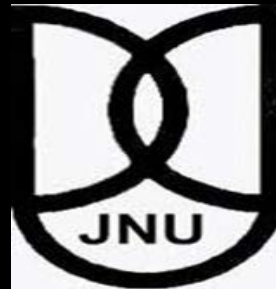


**PRELIMINARY RESULT FROM SURFACE AND SUBSURFACE
HYDROLOGICAL INVESTIGATION OF DEHGOLAN-PLAIN,
KURDISTAN, IRAN
USING GEOPHYSICAL
REMOTE SENSING AND GIS TECHNIQUES**

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OUTLINES

- *Introduction*
- *Study Area*
- *Methodology*
- *Result and discussion*
- *Conclusion*

DEFINITION

- Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations (Oseji et al., 2005).
- Remote sensing is defined as the use of electromagnetic radiation sensor to record images of the environment which can be interpreted to useful information (Paul J. Curran 1985).
- GIS (Geographic Information System) databases are used to the extraction of information from remote sensing imagery.

Water Scenario in IRAN

- Iran is located in an arid and semiarid climate region.
- Annual precipitation: 250 mm, much less than of Asia and world (respectively 732 and 831 mm).
- Irrigation is the dominant water use in many arid and semi-arid river basins
- 86.8 (BCM); water consumption (1996), 90% agriculture , 7% domestic and industry consumption.
- Water consumption in 2001: 93.1 BCM, same ratio as 1996
- Predicted water consumption in 2021: 130 BCM

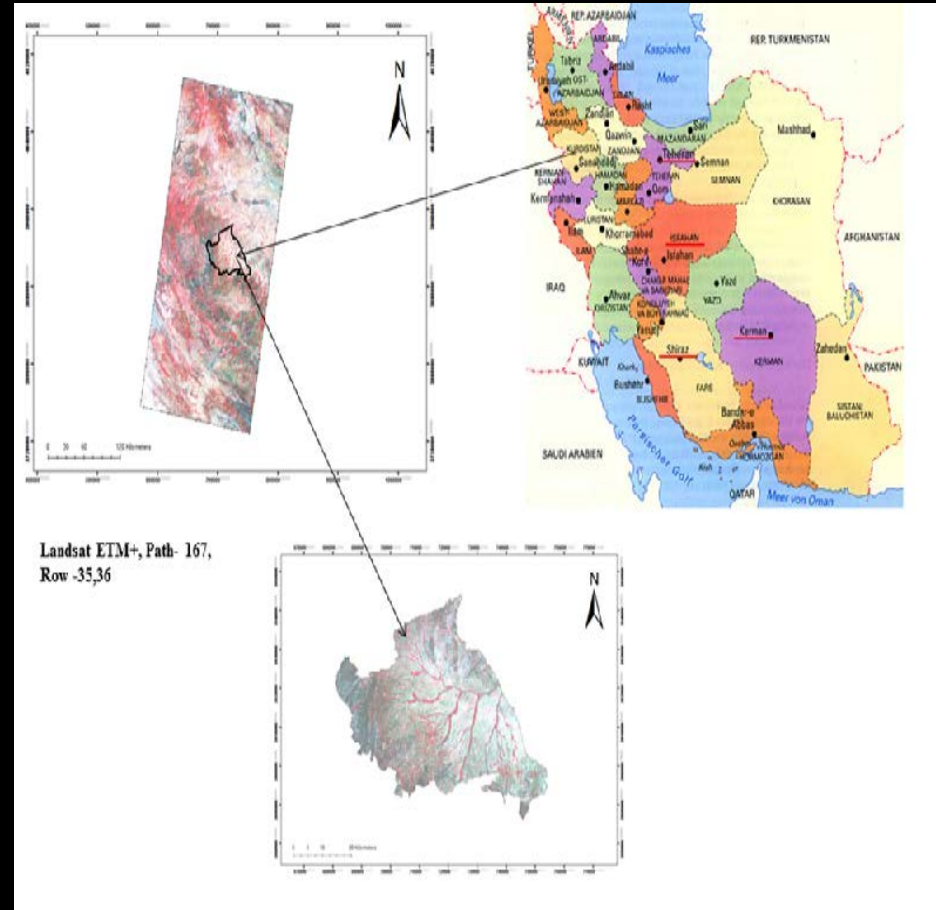
WATER SCENARIO IN KURDISTAN

- Annual rainfall; 500 millimetres of (more than double the average precipitation in Iran).
- Kurdistan province with only 7.1% area of Iran receives around 5.3 of total annual rainfalls
- Water status of Kurdistan in terms of river basin: SefidRood- basin, Sirwan-basin, Zarine-Basin, Chuman-Ghazalcha-Basin

Class	Value	Unit	Percentage
Annual Rainfall	2.14	MCM	5.3
Annual Surface Runoff	8.7	MCM	9.7
Underground water resources	7.15	MCM	2
Volume of Output	3.6	MCM	.
Water Consumption in Agriculture	1.88	MCM	.
Water consumption and the influence	4.1	MCM	57.3
Annual evapotranspiration	9.7	MCM	8.2

STUDY AREA

- Dehgolan Basin is located in Kurdistan province and eastern part of Sanandaj City in Iran.
- Eastern part of it is limited by Qorveh-Plain
- Geographical coordination: located between $48^{\circ}12'00''$ to $47^{\circ}08'00''$ longitude (E) and $35^{\circ}00'00''$ and $36^{\circ}00'00''$ Latitude.
- The whole basin area: 2550 square km



Geological Setting of Study Area

- Geologically belongs to Sanandaj-Sirjan zone.
- Common history with the region of Iran-Central zone but its structure and slope is more like that of Zagros (Stöcklin, 1968).
- The length :1500 km and width:;150 to 250 km.
- Basic structure that starts at late Precambrian and finished with tectonic inversion in early Cimmerian
- The Sanandaj – Sirjan rocks divided into three major tectonic units; late Precambrian stratigraphy - Middle Triassic, Upper Triassic - Cretaceous and Tertiary series (Agha Nabati 2004).
- The oldest rock units belong to the Jurassic.

Stratigraphy

- Dolomite and lime, Shale and Sandy limestone , Quartzite, Shale and Sandstone , Shale and Sandstone , Basalt, Sandstone and red Conglomerates , Sandstone, Sandy Marl, Andesitic and volcanic lavas , Igneous granite and granodiorite rocks.

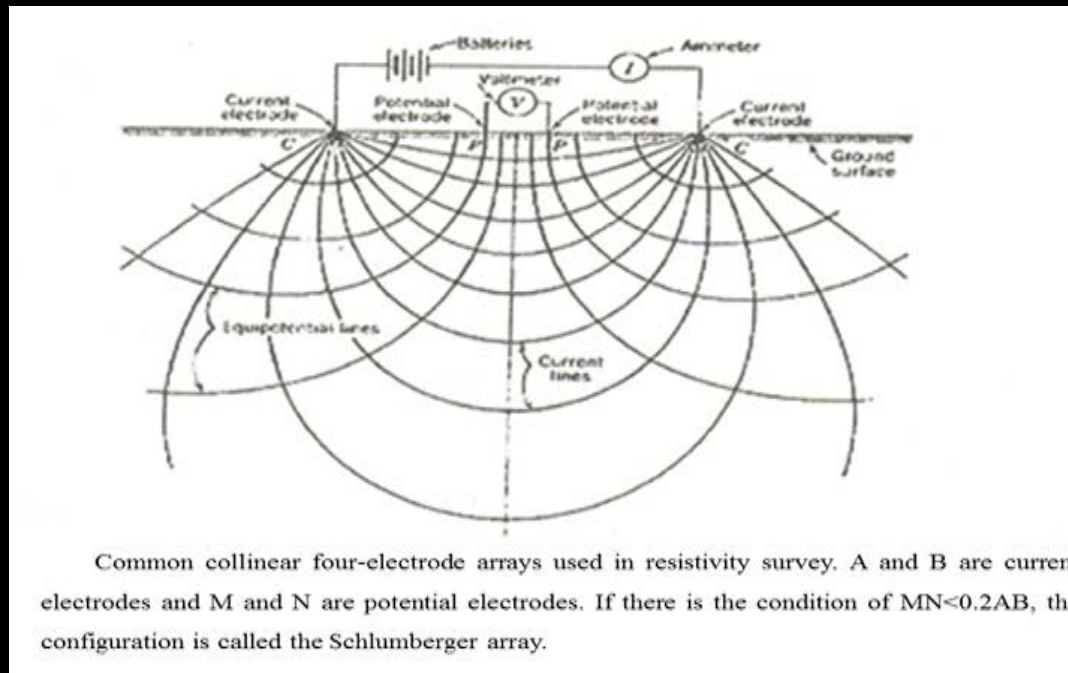
Methodology

- Multidisciplinary approach was considered, integrated with various datasets and various magnitudes.
- Borehole information and lithology data from 12 drillings were modeled using Rockworks software.
- Ground truth surveys with GPS, topographic analysis been performed to generate a GIS database, aiding in further correlation with results from remote sensing observations by satellite images.

