Delineation and Evaluation of Subsurface Water Storage to Cope up with the Climatic Variability and Change : Case Studies From Arid to Semi Arid Region Of Western India.

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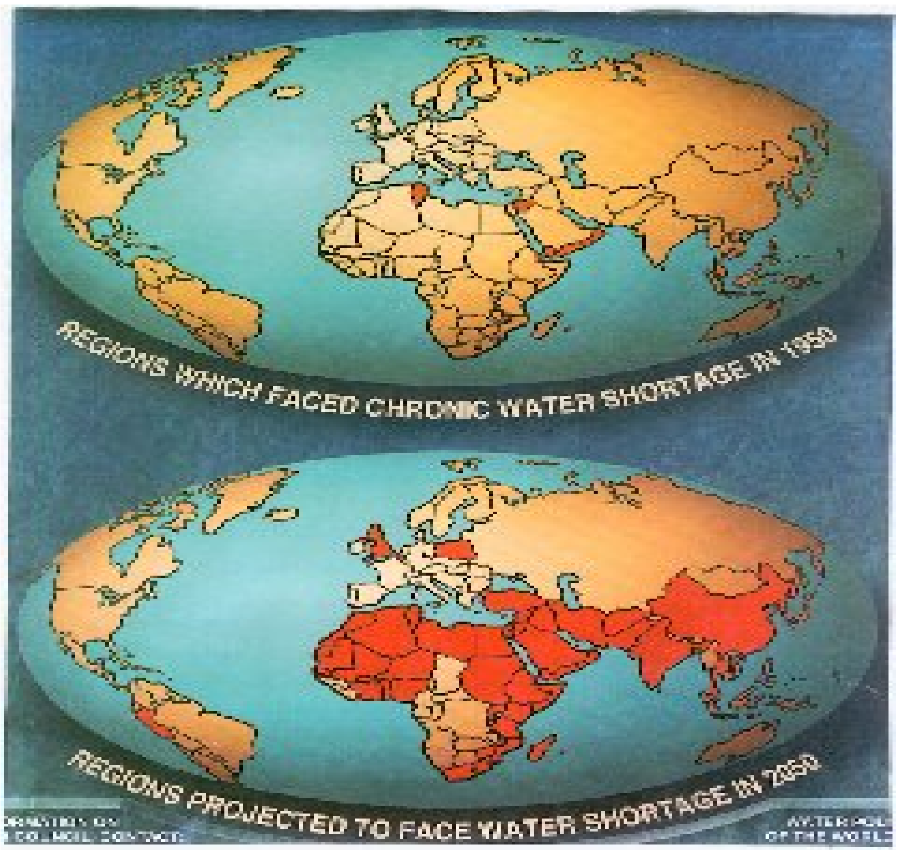
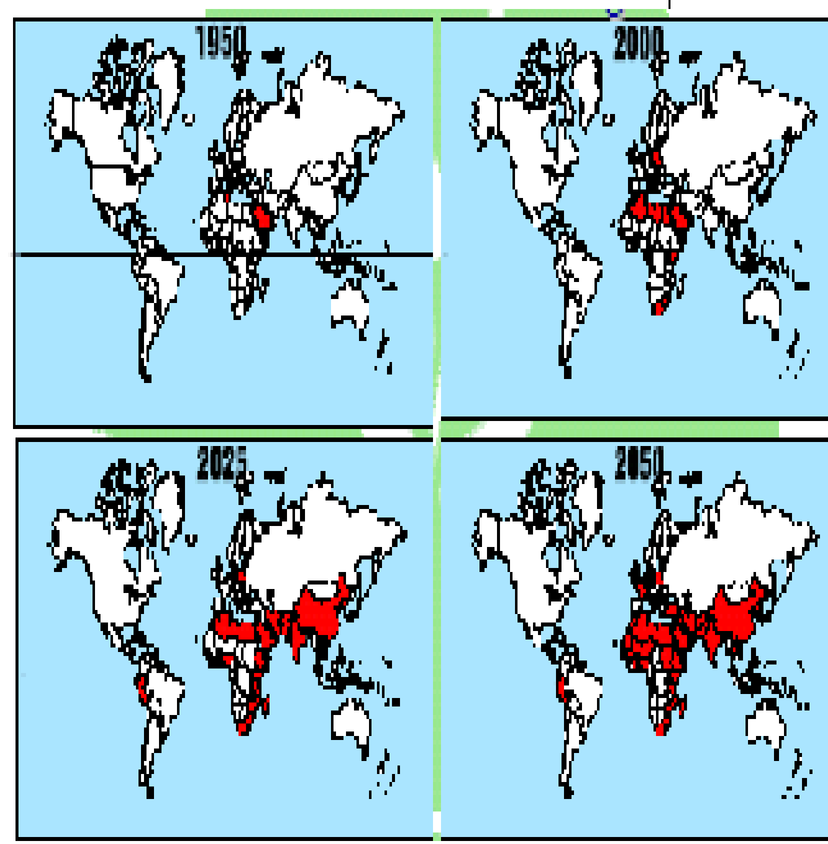
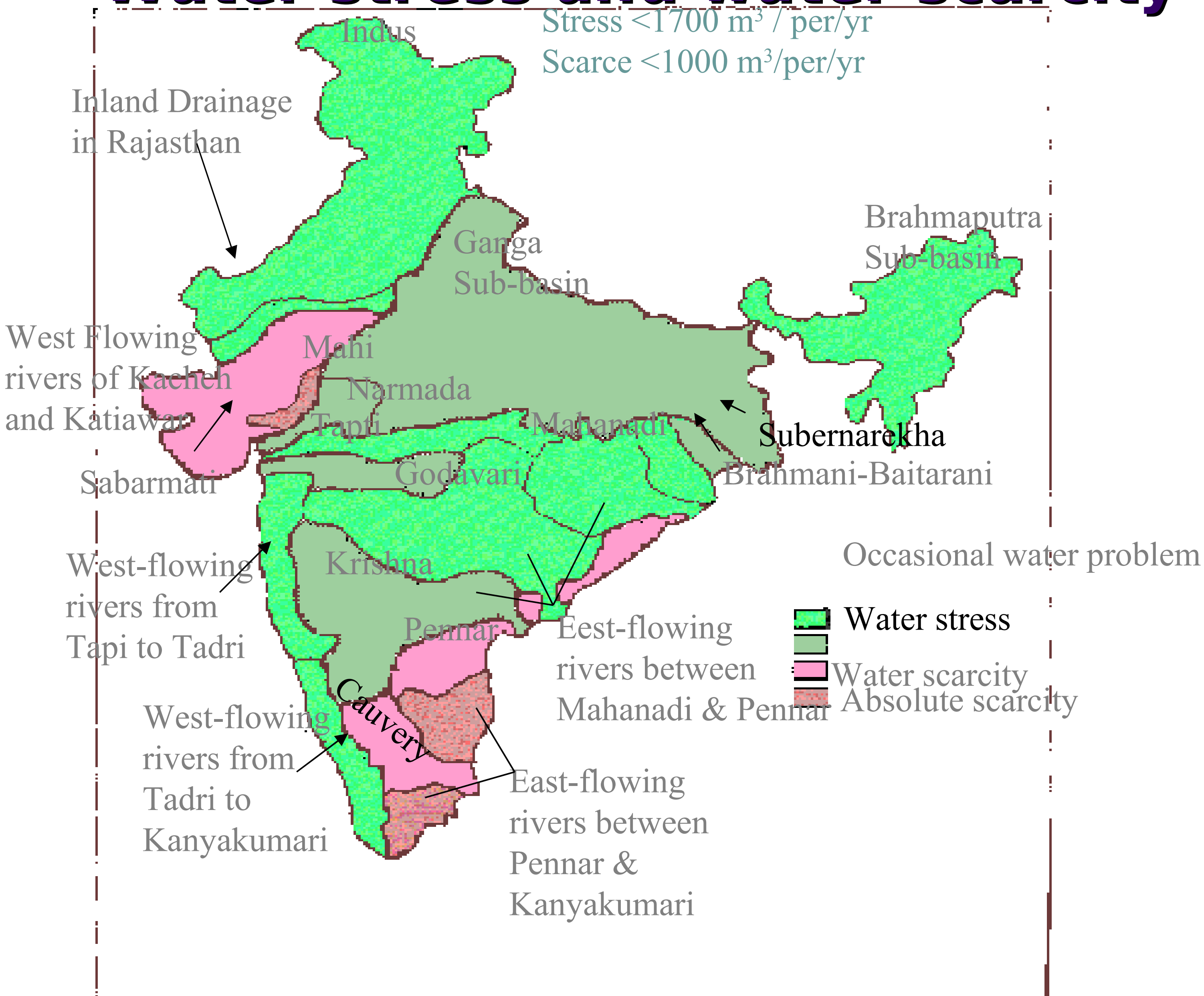
Evolution of World Water Shortage in 100 Years





