# Bharathidasan University

## Tiruchirappalli – 620 023, Tamil Nadu

**6 Yr. Int. M.Tech. Geological Technology and Geoinformatics**

**Course Code : MTIGT1003     4 Credits**

**GIS BASED 3D VISUALIZATION IN GEOLOGICAL TECHNOLOGY**

**Unit-5:   3D Visualization of Groundwater**

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**Professor, Department of Remote Sensing**

# *Course Objectives*

- To learn the fundamentals of 3D visualization in GIS
- To study the possible methods of visualizing various Geological data
- To understand the ways and means of representing topographic relief in a 3 dimensional pattern
- To learn the methods of generating 3D images and interpretation of important geological structures using Geophysical data
- To learn the application of Geoinformatics in natural disaster mitigation.

# MTIGT1003: GIS BASED 3D VISUALIZATION IN GEOLOGICAL TECHNOLOGY 4 Credits

**Unit-1: Principles of 3D Visualization:** Data Input (x, y, z) – Monoscopic and Stereoscopic 3D visualization; TIN – Vertical Exaggeration – DEM based visualization – Concepts of Shaded Relief mapping. **12 Hrs.**

**Unit-2: 3D Visualisation of Topographic Data:** Generation of x, y, z data – 3D visualization of topography – DEM based topographic analysis – shaded relief – applications. **12 Hrs.**

**Unit-3: 3D Visualisation of Geophysical Data:** X, Y, Z data from different sources – Generation of DEM, Different processed outputs of DEM, Shaded relief maps of Gravity, Magnetic and Resistivity data – Its applications. **16 Hrs.**

**Unit-4: 3D Visualisation of Subsurface Lithology:** Collection of borehole data – working out lithology and lithotop of various horizons – DEM of shaded relief of thickness of various formations, Depth of various formations and litho top of various formation – their interpretations. **12 Hrs.**

**Unit-5: 3D Visualisation of Groundwater:** Collection of water level and other aquifer variables (Transmissivity, Permeability, Storage co-efficient, etc.) – Generation of x, y, z – Generation of DEM and shaded relief of groundwater systems and interpretation. **12 Hrs.**

**Unit-6: Current Contours: (Not for Final Exam only for Discussion):** Step-by-step procedures for generation of high resolution DEM using CARTOSAT Stereo data; Derivation DEM products like Anaglyph and 3D Fence Diagram. Use of DEM for automated mapping of Geological Structures in GIS.

# *Course outcomes*

After the successful completion of this course, the students are able to:

- Understand the concepts, develop GIS database and generate 3D visualization of Geological and other terrain features
- Know the fundamentals pertaining to volume estimation, drainage mapping, watershed delineation, slope classification using 3D visualization techniques
- Learn the method of 3D visualization of topographic data
- Understand the method of visualization of Geophysical data and their application
- Learn the method 3D visualization of subsurface lithology and its applications
- Understand the method of 3D visualization of groundwater and its applications.

# References


- Burrough, PA., Principles of Geographical Information Systems, Oxford University Press, 1997.
- DeMers, Michael N, Fundamentals of Geographic Information Systems, John Wiley and Sons, 1999.
- David J., Bringing Geographical Information Systems into Business, Second Edition Grimshaw, John Wiley and Sons, 1999.
- Christian, Serving Maps on the Internet: Geographic Information on the World Wide Web Harder, ESRI Press, 1998.
- Graeme F. Bonham-Carter, Geographic Information Systems for Geoscientists: Modelling with GIS, Pergamon Publications, 1994.
- Sabins, F.F.Jr., Remote Sensing Principles and Interpretation, Freeman, Sanfrancisco. 1978.
- Lillisand, T.M. and P.W. Kiefer, Remote Sensing and Image Interpretation, John Wiley & Sons, New York, 1986.

# Unit-5: 3D Visualisation of Groundwater

**Unit-5: 3D Visualisation of Groundwater:** Collection of water level and other aquifer variables (Transmissivity, Permeability, Storage co-efficient, etc.) – Generation of x, y, z – Generation of DEM and shaded relief of groundwater systems and interpretation.

**12 Hrs.**

# Monoscopic methods of Depth Perception

**Distances to objects, or depth can be perceived monoscopically on the basis of**

- **Relative sizes of objects**
- **Hidden objects**
- **Shadows and**
- **Differences in focusing of the eye for viewing objects at varying distances.**

# Concepts of Shaded Relief mapping

Initially, to create shaded Relief map, slope and aspect are to be calculated based on the plane defined for each triangle.

Slope can be written in degrees by specifying degree and Aspect is always reported in degrees. Zero is north, and values increase clockwise like a compass. Flat triangles will be assigned an aspect value of -1.

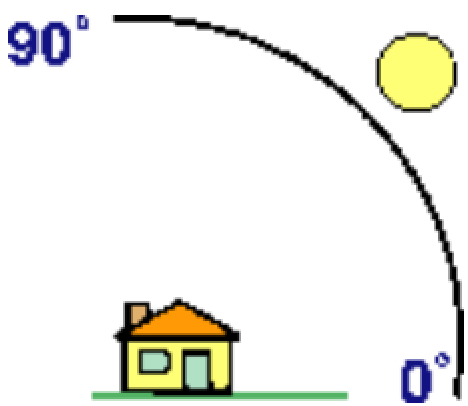
Optionally, a hillshade field can be written containing a brightness value for each triangle. Values range from zero to 255.

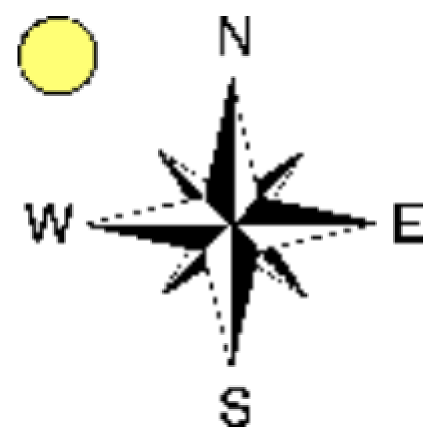
The brightness value is based on the relation between the plane defined by each triangle and a **light source**. The position of the light source defaults to the northwest, with an azimuth of 315 degrees (compass-based with 0 north, positive clockwise) and an altitude of 45.

For Hill shade, it is necessary to obtain the hypothetical illumination of a surface by determining illumination values for each cell in a raster.

It should be done by setting a position for a hypothetical light source and calculating the illumination values of each cell in relation to neighboring cells.

It can greatly enhance the visualization of a surface for analysis or graphical display, especially when using transparency.



# Depiction of Water Level data

- Data Collection – For 2 seasons in a year and/or for 30 to 50 years – to understand the historic changes that had happened
- Pre-monsoon (March to June of previous year) and Post-Monsoon (Dec.–same year, Jan. & Feb. of next year) – Make a separate list of maxima values for each well for both Pre- & Post-monsoon periods for each year and calculate Natural Recharge by calculating the difference between two monsoons,
- i.e., **NR = (Pre-monsoon WL – Post-monsoon WL)**

- Calculate average NR and/or WL values for each well for the entire 30 to 50 years data collected along with Decimal Degree Longitude & Latitude for each well.
- Plot the well locations in GIS and generate DEM for NR and / or WL separately
- Every year NR values can plotted, generate DEM and stack them one below the other to understand the spatial changes of NR happened over a period of several years, for e.g. 50 years.

