CHAPTER - 1

INTRODUCTION

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1.1 GENERAL

In any area or region where both surface and ground waters are present, irrigation is usually based on the use of both by irrigating the two resources total availability of water for meeting any demand is considerably improved. This, however, calls for a close examination of the various technical, economic and administrative issues involved with a view of laying down policies and programmes to ensure a balance and harmonised development of two sources. Conjunctive use is defined as the development and management of multiple water resources in a co-ordinated manner such that yield of the system over a period exceed the sum yield of individual components of the system resulting from an uncoordinated operation. It is not merely providing ground water supply in distribution system as a back up for a surface water system or vice-a-versa. Rather it is a concept in which one system compliments and supplements the other to compensate for inadequacies of both.

Apart from various strategies of investigation to construction, economical and social aspects, conjunctive use can be broadly defined as – integrated process of intake conveyance, regulation, measurement, distribution and application of water in the field at the proper time and amount and proper drainage for maximum crop yield. When one talks about proper and timely application of water and proper drainage we have to consider the conjunctive of surface and ground water as neither of two can alone meet the present nor the future requirement of irrigation. Planning of conjunctive use of surface and ground water calls for greater ingenuity than is needed for the separate use as the former will provide more water at less cost than would otherwise possible.

Conjunctive use of surface and ground water can enhance the reliability of water supplies by providing independent sources that have distinctly different costs and constraints. Ground water's role in stabilizing supplies (through improving reliability and reducing the impact of drought) can be of real greater value than it's role in adding to total quantity. Unfortunately, the potential for using the subsurface as a natural storage facility has not been fully developed, and most large water supply systems continue to depend exclusively on surface water supplies. One barrier to the development of conjunctive use systems is the lack of guidelines on how to operate such systems and how to evaluate the benefits of capacity expansion. As a result, ground water has traditionally been used only as a backup supplies for times of shortage.

Surface and subsurface storage have different operating costs and constraints. Surface storage can be filled and drained rapidly, while ground water pumping and recharge rate are limited and may entail additional operating costs. However, aquifer storage capacity considerably exceeds the available surface storage in many watersheds. Beyond these differences surface and subsurface storage differ in their environmental consequences, water quality, flood control ability, power generation potentials, losses from seepage and evaporation, and legal control.

Such differences suggest that the control of surface and subsurface storage should be quite different. It was observed that in contrast to the rather long-term failure modes encountered in excessive reliance on ground water supplies, shorter scale (e.g., annual or seasonal) failures may result from exclusive use of surface supplies. The difference in time scale results because typical surface storage reservoir volumes are much smaller compared to abstractions than are ground water supplies. By taking advantage of the distinctly different characteristics of surface and substorage, efficient operation policies can produce significant improvements in supply reliability. Also, surface and subsurface storage yield significantly different water supply benefits when added to an existing system. These benefits depend on current mix of surface and subsurface storage and the uncertainty of water supplies.

However, in recent past, the ground water development has also taken appreciable lead with the development of electric energy and land development measures in the shape of consolidation of holdings and larger coverage of land under agriculture. This type of development has indirectly controlled the water table rise in certain areas and has ultimately checked the undesirable water logging but on the other hand, excess use of ground water in certain regions has also caused water table declines. In the command areas, where the quality of ground water is poor, the ground water development has not taken place and accumulation of ground water has given rise to the problems of water logging and salinity development. These types of situations obviously call for systematic use of surface and ground water based on conjunctive use planning. The conjunctive use of surface and ground water can be sound policy for water resources management to avoid degradation and deterioration of agricultural land.

1.2 THE OBJECTIVES AND ADVANTAGES OF CONJUNCTIVE USE

In many parts of the world the growing demand for irrigation water cannot be met entirely from surface water alone. The optimal development of water resources management can be achieved through the conjunctive use of surface and ground water. The main objective of a conjunctive use program is to maximize the benefits while managing water deficit, water logging and salinity problem, and also maintaining the required level of service.

The researchers have considered the ground water availability as a constant quantity over a period of time. The conjunctive use of surface and ground water sources may be practiced in order to attain one or some of the following objectives, which when attained become advantages of the same

Combined Economic System

To create the most economic system which make higher supply of water with better regulation.

Elimination of Overdraft

Reduce or eliminate areas of continuous overdraft of the ground water basin.

Investment Criteria

Investments for surface water projects are generally large and they also have long gestation periods. So, a staged development of a water supply or irrigation project by utilizing ground water first, as small increments of growth, well by well, and later diverting stream flows.