River Basins- Water stress and water scarcity

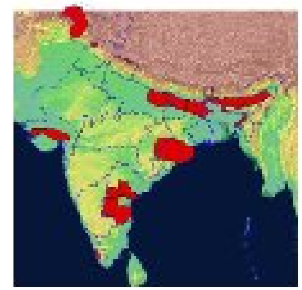


Floods in India and its impacts

1986

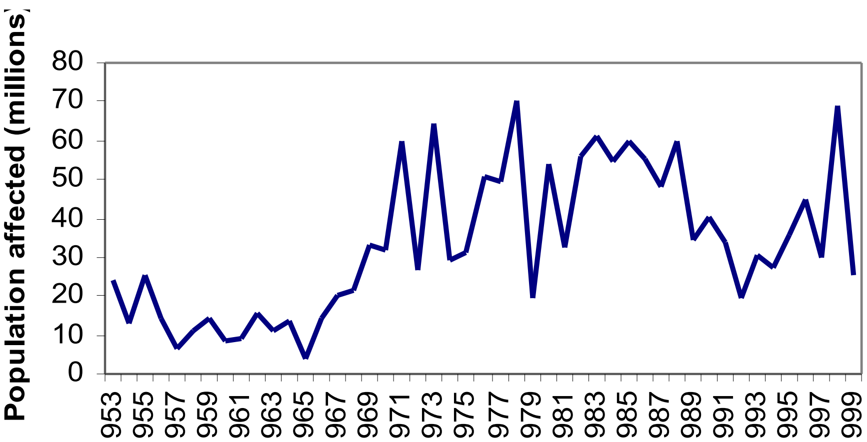
1988

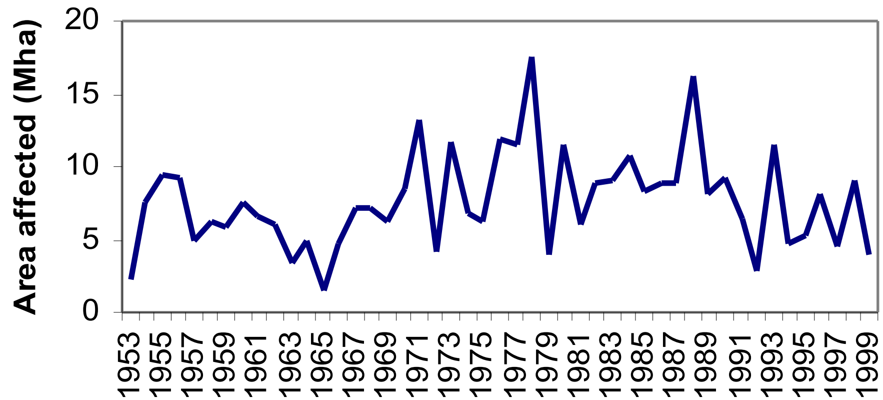
2000



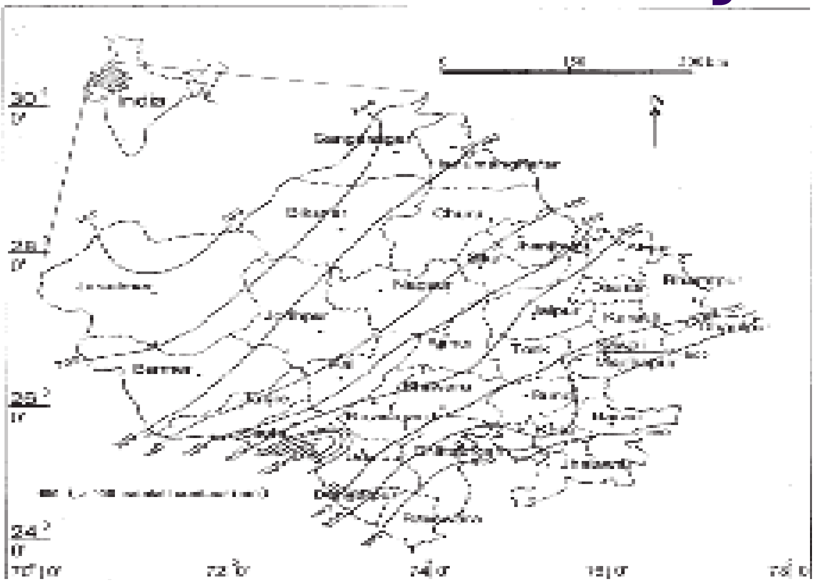
2001

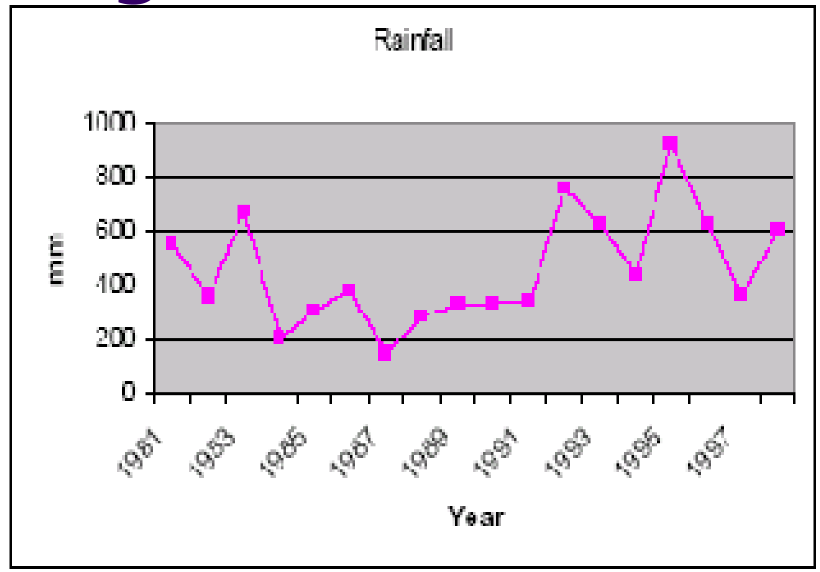
2003

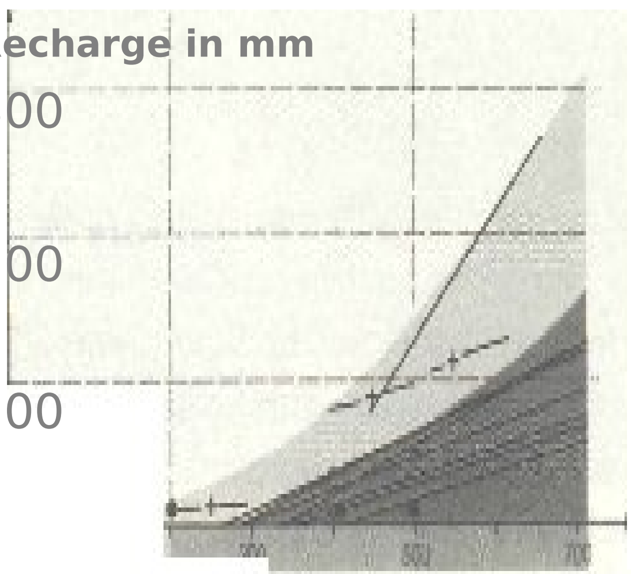




Western India- Hydrological extremes

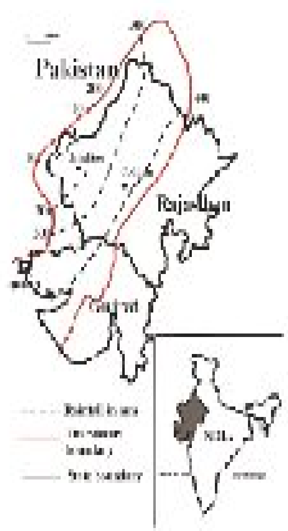


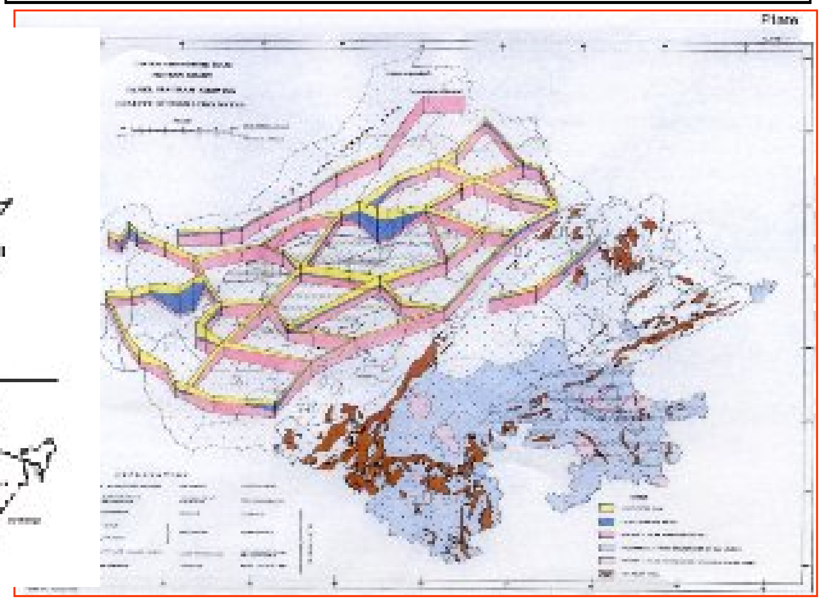




100 300 500 700

Precipitation in mm





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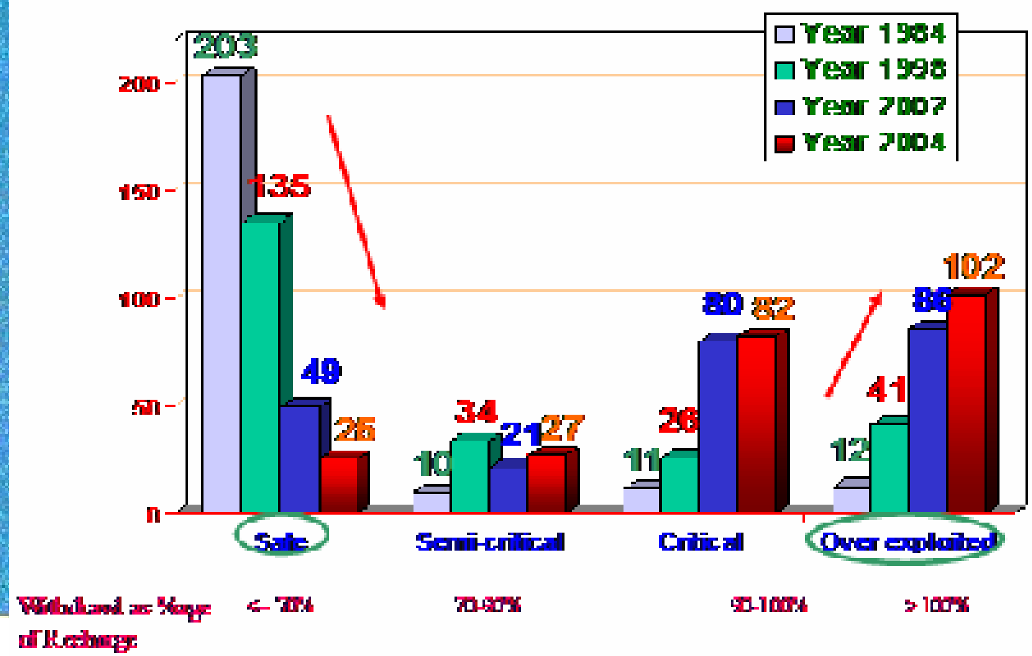
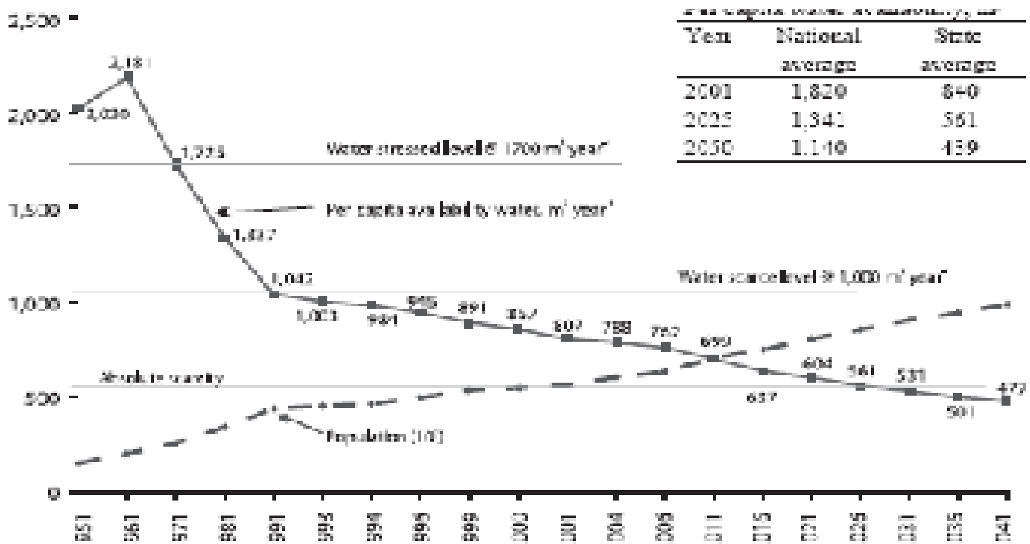
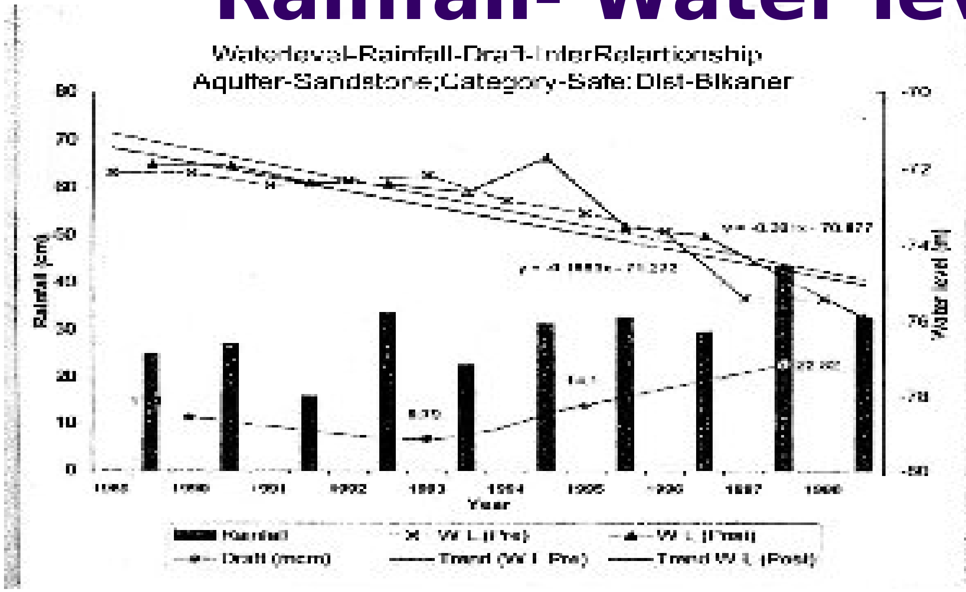
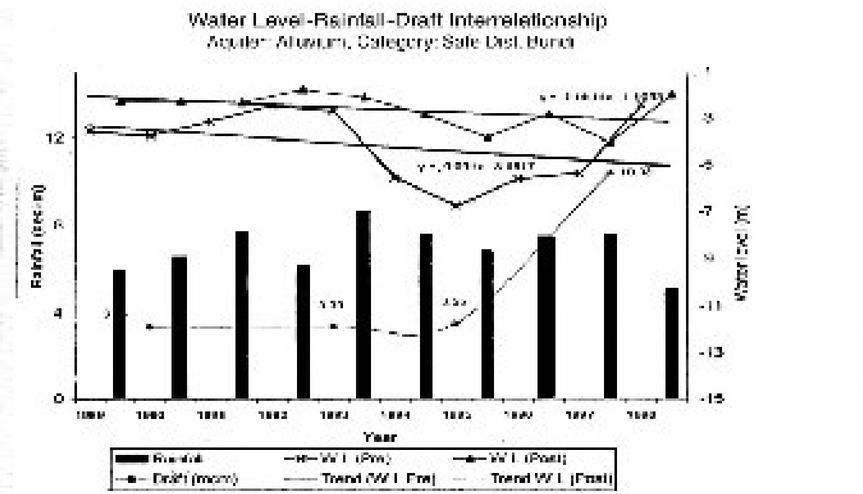


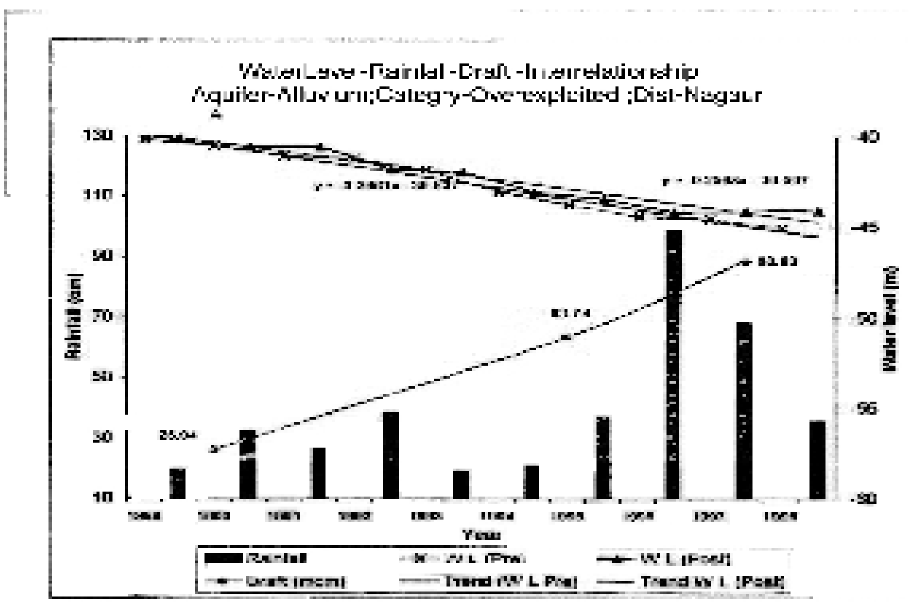


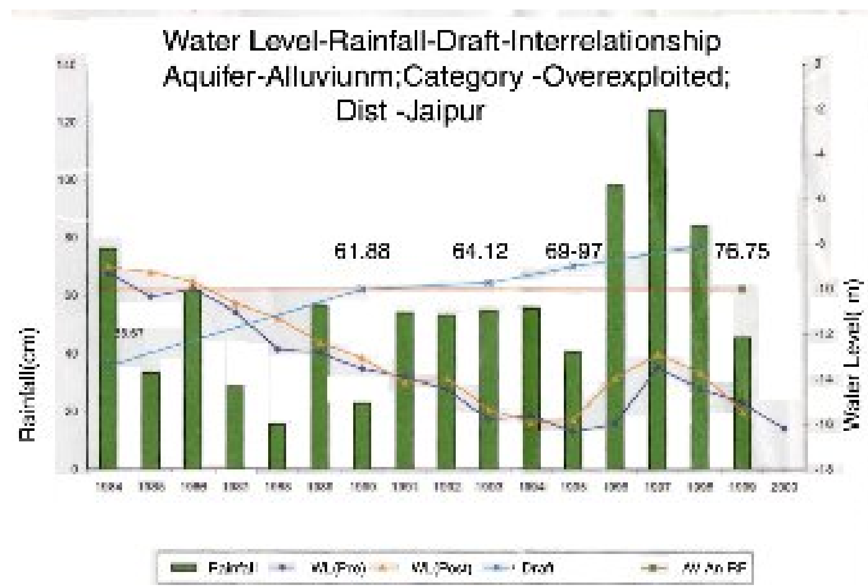
Year	National average	State average
2001	1,820	840
2025	1,341	561
2050	1,140	439

Rainfall- Water level-Draft trend







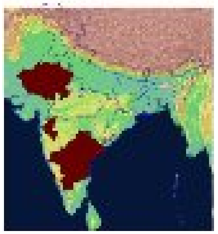


Climate Change- Challenges & Opportunities in Arid zone

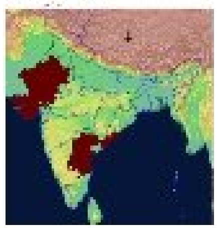
- **Climate change is now a reality .**
- **Arid zone must recognise and react to the reality**
- **Need to Adapt to the consequences of Climate Change or to Mitigate the causes of it**

Floods in Western India

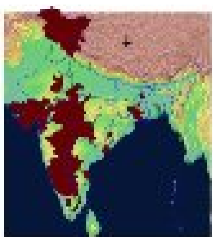
Temporal-spatial spread of drought & impacts



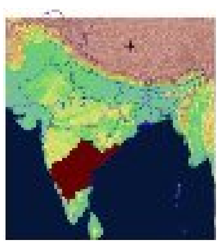
1984



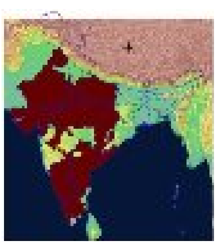
2000



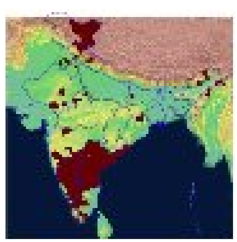
1986



2001



1997



2002

Drought is occurring in some or the other part of the country

Primary impacts: water availability, *a*griculture production, hydropower generation

Secondary Impact: Agricultural GDP dips, increase in commodity prices, livelihood of people dependent on rainfed farming (marginal farmers & farm laborers surviving) affected

Needs for Enhanced Storage

•Need of sufficient storage capacity under growing water demands and increasing climate variability …….

