GUIDELINES FOR PLANNING CONJUNCTIVE USE OF SURFACE AND GROUND WATERS IN IRRIGATION PROJECTS

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FOREWORD

The available Water Resources, both surface and ground, are not adequate enough to cover the entire cultivated area in the country. It is estimated that even on full exploitation, the available water resources could cover only half the cultivated area for irrigation. It is therefore important that both the surface and ground water resources have to be used in an integrated manner, by planning conjunctive use, rightly recommended by the National Water Policy 1987. The policy recommends planning for conjunctive use right at the formulation of the project itself. Even in the existing irrigation projects, the conjunctive use planning has a great scope as it would not only reduce the ill-effects of waterlogging but also helps in optimum utilisation of both the resources. Conjunctive use has been practiced in the country in some form or the other, although it may not have been done in a planned manner.

At present, there are no ready guidelines except the subject was dealt with by Irrigation Commission (1972) and National Commission on Agriculture (1976). The necessity for such guidelines was expressed by different persons in different forum. Recognising the need, the IMO in Central Water Commission who is also managing INCID Special Committee on Drainage, has prepared detailed guidelines for planning of conjunctive use in irrigation projects, based on a number of documents including those published by United Nations Organisation. The draft guidelines were circulated widely eliciting views from various experts including the concerned Central and State Organisations before holding a National Level Workshop. The responses received from various organisations were compiled as a compendium for discussion at the National Workshop, organised jointly by Central Water Commission and INCID on 21st and 22nd September, 1994 at New Delhi. The Workshop inaugurated by Shri P.K. Thungon, Hon'ble Minister of State for Urban Development & Water Resources on 21st September, 1994 was well attended by over 100 participants representing Ministry of Water Resources, CWC, INCID, Central Ground Water Board, WAPCOS (I) Ltd., NWDA, ICAR, Ministry of Agriculture, State Irrigation Departments, WALMIS, Agricultural Universities, CSSRI and other National and State Level Institutes and a host of other organisations. As per the recommendations at the two day Workshop, a small Group was constituted to modify the guidelines considering several suggestions made by various members, under the Chairmanship of Shri A.D.Mohile, Acting Member (WP&P), CWC and Chairman, INCID Spl. Committee on Drainage with representatives of CGWB (Dr. P.J.S. Bhamrah), INCID (Shri N.K. Dikshit), WAPCOS (Shri L.N. Gupta), WTC (Dr. P.B.S. Sarma), MOWR (Shri Antony Balan) and WALMI, U.P. (Shri V.K. Jain). They made strenuous efforts in amending the guidelines, which have been printed under CWC & INCID banner. It is hoped that these guidelines will be of considerable use to all those concerned with conjunctive use planning for integrated development of surface and ground waters and will help greatly in optimum utilisation of scarce water resources.

Shri A.D.Mohile, Acting Member (WP&P), CWC who is also Chairman, INCID Spl. Committee on Drainage and his two Directorates under S/Shri C.D. Khoche and P.C. Mathur, Directors have made significant contributions in preparing the first draft of the guidelines and its subsequent revision through the small Group constituted for the purpose .

Shri A.S. Rao, Member - Secretary, INCID and Chief Consulting Engineer, WAPCOS and his colleagues in INCID Sectt including Shri N.K. Dikshit, Consultant who made considerable efforts in compiling the compendium of responses, organizing the workshop and finalisation of the guidelines and in bringing out this document need special compliments. Special thanks are also due to Shri R.Rajappa, Chairman and Managing Director, WAPCOS (I) Ltd., who took keen interest in the subject and provided excellent support with all the infrastructure facilities to the INCID Sectt. The services rendered by Shri Vimal Kumar Gaur, Computer Operator, INCID in preparing the typescript deserve full appreciation.

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Chairman, INCID & CWC.

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GUIDELINES FOR PLANNING OF CONJUNCTIVE USE OF SURFACE AND GROUND WATERS IN IRRIGATION PROJECTS

1. INTRODUCTION, OBJECTIVE AND SCOPE.

1.1 Background.

The National Water Policy, 1987 recognises the need for conjunctive use and recommends that the conjunctive use of surface water and groundwater should be ensured from project planning stage and should form an essential part of the project. The earlier practice of planning surface and groundwater independently does not permit optimum utilisation of water resources in the command and prevents flexibility of system operation. The practice of planning surface irrigation without much consideration of groundwater status has often resulted in water-logging and salinity problems in command area due to gradual rise of groundwater caused by irrigation. Even in case where waterlogging is not developed, lack of integrated planning leads to non-utilisation of available water resources, both surface and ground water, in an optimum way.

Recent estimate (1991) of the Working Group set up by Govt. of India on Waterlogging and salinity indicates that in all irrigation commands, the total extent of waterlogged area is 2.46 mha. Also, 3.06 mha area suffers from salinity problems and 0.24 mha from alkalinity problems. This Working Group report relates to the period 1986-91, by which time the gross irrigation potential and the net irrigated area were of the order of 80 mha and 50 mha respectively. Of the net area, around 25 mha would be the irrigation potential related to minor surface and private groundwater development in which the possibility of water-logging and salinity is rather small. Thus the extent of water-logging and salinity problems in major and medium irrigation projects would be rather perceptible. In this context, the conjunctive use of surface and groundwater sources in major and medium irrigation projects assumes importance as one of the means of achieving sustainable irrigation.