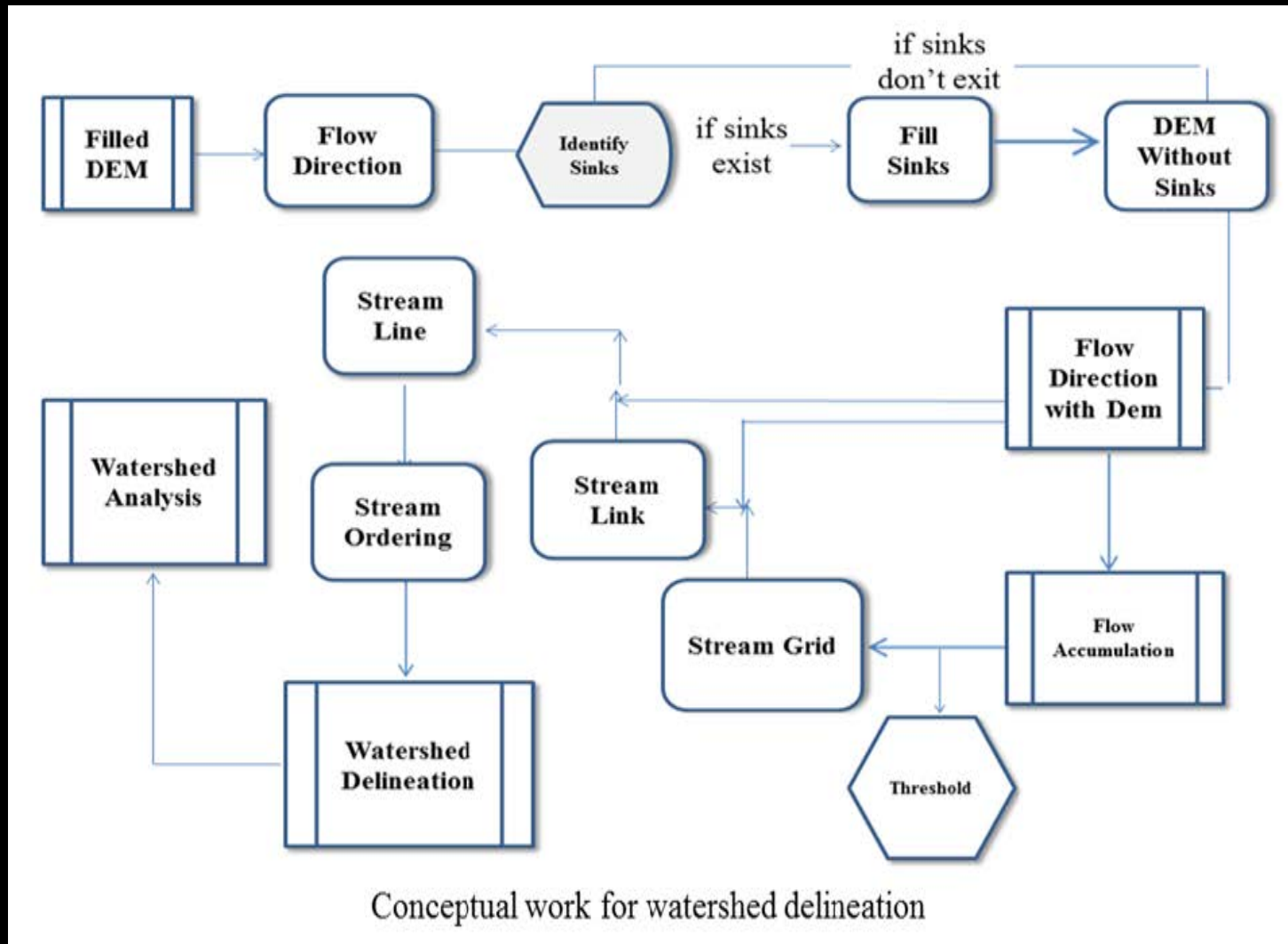
•Resistivity Survey

- Groundwater investigation performed by VES survey using Schlumberger configuration
- Total of 196 VES profiles were obtained.
- Electrical current made by injection 2 electrode current A,B
- The potential difference V measured by potential electrodes M and N and converted to apparent resistivity
- $\rho_a = K \frac{V}{I}$ (Equation1)
- K = geometric factor, I = electrical current
- K can be calculated as:
- $K = \frac{2\pi}{\frac{1}{Am} - \frac{1}{BM} - \frac{1}{AN} - \frac{1}{BN}}$ (Equation2)

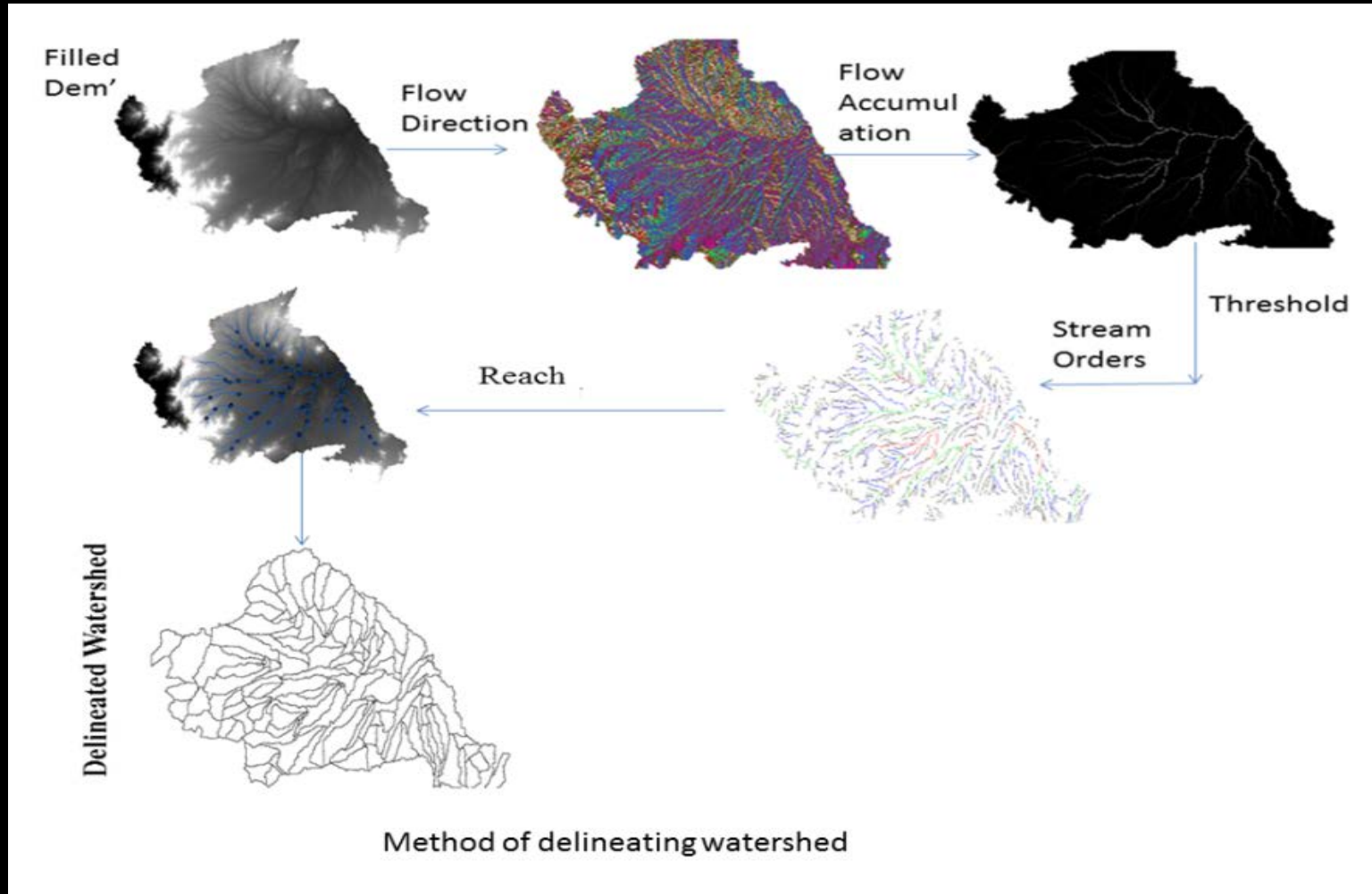
- The half current electrodes separation ($\frac{AB}{2}$) increased from 1 to 300m or 400m depending on the accessibility
- MN gradually increased from 1m to 30m
- Correlation VES results with the lithological and information from 12 boreholes as pilot study is very important.