Land Subsidence

Control current land subsidence and protect areas from further subsidence.

Increase in Yield

This results in a reduction in loss from the fresh water system in the form of the reduced flow to ocean or reduced evaporation from surface reservoirs. For example, excess water in a river flowing to the ocean is diverted and stored under ground for subsequent use.

Misdistribution

To offset misdistribution of runoff. (Too much water in some months. Shortage in others.)

Flexibility in Supply

Higher flexibility in supply according to the demand curve for various crops with different base and critical periods, by evening out peaks in stream flow and pumping ground water as and when needed.

Improvement in Ground Water Storage

Increase storage of ground water for water needs during drought years and surface water shortages.

Better Quality Control

Mixing system of different quality water either in the supply system or in the aquifer, to reduce salinity to the extent that the quality of the mixture remains within the limits.

Capital Investment

Reducing of capital investments and operational expenditures by smaller surface water distribution system as wide dispersion of wells provides shortening conveyance distances for surface water.

Preservation of Storage Capacity

Protect the aquifer capacity by controlling compaction of water-bearing materials, and preserving storage capacity in critical areas.

Deterioration

Control and prevent deteriorating ground water quality in localized areas of the ground water basin.

Augmentation of Canal

Augmentation of canal supplies from ground water reservoirs can be done in order to make up deficiencies in river supplies. The ground water can be utilized as a dependable balancing reservoir from which supplies can be drawn in to existing canals.

Heavy Duty Tubewells

Heavy-duty tubewells can be planned and constructed in tail ends of canal water supply for irrigation use.

Efficient Use of Ground Water

More intensively and effectively use the ground water available to meet water demands (in conjunction with available surface supplies) at an overall cost likely to be lower than importing new surface water.

Future Development

Turn the watershed from a reactive agent to proposed water transfers outside the watershed to a pro-active agent in managing the impacts of future planned water transfers.

1.3 THE PRINCIPLES OF CONJUNCTIVE USE IN WATER RESOURCES PLANNING AND MANAGEMENT

Conjunctive use planning must include the principles involved in the two systems considered independently, but they must also include principles to guide the optimal development of the complementary of the two systems with respect to storage, transport, energy, water quality and the time. Conjunctive use requires that the individual principles of planning and their related steps must be accomplished for the total water resource. All relevant systems must be considered as a unit. The fundamental principles for conjunctive use are as follows

Storage Capacity Analysis

Necessity for conjunctive use is that the water should be available when needed. This characteristic usually requires storage capacity in which flows during some time periods in excess of need can be stored and subsequently withdrawn when the flows of water are inadequate. Furthermore, the manner in which these sites are utilized is probably the most important single factor in determining the reliability of the supply.

The evaluation of water storage requirements must also include recharge and potential recharge of ground water under the modified conditions. This evaluation involves recharge by deep percolation under irrigation areas and canal seepage.

Water Transport Facilities

The same comments are true with respect to the second essential requirement that of providing water where needed. To meet this requirement, use must be made of natural resources in the form of useful routes from place where the water adjusts to the place of the final use. In the conjunctive use planning, subsurface routes can complement surface channel routes in both the physical and economic sense.

As the required capacity of a surface transport system decreases, the cost for unit of water transferred increases exponentially. This suggests that the subsurface transport could be rather more cost effective, under some circumstances, than construction of the smaller final surface distributaries.

Energy Production and Use

Energy resources represent another area appropriate for integrated analysis under conjunctive use. In general, energy is required to extract water from ground water storage when it is needed. If that energy is unreliable, so is the ground water resources. Releases from surface water storage systems, in general provide a release of energy. Thus, there is atleast an appearance of complementarity.

Recharge Capacity Analysis

Recharge capability includes the natural watershed recharge, the recharge resulting from water transport and use, particularly by irrigation and any potential spatial purpose artificial recharge locations. One subsystem losses often provide another subsystems supplies. Losses from surface storage like deep percolation of irrigation water and canal seepage should be analyzed conjunctively in any event. Significant planning attention must be given to the ultimate fate of such losses and to the alternatives for diverting these to useful purpose. Otherwise, these losses create problems of water logging and salinity concentration.

Commonality of Sources

This brings up another principles of conjunctive use. Both surface and ground water systems share a common input of water resource, i.e. the precipitation. When the total water resources do not limit the total development, this will not create any serious problems. When the water resources are limiting, independent development simply cannot make the best use of that limiting resources. Independently planned and managed subsystems, in this case will almost invariably create serious problems for other subsystems management.

