Aquifer Mapping

Process

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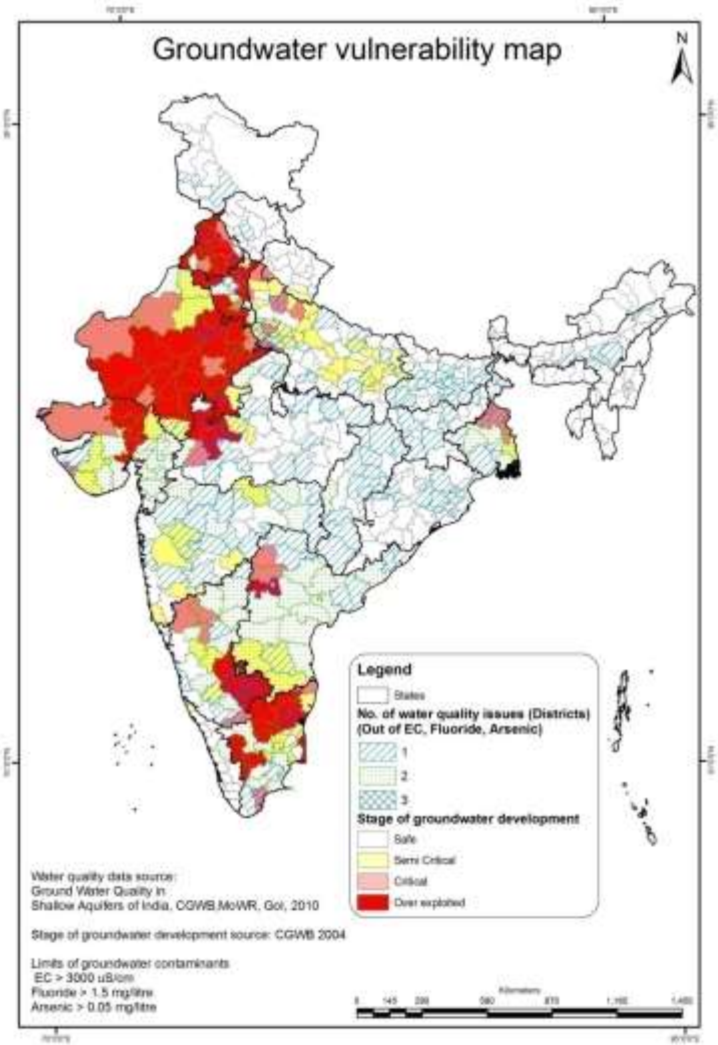
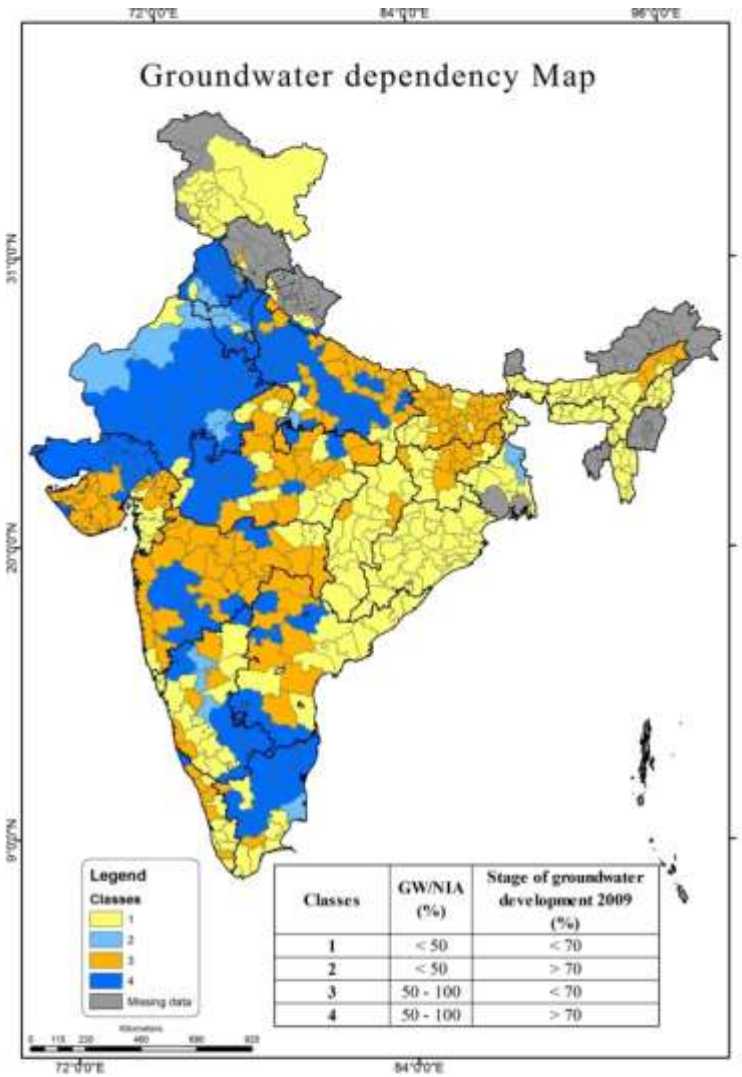
Step 1: Reconnaissance



- Situational analysis (SA) at regional scale (minimum possible is 'block level' from established sources
  - Groundwater dependence: based on data from Minor Irrigation Census, Agriculture Census and State-level sources
  - Groundwater usage: from above sources + CGWB and State Agencies dealing with groundwater
- SA in sample locations at more local scales through field visits that include
  - qualitative information regarding patterns of usage, seasonality of groundwater use and sources
  - Some information regarding the hydrogeology – based on information from GSI and CGWB

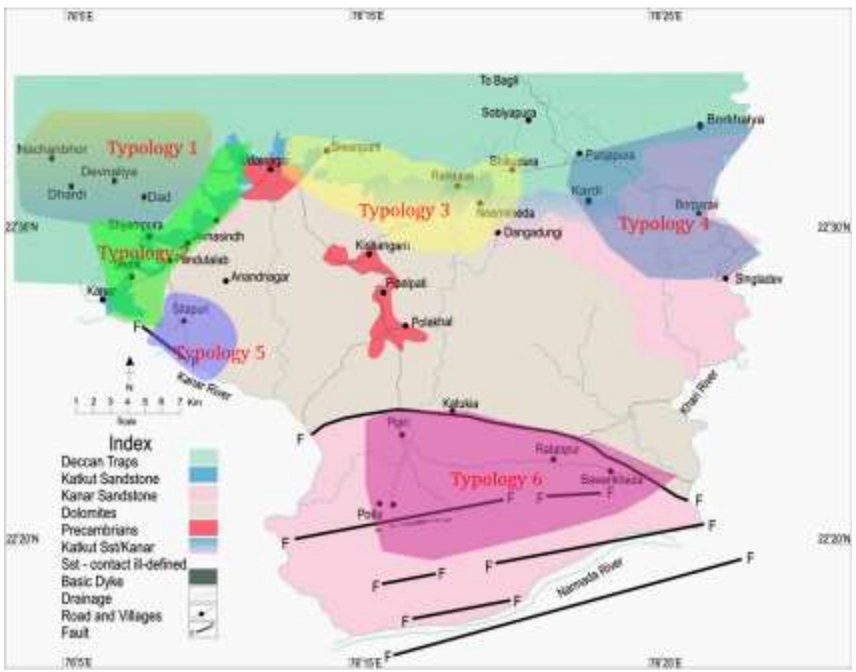
Groundwater dependency



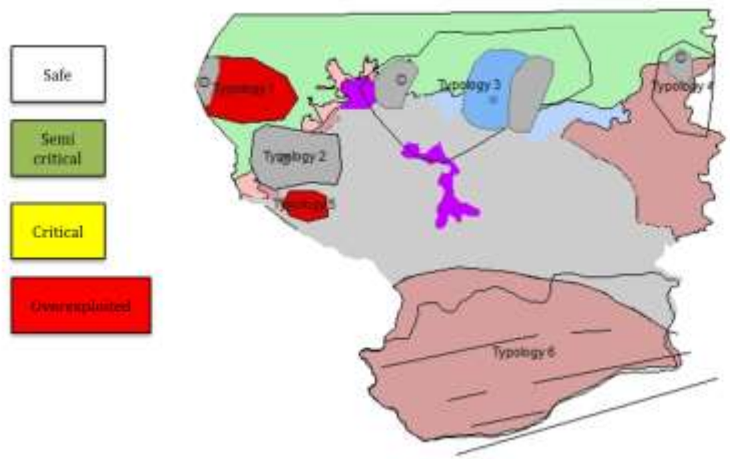
	Low Groundwater Dependence **GWI/NIA < 50%**	**High Groundwater Dependence** **(GWI/NIA >50%**
SGD Less than or Equal to 70% (“Safe”)	Category 1: 240 (44%)	Category 3: 137 (25%)
SGD More than 70% (“Unsafe”)	Category 2: 20 (4%)	Category 4: 143 (27%)

Local geology is important

Typology of groundwater

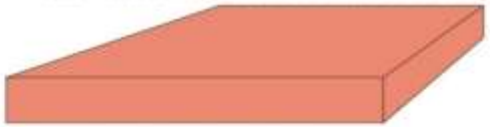


Status of aquifers within the typology

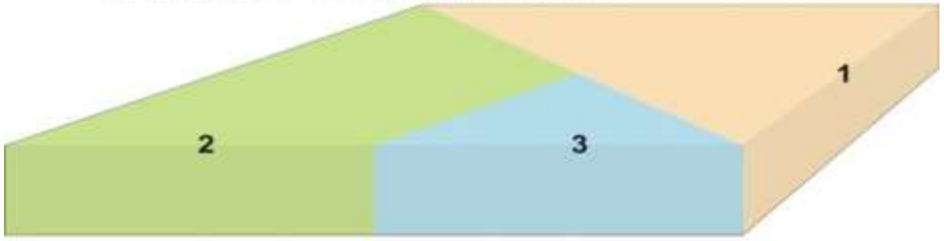


Situation analysis: scale and diversity

GEC classification of unit: *Overexploited*



Likely typology of an *overexploited* unit



TYPE	AQUIFERS	PROBLEM
1.	Multiple	Groundwater overexploitation
2.	Multiple	Groundwater quality
3.	Multiple	Groundwater resources not developed