# Groundwater flow modeling in GIS

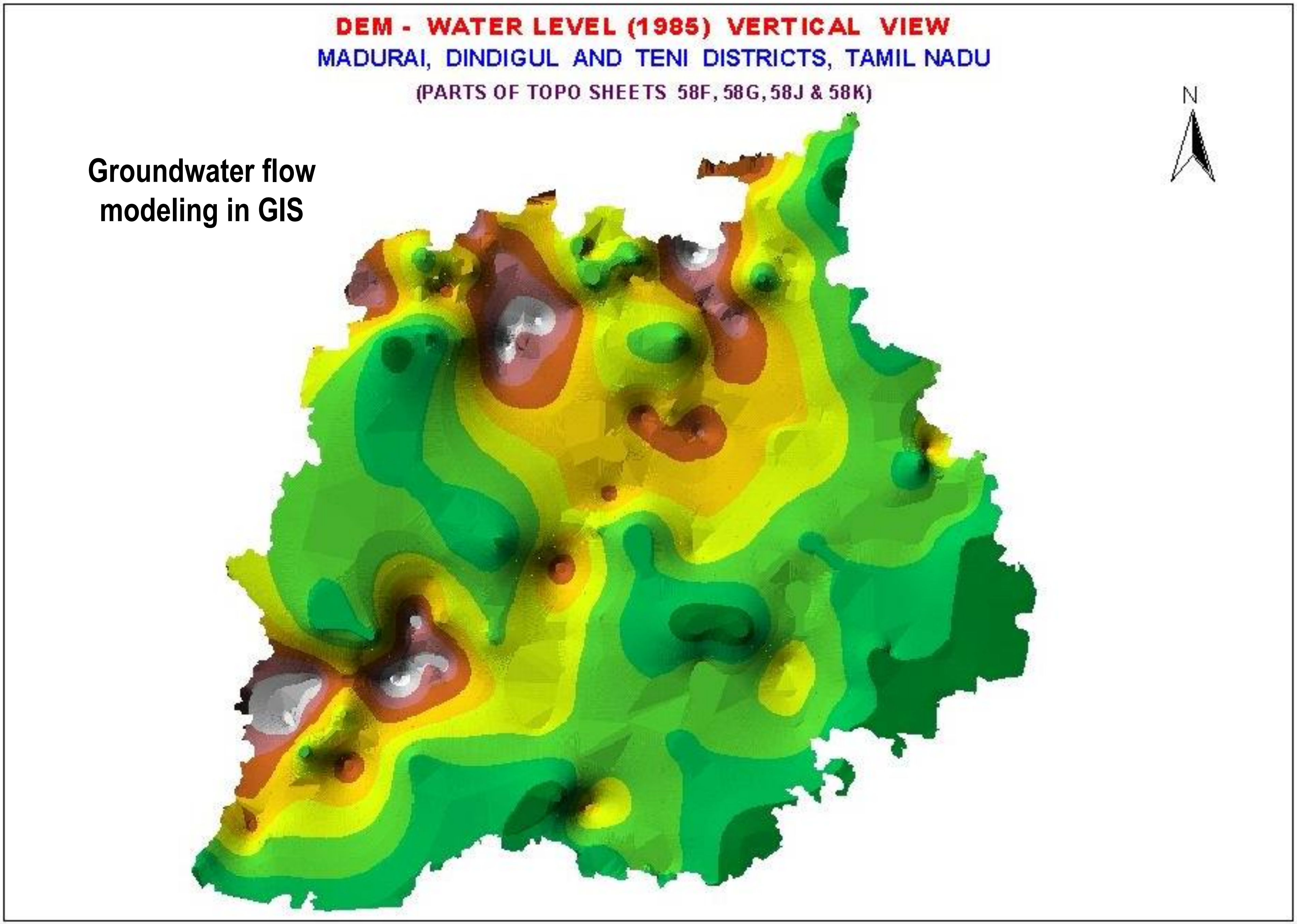



FIG. 1.8

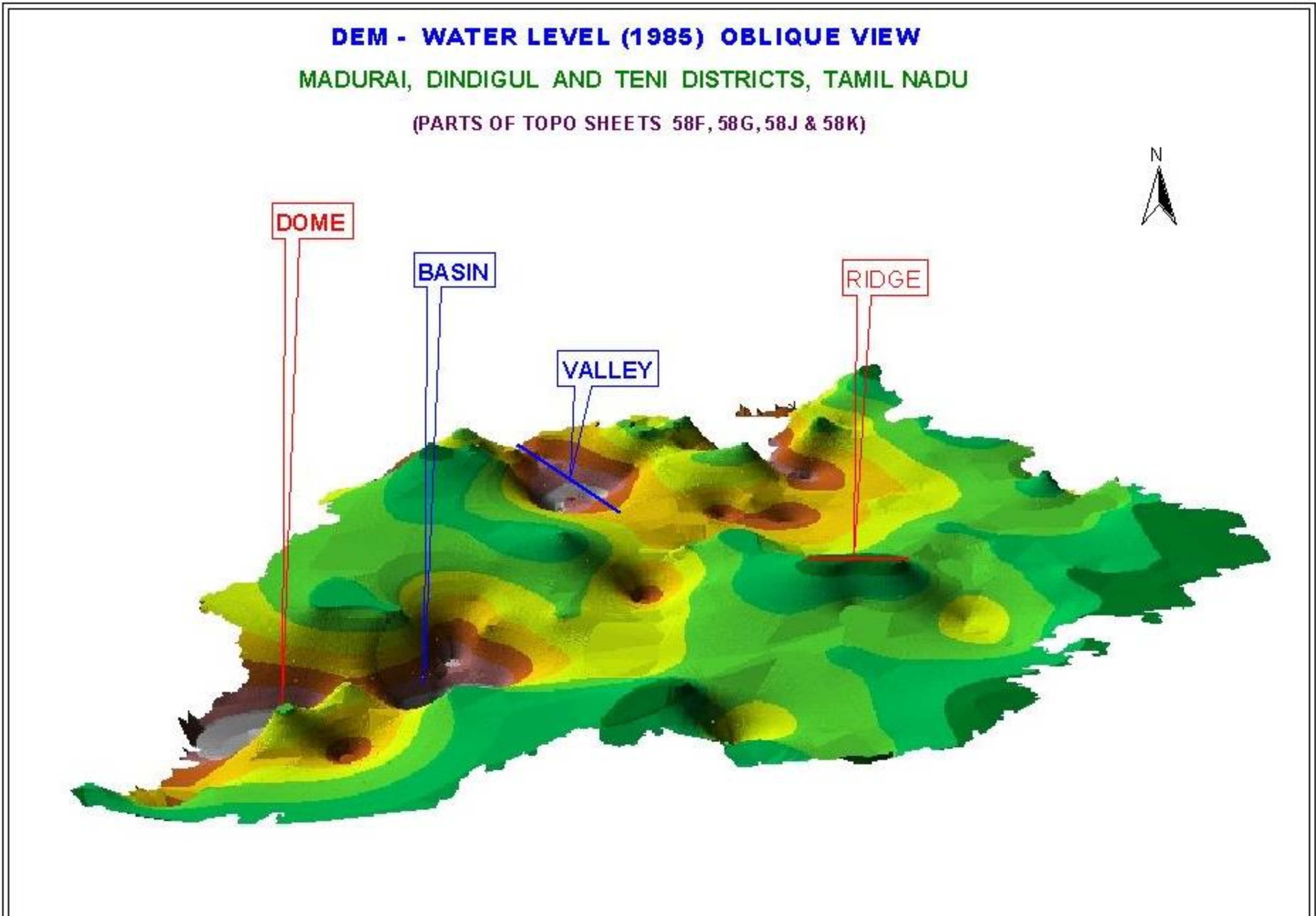
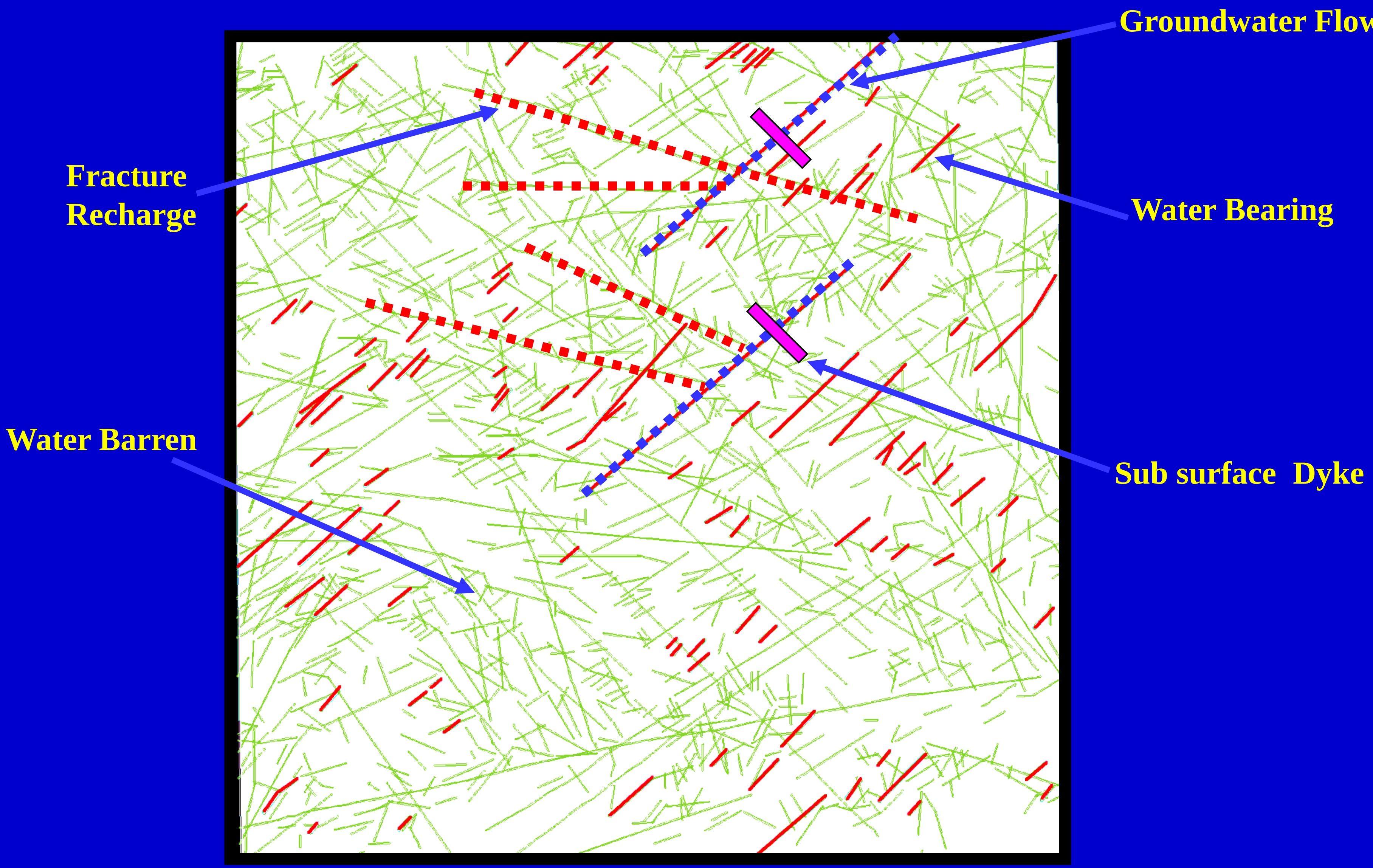

DEM - WATER LEVEL (1985) OBLIQUE VIEW
MADURAI, DINDIGUL AND TENI DISTRICTS, TAMIL NADU
(PARTS OF TOPO SHEETS 58F, 58G, 58J & 58K)
N
DOME
BASIN
VALLEY
RIDGE

FIG. 1.9

# RECHARGE THROUGH FRACTURES



# Quantification of Allowable Recharge

- Determination of size of the Aquifer / GW Reservoir / Container by Geophysical methods
- Calculation of Water level changes during a period of 30 – 50 years of pre- and post-monsoon seasons
- WR Budgetting – Estimation of available surface water resources for various purposes
- Quantification of available SW for Recharge of the container

