STATUS REPORT ON
REVIEW OF GROUND WATER RESOURCES ESTIMATION METHODOLOGY

R&D ADVISORY COMMITTEE ON GROUND WATER ESTIMATION

Central Ground Water Board
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1. BACKGROUND

Assessment of ground water resources are carried out at the state level at periodic intervals. The latest country-wide assessment was carried out for the year 2004 based on the methodology recommended by 'Ground Water Resources Estimation Committee – 1997'. Since, National Water Policy, 2002 suggests periodical reassessment of the ground water potential on a scientific basis, generally after each assessment, the methodology of assessment is reviewed in order to bring out further refinements in the subsequent estimations. An observation on similar lines was also made in the second meeting of Artificial Recharge of Ground Water Advisory Council held on 2007 wherein it was suggested that Ground water assessment methodology be reviewed for validation of practices. As a follow-up action, the methodology of the ground water assessment and the results of 2004 assessments were reviewed in the meetings of R&D Advisory Committee on Ground Water Estimation. The R&D Advisory Committee on Ground Water Estimation, is a Standing Committee constituted by Government of India to look into various aspects of ground water resources estimation. It is chaired by Chairman, Central Ground Water Board and the members of the committee include General Manager, NABARD, Member (SAM), CGWB, Director, Drought Monitoring Cell, Govt. of Karnataka and Director GSDA, Government of Maharashtra. The constitution of the R&D Advisory Committee on Ground Water Estimation is given in Annexure 1. During the ninth and tenth meetings of the committee which were held in 2008, various aspects of the ground water estimation methodology were reviewed in an open forum wherein apart from the members of the committee, several delegates participated, including - Member (SM&L), CGWB, Regional Directors and Scientists of CGWB, State Ground Water Departments, IIT Delhi, NIH, Roorkee, Director (Statistics), M.I. Division, MOWR etc. The complete lists of the delegates who have attended the ninth and tenth meetings of R&D Advisory Committee on ground water estimation are given in Annexure 2. This document presents the outcomes of the above mentioned meetings on review of ground water estimation methodology. The document has been prepared by a team comprising –

1. Rana Chatterjee, Scientist 'D', CGWB
2. A.V.S.S. Anand, Scientist 'C', CGWB
3. D. Venkateshwaran, Scientist 'B', CGWB

2. HYDROLOGIC CYCLE & GROUND WATER FLOW PATTERN

The hydrosphere, atmosphere and upper part of the lithosphere constitute the three media in which the water of the earth circulates. Water enters the hydrologic system as *precipitation*, in the form of rainfall or snowmelt. Water leaves the system as streamflow or *runoff*, and as *evapotranspiration*, a combination of evaporation from open bodies of water, evaporation from soil surfaces, and transpiration from the soil by plants. Precipitation is delivered to streams on the land surface as *overland flow* to tributary channels and in the subsurface as *interflow* or *lateral subsurface flow* following *infiltration* into the soil (Sophocleous, 2003).

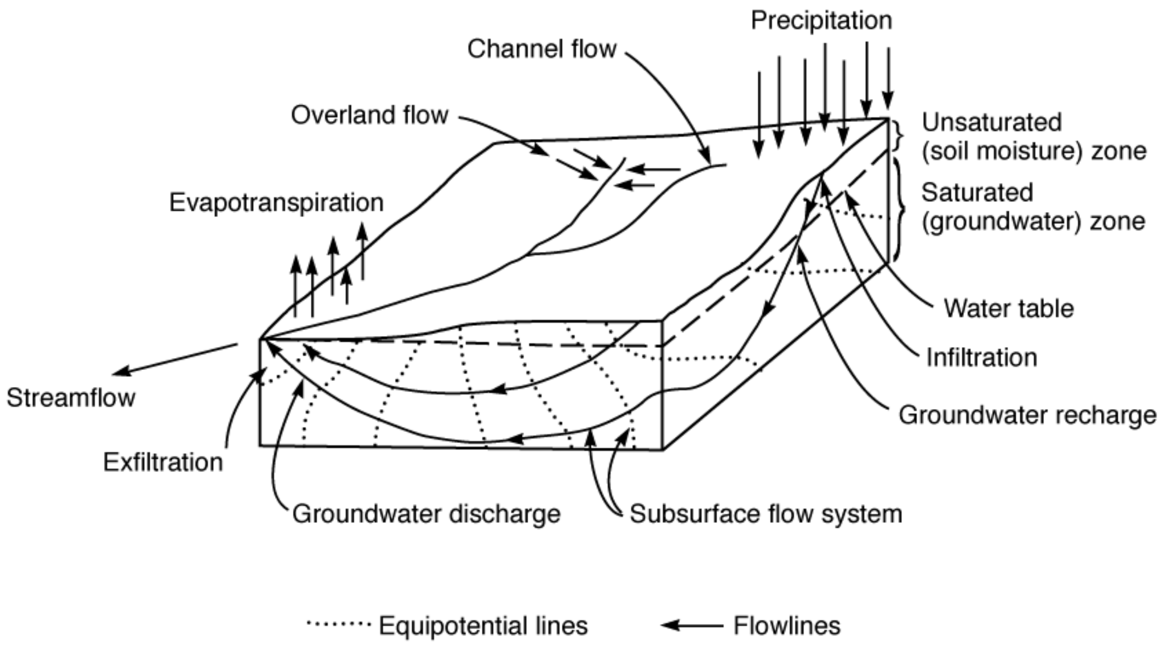

Figure 1. Schematic representation of the hydrologic cycle (from Freeze, 1974).

A portion of the infiltrated water enters the groundwater or aquifer system by passing through the *vadose* or *unsaturated zone*, and it exits to the atmosphere, surface water, or to plants. An aquifer is an underground water saturated stratum of formation that can yield usable amounts of water to a well. The entry of the infiltrated water to the aquifer at the water table surface is known as *Groundwater recharge* and its removal from the aquifer is known as *Groundwater discharge*. As Figure 1 shows, the flow-lines deliver groundwater from the highlands towards the valleys or from the recharge areas to the discharge areas. In a *recharge area* there is a predominant downward groundwater flow. Conversely, in a *discharge area* there is a predominant upward groundwater flow. The patterns of groundwater flow from the recharge to the discharge areas form *groundwater flow systems*, which constitute the framework for understanding the recharge processes (Sophocleous, 2003).

3. METHODOLOGY FOR GROUND WATER RESOURCE ESTIMATION

Ground water being a replenishable resource, its proper and economic development on a sustainable basis requires its realistic assessment. However, the complexities of the processes governing occurrence and movement of ground water make the problem of ground water assessment somewhat difficult, mainly because not only enormous data is to be collected, but a multidisciplinary scientific approach is to be adopted in space and time. Quantification of ground water resources is often critical and no single comprehensive technique is yet identified which is capable of estimating accurate ground water resources.

Ground water resource estimation must be seen as an interactive procedure. Initial estimates are revised and refined by comparing these to results of other methods and ultimately with its field manifestation. The methodologies adopted for computing ground water resources have undergone a continuous change and adohocism adopted earlier have given way to definite field tested norms. The computation methods, like the ground water resources itself, are dynamic in nature and gradual refinement is being taken place with the generation of more and more data input and with better understanding of the science of ground water.

3.1 Historical background

The assessment of water resources of the country dates back to 1901 when First Irrigation Commission assessed the Surface Water Resources as 144 million hectare meters (M.ham) (NABARD, 2006). In 1949 Dr. A. N. Khosla based on empirical formula estimated the total average annual runoff of all the river systems of India including both surface and ground water resources as 167 M.ham (Central Ground Water Board, 1995). Since then attempts have been made from time to time by various Working Groups/ Committees/Task Forces constituted by Govt. of India to estimate the ground water resources of the country based on available data and in response to developmental needs. In 1976, the National Commission of Agriculture assessed the total ground water resources of the country as 67 M.ham. and the Usable ground water was worked out to be 35 M.ham, out of which 26 M.ham was considered available for irrigation (Central Ground Water Board, 1995).

The first systematic methodology to estimate the ground water resources of the country was evolved by Ground Water Over Exploitation Committee in 1979. The committee was constituted by Agriculture Refinance and Development Corporation (ARDC) and was headed by Chairman, CGWB with Members from – State Ground Water Organizations and Financial Institutions. Based on the norms suggested by the committee, the country's Gross Ground Water Recharge has been assessed as 47 M.ham. and the Net Recharge as 32 M.ham (Central Ground Water Board, 1995).

In 1982, Government of India constituted 'Ground Water Estimation Committee' (GEC) drawing Members from various States / Central organizations engaged in hydrogeological studies and ground water development. The Committee submitted its recommendations in the year 1984 and suggested a methodology (GEC-1984) for estimation of dynamic ground water resources. As per the recommendations of the GEC-1984 the State Governments were advised to constitute Working Groups for assessment of ground water potentials. The Working Groups were headed by Irrigation Secretaries-

Incharge of Ground Water Developments and included Heads of Ground Water Department, State Agriculture Departments, representatives from Agriculture Universities and NABARD. Director, CGWB was the convener of the group. The base year for computation of the resource mostly varied between 1991 and 1993 and a National report on Ground Water Resources of India was brought out in 1995 by compiling the data of all the States and Union Territories of the country. As per the report, the total Replenishable Ground Water in India was estimated to be about 432 billion cubic meter. The ground water resource available for irrigation purpose was about 361 billion cubic meter. The Net Ground Water Draft from Irrigation uses was around 115 billion cubic meter and the level of development was 32%. The volumetric resource was converted in terms of area and the Utilizable Irrigation Potential from ground water of the country was worked out to be 64 million hectare (Central Ground Water Board, 1995).

Increasing thrust on ground water and changed scenario of data acquisition led the Government of India to form another Committee in 1995 to review the existing methodology for ground water resource estimation and to suggest revisions if necessary. The committee submitted its report in 1997 wherein a revised and elaborate methodology for resource estimation has been suggested, more commonly called as GEC-1997. While estimating the ground water resources in the hard rock terrains some limitations have been observed. To address these limitations another committee on Ground Water Estimation Methodology in Hard Rock Terrain was formed in 2001 to review the existing methodology for resource estimation in hard rock terrains. The Committee made certain suggestions on the criteria for categorization of blocks to be adopted for the entire country irrespective of the terrain conditions. Based on GEC-1997, the dynamic ground water resources of India was estimated for the entire country with 2004 as base year. The annual replenishable ground water resources is 433 billion cubic metre (bcm). Keeping an allocation for Natural Discharge during non-monsoon season of 34 bcm, the Net Annual Ground Water Availability has been estimated as 399 bcm. The annual ground water draft for all uses is of the order of 231 bcm and the overall Stage of ground water development for the entire country is 58%. Out of total 5723 assessment units in the country, 4078 assessment units have been categorized as Safe, 550 as Semi-Critical, 226 as Critical and 839 as Over-Exploited (Central Ground Water Board, 2006).

As per the recommendations of the committee on Ground Water Estimation Methodology in Hard Rock terrain, a Standing Committee named R&D Advisory Committee on Ground Water Resource Estimation was formed by Govt. of India in 2004 to look into the various aspects of resource estimation. The committee is looking into various issues related to ground water resources estimation methodology, computation procedures and field related issues.

3.2 Existing methodology for ground water resource estimation (GEC-1997)

Ground water resources are estimated assessment unit wise. The assessment unit is watershed in the states occupied predominantly with hard rocks. This is because the ground water balance equations recommended in GEC-1997 can be better applied in the assessment units with hydrologic/ hydrogeologic boundaries. However, in the states covered predominantly with alluvium areas and/ or soft rocks, administrative blocks are chosen as assessment unit since in alluvial areas it is difficult to identify watershed considering the trans boundary aquifer system. The area of watershed varies from 9 sq.km. to about 1900 sq.km. and area of block ranges from 3 to about 9000 sq.km. Within the assessment areas, the hilly areas (slope greater than 20%) are to be excluded since these are not likely to contribute to ground water recharge. The assessment units are to be divided into command and non-command areas for the purpose of computation of ground water resources. The ground water resource in the poor quality areas are to be computed separately (Ministry of Water Resources, 1997).

The ground water recharge is estimated season-wise both for monsoon season and non-monsoon season. The following recharge and discharge components are assessed in the resource estimation - recharge from rainfall, recharge from canal seepage, return flow from irrigation, recharge from water tanks & ponds and recharge from water conservations structures and discharge through ground water draft.

Estimation of ground water draft

Ground water draft is estimated seasonally. The most commonly used method for computation of irrigation draft is – number of structures multiplied by the unit seasonal draft. Alternative methods like area irrigated by ground water and the associated crop water requirements are also recommended for estimation of ground water draft for irrigation. Ground water draft for Domestic & Industrial needs are computed using unit draft method and based on consumptive use pattern of the population.

Estimation of ground water recharge from other sources

Ground water recharge due to return flow from irrigation, seepage from canals, recharge from tanks and ponds and recharge form water conservation structures are to be estimated individually for both monsoon and non-monsoon seasons based on the recommended norms as given in Table I. The details of the norms are given in Annexure I.

Table I Estimation of Recharges from Other Sources

Parameters	Recharge sources	Range of Parameters
Canal seepage factor	Unlined canals	15 to 30 ham/day/million sq.m. of wetted area
	Lined canals & canals in hard rock terrain	20% of above value for unlined canals
Return flow factor	Surface water Irrigation	0.10 – 0.50
	Ground water Irrigation	0.05 – 0.45
Seepage from tanks and ponds	1.4 mm/day over the on average water spread area	
Water conservation structures	50% of the Gross Storage. Out of this, 50% is during monsoon season and the remaining 50% during non-monsoon season	

(Source: Ministry of Water Resources, 1997)

Estimation of ground water recharge from rainfall

Ground water recharge from rainfall is estimated for monsoon and non-monsoon seasons separately.