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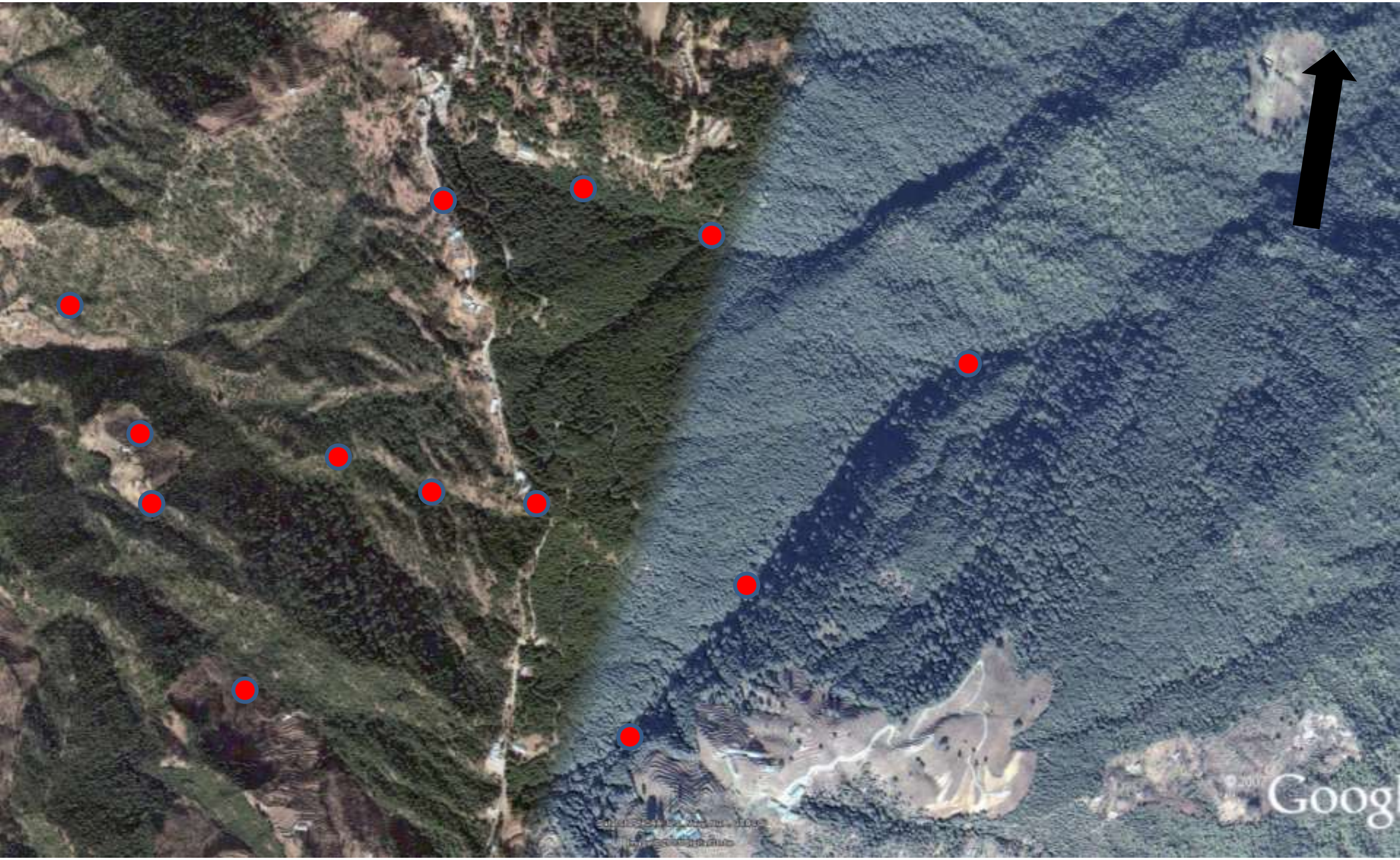
Step 2: Surveys

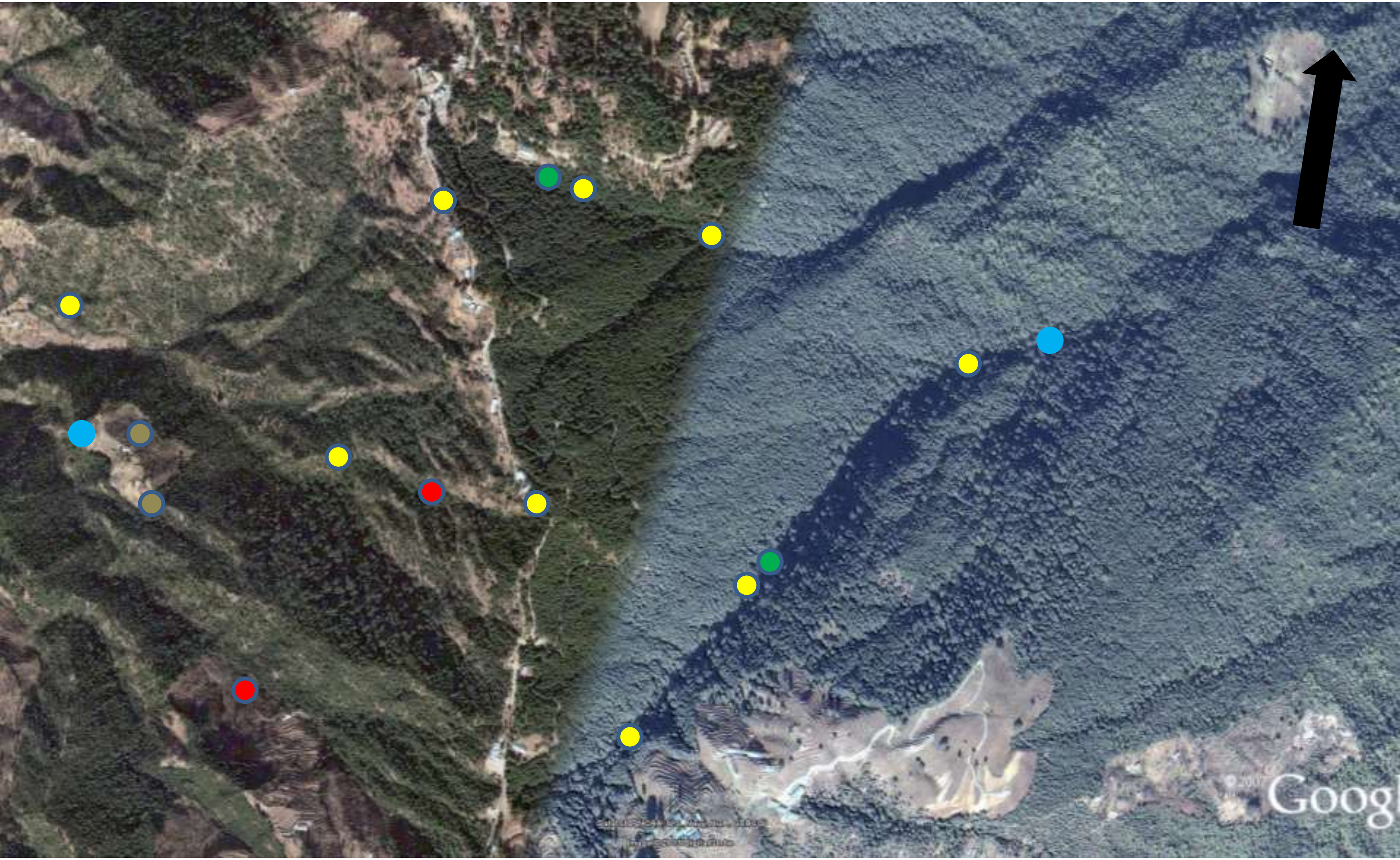
- High scale mapping
  - Local-level geological mapping
  - Well-inventory, including sub-surface sections, fence diagrams and ‘capturing’ narratives regarding well-logs through interviews of well-owners, drillers etc.
  - Study of ‘inflow’ zones
- Geophysics, mainly electrical resistivity surveys to:
  - Gap-fill information not available through above methods
  - To validate information wherever found sparse and/or questionable