Large development of private tubewells, particularly in Punjab, Haryana, Rajasthan and Western U.P., in the command areas of major and medium projects as well as large number of percolation tanks that have come up in Karnataka and Maharashtra and also the policy of giving irrigation only for eight months, adopted in Maharashtra which leads to use of groundwater for perennial crops in hot weather, can in fact be viewed as unplanned conjunctive use through voluntary efforts. This has already led to decline in waterlogged areas. As a planned measure of conjunctive use of surface and ground water, construction of augmentation tubewells in Western Yamuna Canal command area in Haryana could be cited as an example. However, since the process of salinisation and alkalinity development is somewhat irreversible, some long-term damage would have been caused even in these areas due to delay in covering the entire command with conjunctive use. In areas of eastern U.P., Bihar etc. where groundwater development in surface irrigation commands has not taken place extensively, the possibility of waterlogging and salinisation continues. Thus planned development of the conjunctive use of surface and ground water is necessary.

1.2 Introduction to Conjunctive Use.

1.2.1 The Concept.

i. The concept recognises the unified nature of water resources as a single natural resource, although the method of exploitation may involve both surface and groundwater structures.

ii. The process takes advantage of the interactions between the surface and groundwater phases of the hydrological cycle, as also the natural movement of groundwater, in planning the use of waters from the two phases.

Thus separate use of surface and groundwater in itself would not always constitute a conjunctive use. Conjunctive use need not necessarily mean mixing of surface and groundwater before its application on land for irrigation.

Integration of the use of water from two sources on land may involve different levels of time and space integration. For example, if one parcel of land is irrigated with surface water and if the excess irrigation results in additional groundwater recharge and if this recharge is allowed to flow to another adjoining parcel of land where it is extracted and used as groundwater, it is one way to meet conjunctive use. Another form would be to use surface water in one season(say wet season) and to use groundwater in another season(say in dry season) on the same parcel of land. Yet another form would consist of physical mixing of the water in a common distribution network. In respect of run-of-the river schemes, the number of waterings given from surface source may be supplemented with use of groundwater in the command.

1.2.2 The Objective.

The conjunctive use of ground and surface water sources may be practised in order to attain one or more of the following objectives:

i. A higher total amount of supply;

ii. Better regulation of the combined system, using the storage volume of the aquifer;

iii. A phased development of a water supply or irrigation project, by utilising groundwater first, at small increments of growth, well by well, and later diverting streamflows;

iv. Savings in evaporation losses from surface reservoirs;

v. Higher flexibility in supply according to the demand curve, by evening out peaks in streamflow and pumping groundwater as and when needed;

vi. Mixing of different quality water, either in the supply system or in the aquifer, to reduce salinity;

vii. Reduction of capital investments and operational expenditures by shortening conveyance route for surface water;

viii. Inducing groundwater replenishment from streams by extending the duration of flows in the streams by means of dams, or retarding the flow by means of groynes or levees;

ix. Augmenting low flows in rivers by artificially recharging the aquifer.

x. Arresting depletion of groundwater table in areas where no surface irrigation exists at present and excessive groundwater extraction is done, by introducing surface irrigation from small rivers which will also help the groundwater regime through recharge.

Groundwater exploitation always includes lifting of water which increases unit cost of water. Economics of using such water should dictate the adoption of measures at vii, viii and ix.

While conjunctive use can effectively take care of the extra recharge caused by surface irrigation, it need not be conceived as a solution to remedy the bad management practices for surface irrigation such as over irrigation and inequitable distribution.

1.3 Scope of the Guidelines.

The need for conjunctive use is well recognised and is part of the National Water Policy. Accordingly, CWC is already ensuring that projects which do not take into account conjunctive use are not recommended for obtaining Planning Commission's clearance. However, the experience of CWC in examination of such conjunctive use projects indicates that planners in the States face the following difficulties in this regard.

i. Irrigation Planning for conjunctive use requires consideration of groundwater, surface water and agronomic aspects. While separate departments dealing with these exist, a cohesive inter-disciplinary team is normally not available.

ii. For operationalising the conjunctive use, administrative, water pricing and legal procedures may have to be changed. The planners are unable to detail these and get the necessary policy changes done and incorporated in the proposal, primarily because the groundwater is mostly privately owned unlike surface water which is State owned.

iii. They do not have ready guidelines about planning for conjunctive use of surface and ground waters.

The objective of the present guidelines is to fulfil these needs. Apart from detailing the strategies for new projects, the guidelines also discuss specific aspects to be considered in planning conjunctive use for modernisation or rehabilitation of existing projects where such planning has not been done or conjunctive use has not developed. These are general guidelines and do not detail the hydrologic, geohydrologic and agronomic studies which may be necessary for planning conjunctive use.

2. DECIDING THE QUANTUM OF GROUND WATER RESOURCES FOR CONJUNCTIVE USE.

2.1 Introduction.

The quantification of water available for conjunctive use may have to be decided using appropriate methodologies developed in this regard. The steps involved are :

i. Establishing a general groundwater balance of the command area for "without conjunctive use project" conditions.

ii. Delineate the area where groundwater development is to be taken up based on the depth to water table and resource potential of aquifers.

iii. Deciding the additional recharge that would become available in the command area in "with conjunctive use project condition" after considering items like seepage loss from main canals and distribution network which enrich the groundwater, field losses from surface to groundwater due to over irrigation, deep percolation of ponded water etc.

iv. Deciding the minimum quantity of groundwater extraction which would be necessary to stop alarming rise of groundwater level which can lead to water-logging and other problems.

v. Deciding the maximum permissible additional groundwater use in the area in order to avoid unplanned mining of groundwater or which may lead to reduction of water table level leading to ecologic 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.

vi. Deciding the planned quantity of groundwater use, within the two limits.

vii. Deciding the quantum of groundwater use available for irrigation conjunctively with surface water after considering the other (non-irrigation) uses of the planned groundwater use, taking into account quality limitations such as the presence of brackish water.