Rainfall recharge during monsoon season is estimated using two methods – Water level fluctuation Method and Rainfall Infiltration Factor Method.

Water level Fluctuation (WLF) Method

Under this method the change in storage will be computed by multiplying water level fluctuation between pre and post monsoon seasons with the area of assessment and specific yield.

$$\text{Change is Storage} = \nabla S = h * Sy * A \qquad \ldots\ldots(i)$$

Where,

h = rise in water level in the monsoon season, A = area for computation of recharge, Sy = specific yield.

The specific yield values considered in the computations are to be taken preferably from field tests, in the absence of which, the recommended values of specific yield are to be considered. The range of specific yield recommended for different formations are given in the table II. Details are given in Annexure I.

Table II Specific Yield for Different Formations

Formation		**Range of Specific Yield**
Unconsolidated formations	Alluvium	0.04 to 0.20
Semi-consolidated formations	Sedimentary rocks	0.01 to 0.15
Consolidated formations	Crystallines and other hard rocks	0.002 to 0.04

(Source: Ministry of Water Resources, 1997)

The change is storage is calculated from the above relation is the resultant of the recharge from rainfall and other sources during the monsoon period and the gross ground water draft during monsoon season. In order to segregate the rainfall recharge during monsoon season, the following equation is used –

$$Rrf = h \text{ X } Sy \text{ X } A + DG - Rc - Rsw - Rt - Rgw - Rwc \qquad \ldots\ldots\ldots(ii)$$

Where,

DG = Gross ground water draft for all uses during monsoon season

Rc = recharge due to seepage from canals during monsoon season

Rsw = recharge from surface water irrigation during monsoon season

Rt = recharge from storage tanks and ponds

Rgw = recharge from ground water irrigation during monsoon season

Rwc = recharge from water conservation structures during monsoon season

The rainfall recharge thus calculated is the normalized for the normal monsoon season rainfall.

Rainfall Infiltration Factor (RIF) Method

The other method for estimation of rainfall recharge is using Rainfall infiltration factor. The recharge from rainfall is to be estimated as given below

$R_{rf} = f * A *$ normal monsoon rainfall ……….(iii)

Where ;

f = rainfall infiltration factor

A = area

The same Rainfall Infiltration Factor should be used for computation of recharge due to rainfall during monsoon and non monsoon seasons.

The norms adopted for computation of recharge from rainfall is given in Table – III.

Table – III Rainfall Infiltration Factor for different formations

Formation		**Range of Rainfall Infiltration Factor**
Unconsolidated formations –	Alluvium	0.08 to 0.25
Semi-consolidated formations	Sedimentary rocks	0.03 to 0.14
Consolidated formations	Crystallines and other hard rocks	0.01 to 0.12

The rainfall recharge computed by WLF method is to be compared with recharge computed by RIF method. In case the difference between the two sets of data are more than 20%, then rationalized RIF figure is to be considered, otherwise monsoon recharge using WLF method is to be considered. Whenever the percent difference is less than -20%, 80 % of the recharge computed by RIF method is to be used and wherever, the percent difference is more than + 20 %, 120 % of recharge computed by RIF method is to be taken.

Ground water Recharge during Monsoon Season

The total recharge in monsoon season is the sum of the normalized rainfall recharge and the recharge from other sources as expressed in the following equation –

R(normal) = Rrf (normal)+ Rc + Rsw + Rt + Rgw + Rwc ……….(iv)

Where,

R (normal) = Total recharge during monsoon season

Rrf (normal) = Rainfall recharge during monsoon season for normal monsoon season rainfall

Ground water Recharge during non-Monsoon Season

Similar expression as given in equation (iv) above is used for recharge during non-monsoon season wherein all the recharge components including rainfall recharge and recharge from other sources during non-monsoon season are computed. Only difference is that rainfall recharge during non-monsoon is computed using RIF method only. If the rainfall during non-monsoon period is less than 10% of the annual rainfall, the recharge due to rainfall is taken as zero. The total recharge during non monsoon is the sum of recharge from rainfall and recharge from other sources.

Annual Replenishable Ground Water Resource

The Annual Replenishable Ground Water Resource of the area is the sum of recharge during monsoon and non monsoon seasons. An allowance is kept for natural discharge during non monsoon season by deducting 5% of Annual Replenishable Ground Water Resource, wherever WLF method is employed to compute rainfall recharge during monsoon season and 10% if RIF method is used.

Net Annual Ground Water Availability

The Net annual ground water availability is the available resource after deducting the natural discharges from the Annual Replenishable Ground Water Resource and is expressed as:-

Net Annual Ground Water Availability = Annual Replenishable Ground Water Resource – Natural Discharge during non monsoon season ……………(v)

Future Utilization of Ground Water Resource

The allocation for domestic and industrial water supply is kept based on projected population for the year 2025 and present ground water requirements. The ground water available for future irrigation is obtained by deducting the sum of projected demand for Domestic and Industrial use and existing gross irrigation draft from the Net Annual Ground Water Availability.

Stage of Ground Water Development

The stage of Ground water Development is to be computed as given below,

Stage of Ground Water Development = (Existing Gross Ground Water Draft for all uses/ Net Annual Ground Water Availability) X 100 …………….(vi)

Categorization of Assessment Units

The assessment units are to be categorized for ground water development based on two criteria – a) stage of ground water development, and b) long-term trend of pre and post monsoon water levels. The long term ground water level trend is to be computed generally for a period of 10 years. The significant rate of water level decline has been taken between 10 and 20 cm per year depending upon the local hydrogeological conditions. There are four categories, namely – ‘Safe’, ‘Semi-critical’, ‘Critical’ and ‘Over-exploited’ areas. In ‘Over-exploited’ units, the annual ground water abstraction exceeds the annual replenishable resource and there is significant decline in long term ground water level trend either in pre- monsoon or post- monsoon or both. In ‘Critical’ assessment units, the stage of ground water development is above 90 % and within 100% of annual replenishable resource and there is significant decline in the long term water level trend in both pre-monsoon and post-monsoon seasons. Semi-critical units have stage of ground water development between 70% and 100% and significant decline in long term water level trend in either pre-monsoon or post-monsoon season. In 'Safe' assessment units, stage of ground water development is less than or equal to 70% and there is no significant decline in water level.

3.3 Validation processes in built in the ground water resources estimation methodology

There are various validation processes inbuilt in the methodology. These are described in the following paragraphs:–

Recharge due to Rainfall during monsoon season is estimated by subtracting the recharge due to other sources from the change in storage and then by adding gross ground water draft for all uses during monsoon season. This recharge and corresponding rainfall for atleast past five years will be used in normalizing the recharge due to rainfall during monsoon season.This data which yield negative or near zero as the recharge due to rainfall during monsoon indicate that there is an error in the data being used in the computation. The most vulnerable data element in the computation is the water level. In the normalization procedure such pair of data is ignored and the methodology will be applied where the rainfall recharge is neither negative nor near zero. In the situation where in all the pairs of data the rainfall recharge is negative or near zero, the water level fluctuation method is not going to be applied and in place only rainfall infiltration method is adopted. This validation procedure will reduce the error where ever our water levels are not representative.

Percent Difference: The rainfall recharge computed by Water Level Fluctuation method during monsoon season is to be compared with recharge computed by Rainfall Inflitration Factor method. Percent Difference is computed to quantify the difference in between these two estimated figures. The percent difference is calculated by applying the following equation:

$$PD = \frac{R_{Rf}(wtfm) - R_{Rf}(rifm)}{R_{Rf}(rifm)} \times 100$$

Where

PD = Percent Difference
RRf(wtfm) = Rainfall Recharge for normal monsoon season rainfall estimated using Water Table Fluctuation Method
RRf(rifm) = Rainfall Recharge for normal monsoon season rainfall estimated using Rainfall Infiltration Factor Method

In case the difference between the two sets of data is within –20% and +20% , It can be concluded that the estimates by both the methods are in agreement and hence the estimate by water level fluctuation method will be used in the further computations. If the difference is less than –20% then 0.80 times of the estimate calculated using Rainfall Infiltration factor Method will be utilized and if the percent difference is more than +20%, 1.20 times of the estimate calculated using Rainfall Infiltration factor Method will be utilized as the recharge due to rainfall during Monsson season. This is one of the Validation procedure in built in the methodology to assess the accuracy of the computation and if found erroneous, attempt is made to reduce the error.

Water Table Trend: In GEC-1997, Water Table Trend is being considered as a second criteria for assigning the category to the assessment unit in addition to the stage of ground water development. The water Table trend is basically a validationprocedure based on which some of the estimates are marked as to be reassessed. Water Table trend is basically a reflection of the ground situation and hence, if the exercise and the data involved in the exercise are realistic,error free and representative it should match with the ground water level trends. But due to heterogeneity, Anisotropy especially in hard rock areas and in command areas where the aquifers are not ready to accept any recharge, problems may occur. In such situations detailed assessment need to be carried out taking into consideration the representativeness of the data, heterogeneity and anisotropy.

4. REVIEW OF METHODOLOGY

The methodology for ground water resources estimation is based on relatively sound scientific basis. It also meets adequately well the practical requirements for formulating rational ground water development strategies. Further, it commensurates with the available human resources, the level of technical skills and available infrastructure facilities with the state level ground water organizations which have to actually apply the methodology. However, it is also to be recognized that the methodology has considerable scope for refinements and improvements which can be planned to be achieved in a phased manner for future assessment. The review of the methodology consists of three major issues, namely,

* Review of equations used in the methodology.
* Review and refinements of norms used in the estimation of various parameters
* Strengthening of database used for estimation.

4.1 Review of equations used in the methodology

The equations used in the computation of dynamic ground water resources is based on water balance approach. In the existing methodology, the individual components of ground water recharge and withdrawal are being assessed (equ. i, ii, iv). The equations were examined by comparing the resultant withdrawal (net draft) from the ground water reservoir with the individual components of gross ground water draft and return flow from ground water irrigation to find out which of the estimate is closer to the field situations.

Following equations/formulae were reviewed by carrying out exercises in sample assessment units in three states namely Andhra Pradesh, Maharashtra and Rajasthan.

(I) Computation of recharge during the monsoon season.

Original equation (Recommendation of GEC-1997)

(from equ. i & ii, mentioned above)

$R = \nabla S + DG$

$Rrf = R - Rgw - Rwc - Rt - Rsw - Rc$

Alternate Equation

$R = S + DG - Rgw$

$Rrf = R - Rwc - Rt - Rsw - Rc$ ....(vii)

(II) Estimation of normal recharge during the monsoon season

Original equation (Recommendation of GEC-1997)

(equ. iv mentioned above)

$R(normal) = Rrf\ (normal) + Rc + Rsw + Rt + Rgw + Rwc$

Alternate Equation

R(normal) = Rrf (normal) + Rc+Rsw+Rt+Rwc ………(viii)

(III) Stage of Ground Water Development

Original equation (Recommendation of GEC-1997)

(equ. vi, mentioned above)

Stage of ground water development = (Existing gross ground water draft for all uses / net annual ground water availability) X 100

Alternate Equation

Stage of ground water development = (Existing net ground water draft for all uses / net annual ground water recharge) X 100 ……(ix)

IV Review of procedure for estimating Allocation of Ground Water Resources for Domestic and Industrial needs wherever the ground water draft is equal to or more than ground water recharge.

The outcome of the exercises carried out in the three States are summarized in the following paragraphs. Detailed figures are given in Appendix I.

Andhra Pradesh:- The studies were taken up by CGWB in four watersheds in the districts of Srikakulam, Mehaboobnagar, Kareemnagar and West Godavari using the original and modified equations. The hydrogeology of the study area includes Granitic gneiss, Granites and Sand stones. Areas fall in both command and Non-command areas. Categorization of the Assessment units ranges from Safe to Critical. The study concluded that conceptually the draft and return flow from ground water irrigation are two different components in the ground water balance equation and the modification will never give the same result mathematically unless and until the return flow from ground water irrigation tends to zero and it is not going to make any simplicity in the assessment exercise. The Ground Water Department, Government of Andhra Pradesh pointed out that the comparison of stage of Ground Water Development obtained by using Net Draft and Gross Draft has revealed that there is no significant difference upto 100% stage of ground Water Development.

Maharashtra:- CGWB took up the exercise in four watersheds namely TE-11, TE-50B, WF-46,WGK-03 falling in the districts of Jalgaon, Dhule, Ratnagiri and Nagpur. Hydrogeologically the areas fall in Alluvium, Basalt, Granitic Gneisses and includes both command and non-command areas. The Categorization of the areas range from Safe to Over-Exploited. The results of the exercise indicate that the recharge has reduced and Categorization has changed in 2 watersheds out of 4 watersheds due to the modified equation. Deducting same amount of recycled ground water from total recharge and total draft mathematically will never give the same result as earlier. Ground Water Surveys and Development Agency (GSDA), Government of Maharashtra has carried out this exercise for all 1505 watersheds and found that there is reduction in the stage of Ground

Water Development by 4 to 10% category wise. Categorization has changed in 32 watersheds out of 1505 watersheds which are lying in the border category.

Rajasthan:- In the state of Rajasthan, CGWB, WR has taken up exercises in four blocks situated in Alluvium as wells as in hard rock areas. These areas are located in non-command sub-units. Three of these blocks fall in Over-exploited and one is in Safe category. The analysis of the results indicates that the variation in the stage of ground water development computed by the two equations depends on the original stage of ground water development using GEC-1997 equation. Ground Water Department, Government of Rajasthan has also opined the same.

