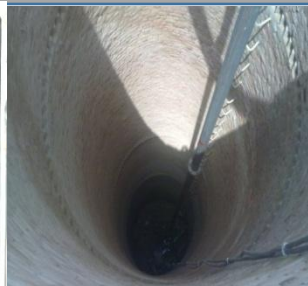
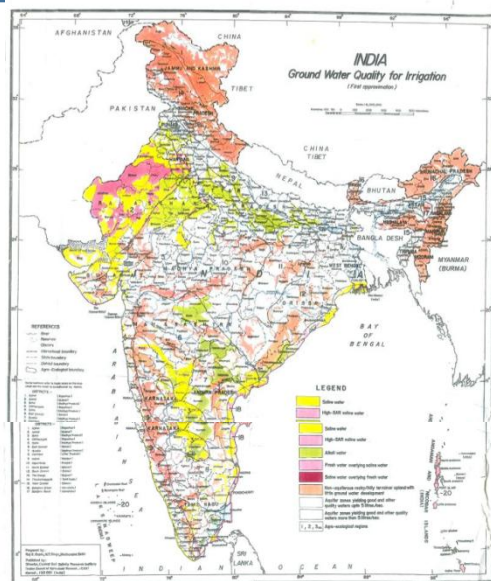
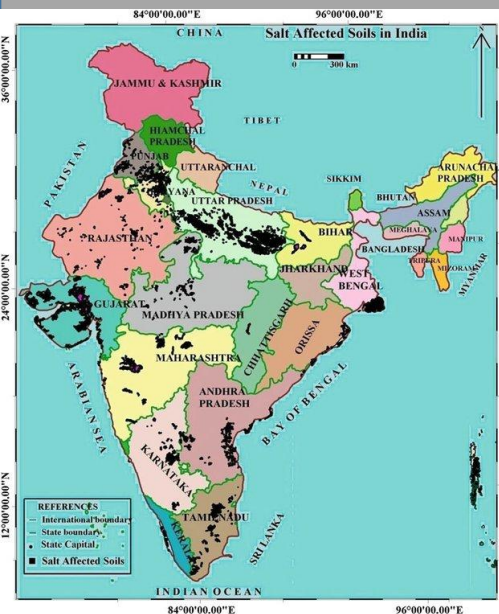


Long Term Estimates of Salinity in Water and Soil- Engineering Approaches for Salt Balances



Dr. Chhedi Lal Verma
Sr. Scientist & Ex. Professor
ICAR Central Soil Salinity Research Institute
Regional Research Station, Lucknow



जल का बृहत् चक्रण

जलं प्रथमो जायते वहति जीवनं रसं तु।
गंगा युगं संवहति वनं कल्पं तथैव च॥

कलि कल्मषेन सन्तप्तो गंगा विष्णु लोके
समागमिष्यति।
संचयं जलं जलभृते रक्षणञ्च व्यापारं कलौ
धर्मः तु जायते।

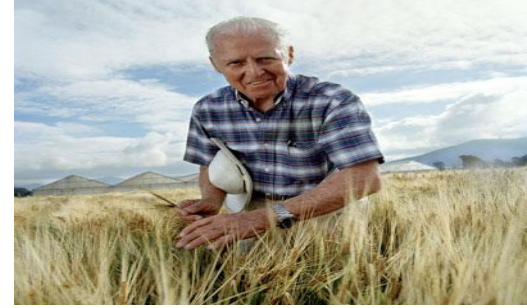
-स्वस्फूर्त

GREEN REVOLUTION

1. High Yielding Dwarf Varieties
2. Chemical Fertilizers
3. Plant Protection Chemicals
4. Improved Tillage Machineries
- 5. Assured Irrigation Water**

Canal=40%

GW=60%



Water Crises

GROUND WATER DECLINE



SCARCITY



DROUGHTS



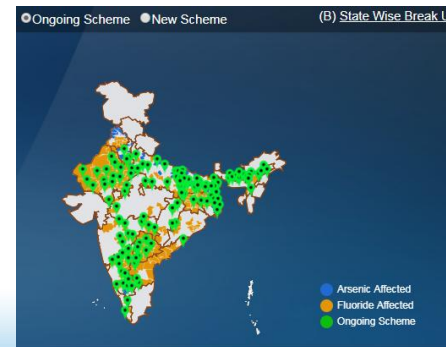
SEWAGE



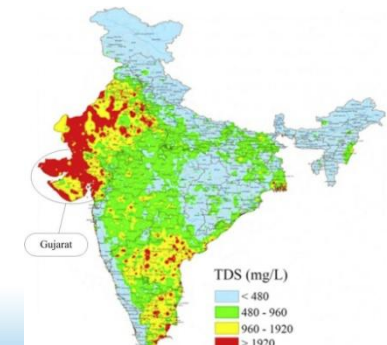
POLLUTION



ARSENIC,



FLUORIDE



SALINE GW

ORIGIN OF SALTS IN SOIL

Primary Minerals: primary minerals

Chemical Weathering: Due to hydrolysis, hydration, solution, oxidation, carbonation and other processes, the salt constituents are gradually released and made soluble.

Released salts are transported away from their source of origin through surface or groundwater streams.

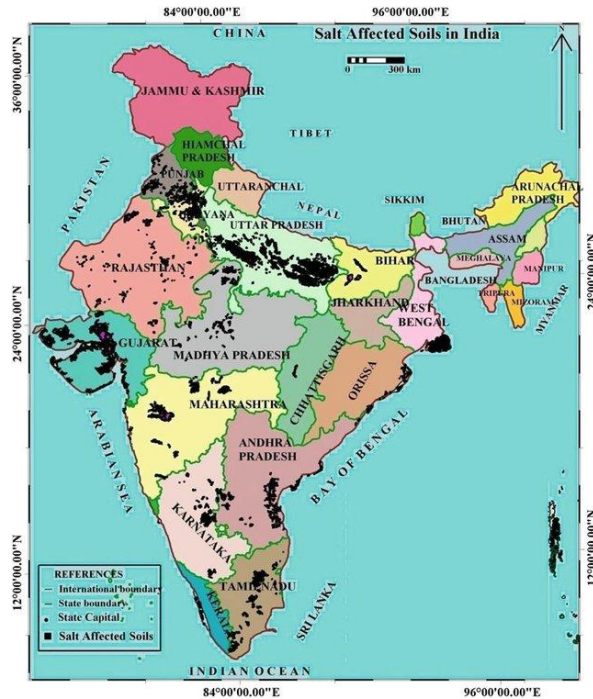
Types:

1. Saline soils - Soils containing sufficient neutral soluble salts to adversely affect the growth of most crop plants. The soluble salts are chiefly sodium chloride and sodium sulphate. But saline soils also contain appreciable quantities of chlorides and sulphates of calcium and magnesium. pH of saturated soil paste is less than 8.2. An electrical conductivity of the saturated soil extract of more than 4 dS/m at 25 °C.

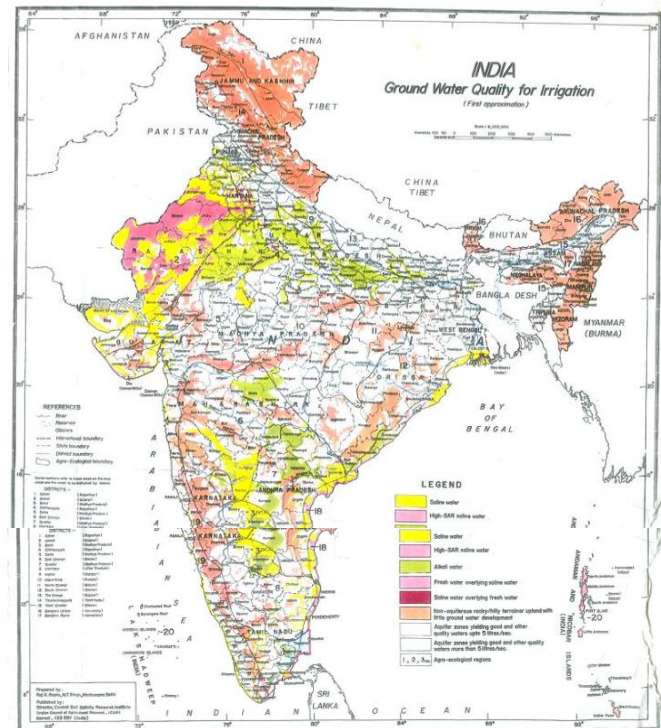
2. **Sodic Soils** - Soils containing sodium salts capable of alkaline hydrolysis, mainly Na_2CO_3 , these soils have also been termed as 'Alkali' in older literature. pH of the saturated soil paste is more than 8.2. $\text{ECe} < 4 \text{ dS/m}$ at 25°C . $\text{pHe} > 8.5$, $\text{ESP} > 15.0$. at 25°C .

