PRIMA Section 2 - 2021, Thematic Area 1-Water management: Topic 2.1.1
"Alleviating Mediterranean water scarcity through adaptive water governance"

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PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

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Advancing non conventional water management for innovative climate-resilient water governance in the Mediterranean Area

Hydrogeological Modeling and Simulation of Groundwater Artificial Recharge , using Visual MODFLOW Flex Software : Case study of Cheria Plain, North-East of Algeria.

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AG-WaMED Masterclass ; first edition
26 June, 2023

UNIVERSITÀ DEGLI STUDI FIRENZE · POLITECNICO MILANO 1863 · POLITÉCNICA · Institut des Régions Arides · ALEXANDRIA UNIVERSITY · H.A.O. "DEMETER" · Université Larbi Tébessi - Tébessa · VU VRIJE UNIVERSITEIT AMSTERDAM

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Abstract

Aquifer Overexploitation significantly lowered the groundwater levels in the Cheria region, northeastern of Algeria, which has cause serious eco-environmental problems (sinkhole collapse). This work studies the possibility of artificial recharge of the Eocene aquifer using hydrogeological modeling.

This study simulates groundwater flow through a 3D numerical model based on the finite difference method. The model was implemented for the years 2021 to 2031 using Visual MODFLOW Flex to simulate the groundwater in three scenarios from present situation to the future, including pumping without recharge, recharge of the entire area by efficient infiltration without pumping, and the scenario of artificial recharge using water from rivers by infiltration basins in two sites, Draa Douamis sinkholes and Eocene limestone outcrops.

The simulation results showed that the exploitation of the aquifer without recharge causes groundwater drawdowns ranging from 3 to 7 m in the north-eastern part and 8 to 12 m in the central and southern parts. However, the level of groundwater increased in the second scenario by 2 to 2.7 m in the north-eastern part and by 3 to 3.62 m in the central and southern parts. Finally, for the last scenario, the rise in piezometric levels at the proposed sites indicates that the response to artificial recharge is positive, which is beneficial to the aquifer.

Study area

The Cheria basin situted in the center part of the study area and is located about forty kilometers southwest of Tebessa city, N-E of Algeria. This basin is delimited by mountains range that rises to altitudes above 1500 m, such as Djebel Dokkane (1551 m) and Djebel Metaguinaro (1713 m).

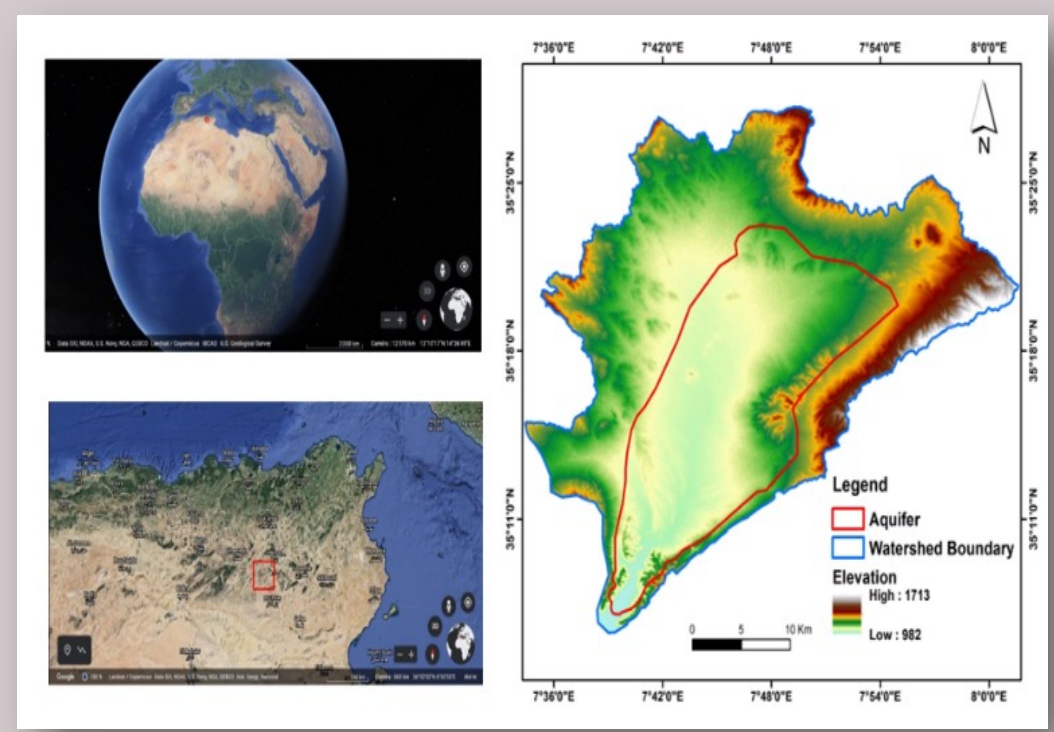

Fig 01. Location of watershed and aquifer of study area.

