



Impacts of Anthropogenic Activities on the Groundwater Resources of Northern Kuwait

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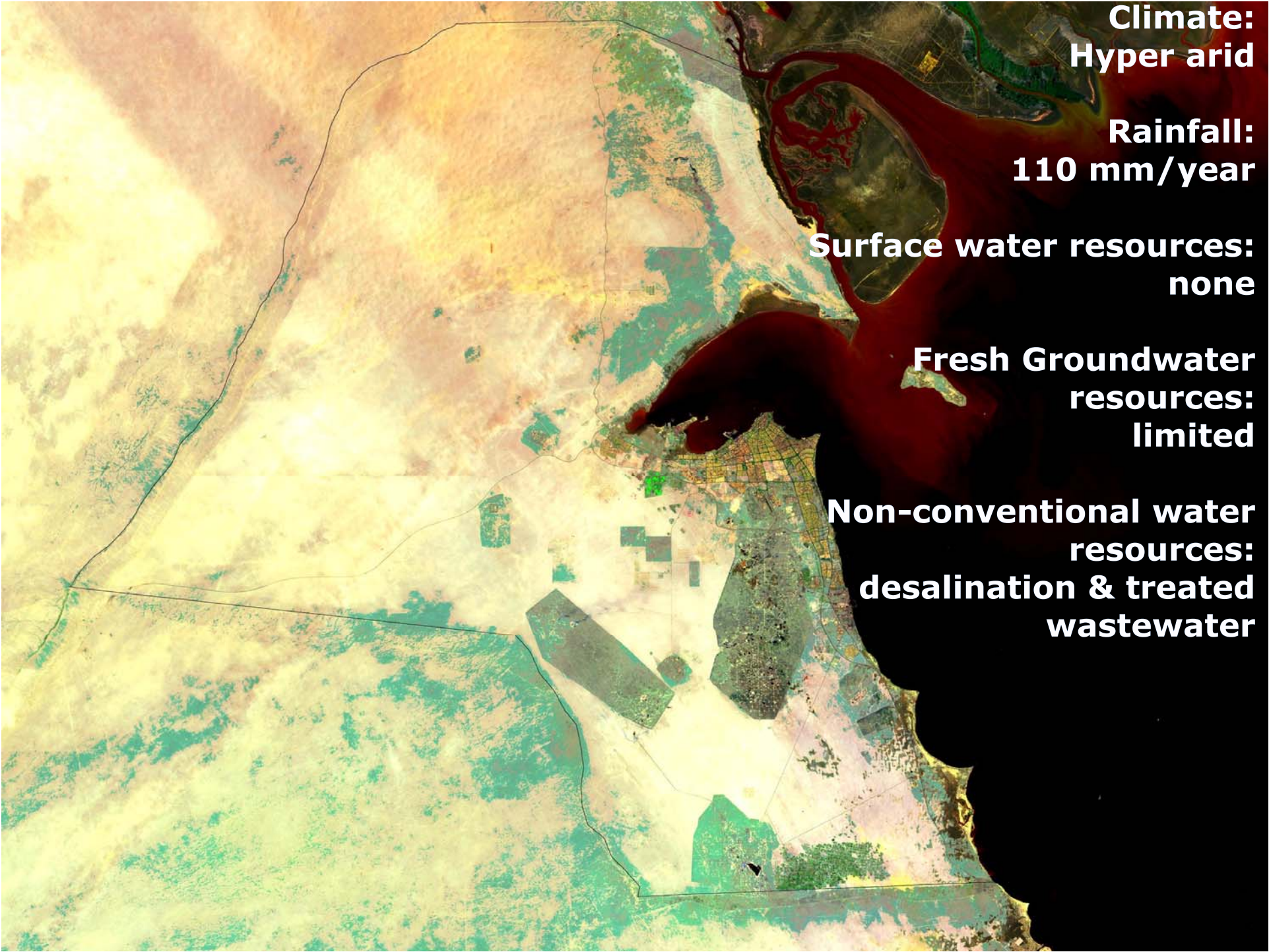
Overview

- Introduction
- Water Resources in Kuwait
- Importance of Northern Kuwait
- Methodology
- Results and Findings
- Conclusions and Recommendations
- Acknowledgements



Introduction

- This study attempted to investigate the effects of anthropogenic activities, including the 1991 Gulf War and subsequent military operations, and increased human activities on the groundwater resources of Northern Kuwait.
- The study was triggered by tentative findings and visual observations of increased human activities as well as significant volumes of oil and soot over the ground surface in that area.
- The study involved field investigations, modelling and intensive laboratory analyses of soil and groundwater samples.



