Water stress, systems thinking and adaptive governance in an urbanizing basin: Water Supply in Bangalore

By
Veena Srinivasan
(ACCUWa PIs: Sharachchandra Lele, Bejoy Thomas, Priyanka Jamwal)

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Project ACCUWa

ATREE

Outline

- Bangalore's Water Problem and Proposed Solutions
- Bangalore in the basin – upstream and downstream issues
- Some conclusions for systems thinking on Bangalore's water issues.

BANGALORE'S WATER SITUATION AND PROPOSED SOLUTIONS

Bangalore Water Supply: Sufficiency

Is there enough water to serve the city's population?

Water Sources	Million Liters/Day
Cauvery supply in 2001	600
Arkavathy (TG Halli) supply in 2001	110
Total surface water delivery Less losses 42%*	412
Total groundwater pumped[1]	570
Total consumption	982
Less Commercial, Industrial consumption (20%)	245
Total use per capita‡	140 LPCD*

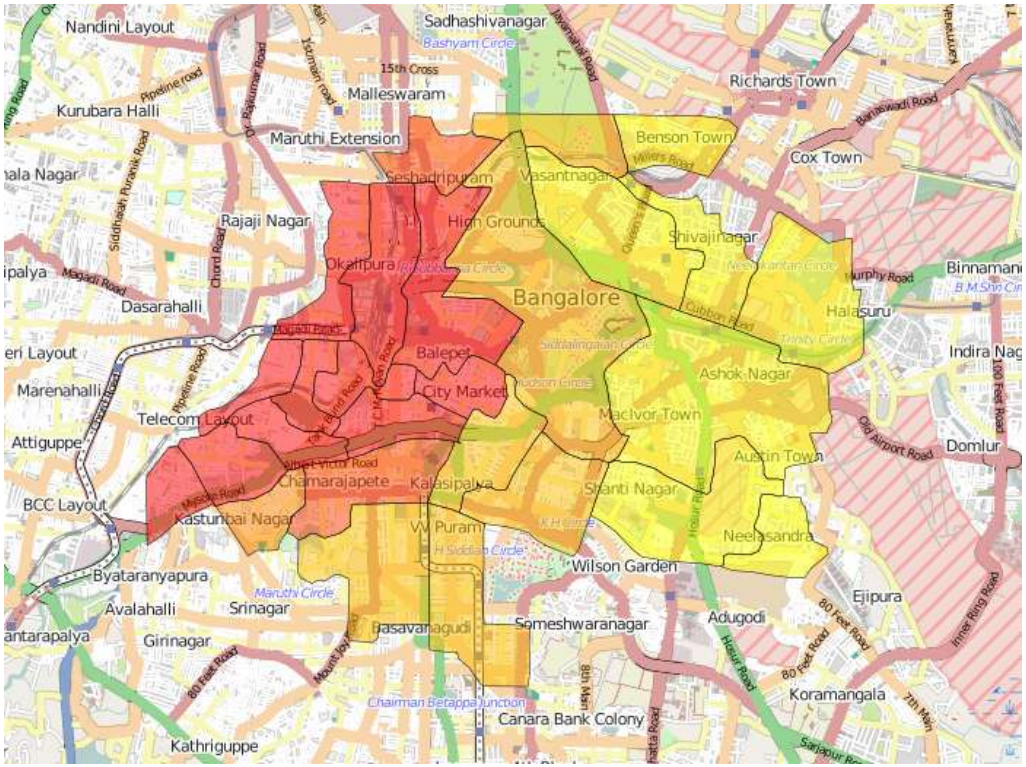
* AUSAID 2001

[1] Estimate based of average of different studies

‡ dividing above by 5.6 million residents in 2001.

Bangalore Water Supply: Equity

Is the current situation fair/equitable?



LPCD Supplied for a sample of wards in Bangalore suggest big variations in supply from 25 to 330 LPCD

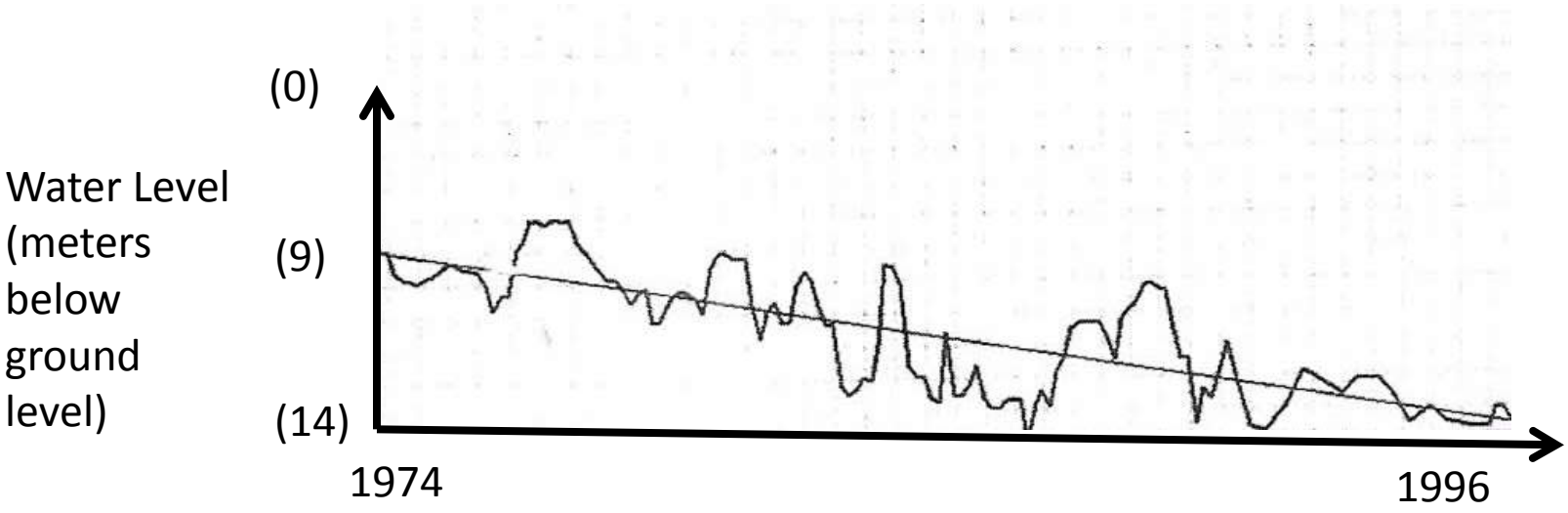
Groundwater extraction is correspondingly higher in wards with lower water supply.

Source: Bangalore Urban Metabolism Project (http://www.urbanmetabolism.in/bump/)

Bangalore Water Supply: Sustainability

Can we sustain supply at current or increased levels into the future?

Sample hydrograph in Yelahanka*

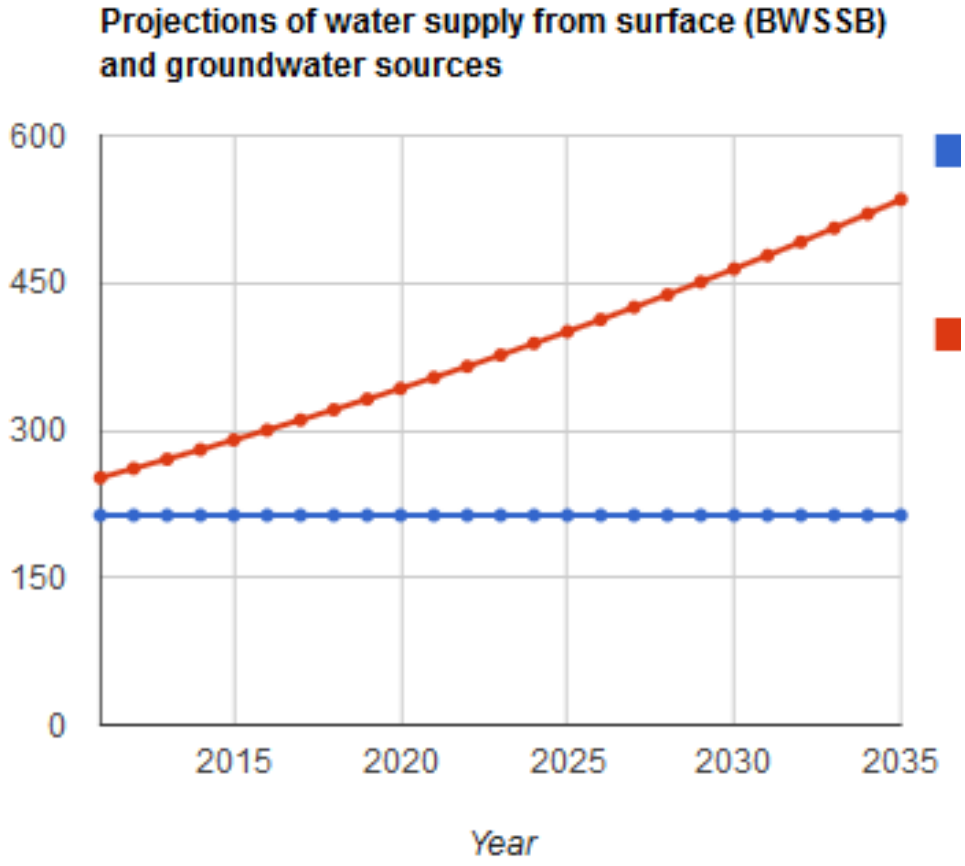


Source: Srikanta Murthy, 2011

Situation is mixed. Even at current extraction rates, GW Levels have been declining in peri-urban areas (but are rising/stable in central Bangalore).

