GSDA Recharge Plan Analysis

IIT Bombay

12th August 2020

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- Way Ahead: Proposed Plan for Integration of GSDA Groundwater Recharge in IITB Water Balance Model

Background

Convergence of GSDA results and IITB model outputs to match with closest ground reality

Objectives:

- To study and understand the Groundwater Recharge Plans prepared by GSDA (Methodology, Execution Methods, Data)
- To document some of the key issues found in the recharge plans (and the raw data)
- To study, analyze and compare the results of the 28 clusters
- To devise a framework for improvements in IITB-PoCRA water balance model using GSDA recharge plans

GSDA Groundwater Recharge Plan

Computation of

- Surface Runoff : Using Strange's Table Method
- Groundwater Budget
  - Groundwater Recharge
  - Groundwater Extraction / Draft

} Important for IITB model refinement

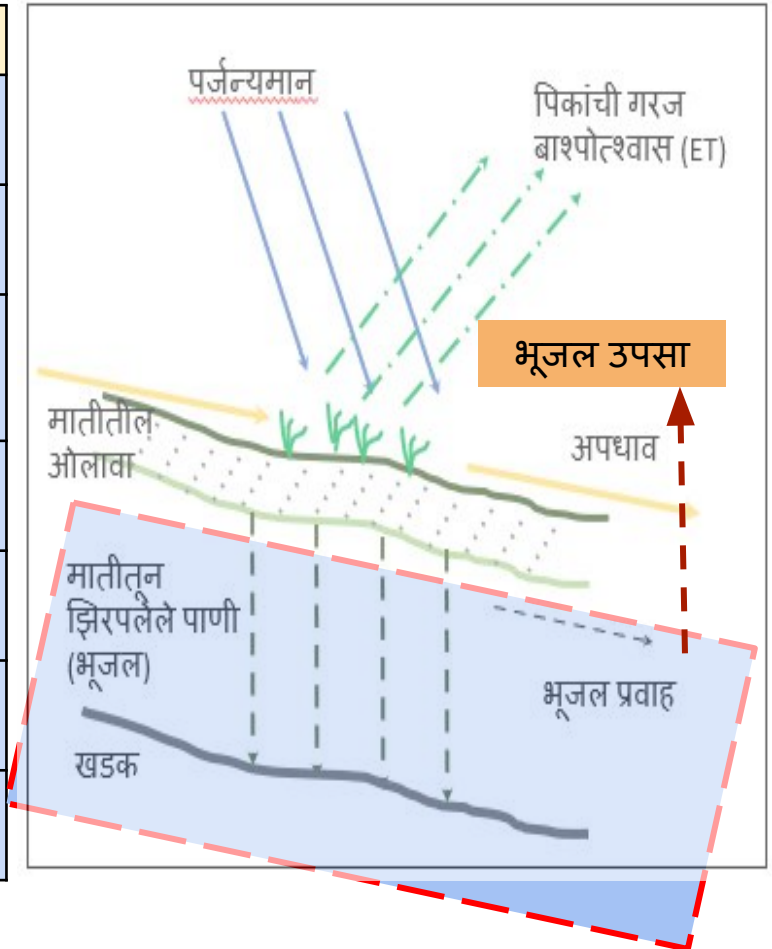
Groundwater Management Action Plan

- Supply side interventions
- Demand side interventions

} Not part of the analysis by IITB team

Groundwater Budget = GW Available - GW Draft

	IITB Water Budget	GSDA Groundwater Budget
Rainfall	Used in computation of groundwater recharge	Not used in any computation
AET	Computed	Not considered
Runoff	Computed	Not considered (Only in Recharge Plan and not in Groundwater Budget)
Soil Moisture	Computed	Not considered
Groundwater Recharge	Computed	Computed
Groundwater Draft / Extraction	-	Computed
Base flows	-	Computed



Methods Used for Computation Components Involved in GW Budget

- Specific Yield: Using Dry Season Specific Yield Approach
  - Source of data used for water levels and extraction considered is not clear though
- Groundwater Recharge
  - Using Water Table Fluctuation Method for calculating rainfall recharge
  - Considering other recharge and GEC equation for computation of GW recharge
- Groundwater extraction
  - Using Well Census Method
    - Data on number of wells from revenue records
    - Average annual draft of well: Calculated from raw data

Methods Used by GSDA

- Groundwater Recharge
  - Using Water Table Fluctuation and Specific Yield
- Groundwater extraction
  - Well Census Method:
- Water Applied to Crop
  - Cropping Pattern Method

Surface Runoff

- Runoff Generated in Cluster = Cluster Area * 75 % dependable rainfall of average annual rainfall * Runoff coefficient for the area
  where, runoff coefficient is taken from Strange Table Method
- When runoff is computed using this method, it does not consider some of the important factors like
  - Rainfall of the concerned year
  - Rainfall distribution for the year
  - Rainfall intensity of the rainfall events

RUN OFF ESTIMATION		
1	Total catchment area (Cluster area) in Ha	3132.00
2	Average annual rainfall in mm	715.74
3	75% dependable rainfall in mm	514.00
4	Average slope of area in %	2 to 4
5	Run off coefficient for the area in fraction	0.12
6	Run off yield from the area in TCM	1851.33
7	Utilizable Run off for harvesting in TCM = 65% of Row 6 (35% left as riparian rights of the downstream)	1203.36
8	Run off booked for existing WCS structures in **TCM**	145.00
9	Run off ultimately available for harvesting (7-8) in **TCM**	1058.36
10	No. of fillings assumed	2.00
11	Approximate water storage capacity that can additionaly be created (50% of 9) in **TCM**	529.18

