GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

GEC-1997

By

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GROUND WATER RESOURCES ESTIMATION

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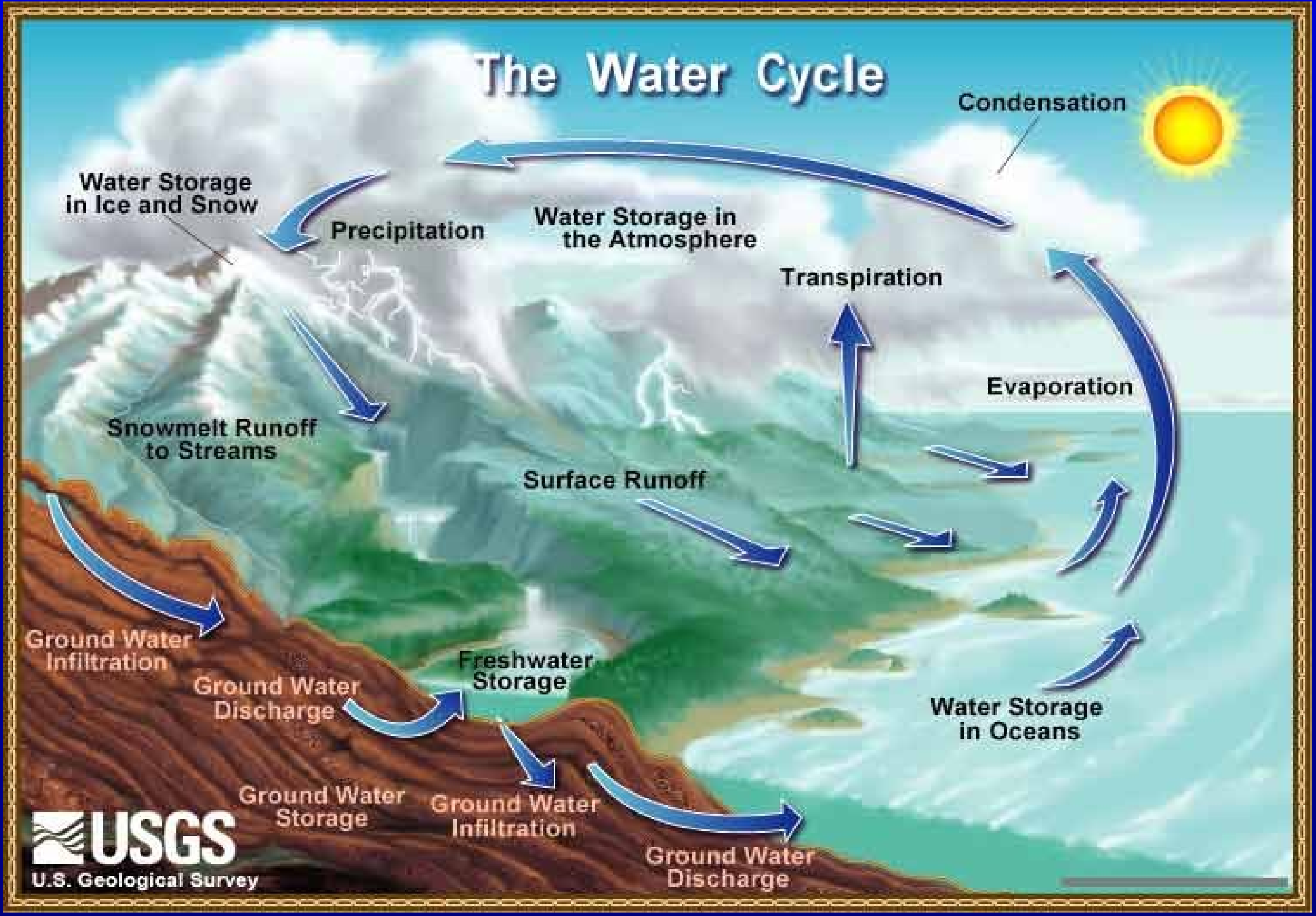

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

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- Evaporation
- Transpiration
- Water Stored in Atmosphere
- Precipitation
- Water Stored in Ice & Snow
- Snow melt Runoff
- Surface Runoff
- Infiltration
- Fresh Water Storage
- Ground Water Discharge to Surface Water Bodies
- Infiltration from surface water bodies

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

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I = P – R

I = P – R – E

I = P – R – E -T

I = P – R – E –T – ICE

I = P – R – E –T – ICE + SNOWR

I = P – R – E –T – ICE + SNOWR - FWST

I = P – R – E –T – ICE + SNOWR – FWST + GWD

I = P – R – E –T – ICE + SNOWR – FWST + GWD + ISW

Is This Feasible for a Regional Scale Assessment

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

GEC-1997

I = P – R – E –T – ICE + SNOWR – FWST + GWD + ISW

I = Infiltration

P = Precipitation

R = Surface Runoff

E = Evaporation

T = Transpiration

ICE = Water Stored in Ice & Snow

SNOWR = Snow melt Runoff

FWST = Fresh Water Storage

GWD = Ground Water Discharge to Surface Water Bodies

ISW = Infiltration from surface water bodies

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

GEC-1997

I = P – R – E –T – ICE + SNOWR – FWST + GWD + ISW

If We Consider Rainfall is the only form of Precipitation

ICE = Water Stored in Ice & Snow can be ignored

If We Consider an area not in the region of Himalayan rivers

SNOWR = Snow melt Runoff can be ignored

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

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Then the Infiltration Can Be Estimated By

$$I = P - R - E - T - FWST + GWD + ISW$$

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Availability of Data

P - Available one set per Block

R - Not Available even one per an Assessment Unit

E & T – One Set Per District

FWST – Design Storage is available not the actual.

GWD - Except For small Project Areas, not even idea to measure at present

ISW – Indirect Measurement

Reliable Parameters In This Method :

P is reliable.

ISW is reliable provided there is a proper method to compute.

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

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Modeling Approach :

Certainly It gives better result provided

One can develop a fully validated model for each assessment unit.

Is It Feasible (Possible) Today?

In Last 60 years after Independence we have flow models in India not more than 30 or 40.

Whether can they be used for parameter estimation?

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Modeling Approach :

We don’t have sufficient data for the lumped parameter model

How can we manage data hungry discrete parameter modeling

Approach

Lumped Parameter Model

Basic Equation

Inflow-Outflow=Change in Storage

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

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Inflow Components

- Rainfall Recharge
- Recharge From canals
- Recharge From Surface Water Irrigation
- Recharge From Ground Water irrigation
- Recharge From Tanks & Ponds
- Recharge From Water Conservation Structures

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Inflow Components (not included in GEC)

- Lateral Inflow across Boundaries
- Sub surface inflow from hydraulically connected streams
- Vertical inter aquifer inflow

Outflow Components

- Gross Draft

GEC-1997

Outflow Components (not included in GEC)

- Lateral Outflow across Boundaries
- Sub surface Outflow from hydraulically connected streams
- Vertical inter aquifer Outflow
- Evapotranspiration

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

GEC-1997

- The parameters not included in GEC are mainly very difficult to compute in the assessment at regional scale.
- Lateral flows are zero when hydrological boundary is selected.
- In other components it is assumed inflow=outflow.
- For Base flow and Evapo-transpiration provision for 5 –10 % as unaccounted discharges is made.