Bangalore Water Supply: Sustainability

Sustainability: Can we sustain supply at current or increased levels into the future?



Source: Bangalore Urban Metabolism Project Scenarios (http://www.urbanmetabolism.in/bump/)

Bangalore Water Supply: Resilience

How resilient is the city to a multi-year drought?

Bangalore currently is heavily dependent on a single source of water the Cauvery.

A major source of vulnerability during multi-year droughts.

- Inter-state conflicts
- Conflicts with Mandya farmers

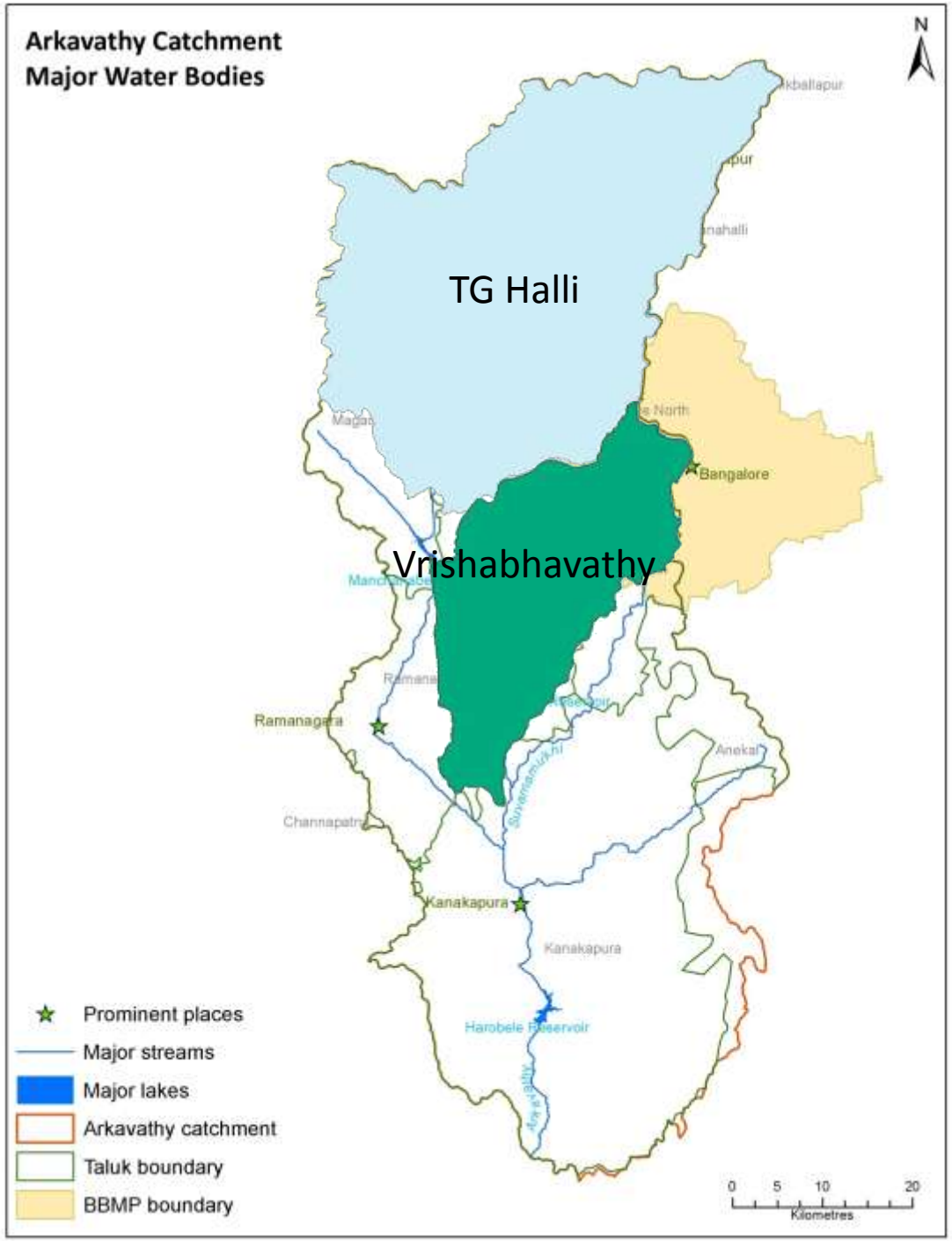
What are the solutions?

Planned:
Cauvery Stage IV Phase 2

Proposed Hard Options:
Netravati (Yettinahole)

Proposed Soft Options:
Wastewater Recycling (Decentralized, Nandi Hills, Agriculture),
Rejuvenating the Arkavathy.
Groundwater Recharge
Rainwater Harvesting
Efficiency Improvement (Fixing Leaky Pipelines)

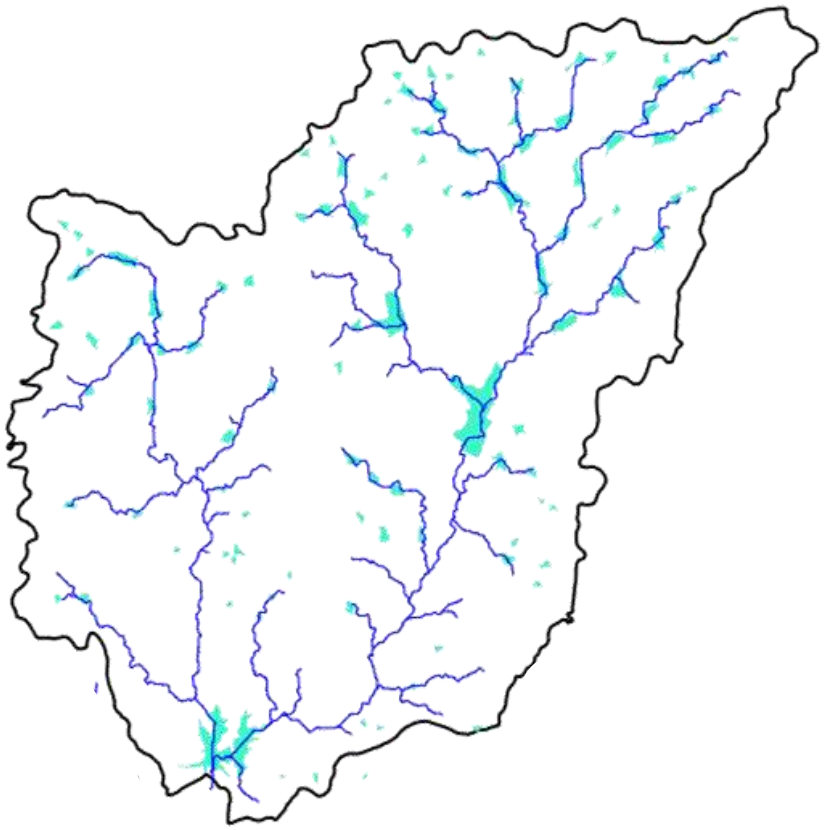
BANGALORE'S WATER SITUATION – WHAT CAN WE LEARN FROM A SYSTEMS PERSPECTIVE?