3. **Saline Sodic Soils: Saline = 2.956 Mha**

Sodic = 3.771 Mha



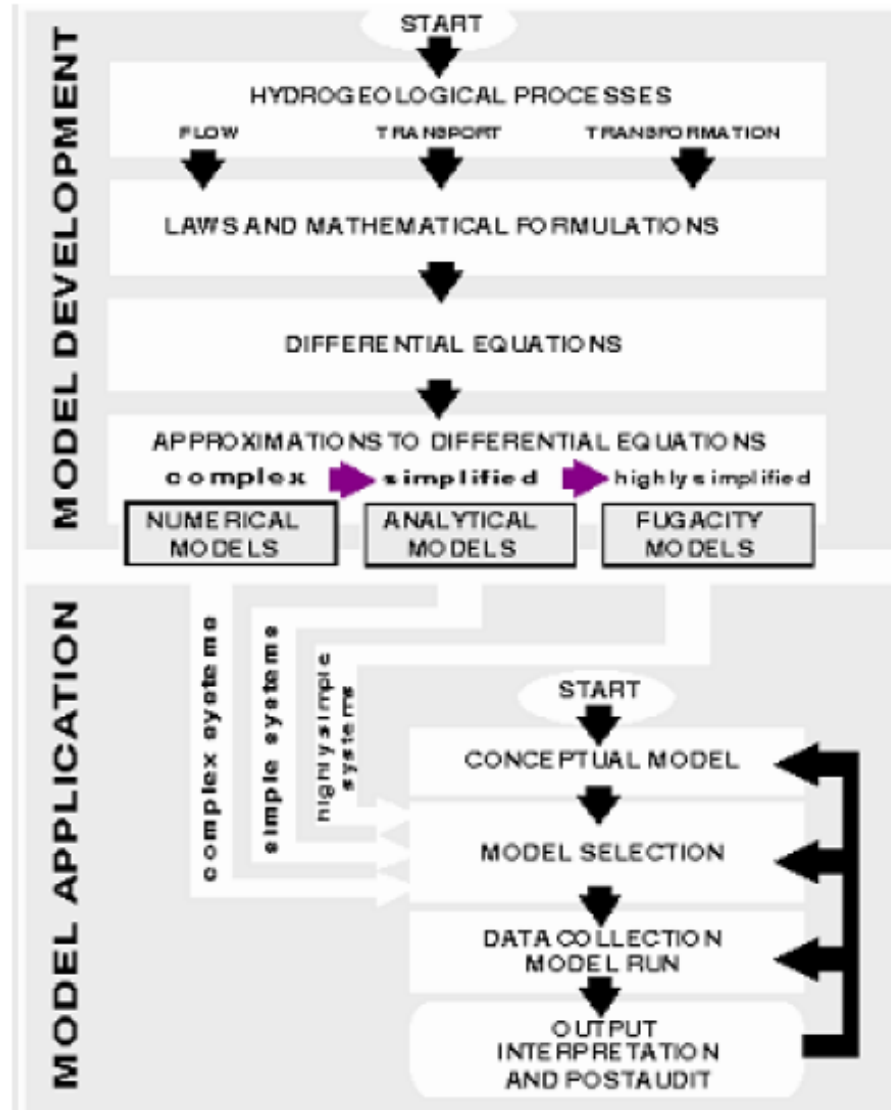
Salt Affected Soil of India



Ground Water Quality Map of India

DEVELOPMENT OF GROUND WATER SIMULATION MODEL

1. Model Objectives
2. Hydrogeological Characterization
3. Model Conceptualization



1. GROUNDWATER FLOW EQUATION

The governing flow equation for three-dimensional saturated flow in saturated porous media is:

$$\frac{\partial}{\partial x} \left(K_{xx} \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(K_{yy} \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left(K_{zz} \frac{\partial h}{\partial z} \right) - Q = S_s \frac{\partial h}{\partial t}$$

where,

- K_{xx}, K_{yy}, K_{zz} = hydraulic conductivity along the x,y,z axes which are assumed to be parallel to the major axes of hydraulic conductivity;
- h = piezometric head;
- Q = volumetric flux per unit volume representing source/sink terms;
- S_s = specific storage coefficient defined as the volume of water released from storage per unit change in head per unit volume of porous material.

2. Solute Transport Model

$$\frac{\partial c}{\partial t} = - \frac{\partial}{\partial x_i} (c v_i) + \frac{\partial}{\partial x_i} \left(D_{ij} \frac{\partial c}{\partial x_j} \right) + R_c \quad i, j = 1, 2, 3$$

where,

c = concentration of the solute;
 R_c = sources or sinks;
 D_{ij} = dispersion coefficient tensor;
 v_i = velocity tensor.

MOST COMMON AVAILABLE MODELS

1. FEFLOW

(Finite Element Subsurface Flow System)

2. HST3D

(3-D Heat and Solute Transport Model)

3. MODFLOW

(Three-Dimensional Finite-Difference Ground-Water Flow Model)

MODFLOW is the name that has been given the USGS Modular Three-Dimensional Ground-Water Flow Model. Because of its ability to simulate a wide variety of systems, its extensive publicly available documentation, and its rigorous USGS peer review, MODFLOW has become the worldwide standard ground-water flow model. MODFLOW is used to simulate systems for water supply, containment remediation and mine dewatering. When properly applied, MODFLOW is the recognized standard model.

4. MT3D

(A Modular 3D Solute Transport Model)

5. SEAWAT

(Three-Dimensional Variable-Density Ground-Water Flow)

6. SUTRA

(2-D Saturated/Unsaturated Transport Model)

7. SWIMv1/SWIMv2

(Soil water infiltration and movement model - simulate soil water balances)

8. Visual MODFLOW

(Integrated Modeling Environment for MODFLOW, MODPATH, MT3D)

9. UNSATCHEM

A software package for simulating water, heat, carbon dioxide and solute movement in one-dimensional variably saturated media. The software consists of the UNSCHEMA (version 2.0) computer program, and the UNSATCH interactive graphics-based user interface.

The UNSCHEMA program numerically solves the Richards' equation for variably-saturated water flow and convection-dispersion type equations for heat, carbon dioxide and solute transport.

The flow equation incorporates a sink term to account for water uptake by plant roots. The heat transport equation considers transport due to conduction and convection with flowing water.

Diffusion in both liquid and gas phases and convection in the liquid phase are considered as CO₂ transport mechanisms. The CO₂ production model is described.

The major variables of the chemical system are Ca, Mg, Na, K, SO₄, Cl, NO₃, H₄S_iO₄, alkalinity, and CO₂.

The model accounts for equilibrium chemical reactions between these components such as complexation, cation exchange and precipitation-dissolution. For the precipitation-dissolution of calcite and dissolution of dolomite, either equilibrium or multicomponent kinetic expressions are used which include both forward and back reactions. Other dissolution-precipitation reactions considered include gypsum, hydromagnesite, nesquehonite, and sepiolite. Since the ionic strength of soil solutions can vary considerably with time and space and often reach high values, both modified Debye-Huckel and Pitzer expressions were incorporated into the model as options to calculate single ion activities.

The program may be used to analyze water and solute movement in unsaturated, partially saturated, or fully saturated porous media. The governing flow and transport equations are solved numerically using finite differences and Galerkin-type linear finite element schemes, respectively.

10. Model Using Machine-Learning Techniques:

Such model use comprehensive set of climatic, topographic, soil, and remote sensing data to develop models capable of making predictions of soil salinity (expressed as electrical conductivity of saturated soil extract) and sodicity (measured as soil exchangeable sodium percentage) at different longitudes, latitudes, soil depths, and time periods.

11. The Soil & Water Assessment Tool (SWAT):

It is a small watershed to river basin-scale model used to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control and regional management in watersheds.

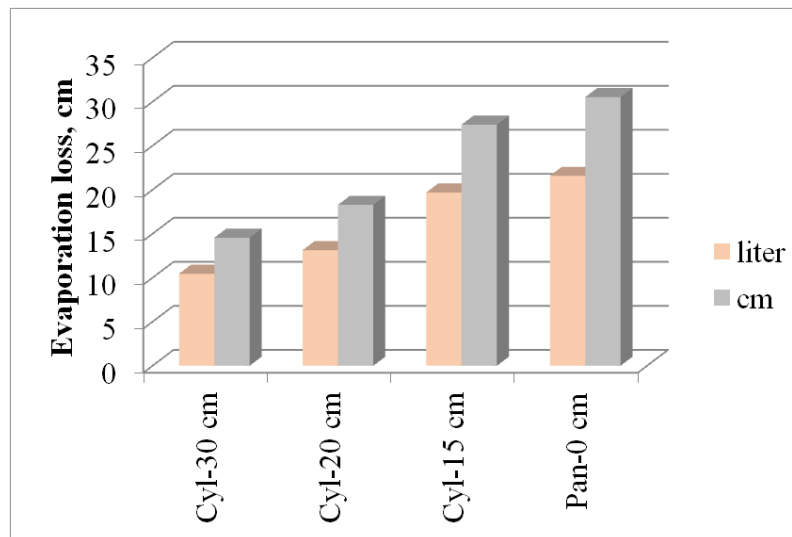
SALT ACCUMULATION MODELLING

The Model : Inverse Appropriated Water Table Depth Model
(Verma, et al. 2020)

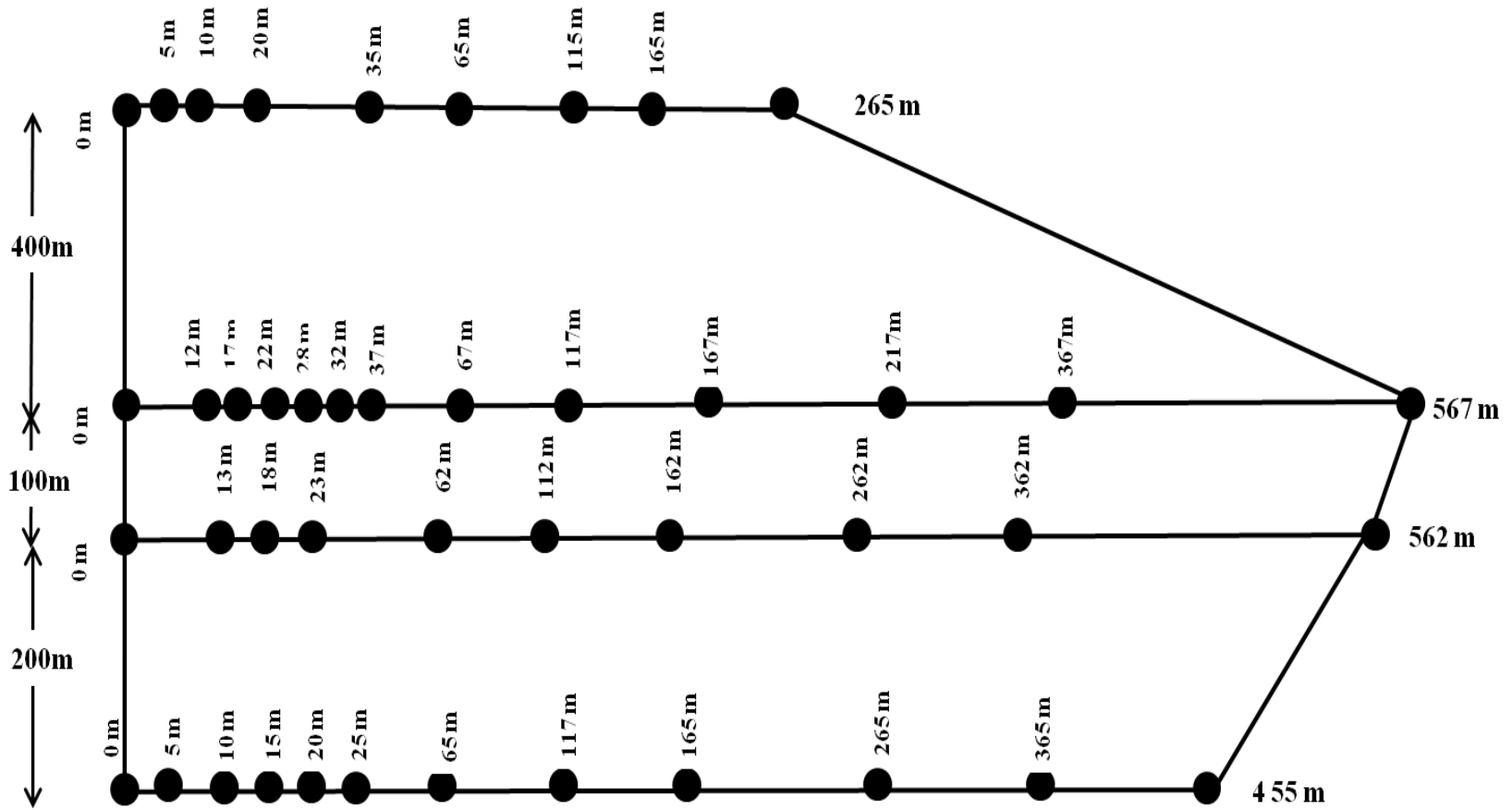
Hypothesis: The rate of change of incremental evaporation loss with respect to the incremental water table depth below ground surface (dy) over a specified time span is inversely proportional to appropriated water table depth below ground surface (y^a). Mathematically it can be expressed as below.