Ground Water Assessment Unit

GEC - 1997

Hard Rock Areas	Hydrological Boundaries
Soft Rock Areas	Administrative Boundaries

Ground Water Assessment Sub-Units

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Hilly Areas	Recharge is Not Possible
Ground Water Worthy Areas	Recharge is Possible
Poor Ground Water Quality Areas	Quality is Beyond Permissible Limits
Good Ground Water Quality Areas	Quality is Within Permissible Limits
Command Areas	Command of any Major or Medium Irrigation Project
Non-Command Areas	Not in the Command of any Major or Medium Irrigation Project

Ground Water Assessment Sub-Units

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- ESSENTIAL DATA ELEMENTS
  - AREA OF ASSESSMENT UNIT
  - HILLY AREA
  - COMMAND AREA
  - POOR GROUND WATER QUALITY AREA
- OPTIONAL DATA ELEMENTS
  - STARTING AND ENDING LATITUDES & LONGITUDES

Ground Water Year

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Predominant Monsoon	South-West Monsoon North-East Monsoon
Ground Water Year	June To May July To June October To September
Monsoon Period	June To September July To October October To December
Non-Monsoon Period	October To May November To June January To September
Pre-Monsoon Monitoring	May/June/September
Post-Monsoon Monitoring	October/November/January

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THE MAIN COMPONENTS ARE

- **COMPUTATION OF GROUND WATER DRAFT**
- **COMPUTATION OF RECHARGE DUE TO OTHER SOURCES**
- **COMPUTATION OF RAINFALL RECHARGE**
- **COMPUTATION OF SUMMARY DETAILS**

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

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COMPUTATION OF RECHARGE DUE TO OTHER SOURCES

- Recharge Due To Canals
- Recharge Due To Surface Water Irrigation
- Recharge Due To Ground Water Irrigation
- Recharge Due To Tanks & Ponds
- Recharge Due To Water Conservation Structures

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

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COMPUTATION OF SUMMARY DETAILS

- Net Annual Ground Water Availability
- Current Stage Of Ground Water Development
- Water Level Trend
- Categorization For Future Ground Water Development
- Ground Water Allocation For Domestic & Industrial Water Supply
- Net Annual Ground Water Availability For Future Irrigation Needs.
- Additional Potential Recharges.
- Static Ground Water Resources.

Estimation Of Ground Water Draft

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Draft Can Be Of Three Types

- Domestic draft
- Irrigation draft
- Industrial draft

Estimation Of Ground Water Draft

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DOMESTIC DRAFT

WELL CENSUS METHOD

No. of different types of abstraction structures

Unit Draft

REQUIREMENT METHOD

Population Census

Percapita Requirement

Estimation Of Ground Water Draft

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IRRIGATION DRAFT

WELL CENSUS METHOD

No. of different types of abstraction structures

Unit Draft

CROPPING PATTERN METHOD

Cropping Pattern

Crop Water Requirement

POWER CONSUMPTION METHOD

Total power consumed

Unit Power Required For Unit Water Lift

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Estimation Of Ground Water Draft

INDUSTRIAL DRAFT

WELL CENSUS METHOD

No. of different types of abstraction structures

Unit Draft

POWER CONSUMPTION METHOD

Total power consumed

Unit Power Required For Unit Water Lift

Estimation Of Ground Water Draft

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$$GGWDft = \sum_{i=1}^{types} No \times Unit\ Draft$$

Where

GGWDft = Gross Ground Water Draft in any season

No. = Number of Abstraction Structures actually in Use.

Unit Draft = Draft For one abstraction structure during the season.

Types = No of Types of Different Structures.

Unit Draft= Draft per day * No of days the structures are in use

Estimation Of Ground Water Draft

Dug wells with Manual Lift : 866
Daily draft during non monsoon = 6m3/day
No of days 100

Dug wells with Electric Pumpset : 49
Daily draft during non monsoon = 30m3/day
No of days 90
What is the Unit Draft During non-monsoon
Gross Ground Water Draft

Estimation Of Ground Water Draft

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Dug wells with Manual Lift : 866

Unit draft during non monsoon = 6 *100m3 =600m3

Draft From Dugwells with Manual Lift =866 *600 = 519600 m3 =51.96ham

Dug wells with Electric Pumpset : 49

Unit draft during non monsoon = 30 * 90 m3 =2700 m3

Draft From Dugwells with Pumpset =2700 *49 = 132300 m3 =13.23ham

Gross Ground Water Draft For Irrigation = 51.96 + 13.23 =65.19ham

Ground Water Draft

GEC-1997

- ESSENTIAL DATA ELEMENTS
  - ESTIMATED DRAFT PER DAY PER STRUCTURE DURING MONSOON & NON-MONSOON
  - ESTIMATED No OF SUCH DAYS THE STRUCTURE IS IN OPERATION DURING MONSOON & NON-MONSOON
  - No. OF DIFFERENT STRUCTURES FOR DIFFERENT TYPES OF DRAFTS
- OPTIONAL DATA ELEMENTS
  - NIL

Estimation Of Recharge Due To Other Sources

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COMMAND AREAS

- **SEEPAGE FROM CANALS**
- **RETURN FLOW FROM SURFACE WATER IRRIGATION**
- **RETURN FLOW FROM GROUND WATER IRRIGATION**
- **RECHARGE DUE TO TANKS/PONDS**
- **RECHARGE DUE TO WATER CONSERVATION STRUCTURES**

Estimation Of Recharge Due To Other Sources

GEC-1997

NON-COMMAND AREAS

- **RETURN FLOW FROM GROUND WATER IRRIGATION**
- **RECHARGE DUE TO TANKS/PONDS**
- **RECHARGE DUE TO WATER CONSERVATION STRUCTURES**

