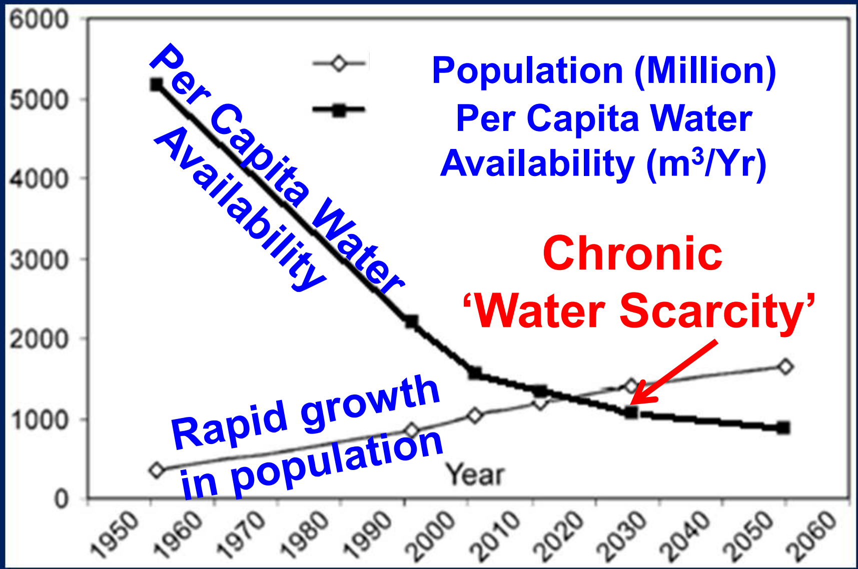
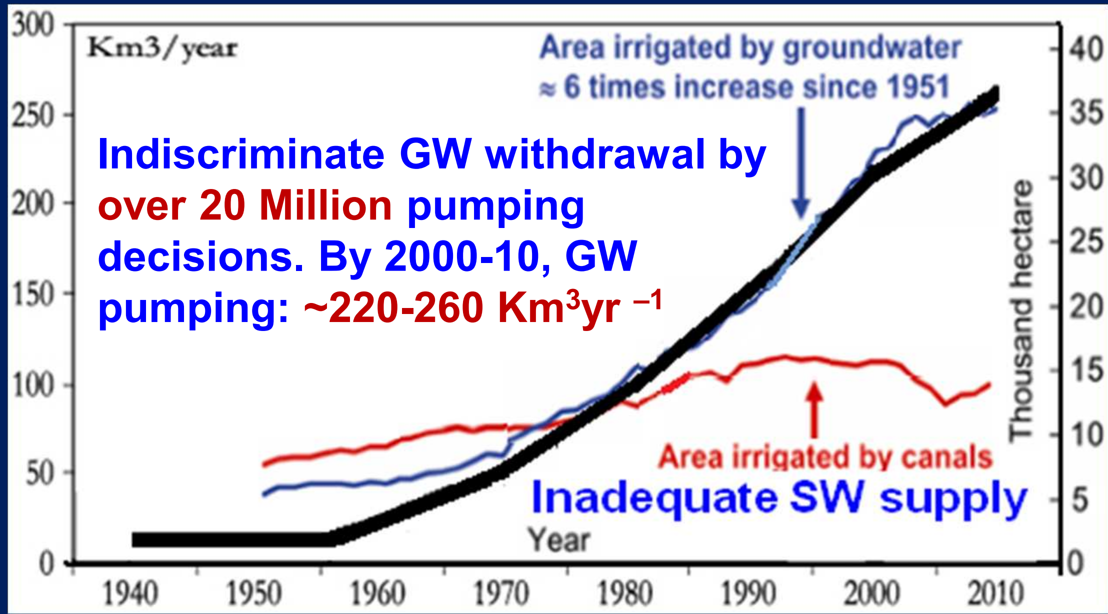
ENSEMBLE MODEL TO RECONSTRUCT PALAEOCLIMATE AND PREDICT INDIA'S GROUNDWATER CHALLENGE AND THE WAY FORWARD

PROF. P. S. DATTA
Ex-Project Director (NRL)
& Ex-Principal Scientist (Hydrology)
IARI, New Delhi, India
E-mail: psdatta1950@gmail.com

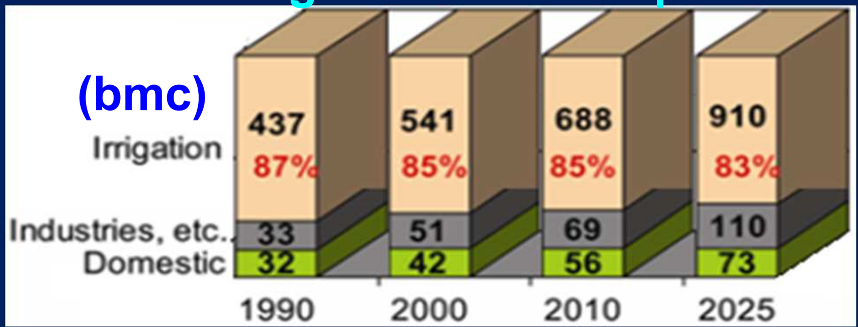
3rd International Interdisciplinary Conference on
Predictions for Hydrology, Ecology and Water Resources Management:
Water Resources and Changing Global Environment (HydroPredict 2012)
24-27 September 2012, Vienna, Austria

Non-Climatic Factors Central to the Present Fresh Water Crisis in India





Increasing water consumption



- Rapid intensification in Agriculture Urbanization, Industrialization, & Competition for economic aspirations.
- Water pollution from unplanned wastes disposal & agro-chemicals application.

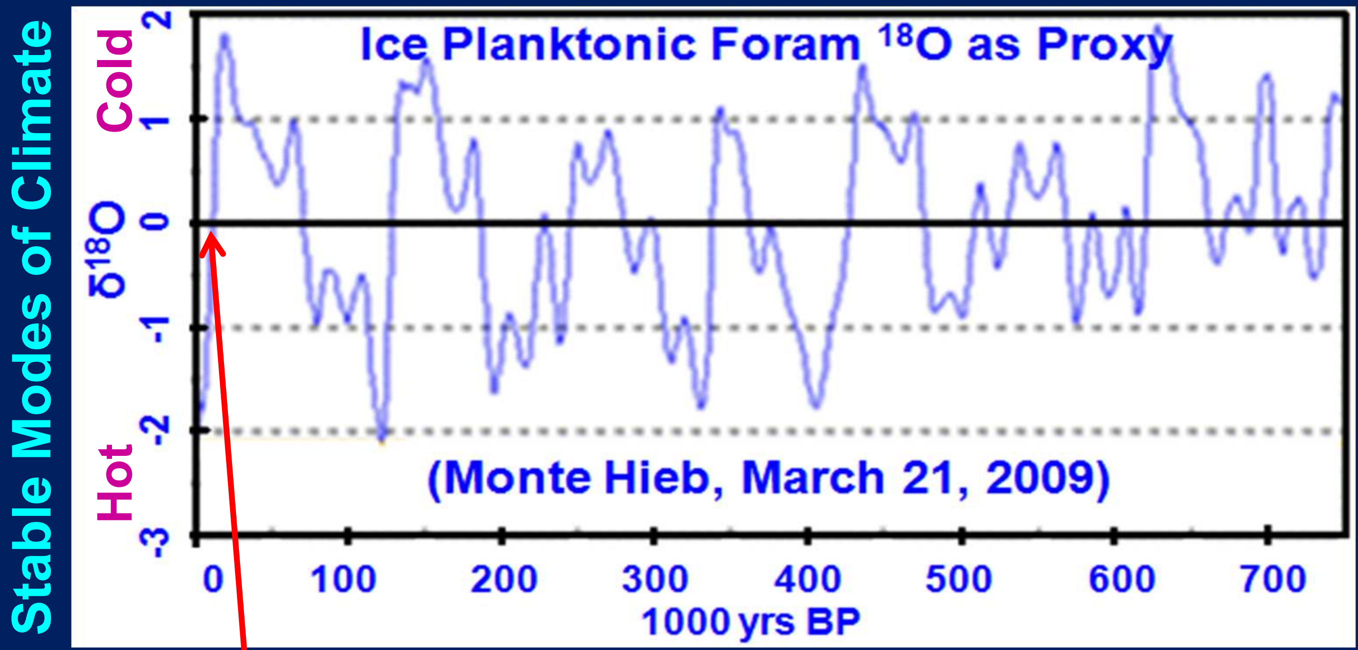
A single template of GW management is difficult from limited knowledge of GW Systems, demand & use in socio-economic context.

Datta et al (2001); Datta (2005, 2011); (Minor Irrigation Census, Govt of India)

SOME UNDENIABLE FACTS ON CLIMATE

Neogene (23-6 My): Climate in SE Asia, humid tropics & subtropics was same, with decline in Temperature & insignificant change in CO_2

(1 My - Present): Different response of tropics & northern extra-tropics by Interglacial periods of 100,000 yr intervals.