Based on the outcome of the studies, it is concluded that the existing equations of GEC – 1997 should be retained for the computation of dynamic ground water resources.

The procedure used for computation of allocation of demestic and industrial needs were studies to eliminate the confusion regarding negative availability of Ground water resources for future irrigation needs. The following procedure is suggested:

- Case I, when GWav ≥ Dgi+ Alld

In such cases Allocation for future domestic requirement = Alld

- Case II, when GWav < Dgi+ Alld

In such cases Allocation for future domestic requirement = (GWav – Dgi) or Dgd, whichever is more.

where,
GWav = Net Annual Ground Water Availability
Dgi = Existing Ground Water draft for Irrigation
Dgd = Existing Ground Water draft for Domestic use
Dg = Existing Ground water draft for all uses
Alld = Computed value of allocation for domestic use
(based on projected population, fractional load and percapita requirement)

4.2 Review and refinements of norms used in estimation of various parameters

The various norms which are being used for the computation of ground water resources include Rainfall Infiltration Factor, Specific Yield, Canal seepage factor, return flow factor for the recharge due to surface water irrigation and ground water irrigation, seepage factor for the recharge due to tanks and ponds, recharge factor water conservation structures, unit draft etc.

These norms were derived from various studies undertaken by CGWB, State Ground Water Departments and Academic Institutes in collaboration with International Agencies.

Some of the prominent studies include:-

- Water Balance Projects of CGWB – 12 in nos. through bilateral cooperation or indigenous efforts – Specific Yield, Rainfall Infiltration Factor (RIF), Canal seepage, return flow from irrigation, recharge from tanks etc.
- Studies in canal and tank command areas by Indian Institute of Science and Narmada Planning Agency, MP – Specific Yield, RIF and recharge from irrigation.

- Studies in various parts of Karnataka – by Indian Institute of Science and National Drinking Water Mission – Specific Yield and RIF.
- Studies by National Geophysical Research Institute – Rainfall recharge in various parts of the country by Isotope technique.
- Studies by Punjab Agricultural University in PAU farm – Return seepage from irrigation.
- Studies by U.P. Irrigation Research Institute, Roorkee by Isotope technique – Rainfall recharge and recharge due to applied irrigation.
- Studies by GSDA, Govt. of Maharashtra and CGWB – Informations on recharge due to water conservation structures.
- Studies by National Institute of Hydrology – Rainfall recharge factor, seepage loss from canals, recharge from percolation tanks and return flow from irrigation.

(Ministry of Water Resources, 1984,1997)

4.2.1 Comparison of norms recommended by various Ground Water Estimation Committees

The norms used for estimation of various components of ground water resources have been periodically evaluated and modified based on field studies carried out by the CGWB, State Ground Water Departments and Academic Institutions to achieve refinement in ground water assessments. The refinement in norms carried out by the subsequent methodologies are summarized in table IV.

Table IV: Comparison of Norms recommended by various Ground Water Estimation Committees over years

Sl. No.	Parameter	Over-Exploitation Committee, 1979	Ground Water Estimation Committee, 1984	Ground Water Resources Estimation Methodology, 1997
1.	Rainfall Recharge factor	Specified range have been suggested for **3** lithological formations; Hard rocks were clubbed under one group	Specific range have been suggested for **8** lithological formations ; Hard rocks were segregated into various types of sandstones, granites, basalts and other meta - sedimentary formations	A single recommended value alongwith specified ranges have been suggested for **13** lithological formations; apart from modifying existing norms, additional formations like laterite, granulite, massive hard rocks etc. have been included. Norms would vary in case watershed developments associated with soil conservation measures are adopted.
2.	Specific Yield	Specified range suggested for **4** lithological formations	Specified range suggested for **10** formations	Single recommended value alongwith Specified range suggested for **13**

				formations including various types of alluvium, granite, basalt, laterite, quartzite, sedimentary formations and massive hard rocks
3.	Canal Seepage factor	**2** Norms recommended for normal type of soils and sandy soils	**3** Norms recommended based on soil types and lining of canals	**3** Norms recommended based on soil types and lining of canals
4.	Return flow factor – Surface water irrigation	**2** Norms recommended based on cropping pattern i.e. paddy and non-paddy	**2** Norms recommended based on cropping pattern i.e. paddy and non-paddy	**6** Norms recommended based on cropping pattern i.e. paddy & non-paddy and depth to water level. Norms would also vary depending upon continuity of water supply.
5.	Return flow factor – Ground water irrigation	A **single** Norms was recommended	**2** Norms recommended based on cropping pattern i.e. paddy and non-paddy	**6** Norms recommended based on cropping pattern i.e. paddy & non-paddy and depth to water level. Norms would also vary depending upon continuity of water supply.
6.	Seepage factor – tanks	Norm recommended based on total water spread area	Norm recommended based on total water spread area	Norm recommended based on average water spread area
7.	Recharge factor – water conservation structures	No norm recommended	Norm for percolation tank recommended	Norm for percolation tank and check dams/nala bunds recommended
8.	Unit Ground Water Draft	No norm recommended	Area irrigated by different abstraction structures recommended state-wise; norms for **11** states recommended	Unit annual ground water draft recommended for different ground water structures – state wise; norms recommended for **17** states

(Source: NABARD, 2006)

The details of norms for different parameters recommended by various formations are presented in Appendix 2. A perusal of table IV would show that successive methodologies have attempted to diversify the norms taking into consideration the heterogeneity in the hydrogeological setup of the country. The salient points on refinements in norms carried out by the ground water estimation committees are as follows.

- ***Rainfall Recharge factor***: Initially, the Over-Exploitation Committee (1979) recommended Rainfall Recharge norms for only three (3) lithological units including one broad group called hard rock. Subsequent methodologies have provided norms for further variations within hard rocks. In GEC-1997 as much as thirteen (13) major lithological units have been identified for which norms on Rainfall Recharge are given. Also in the latest methodology (1997), a single value has been recommended alongwith the range. In case documented field studies indicate the value of Rainfall Recharge of a particular lithological unit is different from the single value assigned for that unit, the field value would be adopted for recharge estimation only if it is within the specified range recommended in the methodology.
- ***Specific Yield***: Initially (1979) specific yield norms were recommend for only four major lithological units including two major hard rock formations viz. Granite and Basalt. Subsequent methodologies i.e. GEC-84 and GEC-97 have recommended specific yield norms for further variations of lithological formations. In GEC-1997, norms have been recommend for thirteen (13) formations. Also, like Rainfall Recharge norms, a single value of specific yield has been recommended for each formation alongwith the range.
- ***Return flow factor for irrigation***: The norms for return flow factors for irrigation water applied by either surface or ground water have also been modified in successive methodologies. While in earlier methodologies, norms were recommended based on cropping pattern only. In GEC-1997, different norms were assigned based on the cropping pattern, depth to water level in the area and continuity of water supply.
- ***Unit ground water draft:*** In GEC-1984 methodology, area irrigated from various types of ground water minor irrigation units were recommended for various states. These areas are to be multiplied by applicable water depth to get the draft of ground water. Since there are wide variations in the crop water requirement and cropping pattern within the states, the norms for unit draft have been simplified in GEC-1997, by recommending state-wise unit annual draft norms for various abstraction structures.

4.2.2 Refinement of norms

As is evident from the above discussion, there is always a need to modify and refine the norms for various parameters to address the diversity in hydrogeology, geology, geomorphology and agro-climatic conditions existing within the macro geographic units of our country. Also there is a need to rationalize and update the norms of rainfall infiltration factor, canal seepage factor and return flow factor for irrigation and recharge from tanks and ponds by taking up field studies in the prevailing hydrogeological situations. Studies on rainfall – recharge relation is also quite important. These would bring in future refinements in ground water resources estimations bring carried out by the States. In order to refine and diversify the norms used for resources computations, initially it is being contemplated to focus on two major parameters which considerably influences the resources assessment. These parameters are – specific yield and unit ground water draft. This would however have to be followed by refinement and diversification of norms of other parameters/ components.

4.2.2.1 Specific yield: Specific yield is one of the most important parameter in the estimation of ground water recharge using Water Table Fluctuation method. At present, the values of specific yield are assigned for broader lithological units. However, within these broader hydrogeological units, there are finer variations. Determination of recharge parameters of these finer variations are required. There are various methods for estimation of specific yield like laboratory method, pumping tests method, water balance method, field saturation and drainage method. Among these methods, pumping test method has wider applicability under various field conditions. During pumping test method, a nest of wells are constructed and ground water is pumped from the main well and water levels are recorded in all the wells. The ratio of volume of water pumped and volume of aquifer dewatered is Specific Yield. The formulas involved in this computation are as follows:-

$$Sy = (Vy/Vb) * 100$$

Where Vy is volume of water drained out and Vb is the total volume of aquifer material dewatered and Sy is Specific Yield (Karanth, 1987). For calculating the Sy using the long duration pumping tests on well fields, two methods can be used.

a) Cone of depression method
b) Analytical method

In the cone of depression method, the actual volume of aquifer material dewatered is computed by subtracting the volume of material outside the actual cone of depression from the volume of cone defined by the radius of influence of pumping well. The ratio of actual volume of water pumped and the actual volume of aquifer material dewatered is specific yield expressed in fraction.

$$Sy = 100 * V3/(V1 - V2)$$

Where Sy = specific yield
V3 = actual volume of water pumped
V1 = volume of cone defined by the radius of influence of pumping well
V2 = volume of material outside the actual cone of depression

In the analytical method suggested by Ramsahoye and Lang, the aquifer material dewatered is computed using the following formula:

$$\text{Log } V = \text{Log } (Qr^2/4T) + (5.45\ Ts)/Q$$

where Q is the discharge in m^3/day, T is the transmissivity in m^2/day, r is the distance of measurement from the pumping well in meters, s is the average drawdown in all the observation wells at 'r' distance in meters. The specific yield will be computed as (Q * t)/V where't' is the time of pumping in days. Both the methods are to be compared for obtaining the realistic estimate of specific yield.

The norms of Specific Yield were derived from field tests carried out in past in water balance projects and related studies carried out by CGWB and State Departments. In order to refine the norms for specific yields, it is being contemplated that pumping tests would be now carried out state-wise. In this process, initially determination of Specific Yield is being envisaged in one state i.e. Andhra Pradesh by conducting pumping tests in select assessment units. Based on the results of these studies, the programme will be replicated in other parts of the country.

4.2.2.2 Ground water draft: The ground water draft in an area represents the direct human interference on the natural hydraulic system. If the draft exceeds the limit of long term average replenishment of natural resources, it creates imbalances in the hydraulic system. This imbalance is reflected in the form of declining ground water levels.

The two widely applied methods for estimation of ground water draft are as follows:-

a) Unit draft method
b) Crop water requirement method.

a) Unit Draft Method:- Unit draft is defined as the water withdrawn from the aquifer through an abstraction structure in a unit time. The ground water draft can be calculated by mulitiplying the unit draft with the number of such abstraction structures. For computing the unit draft, field surveys are to be carried out wherein, hourly discharge from the abstraction structure is measured and number of hours of pumping during a day and number such days of pumping in a season are collected for number of representative abstraction structures. The product of hourly discharge, number of hours of pumping in a day and number of such days in a season will give the ground water draft for the particular abstraction structures during that season. The average of such ground water draft for that season obtained from the number of samples is the unit draft for the particular season. The product of unit draft and number of abstraction structures in use gives the ground water draft. The number of structures are obtained from well census carried out by Central and State Government agencies.
b) Crop water requirement method:- In this method, detailed field investigations are required to collect the area irrigated by ground water for different crops in the study area. The irrigated area under a crop is multiplied with the crop water requirement of that particular crop to compute the ground water applied in the areas. The sum of ground water applied for all the crops in the area is the gross ground water draft for irrigation in that area during that season.

Considering the importance of these data, comprehensive/adequate and up-to-date data on ground water draft are needed. Due to the requirement of real time draft data, sample surveys are to be conducted at various micro and macro levels. Sample draft estimation studies have been conducted by CGWB under various water balance projects with international collaboration and also under regular hydrogeologcial surveys. Similar studies were also carried out by various State Ground Water Departments and Academic institutes. However, countrywide sample survey covering all the states/UTs for the estimation of the ground water draft requires vast resources in terms of time, cost, manpower, etc.

In order to refine the norms on unit ground water draft, studies are being contemplated in a few sample areas in different agro-climatic zones in some states. In addition to the methods mentioned above, an improvised technique is envisaged to be taken up as pilot study. The technique involves computing the gross draft in an area for different crops. The gross draft for a particular crop in the area is divided with the cropped area to obtain draft per unit area for the particular crop. These norms of draft per unit area can be applied for the similar areas.

Based on the experiments of these studies, the programme would be replicated in other parts of the country.

4.3 Strengthening of Database:- Availability of adequate data is the key to the realistic estimation of ground water resources. The following data elements are required for each assessment unit in the estimation of ground water resources using the existing methodology:-

a) Rainfall data – Normal rainfall during monsoon and non-monsoon seasons, rainfall for the assessment year during monsoon and non-monsoon seasons. These data are being collected from IMD and State Revenue Department.
b) Water level data – Pre and post-monsoon water levels from the observation wells for two subsequent calendar years and also long term water level data for computing trend of water levels. These data are being generated, validated and maintained by CGWB and State Ground Water Departments.
c) Canal Data – This includes canal length, bed width, full supply depth, side angle, lining, number of running days during monsoon and non-monsoon seasons, number of outlets and the design discharge of each of the out let. These data are collected from State Irrigation Departments.
d) Cropping Pattern Data – Paddy and non-paddy areas irrigated by different sources. This data is collected from Agriculture Department and State Administration.
e) Abstraction structures Data – Type-wise number of abstraction structures. These data are collected from M.I. Census being conducted by Central and State agencies.
f) Tanks and Ponds data – Name of the tank, water spread area, number of days water is available in the tanks season wise. This data is collected from State Irrigation Departments.
g) Water Conservation Structures Data:- Name of the water conservation structure, storage capacity, number of fillings. These data are collected from various State Agencies involved in watershed management viz; State Irrigation Department, Department of Fisheries, Forest Department, Soil Conservation Department, Zilla Parishads etc.
h) Population data:- Population and growth rate. These data are collected from Census Department.
i) Spatial Data of assessment units:- Assessment unit location, command, non-command, hilly and poor ground water quality area, soil and geology. These data are collected from Geological Survey of India, National Soil Survey and Land Use Planning Department, State Irrigation Department, State Ground Water Departments and CGWB.

