Concept Paper

WTCER

PUBLICATION NO. 4

SOME ALTERNATIVE STRATEGIES FOR MANAGING WATER RESOURCES TO ENHANCE AGRICULTURAL PRODUCTION

SITARAM SINGH

WATER TECHNOLOGY CENTRE FOR EASTERN REGION

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INTRODUCTION

The rainfall in the country is highly irregular, variable and undependable. Its spatial distribution varies from 100 mm in Western Rajasthan to about 11000 mm in Meghalaya. Not only the rainfall, but the potential evapotranspiration from the country's surface (Table 1) also varies widely due to wide variations in topography, temperature, solar radiation, wind speed, and relative humidity. Though the average annual potential evapotranspiration from the country's surface is about 1775 mm, it varies from a minimum of 1239 mm from Jammu and Kashmir to a maximum of 2052 mm from Andhra Pradesh (Hargreaves et al., 1985). The period of the year during which the rainfall exceeds 50 percent of the potential evapotranspiration is taken as the crop growing period. Using information on physiography, soils, bio-climate, and the length of growing season, the entire geographical domain of the country has been divided into 21 agro-ecological regions (NBSS & LUP Staff, 1992). In these regions, under natural conditions, the length of the crop growing period varies from less than 90 days in the low rain fall areas of Ladakh, western Rajasthan, south western parts of the states of Haryana and Punjab, the Kutch Peninsula and northern part of the Kathiawar peninsula, to more than 270 days in western coastal plains of Maharashtra, Karnataka and Kerala states, north eastern states, and the islands of Andaman and Nicobar in the east and Lakshadweep in the west.

The source for all the surface and ground waters is precipitation; hence, water as a resource is one and is indivisible. As the precipitation in the form of rainfall occurs only for a few days in a year, there is a need to conserve it in the soil profile, aquifers, ponds, lakes, reservoirs, and rivers for use during the lean periods. The problems associated with the management of surface and ground water resources requires a thorough understanding of the hydrology of the surface and ground waters, existing surface and ground water facilities, hydrogeology of the ground water basin, agro-ecosystem, soil-water-plant-environment interactions, existing and expected demands, economics associated with the supplies to meet these demands, availability of energy, and social dynamics. For sustained agricultural production, it is necessary to manage the use of water resources such that (i) both surface and ground water suppplies are maintained at desired level, and (ii) the quality of land and water resources does not deteriorate with time.

BASINWISE DISTRIBUTION OF WATER RESOURCES IN THE COUNTRY

Ministry of Water Resources, government of India (Anonymous, 1993), has divided the whole country into twenty river baisns (Fig.1) comprising of twelve major basins, each having a catchment area exceeding 20,000 sq km, and eight composite river basins combining suitably together all the other remaining medium and small river systems for the purpose of planning and management. The twelve major basins are : (i) Indus, (ii) Ganga-Brahmaputra-Meghna, (iii) Godavari, (iv) Krishna, (v) Cauvery, (vi) Mahanadi, (vii) Pennar, (viii) Brahmani-Baitarani, (ix) Sabarmati, (x) Mahi, (xi) Narmada, and (xii) Tapi. Likewise, the eight composite river basins are : (i) Subernarekha-combining Subernarekha and other small rivers between Subernarekha and Baitarani, (ii) East flowing rivers between Mahanadi and Pennar, (iii) East flowing rivers between Pennar and Kanyakumari, (iv) Area of inland drainage in Rajasthan desert, (v) West flowing rivers of Kutch and Saurashtra including Luni, (vi) West flowing rivers from Tapi to Tadri, (vii) West flowing rivers from Tadri to Kanyakumari, and (viii) Minor rivers draining into Myanmar (Burma) and Bangladesh. Since the early 1970s Central Water Commission is maintaining 500 gauge and discharge observation stations in almost all inter-state river systems of the country.