## Groundwater Aquifer Squeezing

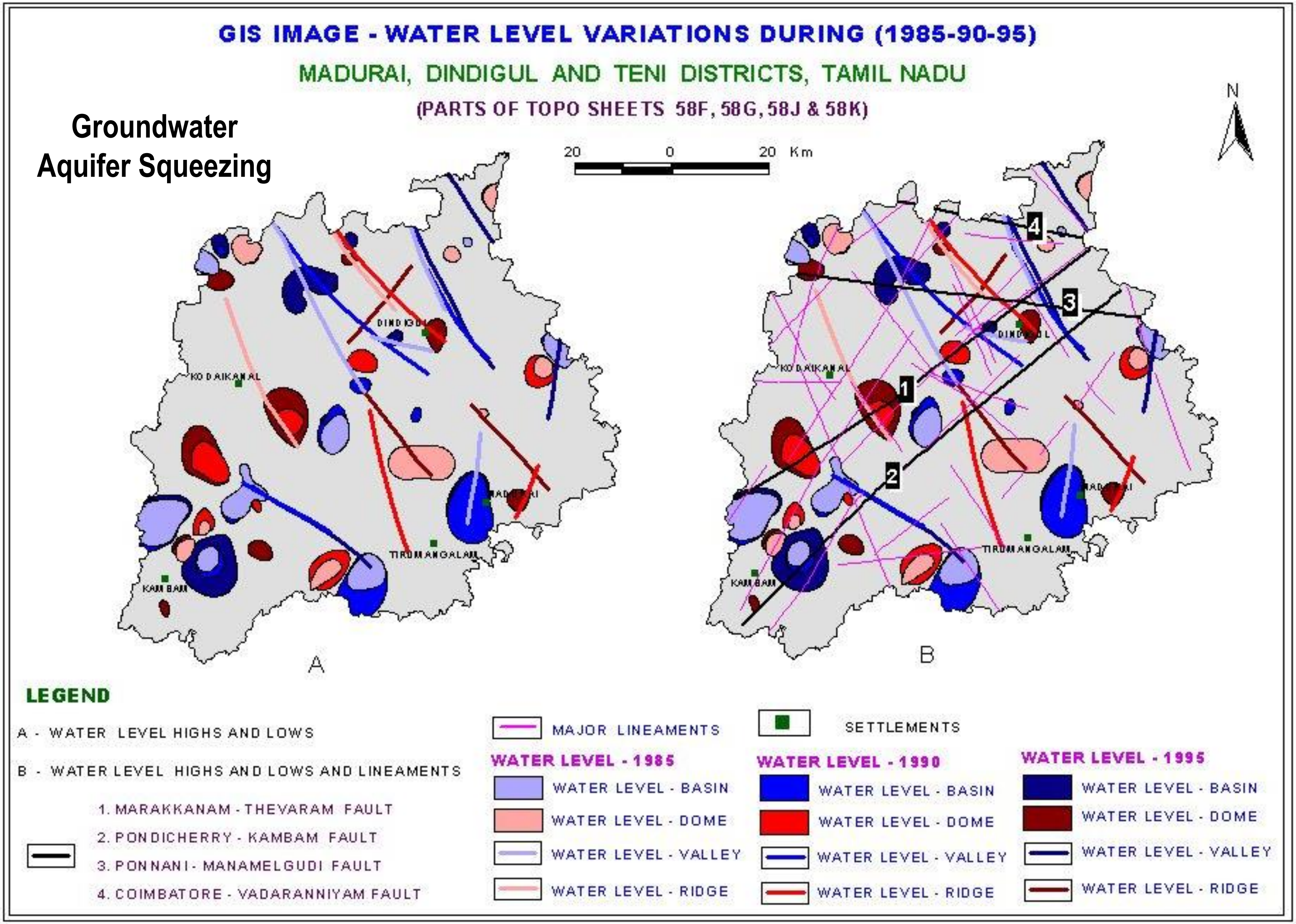
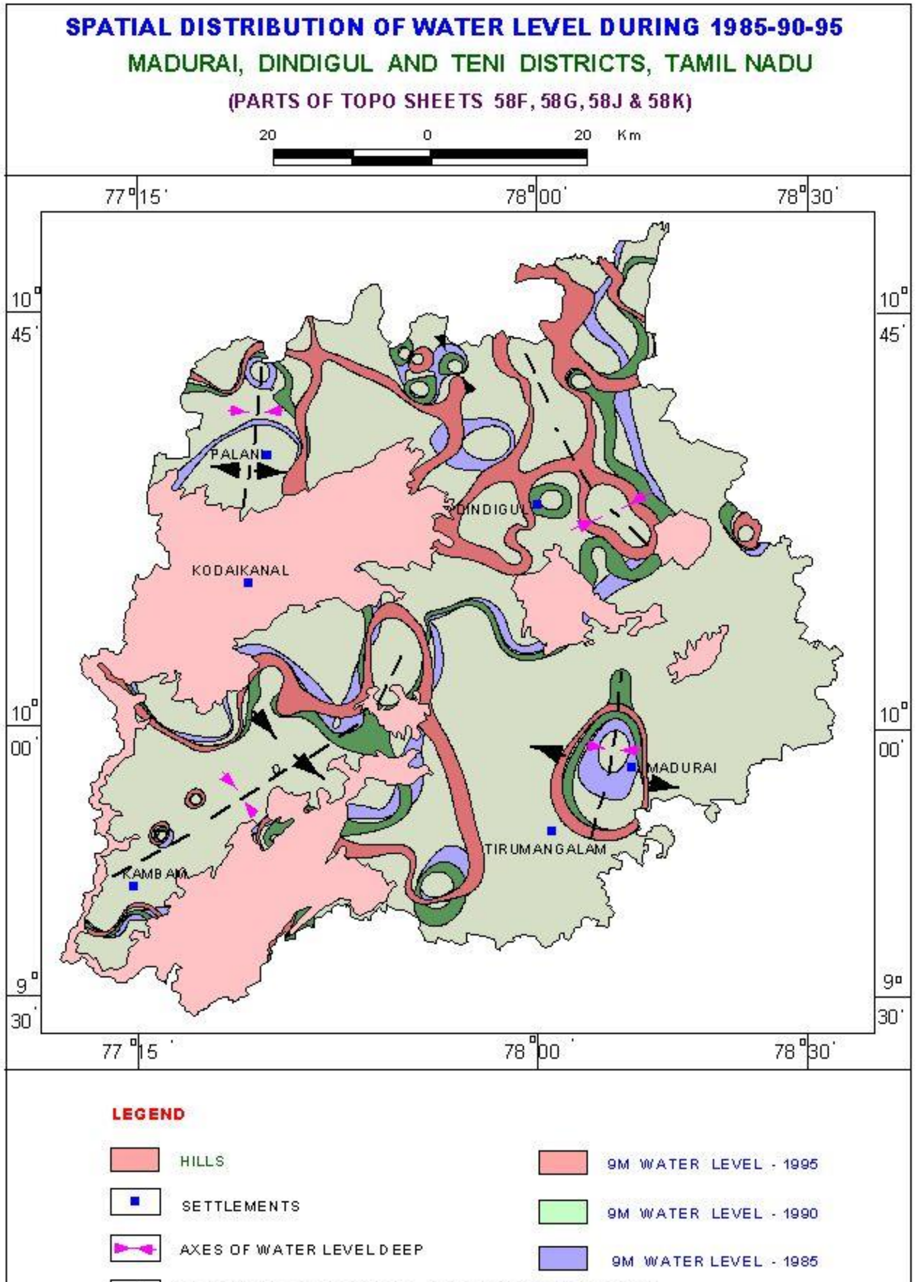
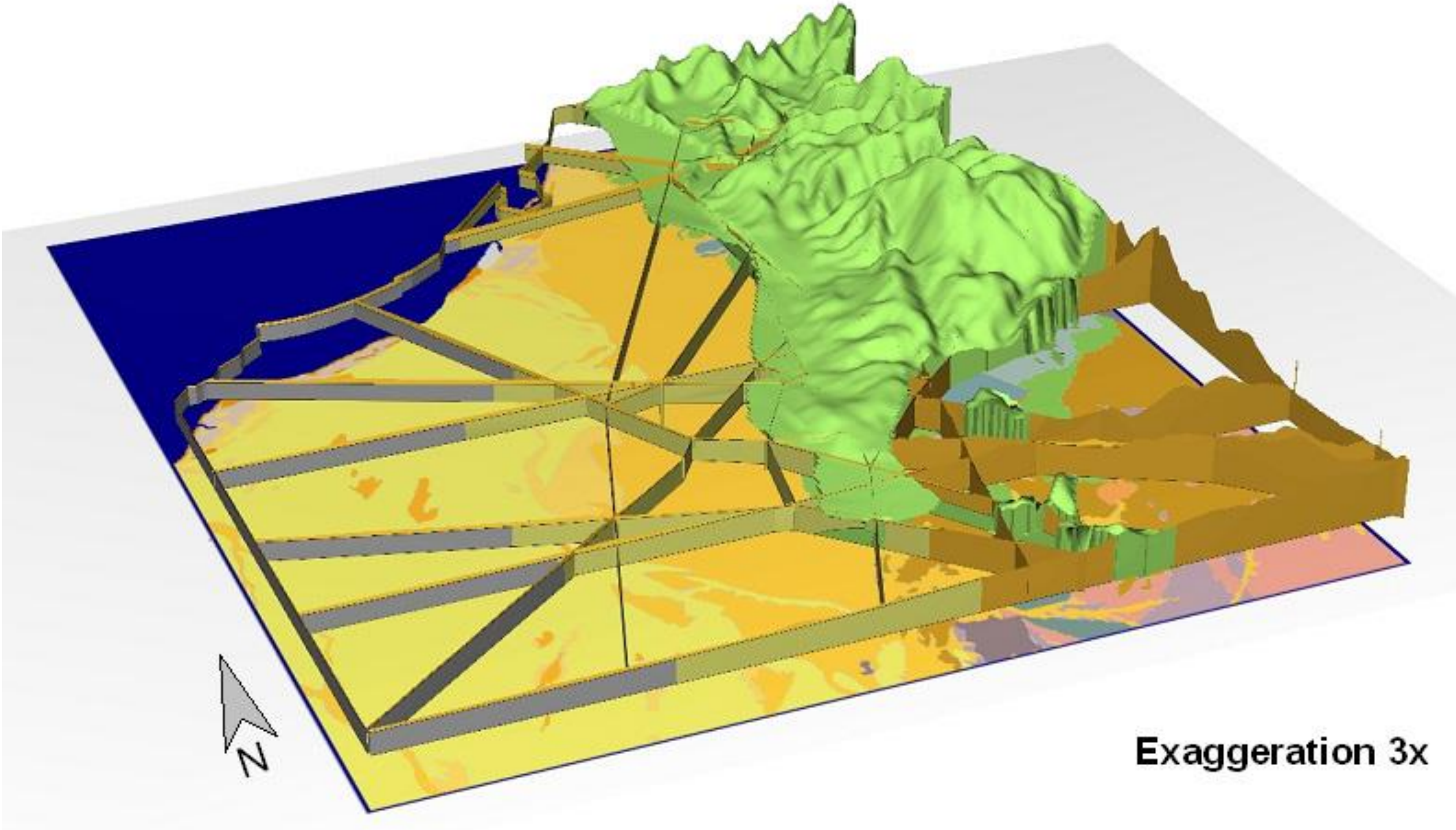



