

Towards Sustainable Groundwater Management in the Northeastern UAE

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Abstract- Groundwater is the main source of irrigation in the northeastern part of the United Arab Emirates (UAE). The excess use of groundwater for irrigation has decreased groundwater flow by almost one tenth. Due to the strategic importance of water resources in the region, and considering the complexity of the aquifer system, the main objective of this paper is to establish an accurate groundwater budget in order to assess water availability in this area. Results show that the current extraction rates are not sustainable and need to be reduced to mitigate the present severe groundwater depletion and to achieve sustainable development in the area.

Keywords- *Water Resources Management, Northeastern UAE*

I. INTRODUCTION

Groundwater resources in UAE can be divided into renewable (shallow aquifers) and non-renewable resources (deep aquifers) (Mohamed et al 2010 a and b) [18-20]. The renewable water resources occur mostly in shallow alluvial aquifers formed by percolating rainfall (Elmahdy and Mohamed 2012, 2014a) [4, 7]. On the other hand, the non-renewable deep groundwater aquifers were formed during two ancient wet periods (6000-9000 and 25,000-30,000 years ago) (Wood and Imes 1995; Elmahdy and Mohamed 2014 b and 2015) [24, 8, 9]. The recharge of shallow aquifers depends mainly on rainfall events and surface runoff, and thus may vary considerably from year to year. Due to the high evaporation rate and surface water runoff in mountains areas, only 10 to 14 % of the total precipitation percolates to recharge the shallow groundwater aquifers in UAE (ESCWA 2003) [10]. Yet, many groundwater aquifers in GCC countries are being mined in an uncontrolled and unplanned manner. Unplanned groundwater mining erodes the economic and social sustainability of the communities that depend on the depleting storage (Dawoud 2005) [3].

As groundwater cannot cover water demands in GCC countries, desalination plants have been constructed to satisfy water needs. In UAE, for example, desalinated water has become one of the main sources of domestic and industrial water (Mangoosh 2004; Mohamed and Almualla 2010a and b) [18-20]. The first desalination plant in the country was established in Abu Dhabi in 1976 with capacity of 250 m³. day⁻¹. Since then, water demands have increased significantly and more plants have been established (FAO 1997) [11]. Currently, there are 35 desalination plants in UAE with total capacity of 700 M m³.yr⁻¹. The production of desalinated water in UAE is about 22% of the total desalinated water produced in the GCC countries (Bushnak 1992) [2]. Reuse of treated wastewater has recently been recognized as one of the dependable resources for water supply in the UAE (Sherif and Al-Asam 2005) [25]. It is mainly used to support the expansion of gardening and landscaping in the country. The annual increase in the use of treated water for irrigation is about 10% (Alsharhan et al 2001) [1].

Previous studies (e.g. Halcrow & Partners 1969; IWACO 1986; Entec 1996; JICA 1986, Elmahdy and Mohamed 2013 a and b) [12, 13, 9 14] show that the groundwater aquifer in Khatt area (Fig. 1) is one of the strategic resources of freshwater in UAE. Khatt area is one of the most cultivated areas in the country with more than 700 farms implanted during the last thirty years. The soil is relatively fertile and contains nutrients and other organic matters. Groundwater constitutes the only fresh water resource used for agricultural activities in this area (Sherif et al 2011a and b) [21, 22]. To meet the agricultural water demands in Khatt area, groundwater resources have been overexploited during the last three decades. However, any study has been undertaken to assess the effect of this excess pumping on the sustainable use of the aquifer. In this study, the groundwater flow is simulated with MODFLOW to provide quantitative assessment for the groundwater resources in the Khatt area. The hydrogeological setting of Khatt springs area was first characterize, and projected groundwater heads models were developed by using seven extraction scenarios to achieve best future management option.