System Time – Response Characteristics

One of the most important additional considerations is the complementarity inherent in the different responsiveness characteristics of the two systems. Surface systems generally require longer periods of time for authorization and construction. The result is the substantial interest costs which are not covered by a corresponding stream of benefits for long periods of time. In contrast, first deliveries of water from ground water development can be gradual or more rapid as the development of water use systems proceed. This suggests that the scheduling of development could include ground water development as an interim supply.

Maintaining Control of Water Developed for Use

Another serious interactive effect is that of maintaining control of any water deliberately added to ground water storage by artificial recharge, whether this is due to special systems or due to deep percolation from the irrigated areas or from canals and distributions of water. If anyone, under law or custom, can provide himself with a well, then any one can also withdraw at any time the water intended by management for storage against future droughts. This has proved to be a difficult problem for conjunctive use.

Water Logging and Root Zone Salinity Balance

For surface water development alone, water logging problem is significant. With water logging, salts accumulate in the root zone as slightly salty irrigation water and agricultural chemicals are applied. With conjunctive use of surface and ground waters the water logging problem is usually resolved due to lowering of water table by using subsurface resource.

Basin Salinity Balance

The salinity problem remains unless and until salt is transported out of each and every sub-volume of the aquifer as rapidly as it is transported in. This is very difficult to achieve. When and where salinization occurs, it gradually increases until irrigation water can no longer be extracted for use, the process is irreversible.

For conjunctive use the problem can be treated by an operational practice. For surface water an accelerated surface transport of salt toward an ultimate disposal site is provided. The ground water will be used only at some distance apart from the source well, in the direction of final salt disposal.

Interaction with Existing Wells

A special interaction which must be recognized and treated is that of existing shallow wells. This is particularly important in India because such shallow wells currently supports a significant portion of existing economic use of ground water. For ground water storage, this may involve frequent lowering of the water table below the bottoms of the existing shallow wells. The conjunctive use project thus effectively destroys the reliability of the existing well resources. Alternate supplies must be provided to maintain equity of treatment and to fulfill moral obligations, even if not required legally or politically.

Reliability Enhancement

For conjunctive use planning reliabilities of supply can be increased substantially since the combined additional cost of artificial recharge and well field development is usually much less than the additional cost of surface storage.

A carefully designed conjunctive use plan can provide substantially increased reliability of supply for both agriculture and urban – industrial users.

1.4 CONSTRAINTS INVOLVED IN CONJUNCTIVE USE PLANNING

There are certain constraints, which inhibit integrated and conjunctive use of surface and ground water in a big way. Some of these are discussed below

Physical Constraints

Quantity of surface water: The quantity of surface water stored in ground water basins as part of program may act as a constraint, if it is inferior in quality to that of native ground water.

Local and regional agencies: Restriction can also be imposed over the conjunctive use by on going programs of local and regional agencies with respect to available under ground space, artificial recharge facilities, and well sites.

Lack of electrical power: The lack of dependable electrical power for operating wells could cause crop losses and urban rationing during shortage of surface supplies. This applies mostly in developing countries.

Drought: A subsequent drought may occur before basin can be refilled following earlier surface water shortage. Periods between wet and dry periods may be seasons or many years.

Operating Constraints

Danger of flood due to over recharge: Ground water levels could not be allowed to rise as part of recharge and storage activities to an elevation which would cause flooding of low lying agricultural areas, building basements and inundation of the lower portions of refuse dumps and sanitary landfills. Also, levels should not rise sufficiently to cause rejection of percolation of storm runoff and consequent reduction in basin yield from natural recharge.

Possibility of effect on quantity and quality of water: New surface reservoirs or change in operation of existing reservoirs upstream from stream diversion point or upstream from surface reservoirs used in conjunctive use program could reduce quantity or degrade quality of water available for program.

Protection of ground water basin: Uses downstream from point of diversion from a stream used to recharge a ground water basin would need to be protected. Such uses include irrigation, municipal, industrial, power generation, fisheries and water – associated with recreation.

Quality of water: Change in land use upstream could alter amount, regimen and quality of water available.