FIG. 2.4

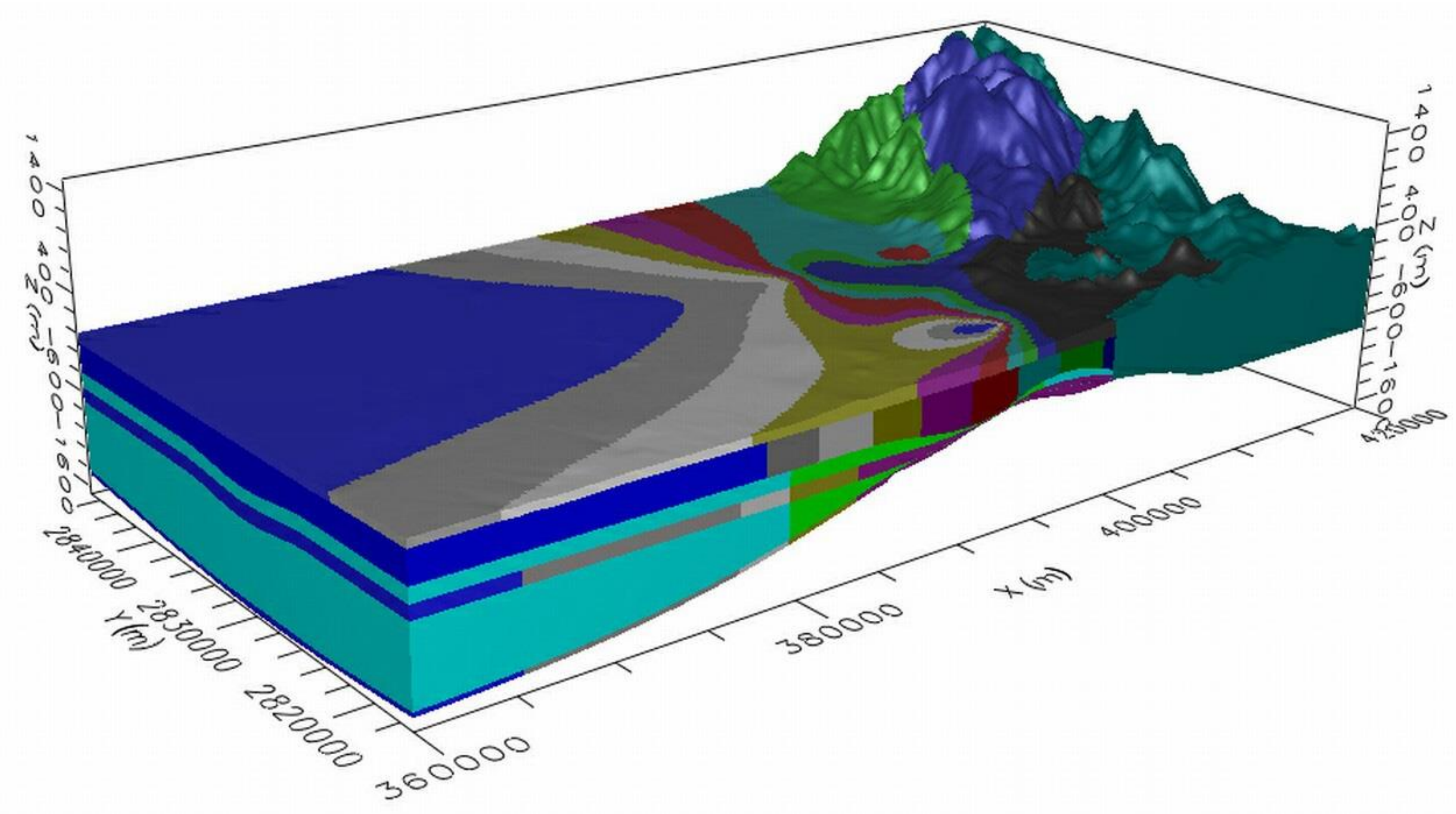


SPATIAL DISTRIBUTION OF WATER LEVEL DURING 1985-90-95
MADURAI, DINDIGUL AND TENI DISTRICTS, TAMIL NADU
(PARTS OF TOPO SHEETS 58F, 58G, 58J & 58K)
20 0 20 Km
77°15'
78°00'
78°30'
10° 45'
10° 00'
9° 30'
PALANI
DINDIGUL
KODAIKANAL
MADURAI
TIRUMANGALAM
KAMBAM
LEGEND
HILLS
SETTLEMENTS
AXES OF WATER LEVEL DEEP
DIRECTION OF WATER LEVEL BASIN WIDENING / SHIFTING
9M WATER LEVEL - 1995
9M WATER LEVEL - 1990
9M WATER LEVEL - 1985

Fig. 2.5




Constructed 3D-geological model for
Khatt Springs area




**Conceptual model of Khatt springs area in which the subsurface stratigraphy is approximated into six layers model based on the variations in the vertical hydraulic conductivities**

