Reprint

DETAILED GUIDELINES FOR IMPLEMENTING THE GROUND WATER ESTIMATION METHODOLOGY

CENTRAL GROUND WATER BOARD

MINISTRY OF WATER RESOURCES

GOVERNMENT OF INDIA

2009

FOREWORD

'Ground Water Estimation Methodology - 1997' sets out the broad policy frame work which will form the basis for the methodology to be followed by all States/Union Territories in the Indian Union for ground water estimation. It was the outcome of the recommendations of a 'High Power Committee' constituted by the Ministry of Water Resources, Government of India. The present report contains detailed guidelines for implementing the ground water estimation methodology.

The two reports supplement and complement each other. This fact can be further clarified through an analogy concerning our day to day activity of climbing from one floor of a building to another. The present report is like the steps which we use while climbing the staircase. The report on 'Ground Water Estimation Methodology - 1997' is like the handrails which we use as support while climbing the steps.

I take this opportunity to congratulate, **Dr S P Rajagopalan**, Scientist F and Head, Computer Applications Division, Centre for Water Resources Development and Management, Calicut, **Mr Santosh Kumar Sharma**, Regional Director, Central Ground Water Board, Nagpur, and **Mr N R Tankhiwale**, General Manager, National Bank of Agriculture and Rural Development, Mumbai who have taken considerable pains to prepare this report. Incidentally all three of them were very active members of the 'Ground Water Estimation Methodology Committee' with **Mr Santosh Kumar Sharma** also serving as its Member Secretary.

I am confident that this report will not only make the task of ground water estimation by all State Ground Water Departments easy and simple, but also a very instructive and fruitful experience

(**Dr. D K Chadha**)

Place : New Delhi
Date : 16th March, 1998

Chairman
Central Ground Water Board
Ministry of Water Resources
Government of India

CONTNTS

ORGANISATION OF THIS REPORT

This report which is organised under 20 chapters is concerned with detailed guidelines for implementing the methodology as given in the report, 'Ground water Estimation Methodology - 1997', and includes the following :

a) Detailed computational procedures to be followed while applying the ground water estimation methodology.

b) The assumptions behind the estimation of all components of ground water assessment.

c) The formats to be adopted for performing the computations and presenting the ground water assessment results.

The report has been deliberately made very exhaustive with the intention to achieve the following purposes :

a) The computational procedure to be employed for the ground water assessment should be free from any ambiguity, and in that process, any scope for discretion and personal bias during the computations should be eliminated as far as possible.

b) The assumptions behind each computation should be clear.

c) A uniformity in the ground water assessment reports prepared by different States/ Union Territories should be ensured.

The type of ground water assessment unit, and characteristics of the ground water year to be adopted by a particular State/ Union Territory for the purpose of ground water assessment are covered in Chapter 1. Location details of each ground water assessment unit, its area and the area of the sub-units within it are covered in Chapter 2. Chapter 3 is concerned with computations of gross ground water draft. The sources which contribute to ground water recharge other than rainfall are canals, irrigation water applied by surface water irrigation, irrigation water applied by ground water irrigation, tanks & ponds and water conservation structures. Chapter 4 to 8 are concerned with estimation of recharge from these five sources. All of them are also collectively referred to as 'Other Sources'. The total recharge from these 'Other Sources' is covered in Chapter 9. Estimation of rainfall recharge by using the rainfall infiltration factor method is covered in Chapter 10. Chapter 11 is concerned with estimation of rainfall recharge during monsoon season by using the water table fluctuation method. Net annual ground water availability in respect of each ground water assessment unit is covered in Chapter 12.

The computations for arriving at the stage of ground water development in the two sub-units of command and non-command areas in respect of each ground water assessment unit are covered in Chapter 13.

The ground water estimation methodology - 1997, recognises that, the water table trend during pre-monsoon and post-monsoon intervals in the command and non-command areas, are an integral part of ground water assessment. The computations required to establish these trends are covered in Chapter 14.

The ground water estimation methodology - 1997, also stipulates that the two sub-units of command and non-command areas within each ground water assessment unit are to be categorised as safe, semi-critical, critical or over exploited depending on both the stage of ground water development, and the water table trend. These aspects are covered in Chapter 15.

The annual ground water allocations to be made for domestic and industrial water supply in relation to their projected demands up to next 25 years are covered in Chapter 16. The net annual ground water availability for future uses is covered in Chapter 17.

Additional potential recharge and static ground water resources are covered in Chapter 18.

The ground water estimation methodology - 1997, also requires that, a summary report of ground water assessment in respect of each ground water assessment unit should be given. This is covered in Chapter 19.

Wherever, a watershed has been adopted as the type of ground water assessment unit it is also necessary to present ground water assessment in terms of an appropriate administrative development unit like Block, Taluka or Mandal as the case may be. This aspect is covered in Chapter 20.

CHAPTER 1

TYPE OF GROUND WATER ASSESSMENT UNIT AND CHARACTERISTICS OF GROUND WATER YEAR

1.1 GENERAL

A ground water assessment unit is a geographic land area for which ground water assessment is to be carried out with the objective of estimating the following components :

a) **Current gross ground water draft.**
b) **Recharge from 'Other Sources'** (These are sources other than rainfall)
c) **Recharge from rainfall.**
d) **Net annual ground water availability.**
e) **Current stage of ground water development**
f) **Water table trend.**
g) **Categorisation for future ground water development .**
h) **Ground Water Allocation for domestic and industrial water supply.**
i) **Net annual ground water availability for future use.**

Each state/Union Territory should adopt a particular type of ground water assessment unit. Ground water assessment is also on the basis of a ground water year. The type of ground water assessment unit and the characteristics of a ground water year which are common for all ground water assessment units in a particular State/Union Territory are discussed in this chapter.

1.2 TYPE OF GROUND WATER ASSESSMENT UNIT

Each State/Union Territory should adopt only one of the following four types of ground water assessment unit for the entire State/Union Territory .

a) **Block**
b) **Taluka**
c) **Mandal**
d) **Watershed.**

The first three types mentioned above are administrative in character, and the last one namely, 'Watershed' is a hydrologic unit. All States/Union Territories are predominantly characterised by either 'Alluvial' terrain or 'Hardrock' terrain. The type of unit to be adopted will depend on the predominant terrain under which a particular State/Union Territory can be characterised.

All States/Union Territories which are predominantly characterised by 'Hardrock' terrain should adopt 'Watershed' as the type of ground water assessment unit. Such

States/Union Territories which have been adopting either 'Block' or 'Taluka' or 'Mandal' as the type of ground water assessment unit can however, continue to do so for the present with the condition that, all of them should switch over to 'Watershed' as the type of ground water assessment unit within five years from now. The reasons for recommending 'Watershed' as the type of ground water assessment unit in 'Hardrock' terrain are as follows :

a) The undulating topography in the 'Hardrock' terrain allows easy demarcation of a hydrologic unit like 'Watershed'.

b) The boundary of a 'Watershed' in 'Hardrock' terrain mostly coincides with the ground water divide as a result of which ground water balance within it can be made very conveniently.

All States/Union Territories which are predominantly characterised by 'Alluvial' terrain should adopt either 'Block' or 'Taluka' as the type of ground water assessment unit. A hydrologic unit like a 'Watershed' as the type of ground water assessment unit is not recommended in the 'Alluvial' terrain for the following reasons.

a) Demarcation of the boundaries of the 'Watershed' in 'Alluvial' terrain is difficult because of the relative flatness of the alluvial areas.

b) The boundary of a 'Watershed' in 'Alluvial' terrain will not usually coincide with the ground water divide, as a result of which there is no particular advantage of adopting 'Watershed' as the type of ground water assessment unit.

1.3 CHARACTERISTICS OF GROUND WATER YEAR

1.3.1 GROUND WATER YEAR

India receives rainfall from both South-West and North-East monsoons. The former is more or less consistently active during June to August, and the latter is more or less consistently active during October and November. Any given State/Union Territory is however, characterised by the fact that the quantum of rainfall received from one of these two monsoons is significantly much higher than that from the other. With these considerations in mind, a ground water year for purposes of ground water assessment can be very conveniently considered to comprise of 12 calendar months beginning from the commencement of the predominant monsoon.

1.3.2 SEASONS WITHIN A GROUND WATER YEAR

The ground water table is at the lowest level (or, farthest from the ground level) just prior to the onset of the predominant monsoon and reaches a peak (highest level or closest to the ground level) a little before the cessation of the predominant monsoon. Thereafter, the ground water table shows a declining trend with the recession limb having two significant segments. The first segment has a relatively steeper slope and extends to about a month after the cessation of the predominant monsoon. The second segment has a much flatter slope and extends up to the time when the predominant monsoon commences again is the next year. Ground water is usually not developed for irrigation use during the one month period corresponding to the first segment of the recession limb of the water table hydrograph as mentioned above, because of availability of adequate moisture in the root zone during this one month period. Keeping the above considerations in mind, a ground water year can be conveniently sub-divided into the following two seasons :

a) 'Monsoon Season' between the commencement of the predominant monsoon and a month after its cessation.
b) 'Non-monsoon Season' covering the rest of the ground water year.

It needs to be emphasised here that, the 'Monsoon Season' as defined above does not coincide with the duration of the predominant monsoon as commonly understood on the basis of occurrence of rainfall, but in fact extends to a month after its cessation. Ground water assessment computations will have to be made separately for these two seasons within a ground water year.

1.3.3 PRE- MONSOON AND POST- MONSOON INTERVALS

Water table data as recorded from a number of observation wells will be made use of in the assessment of ground water. These water table data will have to be recorded during two intervals within a ground water year. These two intervals are referred to as 'Pre-monsoon' and 'Post- monsoon' intervals. The former corresponds to the calendar month just prior to the 'Monsoon Season', and the latter corresponds to the calendar month just after it.

1.3.4 GROUND WATER ASSESSMENT YEAR

The ground water year for which ground water assessment is made and reported is referred to is as the 'Ground Water Assessment Year'.

The components of gross ground water draft and recharge from 'Other Sources' mentioned earlier in Section 1.1. are computed with reference to the 'Ground Water Assessment Year'. The component of recharge from 'Rainfall' is however a little different in the sense that, the rainfall for which the rainfall recharge is computed is not the rainfall during the ground water assessment year but a 'Normal Rainfall' value obtained as the average rainfall over a sufficiently long number of ground water years. The reasons for these are obvious. The components of gross ground water draft and recharge from 'Other Sources' primarily result from human interventions, and hence, their current values associated with the 'Ground Water Assessment Year' have to be considered. The rainfall on the other hand, is a natural phenomenon which varies considerably from year to year. Hence, it is only appropriate that the recharge from 'Rainfall' should be computed with reference to the 'Normal Rainfall' .

Ground water assessment reports are to be prepared once in three years.

1.3.5 SUMMARY

Based on what has been described earlier, the combinations of ground water year, monsoon & non-monsoon seasons, and pre-monsoon & post-monsoon intervals which can be adopted by a particular State/Union Territory are summarised below :

a) Applicable when the predominant monsoon is the south-west monsoon and the same commences by late May or early June

* Ground water year : 12 calendar months between June of one calendar year and May of next calendar year
* Monsoon season : 4 calendar months between June and September
* Non-monsoon season : the remaining 8 calendar months between October of one calendar year and May of the next calendar year
* Pre- monsoon interval : calendar month of May of the previous ground water year
* Post- monsoon interval : calendar month of October

b) Applicable when the predominant monsoon is the south-west monsoon and the same commences by end of June or early July.

* Ground water year	: 12 calendar months between July of one calendar year and June of next calendar year
* Monsoon season	: 4 calendar months between July and October
* Non-monsoon season	: the remaining 8 calendar months between November of one calendar year and June of the next calendar year
* Pre- monsoon interval	: calendar month of June of the previous ground water year
* Post- monsoon interval	: calendar month of November

c) Applicable when the predominant monsoon is the north-east monsoon

* Ground water year	: 12 calendar months between October of one calendar year and September of next calendar year
* Monsoon season	: 3 calendar months between October and December
* Non-monsoon season	: the remaining 9 calendar months between January and September
* Pre- monsoon interval	: calendar month of September of the previous ground water year
* Post- monsoon interval	: calendar month of January

1.4 PRESENTATION OF INFORMATION

Information on the type of ground water assessment unit and the characteristics of ground water year as discussed in the previous sections, and which are common for all ground water assessment units in a particular State/Union Territory are presented in one table (Table 1.1). The format to be adopted for this table is given in Format 1.1.

Format 1.1

Table 1.1 Type of Ground Water Assessment Unit And Characteristics of Ground Water Year

Name of State / Union Territory :

Ground Water Assessment Year :

Sl. No.	Description of item	Quantity
1	Predominant type of terrain (Alluvial / Hardrock)	
2	Predominant monsoon (South -west / North - east)	
3	If predominant monsoon is, 'South - west', the time when it usually commences (late May or early June / late June or early July)	
4	**Type of Ground Water Assessment Unit** (Block / Taluka / Mandal / Watershed)	
5	**Ground Water Year** (June to May / July to June / October to September)	
6	**Monsoon Season** (June to September / July to October / October to December)	
7	**Non - monsoon Season** (October to May / November to June / January to September)	
8	**Pre - monsoon Interval** (May / June / September)	
9	**Post - monsoon Interval** (October / November / January)	

CHAPTER 2

GROUND WATER ASSESSMENT UNIT AND THE SUB-UNITS WITHIN IT

2.1 GENERAL

The type of ground water assessment unit to be adopted by each State/Union Territory has been presented in Chapter 1. Wherever a 'Watershed' is adopted as the type of ground water assessment unit, each such watershed for which ground water assessment is made can typically have a geographic area ranging between ten thousand and thirty thousand hectares (100 and 300 sq.km.). To that extent, a watershed adopted as the assessment unit may have a few sub-watersheds within it. Delineation of individual watersheds should be carried out properly using Survey of India toposheets as the basis, and ensuring that no areas within the State/Union Territory are left out, and that, the boundary of the assessment unit is a real water divide, except for those units which may have an inter-state boundary.

2.2 SUB-UNITS WITHIN AN ASSESSMENT UNIT

Each ground water assessment unit should be further sub-divided in to the following four sub-units.

a) Hilly Area
b) Poor ground water quality area
c) Command Area
d) Non-command Area

2.2.1 HILLY AREA

This sub-unit comprises of all portions of the ground water assessment unit which have ground slopes greater than 20 percent. However, localised pockets like valley fills, terraces, plateau etc., occurring within the region of greater than 20 percent slopes, but having good ground water potential should be included within one of the other three sub-units mentioned above whichever is most appropriate. This sub-unit is characterised by practically negligible ground water recharge, and hence no ground water assessment is made for it.

2.2.2 AREA SUITABLE FOR GROUND WATER RECHARGE

The portion of the ground water assessment unit other than the hilly area as described in Section 2.2.1, is referred to as the area of the ground water assessment unit in which ground water recharge is possible. This area is further sub-divided into three sub-units namely, poor ground water quality area, command area and non-command area.

2.2.3 POOR GROUND WATER QUALITY AREA

This sub-unit comprises of all portions of the ground water assessment unit in which ground water recharge is possible, but in which ground water quality is beyond the permissible limits as adopted by the particular State/Union Territory for purpose of suitability for irrigation use. This sub-unit also includes portions of the assessment unit characterised by brackish/saline ground water and saline soil tracts. Ground water assessment should be separately made for this sub-unit.

2.2.4 GOOD GROUND WATER QUALITY AREA

This area comprises of all portions of the ground water assessment unit in which ground water recharge is possible, and in which ground water quality is well within the permissible limits as adopted by the particular State/Union Territory for purpose of suitability for irrigation use. This area is further sub-divided into command area and non-command area.

2.2.5 COMMAND AREA

This sub-unit comprises of all portions of the good ground water quality area within the ground water assessment unit as described in Section 2.2.4, and which are under the command of surface water irrigation sources like canals, tanks, ponds etc. However those surface water irrigation sources (like tanks and ponds) which irrigate isolated pockets less than 100 hectares should not be considered, and areas served by such sources should be included under the non-command area. Portions of this sub-unit can also be under irrigation by ground water source. Ground water assessment is to be made separately for this sub-unit.

2.2.6 NON-COMMAND AREA

This sub-unit comprises of all portions of the good ground water quality area within the ground water assessment unit as described in Section 2.2.4 and in which there is no surface water irrigation. As discussed in previous section, the areas under the command of tanks and ponds which are only localised pockets less than 100 hectares in

area should be also included within this sub-unit. Irrigation in this sub-unit is predominantly only by ground water source. Ground water assessment is to be separately made for this sub-unit.

2.3 PRESENTATION OF INFORMATION

Each ground water assessment unit is assigned a unique name, and a unique index number (1/ 2/ 3 etc.). All relevant information on the location and area of each ground water assessment unit and the sub-units within it are presented in one table (Table 2.1). The format to be adopted for this table is given in Format 2.1.

Format 2.1

Table 2.1 Location Details and Area of Each Ground Water Assessment Unit and the Sub - units Within It

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Quantity (3)
1	Reference number(s) of Survey of India Toposheet(s) of 1 in 50,000 scale in which the Ground Water Assessment Unit is located	
2	Latitudes within which the Ground Water Assessment Unit is located i) Starting ii) Ending	
3	Longitudes within which the Ground Water Assessment Unit is located i) Starting ii) Ending	
4	Total area in hectares of the **'Ground Water Assessment Unit'**	
5	Area in hectares of the **'Hilly Area'**	
6	Area in hectares of the portion of the Ground Water Assessment Unit in which ground water recharge is possible [(4) - (5)]	
7	Area in hectares of the **'Poor Ground Water Quality Area'**	
8	Area in hectares of the **'Command Area'**	
9	Area in hectares of the **'Non - command Area'**	

CHAPTER 3

GROSS GROUND WATER DRAFT

3.1 GENERAL

Ground water is primarily made use of to meet domestic water supply and irrigation water requirements. In some States/Union Territories ground water may be also important to meet industrial water supply requirements. The gross ground water draft components for the current ground water assessment year which are required to be known in respect of command area, non-command area and poor ground water quality area of each ground water assessment unit are listed below :

a) Command Area

i) Gross ground water draft for 'Irrigation' during monsoon and non-monsoon seasons**.**

They are used for computing recharge from irrigation water applied by ground water irrigation (Chapter 6)

ii) Annual gross ground water draft for 'Irrigation'

It is used for computing net annual ground water availability for 'Future Irrigation Use' (Chapter 17).

iii) Annual gross ground water draft for 'All Uses'

It is used for computing the current stage of ground water development (Chapter13).

iv) Gross ground water draft for 'All Uses' during monsoon season

It is used for computing rainfall recharge during monsoon season by the water table fluctuation method (Chapter 11).

b) Non-command Area

The same four draft components as listed for the command area in 'a' above.

c) Poor Ground water Quality Area

i) Gross ground water draft for 'Irrigation' during monsoon and non-monsoon seasons

They are used for computing recharge from irrigation water applied by ground water irrigation (Chapter 6)

ii) Annual gross ground water draft for 'All Uses'

It is used for computing net annual ground water availability for 'All Future Uses' (Chapter 17)

The norms to be adopted and the assumptions to be made for estimating the draft components are likely to vary considerably from State to State. In other words, the task of estimating the current gross ground water draft components as listed above is a highly location specific problem. Consequently it is difficult to specify a common uniform procedure to be followed by all States/Union Territories for computing the draft components. Hence, all States/Union Territories are given the freedom to adopt a procedure most suitable to them. The only requirement is that all the current gross ground water draft components as listed above should be estimated with as much accuracy as possible. More than one procedure may be also adopted to cross check the ground water draft results. The results of gross ground water draft should be presented in three tables (Tables 3.1, 3.2 and 3.3), one table for each sub-unit. The formats to be adopted for these three tables are given in Formats 3.1, 3.2 and 3.3 respectively.

One of the procedures which can be adopted for computing all the required gross ground water draft components is however, suggested in the next section. The suggested procedure involves the following major tasks to be performed :

a) Different types of wells which are commonly used in the ground water assessment unit are identified and unit ground water draft per well during monsoon and non-monsoon seasons for each type are estimated. The norms as given in Appendix 3.1 may be made use of as a general guideline for this purpose.

b) The number of wells belonging to different types as identified in 'a' above, and which are currently in actual use are then estimated.

c) The gross ground water draft is finally estimated using the results from 'a' and 'b' above.

3.2 SUGGESTED COMPUTATIONAL PROCEDURE

3.2.1 Unit Ground water Draft Per Well

Different types of wells which are commonly used in the ground water assessment unit are first identified. The ground water draft per well per day, and the number of days during which the wells are used in the monsoon and non-monsoon seasons are then estimated for each type of well. These estimates are finally used to obtain the unit

ground water draft per well in the monsoon and non-monsoon seasons for each type of well.

All wells of the same type are such that, each of them,

a) have more or less the same ground water withdrawal per day,

b) are more or less used for the same number of days during monsoon and non-monsoon seasons respectively, and

c) have a single use (either irrigation, domestic water supply or industrial water supply) to which they are put to.

The last requirement mentioned above arises as a result of the need to estimate separately the gross ground water draft for different uses. However, there may be some types of wells which are employed for more than one use. In such cases, a separate type is considered for each use, and unit ground water draft per well should be separately estimated for each of them. Also, the ground water withdrawal from the same type of well will be usually more in the non-command area than in the command area, because of more extensive use of the wells in the non-command area. In such cases also, the same type of well should be actually considered as two different types, and unit ground water draft per well should be separately estimated for each of them.

The computations for obtaining the unit ground water draft per well during monsoon and non-monsoon seasons in respect of all the types of wells which have been identified in the ground water assessment unit are presented in one table (Table 3.4.). The format to be adopted for this table is given in Format 3.4.

3.2.2 Command Area

The number of well belonging to different types (relevant for the command area), and which are currently in actual use are estimated. This will require detailed census of all wells. These results are then used along with the estimates of unit ground water draft per well as described in the previous section, and current gross groundwater draft in the command area during monsoon and non-monsoon seasons for different uses of ground water namely, irrigation, domestic water supply and industrial water supply are estimated.

The required computations are presented in three tables (Tables 3.5, 3.6 and 3.7), one table for each use. The formats to be adopted for these three tables are given in

Formats 3.5, 3.6 and 3.7 respectively. The results for all the different uses of ground water are then summed up to estimate the current gross ground water draft for all uses in the command area. The computations for this are presented in one table (Table 3.8). The format to be adopted for this table is given in Format 3.8.

3.2.3 Non-Command Area

The computational scheme to be adopted for the non-command area is identical to what has been described earlier in Section 3.2.2 for the command area. The computations for the ground water draft components in the non-command area are presented in four tables (Tables 3.9 to 3.12). The formats to be adopted for these four tables are given in Formats 3.9 to 3.12 respectively.

3.2.4 Poor Ground water Quality Area

The computational scheme to be adopted for the poor ground water quality area is identical to what has been described earlier in Section 3.2.2 for the command area. The computations for the ground water draft components in the poor ground water quality area are presented in four tables (Tables 3.13 to 3.16). The formats to be adopted for these four tables are given in Formats 3.13 to 3.16 respectively.

3.2.5 Summary of Gross Ground water draft components

Whatever may be the procedure adopted to estimate the ground water draft components, a summary of all current gross ground water draft components required for ground water assessment (as listed in section 3.1) in respect of the three sub units of command, non-command and poor ground water quality areas are presented in three tables (Tables 3.1, 3.2 and 3.3), one table for each sub unit. The formats to be adopted for these three tables are given in Formats 3.1, 3.2 and 3.3 respectively.