Institutional Weakness

Rare institutional framework is available with the financial and technical resources and/or legal and moral authority to examine integrated approaches to the conjunctive management of the available surface and ground water resources. Instead, decisions concerning water use and resource management are made by a variety of local water districts, cities and agencies, which for the most part are each narrowly focused and knowledgeable only on water issues within their local boundaries. Also, each organization tends to be singularly concerned with one or the other type of water supply, and not their conjunctively managed use. Water planning at these local agencies reflects their limited view of the problem and range of solutions they consider.

Ground Water Information Gaps

Lack of understanding of the ground water system, especially its recharge mechanisms, and lack of sufficient physical data on ground water use and problems in watershed hampers any kind of comprehensive ground water resource management. Ground water management is a fundamental and priority activity of conjunctive use management. It will require developing a ground water-modeling program.

Multiobjective, Multipurpose Decision Making

Given the multiple objectives (economic, social, environmental, etc.) and multiple purposes (agriculture, M&I, habitat, etc.) inherent in conjunctive use management, conflicts, tradeoffs and relationships among competing water interests and objectives, need to be understood and evaluated. To balance these objectives fairly, more public participation will be needed, and more complex, sophisticated optimization approaches may be useful. This analytical capacity and an appropriate perspective will have to be found and developed.

Complexities of Cost Sharing and Financing

In conjunctive use management schemes, partitioning costs and benefits can become quite complex especially because of the difficulties in estimating the benefits for users of the ground water aquifer which tend to be dissipated and long-term in nature. Creative cost-sharing and financing arrangements, based on quantification of estimated benefits, will be needed. Developing these arrangements, in turn, will depend on good technical data and analysis of surface and ground water interactions, sound evaluation of the performance of proposed conjunctive schemes, and public evaluations of the value of tradeoffs among interests and objectives. These arrangements must also be flexible enough to be modified as conditions change and in response to updated information gleaned from on-going monitoring.

Getting Farmers' Participation and Support

In normal years, private farmers pump 91 percent of all ground water used in the watershed. In drought years, their share of ground water pumping is even higher. No monitoring or regulation of private ground water pumping exists in the watershed nor is there any authority to do so. Consequently, if ground water management and conjunctive use activities are to be carried out, farmers' participation and support will be essential in the planning process. While some of the many water interests of farmers in watershed are officially represented through the existing irrigation and reclamation districts, ground water use activities are not. Thus adequate mechanisms to include farmers in any conjunctive use planning and implementation process and to assure their participation and interests as major ground water users in watershed must be identified and put in place.

Ground Water Rights and Legal Constraints on Management

Legal constraints to implement conjunctive use management of the ground water basin may be the most difficult to overcome. Under ground water rights laws, efforts to manage ground water may be severely limited by the legal inability to regulate private ground water pumping. In effect, private land owners have unrestricted rights to pump as much ground water from under their property as they wish, whenever they wish. A public consensus to support the goals and costs of conjunctive use management will be needed to overcome this constraint, particularly from private pumpers. Again, public participation in the planning process will be crucial to develop consensus. Alternately legal constraints could be circumvented by appropriately adjusting economic prices and incentives to farmers in such a way that they self-regulate their ground water and surface water use to match conjunctive use management objectives.

1.5 OBJECTIVES OF PRESENT STUDY

The objectives of the present study are to develop optimal management decisions regarding the use of surface and ground water and to decide the release policy and optimum cropping pattern of left bank main canal command area under Kakrapar weir in districts of Surat and Valsad in Gujarat, details of which are given in chapter 4 and appendix I. The linear programming and fuzzy linear programming models are carried out for different strategies.

1.6 DETAILING THE CONJUNCTIVE USE PLAN

In this section problems and methodologies for detailing conjunctive use of surface and ground water are discussed. It gives a general strategy available and discusses the main advantages and disadvantages of these strategies. The following strategies or their combination are available.

Strategy 1

Considering unit cost of surface water charged to the farmers by N.W.R.W.S. & K. department of Government of Gujarat and unit cost of ground water

Under this strategy economical comparision of surface water and ground water is carried out. This strategy is ideal as for the command area of existing irrigation schemes. Conjunctive use planning should be such that the surface water should be exploited first and remaining water needs should be satisfied with ground water exploitation. This strategy is referred to as the general strategy in some of the forecoming sections.

Strategy 2

Space Integration

Allocating parcels of land permanently to a particular use. For any command area, the exact demarcation of the areas marked for ground water and surface water development to be planned would depend on the local topographic and geohydrologic conditions. In general for alluvial areas this practice may not be difficult to adopt. In high level areas of command ground water pockets can be designed by providing tubewells at 300 m distance apart.