$$\frac{dE}{dy} = \frac{k}{y^a} \quad (1)$$

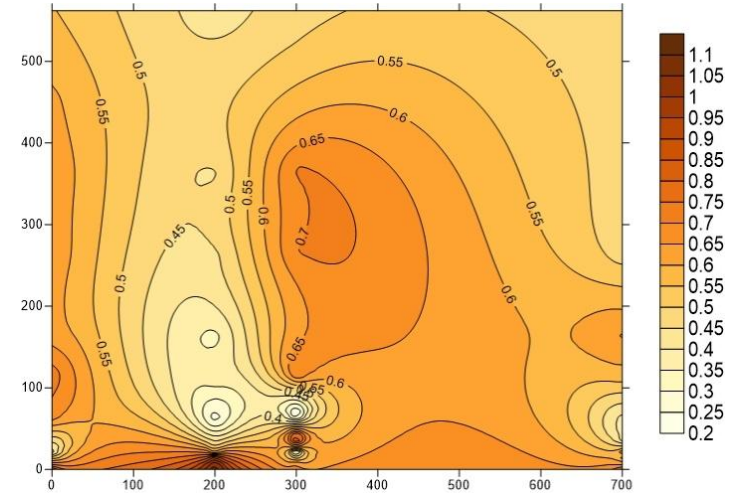
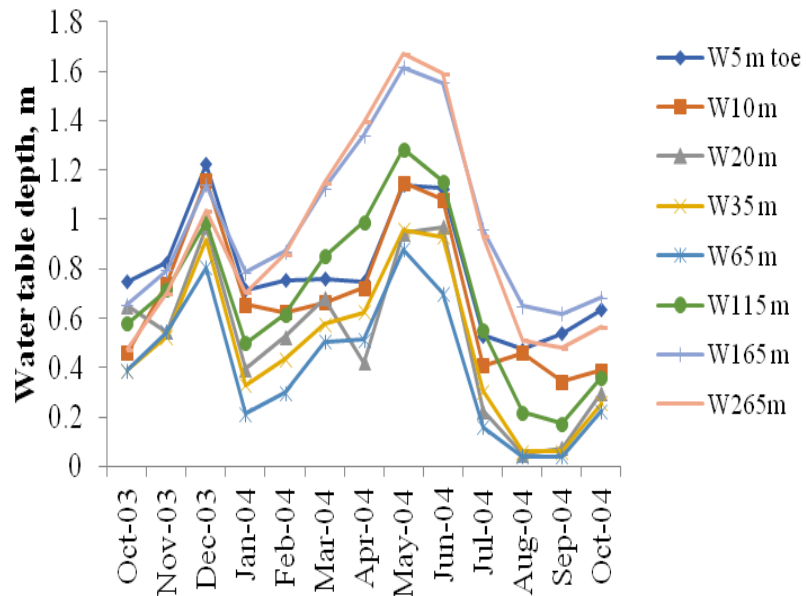
$$E_y = \frac{1}{\left(\frac{1}{E_p}\right) + \alpha y^\beta} \quad (2)$$



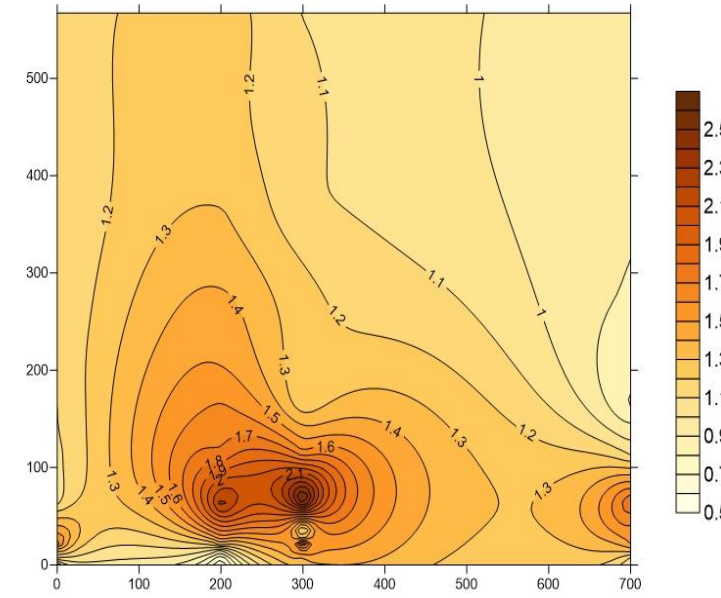
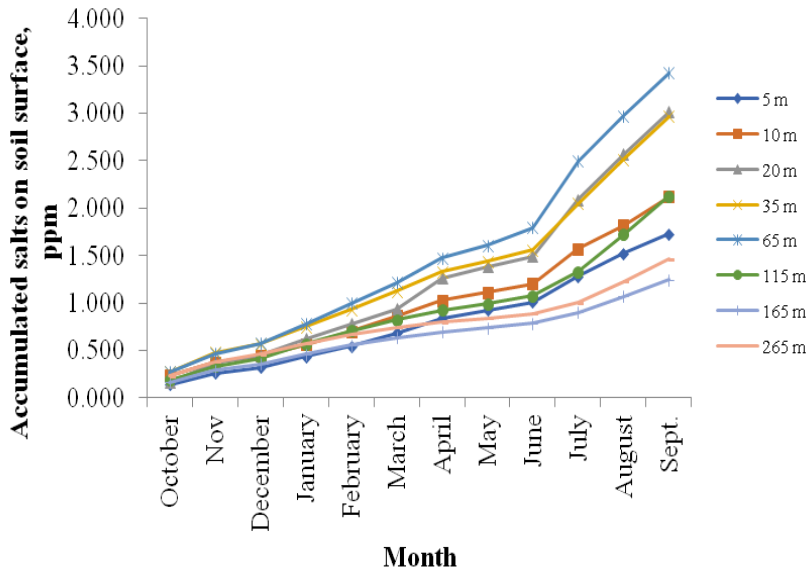
Variation of evaporation loss with water table depth



Water table measuring grid across Sharda Sahayak Canal



Water Table Contour for October

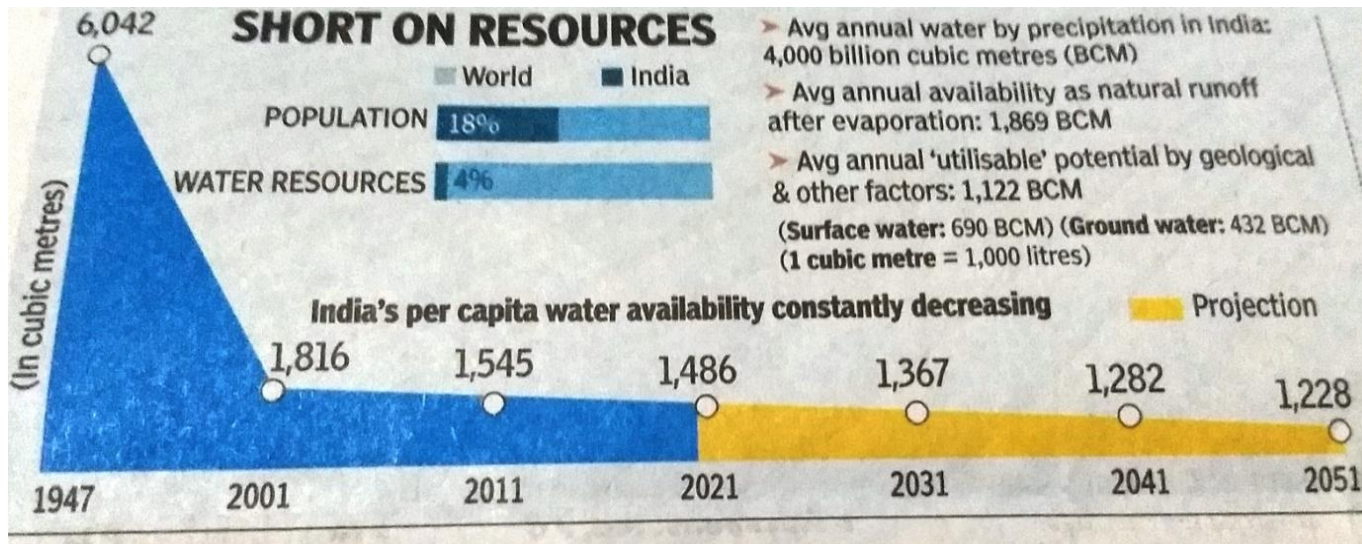


Salt Accumulation Contour for October

Water Table Fluctuations and Salt Accumulation

Growing Demand

Category	Year 2010			Year 2025			Year 2050		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Irrigation	489.0	536.0	556	619	688	734	830	1008	1191
Domestic	39.4	41.6	61	47	52	78	59	67	104
Industrial	37.0	37.0	37	61	67	79	69	81	116
Total	555.4	614.6	654	727	807	881	958	1156	1411

