CONSTRUCTION OF LARGE AND MEDIUM DAMS FOR SUSTAINABLE IRRIGATED AGRICULTURE AND ENVIRONMENTAL PROTECTION

By

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Abstract: Pakistan is suffering from drought conditions since year 2000 till June 2010, due to which reduction in river discharges and lesser rains occurred. The reliance on ground water increased remarkably and extensive pumping was observed during the period. To integrate the available surface water in the system, a series of dams are needed, in a cascading manner for adequate storage as well as flood regulation and which also provide more hydel generation of cheap energy for reducing load-shedding. The catastrophic floods of 2010 critically focused the need of large reservoirs to minimize flood damages to human life, crops, buildings, roads as well as environmental hazards. In using natural resources, agriculture can create good and bad environmental outcomes. The storages and water regulations will enhance agriculture benefits if at the same time reduction of water losses from water conveyance system are also properly managed.

1. Introduction

Water is the essential component both for the existence of mankind and for the sustainable country's economic growth and environment protection is the key to the suitable development of water resources. Today emphasis on proper and balanced utilization of available water resources is more than ever before. Pakistan is suffering from drought conditions since year 2000 till June 2010, due to which reduction in river discharges and lesser rains occurred. The average annual flow across the rivers is 138 MAF. The average escapage below Korti is 31.35 MAF (1976-2011), whilst downstream Kotri requirement is only 8.6 MAF, also considering the raising of Mangla dam and future usage by India, there is still 17.81 MAF water available for future development. It is emphasized that construction of first additional mega reservoir will be replacement of lost storage capacity due to sedimentation and second large dam will add to storage capacity. Unfortunately, Pakistan is quite late to respond to the call of time for development of reservoirs. As an estimate the country has wasted about $149 billion worth of water to the sea till 2010. The canal withdrawals in Indus Basin Irrigation System (IBIS) at the time of Independence were around 60 MAF, which progressively increased to 106 MAF during the period of 1976-81 immediately after the commissioning of Tarbela Dam. Later on, due to sedimentation canal withdrawals dropped to 104 MAF by 2002 and currently stand around 102 MAF. The present storage per capita in Pakistan is 150m3 with the carryover capacity of only 30 days.

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The reliance on ground water increased remarkably and extensive pumping was observed during the period. However during year 2010 from July to September, there were severe floods and below Kotri flows were over 53 MAF. The situation necessitates conservation and integration of water resources to meet the water and energy requirements of the country. The Indus Basin of the country which constitutes the mountain valley of the Indus river and its tributaries, the Indus plains, the Kachhi plain, desert areas of Sindh and the Rann of Kach. On the north, it is surrounded by Hindu Kush, on the northeast by Karakoram and Harmosh ranges, on the western side by Suleman and Kirthar ranges while, Arabian Sea forms its southern boundary. The Himalayan Mountains have highest peaks in the world with vast deposits of snow and ice having the capacity to block and capture the monsoon winds and their moisture. Hindu Kush and Karakoram mountains form the great water, which separates the Indus Basin waters from that of the Central Asia. The Indus Basin is irrigated by the river Indus and its major tributaries which flow in longitudinal valley in structural troughs parallel to the mountains and after cutting through the mountains flowing steep and confined channels emerge into the alluvial plains which stretch over a distance of some 1520 Km to the tidal delta near the Arabian Sea. The Indus river system consists of; Western Rivers, River Indus, River Kabul, River Jhelum, River Chenab and Eastern Rivers, River Ravi, River Sutlej and River Beas. Through Indus Water Treaty, 1960 the Eastern Rivers flows of (23 MAF) were allocated to India and Western river flows to Pakistan.

The country is now suffering from problems like water scarcity for crop production, salinity & sodicity of fertile soils, more erratic and low rainfalls and low carrying capacity of rangelands with is a great hazard to environment as well. It is interesting to mention that those who exploited these resources for the development of the nation (the farmers) are suffering from vagaries of the nature like droughts, disease epidemics, low agricultural productivity and poor standard of living. The most serious dimension of this state of affairs is that the farming community is not realizing the severity of the issue in its true spirit while the public, private and NGOs working for the natural resources rehabilitation, regeneration, protection and conservation are operating under top-down approach. A major challenge is to reverse the degradation of natural resources and minimize damaging effects on the environment. The protection of natural environment is the responsibility of individuals, organization and government agencies.