Tuinhof A, Olsthoorn T, Heederik JP, de Vries J . : 2005: Groundwater storage and water security: making better use of our largest reservoir , Water Sci Technol. 2005;51(5):141-8.

•***A key feature of some aquifers and ground-water systems is the large volume of ground water in storage, which allows the possibility of using aquifers for temporary storage, that is, managing inflow and outflow of ground water in storage in a manner similar to surface-water reservoirs*** **.Even if 8 percent of the 33,000 km3 (Postel 1999) floodwater that runs off to the oceans annually recharge the groundwater, we have a renewable supply of over 2,500 km3 of groundwater annually—which seems several times more than the world uses today**.

*Postel, Sandra. 1999. The pillars of sand: Can the irrigation miracle last? Washington: The Worldwatch Institute 1999)http://www.isnar.org/iwmi/pubs/WWVisn/GrWater.htm - _ftn3_*

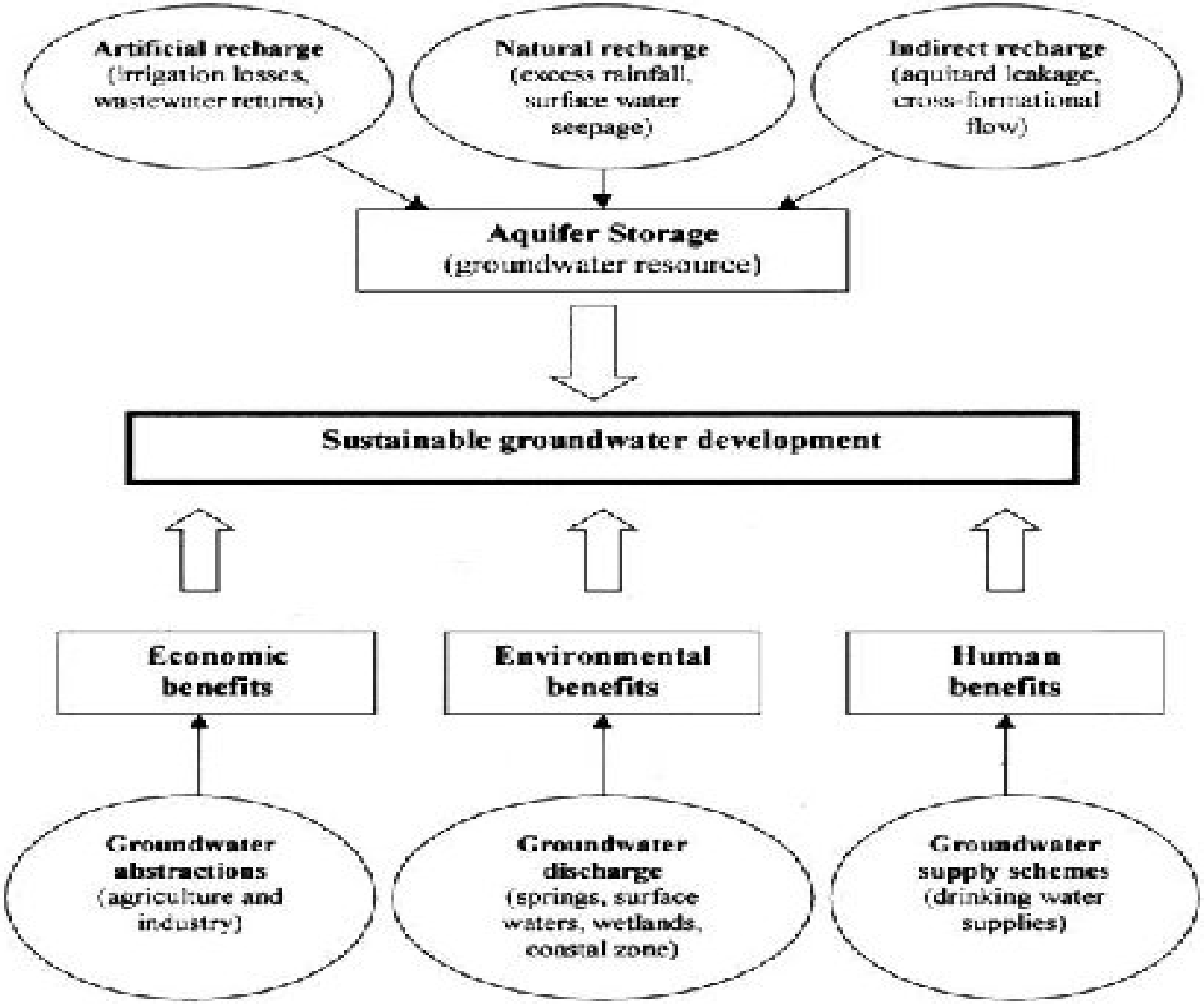
•**The standard reasoning is that even after 800,000 big and small dams around the world, the reservoirs can capture and store no more than a fifth of the rainwater, the bulk of the remainder still running off to the seas. India has built more than its share of the world's dams but 1,150 km3 of its rainwater precipitation still run off to the seas annually in the form of**

CASE STUDIES-I

Major Objective

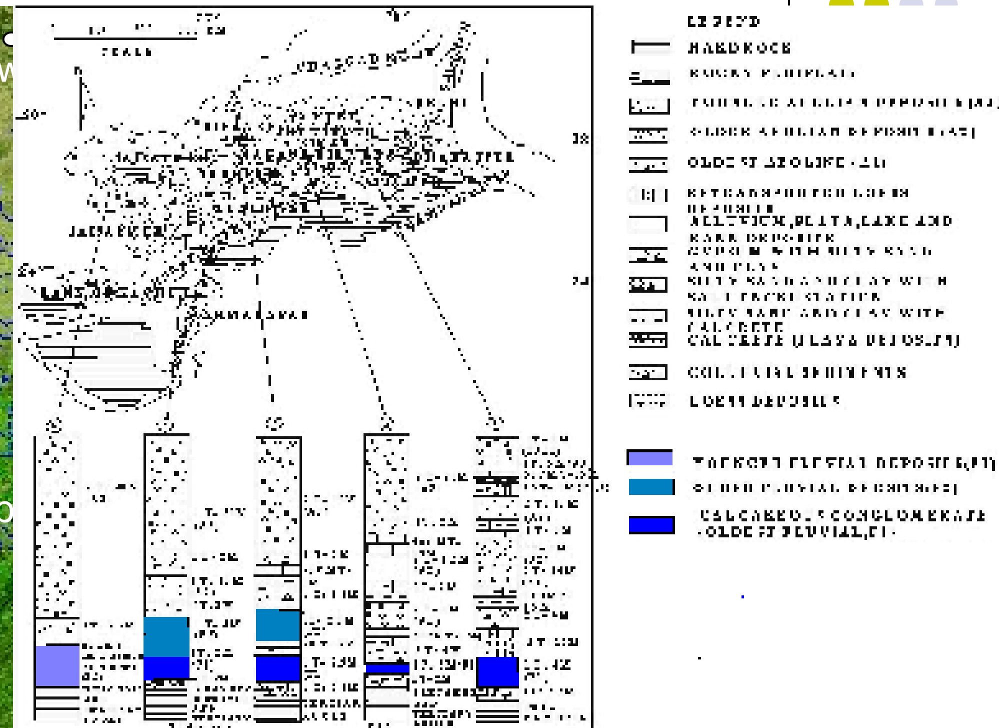
Understanding Subsurface Storage Potentialities in Palaeochannel and Ephemeral River basin –Semiarid to Arid region of Western India

Sustainable management of groundwater resources



Palaeodrainage in Indian Desert Region- IRS P3 WiFS Image

Source:RRSC,Jodhpur



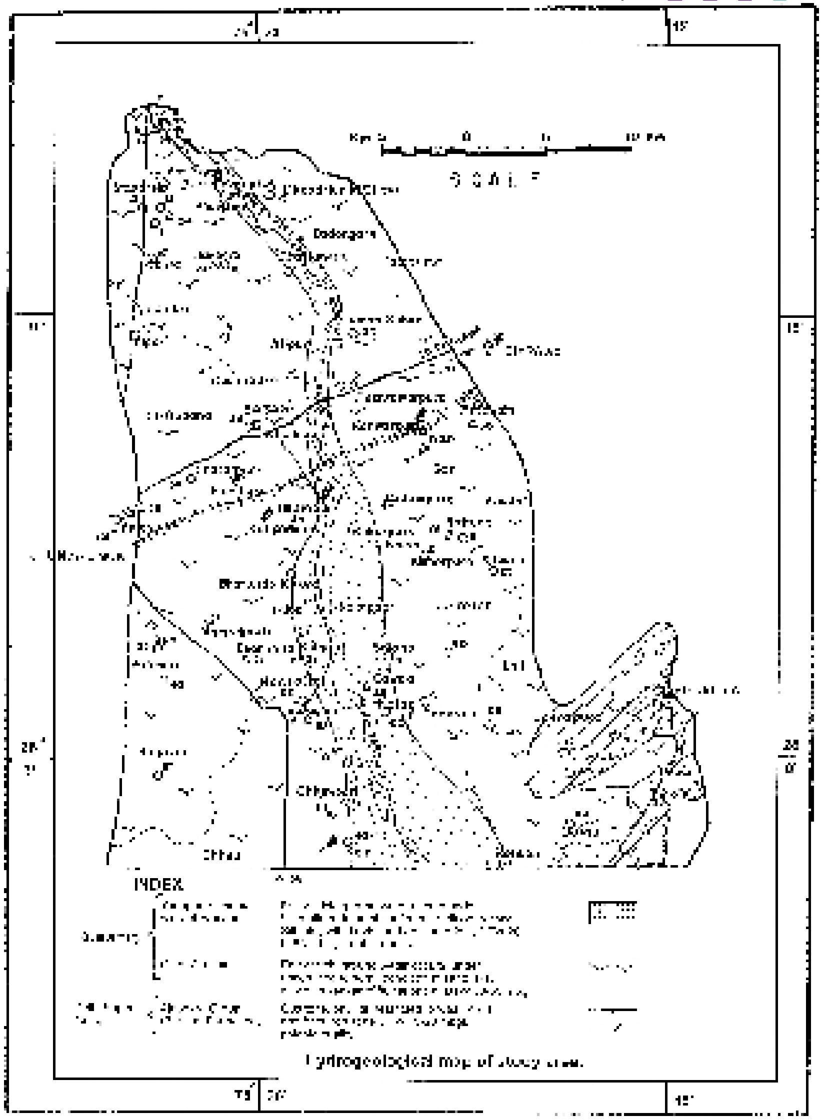
(Sinha & Raghav 2003)

Palaeodrainage –Excellent Storage for Groundwater

HYDROGEOLOGY

Aquifer	Area (sq. km)	Percentage of total area
Younger alluvium	121.18	11.10
Older alluvium	877.92	80.38
Quartzite	89.97	8.24

Depth to water level 13.55 – 61.10 m



Hydrogeological map of study area.

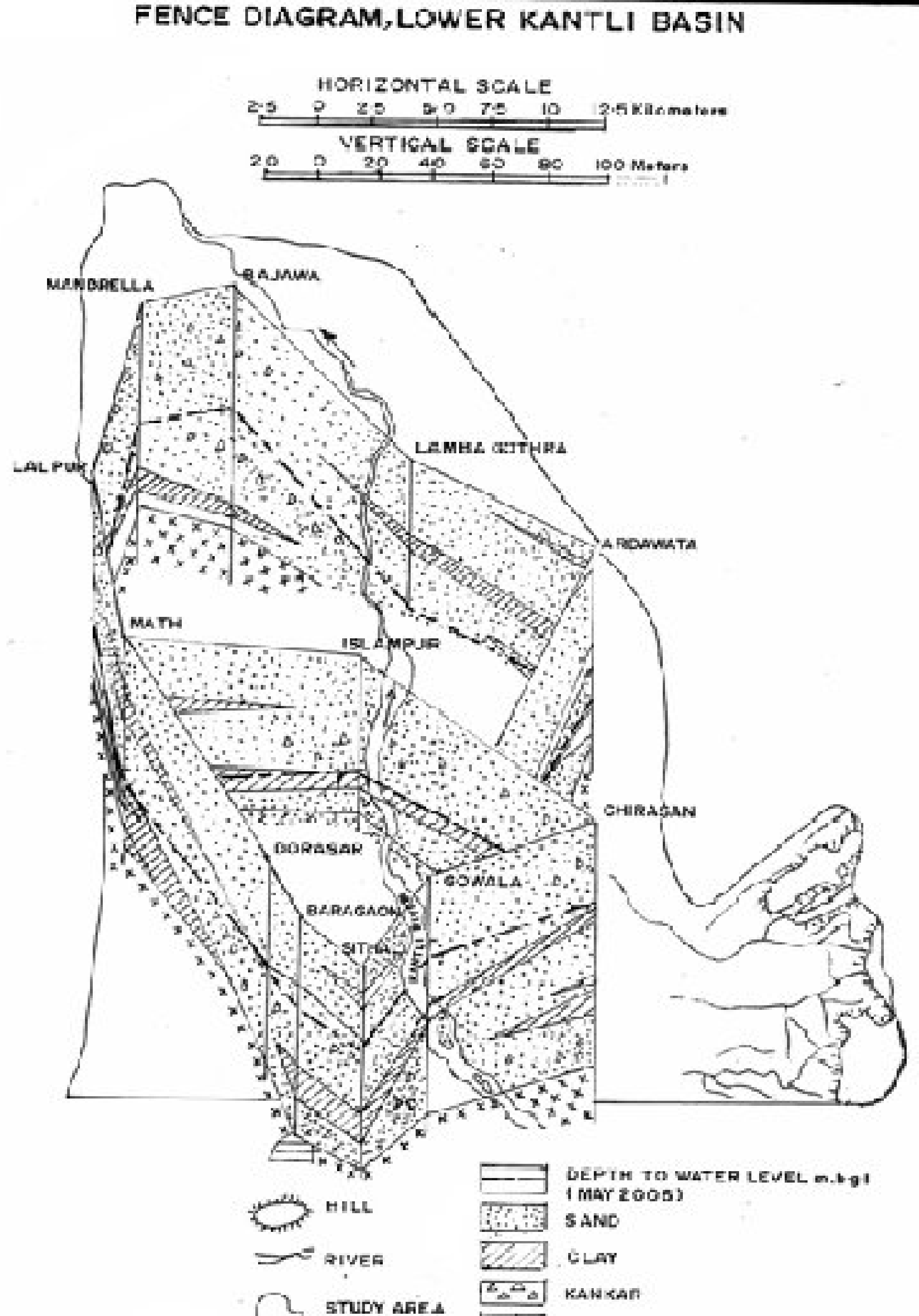
Number of boreholes :
12

Depth of drilling :
60 – 125 m.