II. DESCRIPTION OF THE STUDY AREA

The study area is located in the Musandam peninsula in the west-northern part of UAE (Fig. 1). Its eastern boundaries extend into the main Northern Omani Mountain Chain and into the foreland sandy desert as shown in Fig. 1. The uplifted ridge of Hajar Omani Mountains runs parallel to the east coast of the UAE. The highest elevation point located in the Musandam Peninsula reaches an altitude of 2000 m (Fig. 2a). These Northern Omani Mountains are comprised of Jurassic to Cretaceous Musandam Group limestone (Fig. 2b). The mountain slopes drop directly into the sea. This area is known locally as the Ruus Al Jabal, literally the 'heads of the mountains'. The landscape in that region is characterized by rapid changes of ground

surface elevation, which exceeds 2000 m in some places in a rather short horizontal distance. This phenomenon is manifested between the sharp peaks at Ruus Al Jabal and the low and narrow coastal plain to the north of Ras Al Khaimah. On the other hand, the coastal plain in the south of Ras Al Khaimah, as well as the inland plain becomes wider and the contrast between the low land areas (Al Hamaranyiah) and the highland area to the east becomes less pronounced. The western coastal plain consists of late tertiary to recent alluvial sediments overlying the late cretaceous Juweiza formation. The Juweiza is a flysch-like sequence of marls and shale with varying admixtures of coarse detrital debris of chert, basic igneous rock, and limestone. The exposed section has an estimated thickness of more than 1000 m. In many areas near the coast, the sand is stabilized by vegetation, although the natural flora has been altered in recent times by extensive grazing of domesticated animals. Further inland the sands may be quite barren, as few plants can successfully colonize the mobile dunes. In the Northern Agricultural Region, the Structural Plain is only occupying a small portion of the southwest corner and merging the sandy desert. The climate is typically arid, with average annual temperatures of 35°C and 25°C respectively in summer and winter, a mean annual evapotranspiration near 2100 mm.yr-1 (FAO 1985), and an annual rainfall ranges between 100 mm.yr-1 in the low coastal area and 140 mm.yr-1 in the mountains areas. Annual precipitation falls from January through March, with short but intense rainfall events. Rainfall is the main source of groundwater recharge in the area as shown in Fig. 3.