Groundwater Budget

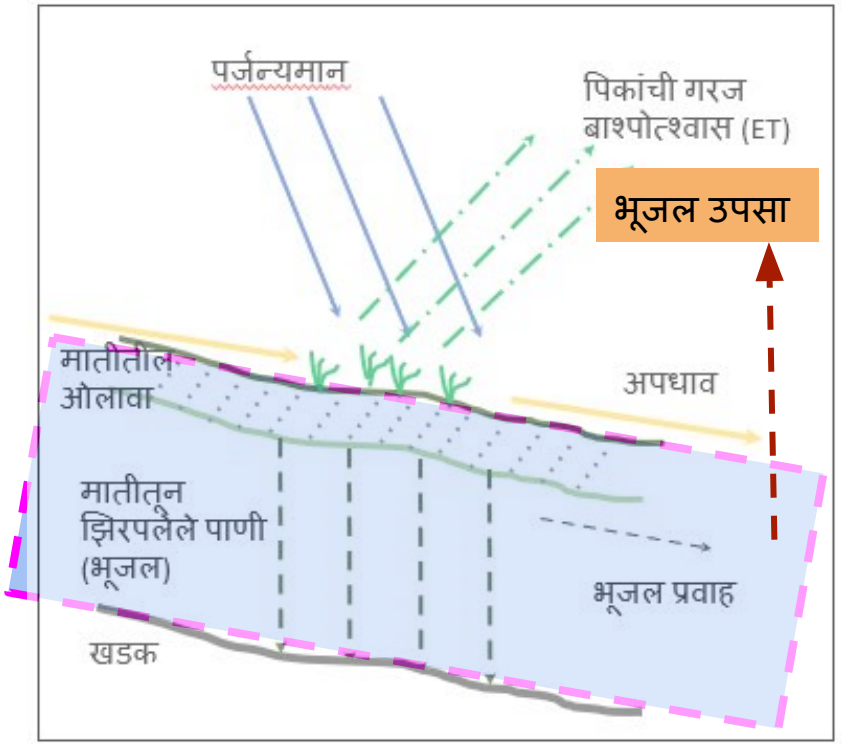
GW Budget = GW Available - GW Draft

[surplus (+), deficit (-)]

where,

GW Available = GW Recharge - Base flows,

GW Draft = Extraction for (Domestic + Agriculture) use



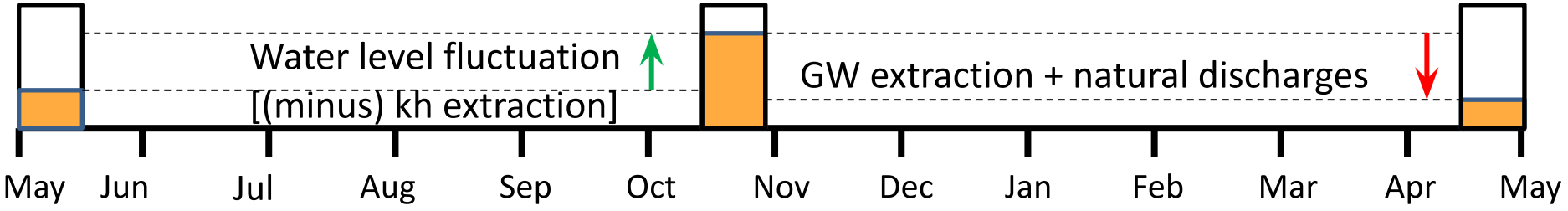
Important Components of GW Budget To be Used

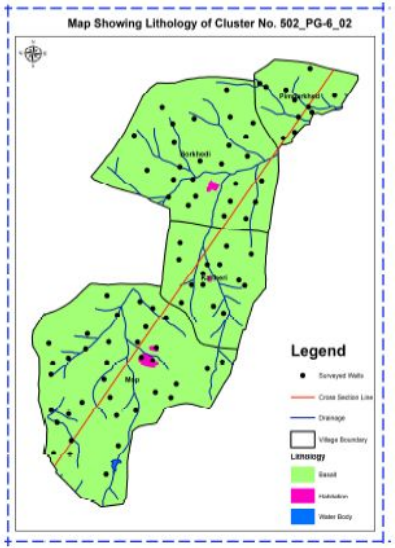
- Groundwater Recharge
- Groundwater Draft for Agriculture

Methods Used by GSDA

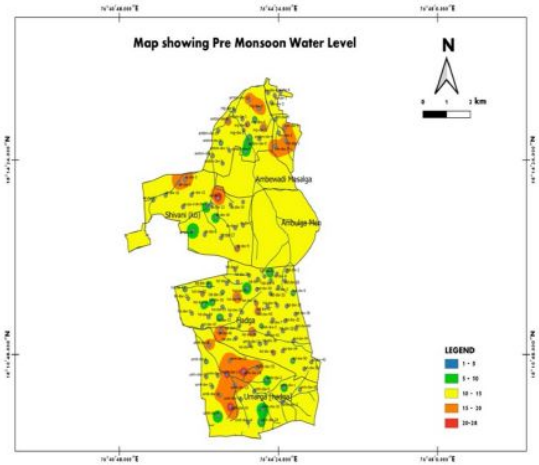
- Groundwater Recharge
  - Using Water Table Fluctuation and Specific Yield
- Groundwater extraction
  - Well Census Method:
- Water Applied to Crop
  - Cropping Pattern Method

Groundwater Recharge

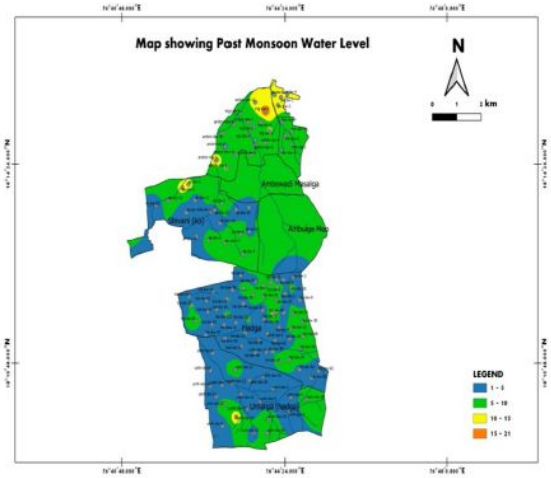




Map showing selected wells for sampling



Pre-monsoon water levels



Post-monsoon water levels

Groundwater Estimation (2018-19)		
Monsoon Recharge		**TCM**
1	Rainfall recharge during monsoon (by WTF) in TCM =(area × wtf × sy) (3132*5*0.009)	1409.40
2	Recharge from WCS during monsoon in TCM	15.40
3	Recharge from groundwater irrigation during monsoon in TCM (considered 10 % of water applied)	45.54
4	Groundwater Draft during monsoon in TCM	455.40
5	Recharge from Surface water irrigation during monsoon in TCM	4.4
6	**Total groundwater recharge during monsoon in TCM =(1+2+(4-3)+5)**	**1839.06**
Non-Monsoon Recharge		
7	Recharge from WCS during non-monsoon in TCM	15.40
8	Recharge from canal in TCM	0
9	Recharge from Surface water irrigation during non-monsoon in TCM (10% of SW applied)	0.00
10	Recharge from Groundwater irrigation during non-monsoon in TCM (considered 10 % of water applied)	96.91
11	Recharge from Tanks and ponds in TCM (as per GEC norms)	0
12	**Total groundwater recharge during non-monsoon in TCM (7+8+9+10+11)**	**112.31**
13	**Gross groundwater recharge (6+12) in TCM**	**1951.37**
14	**Net groundwater availability in TCM (11-(10 %0f 13)) by deducting base flow- Nil**	**1951.37**