Thickness of alluvium :
78 – 102 m.

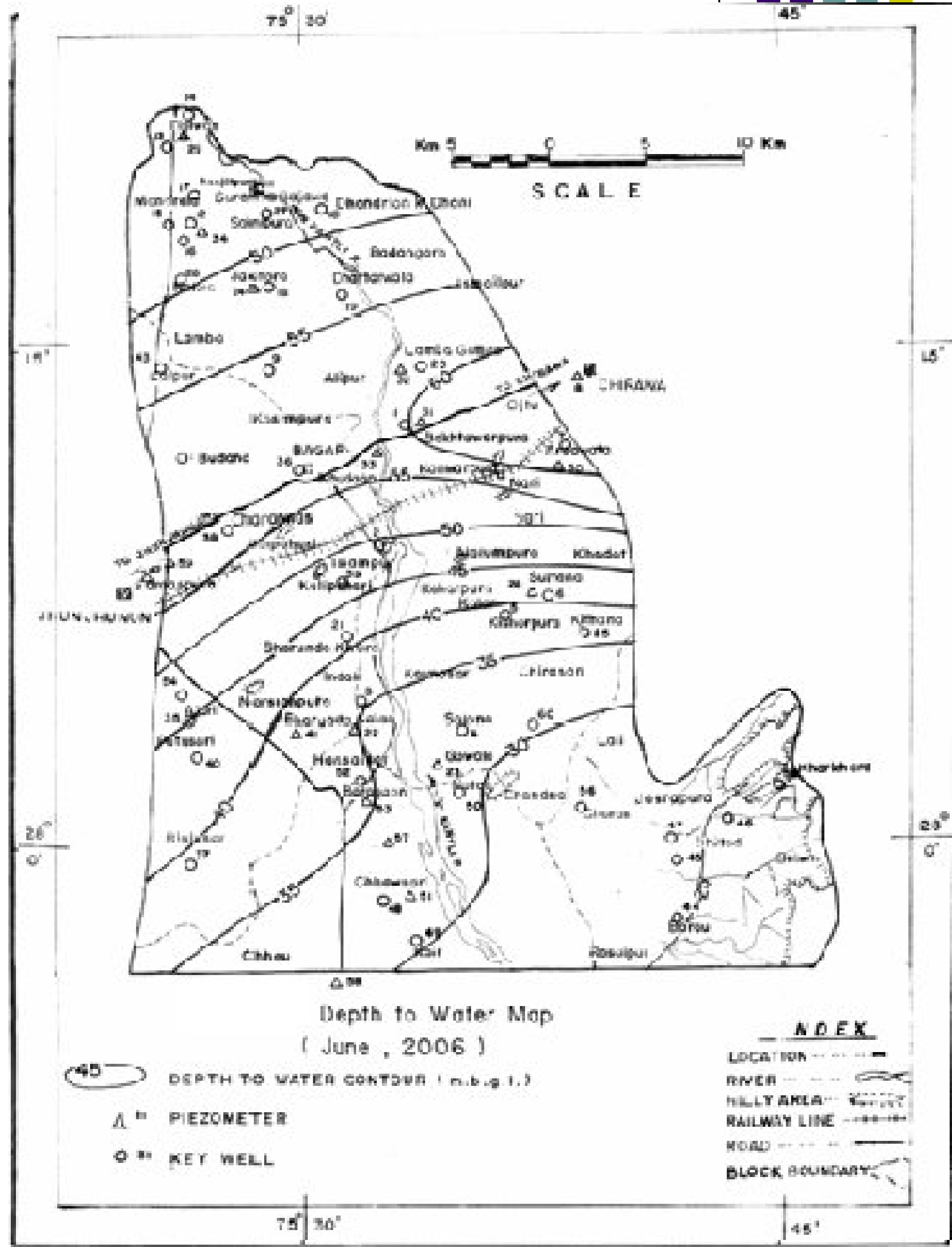
Basament
Malani granite

Depth to water level
35 – 55 m.

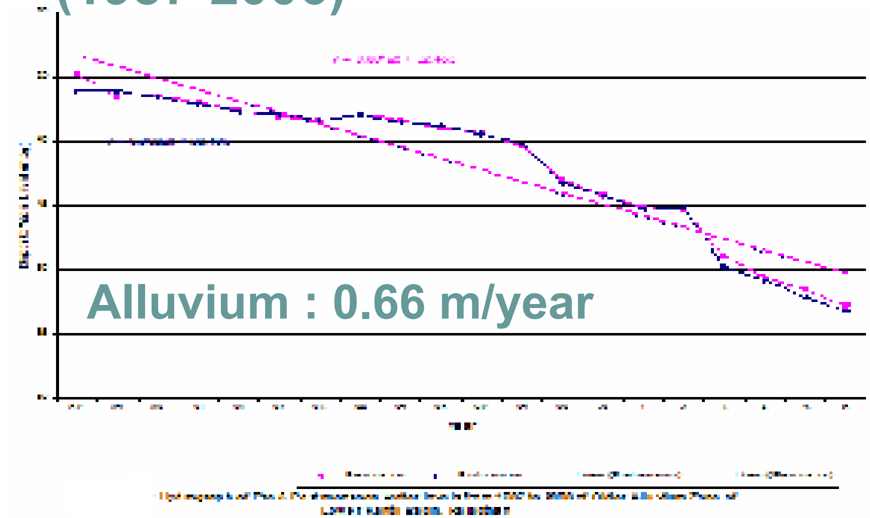


GROUND WATER LEVEL BEHAVIOUR

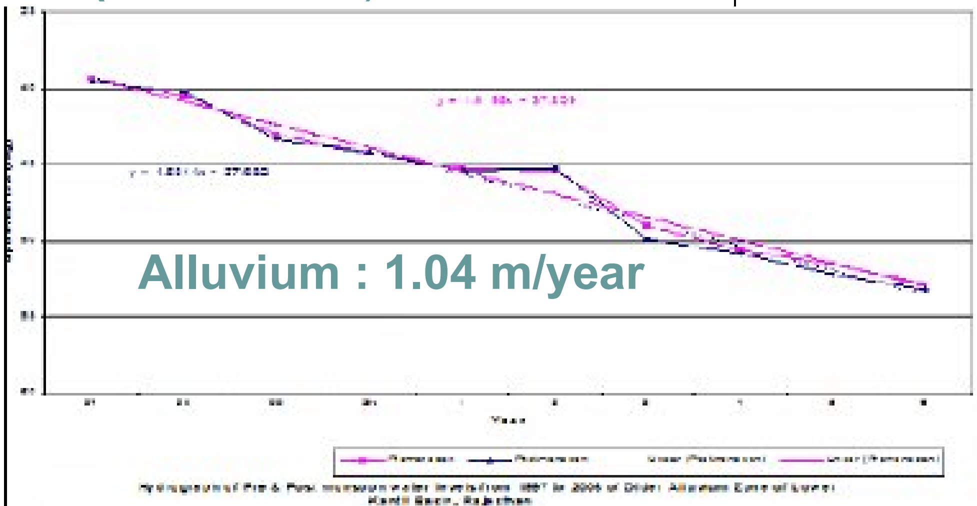
- Depth to water level :
  13.55 – 61.10 m.
- In major part
  between 30 and 50 m
- Southern and southeastern part
  shallow i.e. < 35 m
- Central part
  deeper i.e. 35 – 60 m
- Northern part
  45 – 55 m

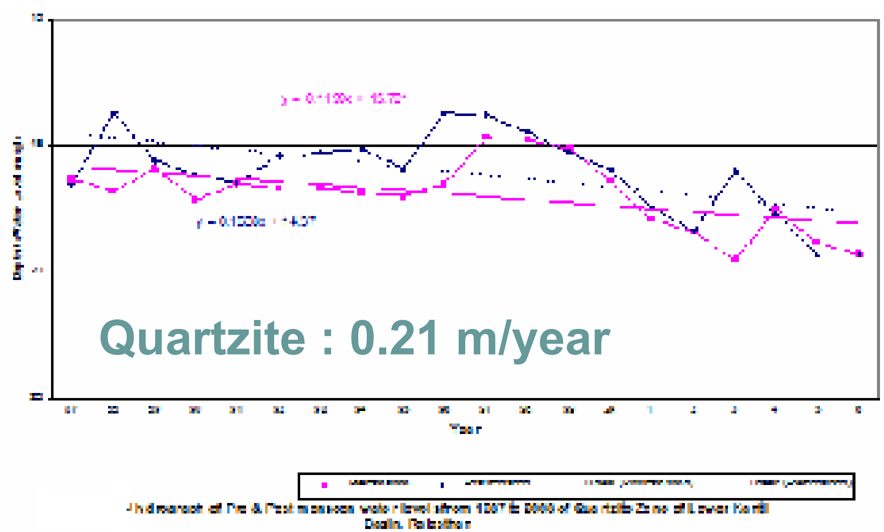


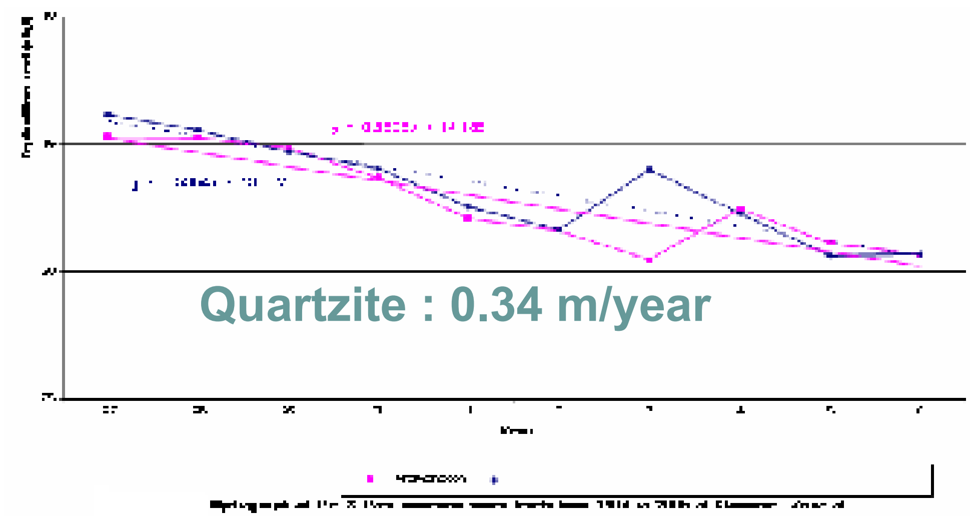
Decline in water level (1987-2006)



Decline in water level (1997-2006)