2. Environmental Aspects of Dam Construction

The construction of large and medium dams completely change the relationship of water and land, destroying the existing ecosystem balance which, in many cases, has taken thousands of years to create. Currently there are around 40,000 large dams which obstruct the world's rivers, completing changing their circulation systems: this is not going to occur without dire environmental impacts. Throughout the past few years, the negative impacts of dams have become so well known that most countries have stopped building them altogether and are now forced to invest their money into fixing the problems created by existing dams.

The environmental impacts due to the construction of dams start from upstream side of the dam with the submergence of land, flora, fauna, infrastructure, heritages etc and displacement of inhabitant. On-site with dust, noise pollution from construction activities, water pollution and habitat destruction is a peril to environment. Also at downstream the environmental threats like species extinction, spread of disease with the slow movement of water, are literally breeding grounds for mosquitoes, snails, and flies, the vectors that carry malaria, schistosomiasis, and river blindness are observed over the years.

3. Case Study of Kurram Tangi Dam Project

Kurram Tangi Dam Project is a multipurpose water resources development Project. It largely focuses on Kurram River system consisting of Kurram, Kaitu and Tochi Rivers. Kurram Tangi Dam Project is located across Kurram River at about 14 KM upstream of Kurram Garhi Head Works and 30 KM North of Bannu City in North Waziristan Agency Khyber Pakhtunkhwa. The river system has a catchment of 9,150 square miles up to its confluence with Indus River. It spreads across the international border between Pakistan and Afghanistan. Of the 6,080 square miles in Pakistan the catchments of Kurram and Kaitu River constitute the area of Project influence.

The objectives are to store water for:

- Supplementing existing command area. (277,500 Acres)
- Irrigated agriculture development of new areas. (84,380 Acres)
- Hydropower generation. (83.4 MW)
- Flood Mitigation.
- Socio-economic uplift and poverty reduction

Table-1 Salient Features

Main Dam	
Dam Type	Concrete Faced Rockfill Dam (CFRD)
Dam height / length	322 ft. / 1035 ft.
Dam crest elevation	2142 ft.
Normal storage elevation	2127 ft.
Reservoir area	10,940 Acres
Gross / Live Storage	1.2 MAF / 0.9 MAF
Power Generation (5 Power Houses)	83.4 MW (350 GWh)
Construction Period	**4 Years**
Project Cost & Economics:	
Project Cost	Rs. 59.561 Billion
B.C Ratio	1.19
EIRR	13.25 %
Resettlement Evaluation	
Number of Affected Persons	12899

Number of Families Affected	1787
Tribes	- Kabul Khel
	- Malik Shahi
	- Miami
	- Saifali
Family Size	7 persons/family
Working Population	2 persons/family
	36% of Total Population
Loss of land due to submergence in reservoir	10940 Acres
Loss of residential houses due to submergence in reservoir	945 Numbers
Loss of infrastructure due to submergence in reservoir	
Metalled Roads	13 Miles
Other Roads / Tracks	35 Miles
Schools / Madressas	40 Nos.
BHU's, MCH's, CHC's	8 Nos.
Trees (Fruit)	1,516 Nos.
Environment and Resettlement Costs	
Land Acquisition	1365.75
Replacement cost for Residential Houses	934.25
Compensation for Farms Produce, Fruits & other Trees	2.80
Relocation of Community Infrastructure	49.90
Infrastructure development for resettlement	106.90
Trust Fund for Project NGO	84.13
Social uplift Programme	36.05
Other cost (work permits, studies, monitoring, administration & contingencies)	210.72
Status: Current status is ready for construction	

Figure-1 Proposed Master Plan Resettlement Colony

Environment and Resettlement Aspects

The irrigated agriculture resulting from the existing engineering works, notably notably a control weir on Kurram River at Kurram Garhi, along with Civil Canals and Marwat Canal has profoundly affected, though within limited boundaries, the socio-economic and natural environment of the region followed by financial and economic profitability. The environmental impacts, in particular, have been beneficial. Comparing these benefits of the existing irrigated agriculture with the scope and size of the proposed Kurram Tangi Dam Project which spans much larger land area and is more comprehensive in nature than merely the one control weir at Kurram Garhi, it can be safely stated that the socio-economic and environmental impacts will be much more all-embracing and similarly pervasive in a positive sense except for displacement of limited populations and submergence of land and property situated in the area of the reservoir to be created behind the Dam at MSL 2100 ft. The compensation for submerged land and property and resettlement of project affected persons form an integral part of the Project policy planning, which is largely guided by opinions and aspirations of indigenous people, public representatives and elders belonging to the Project area.