TG Halli Catchment

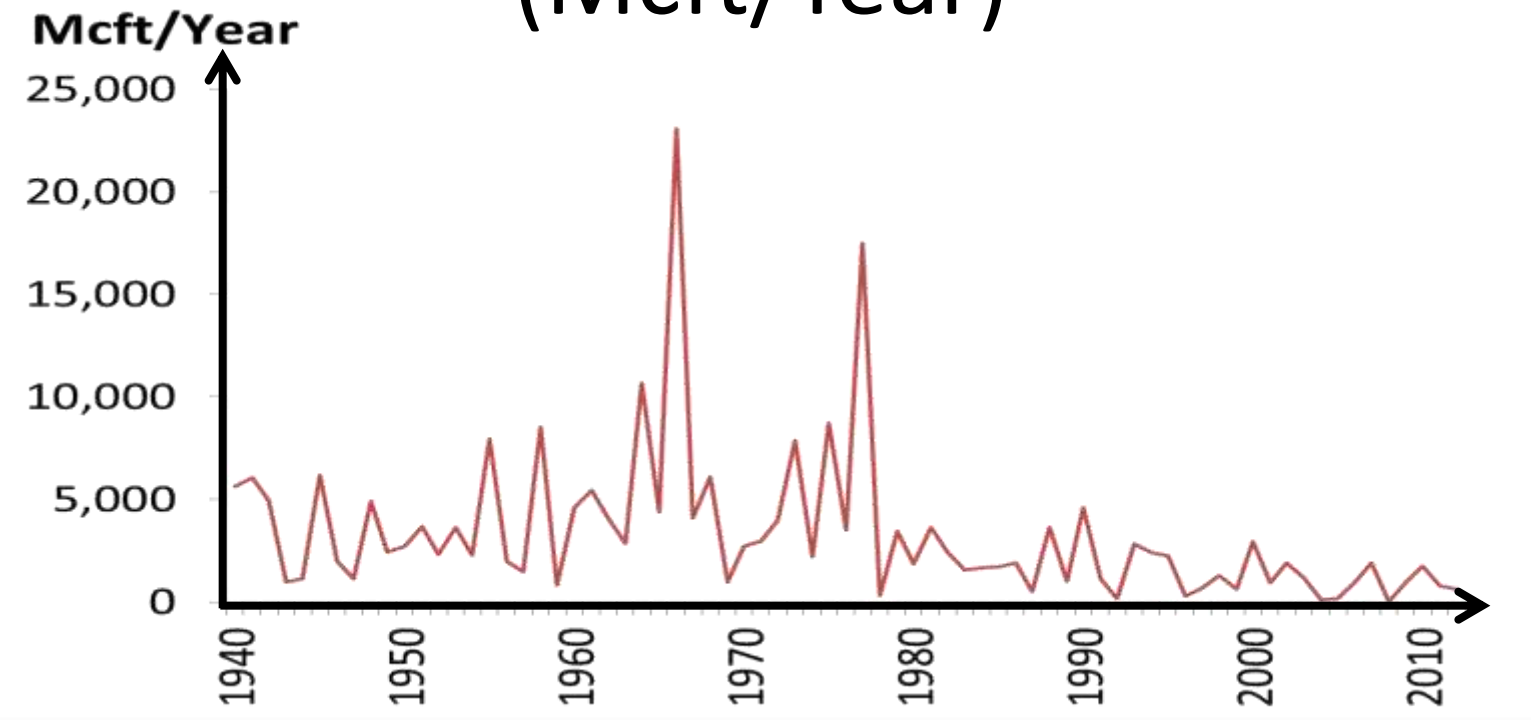
THE UPSTREAM PROBLEM

The Upstream Problem: TG Halli



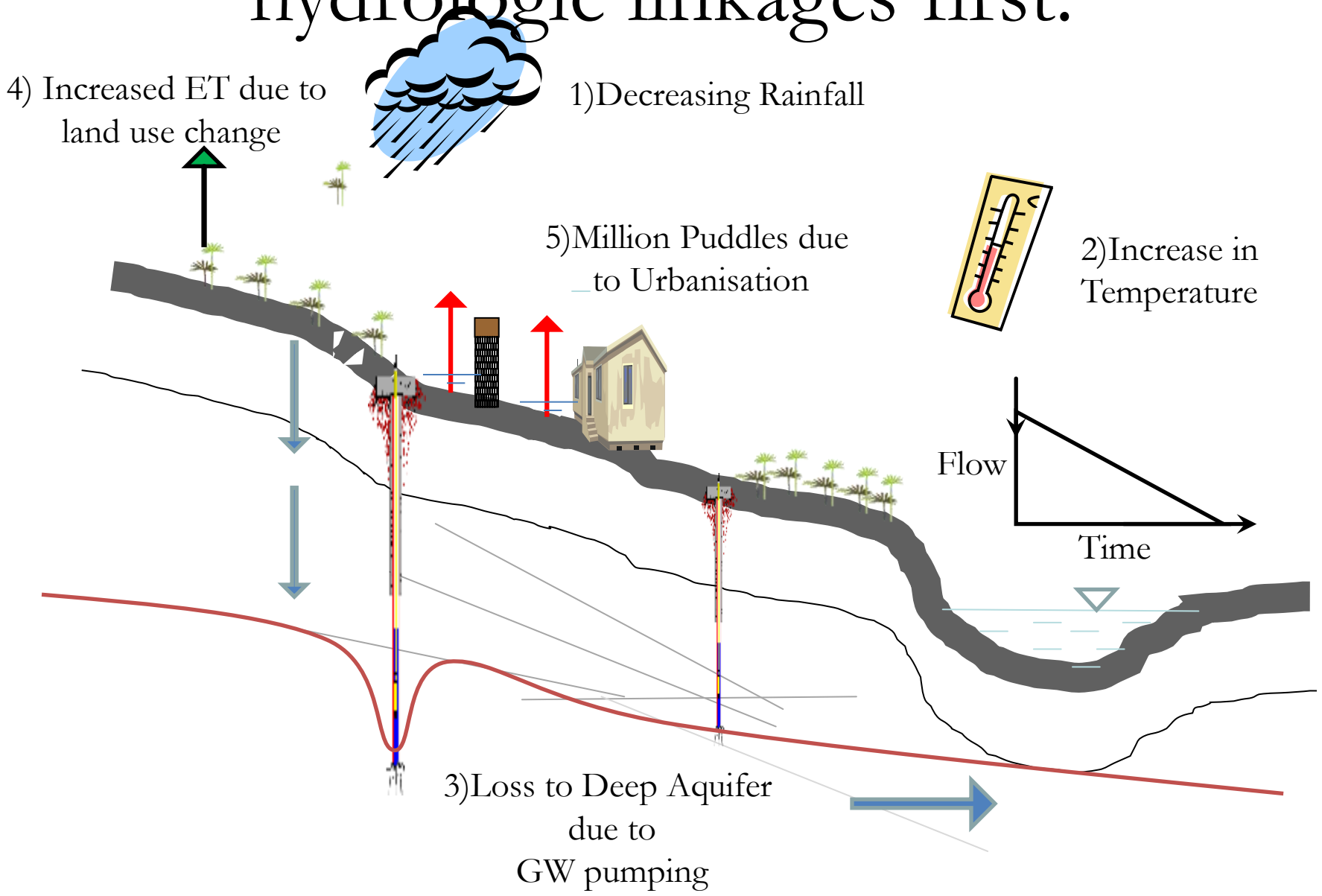
- Approximately 1400 sq km * 800 mm of rainfall
- Used to be a major source of water to Bengaluru
- Design capacity of TG Halli is 148
- Today only yields 30 .

Annual Inflows into TG Halli Reservoir (Mcft/Year)



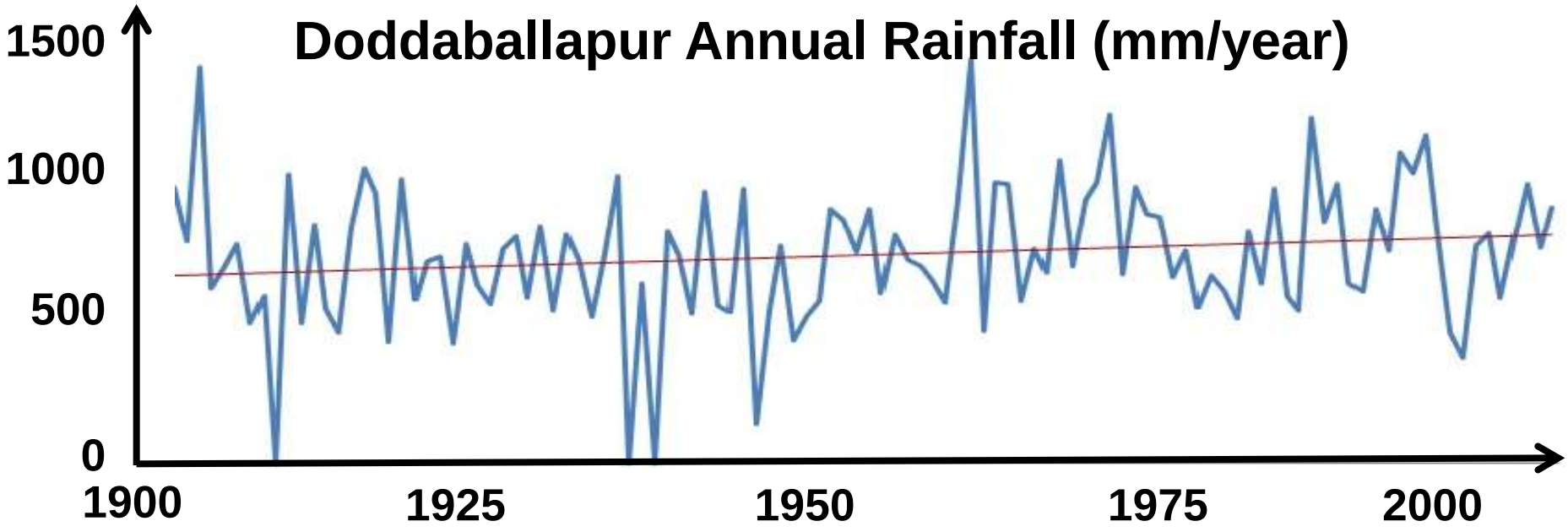
Inflows into the TG Halli reservoir, which supplies Bengaluru, exhibit a sharp declining trend. (No new upstream dams either)

Need to understand socio-hydrologic linkages first.



