Modelling and Water Balance for a Highly Irrigated area in Sinnar

By

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Under the guidance of

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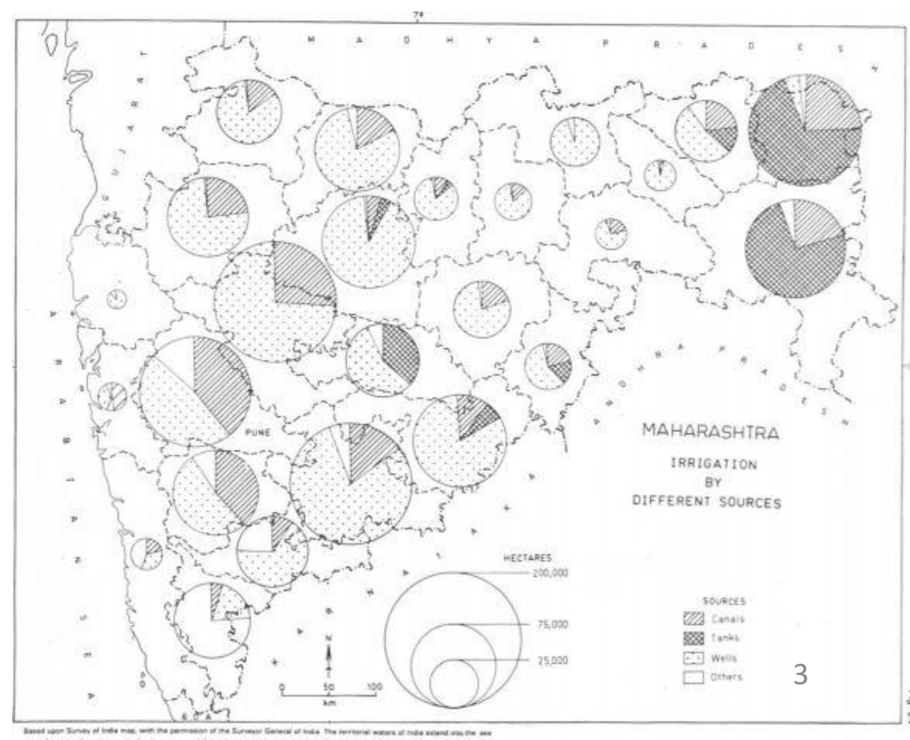
Outline

- Introduction/Motivation
- Study area
- Problem statement
- Field Observations
    - Well readings
    - Cropping pattern
- Modelling
- Conclusions

Irrigation in Maharashtra

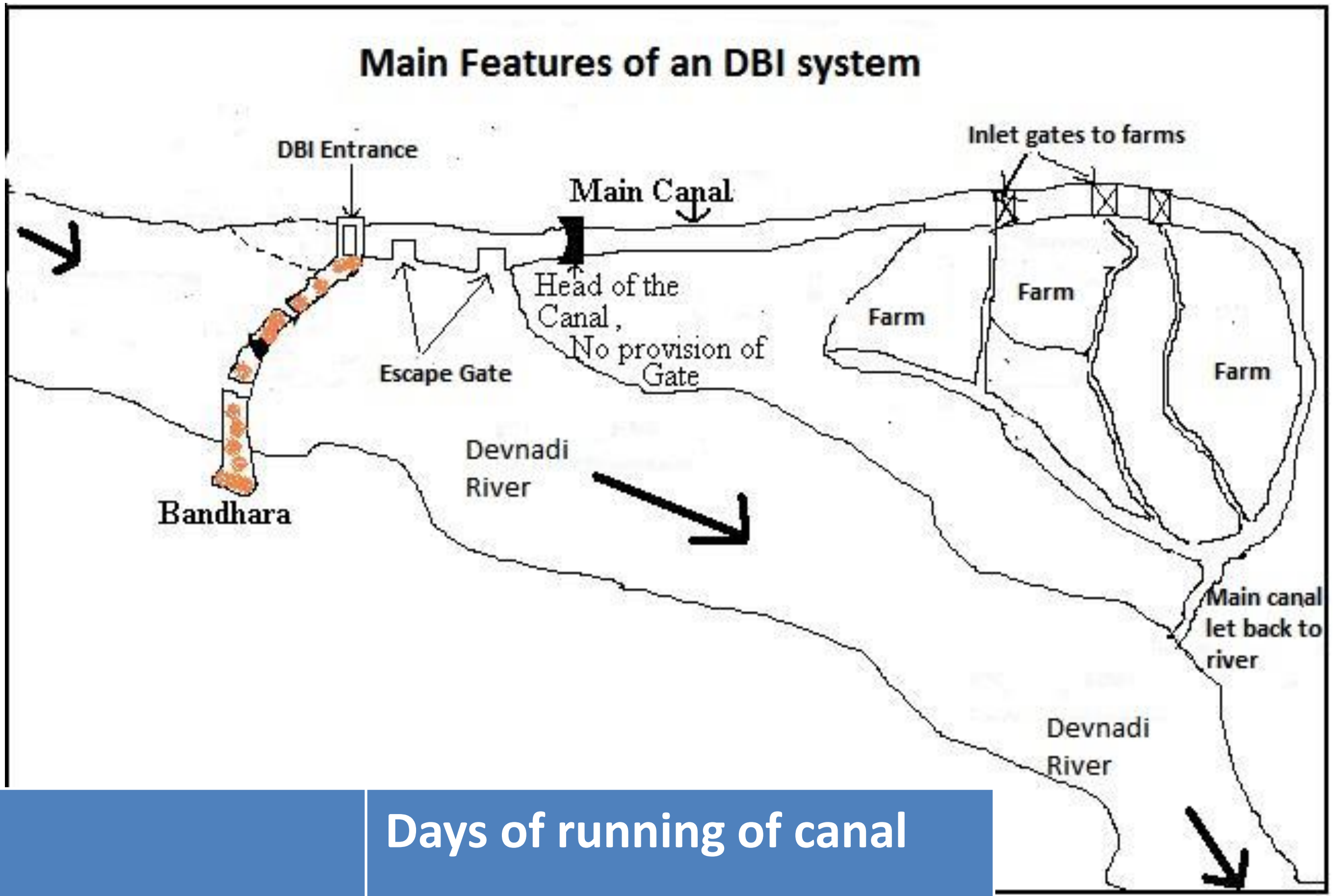
- Water is the most critical factor for enhancing agriculture productivity
- Around 20% of net sown area surface irrigated
- Cost of irrigation in command area
- PMKSY- More crop per drop



DBI

- Diversion based irrigation s/m (Built during colonial time)
- Protective irrigation in Kharif
- Indirect irrigation (through Well)-Rabi
- DBI active from monsoon till early Rabi season

Working of DBI



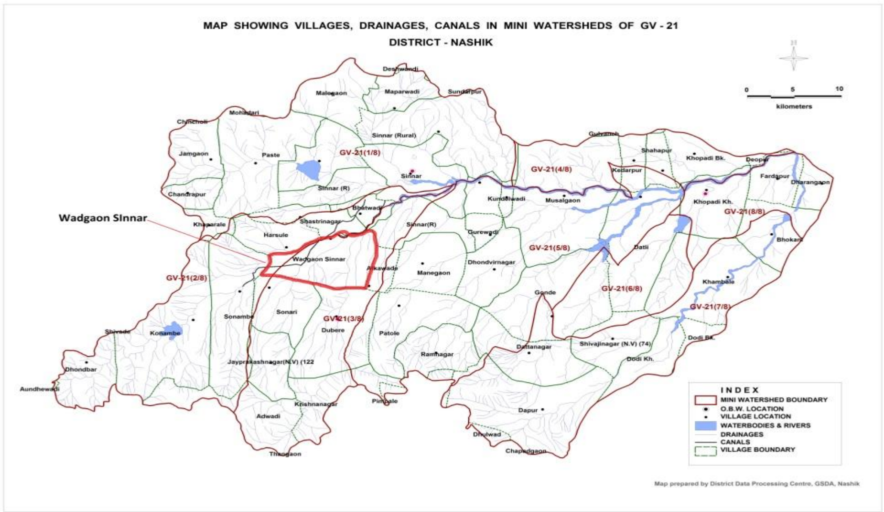
Season	Days of running of canal
Kharif	90
Rabi	40-50

Objectives-Benefit analysis of DBI

- To understand impact of Diversion Based Irrigation system on cropping and groundwater scenario.
- To develop a conceptual model for estimating groundwater flows in and out of the village
- To delineate different zones at village level based on various parameters.
- To build a crop water balance in the village level

Sinnar taluka

- Large scale of vegetable production and Horticulture
- Devnadi river (39,000 ha catchment)
- Part of watershed GV-21 which was categorized as over exploited.



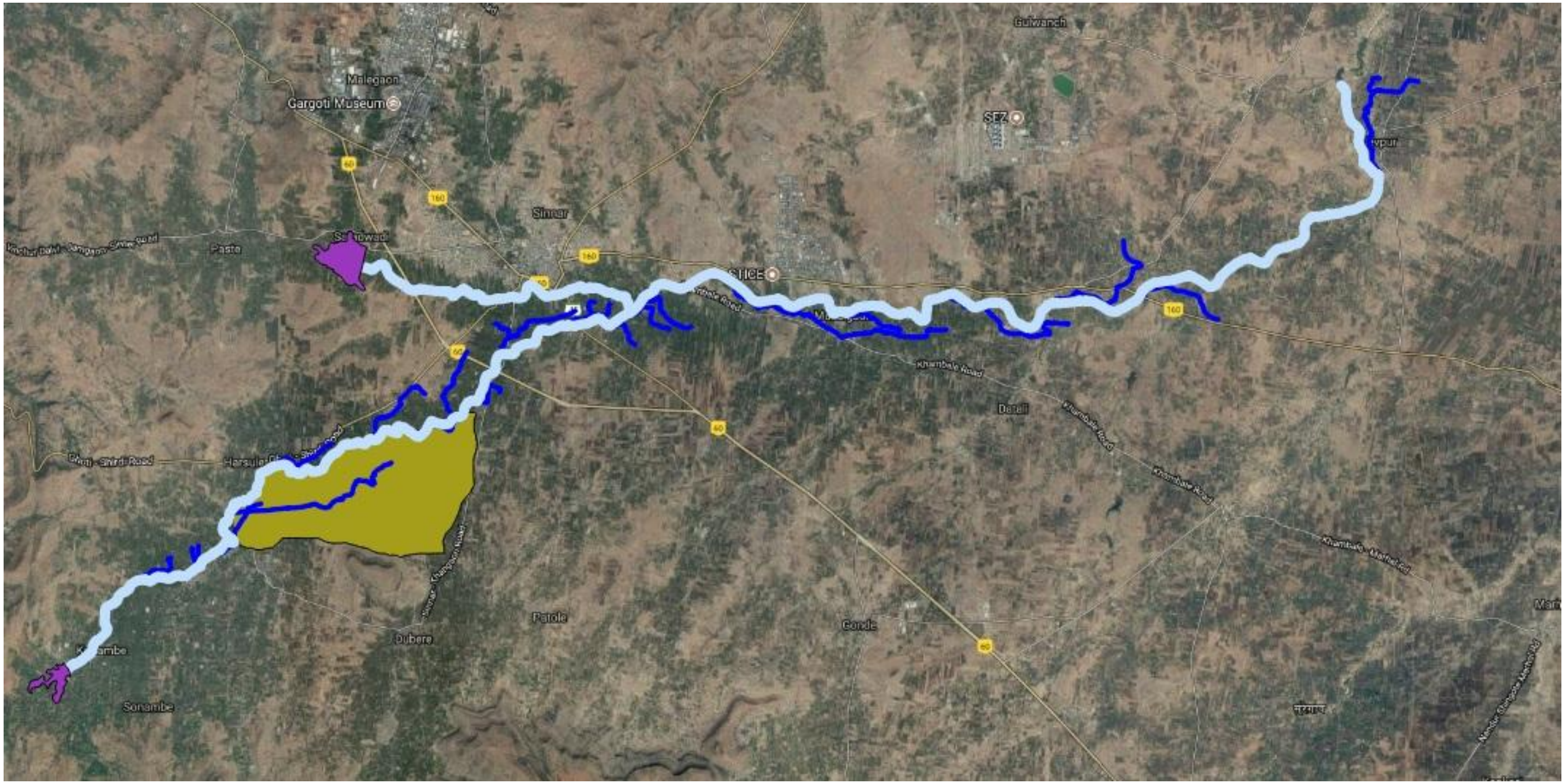
Further

- Falls under Drought Prone area (DPA)
- Drought years from year 2012 to 2015
- DBI irrigation system in the taluka
- DBI system based on Devnadi river
- Around 15 active DBI system in place along the river

