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SYSTEM APPROACH TO OPTIMISE USE OF SURFACE AND GROUND WATER

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ABSTRACT

Conjunctive use of surface and ground water combines the advantages of ground water storage with surface water system and serves as both a remedial and corrective measure for efficient water management and utilisation. It requires careful planning to optimise use of available surface water and ground water resources in totality. It is however seen that the conjunctive use that is being practiced in the country, at the moment, does not really envisage the optimal use of both surface and ground water to take advantage of their correctivity. It is therefore imperative that all programmes on conjunctive use of surface water and ground water to consider the two sources as part of an overall system with their connectivities well defined. System is then optimised with appropriate optimization technique to yield the most beneficial conjunctive use programme.

1. INTRODUCTION

Due to increasing demand of water for agricultural, domestic and industrial purposes, greater emphasis has to be laid on optimum utilisation of water resources. Since independence of our country the tempo of irrigation development has been rapid and emphasis is being laid on storage backed irrigation facilities i.e. by undertaking construction of a number of surface water reservoirs and canal systems. The irrigation projects in our country are planned and implemented separately for surface and ground water. Ground water is a renewable natural resource and has the remarkable distinction of being highly dependable, safe and ubiquitous. The annual utilisable ground water resources of the country for irrigation is quite substantial and have been estimated as 38.28 m.ha.m. (Annexure-I). The present net draft is assessed as 10.65 m.ha.m. leaving a balance of 27.63 m.ha.m. for safe exploitation for irrigation. The development of ground water has largely seen under private sector and it has been found to be haphazard. Over exploitation of ground water in areas like Mehsana and coastal saurashtra (Gujarat), Kurukshetra (Haryana), Union territory of Chandigarh and in some pockets in Tamil Nadu and Kerala has resulted in mining of ground water. On the other hand in some major Canal Command areas such as Sharda Sahayak (U.P.), Ghatprabha and Malprabha (Karnataka), Chambal (Rajasthan), Nagarjuna sagar (Andhra Pradesh), problems of water logging have been noticed. Water logging problems could have been checked if, during the project planning, conjunctive use was envisaged in canal command areas.

Our National Water Policy clearly lays down that both surface and ground water should be viewed as an integrated resource and should be developed conjunctively in co-ordinated manner and their use should be envisaged right from the planning stage.

2. CONCEPTS AND PRINCIPLES OF CONJUNCTIVE USE PLANNING OF SURFACE AND GROUND WATER

The conjunctive use can be defined as the development and management of multiple water resources in a coordinated manner such that the total yield of the system over a period of years exceeds the sum of the yields of the individual component of the system resulting from an uncordinated operation. The objective of the conjunctive use implies not only the joint use of water resources of more than one type but also their exploitation through efficient management in techno-economic terms by taking advantage of the interaction between them and the impact of one on others.

2.1 Principles of conjunctive use

The case of conjunctive use of both surface and ground water system results from a study of the limitations which exist for the two systems, if developed separately. Surface water systems usually have an inadequate number of dam sites at which required storage capacity might be provided with economic and financial feasibility, where as most ground water systems have far greater storage capacities, than that required for modifying the natural stochastic time distributions of the portion of the precipitation potentially reaching the water table. Thus there is great scope for time-wise regulation of the natural fresh water resource under conjunctive use than would be possible under separate independent development. Transport of water in the ground water system requires substantially greater quantities of energy expenditures per unit volume than that required for surface transport particularly where long distances are concerned. However, where small amounts of water and short distances are involved the unit cost of the surface distribution systems are much more than those of subsurface transport. This suggest that there is a major complimentarity which could reduce the total system costs.

Removal of fresh water from storage in surface systems generally provides a release of energy which can be converted for other useful purposes. Removal of fresh water from ground water storage requires an expenditure of energy. The energy obtainable from one system could provide all or part of the energy required for the other.