Format 3.1

Table 3.1 Summary of Current Gross Ground Water Draft Components in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of item	Quantity
1	Current gross ground water draft for **'Irrigation'** in command area in hectare metres a) during **monsoon** season b) during **non-monsoon** season	
2	Current **annual** gross ground water draft for **'Irrigation'** in command area in hectare metres	
3	Current **annual** gross ground water draft for **'All Uses'** in command area in hectare metres	
4	Current gross ground water draft for **'All Uses'** in command area during **monsoon** season in hectare metres	
5	Area in hectares of command area [From Table 2.1]	
6	Current **annual** gross ground water draft for **'Irrigation'** in command area **per unit area** in mm [((2) / (5)) * 1000]	
7	Current **annual** gross ground water draft for **'All Uses'** in command area **per unit area** in mm [((3) / (5)) * 1000]	

Format 3.2

Table 3.2 Summary of Current Gross Ground Water Draft Components in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of item	Quantity
1	Current gross ground water draft for **'Irrigation'** in non - command area in hectare metres i) during **monsoon** season ii) during **non-monsoon** season	
2	Current **annual** gross ground water draft for **'Irrigation'** in non - command area in hectare metres	
3	Current **annual** gross ground water draft for **'All Uses'** in non - command area in hectare metres	
4	Current gross ground water draft for **'All Uses'** in non - command area during **monsoon** season in hectare metres	
5	Area in hectares of non - command area [From Table 2.1]	
6	Current **annual** gross ground water draft for **'Irrigation'** in non - command area **per unit area** in mm [((2) / (5)) * 1000]	
7	Current **annual** gross ground water draft for **'All Uses'** in non - command area **per unit area** in mm [((3) / (5)) * 1000]	

Format 3.3

Table 3.3 Summary of Current Gross Ground Water Draft Components in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of item	Quantity
1	Current gross ground water draft for **'Irrigation'** in poor ground water quality area in hectare metres i) during **monsoon** season ii) during **non-monsoon** season	
2	Current **annual** gross ground water draft for **'All Uses'** in poor ground water quality area in hectare metres	
3	Area in hectares of poor ground water quality area [From Table 2.1]	
4	Current **annual** gross ground water draft for **'All Uses'** in poor ground water quality area **per unit area** in mm [((2) / (3)) * 1000]	

Table 3.4 Unit Gross Ground Water Draft Per Well for Different Types of Wells

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated draft per well per day in cubic metres per day	Estimated number of days the wells are operated during		Estimated gross ground water draft per well in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4) / 10^4]	Non - monsoon season [(3) * (5) / 10^4]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Format 3.5

Table 3.5 Current Gross Ground Water Draft for Irrigation in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for irrigation in hectare metres during [From Table 3.4]		Estimated gross ground water draft for irrigation from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water draft for irrigation in command area (Total of all the types of wells considered)							

Format 3.6

Table 3.6 Current Gross Ground Water Draft for Domestic Water Supply in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for domestic water supply in hectare metres during [From Table 3.4]		Estimated gross ground water draft for domestic water supply from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water draft for domestic water supply in command area (Total of all the types of wells considered)							

Format 3.7

Table 3.7 Current Gross Ground Water Draft for Industrial Water Supply in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Description of Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for industrial water supply in hectare metres during [From Table 3.4]		Estimated gross ground water draft for industrial water supply from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water draft for industrial water supply in command area (Total of all the types of wells considered)							

Format 3.8

Table 3.8 Current Gross Ground Water Draft for 'All Uses' in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of items (in command area) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Gross ground water draft in command area during current ground water assessment year in hectare metres for a) Irrigation [From Table 3.5] b) Domestic Water Supply [From Table 3.6] c) Industrial Water Supply [From Table 3.7] d) 'All Uses' [(1a) + (1b) + (1c)]		

A) Annual gross ground water draft for 'All Uses' during current ground water assessment year in command area in hectare metres [Sum of monsoon and non - monsoon seasons] =

B) Area in hectares of command area [From Table 2.1] =

C) Annual gross ground water draft for 'All Uses' in command area per unit area in millimetres [((A) / (B)) * 1000] =

Format 3.9

Table 3.9 Current Gross Ground Water Draft for Irrigation in Non - command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for irrigation in hectare metres [From Table 3.4]		Estimated gross ground water draft for irrigation from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water draft for irrigation in non - command area (Total of all the types of wells considered)							

Format 3.10

Table 3.10 Current Gross Ground Water Draft for Domestic Water Supply in Non - command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for domestic water supply in hectare metres [From Table 3.4]		Estimated gross ground water draft for domestic water supply from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
	Current gross ground water draft for domestic water supply in non -command area (Total of all the types of wells considered)						

Format 3.11

Table 3.11 Current Gross Ground Water Draft for Industrial Water Supply in Non - Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for industrial water supply in hectare metres [From Table 3.4]		Estimated gross ground water draft for industrial water supply from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
	Current gross ground water draft for industrial water supply in non - command area (Total of all the types of wells considered)						

Format 3.12

Table 3.12 Current Gross Ground Water Draft for 'All Uses' in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of items (in non - command area) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Gross ground water draft in non - command area during current ground water assessment year in hectare metres for a) Irrigation [From Table 3.9] b) Domestic Water Supply [From Table 3.10] c) Industrial Water Supply [From Table 3.11] d) 'All Uses' [(1a) + (1b) + (1c)]		

A) Annual gross ground water draft for 'All Uses' during current ground water assessment year in non - command area in hectare metres [Sum of monsoon and non - monsoon seasons] =

B) Area in hectares of non - command area [From Table 2.1] =

C) Annual gross ground water draft for 'All Uses' in non - command area per unit area in millimetres [((A) / (B)) * 1000] =

Format 3.13

Table 3.13 Current Gross Ground Water Draft for Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for irrigation in hectare metres [From Table 3.4]		Estimated gross ground water draft for irrigation from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water draft for irrigation in poor ground water quality area (Total of all the types of wells considered)							

Note : It is quite possible that there may be no wells in the poor ground water quality area which are used for irrigation

Format 3.14

Table 3.14 Current Gross Ground Water Draft for Domestic Water Supply in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for domestic water supply in hectare metres [From Table 3.4]		Estimated gross ground water draft for domestic water supply from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water draft for domestic water supply in poor ground water quality area (Total of all the types of wells considered)							

Note : It is quite possible that there may be no wells in the poor ground water quality area which are used for domestic water supply

Format 3.15

Table 3.15 Current Gross Ground Water Draft for Industrial Water Supply in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Type of well	Estimated number of wells currently in actual use	Estimated gross ground water draft per well for industrial water supply in hectare metres [From Table 3.4]		Estimated gross ground water draft for industrial water supply from all wells of a given type in hectare metres during		
			Monsoon season	Non-monsoon season	Monsoon season [(3) * (4)]	Non - monsoon season [(3) * (5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water draft for industrial water supply in poor ground water quality area (Total of all the types of wells considered)							

Note : It is quite possible that there may be no wells in the poor ground water quality area which are used for industrial water supply

Format 3.16

Table 3.16 Current Gross Ground Water Draft for 'All Uses' in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of items (in poor ground water quality area) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Gross ground water draft in poor ground water quality area during current ground water assessment year in hectare metres for a) Irrigation [From Table 3.13] b) Domestic Water Supply [From Table 3.14] c) Industrial Water Supply [From Table 3.15] d) 'All Uses' [(1a) + (1b) + (1c)]		

A) Annual gross ground water draft for 'All Uses' during current ground water assessment year in poor ground water quality area in hectare metres [Sum of monsoon and non - monsoon seasons] =

B) Area in hectares of poor ground water quality area [From Table 2.1] =

C) Annual gross ground water draft for 'All Uses' in poor ground water quality area per unit area in millimetres [((A) / (B)) * 1000] =

CHAPTER 4

RECHARGE FROM CANALS

4.1 GENERAL

Recharge from canals which is to be computed separately for the monsoon and non-monsoon seasons of the current ground water assessment year is applicable only for the following two sub-units :

a) Command area

b) Poor ground water quality area

The estimation of recharge from canals involves the following steps to be carried out.

a) The mains, minors and distributories of the canal system are divided in to a number of canal segments with each canal segment fulfilling certain requirements as described later in this chapter.

b) The wetted area for each canal segment is computed

c) A canal seepage factor value is assigned to each canal segment on the basis of certain norms as described later in this chapter.

d) Recharge from each canal segment during the monsoon and non-monsoon seasons are computed

e) Recharge from the canal system as a whole during the monsoon and non-monsoon seasons are finally obtained as the sum of the recharge from each canal segment.

4.2 ASSUMPTIONS

The estimation of recharge from canals is based on the following assumptions

a) Recharge in hectare metres can be computed as the product of the following three parameters :

i) seepage factor expressed in hectare metres per day per million square metres of wetted area

ii) wetted area in million square metres

iii) number of days the canal segment is in operation

b) The seepage factor mentioned in 'a' above, depends only on the following factors-

i) whether the canal segment is lined or unlined

ii) whether the soil type over which the canal segment traverses is normal soil or sandy soil

c) The seepage factor mentioned in 'a' above , can be assigned a value either from the specified norms as given in the Appendix 4.1, or on the basis of results from

documented field studies. The norms as given in Appendix 4.1 strictly apply only for canals in alluvial terrain. The values for seepage factor as given in the norms for lined canals in normal soil may be however made use of in the case of canals in hardrock terrain.

d) The average depth of flow in a canal segment during the duration in which it is in operation can be considered to be 0.6 times the design depth of flow of that canal segment

4.3 COMPUTATIONAL PROCEDURE

4.3.1 Command Area

The computational scheme which is to be adopted for estimating recharge from canals in the command area during monsoon and non-monsoon seasons is as given below.

4.3.1.1 Canal Segments

Mains, minors and distributories in the canal system alone are considered for computing recharge from canals. They are divided in to a number of canal segments, each having a specified length. Each such canal segment in its entire stretch,

a) is either lined or unlined,

b) traverses the same soil/rock type,

c) has same value of design depth of flow, same value of base width and same value of side slope, and

d) is in operation for the same number of days in a given season.

The location details of all the canal segments are presented in one table (Table 4.1) The format to be adopted for this table is given in Format 4.1.

4.3.1.2 Wetted Area

The wetted area in million square metres for each canal segment is computed making use of data on length, base width, side slope and design depth of flow. The results are presented in one table (Table 4.2). The format to be adopted for this table is given in Format 4.2.

4.3.1.3 Canal Seepage Factor

The canal seepage factor in hectare metres per day per million square metres of wetted area is assigned to each canal segment based on either the norms as given in Appendix 4.1 or on the basis of results from documented field studies. The results are presented in one table (Table 4.3). The format to be adopted for this table is given in Format 4.3.

4.3.1.4 Recharge From Canals

The data on wetted area and canal seepage factor as discussed in the previous two sections are then used along with data on the number of days the canal segment is in operation during monsoon and non-monsoon seasons to estimate the recharge due to canal seepage from each canal segment. The results are presented in one table (Table 4.4). The format to adopted for this table is given in Format 4.4.

Recharge from canals in the command area during monsoon and non-monsoon season are finally obtained as the sum of the recharge values computed for each canal segment. These results are also presented in Table 4.4.

4.3.2 Poor Ground water Quality Area

The computational scheme to be adopted for estimating recharge from canals in the poor ground water quality area is identical to what has been described earlier in Section 4.3.1 for command area. The results are presented in four tables (Tables 4.5 to 4.8). The formats to be adopted for these four tables are given in Formats 4.5 to 4.8 respectively.

Format 4.1

Table 4.1 Location Details of Different Canal Segments of the Canal System in the Command Area

Name of Ground Water Assessment Unit :

Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of canal segment	Type (main / minor / distributory)	Length in metres	Starting point of canal segment		Ending point of canal segment	
				Latitude	Longitude	Latitude	Longitude
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Format 4.2

Table 4.2 Wetted Area in Different Canal Segments of the Canal System in the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No. (1)	Name of canal segment (2)	Length in metres [From Table 4.1] (3)	Design depth of flow in metres (4)	Base width in metres (5)	Side slope in degrees (6)	Wetted perimeter in metres $\left[\frac{2 * 0.6 * (4)}{\sin[(6)]}\right] + (5)$ (7)	Wetted area in million square metres $[(7) * (3)] / 10^6$ (8)
1							
2							
3							

Format 4.3

Table 4.3 Canal Seepage Factor for Different Canal Segments of the Canal System in the Command Area

Name of Ground Water Assessment Unit :

Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Terrain Over Which All Canal Segments Traverse : (Alluvial / Hardrock)

Sl. No. (1)	Name of canal segment (2)	Type (lined / unlined) (3)	If terrain is alluvial soil type (normal / sandy) or If terrain is hardrock rock type (4)	Are canal seepage factor values available from documented field studies (Yes/No) (5)	Assigned canal seepage factor in hectare metres per day per million square metres of wetted Area (6)
1					
2					
3					

Format 4.4

Table 4.4 Recharge from Canals in the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of canal segment	Canal seepage factor in hectare metres per day per million square metres of wetted area (From Table 4.3)	Wetted area in million square metres (From Table 4.2)	Number of days the canal segment is in operation during		Recharge from canal segment in hectare metres during	
				Monsoon season	Non-monsoon season	Monsoon season [(3) * (4) * (5)]	Non-monsoon season [(3) * (4) * (6)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Recharge from canals in the command area (Sum of recharge from all canal segments)							

Format 4.5

Table 4.5 Location Details of Different Canal Segments of the Canal System in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of canal segment	Type (main/minor/ distributory)	Length in metres	Starting point of canal segment		Ending point of canal segment	
				Latitude	Longitude	Latitude	Longitude
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Format 4.6

Table 4.6 Wetted Area in Different Canal Segments of the Canal System in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No. (1)	Name of canal segment (2)	Length in metres [From Table 4.5] (3)	Design depth of flow in metres (4)	Base width in metres (5)	Side slope in degrees (6)	Wetted perimeter in metres $\left[\frac{2 * 0.6 * (4)}{\sin[(6)]}\right] + (5)$ (7)	Wetted area in million square metres $[(7) * (3)] / 10^6$ (8)
1							
2							
3							

Format 4.7

Table 4.7 Canal Seepage Factor for Different Canal Segments of the Canal System in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Terrain Over Which All Canal Segments Traverse : (Alluvial / Hardrock)

Sl. No. (1)	Name of canal segment (2)	Type (lined/unlined) (3)	If terrain is alluvial soil type (normal / sandy) or If terrain is hardrock rock type (4)	Are canal seepage factor values available from documented field studies (Yes/No) (5)	Assigned canal seepage factor in hectare metres per day per million square metres of wetted area (6)
1					
2					
3					

Format 4.8

Table 4.8 Recharge from Canals in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of canal segment	Canal seepage factor in hectare metres per day per million square metres of wetted area (From Table 4.7)	Wetted area in million square metres (From Table 4.6)	Number of days the canal segment is in operation during		Recharge from canal segment in hectare metres during	
				Monsoon season	Non-monsoon season	Monsoon season [(3) * (4) * (5)]	Non-monsoon season [(3) * (4) * (6)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Recharge from canals in the poor ground water quality area (Sum of recharge from all canal segments)							

CHAPTER 5

RECHARGE FROM IRRIGATION WATER APPLIED BY SURFACE WATER IRRIGATION

5.1 GENERAL

Recharge from irrigation water applied by surface water irrigation which has to be computed for the monsoon and non- monsoon seasons of the current ground water assessment year is applicable only for the following two sub-units of each ground water assessment unit,

a) command area
b) poor ground water quality area

The computations of recharge from irrigation water applied by surface water irrigation in a given sub-unit and during a given season involves the following steps to be carried out.

a) estimation of irrigation water applied by surface water irrigation
b) estimation average depth to water table below ground level
c) estimation of irrigated are under paddy and non-paddy
d) assigning a return flow factor on the basis of results from 'b' and 'c' above
e) computation of the required recharge on the basis of the results from 'a' and 'd' above

5.2 ASSUMPTIONS

The computation of recharge from irrigation water applied by surface water irrigation is based on the following assumptions .

a) recharge in hectare metres can be obtained as the product of the following parameters :

   i) irrigation water applied in hectare metres
   ii) return flow factor as a fraction

b) the irrigation water applied as mentioned in 'a' above is considered as the sum of water released from all outlets in the canal system. Each such outlet is located in the distributories of the canal systems.

c) the water released in hectare metres from each outlet as mentioned in 'b' above can be computed as the product of the following parameters

   i) design discharge of the outlet in hectare metres per day
   ii) number of days water is actually released from the outlet
   iii)a factor 0.6 (assuming that the actual average discharge from the outlet during the period water is released from it is 0.6 times the design discharge).

d) the return flow factor mentioned in 'a' above depends only on the following factors

i) whether the crop irrigated is paddy or non-paddy

ii) whether the range of depth to water table below ground level is less than 10 metres, between 10 and 25 metres or greater than 25 metres

iii)whether the release from outlets is continuous or rotational.

e) the return flow factor mentioned in 'a' and 'd' above can be assigned a value either on the basis of norms as given in Appendix 5.1 or on the basis of results from documented field studies.

5.3 COMPUTATIONAL PROCEDURE

5.3.1 Command Area

The computational scheme to be adopted for computing the recharge from irrigation water applied by surface water irrigation in command area is described in this section.

5.3.1.1 Irrigation Water Applied

The location details of all the outlets in the canal system are presented in one table (Table 5.1). The format to be adopted for this table is given in Format 5.1.

The actual water released from each outlet during the monsoon and non-monsoon season are computed. The irrigation water applied during these two seasons are obtained as the sum of the releases from each outlet. The computations for these are presented in one table (Table 5.2). The format to be adopted for this table is given in Format 5.2

5.3.1.2 Depth to Water Table Below Ground Level

The average depth to water table below ground level in the command area as a whole during the monsoon and non-monsoon seasons are to be categorised as one of the following three ranges

a) Less than 10 metres
b) Between 10 and 25 metres
c) Greater than 25 metres

The computational scheme to adopted for this purpose is given below :

a) The following data on depth to water table below ground level as recorded from each of the observation wells in the command area are considered.

i) during pre-monsoon interval of current ground water assessment year
ii) during post-monsoon interval of current ground water assessment year

iii)during pre-monsoon interval of ground water year immediately following the current ground water assessment year.

b) The above three water table data items applicable for the command area as a whole are obtained as the arithmetic average of the corresponding data from all the observation wells considered.

c) Average depth of water table below ground level in command area as a whole during the monsoon season is computed as the arithmetic average of the water table data during pre-monsoon and post-monsoon intervals of the current ground water assessment year as obtained in 'b' above.

d) Average depth of water table below ground level in the command area as a whole during the non-monsoon season is computed as the arithmetic average of the water table data during post-monsoon interval of the current ground water assessment year and pre-monsoon interval of the ground water year immediately following the current ground water assessment year as obtained in 'b' above.

e) The results obtained from 'c' and 'd' above or made use of to categorise the depth to water table below ground level in the command area during monsoon and non-monsoon seasons to belong to one of the three ranges mentioned in the beginning of this section.

The computations required for the above scheme are presented in one table (Table 5.3). The format to be adopted for this table is given in Format 5.3.

5.3.1.3 Irrigated Area Under Paddy and Non-paddy

The irrigated area in hectares under paddy and non-paddy in the command area during monsoon and non-monsoon seasons of the current ground water assessment year are estimated by adopting any convenient method. The most obvious method, though it will be time consuming, is through actual field survey. They can be also estimated indirectly, using information on irrigation water applied and irrigation water requirement of the crops. The results of the irrigated area as mentioned above are presented in one table (Table 5.4) . The format to be adopted for this table is given in Format 5.4.

5.3.1.4 Return Flow Factor

The return flow factor for the command area during monsoon and non-monsoon seasons are obtained either on the basis of the norms as given in Appendix 5.1 or on the basis of results from documented field studies. The use of the norms require information on depth water table and irrigated area mentioned in the previous two sections. The computations are presented in one table (Table 5.5) The format to be adopted for this table is given in Format 5.5.

5.3.1.5 Recharge

The estimates of irrigation water applied and the return flow factor are then made use of to compute the recharge from irrigation water applied by surface water irrigation in the command area during the monsoon and non-monsoon seasons of the current ground water assessment year. The computations are presented in one table (Table 5.6). The format to be adopted for this table is given in Format 5.6.

5.3.2 POOR GROUND WATER QUALITY AREA

The computations to be performed for estimating the recharge from irrigation water applied by surface water irrigation in the poor ground water quality area during the monsoon and non-monsoon season of the current ground water assessment year is identical to what has been described earlier in Section 5.3.1 for the command area.

Usually, there will be no observation wells in the poor ground water area.. This limitation can be overcome by assuming that, the range of depth to water table below ground level during both monsoon and non-monsoon seasons in this sub-unit is less than 10 metres if data from observation wells are not available. This assumption will be mostly valid since poor ground water quality areas will be normally associated with shallow water table areas.

The computations for the poor ground water quality area are presented in six tables (Tables 5.7 to 5.12). The formats to be adopted for these six tables are given in Formats 5.7 to 5.12 respectively.

Format 5.1

Table 5.1 Location Details of All Outlets Of the Canal System in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No. (1)	Name of outlet (2)	Distributory in which the outlet is located (3)	Latitude (4)	Longitude (5)	Design discharge in hectare metres per day (6)
1					
2					
3					

Format 5.2

Table 5.2 Irrigation Water Applied by Surface Water Irrigation in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of outlet	Design discharge in hectare metres per day [From Table 5.1]	Number of days water is released from the outlet during		Water released from outlet in hectare metres during	
			Monsoon season	Non-monsoon season	Monsoon season (3) * (4) * 0.6	Non-monsoon season (3) * (5) * 0.6
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Irrigation water applied by surface water irrigation in command area in hectare metres [Sum of water released from each outlet]						

Format 5.3

Table 5.3 Water Table Data during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of observation well (All wells are in command area)	Depth to water table below ground level in metres		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon interval	Post - monsoon interval	Pre - monsoon interval
(1)	(2)	(4)	(5)	(6)
1				
2				
3				
For the command area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a) Depth to water table below ground level in command area in metres

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

Format 5.4

Table 5.4 Irrigated Area Under Paddy and Non - paddy Under Surface Water Irrigation in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

<table>
<tr><th rowspan="2">Sl. No.

(1)</th><th rowspan="2">Type of crop (in command area)

(2)</th><th colspan="2">Irrigated area under surface water irrigation in hectares during</th></tr>
<tr><th>Monsoon season
(3)</th><th>Non - monsoon season
(4)</th></tr>
<tr><td>1</td><td>Paddy</td><td></td><td></td></tr>
<tr><td>2</td><td>Non - paddy
<table><tr><th rowspan="2">Sl. No.</th><th rowspan="2">Crop</th><th colspan="2">Irrigated area in hectares</th></tr><tr><th>Monsoon season</th><th>Non-monsoon season</th></tr><tr><td>1
2
3</td><td></td><td></td><td></td></tr><tr><td colspan="2">Total for Non - paddy</td><td></td><td></td></tr></table></td><td></td><td></td></tr>
</table>

Format 5.5

Table 5.5 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Surface Water Irrigation in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for command area) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigated area under Paddy [From Table 5.4]		
2	Irrigated area under Non - paddy [From Table 5.4]		
3	Range of depth to water table below ground level (< 10 m / 10 - 25 m / > 25 m) [From Table 5.3]		
4	Type of irrigation water supply (Continuous / Rotational)		
5	Is return flow factor for Paddy based on results from documented field studies (Yes / No)		
6	Is return flow factor for Non - paddy based on results from documented field studies (Yes / No)		
7	Return flow factor for Paddy as a fraction		
8	Return flow factor for Non - paddy as a fraction		
9	Return flow factor for the command area as a whole $\left[\frac{(7) * (1) + (8) * (2)}{(1) + (2)} \right]$		

Format 5.6

Table 5.6 Recharge from Irrigation Water Applied by Surface Water Irrigation in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for command area) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigation water applied by surface water irrigation in command area in hectare metres [From Table 5.2]		
2	Return flow factor for computing recharge from irrigation water applied by surface water irrigation in command area as a fraction [From Table 5.5]		
3	Recharge from irrigation water applied by surface water irrigation in command area in hectare metres [(1) * (2)]		

Format 5.7

Table 5.7 Location Details of All Outlets Of the Canal System in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No. (1)	Name of outlet (2)	Distributory in which the outlet is located (3)	Latitude (4)	Longitude (5)	Design discharge in hectare metres per day (6)
1					
2					
3					

Format 5.8

Table 5.8 Irrigation Water Applied by Surface Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of outlet	Design discharge in hectare metres per day [From Table 5.7]	Number of days water is released from the outlet during		Water released from outlet in hectare metres during	
			Monsoon season	Non-monsoon season	Monsoon season (3) * (4) * 0.6	Non-monsoon season (3) * (5) * 0.6
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Irrigation water applied by surface water irrigation in poor ground water quality area in hectare metres [Sum of water released from each outlet]						

Format 5.9

Table 5.9 Water Table Data during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area Format

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of observation well (All wells are in poor ground water quality area)	Depth to water table below ground level in metres		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon interval	Post - monsoon interval	Pre - monsoon interval
(1)	(2)	(4)	(5)	(6)
1				
2				
3				
For the poor ground water quality area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a) Depth to water table below ground level in poor ground water quality area in metres

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =

[(Y2 + Y3) / 2]

b) If water table data are not available, the depth to water table below ground level during both monsoon and non-monsoon seasons may be considered to be less than 10 metres below ground level .

Format 5.10

Table 5.10 Irrigated Area Under Paddy and Non - paddy Under Surface Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

<table>
<tr><td rowspan="2">Sl. No.