Partnering NGO

- Yuva Mitra is a NGO working in Sinnar taluka
- DBI was rejuvenated in the area by YM in a phased manner
- First DBI’s to be rejuvenated were in Lonarwadi and Wadgaon Sinnar villages in year 2011
- Average cost of Rejuvenation of one DBI is around 30 lakhs
- WUA were formed for O&M of these systems in each village
- Problem posed: what is the actual effect of DBI?

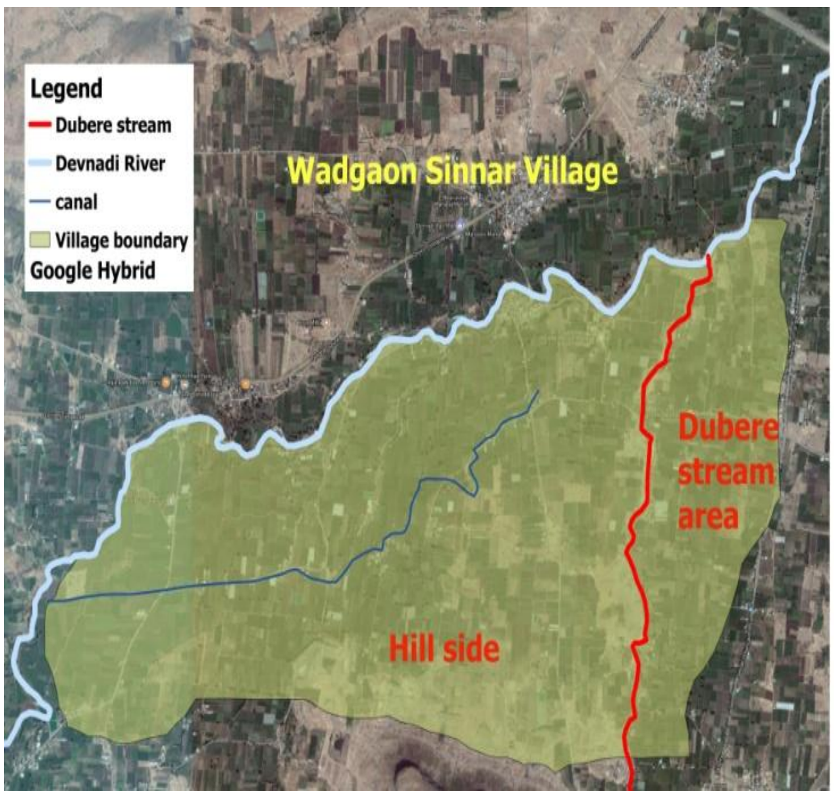
DBI system in Sinnar

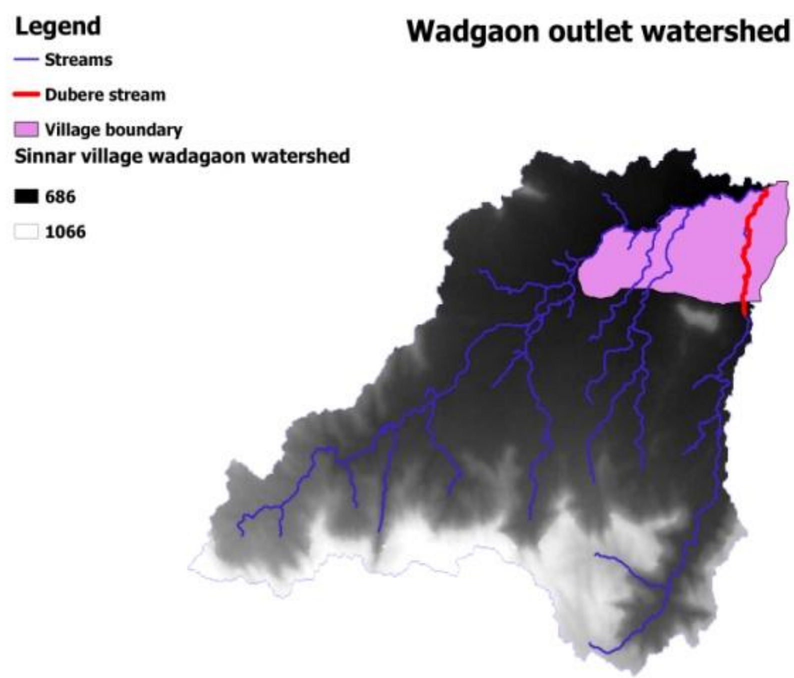


- 12 villages as part of DBI system
- Starts at Konambe and ends at Deopur

Wadgaon Sinnar at a glance

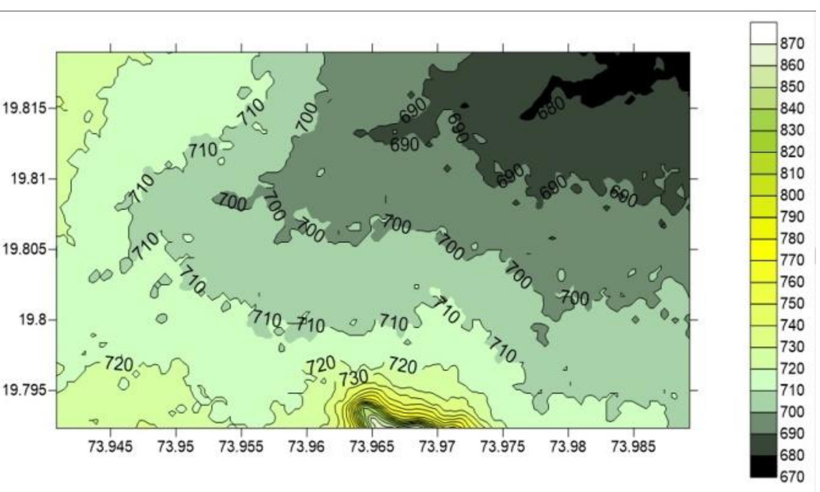
- Village located at up stream of Devnadi
- Partly tanker fed in the year 2015
- Agricultural Village

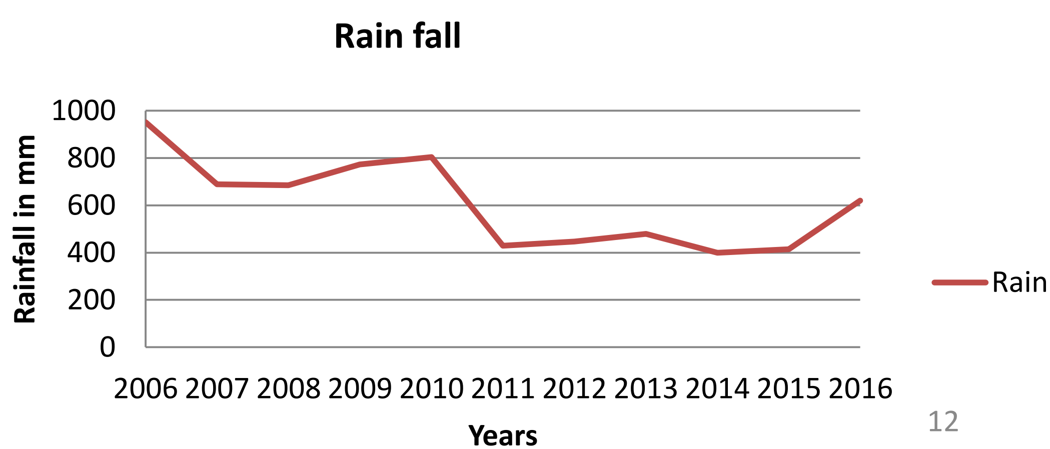




Geography

- Slope gradient of area 0-5%
- Average rainfall 615 mm.
- Clayey and sandy gravelly clay loam soil





Literature

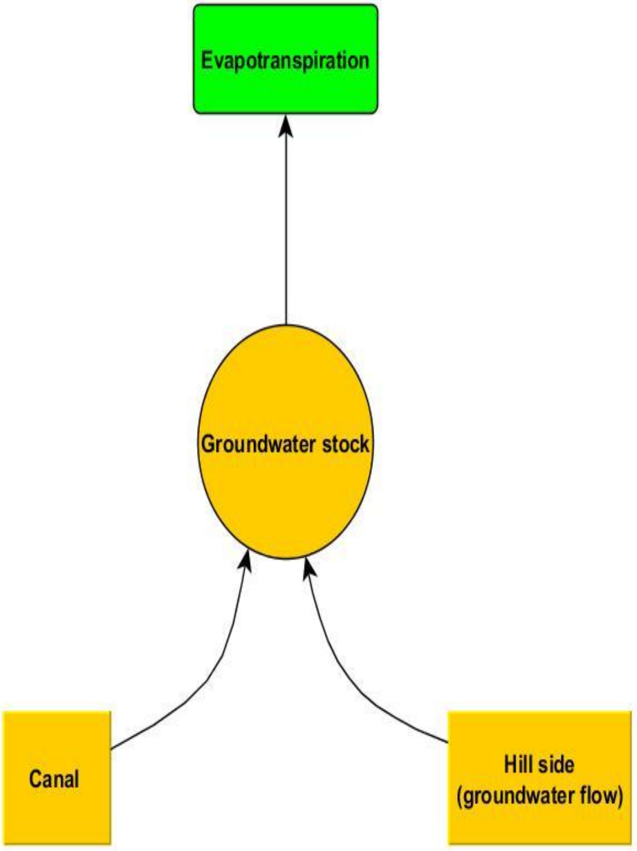
- Modelling done in large scale i.e. Large watersheds and basin level
- Steady state condition boundary conditions are no flow condition
- Steady state possible when there is lack of data
- Village level water balance

Ref:

- (Development of steady state groundwater flow model in lower Walawa Basin- Sri Lanka; Amarsingha Seneviratne)
- Steady state Unconfined Aquifer simulation of the Garegh-Bygone Plain, Iran; Hossein Hashemi