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Geology and hydrogeology

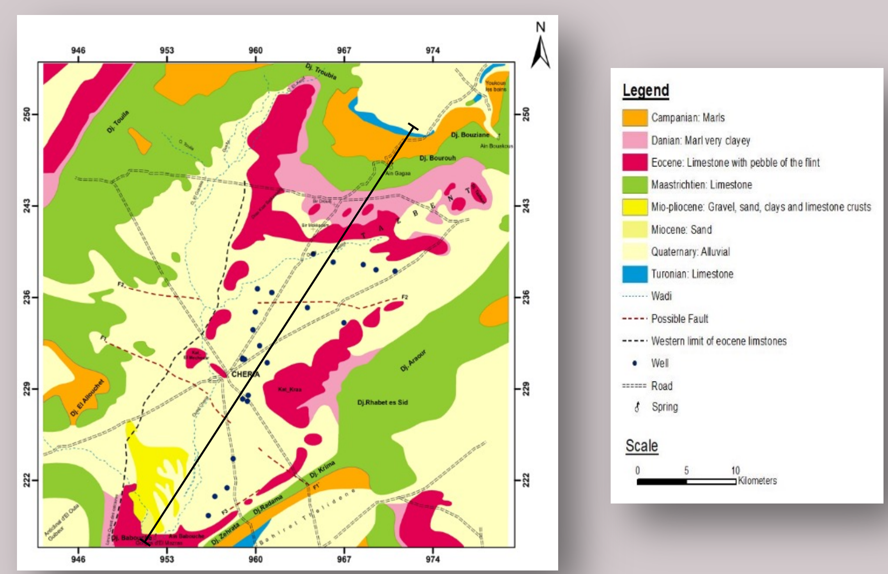

Fig 02. Geological map of the study area.

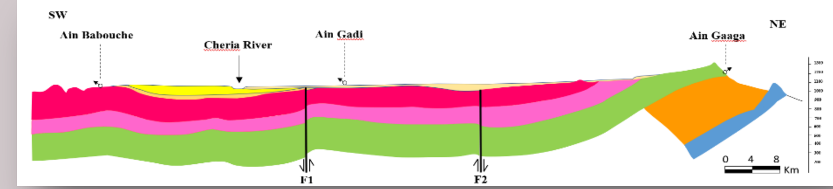

Fig 03. Geological cross section of the studied region

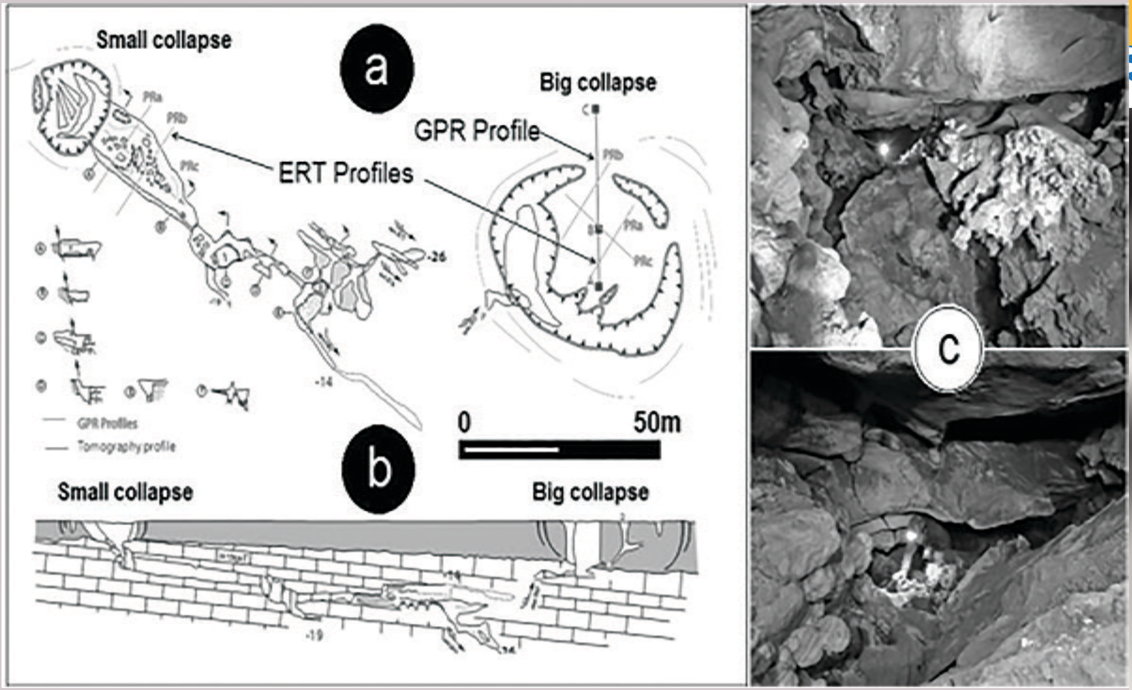

Fig 04 General view of the collapse (authors' pictures; May 05, 2022)

