Three Day Online Training
On
“Groundwater Quality and Stable Isotope Characterization for Salinity “
21st to 23rd, December 2020
under National Hydrology Project

# Overview of Groundwater Quality


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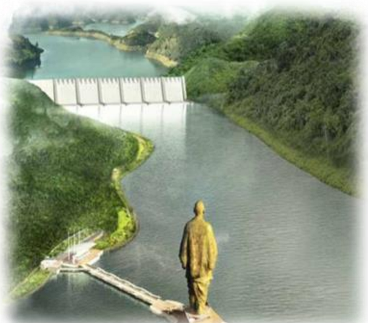
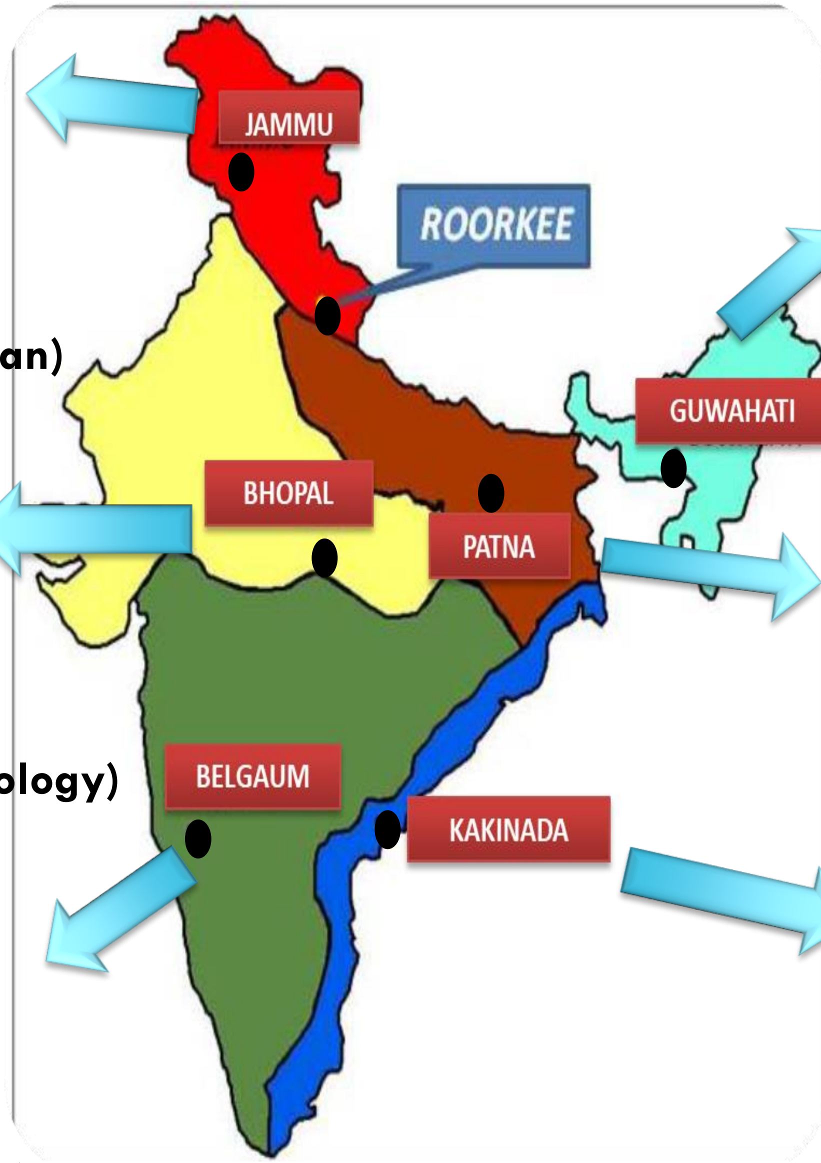
# NIH Regional Centres

**Jammu**
**(Western Himalayan)**



**Bhopal**
**(Central India Hydrology)**

**Belgavi**
**(Deccan Hard Rock)**




Centres for Flood
Management Studies:
**Guwahati(Brahmaputr**

Centres for Flood Management S
**Patna(Ganga Basin)**

**Kakinada**
**(Deltaic)**

# Background

- The environmental consequences of industrialization, intensification of agriculture, exploitation of mineral resources and energy production have made deep cuts into the natural landscape and altered the water quality in large river basins including groundwater.

- A situation of fresh water sharing from surface water to groundwater reserves below aquifers is virtually non-existent during the non-monsoon period due to non-availability of water in rivers. Thus, the rivers quench their thirst with whatever discharge they receive in the form of polluted waste waters from households and effluents from industries (seldom treated) as point sources.

# Background

- A recent survey of CPCB indicated that only about 22% of the total sewage generated in the country are treated before it is discharged to water bodies and the rest 78% receives no treatment.

- Discharge of untreated or inadequately treated industrial wastewaters, which could be more lethal, make the situation worse. The rivers thus can no longer serve fresh water to humanity as their self-assimilative capacities are exhausted.

- As a result, water famine, especially during summer months, has become a news item in this vast sub-continent

# Groundwater is an important, but often overlooked component of the hydrologic cycle…

**Groundwater and surface water are in reality an interconnected resource.**

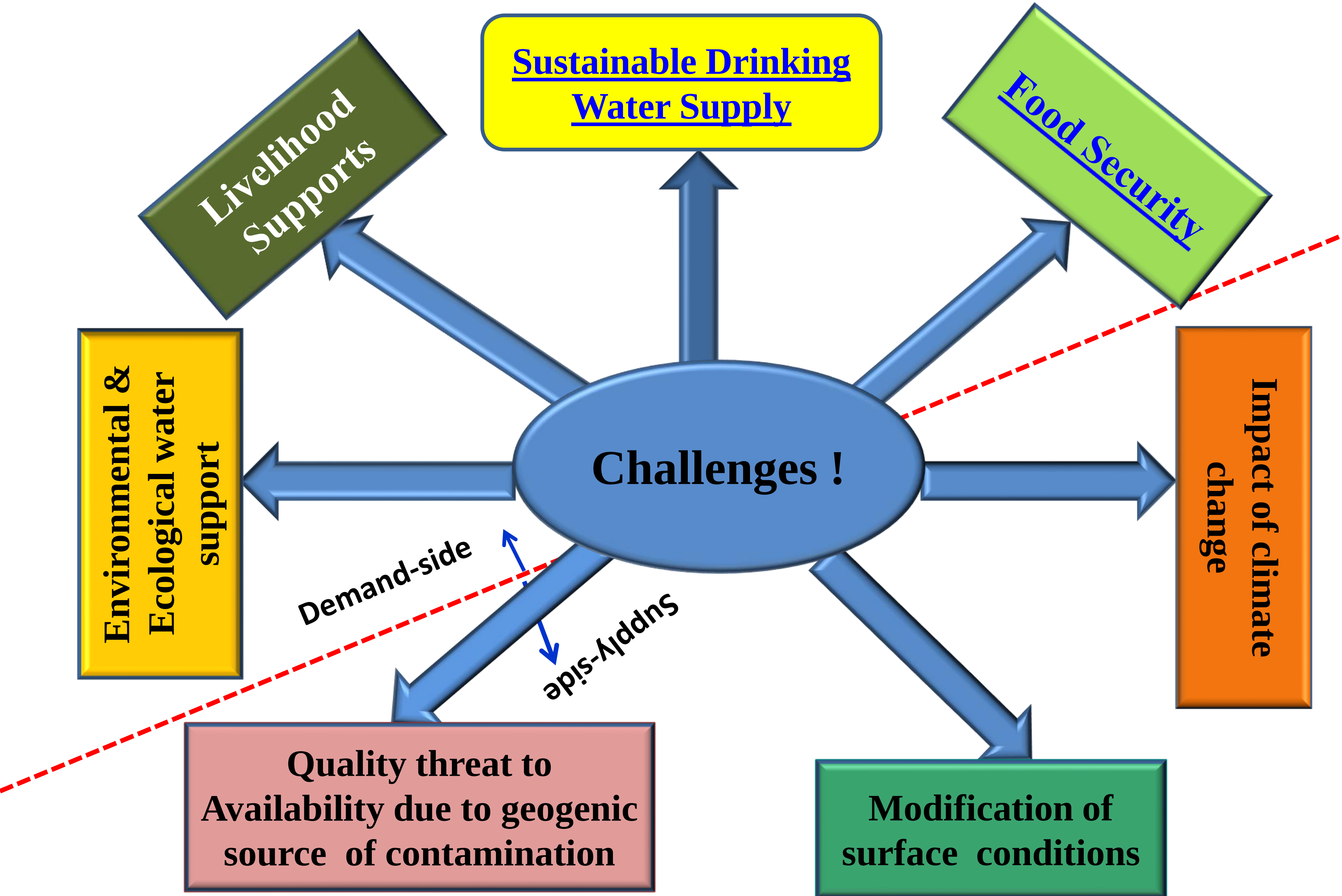
**Water management decisions that ignore the contributions of, or impacts to, groundwater are not sustainable in the long run.**

**Accurate and reliable groundwater resource information (including quality) is critical to planners and decision-makers.**

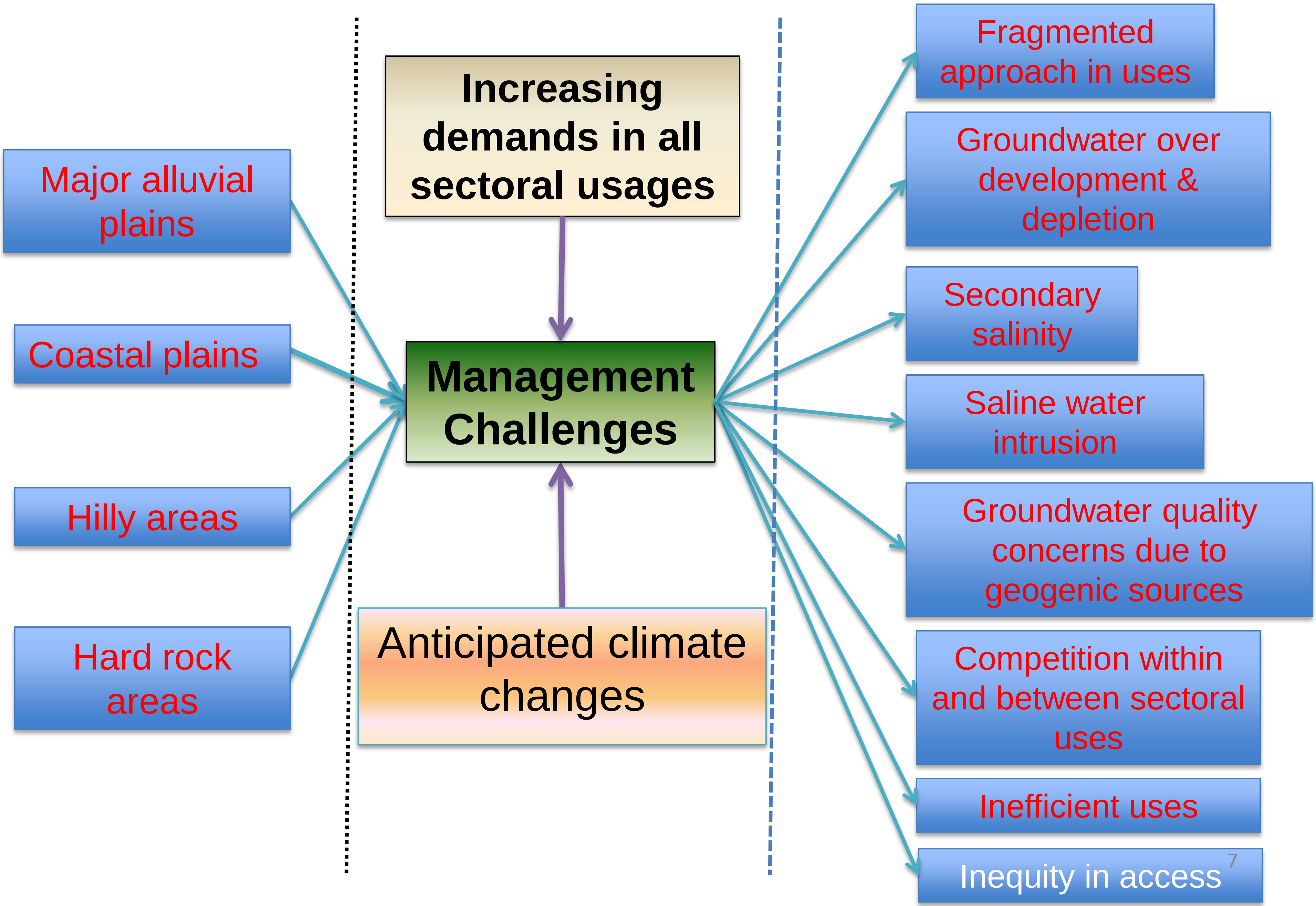
**Huge investment in the areas of ground water exploration, development and management at state and national levels aims to meet the groundwater requirement for drinking and irrigation and *generates enormous amount of data*.**