Groundwater extraction - Well Census Method

Total GW draft = unit draft per well (ham) x number of wells in the watershed

unit draft per well (ham) = discharge per hour in cum/hr x pumping hours per day x total pump operation days

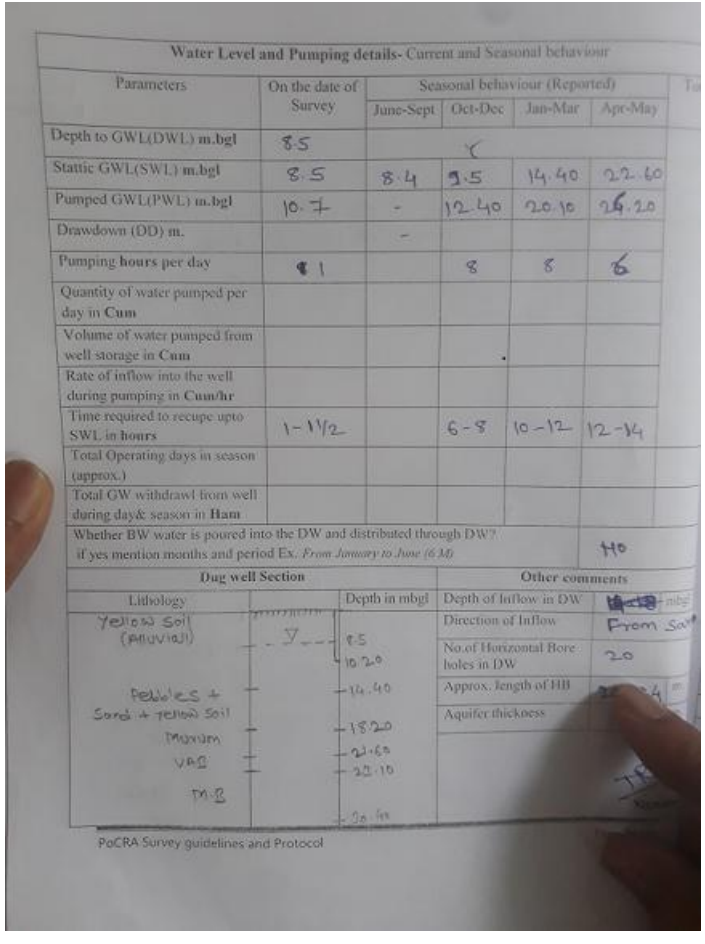
- This is computed season-wise as extraction pattern changes as per the season
- The data for discharge, pumping hours per day and total operational hours to calculate unit draft per well is collected by GSDA (Hydrogeological Survey)
- Number of wells in watershed is taken from the secondary data (as per revenue record)

Groundwater extraction - Cropping Pattern Method

Total GW draft = Σ[extraction per ha for (crop i, irrigation method j) x area under crop i, method j]

- This is computed for all seasons - kharif, rabi and summer
- It requires -
  - Farmer level data - through questionnaires for few selected farmers
  - Cropping pattern of farmer, irrigation method, number of irrigations
  - Amount of water per irrigation = assumed 0.067 ham for flood
  - Aggregate cropping pattern for the cluster
- Extrapolation to whole village
  - Method used to extrapolate farmer level irrigation data to cluster is not explained
  - Different cases of number of irrigations provided are not fully considered
    - Only two cases considered viz. No irrigation and Required (Desired) irrigation

Data and survey formats used by GSDA



Water Level and Pumping details- Current and Seasonal behaviour

Parameters	On the date of Survey	Seasonal behaviour (Reported)			
		June-Sept	Oct-Dec	Jan-Mar	Apr-May
Depth to GWL(DWL) m.bgl	8.5		Y		
Stattic GWL(SWL) m.bgl	8.5	8.4	9.5	14.40	22.60
Pumped GWL(PWL) m.bgl	10.7	-	12.40	20.10	26.20
Drawdown (DD) m.		-			
Pumping hours per day	1		8	8	6
Quantity of water pumped per day in Cum					
Volume of water pumped from well storage in Cum					
Rate of inflow into the well during pumping in Cum/hr					
Time required to recupe upto SWL in hours	1-1½		6-8	10-12	12-14
Total Operating days in season (approx.)					
Total GW withdrawl from well during day& season in Ham					

Whether BW water is poured into the DW and distributed through DW? if yes mention months and period Ex. *From January to June (6 M)* — HO

Dug well Section

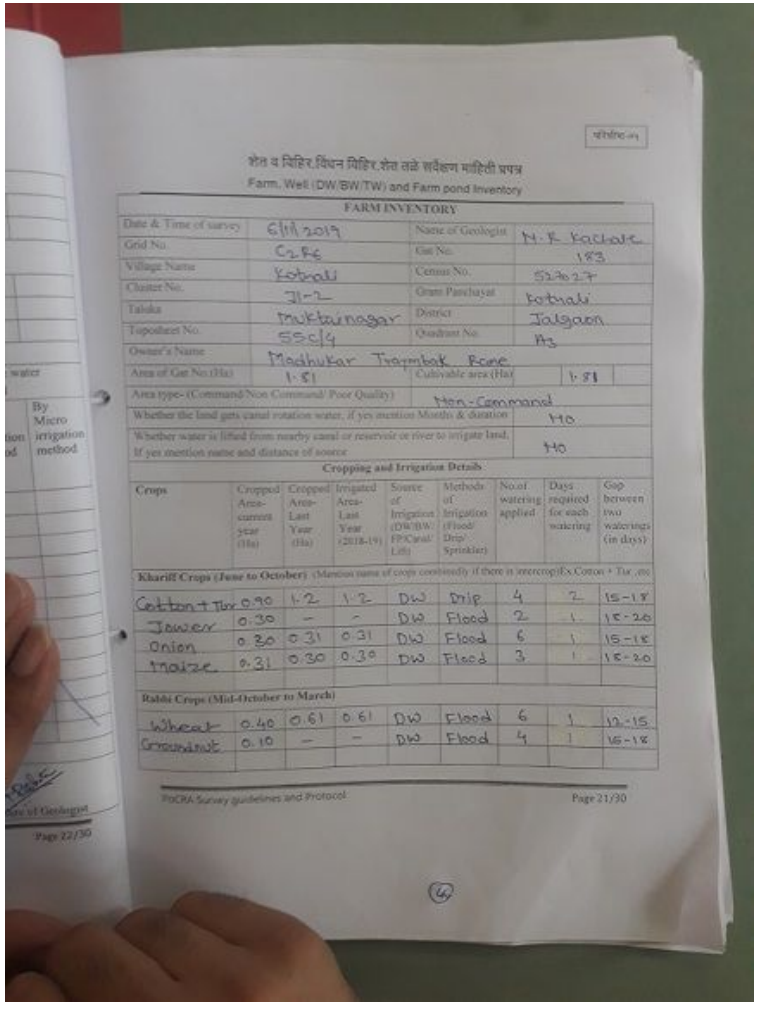
Lithology: Yellow Soil (Alluvial); Pebbles + Sand + Yellow Soil; Murum; VAS; M.S