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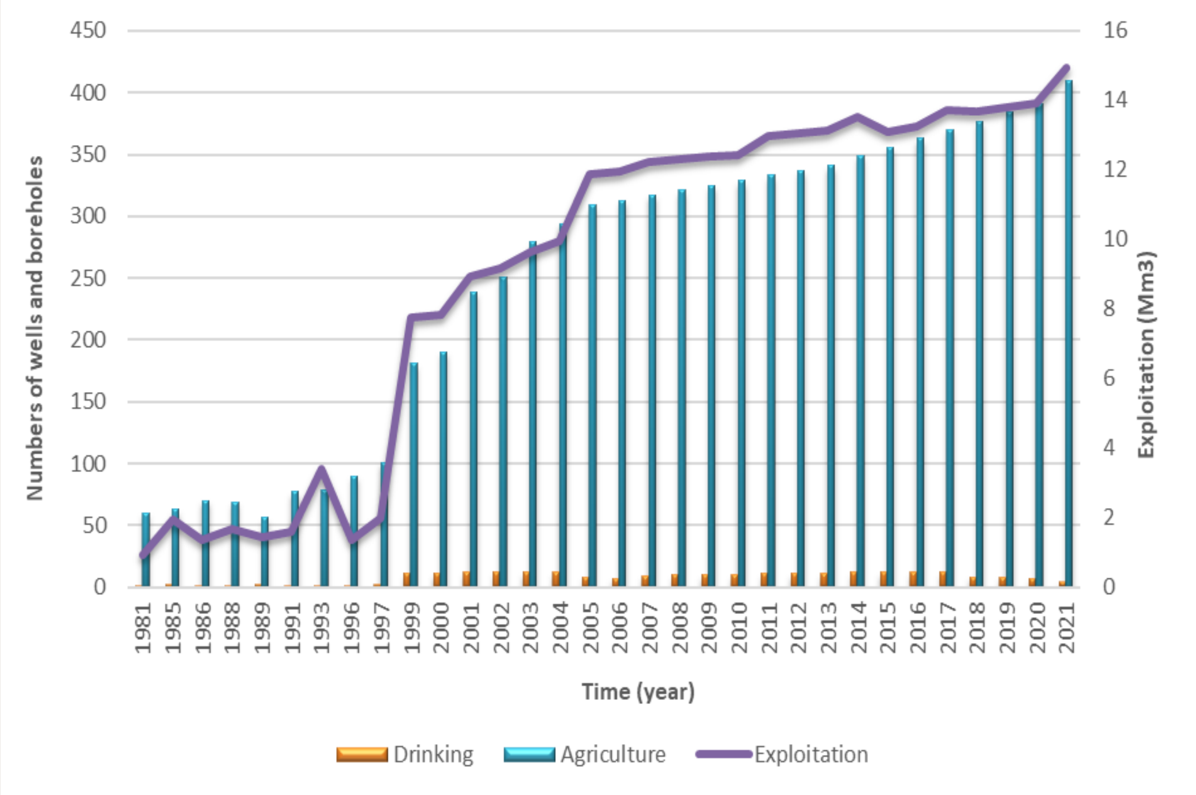


Fig. 5 Evolution of the exploitation rate according to the number of water wells in the Cheria aquifer (1981-2021).

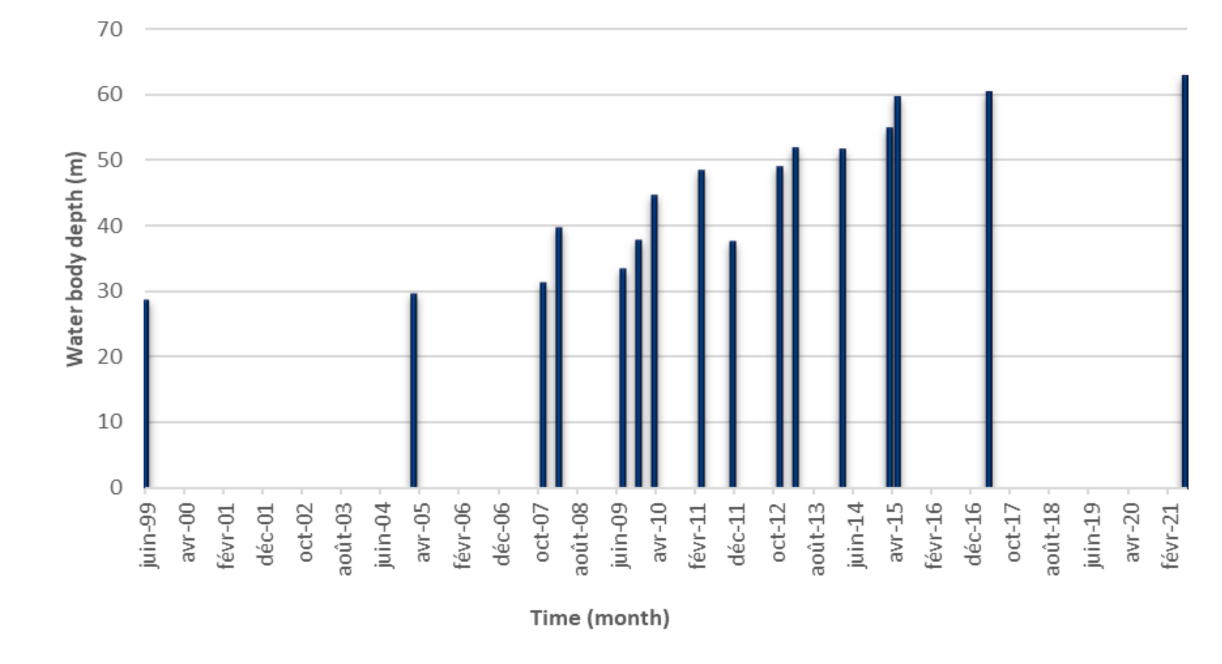


Fig. 6 evolution of the water level depth over time (1999-2021)

Methodology

1- Piezometry

- Two groundwater piezometric-level measurement campaigns was carried out on June 2021 and March 2022 on 26 wells. The depth of the water table was measured by a graduated electric probe, and the geographical coordinates of the boreholes were recorded using a GPS MAP GARMIN 62S.