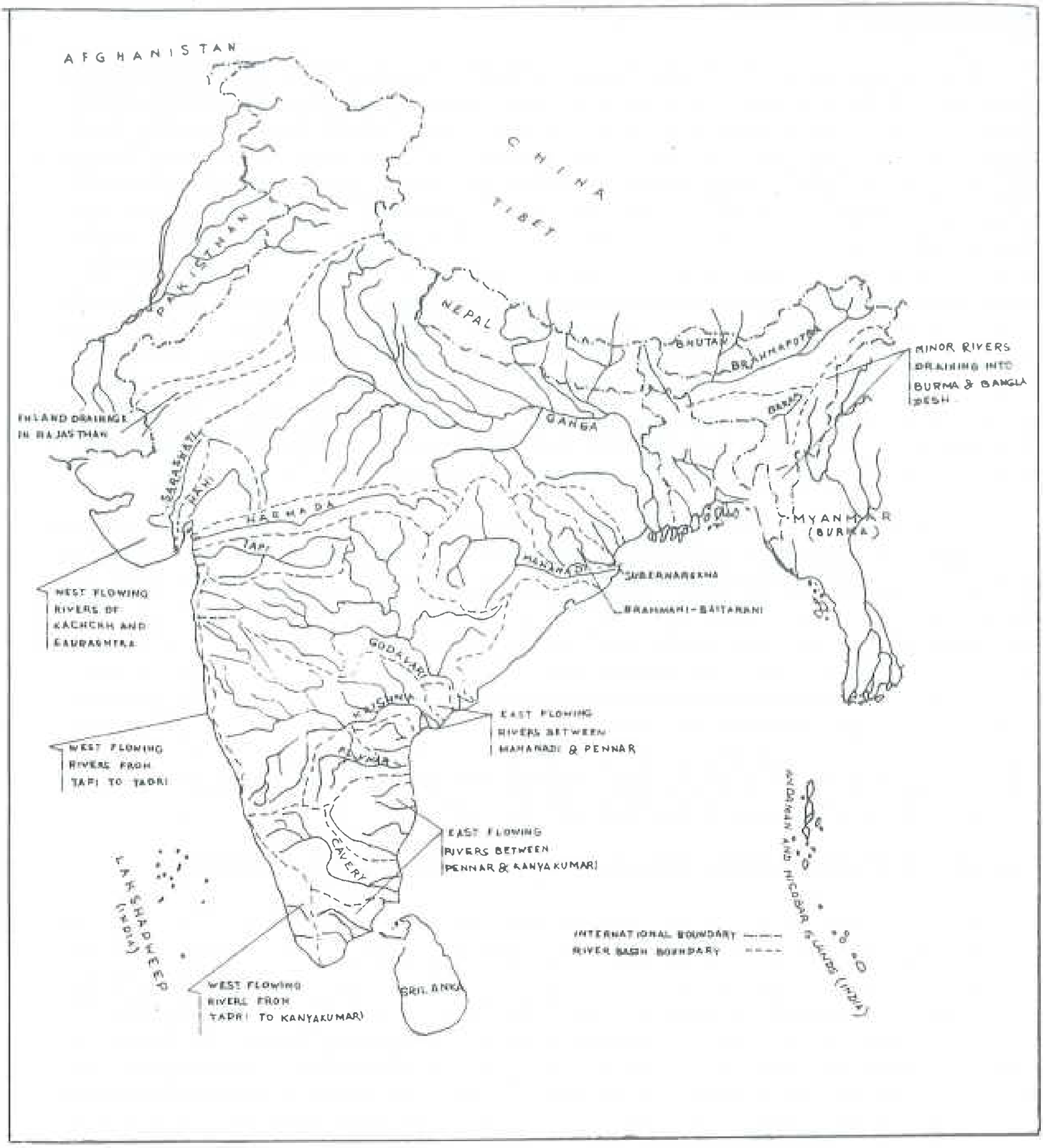

FIG. 1. RIVER BASINS OF INDIA (SOURCE: ANONYMOUS, 1993)

Table 1 : Average annual potential evapotranspiration from the states of India.

Sl. No.	Name of the State	Number of Meterological Stations	Average Annual Potential Evapotranspiration (mm)
1	Andhra Pradesh	39	2051.82
2	Assam	11	1741.81
3	Bihar	26	1854.65
4	Gujarat	25	1992.08
5	Haryana	07	1725.14
6	Himachal Pradesh	03	1360.66
7	Jammu & Kashmi	13	1239.38
8	Karnataka	28	1928.28
9	Delhi	1	1805.50
10	Goa	2	1926.50
11	Kerala	8	1915.50
12	Madhya Pradesh	43	1905.25
13	Maharashtra	30	1966.60
14	Manipur	1	1459.00
15	Meghalaya	3	1520.33
16	Mizoram	3	1618.00
17	Nagaland	1	1459.00
18	Orissa	19	1986.00
19	Punjab	9	1799.66
20	Rajasthan	29	1909.65
21	Tamilnadu	24	1944.00
22	Tripura	1	1913.00
23	Uttar Pradesh	35	1746.75
24	West Bengal	20	1830.75
	INDIA		1774.96

Thus, there is a resonable amount of observed flow data available in the country for most of the river systems. Based on the analysis of these data and other studies, the water resources potential of all the twenty river basins of India are reported in Table 2 (Anonymous, 1993).

Table 2 : Water resources potential of river basins of India (Anonymous, 1993)

Sl. No.	River Basin	Catchment Area (sq. km.)	Water Resources Potential (Mm³)		Ground Water Potential (Mm³)
			Average	75% Dependable	
1.	Indus	321289+	73305	-	25543
2.	Ganga-Brahmaputra-Meghna				
	(a) Ganga	861452+	525023	436312	171725
	(b) Brahmaputra	194413+	537240	491736	27857
	(c) Barak & others	41723+	48357	-	1795
3.	Godavari	312812	110540	80545	46762
4.	Krishna	258948	78124	69411	26646
5.	Cauvery	81155	21358	19375	13598
6.	Subernarekha	29196	12368	9855	2185
7.	Brahmani-Baitarani	51822	28477	20051	5879
8.	Mahanadi	141589	66879*	53786	21293
9.	Pennar	55213	6316	4393	5047
10.	Mahi	34842	11020	5713	4875
11.	Sabarmati	21674	3809	3146	3033
12.	Narmada	98796	45639	30829	11890
13.	Tapi	65145	14879	8860	8173
14.	West flowining rivers from Tapi to Tadri	44940	87411	65663	9479
15.	West flowing rivers from Tadri to Kanyakumari	56177	113532	85285	8810
16.	East flowing rivers between Mahanadi amd Pennar	86643	22520	18768	22788
17.	East flowing rivers between Pennar amd Kanya Kumari	100139	16458	13930	20907

18.	West flowing rivers of Kutch & Saurashtra including Luni	321851	15098*	-	13948
19.	Area of inland drainage in Rajasthan desert	-	Negl.	-	-
20.	Minor river draining into Myanmar and Bangladesh	36302+	31000*	-	-
	Total		1869348		452233

+ Area in Indian territory

A perusal of Fig 1 and Table 2 gives the basinwise regional distribution of water resources in the country. The total surface water resources of the country (yearly average stream flow) as given in Table 2 is 1869 km^3 with a dependability of 50%. Desired dependability for irrigation is 75% at which the runoff would be approximately 1500 km^3. It has been estimated that (i) due to extreme variability in precipitation which disallows storage of flash and peak flows, and (ii) due to non-availability of suitable storage sites in hills and plains, only about 690 km^3 of water out of 1869 km^3 can be stored for beneficial use. In addition, on yearly recharge basis, about 452 km^3 of ground water is available (Table 2) for different uses. It is estimated that about 360 km^3 of ground water would be available for irrigation. Thus a total of 1050 km^3 of utilisable quantum of surface and ground waters is available for irrigation.