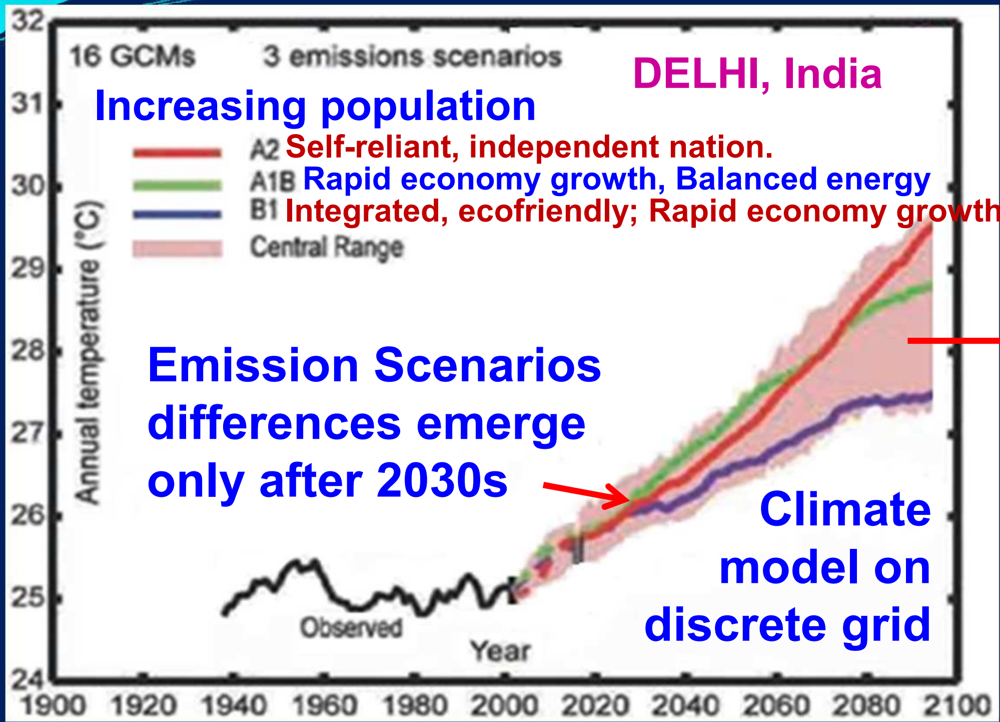


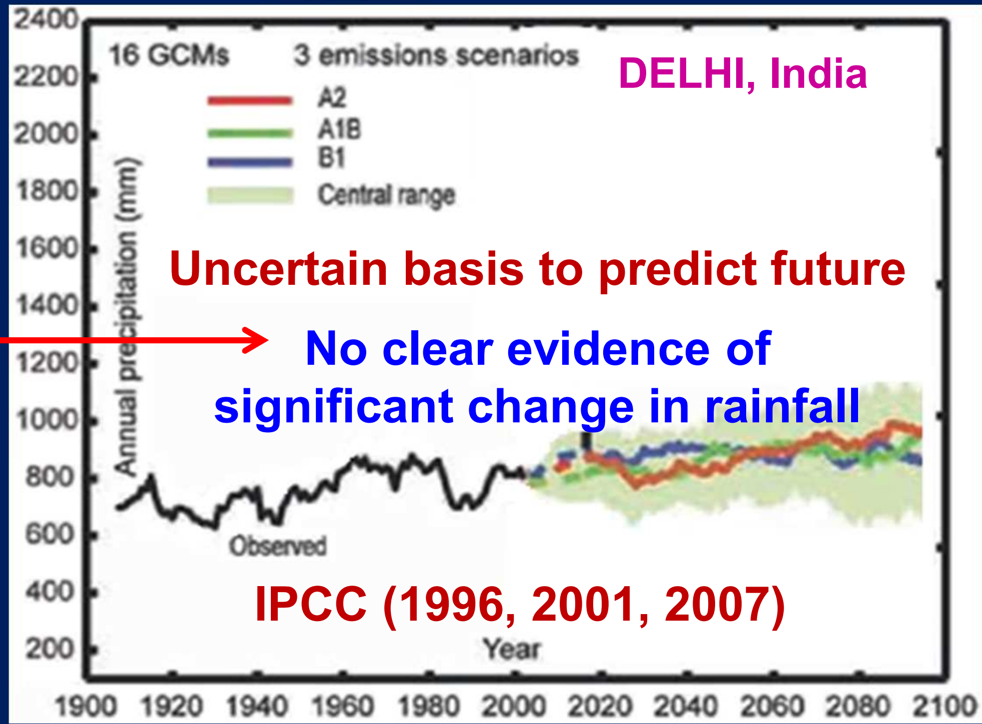
Hot current state, stable for past 10,000 yr

The Region was subjected to different climatic phases ~ 4000 to 1,000,000 yrs back.

Source: Cai et al (2006); Chiang (2009); Anchukaitis et al (2010)

ANTICIPATED CLIMATE INDUCED PROJECTIONS





Temperature			Rainfall		
2020s	2050s	2080s	2020s	2050s	2080s
0.5 to 1.5 °C	1.5 to 2.5 °C	2.5 to 4.5 °C	10 to +20%	15 to +35%	-15 to +35%

IGP : Av. rise 0.5 – 1°C (2020–2029), 3.5 – 4.5°C (2090–2099)

Increased temperatures → Increased/decreased Rainfall, Potential evaporation, Runoff.

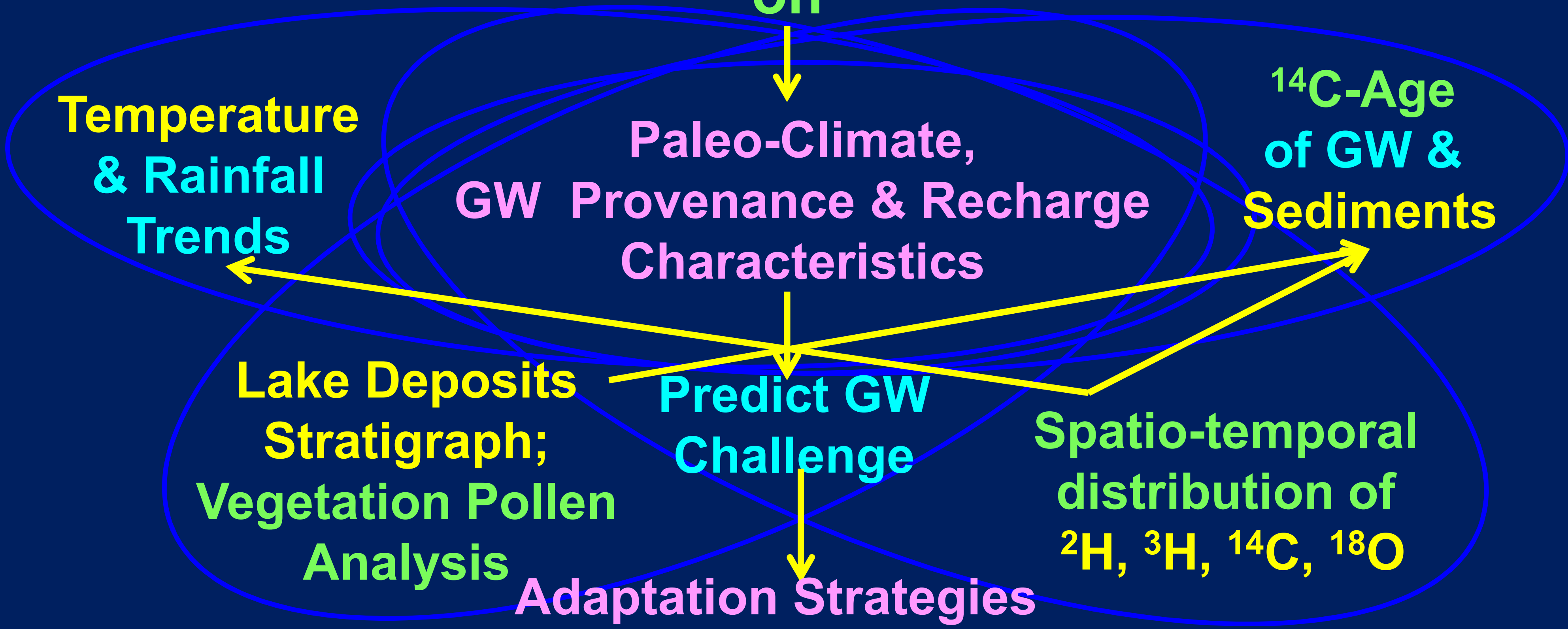
General reduction in rainfall and run-off in EWS River Basins in India.

MATTER OF CONCERN

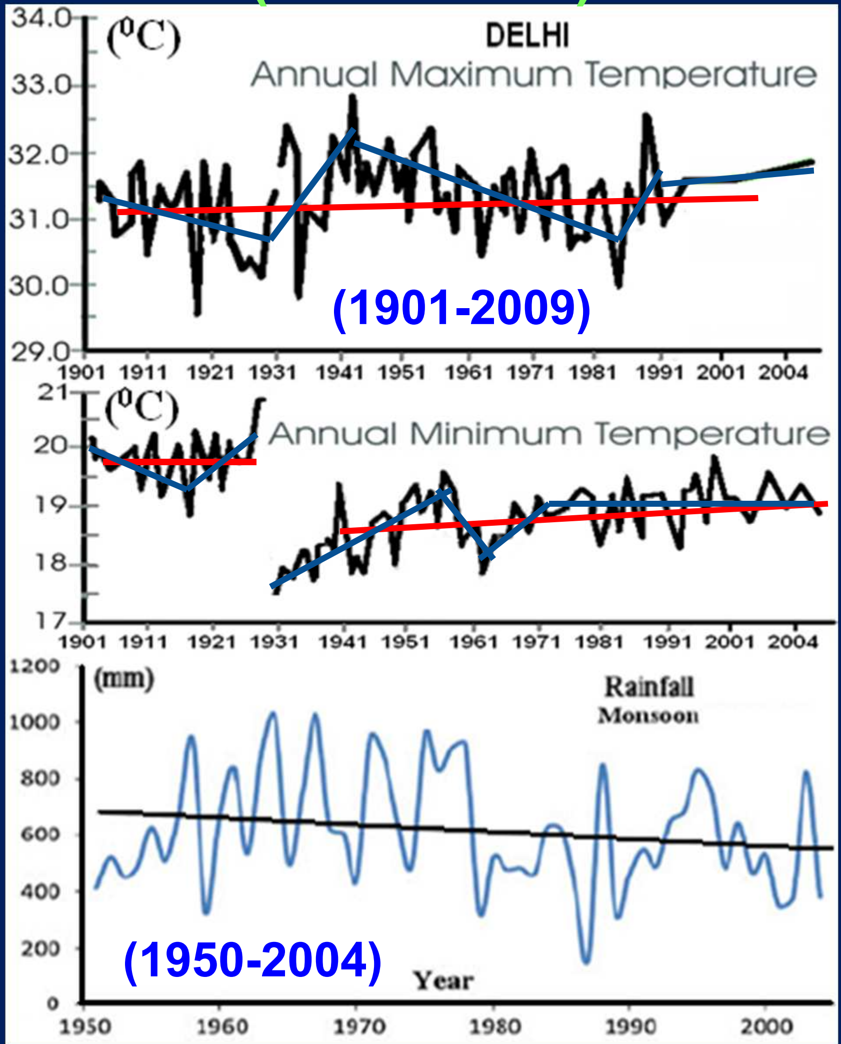
How to overcome the uncertainties in climate change to predict the future of India's GW?

ENSEMBLE MODEL PROVIDES INSIGHT

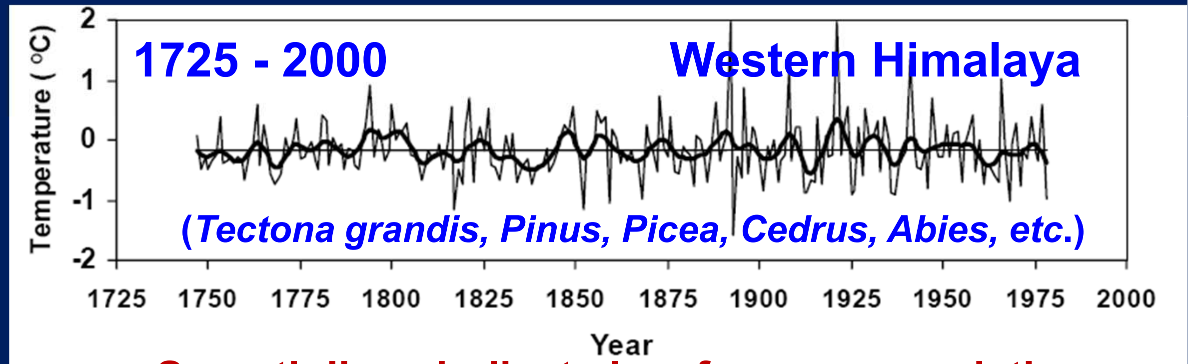
on



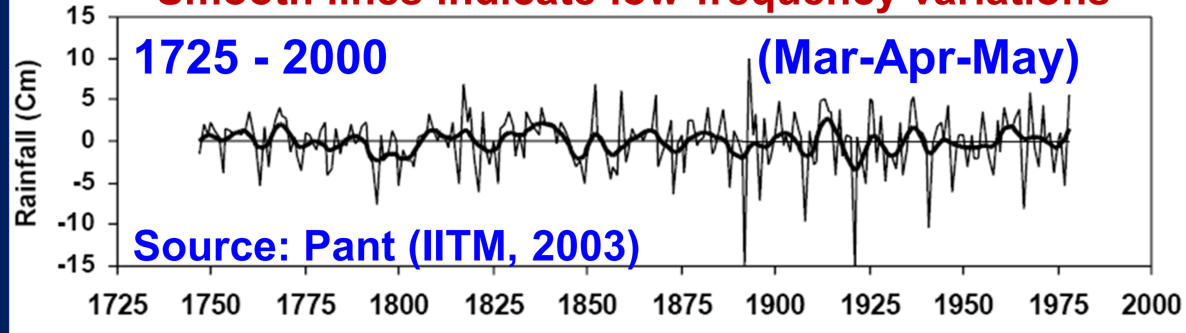
Observational Records (1901-2010)



