Iraqi Geological Journal

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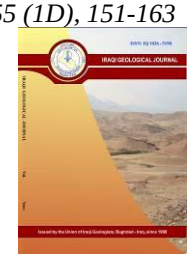

Mapping Groundwater Risk Using Geographic Information Systems and QGIS Techniques of the Upper Al-Sanaf Marsh Sub Basin in Maysan, Southern Iraq

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Received:
7 October 2021

Accepted:
24 January 2022

Published:
30 April 2022

Abstract

It is possible to determine the risks through the existence of contaminated groundwater in some drinking wells. Most of the recent applied studies by groundwater scientists are the exposure of groundwater or aquifers to pollution, especially in areas that contain polluted groundwater due to human use of land. This work intends to produce a map to identify the areas of groundwater at risk. The groundwater risk map is dependent on applying the equation that exemplifies the combination of the map of vulnerability with the map of land uses and land covers using Geographical Information Systems (Version 10.4) and QGIS (Version 3.12) software. In addition, validation work for groundwater risk map with nitrate concentrations have been carried out. The results showed that the area risk map ranges from 117 to 218 (low, medium, high, and very high). The majority of up Al-Sanaf Marsh sub-basin are of low and medium risk, except for some southern, southeastern, northern, and eastern parts the groundwater is high and very high risk.

Keywords: Up Al-Sanaf Marsh; QGIS; Risk; Land use; Land covers

1. Introduction

Groundwater is an important and invaluable resource for sustaining life in various countries. It is possible to determine the risks through the existence of contaminated groundwater in some drinking wells because of human activities to use the lands negatively (Morris and Foster, 2000). The risk is one of the main factors that decision-makers and those interested in the field of water resources feel, as one of the indicators of groundwater pollution or the possibility of contamination (Farjad et al., 2012). The distinction between vulnerability and risk map is very important because pollution risks are determined not only by intrinsic characteristics as relatively static but also by potential pollution activities are which dynamic factors (Lobo-Ferreira and Oliveira, 1997). Freshwater, meaning free from pollutants is necessary for humans and organisms (Abdulrahman et al., 2021). The exploitation and deterioration of the water quantity globally is a major reason for the continuation of studies in various parts of the world (Beg et al., 2021). Several methods were used in order to produce maps to assess the risk of groundwater in the aquifer, including vulnerability map and maps of land uses (Farjad et al., 2012). The main

DOI: 10.46717/igj.55.1D.11Ms-2022-04-27

problems in most parts of the world are the supply of potable water as well as water for domestic use because of an increase or population growth, and the problem is expecting to increase and reach dangerous levels in the future (Awadh et al., 2021). Most academics and water resource scientists predict that future world wars will be because water, especially against water exporting countries (Al-Gburi, 2020). Groundwater is strongly affected by many ecological influences and thus produces unnatural groundwater (Al-Kubaisi and Hassan, 2021). There are various changes that several affect the quality of groundwater according to geographical location, hydrogeological environment and land use (Foster, 2020). The negative changes in the quality of groundwater have harmful effects on human health, including carcinogenic and toxic, which are associated with urban and industrial expansion (Giri and Singh, 2015). The protection and preservation of good groundwater quality is a very important matter nowadays. Pollution is very risky to aquifers for the areas that are completely dependent on aquifers. Pollutants are considered hazardous and can be spread rapidly and on a very large widely in groundwater in locations close to the injection or landfill of waste, especially that hazardous waste (Lee, 2003). The best method for protecting groundwater from pollution is to know the essential transactions that negatively affects groundwater, especially the layers that are located above the aquifer, whether it is a landfill or chemical factories (National Research Council. 1993). The groundwater risk depends on two parts the nature of the characteristics (vulnerability of the aquifer) and the pollution loads above the land (Dimitriou et al., 2008). The groundwater risk maps help those interested in groundwater understand land uses that positively influence groundwater; in addition to proper management to protect it from any radioactive contamination (Baalousha, 2011). Determining the risks of groundwater pollution has become a priority for those interested and researchers helps decision-makers use the land properly. Various and focused studies using modern and sophisticated methods by specialized researchers have intensified in recent years, especially in Iraq, regarding the pollution or exposure of groundwater to pollution. Developed countries or those specialized in the field of groundwater need to make many studies using models and programs to find out the extent of exposure of groundwater to pollution, thus managing this groundwater, which has become one of the global priorities now, especially in Iraq, which suffers from a water shortage. Groundwater is one of the most important natural sources of drinking water that is often exposed or polluted by human uses (Saidi et al., 2010). A variety of studies have been conducted on the groundwater risk, but the studies that have been studied are based on the same approach in the current research (Secunda et al., 1998; Al-Adamat et al., 2003; Al-Rawabdeh et al., 2014; Ouedraogo et al., 2016; Al-Gburi, 2020). The vulnerability to determine the sensitivity of the site's exposure to pollutants, but by including other methods with it, whether heavy metals or land use, determine the actual risks to the aquifer. (Stempvoort et al., 1993). Most of the recent applied studies by groundwater scientists are the exposure of groundwater or aquifers to pollution, especially in areas that contain polluted groundwater due to human use of land. Many countries of the world are facing the largest and most rapid changes at the same time in land use, for example, industrial and human activities, in addition to land cover, for example, for the physical properties of the surface lands (Mas, 1999). The large and rapid changes that occur in most countries in terms of the population lead to an increase, inhuman activities therefore, their results are observed in the change in land use, which has a negative impact on the environment of the region, especially on areas that have a benefit from groundwater. In recent studies, the concept of producing and mapping land use and land covers has become an important scientific development with regard to natural resources and monitoring environmental changes (Alawamy et al., 2020). The assessment of the pollution risks of the aquifer is one of the important and useful tools to prevent groundwater pollution in addition to its proper management (Li and Qian, 2020). The production of risk maps for groundwater provides scientific support for its protection and practical for its management in an acceptable manner, especially in the study area. Groundwater pollution mainly affects the up Al-Sanaf Marsh, which is a natural resource