2.2 Concept of Integrated Approach in Water Resources Development.

The concept of integrated approach in water resources development projects necessarily need to incorporate conjunctive use of surface and ground water in canal irrigation which is possible in different ways, such as,

i) Ground Water can be used in kharif season to supplement the irrigation needs to the extent necessary and it can be used during the Rabi season when rainfall contribution is much less in relation to the irrigation requirements.

ii) Ground water can also be used in meeting the requirements of hot weather crops, instead of drawing supplies from reservoir when evaporation losses are highest.

iii) Ground Water Resources can be conserved and put to beneficial use on a carry over basis specially in the years of severe or partial drought.

iv) Ground Water can also be used in serving isolated pockets, high areas, raising nurseries etc.

v) In case of areas which are water logged or prone to water logging, development of ground water will result in lowering of water table and consequently reduce/prevent water logging and

vi) In case of areas having saline ground water, brackish ground water can be blended with surface water canal supplies.

2.3 System Yield

The true yield of the system and unit cost of the water supplied are both matters which can be investigated. The system yield is bound to be greater than the yield of the two individual components if

i) Advantage can be taken of water which normally over flows the reservoir.

ii) The aquifer can be overpumped for short periods so long as the overall long term abstraction rate does not exceed the recharge rate.

Where water is used from more than one source, it is essential to formulate control rules which inform the operator which source is used for given set of conditions. For a reservoir and an aquifer used for direct supply, it is possible to examine the yield and operating procedures for a number of different operating policies.

a. Reservoir

Reservoir and their operations are generally classified according to whether they are for a single purpose or for more than one purpose. Multiple-purpose reservoirs are more complex in design and operation then single purpose reservoir.

For reservoir what is required is a level which marks the boundary between withdrawals to supply which may exceed the design net yield and withdrawals at the design rate. The derivation on points on the control curve are obtained as

$$Sr = Sm + Ds + C - I + L$$

Where

Sr	=	storage required
Sm	=	Dead storage
Ds	=	Total volume of water required for supply during the period under consideration at the net yield rate.
C	=	Total volume of compensation releases during the period under consideration.
I	=	Design drought inflow
L	=	Reservoir losses during period.

The "when needed" characteristics usually requires storage capacity in which flows during some periods in excess of need can be stored and subsequently withdrawn when the flow of water is inadequate.

Evaluation of storage capacity requirements is a standard procedure in surface water planning. It is infrequently necessary in ground water planning.

(b) Aquifer

Aquifers have certain recharge, storage, transmission and yield characteristic. Recharge opportunities may be significant in unconfined aquifers; confirmed aquifers which out crop in forebay areas and those in direct hydraulic continuity with streams. The feasibility of conjunctive use approach depends on operating a ground water basin over a range of water levels, which interalia requires that there must be space to store recharged water, and in addition, there must be water in storage for pumping when needed.

3. SYSTEM APPROACH FOR CONJUNCTIVE USE

System Approach shall be required in formulation of conjunctive use projects. A schematic diagram of a systematic approach for conjunctive use analysis is illustrated in Fig. 1 (Todd, 1980). The approach is being increasingly used to solve various problems associated with conjunctive use planning, more so with the advent of digital computers. Basically the problems have been solved in two frameworks (a) optimization and (b) simulation.

(a) Optimization

The optimization model solves the problem of allocating the surface water and ground water resources among competing users in an optimal manner. For calculating the alternatives, mathematical techniques and modern computers are employed as without these it becomes almost an impossible task to arrive at a solution. From the spectrum of alternatives obtained on a preliminary examination, a few are chosen for a closer and detailed study. This leads to final solution possible under the various restraints. Some of the important optimization techniques employed are

I. Linear Programming
II. Dynamic Programming
III. Integer Programming
IV. Stochastic Programming
V. Non linear Programming

The different techniques are applied depending on the nature of variables. Linear Programming is one of the most widely used method's for solving the problem of allocating the surface water and ground water resources among competing users in an optimal manner.

A system is said to be linear when the condition of "Super imposition" is valid. That is in