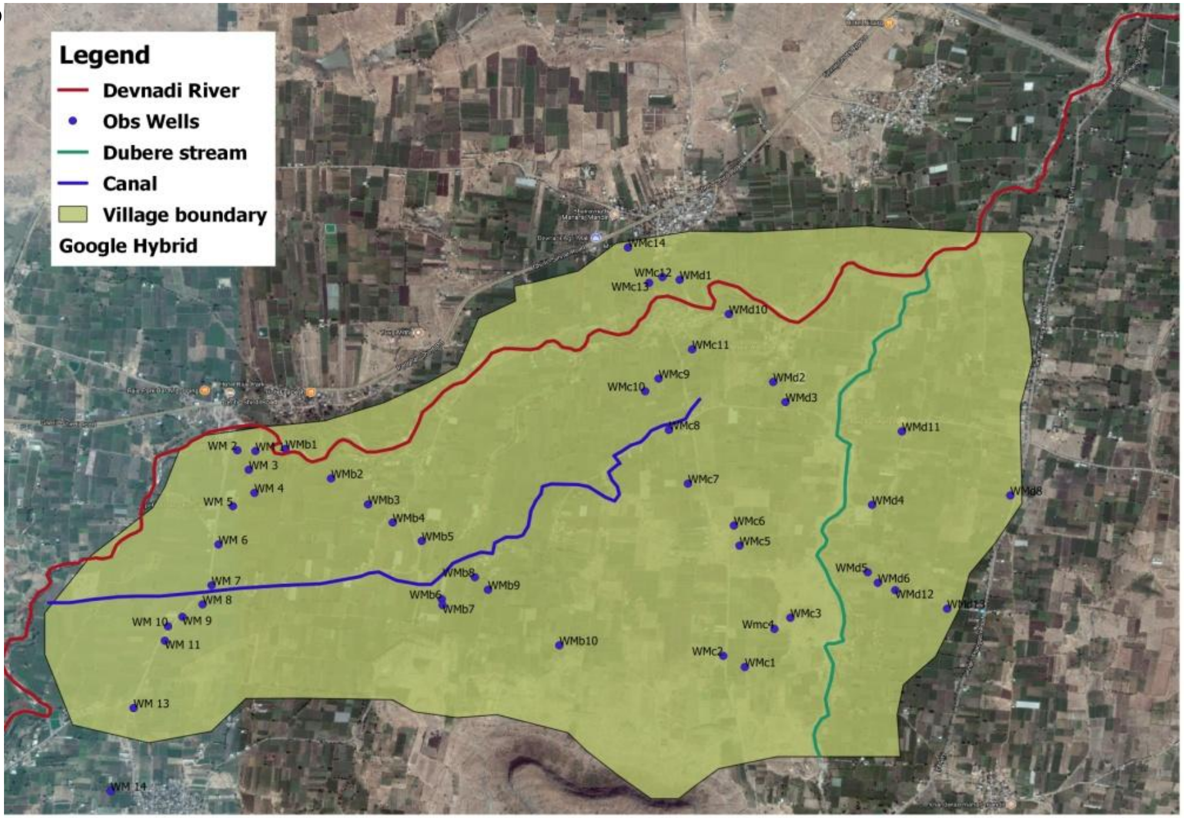
Daily water balance

- Framework for DBI village water balance-
- Estimating stock and flows in the presence and absence of canal on a particular day.

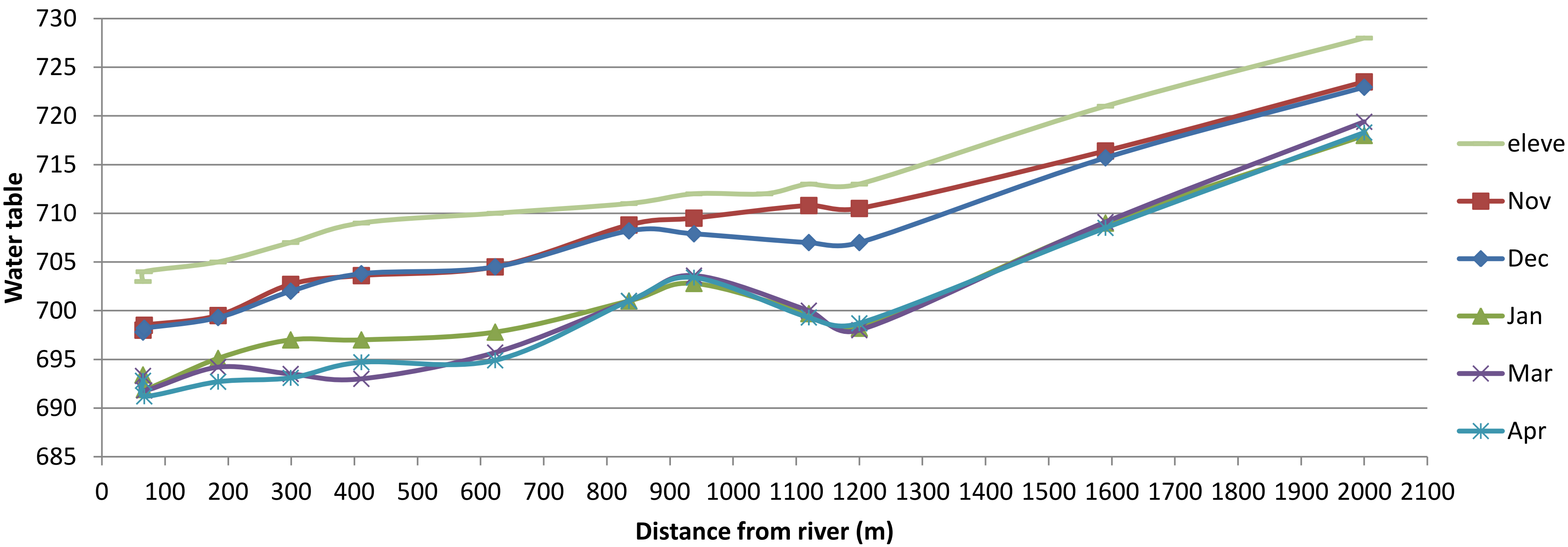


Well observations- Stock

- Selection of wells
- Periodic recording



721 m
710 m
700 m
688 m
Elevation (m)
1-1'
Water table
(mbgl)
688 m
1.8%
0.25 km
0.5 km
0.75 km
1 km
1.25 km
1.5 km
1.75 km
2 km
2.25 km



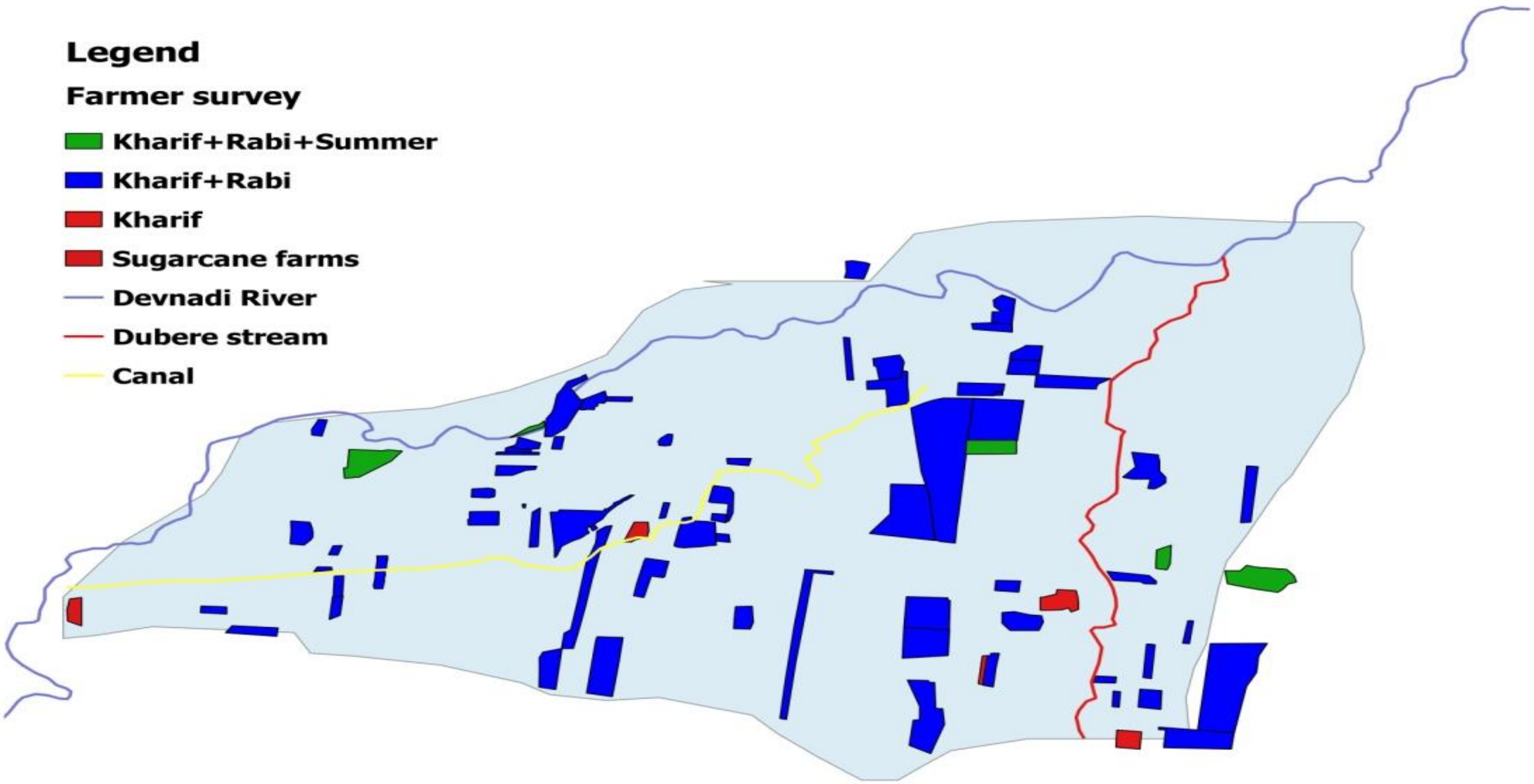
Water table
730
725
720
715
710
705
700
695
690
685
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Distance from river (m)
eleve
Nov
Dec
Jan
Mar
Apr

Flow: Cropping

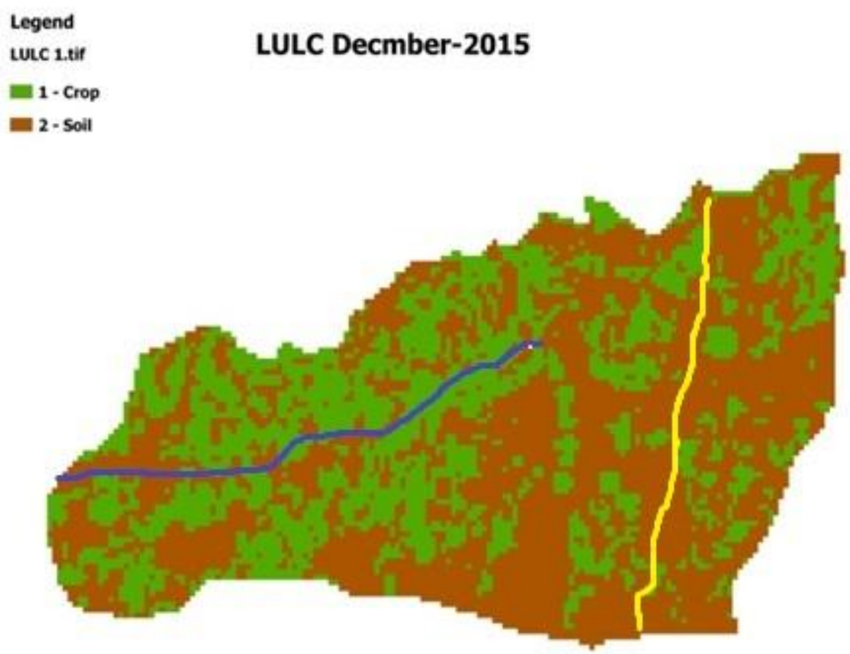
- **Kharif- tomato, soyabean**
- **Rabi- Wheat and onion**
- **Summer- groundnut**
- **ET loads calculated**