4.3.1 Strengthening of water level database

Most of the data as mentioned above are collected from various State and Central Government agencies. The accuracy of the ground water resources estimates depends on the quantity and quality of this database. Of the various types of data required for ground water estimation, one of the major data are that of ground water level which are being collected by Central Ground Water Board (CGWB) and State Ground Water Organizations (SGWO). At present, CGWB is having approximately 15000 monitoring wells and SGWOs are having around 45000 monitoring wells. Ground water levels are being measured four times a year during January, April/ May, August and November. For strengthening the ground water monitoring network and measuring capabilities, a World Bank aided Hydrology Project I was sanctioned in 1997 under the Ministry of Water Resources. The project was implemented with the coordination and participation of 9 Southern States. Under the Project, 2239 purpose built piezometers have been constructed to strengthen the existing ground water monitoring network.and1200 digital water level recorders have been installed at select wells to acquire high frequency water level data so as to monitor short term ground water regime changes. The project was further extended and Hydrology Project II is presently under implementation in 13 states. The project envisages extension and promotion of the sustained and effective use of the Hydrologic Information System by all potential users concerned with water resources planning and management.

5. CONCLUSION

The existing methodology for ground water resources assessment involves estimation of annual ground water recharge and categorization of assessment units based on status of utilization and long term water level trend. The methodology uses Water Level Fluctuation technique which is an internationally accepted method for computation of ground water recharge. Alongwith it, various norms, which were derived from Water Balance Projects are also used for the purpose of computation as well as validation of estimates of various recharge components.

The estimations carried out using the existing methodology in general holds good in most of the cases. However, in some cases, the block level assessment may not match with the field situations at localized areas within the block. This situation arises because of the heterogeneity and complexity of hydrogeological setup of the area. The assessment unit as per the existing methodology is mostly blocks or watershed, the area of which varies widely from 3 sq.km. to about 9300 sq. km. There are likelihoods of variations in ground water situation within this large area of assessment units. The ground water estimations as carried out using the present methodology are the reflections of the overall ground water scenario of an assessment unit. Therefore, any large scale ground water management programmes should be contemplated based on micro-level hydrogeological studies of the area.

There are scopes for further refinements in the ground water resources estimations. One of the major fields of refinement would be refinement of norms of parameters used for computation of ground water resources to address the heterogeneity of the hydrogeological setup of the field. The norms used at present are derived from Water Balance Studies and ground water estimation studies carried out by CGWB in collaboration with International Agencies, State Ground Water Agencies and Academic institutes in different parts of the country. These norms need to be further modified by determining the values of parameters for the micro-level variations in the lithological units, soil types and other factors influencing the recharge to ground water. Initially only two parameters would be taken up for refinements viz. Specific Yield and Unit Ground Water Draft. Studies would be taken up in selected states. Based on these experiences, the programme would be replicated in other parts of the country. This would be followed by refinement and diversification of norms of rainfall infiltration factor, canal seepage factor and return flow factor for irrigation.

There is also considerable scope for refinement in the ground water estimation by strengthening the database used for resources estimation. Since most of the database is generated by various State and Central agencies, a collated effort is required on the part of these organizations. Database required for ground water resources estimation based on GEC-1997 can be grouped into following two categories – (i) Database involving geographical details like watershed boundary, canal command areas & non-command areas, slope of the landform, aquifer disposition, canal morphology, morphology of tanks & ponds, water conservation structures, drainage pattern, cropping pattern, land use pattern, well census, irrigated area etc., (ii) Database on measured data like water level, rainfall, canal discharge, water availability in tanks & ponds, base flow etc.. Database in the first category should be spatially as detailed as possible. The first level of database generation is at assessment unit / sub-unit level (unit -Block / Watershed, sub-unit – Command/ Non-Command). This should be followed by micro-level database generation.

On the other hand, database in the second category needs to be intensified both in time and space. Hydrology Project I & II can play a key role in strengthening of database of one of the most important data element of ground water resources estimation i.e. water level.

Finally, ground water resources estimation discussed in this document focuses on the dynamic ground water resources available in the zone of water level fluctuation, which is a reflection of seasonal recharge and discharge of ground water in the aquifer systems. There is however considerable ground water available in the zone below the water level fluctuation particularly in alluvium belt of Indus-Ganges-Bramhputra basins. Therefore, considering the increasing stress on ground water, alongwith the estimation of replenishable resources of the unconfined aquifer, the availability of ground water and potentiality of the aquifers at depth also need to be studied. Similarly in hilly terrain where spring is an important source of water, spring discharge studies needs to be undertaken in a systematic pattern.

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Annexure 1

(TO BE PUBLISHED IN THE GAZETTE OF INDIA, PART-I, SECTION-II)

Government of India
Ministry of Water Resources
Shram Shakti Bhawan, New Delhi
*****

No. 3/7/2001-GW.II **Dated 22nd April, 2004.**

RESOLUTION

The ground water resources of the country is estimated on the basis of recommendation of "Ground Water Resources Estimation Committee-1997". The principle adopted though reasonably valid in an approximately homogeneous hydrologic terrain like alluvium may not be widely applicable for hard rock terrain where the hydrogeological conditions vary widely within small area and heterogeneous set-up prevail. Almost two thirds of the country is occupied by hard rock terrain. To get a more appropriate methodology for ground water resource estimation for hard rock terrain to supplement GEC-1997, a Committee for "Estimation of Ground Water Resources in Hard Rock Terrain" was constituted in September, 2001. The Committee has since submitted its report in October, 2003. The Committee has rationalized the criteria of categorisation of assessment units and identified several issues, which require revision and in-depth study for reliable assessment of ground water resources in hard rock terrain. Moreover, refinement of the methodology of ground water resource estimate requires extensive Research and Development support. To solve the outstanding issues and pursue R&D work, the Committee recommended constitution of a Standing Committee. On the basis of recommendation of the Committee, it has been decided to constitute a Standing Committee named as 'R&D Advisory Committee on Ground Water Estimation' with the following composition:-

1.	Chairman, CGWB	Chairman
2.	Member(SAM), CGWB	Member
3.	General Manager, NABARD, Mumbai	Member
4. & 5.	Two Representative from State Ground Water Departments in Hard Rock Terrain	Member(s)
6.	Sr. Scientist, CGWB	Member-Secretary

2. The terms of reference of the Committee will be as follows:-

1. To review the scientific studies done in the field of ground water resource assessment.
2. To review the validity of recommendation of GEC-1997 and, if found necessary, suggest alternate methodology for assessment of ground water resource.
3. To consider and resolve issues identified by the Committee for estimation of ground water resources in hard rock terrain viz. :-

    (i) Computation of recharge during the monsoon season in command/non-command areas.
    (ii) Estimation of normal recharge during the monsoon and non-monsoon season.
    (iii) Natural loss during the non-monsoon season.
    (iv) The stage of ground water development.
    (v) Strengthening of database.

4. R&D Studies with reference to ground water resources estimation.
5. Any other aspect relevant to the terms referred above.

3. The Committee may form different Working Groups from among the Members to assist the Committee on different aspects under its purview.

(M. Mehta)
Sr. Joint Commissioner(GW)

ORDER

Ordered that the above Resolution may be published in the Gazette of India for general information.

(M. Mehta)
Sr. Joint Commissioner(GW)

To

The Manager,
Government of India Press,
Faridabad (Haryana).

Copy to:

1. Chairman, Central Ground Water Board, Bhujal Bhawan, NH-IV, Faridabad. He is requested to include two representatives of State Ground Departments in Hard Rock Terrain and also to nominate an officer of the level of Scientist-'D' to work as Member-Secretary of the Committee.
2. Member(SAM), Central Ground Water Board, Bhujal Bhawan, NH-IV, Faridabad.
3. General Manager, NABARD, Plot No. C-24, G-Block, Post Box No. 8121, Bandra, Kurla Complex, East Mumbai-400 051.
4. Scientist-'D'/Superintending Hydrogeologist, Central Ground Water Board, Bhujal Bhawan, NH-IV, Faridabad.

(M. Mehta)
Sr. Joint Commissioner(GW)

Copy also forwarded for information to:

1. PS to Hon'ble Minister(WR)
2. PS to Hon'ble MOS(WR)
3. Sr. PPS to Secretary(WR).
4. PS to AS(WR).

(M. Mehta)
Sr. Joint Commissioner(GW)

No. 3-8/CGWB/M(SAM)/04-
Central Ground Water Board
Ministry of Water Resources
Government of India

Dated 14th June, 2004

Subject: R&D Advisory Committee on Ground Water Estimation

In pursuant with Govt. of India Resolution No. 3/7/2001-GW.II, dated 22.04.04, composition of the 'R&D Advisory Committee on Ground Water Estimation' is as follows:-

1.	Chairman, CGWB	Chairman
2.	Member (SAM), CGWB	Member
3.	General Manager, NABARD	Member
4.	Director, Ground Water Surveys & Development Agency Govt. of Maharashtra, Pune	Member
5.	Director, Drought Monitoring Cell, Govt. of Karnataka, Bangalore	Member
6.	Rana Chatterjee, Sc 'C'	Member Secretary

The terms of reference of the Committee will be as follows:-

1. To review the scientific studies done in the field of ground water resource assessment.

2. To review the validity of recommendation of GEC-1997 and, if found necessary, suggest alternate methodology for assessment of ground water resource.

3. To consider and resolve issues identified by the Committee for estimation of ground water resources in hard rock terrain viz.

    (i) Computation of recharge during the monsoon season in command / non-command areas.

    (ii) Estimation of normal recharge during the monsoon and non-monsoon season.

    (iii) Natural Loss during the non-monsoon season.

    (iv) The stage of ground water development.

(v) Strengthening of database.

4. R&D Studies with reference to ground water resources estimation.

5. Any other aspect relevant to the terms referred above.

The Committee may form different Working Groups from among the Members to assist the Committee on different aspects under its purview.

Sd/-
P.C. Chaturvedi
Member (SAM)

Copy to:

1. Member (ED&MM)/ Member (SML) CGWB & Member Secretary, CGWA, Faridabad/ New Delhi.
2. Sr. Joint Commissioner (GW), MOWR, Shram Shakti Bhawan, New Delhi
3. General Manager, NABARD, Mumbai.
4. Director, GSDA, Pine.
5. Director, Drought Monitoring Cell, Bangalore.
6. Regional Directors, Central Ground Water Board.
7. Head of Department, State of Ground Water Departments.
8. Sh. Rana Chatterjee, Scientist 'C', CGWB, New Delhi.

Sd/-

P.C. Chaturvedi
Member (SAM)

Annexure – 2

List of the delegates attended the Ninth meeting of the R&D Advisory Committee on ground water estimation at CSMRS, New Delhi on 09.05.08

S.No.	Name & Designation
1.	Shri B.M. Jha, Chairman, CGWB
2.	Dr. S.C. Dhiman, Member (SM&L), CGWB
3.	Shri D. Elangovan, General Manager, NABARD.
4.	Sh. A.R. Bhaisare, Regional Director (HP), CGWB
5.	Shri S.B. Khandale, Joint Director, G.S.D.A, Pune.
6.	Shri V.S. Prakash, Director, Disaster Mitigation Cell, Government of Karnataka, Bangalore.
7.	Er. K.S. Takshi, Director, Water Resources & Environment, Govt. Of Punjab, SCO – 32-34, Sector 17-C, Chandigarh
8.	Shri G.S. Marwah, Suptd. Hydrogeologist, Ground Water Department, Jodhpur
9.	Dr. N. Varadaraj, Regional Director, CGWB, SECR
10.	Shri Sushil Gupta, Regional Director, Central Ground Water Board, Chandigarh
11.	Dr. P.C. Chandra, Regional Director, Central Ground Water Board, Patna
12.	Shri T.M. Hunse, Regional Director, Central Ground Water Board, Bangalore.
13.	Sh. G.D. Ojha, Regional Director, Central Ground Water Board, Hyderabad
14.	Shri R.C. Jain, Regional Director, Central Ground Water Board, Ahmedabad
15.	Sh. R.P. Mathur, Regional Director, Central Ground Water Board, Jaipur.
16.	Smt. Anita Gupta, Regional Director, Central Ground Water Board, Dehradun
17.	Dr. A.K. Keshari, Associate Professor, Department of Civil Eng., IIT, Delhi
18.	Dr. C.P. Kumar, Scientist 'E', NIH, Roorkee
19.	Sh. A.K. Srivastava, Director (Stat), Minor Irrigation Division, MOWR
20.	Shri G.C. Saha, OIC, Delhi State Unit, CGWB
21.	Sh. P.K. Parchure, Scientist 'D', CGWB, Nagpur
22.	Shri S.C. Paliwal, Hydrogeologist, Ground Water Department, Rajasthan
23.	Er. Jatinder Pal Singh, Ex. En. Water Resources & Environment, Govt. of Punjab, SCO – 47-48, Sector 17-C, Chandigarh
24.	Sh. Bimaljeet Bhandari, Water Resources & Environment, Govt. of Punjab,