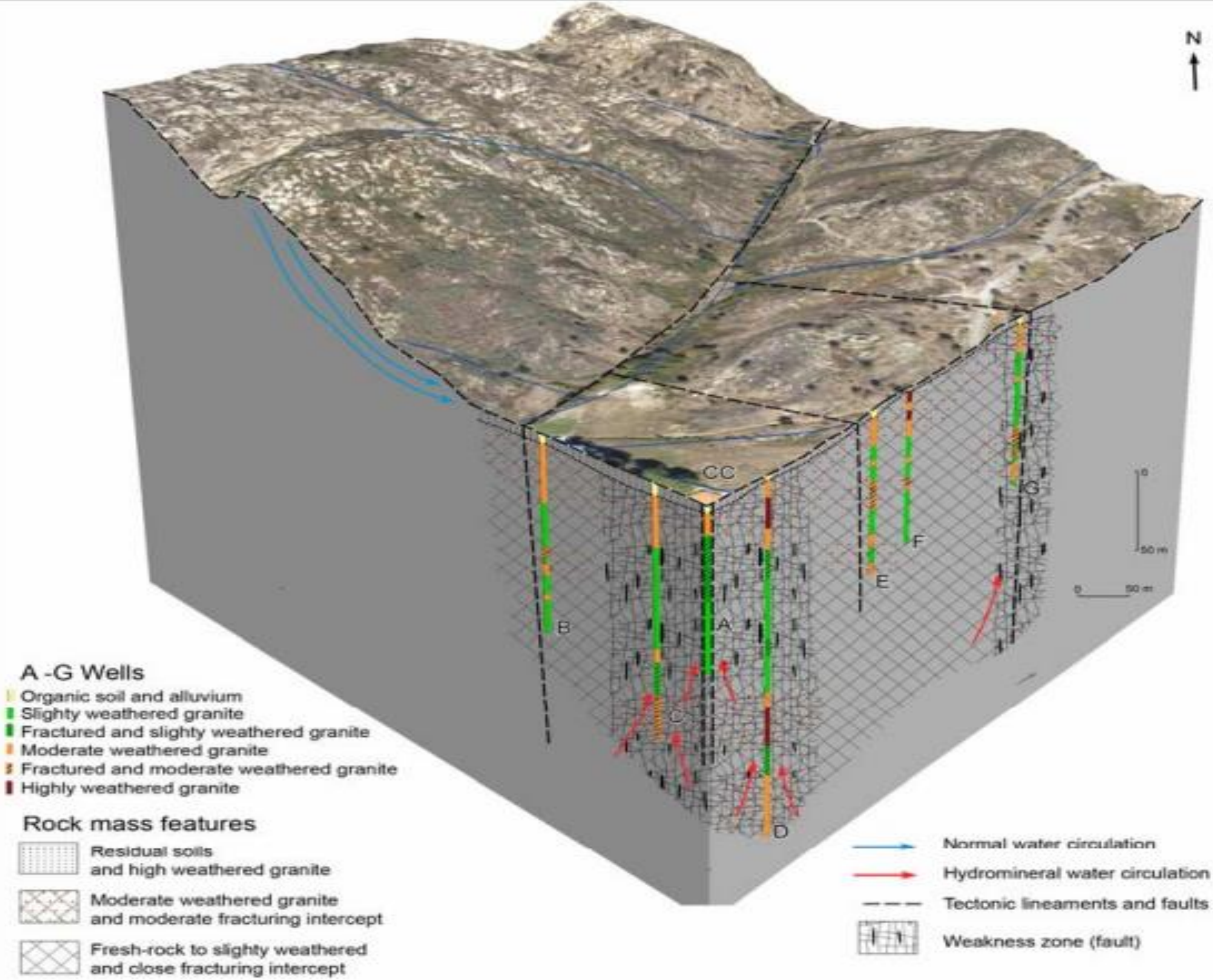


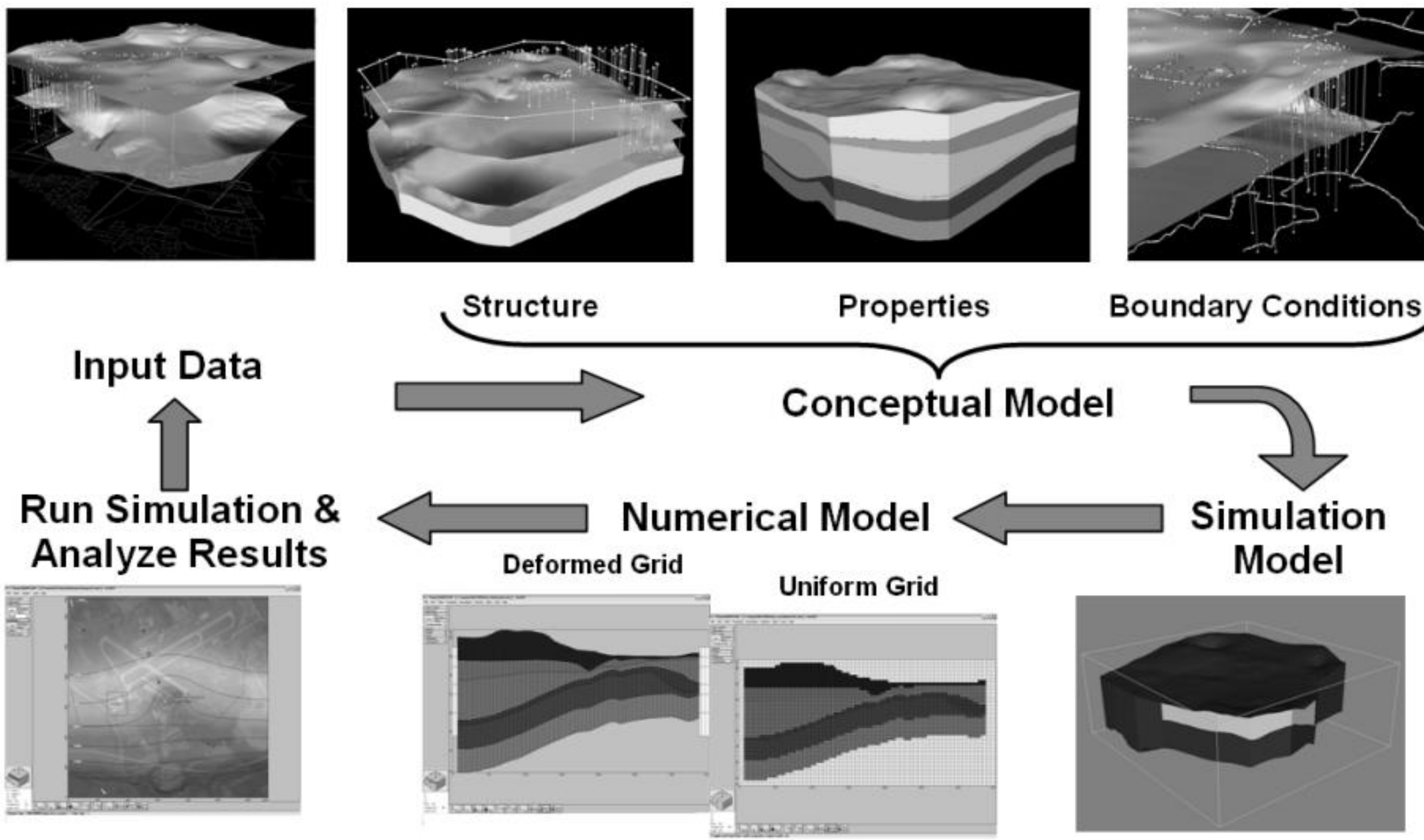

Figure 8. 3D block diagram with well geological and hydrogeomechanical features from Caldas da Cavaca (CC) area.