Table 3 has been derived from Table 2 by dividing the surface and ground water potentials by the catchment area of the basin. Thus Table 3 gives the macroscale potential of surface and ground water availability in different basins of the country. Downstream part of Ganga basin, Brahmaputra, Barak and others, Subernarekha, Brahmani-Baitarani, and Mahanadi basins encompass the eastern region of the country. Though the average surface and ground water potential in Ganga basin is respectively 0.6095 m and 0.1993 m (Mm^3/sq km), it is expected that their would be more availability of water resources in the downstream region of the basin. Likewise the combined surface and ground water potential in Subernarekha, Brahmani-Baitarani, and Mahanadi basins is 0.4984 m, 0.6629 m, and 0.6227 m, respectively. If properly harnessed, this water is sufficient to sustain about 200 percent cropping intensity. However, to achieve such high average cropping intensity the major rice crop during the monsoon season should, wherever possible, be followed by some other dry footed crop suited to different agro-ecological zones in order to increase agricultural production. The water resources potential in Brahmaputra and Barak valley, as shown in Table 3, is very high. If properly developed, there will be enough availability of water to sustain any cropping intensity.

WATER MANAGEMENT

Development of surface and ground water resources plays a vital role in the production of food and fibre. The increased cropping intensity in many irrigation commands has put strains on these sources of waters. In order to ensure nutritional security to the ever increasing population of the country the development and adoption of the appropriate water management technology for sustained availability of water to increase crop, fish and animal production is a basic necessity. The word water management has been interpreted differently by different people. According to The Heritage Illustrated Dictionary of the English Language, International Edition (1973), the verb "manage" means "(1) to direct or control the use of, (2) to exert control over, (3) to direct or administer, (4) to contrive or arrange,......" Similarly the word "management" means "the act, manner, or practice of managing , handling , or controlling something." Thus the term water management implies those cultures, methods, systems, and techniques of water conservation, remediation, development, application, use, and removal that provide a socially and environmentally acceptable level of service or product at the least affordable economic cost. By adopting the water conservation technologies one excercises control over the flow of water in the watershed and thereby stores the water at various sites for different uses. By developing a source of water supply for drinking, industrial, or agricultural usages one directs, administers and controls the use of water. When the municipal and industrial waste waters, or any other salt and micro-organisms ladden water are treated for reuse

Table 3 : Water resources potential per unit catchment area of river basins of India.

Sl. No.	River Basin	Catchment Area (sq km)	AverageSurface Water Resources Potential (Mm^3)/sq km		Average Ground Water Potential (Mm^3)/sq km
			Average	75% Dependable	
1.	Indus	321289+	0.2282	-	0.079
2.	Ganga-Brahmaputra Meghna				
	(a) Ganga	861452+	0.6095	0.5065	0.1993
	(b) Brahmaputra	194413+	2.7634	2.5293	0.1433
	(c) Barak & others	41723+	1.1590	-	0.0430
3.	Godavari	312812	0.3534	0.2575	0.1495
4.	Krishna	258948	0.3017	0.2681	0.1029
5.	Cauvery	81155	0.2632	0.2387	0.1676
6.	Subernarekha	29196	0.4236	0.3375	0.0748
7.	Brahmani-Baitarani	51822	0.5495	0.3869	0.1134
8.	Mahanadi	141589	0.4723	0.3799	0.1504
9.	Pennar	55213	0.1144	0.0796	0.0914

10.	Mahi	34842	0.3163	0.1640	0.1399
11.	Sabarmati	21674	0.1757	0.1452	0.1399
12.	Narmada	98796	0.4620	0.3120	0.1203
13.	Tapi	65145	0.2284	0.1360	0.1255
14.	West flowing rivers from Tapi to Tadri	44940	1.5626	1.1738	0.1694
15.	West flowing rivers from Tadri to Kanyakumari	56177	2.0210	1.5181	0.1568
16.	East flowing rivers between Mahanadi and Pennar	86643	0.2599	0.2166	0.2630
17.	East flowing rivers between Pennar and Kanyakumari	100139	0.1644	0.1391	0.2088
18.	West flowing rivers of Kutch and Saurashtra including Luni	321851	0.0469	-	0.0433
19.	Area of inland drainage in Rajasthan desert	-	-	-	-
20.	Minor rivers draining into Myanmar and Bangladesh	36302+	0.8539	-	-

+ Area in Indian territory

one exerts control over the quality of water by removal of various pollutants. The work on irrigation scheduling of different crops is an act to direct and control the use of water in crop production programmes. Similarly the removal of excess water from agricultural lands, municipal areas, and the flood control measures are the acts to control the regime of water to make it socially and environmentally favourable.

The intended service from water in agriculture is the creation of favourable water regime for crops, fish and animal production systems. Hence agricultural water management signifies those methods, systems, and techniques of water conservation, remediation, development, application, use, and removal that provide a socially and environmentally favourable level of water regime to agricultural production system at the least economic cost. As the agricultural production programmes are arealy distributed under varying conditions of rainfall, climate, soil and topography, agricultural water management is site specific; hence, appropriate water management technology should be developed and adopted to suit the location specific needs. Appropriate water management or development is selection and adoption of the right solutions to meet the developmental needs in a particular environment. It is not necessarily low technology or labour intensive form of management.