Depth in mbgl: 8.5; 10.20; 14.40; 18.20; 21.60; 22.10

Other comments

Depth of Inflow in DW	~~15-18~~ mbgl
Direction of Inflow	From South
No.of Horizontal Bore holes in DW	20
Approx. length of HB	
Aquifer thickness	

PoCRA Survey guidelines and Protocol



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Farm, Well (DW/BW/TW) and Farm pond Inventory

FARM INVENTORY

Date & Time of survey	6/11/2019	Name of Geologist	N.R. Kachare
Grid No.	C2B6	Gat No.	183
Village Name	Kothali	Census No.	527627
Cluster No.	J1-2	Gram Panchayat	Kothali
Taluka	Muktainagar	District	Jalgaon
Toposheet No.	55c/4	Quadrant No.	A3
Owner's Name	Madhukar Trambak Bone		
Area of Gat No.(Ha)	1.81	Cultivable area (Ha)	1.81
Area type- (Command/Non Command/ Poor Quality)	Non-Command		
Whether the land gets canal rotation water, if yes mention Months & duration	HO		
Whether water is lifted from nearby canal or reservoir or river to irrigate land. If yes mention name and distance of source	HO		

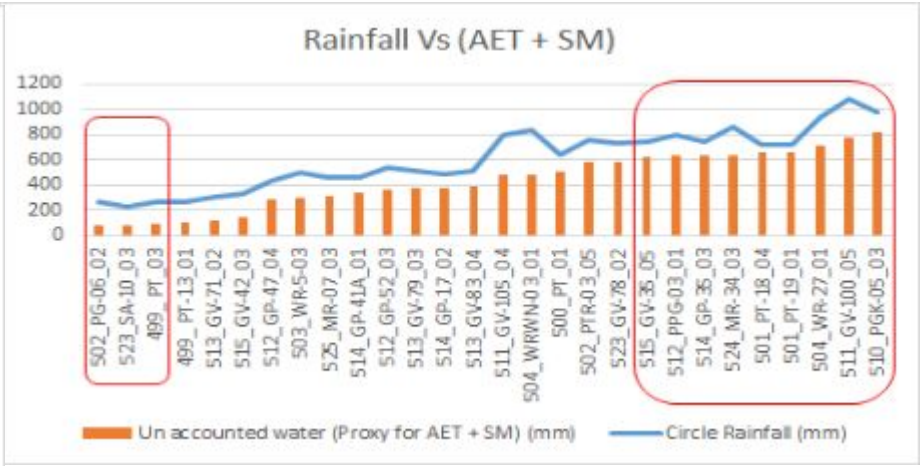
Cropping and Irrigation Details

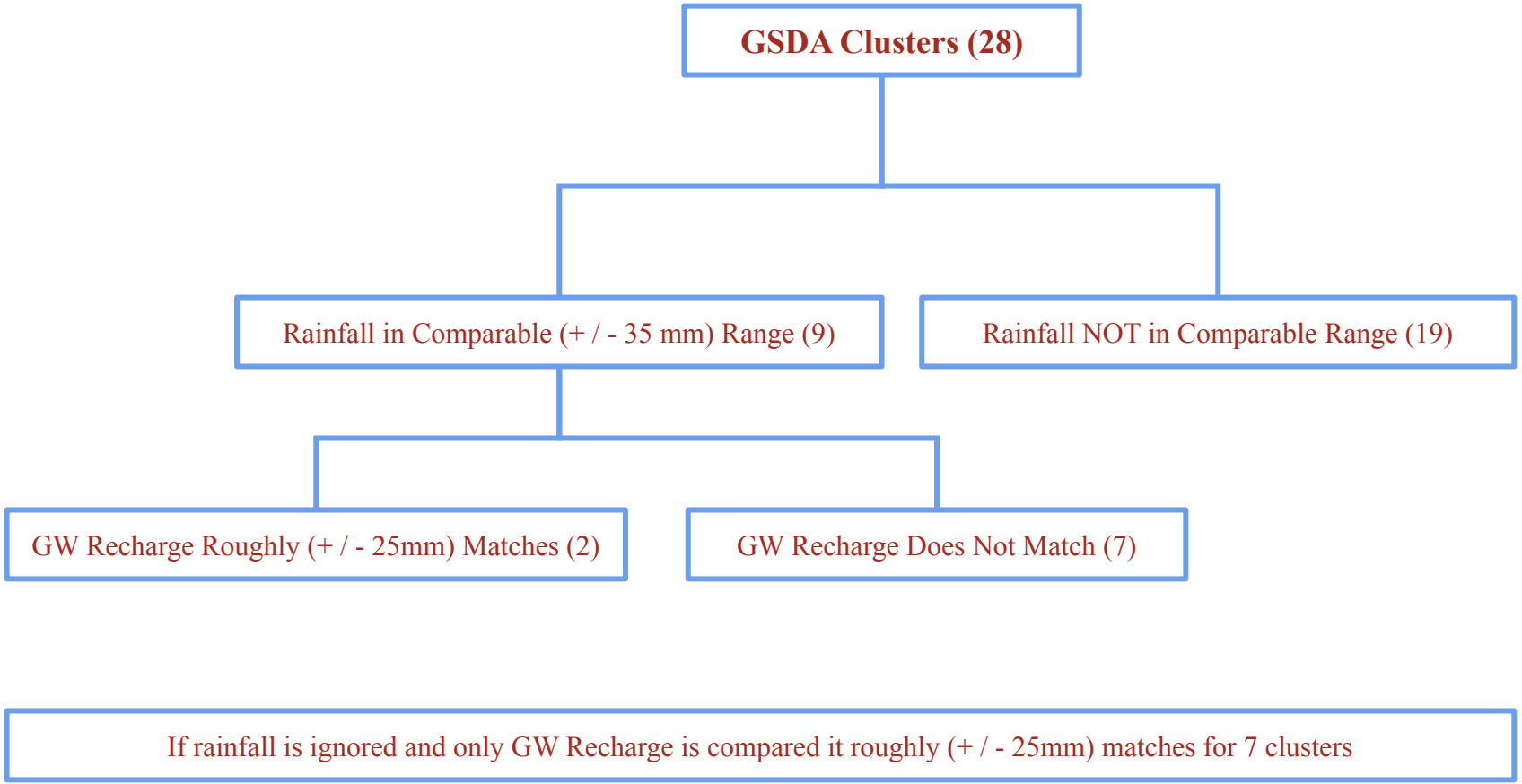
Crops	Cropped Area-current year (Ha)	Cropped Area-Last Year (Ha)	Irrigated Area-Last Year (2018-19)	Source of Irrigation (DW/BW/ FP/Canal/ Lift)	Methods of Irrigation (Flood/ Drip/ Sprinkler)	No.of watering applied	Days required for each watering	Gap between two waterings (in days)
Khariff Crops (June to October) (Mention name of crops continously if there is intercrop)Ex Cotton + Tur ,etc								
Cotton + Tur	0.90	1.2	1.2	DW	Drip	4	2	15-18
Jowar	0.30	-	-	DW	Flood	2	1	15-20
Onion	0.30	0.31	0.31	DW	Flood	6	1	15-18
maize	0.31	0.30	0.30	DW	Flood	3	1	15-20
Rabbi Crops (Mid-October to March)								
Wheat	0.40	0.61	0.61	DW	Flood	6	1	12-15
Groundnut	0.10	-	-	DW	Flood	4	1	15-18