A google image

GPS points on a google image

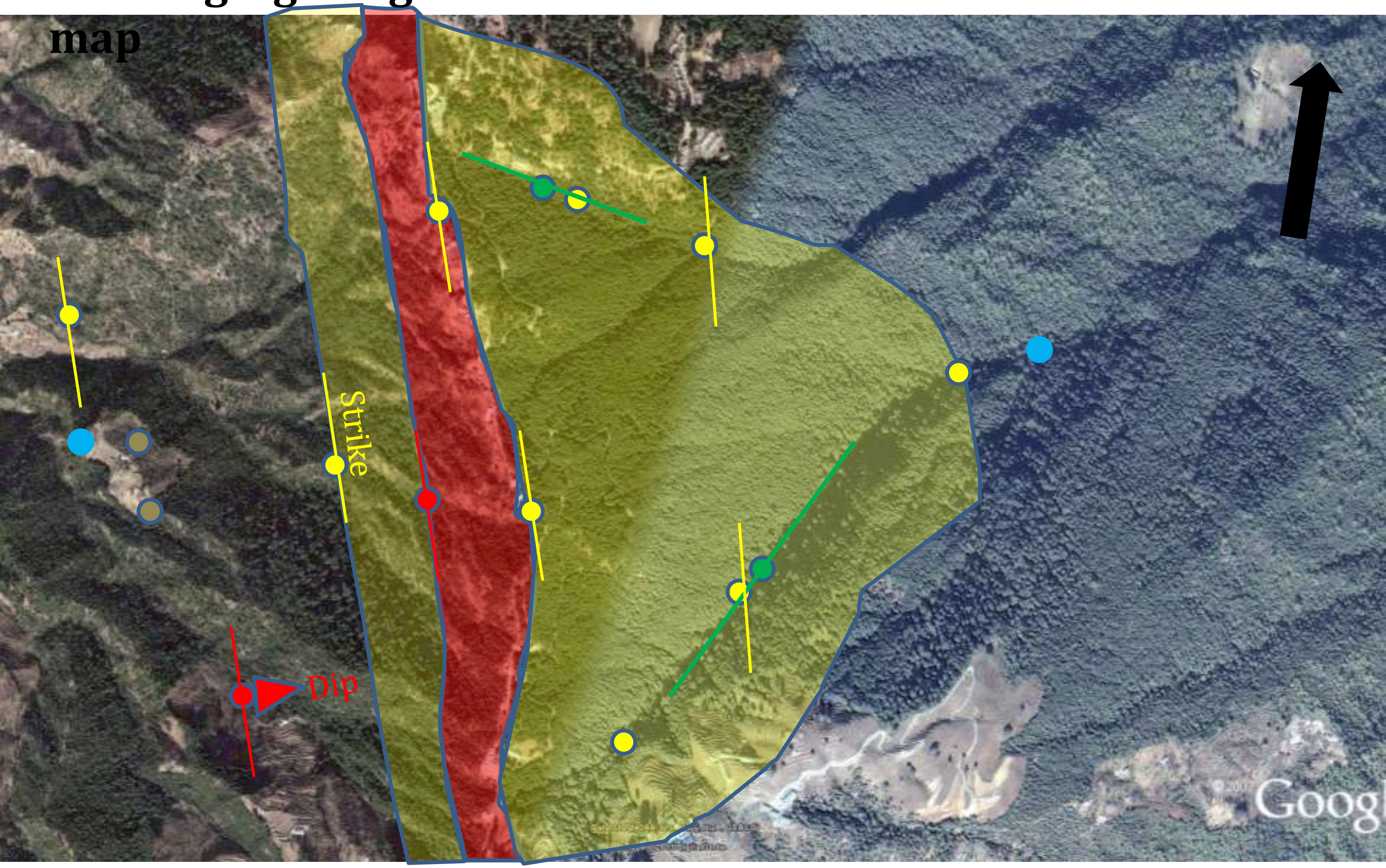


Classifying GPS points on a google image



Quartzite
Phyllite
Debris
Spring
Fracture points

Creating a geological map



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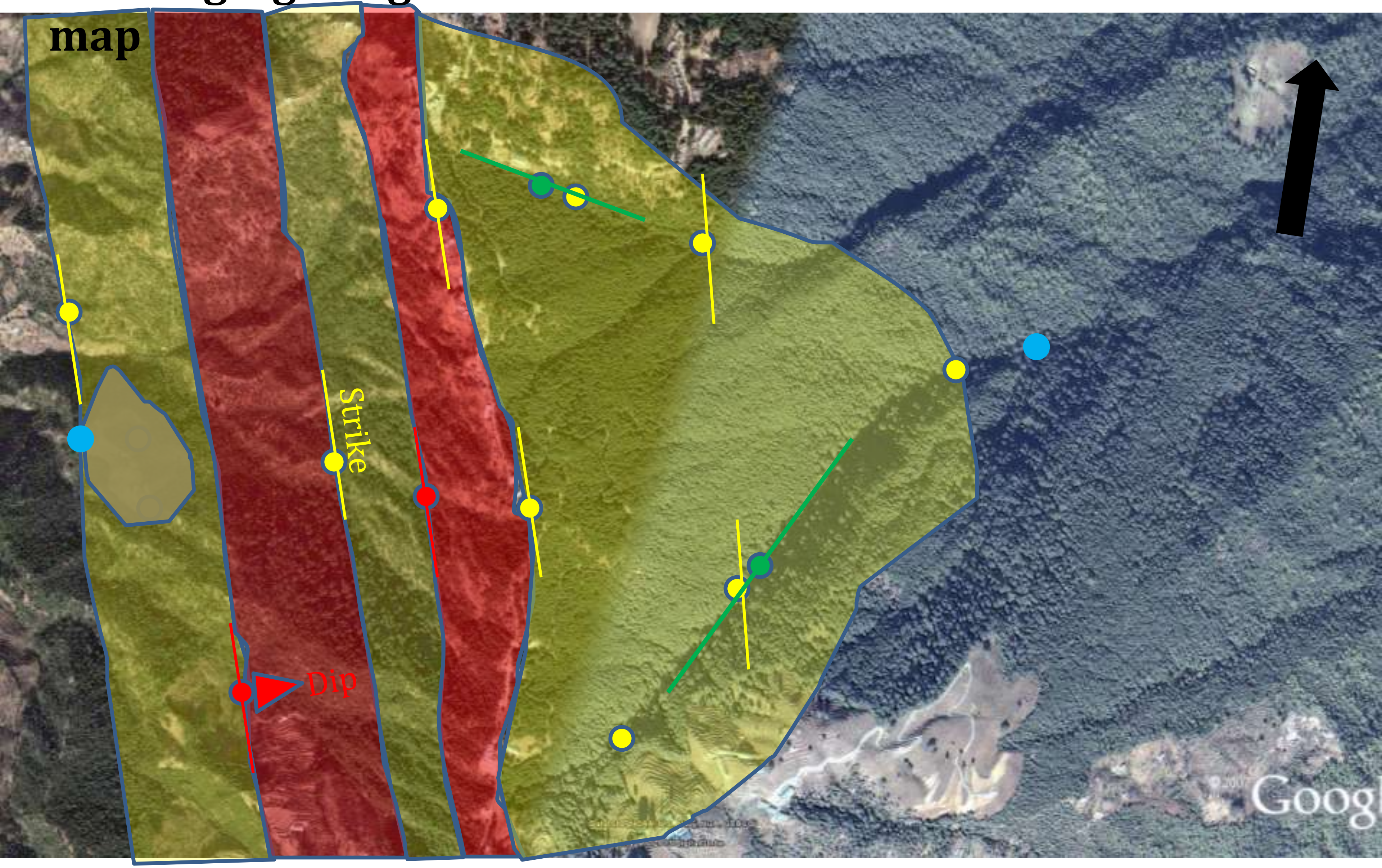
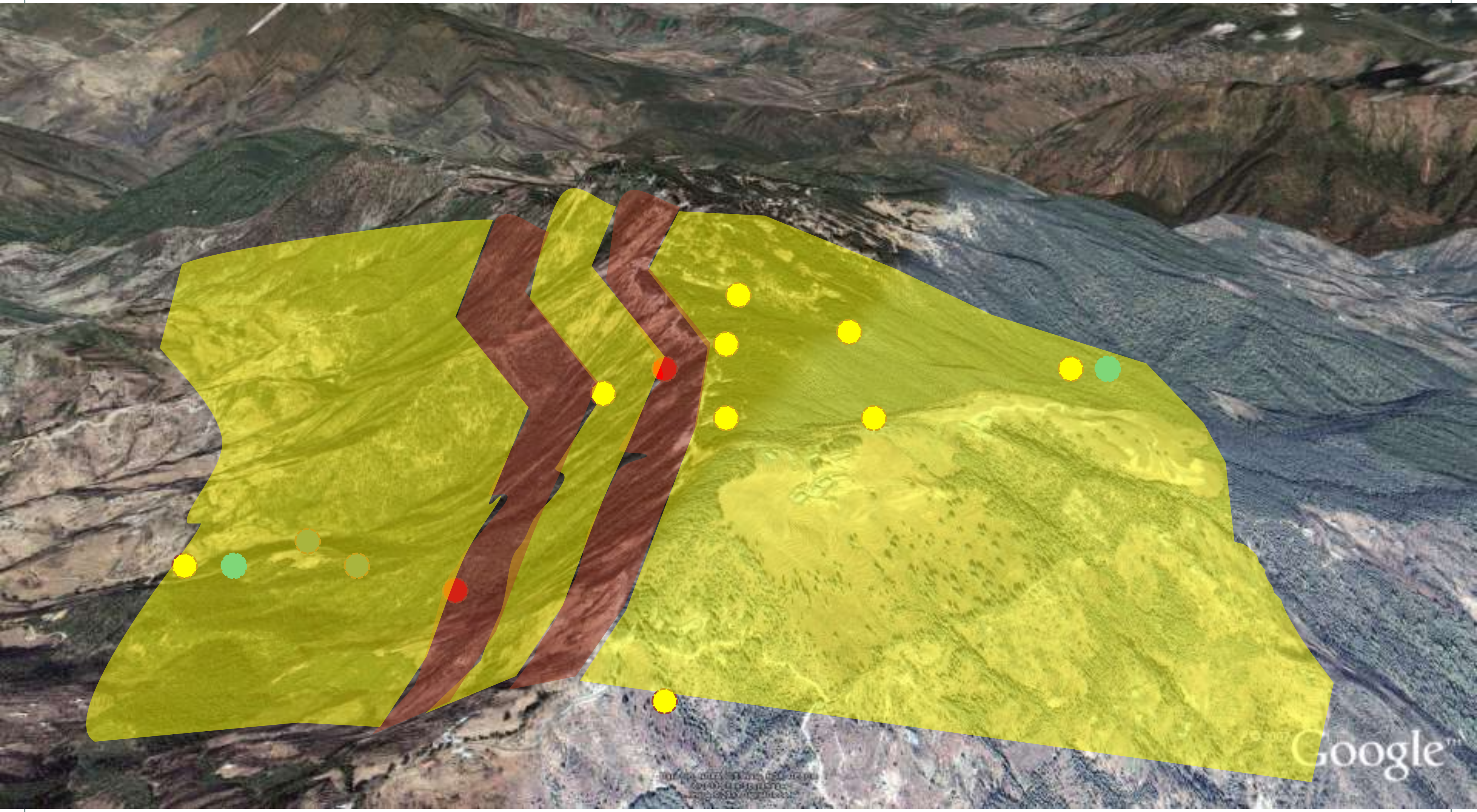