# 3D in Groundwater Movements

- Groundwater level variations can be determined using 3D with monthly and yearly WL data
- Based on the Depth to Bed Rock / Parent Rock / Basement Rock Depth and their topography, it is possible to visualize the flows and movements of groundwater
- Subsurface dyke mechanisms can be suggested in needy areas for preventing gw movements towards downstream

# Groundwater flow model - methodology

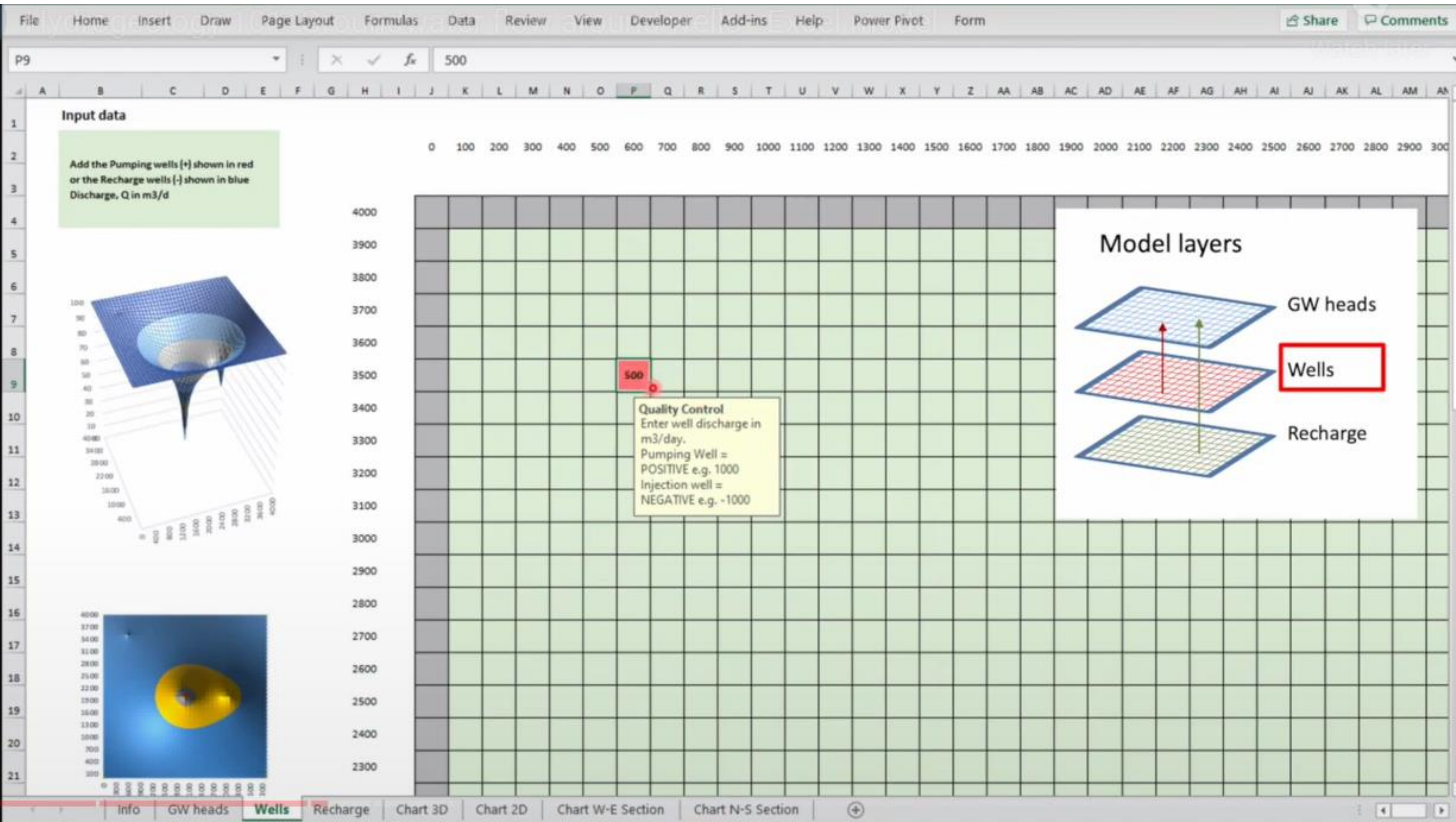
The model building process is presented in a natural workflow from: Data Processing => Conceptual Model => Numerical Model => Simulation => Analysis of Results



# Cone of Depression in Groundwater

- Animation on the rate of depression of groundwater level
- Vulnerable areas for **sea water intrusion** along coastal aquifers or triggering of **pollutant plume dispersal** can be visualized in 3D
- Prevention plans can be easily derived for implementation
- Warnings can be given based on the 3D visualized images to the users in vulnerable area to stop exploiting groundwater.

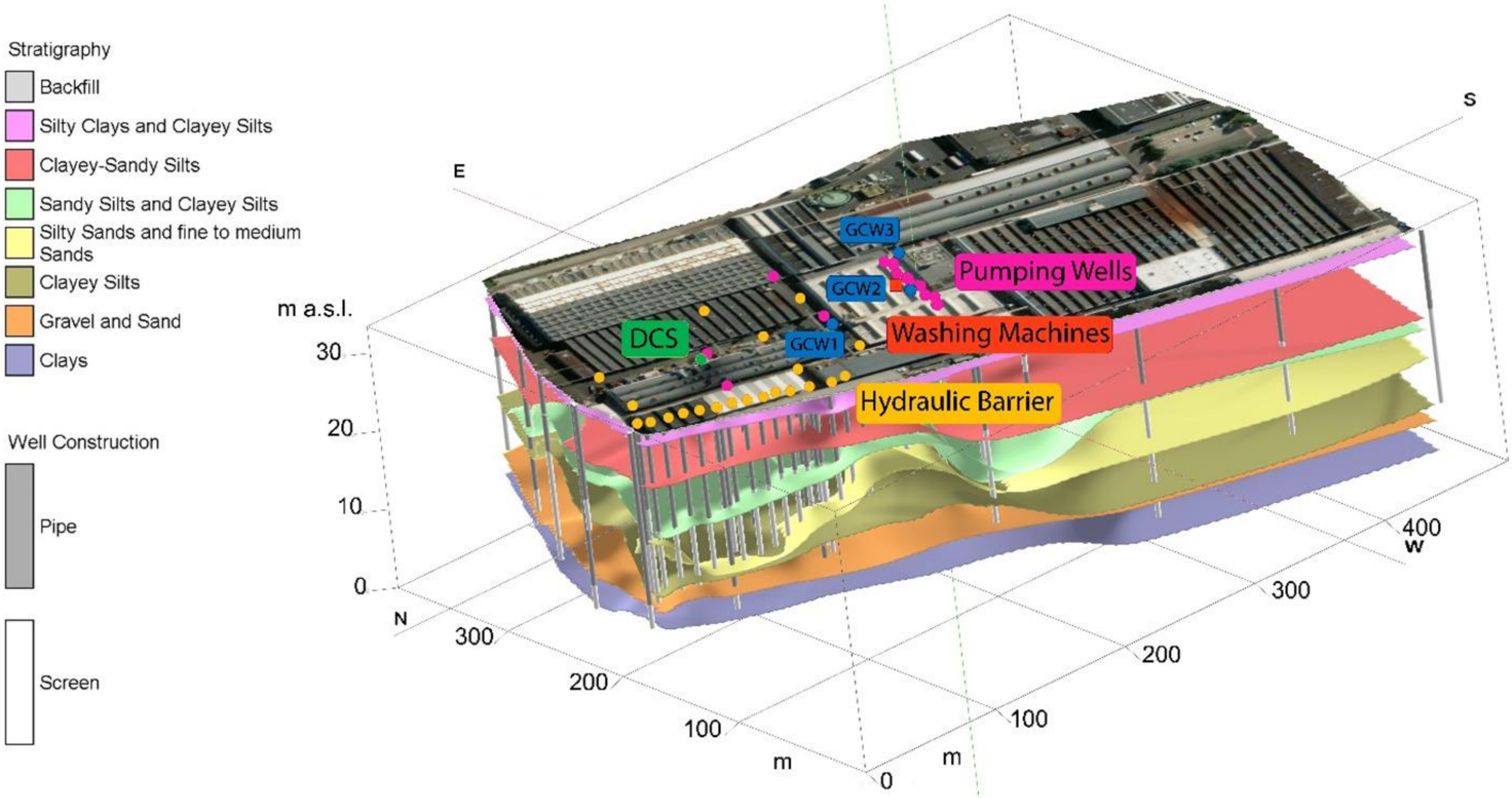
# 3D model showing cone of depression due to over pumping of groundwater