**Climate:
Hyper arid**

**Rainfall:
110 mm/year**

**Surface water resources:
none**

**Fresh Groundwater
resources:
limited**

**Non-conventional water
resources:
desalination & treated
wastewater**

Kuwaiti water facts

Kuwait has the lowest per capita natural water availability in the World
Kuwait has the highest *per capita* production of desalinated water in the World



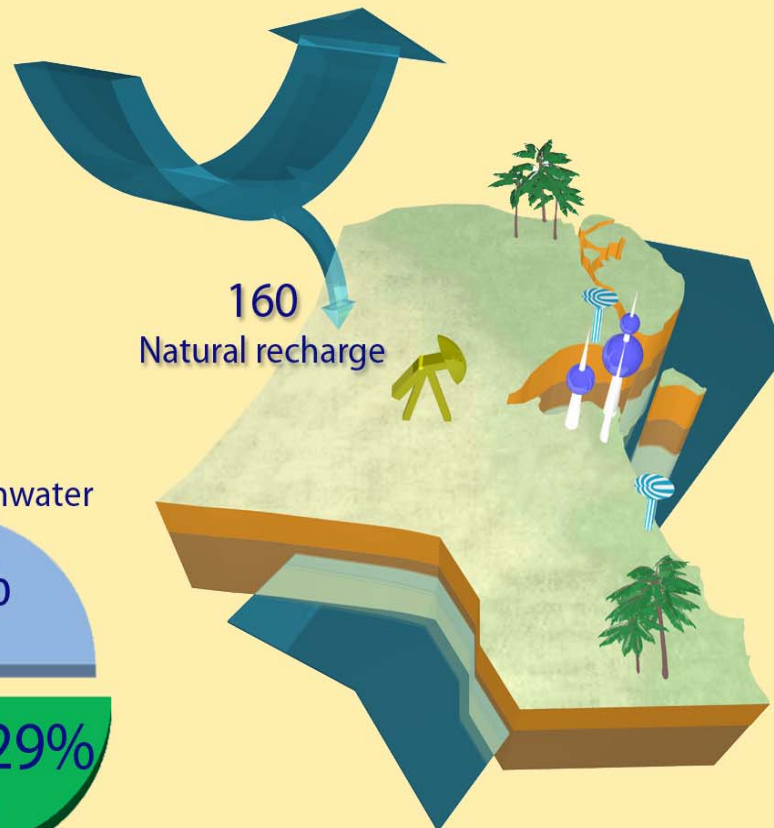
The availability of water in Kuwait, GCC Countries and the World
in cubic metres per person per year.