The incentives proposed for dam affectees consist of provision of alternate agriculture and housing land, compensation for affected houses. In case of reduction in reservoir level, the owners to be allowed to cultivate the land in reservoir area. The resettlement is proposed in nearby housing areas. The preference will be given in providing jobs during construction activities to the Dam affectees. There will be a provision of Vocational Training to the project affectees to facilitate them in obtaining jobs.

4. Water Resource Development in Pakistan

At the time of independence major portion of the Indus Basin formed a part of Pakistan and out of 37 million acres which received irrigation, 31 million acres fall in Pakistan. The water dispute between two countries had risen soon after Independence. India stopped waters in irrigation canals on rivers Ravi and Sutlej being upper riparian. Direct negotiations between Parties failed to resolve the dispute. After protracted negotiations, under the office of World Bank, when the World Bank convinced that existing uses in

Pakistan without storage could not be met by transfer of waters from Western Rivers and the storages on the Western Rivers were required for the purpose. The Indus Water Treaty was signed in 1960 under auspices of the World Bank. As per Indus Water Treaty, the waters of Eastern Rivers (Ravi, Sutlej and Beas) were vested to India while the waters of Western Rivers vested to Pakistan.

The population at the time of Independence in 1947 was 30 million and present population is around 180 million to touch 225 million by 2025. The canal withdrawals of Indus Basin Irrigation System (IBIS) at the time of Independence were around 60 MAF, it progressively increased, almost in keeping with the population growth to 106 MAF during the period of 1976-81 immediately following the commissioning of Tarbela Dam. Later on, due to non-addition of any major reservoir and sedimentation of existing ones (Table–2), the canal withdrawals started stagnating. The average withdrawals figure dropped to 104 MAF by 2002 and currently stands around 102 MAF. The present status of storage per capita in different semi arid countries shows that Pakistan with a figure of 150m3 per capita is almost at the bottom with the carryover capacity of only 30 days.