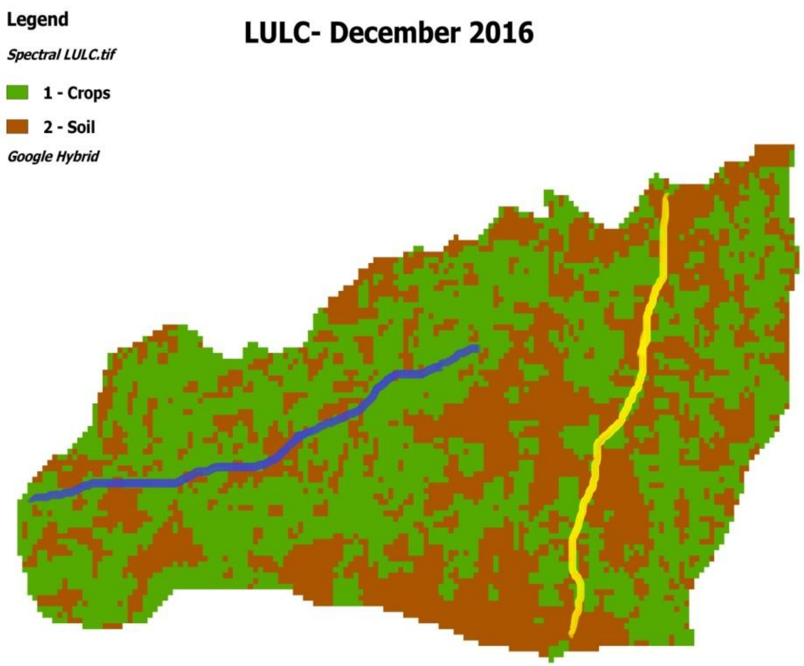
Season		Crops	Cropping percent	No. of watering (on average)	Type of irrigation
Kharif	Soya bean	60	70	Rainfall/flood	Canal/well
	Other vegetable	40	-	Flood	Well/canal
Rabi	Wheat	38	41	Flood	Well
	Onion	41	37	Flood	Well
	Others	22	5-8	Drip/flood	Well

Over view of cropping



LULC of village





Cropping in 2015: 300ha
Cropping in 2016: 425ha

TAO Data

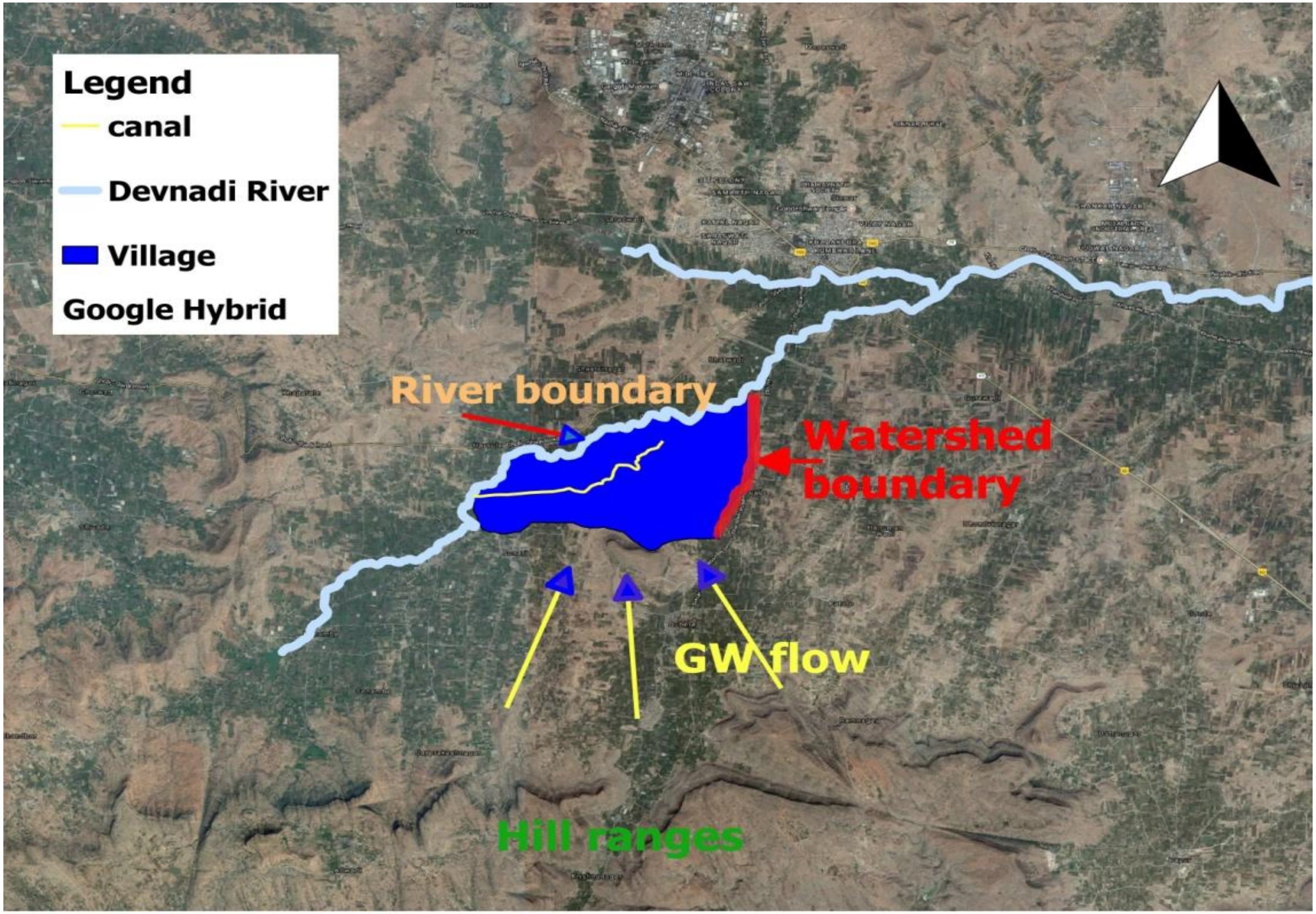
- Data obtained from agricultural officer in Sinnar
- Comparing that data with LULC data

Village		Area (ha)	Cultivable land (ha)
Wadgaon Sinnar		815	693
Rabi	TAO		160
	LULC		425
Kharif	TAO		562

Modelling for given day

- The stocks and flows on a given day- 25/11/2016
- Stock: Groundwater known by Well readings
- Flow: Canal , ET load, River, hill
- Taking snapshot of the day

Boundary condition



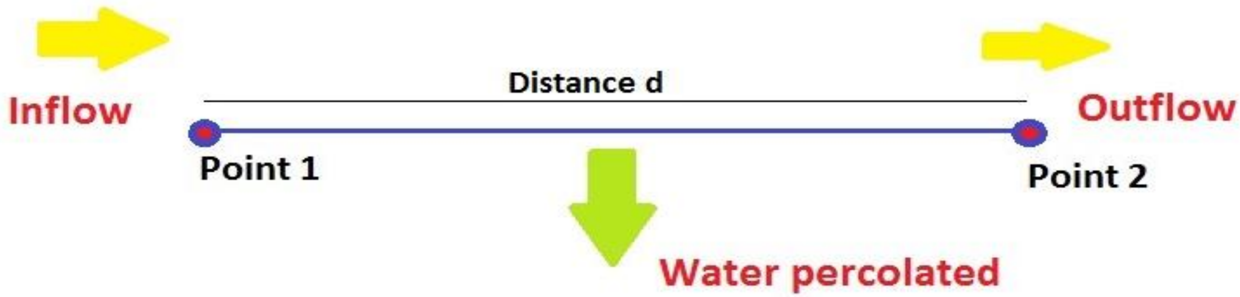
Modelling issues

- Transient, for a given day
- Making steady state condition from transient state condition
- Computing flows from boundary condition
- Finding the ET loads

Measuring Canal

- **Pygmy Current meter used for canal measurement**
- **Flows measured at various points along the canal**

Canal flows



Date	Location	Point 1(lps)	Point 2 (lps)	Distance (km)	Percolate (lps/km)
26/10/2016	Sinnar Vijayvaran	126.6	102.4	1.5	16
27/11/2016	Wadagon Sinnar	28.4	4.8	2.6	9

Total seepage from canal to ground calculated as 2.4 TCM in Wadgaon Sinnar

Steady vs Transient state

$$K\left(\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{\partial^2 h}{\partial z^2}\right)-W_s=0$$

$$\frac{\partial}{\partial x}\left(K_x\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z\frac{\partial h}{\partial z}\right)-W=\frac{S_s}{K}\frac{\partial h}{\partial t} \quad \ldots\ldots$$

$$W_S=W_T+S_y\frac{\Delta h}{\Delta t}$$

Converting Transient to steady

- S 1: Calibration: Run the model with different recharge (RHS) values in steady state to match the well readings.
- S 2: Equate this calibrated recharge with Et load –Sy. Check that these match estimates.
- S 3: Interpret flow budgets and check with canal flow
- S 4: If fine: simulate with no canal condition
- S 5: Compare

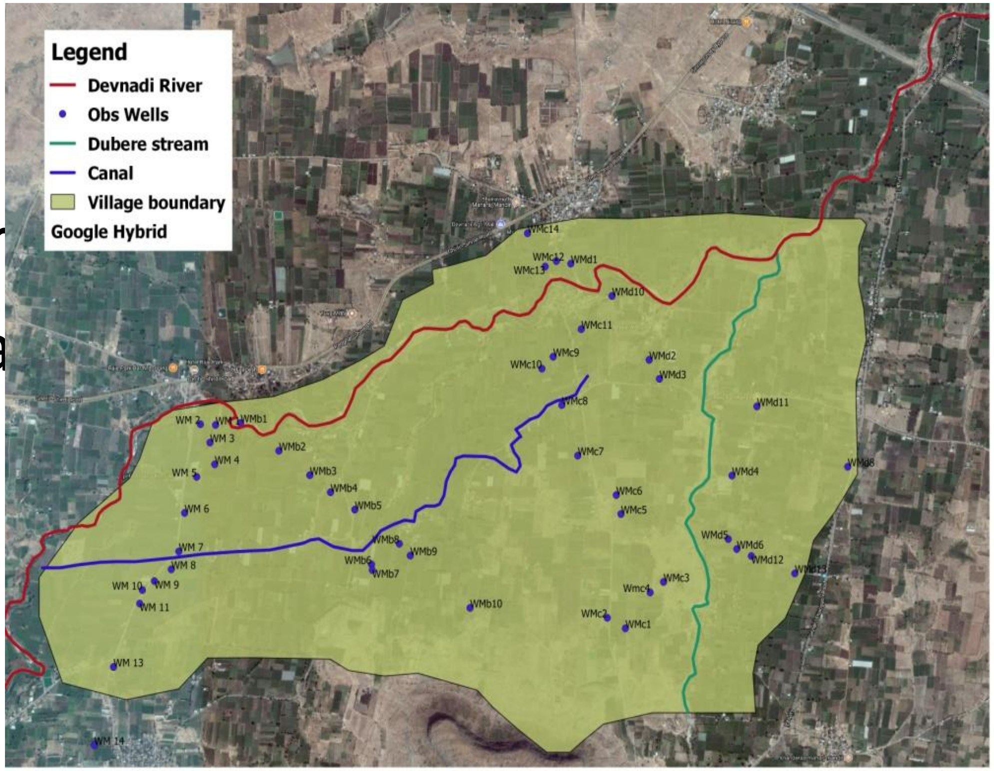
Running the model

- S1.1: Boundary condition, Drains
- S1.2: Layers and K- obs wells and lit
- S 1.3 Specific yield
- S1.4 Recharge (-ve) used for calibration