In hard rock areas ground water movement will be slower and would require larger gradients. If separated parcels to be planned for ground water use, those parcels may have to be isolated and small, say about one hectare.

Clay soils with low permeability would require much larger gradient. In these areas, the strategy of assigning separate land for conjunctive ground water use may not be successful.

Administrative problems

Although the strategy of allocation land to a particular source may be cost effective, it would create certain administrative problems as given below, which need to be considered carefully.

The present practice requires higher charges to be levied from the farmers receiving state tubewell water than those receiving surface water. This type of discrimination would become difficult to justify and implement as the part of the same project. The irrigation department may have to consider charging of a uniform water rate which can be between the two rates from all farmers receiving the water from either source.

Where ground water is to be exploited by private initiative, total cost to the farmers would include the capital cost of the well and operational, maintanance and recurring costs. Unless electric supply is reliable, the farmers may have to go for the use of diesel which would rather be costly.

On the other end they achieve higher productivity due to larger number of irrigations. After considering all these aspects the total disadvantage of the farmers who have to depend on ground water as compared to other farmers would have to be decided and they should be compensated. The water users association consisting of both types of farmers may help in this matter

Another problem is that private initiatives may not at all install the ground water potential. Considering this, it is suggested that as follows

Leaving ground water development to private initiative in reasons with proven large ground water development, almost leading to declining ground water condition.

In areas where ground water development is very slow, the conjunctive use or ground water would have to be the responsibility of the government.

In other areas which fall in between the above two cases, 70% of the minimum ground water exploitation needs to be done by government.

Strategy 3

Space and Time Integration

In this type of strategy

Some parcels of land are permanently on surface water.

Some parcels of land are permanently on ground water, and

Some parcels of land are supplied with surface water in one season and ground water in another.

By this way the two resources are allocated with respect to time and space.

1.7 LINEAR PROGRAMMING

A Mathematical model consisting of linear objective function and various linear constraints will be developed. An objective function is a very important part of the mathematical model. It quantifies the effect of the alternative courses of action in the system model. With the objective function benefits are maximized and operating costs of surface and ground water are minimized. The objective function is subjected to various linear constraints like – crop water requirement constraints; physical, structural and policy constraints and canal and ground water capacity constraints.

A computer programme which uses simplex method will be used to determine unknown variables: By different runs of this model different release policies using available data and cropping patterns for different irrigation intensities, with an increase in 10% starting from existing irrigation intensity, will be tested and optimum release policy and cropping pattern will be suggested, which will provide maximum net returns from the agricultural production with minimum application cost per unit of surface and ground waters.

Sensitivity Analysis

while dealing with all these strategies, unit cost of surface water charged to the farmers by N.W.R.W.S. & K. department of Government of Gujarat and unit cost of ground water are considered.

Sensitivity analysis of the model is carried out by ten different ways in Linear Programming such as

Sensitivity analysis considering unit cost

1. Using unit cost of surface water charged by the N.W.R.W.S. & K. department to the industries and unit cost of ground water.
2. Using unit costs of surface water and ground water.
3. Using average unit cost of surface water during 1990s and ground water.

Sensitivity analysis considering risk and uncertainty in the selling price / yield

1. Using unit cost of surface water charged to the farmers and unit cost of ground water and considering 10% increase in the selling price / yield.
2. Using unit cost of surface water charged to the farmers and unit cost of ground water and considering 20% increase in the selling price / yield.

3. Using unit cost of surface water charged to the farmers and unit cost of ground water and considering 10% decrease in the selling price / yield.
4. Using unit cost of surface water charged to the farmers and unit cost of ground water and considering 20% decrease in the selling price / yield.

Sensitivity analysis considering special cases

1. Using 10 years average Evapotranspiration rate.
2. Using the originally practiced cropping pattern in the Umbhrat branch canal command area, before the project was started.
3. Using surface water restriction method, prevalent in the Chalthan branch canal command area.

1.8 FUZZY LINEAR PROGRAMMING

Using the last 10 years data obtained for the K.L.B.M.C. Command area, the value of each constraint, which is deviating from that of the value of the same in the year 1999-2000 are being observed. These fuzzified values of each constraint are listed and the optimal net benefits, Rs./ha.m are found out using the fuzzy linear programming for the entire K.L.B.M.C command area, as has been done in the linear programming.

Then, the optimal net benefits, Rs./ha.m obtained due to the linear programming and fuzzy linear programming are compared, analysed and then the conclusions are drawn out.