**We need to focus on *improved data management, precise analysis and effective dissemination* of data.**

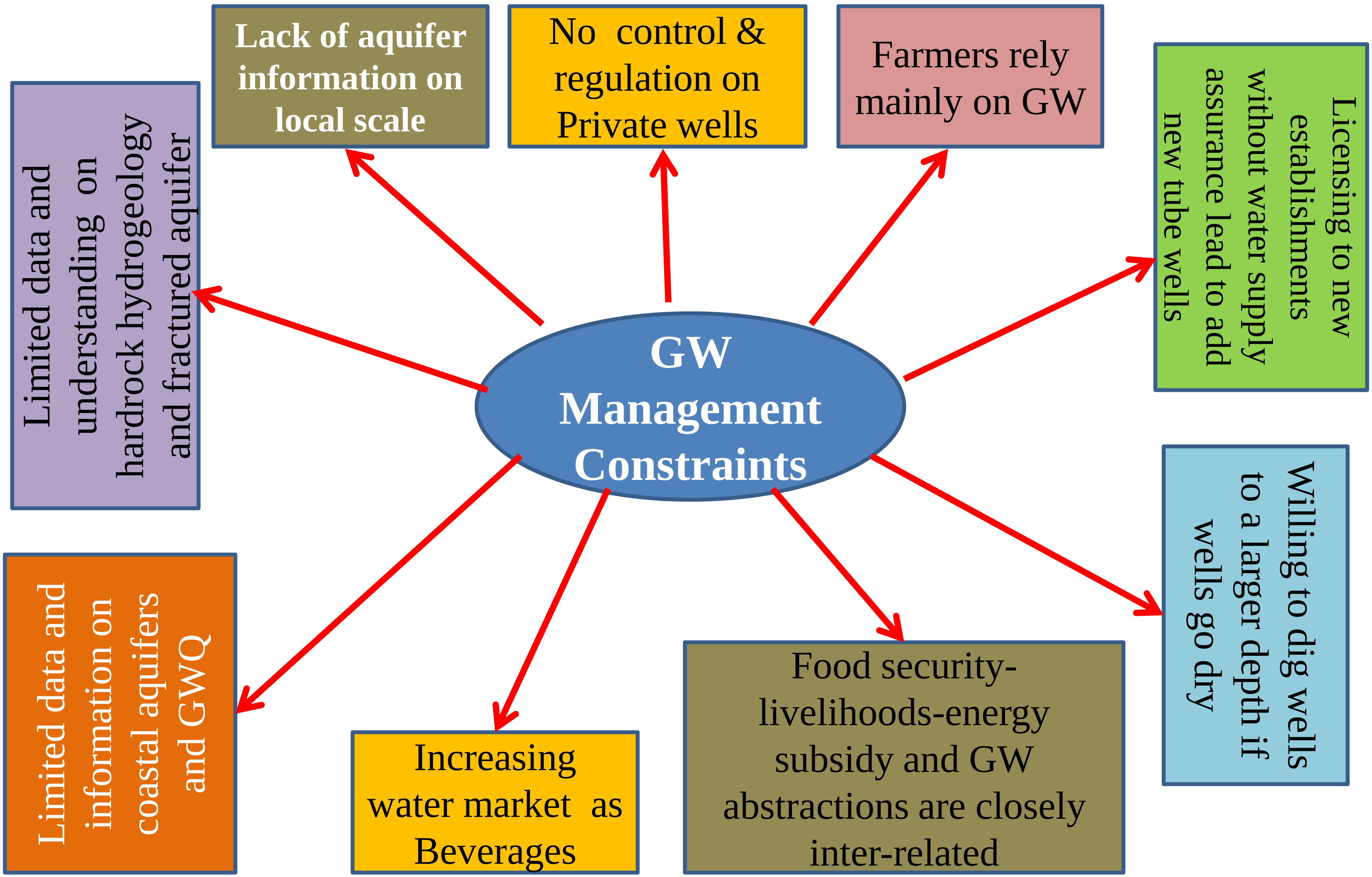
# Groundwater Challenges



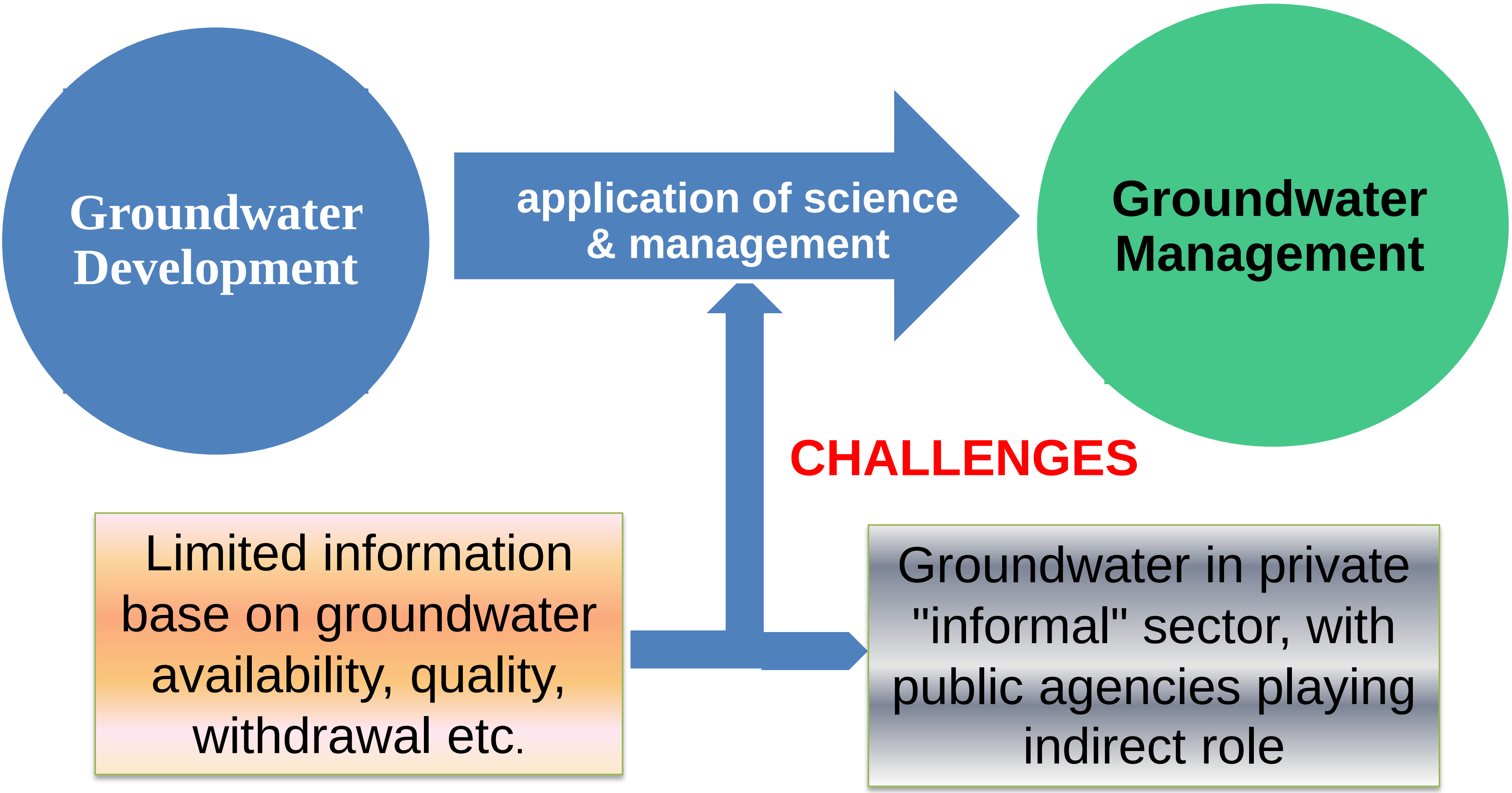
# Groundwater Management Challenges



# GW Management Constraints



# Changeover from Development to Management Mode



# Components of GW System Management

GW System (Aquifer) Management

Task

**Estimation of Aquifer response , rate & direction of flow and contaminants**

Aquifer parameters and geometry

Regular/Periodic monitoring of GW levels and contaminants' concentration

Incorporating monitored data to develop GW resource mapping

Undertake systematic & scientific research on occurrence, use and ways of augmenting and mapping the resource

- Needs understanding of groundwater system.
- Modeling is a powerful tool for groundwater system management.