Properties	Layer 1	Layer 2
Drains	75 m^2/day/m	-
Thickness	12-20 m	10m
K values	1-2 m/day	0.009 m/day
Specific yield	0.025	

S 1.1 Finding BC by wells reading

- Factors affecting wells
  - Spatial
  - Elevation
  - Temporal
  - Distance from river
  - Distance from canal



Determining the B.C

- 48 well readings
- Parameters effecting each well
- Linear regression equation

$$W = aX + cZ + dT + K \cdot$$

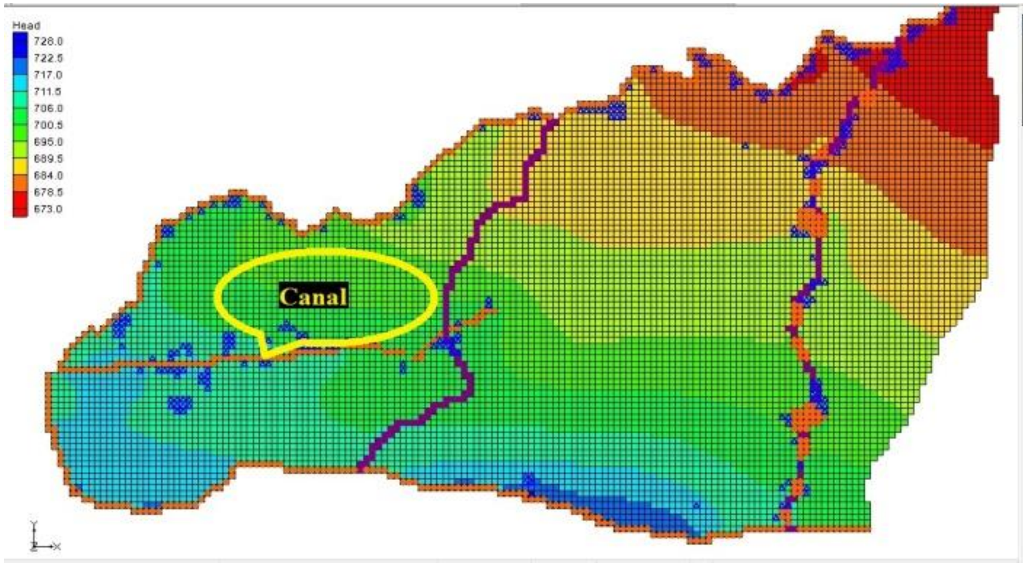
Coefficients

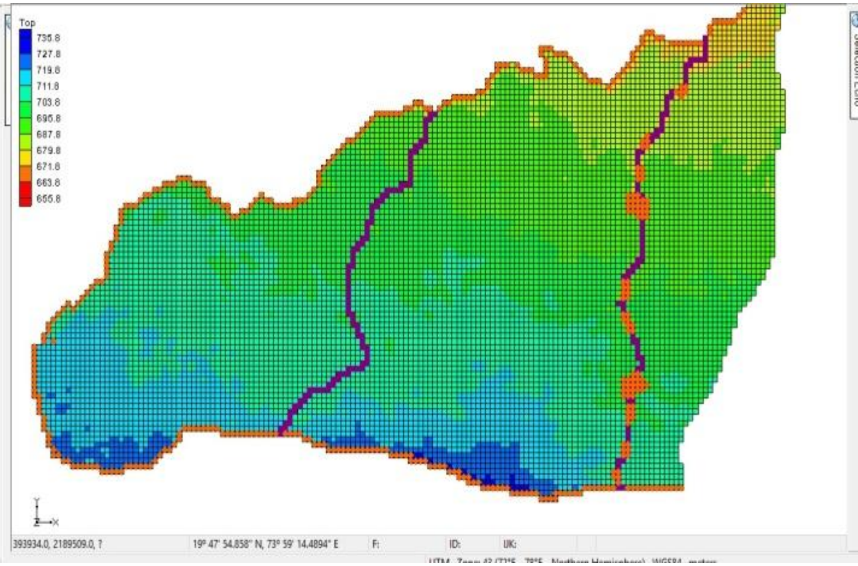
a= 0.0429; c= 0.1353; T=0.0754 and K= -1.1739

- R^2=0.69 for above equation
- Used at hill side

Revision: How to asses canal impact?

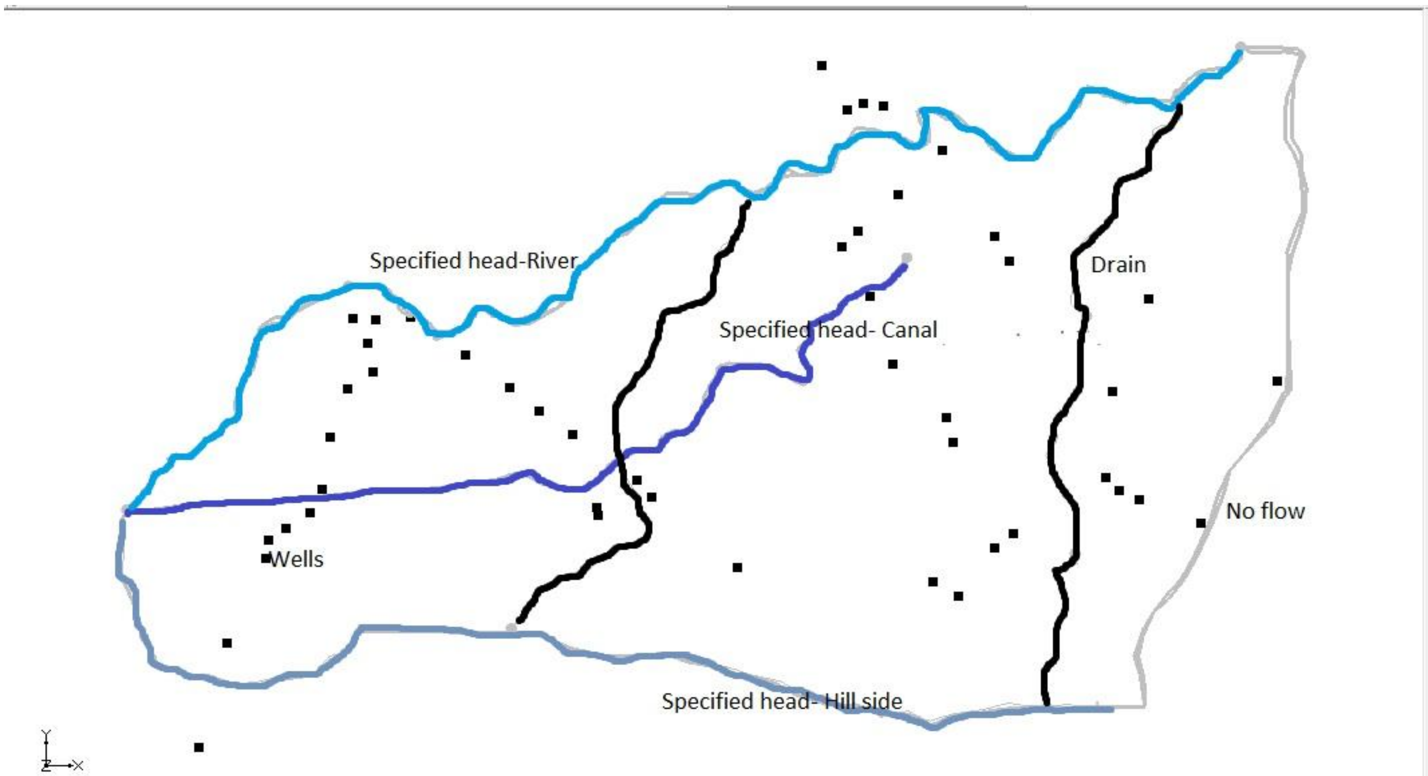
- Considering 2 scenarios
- Scenario 1: as is
- Scenario 2: What if





Recall: Modelling

- Initial conceptual layer in MODFLOW

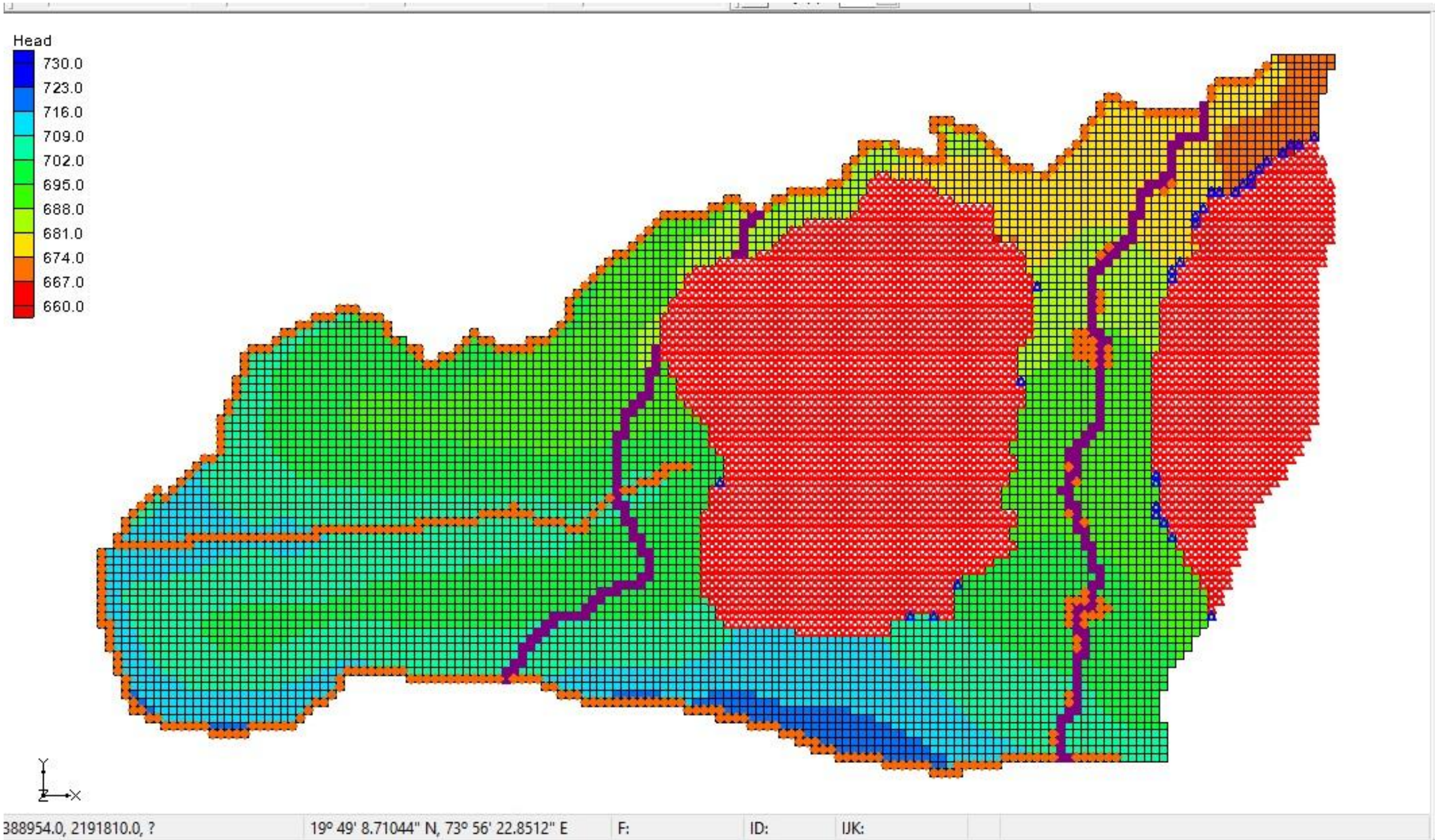


ET loads calculation

- ET loads was calculated using LULC classification and Survey data
- ET loads obtained fro cropping was averaged for whole area