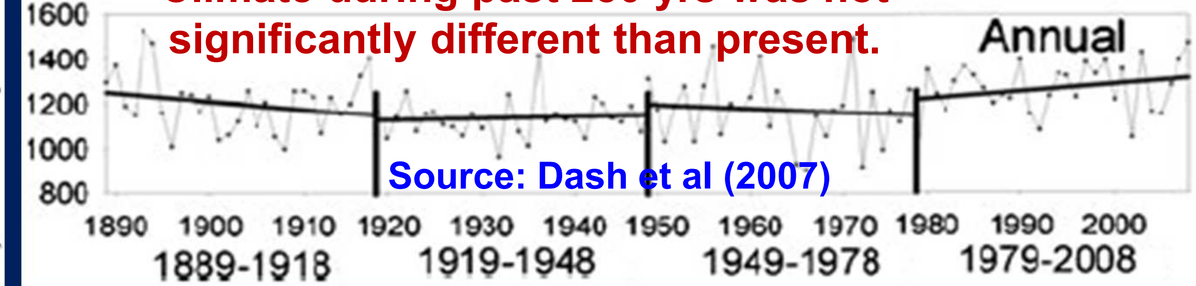
Reconstructed Pre-monsoon Anomalies Using Tree-ring Chronology Network



Smooth lines indicate low-frequency variations

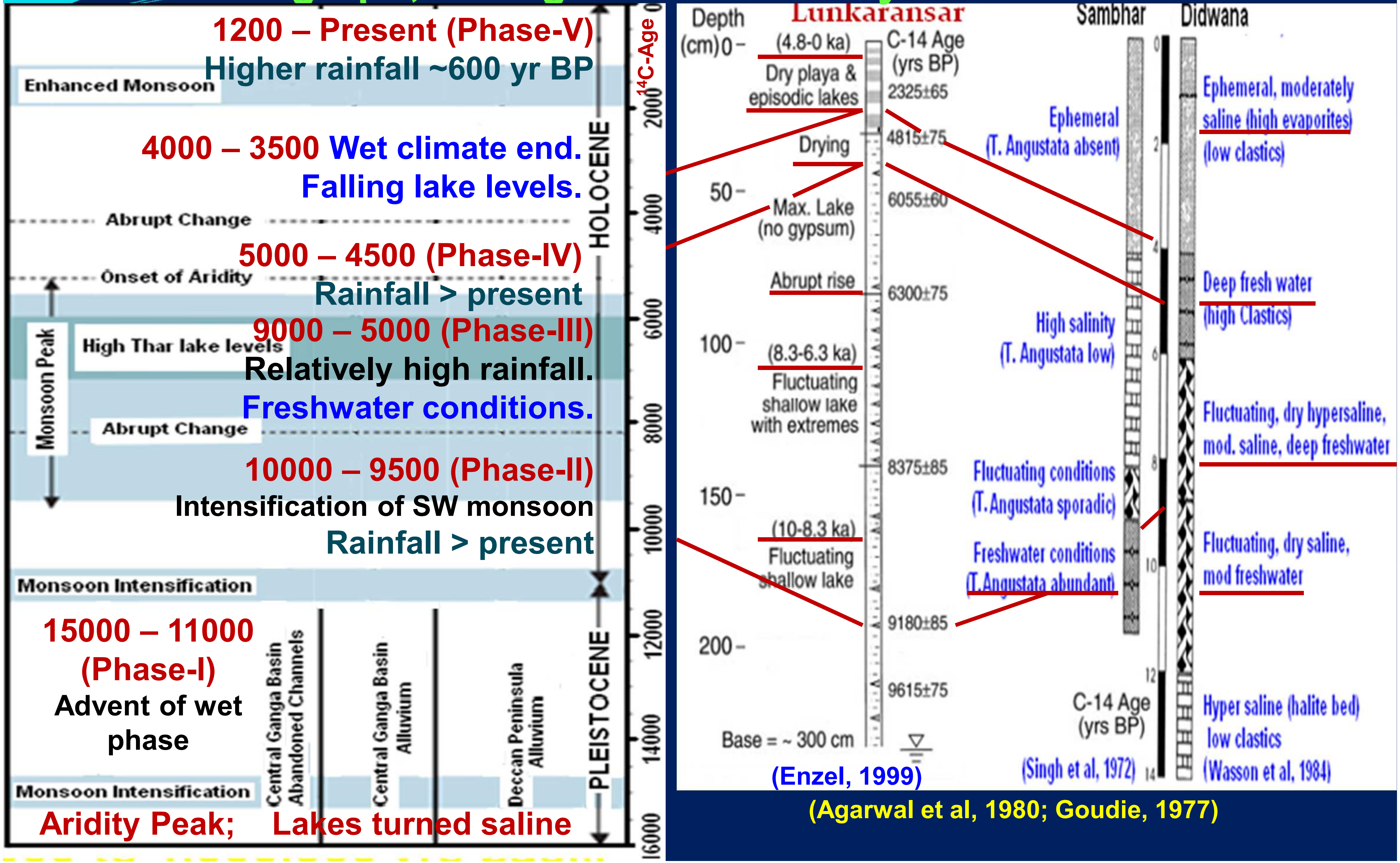


Climate during past 250 yrs was not significantly different than present.



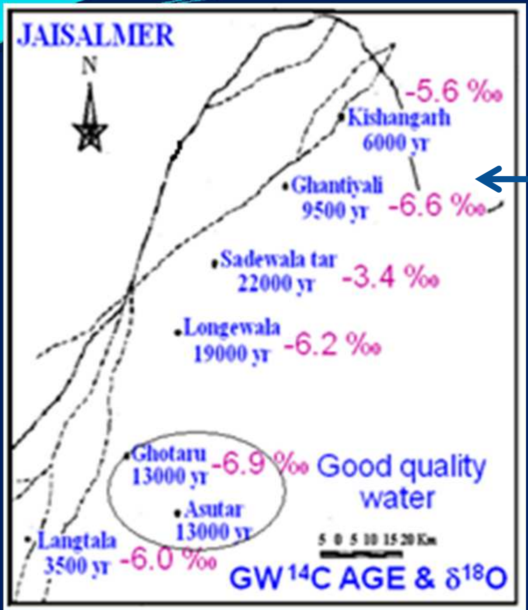
Decreasing trend or insignificant change is possibly due to meso-scale influences in lower atmosphere & monsoon circulation.

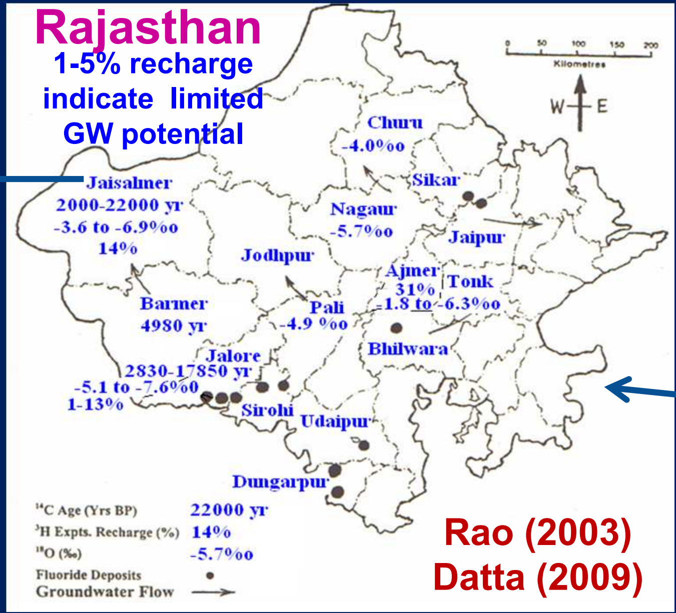
Five Phases of Paleo-Climate based on Lake Deposits Stratigraph, ^{14}C-Age & Pollen Analysis in NW-India



(Agarwal et al, 1980; Goudie, 1977)

GW PROVENANCE & OCCURRENCE OF PALAEOWATERS





Haryana GW

δ18O (−8.2 to +1.5‰)

14C age 8000 to ~20,000 yr BP

Andhra Pradesh GW 14C age

1300 ~6000 yr BP

δ18O (−3.2 to −1.5‰)

Modern ~1000 yr BP

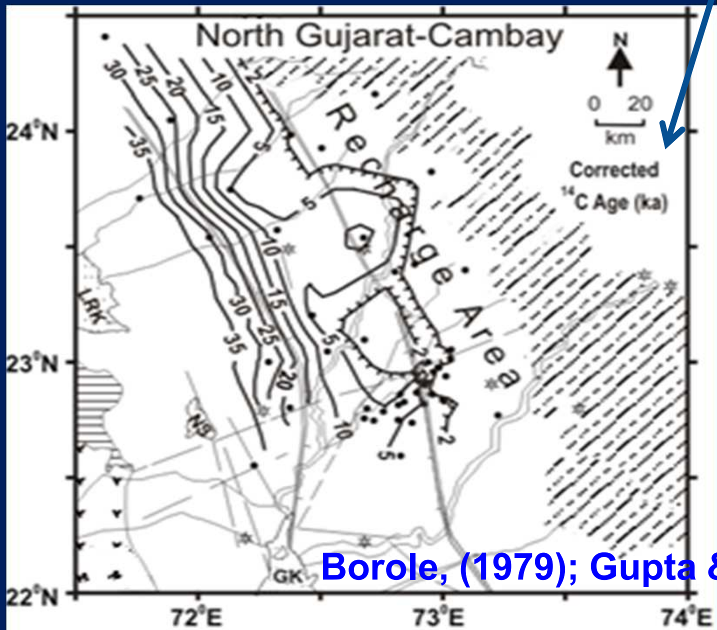
δ18O (−3.2 to +1.7‰)

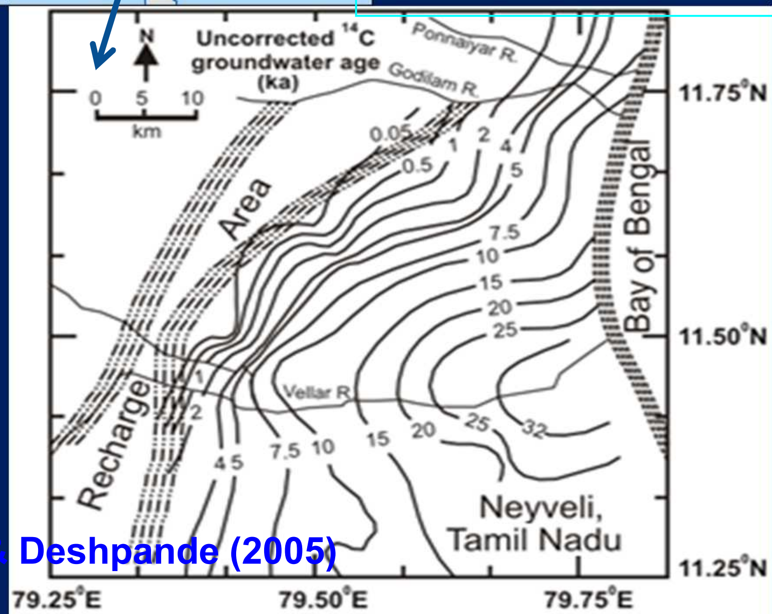
Garduno et al (2009); Sukheja et al, (1984)

Depleted δ18O & 14C age

2,000-22,000 yr BP

suggest origin of most of GW Reserve from past relatively more humid climate.