Watershed Delineation in Soil and Water Assessment Tool (SWAT)



- By giving an outlet or pour points where water flows out of an area.



Land cover/Land use Mapping

- Supervised classification (LANDSAT Image, ETM+, 01/05/2000) was performed by using ERDAS Imagine 9.3 software.

NDVI

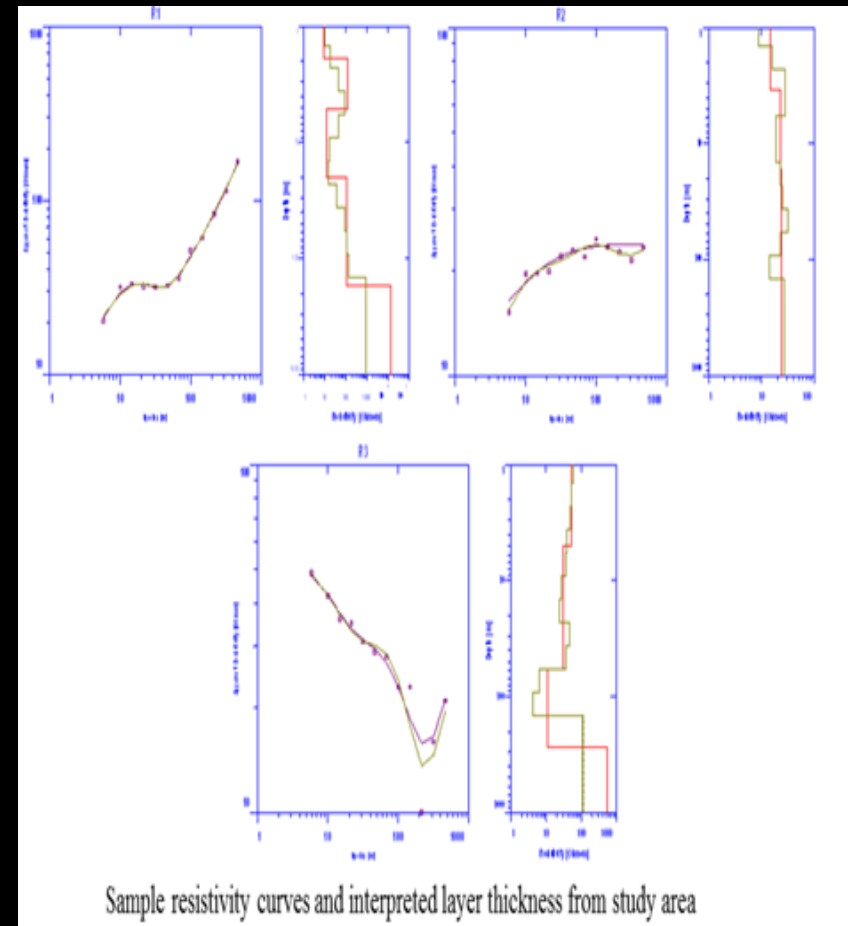
- The NDVI for study area calculated as:

$$\text{NDVI} = \frac{\text{Band4} - \text{Band3}}{\text{Band4} + \text{Band3}}$$

RESULTS AND DISCUSSION

RESISTIVITY SURVEYS MODELLING

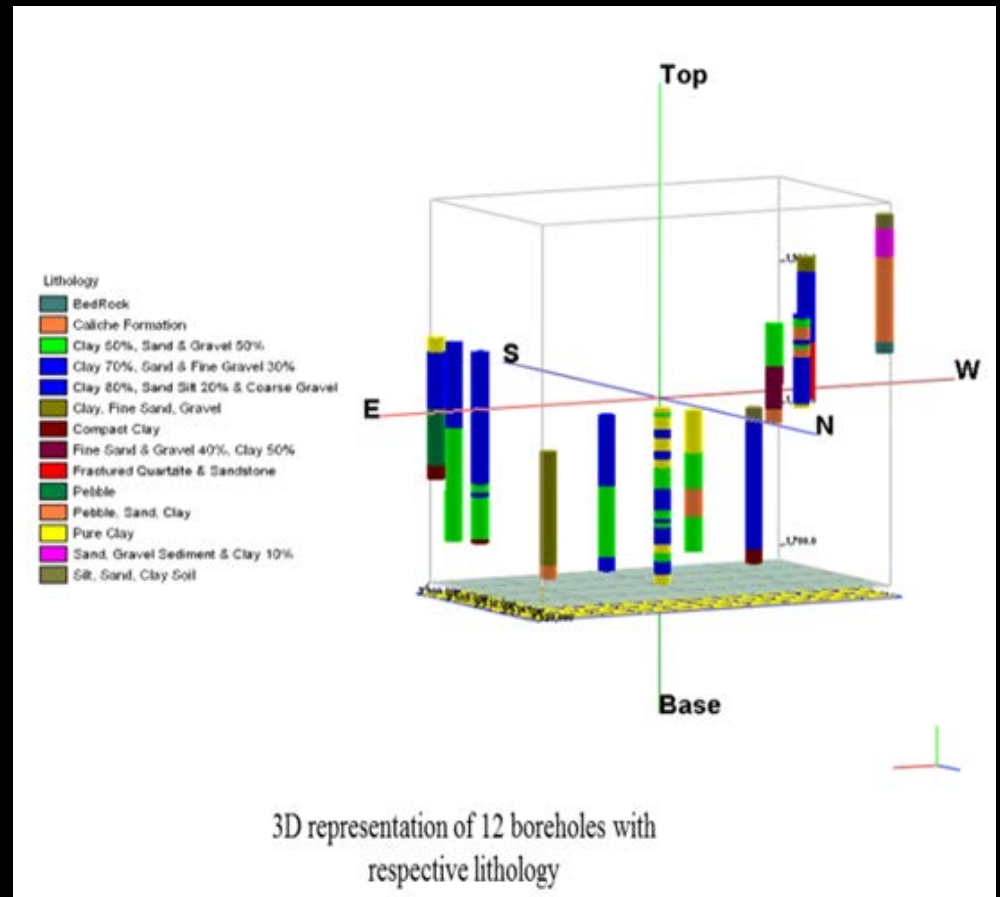
- Data from 12 drillings were selected as a pilot study to generate subsurface 3D models and groundwater flow regime pattern using Rockworks software