The agricultural water management research should contribute in generating environment friendly technololgy of water conservation, removal, development, and utilization to bring more areas under production by creating favourable water regime to enhance crop, fish, and animal production. Hence, the research should aim to develop new knowledge and technology for (i) effective development, management, and conservation of on-farm water resources for its sustained availability, (ii) significant reduction in the use of irrigation water per unit irrigated area, (iii) removal of excess water from agricultural lands, (iv) development of sustainable cropping system in relation to the availability of water, (v) devising multiple uses of water in agricultural production programmes to enhance water productivity, (vi) reuse of the poor quality industrial, municipal and other waste water, and (vii) avoiding/reversing the contaminations and further degradation of soil and water resources. Applied, strategic and basic research should form the core of research activities to develop short and long term approaches to various water management problems. The new knowledge and technology should be disseminated amongst researchers, government functionaries, non-governmental organisations and farmers for its adoption to enhance agricultural productivity and environmental security.

DEVELOPMENT OF MAJOR AND MEDIUM IRRIGATION POTENTIAL

Statewise development of irrigation potential vis-a-vis ultimate for major and medium irrigation projects is given in Table 4. As is evident from the table, an irrigation potential of 30.764 million ha out of the maximum potential of 58.475 million ha has been created till the end of seventh plan. Out of the 16 major states six states viz., Tamil Nadu (96%), Punjab (83%), Rajasthan (70%), Haryana (69%), Andhra Pradesh (62%), and Jammu & Kashmir (62%) have already achieved sixty percent or more of the ultimate major and medium irrigation potential. Three states viz., West Bengal (57%), Karnataka (54%), and Uttar Pradesh (54%) have achieved between 50 to 60 percent of the ultimate potential. Five states viz., Kerala (48%), Maharashtra (47%), Gujarat (43%), Bihar (43%) and Orissa (40%) have achieved between 40 to 50 percent of the potential. The remaining two states which have realised less than 40 percent of the potential are Madhya Pradesh (33%), and Assam (19%). The average development of major and medium irrigation potential for the country as a whole till the end of seventh plan has been estimated to be 53 percent.

The major and medium irrigation potential has been created after incurring large expenditure which has increased progressively during successive plan periods (Table 5). Beginning with an expenditure of Rs. 380 crore during first plan, it rose to Rs. 7369 crore during sixth plan. The outlay during seventh plan and the period 1990-95 have been to the tune of Rs. 11505.56 crore and Rs. 26430 crore, respectively. During 1990-95, there was a target to create 6.5 million ha of irrigation potential. Thus it is estimated that an irrigation potential of 37.264 million ha would have been created till 1994-95.

Table 4 : Statewise major and medium irrigation development upto the end of VIIth plan (Thousand ha).

Sl.No.	State/Union Territory	Ultimate major and medium irrigation potential potential	Potential Created till the end of VIIth Plan	Percent Development
1.	Andhra Pradesh	5000	3081	62
2.	Arunachal Pradesh	**	—	—
3.	Assam	970	183	19
4.	Bihar	6500	2808	43
5.	Goa	62	11	18
6.	Gujarat	3000*	1275	43
7.	Haryana	3000	2069	69
8.	Himachal Pradesh	50	8	16
9.	Jammu & Kashmir	250	155	62
10.	Karnataka	2500*	1339	54
11.	Kerala	1000	483	48
12.	Madhya Pradesh	6000	1972	33
13.	Maharashtra	4100	1932	47
14.	Manipur	135	60	44
15.	Meghalaya	20	—	—
16.	Mizoram	**	—	—
17.	Nagaland	10	—	—
18.	Orissa	3600	1422	40
19.	Punjab	3000	2489	83
20.	Rajasthan	2750*	1935	70
21.	Sikkim	20	—	—
22.	Tamil Nadu	1500	1435	96
23.	Tripura	100	10	10
24.	Uttar Pradesh	12500	6759	54
25.	West Bengal	2310	1322	57
	Union Territories	98	19	19
	Total	58475	30764	53

Table 5 : Planwise financial expenditure on major and medium irrigation Projects.

Sl.No.	Plan/annual plan	Expenditure in Crores
1.	First Plan (1951-56)	380.00
2.	Second Plan (1956-61)	380.00
3.	Third Plan (1961-66)	581.00
4.	Annual Plans (1966-1969)	434.00
5.	Fourth Plan (1969-74)	1237.00
6.	Fifth Plan (1974 - 78)	2442.00
7.	Annual Plans (1978-80)	2056.00
8.	Sixth Plan(1980-85)	7369.00
9.	Seventh Plan(1985-90) outlay	11505.56
10.	Outlay for (1990-95)	26430.00
	Total	52814.56

Even though the eastern part of India receives high rainfall, only 43.5% of net sown area in Bihar, 30.7% in Orissa and 35.8% in West Bengal is irrigated as compared to 92.7% of net sown area irrigated in Punjab. It is one of the major reasons for low cropping intensity and agricultural productivity. In order to bring more areas under assured irrigation, it is necessary to appraise the spatial and temporal availability of surface and ground water resources, and status of their development to identify the gaps for further conservation and development.

MULTIPLE USE OF IRRIGATION WATER

The expenditure of Rs. 52814.56 crores on major and medium irrigation projects has primarily been with the aim of irrigating cropped lands for producing foodgrains. Similarly, the farmers have invested heavily on wells, primemovers and pumps, and water conveyance systems mainly for irrigation. The increase in productivity of water in agriculture through its multiple use has never been an objective of the major, medium, and minor irrigation projects. The productivity of canal and well waters in agriculture could be increased by (i) economizing the use of water in crop production, (ii) routing the water through fish pond cum secondary reservoirs before its use in crop production, and (iii) storing water in secondary reservoirs for irrigation and aquaculture. In the second systerm water is released for irrigation by gravity, while the third one is pumped for irrigation. The second and third approaches are examples of additional use of surface and ground water supply, without appreciably degrading its quality, before it is used as irrigation water for crop production. As the water is diverted from a canal outlet to a fish pond cum secondary reservoir, there is additional loss due to evaporation and seepage from the pond. During the process of fish production the water in the fish pond is loaded with (i) manures and inorganic fertilizers to promote the growth of planktons that are eaten by the fish, (ii) fish feed applied for fish consumption, and (iii) excreta of the fish. The aforesaid loading processes certainly alter the quality of water, but this alteration is favourable as the water becomes rich in nutrients. The use of such nutrient rich irrigation water is benefiicial for crop production.