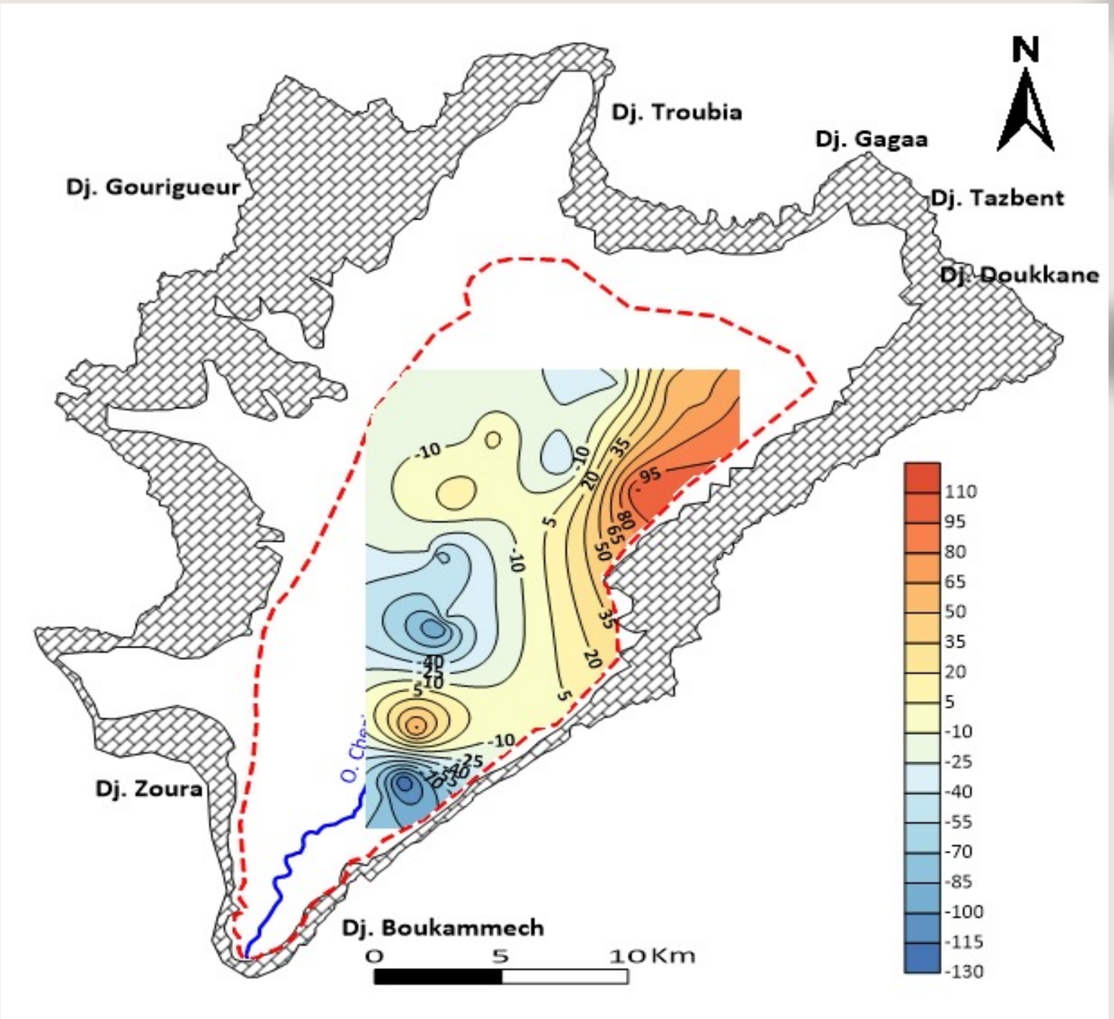


Figure 07. Piezometric drawdown map between 1999 and 2021

Groundwater modeling

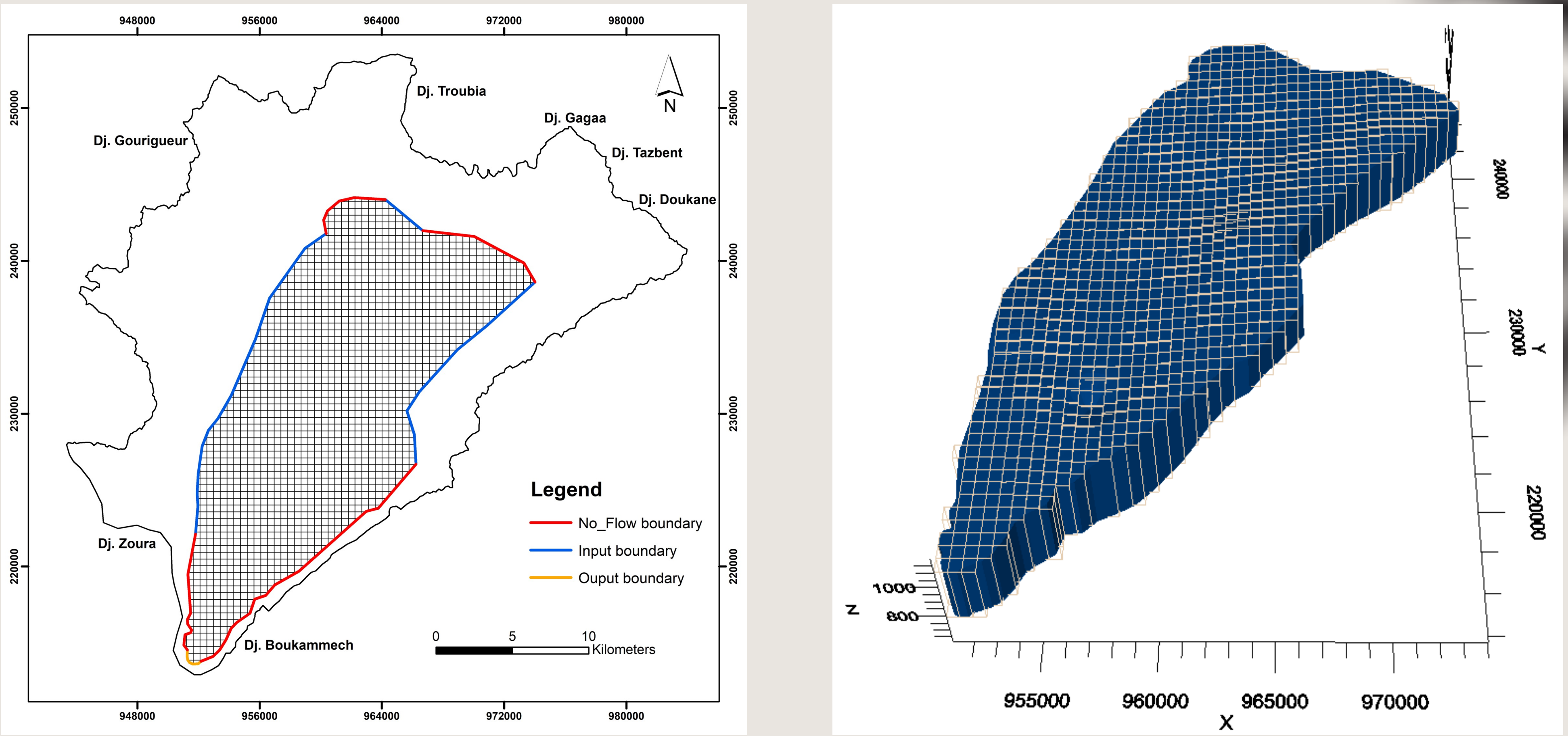


Figure 08. a) Boundary conditions of the model b) 3D Numerical grid created for Eocene groundwater model

1st scenario:

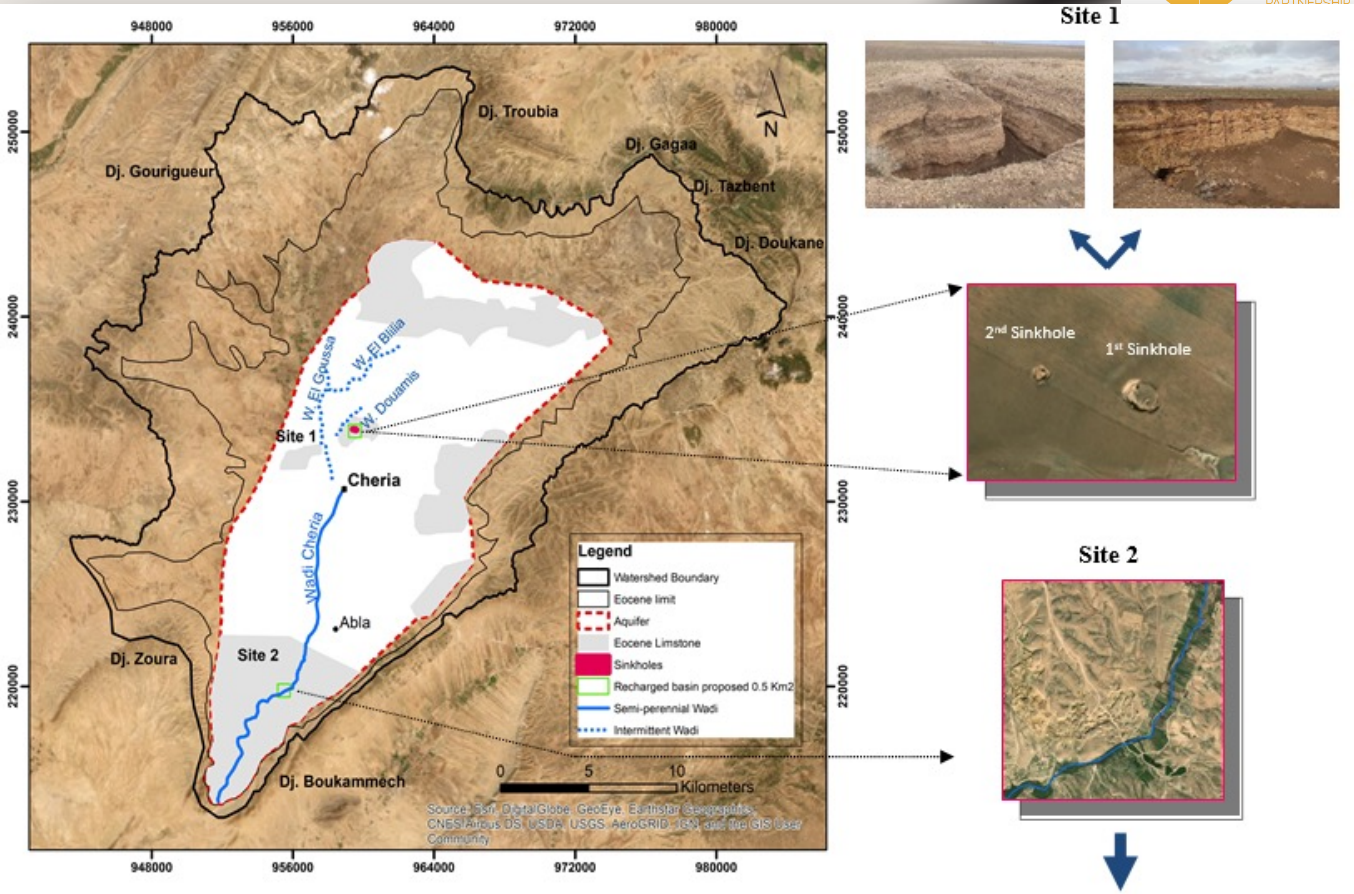
This scenario follows the evolution of the piezometric level from 2021 to 2031, which corresponds to a long-term operation by maintaining the number of wells and by considering that there is no recharge.

2nd scenario:

In this scenario, the pumping was stopped for ten years (2021–2031) to observe the recharge of the entire layer by effective infiltration for an average of 17 mm/year,

3rd scenario: Implementation of an artificial recharge device

The simulation of artificial recharge of the aquifer was carried out over a period of 10 years. Based on the data collected, the recharge basin type was suggested as an artificial recharge method to capture and infiltrate flood water from streams in two northern and southern areas.



