CHAPTER - 2

CONJUNCTIVE USE

****

2.1 GENERAL

Conjunctive use of surface and ground water is one of several relatively new techniques with ancient roots for improving water system performance. The contemporary application of conjunctive use has become increasingly sophisticated and integrated with other innovative and traditional water management techniques, such as water transfers, water reuse, demand management, and aquifer remediation. The present work is focus over benefits, methods, management applications, operations and prospects of conjunctive use of surface and ground water. The intensive water development has motivated the implementation of an elaborate and broad range of conjunctive use strategies focused on flexibility and efficiency in water allocation.

Conjunctive management of surface and ground water can be defined as the management of water taking advantage of the connection between surface and subsurface hydrology, and their distinct storage capacity, dynamics and other properties. This management should provide greater benefit than if both surface and ground water systems were operated separately. Implementation of conjunctive use techniques can occur in different temporal patterns, or strategies, according to the region development status and planning objectives. It gives a general strategy available and discusses the main advantages and disadvantages of these strategies.

2.2 DEVELOPMENT OF CONJUNCTIVE USE PLANNING IN INDIA

Water resources of the country are available from rainfall and melting of snow after meeting the evapotranspiration losses. A major portion of this water flows down as the surface water in rivers and streams, while the remaining portion seeps into the ground. Per capita availability of renewable fresh water in India which is at 1,860 cubic meters presently is likely to reduce further. Deteriorating quality of surface and ground water is further affecting the net availability of water for consumptive uses. This has direct impact on health and productivity of the people. The water related ecological issues and strategies to ensure integrated water management are becoming most crucial challenges for sustainance of the built environment.

Indian rivers carry an average annual surface flow of 1,869 BCM but due to topography constraints and uneven distribution of water resources, only 690 BCM of the surface water could be utilised. The total surface water storage feasible through major, medium and minor irrigation projects is about 420 BCM. The storage built up so far is about 174 BCM and as a result vast quantity of surface water flows out to sea without utilization. Replenishable ground water potential is 432 BCM, thus making total water resource available for utilisation 1,296 BCM.

India being an agrarian country nearly 70% of the population engaged in agriculture and related activities and about 90% of the water resources is consumed for irrigation purposes. Of the total cropped area of 160 Mha, only 65 Mha is provided irrigation and the remaining is under rain-fed. The total irrigation potential is feasible is estimated to be 140 Mha, of which 58.5 Mha through major and medium irrigation projects and 81.5 Mha through minor irrigation, of which 17.50 Mha through surface water and 64 Mha through ground water.

Though, the ground water potential is quite substantial, the irrigation projects in our country are planned and implemented separately for surface and ground water. In general ground water has been developed by private sector and it has been found to be haphazard and unplanned.

Over-exploitation in areas like Mehsana in Gujarat, part of Meerut and Varanasi districts in U.P., Coimbatore in Tamilnadu and Karnal in Haryana has resulted in mining of ground water.

On other hand, in some major irrigation project commands such as Sarda Sahayak in U.P., Chambal in Rajasthan, Nagarjuna Sagar in Andhra Pradesh, Ghatprabha and Malprabha in Karnataka, problems of water logging have been noticed. Areas which have already been affected by water logging and secondary soil salinization problems due to poor sub-surface drainage should make use of ground water for irrigation purposes as abstraction of ground water through dug wells and shallow tube wells will lower the water table and reclaim the affected soil.

Some state governments took up schemes of tapping deep aquifers to provide better irrigation facilities. However, combining surface and ground water was mostly adopted to meet specific requirements without considering optimum utilization. It was from sixties onwards that increased attention of central and state governments was focused on increased use of surface and ground water resources conjunctively.

Based on studies conducted by an expert committee, a statewise list of project commands wherein integrated and conjunctive use of surface and ground water is suggested to be taken up as pilot schemes has been prepared which is given in Table 2.1

Table 2.1: Statewise List of Project Commands wherein Integrated and Conjunctive Use of Surface and Ground Water is Suggested to be Taken Up as Pilot Schemes

Sr No.	State	Name of the project command
1	Andhra Pradesh	i. Krishna - Godavari Delta System ii. Nagarjunasagar
2	Bihar	i. Sone ii. Gandak
3	Gujarat	i. Mahi - Kadana ii. Uka i- Kakarapar
4	Karnataka	i. Ghatprabha
5	Maharashtra	i. Ghod ii. Nira
6	Madhya Pradesh	i. Chambal ii. Tama
7	Orissa	i. Mahanadi Delta ii. Hirakund
8	Rajasthan	i. Chambal
9	Tamilnadu	i. Cauvery Bhavani ii. Lower Bhavani
10	Uttar Pradesh	i. Gandak ii. Sarda Sahayak
11	West Bengal	i. Mayurakshi ii. Kangsabati

N.B. Haryana and Punjab have not been included as conjunctive use of surface and ground water is already in vogue on a fairly large scale in these states. However, there is scope for making existing systems more efficient

2.3 DECIDING THE QUANTUM OF CONJUNCTIVE USE

The quantification of water available for conjunctive use may have to be decided by a trial and error procedure. The steps involved are

Establishing a general ground water balance of the command area for "without project" conditions.