Estimation Of Recharge Due To Canals

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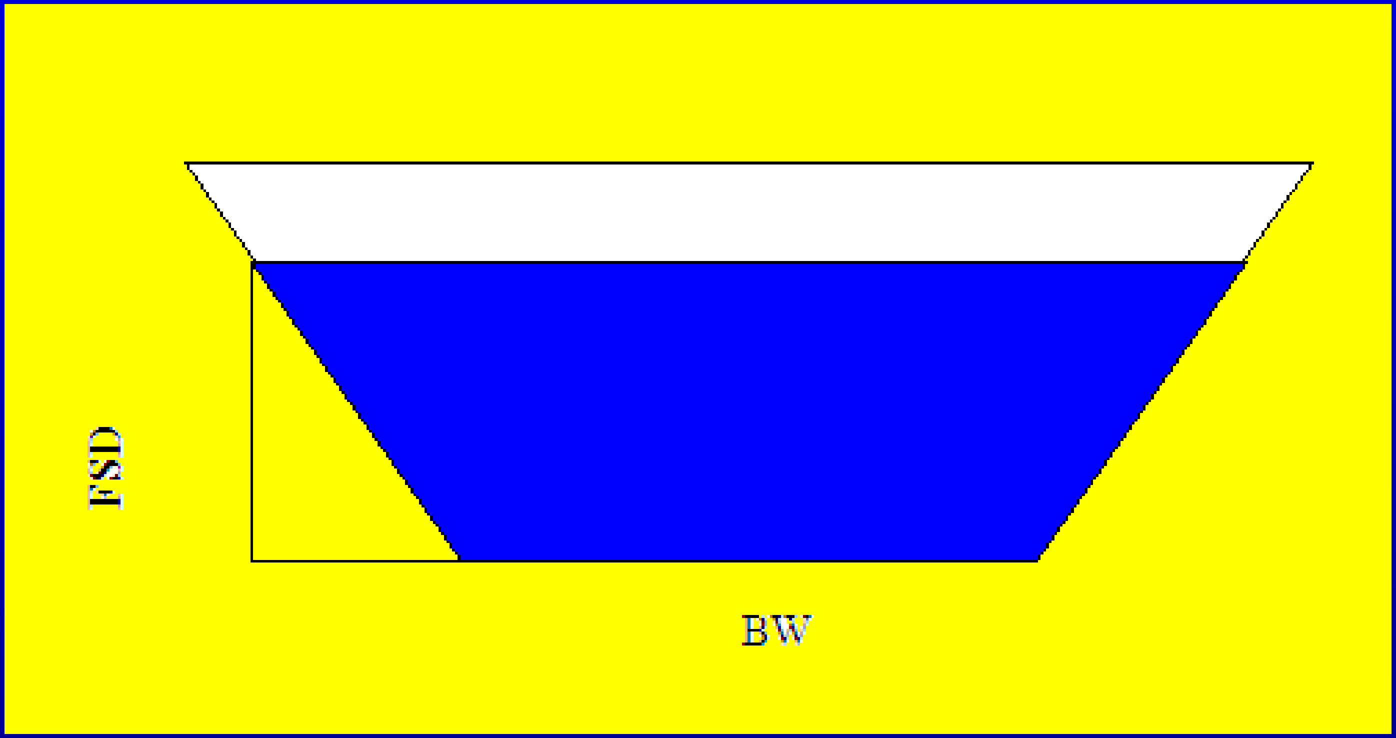
$$Rc = WA*Days*SF$$

Where

- **Rc = The recharge due to canal segment in ham**
- **WA=Wetted Area in Million Sq.m**
- **SF = Seepage Factor in ham/Million Sq.m/day**

Estimation Of Recharge Due To Canals



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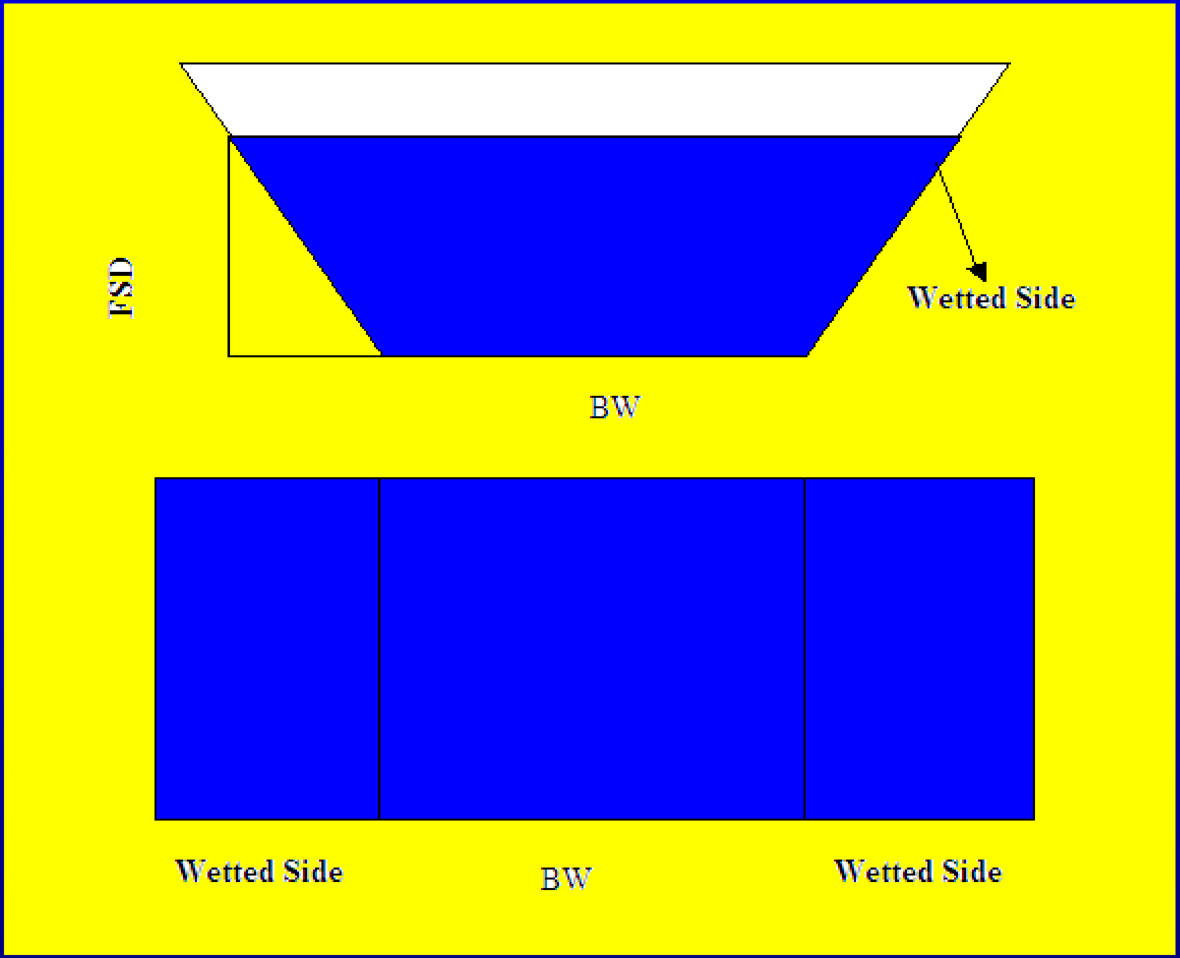
Estimation Of Recharge Due To Canals



