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New Approach For Prediction Groundwater Depletion

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ABSTRACT

Current approaches to quantify groundwater depletion involve water balance and satellite gravity. However, the water balance technique includes uncertain estimation of parameters such as evapotranspiration and runoff. The satellite method consumes time and effort. The work reported in this paper proposes using failure theory in a novel way to predict groundwater saturated thickness depletion. An important issue in the failure theory proposed is to determine the failure point (depletion case). The proposed technique uses depth of water as the net result of recharge/discharge processes in the aquifer to calculate remaining saturated thickness resulting from the applied pumping rates in an area to evaluate the groundwater depletion. Two parameters, the Weibull function and Bayes analysis were used to model and analyze collected data from 1962 to 2009. The proposed methodology was tested in a nonrenewable aquifer, with no recharge. Consequently, the continuous decline in water depth has been the main criterion used to estimate the depletion. The value of the proposed approach is to predict the probable effect of the current applied pumping rates on the saturated thickness based on the remaining saturated thickness data. The limitation of the suggested approach is that it assumes the applied management practices are constant during the prediction period. The study predicted that after 300 years there would be an 80% probability of the saturated aquifer which would be expected to be depleted. Lifetime or failure theory can give a simple alternative way to predict the remaining saturated thickness depletion with no time-consuming processes such as the sophisticated software required.

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1. Introduction

1.1. Groundwater depletion

Groundwater depletion is the continuous reduction of groundwater storage volume when groundwater abstraction exceeds aquifer recharge so that in the long term the groundwater cannot sustain development activities. Groundwater depletion represents a great challenge, especially in nonrenewable aquifers such as the Nubian Sandstone aquifer in the Western Desert, Egypt. This aquifer suffers from continuous water level decline as a result of over-pumping during and after the development of El Kharga Oasis (Barber, 1977; Soliman, 2013). Initially, the wells in this region were flowing. However, after nearly 50 years of continuous pumping the head drop in some areas is estimated to be 60 m (Soliman, 2013). The average thickness of the aquifer in the Oasis is around 400 m (Ezzat, 1976,; Himida, 1968).

1.2. Quantifying groundwater depletion

Current approaches for quantification of groundwater depletion are based on the water balance method and volumetric approach such as the temporal gravity method to estimate dynamic storage. McGuire et al. (2003) used integrated measurements of changes in groundwater levels and storativity to estimate groundwater depletion. Kjelstrom (1995) used water balance and pumping tests. Faunt et al. (2009) used deterministic calibrated groundwater flow models to quantify groundwater depletion. David and Allen (2015) used a logistic equation to study changes in groundwater storage. Many researchers such as Rodell and Velicogna (2009) and Famiglietti et al. (2011) quantified groundwater depletion using gravity changes over time by a satellite technique. This work is concerned with exploring lifetime approaches in predicting saturated thickness depletion of the non-renewable aquifer.

1.3. Study site location

The El Kharga Oasis is located in the Western Desert of Egypt along the Nile Valley at longitude 30° 20′ and 30° 40′ east and

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latitude 25° 05′ and 25° 30′ north (CONOCO, 1987) (Fig. 1). This region is characterized by low rainfall estimated to be 2.35 mm/year.

1.4. Geology and hydrogeology

The groundwater aquifer in the study area consists of Nubian Sandstone deposits of Lower Cretaceous age (Fig. 2). The Nubian deposits consist of sandstone intercalated with discontinuous clay lenses (Hermina, 1967; Diab, 1978). The aquifer is underlain by Pre-Cambrian basement rocks and igneous rocks, (Shata, 1961). The thickness of the aquifer is limited in the south of El Kharga Oasis and attains its maximum thickness in the northern part where the average thickness is about 400 m (Himida, 1968). Intercalated discontinuous clay lenses in the Nubian sandstone form confining conditions in some parts of the aquifer and divide the aquifer into shallow and deep levels. However, regionally the whole aquifer could be considered as one hydrogeologic unit (Ezzat, 1974). Many hydrogeological studies (e.g. Thorweihe and Manfred, 2002) indicate that the groundwater in the Nubian aquifer is a nonrenewable resource. Hydraulic conductivity of the aquifer varies spatially and vertically according to clay content within the sandstone beds (Ezzat, 1976). The groundwater in this region was drawn from shallow wells before 1960. In early 1960, a heavy drilling program in the Western Desert was developed to exploit deeper aquifers to expand agricultural activities. Water abstraction approximated fifty million m^3/year from 270 shallow wells. After drilling deep wells, groundwater abstraction approached 117 million m^3/year from 190 deep wells. All wells initially were artesian wells. However, with unmanaged abstraction water depths increased continuously with

Fig. 2. Geological map of Nubian sandstone in the Western Desert (Egypt) and its extension to nearby countries.

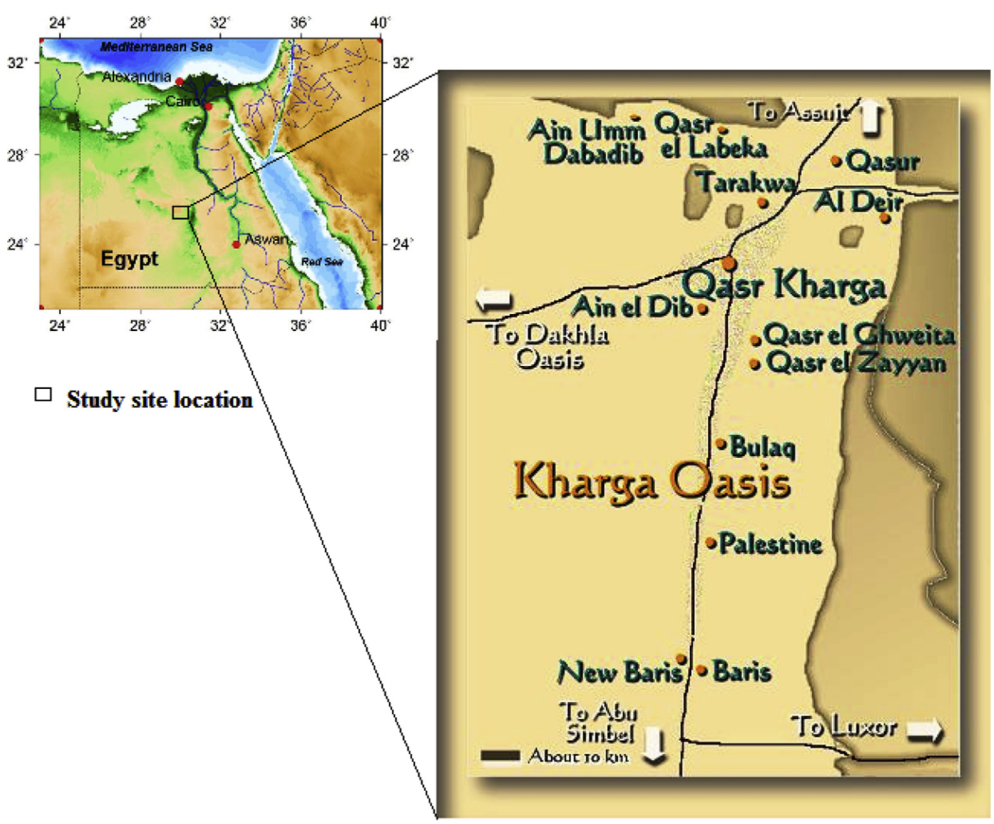

Fig. 1. Map showing the location of study area.

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