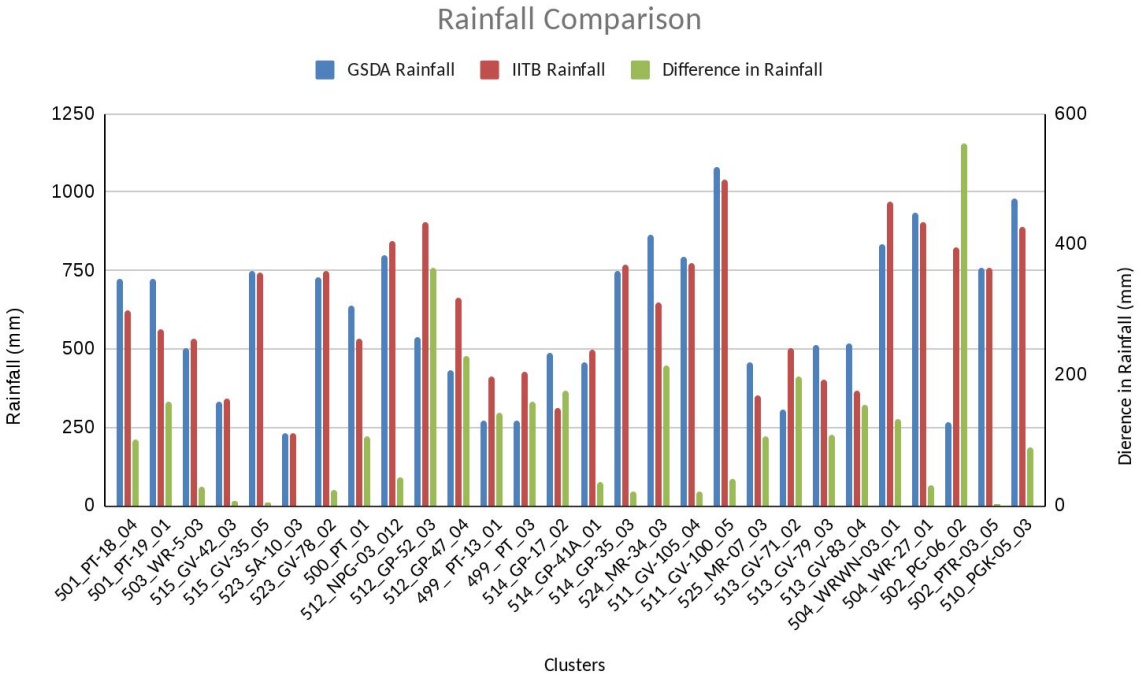
PoCRA Survey guidelines and Protocol — Page 21/30

GSDA GW Recharge Results: Observations

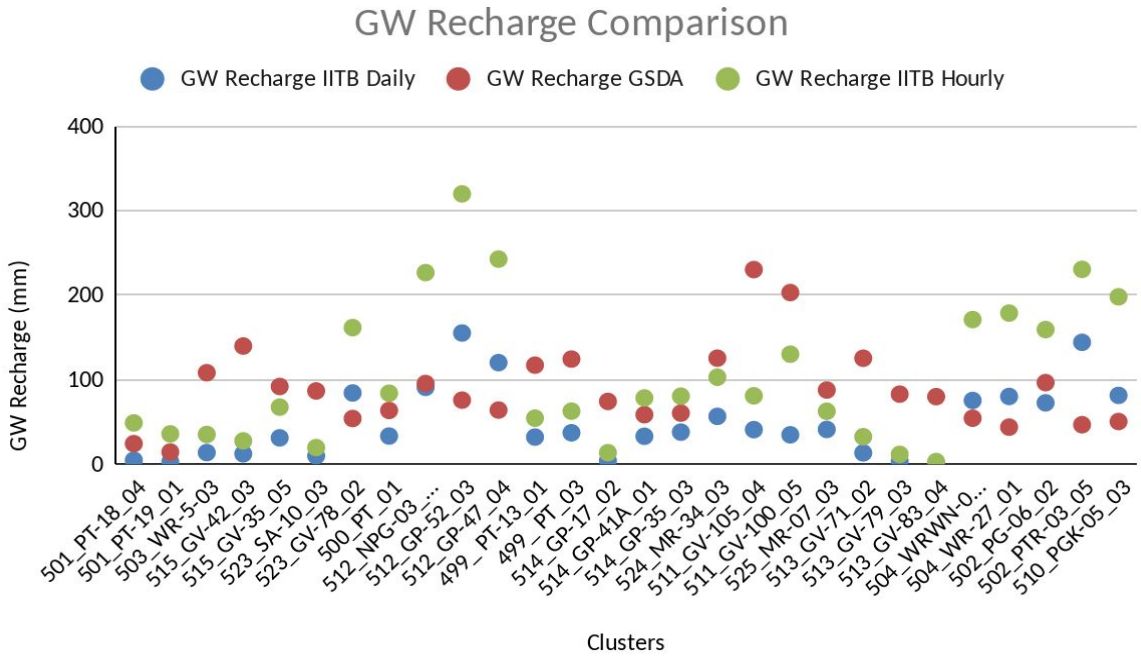
- At least for 12 clusters the results of GSDA do not appear consistent with the concept of water balance
  - 9 clusters with more than 600 mm of unaccounted rainfall (can assumed to contribute to AET kharif and Soil moisture at the end of kharif; part of it to base flows and water storage structures)
  - 3 clusters with unaccounted rainfall of less than 100 mm