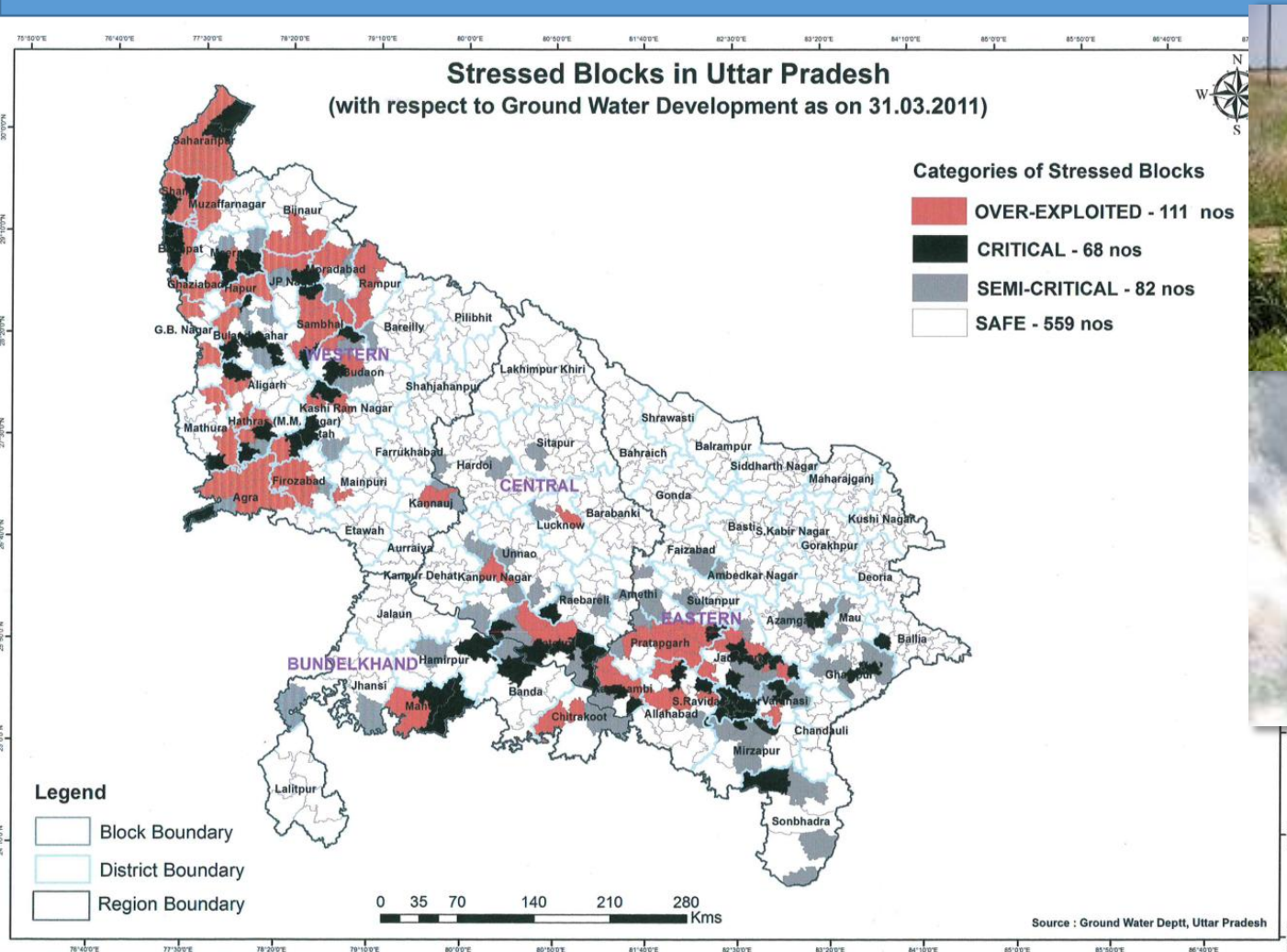


Percapita water availability.

Ground water utilization as a percent of ground water recharge in different states.

S.N	States	Ground water utilization, % of recharge	S.N.	States	Ground water utilization, % of recharge
1.	Andhra Pradesh	40-50	15.	Madhya Pradesh	40-50
2.	Arunachal	10-20	16.	Maharashtra	40-50
3.	Assam	20-30	17.	Manipur	10-20
4.	Bihar	30-40	18.	Meghalaya	10-20
5.	Chhattisgarh	10-20	19.	Mizoram	10-20
6.	Delhi	100	20.	Orissa	10-20
7.	Goa	50-60	21.	Punjab	100
8.	Gujarat	70-80	22.	Rajasthan	100
9.	Haryana	100	23.	Sikkim	10-20
10.	H. P.	20-30	24.	Tamil Nadu	70-80
11.	J. & K.	10-20	25.	Tripura	10-20
12.	Jharkhand	10-20	26.	Uttarakhand	60-70
13.	Karnataka	60-70	27.	Uttar Pradesh	60-70
14.	Kerala	40-50	28.	West Bengal	30-40

GROUNDWATER OVEREXPLOITATION



- 70% of agriculture depend on GW in UP
- GW levels falling in 630 of 820 blocks
- Number of overexploited blocks is increasing

SOLUTION OF WATER RELATED PROBLEMS

- Storage and Direct Use of Rainwater**
- Storage and Direct Use of Surface Runoff**
- Ground Water Recharge Using Rain and Runoff Water**
- Use of Poor Quality Water**
- Dilution of pollutants by Mixing Good Quality Water**

A. Ground Water Recharge Through Runoff Water

- * **Surface inundation due to rainfall at specific locations**
- * **Low lying fields**
- * **Non- functional surface drains**



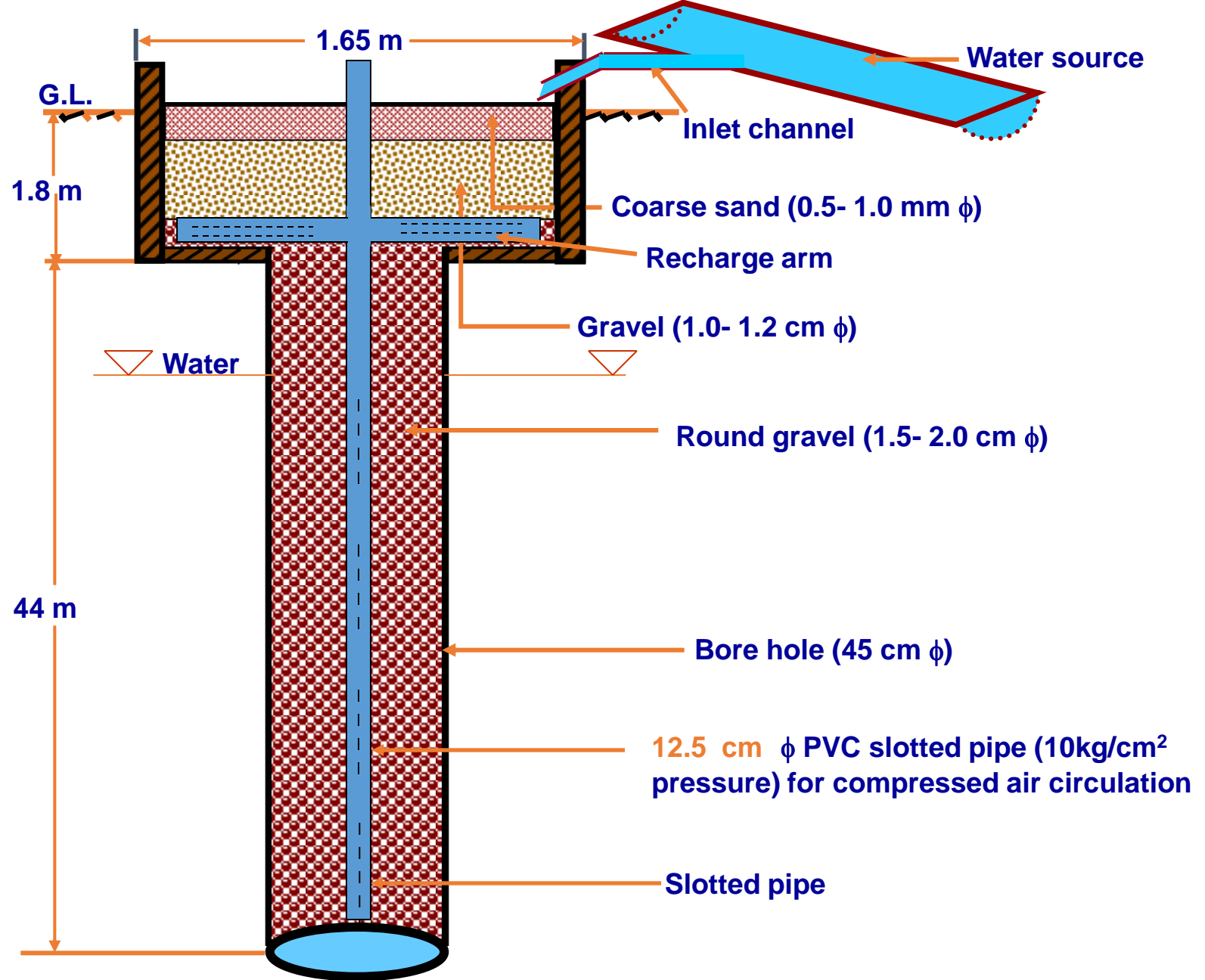
Small GR structures

- * **Acts as drainage outlet**
- **Save crops from water stagnation**
- **Raise water table**
- **Improve groundwater quality (EC, RSC, fluoride, nitrate, fluoride, arsenic)**