	SCO – 32-34, Sector 17-C, Chandigarh .
25.	Dr. S.K. Jain, TS to M (SAM), CGWB, Faridabad
26.	Shri Sunil Kumar, Scientist 'D', CGWB, Faridabad
27.	Dr. Uma Kapoor, Scientist 'D', CGWB, New Delhi
28.	Sh. Sanjay Marwah, Scientist 'D', CGWB, Chandigarh
29.	Sh. A.K. Agarwal, Scientist 'D', CGWB, Patna
30.	Sh. S. Bhattacharya, Scientist 'D', CGWA, New Delhi
31.	Sh. S.K. Sinha, Scientist 'D', CGWB, Faridabad
32.	Sh. Rana Chatterjee, Scientist 'D', CGWB, New Delhi

List of the delegates attended the Tenth meeting of the R&D Advisory Committee on ground water estimation at CGWA, New Delhi on 17.09.08

S.No.	Name & Designation
1.	Shri B.M. Jha,Chairman, CGWB.
2.	Dr. S.C. Dhiman, Member (SM&L), CGWB.
3.	Sh. A.R. Bhaisare, Member In-charge (SAM), CGWB
4.	Shri S.B. Khandale, Joint Director, G.S.D.A, Pune.
5.	Sh. S.S. Rajshekhar, General Manager (TSD), NABARD, Mumbai
6.	Er. BimalJeet Bhandari, Executive Engineer (Agronomist), Water Resources & Environment, Govt. Of Punjab, SCO – 32-34, Sector 17-C, Chandigarh
7.	Shri G.S. Marwah, Suptd. Hydrogeologist, Ground Water Department, Jodhpur
8.	Sh. B.M. Murali Krishna Rao, Director, A.P. State Ground Water Department
9.	Shri Sushil Gupta, Regional Director, Central Ground Water Board, Chandigarh
10.	Dr. P.C. Chandra, Regional Director, Central Ground Water Board, Patna
11.	Sh. R.P. Mathur, Regional Director, Central Ground Water Board, Jaipur.
12.	Sh. B. Jayakumar, Regional Director, Central Ground Water Board, Nagpur
13.	Dr. A.K. Keshari, Associate Professor, Department of Civil Eng., IIT, Delhi
14.	Dr. C.P. Kumar, Scientist 'E', NIH, Roorkee
15.	Sh. A.D. Rao, Sc 'D' & HOO, Central Ground Water Board, Hyderabad
16.	Shri S.C. Paliwal, Hydrogeologist, Ground Water Department, Rajasthan
17.	Dr. P. Nandkumaran, TS to Chairman, CGWB, Faridabad
18.	Dr. S.K. Jain, TS to M (SAM), CGWB, Faridabad
19.	Sh. Y. B. Kaushik, Scientist 'D', CGWB, Faridabad
20.	Sh. Sanjay Marwah, Scientist 'D', CGWB, Chandigarh
21.	Sh. A.K. Agarwal, Scientist 'D', CGWB, Patna
22.	Dr. P.N. Rao, Scientist 'D', CGWB, Hyderabad
23.	Sh. S.K. Sinha, Scientist 'D', CGWB, Faridabad
24.	Sh. A.V.S.S. Anand, Scientist 'B', CGWB, SUO, Vishakhapatnam
25.	Sh. D. Venkateshwaran, Scientist 'B', CGWB, CR, Nagpur
26.	Sh. Rana Chatterjee, Scientist 'D', CGWB, New Delhi

Annexure - 3

Norms of parameters recommended by GEC-1997

Norms for specific yield

S. No	Formation	Recommended Value (%)	Minimum Value (%)	Maximum Value (%)
(a)	Alluvial areas			
	Sandy alluvium	16.0	12.0	20.0
	Silty alluvium	10.0	8.0	12.0
	Clayey alluvium	6.0	4.0	8.0
(b)	Hard rock areas			
	Weathered granite, gneiss and schist with low clay content	3.0	2.0	4.0
	Weathered granite, gneiss and schist with significant clay content	1.5	1.0	2.0
	Weathered or vesicular, jointed basalt	2.0	1.0	3.0
	Laterite	2.5	2.0	3.0
	Sandstone	3.0	1.0	5.0
	Quartzite	1.5	1.0	2.0
	Limestone	2.0	1.0	3.0
	Karstified limestone	8.0	5.0	15.0
	Phyllites, Shales	1.5	1.0	2.0
	Massive poorly fractured rock	0.3	0.2	0.5

Note: Usually the recommended values should be used for assessment, unless sufficient data based on field study is available to justify the minimum, maximum or other intermediate values.

Norms for Rainfall Infiltration Factor

S. No	Formation	Recommended Value (%)	Minimum Value (%)	Maximum Value (%)
(a)	Alluvial areas			
	Indo-Gangetic and inland areas	22	20	25
	East coast	16	14	18
	West coast	10	8	12
(b)	Hard rock areas			
	Weathered granite, gneiss and schist with low clay content	11	10	12
	Weathered granite, gneiss and schist with significant clay content	8	5	9
	Granulite facies like charnockite etc.	5	4	6
	Vesicular and jointed basalt	13	12	14
	Weathered basalt	7	6	8
	Laterite	7	6	8
	Semi-consolidated sandstone	12	10	14
	Consolidated sandstone, quartzite ,limestone (except cavernous limestone)	6	5	7
	Phyllites shales	4	3	5
	Massive poorly fractured rock	1	1	3

Note: 1. Usually, the recommended values should be used for assessment, unless sufficient information is available to justify the use of minimum, maximum or other intermediate values.

2. An additional 2% of rainfall recharge factor may be used in such areas or part of the areas where watershed development with associated soil conservation measures are implemented. This additional factor is subjective and is separate from the contribution due to the water conservation structures such as check dams, nalla bunds, percolation tanks etc. The norms for the estimation of recharge due to these structures are provided separately. This additional factor of 2% is at this stage, only provisional, and will need revision based on pilot studies.

Norms for Canal Seepage Factor

(a) Unlined canals in normal soils with some clay content along with sand :	1.8 to 2.5 cumecs per million sq m of wetted area (or) 15 to 20 ham/day/million sq m of wetted area
(b) Unlined canals in sandy soil with some silt content :	3.0 to 3.5 cumecs per million sq m of wetted area (or) 25 to 30 ham/day/million sq m of wetted area
(c) Lined canals and canals in hard rock area :	20% of above values for unlined canals

Notes :

1. The above values are valid if the water table is relatively deep. In shallow water table and waterlogged areas, the recharge from canal seepage may be suitably reduced.
2. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

Norms for Return flow from irrigation

The recharge due to return flow from irrigation may be estimated, based on the source of irrigation (ground water or surface water), the type of crop (paddy, non-paddy) and the depth of water table below ground level, using the norms provided below.

Norms as percentage of applied irrigation water

Source of Irrigation	Type of Crop	Water table below ground level		
		<10 m	10-25 m	>25m
Ground water	Non-paddy	25	15	5
Surface water	Non-paddy	30	20	10
Ground water	Paddy	45	35	20
Surface water	Paddy	50	40	25

Notes:

1. For surface water, the recharge is to be estimated based on water released at the outlet. For ground water, the recharge is to be estimated based on gross draft.
2. Where continuous supply is used instead of rotational supply, an additional recharge of 5% of application may be used.
3. Where specific results are available from case studies is some states, the adhoc norms are to be replaced by norms evolved from these results.

Norms for seepage factor for recharge from storage tanks and ponds

1.4 mm/day for the period in which the tank has water, based on the average area of water spread. If data on the average area of water spread is not available, 60% of the maximum water spread area may be used instead of average area of the water spread.

Norms for recharge from percolation tanks

50% of gross storage, considering the number of fillings, with half of this recharge occurring in the monsoon season, and the balance in the non-monsoon season.

Norms for recharge due to check dams and nala bunds

50% of gross storage (assuming annual desilting maintenance exists) with half of this recharge occurring in the monsoon season, and the balance in the non-monsoon season.

Average Annual Gross Draft for Ground Water Structures in Different States

S. No.	State	Type of ground water structure	Average gross unit draft (ham)
1.	Andhra Pradesh	Dugwell with Mhot	0.35
		Dugwell with Pumpset	0.65
		Borewell with Pumpset	1.3
		Shallow Tubewell	2.05
		Medium Tubewell	4.1
		Deep Tubewell	5.85
2.	Assam	Shallow Tubewell with Pumpset	3.0
3.	Bihar	Dugwell	0.6
		Private tube well with Pumpset	1.0
		Bamboo boring with Pumpset	0.75
		Deep tube well	30.0
4.	Gujarat	Dugwell with Pumpset	0.8
		Borewell with Pumpset	1.2
		Private shallow Tubewell	1.85
		Medium Deep Tubewell	6.0
		Deep Tubewell	30.0
5.	Haryana	Dugwell with Pumpset	1.5
		Private shallow Tubewell with Pumpset	1.81
		Deep Tubewell	15.0
6.	Himachal Pradesh	Medium Deep Tubewell with Pumpset	2.5
7.	Karnataka	Dugwell with Pumpset	0.9
		Borewell with Pumpset	1.7
		Dug cum Borewell with Pumpset	1.98
8.	Kerala	Dugwell with Pumpset	0.5
		Borewell with Pumpset	0.7
9.	Madhya Pradesh	Dugwell with Mhot	0.8
		Dugwell with Pumpset	1.5
		Borewell with Pumpset	1.5

S. No.	State	Type of ground water structure	Average gross unit draft (ham)
		Private shallow tubewell with Pumpset	3.0
10.	Maharashtra	Dugwell with Mhot	0.45
		Dugwell with Pumpset	1.57
11.	Orissa	Dugwell with Mhot	0.21
		Dugwell with Pumpset	1.0
		Filter Point with Pumpset	2.1
		Private Tubewell with Pumpset	7.0
		Deep Tubewell with Pumpset	17.5
12.	Punjab	Shallow Tubewell with Pumpset	1.3 - 3.4
		Deep Tubewell with Pumpset	18.0
13.	Rajasthan	Dugwell with Pumpset	0.52
		Private Tubewell with Pumpset	1.4
		Dug cum borewell with Pumpset	1.23
		Deep Tubewell	2.28
14.	Tamil Nadu	Dugwell with Pumpset	0.4 -1.0
		Private Tubewell with Pumpset	1.0 - 2.0
		Borewell with Pumpset	1.0
15.	Tripura	Shallow Tubewell with Pumpset	3.0
		Artesian Well	0.37
16.	Uttar Pradesh	Dugwell with Mhot	0.37
		Dugwell with Pumpset	0.75
		Private Tubewell with Pumpset	3.7
		Deep Tubewell	22.0
17.	West Bengal	Dugwell with Pumpset	0.3
		Private Tubewell with Pumpset	1.52
		Deep Tubewell with Pumpset	18.5

APPENDICES

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Type of Assessment unit	District/Taluka	Lithology	Command/ Non-command	Database			
							Assessment area (ha)	No. of Observation wells	Normal Annual Rainfall (mm)	
									2004	2006/2007
1	Maharashtra	TE-11	Watershed	Jalgaon/Yawal	Sandy alluvium	Both	37110	2	717	717
2		TE-50B	Watershed	Dhule/Dhule	Vesicular Jointed Basalt	Both	5080	3	651	651
3		WF-46	Watershed	Raigad/Alibag	Basaltic lava flows	Non-command	15895	3	2249 (mon)	2080 (mon)
4		WGK-03	Watershed	Nagpur/Ramtek	Weathered Gneissess	Command	11574	1	1223.2	1223.2
5	Andhra Pradesh	SK1_F_PMD_Bendigedda_Palasa	Watershed	Srikakulam	Granite Gneiss	Command	4521	1		1249
6			Watershed		Granite Gneiss	Non-command	23044	1		1249
7		MBNR_14_D_44_33	Watershed	Mehboobnagar	Granite	Non-command	28090.63	3		626
8		KNR_E_21_Pegadapally	Watershed	Karimnagar	Granite	Command	34902	1		1043
9			Watershed		Granite	Non-command	11148	1		1043
10		WG_Yarrakalava-1 Chintalapudi	Watershed	West Godavari	Sedimentaries - Sandstone	Non-command	34659	2		933

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Type of Assessment unit	District/Taluka	Lithology	Command/ Non-command	Database			
							Assessment area (ha)	No. of Observation wells	Normal Annual Rainfall (mm)	
									2004	2006/2007
11	Rajasthan	Kot Kasim	Block	Alwar	Older Alluvium	Non-command	30659	11	648.6	655.5
12		Peepal Khoont	Block	Banswara	Gneiss	Non-command/command	16812	8	861.7	861.7
					Basalt	Non-command/command	43975	18	861.7	861.7
					Total		60787	26	861.7	861.7
13		Jaswantpura	Block	Jalore	Younger Alluvium	Non-command/command	625	3	474.4	478.5
					Older Alluvium	Non-command/command	4375	9	474.4	478.5
					Weathered Granite	Non-command/command	43237	14	474.4	478.5
					Total		48237	26	474.4	478.5
14		Khetri	Block	Jhunjhunu	Younger Alluvium	Non-command	5537	2	560.3	558.2
					Older Alluvium	Non-command	12636	1	560.3	558.2
					Quartzite/ Phyllite/Schist	Non-command	3921	2	560.3	558.2
					Total		22094	5	560.3	558.2