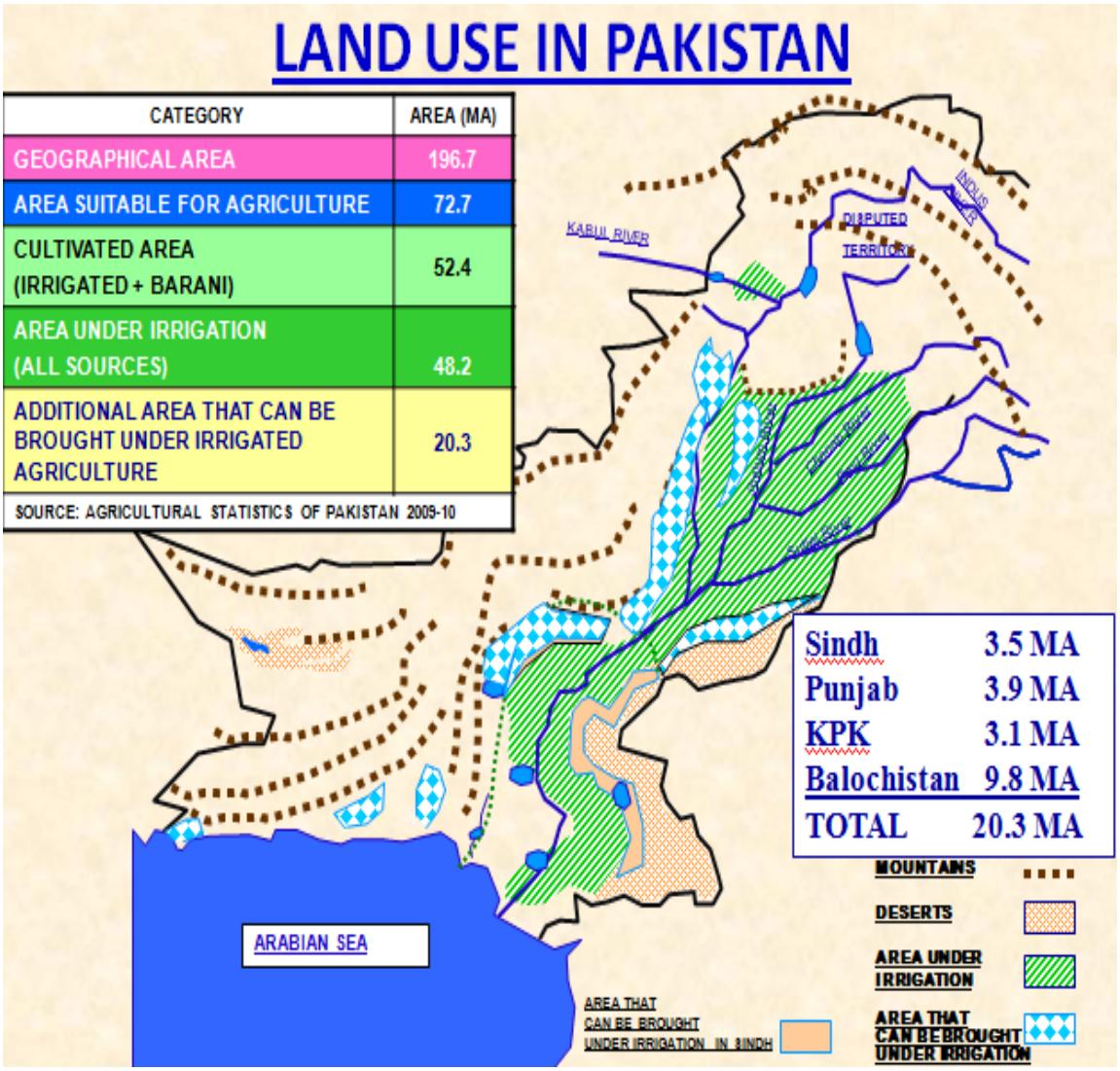

Figure-2 Land in use for irrigation

5. Water Availability and Challenges

The average annual river flows is approximately 138 MAF, out of which almost 82% (113.16 MAF) occurs during summer and 18 % (24.84 MAF) in winter, out of which 104 MAF is available at the canal heads for irrigation purposes, whereas, only 58.3 MAF reaches at the farm gate and 45.7 MAF is lost in conveyance system. The projected demand for agricultural usage is 119.0 MAF by the year 2025. The current industrial demand is about 4.02 MAF, which will increase to 4.8 MAF by the year 2025. The anticipated use for municipal and environmental uses are 6.90 MAF and 1.46 MAF respectively which will be increased to 10.50 MAF and 1.70 MAF respectively by year 2025 as shown in Table-2.

Table–2: Current & Future Water Requirements of Pakistan (2010 – 2025)

(MAF)

Sr. No.	Usage	Present & Future Water Requirements				Additional Requirements in 2025
		2010	2015	2020	2025	
1	Agricultural	107	111	115	119	12
2	Industrial	4.02	4.28	4.54	4.8	0.78
3	Municipal	6.90	8.10	9.30	10.50	3.60
4	Environmental	1.46	1.54	1.62	1.70	0.24
5	**Total**	**119.38**	**124.92**	**130.46**	**136**	**16.62**

Source: National Water Policy 2003 (Draft) and updated upto 2010

Moreover, as per global standards, 1000 m3 per capita is the threshold value for water scarcity. Pakistan at present is striving with water scarcity and only 1038 m3 of water is available per capita, which will further be reduced to 809 m3 per capita till year 2025. The Table–3 show the anticipated growth in the population and the decline in per capita water availability. This water scarcity stage creates human health hazards and livelihood issues.