that has economic and tourism benefits for the country. The aim of this work is to produce a map to identify the areas of groundwater at risk.

2. Study Area

The up AL-Sanaf Marsh sub-basin is located of the northeast Maysan governorate, south of Iraq between coordinates 3598723.20 - 3536533.63 and 701215.71 - 751283.87. It occupies 1554.3 km^2, from the south of the up AL-Sanaf Marsh sub-basin south Dewereg sub-basin, from the west AL-Teeb River, from the southeastern Dewereg River, from northeastern the Hemrin hill and from the center of the band hill. The borders of the up AL-Sanaf Marsh sub-basin from the northeastern and eastern sides are the Iran Stat. Steep slopes from the north and northeast towards the south and southwest characterize the up AL-Sanaf Marsh sub-basin. The elevations of the up AL-Sanaf Marsh sub-basin range from 3-270 m above sea level (Fig. 1).

The up AL-Sanaf Marsh sub-basin consists of two geological formations ranging in age from the Middle Pliocene (Tertiary period) to the Holocene (Quaternary period); which are the Bai-Hassan Formation and Quaternary sediments including the (Aeolian deposits, Flood plain deposits, Depression fill deposits and Alluvial fan deposits) (Fig. 2) (Jassim and Goff, 2006). The Bai Hassan Formation locates the eastern part and western part, which covers about 676.575 km^2, while the Quaternary sediments is covered most parts of the up AL-Sanaf Marsh sub-basin, it covers approximately 877.732 km^2. Depending on the tectonic and structural conditions, the part northeaster from the study area located Buzurgan subzone within the foothill zone (unstable shelf); Most up AL-Sanaf Marsh sub-basin of the Tigris subzone (Zubair subzone) within Mesopotamia zone (stable shelf) (Fouad, 2010).