# Major water quality components

## Chemical properties

(composition, partitioning, solubility of gases and other materials, osmosis, Diffusion, dispersion and other processes

## Biological processes

(Photosynthesis, respiration, Nature and density of biological Communities Other biological processes

## Water Quality

## Physical properties

(Thermal stability, viscocity, stratification, Transpirancy, vepour pressure and other other processes

## Hydrological processes

Flow regime, velocity, bed characters, periodicity, Advection, convection, Mixing, turbulence, Meandering, scouring, depositing

# Why should we devote resources for assessing groundwater conditions?

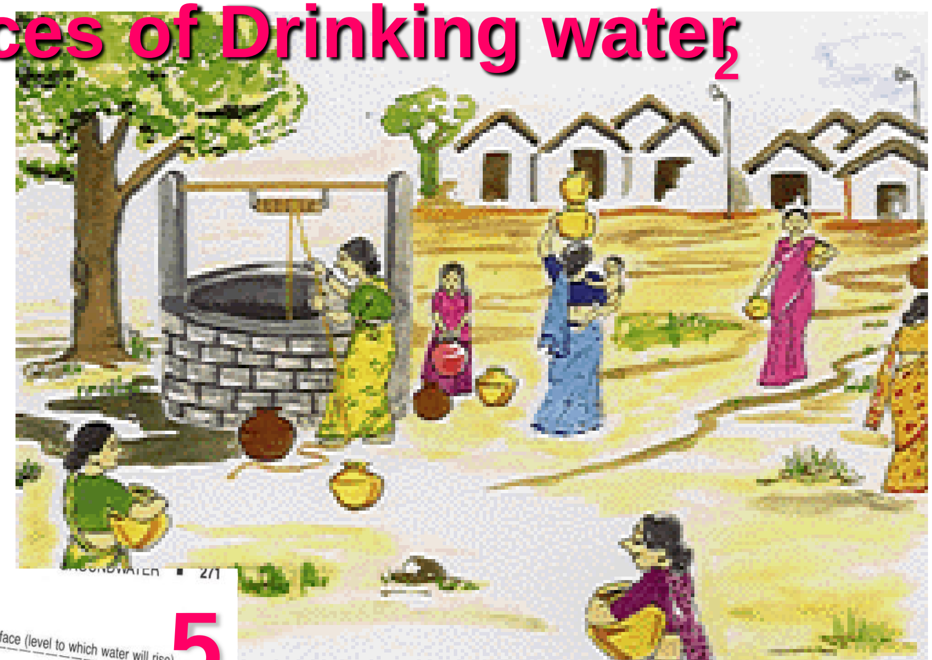
**Groundwater is a vital natural resource for our country…**

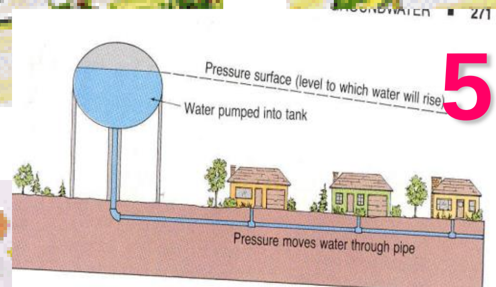
- **A major source of drinking water and irrigation water supply**
- **Groundwater baseflow sustains streamflow during low flow periods**
- **Dependence on groundwater is rapidly increasing**
- **There's a lot of stress on groundwater resource – contamination, over-pumping…**

**As per the National Water Policy of India (2012) in planning and operation of systems, water allocation priorities should be broadly as:**

(i) Drinking water,
(ii) Irrigation,
(iii) Hydropower,
(iv) Ecology,
(v) Agro-industries and non-agricultural industries and
(vi) Navigation.

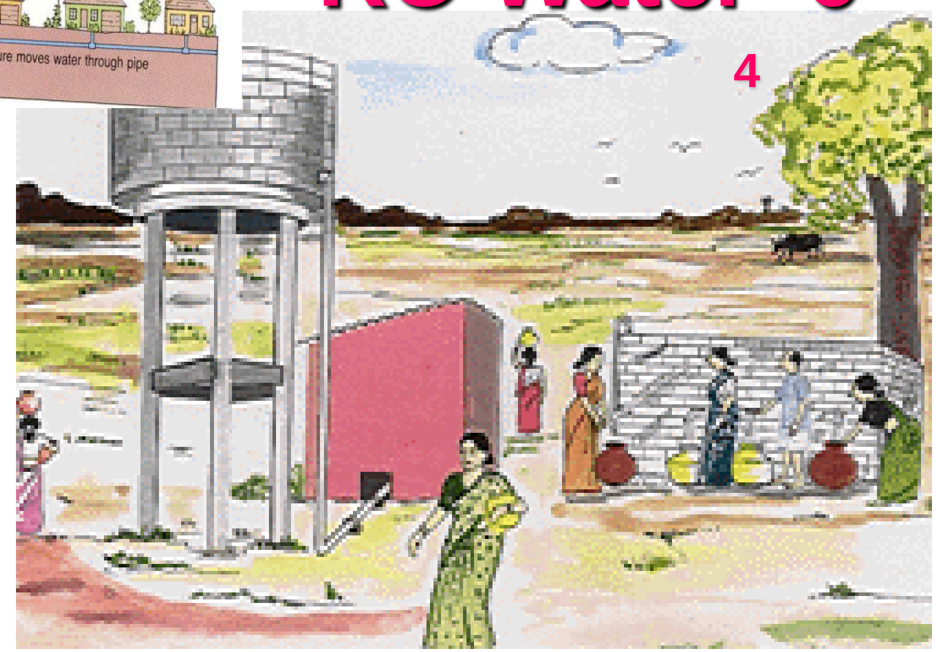
# Development in sources of Drinking water


**Alkaline water 7**

**RO Water 6**

# Major Water Quality Issues

## Common issues of Surface and Ground water

- Pathogenic (Bacteriological) Pollution
- Salinity
- Toxicity (micro-pollutants and other industrial pollutants)

## Surface Water

- Eutrophication
- Oxygen depletion
- Ecological health

## Ground Water

- Fluoride
- Nitrate
- Arsenic
- Iron
- Sea water intrusion

# Major sources of water pollution

- Urban and domestic waste
- Industrial waste
- Agricultural sources
- Mining wastes
- Induced contaminated sources
- Radioactive substances etc.
- Washoff from landfill sites

# ...Other Issues

- Oil spills in deltas and non aqueous contaminants
- Sand mining, river bank erosion, safe sand mining zones identification
- River Bank Filtration Possibilities
- Identification of Submarine groundwater discharge Zones/Sea water Intrusion

# The Indian situation

- Groundwater [Depleted]
- Surface water [Polluted]
- Rainfall [Wasted]

- Population [ ]
- Demand [ ]
- Consumption [ ]

SCARCITY

- Industrial Growth [ ]
- Economy-Industry [ ]
- Water Business[ ]

- Agriculture [ ]
- Health & Environment[ ]
- Future [ ? ]

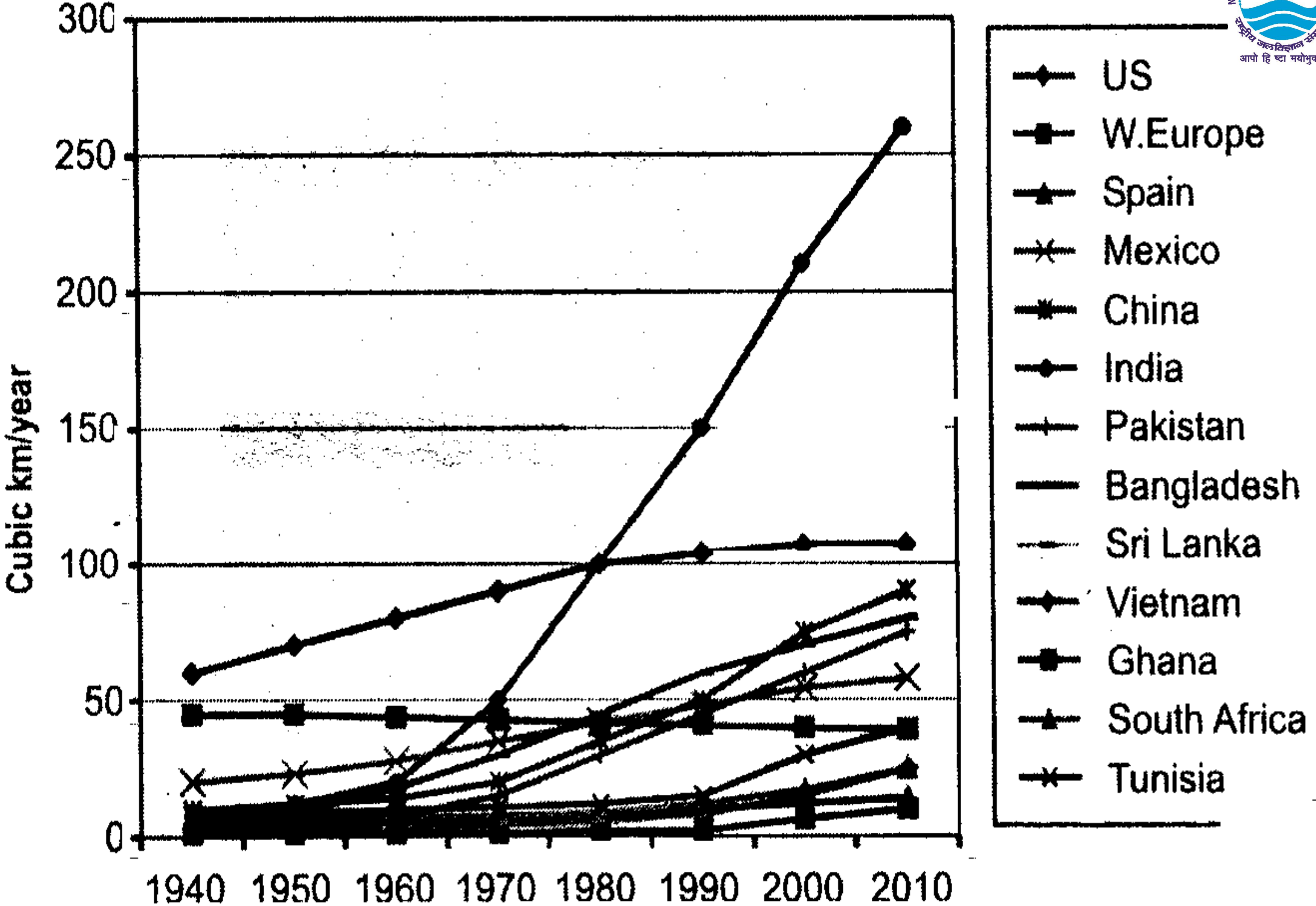
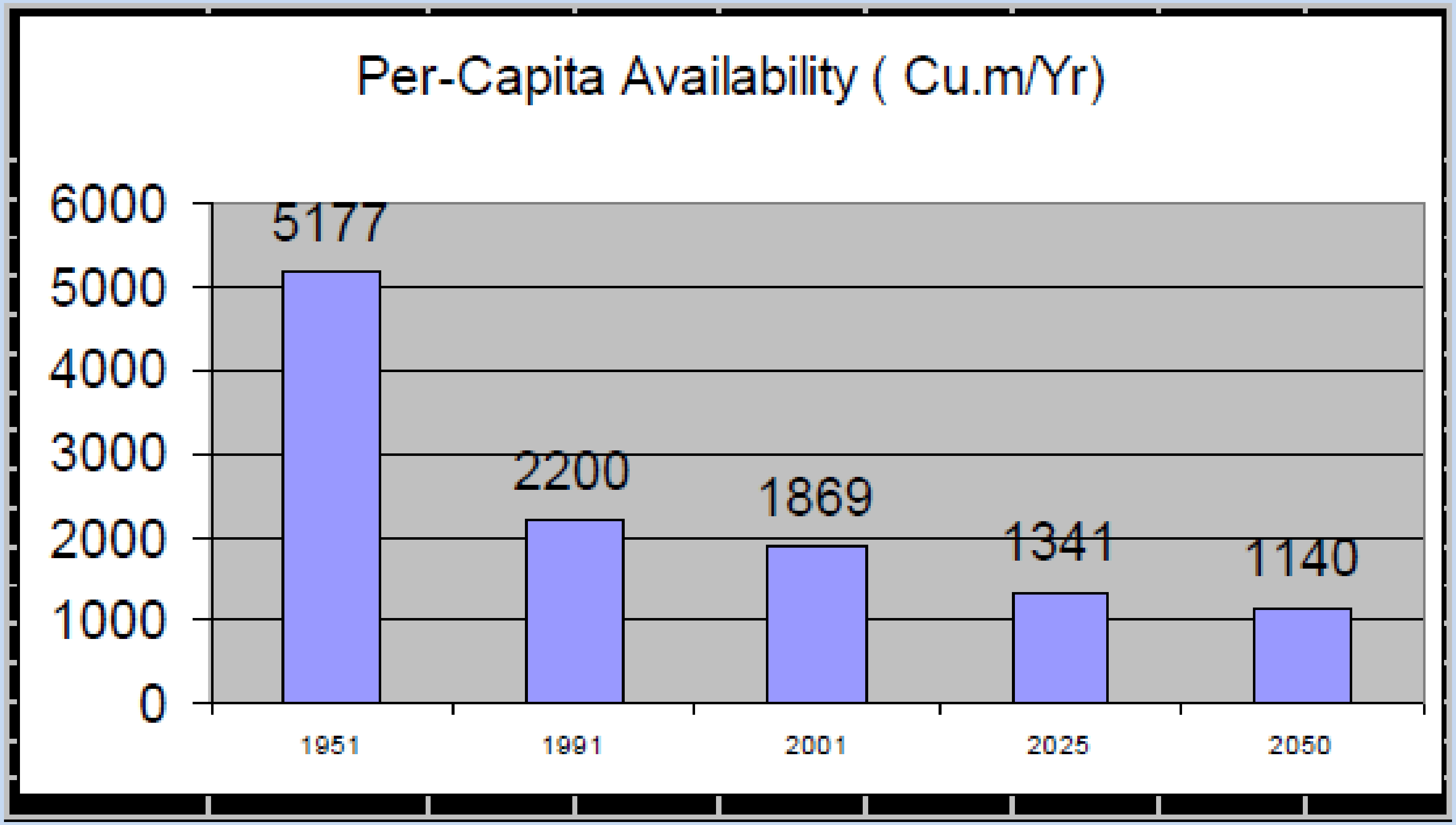