Table–3: Water Availability Per Capita/Year (m^3)

Year	Population (million)	Water Availability (Cubic Meter)	Global Criteria
1951	34	5260	1000 m^3 per capita is the threshold value (Falkenmark & Wedstrand 1992)
2010	172	1038	
2020	204	877	
2025	221	809	

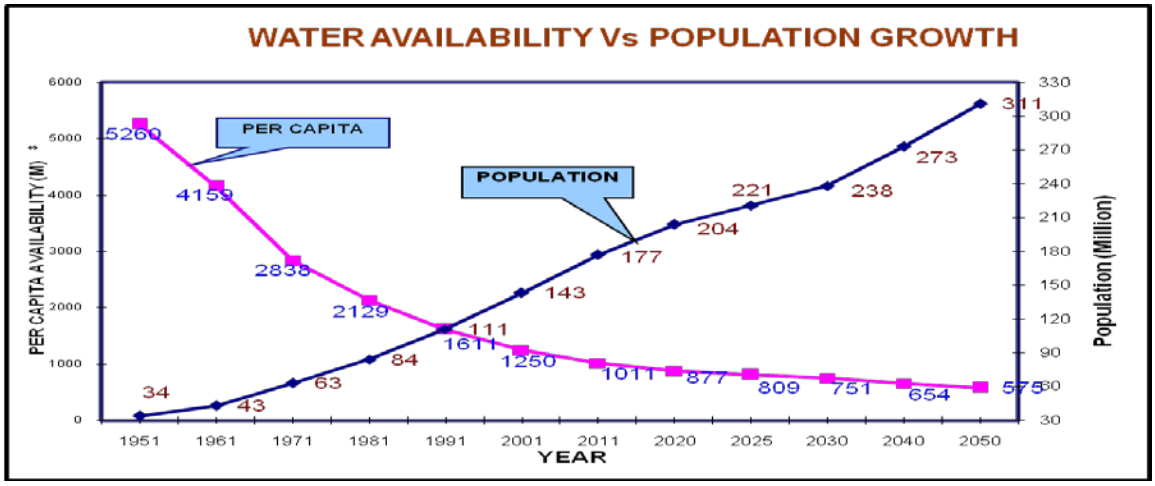

Figure-3 Graph of water availability vs population growth

Average Annual Flows of Rivers of Indus Basin

The catchment area of the Indus river system is 364,700 squarer miles, whereas, the average annual flows across the rivers are as given in Table-4.

Table-4: Average Annual Flows of Rivers of Indus Basin

(MAF)

River	Average Annual Flow (1922-61)	Average Annual Flow (1985-95)	Average Annual Flow (2000-09)	Average Annual Flow (2009-10)	Average Annual Flow (2010-11)
Indus	93	62.7	81.28	81.31	72.07
Jhelum	23	26.6	18.52	21.05	25.73
Chenab	26	27.5	22.52	17.90	25.80
Ravi	7	5	1.1	0.28	2.05
Sutlej	14	3.6	0.39	0.01	2.25
Kabul	26	23.4	18.9	17.4	28.61
Total	189.0	148.80	142.71	138.00	156.51

Source: WRM Directorate, WAPDA, Average Annual River Flows.

Pakistan has three major reservoirs, which have original storage capacity of 15.74 MAF, but with the passage of time, these have lost almost 26% till 2010, of their storage capacity due to sedimentation as shown Table-5.

Table–5: Reservoir Sedimentation

Reservoir	Storage Capacity		Storage Loss		
	Original	Year 2010	Year 2010	Year 2012	Year 2025
	MAF	MAF	MAF	MAF	MAF
Tarbela	9.68 (1974)	6.78 (70%)	2.90 (30%)	3.18 (33%)	4.30 (44%)
Mangla	5.34 (1976)	4.46 (83%)	0.88 (17%)	0.90 (17%)	1.14 (21%)
Chashma	0.72 (1971)	0.37 (51%)	0.35 (49%)	0.29 (40%)	0.38 (52%)
Total	15.74	11.61 (74%)	4.13 (26%)	4.37 (28%)	5.82 (37%)

Source: WRM Directorate, WAPDA.

6. Average Escapages Below Kotri

Over the past thirty five years, up to September 2010, 1094.88 MAF of water had gone into the sea unutilized, equivalent to 10 years of canal withdrawals. Excluding the water required for protecting the ecosystem below Kotri, rest represents a direct economic loss. In monetary terms, after deducting 300 MAF required for environmental purposes, the value of unutilized water is US$ 149 billion. For better water management, storage capacity should be equivalent to at least 40% of annual river flows but Pakistan's live storage capacity of about 12 MAF is nearly about 8% of average annual river flows.