GSDA Clusters (28)
Rainfall in Comparable (+ / - 35 mm) Range (9)
Rainfall NOT in Comparable Range (19)
GW Recharge Roughly (+ / - 25mm) Matches (2)
GW Recharge Does Not Match (7)
If rainfall is ignored and only GW Recharge is compared it roughly (+ / - 25mm) matches for 7 clusters



Rainfall In Reasonable Range (+ / - 25 mm)	7
Rainfall Deviation of (>25 and <50) mm	5
Rainfall Deviation of (>50 and <100) mm	1
Rainfall Deviation more than 100 mm	15



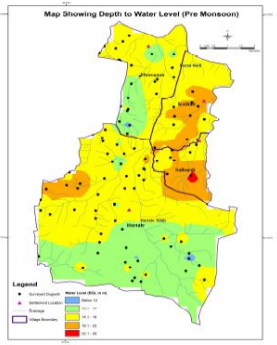
GWR IITB Daily < GWR GSDA < GWR IITB Hourly (GSDA recharge falls in between daily and hourly IITB estimates)	7
GWR GSDA < GWR IITB Daily < GWR IITB Hourly (Both daily and hourly IITB estimates are higher than GSDA recharge)	7
GWR IITB Daily < GWR IITB Hourly < GWR GSDA (Both daily and hourly IITB estimates are lower than GSDA recharge)	14

Issues in GSDA reports and data

WTF method for computing GW recharge

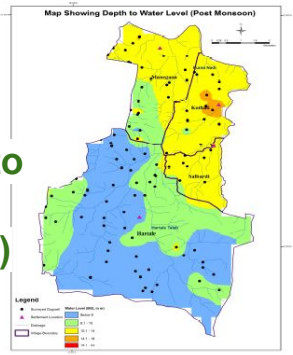
iv) **Depth to groundwater level map – Pre-monsoon (Summer) (Fig-10):**

Depth to groundwater level in summer varies from 8 to 21 mbgl; however the depth to GW level between 11 to 18 mbgl is more common.

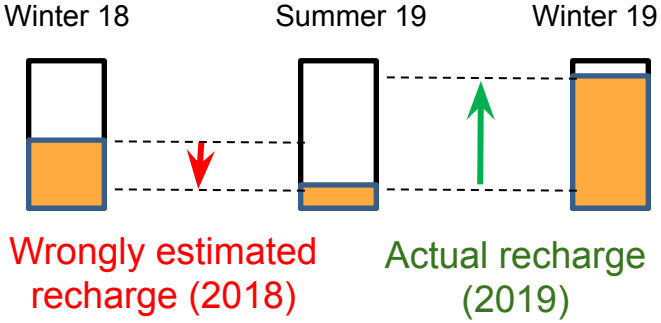


v) **Depth to groundwater level map – Post-monsoon (Winter) (Fig-11):**

Depth to groundwater level in winter varies from 2 to 15 mbgl; however the depth to GW level between 3 to 14 mbgl is more common

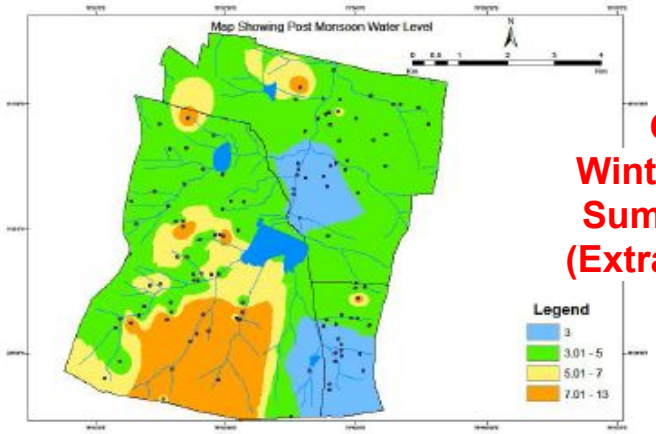


Case I: Summer (2018) to Winter (2018) (Recharge 2018)



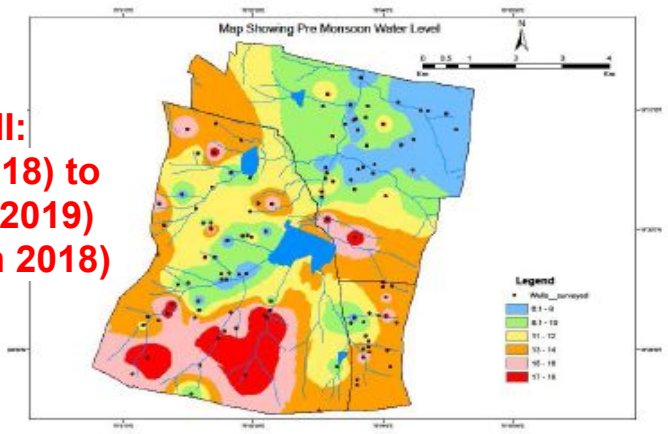
Depth to groundwater level map – Post-monsoon (Winter 2018) (Fig-11):

Depth to groundwater level in winter 2018 varies from 3 to 13 m bgl. However the depth to GW level between 3 to 7 m.bgl is more common.



Depth to groundwater level map – Pre-monsoon (Summer 2019) (Fig-12):

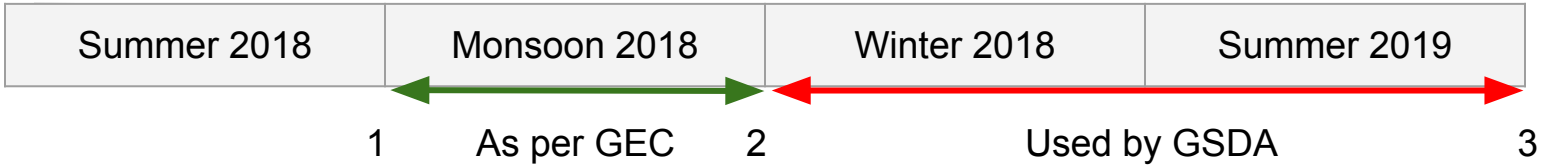
Depth to groundwater level in summer 2019 varies from 6 to 18 m bgl. However the depth to GW level between 8 to 12 m.bgl is more common.