Sources of water in Kuwait in million cubic metres per year

610
Produced freshwater

350
Groundwater

260
Wastewater



160
Natural recharge

Produced freshwater

50%

21%

29%

Wastewater

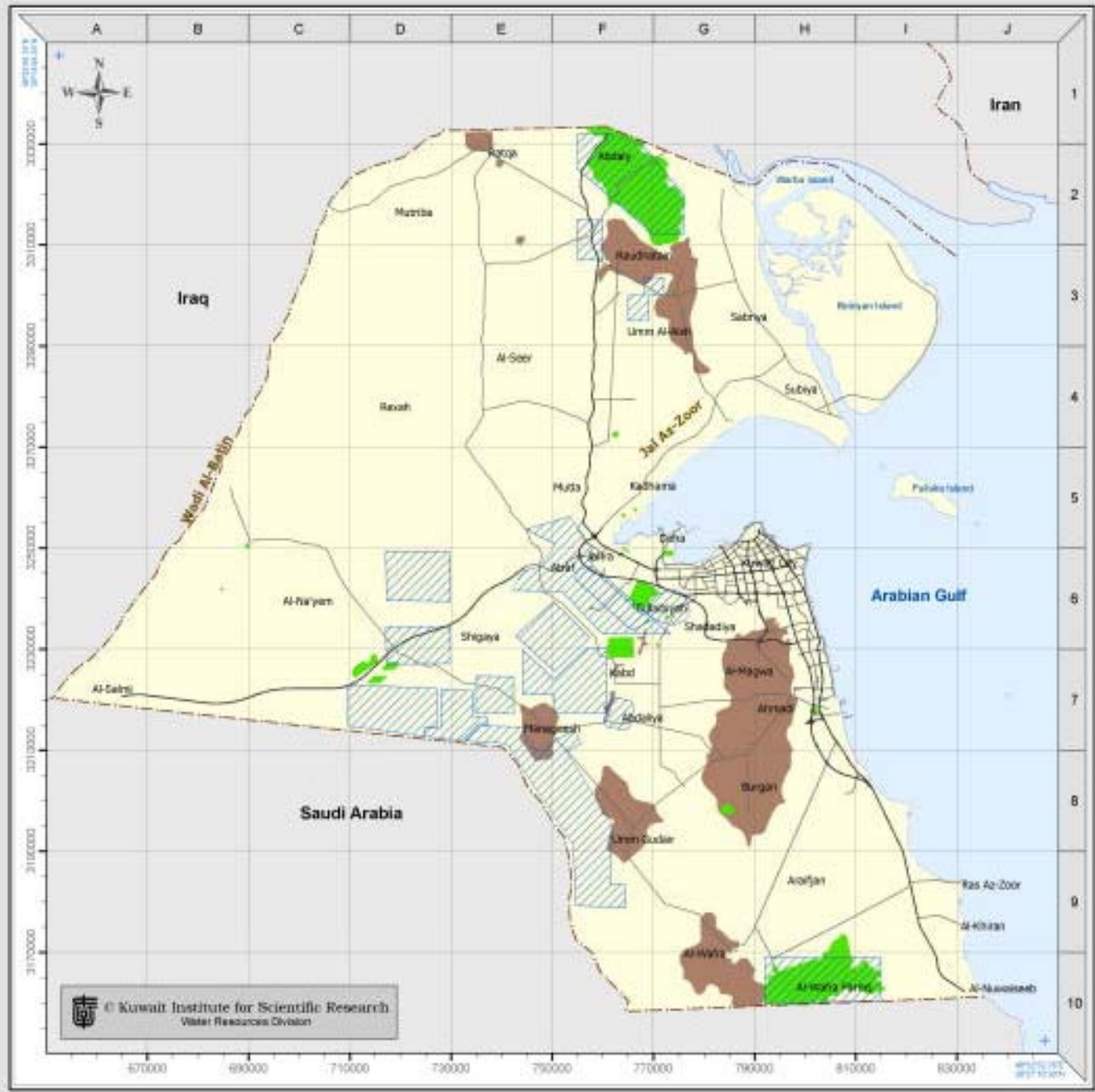
Groundwater



Introduction (Why Northern Kuwait)?

- Al-Raudhatain and Umm Al-Aish depressions of Northern Kuwait host the only fresh groundwater reserves in the country.
- It is believed that the fresh groundwater reserves originated from percolating rain that fell over the area over thousands of years.