As the major loss of water in crop production is due to evaporation and deep percolation, the loss from fish ponds also is due to evaporation from open water surface and seepage. Unless the pond is lined, the loss of water per unit area would be more from a fish pond that from a cropped field as the water supply in the pond is not limiting to evaporation and percolation. However, when the new irrigation water is used in replacing the old resident water in the pond, the nutrient rich old water is available for reuse as irrigation water. If the water is not utilised in irrigating crops, it would go waste. The use of the aforesaid waste water from a fishpond ensures multiple use of water in agriculture.

CAPACITY OFTHE FISH POND FOR MULTIPLE USE OF CANAL WATER

The fish pond could be located anywhere in the culturable command area of the canal where there is reliance on water supply. It may also store water for irrigation. A fish pond cum secondary reservoir should be located near the canal outlet to the water course such that the water should flow from the outlet to the water course through the pond (Fig 2). Normally the flow of water in minors and outlets is periodic, depending upon the water requirement of crops and availability of water in the reservoir feeding the canal network. For example, on an average, the Phulnakhara distributary (in Cuttack district of Orissa) supplies water to cropped fields for 162 days in a year (Mishra, A, 1997). During the period of its operation the flow from the outlets to the water courses is continuous; only when the farmers do not need water they stop the flow using their ingenuity. The Water Allowance Committee on Upper Bari Doab canal system in Punjab (Anonymous, 1992) has recommended 196 days of canal operation in a year, 133 days during April to September and 63 days during October to March, for rice-wheat cropping system. The water release patterns in the commands of Phulnakhara distributary and Upper Bari Doab canal are given in Table 6. In the command of Paladugu distributary taking off from the Guntur branch canal of the Nagarjunsagar right canal, the pipe outlets discharge water to water courses for 6 days in a week (Anonymous, 1996). The periodic flow through the pond is desirable for intermittent exchange of water for increasing water aeration and eliminating toxicity from the pond to make the environment more congenial for fish production.

The capacity of the reservoir should be such that there should be total exchange of water in the pond during each cycle of flow. The seepage loss from the pond should be as low as possible to ensure adequate availability of water for crop production and reduce filling time of the pond. Normally the common Indian corps grow well in about 1.5 m to 2.5 m depth, WD_f, of water. If the evaporation and seepage loss is ES_1 m/day then in a maximum irrigation cycle of N days the total loss becomes $(ES_1 \cdot N)$ m. Hence the depth of pond should be $(WD_f + ES \cdot N)$ m below the ground level for rearing of the fish. As the pond is also to be used as a secondary reservoir, therefore, its height should be raised upto the full supply level of the minor (or water course) from which the outlet would discharge water into the pond. Any water stored in the pond above the ground level would be used for irrigating field crops. If the elevation of the full supply level above the ground is Fs_e m, then the total depth of pond below the full supply level becomes $(Wd_f + ES_1 \cdot N + FS_e)$m.

Table 6 : Monthwise water release pattern in Phulnakhara distributary and Upper Bari Doab canal etwork.

Months	Average water release days in the command of Phulnakhara distributary	Proposed water release days in the command of Upper Bari Doab canal
April	20	7
May	10	13
June	1	30
July	9	31
August	20	28
September	21	24
Kharif Season	81	133
October	26	7
November	11	14
December	0	12
January	5	9
February	18	7
March	21	14
Rabi Season	81	63
Grand total	162	196

The consumption of water by the fish for its metabolic activities is so small that it may be considered negligible. Hence, the loss of water due to evaporation and seepage is the only extra loss in the proposed system of water management. In addition, there is additional need of water for the first filling of the pond below the ground level at the start of the stocking of the fish. The number of fish ponds and the number of fish pond cum secondary reservoirs that could be fed by an outlet is a policy decision which would be governed by the allowable amount of additional evaporation and seepage losses in the system. The water charges for the fish production could be determined on the basis of volume of water used in production process which may be estimated by employing the measures of water spread area for evaporation and wetted surface area of the pond for seepage loss.

A perusal of Table 6 indicates that the Phulnakhara distributary supplies water during all the months except December. The supply from the Upper Bari Canal network looks more assured. Under the present schedule of canal operation the water in the pond would get exchanged several times in a year, though at irregular intervals. The effect of the irregular supply of water on fish production needs to be studied on real life system in canal command. Under such a water regime and normal management conditions the common Indian carps would attain weights of 0.6 kg to 1.15 kg in a year. The fish pond cum secondary reservoir should be constructed only near those outlets which could receive assured supply of water on almost all days of canal operation. If fish production is integrated with the crop production, the canal operation schedule should be revised taking requirementss of the fish farming into consideration.