(1)</td><td rowspan="2">Type of crop
(for poor ground water quality area)

(2)</td><td colspan="2">Irrigated area under surface water irrigation in hectares during</td></tr>
<tr><td>Monsoon season
(3)</td><td>Non - monsoon season
(4)</td></tr>
<tr><td>1</td><td>Paddy</td><td></td><td></td></tr>
<tr><td>2</td><td>Non - paddy
<table><tr><td rowspan="2">Sl. No.</td><td rowspan="2">Crop</td><td colspan="2">Irrigated area in hectares</td></tr><tr><td>Monsoon season</td><td>Non-monsoon season</td></tr><tr><td>1
2
3</td><td></td><td></td><td></td></tr><tr><td colspan="2">Total for Non - paddy</td><td></td><td></td></tr></table></td><td></td><td></td></tr>
</table>

Format 5.11

Table 5.11 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Surface Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for poor ground water quality area) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigated area under Paddy [From Table 5.10]		
2	Irrigated area under Non - paddy [From Table 5.10]		
3	Range of depth to water table below ground level (< 10 m / 10 - 25 m / > 25 m) [From Table 5.9]		
4	Type of irrigation water supply (Continuous / Rotational)		
5	Is return flow factor for Paddy based on results from documented field studies (Yes / No)		
6	Is return flow factor for Non - paddy based on results from documented field studies (Yes / No)		
7	Return flow factor for Paddy as a fraction		
8	Return flow factor for Non - paddy as a fraction		
9	Return flow factor for the poor ground water quality area as a whole $\left[\frac{(7) * (1) + (8) * (2)}{(1) + (2)}\right]$		

Format 5.12

Table 5.12 Recharge from Irrigation Water Applied by Surface Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of item (for poor ground water quality area)	Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1	Irrigation water applied by surface water irrigation in poor ground water quality area in hectare metres [From Table 5.8]		
2	Return flow factor for computing recharge from irrigation water applied by surface water irrigation in poor ground water quality area as a fraction [From Table 5.11]		
3	Recharge from irrigation water applied by surface water irrigation in poor ground water quality area in hectare metres [(1) * (2)]		

CHAPTER 6

RECHARGE FROM IRRIGATION WATER APPLIED BY GROUND WATER IRRIGATION

6.1 GENERAL

Recharge from irrigation water applied by ground water irrigation which has to be computed for the monsoon and non-monsoon seasons of the current ground water assessment year is applicable for the following three sub-units of each ground water assessment unit:

a) Non-command area
b) Command area
c) Poor groundwater quality area

The computation of recharge from irrigation water applied by ground water irrigation in a given sub-unit and during a given season involves the following steps to be carried out:

a) Estimation of irrigation water applied by ground water irrigation .
b) Estimation of average depth to water table below ground level.
c) Estimation of irrigated area under paddy and non-paddy.
d) Assigning a return flow factor on the basis of results from 'b' and 'c' above.
e) Computation of the required recharge on the basis of results from 'a' and 'd' above.

6.2 ASSUMPTIONS

The computation of recharge from irrigation water applied by ground water irrigation is based on the following assumptions :

a) Recharge in hectare metres can be obtained as the product of the following parameters :
   i) Irrigation water applied in hectare metres
   ii) Return flow factor as a fraction
b) The irrigation water applied as mentioned in 'a' above is considered as the gross groundwater draft for irrigation as obtained in Chapter 3. In other words, the transmission losses are considered as nil.
c) The return flow factor mentioned in 'a' above depends only on the following parameters:
   i) Whether the crop irrigated is paddy or non-paddy.
   ii) Whether the range of depth to water table below ground level is less than 10 metres, between 10 and 25 metres or greater than 25 metres.

d) The return flow factor mentioned in ‘a’ and ‘c’ above can be assigned a value either on the basis of norms as given in Appendix 6.1 or on the basis of results from documented field studies.

6.3 COMPUTATIONAL PROCEDURE

6.3.1 Non- command Area

The computational scheme to be adopted for computing the recharge from irrigation water applied by ground water irrigation in the non-command area is described in this section.

6.3.1.1 Irrigation Water Applied

The gross ground water draft for irrigation , during the monsoon and non-monsoon seasons in the non-command area as computed in Chapter 3 are considered as the irrigation water applied by ground water irrigation. These results are presented in one table (Table 6.1). The format to be adopted for this table is given in Format 6.1.

6.3.1.2 Depth to Water Table Below Ground Level

The computational scheme to be adopted for characterising the depth to water table below ground level in the non-command area during monsoon and non-monsoon seasons to belong to one of the following three ranges,

a) Less than 10 metres
b) Between 10 and 25 metres
c) Greater than 25 metres

is identical to what has been described for irrigation water applied by surface water irrigation in Chapter 5. The necessary computations are presented one table (Table 6.2). The format to be adopted for this table is given in Format 6.2.

6.3.1.3 Irrigated Area Under Paddy and Non-Paddy

The area irrigated by ground water irrigation under paddy and non-paddy in the non-command area during monsoon and non-monsoon seasons of the current ground water assessment year are presented in one table (Table 6.3). The format to be adopted for this table is given in Format 6.3.

6.3.1.4 Return Flow Factor

The return flow factor for the non-command area during monsoon and non-monsoon seasons with reference to ground water irrigation are obtained either on the basis of norms as given in Appendix 6.1, or on the basis of documented field studies.

The use of the norms require the information on depth of water table and irrigated area as discussed earlier. The computations are presented in one table (Table 6.4). The format to be adopted for this table is given in Format 6.4.

6.3.1.5 Recharge

The estimates of irrigation water applied, and the estimate of the return flow factor as described earlier are made use of to compute the recharge from irrigation water applied by ground water irrigation in the non-command area during monsoon and non-monsoon seasons of the current ground water assessment year. The computations are presented in one Table (Table 6.5). The format to be adopted for this table is given in Format 6.5.

6.3.2 Command Area

The computations to be performed for estimating the recharge from irrigation water applied by ground water irrigation in the command area during monsoon and non-monsoon seasons of the current ground water assessment year are identical to what have been described earlier in Section 6.3.1 for the non-command area. The necessary computations are presented in five tables (Tables 6.6 to 6.10). The formats to be adopted for these five tables are given in Formats 6.6 to 6.10 respectively.

One of the above tables namely, Table 6.7 on depth to water table in the command area is the same as Table 5.3 in Chapter 5. It is included again here only for the convenience to have the whole set of computations self contained in all respects.

6.3.3 Poor Ground Water Quality Area

The computations to be performed for estimating the recharge from irrigation water applied by ground water irrigation in the poor ground water quality area during monsoon and non-monsoon seasons of the current ground water assessment year are identical to what have been described earlier in Section 6.3.1 for the non-command area. The necessary computations are presented in five tables (Tables 6.11 to 6.15). The formats to be adopted for these five tables are given in Formats 6.11 to 6.15 respectively.

One of the above tables namely, Table 6.12 on depth to water table in the poor ground water quality area is the same as Table 5.9 in Chapter 5. It is included again here

only for the convenience to have the whole set of computations self contained in all respects.

As discussed earlier in Chapter 5 (Section 5.3.2), the range of depth to water table below ground level in the poor ground water quality area during both monsoon and non-monsoon seasons can be assumed to be less than 10 metres if no water table data are available.

Format 6.1

Table 6.1 Irrigation Water Applied by Ground Water Irrigation in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for non - command area) (2)	Quantity (3)
1	Irrigation water applied by ground water irrigation in non - command area during monsoon season in hectare metres [From Table 3.2]	
2	Irrigation water applied by ground water irrigation in non - command area during non - monsoon season in hectare metres [From Table 3.2]	

Note : Irrigation water applied by ground water irrigation during a given season is considered to be the same as the gross ground water draft for irrigation during that season

Format 6.2

Table 6.2 Water Table Data during Monsoon and Non-monsoon Seasons in Non - command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of observation well (All wells are in non - command area)	Depth to water table below ground level in metres		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon interval	Post - monsoon interval	Pre - monsoon interval
(1)	(2)	(4)	(5)	(6)
1				
2				
3				
For the Non - command area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a) Depth to water table below ground level in non - command area in metres

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

Format 6.3

Table 6.3 Irrigated Area Under Paddy and Non - paddy Under Ground Water Irrigation in Non -command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

<table>
<tr><td rowspan="2">Sl. No.

(1)</td><td rowspan="2">Type of crop
(All crops are in non - command area and are irrigated by ground water irrigation)

(2)</td><td colspan="2">Irrigated area under ground water irrigation in hectares during</td></tr>
<tr><td>Monsoon season
(3)</td><td>Non - monsoon season
(4)</td></tr>
<tr><td>1</td><td>Paddy</td><td></td><td></td></tr>
<tr><td>2</td><td>Non - paddy
<table><tr><td rowspan="2">Sl. No.</td><td rowspan="2">Crop</td><td colspan="2">Irrigated area in hectares</td></tr><tr><td>Monsoon season</td><td>Non-monsoon season</td></tr><tr><td>1
2
3</td><td></td><td></td><td></td></tr><tr><td colspan="2">Total for Non - paddy</td><td></td><td></td></tr></table></td><td></td><td></td></tr>
</table>

Format 6.4

Table 6.4 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Ground Water Irrigation in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for non - command area and under ground water irrigation) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigated area under Paddy [From Table 6.3]		
2	Irrigated area under Non - paddy [From Table 6.3]		
3	Range of depth to water table below ground level (< 10 m / 10 - 25 m / > 25 m) [From Table 6.2]		
4	Is return flow factor for Paddy based on results from documented field studies (Yes / No)		
5	Is return flow factor for Non - paddy based on results from documented field studies (Yes / No)		
6	Return flow factor for Paddy as a fraction		
7	Return flow factor for Non - paddy as a fraction		
8	Return flow factor for the non - command area as a whole $\left[\frac{(6) * (1) + (7) * (2)}{(1) + (2)}\right]$		

Format 6.5

Table 6.5 Recharge from Irrigation Water Applied by Ground Water Irrigation in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigation water applied by ground water irrigation in non - command area in hectare metres [From Table 6.1]		
2	Return flow factor for computing recharge from irrigation water applied by ground water irrigation in non - command area as a fraction [From Table 6.4]		
3	Recharge from irrigation water applied by ground water irrigation in non - command area in hectare metres [(1) * (2)]		

Format 6.6

Table 6.6 Irrigation Water Applied by Ground Water Irrigation in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for command area) (2)	Quantity (3)
1	Irrigation water applied by ground water irrigation in command area during monsoon season in hectare metres [From Table 3.1]	
2	Irrigation water applied by ground water irrigation in command area during non - monsoon season in hectare metres [From Table 3.1]	

Note : Irrigation water applied by ground water irrigation during a given season is considered to be the same as the gross ground water draft for irrigation during that season

Table 6.7 Water Table Data during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of observation well (All wells are in command area)	Depth to water table below ground level in metres		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon interval	Post - monsoon interval	Pre - monsoon interval
(1)	(2)	(4)	(5)	(6)
1				
2				
3				
For the command area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a) Depth to water table below ground level in command area in metres

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

Format 6.8

Table 6.8 Irrigated Area Under Paddy and Non - paddy Under Ground Water Irrigation in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

<table>
<tr><th rowspan="2">Sl. No.
(1)</th><th rowspan="2">Type of crop
(All crops are in command area and are irrigated by ground water irrigation)
(2)</th><th colspan="2">Irrigated area under ground water irrigation in hectares during</th></tr>
<tr><th>Monsoon season
(3)</th><th>Non - monsoon season
(4)</th></tr>
<tr><td>1</td><td>Paddy</td><td></td><td></td></tr>
<tr><td>2</td><td>Non - paddy
<table>
<tr><th rowspan="2">Sl. No.</th><th rowspan="2">Crop</th><th colspan="2">Irrigated area in hectares</th></tr>
<tr><th>Monsoon season</th><th>Non-monsoon season</th></tr>
<tr><td>1
2
3</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Total for Non - paddy</td><td></td><td></td></tr>
</table></td><td></td><td></td></tr>
</table>

Format 6.9

Table 6.9 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Ground Water Irrigation in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for command area and under ground water irrigation) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigated area under Paddy [From Table 6.8]		
2	Irrigated area under Non - paddy [From Table 6.8]		
3	Range of depth to water table below ground level (< 10 m / 10 - 25 m / > 25 m) [From Table 6.7]		
4	Is return flow factor for Paddy based on results from documented field studies (Yes / No)		
5	Is return flow factor for Non - paddy based on results from documented field studies (Yes / No)		
6	Return flow factor for Paddy as a fraction		
7	Return flow factor for Non - paddy as a fraction		
8	Return flow factor for the command area as a whole $\left[\frac{(6) * (1) + (7) * (2)}{(1) + (2)}\right]$		

Format 6.10

Table 6.10 Recharge from Irrigation Water Applied by Ground Water Irrigation in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigation water applied by ground water irrigation in command area in hectare metres [From Table 6.6]		
2	Return flow factor for computing recharge from irrigation water applied by ground water irrigation in command area as a fraction [From Table 6.9]		
3	Recharge from irrigation water applied by ground water irrigation in command area in hectare metres [(1) * (2)]		

Format 6.11

Table 6.11 Irrigation Water Applied by Ground Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Quantity (3)
1	Irrigation water applied by ground water irrigation in poor ground water quality area during monsoon season in hectare metres [From Table 3.3]	
2	Irrigation water applied by ground water irrigation in poor ground water quality area during non - monsoon season in hectare metres [From Table 3.3]	

Note : Irrigation water applied by ground water irrigation during a given season is considered to be the same as the gross ground water draft for irrigation during that season

Format 6.12

Table 6.12 Water Table Data during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of observation well (All wells are in poor ground water quality area)	Depth to water table below ground level in metres		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon interval	Post - monsoon interval	Pre - monsoon interval
(1)	(2)	(4)	(5)	(6)
1				
2				
3				
For the poor ground water quality area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a) Depth to water table below ground level in poor ground water quality area in metres

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

b) If water table data are not available, the depth to water table below ground level during both monsoon and non-monsoon seasons may be considered to be less than 10 metres below ground level .

Format 6.13

Table 6.13 Irrigated Area Under Paddy and Non - paddy Under Ground Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

<table>
<tr><td rowspan="2">Sl. No.

(1)</td><td rowspan="2">Type of crop
(All crops are in poor ground water quality area and are irrigated by ground water irrigation)

(2)</td><td colspan="2">Irrigated area under ground water irrigation in hectares during</td></tr>
<tr><td>Monsoon season
(3)</td><td>Non - monsoon season
(4)</td></tr>
<tr><td>1</td><td>Paddy</td><td></td><td></td></tr>
<tr><td>2</td><td>Non - paddy
<table>
<tr><td rowspan="2">Sl. No.</td><td rowspan="2">Crop</td><td colspan="2">Irrigated area in hectares</td></tr>
<tr><td>Monsoon season</td><td>Non-monsoon season</td></tr>
<tr><td>1
2
3</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Total for Non - paddy</td><td></td><td></td></tr>
</table></td><td></td><td></td></tr>
</table>

Format 6.14

Table 6.14 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Ground Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for poor ground water quality area and under ground water irrigation) (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigated area under Paddy [From Table 6.13]		
2	Irrigated area under Non - paddy [From Table 6.13]		
3	Range of depth to water table below ground level (< 10 m / 10 - 25 m / > 25 m) [From Table 6.12]		
4	Is return flow factor for Paddy based on results from documented field studies (Yes / No)		
5	Is return flow factor for Non - paddy based on results from documented field studies (Yes / No)		
6	Return flow factor for Paddy as a fraction		
7	Return flow factor for Non - paddy as a fraction		
8	Return flow factor for the poor ground water quality area as a whole $\left[\frac{(6) * (1) + (7) * (2)}{(1) + (2)}\right]$		

Format 6.15

Table 6.15 Recharge from Irrigation Water Applied by Ground Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Monsoon season (3)	Non - monsoon season (4)
1	Irrigation water applied by ground water irrigation in poor ground water quality area in hectare metres [From Table 6.11]		
2	Return flow factor for computing recharge from irrigation water applied by ground water irrigation in poor ground water quality area in hectare metres [From Table 6.14]		
3	Recharge from irrigation water applied by ground water irrigation in poor ground water quality area in hectare metres [(1) * (2)]		

CHAPTER 7

RECHARGE FROM TANKS AND PONDS

7.1 GENERAL

Recharge from tanks and ponds which are to be computed for the monsoon and non-monsoon seasons of the current ground water assessment year are applicable for the following sub-units.

a) Command area
b) Non-command area
c) Poor Ground Water Quality Area

The computation of recharge from tanks and ponds in a given sub-unit and during a given season involves the following steps to be carried out.

a) Estimation of the number of days when water is actually available and the average water spread area during that period

b) Computation of recharge using results from 'a' above

7.2 ASSUMPTIONS

The computation of recharge from tanks and ponds is based in the following assumptions :

a) Recharge in hectare metres from each tank and pond can be obtained as the product of the following parameters

   i) Average area of water spread
   ii) Number of days water is actually available
   iii) A recharge factor of 0.00144 metres per day per hectare

b) The average area of water spread mentioned in 'a' above is obtained as the arithmetic average of water spread areas recorded during different time intervals. However, if such periodic data are not available, the average area of water spread can be taken as 0.6 times the maximum water spread area.

c) The total recharge from tanks and ponds is obtained as the sum of recharge computed for each tank/ pond.

7.3 COMPUTATIONAL PROCEDURE

7.3.1 COMMAND AREA

All tanks and ponds in the command area are identified, and their location details are presented in one table (Table 7.1). The format to be adopted for this table is given in Format 7.1. The computational scheme to be adopted to estimate the recharge from tanks and ponds in the command area during the monsoon and non-monsoon seasons of

the current ground water assessment year comprises of the following steps :

a) The average water spread area in hectares of each tank/ pond and the number of days when water was actually available in each of them during the monsoon and non-monsoon seasons of the current ground water assessment year are obtained. The average water spread area is arrived at either as,

   i) the arithmetic average of water spread areas recorded periodically during the season under consideration, or as,
   ii) 0.6 times the maximum water spread area during the season under consideration, if periodic water spread area data are not available

b) The recharge from each tank/ pond in hectare metres during the monsoon and non-monsoon seasons of the current ground water assessment year are computed as the product of the average water spread area, the number of days water was available and a factor of 0.0014 metres per day.

c) The recharge from tanks and ponds in the command area during the monsoon and non-monsoon seasons of the ground water assessment year are finally obtained as the sum of the recharge from each tank/ pond.

The computations as described above are presented in one table (Table 7.2) . The format to be adopted for this table is given in Format 7.2.

7.3.2 NON-COMMAND AREA

The computational scheme for estimating recharge from tanks and ponds in the non-command area is identical to what has been described earlier in Section 7.3, for the command area . The computations are presented in two tables (Tables 7.3 and 7.4). The formats to be adopted for these two tables are given in Formats 7.3 and 7.4 respectively.

7.3.3 POOR GROUND WATER QUALITY AREA

The computational scheme for estimating recharge from tanks and ponds in the poor ground water quality area is identical to what has been described earlier in Section 7.3, for the command area . The computations are presented in two tables (Tables 7.5 and 7.6). The formats to be adopted for these two tables are given in Formats 7.5 and 7.6 respectively.

Format 7.1

Table 7.1 Location Details of Tanks and Ponds in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Name of tank / pond in command area (2)	Latitude (3)	Longitude (4)	Year of construction (5)
1				
2				
3				

Format 7.2

Table 7.2 Recharge from Tanks and Ponds in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of tank / pond in command area	Average water spread area in hectares during		Number of days water is available during		Recharge in hectare metres during	
		Monsoon season	Non - monsoon season	Monsoon season	Non - monsoon season	Monsoon season $\frac{1.44 * (3) * (5)}{1000}$	Non - monsoon season $\frac{1.44 * (4) * (6)}{1000}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Total recharge from all tanks and ponds in the command area							

Format 7.3

Table 7.3 Location Details of Tanks and Ponds in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Name of tank / pond in non - command area (2)	Latitude (3)	Longitude (4)	Year of construction (5)
1				
2				
3				

Format 7.4

Table 7.4 Recharge from Tanks and Ponds in Non - command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of tank / pond in non - command area	Average water spread area in hectares during		Number of days water is available during		Recharge in hectare metres during	
		Monsoon season	Non - monsoon season	Monsoon season	Non - monsoon season	Monsoon season $\frac{1.44 * (3) * (5)}{1000}$	Non - monsoon season $\frac{1.44 * (4) * (6)}{1000}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Total recharge from all tanks and ponds in the non - command area							

Format 7.5

Table 7.5 Location Details of Tanks and Ponds in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Name of tank / pond in poor ground water quality area (2)	Latitude (3)	Longitude (4)	Year of construction (5)
1				
2				
3				

Format 7.6

Table 7.6 Recharge from Tanks and Ponds in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of tank / pond in poor ground water quality area	Average water spread area in hectares during		Number of days water is available during		Recharge in hectare metres during	
		Monsoon season	Non - monsoon season	Monsoon season	Non - monsoon season	Monsoon season 1.44 * (3) * (5) / 1000	Non - monsoon season 1.44 * (4) * (6) / 1000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Total recharge from all tanks and ponds in poor ground water quality area							

CHAPTER 8

RECHARGE FROM WATER CONSERVATION STRUCTURES

8.1 GENERAL

With increasing focus on sustainable development of ground water resources, all States/ Union Territories have been implementing several water conservation schemes with the aim of increasing ground water recharge. The water conservation structures include percolation tanks, check dams, nulla bunds etc. Recharge from water conservation structures are to be computed during monsoon and non-monsoon seasons of the current ground water assessment year for the following sub-units within each ground water assessment unit :

a) Command area
b) Non-command area
c) Poor ground water quality area

The computations of recharge from water conservation structures in a given sub-unit, and during a given season involves the following steps to be carried out :

a) Computing recharge from each water conservation structure based on gross storage of that structure

b) Obtaining the total recharge as the sum of the recharge from each water conservation structure

8.2 ASSUMPTIONS

The computations of recharge from water conservation structures are based on the following assumptions :

a) Annual recharge in hectare metres from each water conservation structure can be obtained as the product of the following three parameters :

   i) Storage capacity of the structure in hectare metres

   ii) Number of fillings which take place in a ground water year (This can be a fraction greater than zero)

   iii) A factor of 0.5

b) The annual recharge from all water conservation structures is obtained as the sum of the recharge from each structure

d) The annual recharge from all water conservation structures is distributed equally during the monsoon and non-monsoon seasons of a ground water year

8.3 COMPUTATIONAL PROCEDURE

8.3.1 COMMAND AREA

All water conservation structures in the command area are identified, and their location details are presented in one table (Table 8.1). The format to be adopted for this table is given in Format 8.1. The scheme for computing recharge from water conservation structures in the command area during the monsoon and non-monsoon seasons of the current ground water assessment year comprises of the following steps

a) The storage capacity in hectare metres of each water conservation structure and the number of fillings in each of them during the current ground water assessment year are obtained. The gross annual storage in hectare metres of each structures is then obtained as the product of these two values.

b) The annual recharge in hectare metres from each water conservation structure is obtained as 0.5 times the gross annual storage of that structure

c) The annual recharge is hectare metres from all water conservation structures in the command area is obtained as the sum of the recharge from each structure

d) Recharge from water conservation structures in command area during monsoon and non-monsoon seasons are both taken as 0.5 times the annual recharge

The above computations are presented in one table (Table 8.2). The format to be adopted for this table given in Format 8.2.

8.3.2 Non-command Area

The computational scheme to be adopted for estimating the recharge from water conservation structures in the non-command area during monsoon and non-monsoon seasons of the current ground water assessment year is identical to what has been described earlier in Section 8.3.1 for the command area. The computations are presented in two tables (Tables 8.3 and 8.4). The formats to be adopted for these two tables are given in Formats 8.3 and 8.4 respectively.

8.3.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating recharge from water conservation structures in poor ground water quality area during the monsoon and non-monsoon seasons of the current ground water assessment year is identical to what has been described earlier in Section 8.3.1 for the command area. The computations are presented in two tables (Tables 8.5 and 8.6). The formats to be adopted for these two tables are given in Formats 8.5 and 8.6 respectively.

Format 8.1

Table 8.1 Location Details of Water Conservation Structures in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No. (1)	Name of water conservation structure (in command area) (2)	Type (percolation tank / check dam / nulla bund) (3)	Latitude (4)	Longitude (5)	Year of construction (6)
1					
2					
3					

Format 8.2

Table 8.2 Recharge from Water Conservation Structures in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of water conservation structure (in command area)	Storage capacity in hectare metres	Number of fillings during the ground water assessment year	Gross storage in hectare metres [(3) * (4)]	Recharge in hectare metres	
					Monsoon season [0.25 * (5)]	Non - monsoon season [0.25 * (5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Recharge from water conservation structures in command area (Total of recharge from each structure)						

Format 8.3

Table 8.3 Location Details of Water Conservation Structures in Non - command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No. (1)	Name of water conservation structure (in non - command area) (2)	Type (percolation tank / check dam / nulla bund) (3)	Latitude (4)	Longitude (5)	Year of construction (6)
1					
2					
3					

Format 8.4

Table 8.4 Recharge from Water Conservation Structures in Non - command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of Water Conservation Structure (in non - command area)	Storage capacity in hectare metres	Number of fillings during the ground water assessment year	Gross storage in hectare metres [(3) * (4)]	Recharge in hectare metres	
					Monsoon season [0.25 * (5)]	Non - monsoon season [0.25 * (5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Recharge from water conservation structures in non - command area (Total of recharge from each structure)						

Format 8.5

Table 8.5 Location Details of Water Conservation Structures in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No. (1)	Name of water conservation structure (in poor ground water quality area) (2)	Type (percolation tank / check dam / nulla bund) (3)	Latitude (4)	Longitude (5)	Year of construction (6)
1					
2					
3					

Format 8.6

Table 8.6 Recharge from Water Conservation Structures in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of water conservation structure (in poor ground water quality area)	Storage capacity in hectare metres	Number of fillings during the ground water assessment year	Gross storage in hectare metres [(3) * (4)]	Recharge in hectare metres	
					Monsoon season [0.25 * (5)]	Non - monsoon season [0.25 * (5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Recharge from water conservation structures in poor ground water quality area (Total of recharge from each structure)						

CHAPTER 9

RECHARGE FROM OTHER SOURCES

9.1 GENERAL

The sources of ground water recharge other than rainfall are five in number as listed below:

a) Canals
b) Irrigation Water Applied by Surface Water Irrigation
c) Irrigation Water Applied by Ground Water Irrigation
d) Tanks and Ponds
e) Water Conservation Structures

The above five sources are together referred to as **'**Other Sources'. The estimation of recharge from these five sources have been presented in Chapters 4 to 8. Recharge from **'**Other sources' in a given sub-unit is obtained as the sum of the recharge from those sources which are applicable for that sub-unit .