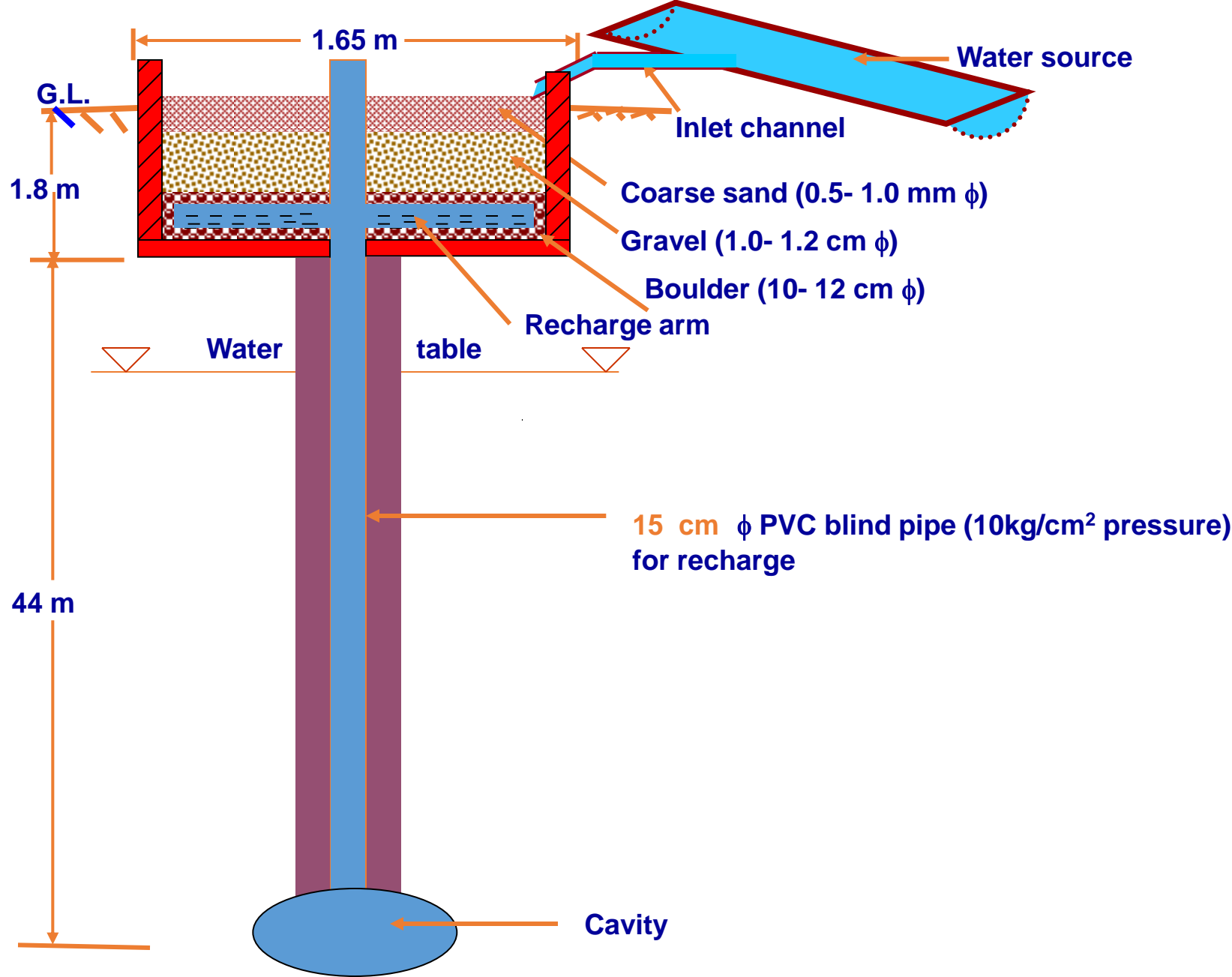


Technologies Demonstrated

State/ District	Technology/intervention	No. of sites
Haryana		29
Karnal, Kaithal, Jind, Kurukshetra, Yamunanagar, Sonipat	Recharge shaft	21
	Recharge cavity	08
Punjab		05
Patiala	Recharge shaft	05
Uttar Pradesh		03
Unnao	Recharge cavity	03
Gujarat		12
Bharuch	Recharge well	12
Total		39



Recharge Shaft for different selected sites of FPARP



Recharge cavity for different selected sites of FPARP

Installation of Recharge Wells



Construction of Recharge Filter

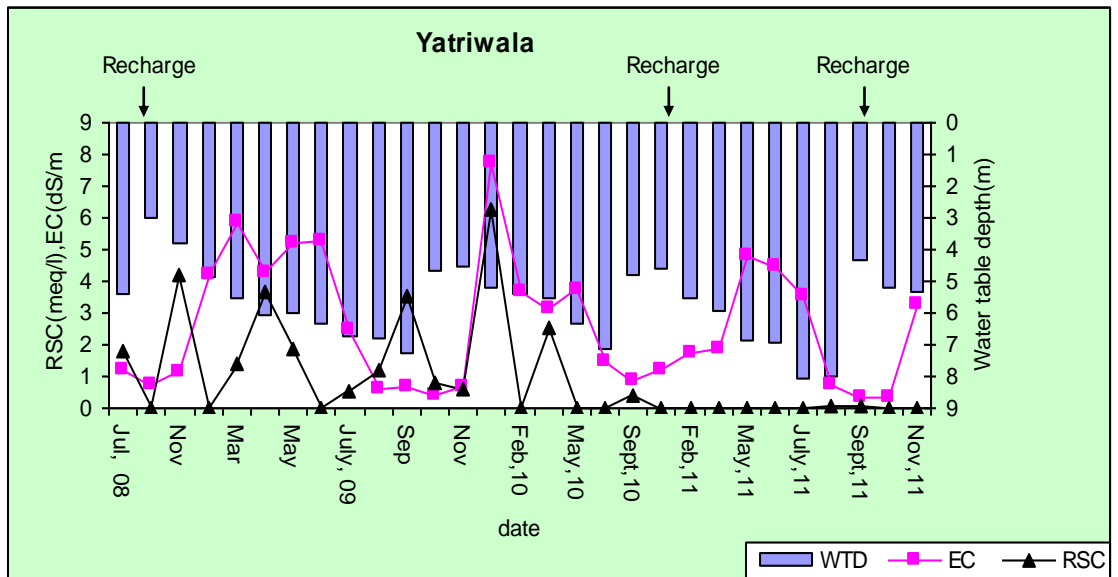
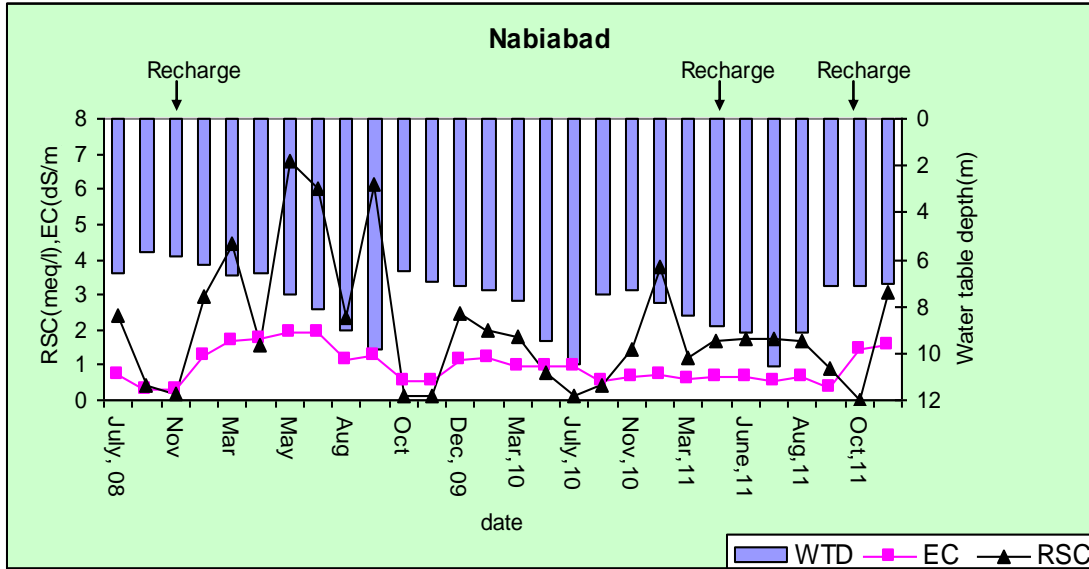


Clogging of filtering media



Monitoring of Groundwater





Hydraulic and Economic Impact of Groundwater Recharge Structure During 2009

Site	Runoff Area (ha)	Runoff Volume (m ³)	Investment Cost (Rs/m ³ recharge water)	Paddy saved	Net Saving (Rs.)
1	12	12480	3.5	25% in 1 ha area	24500
2	20	20800	2.1	30% in 2 ha area	58800

- Recharge Rate : 2500-3500 m³ / weak (4-6 l/s)
- Water table Rise : 0.6-3.3 m
- Reduction in ground water salinity : 0.2-2.4 dS/m

Improvement in GW Quality due to Recharge During 2009

S.N.	State/Village	EC (dS/m)			RSC		
		May/ June	Aug.	Oct.	May/ June	Aug.	Oct.
1	Haryana						
	a) Nabiabad (Karnal)						
	b) Paju Kalan (Jind)	1.9	1.1	0.5	6.0	2.4	0.2
	Dussain (Kaithal)	1.2	0.9	0.5	5.6	3.4	0.62
		1.4	1.1	0.5	6.7	3.9	2.1
2	Punjab Jodhpur (Patiala)	2.0	1.7	1.1	7.1	3.4	3.2
3	Gujarat Borebhete (Bharuch)	1.9	0.3	-	-	-	-