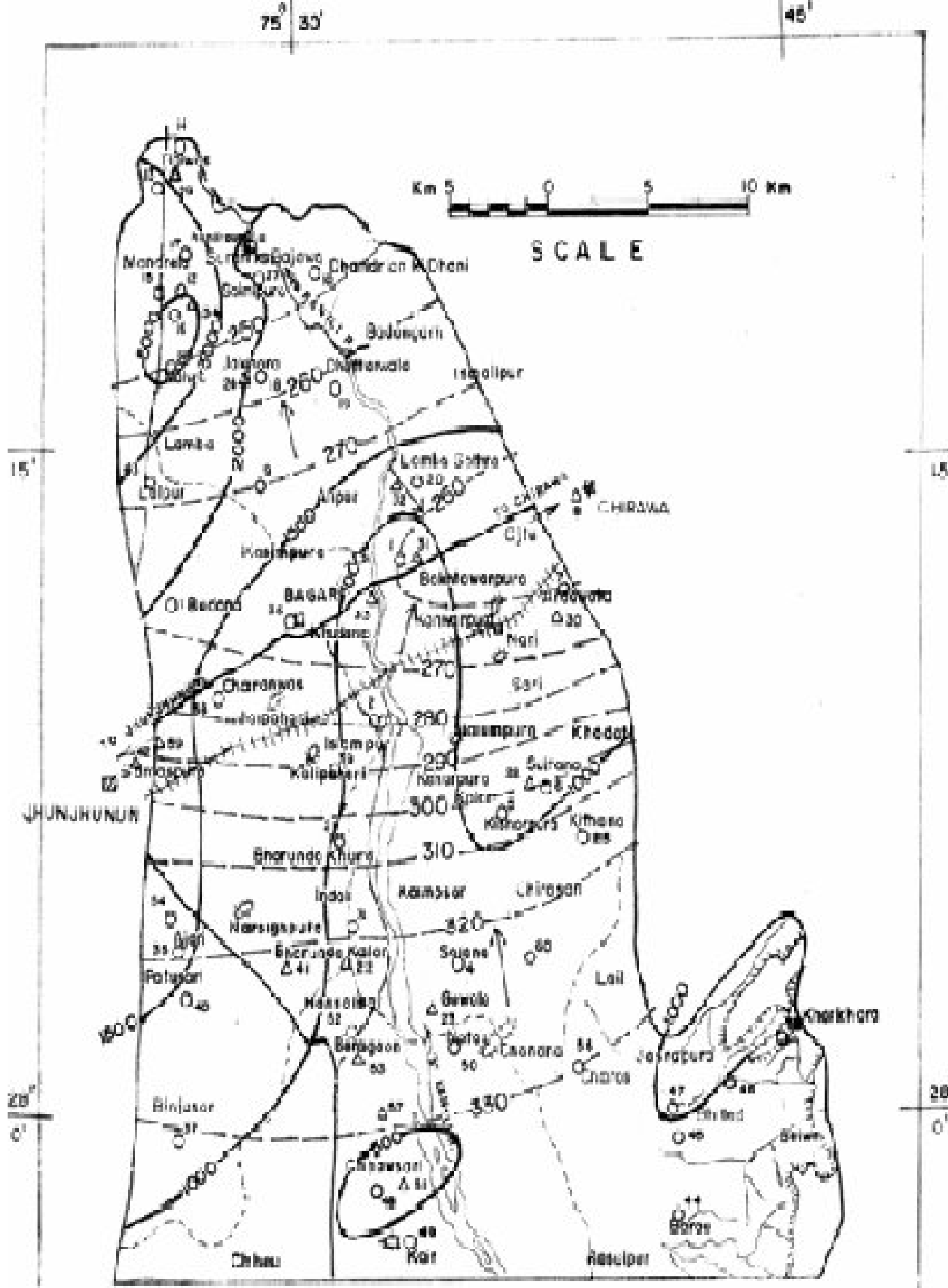
CHEMICAL QUALITY

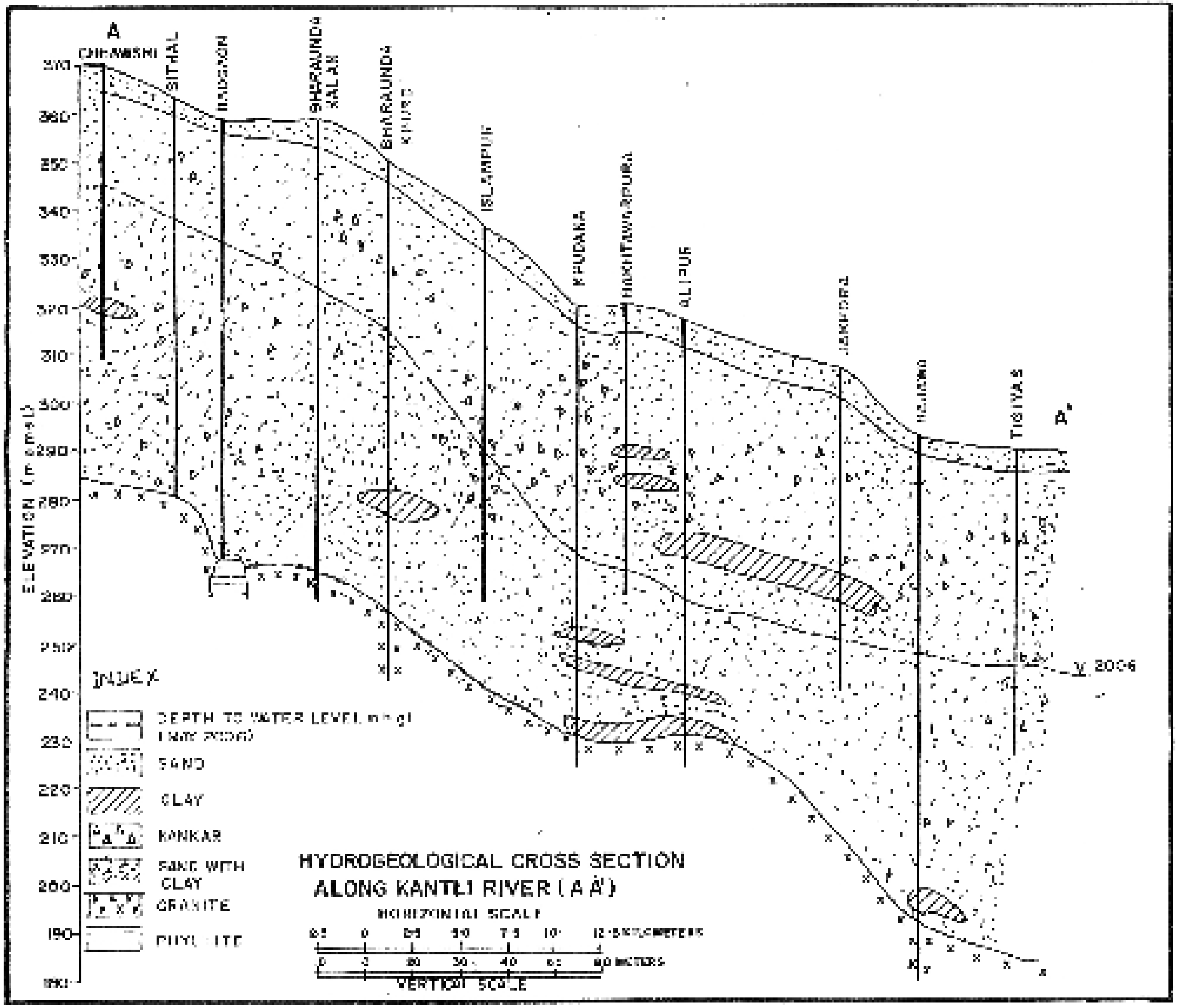
The ground water is fresh and potable in major part of the area.

EC: 500 – 1500 micromhos/cm at 25° in major part of the area.

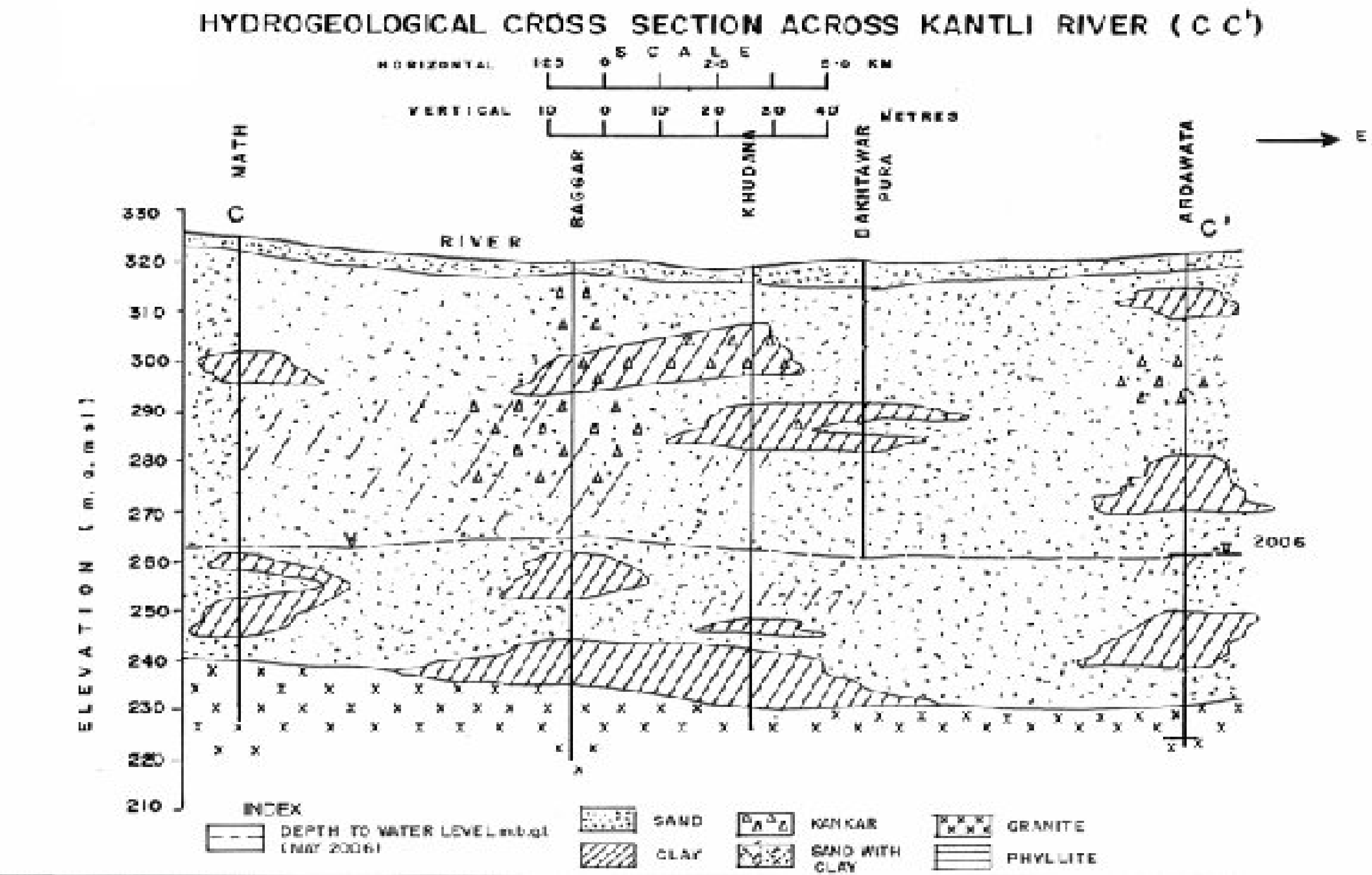
EC:1500 –5091 micromhos/cm at 25° in north western part.

Chloride: 35 – 1118 ppm. Concentration of salts increases in the direction of flow of Kantli river from south to north direction.





Ground elevation	-	370 – 290 m amsl.
Thickness of alluvium	-	69 – 102 m.
Basement	-	Malani granite



Ground elevation	-	319 - 325 m amsl.
Thickness of alluvium	-	85 - 100 m.
Basement	-	Malani granite

Aquifer Storage Space

Pot. Zone	Pot.Zone area (sq.km.)	Average depth to water level below 3m (Post 06)	Aquifer thickness (m)	Sp Yield (%)	Storage space in aquifer (MCM)	Non aquifer saturated thickness (m)	Sp Yield of non aquifer (%)	Storage space in non aquifer (MCM)	Total storage space available (MCM)
A	121.18	31.83	7.96	0.12	115.75	23.87	0.012	34.71	150.46
Ao	877.92	50.22	12.55	0.1	1101.78	37.67	0.01	330.71	1432.50
Q	89.97	16.3	16.3	0.015	21.99	-	-	-	21.99
	1089.07		36.81		1239.53	61.54		365.42	1604.96

Artificial Recharge To Ground Water

To augment the depleted ground water resources, rain water harvesting and artificial recharge to ground is very effective in supply side management of ground water resources.

Average annual rainfall : 465.5 mm.

Aquifer	Area (sq.km)	Volume of water (MCM)	Efficiency (%)	Water to be recharged (MCM)	Percolation Tank		Dug well recharge		Recharge Pit/RTRHS	
					Volume (MCM)	No	Volume (MCM)	No	Volume (MCM)	No.
A	121.18	2.4343	0.9	2.1909	1.3145	4	0.6573	329	0.2191	577
Ao	877.92	17.6577	0.9	15.8919	9.5352	32	4.7676	2384	1.5892	4182
Q	89.97	1.8299	0.9	1.6469	0.9881	3	0.4941	247	0.1647	433
Total	1089.1	21.9219	2.7	19.7297	11.8378	39	5.9189	2960	1.9730	5192

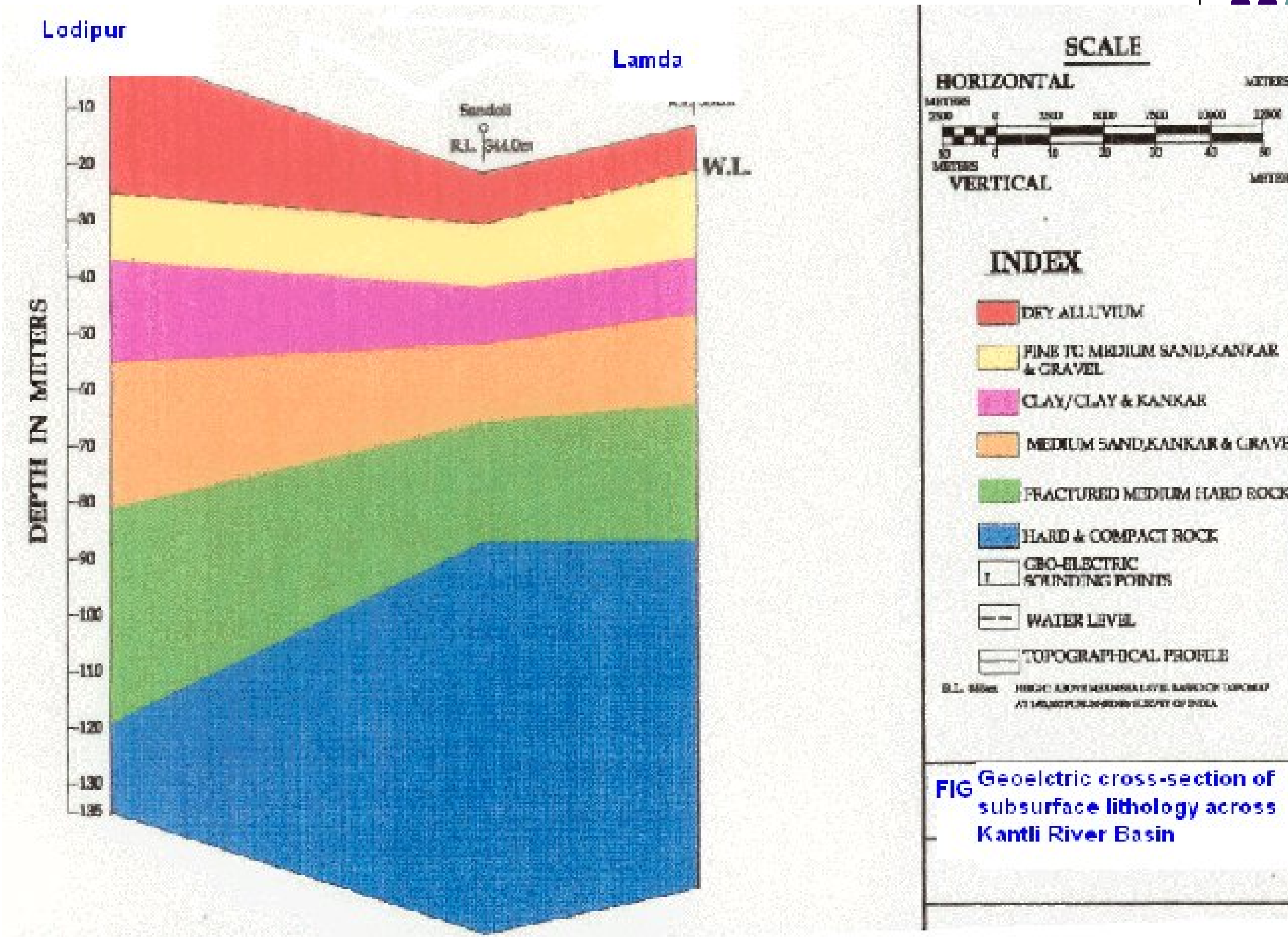
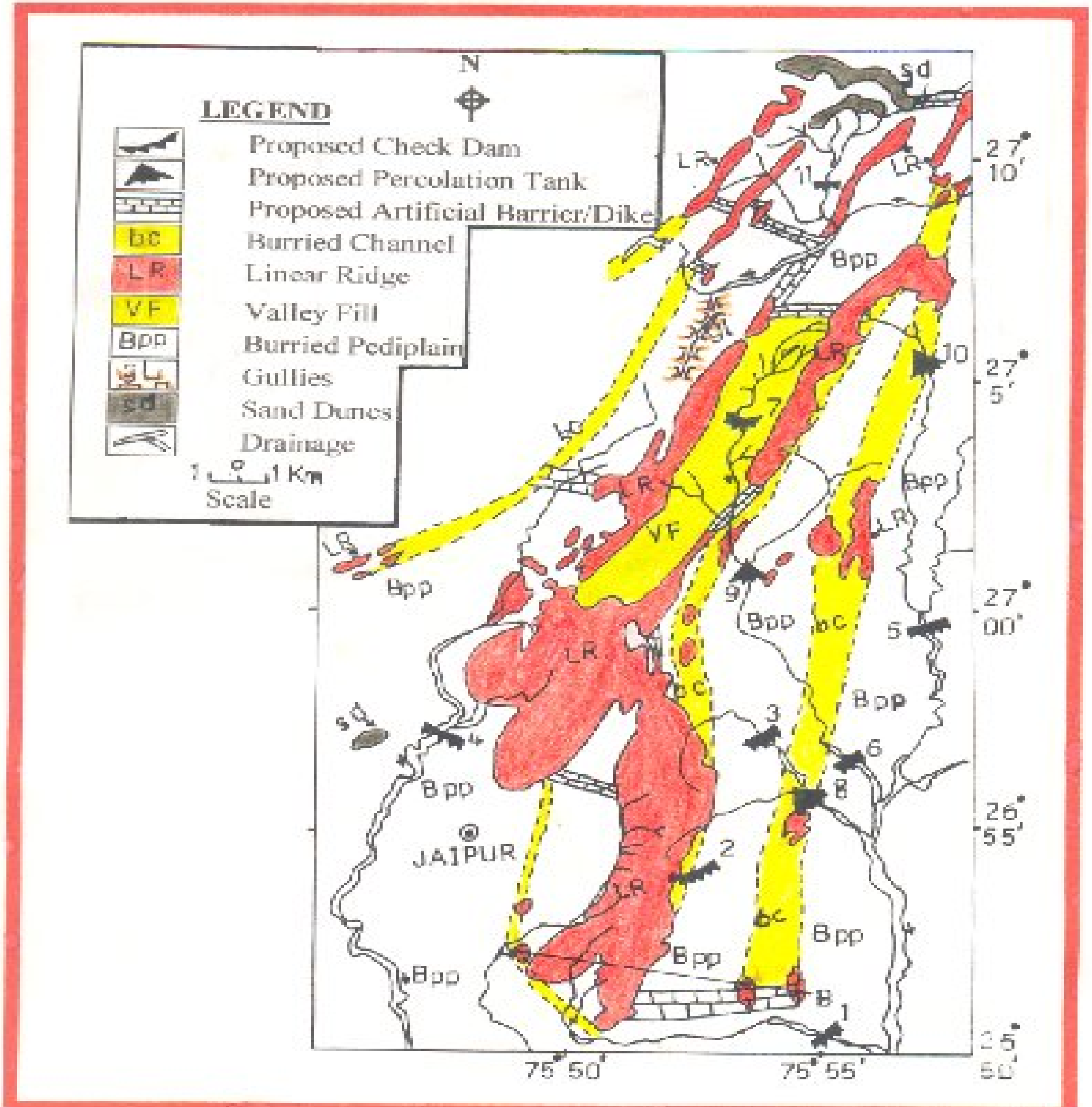


