances of out-migration. Similarly, the range plants and grasses can also tolerate ponding due to extreme floods. There is a need to develop land use options for all the four components of the small dam system: a) watershed area; b) reservoir; c) command area of the dam; and d) left-over spate-farmers.

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Alternative Concepts of Water Storage in Spate Areas of Pakistan

Practical Note #15

Colofon

This note was prepared by Dr. Shahid Ahmad (Former Chief Scientist of Pakistan Agricultural Research Council, currently working as Water Resources Management and Agriculture Development Expert)

The Pakistan Spate Irrigation Network supports and promotes appropriate programmes and policies in spate irrigation, exchanges information on the improvement of livelihoods through a range of interventions, assists in educational development and supports in the implementation and start-up of projects in Spate irrigation. For more information www-spate-irrigation.org

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