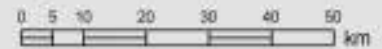
General Map of Kuwait

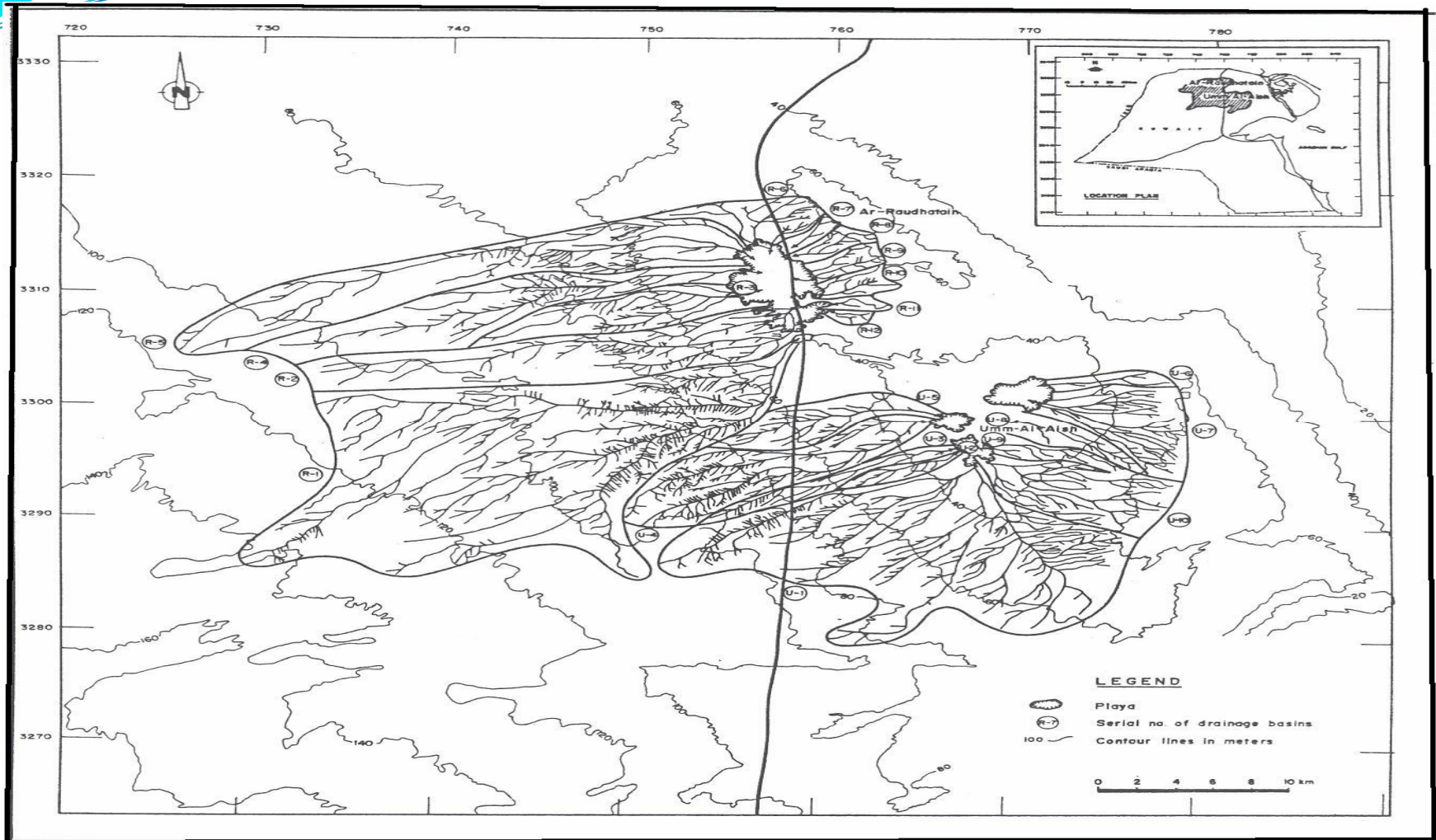


Legend

- Political Boundary
- Dual Highway
- Major Road
- Oil Field
- Agricultural Area
- Water Field

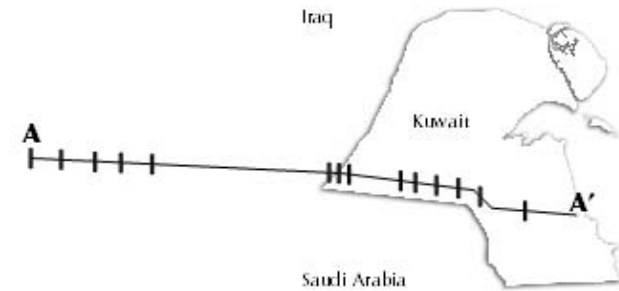
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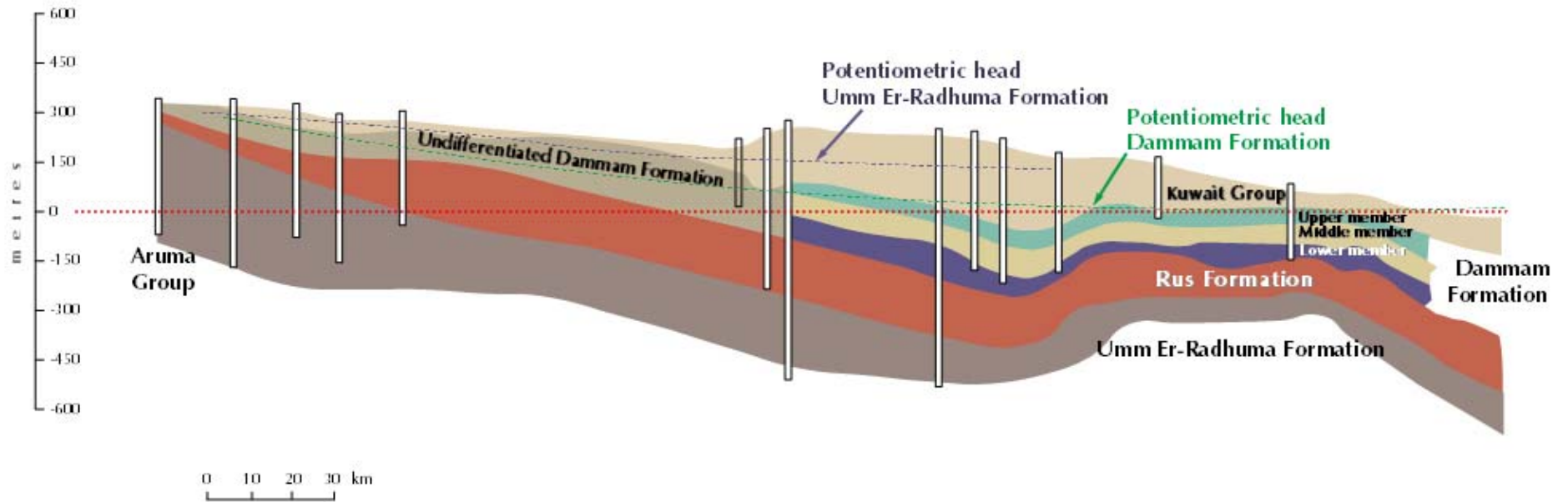