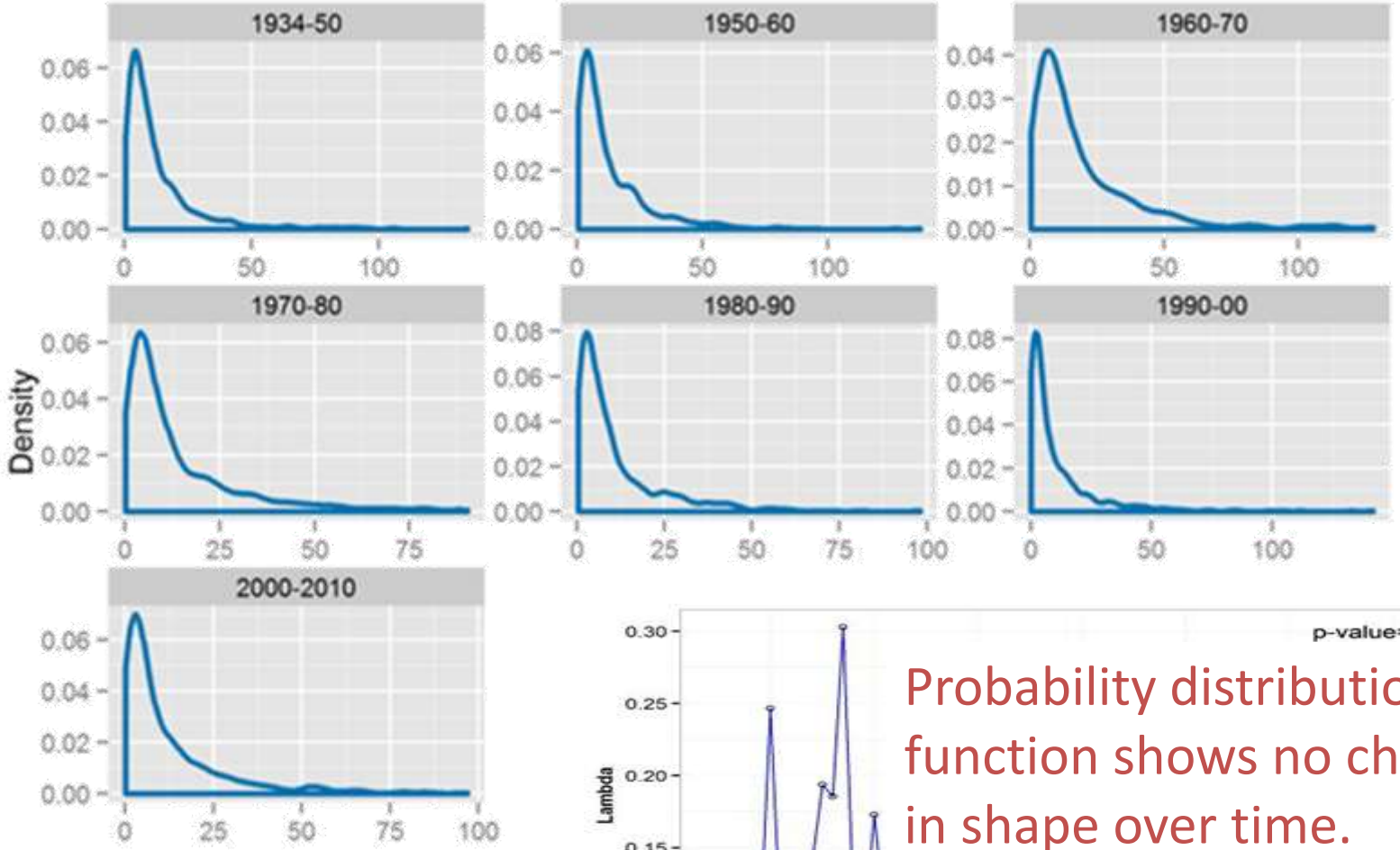
#1: Total Annual Rainfall

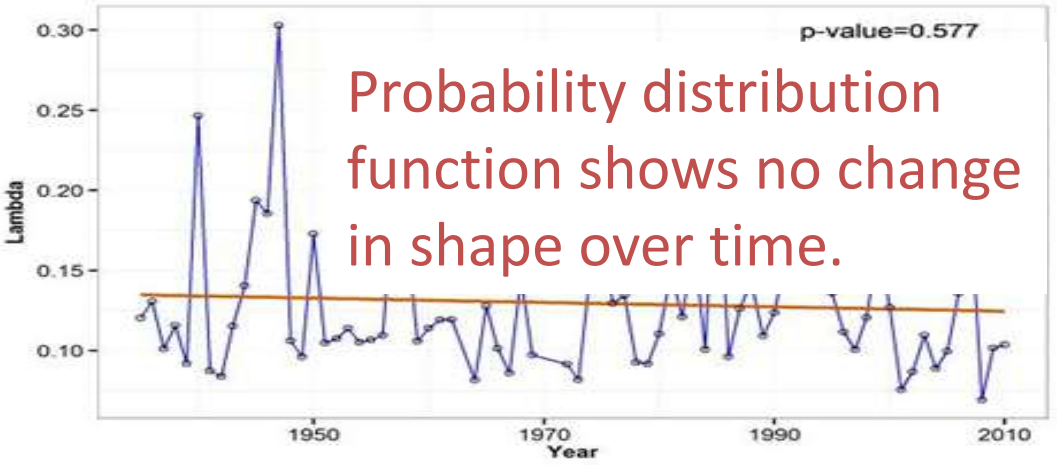
Hypothesis 1. Rainfall is decreasing in magnitude and intensity.



Station rainfall data suggest no trend in rainfall patterns

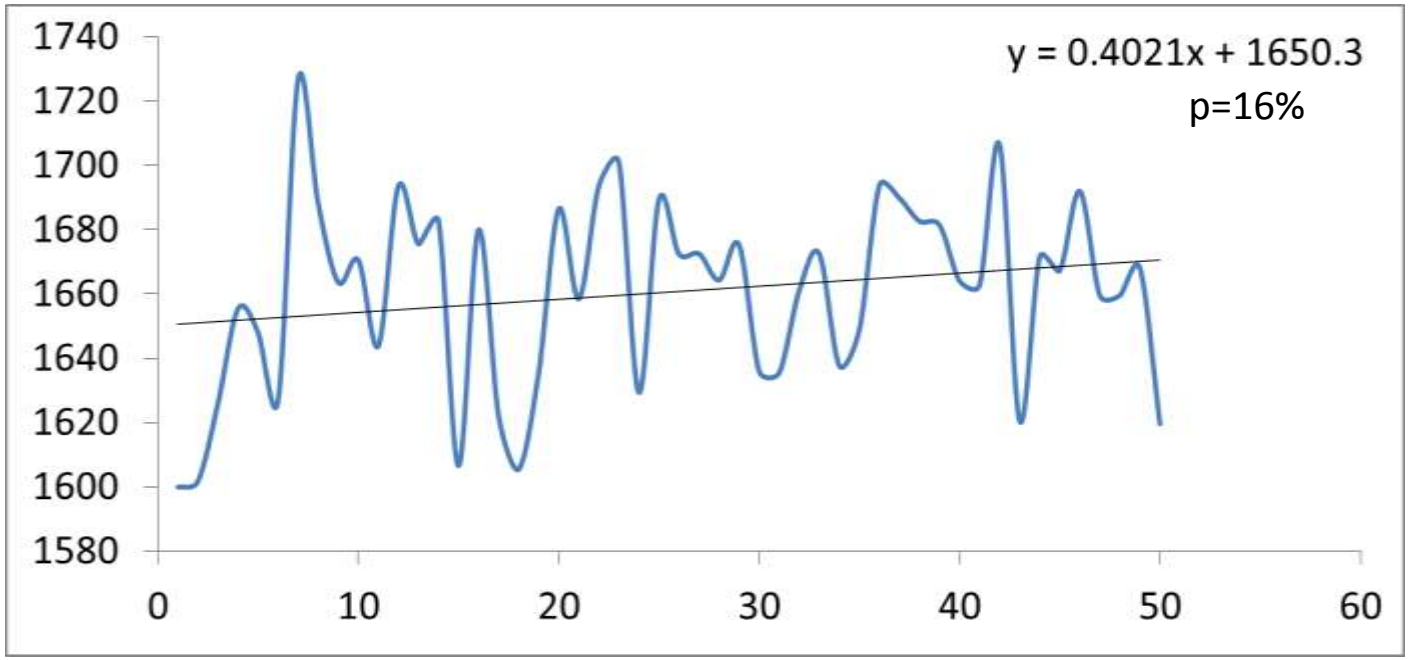
#1: Rainfall intensity





Probability distribution function shows no change in shape over time.

#2: Temperature



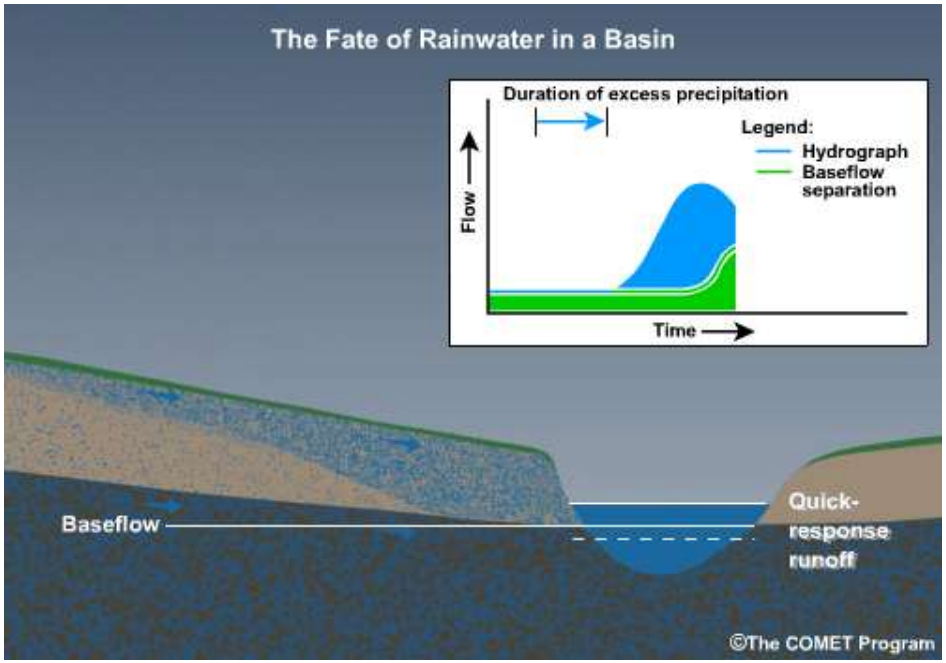
We used the “Hargreaves Equation” to assess effect of temperature on Potential Evapotranspiration (PET)

But trend over time was NOT statistically significant.