SUBSURFACE MODELING

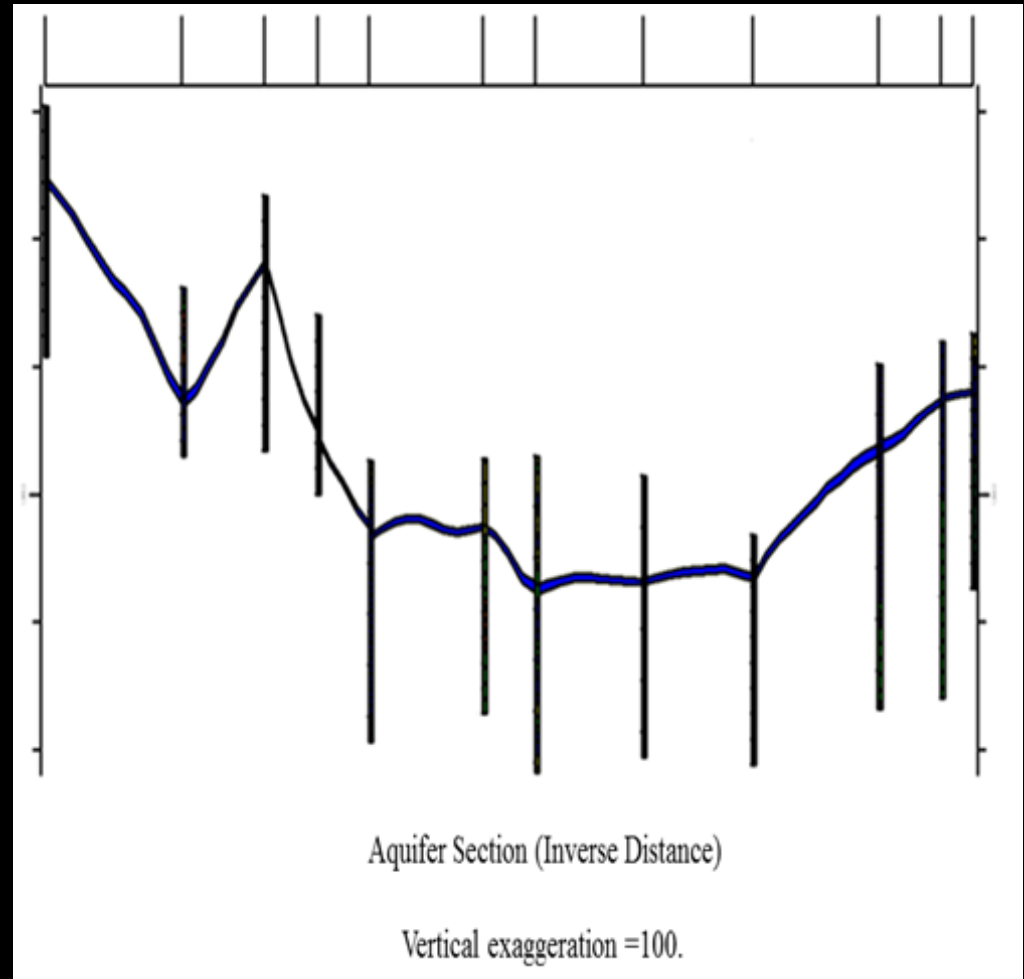
3D MODEL OF BOREHOLES

- 3 dimensional model of boreholes was generated to show their relative positioning in 3D space.
- The top of individual boreholes is also an indicator of altitude values with respective ground surface



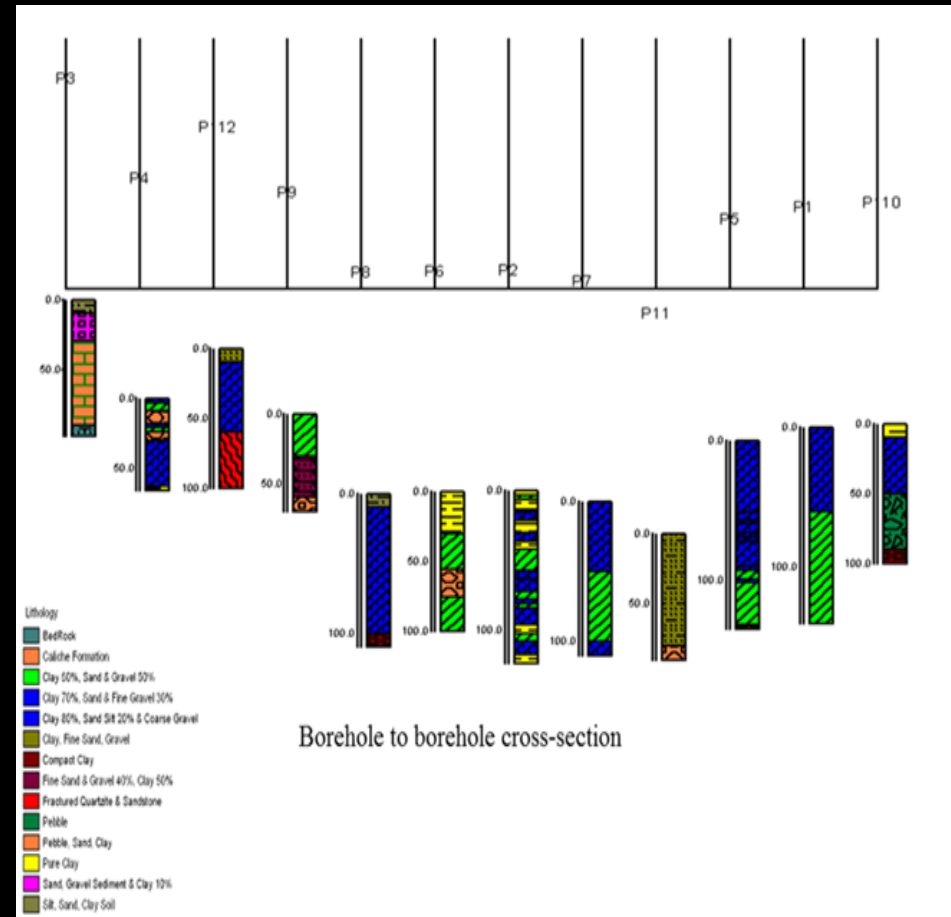
AQUIFER SECTION (INVERSE DISTANCE)

- Aquifer Section (Inverse Distance) Model, illustrates the interrelationship of water level and lithologs (12 boreholes).
- Direction of water movement follows north-west to south east



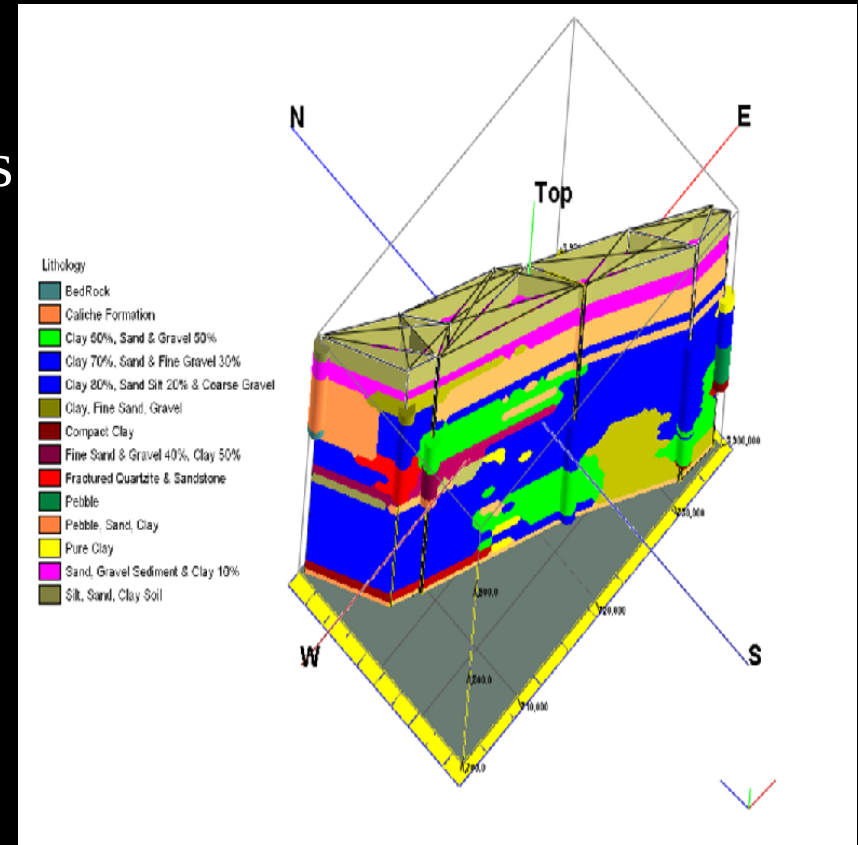
HOLE TO HOLE LOG SECTION

- Generated to compare relative positioning of all boreholes from NW to SE direction.
- Decreasing trend in elevation was observed as we move towards eastern side.
- Drilling depth was found to be more in eastern side
- This can be attributed to the fact that the NW part is dominated by rocky type whereas the SE aquifers are dominated by loose gravelly materials and clay.