Since the groundwater use for irrigation would itself lead to further returning of part of this as field loss to groundwater, this would also have to be considered.

2.2 Describing Groundwater Status and Groundwater Balance "Without Conjunctive Use Project".

The hydrological framework/set-up may be determined by compiling available data from CGWB or State Govt. reports to demarcate hydrogeological situations of different zones of existing and proposed command to plan irrigation, and to examine existing canal alignments in order to delineate areas where canal lining would be essential.

The various steps are discussed below:-

The establishment of an accurate groundwater balance is a specialized task to be conducted by geohydrologists in conjunction with surface water hydrologists, hydrometeorologists etc. Planners of surface irrigation projects are not expected to prepare a final groundwater balance without consulting the concerned scientific organisation dealing with groundwater. However, using the norms prepared by such organisations (including the norms of NABARD) a fairly good preliminary groundwater balance can be established by them. It would be clear from the following paras that in the present form, the guidelines for planning conjunctive use in most cases may not require finalisation of the "without project" groundwater balance.

Groundwater balance is a common concept in hydrological sciences which in fact 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 balance. Thus after defining the space boundaries under consideration, water balance can be expressed as below:

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

When establishing groundwater 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 confining the space. The boundaries of the groundwater basin, that is the groundwater divide can at times be slightly different from the surface water divide. Also, at times, balance of the part of the basin or of an area not corresponding to the basin or catchment may have to be considered. For example, sometimes water balance may have to be established for a command of a branch or a distributory on a ridge. In such cases the natural movement of groundwater according to Darcy's law etc. may itself constitute inflow or outflow in regard to the space under consideration. Usually inflows into the groundwater would consist of:

i. Deep percolation from natural rainfall. This could be as much as 15-20% of the rainfall in alluvial areas and only upto 2 or 3% for certain massive hard rock areas. The NABARD guidelines and experience of the CGWB/State Ground Water Directorates based on field observations specific to the region, may allow a better decision in this regard.

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

Seepage from irrigation tanks and reservoirs is normally not substantial after few years of operation. Seepage from surface canals would depend on (a) status of the system whether lined or unlined, (b) 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 and (c) the type of soils. For unlined canal in a major project, seepage loss could be around 50% of the deliveries at the head. For a medium project, the loss could be nearly 30% and for minor projects including state tubewells irrigating areas of the order of 100 ha.,this loss could be 20%. The corresponding figures for fully lined system where lining upto around 20 ha. blocks is done could be about half of the figures mentioned for the unlined canals. These are very general indications and site specific information may allow better estimation. Sometimes estimates are based on the wetted perimeter of the canals. Results of experiments on canals at various places in India indicate that loss in cubic metre per sec. for a million sq. metres of wetted perimeter ranges from 2.20 to 20.00 in unlined canals and 0.10 to 2.00 in case of lined canals. However, considering that the range mentioned above for 'lined' canals is mostly based on newly lined works, and 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 (a) seepage from field channels, that is, from the outlet to the field, & (b) deep percolation from the field. Field channels are normally unlined in the major part. Seepage from field channels could vary widely and could be as much as 10-30% of the deliveries at the outlet depending on the site conditions. Deep percolation losses result from a tendency of applying slightly larger irrigation than is required strictly for wetting the root zone soil. Unexpected rainfall occurring after irrigation can also lead to higher percolation. For all dry crops, it is customary to take deep percolation loss at about 10-15% of the water supplied to the field. Where water management is poor and very heavy irrigation is given by the 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 rates would depend on (a) type of soil (b) whether sufficient time is elapsed after introducing irrigation to allow hard pan formation below the roots of the paddy and (c) whether crop rotations requires the hard pan to be ploughed through for the next crop. The customary rate for percolation through paddy is 3 mm per day to 16 mm per day. Much higher initial rates normally stabilise to lower figure after hard pan formation, and need not be considered in a long term water balance.

iii. Net lateral inflow from other areas into the space under consideration through groundwater movement is normally insignificant if the hydrologic unit like a basin, a sub basin or catchment is considered. However, for deep seated confined aquifer both inflows and outflows from and to other areas in to/out of the area under consideration could be significant and need to be considered where the deep aquifer is being exploited.

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

Outflows from groundwater would normally consist of:

(a) Base flows or return flows into the surface stream network.

(b) Direct evapotranspiration, via capillary rise or from swampy low lying areas where groundwater comes to surface and

(c) Evapotranspiration from trees with roots touching capillary fringe.

(d) Artificial discharge due to pumping.

(e) Net outflow from bottom of the aquifer (particularly in case of semi confined aquifer).

Artificial withdrawal of groundwater 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. they are difficult in case of numerous irrigation withdrawals. Approximate estimates can be built on the basis of a number of water structures (state tubewells, private tubewells, bore wells, open wells with pumps, open wells with persian wheels, other open wells etc.), norms of areas irrigated per structure and norms of deltas used in such irrigation. In general, deep State tubewells support an irrigated area of about 30-50 ha. each, private shallow tubewells will support an area of 2-5 ha. and dug wells with pumps will support an area of 1-2 ha. depending upon hydrogeological agroclimatic and crop situation. An annual delta of around 0.6 m.is a reasonable assumption. More site specific information based on sample survey should however be used, whenever possible. The minor irrigation census data may also be helpful in this regard.

