How Efficient is an Integrative Approach of GIS and Resistivity Data in Groundwater Exploration? A Case Study of Esna, Luxor, Egypt

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Keywords: GIS, DC Resistivity Sounding, Groundwater Exploration, Esna,

Presently, Geographical Information System (GIS) technique and direct current (DC) resistivity soundings are widely used for characterizing the groundwater aquifers. In this study, an integrated suite of quantitative morphometric analysis and DC resistivity data is used to evaluate the hydrogeological conditions at western part of Esna area, Luxor, Egypt. The geo-hydrological characteristics are assessed and an attempt is made to identify the groundwater potential zones through geo-morphometric specs. Geomorphological analysis of the drainage network of the area points out to the existence of five hydrographic basins. According to the morphometric analysis of drainage basins results, DC resistivity measurements in the form of 1D survey are carried out to demonstrate the subsurface layer distributions and delineate the groundwater aquifers in the main basin of the area. The DC inversion results indicate that the main Pleistocene aquifer overlies the saline Pliocene-Pleistocene aquifer. Further, an integrated relationship between salinity and electrical resistivity is established. The obtained results can serve as a basis for monitoring, planning and management of water resources in this area, and as a whole, they constitute an encouraging example using an integrated approach of morphometric and resistivity data in groundwater exploration.

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Outline

OUTLINE

- *Aims*
- *Location /Local geology*
- *Geographic Information System (GIS) /Morphometric analysis*
- *DC Resistivity measurments/Inversion*
- *Geoeelctrical Results and discussion*
- *Conclusions and outlook*

Aim

AIMS AND WORKFLOW

Investigating to what degree an integration of morphmetric analysis and DC resistivity data are successful in groundwater exploration/assessment.

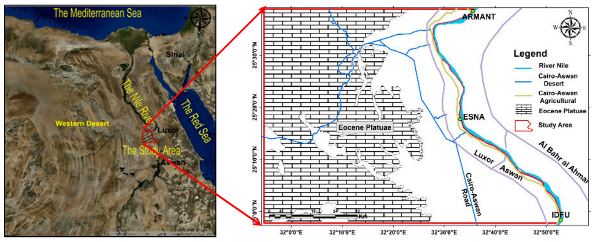
Methodology and workflow

- Establishing the high priority area (west Esna) for water flooding potentiality using morphometric analysis. Consequently high chance for runoff water harvesting and increasing groundwater recharge possibilities.
- Delineating the groundwater aquifer/geometry using DC resistivity sounding.
- Establishing a relationship between water salinity and aquifer resistivity to predicate the salinity variations at different depths.
- Establishing 3D visualization model and schematic block diagram of the groundwater condition s of the study area.

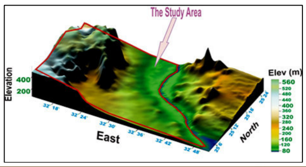
✓

Location and local geology

LOCATION/TOPOGRAPHY



Location map of the study area.



- High relief topography.
- Gentle surface slopes towards the northeast direction.

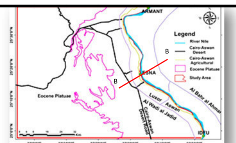
Location and local geology

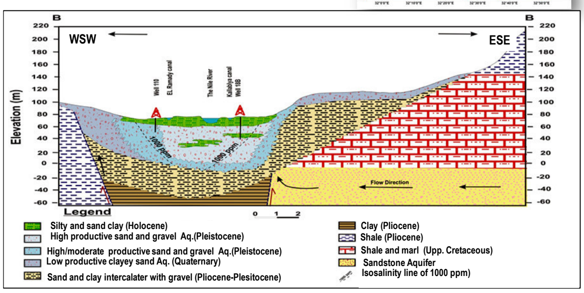
LOCATION/TOPOGRAPHY

Location and local geology

GEOLOGY/HYDROGEOLOGY

- The Quaternary aquifer was deposited by the River Nile in a structural low formed during Miocene rifting related to the opening of the Red Sea.