- Quartzite
- Phyllite
- Debris
- Spring
- Fracture points

Interpolating geology

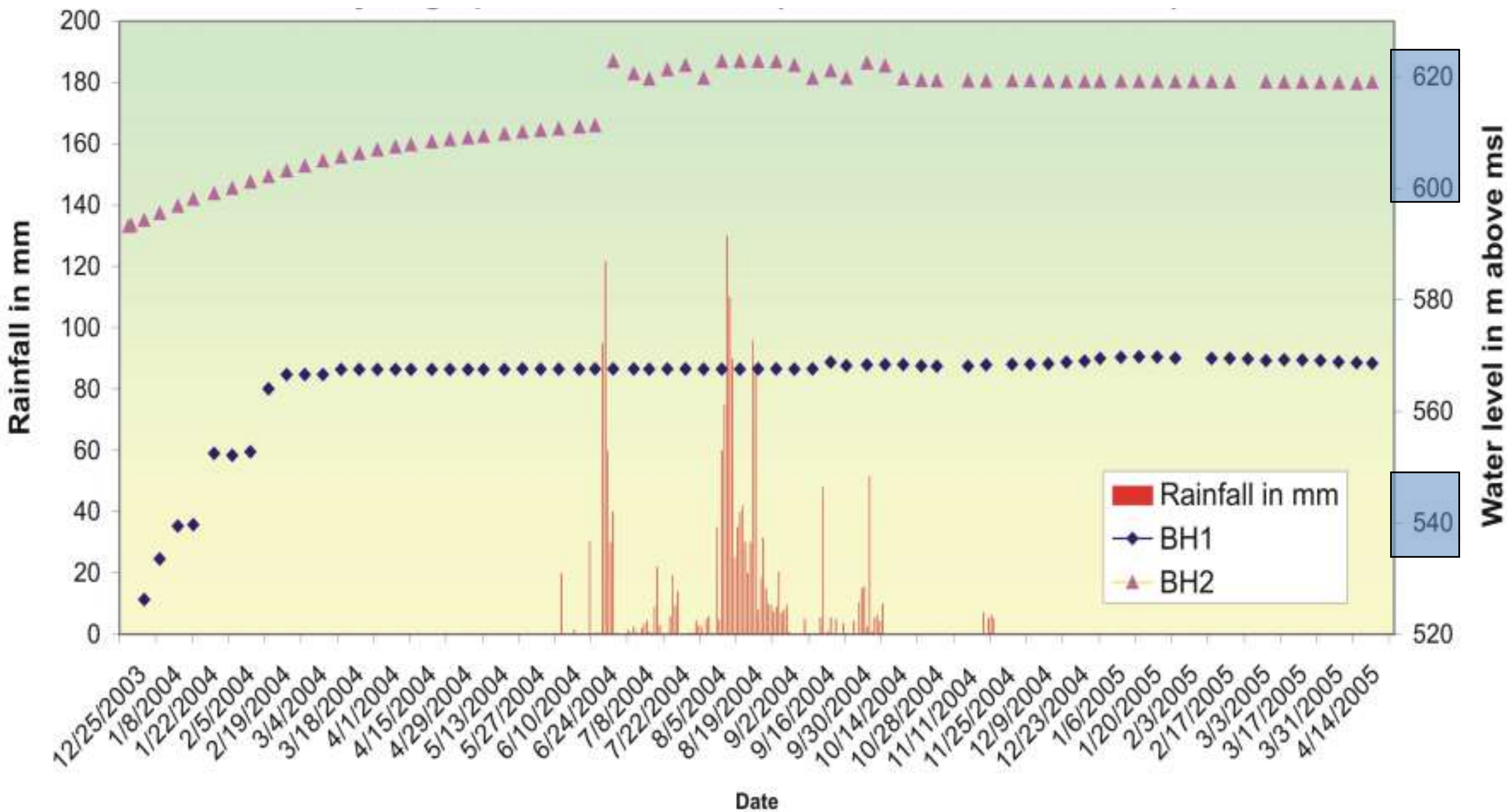


Step 3: Groundwater level and water quality monitoring

- Groundwater level monitoring
  - All wells at least twice a year – pre and post-monsoon
  - Representative sample – 20-30% well (preferably also aquifer-based, decided on the basis of well-inventory data in step 2) monitored on a monthly basis and with an increased frequency during the monsoon season (weekly or daily as is possible)
  - Installation of recorders in piezometers or existing wells that are not in regular use (observation wells) as is possible – *desirable but not mandatory*
- Water quality
  - Groundwater quality measurements that accompany groundwater level measurements – through field probes testing pH, salinity, TDS, hardness etc
  - Seasonal field testing of water quality with kits for specific parameters that are likely in the area – F, As, NO3, Cl, PO4 etc.
  - Lab-testing of smaller number of samples on key wells – major ions

Where are the aquifers in this photograph?

They can be separated on the basis of their respective water levels



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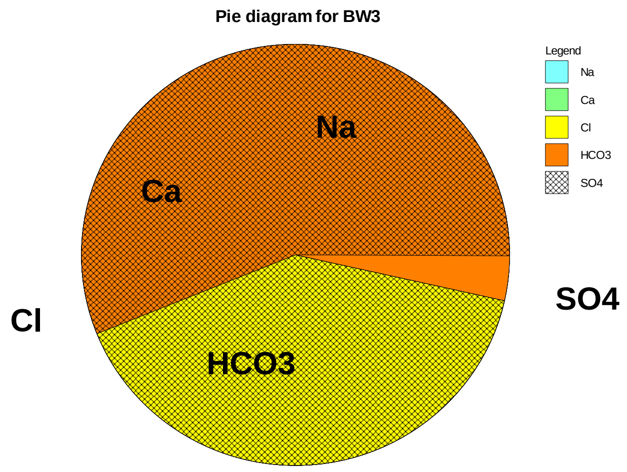
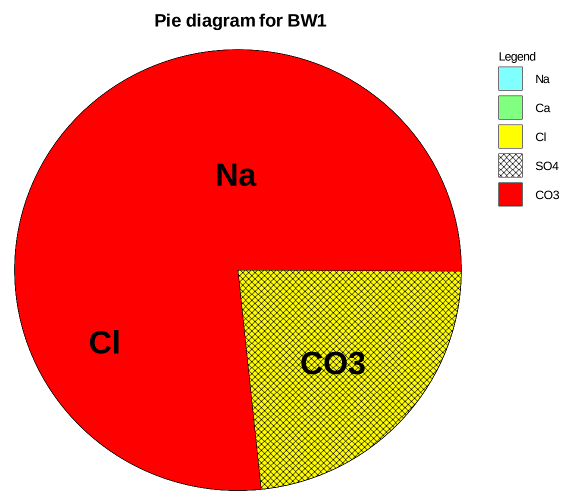
…and their water quality