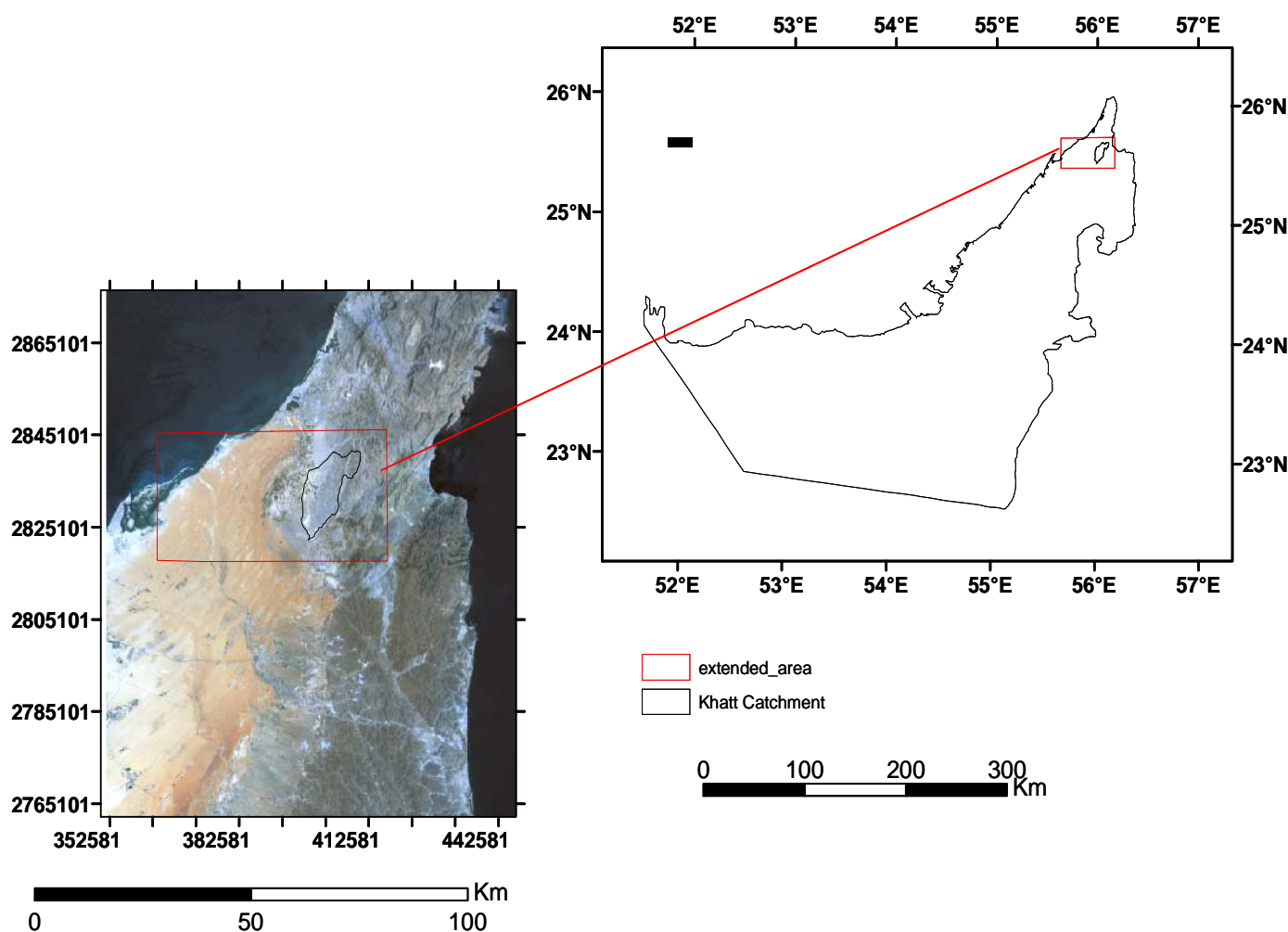


Fig. 1 Location map of the study area

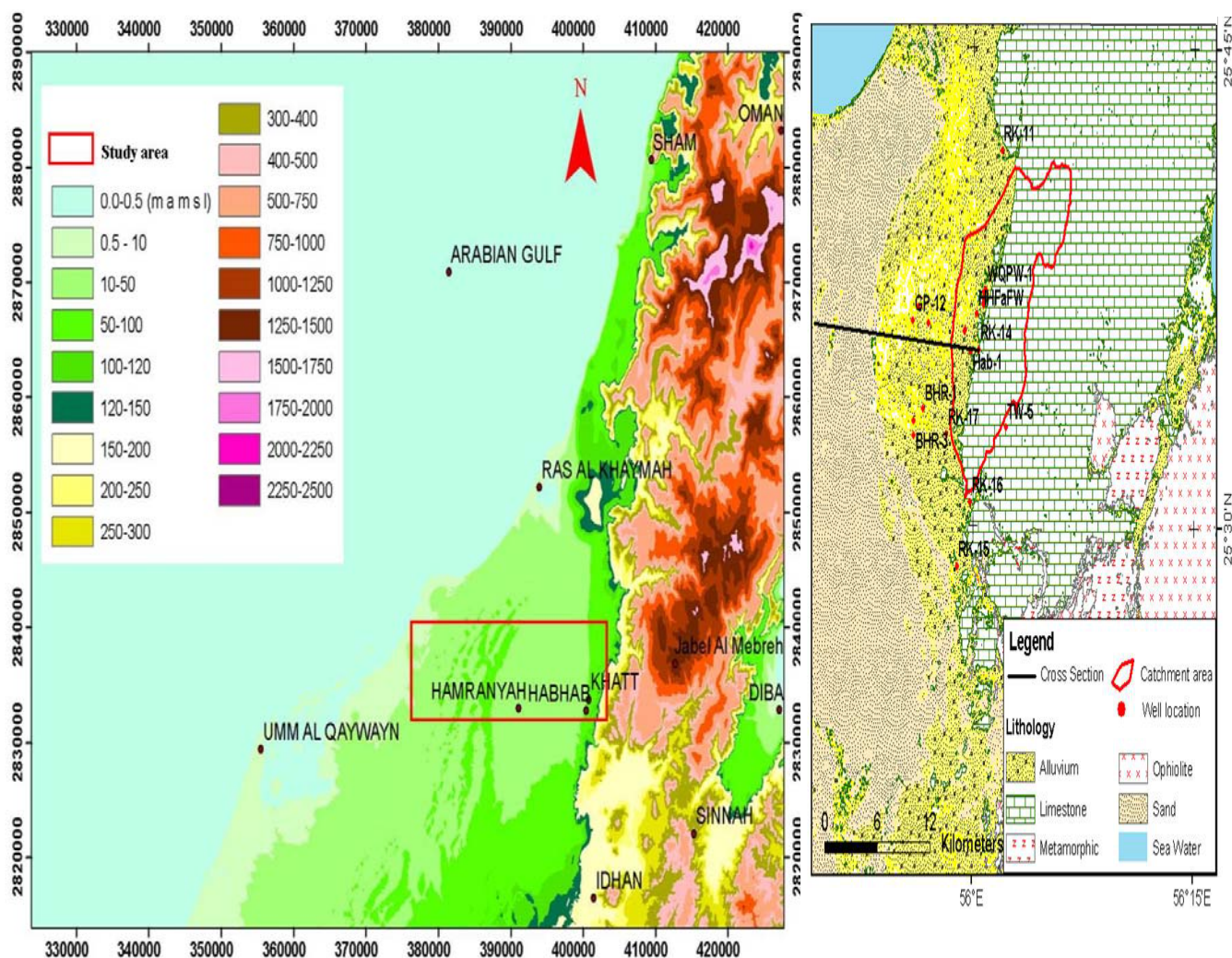


Fig. 2 Topographic map (a) and Geological map (b) of Khatt springs area including wells location, and Khatt springs catchments area (modified after IWACO 1986)

The data collected from thirty boreholes (drilled between 1969 and 2004) (Fig. 2b) and the available hydrogeological map (IWACO 1986) [13] are used together to build the geological cross sections (Fig. 4) and the digital hydrogeological map of the study area. Figs. 2b and 4 show that the groundwaters in the study area are located in different aquifer types made up of the Quaternary alluvial aquifers, the Upper Cretaceous Juweiza aquifer, and the Jurassic – Cretaceous Carbonate aquifer. The Quaternary aquifer covers most part of the northern emirates from the western Omani Gulf to the eastern Arabian Gulf. Groundwater is fresh in the mountains areas, particularly in the northeastern parts of UAE and mainly in the Bajadas. However, it becomes saline to brackish near the coastal areas. In large portions of the eastern side the Quaternary is underlain by Miocene deposits. The upper portion of these Miocene deposits may be water bearing and permeable. In these areas the Quaternary sediments and the permeable Miocene sediments constitute one aquifer. These are known to be pre-Quaternary channels within which a relatively thick sequence of Quaternary sediments has accumulated (IWACO 1986) [13]. The Quaternary aquifer in the major portion of the Western Bajada and its adjacent part of the Structural Plain seems to be moderately productive (IWACO 1986) [13]. The Quaternary aquifer in the coastal areas has wedge shape. The aquifer occurs along the coast from Ras Al Khaimah to Shams and in an area to the south of Ras Al Khaimah. The portion south of Ras Al Khaimah is an extensive highly productive aquifer. The coastal aquifer between Ras Al Khaimah and Shams is considered to be a local highly productive aquifer (Fig. 2b).