FIG Geoelctric cross-section of subsurface lithology across Kantli River Basin


LEGEND
N
Proposed Check Dam
Proposed Percolation Tank
Proposed Artificial Barrier/Dike
bc Burried Channel
LR Linear Ridge
VF Valley Fill
Bpp Burried Pediplain
Gullies
sd Sand Dunes
Drainage
1 0 1 Km
Scale
JAIPUR
27° 10'
27° 5'
27° 00'
26° 55'
25° 50'
75° 50'
75° 55'

Case Studies - II

Groundwater & Saline Area Management

Major Objective

Interfacing Fresh-Saline Groundwater Zone & Recharge Estimation

Origin of Problem

- About 23% of formation water available in Rajasthan is saline in nature.
- Generally in saline areas, a thin cushion of potable water floating on the saline water is withdrawn for drinking and other use.
- Rajasthan accounts of 49% of villages facing groundwater salinity and 56% of villages with Fluoride contaminated groundwater in India.

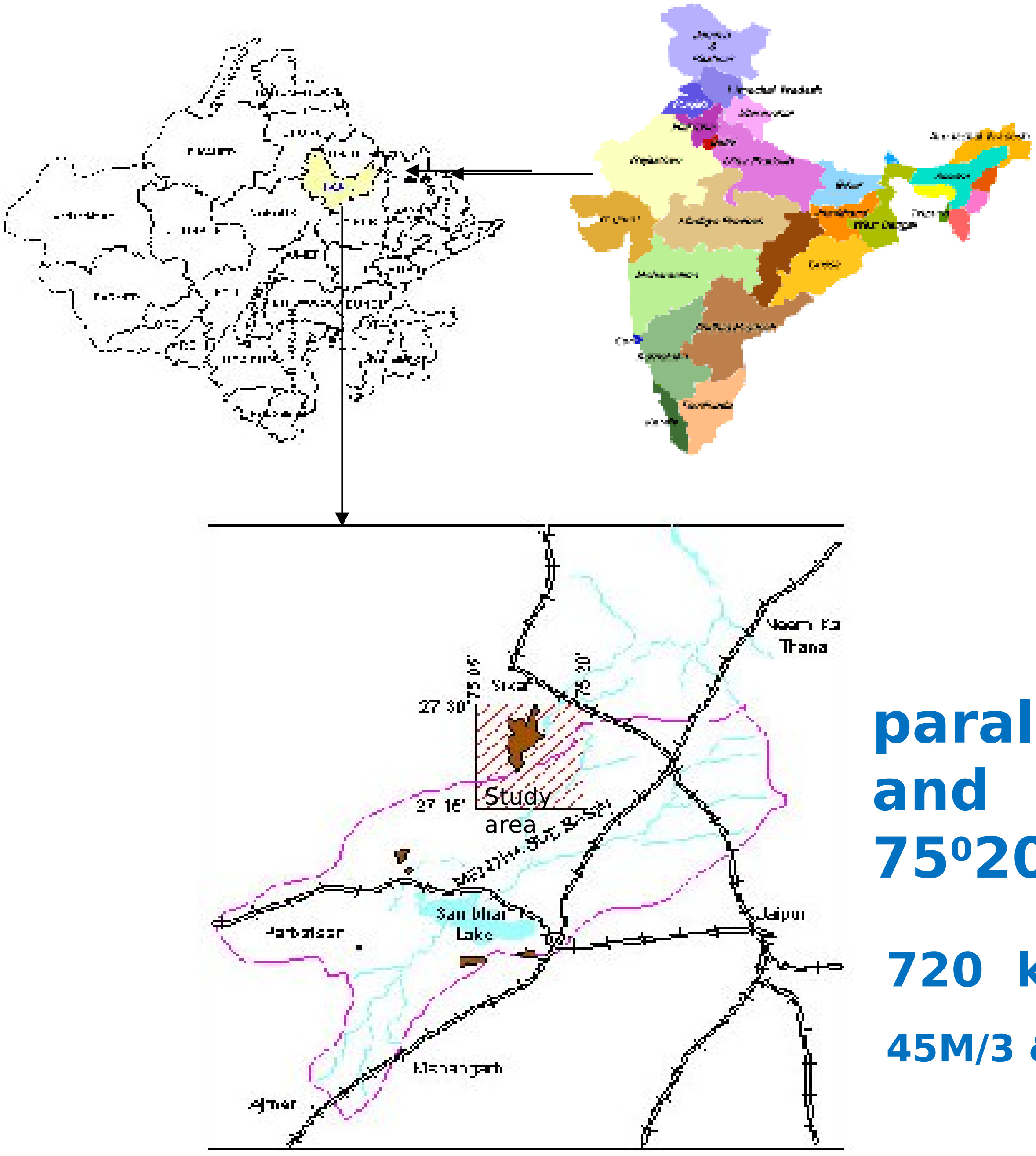
Need For Saline Pockets Investigation

- The saline zones in this dry state of India are quite prominent but so small that they are not reflected even on district level hydrogeological maps.
- The occurrence of well-defined saline pockets within fresh water region warranted the need to take up systematic micro level hydrogeological investigations to understand the precise hydrogeoloical set up of the saline aquifer and its development

The Dynamic Potable and Saline Water Resources of Rajasthan

Water Resources	Potable water	Poor quality water
Potential zone area (km^2)	220169.06	97673.13
Net annual groundwater availability (mcm)	10382.5781	3104.0937
Existing gross groundwater draft for irrigation (mcm)	11599.0104	487.6452
Existing gross groundwater draft for domestic and industrial use (mcm)	139.1914	13.29
Existing gross groundwater draft for all uses (mcm)	12991.2018	500.9352
Allocation for domestic and Industrial requirement as on year 2025 (mcm)	2719.7713	-
Net groundwater availability for future irrigation development (mcm)	-3936.2036	-
Present groundwater balance (mcm)	-2608.6237	2603.1586
Stage of groundwater development (%)	125.13	16.14

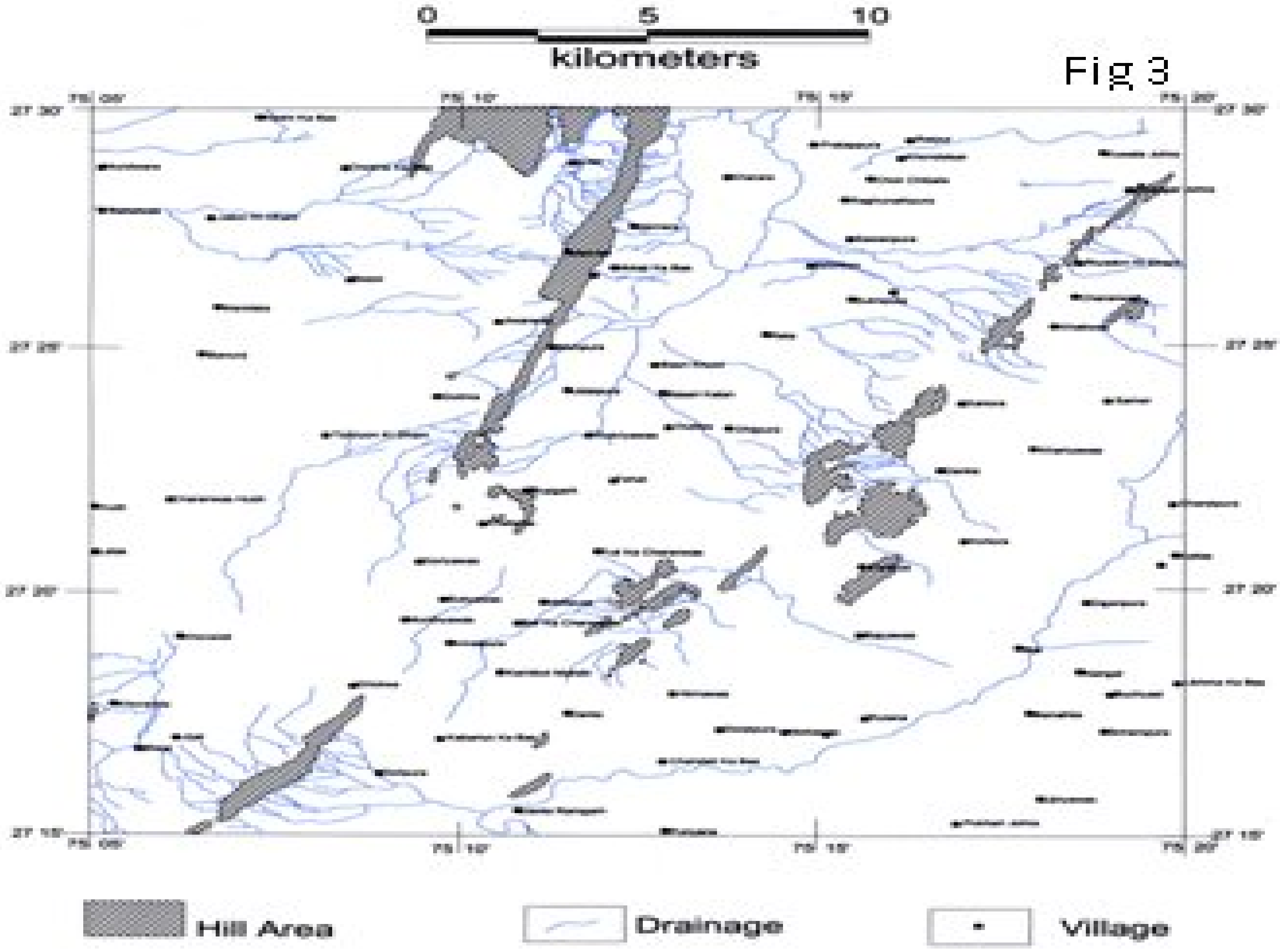
Study Area



parallels $27^{0}15'$ – $27^{0}30'$ and meridians $75^{0}5'$ – $75^{0}20'$

720 km2 (SOI Topo-sheet nos. 45M/3 & 45M/7)