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

2.3. Deciding Additional Groundwater Recharge in the "With Conjunctive Use Project" Conditions.

2.3.1 While the "without conjunctive use project" water balance can be a preliminary one as described in the earlier section, the additional ground water recharge available in"with conjunctive use project" conditions have to be worked out relatively accurately. The various methods given in section 2.2 aided with location specific information would allow such estimation.

2.3.2 Deciding the 'minimum desirable' and maximum permissible extraction to avoid sustainability problems.

In the "with conjunctive use project" condition, groundwater balance of the command area would be distributed. Inputs to the ground water balance could be substantially higher. If the outputs could be held stationary, 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 lands etc. Thus a new groundwater regime would be established. However, depending on the quantum of additional inflow, earlier regime status, soil characteristic, specific yield etc. this new regime may involve unacceptably high groundwater levels leading to waterlogging, salinisation etc. Thus in order to have a new regime within the acceptable range, artificial increase in the out-flow through increased artificial withdrawal would become necessary in many cases.

In the present guidelines instead of linking the quantity of the increased withdrawal to accurate overall water balance, it is linked to:-

i. the additional groundwater recharge as added in the "with conjunctive use project" condition and

ii. the trend shown by the previous groundwater status.

Also in the present guidelines two estimates of the "minimum necessary" and the "maximum desirable" additional withdrawals have been given. The minimum necessary withdrawal is in order to avoid large imbalance leading to large rise in groundwater level. Small rise in groundwater table which will lead to increased base flow in stream network may in many cases be very desirable. The maximum permissible withdrawals are intended to cater to the need for maintaining ecology and in not allowing groundwater to deplete, unless such depletion is likely to be beneficial due to the very high groundwater table or rising tendency in the "without conjunctive use project" condition itself.

Following are the suggested guidelines:

Present groundwater status		Minimum necessary additional withdrawal as percentage of the additional recharge caused by the project	Maximum permissible withdrawal as percebtage of the additional recharge caused by the project
Depth of groundwater	Trend		
Less than 2m	Rising	70%	100%
-do-	Generally steady	50%	80%
-do-	Falling	30%	60%
2m to 6m	Rising	60%	90%
-do-	Steady	40%	70%
-do-	Falling	20%	60%
More than 6m.	Rising	50%	80%
-do-	Steady	30%	60%
-do-	Falling	0%	40%

Notes:

i. For the purpose of this table, a general long - term rise or fall of more than 0.2m/year in case of alluvial condition & of more than 0.5m/year in case of hard rock areas would qualify for classifying the trend as "rising" or "falling".

ii. In case an accurate groundwater regime worked out by the specialists and tested and verified through modelling and field verification in both conditions is available, the maximum/ minimum withdrawal can be worked out on the basis of these water balance studies instead of using the percentage given above. Such detailed studies are desirable in specialised areas having salinity problems.

These general guidelines would require the command area to be divided into zones depending upon the present groundwater status and to plan conjunctive use separately for these zones. If conditions over the command area are homogenous, zones can be large, whereas if the groundwater status is extremely variable zones could be small. In general, it is envisaged that the zone size may vary from minimum of around 3000 ha. to a maximum of around 30,000 ha. for the purpose of planning conjunctive use.

2.3.3 Modifications of estimates for special areas:

The general guidelines given above would require modifications under certain conditions as follows:

i. **Coastal areas :** For coastal areas say within 50 km of the sea, depending upon the local hydrogeological set up, all values may be reduced by 20% to avoid the possibility of saline ingress due to heavy conjunctive use.

ii. **Saline and Shallow Groundwater:** Where the groundwater is saline (conductivity > 4m mhos/cm.) and in shallow, say less than 6 m depth(and particularly less than 3 m depth) the area should normally be considered unfit for either surface irrigation or groundwater use.

It may however be possible to irrigate such areas for crops which require less water or by adopting drip or sprinkler irrigation methods with provision of adequate drainage facilities including sub-surface drainage or vertical drainage. Measures indicated under (iii)(a) below can also be adopted.

Generally, when groundwater is of good quality conjunctive use will have priority over drainage and when it is of poor quality, drainage will have priority over conjunctive use. However conjunctive use is not replacement for drainage, but whenever it is planned, drainage intensity could be reduced. The maintenance of a desirable salt balance would require that a minimum quantity of saline groundwater is carted away so that the groundwater does not become saline in long term through recycling and reuse.

iii. **Saline, deep-seated Groundwater:** Where groundwater is saline but is deep seated (that is more than 6 m depth), the area is problematic but irrigation alongwith conjunctive use of groundwater can be planned after careful studies. The general strategy in such areas could be:

a) Plan for reduction of additional recharge into the command area because any such additional recharge leading to increase in groundwater level may create irreversible sustainability problems. This can be done by lining the canals, by not planning paddy crop, and by planning irrigation in frequent short doses in order to avoid deep percolation.

b) Conjunctive use may be planned to mop up the unavoidable additional deep percolation and canal losses. However, attempts could be made to mop up this deep percolation at comparatively shallow depths through shallow open wells, horizontal sub-surface drainage etc. before it reaches the main saline water table.

c) While quantifying the minimum required and maximum permissible groundwater use, the norms as stated earlier may be increased by say 20% of the additional recharge.