The average escapage below Korti are 31.35 MAF (1976-2011) and Fig. 1 represents the downstream Kotri escapages, while downstream Kotri requirements are approximately 8.6 MAF. Considering the raising of Mangla dam and future usage by India (Treaty 1960), there is still 18 MAF water available for future development as depicted in Table-3. The average river flows indicate a significant storage potential of 11 MAF even after Diamer Basha Dam

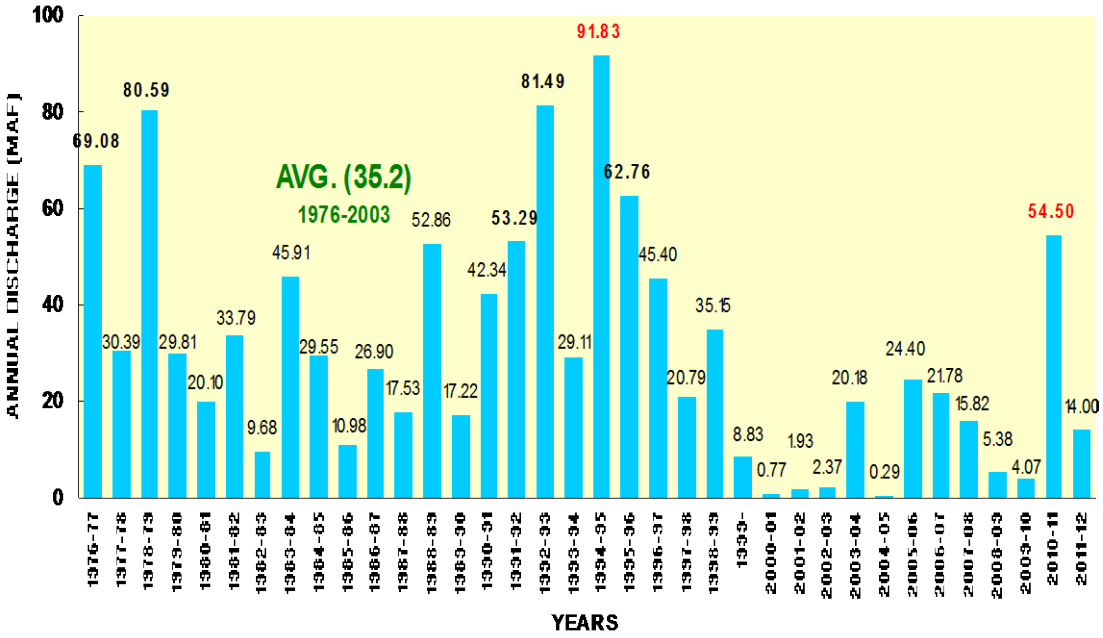

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Fig 4: Escapage downstream Kotri (MAF)

Source: WRMD WAPDA based on data supplied by GO Sindh
* Flows upto March 2012

Table–6: River Flows and Storage Potential

	(MAF)
A. Down Stream Kotri Average Annual Flows (1976 – 2011)	31.35
B. Anticipated Uses: • Down Stream Kotri Requirement @ 5000 Cusecs round the year • Mangla Dam Raising Project • Indian Future Uses on Western Rivers (As per Indus Water Treaty)	 8.60 2.88 2.00
C. Net Water Available - Storage potential (A-B)	17.87
D. Diamer Basha Dam Project (Proposed)	6.40

E. After Diamer Basha Dam Project (C-D)	11.47

7. Water Storage

The storages play an important role to cater for the above mentioned threats. Effects of climate changes can be minimized to greater extent by constructing storages on rivers as:

a) Storage takes care of the increasing frequency and intensity of floods and droughts. Water stored during floods can be utilized during droughts. Moreover floods can be mitigated by storing their peaks and regulation of reservoir operation

b) Water discharged due to glaciers melting can be stored in the reservoirs which can be used for generation of energy and for agriculture. This stored water can also be utilized in subsequent years of low flows after de-glaciations

c) Management of minimum environmental flows to the sea to prevent excessive intrusion of sea water into Indus deltaic region can be regulated and ensured through storages

d) Additional storage takes care of the loss in reservoir capacity due to silting

e) Storages have important role to cater for future increases in water demand as well as reduction in environmental hazards/endangers.