WELLWATER FOR FISH AND CROP PRODUCTION

Ground water is abstracted for irrigation and drinking purposes through dug wells, and shallow and deep tubewells. The progressive energisation of pumpsets (Ladlani, 1990) in different states is shown in Table 7. A perusal of the table reveals that during sixth and seventh plan periods a total of 17.44 lakh and 25.16 lakh pumpsets were electrified. By the end of seventh plan (1989-90) the country had about 82.3 lakh electrically driven pumpsets and an estimated number of 45.6 lakh diesel engine driven pumpsets. Out of these pumpsets, a sizeable percentage is being used in pumping ground water for irrigation. It is estimated that till the end of seventh plan there were 94.87 lakh dugwells, 47.54 lakh private shallow tubewells and 0.64 lakh public tubewells in the country (Anonymous, 1989). During 1989-90 there was a target to construct 2.89 lakh dugwells, 3.53 lakh private shallow tubewells and 0.039 lakh public tubewells, and to install 4.07 lakh electrical pumpsets and 2.00 lakh diesel pumpsets on dugwells, private shallow tubewells, and surface water sources. Similarly, there was a target to energise 30.00 lakh pumpsets during 1990-95.

The pumped ground water, like canal water, could also be routed through a fishpond cum secondary reservoir to diversify the use of well water. Unlike canal water, the ground water supply is highly reliable. Hence, the exchange of water in the fishpond could be as per the requirement of the fish production system. Consequently, a fishpond based on ground water supply could be lined to eliminate seepage losses. In such ponds intensive fish culture could be practised. The pond could be so designed and integrated in the agricultural production system that the energy need to pump water for fish production is minimised to the leveol of meeting the evaporative demand alone. As intensive fish culture requires regular pumping of water, therefore, it is necessary to grow some crop in the field for the utilisation of outflow from the fish pond.

A paradigm of the tubewell based fish, fruits, vegetables, and crop production system exists on the farm of a progressive farmer, Mr. Radha Krishna Sahoo of village Khantallo, near Kishore Nagar, distriict Cuttack, Orissa.

Table 7 : Electrical energisation of pumpsets (in thousands) at the end of different plans.

Names of States	Ultimate Feasible	Cumulative Progress upto							
		1950 -51	1960 -61	1968 -69	1973 -74	1977 -78	1979 -80	1984 -85	1989 -90 (likely)
Andhra Pradesh	1500	N.A.	18.0	123.2	270.2	337.52	405.12	646.95	1121.06
Assam	200	——	——	Neg.	0.7	1.05	1.68	2.74	3.74
Bihar	1000	Neg.	3.2	50.0	96.9	139.98	151.99	191.76	251.24
Goa	——	——	——	——	——	——	——	——	0.54
Gujarat	500	0.9	7.0	42.1	102.7	156.03	202.85	292.39	426.29
Haryana	250	N.A.	3.5	45.4	128.0	166.63	203.36	271.90	340.38
Himachal Pradesh	10	—	Neg.	0.3	1.1	1.46	11.63	2.32	3.05
Jammu & Kashmir	15	N.A.	0.1	0.2	0.5	0.83	0.99	1.35	1.97
Karnataka	600	2.5	16.9	91.8	189.7	262.36	290.31	441.21	672.12
Kerala	150	N.A.	2.7	13.9	37.7	58.92	77.86	131.81	201.38
Madhya Pradesh	1300	N.A.	1.8	24.6	115.6	215.93	279.43	467.82	776.44
Maharashtra	900	0.1	7.2	125.0	322.2	488.71	597.47	935.36	1468.25
Manipur	10	——	——	——	——	——	0.01	0.04	0.04
Megha-laya	10	——	——	Neg.	Neg.	Neg.	0.05	0.06	0.06
Naga-land	10	——	——	Neg.	Neg.	Neg.	——	——	0.02
Orissa	500	N.A.	N.A.	0.5	2.8	6.43	12.96	30.00	46.71
Punjab	500	N.A.	8.6	59.2	129.6	196.30	262.20	406.28	553.50
Raja-sthan	600	N.A.	120	184	73.6	128.96	183.24	275.29	341.83
Sikkim	5	——	——	——	——	——	——	——	——
Tamil-nadu	1000	14.4	117.7	410.0	681.2	809.61	887.23	1033.56	1265.85
Tripura	10	——	——	Neg.	Neg.	0.15	0.25	0.94	1.29
Uttar Pradesh	2400	3.1	9.0	77.7	233.6	298.75	361.75	509.17	636.97

West Bengal	500	N.A.	Neg.	1.2	6.5	20.35	24.07	39.49	79.56
Total States	11970	21.0	197.60	1081.5	2412.6	3290.00	3944.52	5680.44	8192.26
Total U.Ts.	30	N.A.	1.30	7.3	13.6	18.96	21.31	28.13	33.94
Total States & U.Ts.	12000	21	198.90	1088.8	2426.2	3308.96	3965	5708.57	8226.20
SAY	12000	21	200.00	1090	2430	3300	3965		

MANAGEMENT OFWATER AVAILABLE IN LOW ORDER STREAMS

Very often the rain and seepage waters from a watershed flow out of its boundaries through first order streams in which the flow of water is either ephemeral to intermittent, or seasonal. These streams collect water from various segments of the watershed and drain it to other streams, either of the same order or higher order. It is a natural way of collection and drainage of water from the watershed. Several regions having rolling topography that abound in low order streams are quite poor in availability of ground water. In such regions the flow from a low order stream could be utilized by collecting the water in small reservoirs constructed either in the bed of the stream or by its side (Fig.3). The latter one is connected to the stream through a link channel for drawing or releasing water from or to the stream as per necessity. The reservoir should be designed to store sufficient quantity of water for the multiple purpose of fish production, irrigation, human and animal consumption, and recreation. The location, size, and dimensions of the reservoirs would be govemed by topography, soil type, availability and demand of water, and other site specificities. The number of such reservoirs on a low order stream could be determined by (i) the distribution of catchment area along the length of the stream, (ii) volume of temporal runoff generation in various segments of the stream, (iii) demand of water for various purposes, and (iv) availability of natural and dugout sites.