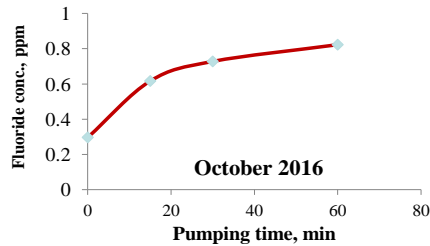
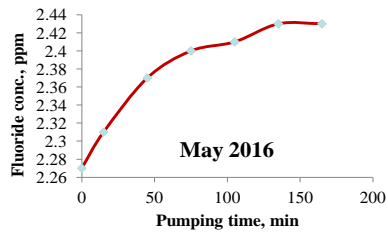
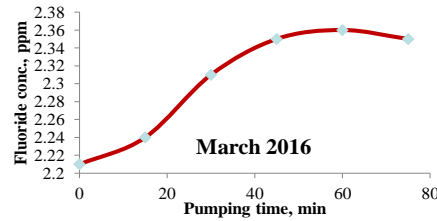
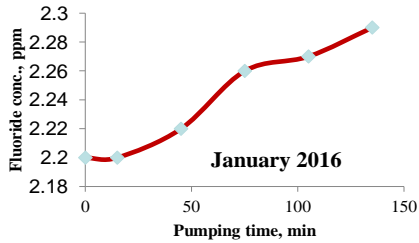
Fluoride levels in Hand Pumps and Open Wells (September 2020)

Name	F, mg/L	TDS, mg/L
Hand Pumps		
Ram Naresh	10.20	1637.0
Suresh	8.96	1439.0
Chandra Pal	0.67	483.0
Sajivan	7.86	2879.0
Shiv Ratan	2.32	356.9
Well-Road	5.94	1305.0
Ballu Yadav	2.98	787.8
Vasdev	0.68	385.4
Putti Gokul	8.95	2240.0
Prem Kumar	1.05	1920.0
Narendra Yadav	2.63	959.9
Putti Lal	0.83	460.8
Average	4.42	1237.8
Wells		
Arun Kumar- Well	9.96	313.9
Main Well	5.17	2142.0
Alok-Well	7.83	4054.0
Average	7.65	2169.97

B. Ground Water Recharge Through Rainwater Harvesting

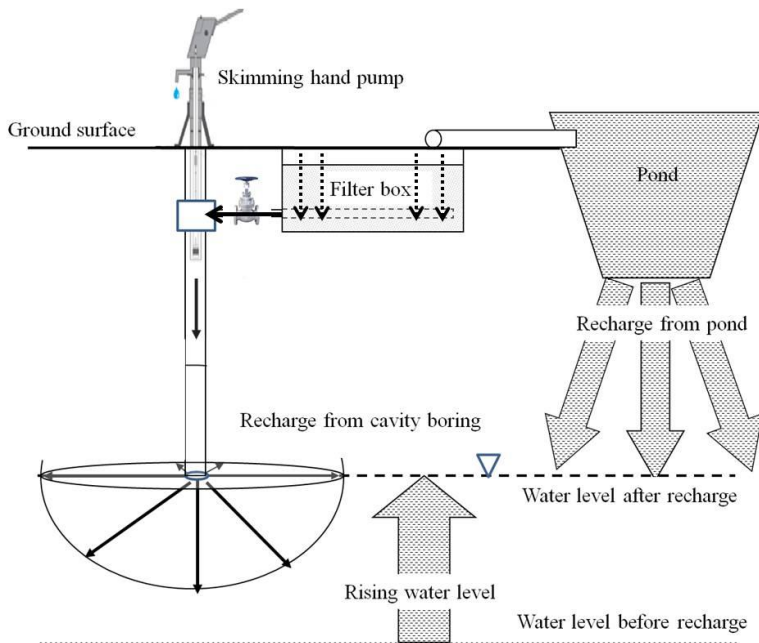


Sirsahakhera, Unnao



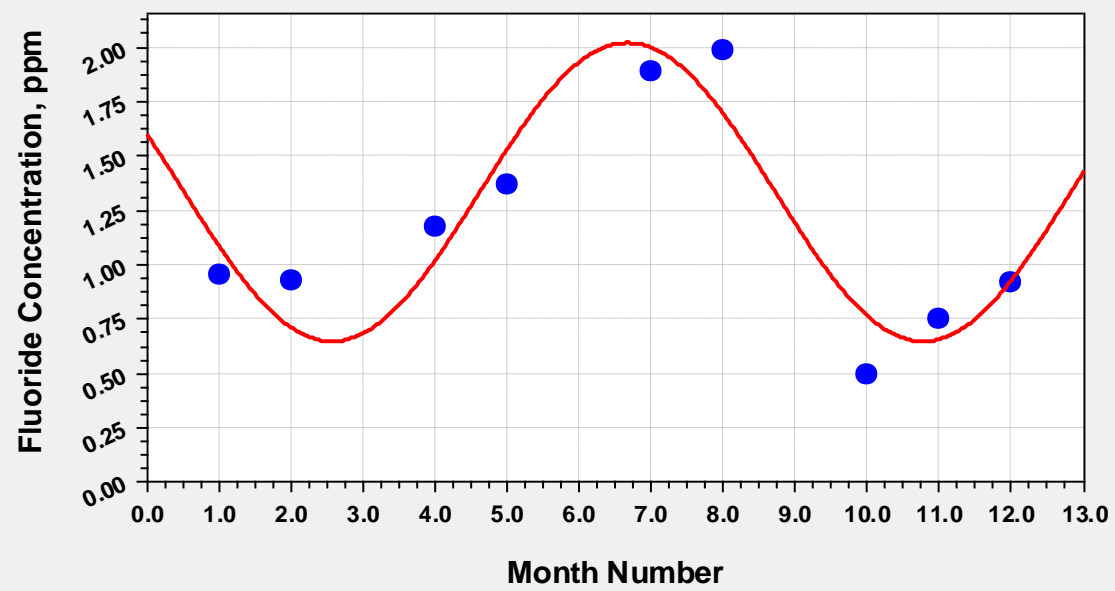
C. Ground Water Recharge Through Skimming Cavity Well



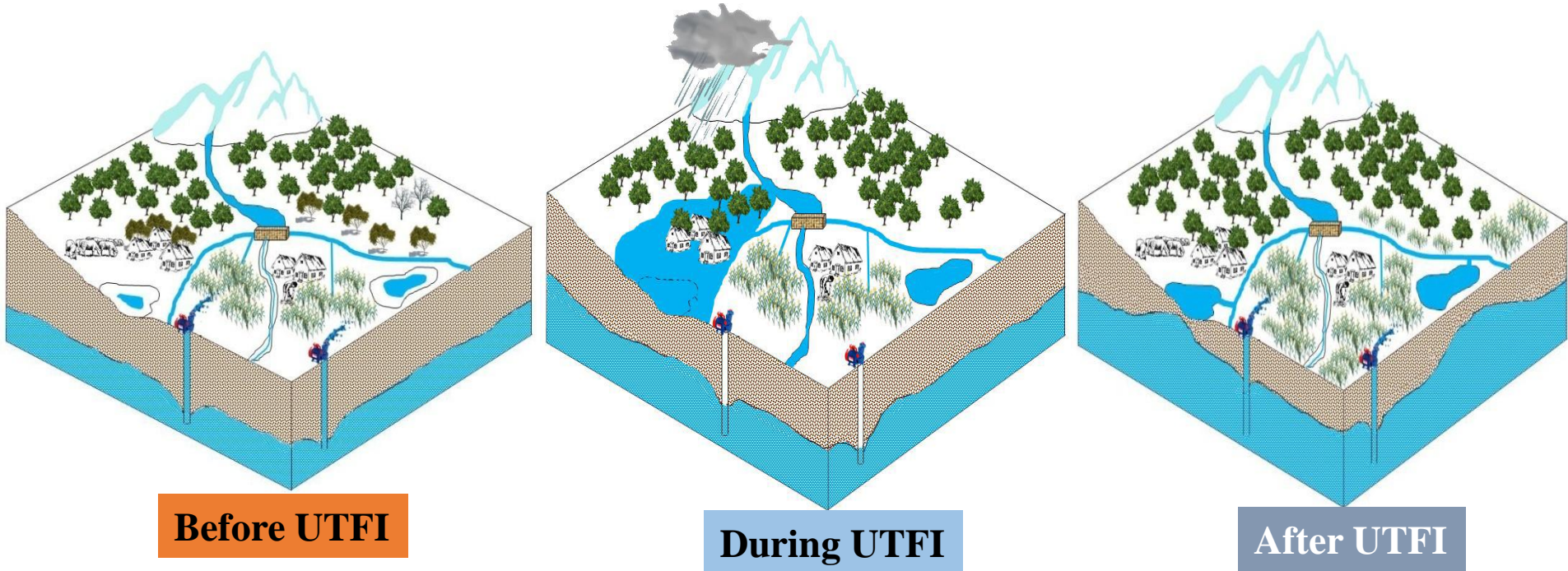


Month T	Rainfall (R_T) mm	Runoff converted to recharge (RCTR) m^3	Rainfall (R_T) mm	Runoff converted to recharge (RCTR) m^3
	2016		2017	
June	156.3	1293.200	48.3	369.357
July	243.7	1994.101	213.5	1735.768
August	180.2	1450.916	356.1	2955.582
September	81.2	606.981	60.6	430.766
October	11.1	51.144	0	0
Total	672.5	5396.342	678.5	5491.473

S = 0.26782631
r = 0.91347743



D. Underground Taming of Flood for Irrigation



UTFI – “Recharging aquifers that have latent or depleted groundwater storage capacity with wet-season high flows” (*Paul et al 2015*)

UTFI PILOTING ON THE UPPER GANGETIC PLAIN

- UTFI pilot demonstration trial established in western Uttar Pradesh in 2015
- Detailed testing, monitoring and evaluation was done till 2018