8. Environment Status – An Outcome of Resource Over Exploitation

In using natural resources, agriculture can create good and bad environmental outcomes. It is by far the largest user of land, water and labour, contributing to land and water scarcity. It is a major player in underground water depletion, agro-chemical pollution, soil exhaustion and global climate change, accounting for upto 30% of green house gas emission. Besides this it is a major provider of environmental services generally unrecognized and unremunerated, sequestering carbon, managing water sheds and preserving biodiversity. Managing the connections among agriculture, natural resources conservation and the environment must be an integral part of using agriculture for development. Over the years since independence the natural resources of the country (land & water) have been harnessed which in turn made it possible to feed the growing population which more quadrupled during the past sixty years. Construction of Tarbela and Mangla dams facilitated the growth of irrigated agriculture and led the cropping intensity to peak. Sectors other than agriculture also developed because of the backward and forward linkage of the agricultural growth thereby having an economy diversification and much less dependent on agriculture.

There are, however, concerns raised with respect to the costs and practices of the past development in terms of environmental degradation, resource misuse and depletion. Population growth and poor management have reduced per capita water availability from 5260 m3 (1951) to 1038 m3 (2010) already discussed under Section 5. Wood logging has contributed to the world's second highest deforestation rate and extensive soil

erosion. Each day the Indus River adds an estimated 500 thousand tons of sediment to the Tarbela Dam, which has reduced its life span by 22% and its water holding capacity by 30%. The irrigation system contributes millions of tons of salt to the commanded farm lands. Approximately 6.8 million hectares or around one third of cropped area in Pakistan are impacted by salinity. The irrigation system also has wrecked havoc on the delta region's ecological balance. The annual estimated cost of environmental and natural resource degradation and damage is about Rs 365 billion or six percent of GDP. These estimates are based on those parameters for which reasonable estimates are available. The highest cost is from inadequate water supply, sanitation and hygiene (Rs 112 billion) followed by agricultural soil degradation (Rs 70 billion), and indoor air pollution (Rs 67 billion), urban air pollution adds another Rs 65 billion. Rangeland degradation and deforestation costs are the lowest at about Rs. 7 billion of total losses [World Bank 2005].

It is imperative to emphasize that serious environmental damages and stress on natural resources have been experienced. Pakistan's natural resource sector is under intense stress. The forest sector is severely damaged, fisheries need major remediation, and agricultural land is increasingly becoming waterlogged, saline and fragmented while groundwater supplies in places like Balochistan are running out. The glaciers in the northern mountains of Pakistan are beginning to melt due to global warming and agriculture will either greatly diminish or require major adjustments as in the beginning floods may occur and later on, low river flows may create drought situation in the country. The solution lies in construction large reservoirs.

9. WAPDA Projects

According to global criteria, Pakistan is already water stressed semi-arid country with annual per capita availability of just over 1000 m3 in meeting the future water requirements, it must also be recognized that water flows in Pakistan are highly uneven across the seasons and years. The year round agricultural requirements can only be met if sufficient additional storage is made available. There are nearly 16.62 MAF shortfalls to the future water requirements. This additional water has to come necessarily from flood flows, for which the need for creation of storages on Indus and other rivers has been recognized. From analyzing the situation, it is clear that the balance of total additional water resources ground water exploitation and conservation measures are only sufficient to meet the requirements of water for nearly two decades or so, afterwards increasing reliance shall have to be placed on other measures such as adoption of conservation techniques to save water at all levels, adoption of demand based high efficiency irrigation system, harnessing hill torrents, and employing modern water management technologies. As these change over can not be brought about in a short period of time, it is necessary that the path to conservation and modernization be developed gradually to sustain future water demands.