Shallow unconfined aquifer

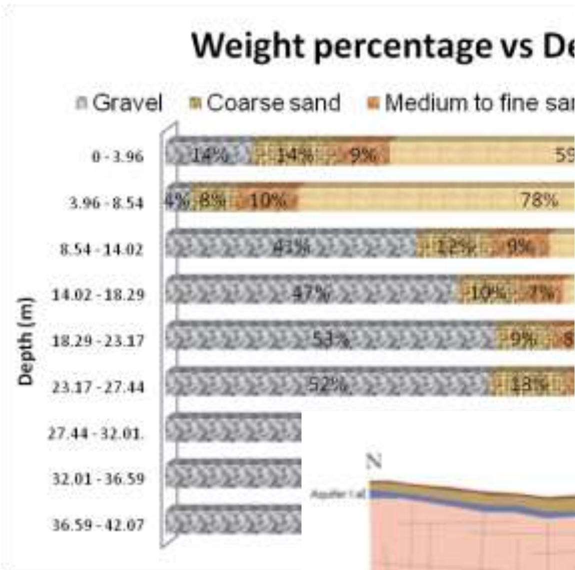


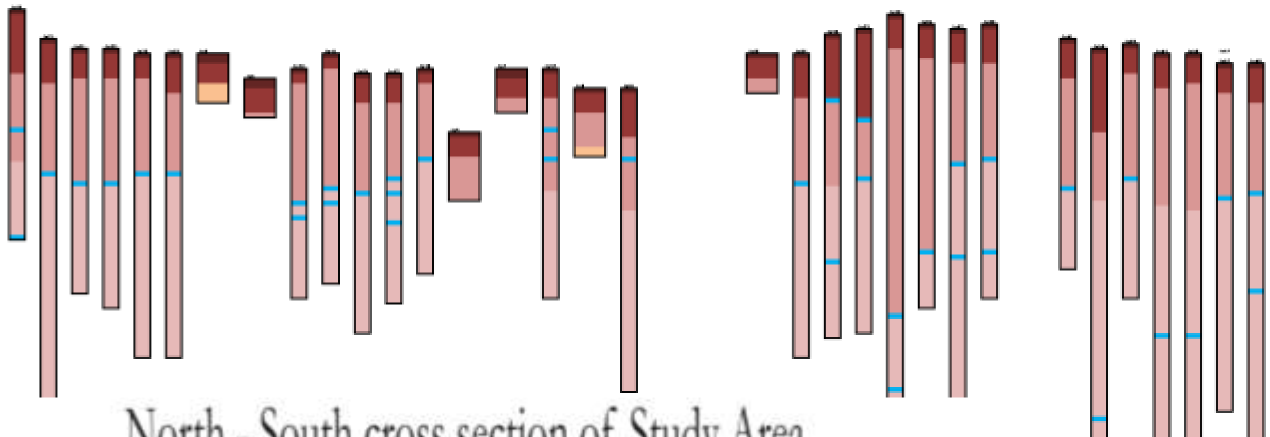
Deeper confined aquifer

Step 4: Aquifer conceptualisation & characterisation

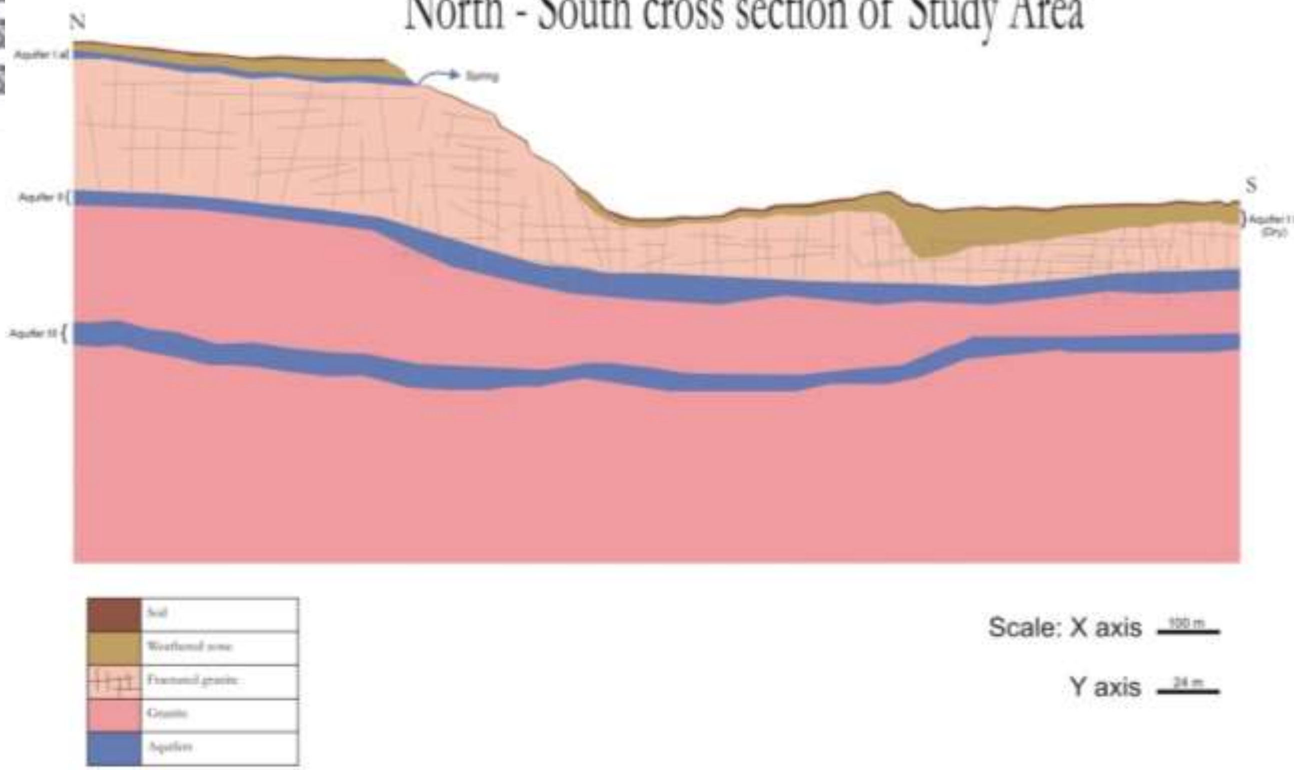
- Overlay of groundwater level (water table / potentiometric contours) to geology maps
- Aquifer conceptualisation
- Aquifer characteristics
  - Transmissivity
  - Storativity
- Well yields
  - Specific capacity

Well logs

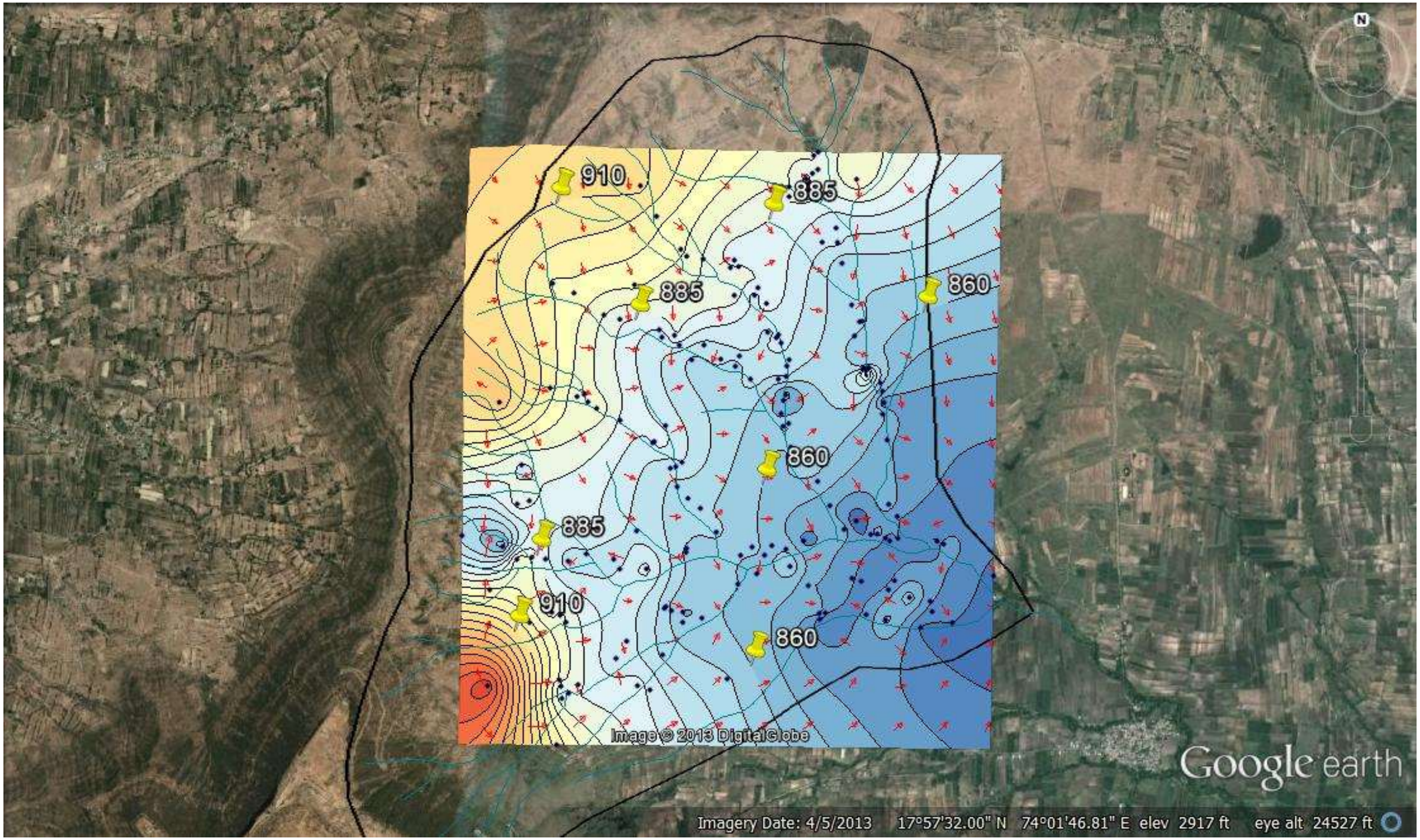




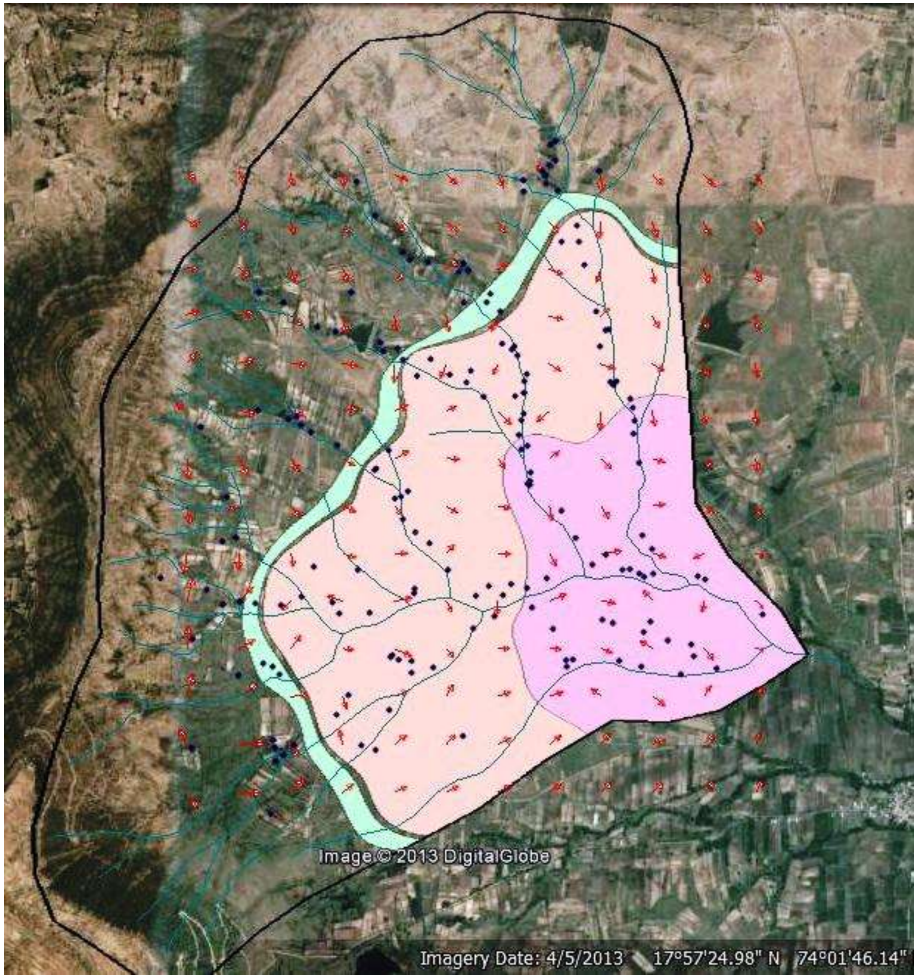
North - South cross section of Study Area