Figure Growth in groundwater use in selected countries (author's estimates)

# PER CAPITA WATER AVAILABILITY



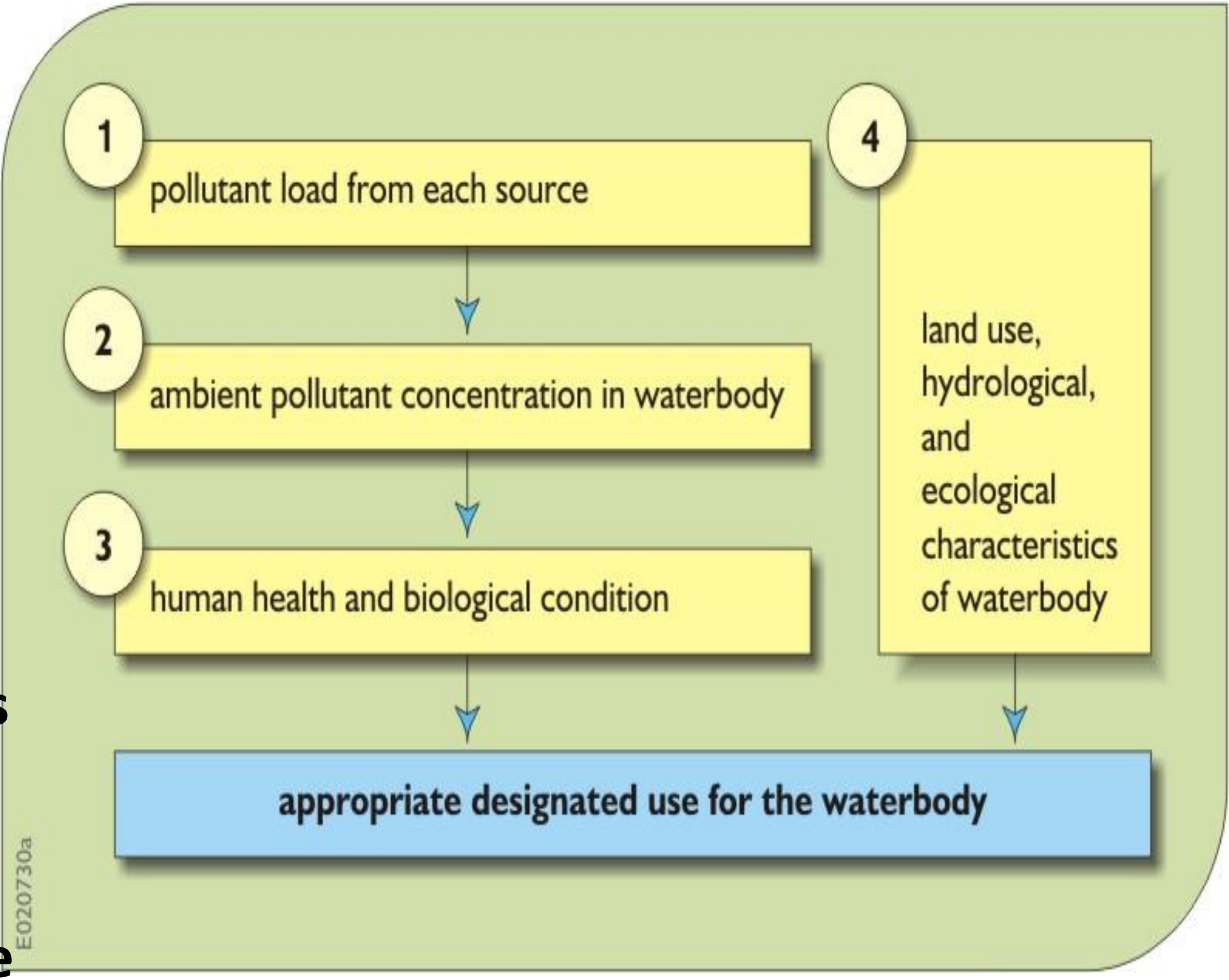

**BENCH MARKS**

**WATER STRESS – Between 1700 & 1000 Cu.m/Year/Person**

**WATER SCARCITY – Below 1000 Cu.m/Year/Person**

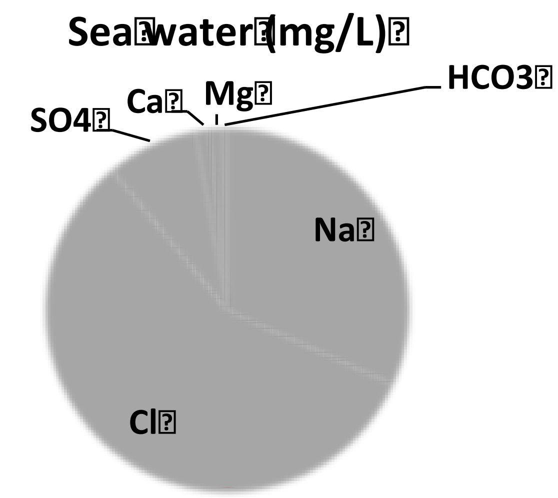
# Water Quality Management Process

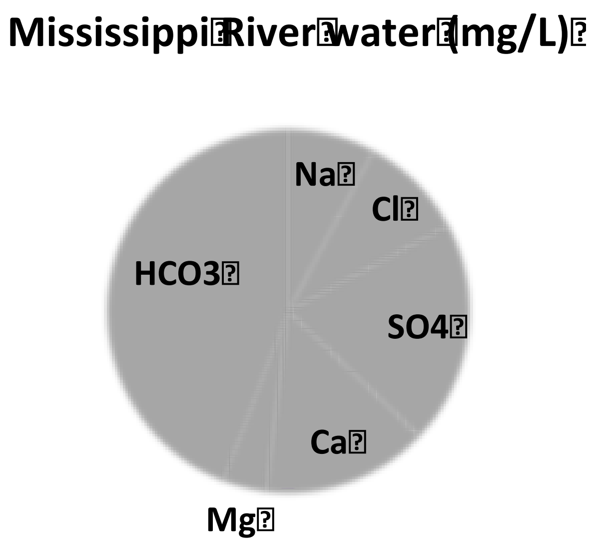
- Identify
  - Problem
  - Indicators
  - Target Values
- Assess source(s)
- Determine linkages
  - Sources → Targets
- Allocate permissible loads
- Monitor and evaluate
- Implement



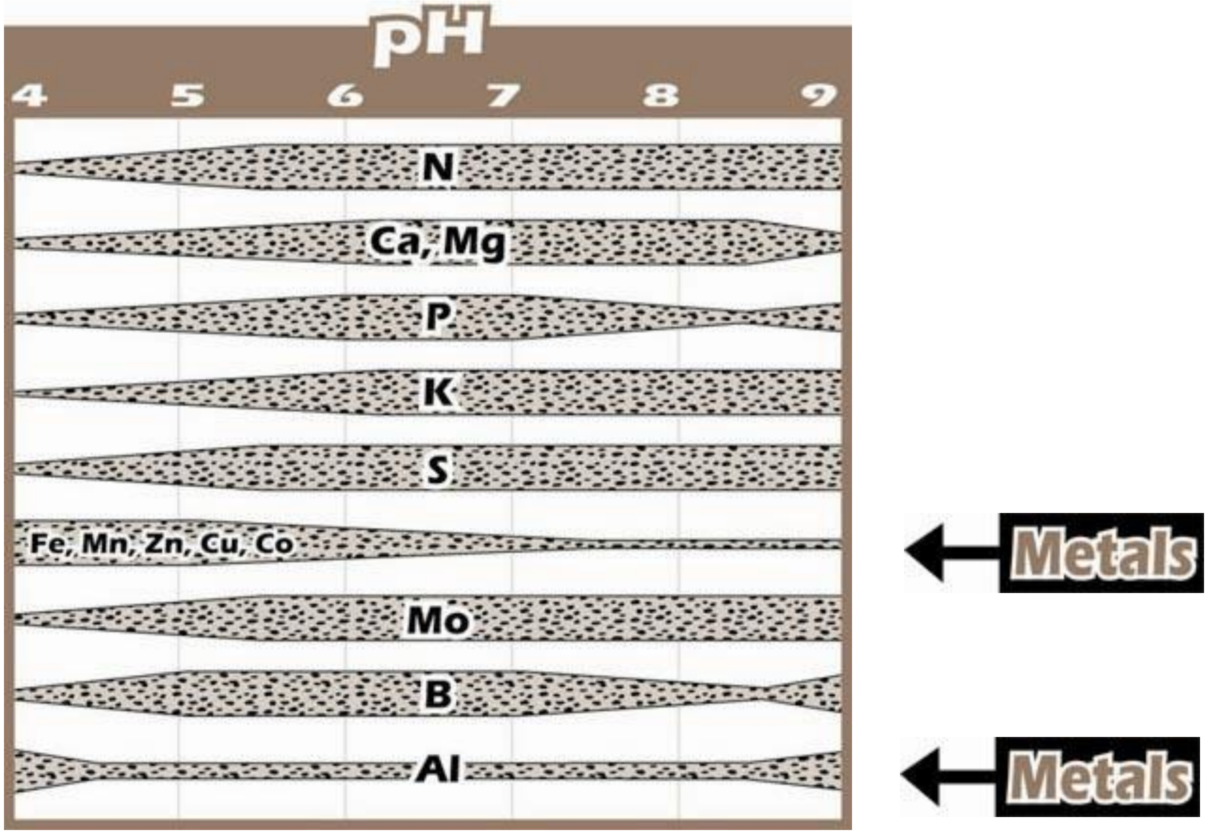
# Average Composition of Sea Water and River water

| Parameter | Sea water (mg/L) | River water (mg/L) |
|---|---|---|
| Na | 10,500 | 20 |
| Cl | 19,000 | 24 |
| $SO_4$ | 2,700 | 51 |
| Ca | 410 | 38 |
| Mg | 390 | 10 |
| $HCO_3$ | 142 | 113 |