d) If conjunctive use involves pumping of saline groundwater, this may have to be mixed with good quality fresh water so that the quality of the irrigation water is acceptable.

iv. Areas with soil salinity where the groundwater is deep seated and is not saline but the command area soils are problematic and have salinity, the following precautions may be necessary in planning irrigation through conjunctive use.

a) Leaching dose which leaches out soil salinity to deeper layers may have to be planned.

b) Quantity of conjunctive use, both minimum necessary and maximum desirable, could be considered as lower than what is shown in the general guidelines.

c) Where the problems are more serious, sub-surface drainage may have to be planned. Depending on the quality of the effluent in the drainage system, it can be either used for irrigation on its own, used for irrigation after mixing with better quality surface water or carted away for wastage elsewhere. The need for maintaining a proper salt balance will dictate the planning.

2.4 Deciding the Quantum of Groundwater for Conjunctive Use.

Guidelines given in para 2.3 would help in quantifying both the minimum necessary and maximum permissible conjunctive use of groundwater with surface water. The exact quantum to be planned between these values is left to the project planner. However, the following notes may help in the decision.

a) A careful study of the economics may help in finding which of the two sources is cheaper in the economic terms. Where small areas could be permanently earmarked for groundwater use, per ha. cost after considering the capital cost and operational charges including fuel costs, for patches receiving only groundwater may be less than those of surface water. This may occur particularly in alluvial areas. If it is so, it would indicate the need of comparatively larger exploration of groundwater for conjunctive use within the limits.

b) Surface water project could be implemented in a single construction phase, if necessary. Conjunctive use of groundwater can however, be planned and executed in stages after monitoring the behaviour of the groundwater regime. If this flexibility is to be used, it may be desirable to initially plan conjunctive use towards the minimum desirable level and then to extend it by a slight adjustment of irrigation etc. at a later stage, if necessary.

c) In some basins, available water supply is adequate and large command areas are available for irrigation in the case of a run-of-the river scheme. Constraint in irrigation planning is lack of storage which is essential for dry season irrigation. In such a situation, particularly if energy is available, large surface irrigation during wet season followed by large groundwater irrigation during dry season would be desirable. This would have advantage of using soil pore space towards water storage to make up for the non-availability of surface storage site. In such planning, unlined canals in paddy cultivation to induce additional recharge may be encouraged which may result in large scale conjunctive use to achieve maximum permissible level.

2.5 Deciding Quantum of Conjunctive Groundwater Use for Irrigation.

After deciding the quantum of additional groundwater withdrawal (over and above the withdrawal in the "without conjunctive use project" stage), the withdrawal available for irrigation use in the command area needs to be decided. For this purpose the following exercise may have to be done:

i. Study the status of water supply in rural and urban areas in the command for domestic and industrial requirements. Where groundwater is already being used, this may have to be continued.

ii. Decide the broad water supply requirements of these areas after 35 years considering the population growth.

iii. Decide a broad plan for this water supply. It may include use of project surface water for water supply, getting water from alternative local supplies which are not connected with the present project as also drawal of groundwater for water supply.

iv. Additional drawal of groundwater for water supply would normally receive priority over the use of additional groundwater for irrigation and other uses in the command area.

In this way, the quantum of groundwater available for conjunctive use for irrigation over the command area would get decided.

3. DETAILING THE CONJUNCTIVE USE PLAN.

3.1 Introduction.

This chapter will deal with problems and methodologies for detailing the conjunctive use for integrating surface and groundwater use. It gives a general strategy available and discusses the main advantages and disadvantages of these strategies. Considering these and the groundwater conditions, the project planner will have to decide the broad strategy to be adopted in a given project and plan accordingly.

3.2 Strategies Available.

As mentioned earlier, the following strategies or their combinations are available.

Strategy 1. Allocating parcels of land permanently to a particular use.

Strategy 2. Allocating surface and groundwater in time so that in a particular season only surface water is used and in other season only groundwater is used.

Strategy 3. Combination of strategy 1 and 2 in which:

(a) some parcels of land are permanently on surface water.

(b) some parcels are permanently on ground-water and

(c) some parcels are supplied with surface water in one season and groundwater in another.

Strategy 4. This is a variation of strategy (3). In this, for parcels at (c) in which both groundwater and surface water are used, the intra annual regime of the uses varies from year to year in order to take advantage of the stabler regime of groundwater. This could involve the groundwater partly for carry over purposes. Also, it may require larger use of surface water in years of surplus surface flows.

Apart from these strategies of use, where a parcel of land is to receive both surface and groundwater, there could be different designs about the distribution network. The distribution networks can either be separate and distinct or could be common. In a common network, the groundwater would be pumped into surface water network and distributed through the lower elements by the surface water network. In such cases either the surface and groundwater can be physically mixed or certain rotations can be on surface water and others on groundwater. One such example is the augmentation tubewell in Western Yamuna Canal in Haryana

In regard to groundwater withdrawal and distribution, there could be different designs in regard to organisational responsibilities for development as also, of operation and maintenance as follows:

a. If the deep tubewell is more than 100 m deep and planned to deliver large discharge of the order of 30 to 60 litres/sec almost continuously, this normally would have to be constructed by the Government. Operation and maintenance can either be by the government or by water users' association covering its command area. If the tubewell is being used as an augmentation tubewell without separate distribution network, then its operation and maintenance would have to be by the government.

b. Where groundwater exploitation for conjunctive use is planned on shallow tubewells, borewells or open wells which would deliver discharge of the order of 10 to 15 litres/sec and are operated for a few hours a day, this development including operation and maintenance is best done through private initiative and individual ownership etc.