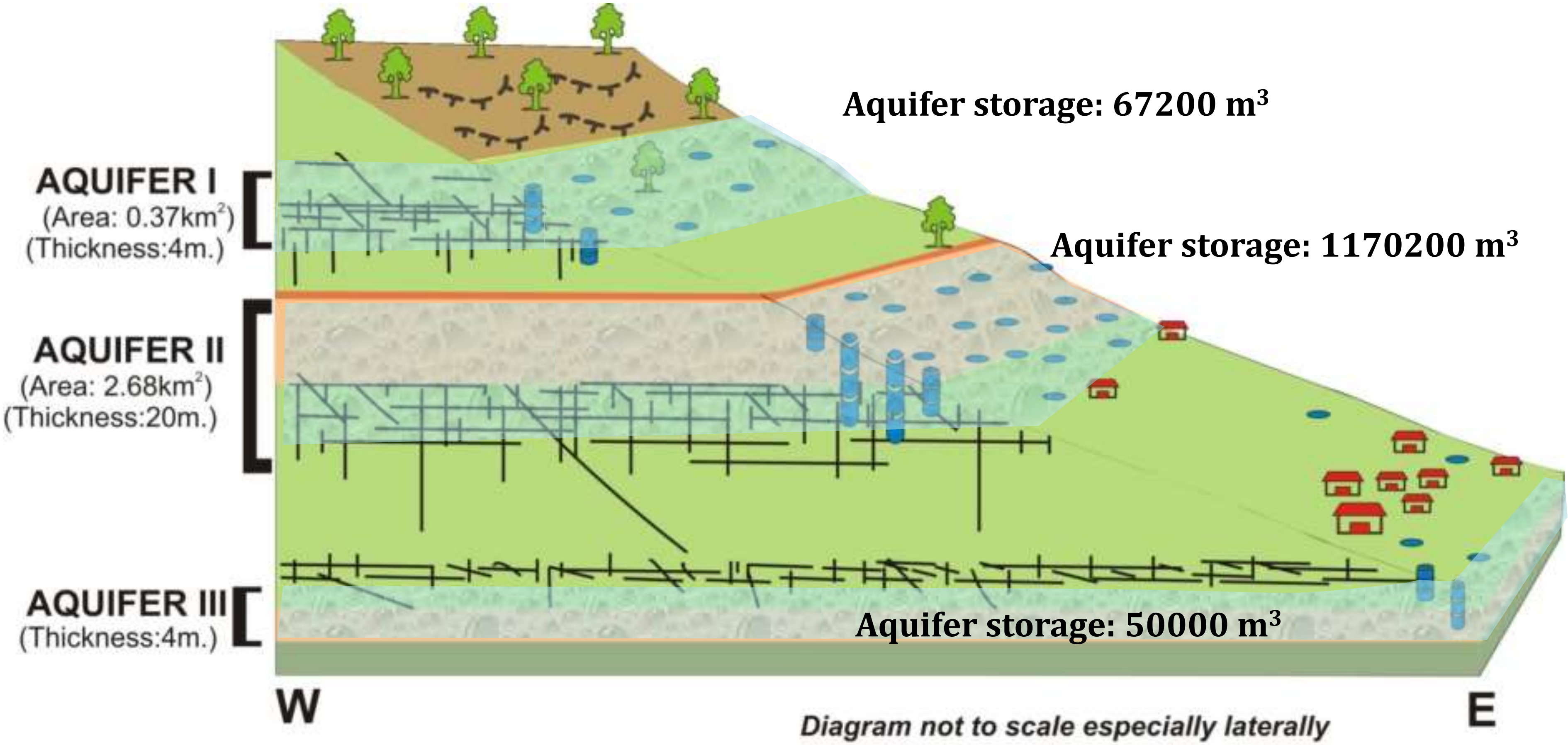
Randullabad: water table contours for three aquifers



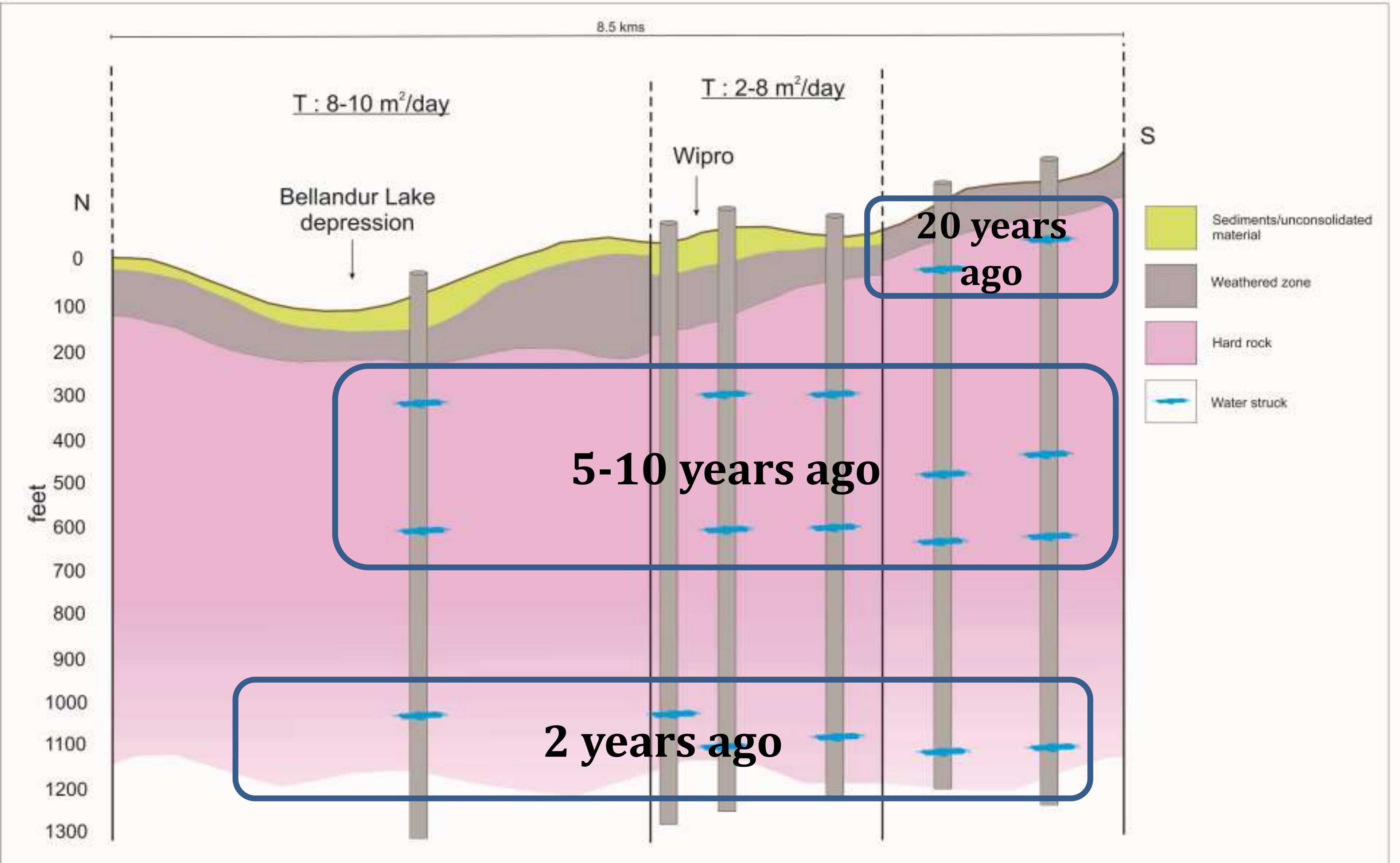
Randullabad: overlay on image – *watersheds*, *aquifer boundaries and groundwater flow*



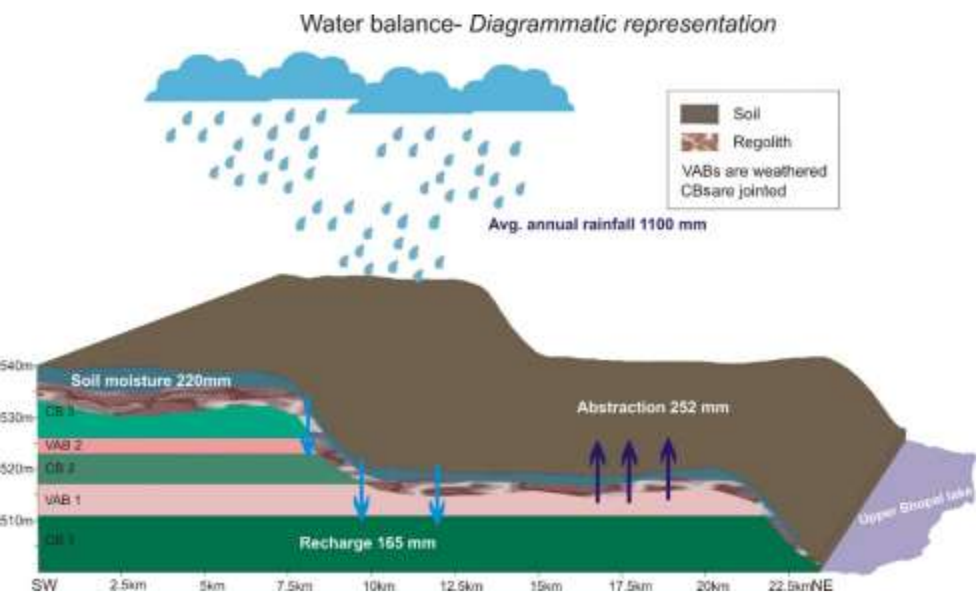
Randullabad: Conceptual model



A hydrogeological section: a part of Bengaluru
– *data entirely derived from participation by citizens*