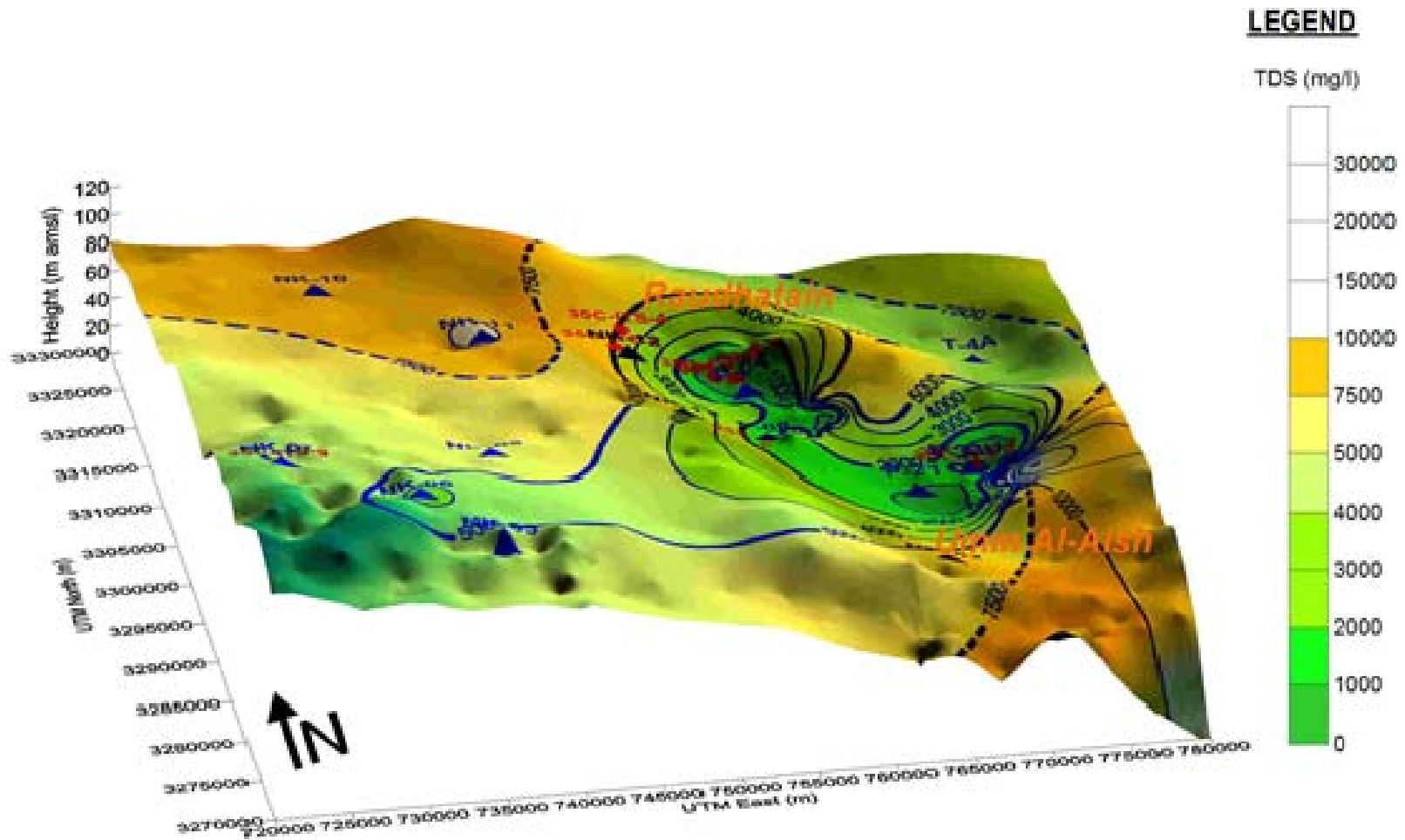
Al-Raudhatain and Umm Al-Aish Depressions and the associated wadi system with catchment boundaries.

Regional Aquifer System



Section A - A'