# Solubility of Specific Ions Based on Water pH



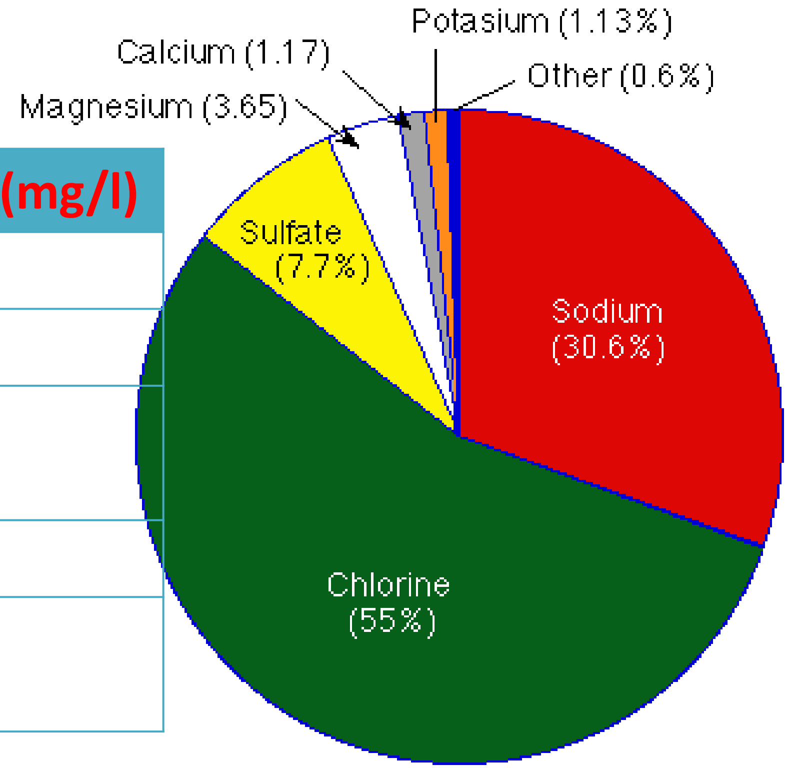

**Toxic metals less available in water at pH 6 to 8.**

# Salinity

- Classification of Ground Water
- Composition Based on Total Dissolved Solids Content

| Type of Water | Dissolved salt content (mg/l) |
|---|---|
| Fresh water | < 1,000 mg/l |
| Brackish water | 1,000 - 3,000 mg/l |
| Moderatly saline water | 3,000 - 10,000 mg/l |
| Highly saline water | 10,000 - 35,000 mg/l |
| Sea water | > 35,000 mg/l |

## Salts in Sea Water




Salts in Seawater

# Water Uses

| Use | Typical quality parameters |
| --- | --- |
| Public Water Supply | Turbidity, TDS, inorganic and organic compounds, microbes |
| Water contact recreation | Turbidity, bacteria, toxic compounds |
| Fish propagation and wildlife | DO, chlorinated organic compounds |
| Industrial water supply | Suspended and dissolved constituents |
| Agricultural water supply | Sodium, TDS |
| Shellfish harvesting | DO, bacteria |

# Water Classification

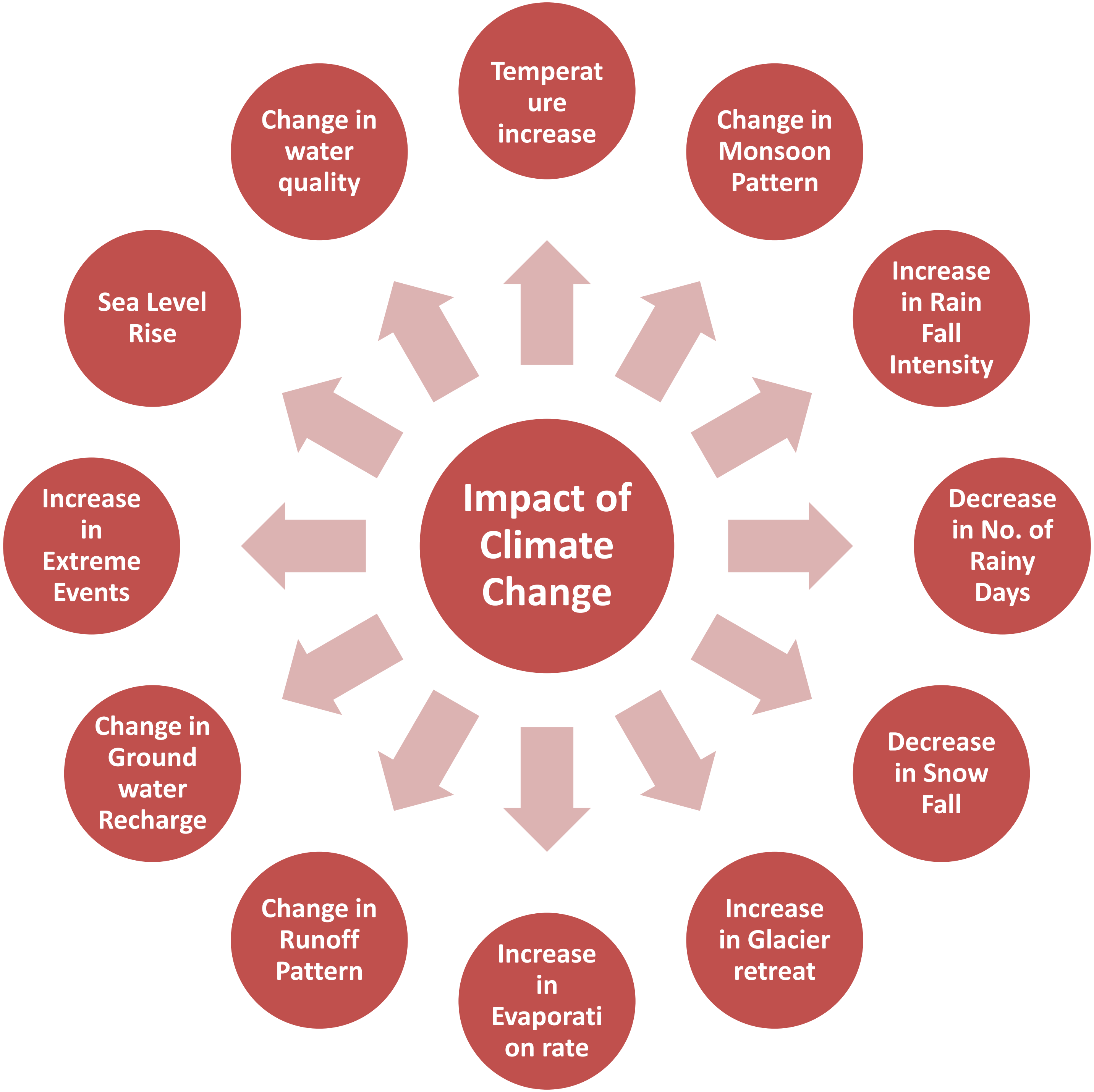
- How?
  - Compare ions with ions using chemical equivalence
  - Making sure anions and cations balance
  - Use of diagrams and models

- Why?
  - Helps define origin of the water
  - Indicates residence time in the aquifer
  - Aids in defining the hydrogeology
  - Defines suitability

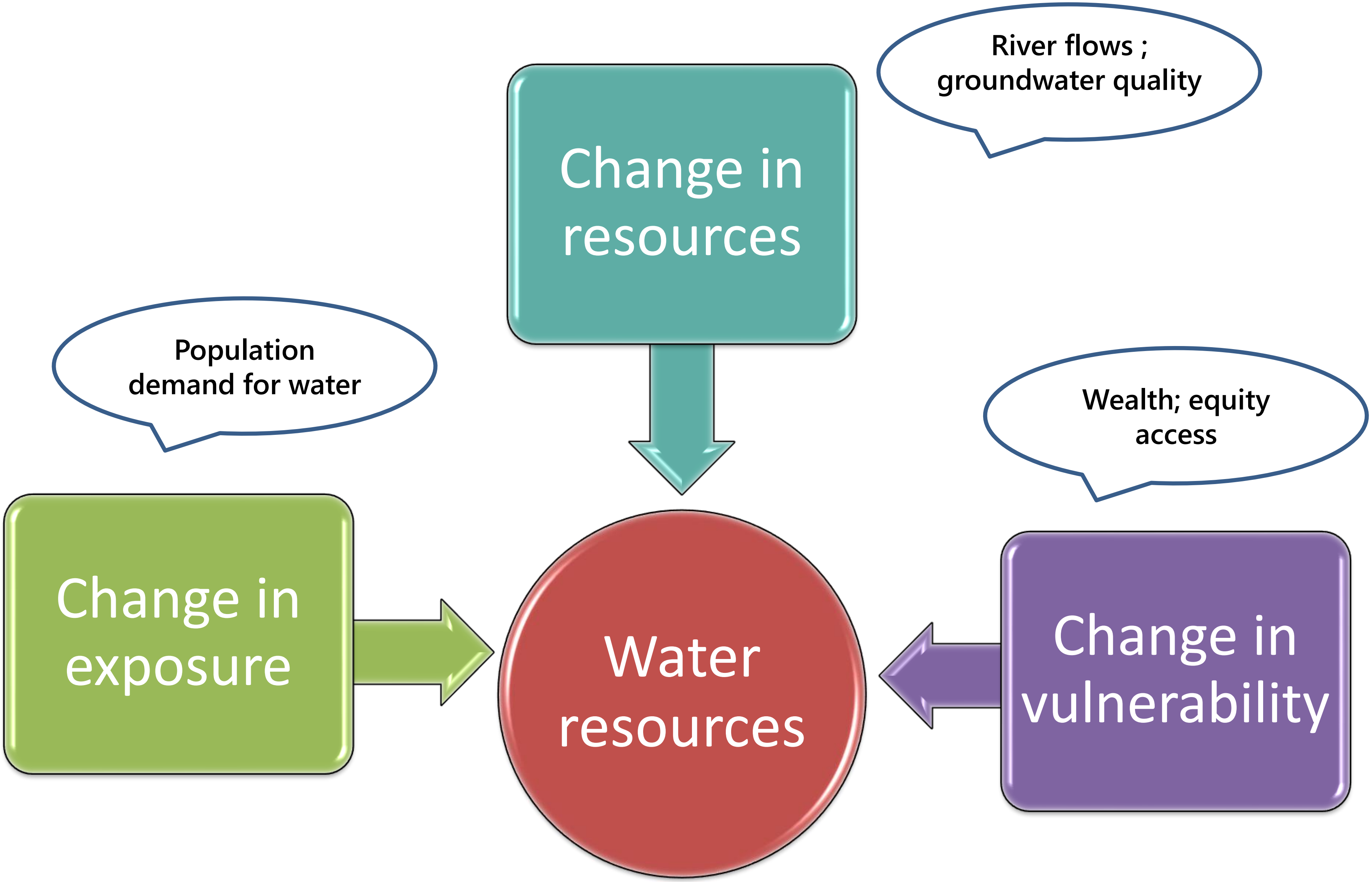
# Climate Change

United Nations Framework Convention on Climate Change (UNFCCC) defines "climate change" as: 'a change of climate which is attributed directly or indirectly to human activities that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'

General Definition: Any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or winds) sustained over several decades or longer.