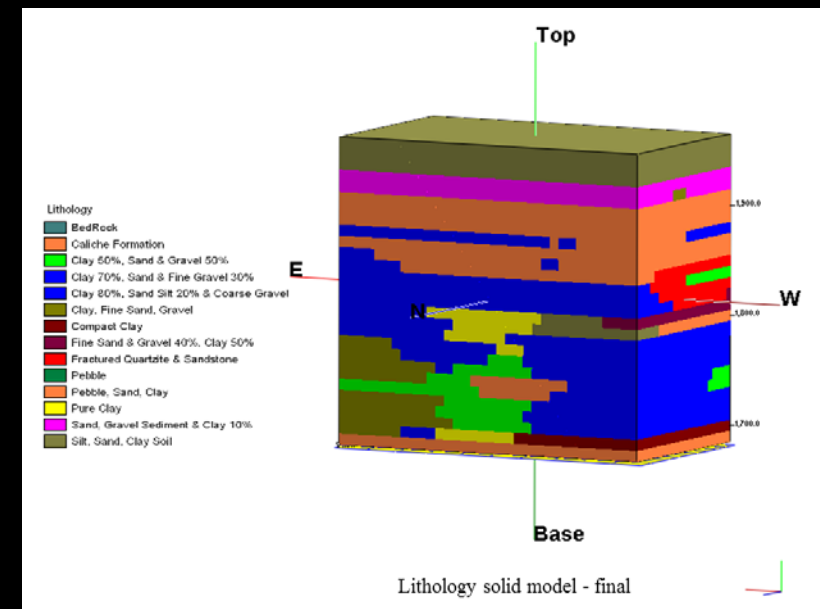
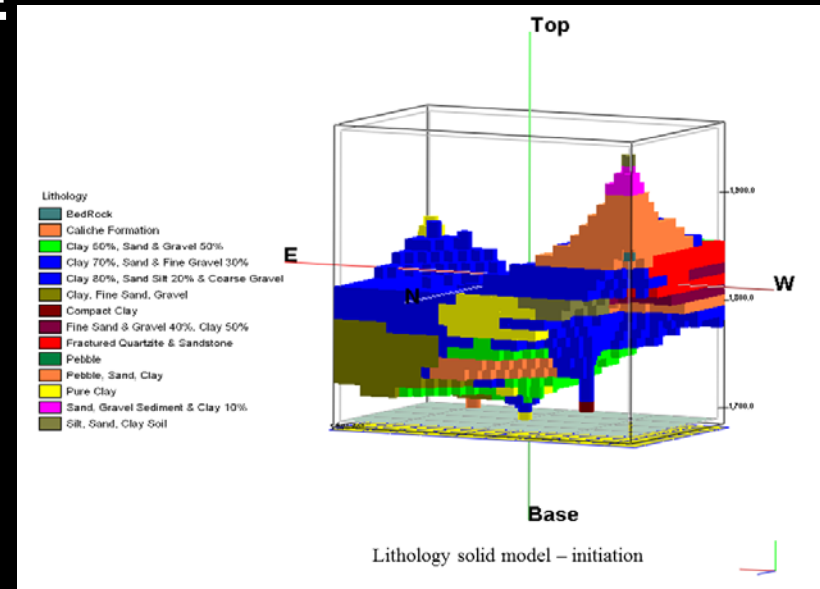
3D FENCE DIAGRAM

- Generated by constructing all possible connections between the 12 boreholes
- Basically made to connect lithologs together to show which type of lithology could be dominant in between 12 boreholes.
- Presence of multi-layered aquifers was detected in NW portions
- Slotted pipe arrangement to increase the overall yield from a borewell
- Thickness of clay increases meaning from west to east that the direction of subsurface water flow should possibly be west to east.



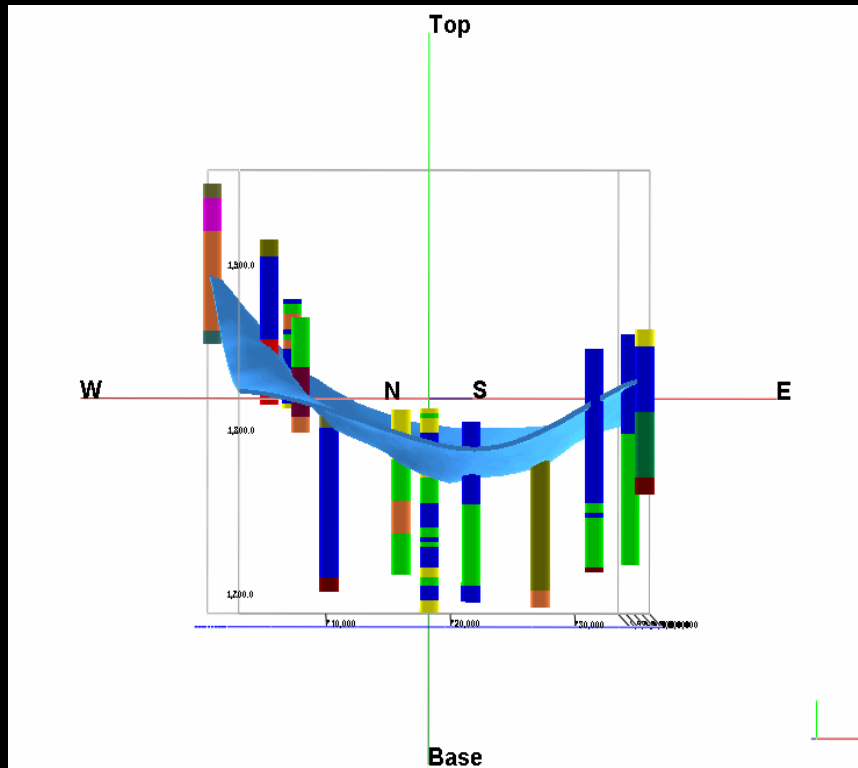
Litholog based Solid Model

- Was extrapolated to the whole subsurface volume covered by 12 boreholes.
- Solid model is helpful later to figure volumetric coverage by a specific lithology
- It is useful to assign the flow characteristics for whole or particular lithology.