Case II: Winter (2018) to Summer (2019) (Extraction 2018)

Incorrect reference for WTF has been used at least for 5 out of 28 clusters (this error may possibly be present in 6 more clusters but cannot be said conclusively)

GW Recharge Computation for 2018-2019 Using Post-monsoon to Pre-monsoon WTF



- Incorrect reference implies errors in computation of GW Recharge
- Only case when even incorrect WTF can have correct result is case II explained below

Recharge for 2018-2019 using WTF		Case I (Extraction more than Recharge)	Case II (Extraction and Recharge are equal))	Case III (Extraction less than Recharge)
1	GW level Pre-monsoon 2018 in mgl (@ end of summer 2018)	8	9	10
2	GW level Post-monsoon 2018 in mgl (@ start of winter of 2018)	3	3	3
3	GW level Pre-monsoon 2019 in mgl (@ end of summer 2019)	9	9	9
4 = (1-2)	WTF which should have been used as per GEC method	5	6	7
5 = (3-2)	WTF used by GSDA	6	6	6
4 = 5 (✔) 4 ≠ 5 (**x**)	Recharge computation	**x**	✔	**x**

GW Recharge in Monsoon (For all 28 Clusters)

As per GEC 2015, groundwater recharge during monsoon season is given as,

Total Groundwater recharge during monsoon

= (Rise in water level in monsoon * Specific yield * Area) + Gross groundwater draft

=1+(4-3).....(from GEC GW Estimation Table)

Whereas GSDA has computed the same using following equation,

Total Groundwater recharge during monsoon

= (Water table fluctuation * Specific yield * Area)

+ Recharge from WCS

+ Gross groundwater draft

+ Recharge from surface water irrigation

= 1+2+(4-3)+5.....(from GSDA GW Estimation Table)

Groundwater Estimation		
Monsoon Recharge		**TCM**
1	Rainfall recharge during monsoon (by WTF) in TCM =(area × wtf × sy) (4605*7*0.013)	3254.16
2	Recharge from WCS during monsoon in Ham	47.00
3	Recharge from groundwater irrigation during monsoon in TCM (considered 10 % of water applied)	82.90
4	Groundwater Draft during monsoon in TCM	829.00
5	Recharge from Surface water irrigation during monsoon in TCM	0
6	Total groundwater recharge during monsoon in TCM =(1+2+(4-3)+5)	**4047.26**

WTF includes recharge due to WCS and surface water irrigation

Inconsistency in WTF Used

- WTF reported in section 4. F. vi of the recharge plan
- WTF used while calculating GW Recharge during Monsoon

vi) **Annual groundwater fluctuation map (2018-19) (Fig-13):**

Annual GW level fluctuates between 3 to 11 m. But major part of the area shows the GW fluctuations between 3 to 9 m. Thus average WTF for the cluster is considered as 6 m.

Rainfall recharge during monsoon (by WTF) in TCM =(area × wtf × sy)
(4605*7*0.013)

- WTF calculated using data (as shared by GSDA) for 16 reports

No. of cluster where data is received	No. of clusters where WTF could not be calculated	No. of clusters where WTF used for calculation is consistent with WTF calculated from raw data	No. of clusters where WTF used for calculation is NOT consistent with WTF calculated from raw data
16	3	5	8

No explanation or details are provided in the recharge plan on if any specific method is used while considering WTF for overall cluster

Out of 8 clusters where WTF is not consistent, 2 clusters shows error of about 75 mm and other 2 of about 25 mm

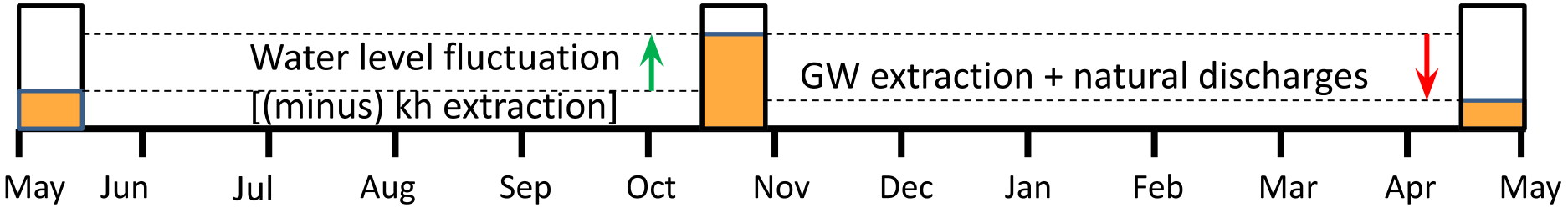
Issues with the raw data shared (16 Clusters)

- Use of different data formats
  - Inconsistency in data points collected
    - Pumping data is not available in 2 clusters and is provided only partly for 10 clusters
    - Data on cropping pattern is either missing or only partly provided in most of the clusters (available only for a cluster)
  - Difficulties in using a standard method for analyzing data received
- What data is important for IITB for GW recharge calculation
  - Pre and Post monsoon water level (For WTF to be used)
  - Pump discharge, pumping hours, operational days in monsoon (for calculation of GW extraction in monsoon)

To compute groundwater recharge both of the above mentioned data points are essential

Specific Yield Calculated by GSDA

- No clarity on the data used for computation of the specific yield
- The method of computing specific yield using dry season method is very much sensitive to the groundwater extraction
  - Extraction data needs to be accurate to the maximum possible extent
- If GSDA has computed specific yield for all the studied clusters then they must have used
  - Water table levels at the start of Rabi (Post-monsoon) and at the start of next monsoon (Pre-monsoon) : This data is missing in raw data
  - Pumping data: Either is not consistent or missing in raw data



	Sanjarpur	Sanjirabad	Manjari	Malunja	Maholi	Hadiyabad		
Area cultiv	270	170	1700	500	820	270		3730
density	34.07	17.06	19.35	45.00	20.12	35.93		28.59
WTF	4.9	4.53	4.59	4.77	4.05	5.43		4.71
dry wtf	3.063	2.831	2.869	2.981	2.531	3.394		2.94
Dry Draft	24.88	10.89	152.63	28.31	32.58	11.84		261.1308
Dft DW	16.640	7.230	103.280	14.400	26.600	7.740		175.89
Sy	0.030	0.023	0.031	0.019	0.016	0.013	0.022	0.022
Sy DW	0.020	0.015	0.021	0.010	0.013	0.008	0.015	0.015
	0.025	0.019	0.026	0.014	0.014	0.011	0.018	
RF recharge	39.8144	17.4317	244.203	45.29	52.12	18.95	417.80928	