Impact of Climate Change
Temperat ure increase
Change in Monsoon Pattern
Increase in Rain Fall Intensity
Decrease in No. of Rainy Days
Decrease in Snow Fall
Increase in Glacier retreat
Increase in Evaporati on rate
Change in Runoff Pattern
Change in Ground water Recharge
Increase in Extreme Events
Sea Level Rise
Change in water quality

# Drivers of Climate Change



# Climate Change effects:

- Higher Temperatures
- More Frequent & Intense Droughts
- Increased Energy Demand
- Increased Water Demand
- More Extreme Events

# Impacts to Water Resources:

- Reduced In-stream Flow
- Saltwater Intrusion
- Higher Evaporation Rates
- Higher Sea Levels/Greater Storm Surges
- Impaired Ecological/Biological Communities
- Economic (commercial & sport fisheries, tourism, industrial capacity)

# Impacts to Water Quality

- Receiving waters become dominated by Effluent flows
- Higher Nutrient concentrations
- Longer contaminant residency times
- Increased Sediment loads from extreme runoff events

# Sources of salinity

- Waters contain salts in solution
- Salt content ranges from
  - 25mg/l in quartzite's to 300,000mg/l in brines
- The type and concentration of salts depend on
  - environment, movement & source of groundwater
- Groundwater contains
  - higher concentrations of dissolved constituents
- Soluble salts in ground water originate
  - primarily from solution of rock materials
- Salinity varies with
  - specific surface area of aquifer material, solubility of materials and contact time
- Salinity generally increases
  - with depth

- **The precipitation that reaches the earth contains**
  - **- small amount of dissolved mineral matter**

- **When it enters the surface of the earth**
  - **- it reacts with the minerals of the soil and the rocks in contact with it**

- **The quantity and type of mineral matter dissolved depends on**
  - **- the chemical composition and physical structure of the rocks**
  - **- the hydrogen ion concentration (pH) and the redox potential (Eh) of water**

- **Carbon dioxide in solution derived from atmosphere and organic processes in the soil.**
  - **-assists the solvent action of water as it moves under ground**

- **Salt concentration of percolating waters depends on**
  - **soluble soil materials, fertilizers and selective adsorption of salts by plants**
  - **soil permeability, drainage facilities, amount of water applied crops and climate**

- **High Salinities may be found**
  - **in soils and ground water of arid climate where leaching by rain water is not effective in diluting the salt solutions**
  - **poorly drained areas, particularly basins having interior drainage, often contain high salt concentration**

- **Ground water passing through Igneous rocks**
  - **dissolves very small quantities of mineral matter**

- **Sedimentary rocks are**
  - **more soluble than igneous rocks because of their high solubility**
- **Commonly added cations are**
  - **Na and Ca**
- **Corresponding anions are**
  - **$HCO_3$ and $SO_4$**

- **The important sources of chloride are**
  - **- from sewerage, connate water and intruded sea water**
- **High concentration of nitrate may indicate**
  - **- Sources of past or present pollution**
- **An important source of salinity in coastal ground water is**
  - **- air borne salts originating from air-water interface over the sea**
- **Chloride deposition in coastal areas**
  - **- range from 4-20kg chloride per hectare**

# APPLICATIONS OF ISOTOPES IN HYDROLOGY

- Identification of Recharge Sources and Zones of Deeper Aquifers and Springs
- Effectiveness of Artificial Recharge to G. Water
- Salinization of Groundwater in Inland / Coastal Aquifers and Seawater Ingress
- Groundwater and Surface Water Interaction
- Recharge to GW Due to Irrigation & Rainfall
- GW Flow Velocity and Direction ( GW Dating)
- Leakage and Seepage from Reservoirs & Canals
- Discharge Measurement of Mountainous Rivers
- Rate of Sedimentation in Lakes & Reservoirs
- Soil Erosion from Watersheds/Catchments
- Separation of Snow & Glacier melt Runoff, Groundwater & Rainfall runoff components
- Interconnections of Water Bodies
- Pollutants Tracing and Sources

# GROUND-WATER MODELING

- The success of any groundwater study, to a large measure, depends upon the availability and accuracy of measured/recorded data required for that study.

- Therefore, identifying the data needs and collection/monitoring of required data form an integral part of any groundwater exercise.

- The first phase of any groundwater study consists of collecting all existing geological and hydrological data on the groundwater basin in question.

- Any groundwater balance or numerical model requires a set of quantitative hydrogeological data that fall into two categories:

  * Data that define the physical framework of the groundwater basin
  * Data that describe its hydrological framework

## Water Resources Management system primarily needs adequate, accurate and good data base in space and time

**In Andhra Pradesh established World Class Monitoring Network for weather parameters, surface water, groundwater, soil moisture etc., and integrating all**

| Sensors | No. of Stations |
|---|---|
| Rainfall | 1602 |
| Air Temperature | 1173 |
| Humidity | 1173 |
| Wind Speed | 1173 |
| Wind Direction | 1173 |
| Pressure | 713 |
| Global Radiation | 86 |
| Soil Moisture | 59 |
| River Gauges | 94 |
| Reservoir Level Sensors | 83 |
| Coastal station with tidal gauge | 5 |
| Piezometers with DWLRs and Telemetry for Real Time GW Monitoring | 1254 |

**M**easure

**M**onitor

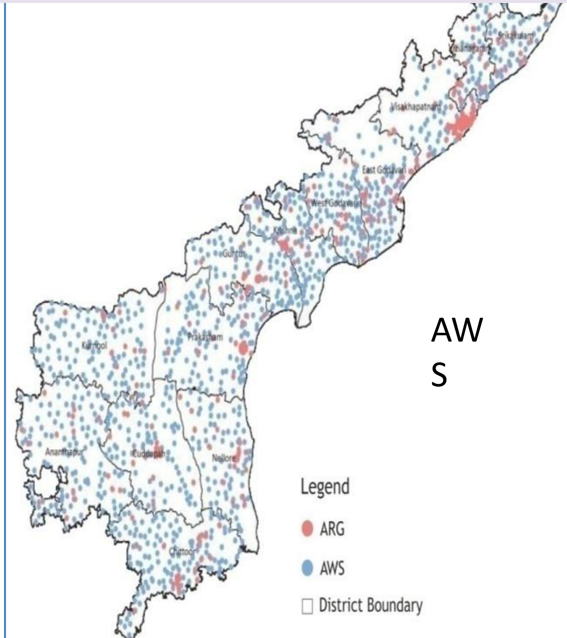
**M**ap

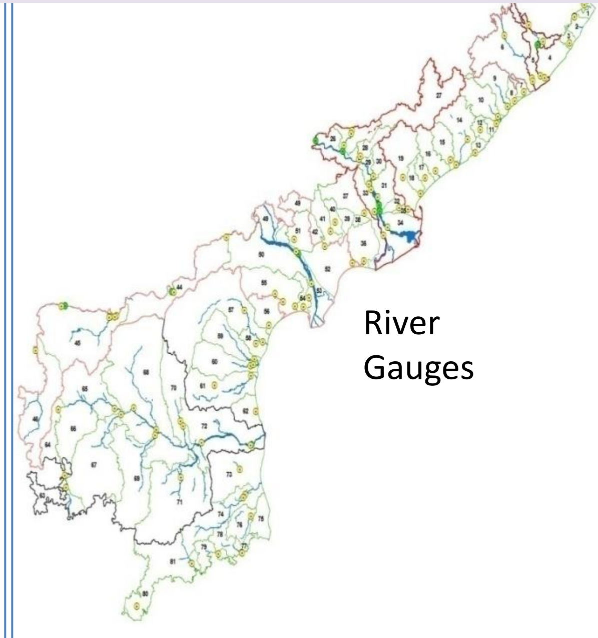
**M**anage Water

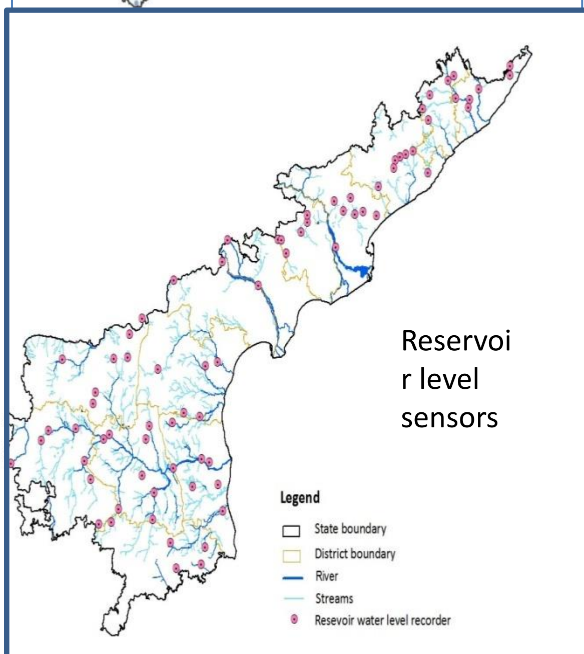
for

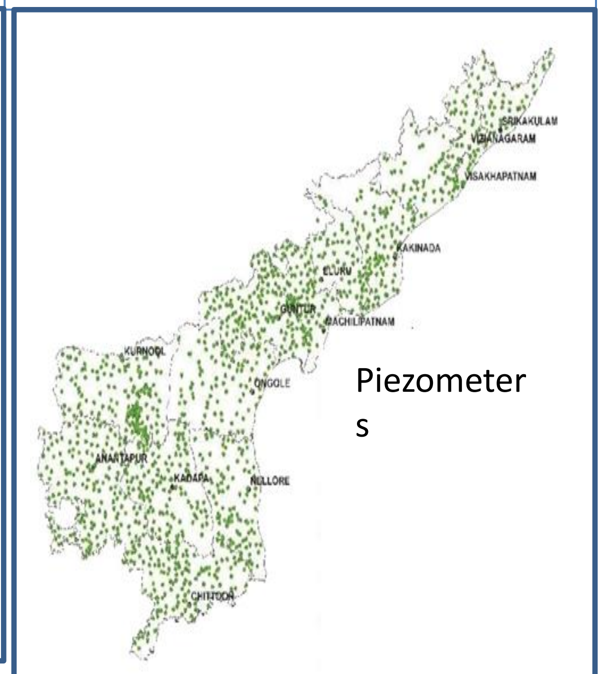
- Realistic assessment of resource
- Planning
- Management
- Sustainable development of water resources