	Onion	Wheat	Others
C.Ratio	35%	35%	30%
ET load	400mm	500mm	350mm
Cropping days	120	120	110

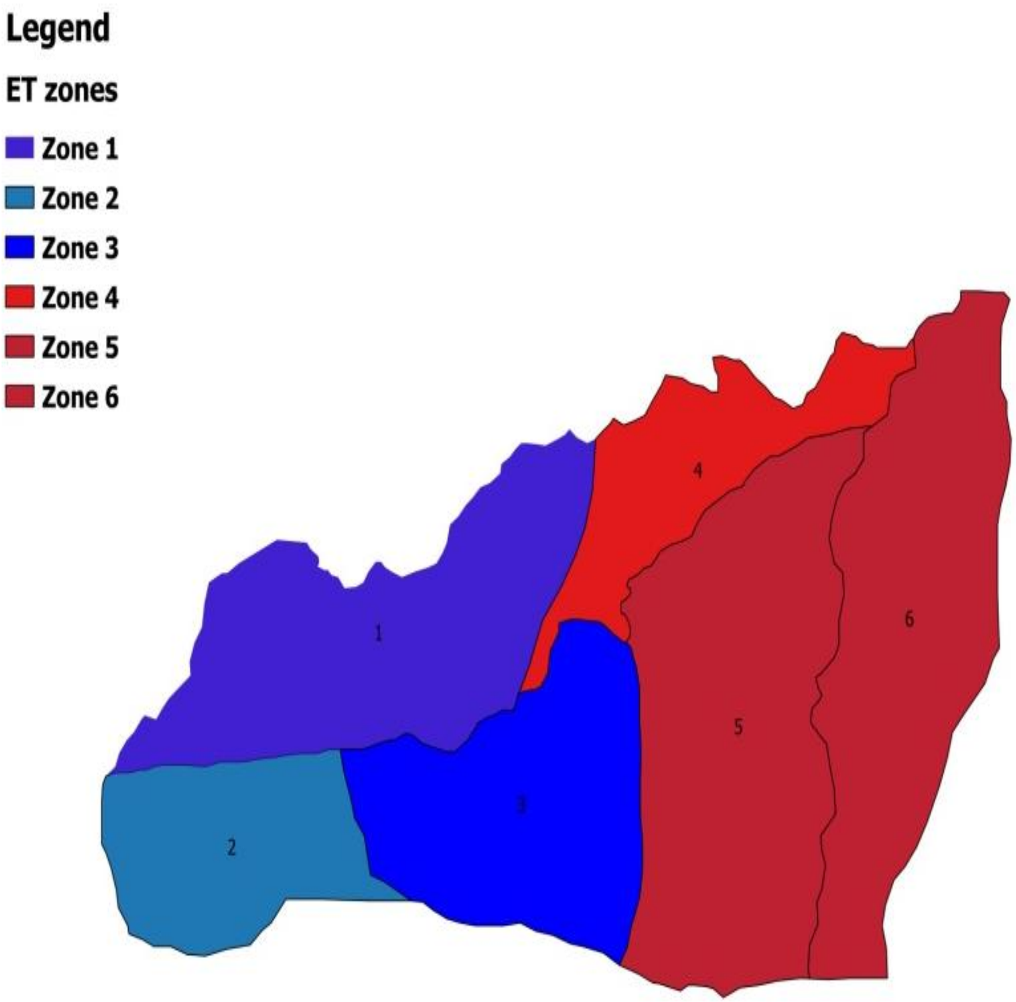
Dry run



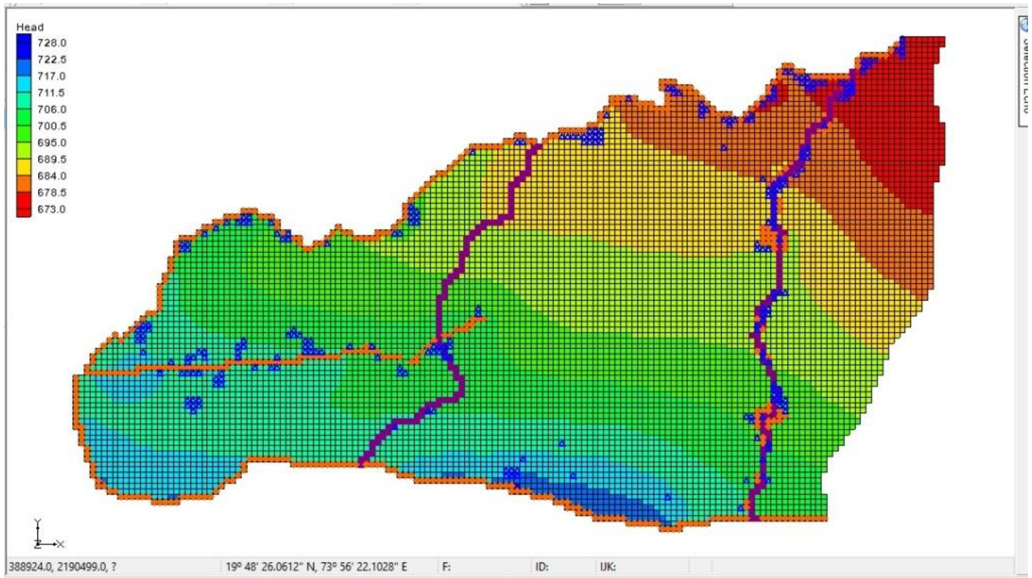
With actual ET load lot of cells go dry in the model which indicate dropping ground water

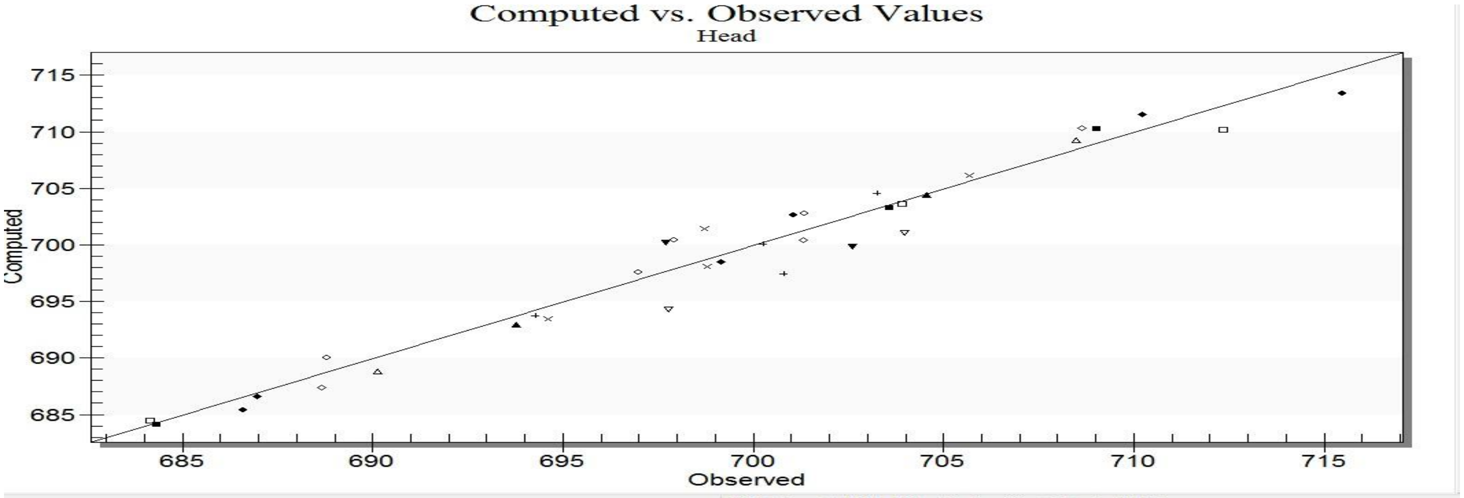
ET zones

ET zones	ET load (mm) field obs	Model recharge after calibratio n
1	2.51	1.3
2	2.59	1
3	2.13	0.8
4	2.31	0
5	1.52	0.3
6	2.30	0.6



Model run 1


Head
728.0
722.5
717.0
711.5
706.0
700.5
695.0
689.5
684.0
678.5
673.0
388924.0, 2190499.0, ?
19° 48' 26.0612" N, 73° 56' 22.1028" E
F:
ID:
IJK:

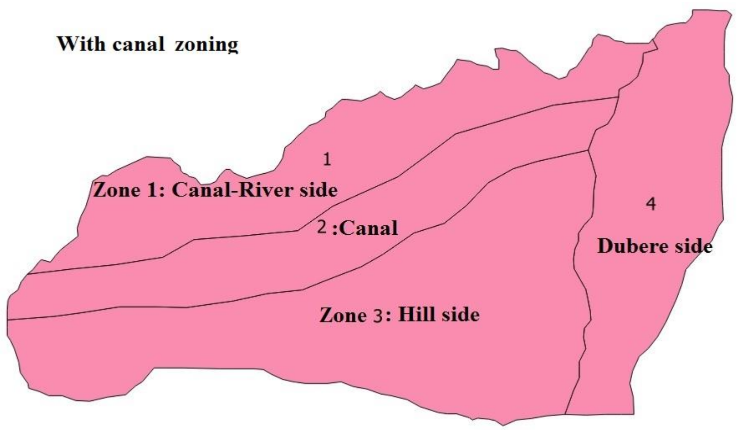

Computed vs. Observed Values
Head
Computed
Observed
715
710
705
700
695
690
685

Equating the recharge

ET zones	MODFLOW ET load (mm)	Actual ET (mm)	Difference (mm)	Calculated drop for 21 days (m)	Obs. Drop (m)
Zone 1	1.3	2.51	1.21	1.01	0.4
Zone 2	1	2.59	1.59	1.34	2.3
Zone 3	0.8	2.13	1.32	1.2	1.8
Zone 4	0	2.31	2.31	1.94	1.3
Zone 5	0.3	1.52	1.22	1.02	1.2
Zone 6	0.6	2.30	1.70	1.43	1.6