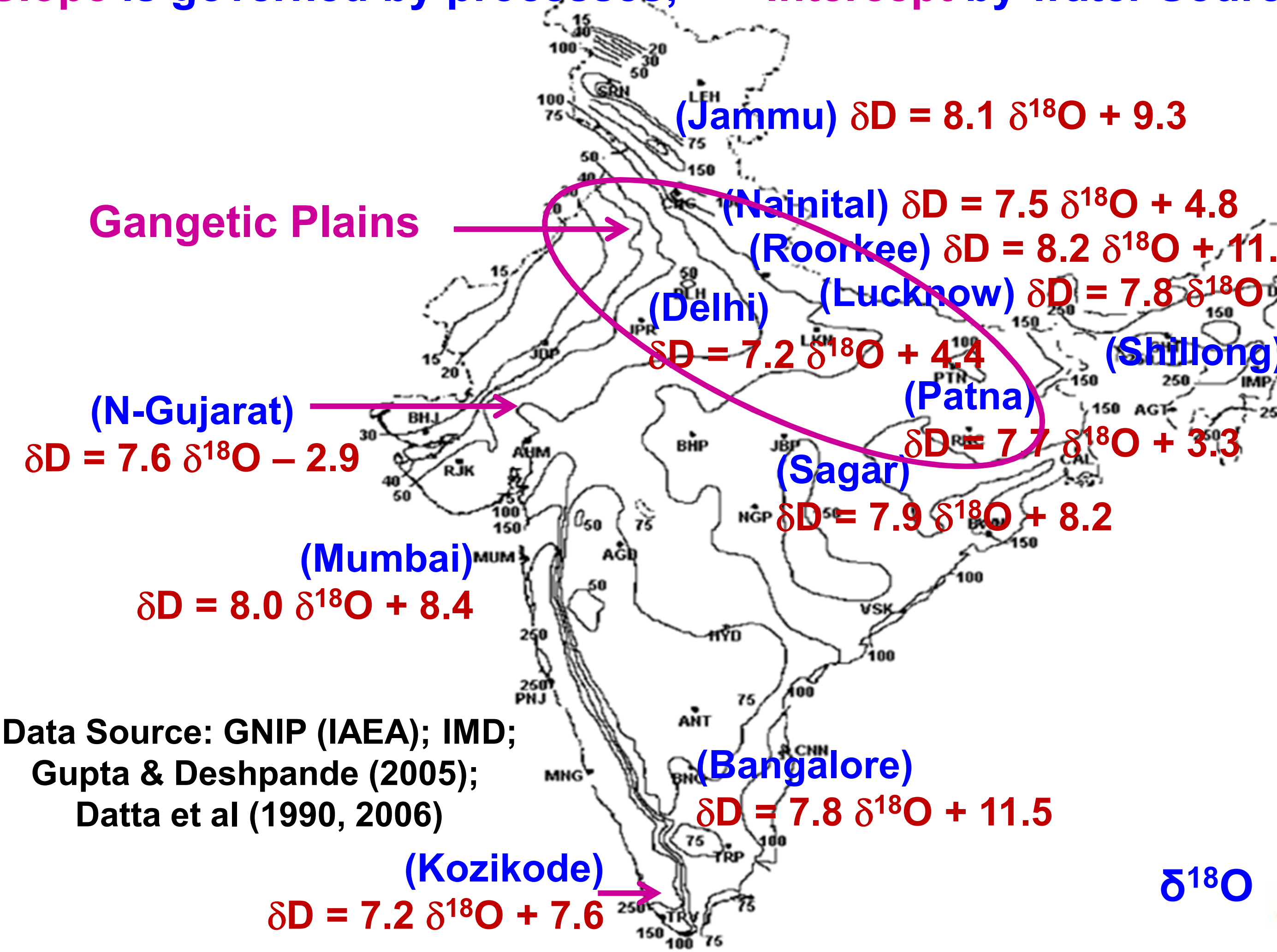




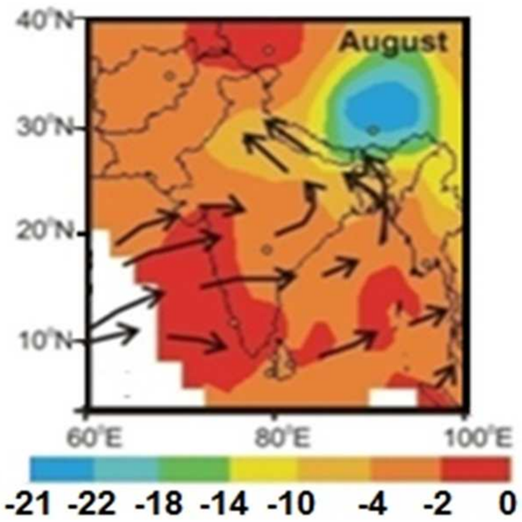
Borole, (1979); Gupta & Deshpande (2005)

LOCAL METEORIC WATER LINES IN INDIA

Slope is governed by processes; Intercept by water Source/Origin/Nature



Data Source: GNIP (IAEA); IMD; Gupta & Deshpande (2005); Datta et al (1990, 2006)



Minor to significant kinetic evaporation of rainfall before GW recharge.

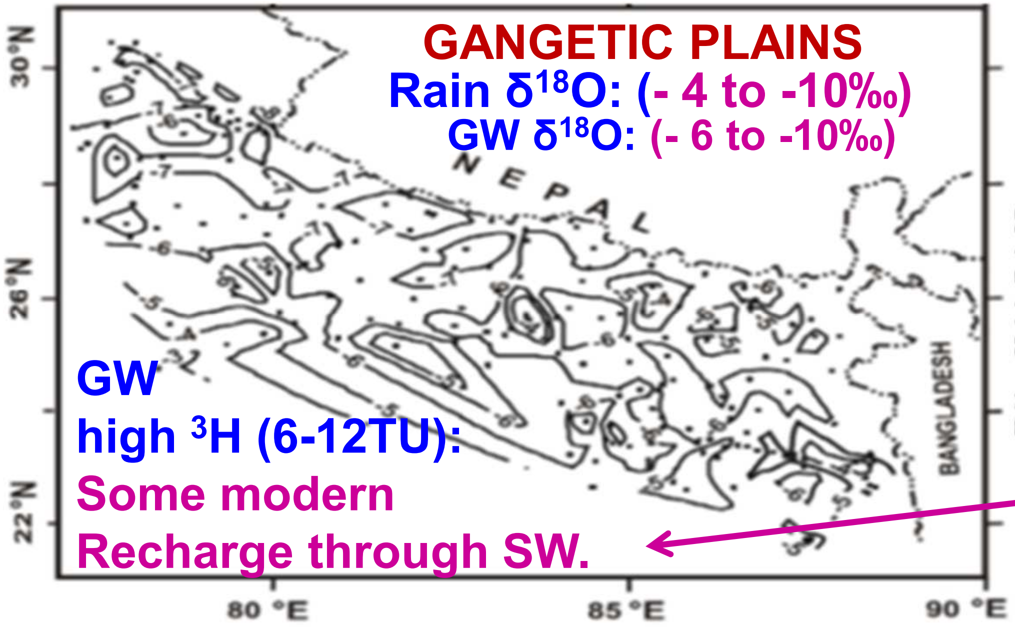
Av. $\delta^{18}O$ and ^{3}H in RAINFALL & GW in INDIA

GANGETIC PLAINS

Rain $\delta^{18}O$: (- 4 to -10‰)

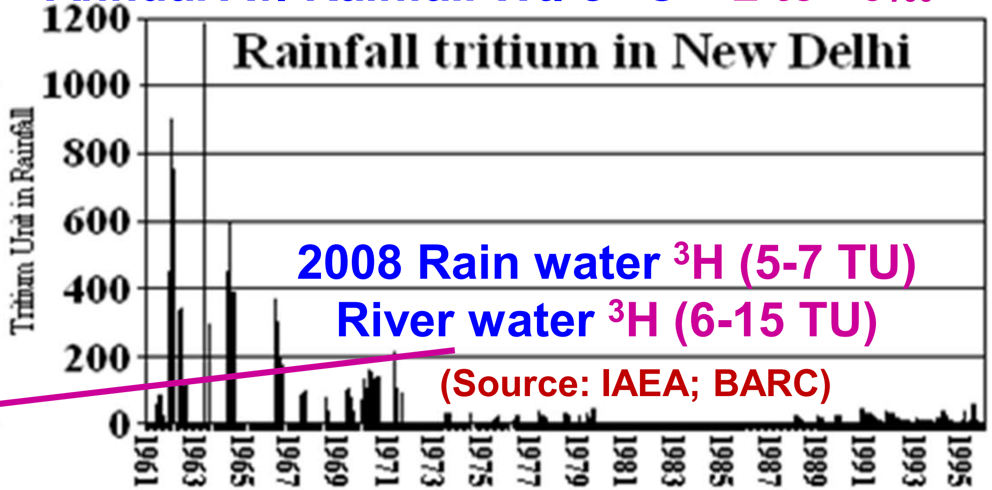
GW $\delta^{18}O$: (- 6 to -10‰)

GW high ^{3}H (6-12TU): Some modern Recharge through SW.



Av. annual rainfall ~117 cm (4000 bcm)

Annual Av. Rainfall Wt. $\delta^{18}O$ –2 to –6‰



2008 Rain water ^{3}H (5-7 TU)

River water ^{3}H (6-15 TU)

(Source: IAEA; BARC)

N-Gujarat Rain $\delta^{18}O$ -2 to -4‰

West Coast Rain δ^{18} : -1 to -2‰

Along west coast: GW $\delta^{18}O$ -1±1‰

CR Rain $\delta^{18}O$ -2 to -4‰

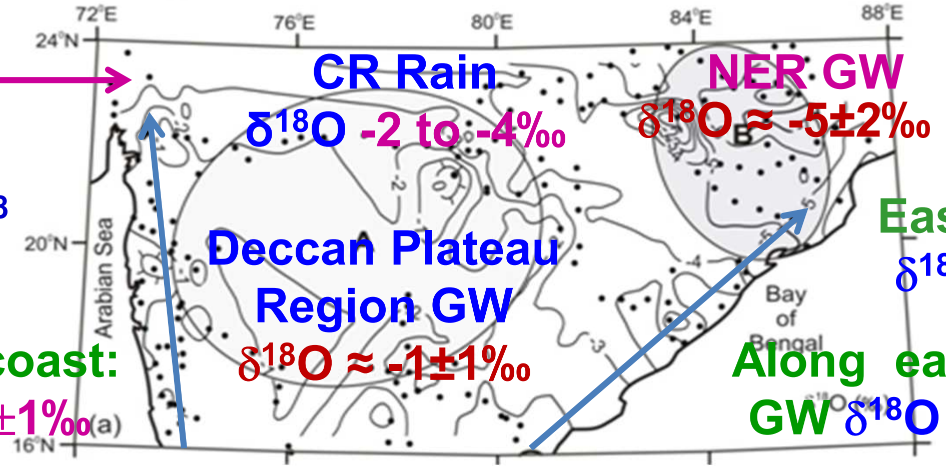
Deccan Plateau Region GW $\delta^{18}O \approx$ -1±1‰