While project planners can use different administrative designs, their appropriateness need to be discussed. A regulatory arrangement to prevent over exploitation of groundwater would be necessary by the Project Authorities.

3.3 Allocating Separate Parcels of Land to Surface and Groundwater (Strategy 1).

3.3.1 Technical detailing :

This strategy is likely to be the most cost effective, if it can be implemented. Individual distribution network for groundwater are likely to be small and of very low order. For example, private tubewell, open wells etc. would directly feed the field channels. Large State tubewells may require one or two minors leading to individual channels. Per ha distribution cost of these low order networks would be much smaller than that of the higher order surface networks involving long transfers through main canals, branches, distributions etc.

However, under these circumstances conjunctive use would be effective only if the distance from the major recharge area (i.e. surface irrigated area) and the well is so small that this groundwater flow is sustained by the gradient available. This gradient could consist of three components, that is:

i. Natural slope of the groundwater table (which may normally correspond to the ground surface slope) that would be available in case the comparatively lower area is earmarked for the use of groundwater.

ii. A slight increase of groundwater in the surface irrigated area can be allowed in case the groundwater is not already very shallow.

iii. Apart from draw-down near the well, a general slight decrease of the groundwater levels in the area planned for groundwater can be allowed to establish necessary gradient.

The exact juxtaposition of the areas marked for groundwater and surface water development to be planned would depend on the local topographic and geohydrologic conditions. However, in general for alluvial areas this practice may not be difficult to adopt. If deep tubewells are planned they could be located around, say 300m, from the boundary of the surface irrigated area and the total width of the strip planned for groundwater development may not exceed say 1 km. If shallow tubewells and open wells are planned, the strip width may have to be limited to about 300m in which say two rows of shallow tubewells or open wells can be planned so that the distance of the wells from the source could be around 100 metres.

In hard rock areas, groundwater movement would be slower and would require larger gradients. If separate parcels are to be planned for groundwater use, these 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 groundwater use may not be successful.

3.4 Integrating Surface Water and Groundwater in Time (Strategy 2).

Normally when the same area is to be supplied with surface water at one point of time and with groundwater at another point of time, it would be costlier to have two separate distribution networks. Therefore, groundwater would have to be used to augment lower portion of the surface network.

Private tubewells, open wells and bore wells irrigating a couple of hectares of land, if required, may be allowed to use the same field channels which carry the surface water.

Unless private sources can take up the irrigation in certain season, augmentation tubewells would have to be planned and operated by the government in order to avoid carriage of groundwater over long distances. It is suggested that augmentation tubewells may feed either minors (distribution elements serving an area of the order of 100-300 ha by whatever name they are called) or they could be located just near outlets. The practice of augmenting distributaries, branches or main canals may in general be avoided unless geohydrological conditions are such that groundwater sources cannot be located near the minors.

Irrigation Acts in some States discourage partial supplies through groundwater at private initiative and partial supplies through surface water in the sense that full irrigation tax is charged even when one watering is supplied through government. If the mixed use of the two waters for the same land is to succeed, these rules may have to be modified.

When groundwater is saline and unfit for direct use for irrigating the land as a single source, conjunctive use has to take the shape of augmentation. Either the two waters can be physically mixed so that the resultant diluted water has the acceptable quality or rotations have to be distributed amongst the two sources. Some scientists prefer the later course since it allows larger surface water dosages for leaching purposes alternated with shorter groundwater doses. Whenever saline water is to be used, agronomists and soil specialists need to be consulted.

3.5 Space & Time Integrations (Strategy 3 & Strategy 4).

Although project planners are free to use any strategy as indicated earlier, it is felt that in many cases the mixed strategy (strategy 2 as enumerated in 3.2) may have to be used in practice. This may become necessary because of the following reasons.

In strategy (1) where areas are to be divided on sourcewise, exactly similar pattern of intra-annual withdrawals may have to be followed for both surface and groundwater. Thus consider a case where the annual irrigation requirement of the command is 100 million cubic metre, out of which 25 million cubic metre is to be met through ground sources. The time variation of the demand of 100 million cubic metre is such that the total demand varies from 8 cum/sec in November to 2 cum/sec in April and 5 cum/sec in July. If strategy(1) is to be followed strictly, 25 percent of the irrigated area would have separate groundwater distribution system, the same pattern would have to be followed for both sources. With such varying demands adjusting rotations of surface canals which cannot run much lower than the designed discharges may create a problem. Also in some years, the surface water availability may be larger. For example, in the illustration mentioned, the surface canal may have been designed for peak capacity of 6 cum/sec considering the November demand. In September the total demand may be only 5 cum/sec to be shared as 3.75 cum/sec through surface and 1.25 cum/sec by groundwater. But during September, reservoir may be spilling in many years. The use of energy to pump groundwater even while the spare capacity is available in the main canal during such months, would be an incorrect planning. A mixed strategy can overcome such difficulties to a good extent. Following general guidelines are mentioned to help in deciding such a mixed strategy.

a. The time pattern of discharges to be planned for surface water use and groundwater use may not exactly be the same.

b. The peak of surface water use and the peak of groundwater use may be adjusted to occur in the same time period because this will allow the design capacity of the surface canal to be minimised and thus construction cost economised. However, if groundwater is saline, care may be taken to avoid its use during the sensitive growth stages

c. Periods where excess surface water and excess distribution capacity is likely to be available in many good years, may be located and comparatively low groundwater use may be planned during these periods.