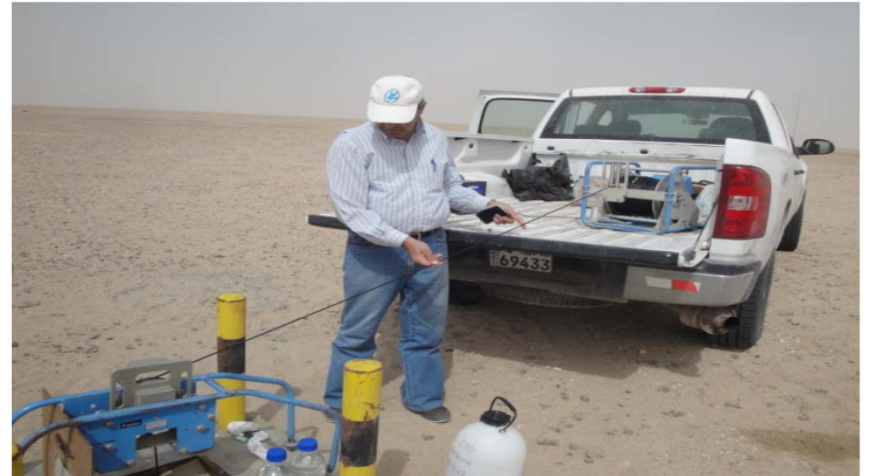
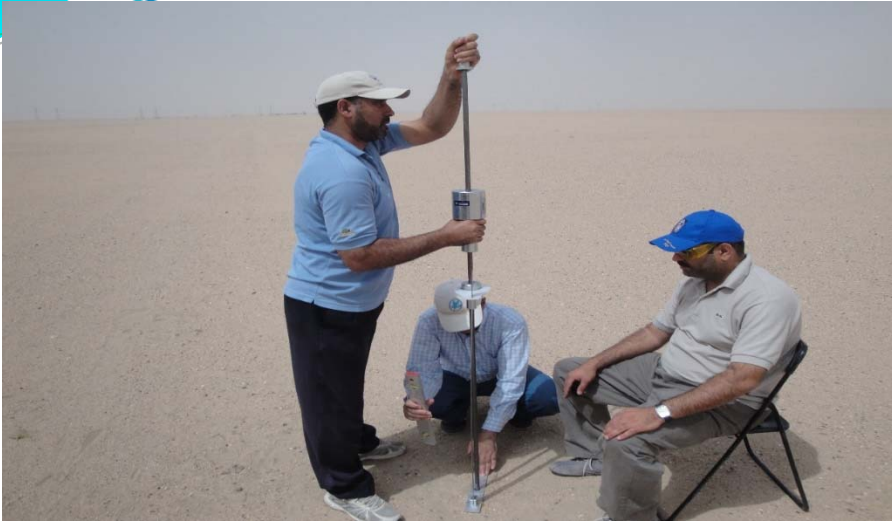


Color-coded groundwater quality and ground surface morphology.

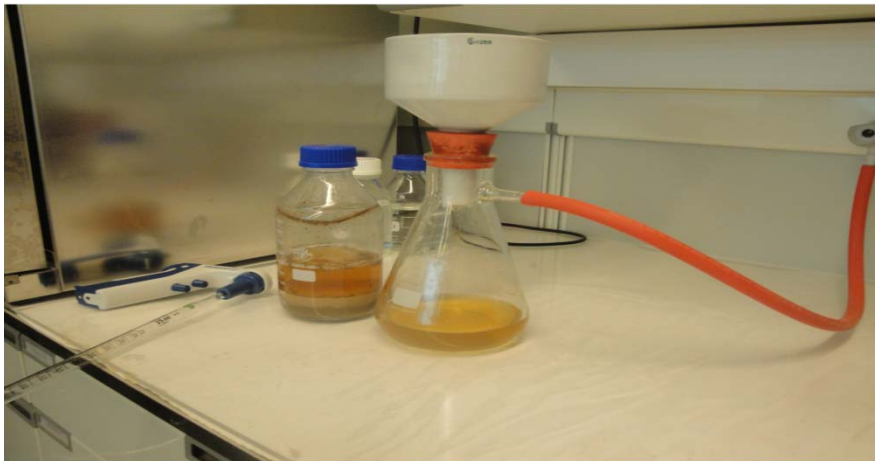
Methodology

- Field measurements of groundwater levels and collection of groundwater samples using existing monitoring wells.
- Onsite field measurements of the collected groundwater samples (temp., EC, ORP and DO).
- Field investigation of the soil characteristics and collection of soil samples.
- Onsite infiltration and penetration tests.
- Detailed laboratory analyses of the collected groundwater and soil samples (soil-water extracts) for pH, Ca, Mg, Na, K, SO_4 , Cl, CO_3 , HCO_3 , NO_3 , NO_2 , and TOC.
- Numerical simulation of rainfall events and the interaction of the rainfall with the storage and transmission characteristic of the catchments in the study area using a rainfall-runoff model (RORB Version 6.14).