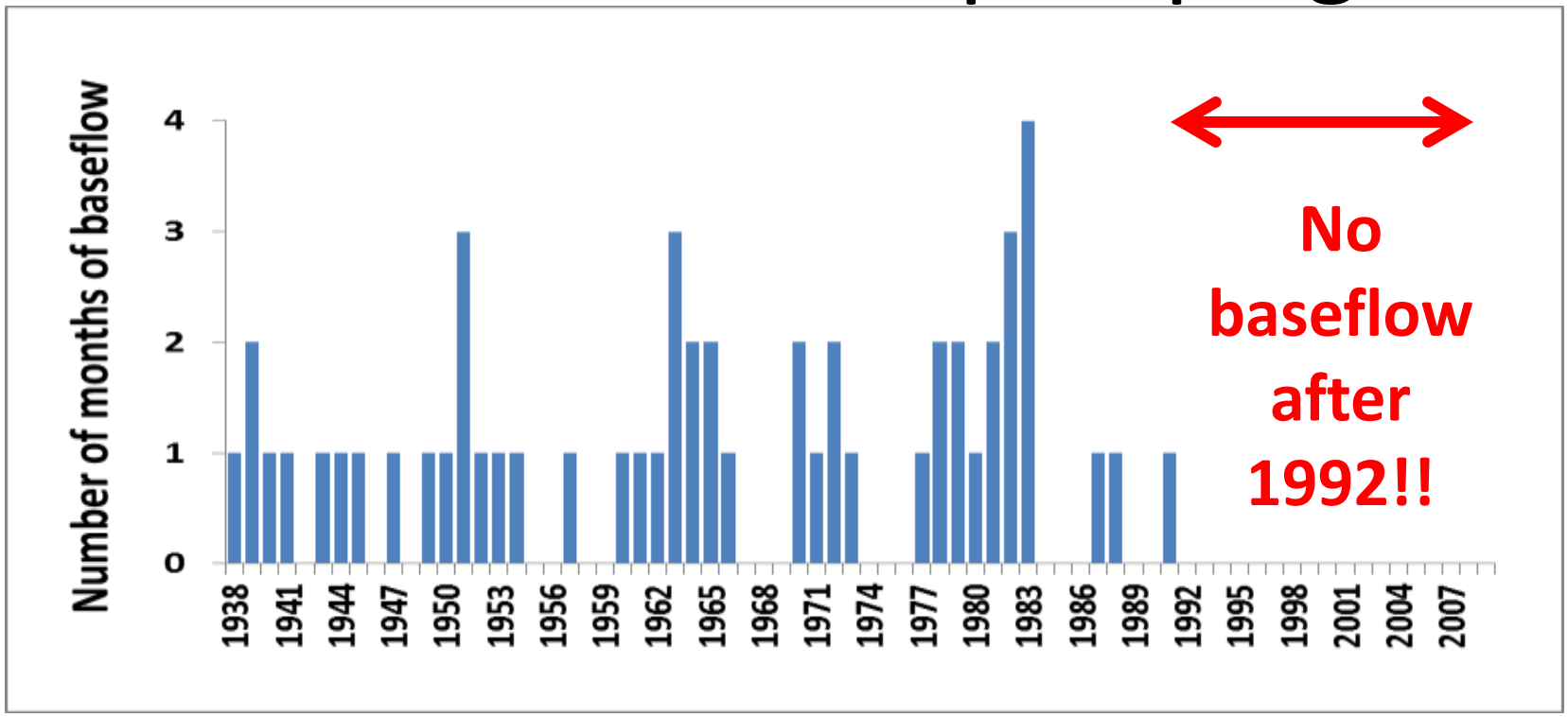
#3: Groundwater pumping

Hypothesis 3. Groundwater pumping is reducing baseflow into TG Halli Reservoir.

Ran a simple model to estimate loss of baseflow into TG Halli using a simple storage-discharge relationship between the aquifer and the stream (baseflow recession). To explain the baseflow loss we need a water table drop of 2-6 m. Obviously, this is observed empirically.



#3: Groundwater pumping



But inflows into TG Halli have continued to decline after 1992. We need to have additional mechanisms of “induced groundwater recharge” to explain losses after 1992.

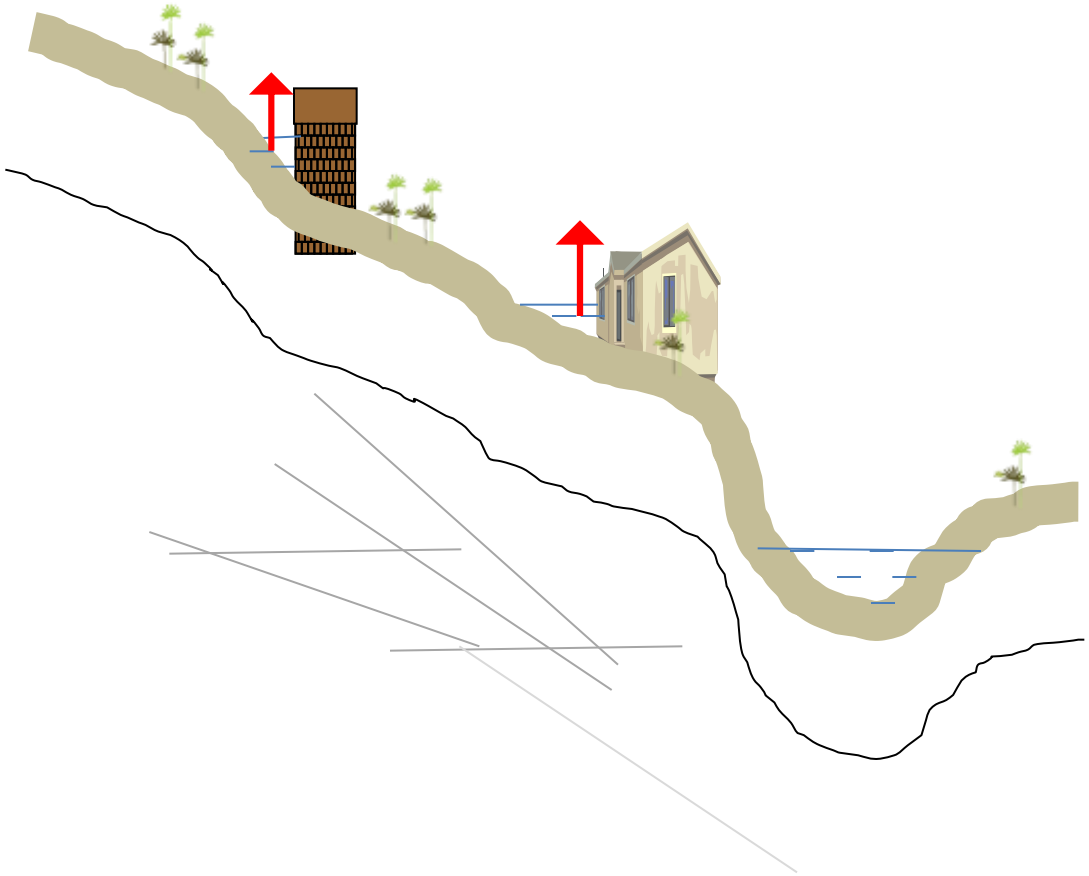
#4: Land Use Change

Hypothesis 4. Evapotranspiration from commercial plantations like Eucalyptus is reducing runoff.

Our field visits and the KSRSAC land use data indicate an increase in plantations in many areas.

Our calculations suggest that even a net conversion of 50 sq km. of the land area from rainfed agriculture to Eucalyptus would be sufficient to eliminate flows into TG Halli reservoir.

#5: Million puddle theory



Hypothesis 5. Unplanned urbanization causing water to collect in a “million puddles” and evaporate

#5: Million Puddle Theory

Type	Hesarghatta	Kumudavati	Arkavathy
Check dam	70	65	142
Culvert	3	26	97
Bridge	4	23	31
Road	0	2	7
Cultivation	10	0	0
Water body	3	0	0
	90	**116**	**277**

We know the number of blockages in each sub-watershed of TG Halli and their average size =>

Estimated blockage/year ~ 12

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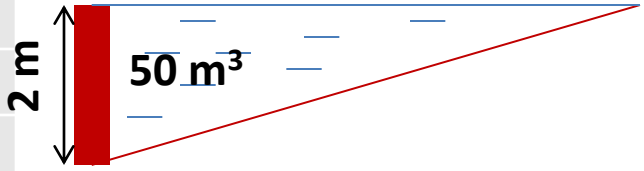