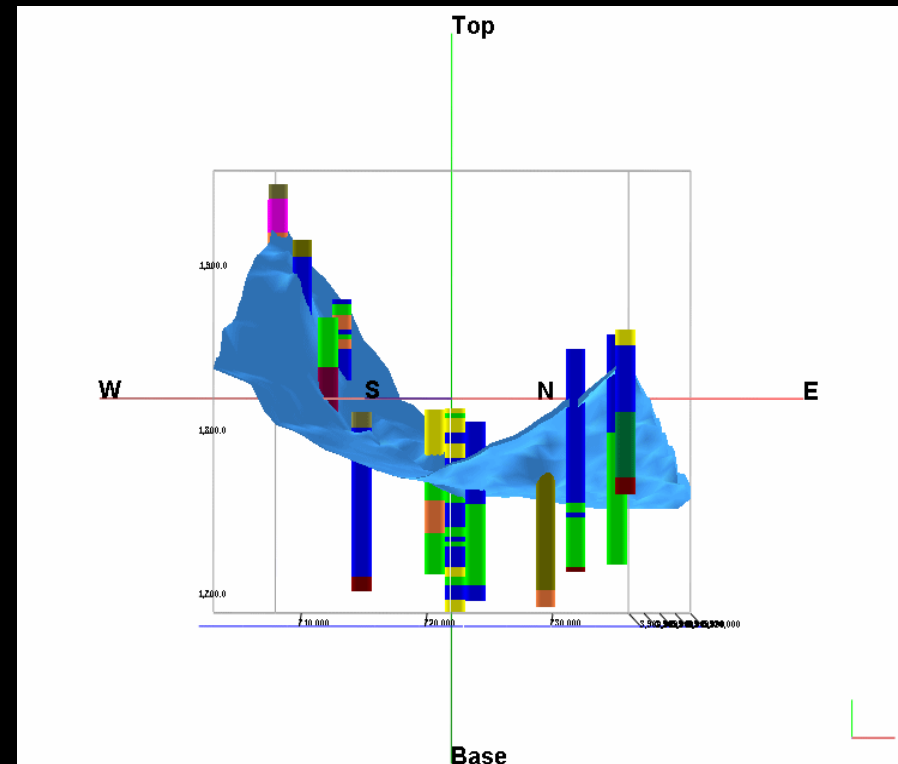


AQUIFER MODEL

- The model is generated to show direction of subsurface water flow, aquifer thickness and aquifer behavior in extrapolated domains
- These models show that the water level and thickness of aquifer is stronger in West to Northwest Direction rather than East to South-East Direction..



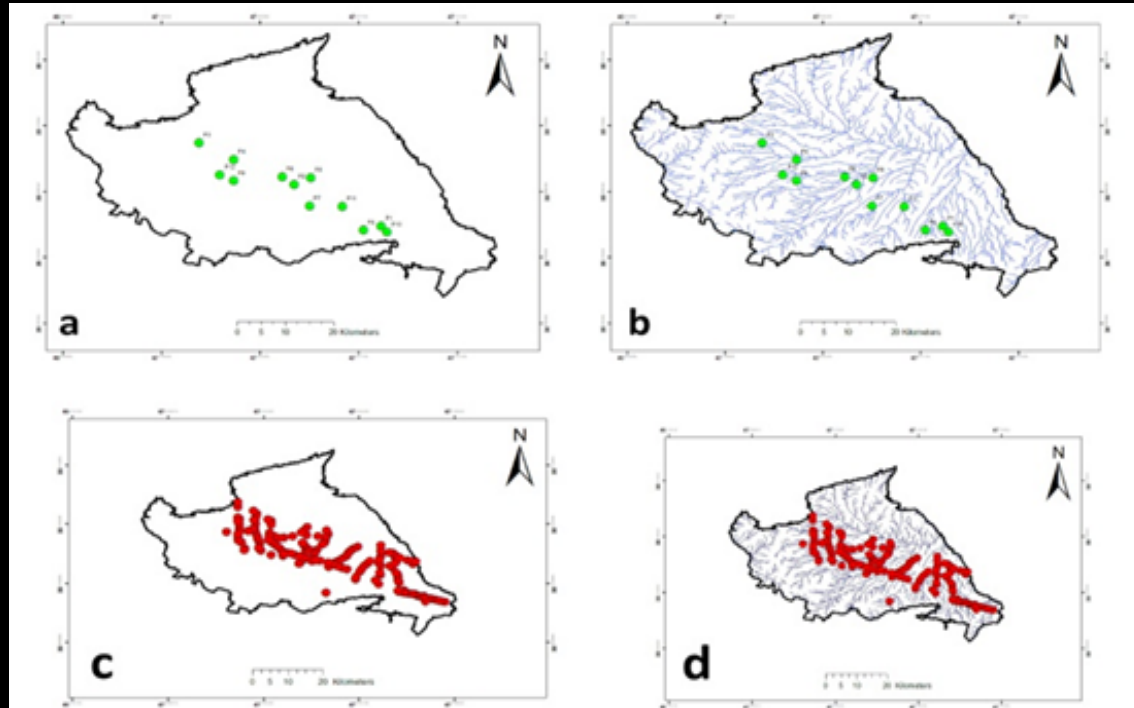
Aquifer Model (Kriging)



Aquifer Model (Inverse Distance)

GIS Data

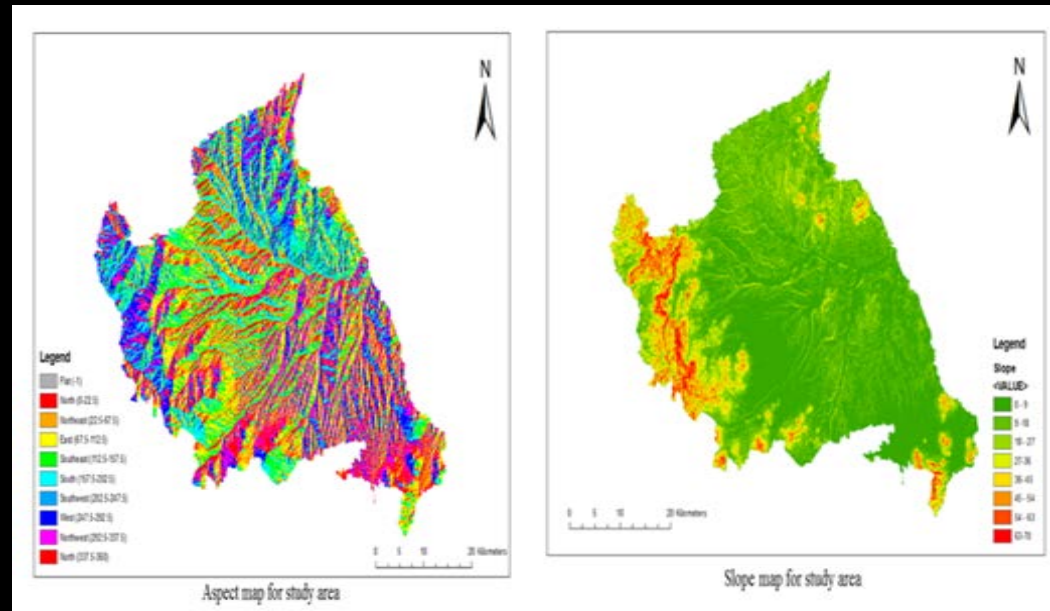
- Drainage maps correlated with observations from Landsat images and Linear Aspect of the Drainage Network from SRTM 90m data.



a) Location of boreholes in area of study, (b) Boreholes distribution along drainage (c) Resistivity surveys location, (d) Resistivity surveys distribution along drainage