NER GW $\delta^{18}O \approx$ -5±2‰

Shillong Rain $\delta^{18}O$: -3 to -11‰

East Coast Rain $\delta^{18}O$: -2 to -7‰

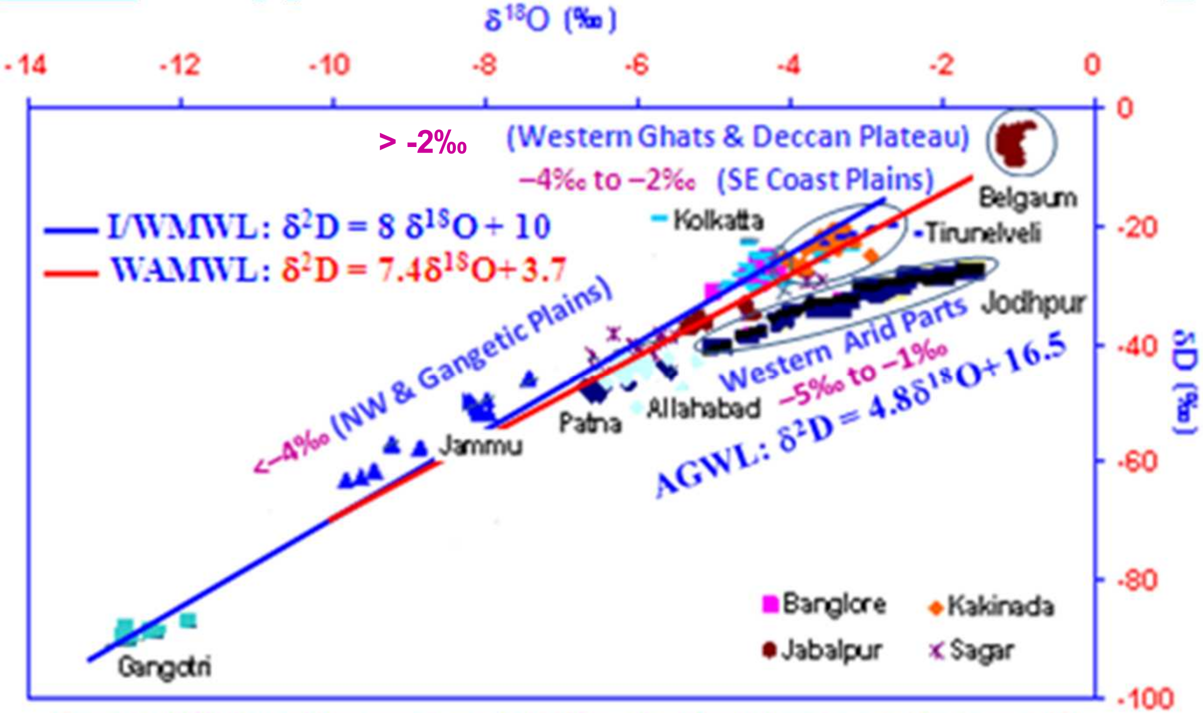
Along east coast: GW $\delta^{18}O$ (-5±2‰)



GW exhibit reasonable correspondence with rainfall $\delta^{18}O$.

Source: Datta et al (1996, 1997, 2006); Gupta & Deshpande (2005)

ISOTOPIC CHARACTERIZATION OF GW IN INDIA

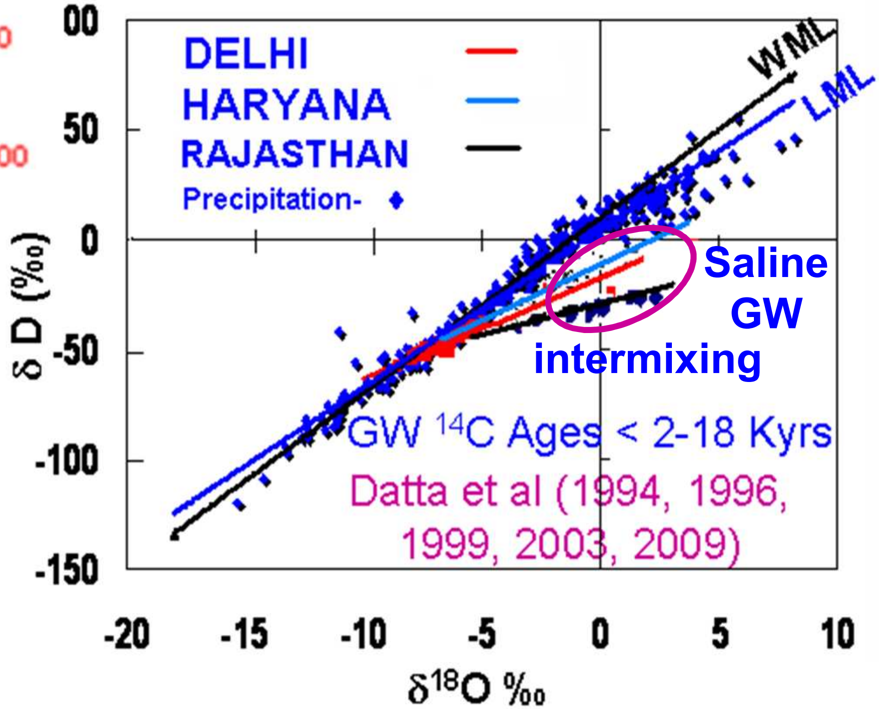


(Source: URL: http://www.prl.res.in/%7Ewebprl/web/announce/ind-gw.pdf)

Recharge from both ^{18}O depleted (NW & IGP) and ^{18}O enriched (W&S) evaporated rainwater.

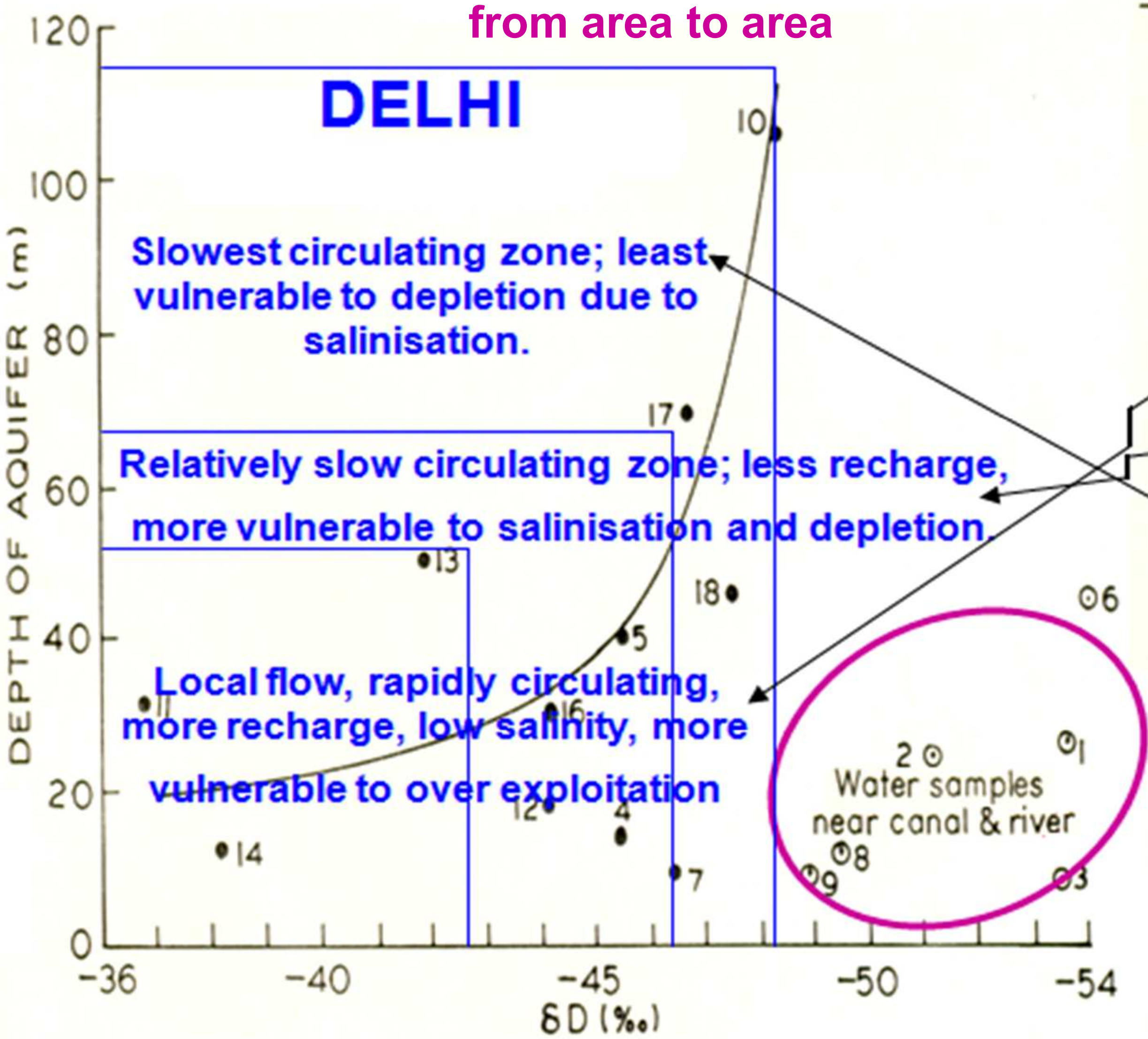
Intermixing of saline GW with fresh water.

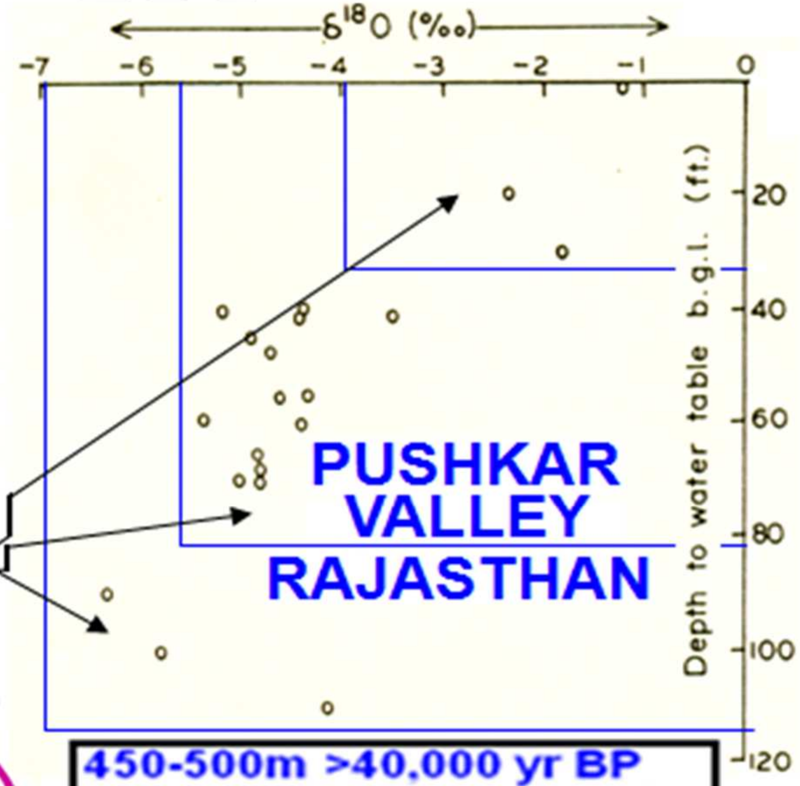
^{3}H age <50 yr &
^{14}C age 2,000-22,000 yr BP
suggest GW Recharge
from both modern rain &
past relatively humid climate.