The Juweiza aquifer is covered by Quaternary sediments and located in major portion of the Western Bajada. This aquifer is mainly made up of sediments (Fig. 4) which were deposited during the Upper Cretaceous age. The productivity of the Juweiza aquifer could be from very low in some areas and high in other areas (IWACO 1986) [13]. The main productive water bearing layers in this aquifer are the limestone layers. A number of wells which were drilled in the aquifer were unproductive; such as wells BHR-2, BHR-3 and BHR-4 shown in Fig. 2b. On a regional scale the Quaternary and the Juweiza aquifers behave as one single aquifer system (IWACO, 1986) [13]. The porosity of the Juweiza aquifer is estimated to be less than 5% (IWACO 1986) [13].

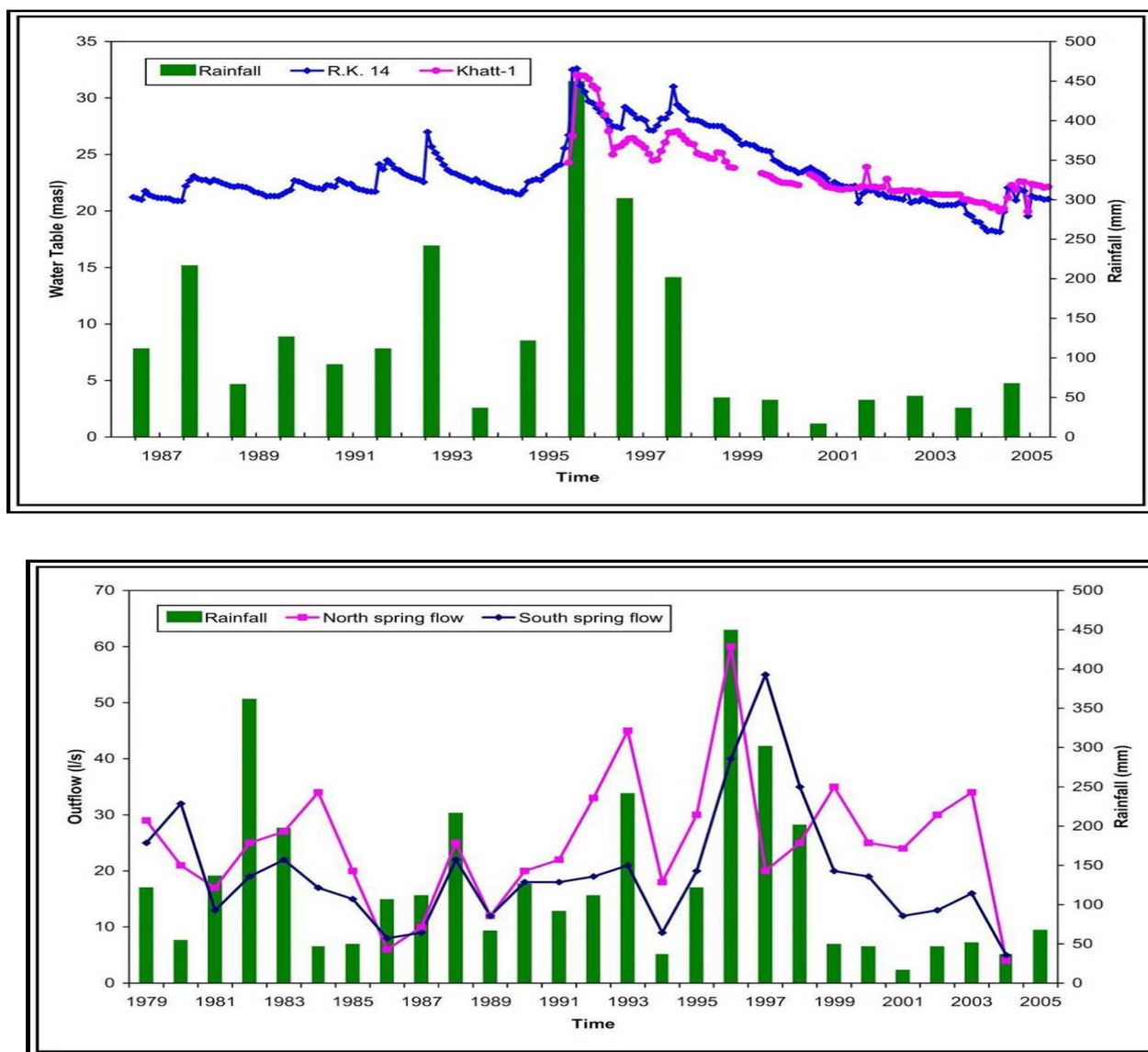


Fig. 3 Rainfall impacts on groundwater table and springs flow variations

III. MANAGEMENT SCENARIOS

Several management scenarios were simulated to evaluate the impact of groundwater overexploitation for irrigation on groundwater levels in Khatt springs area. In the first scenario (base scenario), it was assumed that there will be no change in present extraction rates for the coming 30 years. Results of this scenario indicate that pumping rate introduced will result in significant lowering of the water table (Table 1). The estimated drawdown will be 60 m in the next upcoming 30 years and will completely dewatered the Quaternary alluvial aquifer. When the present extraction rates were increased by 50% in the second scenario to represent the expected increase in water demand in the coming 30 years, dewatering of the Quaternary aquifer occurred and the water table elevation will fall from 35m (bmsl) to 90 m (bmsl) in less than 30 yrs.

In the third scenario, pumping from the wells near Al-Hamranya area (approximately 100 wells) is stopped. In scenario 4, it was assumed that the total extraction rate was increased by 25% from the present rates. The simulated drawdown is reduced by 20 m compared to the second scenario in year 2035. This change is not considered successful as the water table is still continuously dropping. Therefore, reductions in the present extraction rates are found to be mandatory. Reduction of 25 % of the present rate is assumed in scenario 5. This led the water table to rise up to 25 m for the 2005-2035 periods. Stopping the pumping from Al-Hamranya area helped to gain additional 5 m in water table elevation in scenario six. In the last scenario (scenario seven) it was assumed that the total abstraction rate will be reduced by 50%. This presented the best scenario with respect gain in water table elevations. However, this might not be a feasible option as it will require reducing the cultivated areas in the study domain. At any rate, this decision is left to decision makers in the ministry environment and water.