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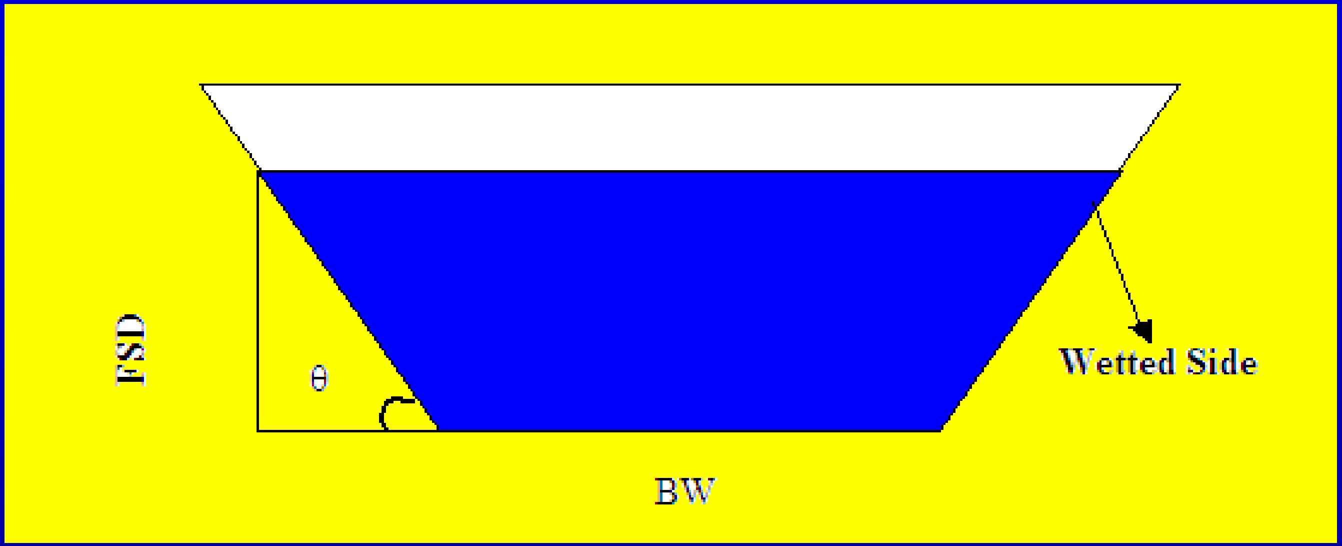
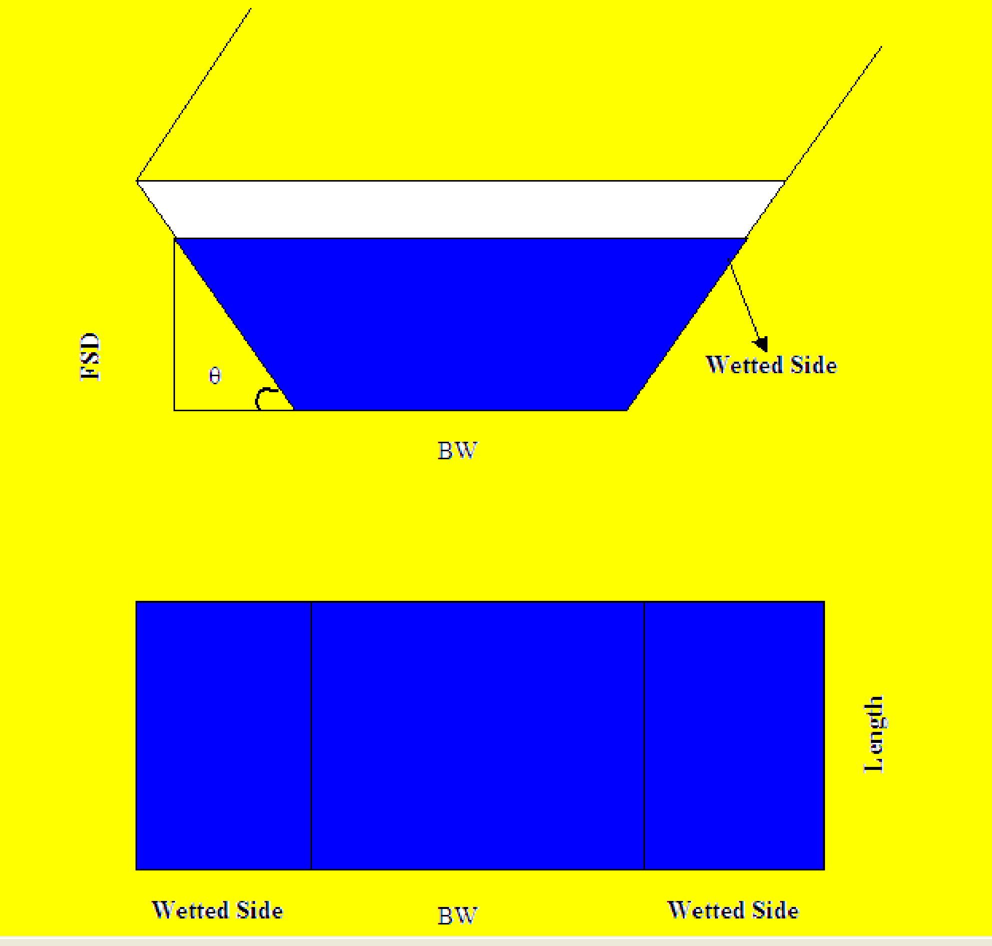
Estimation Of Recharge Due To Canals



$$Sin(\theta) = \frac{FSD}{Wetted\ Side}$$

$$Wetted\ Side = \frac{FSD}{Sin(\theta)}$$

Estimation Of Recharge Due To Canals



Estimation Of Recharge Due To Canals

GEC – 1997

$$Wetted\ Side = \frac{ASD}{Sin(\theta)}$$

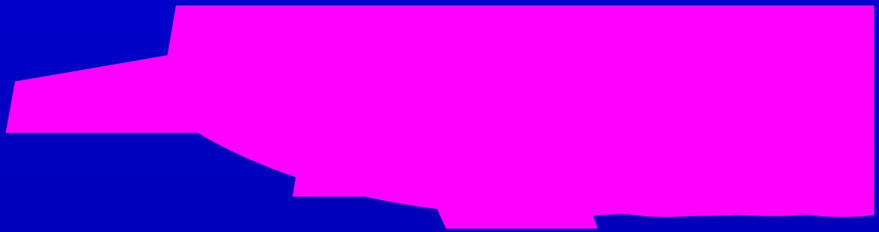
ASD =Average Supply Depth

(Or 0.6*FSD)

θ = Side Angle

Estimation Of Recharge Due To Canals

GEC-1997



Where

WP=Wetted perimeter in m

ASD = Average Supply Depth in m

SideAngle = Side slope of the canal in Degrees

BW = Bed width of the canal in m.

Estimation Of Recharge Due To Canals

WA= WP* L

Where

WA =Wetted Area in Million Sq.m
WP =Wetted perimeter
L = Length of Canal Segment in Kms.

Rc = WA*Days*SF

Where

Rc = The recharge due to canal segment in ham
WA=Wetted Area in Million Sq.m
SF = Seepage Factor in ham/Million Sq.m/day

Estimation Of Recharge Due To Canals

GEC-1997

NORMS FOR CANAL SEEPAGE

Unlined canals in normal soils with some clay content along with sand	1.8 to 2.5 cumecs per millison sq m of wetted area (or) 15 to 20 ham/day/million sq m of wetted area
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
Lined canals and canals in hard rock area	20% of above values for unlined canals

NORMS FOR CANAL SEEPAGE

- 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.

- Where specific results are available from case studies, the adhoc norms are to be replaced by norms evolved from these studies.