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Database									
			Annual Rainfall of the year (mm)		Sp. Yld.		Water level		Water level trend			
									Pre		Post	
			2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007
1	Maharashtra	TE-11	764.5	777.5	0.16	0.16	Pre-37.2-41.10; Post-35.50-37.00	Pre-18.80-35.00 Post-16.30-33.85	F	F	R	R
2		TE-50B	550	550.41	0.03	0.03	Pre-7.55-10.15 ; Post-1.40-4.43	Pre-6.08-10.15 Post-0.60-4.43	F	R	R	R
3		WF-46	2527 (mon)	3320 (mon)	0.017	0.0195	Pre-4.95-6.15 ; Post-0.20-0.50	Pre-3.80-5.30 Post-0.05-0.75	R	R	R	R
4		WGK-03	1247.3	1247.3	0.015	0.015	Pre-12.50-14.00 ; Post-10.30-13.25	Pre-12.50-14.00 Post-10.10-12.80	R	R	R	R
5	Andhra Pradesh	SK1_F_PMD_Bendigedda_Palasa		1051(mon)		0.02		Pre-6.34 ; Post-1.64		11 cm/y - F		4 cm/y - R
6				1051(mon)		0.02		Pre-7.3 ; Post-1.6		55 cm/y - R		8 cm/y - R
7		MBNR_14_D_44_33		355 (mon)		0.03		Pre-15.7 ; Post-15.95		22 cm/y - R		3.4 cm/y-F
8		KNR_E_21_Pegadapally		924 (mon)		0.03		Pre-3.6 ; Post - 2.09		3 cm/y - F		20 cm/y - R
9				924 (mon)		0.03		Pre-3.9 ; Post-5.2		23 cm/y - F		25 cm/y - F
10		WG_Yarrakalava-1 Chintalapudi		715 (mon)		0.03		Pre-12.7 ; Post - 6.14		35 cm/y - F		93 cm/y-R

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Database									
			Annual Rainfall of the year (mm)		Sp. Yld.		Water level		Water level trend			
									Pre		Post	
			2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007
11	Rajasthan	Kot Kasim	870	741		0.15	Pre- 6.93; Post-6.02	Pre- 8.87; Post-8.46	F	F	F	F
12		Peepal Khoont	890 (mon)	1799 (mon)	0.025	0.025	Pre-7.44; Post-4.19	Pre- 7.33; Post-4.16	F	NF	NF	NF
			891 (mon)	1799 (mon)	0.0175	0.0175	Pre-7.39; Post-4.54	Pre- 7.48; Post-4.59	NF	NF	NF	NF
									NF	NF	NF	NF
13		Jaswantpura	575.3 (mon)	930 (mon)	0.1	0.1	Pre-10.88; Post- 10.19	Pre- 12.82; Post-12.23	F	F	F	F
			575.3 (mon)	931 (mon)	0.06	0.06	Pre-26.97; Post-25.44	Pre-31.18; Post-29.78	F	F	F	F
			575.3 (mon)	932 (mon)	0.02	0.02	Pre-16.41; Post-14.27	Pre-18.86; Post-17.00	F	F	F	F
									F	F	F	F
14		Khetri	370	417	0.12	0.12	Pre- 15.73; Post-13.94	Pre-17.73; Post-18.16	NF	NF	F	F
			370	417	0.1	0.1	Pre- 19.60; Post- 19.09	Pre-21.40; Post-21.74	F	F	F	F
			370	417	0.02	0.02	Pre-17.54; Post-15.39	Pre-18.45; Post-17.68	F	F	F	F
			370	417					F	F	F	F

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Annual Recharge (ha m)				Annual Draft (ha.m.)				Stage of GW Development (%)			
			GEC-97		Modified equation		Gross Draft - GEC-97		Net Draft - Modified formula		GEC-97		Modified formula	
			2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007
1	Maharashtra	TE-11	3255.4	3083.3	3148.23	2968.59	2197.22	2354.28	2090.09	2239.59	71.05	80.38	69.88	79.41
2		TE-50B	1295	1467	1145.10	1264.20	1234.25	816.40	1084.34	613.56	100.32	58.58	99.68	51.09
3		WF-46	1530	1751.6	1300.94	1524.67	1216.34	1266	987.26	1039.12	83.68	76.08	79.88	71.74
4		WGK-03	2351	4078.8	2298.66	4026.08	317.45	319.55	265.21	266.79	15	8.7	12.82	7.36
5	Andhra Pradesh	SK1_F_PMD_Bendigedda_Palasa		2883		2821.4		237		165.9		9		6
6				3454		3300.5		769		538.3		23		17
7		MBNR_14_D_44_33		2688		1808		2027		1418.9		74		83
8		KNR_E_21_Pegadapally		5426		4963.2		1666		1166.2		32		25
9				1875		1106		1531		1071.7		86		102
10		WG_Yarrakalava-1 Chintalapudi		7258		5195		4625		3237.5		67		66

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Annual Recharge (ha m)				Annual Draft (ha.m.)				Stage of GW Development (%)			
			GEC-97		Modified equation		Gross Draft - GEC-97		Net Draft - Modified formula		GEC-97		Modified formula	
			2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007
11	Rajasthan	Kot Kasim	5778.3	4629.9	3110.99	3341.32	9020.06	8896.47	6836.58	7607.94	164.32	202.27	231.32	239.68
12		Peepal Khoont	775.01	807.57	656.84	694.56	502.1	482.92	383.93	369.91	80.98	79.73	73.06	71.01
			3226.6	3100	2976.3	2905.68	1074.13	862.71	886.39	716.37	41.61	42.81	37.23	37.96
			4001.6	3907.6	3633.14	3600.24	1576.23	1345.63	1270.32	1086.28	49.24	51.35	43.71	45.11
13		Jaswantpura	630.34	704.77	496.69	501.3	941.4	1406.88	841.16	1203.41	165.94	221.8	178.27	252.69
			2868.3	2941.3	2781.46	2807.28	1887.5	2830.32	1822.33	2696.29	73.12	106.92	72.8	101.1
			1942	2114.5	1603.49	1618.38	2326.95	3429.1	2073.07	2933.03	133.14	180.19	143.65	201.37
			5440.7	5760.6	4881.64	4926.96	5155.85	7666.3	4736.56	6832.73	105.29	147.87	107.2	148.55
14		Khetri	465.08	481.32	427.4	463.61	353.71	488.27	316.03	470.56	80.06	106.78	77.83	106.84
			695.3	735.8	596.38	716.51	750.83	845.64	650.91	808.35	119.81	124.65	121.3	125.35
			2352	2157.9	2039.31	2049.52	2443.05	2655.7	2130.38	2547.31	109.34	129.55	109.96	130.83
			3512.4	3375	3063.09	3229.64	3547.59	3989.61	3097.32	3826.22	107.41	125.24	107.54	126.18

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Categorization				Data Analysis			
							Area represented by a Observation Well (sq.km.)		Recharge per hectare (m)	
			Existing		Modified equation		Area/ no. of Wells	Area/ no. of Wells		
			2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007
1	Maharashtra	TE-11	SC	SC	S	SC	186	186	0.08	0.08
2		TE-50B	OE	S	SC	S	17	17	0.24	0.27
3		WF-46	S	S	S	S	53	53	0.09	0.1
4		WGK-03	Safe	Safe	Safe	Safe	116	116	0.18	0.32
5	Andhra Pradesh	SK1_F_PMD_Bendigedda_Palasa		Safe		Safe		45.2		0.64
6				Safe		Safe		230.4		0.15
7		MBNR_14_D_44_33		SC		SC		93.6		0.10
8		KNR_E_21_Pegadapally		Safe		Safe		349.0		0.155
9				C		OE		111.5		0.167
10		WG_Yarrakalava-1 Chintalapudi		S		S		173.3		0.209

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Categorization				Data Analysis			
							Area represented by a Observation Well (sq.km.)		Recharge per hectare (m)	
			Existing		Modified equation		Area/ no. of Wells	Area/ no. of Wells		
			2004	2006/2007	2004	2006/2007	2004	2006/2007	2004	2006/2007
11	Rajasthan	Kot Kasim	OE	OE	OE	OE	30.659	27.8718	0.02	0.02
12		Peepal Khoont					24.0171	21.015	0.00	0.00
							27.4844	24.4306	0.01	0.01
			Safe	Safe	Safe	Safe			0.01	0.01
13		Jaswantpura					20.8333	20.8333	0.10	0.11
							48.6111	48.6111	0.07	0.07
							30.8836	30.8836	0.00	0.00
			OE	OE	OE	OE			0.01	0.01
14		Khetri					27.685	27.685	0.01	0.01
							128.36	129.36	0.01	0.01
							26.14	43.5667	0.06	0.06
			OE	OE	OE	OE			0.02	0.02

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Review of GEC-97 equation						Changes in estimation between 2004-2006/7			
			Difference in Recharge (%)		Difference in Stage of GW Development (%)		Difference in Categorization (%)		Annual Recharge	Annual Draft	Stage of GW Development	Categorization
			(Modified formula -GEC97 / GEC-97)*100						(2007 -2004 / 2004)*100			
			2004	**2006/2007**	**2004**	**2006/2007**	**2004**	**2006/2007**	**%**	**%**	**%**	
1	Maharashtra	TE-11	-3%	-4%	-2%	-1%	Change SC/S	Same - SC	-5%	7%	13%	Same - SC
2		TE-50B	-12%	-14%	-1%	-13%	Change OE/SC	Same-Safe	13%	-34%	-42%	Change - OE/S
3		WF-46	-15%	-13%	-5%	-6%	Same - S	Same - S	14%	4%	-9%	Same - S
4		WGK-03	-2%	-1%	-15%	-15%	Same - Safe	Same - Safe	73%	1%	-42%	Same-Safe
5	Andhra Pradesh	SK1_F_PMD_Bendigedda_Palasa		-2%		-33%		Same-Safe				
6				-4%		-26%		Same-Safe				
7		MBNR_14_D_44_33		-33%		12%		Same - SC				
8		KNR_E_21_Pegadapally		-9%		-22%		Same-Safe				
9				-41%		19%		Change - C/OE				
10		WG_Yarrakalava-1 Chintalapudi		-28%		-1%		Same-Safe				

Summary of exercises undertaken in selected assessment units to review GEC-1997 equations

Sl. No.	State	Name of Assessment unit	Review of GEC-97 equation						Changes in estimation between 2004-2006/7			
			Difference in Recharge (%)		Difference in Stage of GW Development (%)		Difference in Categorization (%)		Annual Recharge	Annual Draft	Stage of GW Development	Categorization
			(Modified formula -GEC97 / GEC-97)*100						(2007 -2004 / 2004)*100			
			2004	2006/2007	2004	2006/2007	2004	2006/2007	%	%	%	
11	Rajasthan	Kot Kasim	-46%	-28%	41%	18%	Same - OE	Same - OE	-20%	-1%	23%	Same - OE
12		Peepal Khoont	-15%	-14%	-10%	-11%			4%	-4%	-2%	
			-8%	-6%	-11%	-11%			-4%	-20%	3%	
			-9%	-8%	-11%	-12%	Same - Safe	Same - Safe	-2%	-15%	4%	Same - Safe
13		Jaswantpura	-21%	-29%	7%	14%			12%	49%	34%	
			-3%	-5%	0%	-5%			3%	50%	46%	
			-17%	-23%	8%	12%			9%	47%	35%	
			-10%	-14%	2%	0%	Same - OE	Same - OE	6%	49%	40%	Same - OE
14		Khetri	-8%	-4%	-3%	0%			3%	38%	33%	
			-14%	-3%	1%	1%			6%	13%	4%	
			-13%	-5%	1%	1%			-8%	9%	18%	
			-13%	-4%	0%	1%	Same - OE	Same - OE	-4%	12%	17%	Same - OE
			Note: F- Falling trend, R - Rising trend, NF - no significant fall; blank space indicate - 'Data not available'									

Appendix IB

EXERCISES CARRIED OUT BY THE STATE GOVERNMENTS

Ground Water Surveys and Development Agency, Govt. of Maharashtra

Estimation of ground water resources were carried out using GEC-1997 equations and the modified equations for all the 1505 watersheds. The results indicate that there is reduction in net recharge by 15 to 17% where as for net draft, the reduction is between 22 and 24%. This has resulted in changing the category of 38 watersheds. The stage of ground water development has reduced by 4 to 10% category wise. The abstract is as follows:

Component	Semi Critical to Safe	Critical to Semi Critical	Over-Exploited to Critical
Category	30	5	3
Stage of Development	Reduced by 10%	Reduced by 4%	Reduced by 8%

The details are given in Table V.