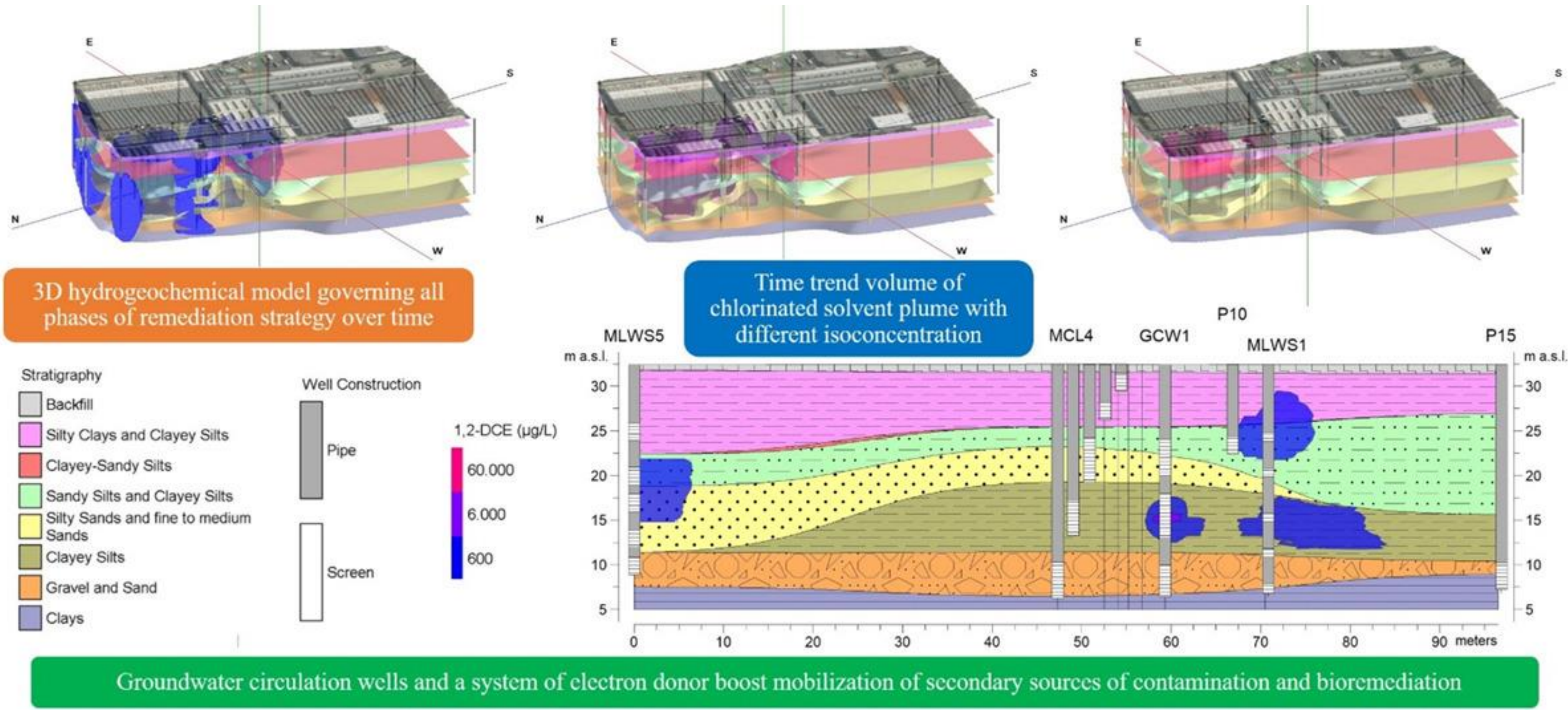
# Pollutant Plume Migration in Groundwater

- Pollutant plumes can be visualized in 3D
- Their migration rate, direction and spreading areas can be determined and the people in those areas can be warned to not tap this GW
- Action plans for removal / digestion can be prepared for further implementation
- Post implementation monitoring using 3D visualization methods are highly easy and useful for protection of groundwater resource.

3D industrial plant geological model that reflects the complex architecture of the stratigraphic horizons. With the stratigraphic model, the position and construction drawings of wells and piezometers present at the site are



- A multi-phase approach was followed handling and releasing data during various remediation stages, from site characterization via pilot testing to full-scale remediation, thus allowing users to monitor, analyze, and manipulate information in 3D space-time.
- Multi-source and multi-temporal scenarios reveal the impact of ongoing hydraulic dynamics and depict the decontamination mechanisms in response to the interventions implemented over time, by quantifying the overall performance of the adopted strategies in terms of removal of secondary sources of pollution still active at the site.



3D hydrogeochemical model governing all phases of remediation strategy over time
Time trend volume of chlorinated solvent plume with different isoconcentration
Groundwater circulation wells and a system of electron donor boost mobilization of secondary sources of contamination and bioremediation
Stratigraphy
Backfill
Silty Clays and Clayey Silts
Clayey-Sandy Silts
Sandy Silts and Clayey Silts
Silty Sands and fine to medium Sands
Clayey Silts
Gravel and Sand
Clays
Well Construction
Pipe
Screen
1,2-DCE (µg/L)
60.000
6.000
600
MLWS5
MCL4
GCW1
P10
MLWS1
P15
m a.s.l.
meters
E
S
N
W

# Aquifer characteristics

- Transmissivity (T), Permeability (P), Storage Capacity (S) and Specific Yield (SY) can be visualized 3 dimensionally
- Groundwater targetting can be done using 3D images
- Porosity can be used to determine quantum of groundwater available on-time
- Groundwater budgetting can be done easily.

# Areas of Artificial Recharge

- Suitable sites can be visualized in 3D
- Parameters favoring AR can be checked
- Based on the convincing parameters, suitable sites can be determined for AR.
- The geological parameter which is unsuitable can be determined and improved to become favorable for AR

# Mechanisms for Artificial Recharge

- By visualizing the suitable sites for AR in 3D, proper viable and pragmatic action plans can be drawn easily and strategically
- Post monitoring – effectiveness of implementation for GW recharge can be monitored and
- suggestions to improve further can be sketched.

Thank you