Recharge from 'Other Sources' during the monsoon and non-monsoon seasons of the current ground water assessment year are to be obtained for the following sub-units within each ground water assessment unit.

a) **Command area**
Sources Applicable : All five

b) **Non-command Area**
Sources Applicable : Irrigation Water Applied by Ground Water Irrigation, Tanks & Ponds, and Water Conservation Structures

c) **Poor Ground Water Area**
Sources Applicable : All five

Recharge from 'Other Sources' in the two sub-units of command and non-command area during the monsoon season of the current ground water assessment year will be made use of for computing rainfall recharge by the water table fluctuation method (Chapter 11). The recharge from 'Other Sources' during both monsoon and non-monsoon seasons of the current ground water assessment year for all the three sub-units of command, non-command and poor ground water quality area will be made use of for computing the net annual ground water availability in those three sub-units (Chapter 12).

9.2 PRESENTATION OF RESULTS

The recharge from 'Other Sources' are presented in three tables (Tables 9.1 to 9.3), one table for each sub-unit. The formats to be adopted for these three tables are given in Formats 9.1 to 9.3 respectively.

Format 9.1

Table 9.1 Recharge from 'Other Sources' in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Type of source (2)	Recharge in hectare metres during	
		Monsoon season (3)	Non - monsoon season (4)
1	Recharge from canals [From Table 4.4]		
2	Recharge from irrigation water applied by surface water irrigation [From Table 5.6]		
3	Recharge from irrigation water applied by ground water irrigation [From Table 6.10]		
4	Recharge from tanks and ponds [From Table 7.2]		
5	Recharge from water conservation structures [From Table 8.2]		
Recharge from 'Other Sources' in command area [(1) + (2) + (3) + (4) + (5)]			

a) Annual recharge from 'Other Sources' in command area in hectare metres = [Sum of monsoon and non-monsoon seasons]

Format 9.2

Table 9.2 Recharge from 'Other Sources ` in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Type of source (2)	Recharge in hectare metres during	
		Monsoon season (3)	Non - monsoon season (4)
1	Recharge from irrigation water applied by ground water irrigation [From Table 6.5]		
2	Recharge from tanks and ponds [From Table 7.4]		
3	Recharge from water conservation structures [From Table 8.4]		
	Recharge from 'Other Sources' in non - command area [(1) + (2) + (3)]		

a) Annual Recharge from 'Other Sources' in Non - command area = in hectare metres
[Sum of monsoon and non-monsoon seasons]

Format 9.3

Table 9.3 Recharge from 'Other Sources' in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Type of source (2)	Recharge in hectare metres during	
		Monsoon season (3)	Non - monsoon season (4)
1	Recharge from canals [From Table 4.8]		
2	Recharge from irrigation water applied by surface water irrigation [From Table 5.12]		
3	Recharge from irrigation water applied by ground water irrigation [From Table 6.15]		
4	Recharge from tanks and ponds [From Table 7.6]		
5	Recharge from water conservation structures [From Table 8.6]		
	Recharge from 'Other Sources' in poor ground water quality area [(1) + (2) + (3) + (4) + (5)]		

a) Annual recharge from 'Other Sources' in poor ground water quality area in hectare metres [Sum of monsoon and non-monsoon seasons] =

CHAPTER 10

RAINFALL RECHARGE BY RAINFALL INFILTRATION FACTOR METHOD

10.1 GENERAL

Recharge from sources other than rainfall, all of them together referred to as, 'Other Sources' have been presented in Chapters 4 to 9. Recharge from 'Other Sources' are to a large extent the result of human interventions, and hence they are computed with reference to the current ground water assessment year. Rainfall is however, a natural phenomenon showing considerable variations from year to year. The 'Normal Rainfall', obtained as the average rainfall over a sufficiently long number of ground water years will be therefore the most appropriate basis for computing rainfall recharge.

The following two methods can be employed for computing rainfall recharge :

a) Rainfall infiltration factor method

b) Water table fluctuation method

The rainfall infiltration factor method alone needs to be employed in each ground water assessment unit for the following cases :

a) command and non-command areas during non-monsoon season
b) poor ground water quality area during both monsoon and non-monsoon seasons.

The water table fluctuation method is to be as far as possible employed in each ground water assessment unit for the remaining cases mentioned below:

a) command area during monsoon season
b) non-command area during monsoon season

Even in the above two cases where the recommended method to be employed is the water table fluctuation method, it is necessary to compute the rainfall recharge by the rainfall infiltration factor method also, because of one or other of the following reasons :

a) Adequate data on depth to water table during pre-monsoon and post-monsoon intervals of a ground water year may not be available as a result of which the water table fluctuation method cannot be employed, and only the rainfall infiltration factor method has to be made use of.

b) The computed rainfall recharge values corresponding to different monsoon season rainfall values through the use of the water balance approach in the water table fluctuation method may be such that all of them are consistently negative or nearly zero. In such a situation, the water table fluctuation method has to be dispensed with, and instead the rainfall infiltration factor method will have to be used. This point will be elaborated in the next chapter.

c) The rainfall recharge as computed by the water table fluctuation method has to be any way compared with that computed by the rainfall infiltration factor method, and finally the rainfall recharge during monsoon season will have to be assigned a value on the basis of a set of criteria so as to avoid unreasonably high or low estimates. This point will be elaborated in the next chapter.

This chapter is concerned with computing rainfall recharge by the rainfall infiltration factor method. The water table fluctuation method will be dealt with in the next chapter.

The computational procedure for estimating rainfall recharge by the rainfall infiltration factor method for the three sub-units of command, non-command and poor groundwater quality areas during the monsoon as well as non-monsoon seasons essentially comprises of the following steps :

a) Estimating the normal monsoon and the normal non-monsoon season rainfall applicable for the three sub-units

b) Assigning a rainfall infiltration factor for the three sub-units

c) Computing the rainfall recharge during monsoon as well as non-monsoon seasons for the three sub-units using results from 'a' and 'b' above

10.2 ASSUMPTIONS

The estimation of rainfall recharge by the rainfall infiltration factor method is based on the following assumptions :

a) The rainfall recharge in a given sub-unit during a given season is considered to be a linear function of only the quantum of rainfall during that season. The distribution of rainfall within the season is therefore ignored.

b) The rainfall recharge during the non-monsoon season is considered to be nil if the normal non-monsoon season rainfall is less than or equal 10% of the normal annual rainfall, and is calculated only if that percentage value is greater than 10.

c) Rainfall recharge in hectare metres can be computed as the product of the following three parameters :

   i) Rainfall infiltration factor as a fraction applicable for the sub-unit under consideration

ii) Quantum of normal rainfall in metres applicable for the sub-unit and season under consideration

iii) Area of the sub-unit under consideration in hectares

d) The rainfall infiltration factor for the given sub-unit depends only on the following factors

i) type of terrain (alluvial/ hardrock)

ii) in the case of alluvial terrain, the geographic location (Indo-gangetic plains and inland areas/ east coast/ west coast)

iii) in the case of hardrock terrain, the rock type.

Other factors like geomorphology, vegetal cover, antecedent moisture status etc., (which may be equally important) have been ignored primarily because of the following reasons :

i) the variation of rainfall infiltration factor in quantitative terms with variation in these factors are not widely available

ii) the specification of norms for assigning rainfall infiltration factors (discussed in the next item) has to be as far as possible simple without sacrificing important considerations

e) The rainfall recharge factor mentioned in 'd' above is to be the assigned a value on the basis of norms given in Appendix 8.1. The recommended value given in the norms should be alone made use of unless, results from documented field studies indicate that a different value can be used. In the latter case also, the rainfall infiltration factor assigned should be within the range of the maximum and the minimum values as specified in the norms.

10.3 COMPUTATIONAL PROCEDURE

10.3.1 Command Area

10.3.1.1 Normal Rainfall

Each state/union Territory has a number of rain gauges for each of which normal monsoon and non-monsoon season rainfall values are available. All such rain gauges are assigned a unique name. Each such rain gauge also has a certain area of influence over which the rainfall as recorded in that rain gauge can be assumed to be uniformly applicable. Those rain gauges which fulfil the condition that, a portion of their respective area of influence fall within the command area under consideration are first identified. The normal rainfall data pertaining to these identified rain gauges form the basis for estimating the normal monsoon and non-monsoon season rainfall applicable for the command area under consideration.

Location details and availability of rainfall data in respect of all the rain gauges which are to be considered for the command area are presented in one table (Table 10.1). The format to be adopted for this table is given in Format 10.1. The computations for estimating the normal monsoon and normal non-monsoon season rainfall as applicable for the command area under consideration are presented in one table (Table 10.2). The format to be adopted for this table is given in Format 10.2.

10.3.1.2 Rainfall Infiltration Factor

The procedure followed for assigning the value for the rainfall infiltration factor applicable for the command area is presented in one table (Table 10.3). The format to be adopted for this table is given in Format 10.3.

10.3.1.3 Rainfall Recharge

The computations of rainfall recharge by the rainfall infiltration factor method for the command area during monsoon and non-monsoon seasons are presented in one table(Table 10.4). The format to be adopted for this table is given in Format 10.4.

The rainfall recharge for the command area during non-monsoon season is taken as the same value computed by the rainfall infiltration factor method. If water table fluctuation method is not to be employed for computing rainfall recharge during monsoon season for the command area, its value is taken as the same value obtained by the rainfall infiltration factor method. Otherwise, the computations for the water table fluctuation method have to be carried out. This is described in the next chapter.

10.3.2 Non-command Area.

The computational procedure for obtaining rainfall recharge during monsoon and non-monsoon seasons by the rainfall infiltration factor method for the non-command area is identical to that described earlier in Section 10.3.1 for the command area. The necessary computations are presented in four tables (Tables 10.5 to 10.8). The formats to be adopted for these four tables are given in Formats 10.5 to 10.8 respectively.

10.3.3 Poor Groundwater Quality Area

The computational procedure of obtaining rainfall recharge during monsoon and non-monsoon seasons by the rainfall infiltration factor method for the poor groundwater quality area is also identical to that described earlier in Section 10.3.1 for the command

area. The necessary computations are presented in four tables (Tables 10.9 to 10.12). The formats to be adopted for these four tables are given in Formats 10.9 to 10.12. respectively.

10.4 SUMMARY OF RAINFALL RECHARGE

The rainfall infiltration factor method alone is to be employed during both non-monsoon and monsoon seasons in the case of the poor ground water quality area. Hence, the estimates of rainfall recharge in the poor groundwater quality area during the monsoon and non-monsoon seasons are taken as the corresponding values obtained by the rainfall infiltration factor method. A summary of recharge from rainfall for this sub-unit is given in one table (Table 10.13). The format to be adopted for this table is given in Format 10.13.

The preferred method for computing recharge from rainfall during monsoon season for the other two sub-units namely, command and non-command areas is the water table fluctuation method which will be covered in the next chapter. The summary of recharge from rainfall for these two sub-units will be presented at the end of the next chapter.

Format 10.1

Table 10.1 Location Details and Availability of Rainfall Data for All Rain Gauges Applicable for the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Rain gauges applicable for the command area					
	Location details			Availability of rainfall data on the basis of which normal rainfall for the rain gauge has been computed		
	Name of rain gauge	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Format 10.2

Table 10.2 Normal Rainfall During Monsoon and Non - monsoon Seasons in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Names of rain gauges applicable for command area	Normal rainfall in mm as obtained for the rain gauge during	
		Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1			
2			
3			
Average of all rain gauges considered			

a) Normal monsoon season rainfall in mm for the command area [average value in Col. (3)] =

b) Normal non - monsoon season rainfall in mm for the command area [average value in Col. (4)] =

c) Annual normal rainfall in mm for the command area [(a) + (b)] =

d) Normal non - monsoon season rainfall as a percentage of annual normal rainfall for the command area [((b) / (c)) * 100] =

Format 10.3

Table 10.3 Rainfall Infiltration Factor in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of Items (in command area)	Quantity
1	Type of predominant terrain (Alluvial / Hardrock)	
2	If terrain is 'Alluvial', the geographic location (Indo - Gangetic and Inland Areas / East Coast / West Coast)	
3	If terrain is 'Hardrock', the rock type (from list given in Appendix 10.1)	
4	Are watershed development programmes with associated soil and water conservation measures carried out in the sub - unit (Yes / No)	
5	Are results from documented field studies available for rainfall infiltration factor in the sub - unit (Yes/ No)	
6	If response to (5) above is 'Yes', a) Rainfall infiltration factor from field studies as a fraction b) Is the value given in '6a' above less than the minimum or greater than the maximum as specified in the norms given in Appendix 10.1 (Yes / No)	
7	Rainfall Infiltration Factor in 'Command Area'	

Format 10.4

Table 10.4 Rainfall Recharge in Command Area By Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (for command area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Normal rainfall during a) Monsoon season in mm b) Non - monsoon season in mm c) Is non - monsoon season rainfall as a percentage of normal annual rainfall greater than 10 percent (Yes / No) [From Table 10.2]	
3	Rainfall infiltration factor as a fraction [From Table 10.3]	
4	Rainfall recharge in command area by rainfall infiltration factor method in hectare metres during a) Monsoon season [(1) * (2a) * (3)] b) Non - monsoon season [= 0 if (2c) is 'No' = (1) * (2b) * (3) if (2c) is 'Yes']	

Format 10.5

Table 10.5 Location Details and Availability of Rainfall Data for All Rain Gauges Applicable for the Non - command Area

Name of Ground Water Assessment Unit :

Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Rain gauges applicable for the non - command area					
	Location details			Availability of rainfall data on the basis of which normal rainfall for the rain gauge has been computed		
	Name of rain gauge	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Format 10.6

Table 10.6 Normal Rainfall During Monsoon and Non - monsoon Seasons in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Names of rain gauges applicable for non - command area	Normal rainfall in mm as obtained for the rain gauge during	
		Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1			
2			
3			
Average of all rain gauges considered			

a) Normal monsoon season rainfall in mm for the non - command area [average value in Col. (3)] =

b) Normal non - monsoon season rainfall in mm for the non - command area [average value in Col. (4)] =

c) Annual normal rainfall in mm for the non - command area [(a) + (b)] =

d) Normal non - monsoon season rainfall as a percentage of annual normal rainfall for the non - command area [((b) / (c)) * 100] =

Format 10.7

Table 10.7 Rainfall Infiltration Factor in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of items (in non - command area)	Quantity
1	Type of predominant terrain (Alluvial / Hardrock)	
2	If terrain is 'Alluvial', the geographic location (Indo - Gangetic and Inland Areas / East Coast / West Coast)	
3	If terrain is 'Hardrock', the rock type (from list given in Appendix 10.1)	
4	Are watershed development programmes with associated soil and water conservation measures carried out in the sub - unit (Yes / No)	
5	Are results from documented field studies available for rainfall infiltration factor in the sub - unit (Yes/ No)	
6	If response to (5) above is 'Yes',	
	a) Rainfall infiltration factor from field studies as a fraction	
	b) Is the value given in '6a' above less than the minimum or greater than the maximum as specified in the norms given in Appendix 10.1 (Yes / No)	
7	Rainfall Infiltration Factor in 'Non - command Area'	

Format 10.8

Table 10.8 Rainfall Recharge in Non - command Area By Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (in non - command area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Normal rainfall during a) Monsoon season in mm b) Non - monsoon season in mm c) Is non - monsoon season rainfall as a percentage of normal annual rainfall greater than 10 percent (Yes / No) [From Table 10.6]	
3	Rainfall infiltration factor as a fraction [From Table 10.7]	
4	Rainfall recharge in non - command area by rainfall infiltration factor method in hectare metres during a) Monsoon season [(1) * (2a) * (3)] b) Non - monsoon season [= 0 if (2c) is 'No' = (1) * (2b) * (3) if (2c) is 'Yes']	

Format 10.9

Table 10.9 Location Details and Availability of Rainfall Data for All Rain Gauges Applicable for the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Rain gauges applicable for the poor ground water quality area					
	Location details			Availability of rainfall data on the basis of which normal rainfall for the rain gauge has been computed		
	Name of rain gauge	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Format 10.10

Table 10.10 Normal Rainfall During Monsoon and Non - monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Names of rain gauges applicable for poor ground water quality area	Normal rainfall in mm as obtained for the rain gauge during	
		Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1			
2			
3			
Average of all rain gauges considered			

a) Normal monsoon season rainfall in mm for the poor ground water quality area [average value in Col. (3)] =

b) Normal non - monsoon season rainfall in mm for the poor ground water quality area [average value in Col. (4)] =

c) Annual normal rainfall in mm for the poor ground water quality area [(a) + (b)] =

d) Normal non - monsoon season rainfall as a percentage of annual normal rainfall for the poor ground water quality area [((b) / (c)) * 100] =

Format 10.11

Table 10.11 Rainfall Infiltration Factor In Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of items (in poor ground water quality area)	Quantity
1	Type of predominant terrain (Alluvial / Hardrock)	
2	If terrain is 'Alluvial', the geographic location (Indo - Gangetic and Inland Areas / East Coast / West Coast)	
3	If terrain is 'Hardrock', the rock type (from list given in Appendix 10.1)	
4	Are watershed development programmes with associated soil and water conservation measures carried out in the sub - unit (Yes / No)	
5	Are results from documented field studies available for rainfall infiltration factor in the sub - unit (Yes/ No)	
6	If response to (5) above is 'Yes', a) Rainfall infiltration factor from field studies as a fraction b) Is the value given in 'a' above less than the minimum or greater than the maximum as specified in the norms given in Appendix 10.1 (Yes / No)	
7	Rainfall Infiltration Factor in 'Poor Ground Water Quality Area'	

Format 10.12

Table 10.12 Rainfall Recharge in Poor Ground Water Quality Area By Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (in poor ground water quality area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Normal rainfall during a) Monsoon season in mm b) Non - monsoon season in mm c) Is non - monsoon season rainfall as a percentage of normal annual rainfall greater than 10 percent (Yes / No) [From Table 10.10]	
3	Rainfall infiltration factor as a fraction [From Table 10.11]	
4	Rainfall recharge in poor ground water quality area by rainfall infiltration factor method in hectare metres during a) Monsoon season [(1) * (2a) * (3)] b) Non - monsoon season [= 0 if (2c) is 'No' = (1) * (2b) * (3) if (2c) is 'Yes']	

Format 10.13

Table 10.13 Summary of Recharge from Rainfall in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (in poor ground water quality area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Recharge from rainfall during monsoon season (By rainfall infiltration factor method)	
	a) in hectare metres [From Table 10.12]	
	b) per unit area in mm [(2a) / (1)]	
3	Recharge from rainfall during non - monsoon season (By rainfall infiltration factor method)	
	a) in hectare metres [From Table 10.12]	
	b) per unit area in mm [(3a) / (1)]	
4	Annual recharge from rainfall in poor ground water quality area	
	a) in hectare metres [(2a) + (3a)]	
	b) per unit area in mm [(2b) + (3b)]	

CHAPTER 11

RAINFALL RECHARGE BY WATER TABLE FLUCTUATION METHOD

11.1 GENERAL

The water table fluctuation method is to be employed for computing rainfall recharge only for the monsoon season, and that too only in the two sub-units of command and non-command areas within a ground water assessment unit.

The water table fluctuation method is based on a water balance approach in which of all the components in the water balance equation, the only component which is considered to be unknown is the rainfall recharge. Another major component (which is known) in the water balance equation is the change in ground water storage during the monsoon season. The estimation of this particular component requires the use of the water table fluctuation during the monsoon season. It is for this reason that, the method has always been some how referred to as the water table fluctuation method. A more appropriate name for the method could however, have been, 'Rainfall Recharge by Ground Water Balance Method'.

The computational procedure in the application of the water table fluctuation method for estimating rainfall recharge during the monsoon season in the command area and non-command areas involves the following steps to be carried out :

a) Computing the monsoon season rainfall during the current ground water assessment year as applicable to the sub-unit.

b) Computing the water table fluctuation during the monsoon season of the current ground water assessment year as applicable to the sub-unit.

c) Assigning the specific yield value applicable for the sub-unit.

d) Application of water balance to compute the rainfall recharge during monsoon season of the current ground water assessment year, i.e., corresponding to the monsoon season rainfall of the current ground water assessment year.

e) Application of a normalisation procedure to compute the rainfall recharge during monsoon season corresponding to the normal monsoon season rainfall applicable for the sub-unit.

f) Compare the estimate of rainfall recharge corresponding to normal monsoon seasons rainfall as obtained in 'e' above with estimate of rainfall recharge

obtained by the rainfall infiltration factor method, and finally based on a set of criteria estimate the rainfall recharge during monsoon season in both command and non-command areas of the ground water assessment unit. This is done to avoid unreasonably high or low estimates of rainfall recharge.

11.2 ASSUMPTIONS

a) The water balance approach followed in the method is essentially a lumped parameter approach. Hence, the spatial variations of individual components in the water balance equation are not considered, and only a single lumped value of each component for the sub-unit (command/ non-command) as a whole is considered.

b) Some natural net output components in the water balance equation namely, baseflow, flow across the boundaries of the sub-unit, and evaporation from the groundwater reservoir within the sub-unit under consideration are all mostly very difficult to estimate, and are therefore ignored. The implication of this assumption is that, the recharge value computed is not that which is exclusively due to rainfall, but that which is due to a combined effect of rainfall as well as all other factors which have been ignored.

c) The specific yield of a particular sub-unit (command/non-command) is to be assigned a value on the basis of the set of norms given in Appendix 11.1. The recommended value specified in the norms alone are to be used, unless results from pump tests (each being of duration not less than 24 hours) indicate that, a different value can be used. In the latter case also, the specific yield which is assigned should be within the range of the maximum and minimum values as specified in the norms. These norms also assume that the specific yield depends only on the following factors

   i) Type of terrain (alluvial/ hardrock)
   ii) In the case of alluvial terrain, the type of alluvium (sandy/ silty/ clayey)
   iii) In the case of hardrock, the rock type.

   However, it is also recommended that, an alternative approach called the 'Dry Season Ground Water Balance Method' should be attempted for assigning the specific yield value. The dry season refers to that portion of the non-monsoon season in which the rainfall is practically nil. Usually only three components in the ground water balance equation namely, gross ground water draft, return flow from ground water irrigation and change in ground water storage can be estimated reliably. Hence, the dry season ground water balance method will give reliable estimates of specific yield only when these three components are significant and all other components in the water balance equation are practically nil. Consequently it is recommended that, the dry season ground water balance method is to be employed only for the sub-units of non-command area characterised predominantly by hardrock terrain where the above requirement is normally fulfilled. The specific yield value so obtained will override the specified norms.

d) The rainfall recharge is considered as a linear function of rainfall while carrying out the normalisation procedure for estimating the rainfall recharge

during monsoon season corresponding to the normal monsoon season rainfall as applicable to the sub-unit.

11.3 COMPUTATIONAL PROCEDURE

11.3.1 Command Area

11.3.1.1 Monsoon Season Rainfall

The computation of monsoon season rainfall for the current ground water assessment year as applicable to the command area is presented in one table (Table 11.1). The format to be adopted for this table is given in Format 11.1.

11.3.1.2 Water Table Fluctuation

The computations of water table fluctuation during the monsoon season of the current ground water assessment year as applicable to the command area is presented in one table (Table 11.2). The format to be adopted for this table is given in Format 11.2.

11.3.1.3 Specific Yield

The procedure followed for assigning a value for the specific yield as applicable for the command area is presented in one table (Table 11.3). The format to be adopted for this table is given in Format 11.3.

11.3.1.4 Ground Water Balance

The computations of rainfall recharge during monsoon season of the current ground water assessment year for the command area through the use of ground water balance equation is presented in one table (Table 11.4). The format to be adopted for this table is given in Format 11.4.

11.3.1.5 Normalisation Procedure

The rainfall recharge computed through the water balance approach as described in the previous section corresponds to the monsoon season rainfall of the current ground water assessment year. Similar computations made earlier for other previous ground water assessment years will have given estimates of rainfall recharge corresponding to the monsoon season rainfall of those respective ground water assessment years. All of them together result in a set of ordered pairs of data on monsoon season rainfall and their associated rainfall recharge. Each time a ground water assessment is made, one pair of data on monsoon season rainfall and its associated recharge gets added to this

set. Such a set of data for the command area is presented in one table (Table 11.5). The format to be adopted for this table is given in Format 11.5.