Field Activities



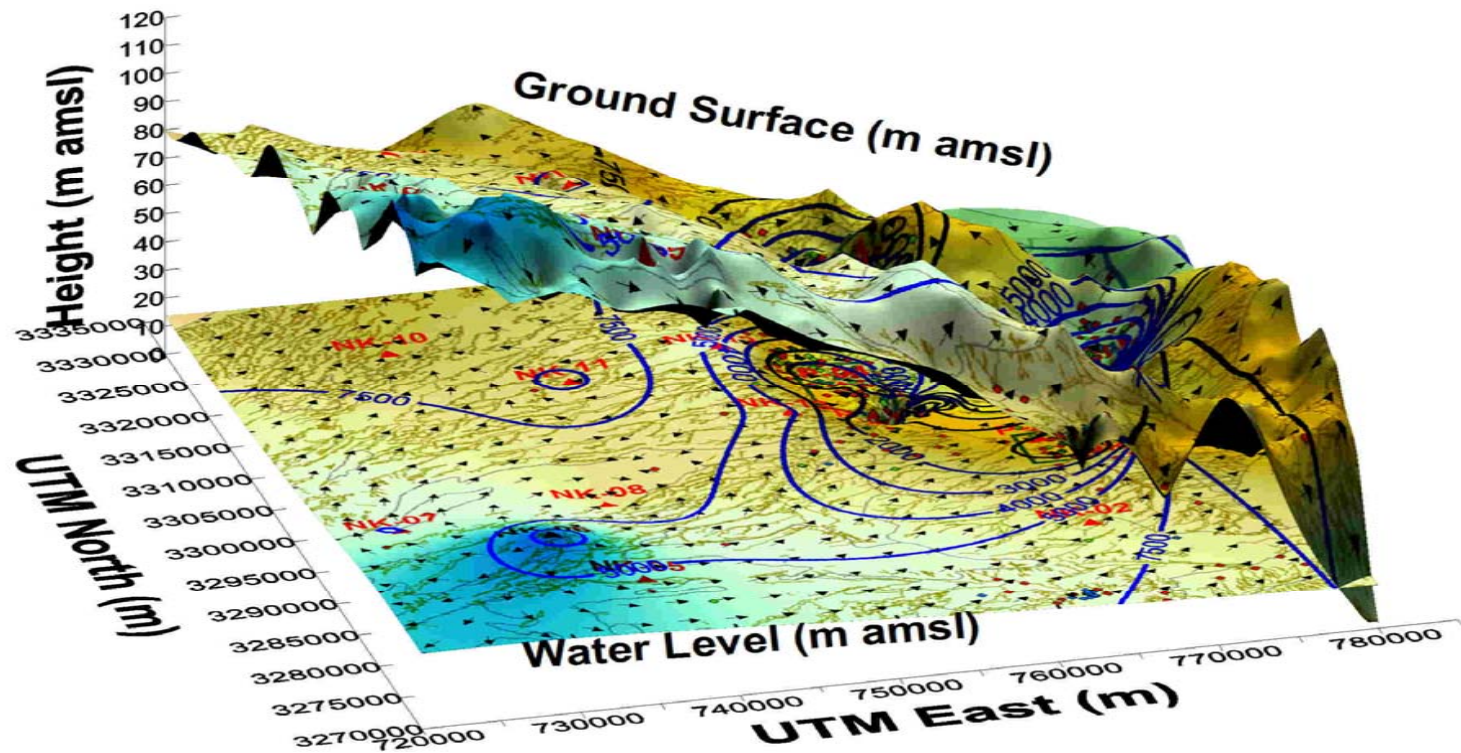
Laboratory Analyses





Results

- Surface elevation contours show that the area has a general slope toward northeast with two depressions breaking the general trend.
- The more northerly one, defined by the closed 40-m contour is known as Al-Raudhatain depression and the other somewhat to the southeast and defined by a closed 30-m contour is known as Umm Al-Aish.
- A large number of dry river channels ('wadis') terminate in these depressions and these carry surface (and subsurface) runoff to these depressions whenever there are some high intensity rainfall events in the area.