# World Class Monitoring  Network for hourly monitoring



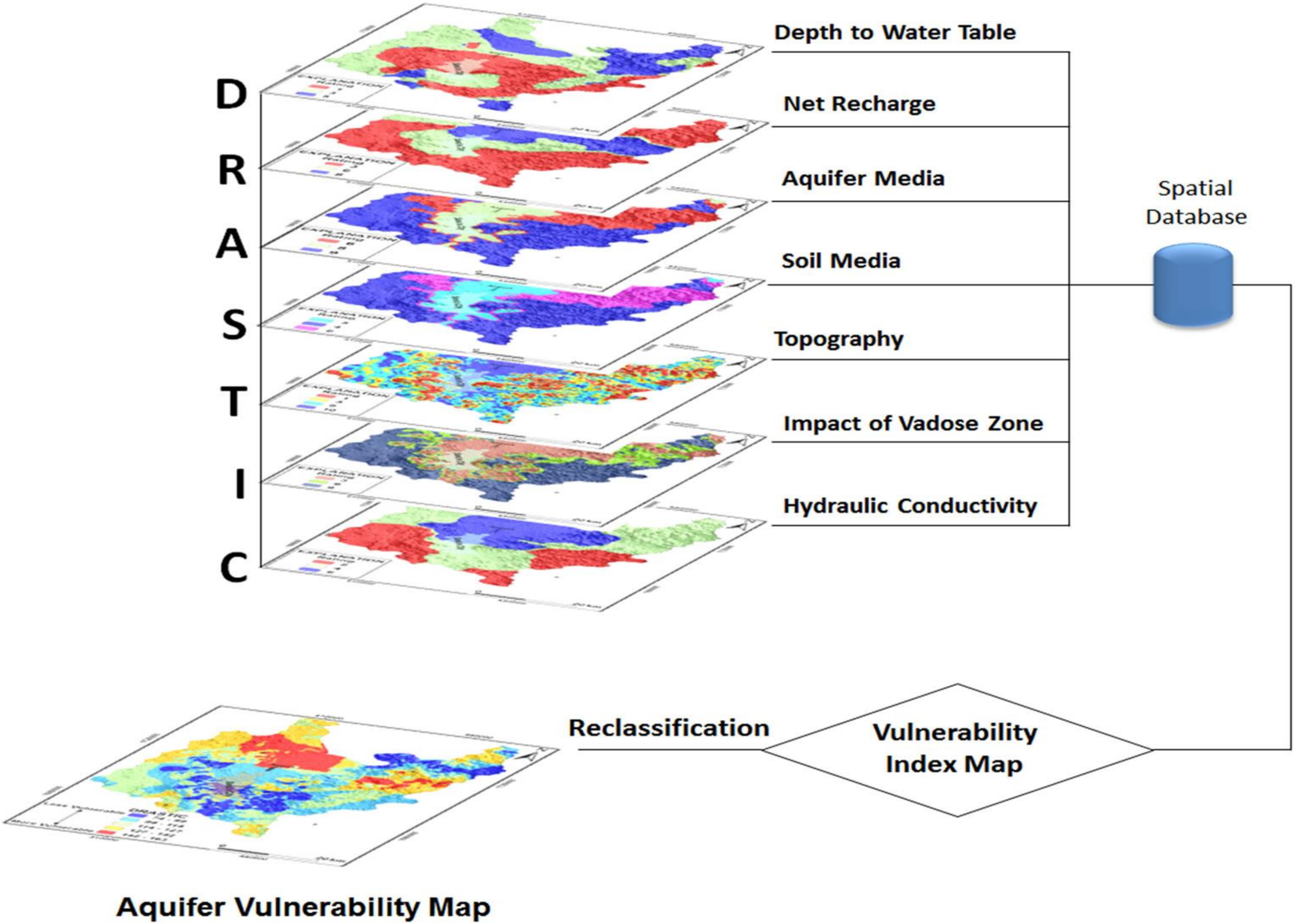



# MAPPING OF GROUNDWATER CONTAMINATION VULNERABLE ZONES USING DRASTIC APPROACH

# AND

# DEVELOPMENT OF WATER QUALITY INDEX

# Methodology



# DRASTIC APPROACH

- D – Depth to Groundwater
- R – Net Recharge
- A – Aquifer Media
- S – Soil Media
- T – General Topography or Slope
- I – Vadose zone
- C – Hydraulic conductivity of the aquifer