Deciding the additional recharge that would become available in command area in "with recharge condition" after considering items like seepage loss from main canals and distribution from surface to ground water due to over irrigation, deep percolation of ponded water etc.

Deciding the minimum quantity of ground water extraction which would be necessary to stop a dangerous rise of ground water level.

Deciding the maximum permissible additional ground water use in the area in order to avoid unplanned mining of ground water or which may lead to reduction of water table level leading to ecological problems such as drying up of wells, impairing the health of deep rooted trees or reduction in low flows in rivers and streams to an unacceptable level.

Deciding the planned quantity of ground water use, within the two limits.

Deciding the quantum of ground water use available for irrigation conjunctively with surface water after considering the other (non-irrigation) uses of planned ground water use.

Since the ground water use for irrigation will itself lead to further returning of part of this as field loss to ground water, this is also to be considered.

Describing Ground Water Status and Ground Water Balance "Without Project" Condition

Ground water balance is a type of water balance. Water balance is a common concept in hydrological sciences which infact is the statement of the principle of conservation of mass used in basic physics. Considering water equivalent in the liquid state and considering that water density is fairly constant, the mass balance can be expressed as a volume of balance. Thus after defining the space boundaries under consideration water balance can be expressed as

Volume of water flowing into the space in the given time equal the volume of water flowing out of the space in that time plus storage increase of water stored in that time.

When establishing ground water balance, generally, basin or sub-basin is considered as an area of study. A reasonable depth below the ground surface has to be considered to fix the bottom boundary of the ground water basin that is ground water ridge can at times be slightly different from surface water ridge. Also at times balance of the basin or catchment may have to be considered. The natural movement of ground water according to Darcy's law etc. should be considered.

Inflow into Ground Water

Usually inflow into ground water would consist of

Deep percolation from natural rainfall.

This could be as much as 15-20% of the rainfall in alluvial areas and only up to 2-3% for certain massive hard rock areas.

Seepage from canals and tanks, deep percolation from irrigated field.

Seepage from irrigation tanks and reservoirs is normally considered negligible after first few years of operation.

Seepage from surface canals, which depends upon

Status of the system whether lined or unlined.

Order of the system, which reveals how large the distribution network is and how long the water has to travel on land surface before its use.

The type of soil.

For unlined canal in a major project, seepage loss could be nearly 30% and for minor projects including state tube wells irrigating areas of the order of 100 ha, this loss could be 20%. The corresponding figures for fully lined system where lining up to around 20 ha blocks is done could be about half of the figures mentioned for the unlined canals. These are very general indication and site specific information may allow better estimation. Sometimes, estimates are based on the wetted perimeters of the canals. Results of experiments on canals at various places in India indicate the loss in cubic meter per second for every million sq. meters of wetted perimeter ranges from 2.2 to 20.0 in unlined canals and 0.1 to 2.0 in case of lined canals. Considering the deterioration through cracking etc. the losses under lined condition can perhaps be considered at 50% of the unlined rates.

Field losses would consist of seepage from field channels that is from the chak to the field and deep percolation from the field. Field channels are normally unlined in major part. Seepage from field channels could be considered at about 10% to 15% of the deliveries at the chak. Deep percolation losses result from a tendency of applying slightly higher irrigation than is required strictly for wetting the root zone. For all dry crops it is customary to take deep percolation loss at about 10 to 15% of the water supplied to the field. Where water management is poor and very heavy irrigation are given by head reach farmers, deep percolation can be considered larger.

For ponded crops particularly for paddy, deep percolation almost throughout the growth season is unavoidable. The minimum rate for percolation through paddy is 3 mm per day. Much higher initial rates normally stabilize to lower figure after hard pan formation and need not be considered in a long term water balance.

Inflow from other areas into the space under consideration through ground water movement is normally insignificant if the hydrologic unit like basin, a sub-basin or catchment is considered.

Where area under consideration is 'doab' forming the command of a ridge branch, say bounded by the main canals at the upper boundaries and by two or three rivers/streams as other boundaries, ground water movement from adjoining areas become more important. However, if the ground water table is generally higher than the stream and the streams are effluent (i.e. receiving supplies from ground water) ground water movement across the streams can often be neglected.

Outflow from Ground Water

The outflow from ground water would normally consists of

Base flow or return flow into the surface stream network.

Direct evapotranspiration, via capillary rise or from swampy low lying areas where ground water comes to surface.

Evapotranspiration from deep rooted trees touching ground water.

Artificial withdrawal of ground water for non-irrigation use can also constitute an important withdrawal. While volumetric measurement of such withdrawals may be possible under a few cases of planned withdrawals for water supply etc.