GW STRATIFICATION

Depth & Thickness of stratified zones vary from area to area



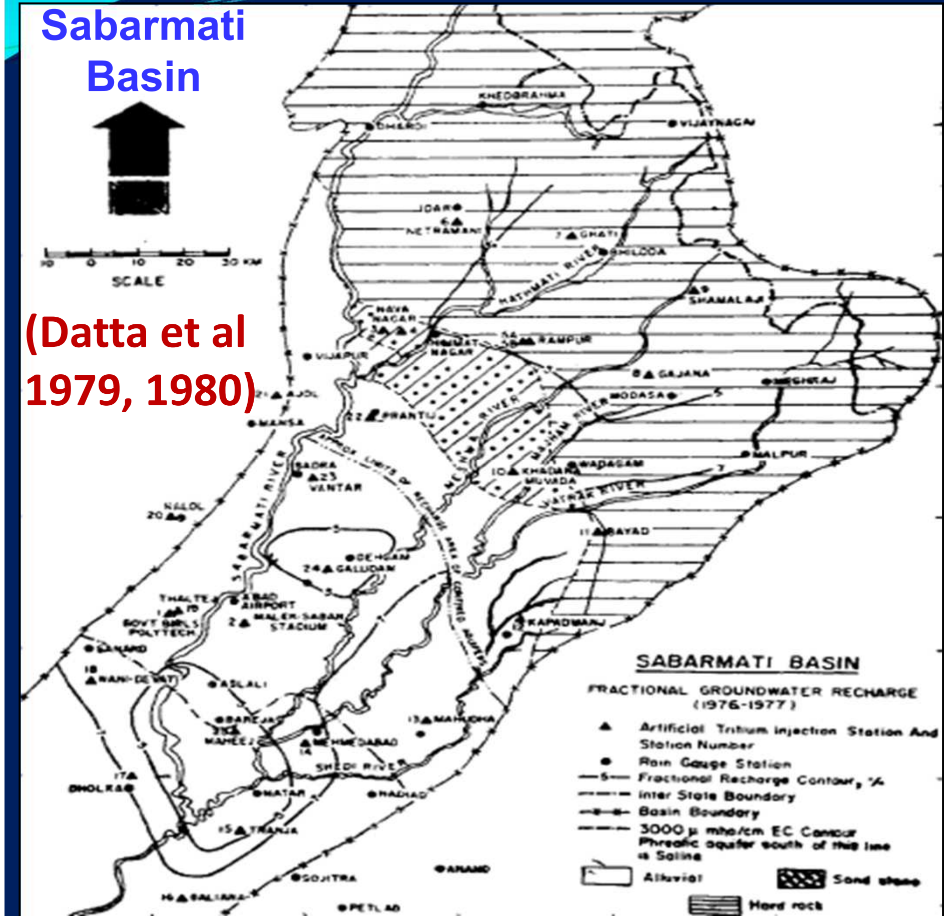


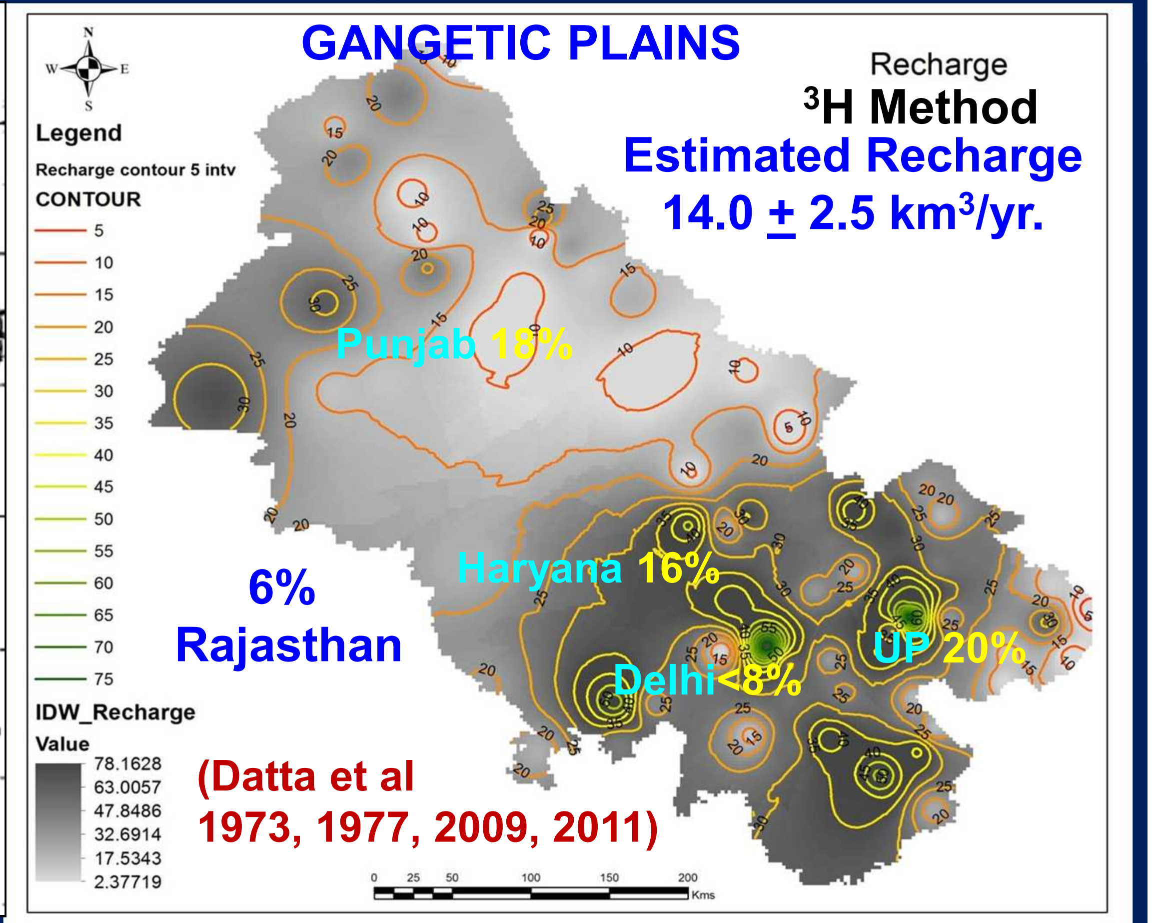
450-500m >40,000 yr BP
δ18O -4.45 ‰
~200m ~9,000-17,000 yr BP
δ18O - 7.00 ‰
Aquifers are Independent

JAISALMER
GW Salinity increases with depth >100m

Datta et al (1994, 1998); Reddy (2011)

GW Recharge (%) from Rainfall in NW India



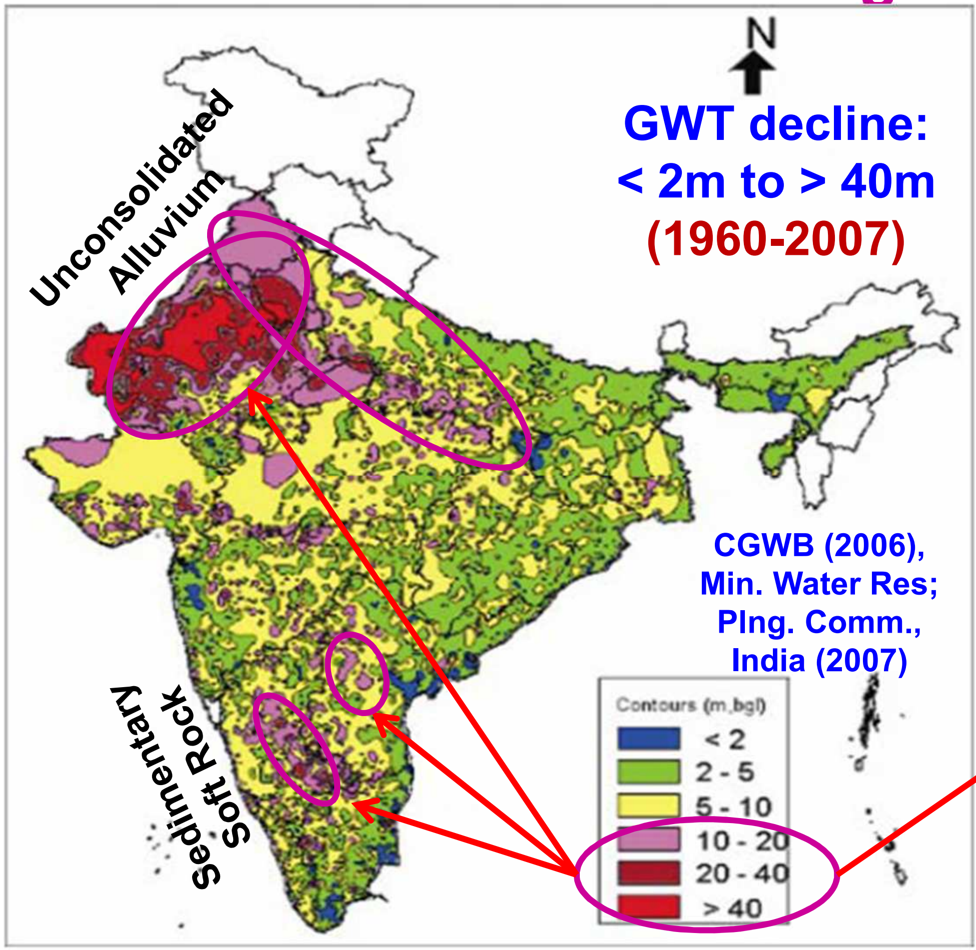


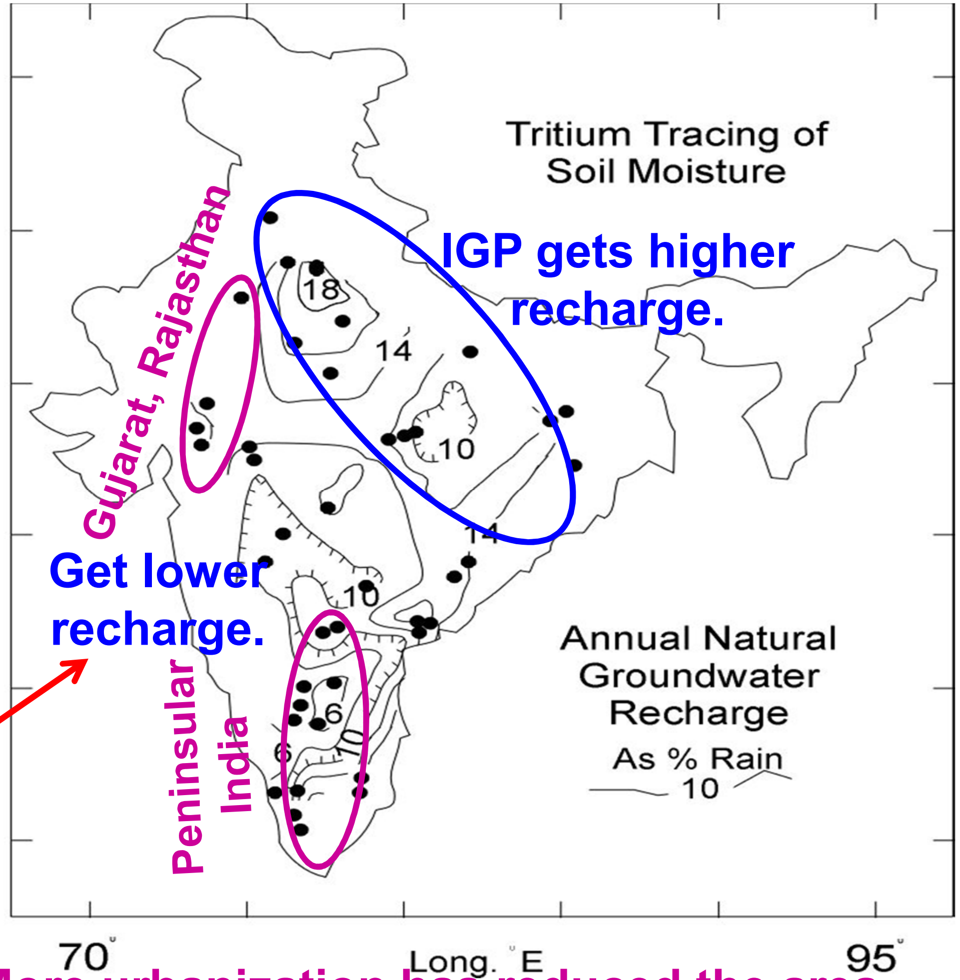
Av. GW Recharge: <7%
0.66 km³/yr = 660 MCM

Increase in temperature & snow-melt run-off may increase recharge in IGP.