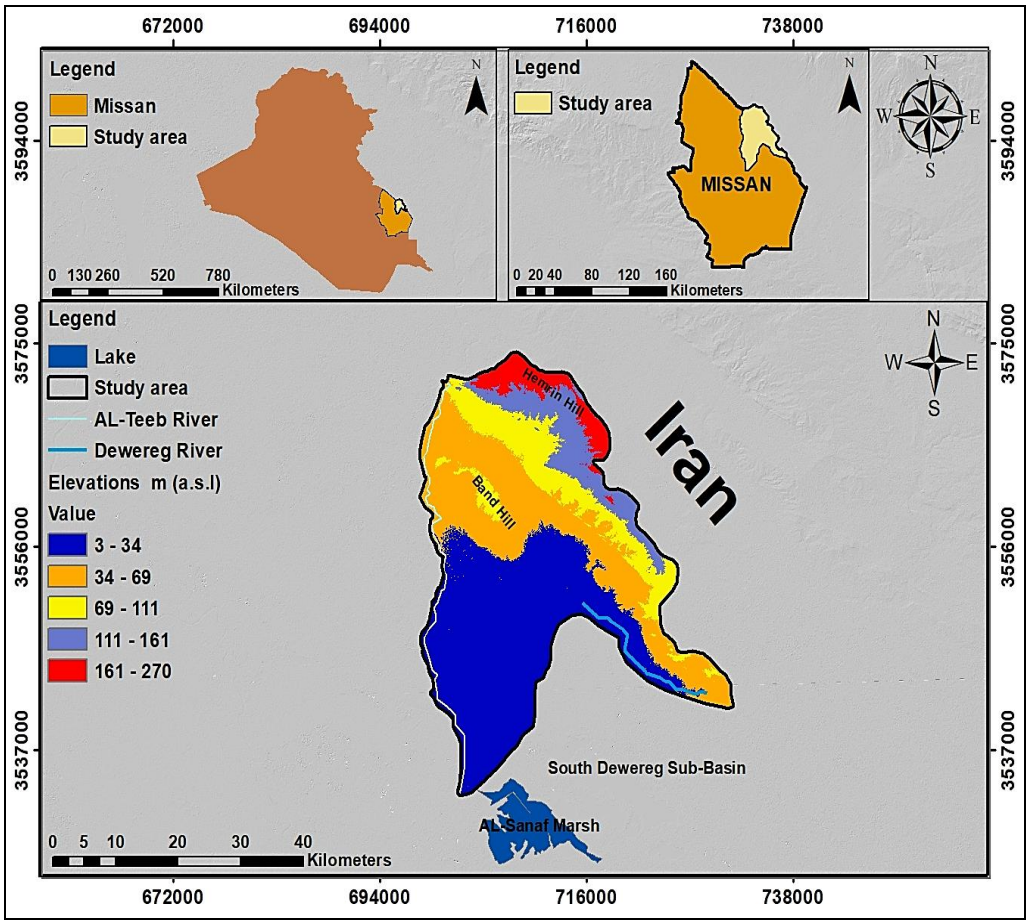

Fig. 1. Location map of the up Al-Sanaf Marsh sub-basin

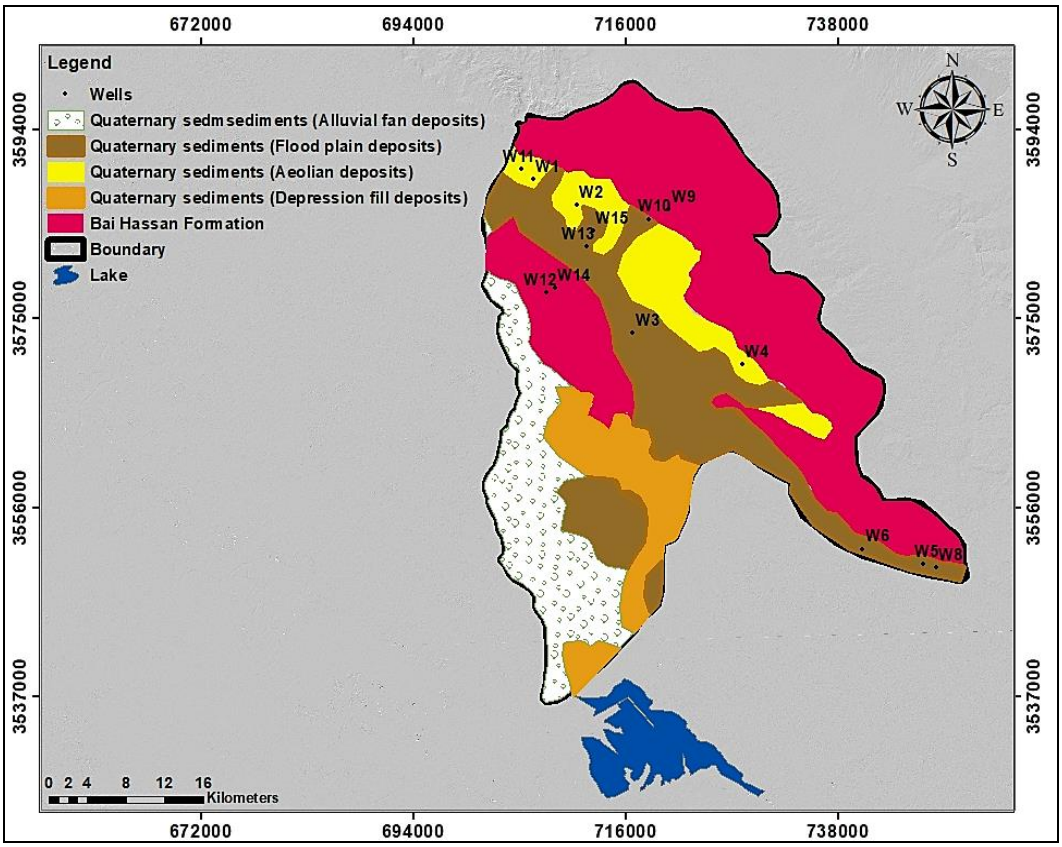

Fig. 2. Geological map of the up Al-Sanaf Marsh sub-basin modified after (Jassim and Goff, 2006)

3. Materials and Methods

The method of work includes collecting accurate and sensitive information to obtain the final map. The obtaining a Digital Elevation Model (DEM) from the United State Geological Survey website (USGS). For drawing a map, that determines the elevations and area of the up AL-Sanaf Marsh sub-basin northeast of Maysan governorate. The groundwater vulnerability map was obtained from Al-Abadi et al. (2017). All vulnerability maps are categorised according to (Table 1) (Aller, 1985). The QGIS software is used to obtain a land uses and land covers map for the sub-basin. The date of extracting the map of land uses and land covers of the up Al-Sanaf Marsh sub-basin through the QGIS software is 2020/1/15. Then a map of LULC for the sub-basin is entered into the Arc GIS software use a tool Interactive Supervised Classification (ISC) to give specific values for each category of LULC within the map. The value of each description was given from land use and land covers categories depending on the data values in Tables 2, 3, and 4 (Secunda et al., 1998), (Shirazi et al., 2013) and (Zwahlen, 2003). The values in the land use map are not final; but only represent the values of the rating (Lr), through the spatial analysis tools in the Arc GIS software; multiplying with the value of the weight (LULC) (Lw =5) produces a map land use and land covers, as in the following equation:

$$\text{Land use and Land covers} = Lr * Lw \qquad (1)$$

A groundwater risk map was produced of the up AL-Sanaf Marsh sub-basin by combining the groundwater vulnerability map and the land use, land covers (LULC) map by using the algebraic map tool in the GIS Software. The diagram shows in detail how to create the risk map (Fig. 3). In addition, the vulnerability map and the risk map were reclassified according to international standards. At the end of the work, the end map was compared with the concentrations of nitrates. Water wells were analysed by Al-Ghanimy et al. (2019).

Table 1. Ranges of vulnerability using the DRASTIC method (Aller, 1985)

Drastic vulnerability index	Vulnerability degree
Less than 100	Very low
100-125	Low
125-150	Medium
150-200	High
More than 200	Very high

Table 2. Land use, Land covers categories and the modified weight of these parameters (Secunda et al., 1998)

No	Land use and Land cover category	Land use rating
1	Built up area	8
2	Irrigated field crops	8
3	Uncultivated land	5

Table 3. Land use, Land covers categories and weight of this parameter (Shirazi et al., 2013)

No	Land use and Land cover category	Land use rating
1	Animal husbandry, horticulture, urban and Agricultural area	8
2	Palm trees and other permanent crops land	5
3	Waterbody	3
4	Swamps and marshland, grass and wetland and Others	2
5	Forest land	1

Table 4. Land use, Land covers categories and weight of this parameter (Zwahlen, 2003)

No	Land use and Land cover category	Land use rating
1	Detached houses without sewer systems	9
2	Roads, unsecured	8
3	Waterbody	3
4	Hazardous waste site	18
5	Open field	5