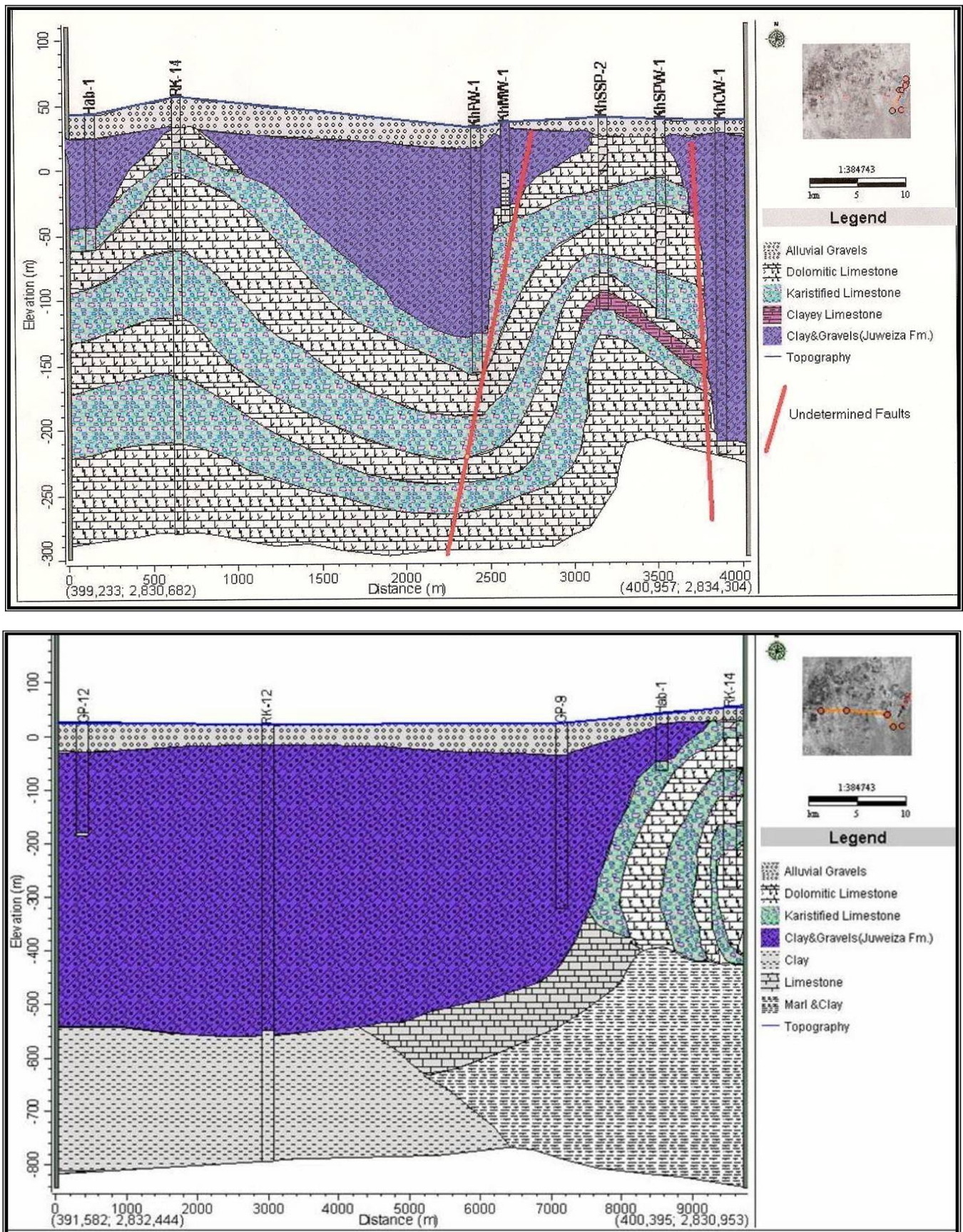


Fig. 4 Cross-sections in Khatt springs area (MEW 2007)

TABLE 1 SIMULATED HYDRAULIC HEADS (AMSL) IN THE DIFFERENT GROUNDWATER MANAGEMENT SCENARIOS IN STUDY AREA

Scenario	Year 2005	Year 2015	Year 2025	Year 2035
1	35	-40	-45	-50
2	35	-60	-75	-90
3	35	-55	-65	-80
4	35	-50	-60	-70
5	35	-20	-15	-10
6	35	-15	-10	-5
7	35	-5	0	5

IV. CONCLUSIONS

Based on the above discussion, the main conclusions are as follows:

1. Groundwater levels have been declining since 2005 due to the excessive pumping to meet the increasing agricultural demands.
2. Keeping the present groundwater extraction rates will result in complete dewatering of the Quaternary Aquifer.
3. Decreasing the present groundwater extraction by 25% will lead to water table rise in the coming 30 year.
4. Also decreasing the present groundwater extraction by 50% was the best scenario; however, it might not be feasible.

Results obtained show that the current extraction rates are not sustainable and need to be reduced by at least 25% to mitigate the present groundwater depletion and to achieve sustainable development in the future. This can be achieved by using the modern irrigation techniques and changing crops distribution.

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