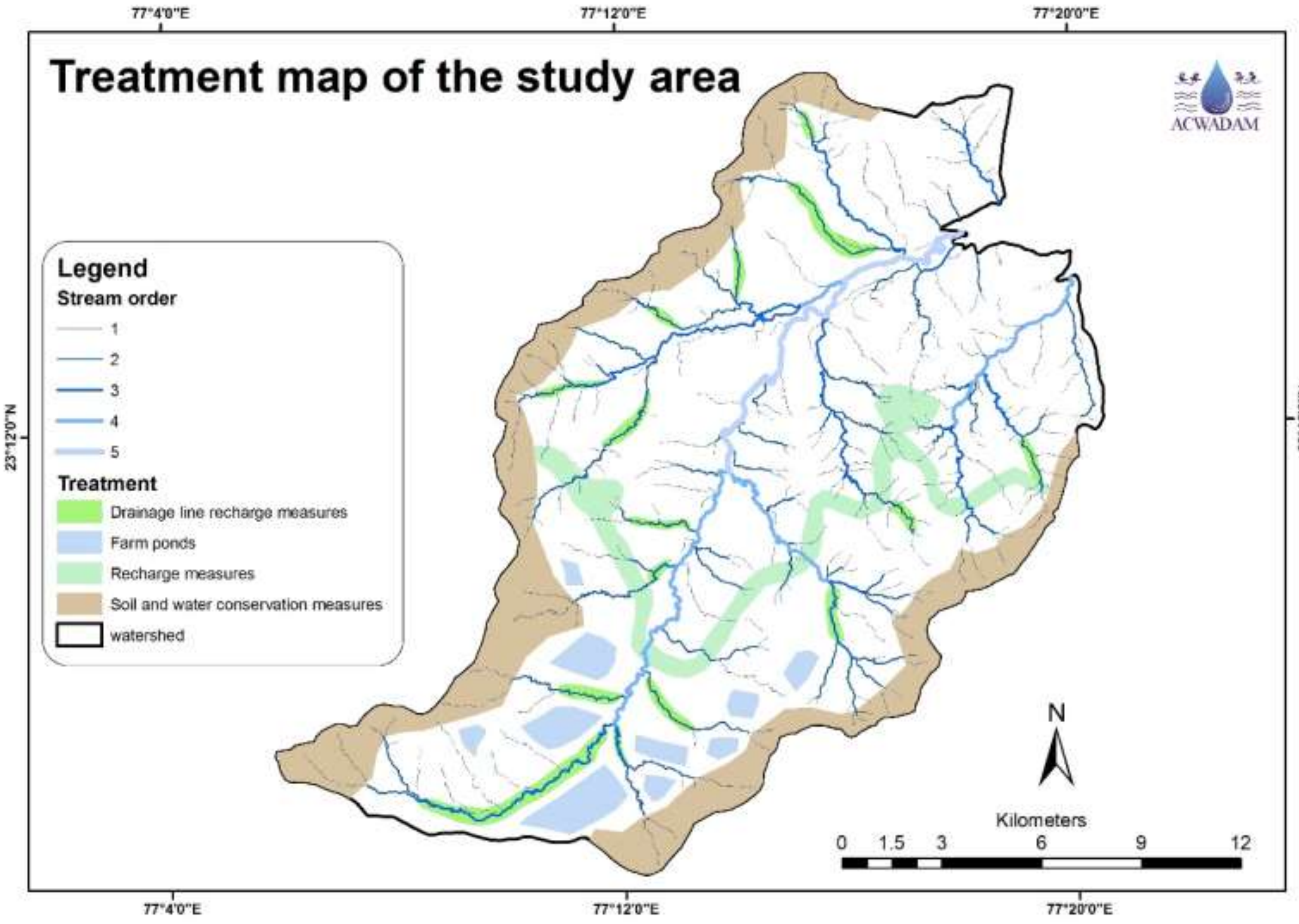


Step 5: Assessment and strategic plan

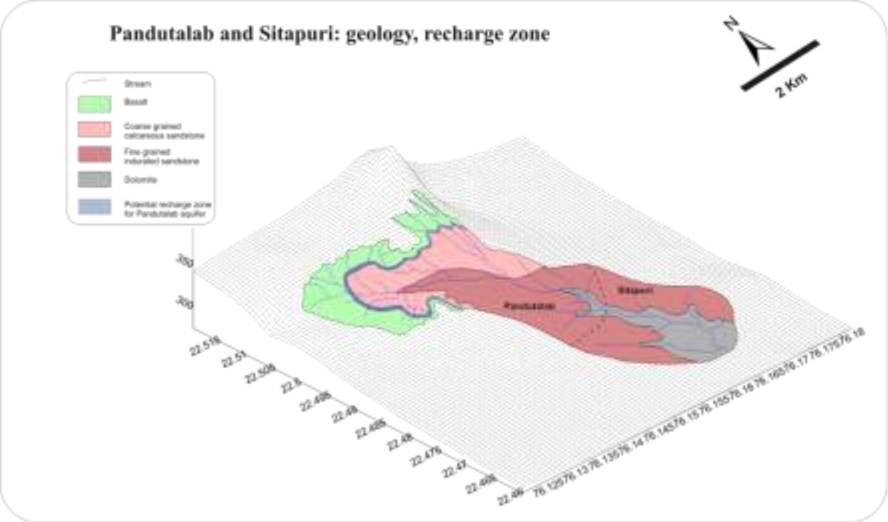


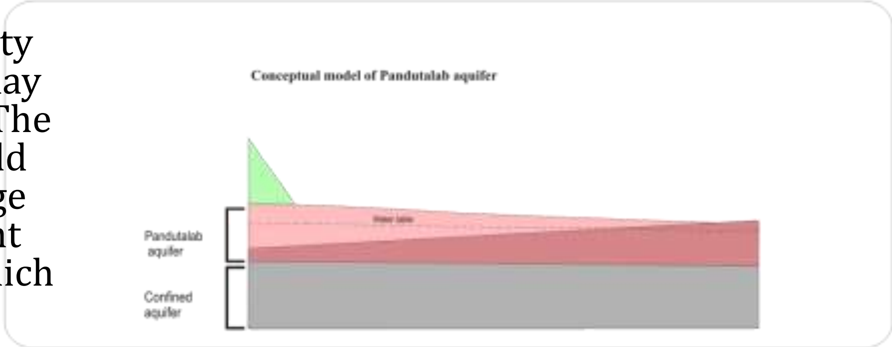
- AQUIFER MAP (includes the following)
  - Groundwater balance preferably at actual aquifer scale or at least at micro-watershed scale
  - Aquifer map – map, cross-section depicting conceptual hydrogeological model and including details from groundwater balance above along with aquifer characteristics
    - Storage & Transmission
    - Quality
    - Recharge (actual & potential) , Abstraction & Base flow
  - Problems / issues of serious concern
- Groundwater management plan (included in the map document)
  - Areas conducive for groundwater recharge and description of measures
  - Groundwater discharge zones
  - Well-sites for participatory groundwater management strategy
  - Details of PGWM strategy
  - Additional details, as and when required