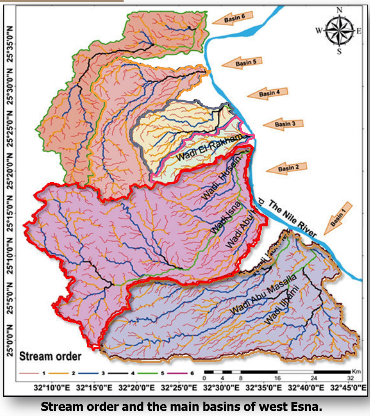


Geological map of the study area. Hydro geologic section of the study area (after RIGW 1997).

GIS / Morphometric analysis

MORPHOMETRIC ANALYSIS

- The advent of geographical information system (GIS) tools opened new path in water resource interpretation.
- Morphometric analysis can be achieved through measurement of linear, aerial and relief aspects (DEM) of basins using ArcGIS.
- The drainage basin analysis is important in in understanding the geo-hydrological behavior of drainage basin (D-8 algorithm and Strahler techniques).



Stream order and the main basins of west Esna.

GIS / Morphometric analysis

MORPHOMETRIC ANALYSIS

Morphometric Parameter	Formula	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6
Basin Area (A) Km²	GIS software Analysis	878.59	**1024.43**	109.47	163.1	353.1	389.54
Basin Perimeter (P) Km		182.11	**201.87**	62.35	67.72	121.17	154.5
Basin Length (L_b) Km		50.7	**53.99**	22.56	22.92	35.69	47.1
Stream Length (L_u) Km (All order)		895.35	**976.17**	124.71	182.72	357.27	360.14
No. of streams (N_u) (All order)		369	**423**	54	70	161	187
Length of Overland Flow (Lof) Km	Lof=1/2D D= L_u/A	0.51	**0.48**	0.57	0.56	0.51	0.46
Length of Overland Flow value indicated good surface runoff of the study area							
Linear Parameters (one Dimensional)							
Drainage Frequency (F_s) / Km²	N_u/A	0.42	**0.413**	0.493	0.429	0.456	0.48
Drainage Density (D_d)	L_u/A	1.019	**0.953**	1.139	1.121	1.012	0.925
		Moderate Drainage Density indicates the basins is moderate permeable sub-soil					
Texture ratio (R_t)	N1/P	1.554	**1.650**	0.593	0.753	1.048	0.926
Drainage Texture (D_t)	N_u/P	2.026	**2.095**	0.866	1.034	1.329	1.21
Drainage Intensity (D_i)	F_s/D_d	0.412	0.433	0.433	0.383	0.451	0.519
Infiltration Number (I_f)	F_s * D_d	0.428	**0.393**	**0.562**	0.481	0.461	0.444
Low value of D_d, F_s, and D_i indicates surface runoff quickly removed from the basins							

GIS / Morphometric analysis

MORPHOMETRIC ANALYSIS

Shape Parameter (two Dimensional)

Morphometric Parameter	Formula	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6
Form Factor (R_f)	A/L_b^2	0.342	**0.351**	**0.215**	0.311	0.277	0.176
Elongation Ratio (R_e)	R_e= 2√(A/π)/L_b	0.66	**0.67**	0.523	0.629	0.594	0.473
Compactness Coefficient (Cc)	Cc= P/2(√πA)	1.734	**1.78**	1.681	1.496	1.819	2.209
Runoff Volume	Rational equation *	26165.76	**30549.43**	6571.49	8916.13	13162.03	11418.5

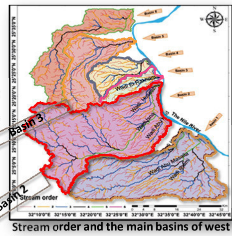
- **Rational equation**: V = R * C * A* P .....(1) R = 1.05 − 0.0053 √A ......(2)

where **V** is the surface runoff volume, **P** is the total rainfall depth, **C** is runoff coefficient, **A** is the basin area upstream the point of interest, and **R** is the reduction factor that depends on basin area (HELWA, M., 1993).