The normalisation procedure is one in which the set of ordered pairs of data as contained in Table 11.5 are used to estimate the rainfall recharge during monsoon season for the command area corresponding to the normal monsoon season rainfall applicable to it. The rainfall recharge thus estimated after carrying out the normalisation procedure is referred to as the rainfall recharge in the command area during monsoon season by the water table fluctuation method. The following scheme can be followed to carry out the normalisation procedure:

a) If the set of ordered pairs of data as contained in Table 11.5 are such that all the rainfall recharge values are negative or nearly zero, the water table fluctuation method is dispensed with, and the rainfall recharge in the command area during monsoon season is adopted as the one obtained by the rainfall infiltration factor method.

b) From among the set of ordered pairs of data as contained in Table 11.5, all those pairs in which the rainfall recharge values are negative or nearly zero are eliminated, and only the remaining pairs of data are used for further computations in the normalisation procedure. The set of all such ordered pairs of data are presented in one table (Table 11.6). The format to be adopted for this table is given in Format 11.6.

   Table 11.6 also has information on the deviation of each monsoon season rainfall (for which the recharge has been computed) from the normal monsoon season rainfall as a percentage of the latter. A monsoon season rainfall is normal if the deviation as defined above is between +20% and -20%. However, if the deviation is less than -20%, the associated monsoon season rainfall is below normal, and if deviation is greater than +20%, the associated monsoon season rainfall is above normal. It is ideal that the set of ordered pairs of data as given in Table 11.6 contain some monsoon season rainfall values which are above normal, and some others which are below normal. This will ensure that, the normalisation procedure (which is some form of interpolation) is more accurate.

   In this set of all such ordered pairs of data, let ‘r(i)’ be the monsoon season rainfall and ‘R(i)’ be the associated rainfall recharge. Let the total number of ordered pairs of data in Table 11.6 be ‘N’. Two methods can be followed for the normalisation procedure.

c) The first method which is relatively more simple allows rainfall recharge for normal monsoon season rainfall to be obtained directly from each pair of rainfall and recharge data. This method can be therefore followed even if only one ordered pair of rainfall and recharge data is available. If more than one pair of data are available, the rainfall recharge corresponding to normal

monsoon season rainfall can be calculated for each pair, and an average of those values can be then obtained. The computational procedure followed in this method is presented in one table (Table 11.7). The format to be adopted for this table is given in Format 11.7.

d) The second method is also simple, except that, it involves a little more formal application of linear regression analysis. Though this method can be theoretically applied even if the number of ordered pairs of data, 'N' as contained in Table 11.6, is only two, it is recommended that, this method should be made use of only if 'N' is greater than or equal to 5. The linear regression analysis makes use of the pairs of data on monsoon season rainfall, r(i) and its associated rainfall recharge R(i). In order to avoid handling numbers with large magnitude, the rainfall, r(i) is expressed in metres (with accuracy of 2 decimal places), and the recharge, R(i) is expressed in thousand hectare metres (with accuracy of 2 decimal places). The computational procedure followed in this method is presented in one table (Table 11.8). The format to be adopted for this table is given in Format 11.8.

11.3.1.6 Rainfall Recharge

The water table fluctuation method as described above may yield rainfall recharge estimates which are either unreasonably high or unreasonably low. This is taken care of by:

a) first computing a term PD which is the difference between the rainfall recharge by the water table fluctuation method and that by the rainfall infiltration factor method expressed as a percentage of the latter, and

b) finally assigning a value for the rainfall recharge during monsoon season in the command area on the basis of a set of criteria which depends on the computed value of PD.

The set of criteria to be adopted in the above scheme is,

a) if PD is greater than or equal to -20%, and less than of equal to +20%, the rainfall recharge is taken as that obtained by the water table fluctuation method.

b) if PD is less than -20%, the rainfall recharge is taken as equal to 0.8 times the value obtained by the rainfall infiltration factor method.

c) if PD is greater than +20%, the rainfall recharge is taken as equal to 1.2 times the value obtained by the rainfall infiltration factor method.

The computational procedure for this is presented in one table (Table 11.9). The format to be adopted for this table is given in Format 11.9.

11.3.2 Non-command Area

The computational procedure for obtaining the rainfall recharge during monsoon season in the non-command area is almost identical to that described earlier in Section

11.3.1 for the command area. The only major difference is that while assigning a value for specific yield applicable for the non-command area characterised by hardrock terrain, the dry season ground water balance method should also be attempted wherever possible. The necessary computations of rainfall recharge by the water table fluctuation method for the non-command area are to be presented in nine tables (Tables 11.10 to 11.18). The formats to be adopted for these nine tables are given in Formats 11.10 to 11.18 respectively.

11.3.2.1 Dry Season Ground Water Balance Method

A convenient computational scheme for the estimation of the specific yield by the dry season ground water balance method comprises of the following steps

a) The values for the following variables are obtained

N_1 = The number of calendar months during the non-monsoon season

$N_1 = 8$ when predominant monsoon is 'South-west'.

$N_1 = 9$ when predominant monsoon is 'North-east''

N_2 = The number of calendar months during the dry season

It is recommended that, N_2 is taken as 5 (between January and May), when the predominant monsoon is 'South-west', and N_2 is taken as 3 (between March and May), when the predominant monsoon is 'North-east'.

B_1 = Gross ground water draft for 'All Uses' in hectare metres during the non-monsoon season (Chapter 3)

B_2 = Gross ground water draft for 'All Uses' in hectare metres during the dry season.

B_2 is obtained as,

$$B_2 = B_1 * (N_2 / N_1)$$

C_1 = Recharge from irrigation water applied by ground water irrigation in hectare metres during the non-monsoon season (Chapter 6)

C_2 = Recharge from irrigation water applied by ground water irrigation in hectare metres during the dry season.

C_2 is obtained as,

$$C_2 = (C_1 * (N_2 / N_1)$$

D_2 = Base flow in hectare metres during dry season

D_2 is obtained by actual measurement of base flow. However, D_2 can be mostly assumed as zero since the streams in hardrock terrain will also mostly go dry during the dry season

Z_2 = Fall in water table in metres during the dry season.

Z_2 is obtained using the water table data from observation wells in which, in addition to the pre-monsoon and post-monsoon intervals, water table data is also available at the beginning and end of the dry season.

A_2 = Area in hectares of the sub-unit

b) The ground water balance during the dry season can be expressed as,

$$D_2 + B_2 - C_2 = Z_2 * A_2 * S_y$$

Where, S_y is the required specific yield as a fraction, and other terms are as defined in 'a' above.

c) The specific yield, S_y as a fraction by the dry season ground water balance method can be computed from the water balance equation in 'b' above as,

$$S_y = (D_2 + B_2 - C_2) / (A_2 * Z_2)$$

The computations for estimating the specific yield in the non-command area characterised by hardrock terrain by the dry season ground water balance method as described above is presented in one table (Table 11.12a). The format to be adopted for this table is given in Format 11.12a.

11.4 SUMMARY OF RAINFALL RECHARGE

A summary of recharge from rainfall for the case of poor ground water quality area (for which the rainfall infiltration factor method alone is made use of to compute rainfall recharge during both monsoon and non-monsoon seasons) has been covered earlier in chapter 10. Based on the results obtained in Chapters 10 and 11, a summary of all required rainfall recharge components in the other two sub-units namely, command and non-command areas are presented in two tables (Tables 11.19 and 11.20), one for each sub-unit. The formats to be adopted for these two tables are given in Formats 11.19 and 11.20 respectively.

Format 11.1

Table 11.1 Rainfall During Monsoon Season of the Current Ground Water Assessment Year in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Rain gauges applicable for command area	
	Name	Rainfall during monsoon season of current ground water assessment year as recorded in the rain gauge
(1)	(2)	(3)
1		
2		
3		
Monsoon season rainfall in mm during current ground water assessment year in command area (average of all rain gauges considered)		

Format 11.2

Table 11.2 Water Table Fluctuation During Monsoon Season of Current Ground Water Assessment Year in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Observation wells in command area		
	Name	Depth to water table below ground level in metres in the observation well as recorded in current ground water assessment year	
		Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)
1			
2			
3			
Average of all wells considered		y_1 =	y_2 =

a) Water table fluctuation in metres during monsoon season of the current ground water assessment year in command area = $[y_1 - y_2]$

Format 11.3

Table 11.3 Specific Yield in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of items (for command area) (2)	Quantity (3)
1	Type of terrain (Alluvial / Hardrock)	
2	If terrain is 'Alluvial' , the soil type (Sandy / Silty / Clayey)	
3	If terrain is 'Hardrock', the rock type (From list in Appendix 11.1)	
4	Are results of specific yield available from pump tests (Yes / No)	
5	If (4) is 'Yes', a) Specific yield from pump tests as a fraction b) Is the value in '5a' less than the minimum or greater than the maximum as specified in Appendix 11.1 (Yes / No)	
6	Specific Yield in Command Area as a Fraction	

Format 11.4

Table 11.4 Ground Water Balance Computations During Monsoon Season of Current Ground Water Assessment Year In Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of items (for command area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Recharge from 'Other Sources' in hectare metres during monsoon season [From Table 9.1]	
3	Gross ground water draft in hectare metres for 'All Uses' during monsoon season [From Table 3.1]	
4	Water table fluctuation in metres during monsoon season [From Table 11.2]	
5	Specific yield as a fraction [From Table 11.3]	
6	Change in ground water storage in hectare metres during monsoon season [(1) * (4) * (5)]	
7	Rainfall recharge in hectare metres during monsoon season in command area by ground water balance approach [(6) + (3) - (2)]	
8	Rainfall in mm during monsoon season in command area for which the rainfall recharge in (7) above corresponds to [From Table 11.1]	

Format 11.5

Table 11.5 Complete Set of Data on Monsoon Season Rainfall And Corresponding Rainfall Recharge in Command Area As obtained by Ground Water Balance Approach

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	[From Table 11.4 of this Ground Water Assessment Report and Table 11.5 of the Previous Assessment Report]		
	Ground water year	Monsoon season rainfall in millimetres	Rainfall recharge during monsoon season in hectare metres
(1)	(2)	(3)	(4)
1			
2			
3			

Note : The last pair of data on monsoon season rainfall and its corresponding rainfall recharge as given above is for the current ground water assessment year

Format 11.6

Table 11.6 Valid Set of Data on Monsoon Season Rainfall And Corresponding Rainfall Recharge in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Normal Monsoon Season Rainfall in Command Area in mm, 'NMR' =
[From Table 10.2]

Sl. No.	[From Table 11.5]			Deviation of monsoon season rainfall from normal monsoon season rainfall value as a percentage (3) - 'NMR' [(——————) * 100] 'NMR'
	Ground water year	Monsoon season rainfall in mm	Rainfall recharge during in hectare metres	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				

Note : Only those ground water years in Table 11.5 are considered for which rainfall recharge values during monsoon season are neither negative nor nearly zero

Format 11.7

Table 11.7 Rainfall Recharge During Monsoon Season in Command Area By Water Table Fluctuation Method (Using Normalisation Procedure No.1)

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Normal Monsoon Season Rainfall in Command Area in mm, 'NMR' =
[From Table 10.2]

Sl. No.	[From Table 11.6]		Recharge corresponding to normal monsoon season rainfall in hectare metres
	Rainfall during monsoon season in mm	Corresponding rainfall recharge in hectare metres	[('NMR' * (3)) / (2)]
(1)	(2)	(3)	(4)
1			
2			
3			
Rainfall recharge during monsoon season in hectare metres in command area by 'Water Table Fluctuation Method' [Average of recharge values in Col. (4)]			

Note : This normalisation procedure assumes that the relation between recharge, 'y' and rainfall, 'x' is of the form, y = a * x where 'a' is a constant.

Format 11.8

Table 11.8 Rainfall Recharge During Monsoon Season in Command Area By Water Table Fluctuation Method (Using Normalisation Procedure No.2 which Employs Linear Regression Analysis)

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Normal Monsoon Season Rainfall in Command Area in metres, 'NMR' =
[From Table 10.2]

Sl. No. (i)	[From Table 11.6]		$(x(i))^2$	x(i) * y(i)
	Rainfall during monsoon season in metres x(i)	Corresponding recharge in thousand hectare metres y(i)		
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total	S_1 =	S_2 =	S_3 =	S_4 =

Number of pairs of data considered , 'N' =

A) Regression Constants 'a' and 'b' in y = a * x + b

$$a = \left[\left(\frac{(N * S_4) - (S_1 * S_2)}{(N * S_3) - S_1^2} \right) \right] = \qquad b = \left[\left(\frac{S_2 - (a * S_1)}{N} \right) \right] =$$

B) Rainfall recharge during monsoon season in hectare metres = in command area by 'Water Table Fluctuation Method'
[(a * 'NMR' + b) * 1000]

Format 11.9

Table 11.9 Rainfall Recharge During Monsoon Season in Command Area After Comparing Results From Water Table Fluctuation Method and Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of item (in command area)	Quantity
1	Is the water table fluctuation method used for computing rainfall recharge during monsoon season (Yes/No)	
2	If response to (1) is 'NO' * Rainfall recharge during monsoon season in hectare metres in command area (Same as by rainfall infiltration factor method) [From Table 10.4]	
3	If response to (1) is 'YES' * Rainfall recharge during monsoon season in hectare metres in command area a) By Water Table Fluctuation Method [From Table 11.7 or 11.8] b) By Rainfall Infiltration Factor Method [From Table 10.4] * Difference between (3a) and (3b) expressed as a percentage of (3b), 'PD' $\left[\frac{((3a) - (3b))}{(3b)} * 100\right]$ * Rainfall recharge during monsoon season in hectare metres in command area [= (3a) if 'PD' is between - 20 and + 20% = 0.8 * (3b) if 'PD' is less than - 20% = 1.2 * (3b) if 'PD' is greater than + 20%]	

Format 11.10

Table 11.10 Rainfall During Monsoon Season of the Current Ground Water Assessment Year in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Rain gauges applicable for non - command area	
	Name	Rainfall during monsoon season of current ground water assessment year as recorded in the rain gauge
(1)	(2)	(3)
1		
2		
3		
Monsoon season rainfall in mm during current ground water assessment year in non - command area (average of all rain gauges considered)		

Format 11.11

Table 11.11 Water Table Fluctuation During Monsoon Season of Current Ground Water Assessment Year in Non - Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Observation wells in non -command area		
	Name	Depth to water table below ground level in in metres in the observation well as recorded in current ground water assessment year	
		Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)
1			
2			
3			
Average of all wells considered		y_1 =	y_2 =

a) Water table fluctuation in metres during monsoon season = of the current ground water assessment year in non - command Area
[y_1 - y_2]

Format 11.12

Table 11.12 Specific Yield in Non - Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of items (for non - command area) (2)	Quantity (3)
1	Type of terrain (Alluvial / Hardrock)]	
2	If terrain is 'Alluvial' , the soil type (Sandy / Silty / Clayey)	
3	If terrain is 'Hardrock', the rock type (From list in Appendix 11.1)	
4	Are results of specific yield available from pump tests (Yes / No)	
5	If (4) is 'Yes', a) Specific yield from pump tests as a fraction b) Is the value in '5a' less than the minimum or greater than the maximum as specified in Appendix 11.1 (Yes / No)	
6	Is the 'Dry Season Ground Balance Method' used for computing specific yield value (Yes / No)	
7	If (6) is 'Yes', Specific yield as a fraction from "Dry Season Ground Water Balance Method' [From Table 11.12a]	
8	Specific Yield in Non - command Area as a Fraction	

Format 11.12a

Table 11.12a Estimation of Specific Yield by Dry Season Ground Water Balance Method in Non - Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

<table>
<tr><th>Sl. No.
(1)</th><th>Description of item
{ in non - command area (‘Hardrock’ terrain)}
(2)</th><th>Quantity
(3)</th></tr>
<tr><td>1</td><td>Area in hectares [From Table 2.1]</td><td></td></tr>
<tr><td>2</td><td>Number of calendar months during
a) Non - monsoon season
[From Table 1.1]
b) Dry season</td><td></td></tr>
<tr><td>3</td><td>Gross ground water draft for ‘All Uses’ in hectare metres during
a) Non - monsoon season
[From Table 3.2]
b) Dry season
[((2b) / (2a)) * (3a)]</td><td></td></tr>
<tr><td>4</td><td>Recharge from ground water irrigation in hectare metres during
a) Non - monsoon season
[From Table 6.5]
b) Dry season
[((2b) / (2a)) * (4a)]</td><td></td></tr>
<tr><td>5</td><td>Base flow (if any) during dry season in hectare metres</td><td></td></tr>
<tr><td>6</td><td>Fall in water table during dry season in metres
<table>
<tr><th rowspan="2">Sl. No.</th><th rowspan="2">Name of observation well</th><th colspan="2">Depth to water table below ground level in metres at end and beginning of dry season</th></tr>
<tr><th>End</th><th>Beginning</th></tr>
<tr><td>1
2
3</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Average of all wells</td><td>y_1 =</td><td>y_2 =</td></tr>
</table></td><td></td></tr>
<tr><td>7</td><td>Fall in water table during dry season ($y_1 - y_2$) =

Specific yield by ‘Dry Season Ground Water Balance Method’ as a fraction
[((3b) + (5) - (4b)) / ((6) * (1))]</td><td></td></tr>
</table>

Format 11.13

Table 11.13 Ground Water Balance Computations During Monsoon Season of Current Ground Water Assessment Year In Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of items (for non - command area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Recharge from 'Other Sources' in hectare metres during monsoon season [From Table 9.2]	
3	Gross ground water draft in hectare metres for 'All Uses' during monsoon season [From Table 3.2]	
4	Water table fluctuation in metres during monsoon season [From Table 11.11]	
5	Specific yield as a fraction [From Table 11.12]	
6	Change in ground water storage in hectare metres during monsoon season [(1) * (4) * (5)]	
7	Rainfall recharge in hectare metres during monsoon season in non - command area by ground water balance approach [(6) + (3) - (2)]	
8	Rainfall in mm during monsoon season in non - command area for which the rainfall recharge in (7) above corresponds to [From Table 11.10]	

Format 11.14

Table 11.14 Complete Set of Data on Monsoon Season Rainfall And Corresponding Rainfall Recharge in Non - command Area As obtained by Ground Water Balance Approach

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	[From Table 11.13 of this Ground Water Assessment Report and Table 11.14 of the Previous Assessment Report]		
	Ground water year	Monsoon season rainfall in millimetres	Rainfall recharge during monsoon season in hectare metres
(1)	(2)	(3)	(4)
1			
2			
3			

Note : The last pair of data on monsoon season rainfall and its corresponding rainfall recharge as given above is for the current ground water assessment year

Format 11.15

Table 11.15 Valid Set of Data on Monsoon Season Rainfall And Corresponding Rainfall Recharge in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Normal Monsoon Season Rainfall in Non - command Area in mm, 'NMR' =
[From Table 10.6]

Sl. No.	[From Table 11.14]			Deviation of monsoon season rainfall from normal monsoon season rainfall value as a percentage (3) - 'NMR' [(——————) * 100] 'NMR'
	Ground water year	Monsoon season rainfall in mm	Rainfall recharge during in hectare metres	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				

Note : Only those ground water years in Table 11.14 are considered for which rainfall recharge values during monsoon season are neither negative nor nearly zero

Format 11.16

Table 11.16 Rainfall Recharge During Monsoon Season in Non - command Area By Water Table Fluctuation Method (Using Normalisation Procedure No.1)

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Normal Monsoon Season Rainfall in Non - command Area in mm, 'NMR' =
[From Table 10.6]

Sl. No.	[From Table 11.15]		Recharge corresponding to normal monsoon season rainfall in hectare metres
	Rainfall during monsoon season in mm	Corresponding rainfall recharge in hectare metres	[('NMR' * (3)) / (2)]
(1)	(2)	(3)	(4)
1			
2			
3			
Rainfall recharge during monsoon season in hectare metres in non - command area by 'Water Table Fluctuation Method' [Average of recharge values in Col. (4)]			

Note : This normalisation procedure assumes that the relation between recharge, 'y' and rainfall, 'x' is of the form, y = a * x where 'a' is a constant.

Format 11.17

Table 11.17 Rainfall Recharge During Monsoon Season in Non - command Area By Water Table Fluctuation Method (Using Normalisation Procedure No.2 which Employs Linear Regression Analysis)

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Normal Monsoon Season Rainfall in Non - command Area in metres, 'NMR' =
[From Table 10.6]

Sl. No. (i) (1)	[From Table 11.15] Rainfall during monsoon season in metres x(i) (2)	[From Table 11.15] Corresponding recharge in thousand hectare metres y(i) (3)	$(x(i))^2$ (4)	x(i) * y(i) (5)
1				
2				
3				
Total	S_1 =	S_2 =	S_3 =	S_4 =

Number of pairs of data considered , 'N' =

A) Regression Constants 'a' and 'b' in y = a * x + b

$$a = \left[\left(\frac{(N * S_4) - (S_1 * S_2)}{(N * S_3) - S_1^2} \right) \right] =$$

$$b = \left[\left(\frac{S_2 - (a * S_1)}{N} \right) \right] =$$

B) Rainfall recharge during monsoon season in hectare metres = in non - command area by 'Water Table Fluctuation Method' [(a * 'NMR' + b) * 1000]

Format 11.18

Table 11.18 Rainfall Recharge During Monsoon Season in Non - command Area After Comparing Results From Water Table Fluctuation Method and Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of item (in non - command area)	Quantity
1	Is the water table fluctuation method used for computing rainfall recharge during monsoon season (Yes/No)	
2	If response to (1) is 'NO' * Rainfall recharge during monsoon season in hectare metres in non - command area (Same as by rainfall infiltration factor method) [From Table 10.8]	
3	If response to (1) is 'YES' * Rainfall recharge during monsoon season in hectare metres in non - command area a) By Water Table Fluctuation Method [From Table 11.16 or 11.17] b) By Rainfall Infiltration Factor Method [From Table 10.8] * Difference between (3a) and (3b) expressed as a percentage of (3b), 'PD' $[\frac{((3a) - (3b))}{(3b)} * 100]$ * Rainfall recharge during monsoon season in hectare metres in command area [= (3a) if 'PD' is between - 20 and + 20% = 0.8 * (3b) if 'PD' is less than - 20% = 1.2 * (3b) if 'PD' is greater than + 20%]	

Format 11.19

Table 11.19 Summary of Recharge From Rainfall in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (in command area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Is recharge from rainfall during monsoon season computed by 'Water Table Fluctuation Method' (Yes / No)	
3	Recharge from rainfall during monsoon season (By water table fluctuation method if (2) is 'Yes', or by rainfall infiltration method if (2) is 'No')	
	a) in hectare metres [From Table 11.9]	
	b) per unit area in mm [(3a) / (1)]	
4	Recharge from rainfall during non - monsoon season (By rainfall infiltration factor method)	
	a) in hectare metres [From Table 10.4]	
	b) per unit area in mm [(4a) / (1)]	
5	Annual recharge from rainfall in command area	
	a) in hectare metres [(3a) + (4a)]	
	b) per unit area in mm [(3b) + (4b)]	

Format 11.20

Table 11.20 Summary of Recharge From Rainfall in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (in non - command area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Is recharge from rainfall during monsoon season computed by 'Water Table Fluctuation Method' (Yes / No)	
3	Recharge from rainfall during monsoon season (By water table fluctuation method if (2) is 'Yes', or by rainfall infiltration method if (2) is 'No')	
	a) in hectare metres [From Table 11.18]	
	b) per unit area in mm [(3a) / (1)]	
4	Recharge from rainfall during non - monsoon season (By rainfall infiltration factor method)	
	a) in hectare metres [From Table 10.8]	
	b) per unit area in mm [(4a) / (1)]	
5	Annual recharge from rainfall in non - command area	
	a) in hectare metres [(3a) + (4a)]	
	b) per unit area in mm [(3b) + (4b)]	

CHAPTER 12

NET ANNUAL GROUND WATER AVAILABILITY

12.1 GENERAL

Net annual ground water availability in respect of each ground water assessment unit is computed for the following cases :

a) Command area
b) Non-command area
c) Poor ground water quality area

The computation of net annual ground water availability in a given sub-unit comprises of the following steps to be carried out :

a) Obtaining the total annual ground water recharge as the sum of recharge from rainfall and recharge from 'Other Sources' during both monsoon and non-monsoon seasons.

b) Estimating a value for the unaccounted annual natural discharge

c) Obtaining the net annual ground water availability by subtracting 'b' from 'a'.

12.2 ASSUMPTIONS

The estimation of net annual ground water availability is based on the following assumptions :

a) Some natural discharge terms like baseflow, evaporation from ground water reservoir etc. have been left unaccounted while obtaining the total annual ground water recharge. This is taken care of by assigning a value for the unaccounted discharge, and subtracting it from the annual ground water recharge to arrive at the net annual ground water availability.

b) The unaccounted natural discharge is assigned as 5 percent of the total annual ground water recharge if water table fluctuation method has been employed to compute rainfall recharge during monsoon season. This will take care of the unaccounted natural discharge during non-monsoon season, a season for which rainfall infiltration factor method alone is employed to compute rainfall recharge.

c) The unaccounted natural discharge is assigned as 10 percent of the total annual ground water recharge if rainfall infiltration factor method alone has been employed to compute rainfall recharge during monsoon season also. This will take care of unaccounted natural discharge during both monsoon and non-monsoon seasons.