d. In time periods where total irrigation use is very much lower than the annual peak, proportionately larger groundwater use can be planned. This may allow some elements of surface network to be fed entirely from groundwater during those periods.

e. The total volume of surface water used and groundwater used would have to correspond to the decisions about the conjunctive use taken as per guidelines in Chapter 2.

f. After deciding the time patterns, calculate ratio of groundwater used to the total water used in each time period. The lowest value of this ratio would roughly indicate the ratio of the command area which can be fed exclusively from the groundwater through separate local distribution network. The difference between the lowest and the highest ratio would indicate the proportion of the command area which would receive surface water in some seasons and groundwater in other seasons. This area would be planned separately to be served either through augmentation into the government surface network or through individual private groundwater network apart from the surface network. The remaining area would have to be served exclusively through surface water. The intermediate area which has possibility of using both the sources would provide some year to year flexibility in the use of the two sources, after considering the current water availability position.

3.6 Administrative Problems and Policy Issues.

3.6.1 The implementation of a specific conjunctive use strategy decided for a project from technical considerations discussed in earlier paragraphs may create some administrative problems which need to be considered carefully. Some of these problems and suggested measures are discussed below:

a. Where the groundwater is being exploited through a State tubewell, the present practice requires a higher charge 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, when in fact the groundwater use is designed as complementary to the surface water use as part of the same project. The irrigation departments may have to consider charging a uniform water rate which can be in between the two rates from all farmers receiving the water from either source. This would require procedural and perhaps legal changes.

b. Where groundwater for conjunctive use is to be exploited by private initiative, the total cost to the farmers would include the capital cost of the well (or in case of well constructed through loans, repayment instalments) and running and operational cost. Unless electric supply is reliable, the farmer may have to go in for the use of diesel which would rather be costly. Thus these farmers would have to take investment risks and would have to make larger payments. On the other hand privately owned groundwater sources would normally allow these farmers a better management control leading to higher productivity. They can also plan larger number of irrigation and can follow crop calendar which does not depend upon the canal supply. The possibilities of using drip and sprinkler for higher productivity (although with further large investment) are also open to them. After considering all these aspects, the total disadvantages of the farmers who depend on groundwater as compared to other farmers would have to be decided. After this is decided, methods for compensating these farmers for their additional expenses can be found without affecting the overall financial position of the project. This can perhaps be done through a slight increase in surface water charges and pooling this additional funds to compensate the groundwater users. This difficult operation can better be done through water users associations consisting of both types of farmers.

Another problem in leaving groundwater component of conjunctive use to private initiative is that the component may not at all be installed. In such a situation, the lack of groundwater use may endanger sustainability of the whole project. Considering these, it is suggested that :

i. Leaving groundwater development to private initiative can be resorted only in regions with proven large groundwater development.

ii. In areas where groundwater development has been very slow, the conjunctive use of groundwater would have to be the responsibility of the government.

iii. In other areas which fall in between the above two cases, part of the development would have to be through government efforts and only the remaining part would have to be through private initiative. As a general guideline, the development of groundwater corresponding to 70% of the minimum groundwater exploitation needs to be done by the government in such areas.

3.6.2 Water resources planning in general and conjunctive use planning in particular involves consideration of a large number of water related issues some of which have already been mentioned in discussions above. Detailed discussion on these aspects is not intended in these guidelines. However, in preparing the conjunctive use plan, it may be ensured that it forms a part of overall basinwise Master Plan. Also, in finalising the plan, consultation may be held with experts in the concerned specialised departments such as agriculture, environment, groundwater, public health, meteorology etc. apart from the involvement of water resources departments. Involvement of agricultural research stations, Universities and farmers' organisations would also be beneficial. It would be advisable to form a multidisciplinary group comprising of members from all the above disciplines for planning and implementation of conjunctive use plans.

3.6.3 As mentioned above, conjunctive use planning involves consultation with different departments/ institutions and groups. In order to make such consultations more effective and coordination more streamlined, it would be appropriate to have a high level coordinating agency in each State. Such an agency should have representation from concerned departments at decision making level and preferably under the chairmanship of Chief Secretary of the State.

3.7 Technological Aspects.

In implementation of the conjunctive use plans, many technological aspects and problems will have to be considered and overcome. This could be regarding well spacings, depths of wells and phasing of these wells in time. If conjunctive use is planned for control of groundwater level, it may be possible in case of deep seated groundwater to wait for a few years. Also when planning conjunctive use in hard rock areas with low water yield capacity, in order to overcome the impracticability of such low yields, the wells may have to be interconnected and operated or they may have to be located at favourable hydro-geological situations, such as weak lineaments. In certain areas, tapping of groundwater from shallow depths without disturbing deep seated saline water would have to be resorted to in order to avoid mixing of good quality recharge with saline water. Such dug wells with laterals for exploitation of groundwater from shallow depths are called skimming wells. In such situation, the pumping rate of groundwater, the depth of well and its spacing would have to be decided carefully so as not to disturb the saline groundwater.

4. CONJUNCTIVE USE PLANNING IN EXISTING COMMANDS.

These guidelines can also be used for planning and dealing with Conjunctive use in existing commands. Any scheme for modernisation and improvement of existing commands needs to include conjunctive use proposals.