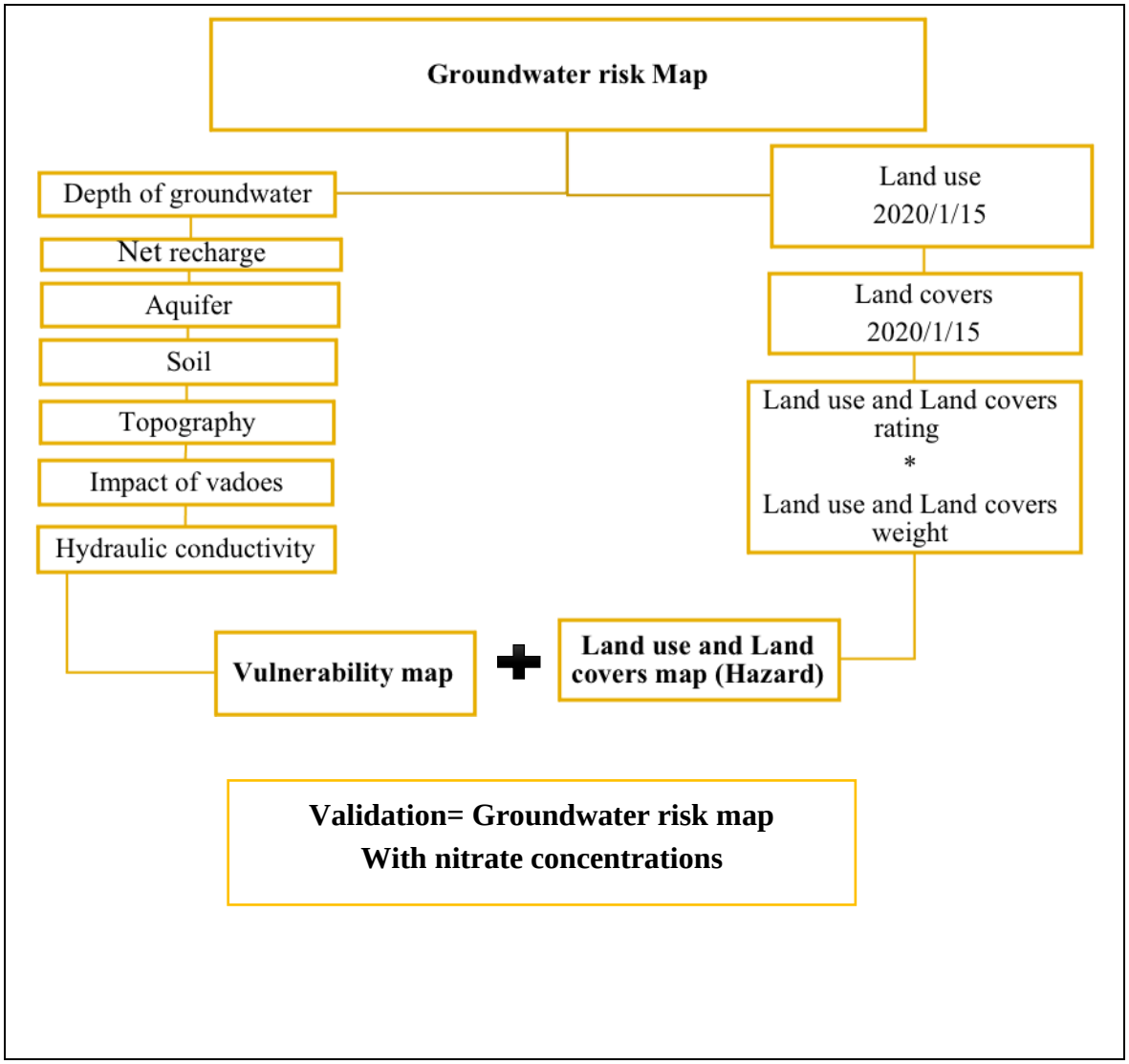

Fig. 3. Methodology of risk method of the up AL-Sanaf Marsh sub-basin

4. Results and Discussion

4.1. Vulnerability Map

Several studies and evaluations that been applied to the areas exposed to pollution, especially those containing aquifers (Al-Gburi and Al-Tamimi, 2020). The vulnerability map is the possibility of a contaminant or groups of contaminants to transport by way of the infiltrated water and spreads in the aquifer (Al-Madhlom et al., 2016). It is necessary to legislate important laws to protect groundwater in order to reduce or rationalize the use of groundwater and preserve it through the infiltration of pollutants (fertilizers, agricultural pesticides, sewage, and industrial pollutants) into the aquifer (Aller et al., 1987). The vulnerability map appeared of the up AL-Sanaf Marsh, categorized into three parts (very low vulnerability, low vulnerability and medium vulnerability), the values range between of 78-129 (Fig. 4) depending on Al-Abadi et al. (2017). The very low vulnerability zone is combined with the low vulnerability zone of the vulnerability map final, as it does not affect the aquifer.