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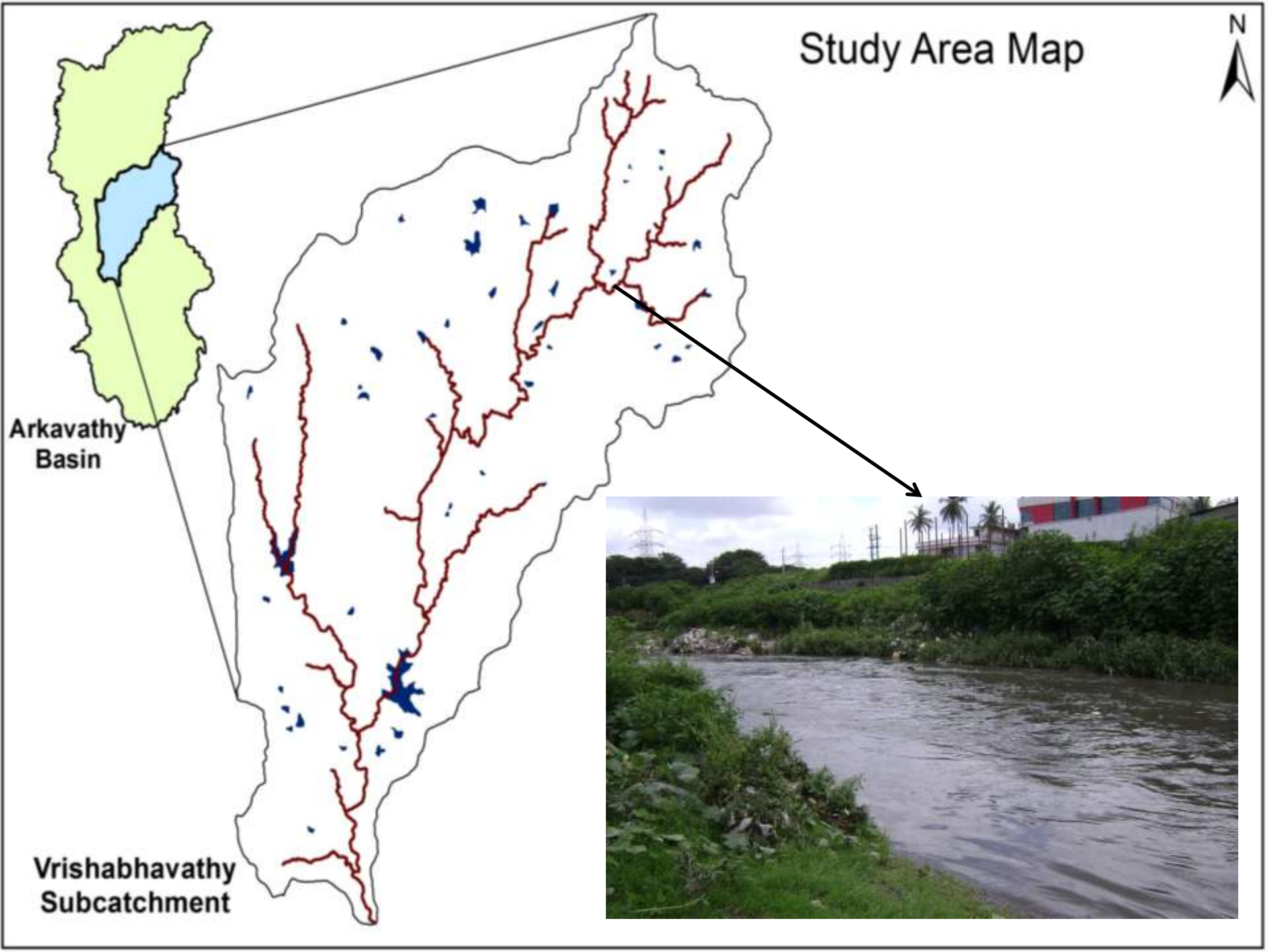
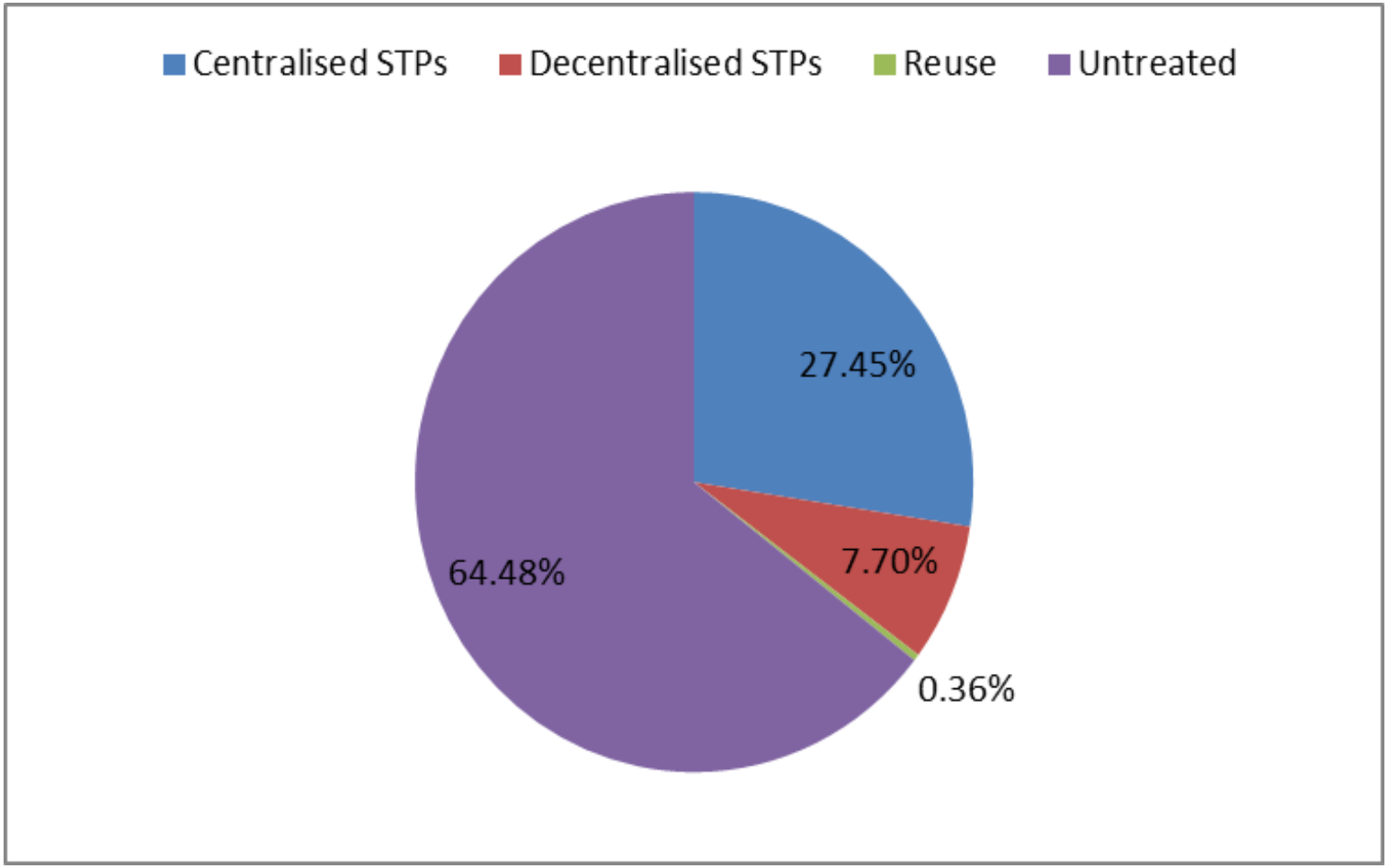
THE DOWNSTREAM PROBLEM