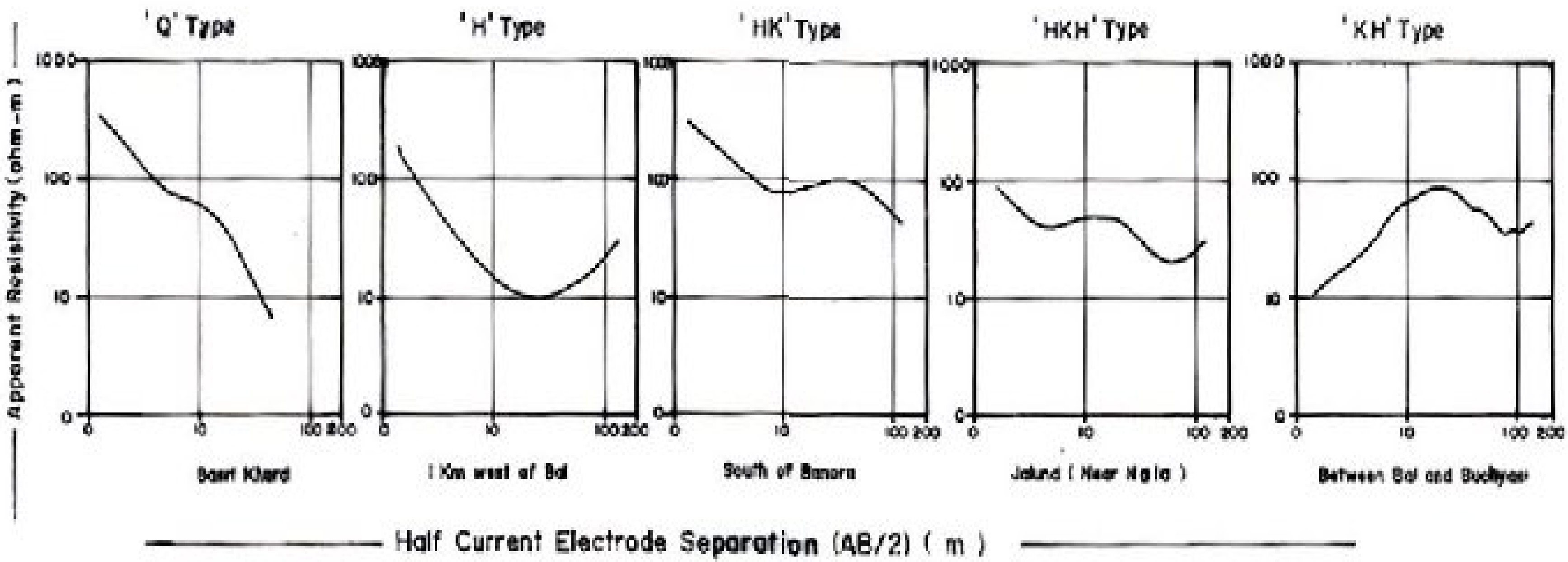
Physiography & Drainage



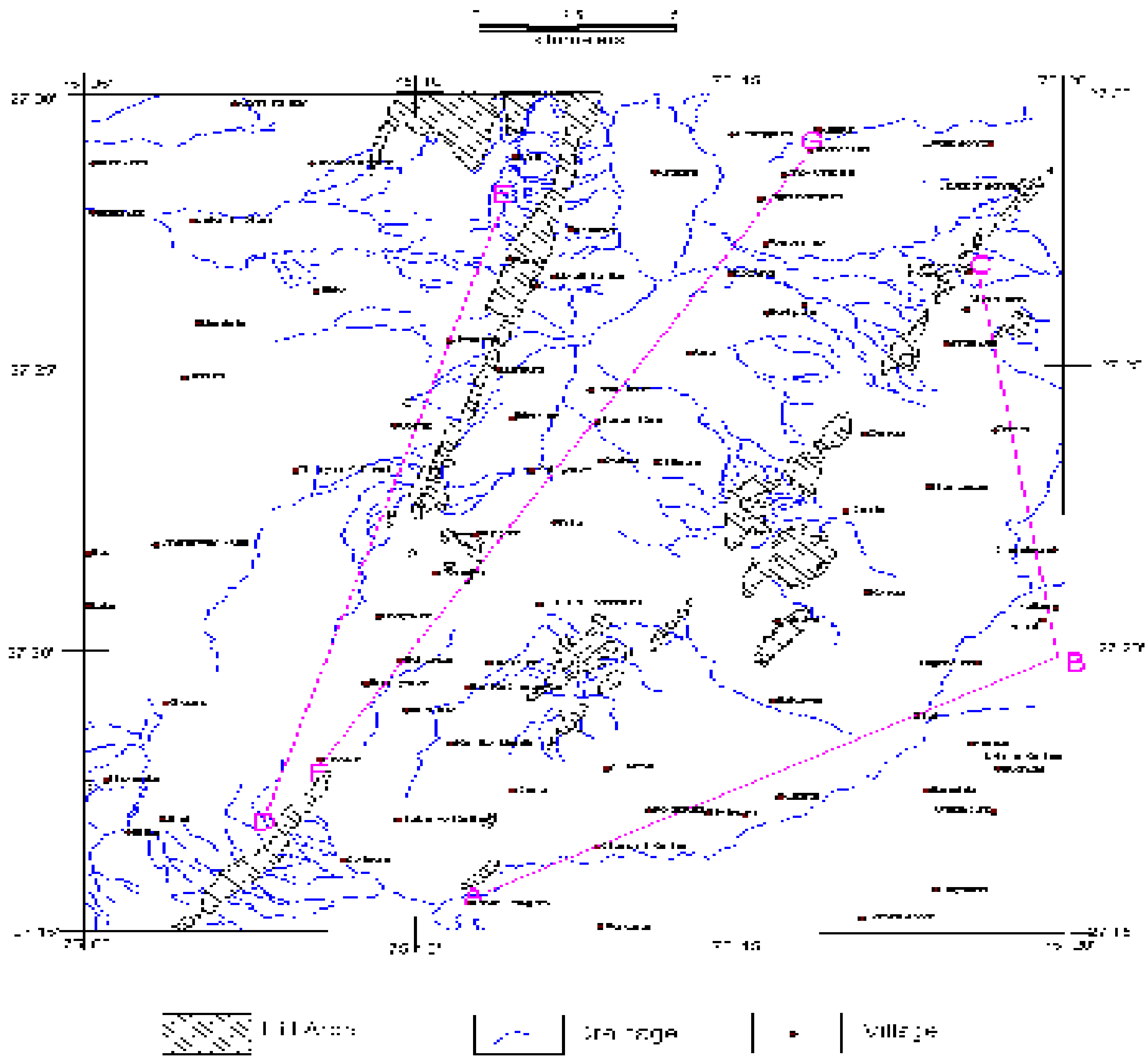
Geo Electrical Resistivity Sounding

- 83 VES of Schlumberger array were interpreted:
- Q', 'H', 'HK', 'HKH' and 'KH' type curves are encountered in the area.
- 'A' type curve is not represented in the area.
- 'Q' type curves are noticed in saline formation water areas.
- 'H' type curves are noticed in hard rock areas.
- The potential areas are represented by 'HKH' and 'KH' type curves.
- 'HK' type curves indicate presence of finer clastics and deterioration of groundwater quality with depth.

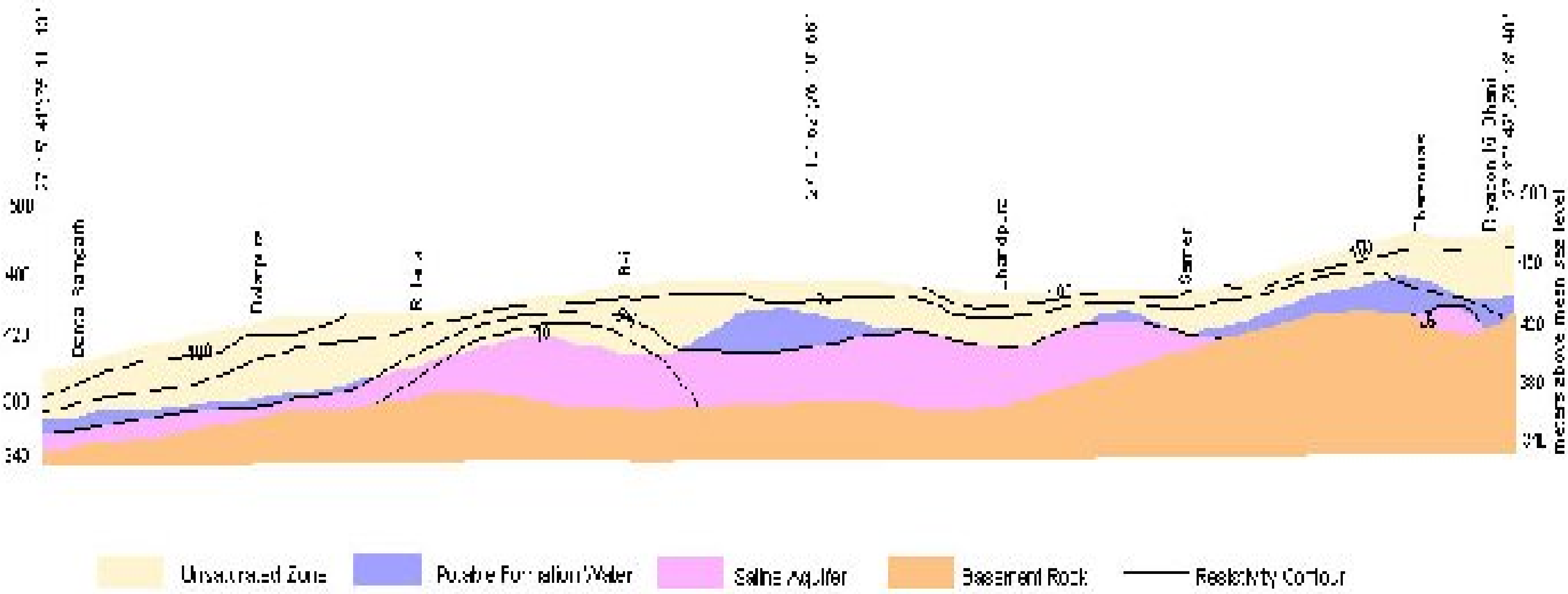
Representatives Schlumberger VES Type Curves of Study Area