Decline in Himalaya glaciers retreat since 1970 and higher variability & declining rainfall trends in monsoon months may decrease recharge.

Present Av. GW Recharge from Rain in India: 11.5 ± 3.6%





GW development: 100-300% (Delhi), 125% (Punjab), 109% (Haryana), 125% (Rajasthan), 70-100% (UP), 85% (Tamil Nadu), 76% (Gujarat)

More urbanization has reduced the area directly exposed to rainfall intake for GW recharge, decreasing the GW potential.

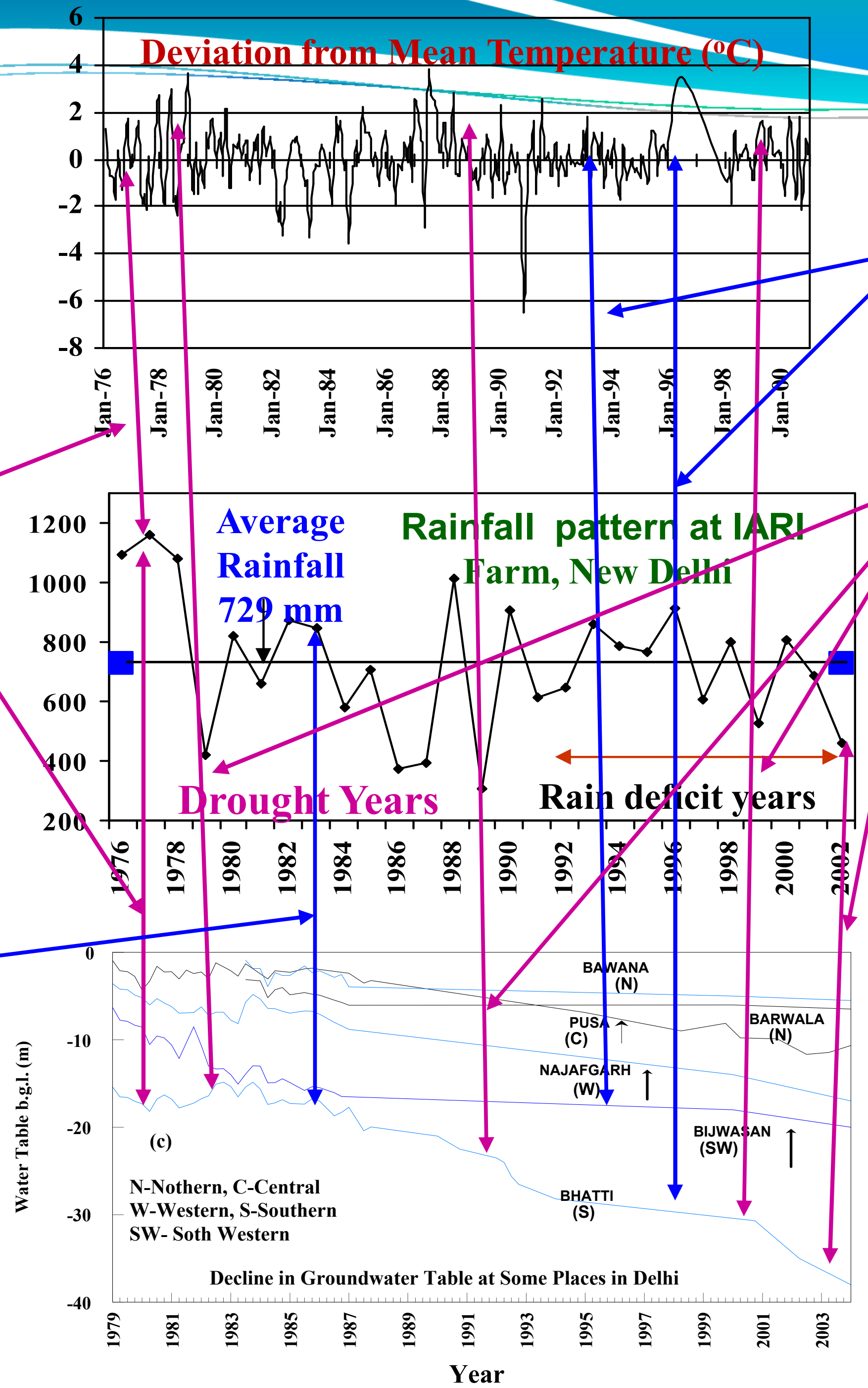
Anticipated rise in sea levels may threaten coastal aquifers by saline intrusion in West Bengal, Gujarat, Tamil Nadu, Andhra Pradesh & Maharashtra.

Datta et al (1973, 1977, 1979, 1980, 2009); Gupta & Deshpande (2005)

Temperature & Rainfall Influence on Delhi GW

1977
High rainfall, less temp. anomaly; GWT within 6-8m bgl .

1983
Less rainfall, GWT declined to 10-14m bgl.



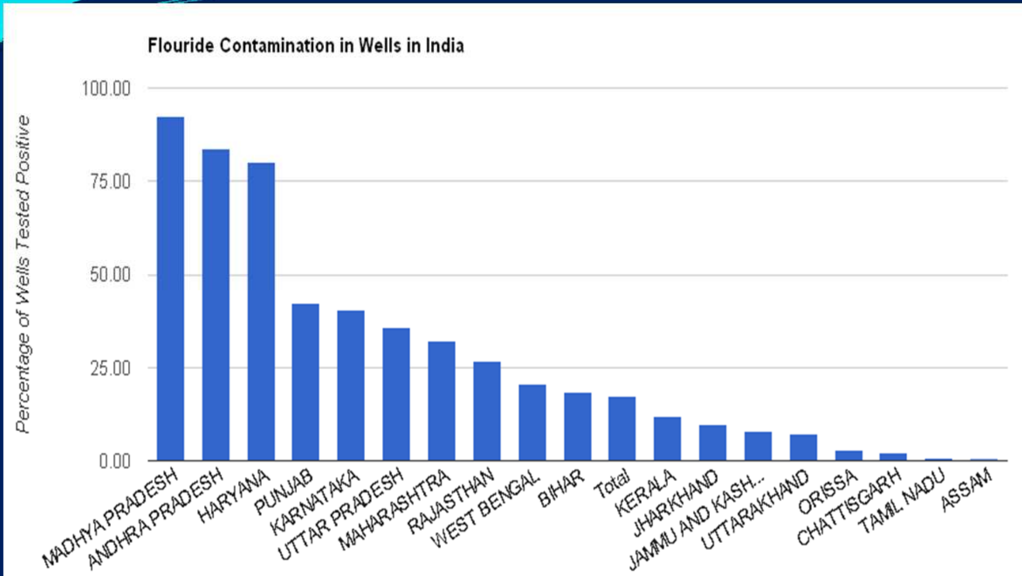
1993 -1996: normal rainfall & less temp. anomaly kept the water table stable.

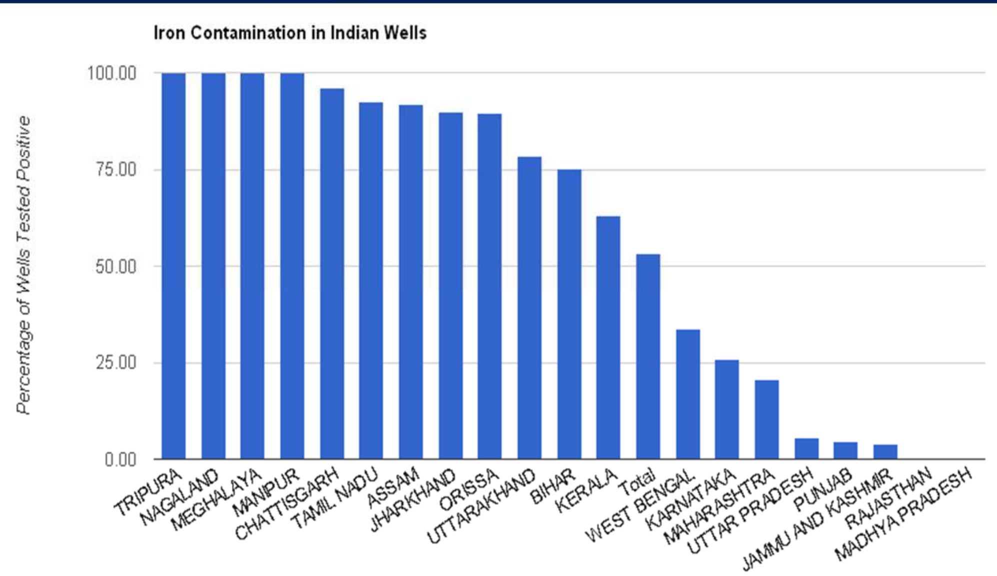
1979 &1989, 1999 & 2002 very low rainfall high temp. anomaly, GWT declined considerably.

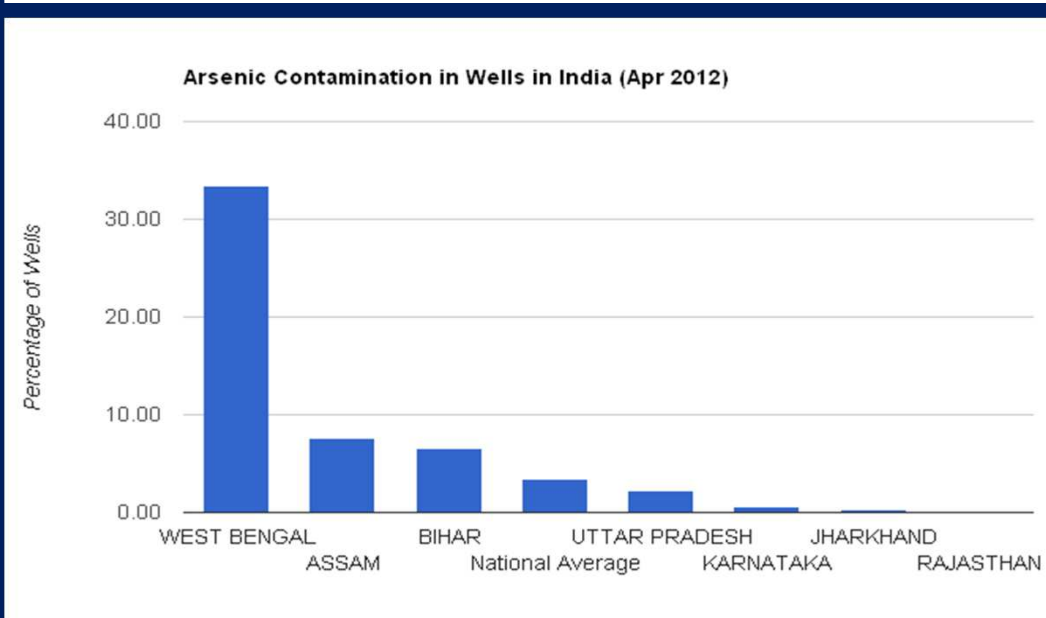
It is not certain how individual water catchment areas respond to changing temperature and rainfall.