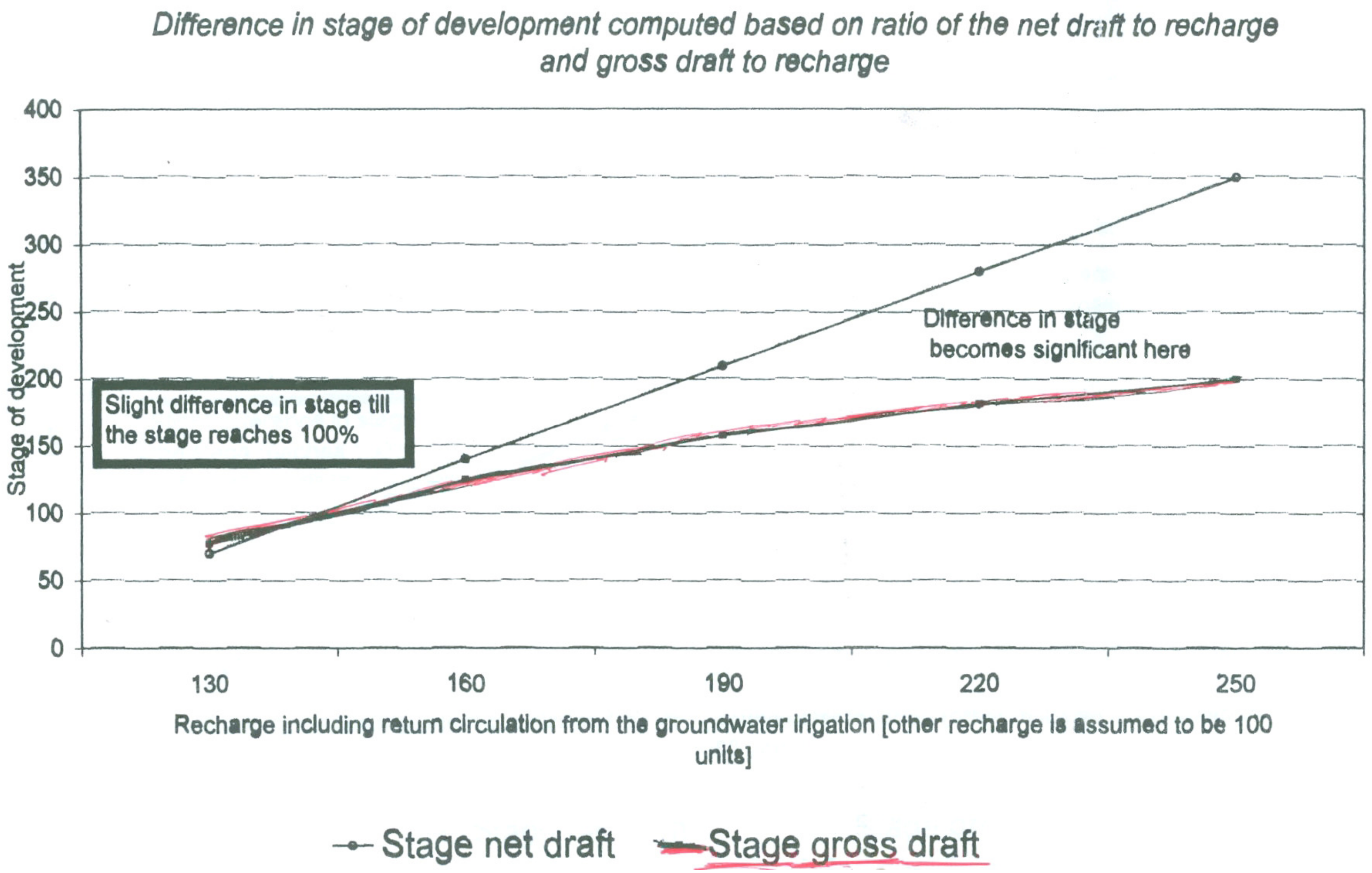
Ground Water Department, Government of Andhra Pradesh

In Andhra Pradesh, the comparative study of stage of ground water development using "Gross Draft concept" and "Net Draft concept" has revealed significant differences in only few cases. Upto 100% stage of development, there is no significance difference and even though there is significant difference in some cases, it need not be considered. The comparative study is summarized in Figure 2 & 3.

TableV

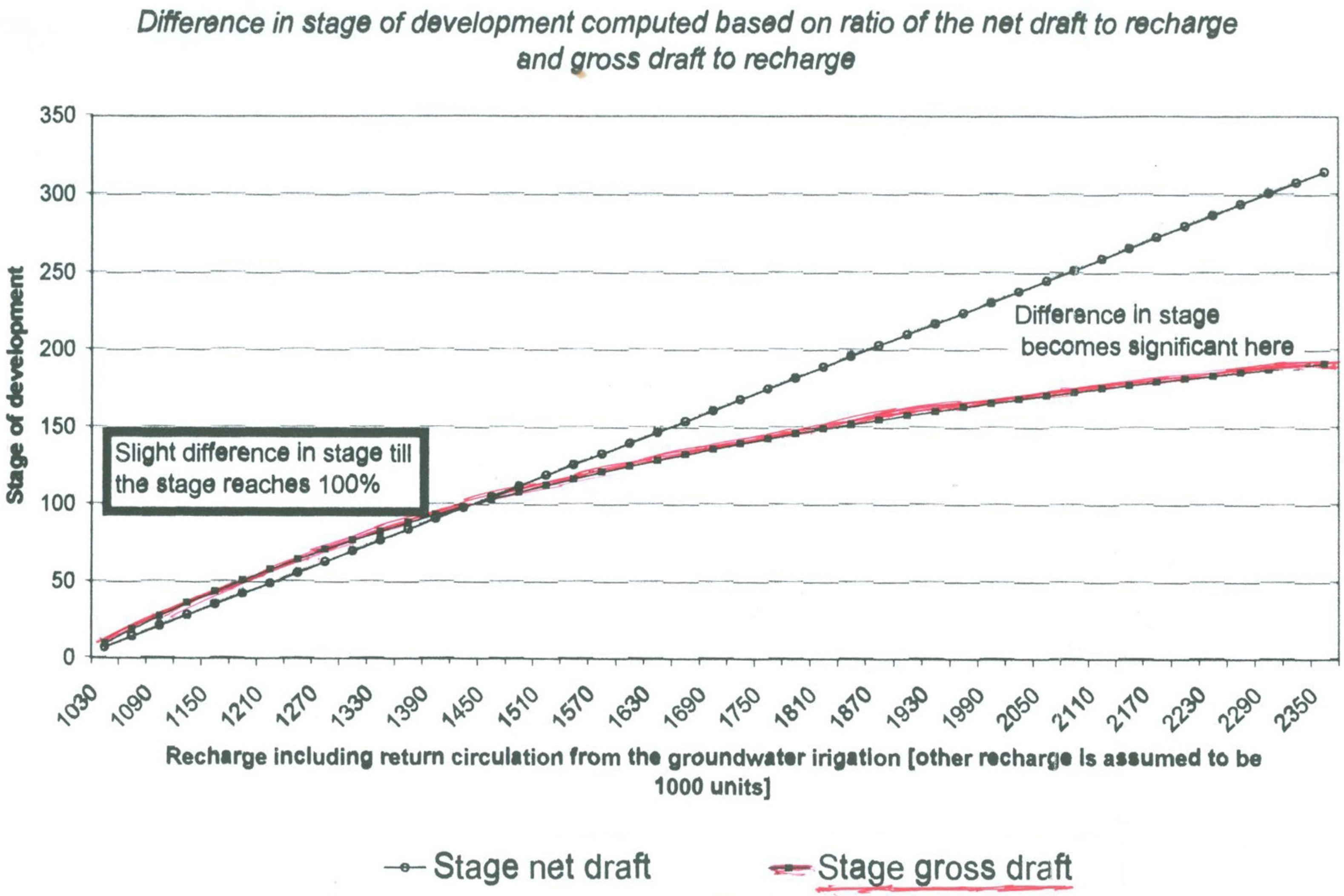
Sr. No.	District	Basin	WS	Recharge from Rainfall	Recharge from Canal	Recharge from SW Irri.	Recharge from GW Irri.	Recharge from Tanks	Recharge from WCS	As per existing methodology				As per R&D Adv.Comm. Recommendations				
										Net GW Available	Gross Draft	Stage of Dev.	Category	Rainfall Recharge	Net GW Recharge	Net Draft	Stage of Dev.	Category
1	NASHIK	TE	68 B	1341.84	15.81	172.50	345.91	0.00	17.27	1798.67	1310.82	72.88	SEMI CRITICAL	1341.84	1470.06	1310.82	65.64	SAFE
2	NASHIK	TE	93	917.06	97.35	501.95	385.59	30.82	32.98	1867.46	1392.72	74.58	SEMI CRITICAL	993.70	1573.95	1392.72	63.99	SAFE
3	NASHIK	TE	109	831.19	0.00	0.00	268.37	11.23	35.34	1088.82	986.11	90.57	CRITICAL	831.19	833.87	986.11	86.07	SEMI CRITICAL
4	NASHIK	TE	130	1682.38	127.28	501.95	580.57	0.00	216.91	2953.63	2113.16	71.54	SEMI CRITICAL	1682.38	2402.08	2113.16	63.80	SAFE
5	NASHIK	GV	23	3324.98	95.93	323.12	988.13	101.51	224.99	4805.72	3562.28	74.13	SEMI CRITICAL	3324.98	3867.00	3562.28	66.57	SAFE
6	NASHIK	GV	34-A	337.33	0.00	0.00	84.39	0.00	19.47	419.12	318.75	76.05	SEMI CRITICAL	337.33	338.95	318.75	69.14	SAFE
7	DHULE	TE	50B	483.77	0.98	10.61	149.91	11.28	638.46	1230.27	1234.25	100.32	OVER EXPLOITED	483.77	1087.85	1234.25	99.68	SEMI CRITICAL
8	DHULE	TE	63	2037.54	28.77	510.32	798.12	0.00	1350.00	4422.56	3236.97	73.19	SEMI CRITICAL	2037.54	3673.92	3236.97	66.38	SAFE
9	DHULE	TE	101	731.14	20.68	874.41	809.39	33.70	2318.19	4457.71	3251.21	72.93	SEMI CRITICAL	731.14	3690.02	3251.21	66.17	SAFE
10	JALGAON	TE	11	2894.58	117.00	2.80	107.12	0.00	133.85	3092.58	2197.22	71.05	SEMI CRITICAL	2894.58	2990.82	2197.22	69.88	SAFE
11	JALGAON	TE	24	2403.34	450.95	340.70	670.02	37.82	16.45	3723.32	2761.16	74.16	SEMI CRITICAL	2403.34	3086.79	2761.16	67.74	SAFE
12	AHMEDNAGAR	GV	26B	176.40	17.09	83.93	57.22	0.00	0.00	317.91	235.51	74.08	SEMI CRITICAL	177.24	264.35	235.51	67.45	SAFE
13	AHMEDNAGAR	GV	123	1390.10	193.65	395.36	673.54	3.80	381.50	2886.04	2716.31	94.12	CRITICAL	1424.19	2278.58	2716.31	89.65	SEMI CRITICAL
14	PUNE	BM	17	2252.16	0.00	0.00	700.15	0.00	294.65	3084.60	2287.28	74.15	SEMI CRITICAL	2252.16	2419.46	2287.28	65.60	SAFE
15	PUNE	BM	27	1392.71	0.00	0.00	454.76	41.57	228.22	2011.39	1477.33	73.45	SEMI CRITICAL	1392.71	1579.37	1477.33	64.75	SAFE
16	SOLAPUR	BM	94	1617.53	0.05	333.72	384.21	0.00	53.75	2269.80	1595.89	70.31	SEMI CRITICAL	1667.68	1952.44	1595.89	62.06	SAFE
17	SOLAPUR	SA	16	503.63	0.00	0.00	152.08	0.00	46.84	667.42	648.60	97.18	CRITICAL	539.49	557.01	648.60	89.14	SEMI CRITICAL
18	KOLHAPUR	KR	67	617.07	0.00	0.00	298.68	0.00	10.30	879.75	688.76	78.29	SEMI CRITICAL	617.07	596.00	688.76	65.45	SAFE
19	SANGLI	KR	36	2302.84	165.97	86.51	832.38	0.20	299.15	3502.68	3504.27	100.05	OVER EXPLOITED	2315.75	2724.20	3504.27	98.08	SEMI CRITICAL
20	SANGLI	KR	50	3184.85	0.00	0.00	1035.93	0.73	144.50	4147.71	4265.45	102.84	OVER EXPLOITED	3322.97	3294.79	4265.45	98.02	SEMI CRITICAL
21	SANGLI	KR	53	1086.34	0.00	0.00	241.49	0.00	52.72	1311.52	986.42	75.21	SEMI CRITICAL	1086.34	1082.10	986.42	68.84	SAFE
22	SATARA	KR	6	2686.50	211.27	1021.51	814.95	0.00	282.89	4766.27	3499.10	73.41	SEMI CRITICAL	2686.50	3992.07	3499.10	67.24	SAFE
23	AURANGABAD	GV	34B	3137.52	30.07	426.47	924.56	376.83	387.45	5018.74	3804.76	75.81	SEMI CRITICAL	3137.52	4140.41	3804.76	69.56	SAFE
24	AURANGABAD	GV	41	2628.29	20.42	18.82	920.52	283.20	444.75	4073.64	3737.21	91.74	CRITICAL	2628.29	3202.79	3737.21	87.94	SEMI CRITICAL
25	AURANGABAD	GP	9	952.64	1.92	87.91	351.90	11.24	247.25	1570.22	1450.32	92.36	CRITICAL	952.64	1235.91	1450.32	88.88	SEMI CRITICAL
26	AURANGABAD	GP	11	641.47	1.26	268.13	196.79	5.68	43.30	1098.79	810.03	73.72	SEMI CRITICAL	641.47	911.84	810.03	67.25	SAFE
27	JALNA	GP	12B	780.13	0.00	0.00	167.17	4.04	45.96	947.43	673.75	71.11	SEMI CRITICAL	780.13	788.62	673.75	64.24	SAFE
28	BEED	MR	6	4184.32	0.00	0.00	842.71	29.36	275.92	5065.69	3660.04	72.25	SEMI CRITICAL	4184.32	4265.11	3660.04	66.06	SAFE
29	OSMANABAD	MR	30	4009.75	79.95	218.47	901.44	7.43	250.41	5194.08	3692.35	71.09	SEMI CRITICAL	4146.10	4467.24	3692.35	62.48	SAFE
30	LATUR	MR	20	1942.91	48.48	508.33	707.13	0.00	1452.52	4426.40	3156.97	71.32	SEMI CRITICAL	1942.91	3754.63	3156.97	65.25	SAFE
31	LATUR	MR	32B	760.82	0.00	0.00	168.63	0.00	145.34	1021.04	718.50	70.37	SEMI CRITICAL	760.82	860.85	718.50	63.88	SAFE
32	AMRAVATI	PTP	6	4543.78	13.29	51.84	980.39	1.94	54.87	5363.81	4031.77	75.17	SEMI CRITICAL	4546.24	4434.77	4031.77	68.81	SAFE
33	AMRAVATI	WR	8	1821.40	0.00	0.00	384.89	1.48	10.00	2106.88	1603.02	76.09	SEMI CRITICAL	1821.40	1741.23	1603.02	69.96	SAFE
34	NAGPUR	WR	29	1084.52	0.00	0.00	199.72	3.62	34.78	1256.51	922.87	73.45	SEMI CRITICAL	1084.52	1066.78	922.87	67.79	SAFE
35	NAGPUR	WRJ	1	3194.95	0.00	0.00	515.82	4.72	32.76	3560.83	2573.36	72.27	SEMI CRITICAL	3194.95	3070.80	2573.36	67.00	SAFE
36	BHANDARA	WGC	6	2457.23	0.28	8.78	1051.29	18.51	0.00	3359.28	2946.99	87.73	SEMI CRITICAL	2948.70	2827.45	2946.99	67.05	SAFE
37	WARDHA	WRJ	1	1841.50	0.00	0.00	376.16	2.76	30.65	2138.52	1563.94	73.13	SEMI CRITICAL	1841.50	1781.17	1563.94	66.69	SAFE
38	CHANDRAPUR	N	0	165.15	0.00	0.00	25.62	0.00	6.50	187.41	132.19	70.54	SEMI CRITICAL	165.15	163.06	132.19	65.35	SAFE