Approximate estimates can be built on the basis of a number of water structures (state tube wells, private tube wells, bore wells and open wells), norms of areas irrigated per structure and norms of deltas used in such irrigations. In general in the northern alluvial tracts deep state tube wells support an irrigated area of about 70 ha each and private shallow tube wells irrigate about 3 ha each. Bore wells in hard rock common in peninsula would irrigate about 1 ha. Open wells with pumps or persian wheels would irrigate about 3 ha. Annual delta of 0.6 m is a reasonable assumption. More site specific information based on sample survey should however be used, whenever possible.

Out of the total canal losses, a small part may enter rivers through surface drains. Another small part may cause local drainage congestion and water logging along canals and a major part would however reach ground water.

Perhaps around 70% of the canal losses can be taken as entering to the ground water. To direct evapotranspiration from ground water due to various causes a fair estimate can be around 10% of the total flow. In arid or semi arid areas where ground water is deep this loss may be insignificant, where as in wet and swampy areas it can be substantial.

Deciding Additional Ground Water Recharge in the "With Project" Conditions

While the "without project" water balance can be a preliminary one as described in the earlier section, the additional ground water recharge available in "with project" condition has to be worked out relatively accurately. The various methods given in previous section aided with location specific information would allow such estimation.

Deciding the minimum desirable and maximum permissible explanation to avoid sustainability problems

In "with project" condition, ground water balance of the command area would be distributed. Inputs to the ground water balance could be substantially higher. If the outputs could be held stationery, the resulting change of storage would lead to increase in ground water levels. In practice, the increased water levels would lead to increased outflows in the form of larger base/return flows into the stream network and larger evapotranspiration through swampy land. Thus, a new ground water regime would be established.

However, depending on the quantum of additional inflow, earlier regime status, soil characteristics, specific yield etc. This new regime may involve unacceptably high ground water levels leading to water logging, salinization etc. Thus in order to have a new within the acceptable range, artificial increase in the outflow through increased artificial withdrawal would become necessary in many cases.

The maximum necessary withdrawal is in order to avoid large imbalance leading to large rise in ground water. Small rise in ground water table which will lead to increased base flow in the stream network may in many cases be very feasible. The maximum permissible withdrawals are intended to cater to the need for maintaining ecology and in non allowing ground water to deplete, unless such depletion is likely to be beneficial due to the very high ground water table or rising tendency in the "without project condition" itself.

Following are the suggested guidelines (Table 2.2) in which minimum necessary and maximum permissible additional withdrawals are expressed as percentage of the additional recharge caused by the project.

TABLE 2.2: Minimum Necessary and Maximum Permissible Groundwater Withdrawal

Present ground water status		Minimum necessary withdrawal (as % of the additional recharge caused by the project)	Minimum necessary withdrawal (as % of the additional recharge caused by the project)
Depth of ground water	Trend		
Less than 2 m	1. Rising	70	100
	2. Generally steady	50	80
	3. Falling	30	60
2 m to 6 m	1. Rising	60	90
	2. Generally steady	40	70
	3. Falling	20	60
More than 6 m	1. Rising	50	80
	2. Generally steady	30	60
	3. Falling	0	40

N.B. For the purpose of this table, a general long term rise or fall of more than 0.2 m/year in case of hard rock areas would qualify for classifying the trend "Rising " or "Falling".

2.4 ECONOMIC ANALYSIS OF PROJECTS WITH CONJUNCTIVE USE

The overall economy of project not only depends upon most optimal utilization of ground and surface water but some other factors also make impact over the economy of the project. Following are some of the factors, which are relevant to economic analysis of conjunctive use which need to be kept in view.

Farmers' Cost

All types of farmers' cost in regard to private exploitation of ground water and in regards to field channels are to be included in overall cost.

Cost of Energy

While calculating the operational costs of the ground water sources, the economic analysis of the costs of the energy (and not the administered price of electricity as prevalent) needs to be included. For this purpose capital cost of the power generation, transmission and distribution cost of the power system operation, fuel cost, staff charges, etc. needs to be reflected in the economic analysis.

Pumping Head

The pumping head to be considered in deciding the power requirements needs to include the prevalent average depth to ground water in the "without project" condition. The general decline of a few meters which would be necessary to include ground water flow from surface irrigated areas in the "with project" condition as also the drawals down at the well.

Efficiency of Equipments

The overall efficiency of the prime mover and the pump considering the electrical and mechanical efficiencies, hydraulic losses, losses at the foot valve, bends, etc. may be assumed at practicable low figures to reflect achievable conditions. In general, an overall energy efficiency of 50% is suggested.

Working Period

The total ground water drawl possible per lifting unit depends not only on the head of the capacity and efficiency but also on the number of working hours. Although, it would be advisable to work the units for as many hours as possible to save capital costs, practicable limits imposed by maintenance needs, social acceptance, night irrigation practices and likely power or diesel availability needs to be considered. Where this limit requires less hours of working, larger instalments with consequently larger capital cost needs to be provided for and these would be reflected in the economic analysis.