While planning conjunctive use in existing commands, the following special considerations need to be kept in view:

a. Management improvements in surface water distribution for better equity and reliability need to receive preference over conjunctive use possible due to recharge from excess of irrigation water

b. Proposals for reduction of carrying capacities of parts of surface distribution system, to make over-irrigation in head reaches difficult, need to be considered. Proposals for removing unnecessary human controls which can lead to malpractices also need to be considered.

c. Lining as a general measure for reduction of seepage is not recommended due to high cost involved. Only selective lining of problem reaches may be considered.

d. Since the extent of surface distribution network has already been dealt in such cases, it may be difficult to allocate separate parcels of land exclusively for groundwater use. However, if any small high patches or other patches have been left out in surface distribution, these may be taken up under the conjunctive use proposals through pumping.

e. Systematic groundwater observations on a continuous basis are necessary for sustaining the conjunctive use in the command on a long term basis.

5. ECONOMIC ANALYSIS OF PROJECTS WITH CONJUNCTIVE USE.

The general procedure and guidelines in regard to the economic analysis of irrigation projects are already known to the State Governments etc. The following additional points are relevant to the conjunctive use which need to be kept in view while presenting the economic analysis.

i. The principle of including costs incurred by the Govt. or by private parties, in the economic analysis needs to be followed in regard to the conjunctive use. Thus the estimate of the farmers' cost in regard to private exploitation of groundwater and in regard to field channels etc. for public tubewells needs to be included.

ii. While calculating the operational costs of the groundwater sources, the economic analysis of the costs of the energy (and not the administered price of electricity as prevalent) needs to be included.

iii. The pumping head to be considered in deciding the power requirements needs to include the prevalent average depth to groundwater in the "future without project" condition, the general decline of a few metres which would be necessary to induce groundwater flow from surface irrigated areas in the "future with project" condition as also the draw down at the well.

iv. 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 a practicable low figure to reflect achievable field conditions. In general, an overall energy efficiency of around 50% is suggested.

v. The total groundwater drawal possible per lifting unit depends not only on the head, 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 cost, practicable limits imposed by maintenance needs, social acceptance, night irrigation practices and likely power or diesel availability needs to be considered. Where these limits require 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.

6. GUIDELINES FOR PRESENTATION OF THE STUDIES.

As a result of the discussions in the other sections of the report, the following needs to be presented in a separate chapter on conjunctive use of surface and groundwaters.

6.1. Status of groundwater "future without conjunctive use project" condition including preliminary water balance and information about the rising or the falling trends in different zones. Preliminary map of average water table contours over the last few years for pre-monsoon and post-monsoon conditions may be given. Trend analysis of few groundwater observation wells data in the area available with Central and State agencies may also be presented.

6.2. Additional recharge of groundwater in view of the water use proposed in the project report including conjunctive use.

6.3. Estimation of the minimum desirable and maximum permissible conjunctive use in different zones of the command area.

6.4. A broad plan for additional water supply in the command area and nearby area (this plan if included elsewhere in the water supply component, only a cross reference needs to be made in the conjunctive use chapter).

6.5. The portion of groundwater drawal, estimating the volume of groundwater to be reserved for water supply.

6.6. Estimation of balance minimum desirable and balance maximum permissible use of groundwater.

6.7. Deciding the planned use for groundwater for irrigation within the two above mentioned limits and based on economics.

6.8. Estimating the intra-annual pattern of surface and groundwater utilisation.

6.9. Estimation of areas to be served exclusively from the two sources and the area which would be served from one source in one season and another source in another season.

6.10. Detailing these areas as separate parcels of land. In case detailing all over the command is difficult, detailing for typical zones covering at least 25% of the command needs to be done.

6.11. Discussing the type of groundwater development, i.e. deep tubewells, shallow tubewells, open wells etc. envisaged in the areas where groundwater could be used exclusively as also in areas where groundwater will be used in part of the season. Discussing the role of Government, private farmers and Water Users' Association, as well as NABARD and other loaning agencies in this regard.

6.12. Discussing the need, if any, of making procedural, legal and financial changes to encourage groundwater development, rationalisation of water rate structure, or to partially equalise the benefits to farmers using groundwater bringing out the decisions reached by the State Governments in this regard.

Discussing the possibility of the desired ground-water development in the command area taking place automatically without any measures by the Government, through private initiative based upon statistics of growth of private groundwater sources in the region.

6.13. Discussing the possibility of changing intra-annual conjunctive use pattern in years of excess flows or deficit flows and their effect on the overall groundwater balance.

6.14. Preparing detailed financial estimate of expenditure involved in the groundwater development and use both capital and recurring expenditure.

6.15. Discussing the installed capacity of groundwater structures required for getting necessary draft, considering the working machinery efficiencies, working hours likely to be available in practice etc.

6.16. Discussing the economic aspects and costs of conjunctive use components and incorporating these in the main cost benefit analysis of the irrigation components.

6.17. Discussing the institutional arrangement for the preparation of the Conjunctive use plan.

6.18. Discussing the means of control of groundwater exploitation through legal, administrative and financial measures. Discussing possibilities of encouraging practice of micro-irrigations e.g. sprinkler and/or drip irrigation in areas where groundwater depletion is likely, through legal and administrative measures.

6.19. Discussing the extent and limitations of mixing surface irrigation water with groundwater in the command area where only brackish/saline groundwater is available after considering changes in cropping pattern in order to effect optimum utilisation of such inferior groundwater and prevent water-logging. Discussing measures for disposal of saline water.