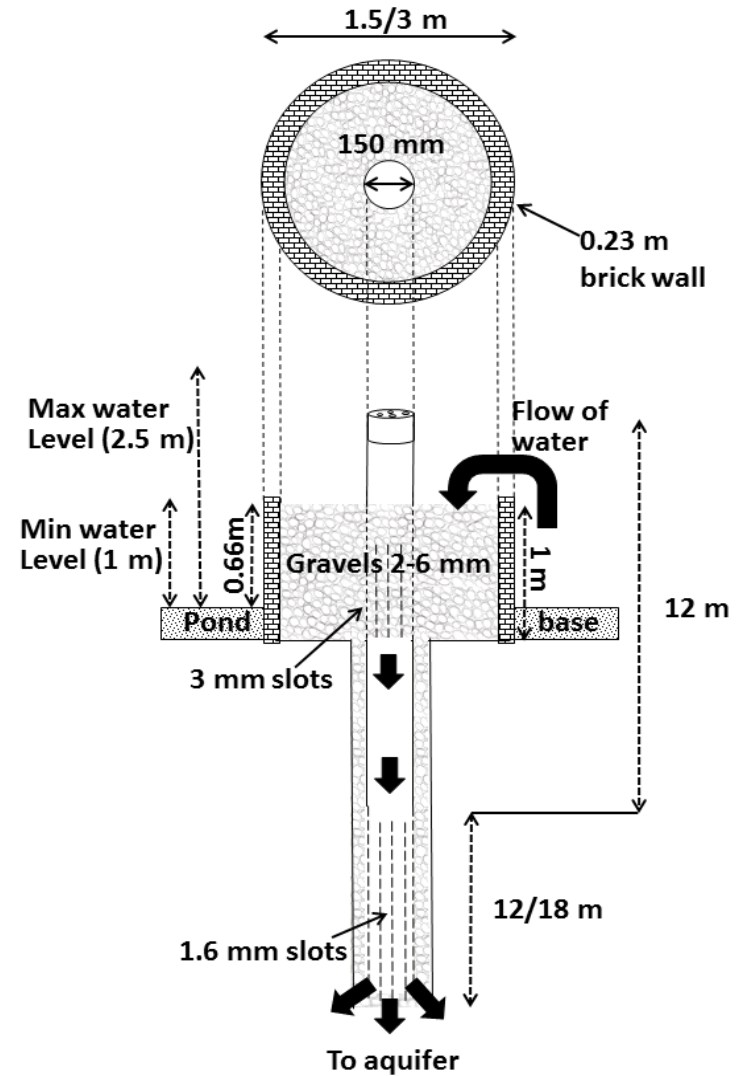


Community pond converted for UTFI in Jiwai Jadid village. The village is periodically flooded and groundwater levels have been falling, which impact on domestic water supplies and agricultural livelihoods.

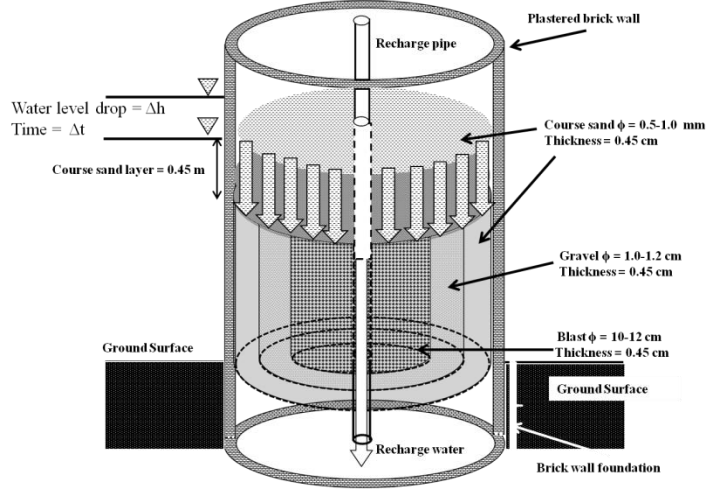
Details of Recharge Wells

Features of the recharge wells

Characteristic	Series-I	Series-II
Diameter	150 mm	150 mm
Depth	24 m	30 m
Perforated Section	18 m	18m
Gravel Pack Diameter	1.5 m	3.0 m
Gravel Pack Height	1.0 m	1.0 m
Filter Box Thickness	0.23 m	0.35 m



Not to scale, for representation purpose only.



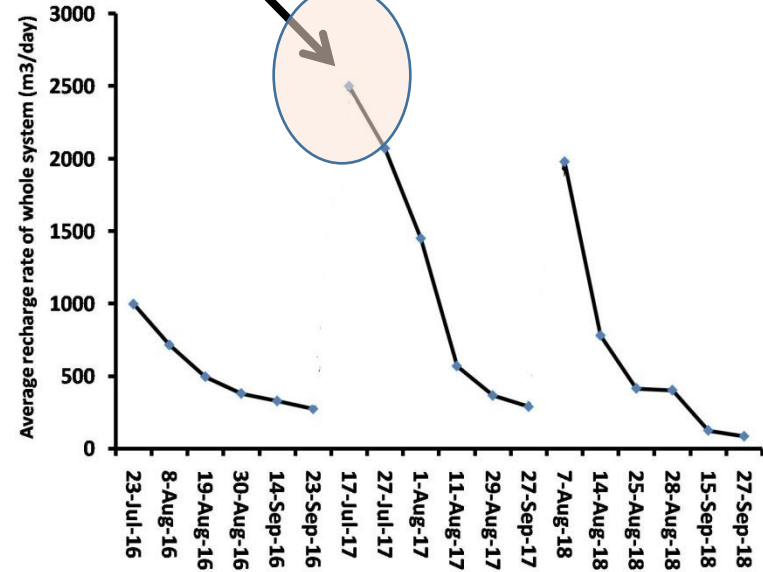
Highest Recharge Rate Observed in 3 Years

2499 m³/day
2.89 lps



Designed Recharge Rate = 5.00 lps
Measured Recharge Rate = 2.89 lps
Safe Enough

Further increase in recharge rate due to drop in water level could be well taken into account.



Implementation Schedule

February 2015



August 2015



September 2015



June 2016



May 2016



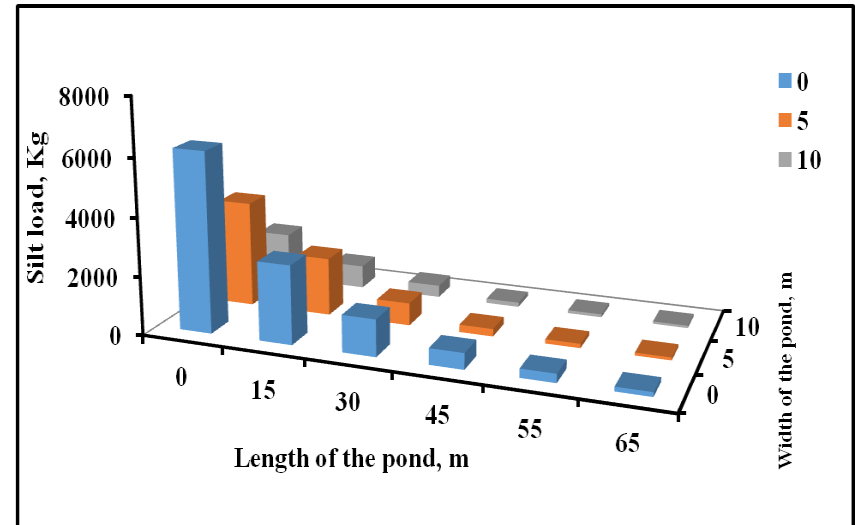
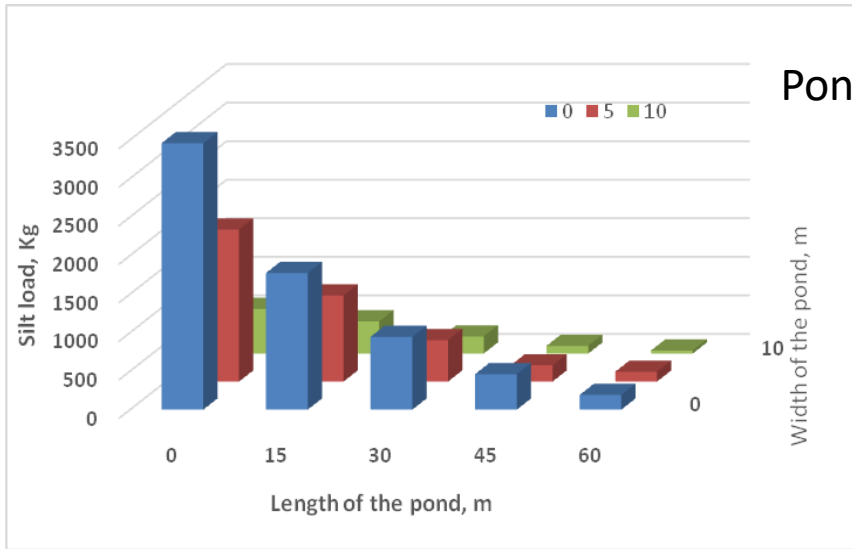
May 2016



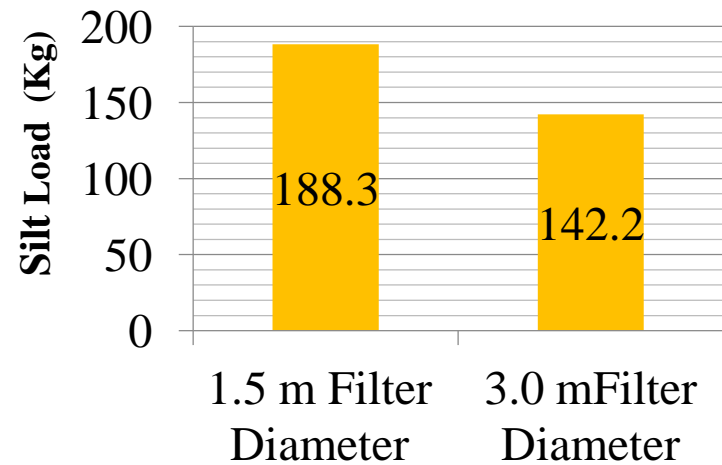
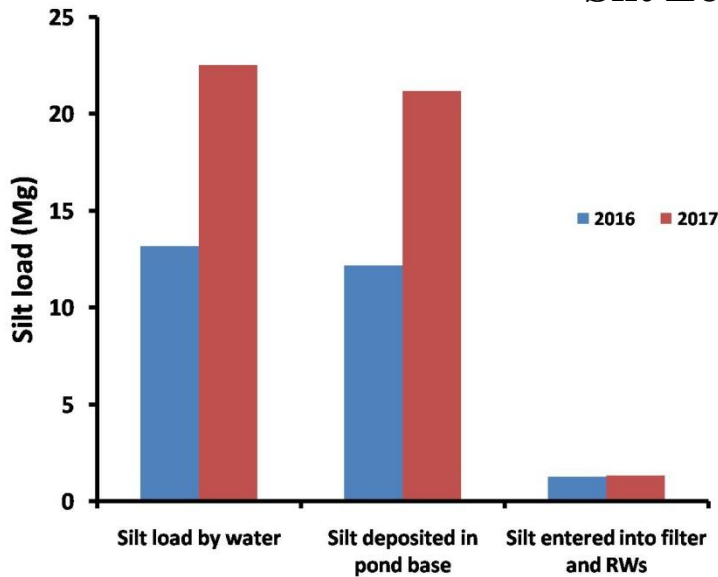
Recharge volume and Irrigation Potential Created