Site 1 : Sinkhole area
site 2 : Eocene limestone outcrops

Figure 09. Location of sites proposed for artificial recharge

Table 01. Parameters of the artificial recharge of the Cheria aquifer for one year

	Site 1			**Site 2**
Wadi	Douamis	El Blilia	El Goussa	Cheria
Flow (m^3/s)	4.68	7.39	16.05	16
	28.12			
Annual inflows (Mm^3/an)	2.02			1.15
Recharge to the water table (80%)	1.62			0.92
Height of recharge (m) — Area of 0.5 Km^2	3.24			1.84

Results

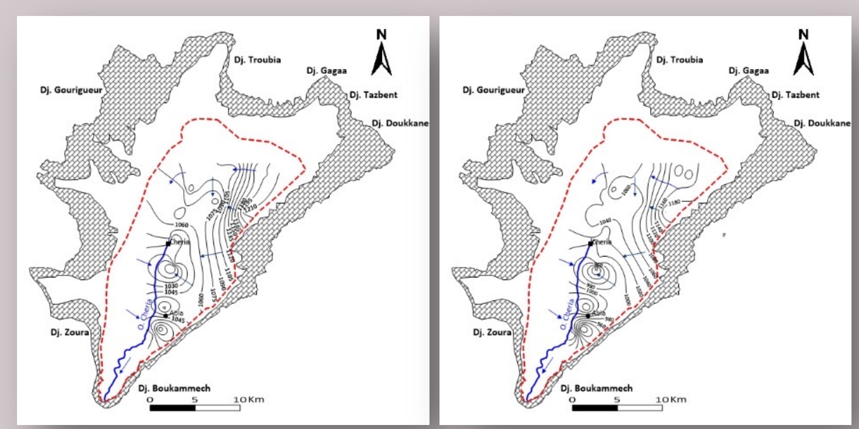


Fig 10. a Piezometric map, June 2021, b Piezometric map, October 2021

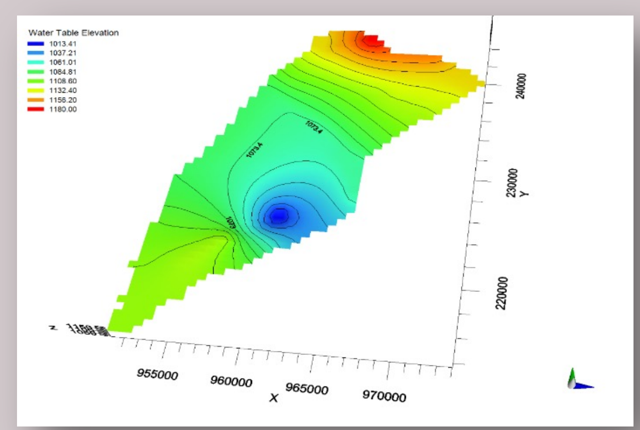


Fig 11. Reconstitution of the piezometric state in steady state, September 1999

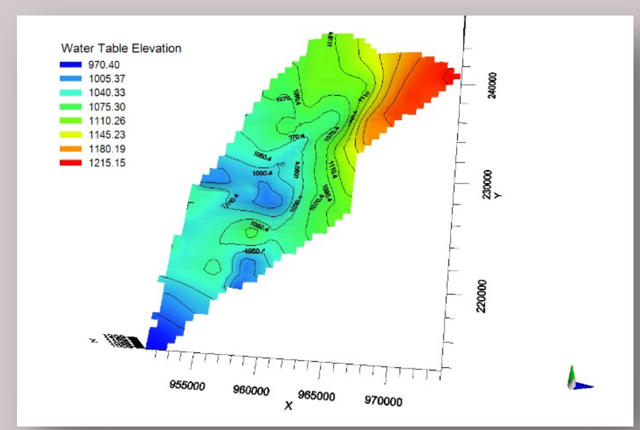


Fig 12. Reconstitution of the piezometric state in transient regime, June 2021

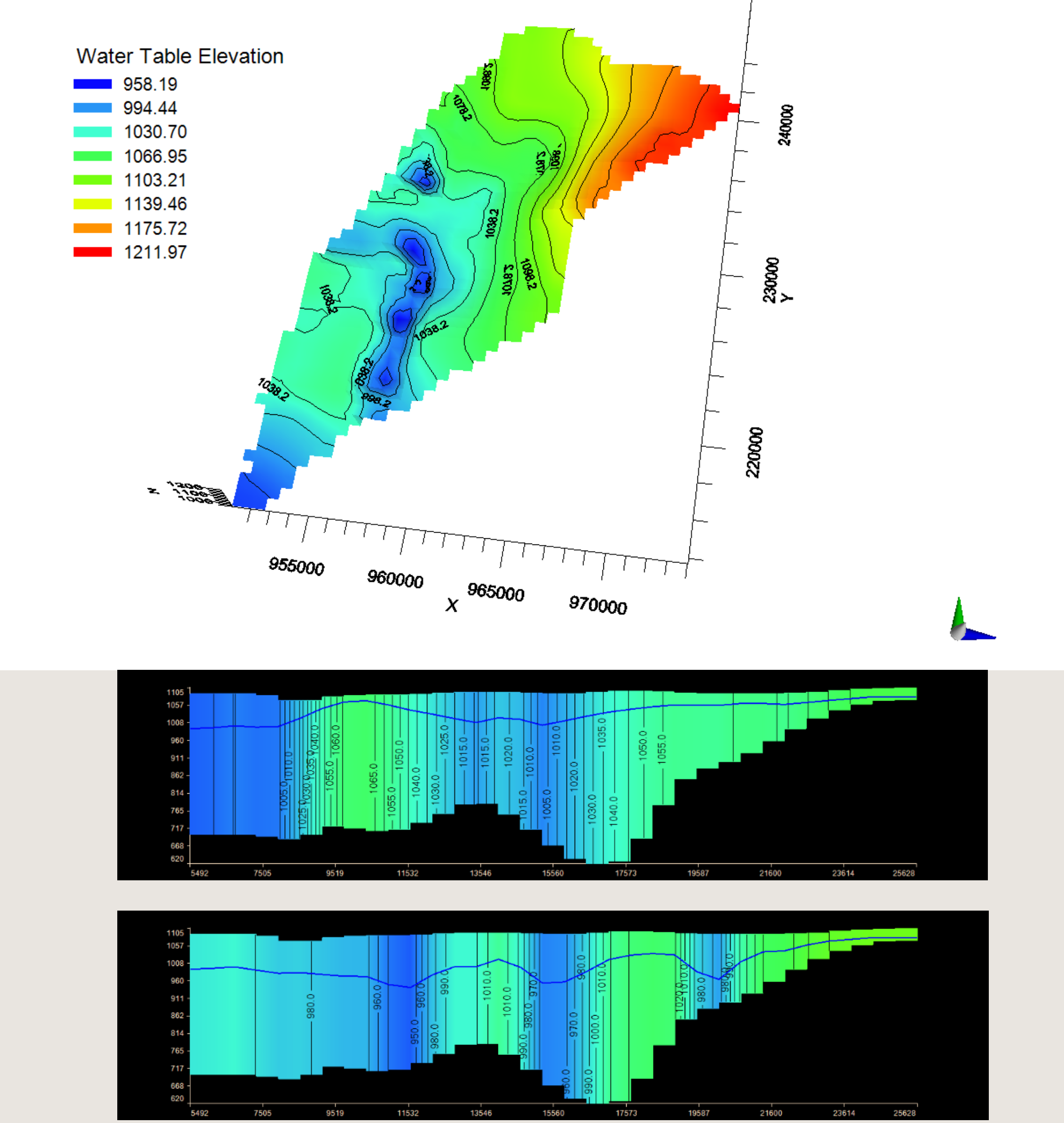


Figure 13. Simulation of a long-term exploitation 2021-2031 without recharge