Datta et al (2004)

STATUS OF GW POLLUTION IN INDIA







More than half of India's wells are moderately to highly polluted.

East & South GW: As & Fe

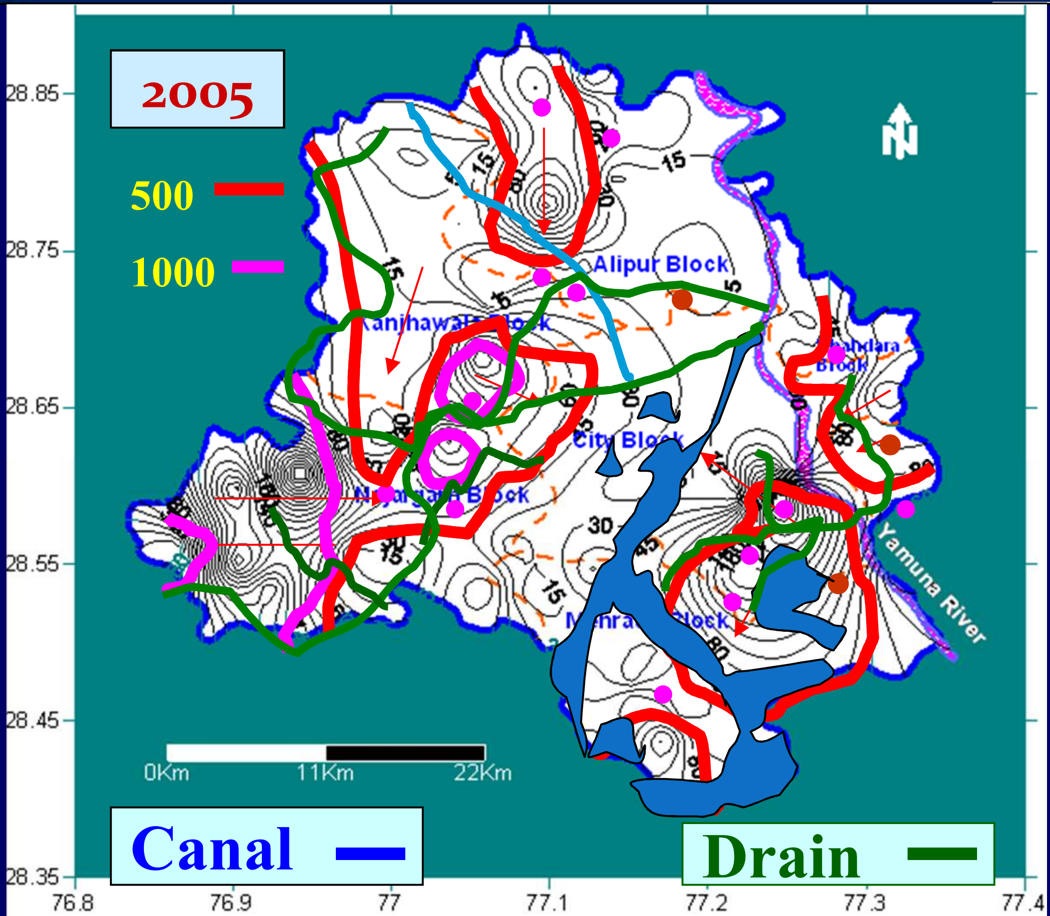
North and West GW: F

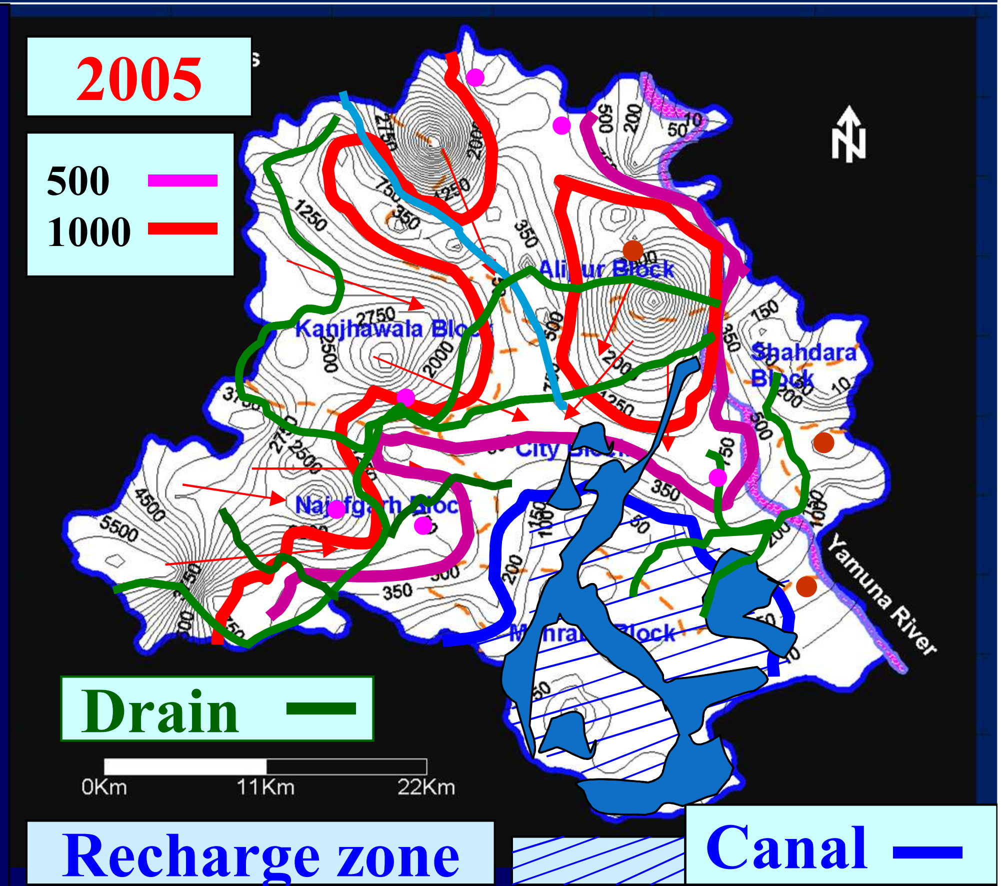
Orissa, Jharkhand, Tamil Nadu, Kerala, Uttarakhand, Bihar & NE-States GW: High Fe

Maharashtra & Karnataka GW: High NO_3

Source: Real Time News (9th Sep, 2012)

High Nitrate (mg/l) and High Chloride (mg/l) Plumes Dynamics in Groundwater of Delhi Region





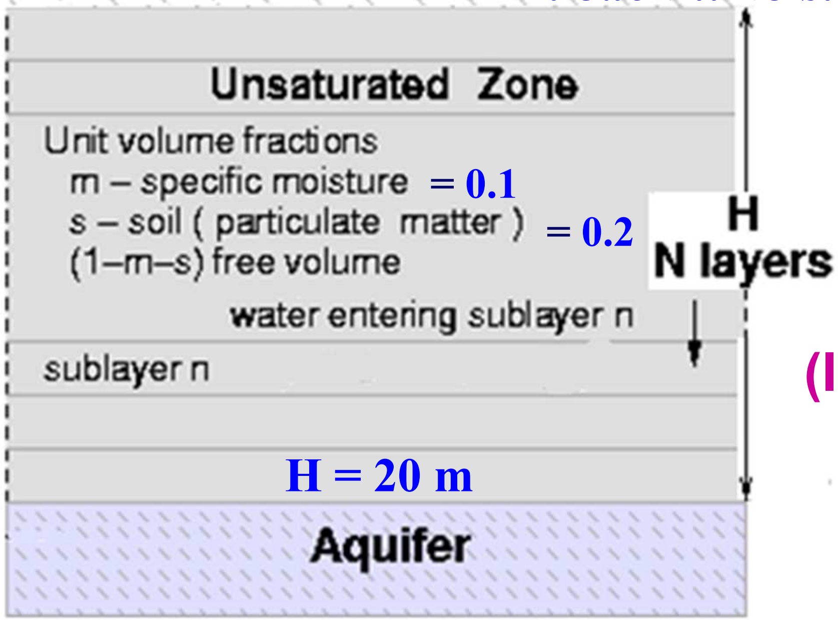
Groundwater is moderately to highly contaminated, with lateral extension of plumes towards the central urban parts along specific flowpaths, induced by withdrawal not in balance with recharge.

Datta & Tyagi (2006)

CONCEPTUAL MODEL TO ASSESS GW RECHARGE AVAILABILITY

Rainfall 'R' falling in 'T' packets of Recharge quantity '$h = (1-m-s)H/N$'

At each time step $T = R/h = NR/(1-m-s)H$



The water after complete mixing in layer *n* leaves this sublayer and enters layer *n+1* with Vol. *v[n+1]*.

Net Recharge (Re) to a layer =

(Input to the layer) + (Mixing in free volume)
– (Output from the layer)
– (retention inside the volume)

$$S_{(T+1)} = (S_T + BRF \times BRV - BDF \times BDV)$$

Estimated Recharge (Re x Area) : 14.8 ± 2.5 km^3/yr
in Punjab, Haryana, Rajasthan & WUP (including Delhi).
Matches with CGWB estimated GW withdrawal : 13.2km^3/yr
Dynamic component of GW in the WT fluctuation zone is replenished annually, and has been assessed as 432 bcm.

TO WRAP UP

Climate Effects on Tropical Water Regimes – Harder to predict

Impact of Climate Change on India’s GW is not apparent.
Basic scientific information is scarce.

Presented evidences suggest:

In the early quaternary North-West India was well watered.

LGM (30000-12000 yrs BP): Pluvial climate preserved GW in deep aquifers and in shallow aquifers by interaction with lakes and rivers & by recharge.

During last 50 years, temperature & rainfall show declining trend or not significant change.

Past decades & decades little rainwater could recharge GW

CONCLUDING REMARKS

For GW recharge to be a major response to Climate resilient GW management, it is desirable to:

- **Monitor:** Variability in GW recharge & pollution dynamics.
- **Revise:** All such estimates time to time , in relation to the changes in land/water use & reconsider.
- **Expand:** Geographical coverage of paleowaters, vertical stratification, lateral non-homogeneity, GW flow-pathways of intermixing, from high-resolution data on paleoclimate records from tree rings, ice-cores and lake-sediments.
- **Identify:** Pollution sources and strategies for containment of pollution spreading from known sources.
- **Develop:** Vulnerability maps of GW contaminants levels.
- **Delineate:** Potential GW recharge & protection zones.

ADAPTATION STRATEGIES

- **Evolve:** Integrated GW management strategy, considering different timescales of GW recharge.
- **Assess:** Past successes & failures and adjust policies according to local condition.
- **Conduct:** Studies on competition among water users (private and public); inter-sectoral (irrigated agriculture and urban water supplies).
- **Examine:** People's adaptive strategies & the policy implications, etc., when GW scarcity is faced.
- **Direct:** Resources & energies to promote GW recharge in hotspot areas, to reduce GHG emissions from pumping and to restore the GW resilience from climate.


Thank you