Estimation Of Recharge Due To Canals

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Canal reach Name – Nandgaon Minor
Reach Type – Unlined
Lithology – Hard Rock
Length –2660m
Full Supply Depth – 5m
Bed Width – 3m
Slope – 45°
Monsoon Running Days – 30
Non-monsoon Running Days -90
Canal Seepage Factor – 3 ham/day/million sq.m during both monsoon & non-monsoon

What is the Recharge Due to The Canal reach ?

Estimation Of Recharge Due To Canals

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WA= 11.56 * 2660 = 30749.6 sq.m = 0.3075 m sq.m

Rc during monsoon = 0.3075 * 30 * 3 = 27.675 ham

Rc during non - monsoon = 0.3075 * 90 * 3 = 83.025 ham

Recharge Due To Canals

GEC-1997

- ESSENTIAL DATA ELEMENTS
  - **NAME OF THE CANAL, TYPE AND LENGTH**
  - **NAME OF THE SEGMENT, LENGTH, DESIGN DEPTH, BASE WIDTH, SIDE SLOPE, LINING, TERRAIN, No. OF RUNNING DAYS DURING MONSOON & NON-MONSOON** SEASONS.
- OPTIONAL DATA ELEMENTS
  - STARTING AND ENDING LATITUDES & LONGITUDES

GEC-1997

Estimation Of Recharge

Due To Surface Water Irrigation

$$Rswi = IWA * RFF$$

Where

Rswi = Recharge due to Surface water irrigation in ham

IWA = Irrigation water applied in ham

RFF = Return Flow Factor as a fraction

$$IWA = AD * days$$

Where

IWA = Irrigation water applied in ham

AD = Average Discharge of the outlet in ham/day

Days = No of days the out let is open.

Estimation Of Recharge

Due To Surface Water Irrigation

GEC-1997

NORMS FOR SURFACE WATER IRRIGATION RETURN FLOW

Crop Type	Water Level mbgl		
	<10m	10m-25m	>25m
Paddy	50%	40%	25%
Non-Paddy	30%	20%	10%

GEC-1997

NORMS FOR SURFACE WATER IRRIGATION RETURN FLOW

1. The recharge is to be estimated based on water released at the outlet.

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, the adhoc norms are to be replaced by norms evolved from these studies.

Estimation Of Recharge

Due To Surface Water Irrigation

GEC-1997

Outlet Name – Nandgaon Minor OL-1

Canal Reach Name – Nandagaon Minor

Design Discharge – 1.646 ham/day

Monsoon Running Days – 30

Non-monsoon Running Days –90

Crop Type – Paddy

Area irrigated During Monsoon – 3000 ha

Area irrigated During Non-Monsoon – 3000 ha

Crop Type – Non-Paddy

Area irrigated During Monsoon – 6000 ha

Area irrigated During Non-Monsoon – 6000 ha

RFF for paddy during Monsoon - 0.5

RFF for Non- Paddy during Monsoon – 0.3

RFF for paddy during Non- Monsoon - 0.5

RFF for Non- Paddy during Non-Monsoon – 0.3

Estimation Of Recharge

Due To Surface Water Irrigation

IWA During Monsoon = 1.646* 0.6 * 30 =29.628ham
IWA During Non-Monsoon = 1.646* 0.6 * 90 = 88.884ham

$$Weighted\ \ Average\ RFF = \frac{Paddy\ Area \times Paddy\ RFF + Non-Paddy\ Area \times Non-Paddy\ RFF}{Paddy\ Area + Non-Paddy\ Area}$$

$$Weighted\ \ Average\ RFF = \frac{3000 \times 0.5 + 6000 \times 0.3}{3000 + 6000} = \frac{1500 + 1800}{9000} = \frac{3300}{9000} = 0.3667$$

Rswi During Monsoon= 29.628 * 0.3667 =10.86 ham
Rswi During Non-Monsoon= 88.884 * 0.3667 = 32.59 ham

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Estimation Of Recharge Due To Ground Water Irrigation

GEC-1997

Rgwi = IWA * RFF

Where

Rgwi = Recharge due to Ground water irrigation in ham

IWA = Irrigation water applied i.e. Gross ground Water Draft in ham

RFF = Return Flow Factor as a fraction

Estimation Of Recharge Due To Ground Water Irrigation

NORMS FOR GROUND WATER IRRIGATION RETURN FLOW

Crop Type	Water Level mbgl		
	<10m	10m-25m	>25m
Paddy	45%	35%	20%
Non-Paddy	25%	15%	05%

NORMS FOR GROUND WATER IRRIGATION RETURN FLOW

1. The recharge is to be estimated based on Gross Ground Water 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, the adhoc norms are to be replaced by norms evolved from these studies.

Estimation Of Recharge

Due To Ground Water Irrigation

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Crop Type – Paddy
Area irrigated During Monsoon – 3000 ha
Area irrigated During Non-Monsoon – 3000 ha

Crop Type – Non-Paddy
Area irrigated During Monsoon – 6000 ha
Area irrigated During Non-Monsoon – 6000 ha

RFF for paddy during Monsoon - 0.45
RFF for Non- Paddy during Monsoon – 0.25
RFF for paddy during Non- Monsoon - 0.45
RFF for Non-Paddy during Non-Monsoon – 0.25

Estimation Of Recharge

Due To Ground Water Irrigation

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Gross Ground Water Draft For Irrigation During Non-Monsoon= 65.19ham

$$Weighted\ \ Average\ RFF = \frac{Paddy\ \ Area \times Paddy\ RFF + Non - Paddy\ \ Area \times Non - Paddy\ RFF}{Paddy\ \ Area + Non - Paddy\ \ Area}$$

$$Weighted\ \ Average\ RFF = \frac{3000 \times 0.45 + 6000 \times 0.25}{3000 + 6000} = \frac{1350 + 1500}{9000} = \frac{2850}{9000} = 0.2778$$

Rgwi During Non-Monsoon= 65.19 * 0.2778 = 18.11 ham

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Estimation Of Recharge Due To Tanks & Ponds

RT = AWSA * Days * RFact

Where

RT = Recharge from tanks & Ponds

AWSA = Average Water Spread Area.

(Or 60% of Design Water Spread Area.)

Days = No. of water is actually available in the Tanks & Ponds.