In high rainfall areas of Orissa and West Bengal, farmers sow the rice seeds by broadcasting during second half of May and early June as the soil moisture is favourable due to premonsoon showers. The rice yields from such a practice is invariably low due to inadequate plant population arising from poor germination, birds scaring and several other factors. The rainfall distribution is such that only a few strategically located plots are submerged with sufficient water for puddling and transplanting during the latter half of June and first half of July, the optimum time for transplanting. In absence of irrigation the farmers are not able to transplant rice in time. It is therefore necessary that wherever feasible water should be stored in reservoirs for creating facility for irrigation and fish production.

In order to have an assured rice crop, it is necessary to supply adequate quantity of irrigation water during mid June to mid July for transplanting, and during mid September to mid October for overcoming moisture stress at grain filling stage. Thus, the reservoirs should be so designed that it should capture and store enough water for irrigation within first few weeks of the onset of monsoon and again during the last few weeks of the withdrawal of monsoon. In high rainfall areas of Orissa

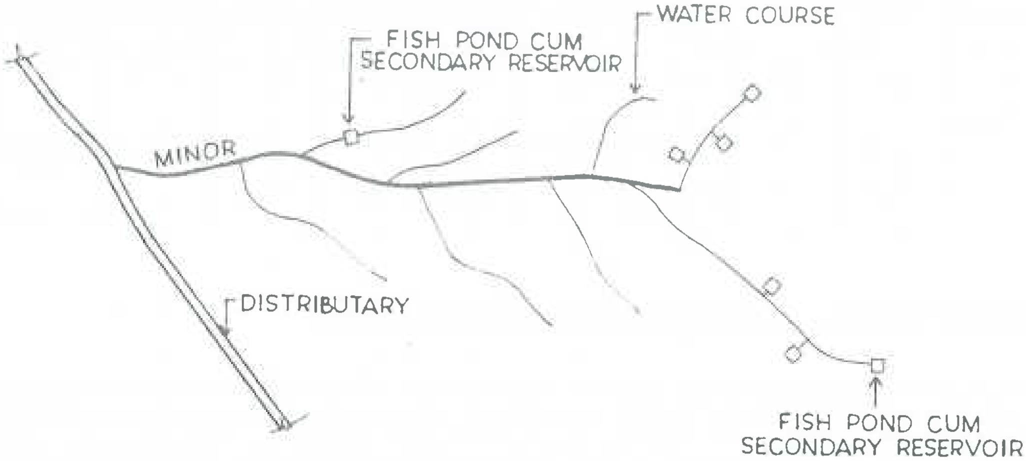

FIG. 2. SCHEMATICS OF FISH POND CUM SECONDARY RESERVOIRS IN CANAL COMMAND.

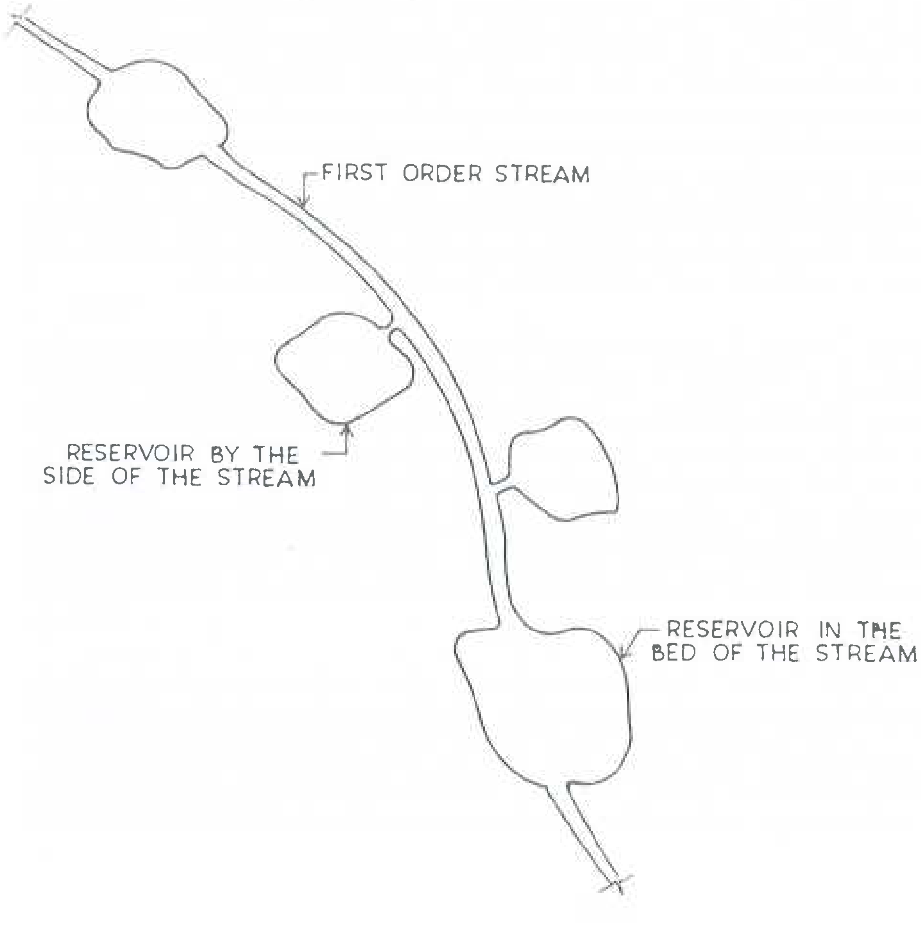

FIG. 3. SMALL RESERVOIRS IN THE BED/SIDE OF A FIRST ORDER STREAM.

and West Bengal, enough water is available during the peak monsoon season to fill small reservoirs. This water would help in providing stability to rice production during dry spells in monsoon season. The water stored at the time of withdrawal of monsoon could also be used for irrigating subsequent low duty post monsoon crops, thereby increasing the cropping intensity and agricultural production.