Study Area Map

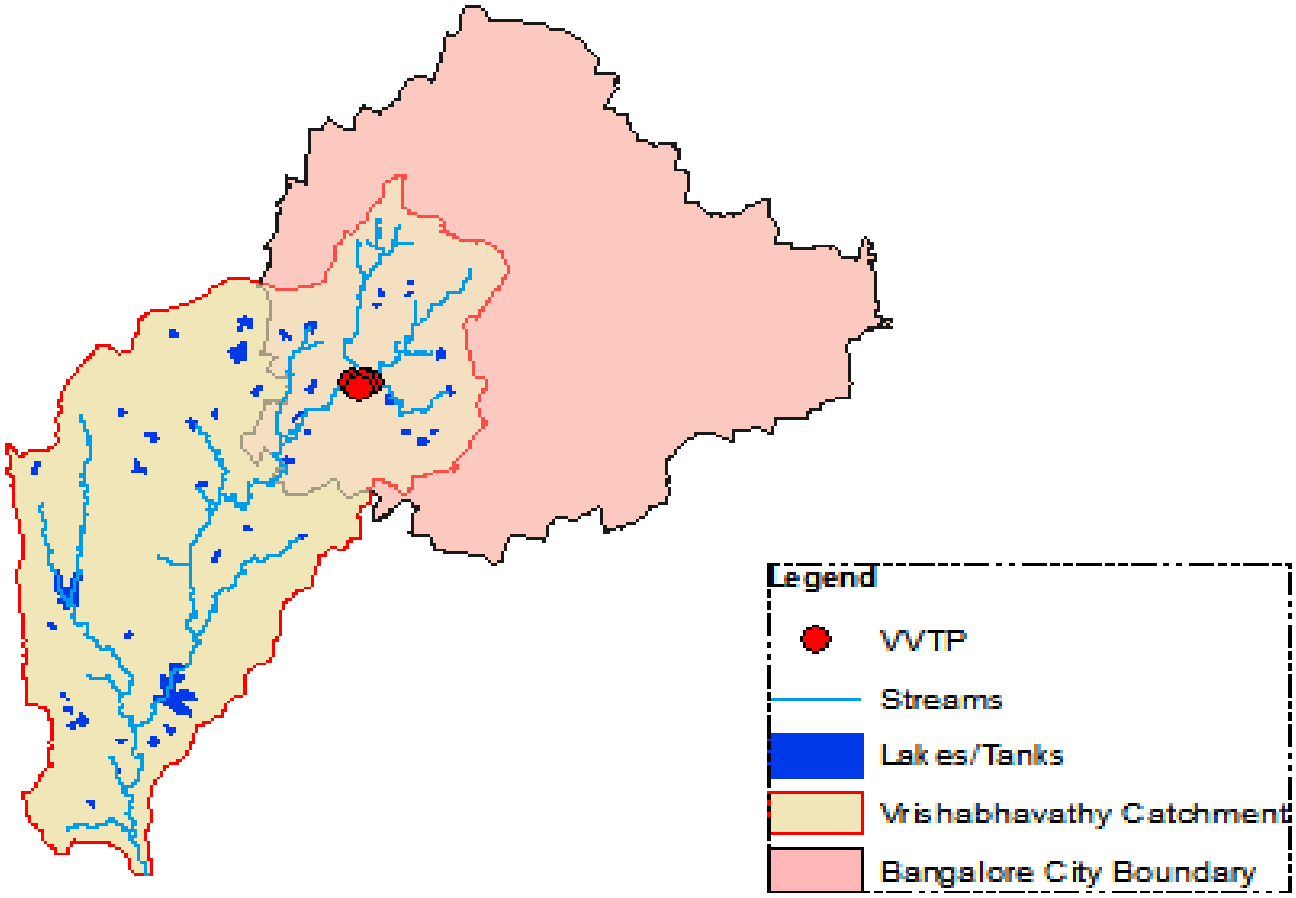


Bangalore's Wastewater Situation



Source: McKinsey CII Report 2014

Bangalore's Wastewater Situation



Source: Jamwal et al, In Submission

Barriers to wastewater recycling and reuse

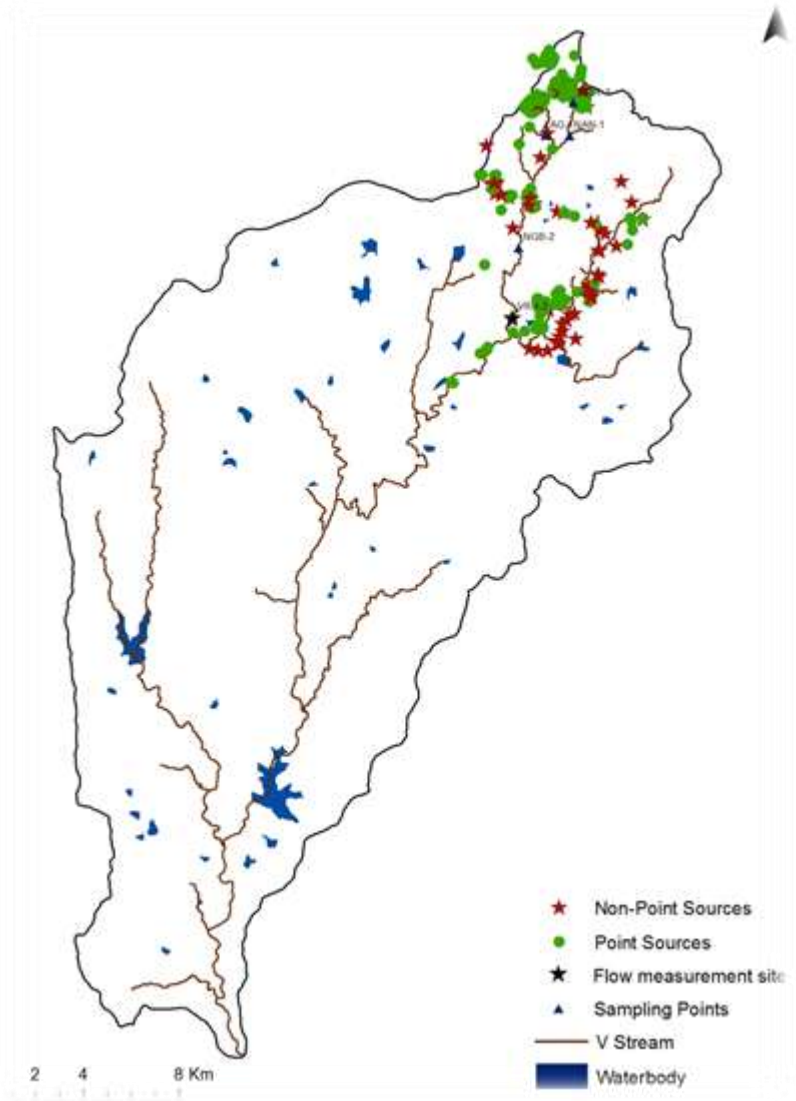
Reuse in Agriculture:

- Downstream Health Impacts

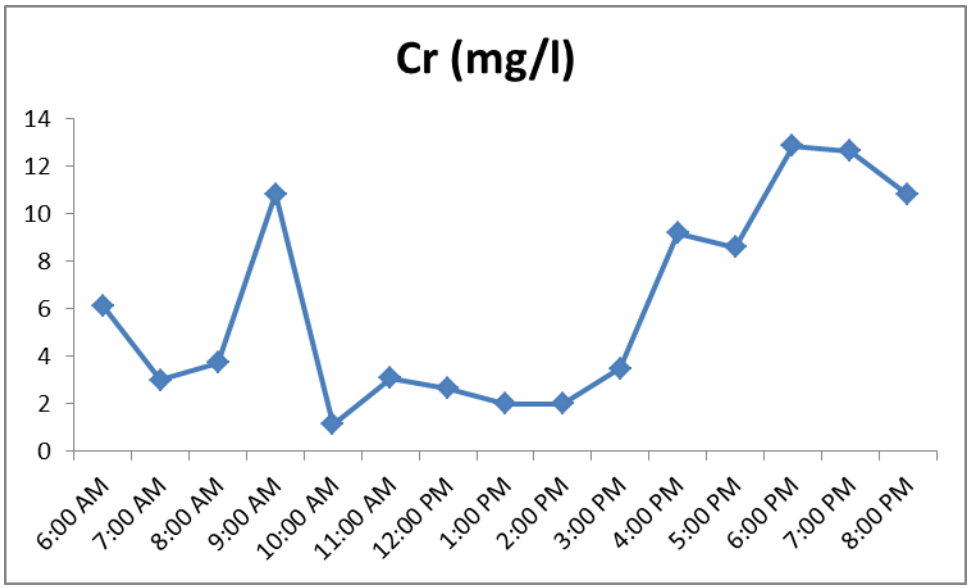
Recycling for urban purposes:

- Centralised: Efficiency and efficacy of WWTPs
- Decentralized: Effective enforcement and capacity building in apartment/commercial complexes

Heavy Metal pollution may have impacts in wastewater reuse in agriculture.

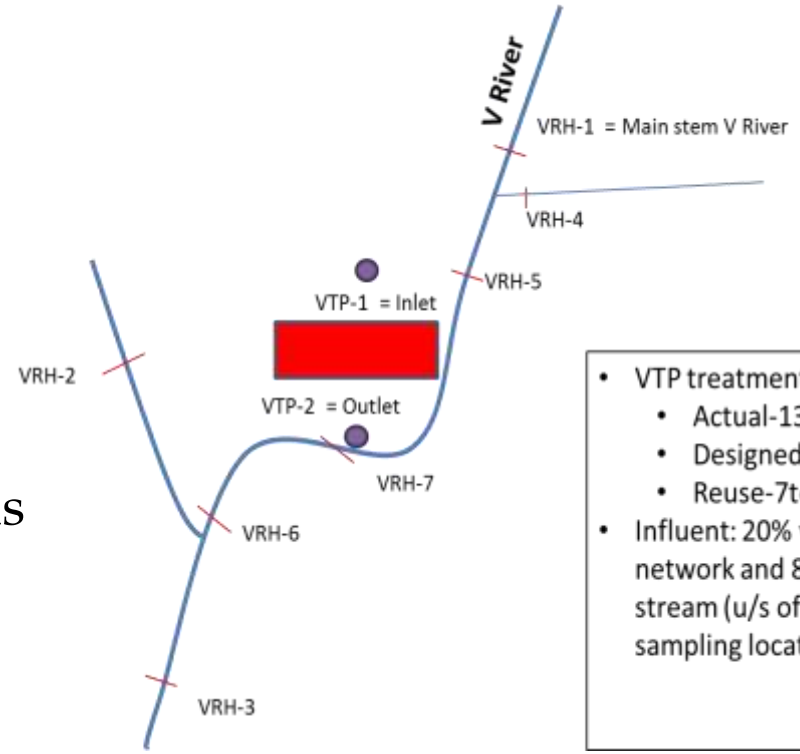


- Maximum Cr $^{6+}$ conc. in stream ≈13mg /l
- Maximum allowable Cr^{6+} load conc. in stream if it receives treated effluent ≈ 0.05mg/l



Wastewater treatment is ineffective

- No significant difference was observed in the water quality of stream samples u/s and d/s of STP
  - Re- suspension of sediments
  - Poor efficiency of STP as the quality of influent sewage has more non biodegradable component
  - Effluent discharge is twenty percent of the total flow in stream