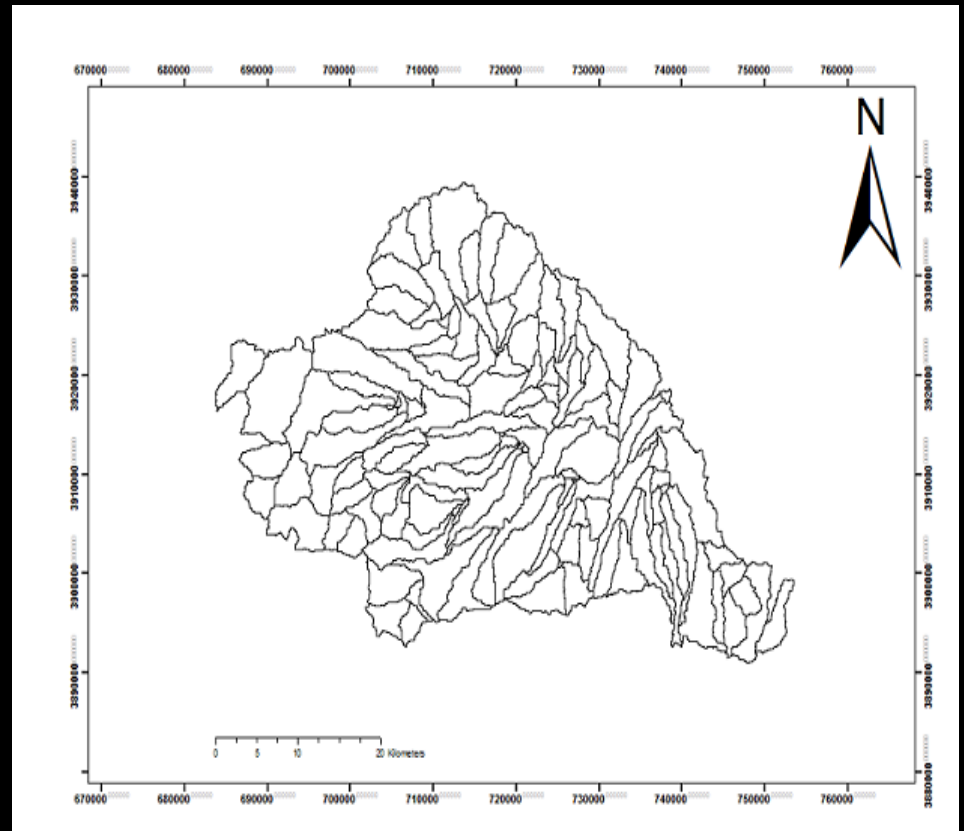
SLOPE AND ASPECT

- The slope and Aspect of a drainage basin are one of the major factors affecting time of overland flow and concentration of water received from rainfall
- Aspect map shows that the elevated areas have east-west faces which direct preferential flow direction in the drainage basins



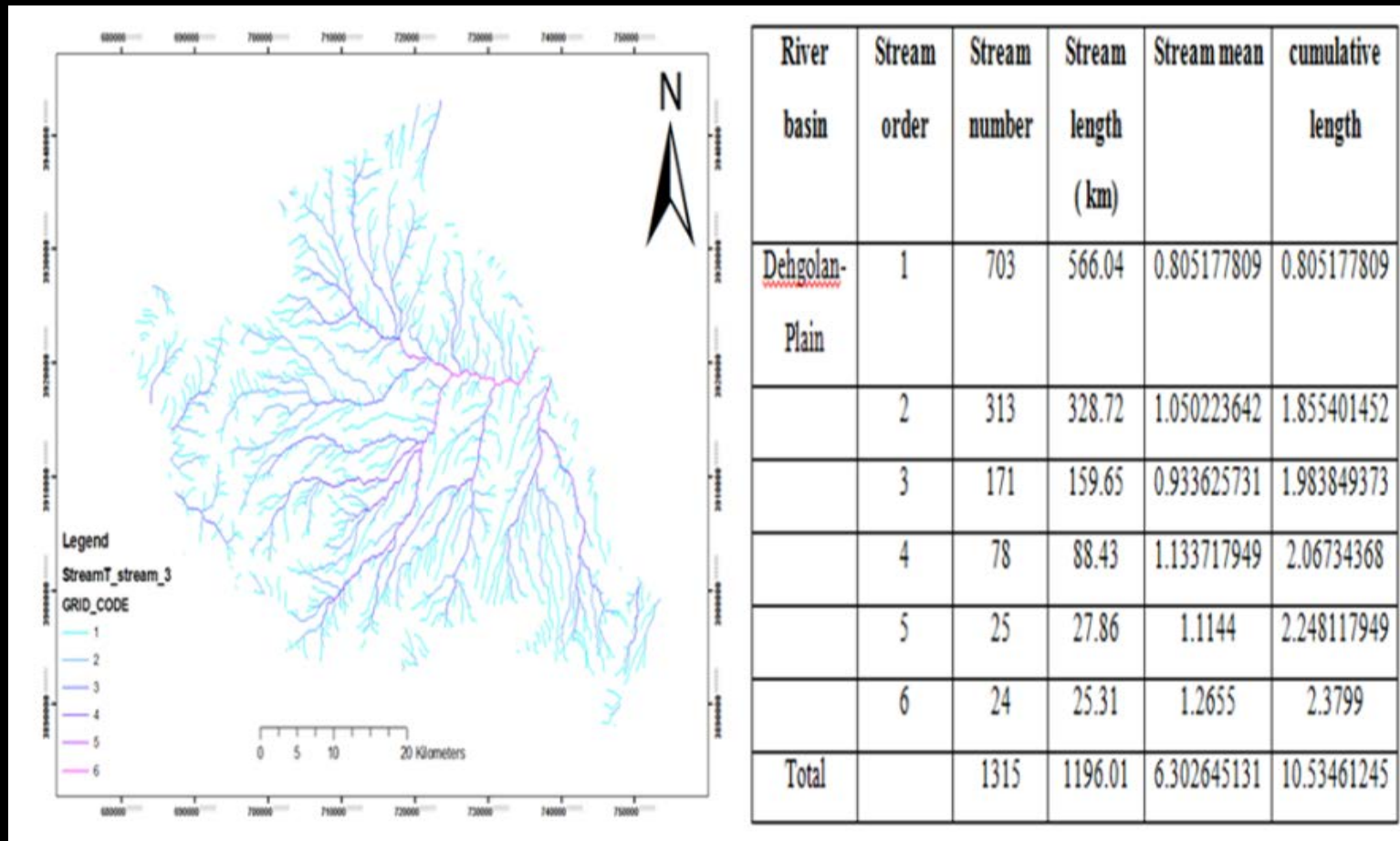
WATERSHED DELINEATED MODEL BY SWAT

- Watershed delineated in SWAT by giving an outlet or pour points where water flows out of an area, this is the lowest point along the boundary of the watershed
- Total number of sub-basins: 136, minimum elevation: 1713m height, maximum: 2665m, mean Elevation: 1899 and Standard deviation was calculated at 117.7



STREAM ORDER (NU)