RFact = A recharge Factor in mm/day

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Estimation Of Recharge Due To Tanks & Ponds

NORM FOR TANK & POND SEEPAGE

1.4 mm / day

Estimation Of Recharge Due To Tanks & Ponds

GEC-1997

Tank Name – Yesamba
Design Water Spread Area – 35ha
Monsoon Running Days – 120
Non-monsoon Running Days –120

Estimation Of Recharge Due To Tanks & Ponds

RT During Monsoon = 35 * 0.6 *120 * 0.0014 = 3.528 ham

RT During Non-Monsoon = 35 * 0.6 *120 * 0.0014=3.528 ham

Estimation Of Recharge Due To Water Conservation Structures

GEC-1997

RWCS = GS*RFact

Where

RWCS = Recharge due to Water Conservation Structures

GS = Gross Storage

RFact = Recharge Factor as a Fraction

GS = Storage Capacity * No. Of Fillings

Estimation Of Recharge
Due To Water Conservation Structures

GEC-1997

NORM FOR SEEPAGE FROM WATER CONSERVATION STRUCTURES

50% of Gross Storage during a year means
25% during Monsoon Season
25% During Non-Monsoon Season

Estimation Of Recharge
Due To Water Conservation Structures

WCS Name – Nandgaon
Type – Percolation tank
Storage Capacity – 3.2ham
No. of Fillings – 1.5

Estimation Of Recharge
Due To Water Conservation Structures

RWCS During Monsoon = 3.2 * 1.5 * 0.25 = 1.20 ham

RWCS During Non-Monsoon = 3.2 * 1.5 * 0.25 = 1.20 ham

Estimation Of Recharge Due To Rainfall

1.Rainfall infiltration factor method

2.Water level fluctuation method

Estimation Of Recharge Due To Rainfall

Rainfall Infiltration Factor Method

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RRF = Area*NMR*RFIF

Where

RRF = Recharge due to rainfall

Area=Total area of the subunit

NMR= Normal Monsoon Rainfall

RFIF = Rainfall infiltration Factor

NORMS FOR RIF

S.No	Geographic Location	Recommended	Minimum	Maximum
1	Indo-Gangetic & Other Inland	**22%**	20%	25%
2	East Coast	**16%**	14%	18%
3	West Coast	**10%**	8%	12%

Estimation Of Recharge Due To Rainfall

Rainfall Infiltration Factor Method

NORMS FOR RIF

S.No	Rock Formation	Recommended	Minimum	Maximum
1	Weathered Granite. Gneiss and Schist with low clay content	**11%**	10%	12%
2	Weathered Granite. Gneiss and Schist with significant clay content	**8%**	5%	9%
3	Rocks belong to Granulite Facies like Chornockite	**5%**	4%	6%
4	Vesicular and Jointed Basalt	**13%**	12%	14%
5	Weathered basalt	**7%**	6%	8%
6	Laterite	**7%**	6%	8%

Estimation Of Recharge Due To Rainfall

Rainfall Infiltration Factor Method

GEC-1997

NORMS FOR RIF

S.No	Rock Formation	Recommended	Minimum	Maximum
7	Semi-Consolidated Sandstone	**12%**	10%	14%
8	Cosolidated Sandstone, Quartzite,Limestone (except cavernous Limestone)	**6%**	5%	7%
9	Phyllites & Shales	**4%**	3%	5%
10	Massive Poorly Fractured Rock	**1%**	1%	3%

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NORMS FOR RIF

- 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.
- 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.

Estimation Of Recharge Due To Rainfall

Rainfall Infiltration Factor Method

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- Area 27565 ha
- Raifall infiltration factor =0.07
- Normal Monsoon Rainfall = 750mm

Estimation Of Recharge Due To Rainfall

Rainfall Infiltration Factor Method

- Area 27565 ha
- Raifall infiltration factor =0.07
- Normal Monsoon Rainfall = 750mm

RRF = 27565 * 0.750*0.07 =1447.16 ham

GEC-1997

Estimation Of Recharge Due To Rainfall

Water Table Fluctuation Method

$$\Delta S = h * SY * A$$

Where

ΔS = Change in storage

h = Rise in water level in the monsoon season

SY = Specified yield

A = Area of sub unit

GEC-1997

Estimation Of Recharge Due To Rainfall

Water Table Fluctuation Method

NORMS FOR Sy

S.No	Formation	Recommended	Minimum	Maximum
1	Sandy Alluvium	**16%**	12%	20%
2	Silty Alluvium	**10%**	8%	12%
3	Clayey Alluvium	**6%**	4%	8%

Estimation Of Recharge Due To Rainfall

Water Table Fluctuation Method

GEC-1997

NORMS FOR Sy

S.No	Rock Formation	Recommended	Minimum	Maximum
1	Weathered Granite. Gneiss and Schist with low clay content	**3%**	2%	4%
2	Weathered Granite. Gneiss and Schist with significant clay content	**1.5%**	1%	2%
3	Weathered or Vesicular or Jointed Basalt	**2%**	1%	3%
4	Laterite	**2.5%**	2%	3%
5	Sandstone	**3%**	1%	5%
6	Quartzite	**1.5%**	1%	2%

Estimation Of Recharge Due To Rainfall

Water Table Fluctuation Method

NORMS FOR Sy

S.No	Rock Formation	Recommended	Minimum	Maximum
7	Limestone	**2%**	1%	3%
8	Karstified Limestone	**8%**	5%	13%
9	Phyllites & Shales	**1.5%**	1%	2%
10	Massive Poorly Fractured Rock	**0.3%**	0.2%	0.5%

GEC-1997

NORMS FOR Sy

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.

Estimation Of Recharge Due To Rainfall

Water Table Fluctuation Method

GEC-1997

Area 27565 ha

Specific yield – 0.02

Pre-Monsoon WL = 9.00

Post-Monsoon WL = 4.00

Estimation Of Recharge Due To Rainfall

Water Table Fluctuation Method

GEC – 1997

Area 27565 ha
Specific yield – 0.02
Pre-Monsoon WL = 9.00
Post-Monsoon WL = 4.00

Δ S=(9.00 – 4.00) * 0.02 * 27565=2756.5ham

Determination of Sy Using Dry Season Ground Water Balance Method

Specific Yield Estimation Using Dry Season Ground Water Balance Method

GEC-1997

$$S_y \, x \, h \, x \, A = D_G - R_{gw} + B$$

Where

h = decline in water level during dry season

SY= Specific yield

A=Area of the micro watershed

R_{GW}=Recharge due to Ground Water Irrigation

D_G=Gross Ground Water Draft

B- base flow in any

Specific Yield Estimation Using Dry Season Ground Water Balance Method

GEC-1997

$$S_y = \frac{D_G - R_{gw} + B}{hxA}$$

Estimation Of Recharge Due To Rainfall

Water Table Fluctuation Method

Δ S= h * SY * A = RF+RC+RSW+RGW+RT+RWCS-DG

Where

Δ S= Change in storage

h = Rise in water level during monsoon season

SY= Specific yield in the zone of fluctuation

A=Area of the sub unit

RRF = Recharge due to Rainfall

RC = Recharge due to Canals

RSW =Recharge due to Surface Water Irrigation

RGW=Recharge due to Ground Water Irrigation

RT=Recharge due to Tanks & Ponds

RWCS=Recharge due to Water Conservation Structures

DG=Gross Ground Water Draft

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Estimation Of Recharge Due To Rainfall
Water Table Fluctuation Method

Hence

RRF =Δ S - RC - RSW -RGW – RT - RWCS +DG

Or

RRF =(h * SY * A)+ DG -RC - RSW -RGW – RT - RWCS

Normalization of Recharge Due To Rainfall During Monsoon Season

GEC-1997

Two Methods Can Be Employed

- As proposed by the GEC-1984 i.e. y=mx
- Using y=mx+c equation

Normalization of Recharge Due To Rainfall During Monsoon Season Y=mX

GEC-1997

$$y = mx$$

$$Rech = mRf$$

$$m = Rech/Rf$$

Normalization of Recharge Due To Rainfall During Monsoon Season Y=mX

GEC-1997

Rainfall	Recharge
1434.80	1329.78
936.10	956.50
767.00	833.29
1164.00	1204.44
1016.18	1060.40