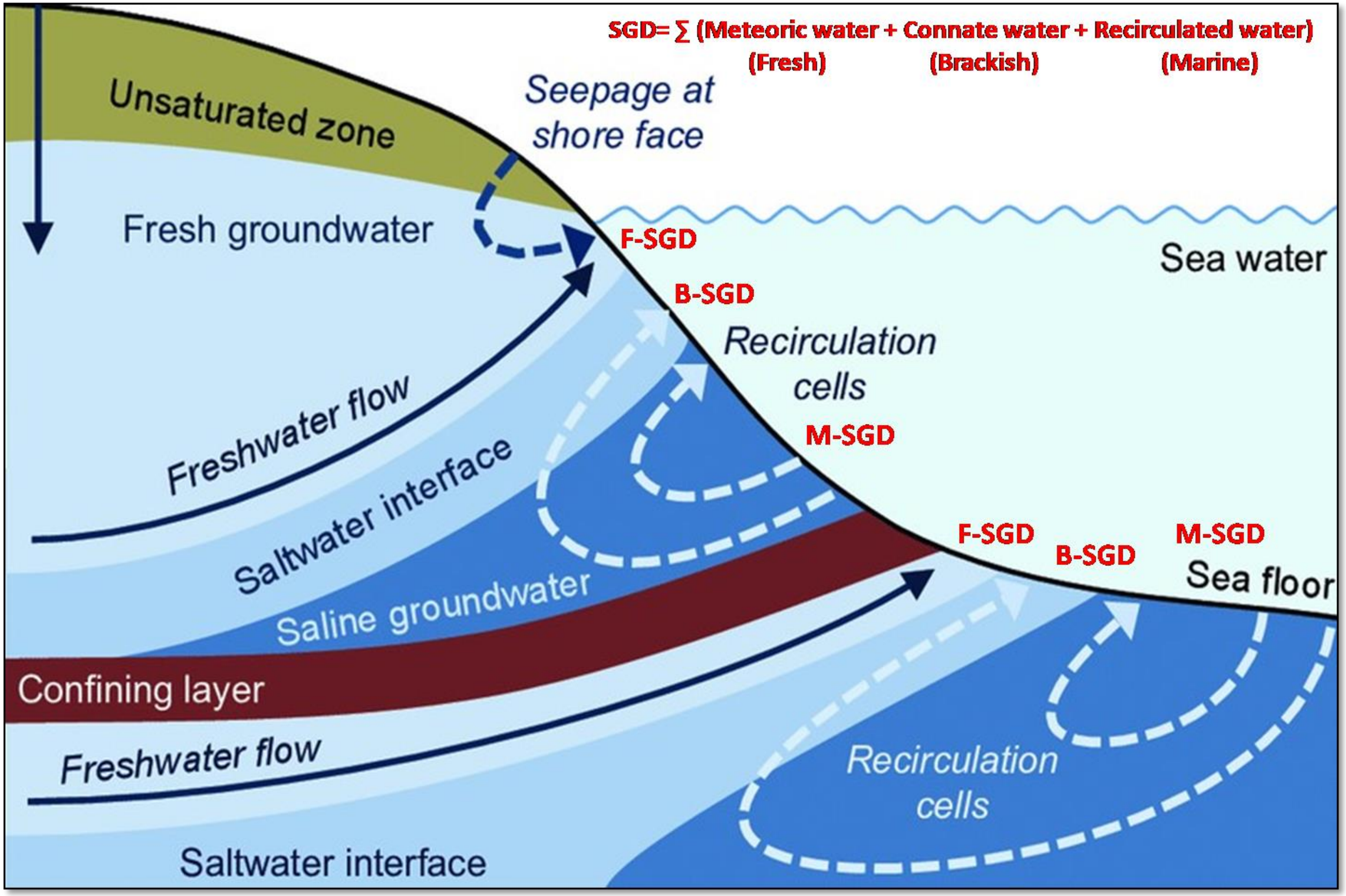
Governing Equation

**DRASTIC Index = Dr * Dw + Rr * Rw + Ar * Aw + Sr * Sw +**
**Tr * Tw + Ir * Iw + Cr * Cw**

r = the rating for the parameter

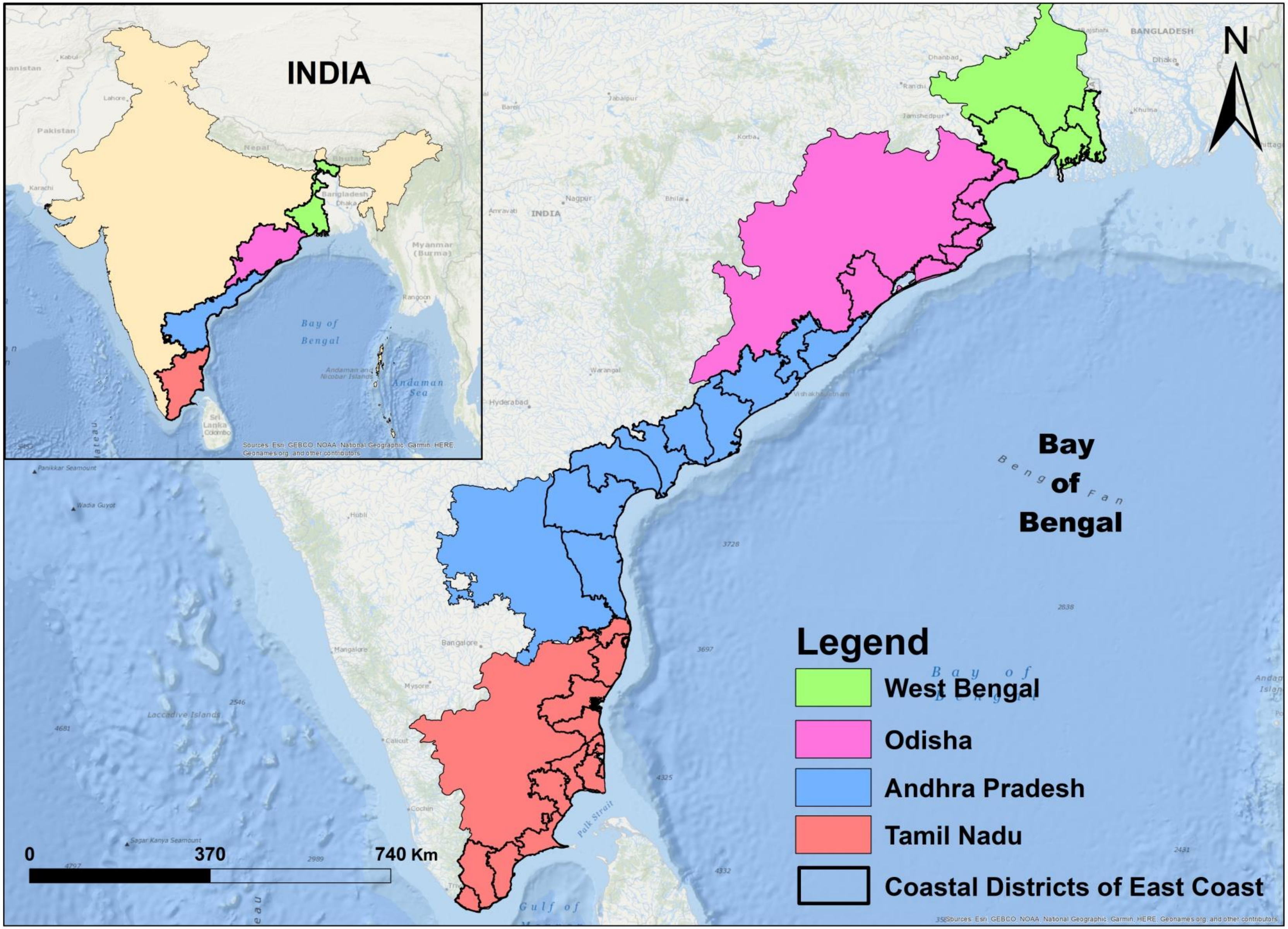
w = an assigned weight for the parameter

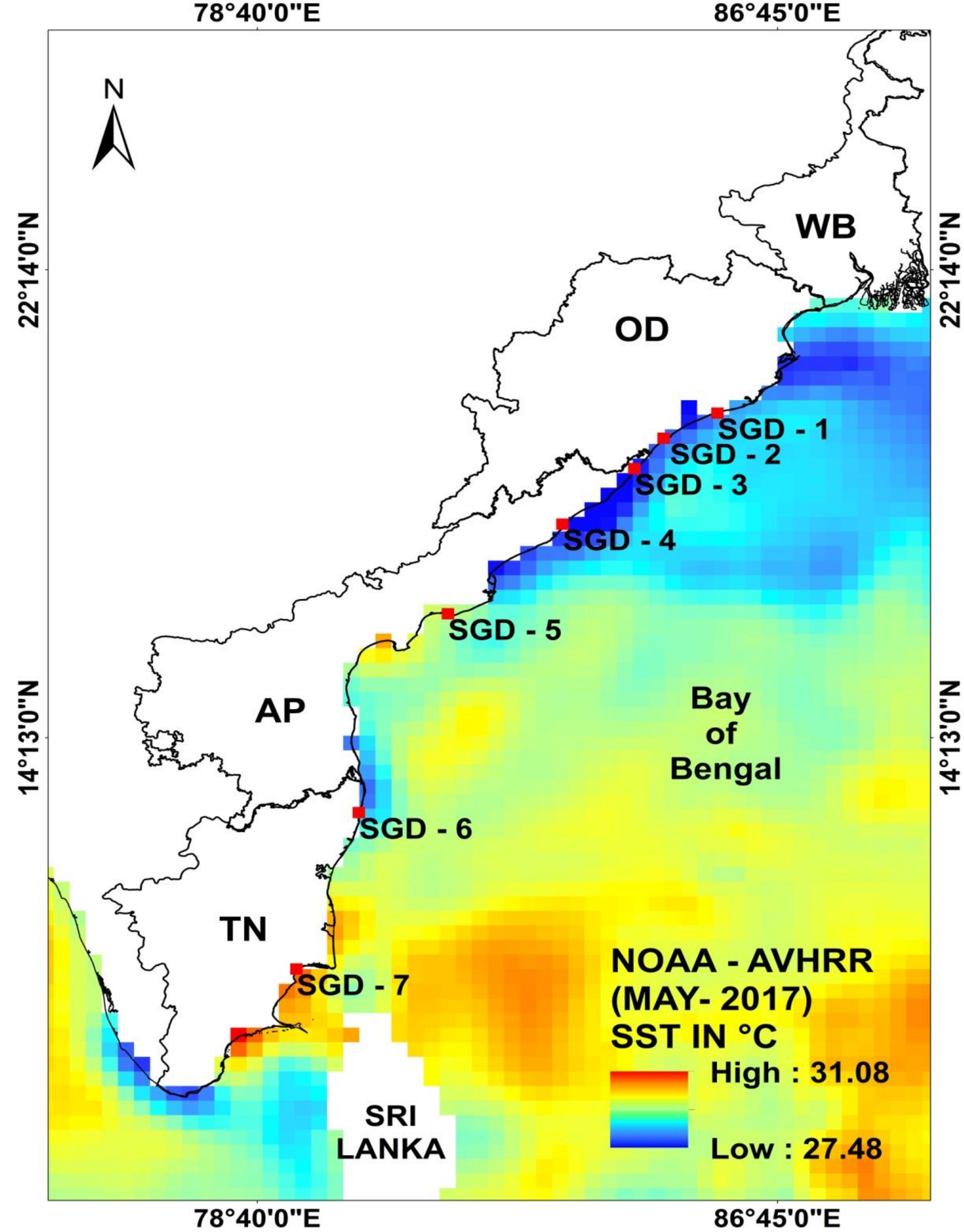
# Submarine Groundwater Discharge (SGD)

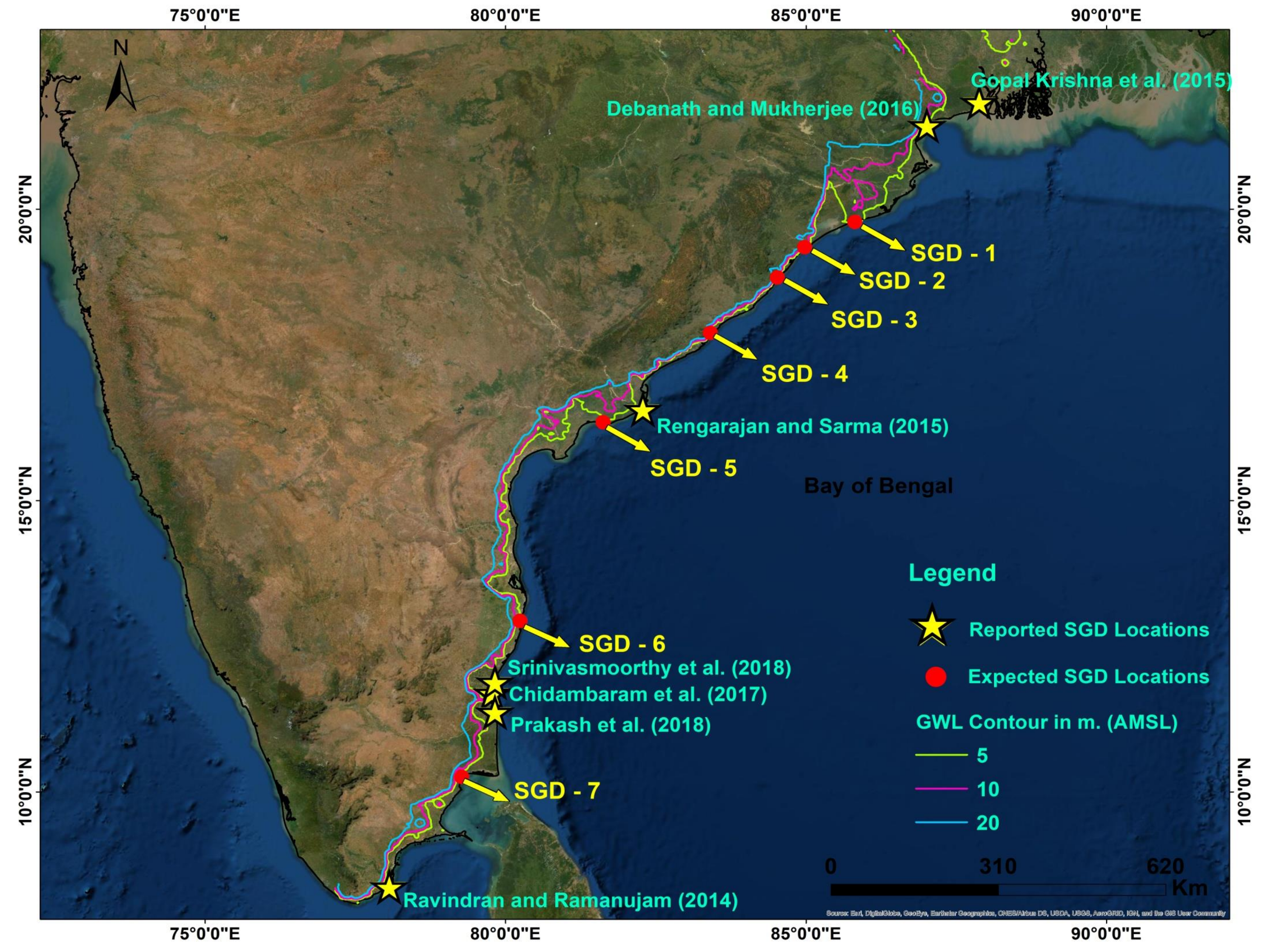



**Principal pathways of submarine groundwater discharge (SGD) to the coastal ocean, including fresh SGD (F-SGD), Brackish SGD (B-SGD) and Marine SGD (M-SGD) through the coastal aquifer (Adopted and modified after Rodellas,V. 2014).**

# East Coast of India




78°40'0"E
86°45'0"E
N
22°14'0"N
14°13'0"N
WB
OD
AP
TN
SGD - 1
SGD - 2
SGD - 3
SGD - 4
SGD - 5
SGD - 6
SGD - 7
Bay of Bengal
SRI LANKA
NOAA - AVHRR (MAY- 2017) SST IN °C
High : 31.08
Low : 27.48



75°0'0"E
80°0'0"E
85°0'0"E
90°0'0"E
20°0'0"N
15°0'0"N
10°0'0"N
N
Gopal Krishna et al. (2015)
Debanath and Mukherjee (2016)
SGD - 1
SGD - 2
SGD - 3
SGD - 4
Rengarajan and Sarma (2015)
SGD - 5
Bay of Bengal
Legend
Reported SGD Locations
Expected SGD Locations
GWL Contour in m. (AMSL)
5
10
20
SGD - 6
Srinivasmoorthy et al. (2018)
Chidambaram et al. (2017)
Prakash et al. (2018)
SGD - 7
0
310
620
Km
Ravindran and Ramanujam (2014)

# Thank You....