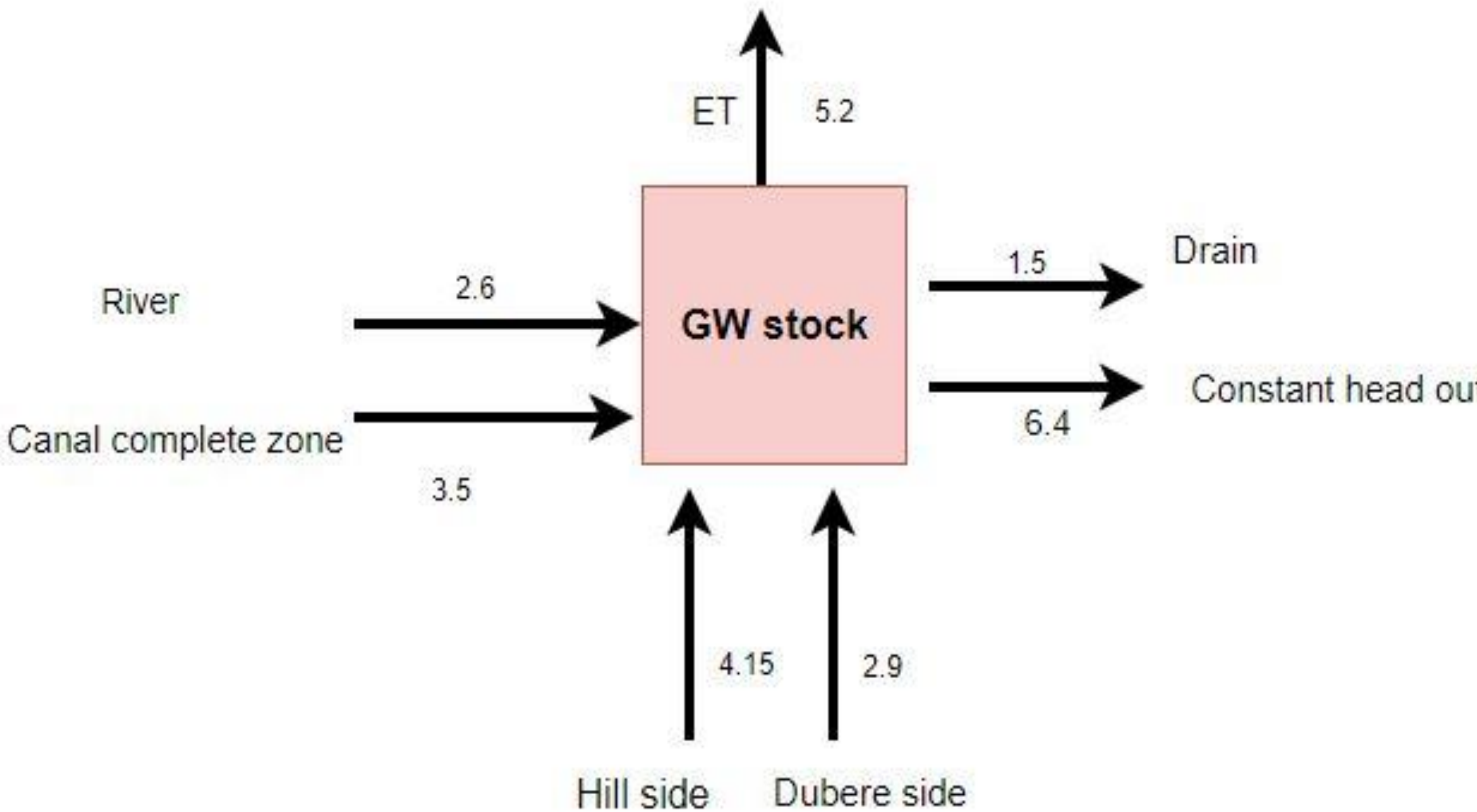
S:3:Zone budget add canal check

Zones	Constant IN (TCM)	Constant Out (TCM)
Zone 2 (model)	2.84	.72
Measured	2.4	-



November	GW stock (TCM)
Zone 1	670
Zone 2	360
Zone 3	1325
Zone 4	535
Total	2900

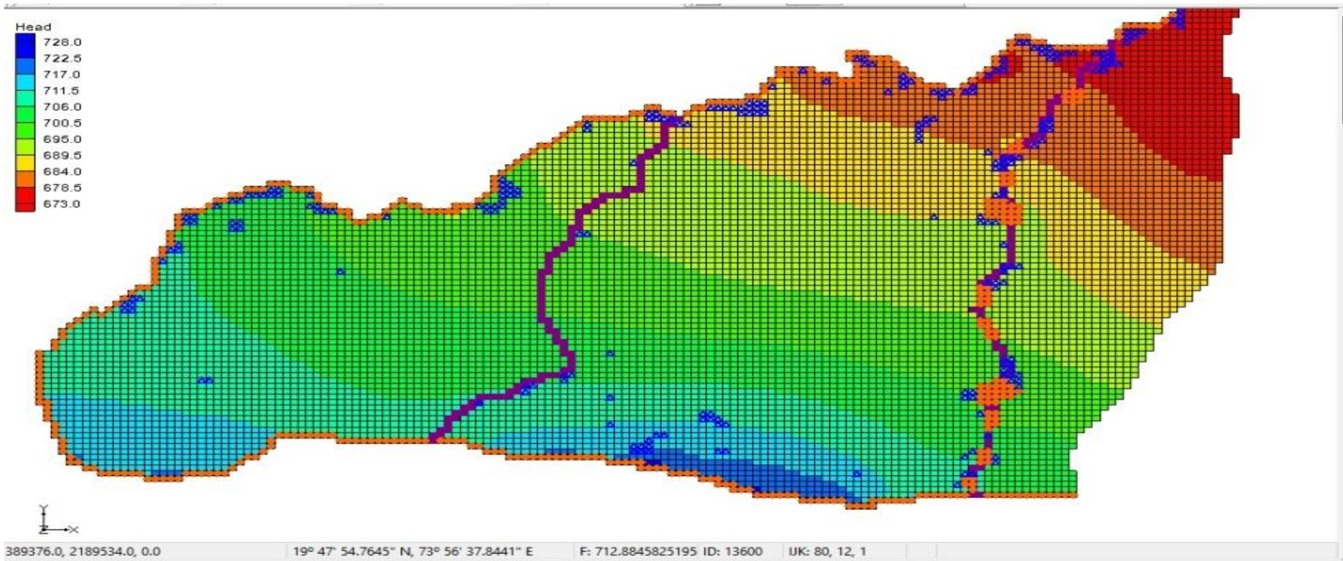
Over view of Flow budget



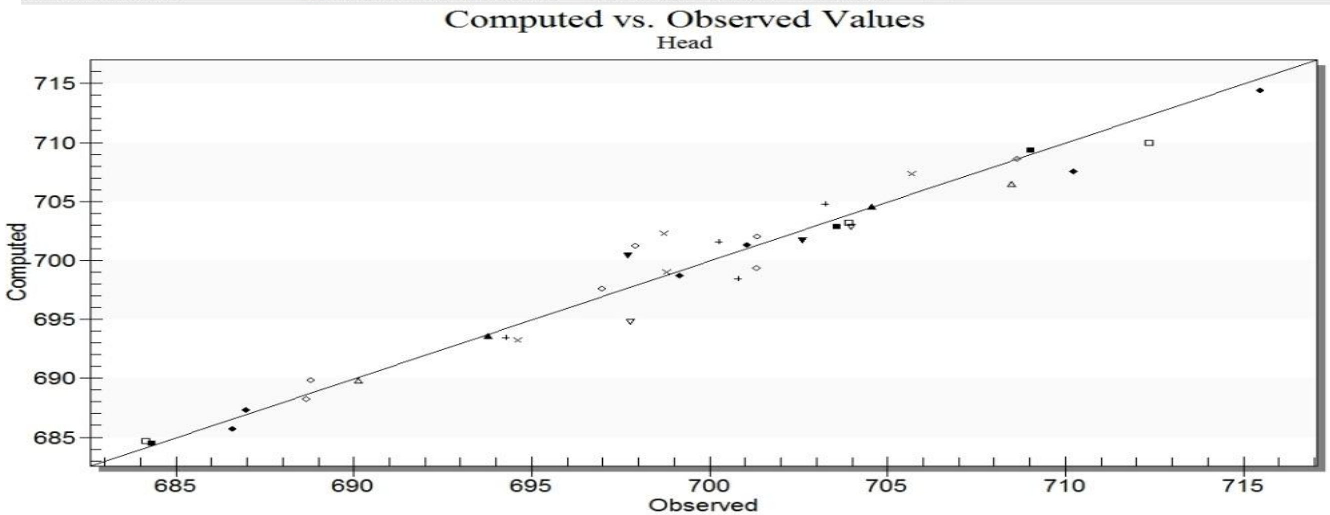
Model run without canal

- To change Recharge (ET load) to match internal well levels/heads.
- Compare the new recharge values with the model 1 values

Model run 2



Head
728.0
722.5
717.0
711.5
706.0
700.5
695.0
689.5
684.0
678.5
673.0
389376.0, 2189534.0, 0.0
19° 47' 54.7645" N, 73° 56' 37.8441" E
F: 712.8845825195 ID: 13600
IJK: 80, 12, 1



Computed vs. Observed Values
Head
Computed
Observed
715
710
705
700
695
690
685

Difference in ET loads

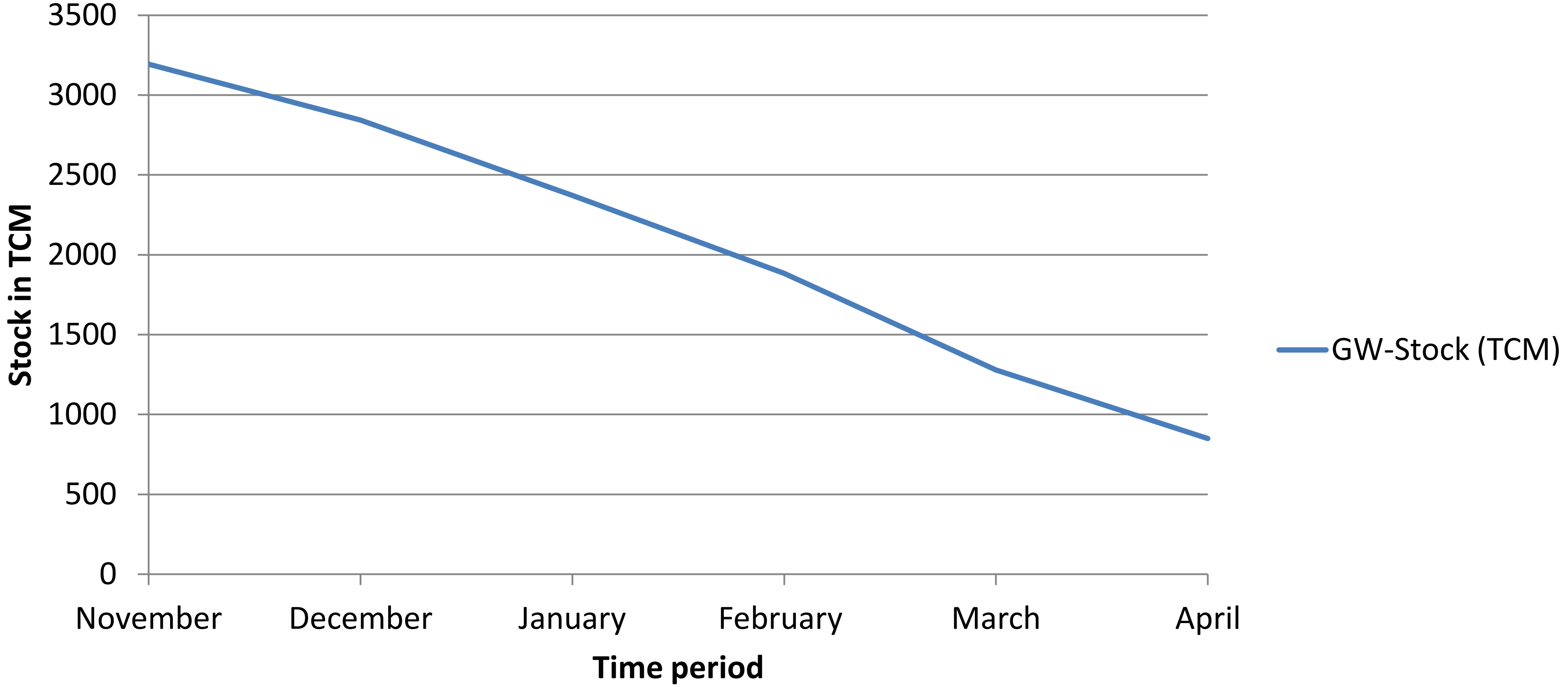
ET zones	MODFLOW recharge load (mm) Scenario 1	MODFLOW recharge load (mm) Scenario 2	Difference
Zone 1	1.3	0.3	1
Zone 2	1	0.3	0.7
Zone 3	0.8	0.8	0
Zone 4	0	0	0
Zone 5	0.3	0.3	0
Zone 6	0.6	0.6	0