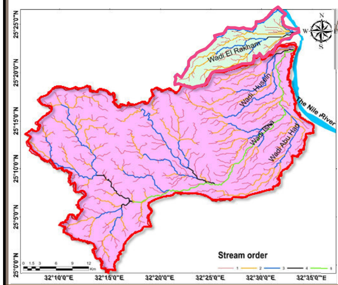
GIS/ Morphometric analysis

MORPHOMETRIC ANALYSIS

1- higher volume of annual flood, 2- larger basin area, 3- larger basin length, 4- lower compactness coefficient, 5- lower basin infiltration number, 6- Very coarse drainage density, 7- coarse drainage texture 8- elongated basin shape, 9- Higher length of Overland Flow



Stream order and the main basins of west Esna.



All these factors together make the two basins have high priority for water flooding potentiality. Consequently high chance for runoff water harvesting and increasing groundwater recharge possibilities .

The selected basins based on morphometric analysis using GIS tool.

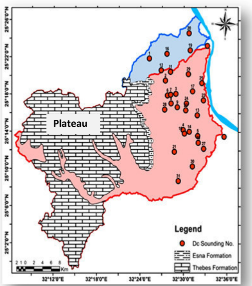
Field data acquisition

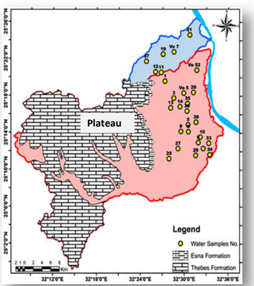
FIELD DATA ACQUISITION

Field data:

27 water samples.

31 Soundings; Schlumberger array; AB/2: 700 m.

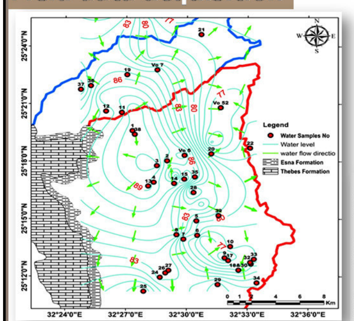




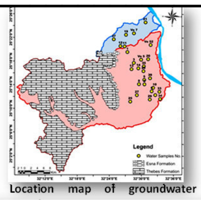
Location map of Dc soundings (left) and groundwater samples (right) of the study area.

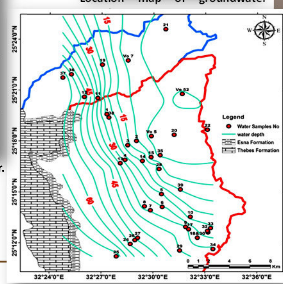
Field data acquisition

FIELD DATA ACQUISITION



Contour map of water Level with flow direction of groundwater.

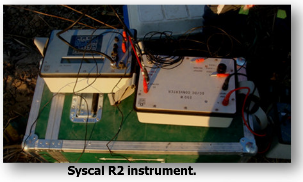

Location map of groundwater



Contour map of water depth at the study area.

DC Data Acquisition

DC DATA ACQUISITION



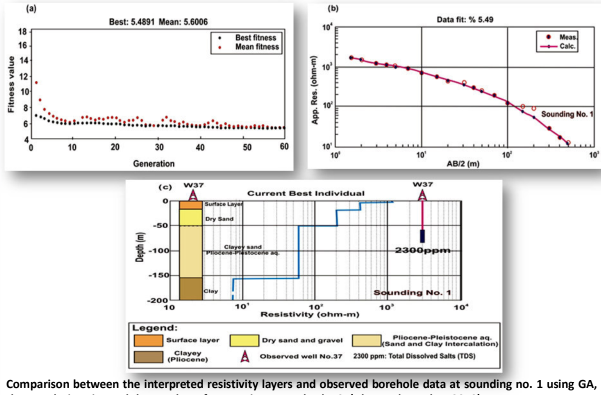
Syscal R2 instrument.