Treatment map for Kolans Basin



Pandutalab and Sitapuri

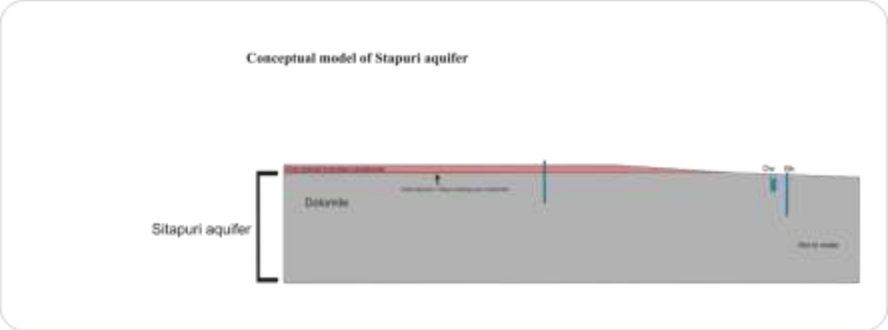




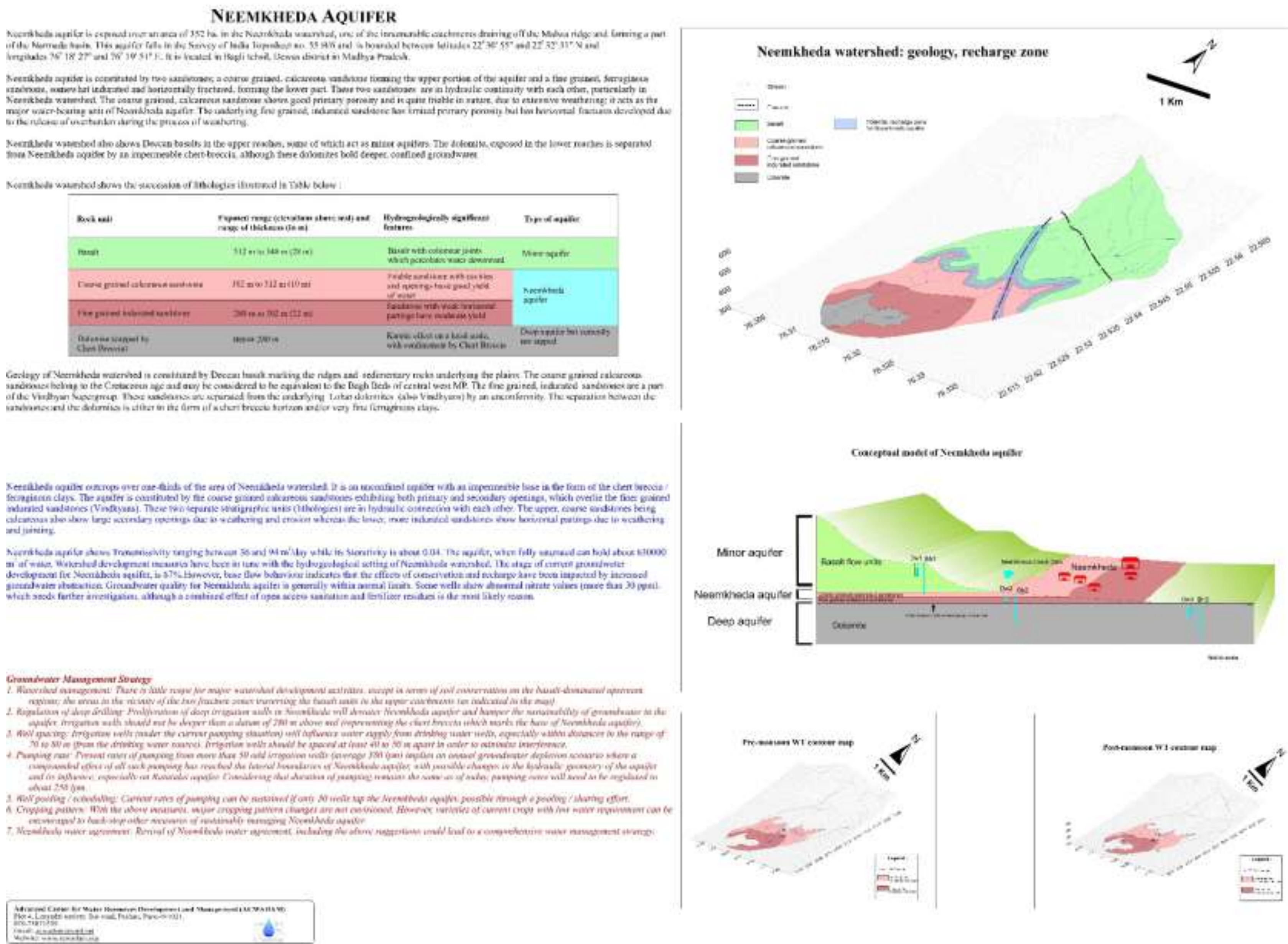
- Sitapuri aquifer shows Transmissivity ranging between 180 and 194 m2/day while its Storativity is about 0.001. The aquifer, when fully saturated can hold about 154260 m3 of water. The stage of current groundwater development for Neemkheda aquifer, is 525%, which falls in over-exploited zone

- Pandutalab aquifer shows Transmissivity ranging between 14 and 54 m2/day while its Storativity is about 0.04. The aquifer, when fully saturated can hold about 2560000 m3 of water.

- The stage of current groundwater development for Pandutalab aquifer, is 10%. Fluoride in Pandutalab aquifer



Aquifer profile



NEEMKHEDA AQUIFER

Neemkheda aquifer is exposed over an area of 352 ha. in the Neemkheda watershed, one of the innumerable catchments draining off the Malwa ridge and forming a part of the Narmada basin. This aquifer falls in the Survey of India Toposheet no. 55 [illegible] and is bounded between latitudes 22° 30' 55" and 22° 32' 31" N and longitudes 76° 18' 27" and 76° 19' 51" E. It is located in Bagli tehsil, Dewas district in Madhya Pradesh.

Neemkheda aquifer is constituted by two sandstones; a coarse grained, calcareous sandstone forming the upper portion of the aquifer and a fine grained, ferruginous sandstone, somewhat indurated and horizontally fractured, forming the lower part. These two sandstones are in hydraulic continuity with each other, particularly in Neemkheda watershed. The coarse grained, calcareous sandstone shows good primary porosity and is quite friable in nature, due to extensive weathering; it acts as the major water-bearing unit of Neemkheda aquifer. The underlying fine grained, indurated sandstone has limited primary porosity but has horizontal fractures developed due to the release of overburden during the process of weathering.

Neemkheda watershed also shows Deccan basalts in the upper reaches, some of which act as minor aquifers. The dolomite, exposed in the lower reaches is separated from Neemkheda aquifer by an impermeable chert-breccia, although these dolomites hold deeper, confined groundwater.

Neemkheda watershed shows the succession of lithologies illustrated in Table below :

Rock unit	Exposed range (elevations above msl) and range of thickness (in m)	Hydrogeologically significant features	Type of aquifer
Basalt	512 m to 540 m (28 m)	Basalt with columnar joints which percolates water downward	Minor aquifer
Coarse grained calcareous sandstone	302 m to 312 m (10 m)	Friable sandstone with cavities and openings have good yield of water	Neemkheda aquifer
Fine grained indurated sandstone	280 m to 302 m (22 m)	Sandstone with weak horizontal partings have moderate yield	Neemkheda aquifer
Dolomite (capped by Chert Breccia)	below 280 m	Karstic effect on a local scale, with confinement by Chert Breccia	Deep aquifer but currently not tapped

Geology of Neemkheda watershed is constituted by Deccan basalt marking the ridges and sedimentary rocks underlying the plains. The coarse grained calcareous sandstones belong to the Cretaceous age and may be considered to be equivalent to the Bagh Beds of central west MP. The fine grained, indurated sandstones are a part of the Vindhyan Supergroup. These sandstones are separated from the underlying Lohan dolomites (also Vindhyans) by an unconformity. The separation between the sandstones and the dolomites is either in the form of a chert breccia horizon and/or very fine ferruginous clays.

Neemkheda aquifer outcrops over one-thirds of the area of Neemkheda watershed. It is an unconfined aquifer with an impermeable base in the form of the chert breccia / ferruginous clays. The aquifer is constituted by the coarse grained calcareous sandstones exhibiting both primary and secondary openings, which overlie the finer grained indurated sandstones (Vindhyans). These two separate stratigraphic units (lithologies) are in hydraulic connection with each other. The upper, coarse sandstones being calcareous also show large secondary openings due to weathering and erosion whereas the lower, more indurated sandstones show horizontal partings due to weathering and jointing.

Neemkheda aquifer shows Transmissivity ranging between 36 and 94 m²/day while its Storativity is about 0.04. The aquifer, when fully saturated can hold about 630000 m³ of water. Watershed development measures have been in tune with the hydrogeological setting of Neemkheda watershed. The stage of current groundwater development for Neemkheda aquifer, is 67%. However, base flow behaviour indicates that the effects of conservation and recharge have been impacted by increased groundwater abstraction. Groundwater quality for Neemkheda aquifer is generally within normal limits. Some wells show abnormal nitrate values (more than 30 ppm), which needs further investigation, although a combined effect of open access sanitation and fertilizer residues is the most likely reason.

Groundwater Management Strategy

1. *Watershed management: There is little scope for major watershed development activities, except in terms of soil conservation on the basalt-dominated upstream regions; the areas in the vicinity of the two fracture zones traversing the basalt units in the upper catchments (as indicated in the map).*
2. *Regulation of deep drilling: Proliferation of deep irrigation wells in Neemkheda will dewater Neemkheda aquifer and hamper the sustainability of groundwater in the aquifer. Irrigation wells should not be deeper than a datum of 280 m above msl (representing the chert breccia which marks the base of Neemkheda aquifer).*
3. *Well spacing: Irrigation wells (under the current pumping situation) will influence water supply from drinking water wells, especially within distances in the range of 70 to 80 m (from the drinking water sources). Irrigation wells should be spaced at least 40 to 50 m apart in order to minimise interference.*
4. *Pumping rate: Present rates of pumping from more than 50 odd irrigation wells (average 350 lpm) implies an annual groundwater depletion scenario where a compounded effect of all such pumping has reached the lateral boundaries of Neemkheda aquifer, with possible changes in the hydraulic geometry of the aquifer and its influence, especially on [illegible] aquifer. Considering that duration of pumping remains the same as of today, pumping rates will need to be regulated to about 250 lpm.*
5. *Well pooling / scheduling: Current rates of pumping can be sustained if only 30 wells tap the Neemkheda aquifer, possible through a pooling / sharing effort.*
6. *Cropping pattern: With the above measures, major cropping pattern changes are not envisioned. However, varieties of current crops with low water requirement can be encouraged to back-stop other measures of sustainably managing Neemkheda aquifer.*
7. *Neemkheda water agreement: Revival of Neemkheda water agreement, including the above suggestions would lead to a comprehensive water management strategy.*

Advanced Center for Water Resources Development and Management (ACWADAM)

Protocols	*Typology 1*	*Typology 2*	*Typology 3*	*Typology 4*	*Typology 5*	*Typology 6*
Geohydrology in WSD including groundwater recharge						
Protection of recharge areas						
Efficient well use						
Pump capacity regulation						
Distance (wrt drinking water well) regulation						
Depth Regulation (wrt drinking well)						
Regulation of Agricultural water use						
Groundwater management through sharing						

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Step 6: Monitoring, Impacts and Mid-course corrections

- Continued monitoring of key wells
  - Groundwater levels
  - Groundwater quality
- Changes in abstraction and recharge, along with changes in base flows
- Usage patterns – cropping and other uses
- Energy
- Other aspects that are crucial to the area

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