12.3 COMPUTATIONAL PROCEDURE

12.3.1 Command Area

The computations for obtaining the net annual ground water availability in the command area are presented in one table (Table 12.1) The format to be adopted for this table is given in Format 12.1.

12.3.2 Non-Command Area

The computations for obtaining the net annual ground water availability in the non-command area are presented in one table (Table 12.2). The format to be adopted for this table is given in Format 12.2.

12.3.3 Poor Ground Water Quality Area

The computations for obtaining the net annual ground water availability in the poor ground water quality area are presented in one table (Table 12.3). The format to be adopted for this table is given in Format 12.3.

Format 12.1

Table 12.1 Net Annual Ground Water Availability in Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of item (in command area)	Quantity
1	Rainfall recharge in hectare metres a) During monsoon season [From Table 11.19] b) During non - monsoon season [From Table 11.19] c) Annual [(1a) + (1b)]	
2	Recharge from 'Other Sources' in hectare metres a) During monsoon season [From Table 9.1] b) During non - monsoon season [From Table 9.1] c) Annual [(1a) + (1b)]	
3	Total annual ground water recharge in hectare metres [(1c) + (2c)]	
4	Is rainfall recharge during monsoon season computed by 'Water Table Fluctuation Method' (Yes/No)	
5	Unaccounted annual natural discharge in hectare metres [0.05 * (3) if response to (4) is 'Yes' and, 0.10 * (3) if response to (4) is 'No']	
6	Net annual ground water availability in command area in hectare metres [(3) - (5)]	
7	Area in hectares of command area [From Table 2.1]	
8	Net annual ground water availability in command area per unit area in millimetres [((6) / (7)) * 1000]	

Format 12.2

Table 12.2 Net Annual Ground Water Availability in Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of Item (in non - command area)	Quantity
1	Rainfall recharge in hectare metres a) During monsoon season [From Table 11.20] b) During non - monsoon season [From Table 11.20] c) Annual [(1a) + (1b)]	
2	Recharge from 'Other Sources' in hectare metres a) During monsoon season [From Table 9.2] b) During non - monsoon season [From Table 9.2] c) Annual [(1a) + (1b)]	
3	Total annual ground water recharge in hectare metres [(1c) + (2c)]	
4	Is rainfall recharge during monsoon season computed by 'Water Table Fluctuation Method' (Yes/No)	
5	Unaccounted annual natural discharge in hectare metres [0.05 * (3) if response to (4) is 'Yes' and, 0.10 * (3) if response to (4) is 'No']	
6	Net annual ground water availability in non - command area in hectare metres [(3) - (5)]	
7	Area in hectares of non - command area [From Table 2.1]	
8	Net annual ground water availability in non - command area per unit area in millimetres [((6) / (7)) * 1000]	

Format 12.3

Table 12.3 Net Annual Ground Water Availability in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Description of item (in poor ground water quality area)	Quantity
1	Rainfall recharge in hectare metres a) During monsoon season [From Table 10.13] b) During non - monsoon season [From Table 10.13] c) Annual [(1a) + (1b)]	
2	Recharge from 'Other Sources' in hectare metres a) During monsoon season [From Table 9.3] b) During non - monsoon season [From Table 9.3] c) Annual [(1a) + (1b)]	
3	Total annual ground water recharge in hectare metres [(1c) + (2c)]	
4	Unaccounted annual natural discharge in hectare metres [0.10 * (3)]	
5	Net annual ground water availability in poor ground water quality area in hectare metres [(3) - (4)]	
6	Area in hectares of poor ground water quality area [From Table 2.1]	
7	Net annual ground water availability in poor ground water quality area per unit area in millimetres [((5) / (6)) * 1000]	

CHAPTER 13

STAGE OF GROUND WATER DEVELOPMENT

13.1 GENERAL

The current annual gross ground water draft for 'All Uses' in the two sub-units of command and non-command areas within a ground water assessment unit have been presented in Chapter 3. The net annual ground water availability in these two sub-units have been presented in Chapter 12. These results are made use of to obtain the stage of ground water development in these two sub-units. The stage of ground water development in a given sub-unit is defined as the current annual gross ground water draft for 'All Uses' in that sub-unit expressed as a percentage of the net annual ground water availability in that sub-unit.

13.2 COMMAND AND NON-COMMAND AREA

13.2.1 COMPUTATIONAL PROCEDURE

Let the net annual ground water availability in a given sub-unit (command/ non-command) in hectare metres be 'B'. Let the current annual gross ground water draft for 'All Uses' in that sub-unit be 'C'. The stage of ground water development in that sub-unit, 'A' as a percentage can be then obtained as,

$$A = (C / B) * 100$$

13.2.2 PRESENTATION OF RESULTS

The computations for obtaining the stage of ground water development in the command and non-command areas are presented in one table (Table 13.1). The format to be adopted for this table is given in Format 13.1.

Format 13.1

Table 13.1 Stage of Ground Water Development in Command and Non - command Areas

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description (2)	Command area (3)	Non - command area (4)
1	Net annual ground water availability in hectare metres [From Table 12.1 / 12.2]		
2	Current annual gross ground water draft for all uses in hectare metres [From Table 3.1 / 3.2]		
3	Stage of Ground Water Development as a percentage [(2) / (1) * 100]		

CHAPTER 14

WATER TABLE TREND

14.1 GENERAL

The water table trend has to be computed in each groundwater assessment unit for the following cases

a) **Pre-monsoon and post-monsoon intervals in command area**
b) **Pre-monsoon and post-monsoon intervals in non-command area**

The above information are made use of, along with results of the stage of ground water development as presented earlier in Chapter 13, to categorize the two sub-units of command and non-command areas as 'Safe', 'Semi-critical', 'Critical' or 'Over Exploited' for purposes of future ground water development. The criteria to be adopted for such a categorization will be covered later in Chapter 15.

The estimation of the trend of water table during a given interval and for a given sub-unit comprises of the following steps :

a) The depth to water table below ground level as recorded in a number of observations wells within the sub-unit are made use of to obtain the depth to water table information applicable for the sub-unit as a whole.

b) The results from 'a' above are used in a scheme of linear regression analysis to establish the trend of water table.

14.2 ASSUMPTIONS

The estimation of the trend of water table is based on the following assumptions:

a) The variation of depth to water table below ground level over successive ground water years is linear.

   Let x be successive years, and y be the depth to water table below ground level in metres. The relation between x and y is,

   y = ax + b
   where 'a' and 'b' are the regression constants

   The value of 'a' obtained by linear regression analysis multiplied by 100 gives the trend of depth to water table below ground level in cm per year. Let this be designated as 'Z'. The water table shows a falling trend if 'Z' is positive and rising trend if 'Z' is negative. The absolute value of 'Z' gives the rise or fall of water table in cm per year.

b) As discussed in 'a' above, the water table shows a neither rising nor falling trend only if 'Z' is equal to zero. However, from a practical point of view it is

necessary to adopt a range of values for 'Z' within which the water table can be considered to show a neither rising nor falling trend. With this consideration in mind, the water table trend is assumed to be,

i) 'Rising' if 'Z' is less than -5 cm per year
ii) 'Falling' if 'Z' is greater than +5 cm per year
iii) 'Neither Rise nor Fall' if 'Z' is between -5 and +5 cm per year

14.3 COMPUTATIONAL PROCEDURE

14.3.1 Command Area

14.3.1.1 Water Table Information Applicable for Command Area

Location details and availability of water table data of all observation wells in the command area of the ground water assessment unit are presented in one table (Table 14.1). the format to be adopted for this table is given in Format 14.1. Ground water assessment is to be carried out once in three ground water years. Unprocessed data on depth to water table below ground level during pre-monsoon and post-monsoon intervals for the assessment year and the two years prior to it as recorded in a number of observation wells within the command area will be available each time the ground water assessment is made. These data are made use of to compute the depth to water table below ground level as applicable to the command area as a whole for the three ground water years mentioned above. The computations are presented in one table (Table 14.2). The format to be adopted for this table is given in Format 14.2.

Similar information applicable for the command area for a number of previous ground water years will be available from groundwater assessments made earlier. The complete set of information on depth to water table below ground level during pre-monsoon and post-monsoon intervals of a number of successive ground water years as applicable for the command area as a whole is presented in one table (Table 14.3). The format to be adopted for this table is given in Format 14.3.

14.3.1.2 Water Table Trend during Pre-monsoon Interval

The depth to water table below ground water level applicable for the command area during the pre-monsoon intervals of successive ground water years as given in Table 14.3 are used in a scheme of linear regression analysis for estimating the water table trend during pre-monsoon interval for the command area.

The application of linear regression analysis requires a set of ordered pairs of data on x (i) and y(i) for i = 1 to N, where 'N' refers to the number of pairs of data, x(i) refers to the year and y(i) refers to the depth to water table below ground level during the pre-monsoon interval. The value of x(i) for i = 1 is 1, and this corresponds to the earliest ground water year for which water table data is available. If water table data is available for the next ground water year, the value of x(i) for i = 2 is 2. However, if water table data is available only after a gap of one ground water year, the value of x(i) for i = 2 is 3. A similar procedure is followed and the complete set of ordered pairs of data on x(i) and y(i) are obtained.

The use of linear regression analysis for obtaining the water table trend in the command area during the pre-monsoon interval is presented in one table (Table 14.4). The format to be adopted for this table is given in Format 14.4.

14.3.1.3 Water Table Trend During Post Monsoon Interval

The computational scheme is identical to what has been described in the previous section, except that, the water table data during post-monsoon interval are now used in place of the pre-monsoon interval data. The computations are presented in one table (Table 14.5). The format to be adopted for this table is given in Format 14.5.

14.3.2 Non -Command Area

The computational scheme for the non-command area is identical to what has been described earlier in Section 14.3.1 for the command area. The computations are presented in five tables(Tables 14.6 to 14.10). The formats to be adopted for these five tables are given in Formats 14.6 to 14.10 respectively.

Format 14.1

Table 14.1 Location Details and Availability of Water Table Data Of All Observation Wells in the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Observation wells in the command area					
	Location details			Ground water years for which water table data are available		
	Name of observation well	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Format 14.2

Table 14.2 Water Table Information for Command Area During the Ground Water Assessment Year and the Two Years Prior to It

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of observation wells in command area	Depth to water table below ground level in metres during					
		Ground water assessment year ( )		One year prior to ground water assessment year ( )		Two years prior to ground water assessment year ( )	
		Pre - monsoon	Post - monsoon	Pre - monsoon	Post - monsoon	Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
For command area as a whole (average of all wells considered)							

Format 14.3

Table 14.3 Water Table Information for Command Area During A Number of Ground Water Years Till the Current Ground Water Assessment Year

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Ground water year	Depth to water table below ground level in metres applicable for command area [From Table 14.2 of this assessment report, and from Table 14.3 of previous assessment report]	
		Pre - monsoon interval	Post - monsoon interval
(1)	(2)	(3)	(4)
1			
2			
3			

Format 14.4

Table 14.4 Water Table Trend During Pre - monsoon Interval In Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (i) (1)	Ground water year (2)	Year x (i) (3)	Depth to water table below ground level in metres during pre - monsoon interval, y (i) [From Table 14.3] (4)	$(x(i))^2$ (5)	x (i) * y (i) (6)
1					
2					
3					
Total		(S_1)	(S_2)	(S_3)	(S_4)

Number of pairs of data considered, 'N' =

a) Trend of depth to water table below ground level during pre - monsoon interval in command area in centimetres per year =

$$\left[\left(\frac{(N * S_4) - (S_1 * S_2)}{(N * S_3) - S_1^2} \right) * 100 \right]$$

b) Water table trend during pre - monsoon interval in command area =
(Rising / Falling / Neither Rise nor Fall)

Format 14.5

Table 14.5 Water Table Trend During Post - monsoon Interval In Command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (i) (1)	Ground water year (2)	Year x (i) (3)	Depth to water table below ground level in metres during post - monsoon interval, y (i) [From Table 14.3] (4)	$(x(i))^2$ (5)	x (i) * y (i) (6)
1					
2					
3					
Total		(S_1)	(S_2)	(S_3)	(S_4)

Number of pairs of data considered, N =

a) Trend of depth to water table below ground level during post - monsoon interval in command area in centimetres per year =

$$\left[\left(\frac{(N * S_4) - (S_1 * S_2)}{(N * S_3) - S_1^2} \right) * 100 \right]$$

b) Water table trend during post - monsoon interval in command area =
(Rising / Falling / Neither Rise nor Fall)

Format 14.6

Table 14.6 Location Details and Availability of Water Table Data Of All Observation Wells in the Non - command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Observation wells in the non - command area					
	Location details			Ground water years for which water table data are available		
	Name of observation well	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Format 14.7

Table 14.7 Water Table Information for Non - command Area During the Ground Water Assessment Year and the Two Years Prior to It

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Sl. No.	Name of observation wells in non - command area	Depth to water table below ground level in metres during					
		Ground water assessment year ( )		One year prior to ground water assessment year ( )		Two years prior to ground water assessment year ( )	
		Pre - monsoon	Post - monsoon	Pre - monsoon	Post - monsoon	Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
For non - command area as a whole (average of all wells considered)							

Format 14.8

Table 14.8 Water Table Information for Non - command Area During A Number of Ground Water Years Till the Current Ground Water Assessment Year

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No.	Ground water year	Depth to water table below ground level in metres applicable for non - command area during [From Table 14.7, of this assessment report, and from Table 14.8 of previous assessment report]	
		Pre - monsoon interval	Post- monsoon interval
(1)	(2)	(3)	(4)
1			
2			
3			

Format 14.9

Table 14.9 Water Table Trend During Pre - monsoon Interval In Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (i) (1)	Ground water year (2)	Year x (i) (3)	Depth to water table below ground level in metres during pre - monsoon interval, y (i) [From Table 14.8] (4)	$(x(i))^2$ (5)	x (i) * y (i) (6)
1					
2					
3					
Total		(S_1)	(S_2)	(S_3)	(S_4)

Number of pairs of data considered, N =

a) Trend of depth to water table below ground level during pre - monsoon = interval in non - command area in centimetres per year

$$\left[\left(\frac{(N * S_4) - (S_1 * S_2)}{(N * S_3) - S_1^2} \right) * 100 \right]$$

b) Water table trend during pre - monsoon interval in non - command area = (Rising / Falling / Neither Rise nor Fall)

Format 14.10

Table 14.10 Water Table Trend During Post - monsoon Interval In Non - command Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (i) (1)	Ground water year (2)	Year x (i) (3)	Depth to water table below ground level in metres during post - monsoon interval, y (i) [From Table 14.8] (4)	$(x(i))^2$ (5)	x (i) * y (i) (6)
1					
2					
3					
Total		(S_1)	(S_2)	(S_3)	(S_4)

Number of pairs of data considered, N =

a) Trend of depth to water table below ground level during post - monsoon interval in non - command area in centimetres per year =

$$\left[\left(\frac{(N * S_4) - (S_1 * S_2)}{(N * S_3) - S_1^2} \right) * 100 \right]$$

b) Water table trend during post - monsoon interval in non - command area = (Rising / Falling / Neither Rise nor Fall)

CHAPTER 15

CATEGORIZATION OF

COMMAND AND NON-COMMAND AREAS

15.1 GENERAL

The two sub-units of command and non-command areas in each ground water assessment unit are to be categorized as one of the following four categories for the purpose of establishing the scope for future ground water development in them.

a) Safe
b) Semi-critical
c) Critical
d) Over Exploited

The above categorization is arrived at by considering both the stage of ground water development as presented earlier in Chapter 13, and the trend of water table during pre-monsoon and post-monsoon intervals as presented earlier in Chapter 14.

15.2 SET OF CRITERIA FOR CATEGORIZATION

15.2.1 Safe

A sub-unit (command/ non-command area) is categorized as 'Safe' with potential for future ground water development if one of the following two criteria is fulfilled :

a) The stage of ground water development is less than or equal to 70 %, and the water table during at least one of the two intervals (either pre-monsoon or post-monsoon) does not show a falling trend.

b) The stage of ground water development is greater than 70% but less than or equal to 90%, and the water table during both pre-monsoon and post-monsoon intervals do not show a falling trend.

In case a sub-unit gets categorized as 'Safe' on the basis of the criterion mentioned in 'b' above, it is to be noted that, caution has to be however exercised, while deciding the actual quantum of additional ground water withdrawal to be made in the future.

15.2.2 Semi-critical

A sub-unit (Command/ non-command area) is categorized as 'Semi-critical' with caution to be exercised for future ground water development if the following

criterion is fulfilled :

a) The stage of ground water development is greater than 70 % but less than or equal to 90 %, and the water table during only one of the two intervals (either pre-monsoon or post-monsoon) shows a falling trend.

In case a sub-unit gets categorized as 'Semi-critical', it is necessary to increase the density of observation wells in that sub-unit so that,

i) the rainfall recharge during monsoon season by the water table fluctuation method can be estimated with greater accuracy.

ii) the trend of water table during pre- monsoon and post-monsoon intervals can be evaluated with greater accuracy, and

iii) the trend of water table during pre- monsoon and post- monsoon intervals consequent to further groundwater development can be more effectively monitored.

15.2.3 Critical

A sub-unit (command/ non-command area) is categorized as 'Critical' with only very marginal scope for future ground water development if one of the following criteria is fulfilled :

a) the stage of ground water development is more than 90%, and the water table during only one of the two intervals (either pre-monsoon or post-monsoon) shows a falling trend.

b) the stage of ground water development is less than or equal to 100%, and the water table during both pre-monsoon and post-monsoon intervals show a falling trend.

In case a sub-unit gets characterised as 'Critical', it is necessary to adopt the following measures in that sub-unit :

i) Increase the density of observation wells for reasons mentioned earlier.

ii) Implement water conservation measures, artificial recharge etc., in a concerted manner so as to ensure more ground water recharge and a sustainable ground water development .

iii) Carry out micro level studies as described in Appendix 15.1 so that the ground water assessment made for the sub-unit can be reassessed more correctly.

15.2.4 Over Exploited

A sub-unit (Command / Non-command area) is categorized as 'Over Exploited' with practically no scope for any future ground water development if the following

criterion is fulfilled :

a) the stage of ground water development is more than 100%, and the water table during both pre-monsoon and post-monsoon intervals show a falling trend.

The three measures of increasing the density of observation wells, implementing water conservation schemes/ artificial recharge programs, and carrying out micro level studies as described earlier in Section 15.2.3 for 'Critical areas' also apply for all sub-units which get categorized as 'Over Exploited'.

15.3 PRESENTATION OF RESULTS

The categorization of command and non-command areas in each ground water assessment unit is presented in one table (Table 15.1). The format to be adopted for this table is given in Format 15.1.

Format 15.1

Table 15.1 Categorisation of Command and Non - command Areas

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Command area (3)	Non - command area (4)
1	Stage of ground water development as a percentage [From Table 13.1]		
2	Does the water table during pre - monsoon interval show a falling trend (Yes/No) [From Table 14.4 / 14.9]		
3	Does the water table during post - monsoon interval show a falling trend (Yes/No) [From Table 14.5 / 14.10]		
4	Categorisation of the sub-unit (Safe / Semi-critical / Critical / Over Exploited)		

CHAPTER 16

ALLOCATION FOR DOMESTIC AND INDUSTRIAL WATER SUPPLY

16.1 GENERAL

Among various demands for water, the 'National Water Policy' assigns the highest priority to domestic water supply. Industrial water supply may be also important for some States/ Union Territories. There is therefore, a need to provide a certain allocation of ground water for domestic and industrial water supply so that, the demands for these two purposes are ensured before planning any future ground water development to meet the demands of other purposes like irrigation .

Unlike irrigation water requirement which primarily depends on the availability of irrigable land, the requirement for domestic and industrial water supply depends on the population. It is also preferable that, a projected population say 25 years from now, and not the current population is considered, while arriving at the annual allocation for domestic and industrial water supply.

The following factors are important for arriving at an estimate for the annual allocation of ground water to meet domestic and industrial water requirements.

a) extent of dependence on ground water
b) per capita per day requirement of water
c) criteria for population projection

The above factors are likely to vary considerably from State to State, and even within a State. In other words, the estimation of allocation for domestic and industrial water supply is highly location specific. Consequently, each State/ Union Territory is given a freedom to arrive at the estimate of the annual allocation on the basis of any procedure most suitable to them. The only requirement is that, the annual allocation of ground water for domestic and industrial water supply should be arrived at for the two sub-units of command and non-command areas in each ground water assessment unit with as much reliability as possible. The results are presented in one table (Table 16.1). The format to be adopted for this table is given in Format 16.1.

The report on "Ground Water Estimation Methodology-1997" however, suggests a procedure which can be made use for estimating the annual allocation of ground water

for domestic and industrial water supply. This procedure which is described in the next section can be adopted if it is found suitable, and if a better procedure is not available.

16.2 SUGGESTED COMPUTATIONAL PROCEDURE

The report on "Ground water Estimation Methodology - 1997" recommends that the allocation for domestic and industrial water supply per unit area can be arrived at using the following equation in which it is assumed that, the requirement for domestic and industrial water supply is 60 lpcd (litres per capita per day).

$$Y = 22 * N * L_g$$

where,

Y is allocation for domestic and industrial water supply per unit area in mm/ year

N is projected population density in thousands per sq.km.

L_g is a measure of the dependence on ground water to meet domestic and industrial water supply as a fraction (less than or equal to 1).
L_g is equal to 1, if domestic and industrial water supply are solely met with ground water, and is equal to 0 if ground water is not at all used to meet domestic and industrial water supply.

If 'TA' is the area of the sub-unit (command/ non-command) in hectares, then the annual allocation for domestic and industrial water supply, 'Z' in hectare metres for the sub-unit can be obtained as,

$$Z = Y * TA / 1000.$$

The computations as described above for both command and non-command areas can be presented in one table (Table 16.2). The format to be adopted for this table is given in Format 16.2.

The above computational scheme however has the limitation that, the per capita per day requirement for domestic and industrial water supply is a fixed value of 60 lpcd. In actual practice the following situations may arise :

a) The per capita per day requirement for domestic and industrial water supply may be different from 60 lpcd
b) The per capita per day requirement for domestic water supply may be different from that for industrial water supply.
c) The dependence on ground water for domestic water supply may be different from that for industrial water supply.

The above situations can be taken care of, and a more general computational procedure can be followed. The computations for this modified procedure is presented

in one table (Table 16.3). The format to be adopted for this table is given in Format 16.3.

16.3 SUMMARY OF ALLOCATION FOR DOMESTIC AND INDUSTRIAL WATER SUPPLY IN COMMAND AND NON-COMMAND AREAS

Whatever may be the procedure followed, a summary of annual allocation of ground water for domestic and industrial water supply in the command and non-command areas in each ground water assessment unit has to be presented in one table (Table 16.1). The format to be adopted for this table is given in Format 16.1.

Format 16.1

Table 16.1 Summary of Annual Ground Water Allocation for Domestic and Industrial Water Supply in Command and Non - Command Areas

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Command area (3)	Non - command area (4)
1	Annual allocation of ground water for domestic and industrial water supply in hectare metres		
2	Area in hectares [From Table 2.1]		
3	Annual allocation of ground water for domestic and industrial water supply per unit area in millimetres [((1) / (2)) * 1000]		

Format 16.2

Table 16.2 Annual Ground Water Allocation for Domestic and Industrial Water Supply in Command and Non - Command Areas (By the method given in the report on 'Ground Water Estimation Methodology - 1997')

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Command area (3)	Non-command area (4)
1	Projected population density at end of 25 years from now in thousands per sq. km.		
2	Extent of dependence on ground water to meet domestic and industrial water supply as a fraction (less than or equal to 1)		
3	Annual allocation of ground water for domestic and industrial water supply per unit area in millimetres [22 * (1) * (2)]		
4	Area in hectares [From Table 2.1]		
5	Annual allocation of ground water for domestic and industrial water supply in hectare metres [((3) * (4)) / 1000]		

Note : The per capita per day requirement for domestic and industrial water supply is assumed as 60 lpcd

Format 16.3

Table 16.3 Annual Ground Water Allocation for Domestic and Industrial Water Supply in Command and Non - Command Areas

(By a method which is a generalisation of the method given in the report 'Ground Water Estimation Methodology - 1997')

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Command area (3)	Non-command area (4)
1	Projected population density at end of 25 years from now in thousands per sq. km.		
2	Domestic water supply requirement in litres per capita per day, lpcd		
3	Extent of dependence on ground water to meet domestic water supply as a fraction (less than or equal to 1)		
4	Industrial water supply requirement in lpcd		
5	Extent of dependence on ground water to meet industrial water supply as a fraction (less than or equal to 1)		
6	Annual allocation of ground water for domestic water supply per unit area in millimetres [(22 / 60) * (1) * (2) * (3)]		
7	Annual allocation of ground water for industrial water supply per unit area in millimetres [(22 / 60) * (1) * (4) * (5)]		
8	Annual allocation of ground water for both domestic and industrial water supply per unit area in millimetres [(6) + (7)]		
9	Area in hectares [From Table 2.1]		
10	Annual allocation of ground water for both domestic and industrial water supply in hectare metres [((8) * (9)) / 1000]		

CHAPTER 17

NET ANNUAL GROUND WATER AVAILABILITY FOR FUTURE USE

17.1 GENERAL

The net annual ground water availability in the three sub-units of command, non-command and poor ground water quality area have been presented in Chapter 12. The current annual gross ground water draft for 'Irrigation' in the command and non-command areas, and current annual gross ground water draft for 'All Uses' in the poor ground water quality area have been presented in Chapter 3. The annual allocations for 'Domestic and Industrial Water Supply' up to twenty-five years from now, in the command and non-command areas have been presented in Chapter 16. These results are made use of to compute the following future ground water availability components in each ground water assessment unit :

a) Command and Non-command Areas

i) Net annual ground water availability for 'Future Irrigation Use'

b) Poor Ground Water Quality Area

i) Net annual ground water availability for 'All Future Uses'

17.2 COMPUTATIONAL PROCEDURE

17.2.1 COMMAND AND NON-COMMAND AREAS

Let the net annual ground water availability in hectare metres in a given sub-unit (command/ non-command) be 'B'. Let the current annual gross ground water draft for 'Irrigation' in hectare metres in that sub-unit be, 'C'. Let the annual allocation for 'Domestic and Industrial Water Supply' in hectare metres in that sub-unit be, 'D'. The net annual ground water availability for 'Future Irrigation Use' in that sub-unit, 'A' in hectare metres can be then computed as,

$A = B - (C + D)$

17.2.2 POOR GROUND WATER QUALITY AREA

Let the net annual ground water availability in hectare metres in the poor ground water quality area be 'F'. Let the current annual gross ground water draft for 'All Uses' in hectare metres in that sub-unit be 'G'. The net annual ground water availability for

'All Future Uses' in hectare metres, in the poor ground water quality area, 'E' can be then computed as,

$$E = F - G$$

17.3 PRESENTATION OF RESULTS

The net annual ground water availability for 'Future Irrigation Use' in the two sub-units of Command, Non-command areas within a ground water assessment unit as computed above are presented in one table (Table 17.1). The format to be adopted for this table is given in Format 17.1.