The small reservoirs constructed in the bed or by the side of the stream would invariably be in the valley of the watershed as the streams are located in the valleys. Thus the water stored in such a reservoir would invariably require additional energy for its lifting to irrigate the adjoining fields. As the catchment area of a stream continuosly increases along its length, the small reservoir could be located to capture water from a desired catchment area to enhance the reliability of storeage of water in the reservoir. The high reliability of storage is particularly important for fish production as the fish can not survive without water. It is expected that the reliability of availability of water from a reservoir fed from a low order stream could be made higher than that of runoff harvesting tank (not located in the valley) capturing water from a small watershed which is part of the catchment of the stream but away from the valley. Thus there is a need to evaluate low order stream based water resource development paradigms and its overall effect on agricultural production.

Water Technology Centre for Eastern Region has constructed a small reservoir in the bed of a first order stream passing through its Deras research farm near Mendhasal by damming the flow of the stream with the help of an earthen embankment having a cross section of 6.2 m bottom width, 3 m top width, and 1.4 m height. A drop inlet structure with SAF outlet has been provided across the embankment for the safe disposal of excess run off water entering the reservoir. The embankment across the natural depression has created a reservoir in the bed of the stream whose water spread area at the level of the cylindrical inlet structure is about 1.2 ha. During the monsoon season of 1996 the research farm did not get any irrigation water from Deras minor irrigation system due to failure of its sluice gate constructed in the main body of the Deras dam to divert water from the reservoir to the right bank canal. Unfortunately, it was a year of poor monsoon in Orissa. Consequently, the rice cultivation on a part of the research farm depended on the supply of water from the aforesaid reservoir. With the help of diesel engine driven centrifugal pump, water was pumped from the reservoir to irrigate rice fields for land preparation to maintenance of favourable water regime for crop production. During the monsoon season of 1996 about 177.12 ha cm of water was diverted from the rservoir to command an area of about 12 ha. The live capacity of the reservoir is estimated to be 90 ha cm. Thus water to the tune of 1.97 times the live capacity of the reservoir was diverted for irrigating rice crops. This way the effect of drought could be partially alleviated.

Table 3 gives the macroscale 75% probable surface runoff potential of Ganga, Brahmaputra, Subernarekha, Brahmani-Baitarani, and Mahanadi basins as 0.5065 m, 2.5293 m, 0.3375 m, 0.3869 m, and 0.3799 m, respectively. In order to utilise the flow of first order streams for agricultural production by storing water in small dugout or natural ponds, it is necessary to have the time distribution of flow from these streams. As mentioned earlier, the stream flow till middle of July is important for rice transplanting. In absence of measured stream flow data from each first order stream, one may assume about 13.5% of 75% probable runoff flowing in the streams till middle of July. Thus one expects 0.0684 m, 0.0456 m, 0.0522 m, and 0.0513 m, respectively, from first order streams in Ganga, Subernarekha, Brahmani-Baitarani, and Mahanadi basins. Assuming that about 20 cm water is required for transplanting and establishment of rice, one requires runoff from 2.92 ha, 4.39 ha, 3.83 ha, and 3.9 ha, respectively, from the catchment of first order streams in Ganga, Subernarekha, Brahmani-Baitarani, and Mahanadi basins. Thus as a rule of thumb, runoff from about 3.76 ha catchment area would sustain rice cultivation in one ha area in eastern region. Hence, in absence of observed data one may have about 2000 m^3 capacity reservoirs for every 3.76 ha catchment are of the first order stream to ensure one ha rice cultivation. After the establishment of rice the pond should be utilised for fish rearing so that the area occupied under pond contributes to agricultural production. The water availabe in the catchment after middle of July is quite sufficient and assured for fish farming.

SUMMARY

Basinwise water resources of the country and statewise development of major and medium irrigation projects have been reviewed. The article also deals with the status of development of pumped irrigation in different states of the country.

The term water management means different things to different group of people. An attempt has been made to present an unified definition of water management in general and agricultural water management in particular.

The planning of major, medium, and minor irrigation projects in the country has so far been only to develop storeage, conveyance, and delivery systems to irrigate crops for the production of foodgrains, fibres, fruits, and vegetables. Similarly, the farmers have invested heavily on wells, pumping equipment, and conveyance system for irrigating crops. Integration of fish production with crop production on the farmers' fields through multiple use of developed water resource has never been a concept in planning and management of irrigation projects. It has been argued that routing the irrigation water through fish pond cum secondary reservoirs before its use in crop production would add another usage of developed water resource in agriculture. During the process of fish production, though there is some additonal loss of water due to evaporation and seepage, but the water in the fish pond becomes nutrient rich due to loading with manures and inorganic fertilizers, fish feed, and the excreta of the fish which is benificial for crop production. In fish farming it is necessary to replace the old resident water in the pond by new irrigation water to increase the availability of oxygen in water and simultaneously decrease the concentration of metabolites for improving the environment for fish production. In this process the nutrient rich old water is available as outflow from the pond which should be reused for irrigating crops to avoid its wastage. The use of the aforesaid waste water from a fish pond ensures multiple use of water in agriculture.

Construction of small ponds in the bed or side of a low order stream to store water for irrigation and fish farming has been proposed for better utilization and management of water available from the low order stream. As a stream has sizeable catchment area monotonously increasing along its length, therefore there is greater reliance about the filling of the ponds and hence availability of water all along the length of the stream during the early monsoon season. The decesion about the number of ponds along the length of the stream should be based on the estimated or gauged stream flow data. In absence of observed data one may construct, as a rule of thumb, about 2000 m^3 capacity ponds for every 3.76 ha catchment area along the length of the stream lying in the major river basins of eastern India, though the value is different for each river system.

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