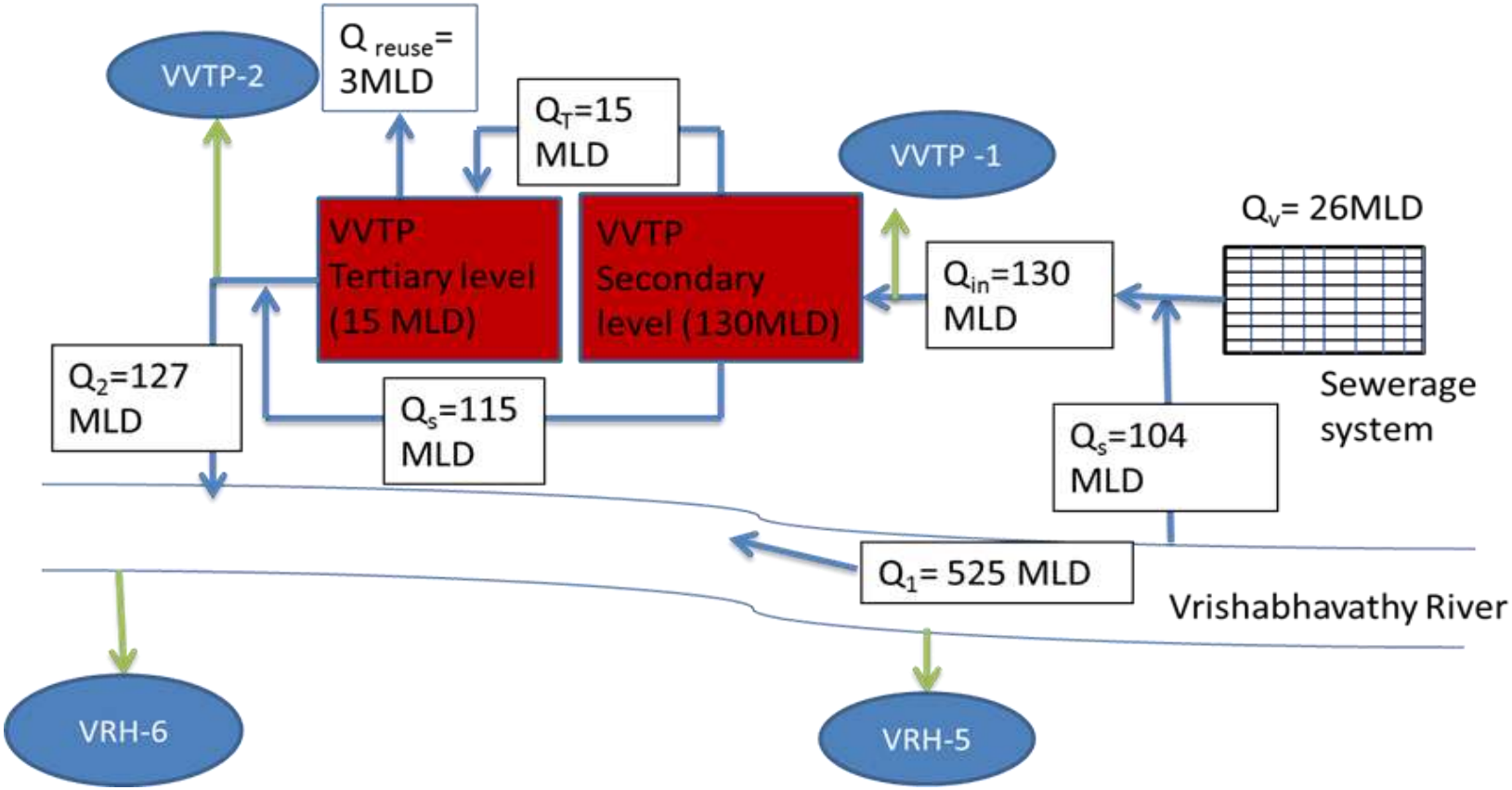


- VTP treatment capacity
  - Actual-130MLD
  - Designed-180MLD
  - Reuse-7to 8MLD
- Influent: 20% via sewerage network and 80% from V-stream (u/s of VRH-5 sampling location)

Most water is treated directly from River NOT Sewerage system.

Source: Jamwal et al. In Review

Only 20% of river water is being treated and that not effectively.



Source: Jamwal et al. In Review

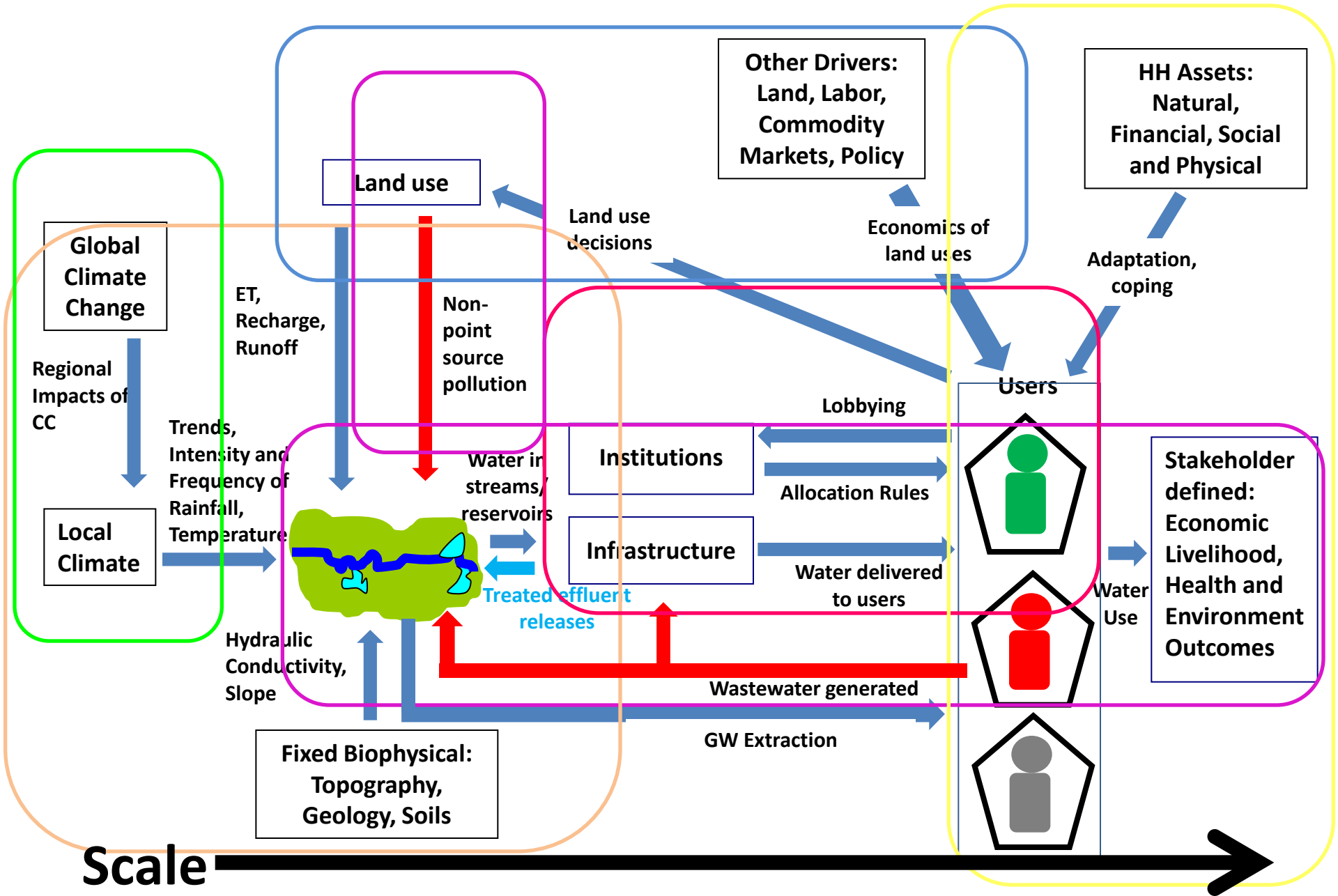
Decentralized Wastewater Treatment still has enforcement problems

- Zero Discharge Notification

- Large Apartment Complexes required to have decentralized wastewater treatment but many break-down after a few months.
  - Lack of enforcement
  - Lack of incentives and capacity

FRAMEWORK FOR A SYSTEM'S GOVERNANCE APPROACH

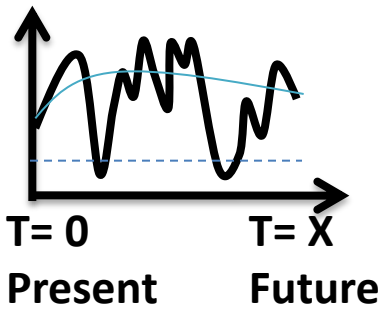
Conceptual Framework



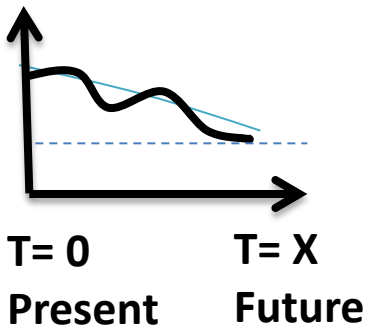
Normative Framework

Need to ask whose problem, when and how?

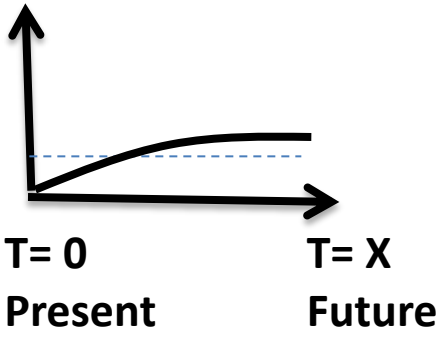
Human Well-being



Drought/ Seasonal Vulnerability



Resource Unsustainability



Chronic Scarcity/ Inequity

Policy Orientation

- In developing models, start with proposed policies and then work back to obtain system boundaries, users and relevant feedbacks

THANK YOU!!

Some small practical steps forward

- Carrot and stick efforts in managing decentralized wastewater in apartment complexes.
- Upstream and downstream impacts and who benefits and loses.
- Redistributing water distribution from centre to periphery.

Wastewater reuse in agriculture

Irrigated area to total cultivated area in three villages along the Vrishabhavathi river (2012-13)

Source: Field survey, 2013

No. of households in the sample	**83**
No. of cultivator households	62
Cultivated area (in acres)	110
Irrigated area (in acres, % of total cultivated area in brackets)	95.43 (86.5 %)
Rainfed area (in acres, % of total cultivated area in brackets)	14.88 (13.5 %)