The conditions were extremely difficult due to the resistance contact and inhomogeneity of the surface cover.

Some precautions were carried out as digging a hole, adding water, adding bentonite..etc.

DC Resistivity inversion

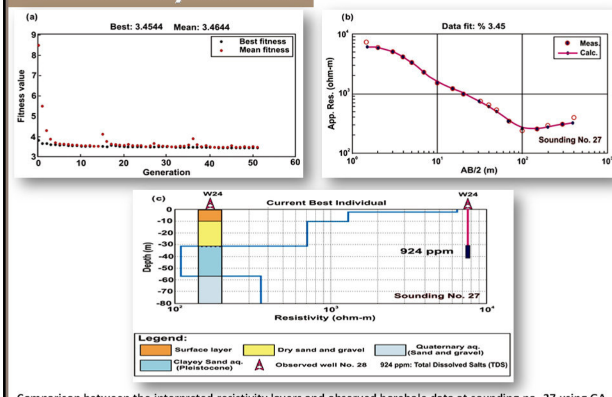
DC RESISTIVITY INVERSION



Comparison between the interpreted resistivity layers and observed borehole data at sounding no. 1 using GA, the population size and the number of generations were both 50, (Akca and Basokur, 2010).

DC Resistivity inversion

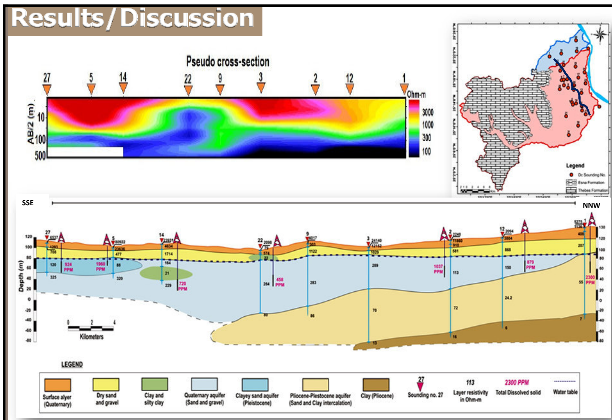
DC RESISTIVITY INVERSION



Comparison between the interpreted resistivity layers and observed borehole data at sounding no. 27 using GA, the population size and the number of generations were both 50, (Akca and Basokur, 2010).

Results/Discussion

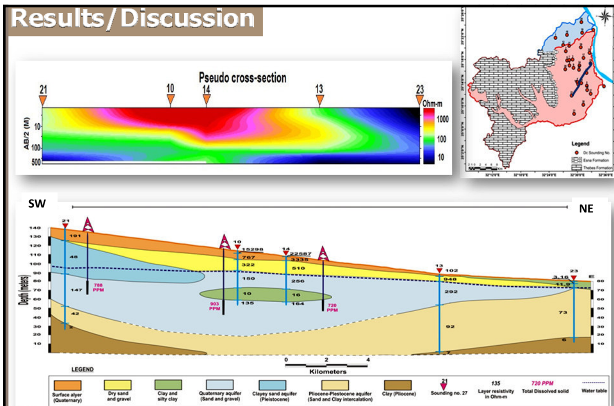
RESULTS /DISCUSSION



Apparent resistivity (above) and stitched resistivity (bottom)sections.