The net annual ground water availability for 'All Future Uses' in the Poor Ground Water Quality Area as computed above is presented in one table (Table 17.2). The format to be adopted for this table is given in Format 17.2.

Format 17.1

Table 17.1 Net Annual Ground Water Availability for Future Irrigation Use in Command and Non-command Areas

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Command area (3)	Non - command area (4)
1	Area in hectares [From Table 2.1]		
2	Net annual ground water availability in hectare metres [From Table 12.1 / 12.2]		
3	Current annual gross ground water draft for Irrigation in hectare metres [From Table 3.1 / 3.2]		
4	Annual allocation of ground water for domestic and industrial water supply up to next 25 years in hectare metres [From Table 16.1]		
5	Net annual ground water availability for 'Future Irrigation Use' in hectare metres [(2) - ((3) - (4))]		
6	Net annual ground water availability for 'Future Irrigation Use' per unit area in millimetres [((5) / (1)) * 1000]		

Format 17.2

Table 17.2 Net Annual Ground Water Availability for All Future Uses in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (in poor ground water quality area) (2)	Quantity (3)
1	Area in hectares [From Table 2.1]	
2	Net annual ground water availability in hectare metres [From Table 12.3]	
3	Current annual gross ground water draft for 'All Uses' in hectare metres [From Table 3.3]	
4	Net annual ground water availability for 'All Future Uses' in hectare metres [(2) - (3)]	
5	Net annual ground water availability for 'All Future Uses' per unit area in millimetres [((4) / (1)) * 1000]	

CHAPTER 18

ADDITIONAL POTENTIAL RECHARGE AND STATIC GROUND WATER RESOURCE

18.1 GENERAL

In addition to the ground water assessment components covered in the earlier chapters, it is necessary to compute the following two components in respect of each ground water assessment unit :

a) Additional Potential Recharge
b) Static Ground Water Resource

18.2 ADDITIONAL POTENTIAL RECHARGE

In any ground water assessment unit there may be areas which are under waterlogged, shallow water table or flood prone conditions. In all such areas, the rejected discharge will be considerable, and the water table fluctuation will be also subdued. The computation of rainfall recharge considering the water table fluctuation data is therefore likely to lead to an underestimation of the recharge in all such areas of the ground water assessment unit. It is also always desirable that, the ground water table in such areas should be lowered down to an acceptable optimum level before the commencement of the monsoon so as to provide additional scope for recharge from rainfall during the monsoon season. The additional recharge from rainfall so induced is referred to as the additional potential recharge.

Additional potential recharge is to be computed separately for the following areas in each ground water assessment unit :

a) Waterlogged and Shallow Water Table Areas
b) Flood Prone Area

18.2.1 Waterlogged and Shallow Water Table Areas

18.2.1.1 Assumptions

a) Waterlogged and shallow water table areas are characterised by depth to water table below ground level being less than 5 metres

b) The optimum limit to which the water table can be lowered is 5 metres below ground level

c) The potential recharge in hectare metres can be computed as the product of the following three parameters

i) Area in hectares
ii) Specific yield of the aquifer in the zone up to 5 metres below ground level
iii) Difference between the actual depth to water table below ground level in metres and the optimum limit of 5 metres mentioned in 'b' above

18.2.1.2 Computational Procedure

The computational procedure for estimating the potential recharge in hectare metres in the waterlogged and shallow water table areas within the ground water assessment unit involves the following steps :

a) The portions of the ground water assessment unit characterised by waterlogged and shallow water table conditions are identified, and the area and the average depth to water table below ground level of those portions are obtained. Let the area in hectares be 'A', and the depth to water table below ground level in metres be 'D'

b) The specific yield , S_y of the aquifer formation in the zone up to 5 metres below ground level is obtained

c) The potential recharge in waterlogged and shallow water table areas, 'Y' in hectare metres is finally computed as

$Y = (D - 5) * A * S_y$

It also needs to be emphasised that, unlike the 'Net Annual Ground Water Availability' as presented earlier in Chapter 12 which is available year after year, the additional potential recharge in waterlogged and shallow water table areas is a one time availability of ground water which ceases as and when the water table is lowered down to the accepted optimum level of 5 metres below ground level.

18.2.2 Flood Prone Area
18.2.2.1 Assumptions

Potential recharge in flood prone area depends on several factors like,

i) Area under flood prone conditions
ii) Retention period of the flood
iii) Soil strata in the flood prone area
iv) Silt load in the river which get deposited in the flood prone area.

The collection of data on all these factors is usually very difficult, and hence, potential recharge in flood prone area is computed on the same basis adopted for computing recharge from tanks and ponds as described earlier in Chapter 7.

18.2.2.2 Computational Procedure

The computational procedure for estimating the potential recharge in hectare metres in the flood prone area involves the following steps :

a) The portion within the ground water assessment unit under flood prone conditions is identified, and its area in hectares, as well as the number days during a year when water is retained in it are obtained. Let 'A' be the area is hectares, and 'N' be the number of days water is retained in a year.

b) The annual potential recharge 'Y', in the hectare metres in the flood prone area within the ground water assessment unit is finally computed as,

$Y = 1.44 * N * A / 1000.$

18.3 STATIC GROUND WATER RESOURCE

The 'Net Annual Ground Water Availability' as computed earlier in Chapter 12 is the 'Dynamic' component of the ground water resource which is available in the zone of water table fluctuation. All plans for ground water development are made on the basis of this dynamic component which is available year after year.

The static ground water resource in a ground water assessment unit can be considered to be that which is available below the zone of water table fluctuation, and above an acceptable limit of water table level up to which exploitation of ground water can be permitted under special circumstances. The static ground water resource, unlike the dynamic ground water resource, is not available year after year. Also, any development of the static ground water resource is synonymous to ground water mining. Consequently, the static ground water resource can be considered for development only during periods of extreme drought condition, and that too probably only to meet drinking water supply. The static water resource thus mined, can be expected to be recouped during those years of excess rainfall.

18.3.1 Computational Procedure

The computational procedure for computing the static ground water resource comprises of the following steps.

a) The area of the ground water assessment unit for which the static ground water resource is to be computed is obtained. The maximum value for this area can be the area of the two sub-units of command and non-command areas within the ground water assessment unit. Let this area in hectares be 'A'

b) The depth below ground level up to which the zone of water table fluctuation occurs is obtained. This can be taken as the maximum depth below ground

level recorded during the pre-monsoon interval. Let this depth below ground level in metres be 'Z_1'

c) An acceptable depth below ground level up to which ground water can be mined in obtained. This will be usually less than the maximum depth below ground level up to which the saturated aquifer formation extends. Let this acceptable depth below ground level in metres be 'Z_2'.

d) The specific yield of the aquifer formation in the depth horizon between 'Z_1' and 'Z_2' as defined above is obtained. Let this specific yield value as a fraction be 'S_y'

e) The static ground water resource, 'Y' in the hectare metres is finally computed as,

$$Y = A * (Z_2 - Z_1) * S_y$$

18.4 PRESENTATION OF RESULTS

The computations for obtaining the potential recharge in waterlogged and shallow water table areas, and in flood prone areas as described earlier in Section 18.2 are presented in one table (Table 18.1), The format to be adopted for this table is given in Format 18.1.

The computations for obtaining the static ground water resource as described earlier in Section 18.3 are presented in one table (Table 18.2). The format to be adopted for this table is given in Format 18.2.

Format 18.1

Table 18.1 Potential Recharge Under Specified Conditions in Each Ground Water Assessment Unit

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Quantity (3)
	A) **Waterlogged and Shallow Water Table Area**	
1	Area, in hectares	
2	Average depth to water table below ground level, in metres (This should be less than 5 metres)	
3	Specific yield, as a fraction	
4	Potential Recharge in water logged and shallow water table area, in hectare metres [(1) * (5.0 - (2)) * (3)]	
	B) **Flood Prone Area**	
5	Area, in hectares	
6	Number of days in a year when water is retained in the flood prone area	
7	Potential recharge in flood prone area, in hectare metres [1.44 * (5) * (6) / 1000]	
8	**Total Potential Recharge in the Ground Water Assessment Unit**, in hectare metres [(4) + (7)]	

Format 18.2

Table 18.2 Static Ground Water Resource in Each Ground Water Assessment Unit

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Quantity (3)
1	Area considered for static ground water resource estimation, in hectares	
2	Depth below ground level up to which the zone of water table fluctuation extends, in metres	
3	Depth below ground level up to which the saturated aquifer formation extends, in metres	
4	Acceptable depth below ground level up to which ground water mining can be permitted, in metres [This is less than or equal to (3)]	
5	Specific yield of the depth zone considered for static ground water resources estimation, as a fraction	
6	**Static Ground Water Resource in the Ground Water Assessment Unit**, in hectare metres [(1) * ((4) - (2)) * (5)]	

CHAPTER 19

SUMMARY REPORT ON EACH GROUND WATER ASSESSMENT UNIT

19.1 GENERAL

The report on 'Ground Water Estimation Methodology - 1997', requires that a summary report on each ground water assessment unit should be prepared in the form of a single concise table. This table should also be accompanied by two graphical plots, one for the command area, and the other for the non-command area, which show the trend of depth to water table below ground level during pre-monsoon and post-monsoon intervals in those two sub-units. The intentions behind this requirement are many. Some of the more important among them are listed below :

a) A comprehensive understanding of the ground water assessment in each ground water assessment unit can be obtained from a single concise table of information

b) The relative importance of each ground water assessment component can be better appreciated as a result of which more attention can be focused in the future for refining the methodology for computing those components which are relatively more important

c) A concise table of information will be made available so that the task of refining the norms adopted in ground water assessment as and when it is undertaken can be more efficiently accomplished.

19.2 PRESENTATION OF INFORMATION

The summary report on ground water assessment for each ground water assessment unit is to be presented in one table (Table 19.1). The format to be adopted for this table is given in Format 19.1. The graphical plots showing the trend of depth to water table below ground level during the pre-monsoon and post-monsoon intervals in the command and non-command areas are presented in two figures (Figures 19.1 and 19.2), one figure for each sub-unit. The formats to be adopted for these two figures are given in Formats 19.2 and 19.3 respectively.

Format 19.1

Table 19.1 Summary Report in Respect of Each Ground Water Assessment Unit

Name of State / Union Territory :

Name of Ground Water Assessment Unit :

Index Number of Ground Water Assessment Unit :

Type Ground Water Assessment Unit (Watershed / Block / Taluka / Mandal) :

Predominant Type of Rock Formation :

Area in hectares of
- a) Ground Water Assessment Unit :
- b) Command Area :
- c) Non - command Area :
- d) Poor Ground Water Quality Area :

Ground Water Assessment Year :

A. Command and Non - command Areas

Sl. No.	Description of item	Non - command area		Command area	
		in hectare metres	in mm	in hectare metres	in mm
1	Recharge from 'Rainfall' during monsoon season				
2	Recharge from 'Other Sources' during monsoon season				
3	Recharge from 'Rainfall' during non - monsoon season				
4	Recharge from 'Other Sources' during non - monsoon season				
5	Annual ground water recharge [(1) + (2) + (3) + (4)]				
6	Unaccounted annual natural discharge				
7	Net annual ground water availability [(5) - (6)]				
8	Current annual gross ground water draft for 'All Uses'				

Sl. No.	Description of item	Non - command area		Command area	
		in hectare metres	in mm	in hectare metres	in mm
9	Current annual gross ground water draft for 'Irrigation'				
10	Annual ground water allocation for domestic and industrial water supply up to next 25 years				
11	Net annual ground water availability for 'Future Irrigation Use' [(7) - (9) - (10)]				
12	Was the rainfall recharge during monsoon season obtained by using the water table fluctuation method (Yes / No)				
13	If response to Sl. No. 12 is 'Yes', how was specific yield value obtained (Norms / Pumping test / Dry season water balance method)				
14	**Stage of ground water development** as a percentage [((8) / (7)) * 100]				
15	Does the water table during pre - monsoon interval show a falling trend (Yes / No)				
16	Does the water table during post - monsoon interval show a falling trend (Yes / No)				
17	**Categorisation for future ground water development** (Safe / Semi-critical / Critical / Over exploited)				

B. Poor Ground Water Quality Area

Sl. No.	Description of item (in poor ground water quality area)	in hectare metres	in millimetres
1	Recharge from 'Rainfall' during monsoon season		
2	Recharge from 'Other Sources' during monsoon season		
3	Recharge from 'Rainfall' during non - monsoon season		
4	Recharge from 'Other Sources' during non - monsoon season		
5	Total annual ground water recharge [(1) + (2) + (3) + (4)]		
6	Unaccounted annual natural discharge		
7	Net annual ground water availability [(5) - (6)]		
8	Current annual gross ground water draft for 'All Uses'		
9	Net annual ground water availability for 'All Future Uses' [(7) - (8)]		

C. Potential Recharge (If any) **in Ground Water Assessment Unit**

a) Potential recharge in waterlogged and shallow water table areas in hectare metres =

b) Potential recharge in flood prone area in hectare metres =

c) Total potential recharge in hectare metres [(a) + (b)] =

D. Static Ground Water Resource (If any) **in Ground Water Assessment Unit**

a) Static ground water resource in hectare metres =

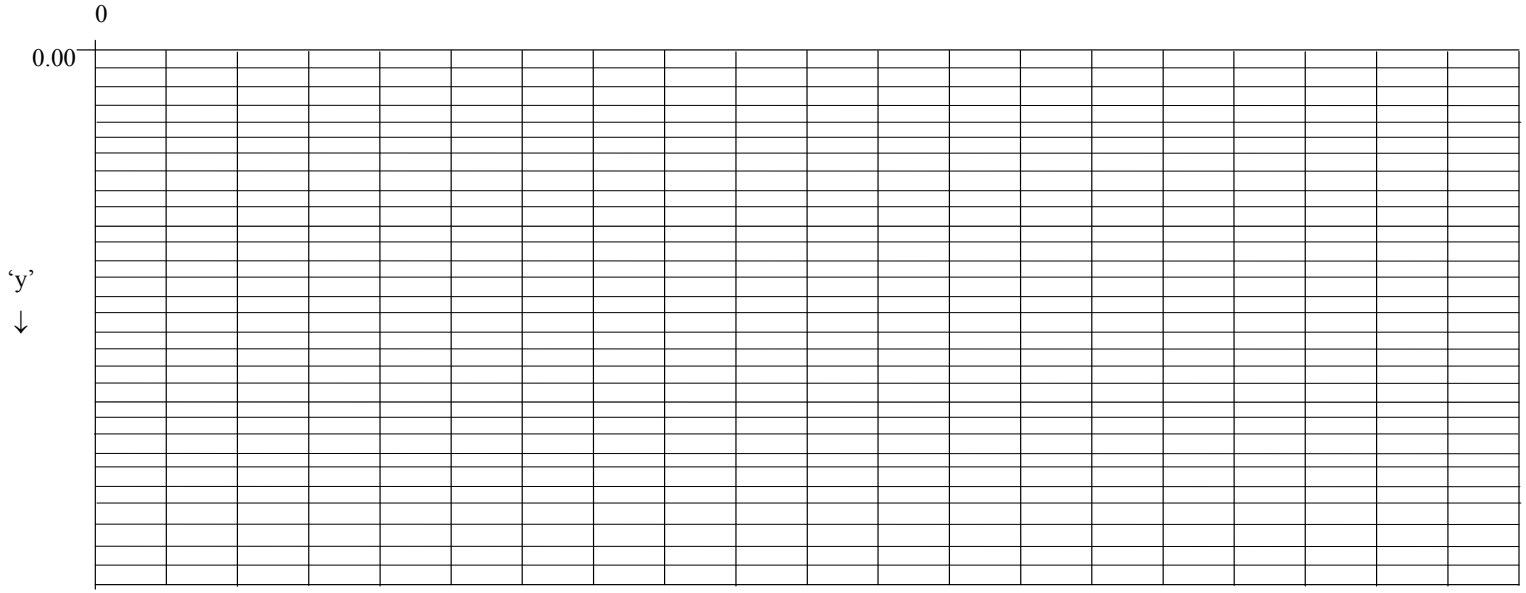
Format 19.2

Figure 19.1 Variation of Depth to Water Table Below Ground Level, 'y' in metres Over Successive Ground Water Years in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Year (1, 2, 3, etc.) →



Year '1' which is the earliest ground water year for which water table data is available =

—⌫— Pre - monsoon interval Shows a Rise / Fall of cm per year
[From Table 14.4]

—o— Post - monsoon interval Shows a Rise / Fall of cm per year
[From Table 14.5]

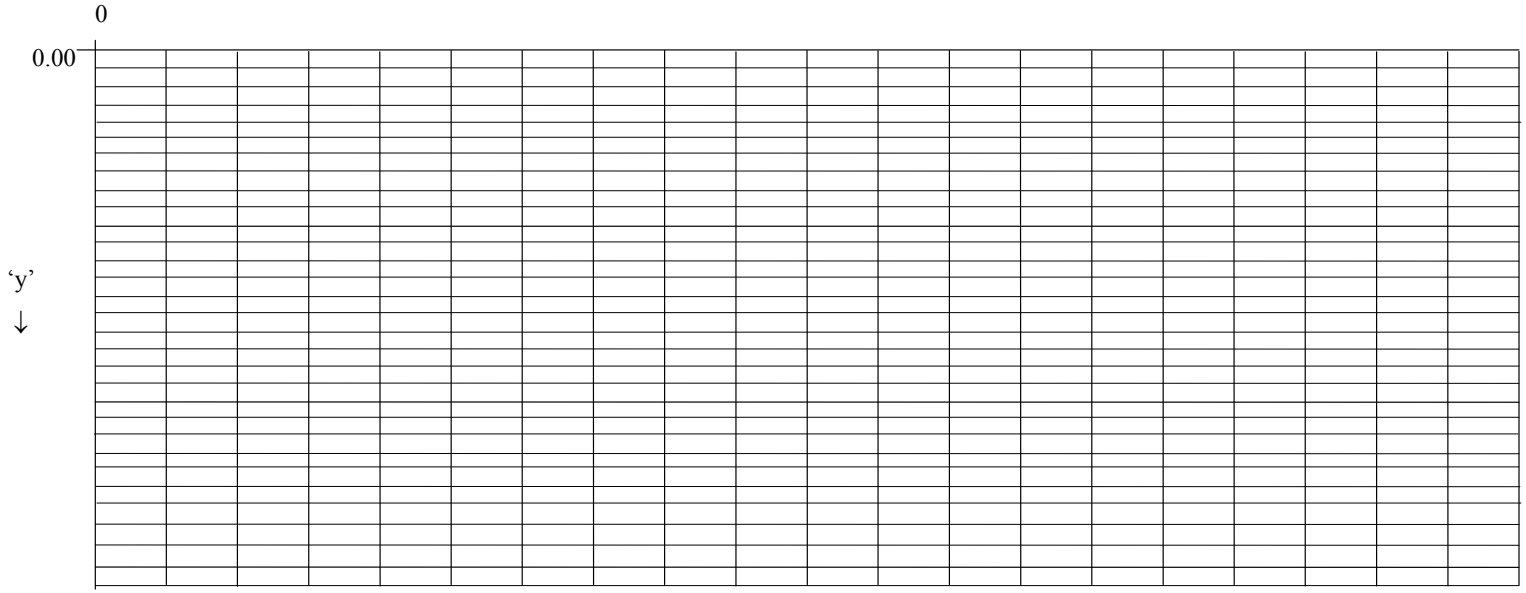
Format 19.3

Figure 19.2 Variation of Depth to Water Table Below Ground Level, 'y' in metres Over Successive Ground Water Years in Non - command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Index Number of Ground Water Assessment Unit :

Year (1, 2, 3, etc.) →



Year '1' which is the earliest ground water year for which water table data is available =

—⌫— Pre - monsoon interval Shows a Rise / Fall of cm per year
[From Table 14.9]

—o— Post - monsoon interval Shows a Rise / Fall of cm per year
[From Table 14.10]

CHAPTER 20

GROUND WATER ASSESSMENT IN TERMS OF ADMINISTRATIVE DEVELOPMENT UNIT

20.1 GENERAL

Ground water assessment units as adopted by a particular State/Union Territory can be, Block, Taluka, Mandal or Watershed. Whenever a 'Watershed' has been adopted as the ground water assessment unit, it is also necessary to present the results of ground water assessment in terms of an appropriate administrative development unit like, Block, Taluka or Mandal as the case may be. Each such administrative development unit will have to be sub-divided in to four sub-units namely, 'Hilly Area', 'Command Area', 'Non-command Area' and 'Poor Ground Water Quality Area' following the same guidelines described in Chapter 2. Ground water assessment is not made for the 'Hilly Area'. Ground water assessment results for the other three sub-units which are to be obtained are given below :

i) Command and Non-command areas

a) Net annual ground water availability
b) Current annual gross ground water draft for 'All Uses'
c) Stage of ground water development
d) Categorization as safe, semi-critical, critical or over exploited
e) Current annual gross ground water draft for 'Irrigation'
f) Annual allocation of ground water for 'Domestic and Industrial Water Supply'
g) Net annual ground water availability for 'Future Irrigation Use'

ii) Poor Ground Water Quality Area

a) Net annual ground water availability
b) Current annual gross ground water draft for 'All Uses'
c) Net annual ground water availability for 'All Future Uses'

20.2 ASSUMPTIONS

The ground water assessment for a given administrative development unit is based on the ground water assessment results obtained for those watersheds which are partly or wholly contained within the administrative development unit under consideration.

20.3 COMPUTATIONAL PROCEDURE

20.3.1 Administrative Development Unit and its Sub units

Each administrative development unit is assigned a unique name, and a unique index number (1/ 2/ 3 etc.). Location details of each administrative development unit, its area and area of the sub-units within it are presented in one table (Table 20.1.). The format to be adopted for this table is given in Format 20.1.

20.3.2 Command Area

20.3.2.1 Net annual ground water availability

The computational scheme for estimating the net annual ground water availability in the command area of the administrative development unit under consideration comprises of the following steps.

a) All those watersheds which have a portion of their command area falling within the command area of the administrative development unit under consideration are identified, and the area of each of those portions are obtained. Let the number of such watersheds be 'N', and let X(i), for i = 1 to N be the area of each of those portions. The sum of X(i) for i = 1 to N will be equal to the area of the command area of the administrative development unit.

b) Let Y(i), for i = 1 to N be the net annual ground water availability per unit area in the command areas of each of the N watersheds.

c) The net annual ground water availability in the command area of the administrative development unit under consideration is obtained as the sum of the product of X(i) and Y(i), for i = 1 to N.

The computations as described above for estimating the net annual ground water availability in the command area of a given administrative development unit are presented in one table (Table 20.2). The format to be adopted for this table is given in Format 20.2.

20.3.2.2 Current Annual Gross Ground Water Draft For All Uses

The computational procedure for this is similar to what has been described earlier, except that, Y(i) for i = 1 to N now represent the current annual gross ground water draft for 'All Uses' per unit area in the command areas of each of the N watersheds.