Normalization of Recharge Due To Rainfall During Monsoon Season
Y=mX

Rainfall	Recharge	Recharge/Rainfall
x	y	m=y/x
1434.80	**1329.78**	**0.927**
936.10	**956.50**	**1.022**
767.00	**833.29**	**1.086**
1164.00	**1204.44**	**1.035**
1016.18	**1060.40**	**1.044**

GEC-1997

Normalization of Recharge Due To Rainfall During Monsoon Season

Y=mX

GEC-1997

m	NMR	m x NMR
0.927	**1016.18**	942.00
1.022	**1016.18**	1038.54
0.975		990.27
1.035	**1016.18**	1051.75
1.044	**1016.18**	1060.89
0.927	**1016.18**	942.00
0.991	**1016.18**	1007.03

Normalization of Recharge Due To Rainfall During Monsoon Season Y=mX+c

G E C - 1 9 9 7

$$y = mx + c$$

$$10 = m*3 + c$$

$$16 = m*5 + c$$

$$10 = 3m + c$$

$$16 = 5m + c$$

Normalization of Recharge Due To Rainfall During Monsoon Season
Y=mX+c

GEC - 1997

$$10 = 3m + c$$

$$16 = 5m + c$$

$$-6 = -2m$$

$$m = 6/2 = 3$$

$$10 = 3*3 + c$$

$$10 = 9 + c$$

$$c = 10 - 9 = 1$$

Normalization of Recharge Due To Rainfall During Monsoon Season Y=mX+c

GEC-1997

y=mx+c

1329.78 =m***1434.8**+c

956.50 =m* **936.10** +c

1329.78 = **1434.8**m+c

956.50 = **936.10**m+c

Normalization of Recharge Due To Rainfall During Monsoon Season Y=mX+c

G E C – 1 9 9 7

1329.78 = **1434.8**m+c

956.50 = **936.10**m+c

373.28= 498.7m

m=373.28/ 498.7 =0.749

1329.78 = **1434.80 *** 0.749 +c

1329.78 =1074.67+c

C= **1329.78** - 1074.67 = 255.11

Normalization of Recharge Due To Rainfall During Monsoon Season
Y=mX+c

m=0.749

C= 255.11

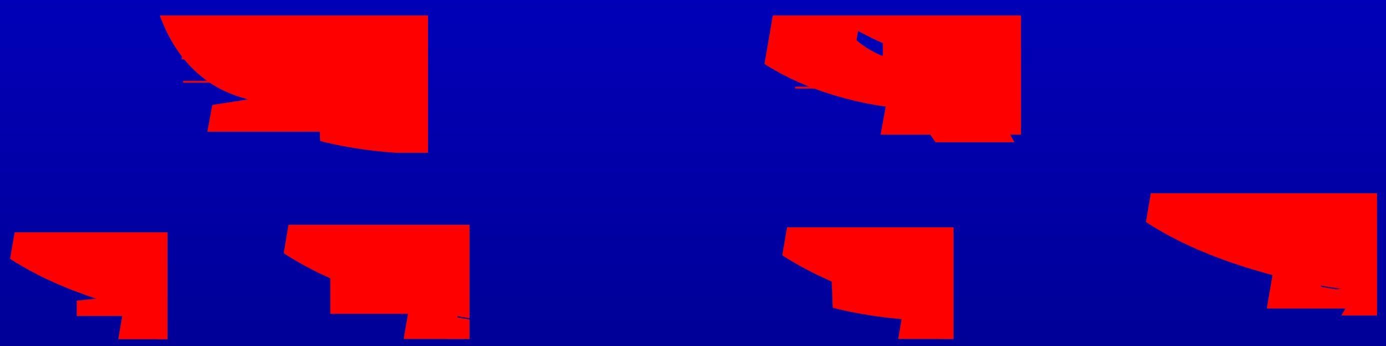
NMR=**1016.18**

Rech=0.749*1016.18 + 255.11=1016.23

Estimation Of Recharge Due To Rainfall
Water Table Fluctuation Method
NORMALIZATION

GEC-1997

For normalizing the rainfall recharge at least 5 years data of rainfall and the corresponding rainfall recharge is used. Fitting a linear regression curve for this data set will give an equation in y=ax+b form



Where

r i= Rainfall

R i= Recharge due to rainfall

Normalization of Recharge Due To Rainfall During Monsoon Season
Y=mX+c

GEC-1997

S.No	RF	Rech	RF^2	RF*Rech
1	1.4348	1.3298	2.0587	1.9080
2	0.9361	0.9565	0.8763	0.8954
3	0.7670	0.8333	0.5883	0.6391
4	1.1640	1.2044	1.3549	1.4019
5	1.0162	1.0604	1.0327	1.0778
5	5.3181	5.3844	5.9109	5.9222
N	S1	S2	S3	S4

Normalization of Recharge Due To Rainfall During Monsoon Season Y=mX+c

GECC-1997

$$a = \frac{5*5.9222 - 5.3181*5.3844}{5*5.9109 - 5.3181*5.3181}$$

$$a = \frac{29.611 - 28.6348}{29.5545 - 28.2822} = \frac{0.9762}{1.2723} = 0.7673$$

Normalization of Recharge Due To Rainfall During Monsoon Season
Y=mX+c

$$b = \frac{5.3844 - 0.7673 * 5.3181}{5}$$

$$b = \frac{5.3844 - 4.0806}{5} = \frac{1.3038}{5} = 0.26076$$

GEC-1997

Normalization of Recharge Due To Rainfall During Monsoon Season
Y=mX+c

GEC - 1997

$$Rrf = 0.7673 * 1.0162 + .26076$$

$$= 0.7797 + .26076 = 1.04046$$

$$= 1040.46 ham$$

Estimation Of Recharge Due To Rainfall
Water Table Fluctuation Method
PERCENT DIFFERENCE

GEC-1997

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**

Estimation Of Recharge Due To Rainfall

Water Table Fluctuation Method

PERCENT DIFFERENCE

G E C - 1 9 9 7

The rainfall recharge for Normal Monsoon Season Rainfall is finally adopted as per the following criteria.