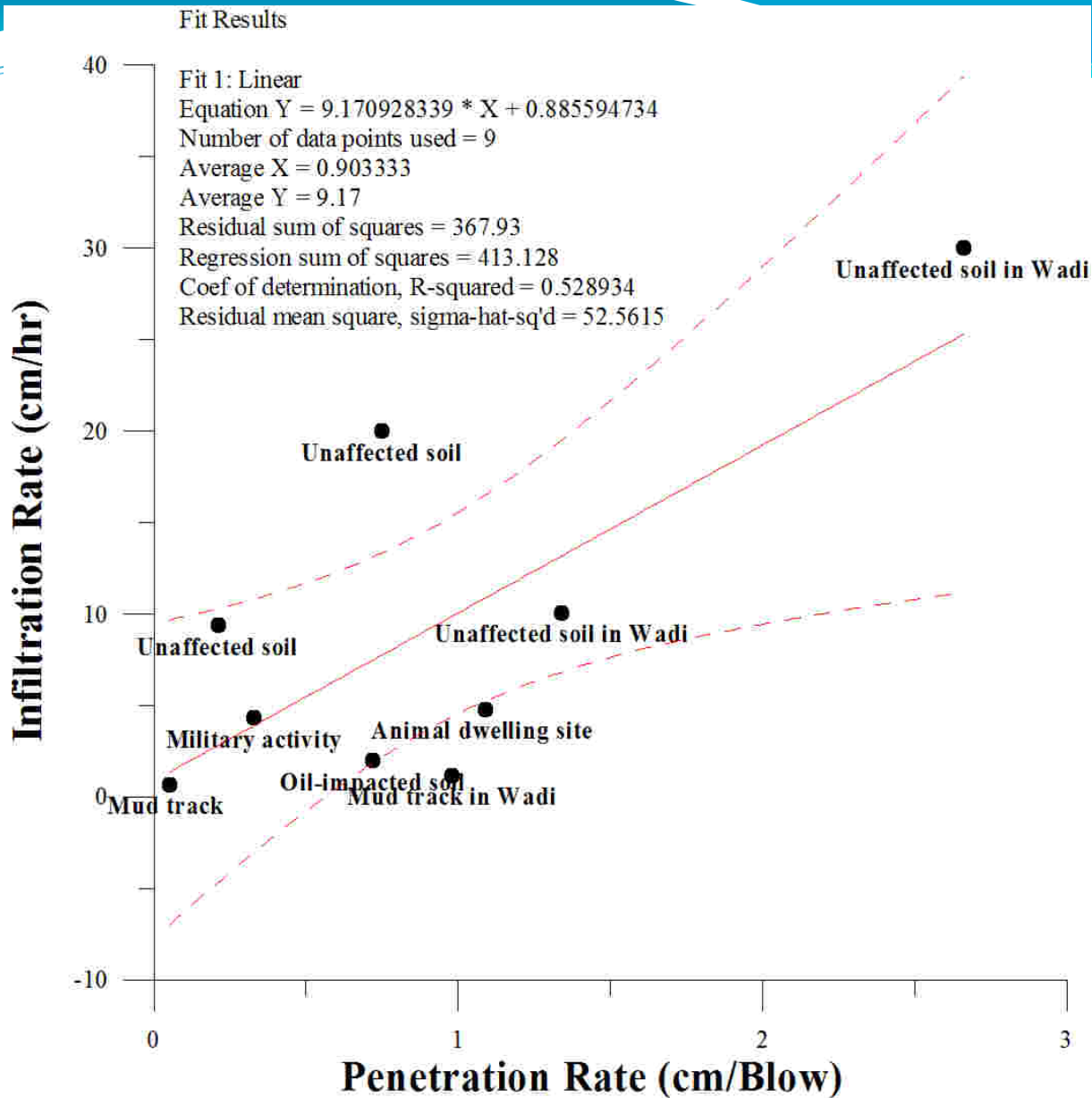


Three-dimensional representation of ground surface disposition and potentiometric surface of groundwater in the study area.



Results

- In general, the infiltration rate increased with the penetration rate, suggesting better permeability for soil that allowed higher penetration rate.
- It could further be observed that most of the low penetration rates (suggesting harder soil) and low infiltration rates (suggesting lower permeability) were associated with areas with mud tracks and animal dwellings, impacted with oil pollution and those that had experienced military activities.
- Pristine soil, unaffected by any of the aforesaid activities, generally showed higher penetration and infiltration rates.



Cross plot of infiltration rate against penetration rate.



Results

- Extracts of soils from areas with no human activities were characterized by lower values of TDS, TOC, sulfate, nitrate, and nitrite compared to those with human activities.
- Not much correspondence between the chemical quality of the runoff and that of underlying groundwater away from the main depressions could be observed. This was expected because recharge from the rainfall runoff was mainly confined to the two main depressions in the area and to a limited extent along the wadis.



Results

- Lower values of TDS, TOC, and sulfate for both the runoff samples and the groundwater samples in Al-Raudhatain and Umm Al-Aish depressions indicated possible recharge in this area.
- Monitoring wells located on wadis and depressions had isotopic composition similar to the runoff water samples, suggesting that the groundwater in them possibly received recharge from rainfall (supporting the hypothesis of recent recharge).



Conclusion & Recommendations

- Recharge from rainfall mainly takes place in the two major depressions of northern Kuwait, namely Al-Raudhatain and Umm Al-Aish, and, to some extent, along the wadis of that part of Kuwait.
- Human interferences like animal rearing and grazing, off-road driving, military activities, and pollution from oil industry can consolidate the soil surface and reduce the recharge rate.
- Additionally, these activities pollute the soil with different types of contaminants that can be leached by the infiltrating runoff and carried to the groundwater.



Conclusion & Recommendations

- Consolidation of soil surface and introduction of pollutants have significant negative effects on the usable (both fresh and brackish) groundwater accumulations in northern Kuwait.
- Careful control of human activities within this fragile area is, therefore, called for.
- The study provided baseline data for monitoring the long-term effects of these activities (including those caused by the climate change) on the recharge rates and the groundwater quality.
- This, in turn, will lead to effective measures for protecting the valuable groundwater resource.

Conclusion & Recommendations

- Based on findings of the study, the wadis and the depressions and their vicinities should be avoided as much as possible for carrying out any form of human activity that may cause soil pollution and reduction of soil permeability, as these are the areas where natural recharge to the groundwater mainly occurs.
- The findings of this study are expected to have immense implications on the management of the groundwater reserves of northern Kuwait.
- Additionally, the findings of the study are expected to help in devising ways to improve natural recharge to the aquifers, thus improving both the usable groundwater volume available and its safe yield.



Acknowledgments

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- Last but certainly not least, our special thanks to the Scientific and Organizing Committees of the WSTA 12th Gulf Water Conference for accepting the article and providing us with the opportunity to present it in this important scientific gathering.

Thank You,,,