Figure 2



Difference in stage of development computed based on ratio of the net draft to recharge and gross draft to recharge
400
350
300
250
200
150
100
50
0
Stage of development
Slight difference in stage till the stage reaches 100%
Difference in stage becomes significant here
130
160
190
220
250
Recharge including return circulation from the groundwater irigation [other recharge is assumed to be 100 units]
Stage net draft
Stage gross draft

Figure 3



Difference in stage of development computed based on ratio of the net draft to recharge and gross draft to recharge
Stage of development
Slight difference in stage till the stage reaches 100%
Difference in stage becomes significant here
Recharge including return circulation from the groundwater irigation [other recharge is assumed to be 1000 units]
Stage net draft
Stage gross draft

Appendix II

NORMS RECOMMENDED BY GROUND WATER ESTIMATION COMMITTEES

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
Rainfall recharge	1	Alluvium- Sandy areas	20 to 25%	1	Alluvium- Sandy areas	20 to 25%	1	Alluvial areas - Indo-Gangetic and Inland areas	20-25% (22%)
	2	Alluvium- larger clay content	15 to 20%	2	Alluvium- Larger clay content	10 to 20%	2	Alluvial areas - East coast	14-18% (16%)
	3	Hard rock	10 to15%	3	Semi-consolidated Sandstones – Friable and Highly porous	10 to 15%	3	Alluvial areas - West coast	8-12% (10%)
				4	Granitic Terrain - weathered and fractured	10 to 15%	4	Weathered granite, gneiss and schist with low clay content	10-12% (11%)
				5	Granitic Terrain - Un-weathered	05 to 10%	5	Weathered granite, gneiss and schist with significant clay content	5-9% (8%)
				6	Basaltic Terrain - Vesicular and jointed Basalt	10 to 15%	6	Granulite facies like charnockite etc.	4-6% (5%)
				7	Basaltic Terrain - Weathered Basalt	04 to 10%	7	Vesicular and jointed basalt	12-14% (13%)

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
				8	Phyllites, limestones, sand stones, quartzites, shales, etc.	03 to 10%	8	Weathered basalt	6-8% (7%)
							9	Laterite	6-8% (7%)
							10	Semi-consolidated sandstone	10-14% (12%)
							11	Consolidated sandstone, quartzite ,limestone (except cavernous limestone)	5-7% (6%)
							12	Phyllites shales	3-5% (4%)
							13	Massive poorly fractured rock	1-3% (1%)
Specific Yield	1	Sandy Alluvial areas	12 to 18%	1	Sandy alluvial area	12 to 18%	1	Sandy alluvium	12-20% (16%)
	2	Silty Alluvial areas	06 to 12%	2	Valley fills	10 to 14%	2	Silty alluvium	8-12% (10%)
	3	Granites	03 to 04%	3	Silty/ Clayey alluvial area	05 to 12%	3	Clayey alluvium	4-8% (6%)
	4	Basalt	02 to 03%	4	Granites	02 to 04%	4	Weathered granite, gneiss and schist with low clay content	1-2% (1.5%)
				5	Basalts	01 to 03%	5	Weathered granite, gneiss and schist	1-3% (2%)

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
								with significant clay content	
				6	Laterite	02 to 04%	6	Weathered or vesicular, jointed basalt	1-3% (2%)
				7	Weathered phyllites, Shales, Schist & associated rocks.	01 to 03%	7	Laterite	2-3% (2.5%)
				8	Sandstone	01 to 08%	8	Sandstone	1-5% (3%)
				9	Limestone	03%	9	Quartzite	1-2% (1.5%)
				10	Highly Karstified Limestone	07%	10	Limestone	1-3% (2%)
							11	Karstified limestone	5-15% (8%)
							12	Phyllites, Shales	1-2% (1.5%)
							13	Massive poorly fractured rock	0.2-0.5% (0.3%)
Recharge due to Seepage from Canals	1	**For canals in normal type of soils which have some clay content along with sand**	15 to 20 ham/day/10^6 sq. metre of the wetted area, or 6 to 8 cusec/10^6 sq. ft. of the	1	**For unlined canals in normal type of soil with some clay content along with sand**	15 to 20 ha.m/day/10^6 sq.m. of wetted area of canal or 06 to 08 cusec/10^6 sq.ft. of wetted area of canal or 1.8 to 2.5	1	**Unlined canals in normal soils with some clay content along with sand**	1.8 to 2.5 cumecs per million sq m of wetted area (or) 15 to 20 ham/day/m

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
			wetted area, or 1.8 to 2.5 cumec/10^6 sq. metre of the wetted area			cumec/10^6 sq.m. of wetted area			illion sq m of wetted area
	2	**For canals in sandy soils**	25 to 30 ham/day/10^6 sq. metre of the wetted area, or 10 to 12 cusec/10^6 sq. ft. of the wetted area, or 3 to 3.5 cumec/10^6 sq. metre of the wetted area	2	**For unlined canals in sandy soils For unlined canals in sandy soils**	25 to 30 ha.m/day/10^6 sq.m. of wetted area or 10 to 12 cusec/10^6 sq.ft. of wetted area or 3.0 to 3.5 cumec/10^6 sq.m. of wetted area	2	**Unlined canals in sandy soil with some silt content**	3.0 to 3.5 cumecs per million sq m of wetted area (or) 25 to 30 ham/day/million sq m of wetted area
				3	**For lined canals**	20 percent of the above values	3	**Lined canals and canals in hard rock area**	20% of above values for unlined canals

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
Return Seepage from Irrigated Fields – Surface Water irrigation	1	**Non-paddy**	35% of the water delivered at the outlet	1	**Non-paddy**	35% of the water delivered at the outlet	1	**Non-paddy, Water level - <10 m**	30%
	2	**Paddy**	40% of the water delivered at the outlet	2	**Paddy**	40% of the water delivered at the outlet	2	**Non-paddy, Water level – 10 m to 25 m**	20%
							3	**Non-paddy, Water level – > 25 m**	10%
							4	**Paddy, water level - <10 m**	50%
							5	**Paddy, water level - 10 m to 25 m**	40%
							6	**Paddy, water level - >25m**	25%
Return Seepage from Irrigated Fields – Ground Water irrigation	1		30% of the water delivered at the outlet	1	**Non-paddy**	30% of the water delivered at the outlet	1	**Non-paddy, Water level - <10 m**	25%
				2	**Paddy**	35% of the water delivered at the outlet	2	**Non-paddy, Water level – 10 m to 25 m**	15%
							3	**Non-paddy, Water level – > 25 m**	5%
							4	**Paddy, water level**	45%

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
								- <10 m	
							5	**Paddy, water level - 10 m to 25 m**	35%
							6	**Paddy, water level - >25m**	20%
Seepage from Tanks			44 to 60 cm. per year over the total water spread			44 to 60 cm per year over the total water spread			1.4 mm/day for the period in which the tank has water, based on the average area of water spread or 60% of the maximum water spread area
Seepage from Water Conservation Structures		-	-	1	Percolation tanks	50% of its Gross Storage	1	Percolation tanks	50% of gross storage, considering the number of fillings, with half of this

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
									recharge occurring in the monsoon season, and the balance in the non-monsoon season
							2	Check dams and nala bunds	50% of gross storage with half of this recharge occurring in the monsoon season, and the balance in the non-monsoon season
Unit draft *					1. *Andhra Pradesh* Dugwell with mhot Dugwell with pump set Private Tubewell 2. *Bihar*	 0.5 ha 2.0 4.0		1. *Andhra Pradesh* Dugwell with Mhot Dugwell with Pumpset Borewell with Pumpset	 0.35 ham 0.65 1.3

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
					Dugwell without Pump			Shallow Tubewell	2.05
								Medium Tubewell	4.1
					(i) Upto 3 m dia	0.6		Deep Tubewell	5.85
					(ii) From 3 to 6 m dia	1.0		2. *Assam*	
								Shallow Tubewell with Pumpset	3.0
					Dug cum borewell	2.0			
					Tubewell			3. *Bihar*	
								Dugwell	0.6
					(i) 10 cm dia	4.0		Private tube well with Pumpset	1.0
					(ii) 5 cm dia	2.0			
								Bamboo boring with Pumpset	0.75
					Diesel Pump set on Dugwell/ Surface water sources			Deep tube well	30.0
								4. *Gujarat*	
					(i) 5 HP Pump set	2.0		Dugwell with Pumpset	0.8
					(ii) Pump above 5 HP	4.0			
								Borewell with Pumpset	1.2
					3. *Haryana*			Private shallow Tubewell	1.85
					Dugwell	1.2		Medium Deep Tubewell	6.0
					Shallow Tubewell	4.3			
								Deep Tubewell	30.0
					4. *Punjab*				
					Dugwell	1.0		5. *Haryana*	
					Shallow Tubewell	5.0		Dugwell with	1.5

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
					5. *Madhya Pradesh*			Pumpset	
								Private shallow Tubewell with Pumpset	1.81
					Dugwell	1.0			
					Shallow Tubewell	6.8		Deep Tubewell	15.0
					6. *Maharashtra*			*6. Himachal Pradesh*	
					Dugwell with Pump set	2.0		Medium Deep Tubewell with Pumpset	2.5
					Dugwell with mhot	0.5			
					7. *Tamil Nadu*			*7. Karnataka*	
								Dugwell with Pumpset	0.9
					Private Tubewell	8.0			
					Filter Point	4.0		Borewell with Pumpset	1.7
					Boring in well	0.8			
					Deepening of well	0.8		Dug cum Borewell with Pumpset	1.98
					8. *Uttar Pradesh*				
								8. Kerala	
					Masonry well	1.0		Dugwell with Pumpset	0.5
					Persian wheel (addl.)	0.5		Borewell with Pumpset	0.7
					Boring (small/ Marginal farmers) addl.	0.5			
								9. Madhya Pradesh	
					Pump set on boring Tubewell	5.0		Dugwell with Mhot	0.8
								Dugwell with	1.5

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
								Pumpset	
					9. *Tripura*			Borewell with Pumpset	1.5
					Shallow tubewell	4.0			
					Artesian well	0.5		Private shallow tubewell with Pumpset	3.0
					10. *West Bengal*				
					Shallow Tubewell	3.0			
					Dugwell	0.4		*10. Maharashtra*	
								Dugwell with Mhot	0.45
					11. *Rajasthan*			Dugwell with Pumpset	1.57
					Dugwell	2.0			
					Low duty Tubewell	2.0			
					Dug cum borewell	4.0			
								11. Orissa	
								Dugwell with Mhot	0.21
								Dugwell with Pumpset	1.0
								Filter Point with Pumpset	2.1
								Private Tubewell with Pumpset	7.0
								Deep Tubewell with Pumpset	17.5
								12. Punjab	
								Shallow Tubewell with Pumpset	1.3 - 3.4
								Deep Tubewell with Pumpset	18.0

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
								13. Rajasthan	
								Dugwell with Pumpset	0.52
								Private Tubewell with Pumpset	1.4
								Dug cum borewell with Pumpset	1.23
								Deep Tubewell	2.28
								14. Tamil Nadu	
								Dugwell with Pumpset	0.4 -1.0
								Private Tubewell with Pumpset	1.0 - 2.0
								Borewell with Pumpset	1.0
								15. Tripura	
								Shallow Tubewell with Pumpset	3.0
								Artesian Well	0.37
								16. Uttar Pradesh	
								Dugwell with Mhot	0.37
								Dugwell with Pumpset	0.75
								Private Tubewell with Pumpset	3.7

Parameters	Over-exploitation Committee, 1979			GEC – 1984			GEC - 1997		
								Deep Tubewell	22.0
								17. West Bengal	
								Dugwell with Pumpset	0.3
								Private Tubewell with Pumpset	1.52
								Deep Tubewell with Pumpset	18.5

* In case of *Unit Draft*, 'GEC-1984' recommended area irrigated in 'ha' for different structures. These areas are to be multiplied by applicable water depth to get the draft of ground water. In GEC-1997, annual unit gross drafts for different structures are given in 'ham'.