If -20% < PD < +20% Final Rainfall Recharge = RRf(wtfm)

If PD < -20% Final Rainfall Recharge = RRf(rifm)* 0.8

If PD > +20% Final Rainfall Recharge = RRf(rifm)* 1.2

Total Ground Water Recharge

GEC-1997

$$TGWR = R_{Rf} + R_{C} + R_{SW} + R_{GW} + R_{T} + R_{WCS}$$

Where

TGWR = Total Ground Water Recharge

R_{RF} = Recharge due to Rainfall

R_{C} = Recharge due to Canals

R_{SW} =Recharge due to Surface Water Irrigation

R_{GW}=Recharge due to Ground Water Irrigation

R_{T}=Recharge due to Tanks & Ponds

R_{WCS}=Recharge due to Water Conservation Structures

Total Ground Water Recharge During Monsoon Season

GEC-1997

$$TGWR_m = R_{Rf} + R_C + R_{SW} + R_{GW} + R_T + R_{WCS}$$

Where

$TGWR_m$ = Total Ground Water Recharge During Monsoon

R_{RF} = Recharge due to Rainfall

R_C = Recharge due to Canals

R_{SW} =Recharge due to Surface Water Irrigation

R_{GW}=Recharge due to Ground Water Irrigation

R_T=Recharge due to Tanks & Ponds

R_{WCS}=Recharge due to Water Conservation Structures

Total Ground Water Recharge During Non-Monsoon Season

GEC-1997

$$TGWR_n = R_{Rf} + R_C + R_{SW} + R_{GW} + R_T + R_{WCS}$$

Where

$TGWR_n$ = Total Ground Water Recharge During Monsoon

R_{RF} = Recharge due to Rainfall

R_C = Recharge due to Canals

R_{SW} =Recharge due to Surface Water Irrigation

R_{GW}=Recharge due to Ground Water Irrigation

R_T=Recharge due to Tanks & Ponds

R_{WCS}=Recharge due to Water Conservation Structures

Total Annual Ground Water Recharge

The sum of recharge during Monsoon and Non-Monsoon seasons will be the Total Annual Ground Water Recharge.

Net Annual Ground Water Availability

GEC-1997

NAGWA = TAGWR – UND

Where

NAGWA = Net Annual Ground Water Availability

TAGWR = Total Annual Ground Water Recharge

UND = Unavoidable Natural Discharges

(5% - 10% of Total Annual Ground Water Recharge)

Stage Of Ground Water Development

GEC-1997

Ground Water Level Trend

GEC-1997

GEC-1997 has recommended to categorize the assessment sub unit based on the stage of ground water development and the long term ground water level trend.

Categorization Of The Sub-Unit

GEC-1997

Stage Of Ground Water Development (%)	Ground Water Level trend	Category
<=70	**Either Pre-monsoon or Post Monsoon Water levels does not show a Falling Trend**	**Safe**
70-90	Both the trends during Pre and Post Monsoon Seasons do not show a Falling Trend	Safe
70-90	Either Pre-monsoon or Post Monsoon Water levels Shows a Falling Trend	Semi-critical
>90	Either Pre-monsoon or Post Monsoon Water levels Shows a Falling Trend	Critical
<100	Both the trends during Pre and Post Monsoon Seasons show a Falling Trend	Critical
>100	Both the trends during Pre and Post Monsoon Seasons show a Falling Trend	Over exploited

Categorization Of The Sub-Unit (Based On GEC-2004)

GEC-2004

Stage	Declining Pre-Monsoon Trend	Declining Post-Monsoon Trend	Category
<=70%	No	No	Safe
<=70%	No	Yes	To Be Reassessed
<=70%	Yes	No	To Be Reassessed
<=70%	Yes	Yes	To Be Reassessed
>70% and <=90%	No	No	Safe
>70% and <=90%	No	Yes	Semi-Critical
>70% and <=90%	Yes	No	Semi-Critical
>70% and <=90%	Yes	Yes	To Be Reassessed
>90% and <=100%	No	No	To Be Reassessed
>90% and <=100%	No	Yes	Semi-Critical
>90% and <=100%	Yes	No	Semi-Critical
>90% and <=100%	Yes	Yes	Critical
>100%	No	No	To Be Reassessed
>100%	No	Yes	Over-Exploited
>100%	Yes	No	Over-Exploited
>100%	Yes	Yes	Over-Exploited

Allocation Of Ground Water For Domestic And Industrial Needs

$$A = 22 * N * L_g$$

Where

A = Allocation for domestic and Industrial water Requirement in mm/year.

N = Projected Population density in the sub unit in thousands per square kilometer.

L_g = Fractional Load on ground water for domestic and industrial water supply (≤ 1.0)

365*60lpcd=21900l/year =22 m^3 /year

GEC-1997

Net Annual Ground Water Availability For Irrigation

NAGWAFI = NAGWA – AFDIWR

Where

NAGWAFI = Net Annual Ground Water Availability For Irrigation Use

NAGWA = Net Annual Ground Water Availability

AFDIWR = Allocation For Domestic and Industrial Water Requirement.

GEC-1997

Net Annual Ground Water Availability For Future Irrigation Development

GEC-1997

NAGWAFFID = NAGWAFI – CGGWDFI

Where

NAGWAFFID = Net Annual Ground Water Availability For Future Irrigation Use

NAGWAFI = Net Annual Ground Water Availability For Irrigation Use

CGGWDFI = Current Gross Ground Water Draft For Irrigation

Additional Potential Recharges

GEC - 1997

1. Water logged and Shallow Water Table Areas.

2. Flood Prone Areas.

Potential Recharge In Water Logged And Shallow Water Table Areas

GEC-1997

$$PRWL = (5\text{-}DTW) * A * S_Y$$

Where

PRWL = Potential Recharge in Water Logged and Shallow Water Table Areas

DTW = Average Depth To Water Level

A = Area of the Water logged Zone

S_Y = Specific Yield in the zone upto 5.0m bgl.

Potential Recharge In Flood Prone Areas

GEC-1997

PRFL = 1.4 * N * A/1000

Where

PRFL = Potential Recharge in Flood Prone Areas

N = No of Days Water is Retained in the Area

A = Flood Prone Area

Static Ground Water Resources

G E C - 1 9 9 7

$$SGWR = A * (Z_2 - Z_1) * S_Y$$

Where

SGWR = Static Ground Water Resources

A = Area of the Assessment Unit

Z_2 = Maximum depth up to which saturated formation extends

Z_1 = Maximum extension of Zone of Water Table Fluctuation

S_Y = Specific Yield in the Zone of Static Water Resources.

Ground Water Resources In Confined Aquifers

G E C - 1 9 9 7

There are two types of situations of occurrence of confined aquifers.

In hard rock areas,

the upper water table aquifer in the weathered zone is connected to the deeper fracture zone, which is semi-confined.

no separate assessment is to be made for the confined aquifer.

Ground Water Resources In Confined Aquifers

GEC-1997

There are two types of situations of occurrence of confined aquifers.

In specific alluvial areas,

If the confined aquifer is hydraulically connected to the overlying shallow water table aquifer, it is a semi confined aquifer. no separate assessment is to be made for the confined aquifer.

If there is no hydraulic connection to the overlying water table aquifer, the resource may have to be estimated taking care to avoid duplication of resource assessment from the upper unconfined aquifers.

Apportioning

Where the assessment unit is a watershed, there is a need to convert the ground water assessment in terms of an administrative unit such as block/ taluka/ mandal.

- **The ground water assessment in the sub units, non-command and command areas of the watershed may be converted into depth unit (mm), by dividing the annual recharge by the respective area.**
- **The contribution of this sub units of the watershed to the block, is now calculated by multiplying this depth with the area in the block occupied by this sub unit.**
- **The total ground water resource of the block should be presented separately for each type of sub unit, namely for non-command areas, command areas and poor ground water quality areas, as in the case of the individual watersheds.**

GROUND WATER RESOURCES ESTIMATION

USING GEC-1997 METHODOLOGY

GEC-1997

Thank You