Results/Discussion

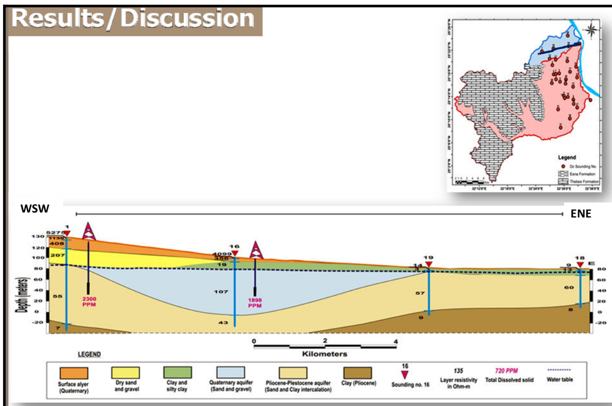
RESULTS /DISCUSSION



Apparent resistivity (above) and stitched resistivity (bottom)sections.

Results/Discussion

RESULTS /DISCUSSION

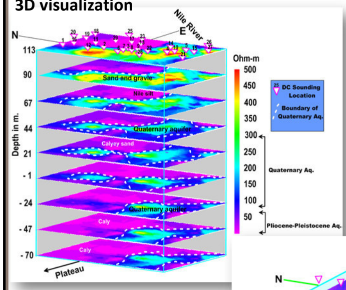


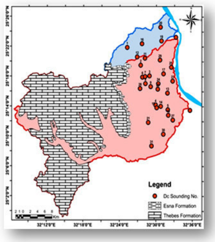
Stitched resistivity (bottom)section.

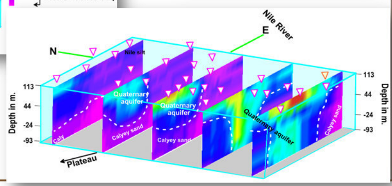
Results/Discussion

RESULTS /DISCUSSION

3D visualization







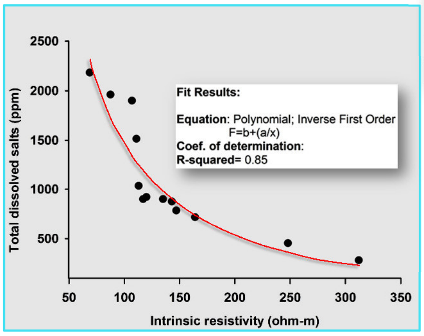
3D visualization resistivity model shows the resistivity distribution with different depths.

Results/Discussion

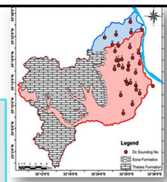
RESULTS /DISCUSSION

Salinity Prediction

Correlation from the field data



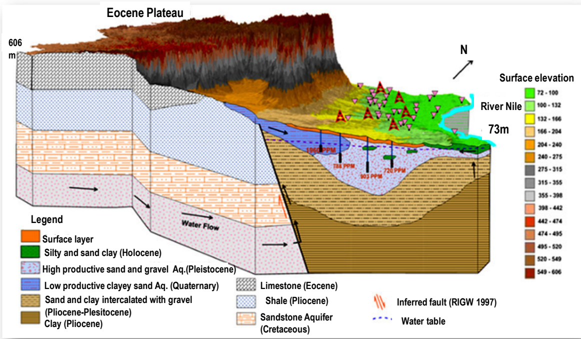
Correlation between Interinsic ressitivity versus TDS of collected samples .



Results/Discussion

RESULTS /DISCUSSION

3D Schematic model



Conclusion/Outlook

CONCLUSION/OUTLOOK

- ✓Overall, the study demonstrates the advantages of using an integrated approach using (GIS) and DC resistivity data to evaluate the hydrogeological conditions at Esna area.
- ✓ The use of GIS identified the optimum locations for water flooding potentiality. Consequently high chance for runoff water harvesting and increasing groundwater recharge possibilities .
- ✓ The sequential use of GIS and DC resistivity data show the importance of such tools for planning and management of water resources in the area.
- ✓ From all applied studies showed that the study area can be considered as a promising development area.
- ✓The overall geoelectrical results indicated that the prediction of TDS of the main aquifers using an empirical relationships is recommended.
- ✓Continuous geophysical monitoring is essential to evaluate the reclamation impacts on the groundwater potentiality to avoid the deterioration of the aquifer system.