- Stream ordering done according to Strahler's stream ordering system

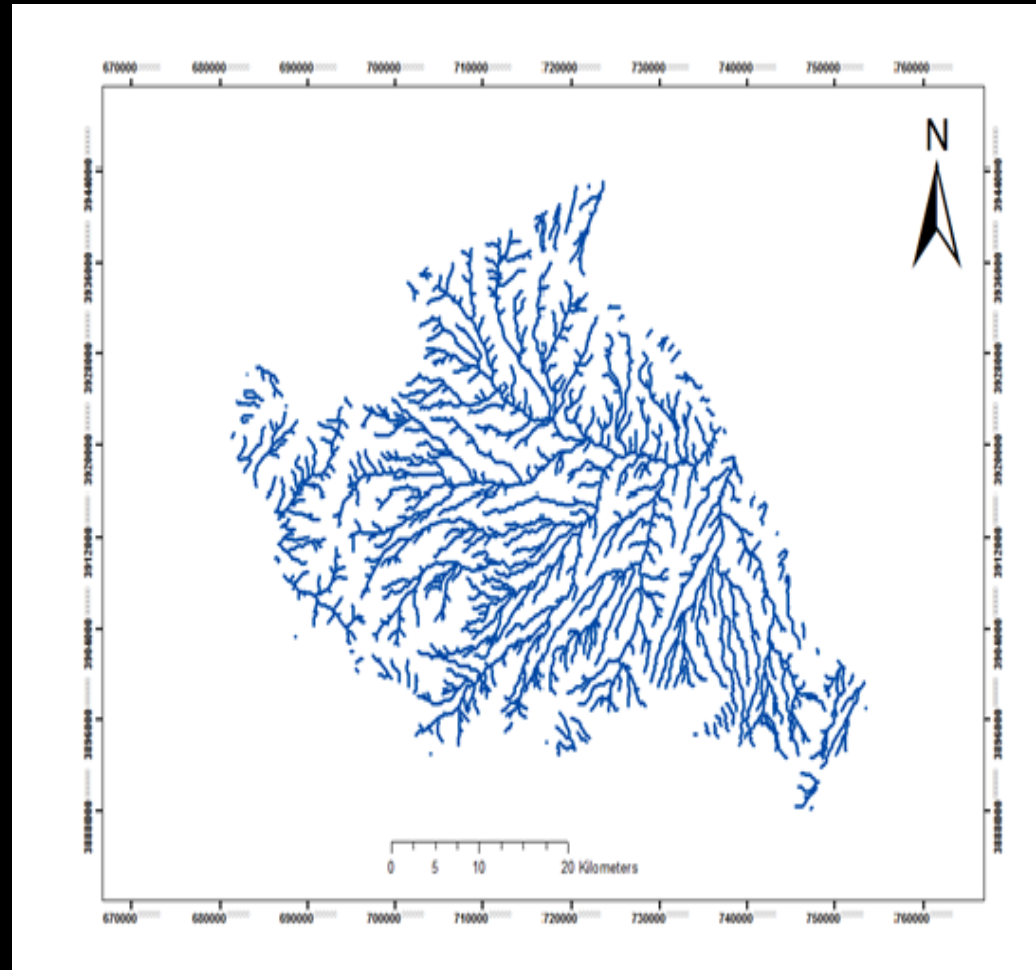


DRAINAGE DENSITY

- The drainage density indicates the closeness of spacing of channels.
- (Dd) of the study area; 6.74 km/sq. km.

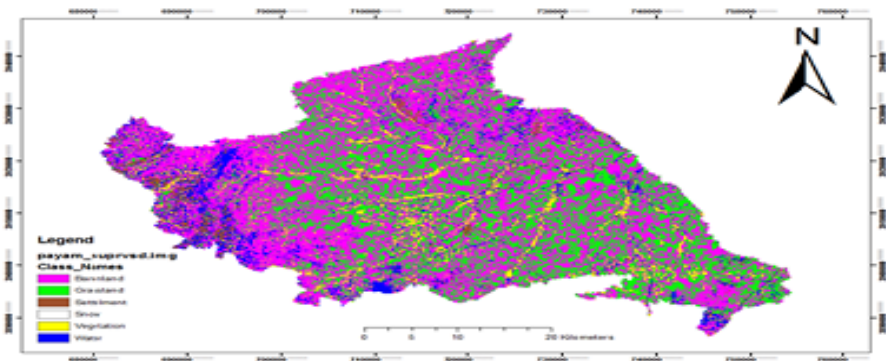
Drainage Pattern

- Drainage patterns of stream network from the basin have been observed as mainly dendritic type which indicates the homogeneity in texture and lack of structural control

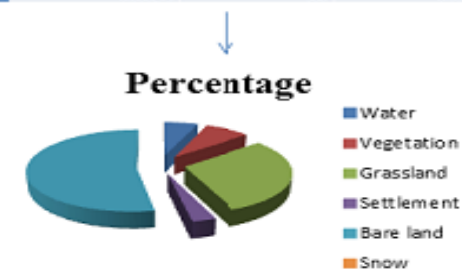


LAND USE/LAND COVER OF STUDY AREA

- Majority: Barrenland (30.8%) and Grassland (17.46%) respectively and lowest belongs to snow cover (0.2%)



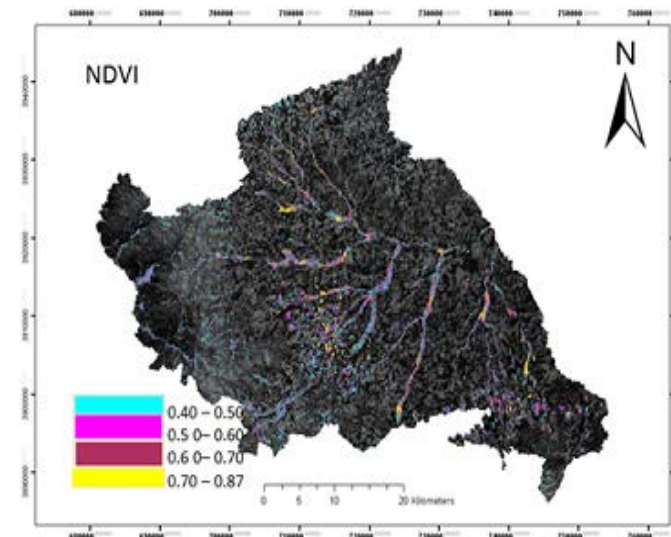
Classes	percentage	Area	Size	Value
Water	3.396185	4464490	4.48449	149483
Vegetation	4.780233	6308340	6.30834	210278
Grassland	17.4627	23045040	23.04504	768168
Settlement	1.824021	2407110	2.40711	80237
Bare land	30.5398	40630390	40.63039	1361013
Snow	0.000273	360	0.00036	12



LULC Map of study area using Supervised Classification

NDVI Evaluation

- Calculated NDVI shows the healthy vegetation with the highest value of NDVI that is shown by yellow color.
- High NDVI is suggestive of higher moisture zone.
- Blue light color indicates unhealthy vegetation with lowest value of NDVI with low availability of moisture zone



CLASS	MIN	MAX	MEAN	STDEV	AREA(Sqkm)
1	0.400004	0.499998	0.444057	0.029045	45.696
2	0.500130	0.599949	0.547557	0.028976	28.170
3	0.600039	0.699965	0.648247	0.028813	21.687
4	0.700004	0.872008	0.747046	0.033231	14.962

NDVI of Study Area (Landsat Image, 01/05/ 2000, Path167, Row35, 36)

Conclusions

- The methodology adopted successfully allowed for seamless integration of information regarding surface and subsurface hydrology in the study area. This can later be used for much rigorous hydrological modelling integrating various flows and interactions both in **vertical as well as horizontal dimensions.** Generated models from boreholes lithology, resistivity surveys gives suitable set of information for assessment of water level depth and its behavior under various geological conditions for a part of the study area. This data set can later be used in SWAT for better **description of hydrological models for whole study area.**

Thank You

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STRATIGRAPHY

Dolomite and Lime

- Teygh Ghasemi altitudes in the East area consist of the yellow highly crystalline and crushed dolomite formation, the thickness of its lower reaches is not clear. Due to the type of these units and many correlations, it receives high amount rainfalls. Late Triassic - early Jurassic is the established age of this unit.

Shale and sandy limestone

- Adjacent and spread on pervious unit, consists of shale with a thickness of 122 m within the crystalline layers of sandy limestone with traces of chopped fossils observed. The age of this unit is Triassic and the permeability is low.

Quartzite, Shale and Sandstone (Jq)

- In the southern highlands and mountains range of the study area (Seraj Seri and Cahrgah Mountain) quartzite, shale with a thickness of 522 m is observed within the single layers of limestone. Sandstone and volcanic rocks are rarely seen.

Shale and Sandston

- The upper part (Jq) contains grey shale and sandstone with a thickness of 622 to 722 meters made up of units with large lenses of argillaceous limestone crushed and broken by rough topography. It rarely contains fossils (Jl) and volcanic rocks of andesitic type which are associated with shale (Jv). This unit is inclined with its lower units.

Basalt

- In the southern and southern-west of study area a series of volcanic rocks specifically of the basaltic type has been observed, which implies the onset of volcanic activity in the late Jurassic period. It belongs to the Lower Cretaceous age and is less important in terms of the hydrogeological condition.

Sandstone

- This unit is about 252 m in thickness and composed of sand, grey to light grey limestone shale and volcanic rocks of andesitic. This unit lies on an older rock unit with the same slope. The fossils found are belonging to Aptian in the geologic timescale .

Sand Marl (Mms)

- This unit is mounted in the northern part of SAVAR Mountain and in the vicinity of KhodaKarami village. It is made up of coarse sandstone and sandy marl with blue colour.

Silty clays, gypsum, sand marl and sandstone (Pm)

- The northern area of study is not high in altitude and consists of various materials such as silty clays, chalk, marl sand, sandstone, conglomerate and lime plaster. Horizons of the possible erosion help to reduce its height. It has a Pliocene age. It seems that this unit has no capability to be considered as a proper aquifer.