	Sanjarpur	Sanjirabad	Manjari	Malunja	Maholi	Hadiyabad
Area cultiv	270	170	1700	500	820	270
density	=92/2.7	=29/1.7	=329/17	=225/5	=165/8.2	=97/2.7
WTF	4.9	4.53	4.59	4.77	4.05	5.43
dry wtf	=D36*(5/8)	=F36*(5/8)	=H36*(5/8)	=J36*(5/8)	=L36*(5/8)	=N36*(5/8)
Dry Draft	=SUM(D27:E28)	=SUM(F27:G28)	=SUM(H27:I28)	=SUM(J27:K28	=SUM(L27:M2	=SUM(N27:O2
Dft DW	=SUM(D27:D28)	=SUM(F27:F28)	=SUM(H27:H28)	=SUM(J27:J28)	=SUM(L27:L28	=SUM(N27:N2
Sy	=D38/(D34*D37)	=F38/(F34*F37)	=H38/(H34*H37)	=J38/(J34*J37)	=L38/(L34*L37	=N38/(N34*N3
Sy DW	=D39/(D34*D37)	=F39/(F34*F37)	=H39/(H34*H37)	=J39/(J34*J37)	=L39/(L34*L37	=N39/(N34*N3
	=AVERAGE(D40,	=AVERAGE(F40,I	=AVERAGE(H40,	=AVERAGE(J4	=AVERAGE(L4	=AVERAGE(N4
RF recharge	=D34*D36*D40	=F34*F36*F40	=H34*H36*H40	=J34*J36*J40	=L34*L36*L40	=N34*N36*N40

Other Observations on Specific Yield

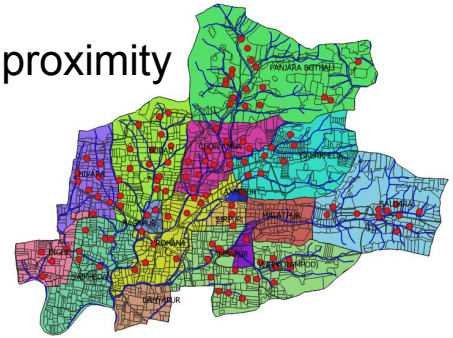
5.9 NORMS FOR ESTIMATION OF RECHARGE

5.9.1 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

Other Issues / Observations

- Pumping hours data (and hence GW extraction) for April-May as mentioned in the report is not consistent with the raw data for some of the clusters (at least 6 out of 16)
- Number of wells/borewells considered for aggregation while calculating GW draft
  - As per revenue record
  - No clarity on number of operational wells considered while aggregating
- Average unit draft per well: On higher side in some clusters
  - Possibly because selected wells are in concentrated in stream proximity
- Error while using spreadsheet formulae (1-2 clusters)
  - Average calculated



Wardha cluster - 504_WRWN-03_01

		Saldara	
Well Type		DW	BW
Total no. of irrigation wells in the area		35	1
Total no. of wells in use		35	1
Total no. of wells surveyed		11	1
No of perennial wells (perennial pumping)		2	1
% of perennial wells (perennial pumping)		18	100
Average depth of wells in the area in m		9	45
Average pump discharge/well /per hour (cum/hr)		21	20
Average pumping hours a day	June-Sept	0	0
	Oct-Dec	5	6
	Jan-March	2	6
	April -May	4	3
Average pump operation days	June-Sept	0	0
	Oct-Dec	24	40
	Jan-March	17	30
	April -May	15	20
	Total	56	90
Average annual draft of a well (unit draft) in Ham	June-Sept	0	0
	Oct-Dec	0.24	0.48
	Jan-March	0.07	0.36
	April -May	=G17*G1	
	Total	3*G9/10	
Total groundwater draft in the area in Ham	June-Sept	000	
	Oct-Dec	8.57	0.48
	Jan-March	2.54	0.36
	April -May	4.41	0.12
	Total	15.52	0.96
	Total	16.48	
	TOTAL		

Average pump operation days						
June-Sept						0
Oct-Dec	15	25	35	40	20	23.8
Jan-March	13	20	20	25	10	17.3
April -May						15
Average annual draft of a well (unit draft) in Ham						
June-Sept						0
Oct-Dec	0.117	0.18	0.315	0.36	0.216	0.2028
Jan-March	0.108	0.18	0.216	0.27	0.09	0.1642
April -May						0.025
Total groundwater draft in the area in Ham						
June-Sept						
Oct-Dec						
Jan-March						
April -May						

Error In Average Values

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	Average
How it is entered in data		15									15
What it should have been so as to use formula in excel	0	15	0	0	0	0	0	0	0	0	1.5

Data used for illustration is of Saldara village from Arvi cluster of Wardha		
Total no of wells in use in a village	35	35
Avg pump discharge/well/hr	21	21
Avg pumping hours	4	4
Avg operational days in April-May	15	1.5
Avg draft of a well in April-May	0.126	0.0126
Avg annual draft of a well (assuming computation for other seasons is correct) in Ham	0.4436	0.3302
Total draft (Ham)	15.524	11..556

Calibrating GW Recharge With 2018/2019 As Reference

Issues in calibrating model based on results of GSDA for 2018-2019 / 2019-2020

- For clusters where incorrect WTF is used
  a. **What about WTF error? How do we address it while calibrating?**
  b. Difficulties in ground truthing the data used (which is mostly dynamic data i.e. subject to change for different years)
  c. It is also difficult to understand and quantify error in calculating groundwater draft for each and every cluster (inconsistency)
  d. Error in the computing GW recharge during Monsoon due to use of different equation
     i) Ignored given its little contribution to overall recharge
     ii) Can be calibrated (Either using GSDA data or MLP app data for WCS)
- For clusters where correct WTF is used
  - Even when correct WTF has been used, issues mentioned as b, c and d persist.
  - Data on WTF can be used in its entirety only when corresponding pumping data is available: This is not the case for any of the cluster

All these factors make this method of calibration unsuitable as far as feasibility of execution and reliability of results is concerned.

IITB team shall work on the modified strategy to use whatever data we have got from GSDA in next phase (phase iv).

Integrating GW recharge component: Ongoing

- Adopt GSDA method in the selected catchments (4-5) to estimate GW recharge
  - Selection of wells, well level monitoring - record pre-monsoon and post-monsoon levels
  - Specific yield as used by GSDA
  - Recharge from WCS and other sources as estimated by GSDA
  - Compute kharif GW extraction using pump discharge, pump hours, operating days etc as observed in the field.
- Compare IITB model GW recharge (hourly) and GW recharge calculated using GSDA method
- Gaps in these two are proposed to be reduced by changes in our model
  - Stream flow model - accounts for GW recharge in the stream proximity regions
  - Incorporating concept of ponding in the water balance model
  - Modifying conductance to aquifer considering aquifer thickness
  - Modifying base flows
  - Updating kharif availability / use of groundwater in the model
- The model will be corrected so that GW recharge estimated by model falls within reasonable band of the GW recharge as calculated using GSDA method ensuring consistency with observed and measured runoff (using stream flow measurement)

THANK YOU!!!