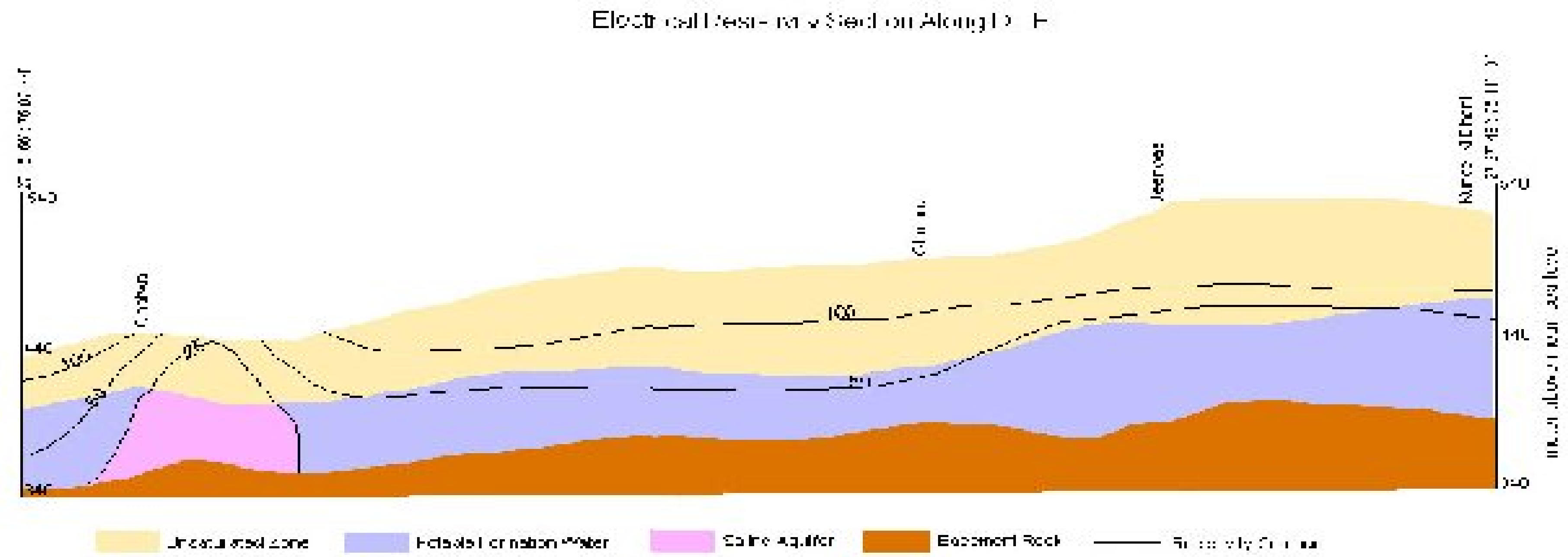


Electrical Resistivity Section Lines

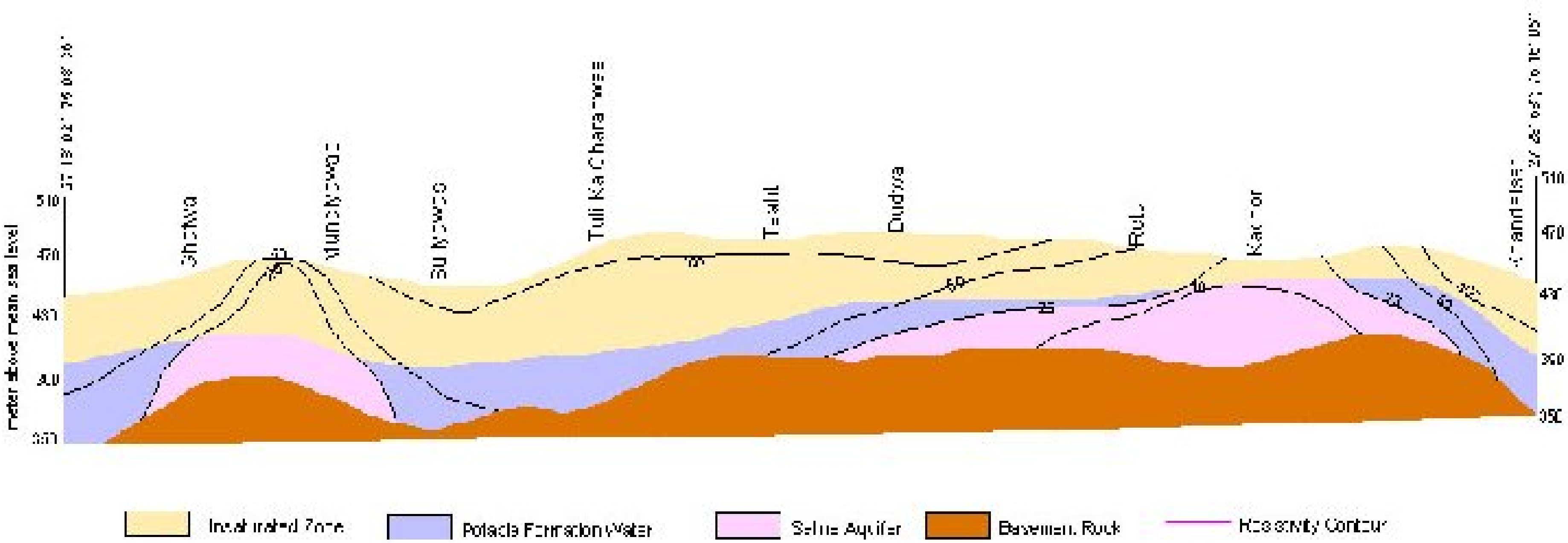


Electrical Resistivity Section Along A - B - C

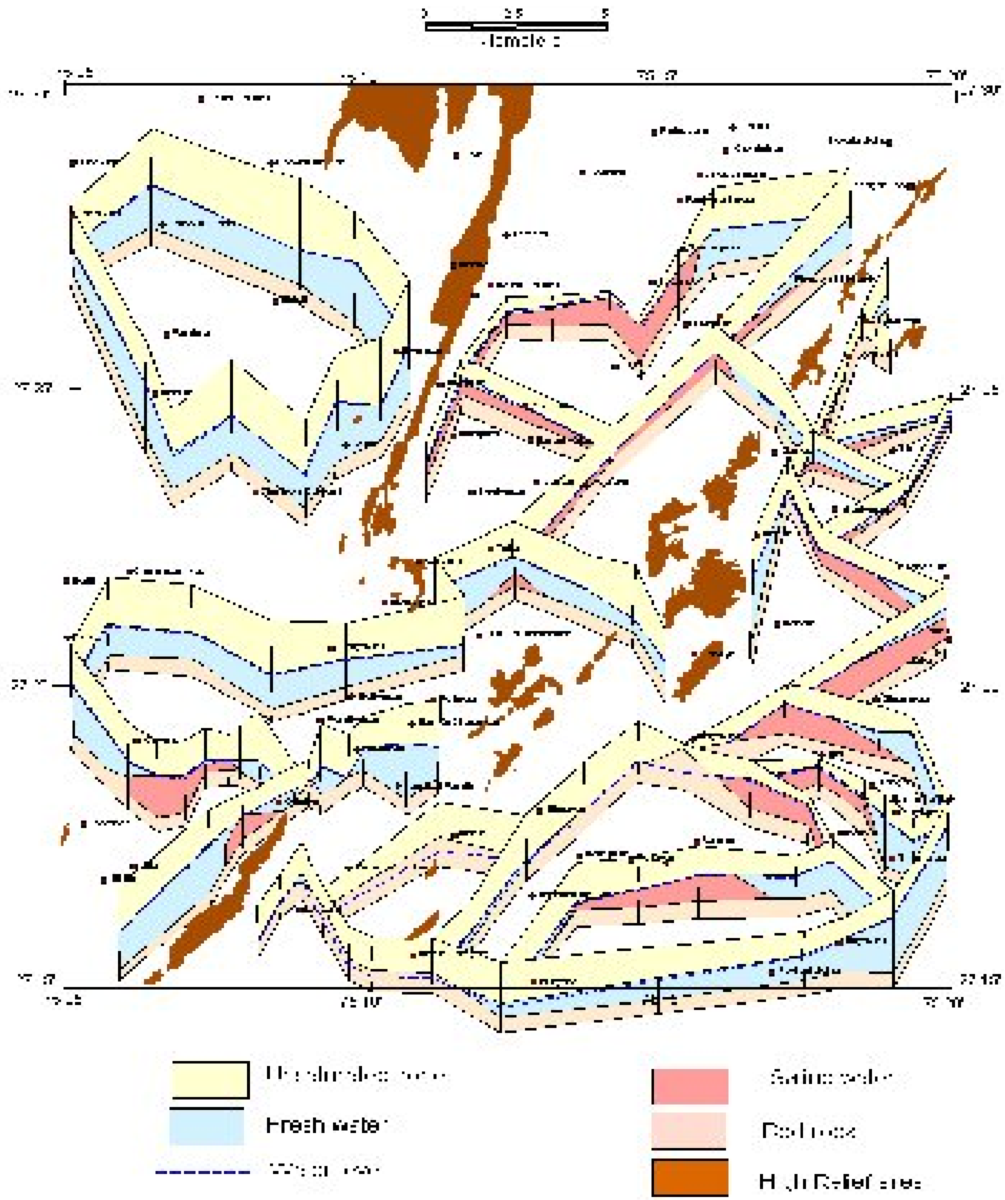



Electrical Resistivity Section Along D - E
Unsaturated Zone
Potable Formation Water
Saline Aquifer
Basement Rock
Resistivity Contour

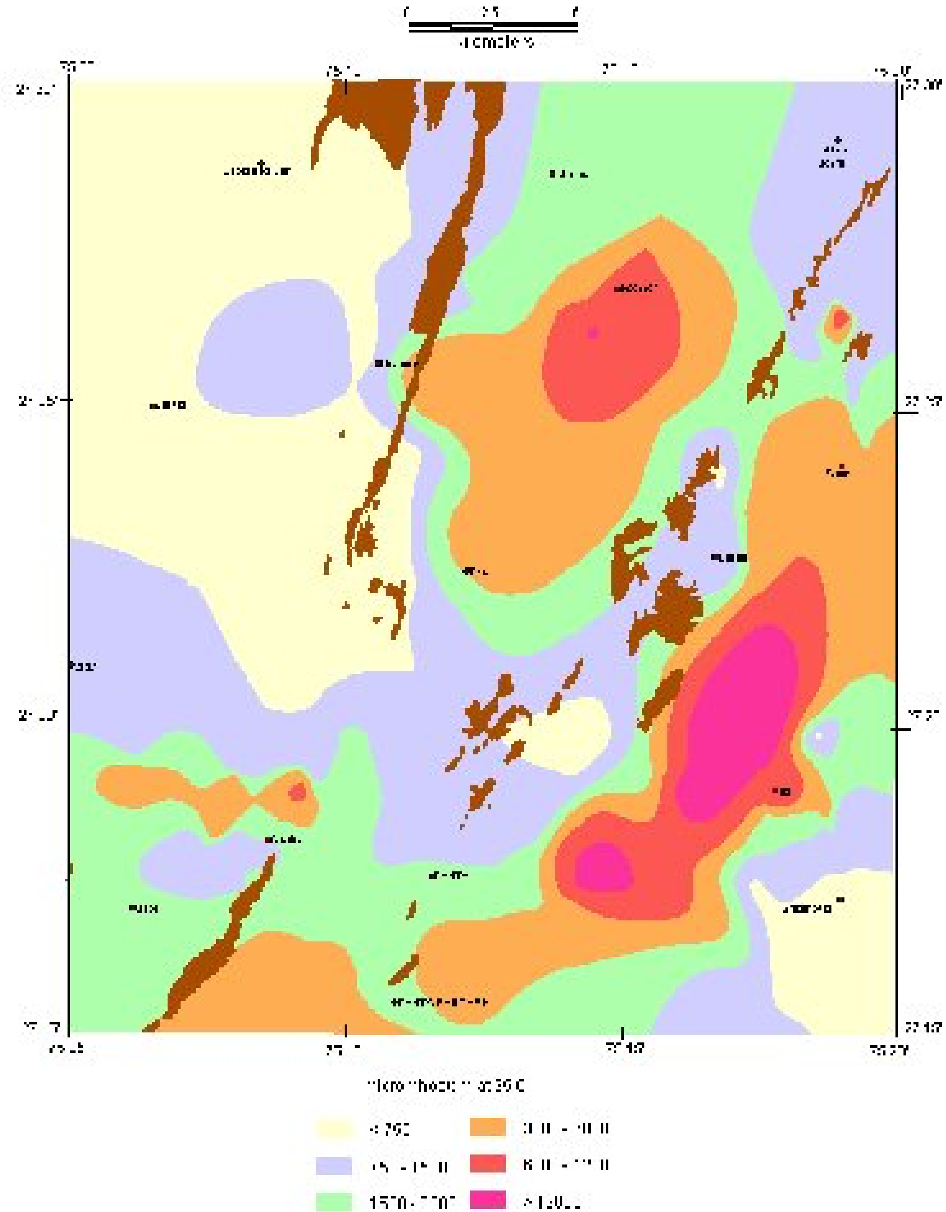
Electrical Resistivity Section Along F – G



Panel Diagram Showing Aquifer Geometry



Electrical Conductivity of Formation Water



Estimate of Groundwater Recharge

An approximate estimate of groundwater recharge on construction of the contour trench can be made as follows:

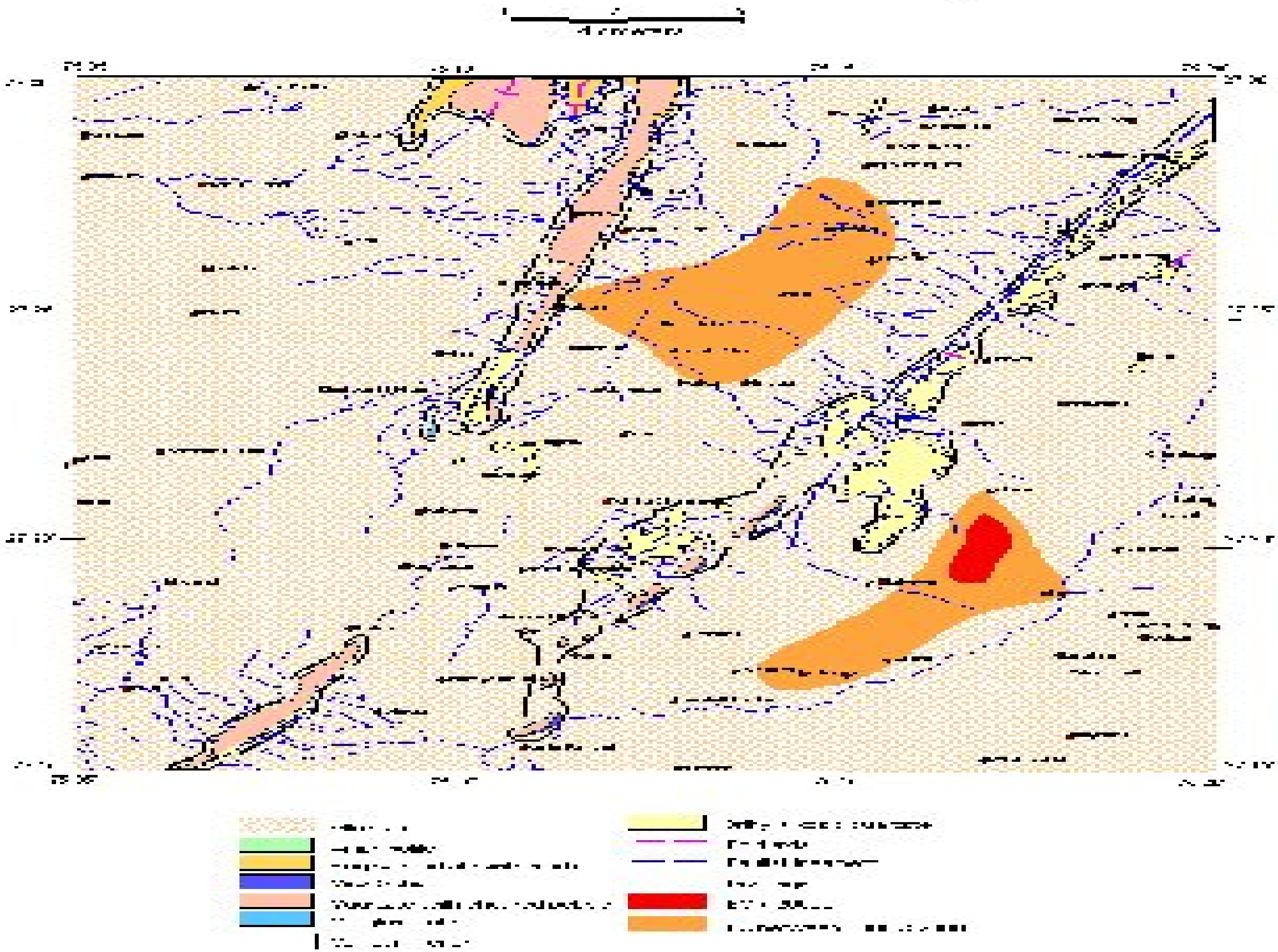
- **Mean annual rainfall (1974-2006) : 488.8 mm**
- **Catchment area of ridges and hillocks : 120 km^2**
- **Rainfall run-off co-efficient of rocky terrain : 0.5**
- **Groundwater Recharge component : 0.5**

Monsoon run-off available for groundwater recharge:

Area* Mean annual rainfall* Run-off co-efficient* Recharge component

120* 1000* 1000* 0.488* 0.5* 0.5 = 14640000 cubic meter/yea *or* ***14.64 million cubic meter/year***

Layout of Contour Trench Proposed for Ground Water Recharge



MAR MAY HELP IN REDUCING THE GLOBAL WARMING

Potential of MAR for Energy savings , reduction of Green house gases & resultant Carbon credits….

- Dominant contribution to energy production in Western India is from Thermal Power Plants
- The enormous quantum of power saved will reduce the Green house Gas (GhG) emissions
- Reduction in GhG to contribute towards reducing the global warming.

Potential of MAR for Energy savings , reduction of Green house gases & resultant Carbon credits

- Gross Ground water draft :2415MCM/annum
- Wells with electric connections :1,31,414
- Dynamic head : 25-100 m
- Lifting 1 m^3 of water by one meter : 0.01 kWh
- Lifting 2415 MCM needs nearly 1550 Million kWh of electricity under present situation
- Energy cost Rs.5347.5 Million (considering the cost of power delivered @ Rs 3.45 /kWh)

Potential of MAR for Energy savings , reduction of Green house gases & resultant Carbon credits..

- MAR on full scale implementation would reduce average dynamic head
- Reduction by 10m :Saving 258 Million kWh of power valued at Rs 888 Million
- Reduction by 20m :Saving 515 Million kWh of power valued at Rs 1775 Million
- Reduction by 30m :Saving 775 Million kWh of power valued at Rs 2670 Million

Potential of MAR for Energy savings , reduction of Green house gases & resultant Carbon credits….

- The potential for carbon credits due to reduction in power consumption has been computed by considering the Average coefficients as followed in the USA.

Carbon dioxide = 1.34 lb/kWh

Methane = 0.0111 lb/kWh

Nitrous oxide = 0.0192 lb/kWh

Potential of MAR for Energy savings , reduction of Green house gases & resultant Carbon credits….

- The saving of 775 Million kWh of power implies saved emissions of GhG as follows:
- **Carbon dioxide** = 1038.5 Million lb or **4,71,188 Metric tons** (1 metric ton =2204 lb)
- Methane = 8.6 Million lb or 3902 Metric tons
- Nitrous oxide = 14.9 Million lb or 6760 Metric tons
- At the @ US $ 10/metric tonne of carbon dioxide , the carbon saving would be worth US $ 4.7 Million or Rs 211 Million/year.(considering 1US $= Rs 45)

In conclusion …

"If society continues to use precious groundwater resources without recompense or replenishment, the water (management) crisis will only deepen"

The Water Which Came Down From Heaven ..Those Spring Up Their Own.The Bright And Pure Water That Finally Reaches The Sea .May These Divine Water May Protect Me

- ***Rigveda (Vii-49-2)***

Thank you