To meet future water requirements, to an appreciable measure, it would be necessary to create large storages on Indus River. It is well known that storage projects take considerable time and effort for completion and need mobilization of heavy capital investment. Considering the acute shortage of water in coming years, the need for

starting work on a major storage project is eminent. In view of above situation, Government of Pakistan through WAPDA has launched a comprehensive integrated water resource and hydropower development plan, for development of water resources and hydropower generation. Table–7 summarizes such projects at different stages of implementation. Kalabagh is ready for construction but pended requiring provincial consensus.

Table–7: Water Sector Infrastructure Projects

S. No.	Name of Project	Province	River	Gross Storage Capacity (MAF)	Generation Capacity (MW)
i.	**COMPLETED PROJECTS (after the year 2000)**				
1	Mirani Dam	Balochistan	Dasht	0.152	-
2	Sabakzai Dam	Balochistan	Zhob	0.015	-
3	Mangla Dam Raising	AJK	Jhelum	2.88 (additional)	644 GWh
4	Satpara Dam	GB/KPK	Satpara Nullah	0.053	17.3
5	Ghazi Barotha Hydropower	KPK	Indus	-	1450
6	Khan Khwar Hydropower	KPK	Indus	-	72
ii.	**Under Construction**				
1	Diamer Basha Dam	GB	Indus	6.40	4500
2	Gomal Zam Dam	KPK	Gomal	0.82	-
3	Darawat Dam	Sindh	Nai Baran	0.122	0.45
iii.	**Ready for Construction (Approved Process)**				
1	Nai Gaj Dam	Sindh	Gaj	0.16	4.4
2	Hinggol Dam	Balochistan	Hinggol	1.206	1.0
3	Noulong Dam	Balochistan	Mula	0.20	4.4
4	Winder Dam	Balochistan	Winder	0.0362	0.3
5	Ghabbir Dam	Punjab	Ghabbir Nullah	0.026	0.15
6	Kalabagh Dam (require provincial consensus)	Punjab	Indus	7.9	3600
7	Kurram Tangi	KPK	Kurram	0.90	83.4
iv.	**Feasibility Study Completed**				

1	Munda Dam	KPK	Swat	0.676	740
2	Akhori Dam	Punjab	Off Channel	7.6	600
3	Bara Dam	KPK	Bara	0.085	5.8
4	Daraban Dam	KPK	Khora	0.0697	0.75

10. Way Forward

The storages and water regulations will enhance agriculture benefits if at the same time reduction of water losses from water conveyance system are also properly managed. Conservation measures will include following activities at National, Regional and Farm levels are appropriately undertaken at mass scale.

- Lining of main and branch canals,
- Lining of distributaries and minor canals, and
- Irrigation system rehabilitation program/adoption of HEIS.

Remodeling and modernization should take care of inequitable distribution of water. At present 60 percent of irrigation areas at the tail commands are either getting no water or the supplies are far below the authorized supplies. The irrigation system should now begin moving towards a demand based supply system. This may involve huge expenses and may not be economical as a large scale measure. Pilot schemes can be implemented at strategic locations in all provinces. There is a great potential for reducing water use through introduction of High Efficiency Irrigation Systems (HEIS); Sprinkler and Drip for many crops, while, it is true that capital investment can be intensive for modern mechanized irrigation such, consideration should be given to their introduction and means of financing them, to support the increasing scarcity of water in Pakistan.

Pakistan water resources are diminishing at an alarming rate, as can be concluded from the stated facts in this paper. The quality of water is also deteriorating with time. To improve the situation it is dire need of time to construct storage facilities and improve flood regulation, irrigated agriculture alongwith environmental protection. It is concluded and recommended that:

- Surplus water of at least 18 MAF is available for immediate development,
- Sedimentation of existing reservoirs is enhancing with time thereby reducing the water availability,
- It is strongly recommended that construction of storages of ready multi-purpose projects of should be started immediately,
- The high efficiency irrigation systems like drip and sprinkler need to be developed at appropriate sites for popularizing such technologies among farmers. The ultimate

solution of water scarcity lies in adoption of such technologies depending upon economic feasibilities and in attaining more production per drop of water,

- Environmental awareness among the public must be raised and environmental laws must be implemented in both public & private sectors.

The issue of environment degradation is not properly managed. The urgency of addressing Pakistan's environmental problems is not over emphasized but the consequences of environmental degradation demand careful attention.

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