The computations for estimating the current annual gross ground water draft for 'All Uses' in command area of the given administrative development unit are presented in one table(Table 20.3). The format to be adopted for this table is given in Format 20.3

20.3.2.3 Current Annual Gross Ground Water Draft for Irrigation

The computational procedure for this is similar to what has been described earlier, except that, Y(i) for i =1 to N now represent the current annual gross ground water draft for 'Irrigation' per unit area in the command areas of each of the 'N' watersheds.

The computations for estimating annual gross ground water draft for 'Irrigation' in the command area of the given administrative development unit are presented in one table (Table 20.4). The format to be adopted for this table is given in Format 20.4.

20.3.2.4 Allocation for Domestic and Industrial Water Supply

The computational procedure for this is similar to what has been described earlier, except that, Y(i) for i = 1 to N now represent the annual allocation of ground water for 'Domestic and Industrial Water Supply' per unit area in the command areas of each of the 'N' watersheds.

The computations for estimating annual allocation of ground water for 'Domestic and Industrial Water Supply' in the command area of the given administrative development unit are presented in one table(Table 20.5). The format to be adopted for this table is given in Format 20.5

20.3.2.5 Water Table Trend

The water table trend in the command area of the given administrative development unit has to be obtained for both pre-monsoon and post-monsoon intervals. The computational scheme for estimating the water table trend in respect of the pre-monsoon interval comprises of the following steps :

a) All those watersheds which have a portion of their command area falling within the command area of the given administrative development unit are identified, and area of each of those portions are obtained. Let the number of such watersheds be 'N', and let X(i), for i = 1 to N represent the area of each of those portions. Let 'TA' represent the sum of X(i) for i = 1 to N. 'TA' incidentally, represents the area of the command area of the administrative development unit under consideration.

b) A Weightage factor W(i), for i = 1 to N is assigned to each of the N watersheds using the relation, W(i) = X(i)/TA. The sum of W(i) for i = 1 to N will be equal to 1.

c) Let Z(i) for i = 1 to N represent the trend of depth to water table below ground level in cm per year during pre-monsoon interval in the command area of each

of the N watersheds. Z(i) is positive for a falling water table condition, and negative for a rising water table condition.

d) The algebraic sum of W(i)*Z(i) for i = 1 to N is obtained. Let it be equal to 'AS'. This represents the trend of depth to water table below ground level in cm per year during pre-monsoon interval in command area of the given administrative development unit.

e) The water table in the command area of the administrative development unit under consideration during pre-monsoon interval shows

i) a falling trend if 'AS' is greater than or equal to +5 cm per year
ii) a rising trend if 'AS' is less than or equal to -5 cm per year
iii) neither a falling nor a rising trend if 'AS' is greater than -5 and less than +5 cm per year

The computational scheme for estimating the water table trend in respect of the post- monsoon interval is identical to what has been described above, except that Z(i) for i = 1 to N now represent the trend of depth to water table below ground level in cm per year during post-monsoon interval in the command area of each of the N watersheds.

The computations as described above for obtaining the water table trend in command area of the given administrative development unit during pre- monsoon and post- monsoon intervals are presented in one table (Table 20.6). The format to be adopted for this table is given in Format 20.6.

20.3.3 Non-Command Area

The computations to be performed for estimating the following components,

a) Net annual ground water availability
b) Current annual gross ground water draft for 'All Uses'
c) Current annual gross ground water draft for 'Irrigation'
d) Annual ground water allocation for 'Domestic and Industrial Water Supply', and
e) Water table trend

in the non-command area of the given administrative development unit are respectively identical to those given earlier in Section 20.3.2 for the command area. The computations are to be presented in five tables (Tables 20.7 to 20.11). The formats to be adopted for these five tables are given in Formats 20.7 to 20.11 respectively.

20.3.4 Poor Ground water Quality Area

The computations to be performed for estimating the following components,

a) Net annual ground water availability , and

b) Current annual gross ground water draft for 'All Uses'.

in the poor ground water quality area of the given administrative development unit are respectively identical to those given earlier in Section 20.3.2 for the command area. The computations are to be presented in two tables (Table 20.12 and 20.13). The formats to be adopted for these two tables are given in Formats 20.12 and 20.13 respectively.

20.3.5 Summary Report on Ground Water Assessment for Each Administrative Development Unit

The summary report on ground water assessment for each administrative development unit is to be presented. This summary report should contain the following information in addition to the ground water assessment components discussed earlier :

a) For Command and Non-command Area

i) Stage of ground water development computed as the current annual gross ground water draft for 'All Uses' expressed as a percentage of the net annual ground water availability.

ii) Categorization as safe, semi-critical, critical or over exploited on the basis of the set of criteria discussed earlier in Chapter 15. It may be recalled that, this set of criteria considers both the stage of ground water development, and the water table trend during pre-monsoon and post-monsoon intervals.

iii) The net annual ground water availability for 'Future Irrigation Use' computed by subtracting the sum of the current annual gross ground water draft for 'Irrigation' and the annual allocation of ground water for 'Domestic and Industrial Water Supply' from the net annual ground water availability .

b) For Poor Ground water Quality Area.

i) The net annual ground water availability for 'All Future Uses' is computed by subtracting the current annual gross ground water draft for 'All Uses' from the net annual ground water availability.

The summary report as discussed above is presented in one table (Table 20.14). The format to be adopted for this table is given in Format 20.14.

Format 20.1

Table 20.1 Location Details and Area of Each Administrative Development Unit and the Sub - units Within It

(When Ground Water Assessment Unit is a 'Watershed')

Name of Administrative Development Unit :

Index Number of Administrative Development Unit :

Type of Administrative Development Unit :
(Block / Taluka / Mandal)

Ground Water Assessment Year :

Sl. No. (1)	Description of item (2)	Quantity (3)
1	Reference number(s) of Survey of India Toposheet(s) of 1 in 50,000 scale in which the Administrative Development Unit is located	
2	Latitudes within which the Administrative Development Unit is located i) Starting ii) Ending	
3	Longitudes within which the Administrative Development Unit is located i) Starting ii) Ending	
4	Total Area in hectares of the **'Administrative Development Unit'**	
5	Area in hectares of the **'Hilly Area'**	
6	Area in hectares of the portion of the Administrative Development Unit in which ground water recharge is possible [(4) - (5)]	
7	Area in hectares of the **'Poor Ground Water Quality Area'**	
8	Area in hectares of the **'Command Area'**	
9	Area in hectares of the **'Non - command Area'**	

Format 20.2

Table 20.2 Net Annual Ground Water Availability in Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			
	Name of watersheds	Net annual ground water availability per unit area in the command area of the watershed in millimetres (From Table 12.1 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Net annual ground water availability in command area of the administrative development unit

a) in hectare metres = [Total in Col. (5)]

b) per unit area in millimetres = [((a) / (Total in Col. (4))) * 1000]

Format 20.3

Table 20.3 Annual Gross Ground Water Draft for 'All Uses' in Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			
	Name of watersheds	Annual gross ground water draft for 'All Uses' per unit area in the command area of the watershed in millimetres (From Table 3.1 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Annual gross ground water draft for 'All Uses' in command area of the administrative development unit

a) in hectare metres =
[Total in Col. (5)]

b) per unit area in millimetres =
[((a) / (Total in Col. (4))) * 1000]

Format 20.4

Table 20.4 Annual Gross Ground Water Draft for 'Irrigation' in Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			
	Name of watersheds	Annual gross ground water draft for 'Irrigation' per unit area in the command area of the watershed in millimetres (From Table 3.1 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Annual gross ground water draft for 'Irrigation' in command area of the administrative development unit

a) in hectare metres = [Total in Col. (5)]

b) per unit area in millimetres = [((a) / (Total in Col. (4))) * 1000]

Format 20.5

Table 20.5 Annual Ground Water Allocation for Domestic & Industrial Water Supply in Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their command area contained within the command area' of the administrative development unit			
	Name of watersheds	Annual allocation for domestic & industrial water supply per unit area in command area of the watershed in millimetres (From Table 16.1 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Annual ground water allocation for domestic & industrial water supply in command area of the administrative development unit

a) in hectare metres =
[Total in Col. (5)]

b) per unit area in millimetres =
[((a) / (Total in Col. (4))) * 1000]

Format 20.6

Table 20.6 Water Table Trend in Command Area

Name of Administrative Development Unit :

Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their command area contained within the command area of the administrative development unit					Pre - monsoon iterval	Post - monsoon interval
	Name of watersheds	Trend of depth to water table below ground level in cm / year		Area of portion of watershed as defined above in hectares	Weightage factor (5) / (Total in Col (5))		
		Pre - monsoon interval [From Table 14.4 of the watershed]	Post - monsoon interval [From Table 14.5 of the watershed]			[(3) * (6)]	[(4) * (6)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Trend of depth to water table below ground level in command area in cm per year [algebraic sum of Col. (7) for pre - monsoon and Col. (8) for post - monsoon]							

Water table trend in command area of the administrative development unit

(Rising / Falling / Neither Rise nor Fall) a)During Pre - monsoon Interval =

b) During Post - monsoon Interval =

Format 20.7

Table 20.7 Net Annual Ground Water Availability in Non - command Area

Name of Administrative Development Unit :

Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their non - command area contained within the non - command area of the administrative development unit			
	Name of watersheds	Net annual ground water availability per unit area in the non - command area of the watershed in millimetres (From Table 12.2 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Net annual ground water availability in non - command area of the administrative development unit

a) in hectare metres = [Total in Col. (5)]

b) per unit area in millimetres = [((a) / (Total in Col. (4))) * 1000]

Format 20.8

Table 20.8 Annual Gross Ground Water Draft for 'All Uses' in Non - command Area

Name of Administrative Development Unit :

Index Number of Administrative Development Unit :

Ground Water Assessment Year :

Sl. No.	Watersheds which have a portion of their non - command area contained within the non - command area of the administrative development unit			
	Name of watersheds	Annual gross ground water draft for 'All Uses' per unit area in the non - command area of the watershed in millimetres (From Table 3.2 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Annual gross ground water for 'All Uses' in non - command area of the administrative development unit

a) in hectare metres =
[Total in Col. (5)]

b) per unit area in millimetres =
[((a) / (Total in Col. (4))) * 1000]

Format 20.9

Table 20.9 Annual Gross Ground Water Draft for 'Irrigation' in Non - command Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their non - command area contained within the non - command area of the administrative development unit			
	Name of watersheds	Annual gross ground water draft for 'Irrigation' per unit area in the non - command area of the watershed in millimetres (From Table 3.2 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Annual gross ground water draft for 'Irrigation' in non - command area of the administrative development unit

a) in hectare metres = [Total in Col. (5)]

b) per unit area in millimetres = [((a) / (Total in Col. (4))) * 1000]

Format 20.10

Table 20.10 Annual Ground Water Allocation for Domestic & Industrial Water Supply in Non - command Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their non - command area contained within the non - command area of the administrative development unit			
	Name of watersheds	Annual allocation for domestic & industrial water supply per unit area in non - command area of the watershed in millimetres (From Table 16.1 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Annual ground water allocation for domestic & industrial water supply in non - command area of the administrative development unit

a) in hectare metres = [Total in Col. (5)]

b) per unit area in millimetres = [((a) / (Total in Col. (4))) * 1000]

Format 20.11

Table 20.11 Water Table Trend in Non - command Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their non - command area contained within the non - command area of the administrative development unit					Pre - monsoon interval [(3) * (6)]	Post - monsoon interval [(4) * (6)]
	Name of watersheds	Trend of depth to water table below ground level in cm / year		Area of portion of watershed as defined above in hectares	Weightage factor (5) / (Total in Col (5))		
		Pre - monsoon interval [From Table 14.9 of the watershed]	Post - monsoon interval [From Table 14.10 of the watershed]				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Trend of depth to water table below ground level in non - command area in cm per year [algebraic sum of Col. (7) for pre - monsoon and Col. (8) for post - monsoon]							

Water table trend in non - command area of the administrative development unit

(rising / falling / neither rise nor fall)

a) During pre - monsoon interval =

b) During post - monsoon interval =

Format 20.12

Table 20.12 Net Annual Ground Water Availability in Poor Ground Water Quality Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			
	Name of watersheds	Net annual ground water availability per unit area in the poor ground water quality area of the watershed in millimetres (From Table 12.3 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	(3) * (4) / 1000
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Net annual ground water availability in poor ground water quality area of the administrative development unit

a) in hectare metres =
[Total in Col. (5)]

b)per unit area in millimetres =
[((a) / (Total in Col. (4))) * 1000]

Format 20.13

Table 20.13 Annual Gross Ground Water Draft for 'All Uses' in Poor Ground Water Quality Area

Name of Administrative Development Unit : Ground Water Assessment Year :

Index Number of Administrative Development Unit :

Sl. No.	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			(3) * (4) / 1000
	Name of watersheds	Annual Gross ground water draft for 'All Uses' per unit area in the poor ground water quality area of the watershed in millimetres (From Table 3.3 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Annual gross ground water for 'All Uses' in poor ground water quality area of the administrative development unit

a) in hectare metres = [Total in Col. (5)]

b) per unit area in millimetres = [((a) / (Total in Col. (4))) * 1000]

Format 20.14

Table 20.14 Summary Report in Respect of Each Administrative Development Unit

(When Ground Water Assessment Unit is a 'Watershed')

Name of State / Union Territory :

Name of Administrative Development Unit :

Index Number of Administrative Development Unit :

Type Administrative Development Unit (Block / Taluka / Mandal) :

Predominant Type of Rock Formation :

Area in hectares of

a) Administrative Development Unit :
b) Command Area :
c) Non - command Area :
d) Poor Ground Water Quality Area :

Ground Water Assessment Year :

A. Command and Non - command Areas

Sl. No.	Description of item	Non - command area		Command area	
		in hectare metres	in mm	in hectare metres	in mm
1	Net annual ground water availability				
2	Current annual gross ground water draft for 'All Uses'				
3	Current annual gross ground water draft for 'Irrigation'				
4	Annual allocation of ground water for domestic and industrial water supply up to next 25 years				
5	Net annual ground water availability for 'Future Irrigation Use' [(1) - (3) - (4)]				

Sl. No.	Description of item	Non - command area	Command area
6	**Stage of ground water development** as a percentage [((2) / (1)) * 100]		
7	Does the water table during pre - monsoon interval show a falling trend (Yes / No)		
8	Does the water table during post - monsoon interval show a falling trend (Yes / No)		
9	**Categorisation for future ground water development** (Safe / Semi-critical / Critical / Over Exploited)		

B) Poor Ground Water Quality Area

Sl. No.	Description of item (in poor ground water quality area)	in hectare metres	in millimetres
1	Net annual ground water availability		
2	Current annual gross ground water draft for 'All Uses'		
3	Net annual ground water availability for 'All Future Uses' [(1) - (2)]		

Appendix 3.1 Average Annual Gross Ground Water Draft Per Well From Different Types Of Wells Used In Different States In India

Sl. No.	Name of State	Type of well	Average annual gross ground water draft per well in hectare metres
(1)	(2)	(3)	(4)
1	Andhra Pradesh	Dugwell with Mhot	0.35
		Dugwell with Pumpset	0.65
		Borewell with Pumpset	1.30
		Shallow Tubewell	2.05
		Medium Tubewell	4.10
		Deep Tubewell	5.85
2	Assam	Shallow Tubewell with Pumpset	3.00
3	Bihar	Dugwell	0.60
		Private Tubewell with Pumpset	1.00
		Bamboo Boring with Pumpset	0.75
		Deep Tubewell	30.00
4	Gujarat	Dugwell with Pumpset	0.80
		Borewell with Pumpset	1.20
		Private Shallow Tubewell	1.85
		Medium Deep Tubewell	6.00
		Deep Tubewell	30.00
5	Haryana	Dugwell with Pumpset	1.50
		Private Shallow Tubewell with Pumpset	1.81
		Deep Tubewell	15.00
6	Himachal Pradesh	Medium Deep Tubewell with Pumpset	2.50
7	Karnataka	Dugwell with Pumpset	0.90
		Borewell with Pumpset	1.70
		Dug cum Borewell with Pumpset	1.98
8	Kerala	Dugwell with Pumpset	0.50
		Borewell with Pumpset	0.70
9	Madhya Pradesh	Dugwell with Mhot	0.80
		Dugwell with Pumpset	1.50
		Borewell with Pumpset	1.50
		Private Shallow Tubewell with Pumpset	3.00
10	Maharashtra	Dugwell with Mhot	0.45
		Dugwell with Pumpset	1.57

Sl. No.	Name of State	Type of well	Average annual gross ground water draft per well in hectare metres
(1)	(2)	(3)	(4)
11	Orissa	Dugwell with Mhot	0.21
		Dugwell with Pumpset	1.00
		Filter Point with Pumpset	2.10
		Private Tubewell with Pumpset	7.00
		Deep Tubewell with Pumpset	17.5
12	Punjab	Shallow Tubewell with Pumpset	1.30 to 3.40
		Deep Tubewell with Pumpset	18.00
13	Rajasthan	Dugwell with Pumpset	0.52
		Private Tubewell with Pumpset	1.40
		Dug cum Borewell with Pumpset	1.23
		Deep Tubewell	2.28
14	Tamil Nadu	Dugwell with Pumpset	0.40 to 1.00
		Private Tubewell with Pumpset	1.00 to 2.00
		Borewell with Pumpset	1.00
15	Tripura	Shallow Tubewell with Pumpset	3.00
		Artesian Well	0.37
16	Uttar Pradesh	Dugwell with Mhot	0.37
		Dugwell with Pumpset	0.75
		Private Tubewell with Pumpset	3.70
		Deep Tubewell	22.00
17	West Bengal	Dugwell with Pumpset	0.30
		Private Tubewell with Pumpset	1.52
		Deep Tubewell with Pumpset	18.50

Appendix 4.1 Norms For Canal Seepage Factor

Sl. No.	Canal type (unlined / lined)	Soil type (normal / sandy)	Seepage factor in hectare metres per day per million square metres of wetted area
1	Unlined	Normal Soil	15 to 20
2	Unlined	Sandy Soil	25 to 30
3	Lined	Normal Soil	3 to 4
4	Lined	Sandy Soil	5 to 6

Note :

1) The above norms strictly apply only for alluvial terrain in which the water table is also relatively deep.

2) The seepage factor in the case of canals in hard rock terrain is assumed to be the same as that given above for lined canals in normal soil, i.e., 3 to 4 hectare metres per day per million square metres of wetted area.

3) The values for the seepage factor as given above may be also suitably reduced in the case of canals in shallow water table and waterlogged areas.

4) The seepage factor can be also adopted on the basis of results from documented field studies wherever they are available.

Appendix 5.1 Norms For Return Flow Factor For Irrigation Water Applied by Surface Water Irrigation

Sl. No.	Type of crop (Paddy / Non - paddy)	Range of depth to water table below ground level (< 10 metres / 10 to 25 metres / > 25 metres)	Return flow factor as a fraction
1	Paddy	< 10 metres	0.50
2	Paddy	10 to 25 metres	0.40
3	Paddy	> 25 metres	0.25
4	Non - paddy	< 10 metres	0.30
5	Non - paddy	10 to 25 metres	0.20
6	Non - paddy	> 25 metres	0.10

Note :

1) The return flow factors as given above are applicable for rotational supply of irrigation water from the outlet. They are to be increased by another 0.05 if the supply of irrigation water from the outlet is continuous. For example, in the case of non - paddy with range of depth to water table being less than 10 metres, the return flow factor is to be taken as 0.35 (0.30 + 0.05) when the supply of surface water irrigation from the outlet is continuous.

2) The return flow factor can be also adopted on the basis of results from documented field studies wherever they are available.

Appendix 6.1 Norms For Return Flow Factor For Irrigation Water Applied by Ground Water Irrigation

Sl. No.	Type of crop (Paddy / Non - paddy)	Range of depth to water table below ground level (< 10 metres / 10 to 25 metres / > 25 metres)	Return flow factor as a fraction
1	Paddy	< 10 metres	0.45
2	Paddy	10 to 25 metres	0.35
3	Paddy	> 25 metres	0.20
4	Non - paddy	< 10 metres	0.25
5	Non - paddy	10 to 25 metres	0.15
6	Non - paddy	> 25 metres	0.05

Note :

1) The return flow factors can be also adopted on the basis of results from documented field studies wherever they are available.

Appendix 10.1 Norms for Rainfall Infiltration Factor

A) **For Alluvial Terrain**

Sl. No.	Geographic location	Rainfall infiltration factor as a fraction		
		Recommended value	Maximum value	Minimum value
1	Indo - Gangetic plains and inland areas	0.22	0.25	0.20
2	East coast	0.16	0.18	0.14
3	West coast	0.10	0.12	0.08

B) **For Hardrock Terrain**

Sl. No.	Rock type	Rainfall infiltration factor as a fraction		
		Recommended value	Maximum value	Minimum value
1	Vesicular and Jointed Basalt	0.13	0.14	0.12
2	Semi-consolidated Sandstone	0.12	0.14	0.10
3	Weathered Granite, Gneiss and Schist with Low Clay Content	0.11	0.12	0.10
4	Weathered Granite, Gneiss and Schist with Significant Clay Content	0.08	0.09	0.05
5	Weathered Basalt	0.07	0.08	0.06
6	Laterite	0.07	0.08	0.06
7	Consolidated Sandstone, Quartzite, Non-cavernous Limestone	0.06	0.07	0.05
8	Granulite Facies like Charnockite etc.	0.05	0.06	0.04
9	Phyllites, Shales	0.04	0.05	0.03
10	Massive Poorly Fractured Rock	0.01	0.03	0.01

Note :

1) The recommended value of the 'Rainfall Infiltration Factor' alone as given above is to be adopted unless, results from documented field studies indicate that a value different from the recommended value can be used. Even in the latter case, the 'Rainfall Infiltration Factor' which is adopted has to be within the range of the maximum and minimum values as specified above.

2) The 'Rainfall Infiltration Factor' obtained on the basis of the norms as given above has to be increased by 0.02 for those sub-units in which watershed development with associated soil and water conservation measures are implemented.

Appendix 11.1 Norms for Specific Yield

A) **For Alluvial Terrain**

Sl. No.	Type of alluvium	Specific yield as a fraction		
		Recommended value	Maximum value	Minimum value
1	Sandy	0.16	0.20	0.12
2	Silty	0.10	0.12	0.08
3	Clayey	0.06	0.08	0.04

B) **For Hardrock Terrain**

Sl. No.	Rock type	Specific yield as a fraction		
		Recommended value	Maximum value	Minimum value
1	Karstified Limestone	0.08	0.15	0.05
2	Sandstone	0.03	0.05	0.01
3	Weathered Granite, Gneiss and Schist with Low Clay Content	0.03	0.04	0.02
4	Laterite	0.025	0.03	0.02
5	Limestone	0.02	0.03	0.01
6	Weathered or Vesicular Jointed Basalt	0.02	0.03	0.01
7	Weathered Granite, Gneiss and Schist with Significant Clay Content	0.015	0.02	0.01
8	Quartzite	0.015	0.02	0.01
9	Phyllites, Shales	0.015	0.02	0.01
10	Massive Poorly Fractured Rock	0.003	0.005	0.002

Note :

1) The recommended value of the 'Specific Yield' alone as given above is to be adopted, unless results from pump tests indicate that a value different from the recommended value can be used. Even in the latter case, the 'Specific Yield' which is adopted has to be within the range of the maximum and minimum values as specified above.

2) The 'Specific Yield' can be also adopted on the basis of 'Dry Season Ground Water Balance Method'. This method can be however used, only for non - command area in hardrock terrain.

Appendix 15.1 Micro Level Studies in 'Critical' and 'Over Exploited' Areas

It is necessary to carry out micro level studies in those sub-units of command and non-command areas which get categorized as 'Critical' or 'Over Exploited'. The approach to be followed in the micro level studies are given below :

1 Micro level studies in hardrock terrain should be based only on watershed as the type of ground water assessment unit.

2 The sub-units for which micro level studies are to be undertaken may be further subdivided in to suitable sub-areas on the basis of hydrologic (sub-watersheds), hydrogeologic (recharge/discharge/transition area) and geochemical considerations.

3 The number of observation wells should be increased so as to adequately well represent each such sub-area. There should be continuous water table data monitoring from at least one observation well in each sub-area.

4 Hydrological and hydrogeological parameters, particularly the specific yield, should be collected for different formations in each sub-area.

5 Details regarding other parameters like seepage from canals and other surface water sources should be collected after field studies, instead of adopting recommended norms. Base flow should be estimated based on stream gauge measurement.

6 The data on number of existing well structures and unit draft should be reassessed after fresh surveys and should match with the actual irrigation pattern in the sub-unit.

7 All data available with Central Ground Water Board, State Ground Water Departments and other agencies including Research Institutions and Universities etc., should be collected for the watershed/sub-areas and utilised for reassessment.

8 Ground water assessment for each sub-areas may be computed adopting the recommended methodology and freshly collected values of different parameters. The assessment may be made separately for monsoon and non-monsoon seasons as well as for command and non-command areas.

9 The ground water potential so worked out may be cross-checked with behavior of ground water levels in the observation wells and both should match. If it does not, the factors that cause such an anomaly should be identified and the revised assessment should be re-examined.

10 Based on the micro-level studies, the sub-areas within the unit and the unit as a whole may be categorized as per the criteria given in Chapter 15.