Area under new ET

	Scenarios	Area (ha)	Cropping area (ha)	Cropping percent	ET load (mm)
Zone1	With Canal	160	104	65	2.5
	Without canal	160	63	39	1.5
Zone2	With Canal	85	58	68	2.59
	Without canal	85	44	51	1.89

Change in cropping in zone 1 is 39%
Change in cropping in zone 2 is 24%
Simple Cost benefit analysis of canal:
Complete irrigation during Kharif and nearly 1/3rd time for Rabi irrigation provided for 54ha of land by canal
Rejuvenation Infrastructure Cost/ha= Rs.55000.

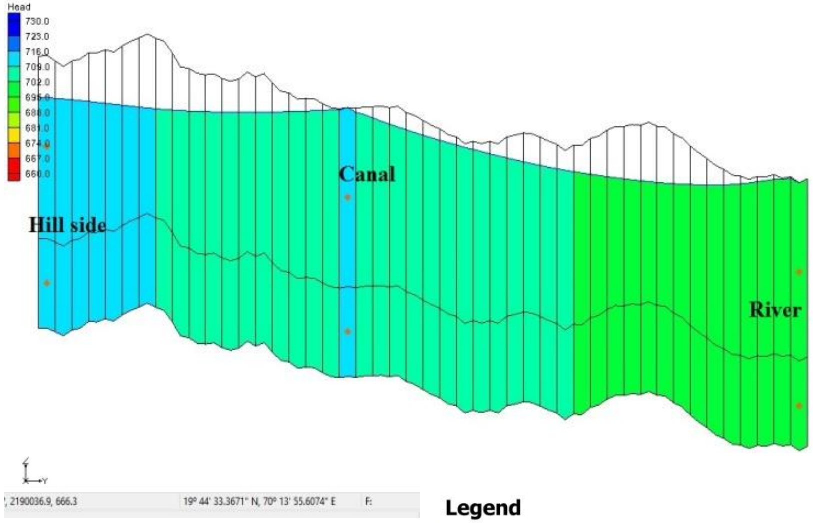
Re check: GW stock

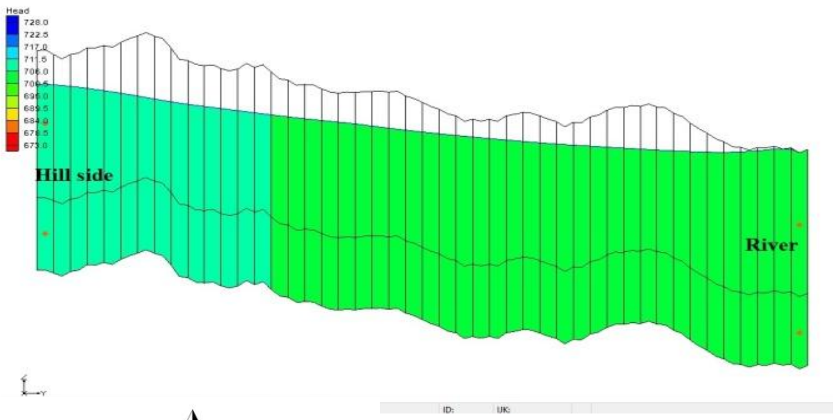


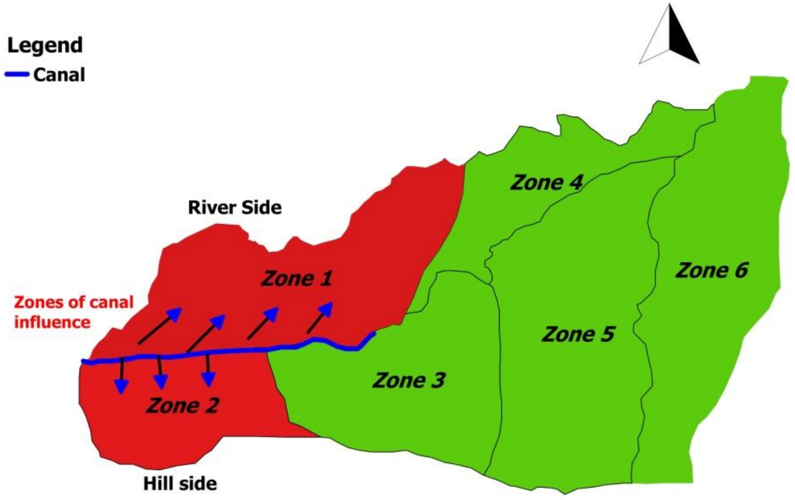
- **GW stock decreases from 3194 TCM in November to 850 TCM in April**
- **Larger Drop in the month February and March**

Output 2

- Canal 'blocking' the sub surface flow

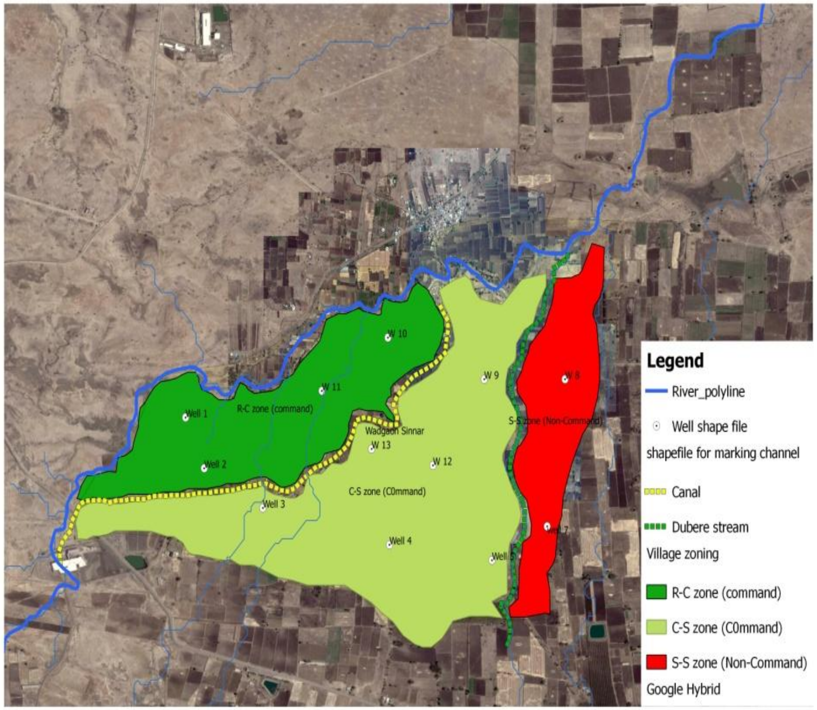


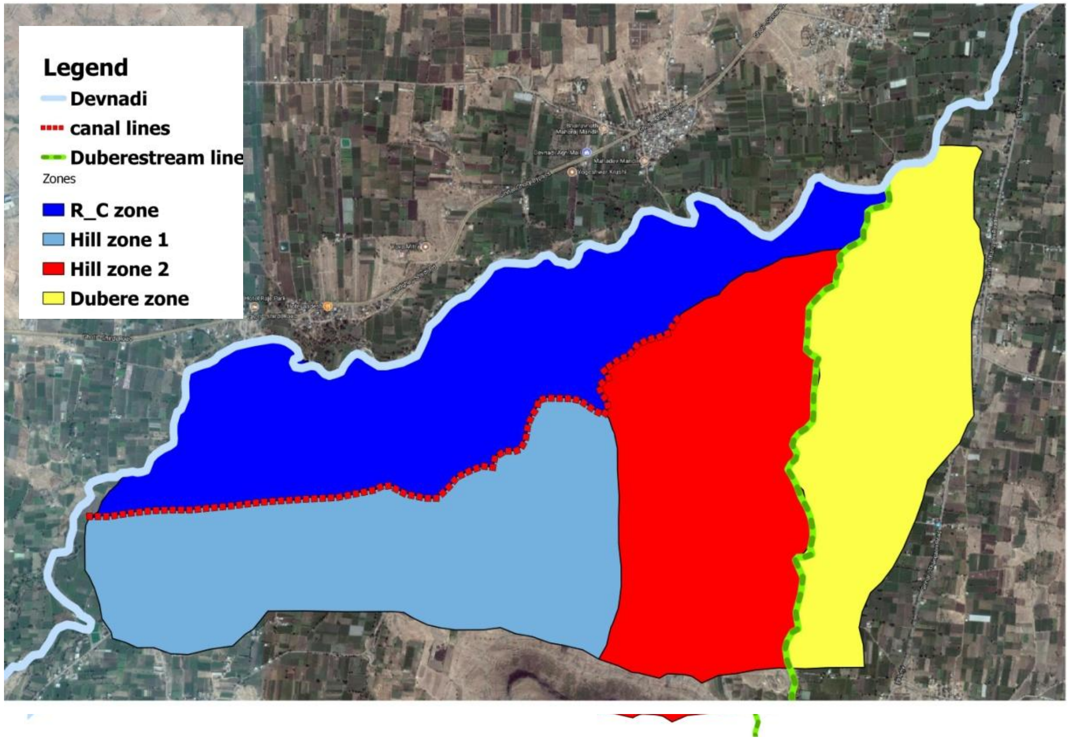




Comment

- Initial zoning
- New zoning





Conclusions

- Area under the influence of DBI was quantified
- DBI is much better alternative to conventional system
- DBI rejuvenation should be done
- Cost recovery in 4-5 years depending on crop

Scope of Future works and limitation

- Understanding Inter well pumping in the village. To determine the water pockets in the village
- Transient state modelling of village, considering the whole watershed of village
- Complete length of canal could not be simulated


Thank You