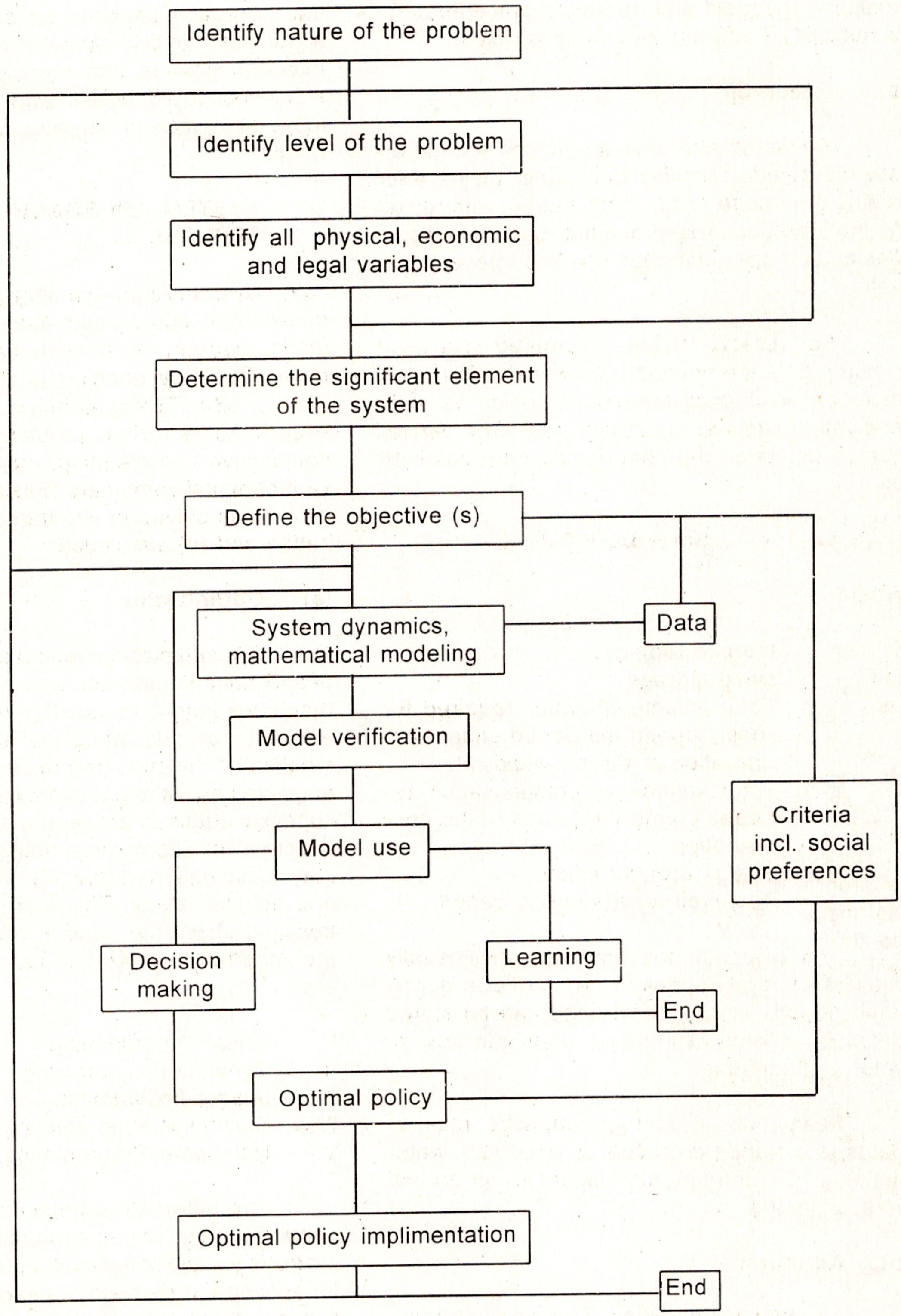

Fig. 1 : Schematic diagram of a systematic approach for studying conjunctive use problems (Todd, 1980)

a linear system the response to every disturbance runs its course independent of preceding or succeeding inputs to the system, the total result in the system is no more or less than the sum of the separate components of the system response.

A linear Programming problem arises when two or more activities are competing for limited resources and when it can be assumed that all relationships within the problem are linear. This refers to techniques for solving a general class of opimization problems dealing with the interaction of many variable subject to certain restraining conditions.

The following conditions must be satisfied before applying linear programming for optimization problems.

(a) Objective function which is to be either maximized or minimized must be expressed as a linear function.

(b) A set of linear constraints which contains the technical specification of the problem in relating to the given resources or requirements must be stated.

(c) A set of non negative constraints.

The complete mathematical statement of a linear programming problem includes a set of simulataneous linear equations which represent the conditions of the problem and a linear function which express the objective of the problem.