Year	Recharge days	Avg. Recharge rate, m ³ /day	Range of recharge rate m ³ /day	Recharge volume, m ³	Irrigation potential created ha
2016	85	492	220-997	40435	16.17
2017	78	1207	290-2499	72426	28.97
2018	62	631	85-1978	35253	14.10

Silt Load Distribution

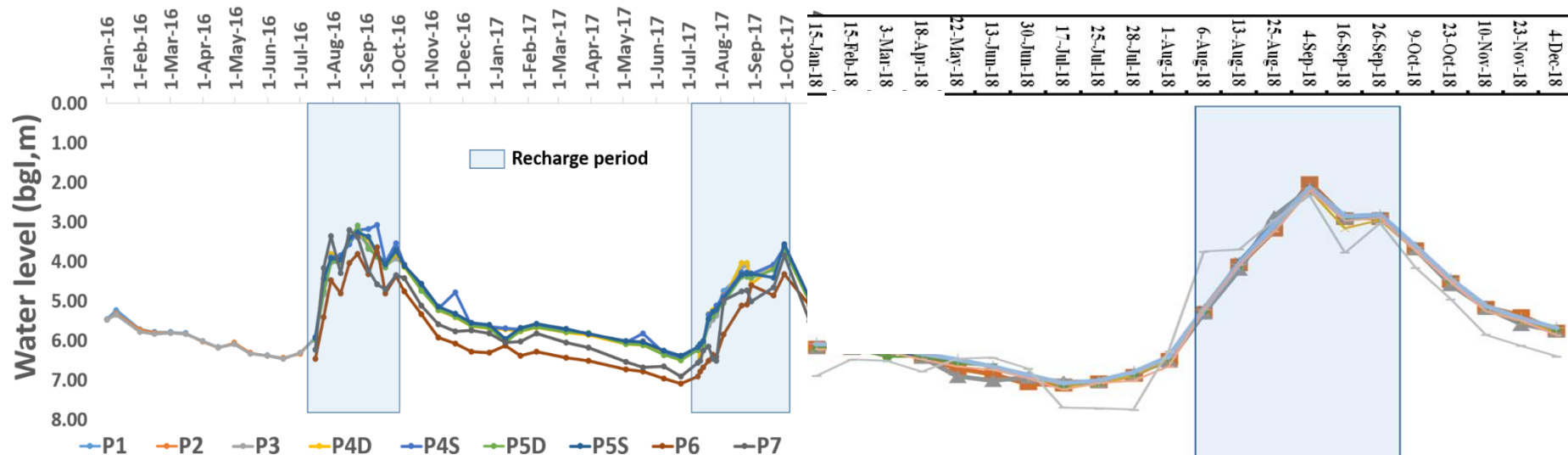


Silt Load Distribution at Pond Bottom



Silt Load Distribution in Systems

Pumped out Silt



Monitoring ground water levels

Heavy Metals Concentration in Ground Water

Element	Before Recharge Period (Mean and Standard deviation)	After Recharge Period (Mean and Standard deviation)	BIS acceptable limit (IS 10500 : 2012) (ppb)
Iron , ppb	228.04 ±5.64	229.10 ± 9.03	3000
Zinc , ppb	28.14 ±5.20	11.45 ± 4.30	5000
Manganese (Mn) , ppb	15.40 ±1.70	17.63 ± 6.37	100
Arsenic (As) , ppb	12.06 ±3.19	14.51 ± 1.95	10 -50
Lead (Pb) , ppb	2.80 ± 1.44	2.39 ± 0.73	10
Chromium (Cr) , ppb	11.22 ± 1.29	12.32 ± 4.31	50
Cobalt (Co) , ppb	0.23 ±0.17	0.88 ± 0.15	
Mercury (Hg) , ppb	1.88 ±0.53	1.12 ± 0.33	1
Nickel (Ni) , ppb	10.01 ±2.16	18.86 ± 4.22	200
Fluoride (F) , ppb	300 ± 100	270 ± 90	1000
Phosphate (ppm)	0.05 ± 0.05	0.05 ± 0.04	-
Nitrate (ppm)	8.15 ±3.69	9.11 ± 3.99	45
Ammoniacal Nitrogen (ppm)	0.43 ± 0.12	0.38±0.13	-

Heavy Metals and Fluoride Analysis

No contamination w.r.t. As, Cr, Pb, Ni, Cd, Fe, Mn, Cu, Zn was found.

Fluoride was also found within permissible limits of BIS and WHO.

Coliform Test: Negative

FURTHER INFORMATION



For more information:
Maha Nee Centre for Water
Tel: +91 522 222 2222

PRESS RELEASE

Ganga floodwaters to be stored underground
New project will reduce floods and boost irrigation

(20 Oct, 2015 – Uttar Pradesh, India) A new initiative launched today in Uttar Pradesh could revolutionize flood management while at the same time boost groundwater stocks for dry season irrigation. Located in the state capital, Lucknow, the project will be the first ever to adopt the new approach which is being developed by scientists at the International Water Management Institute (IWMI).

The initiative, called Underground Taming of Floods for Irrigation (UTFI), channels surplus surface water from flood prone rivers or their distributary canals during the wet season when there is a high flood risk to a modified underground brick structure in the ground where the water flows safely down below ground, where it infiltrates the local aquifer. This water can then be pumped back up again during the dry season to feed farmers on command or directly their crop production.

"This is an exciting concept which has never really been done before and whose benefits go directly to local and water communities," said Paul Fawcett, of the International Water Management Institute (IWMI), who leads the research. "Tapping this into practice will save on the large funds spent each year on relief and restoration efforts of flood victims and on subsidies for groundwater extraction during the non-rainy season. We hope our approach would tackle the root causes of the problem rather than the consequences."

The Ganga basin suffers from regular floods with the mighty Ganga and its tributaries like Ramganga, Gomti, Mandauli, Kosi all flooding annually. During the rainy season, large volumes of excess water run off the Himalayan range often causing great damage downstream. On the other hand, some of the same regions face a shortage of water aggravated by over-irrigation production which is largely dependent on groundwater pumping particularly in dry seasons when canal water is not available with this technology, IWMI's experts have devised a way to effectively capture excess water during monsoons and store this in aquifers underground.

The size of the land around the pilot that would receive direct benefits is currently under investigation. With floods being a common occurrence across the Ganga basin, researchers hope that the scaling up of this information would help in effectively protecting farms and assets downstream, boosting agricultural productivity and improving resilience to climate shocks at the river basin scale. This will be especially important to help communities deal with climate change which is likely to bring even more variability in water supply and rainfall.

Underground Taming of Floods for Irrigation (UTFI)

A Pioneering Pilot Project, India
State – Uttar Pradesh
District – Rampur
Village – Jwa Jwad

The current situation
Floods and droughts have been a common occurrence across India. During the rainy season, large volumes of excess water run off the Himalayan range often causing great damage downstream. Sometimes this is followed by great damage downstream. Sometimes this is followed by seasonal or prolonged drought.

In addition, year-round agriculture production is heavily dependent on groundwater water pumped can cause rural which causes groundwater which causes negative implications for water use for domestic water use for domestic.

Hence, it is becoming solutions to tackle droughts to protect livelihoods.

What are we trying
Underground Taming involves diverting times groundwater via modified for this downstream to reduce conditions in the

A simple solution to the old problem of floods

07/03/16
Lou Del Bello

नदियां नूतन युग फर्माई

धन्यवाद

Identifying priority watersheds to mitigate flood and drought impacts by novel conjunctive water use management

K. Bhandari – Paul Fawcett

1. Before UTFI (dry season) scenario shows how the villages in the plains are flooded due to excess runoff from upstream

2. Before UTFI (monsoon) scenario shows how the recharge structures would help to reduce flooding in the villages and raise groundwater levels

3. After UTFI

UTFI Concept as illustrated in the diagrams

1. Before UTFI (dry season) scenario in the dry season
2. Before UTFI (monsoon) shows how the villages in the plains are flooded due to excess runoff from upstream
3. After UTFI depicts how the recharge structures would help to reduce flooding in the villages and raise groundwater levels

New systems for water conservation and management

Abstract: New systems for water conservation and management are being developed and implemented in the Ganga basin. These systems are designed to reduce water loss and improve water use efficiency. The systems include: 1) Rainwater harvesting, 2) Groundwater recharge, 3) Water recycling, 4) Water conservation, 5) Water management.

Introduction

Climate variability has always been one of the most significant factors in the development of the Ganga basin. The basin is characterized by high variability in rainfall and temperature. This variability has led to the development of a wide range of water management systems. The UTFI system is a novel approach to water management that combines rainwater harvesting, groundwater recharge, and water recycling. This system is designed to reduce water loss and improve water use efficiency. The UTFI system is a novel approach to water management that combines rainwater harvesting, groundwater recharge, and water recycling. This system is designed to reduce water loss and improve water use efficiency.

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SPECIAL SESSION UNDERGROUND TAMPING OF FLOODS FOR IRRIGATION

2017 at 13:45 - 17:30 PM
Room, India Habitat
Delhi, India

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Turn over for more details

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