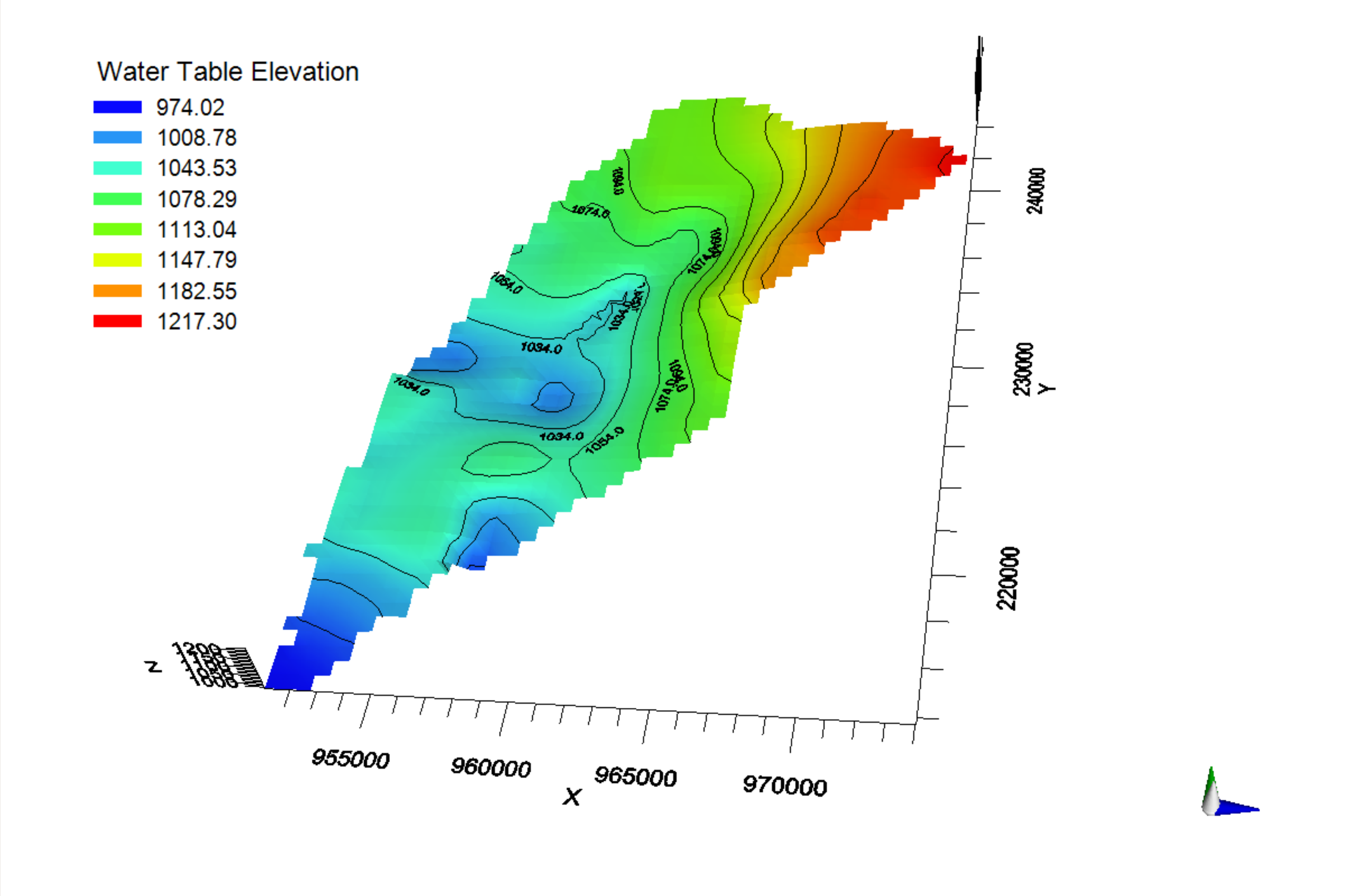


Figure 14. Simulation with recharge (17 mm/year) without pumping 2031

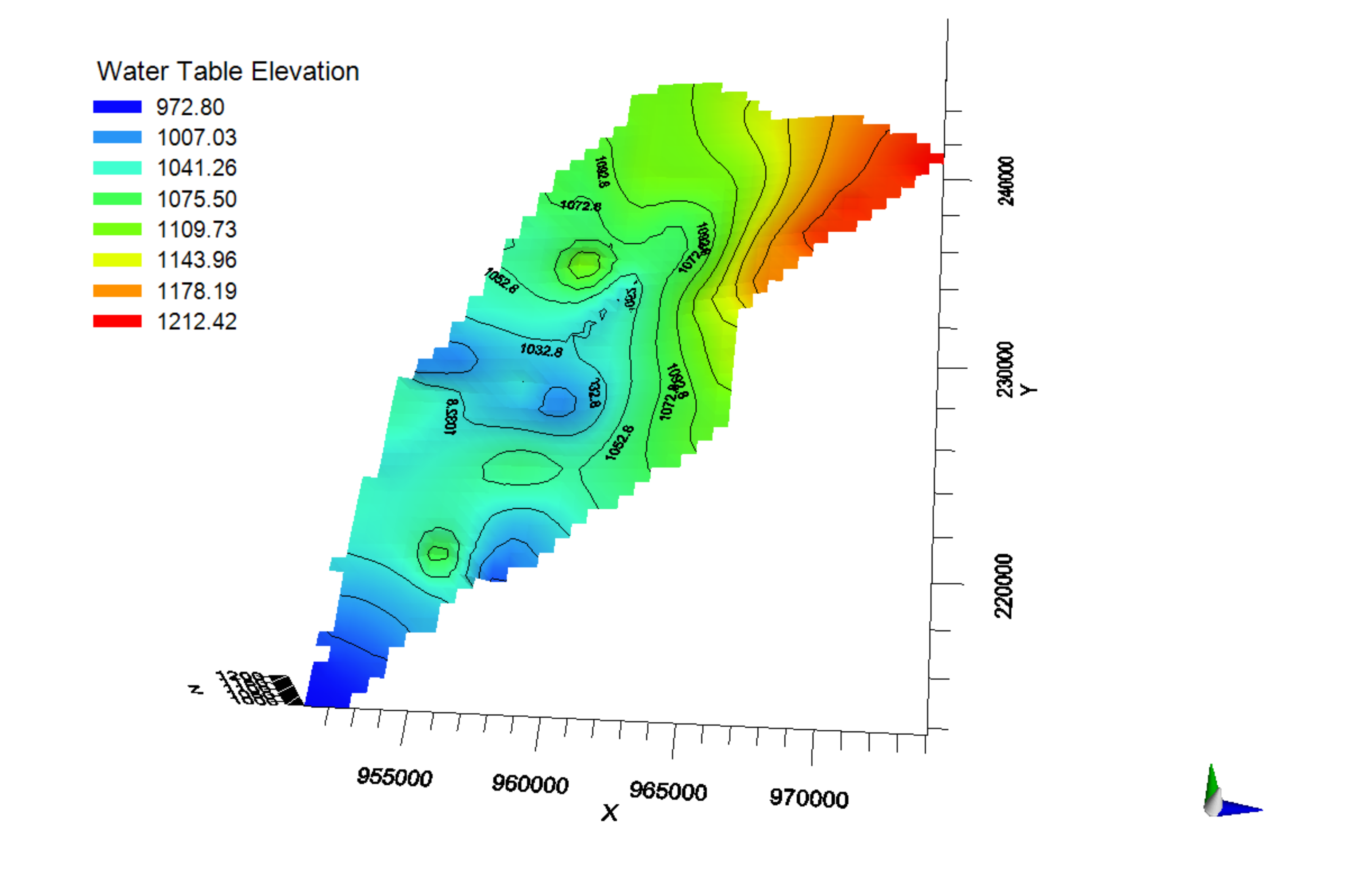


Figure 15. Effects of artificial recharge, predictive model for 2031 assuming two recharge sites with an area of 0.5 km^2

Conclusion

The piezometric mapping revealed a significant change in the flow direction after 22 years in the northern part from N-S to E-W and remains the same in the southern part toward the drainage axis (Cheria River).

A three-dimensional single-layer groundwater flow model (Visual MODFLOW Flex) was used to predict the changes in piezometric levels of the Cheria Eocene aquifer from 2021 to 2031.

The simulation showed that continued exploitation without recharge over time reduced the water table and caused a significant decline in the groundwater level of about **3 to 12 m**.

However, with the natural recharge of an average of **17 mm/year** of infiltration, the piezometric level has increased slightly by **2 to 3.6 m** per ten years.

To relieve the water table and recover the deficit caused by overexploitation and the acute drought during the last decades in the Cheria region, it seems imprtant to think of a third scenario that simulates artificial recharge from the rivers, especially during high flood periods.

The presence of subsidence and fissured limestone in the study area under a semi-arid climate led to the choice of infiltration basins as a method of artificial recharge. After simulation, a piezometric dome has formed locally in the two selected sites, indicating the rise in the piezometric level with a value of **4 m per year**. It is considered that the application of such recharge systems will improve the groundwater regime, which is beneficial for groundwater management in the Cheria area.

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