Dynamic Programming is also the most used optimization technique in water resources system. This solves the problem in stages, with each stage involving exactly one optimizing variable. The computation of different stages are linked through recursive computations in a manner that yields a feasible optimal solution to the entire problem when the last stage is reached.

b. Simulation

Simulation models provide the reaction of the system to conditions that may be imposed on it as a consequence to planned development programmes. The advantage of the system i.e. determination of system yield can be assessed by simulation. For assessing the scheme the control rules devised and additional capital costs proposed are tested for variety of demand rates. The simulation starts by choosing a design demand. At the beginning of the record an arbitarary reservoir level is chosen with an arbitrary history of aquifer abstractions. Then on a monthly (or weekly) basis the procedure is as follows.

1. What is reservoir level.

2. Can the full rate which is limited by the aquifer characteristics be taken.

3. If the full rate is taken how much must be pumped from the aquifer to meet the design demand.

4. If the full rate cannot be taken how much must be pumped from the aquifer to meet design demand. Can this be done without involving aquifer constraints.

5. Having deducted water taken from the reservoir for supply the period of inflow-known from the record is added.

6. The process is repeated,

At the end of simulation run computer output is investigated to see if all the rules have been obeyed. If the reservoir does not empty in terms of dynamic reserve the demand is increased and the simulation is repeated until the reservoir just empties during the period of record (and vice versa). Eventually a system yield is be determined. The purpose of simulation model can be identified as given below.

i. The definition of sub-surface Water Resources system.

ii. Evolve alternative planning strategies and therby to choose the optimal scheme for implementation.

4. ADVANTAGES OF CONJUNCTIVE USE OF SURFACE AND GROUND WATER

The various advantages of conjunctive use are summarised below.

i. Provides larger water storage and greater water conservation.

ii. Greater utilisation of ground water leads to smaller surface distribution system.

iii. Use of Ground water would aid in controlling the water table and would require a small drainage system in a basin due to practice of conjunctive use.

iv. Smaller evapotranspiration loss because of greater underground storage.

v. Release of stored surface waters for artificial recharge resulting in greater flood moderation.

vi. Ready integration with existing development

vii. Better timing of water distribution.

viii. Greater control over outflow.

ix Adjustment of power load.

x. Use of saline aquifers due to mixing of water.

5. CONJUNCTIVE USE IN INDIA

5.1 Command Area Development Projects.

In many command areas conjunctive use of water has been in practice. The augmentation tubewells are generally installed along the side of the existing canals discharging into the canals there by supplementing the canal supplies. The practice has been in vogue in Haryana, Punjab and Uttar Pradesh. All irrigation commands have a good scope for conjunctive use of surface and ground water because part of the irrigation water flow through unlined distribution systems and water applied in the field gets partly converted into ground water. The magnitude of such conversion depends upon the soil texture, cropping pattern and intensity and climate.

In India, a number of conjunctive use projects have been introduced in the existing surface irrigation systems. But the conjunctive use that is being practised in the country, at the moment, does not really envisage the optimal use of both surface and ground water resource together. Most of the major irrigation projects have been designed keeping in view the surface water inputs only and the exploitation of ground water is being thought of only after problems like water logging, salinisation etc, manifest in canal commands. They are thus supplemental or joint use projects since they seldom exploit the complementarity of two systems to allow a more cost-effective development. Until this is achieved, optimality in resource use cannot be ensured. Though the use of ground water for irrigation purposes has been going on at fast pace in different states for providing more water for irrigation. This has no doubt, helped considerably in many ways but optimality in resource use has not been achieved in terms of an ideal conjunctive use.

5.2 Studies on Planning Conjunctive Use

Central Ground Water Board, Ministry of Water Resources has taken up studies in project planning for conjunctive use of surface and ground water in selected canal command areas (Sharda Sahayak, Indira Gandhi Nahar Pariyojna, Mahikadna, Hirakud, Tungbhadra and Ghatprabha) in March 1990. The first three areas have been taken up as phase-I programme and remaining three as phase II programme. The basic objectives of these studies are

i) Evaluation of hydrogeological situation and quantification of different components of water balance in canal command area under study.

ii) Identification of the critical areas from the point of view of water logging and salinity in the canal command area.

iii) Evolution of suitable plan for controlling the problem of rising water table in the areas adopting the technique of conjunctive use of surface and ground water and proper drainage etc.

iv) Preparation of sectorwise plans for development of ground water resources in conjunction with surface water.

v) Estimation of cost and cost benefit ratio for total command area under ground water.

The work of the project is in progress. The results so far achieved in these project areas have been briefly outlined here.

5.2.1 Sharda Sahayak Command Area, Uttar Pradesh

The Sharda Sahayak Command area constitutes about 16,,000 sq. km spread over 14 districts of U.P. However an area of 8270 sq.km falling in parts of Lucknow, Barabanki, Rai Bareli, Pratapgarh. Sultanpur and Jaipur district of U.P. forming Sai-Gomti Doab has been takenup for conjunctive use studies.

The main source of ground water recharge in the area is rainfall, seepage from canals and return flow from irrigation The total utilisable resource in the area is 71848 MCM and the net ground water draft is 1008 MCM leaving a ground water balance of 70848 MCM available for further development.

A mathematical model has been devised using USGS3D MODFLOW source code to simulate the ground water flow in parts of the Sai-Gomti interfluve comprising an area 3800 sq.km. The model will be used to decide the conjunctive use strategy.

5.2.2 IGNP Command Area, Rajasthan

Introduction of irrigation through IGNP in Rajasthan has opened up vast possibilities for increasing agricultural production but it has also posed a serious problem of water logging and salinity which requires proper planning and management for effective use of the irrigation potential created. As a result of seepage from canals and irrigated fields, water table is gradually coming up and simultaneously salts of the soils are also coming up on the surface through capillary action and evaporation, forming salt encrustations on the soil surface and causing the salinity problem. Water logging and salinity occurs in areas where there is no proper vertical/ lateral drainage system to drain out the excess irrigation water. The investigations are in progress in the IGNP area under the project.

5.2.3 Mahi-Kadana Command Area, Gujarat

Ground Water in the Mahi-Kadana Command area occurs both under water table and confined conditions. The utimated annual recharge to the phreatic aquifer is 1042 MCM and the draft is 147 MCM. The quality of ground water is generally good, however the deeper aquiferes are reported to yield inferior quality water. Since 1980-81 the irrigation has been appraciably increased due to which water table in certain areas has become shallow causing water logging conditions. A mathematical model is being developed to simulate the hydrogeological conditions in the study area and to generate various scenarios in order to refine the ground water development strategy and to design different ground water structures to achieve optimum development.

5.2.4 Hirakud Command, Orissa

The area is underlain mostly by pre-cambrian hard crystllines. The other formations are lower Gondwanas, laterite and alluvium of recent to sub recent age. Ground Water occurs under water table condition in the weathered residum and in semi-confined condition in the joints and fractured zones as greater depth. Depth of water level varies from 0.72 to 7.85 m in major part of the area.

The available utilisable ground water resources of all 13 blocks is 1352 MCM and out of which the contribution from Hirakud canal seepage and return flow from applied irrigation water from canals are 716 MCM. The total ground water draft is 29 MCM leaving a balance of 1323 MCM for further development indicating that there is tremendous scope for development of ground water in the area.

5.2.5 Ghatprabha Canal Command, Karnataka

In major part of the command area, ground water occurs under water table conditions, with the depth to water varying from less than one metre to as deep as 22m below ground level. The total annual utilisable ground water resource in the area is estimated as 971 MCM and net draft as 485 MCM leaving a balance of 486 MCM available for further development. Water logging occurs in the area due to intensive canal irrigation and consequent rise in water level.

5.2.6 Tungbhadra Canal Command, Andhra Pradesh and Karnataka

Unlike all other intensively developed canal systems, Tungbhadra canal command areas are sporadically distributed and contain several pockets of ill developed and underdeveloped area due to paucity of canal water supplies and

Ground Water Resource Estimates as Per Norms of Ground Water Commiitee

Sl. No.	State/UTs	Total Replenishable Ground Water Resource (m.ha.m/yr)	Provision For Drinking, Industrial, other uses (m.ha.m./Yr)	Utilisable Ground Water Resources for Irrigation (m.ha.m./Yr)	Net Draft	Balance Ground Water Potential Available for Exploitation	Level of Ground Water Develo-ment (%)
1.	Andhra Pradesh	4.3666	0.6505	3.6861	0.7410	2.9451	20.10
	Water						
2.	Arunachal Pradesh	0.1439	0.0216	0.1223	0.0000	0.1223	0.00
3.	Assam	2.3528	0.3529	1.9999	0.056	1.9543	2.28
4.	Bihar	3.3773	0.5067	2.8706	0.6761	2.1945	23.55
5.	Gujarat						
	Un-confined	2.0377	0.3057	1.7420	0.5336	1.1984	30.81
	Confined	0.2175	0.0327	0.1848	0.1075	0.0773	58.17
6.	Goa	0.0605	0.0151	0.0454	0.0035	0.0419	7.71
7.	Haryana	0.8524	0.1276	0.7248	0.5085	0.2163	70.16
8.	Himachal Pradesh	0.0357	0.0072	0.0285	0.0062	0.0223	21.75
9.	Jammu & Kashmir	0.4426	0.0689	0.3737	0.006	0.3691	1.23
10.	Karnataka	1.187	0.2728	1.3759	0.4669	0.9090	33.93
11.	Kerala	0.8117	0.1246	0.6871	0.0656	0.6215	9.55
12.	Madhya Pradesh	5.9718	0.8958	5.0760	0.6326	4.4434	12.46
13.	Maharashtra	3.8836	0.6738	3.2098	0.7076	2.5022	22.04
14.	Manipur	0.0118	0.0018	0.0100	0.0000	0.0100	0.00
15.	Meghalaya	0.0425	0.0064	0.0361	0.000024	0.036076	0.07
16.	Mizoram			Not Assessed.			
17.	Nagaland	0.0052	0.0008	0.0044	0.0000	0.0044	0.00
18.	Orissa	2.3280	0.3492	1.9788	0.0950	1.838	4.80
19.	Punjab	1.7971	0.2695	1.5276	1.5181	0.0095	99.38
20.	Rajasthan	1.6224	0.2938	1.3286	0.4927	0.8359	37.08
21.	Sikkim			Not Assessed.			
22.	Tamil Nadu	3.0162	0.4526	2.5636	1.1987	1.3649	46.76
23.	Tripura	0.0629	0.0094	0.0535	0.0049	0.0486	9.16
24.	Uttar Pradesh	8.0450	1.2068	6.8382	2.4944	4.3438	36.48
25.	West Bengal	2.0708	0.3106	1.7602	0.2911	1.4691	16.54
	Total States	45.1447	6.9268	38.2179	10.594224	27.623676	27.72

Union Territories

1.	Andaman & Nicobar			Not Assessed.			
2.	Chandigarh	0.0035	0.0035		0.0059	-0.0024	168.57
3.	Dadar & Nagar Haveli	0.0075	0.0023	0.0052	0.005	0.0047	9.62
4.	Delhi			Not Assessed.			
5.	Daman & Diu			Not Assessed.			
6.	Lakshadweep			Not Assessed.			
7.	Pondicherry	0.0175	0.0026	0.0149	0.0204	-0.0055	136.91
	Total UTs	0.0789	0.0160	0.0629	0.0555	0.0109	83.58
	Total all India	45.2236	6.9428	38.2808	10.649724	27.634576	27.82

non suitability of soils. This command areas thus presents a unique scenario with very few water logged areas in the midst of considerable number of water starving areas and poses a challenging case for conjunctive use of surface and ground water. The study area comprises of 9970 sq.km in parts of Karnataka (4176 sq km) and Andhra Pradesh (5794 sq.km)

6. CONCLUSION

Conjunctive use of surface water and ground water is needed in order to maintain the productivity of land and also provide assured irrigation necessary to improve agricultural productivity in canal irrigated area. The conjunctive use that is being practiced in the country, at the moment, does not really envisage the optimal use of both surface and ground water resources together. Most of the major irrigation projects have been designed keeping in view the surface water inputs only and exploitation of ground water is thought of only after problems like water logging, salinisation etc. manifest in canal commands. They are thus supplemental or joint use projects since they seldom exploit effective developments. Until this is achieved optimally, total resources use can not be ensured. Central Ground Water Board has takenup studies to evolve plans for conjunctive use of surface and ground water in six major canal command areas of the country. The studies are expected to be completed by the end of 1994.

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