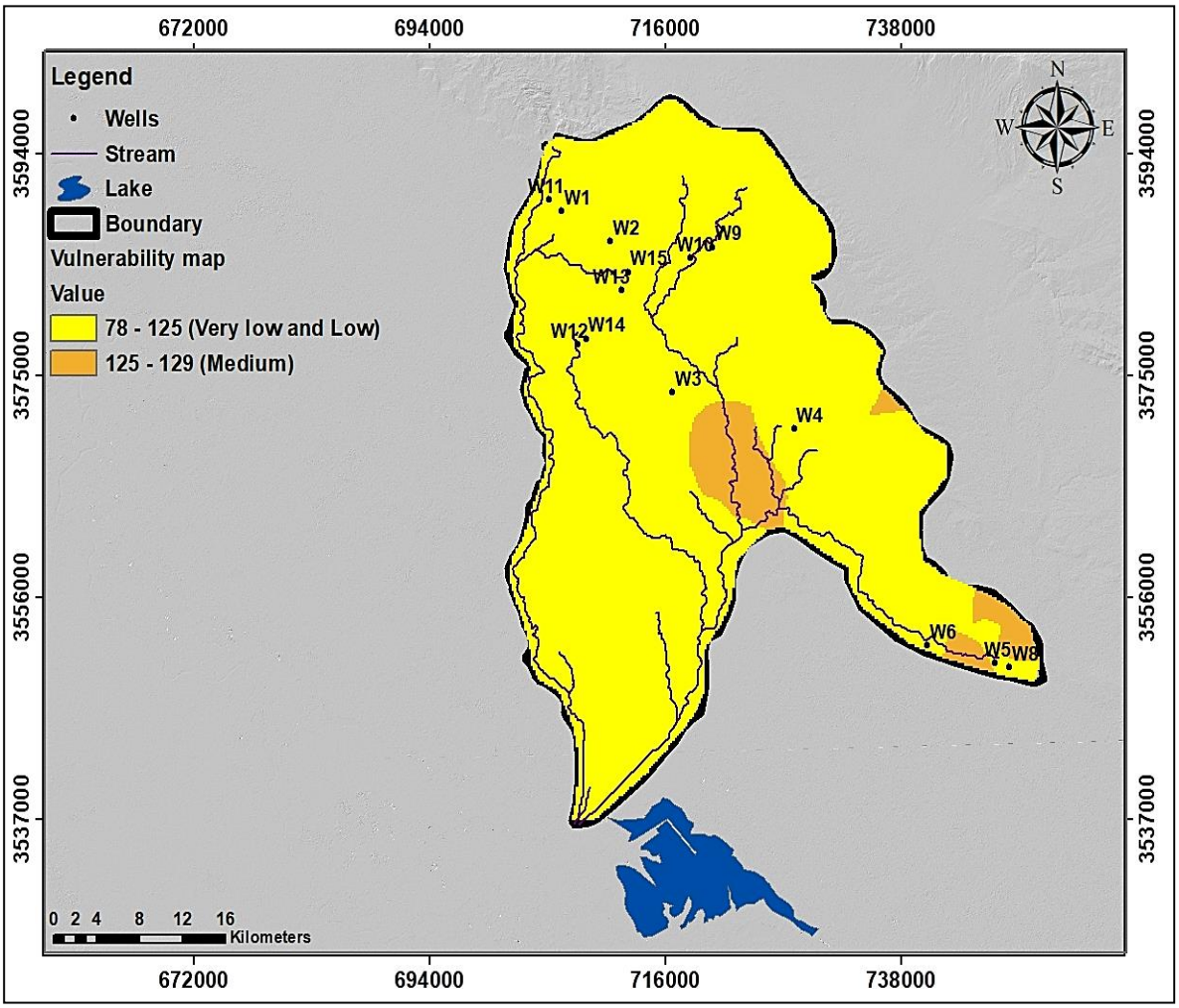

Fig. 4. Groundwater vulnerability map of the up AL-Sanaf Marsh sub-basin depending on Al-Abadi et al. (2017)

4.2. Land Use and Land Covers (LULC)

The land uses map represents most of the anthropogenic activities of buildings and agricultural lands, as well as the industrial activities, these activities consider being negative impacts that lead to pollution of groundwater (Al-Gburi, 2020). The land use and land cover map up the AL-Sanaf Marsh sub-basin have been divided into four categories include (roads, open filed, industrial and houses) (Fig. 5). All categories have values as in Tables 2, 3 and 4 respectively and by equation 1. Most of the sub-basin is an open field. Industrial sites are located in the eastern and southeastern parts; which is considered one the groundwater pollutants. (Fig. 6).

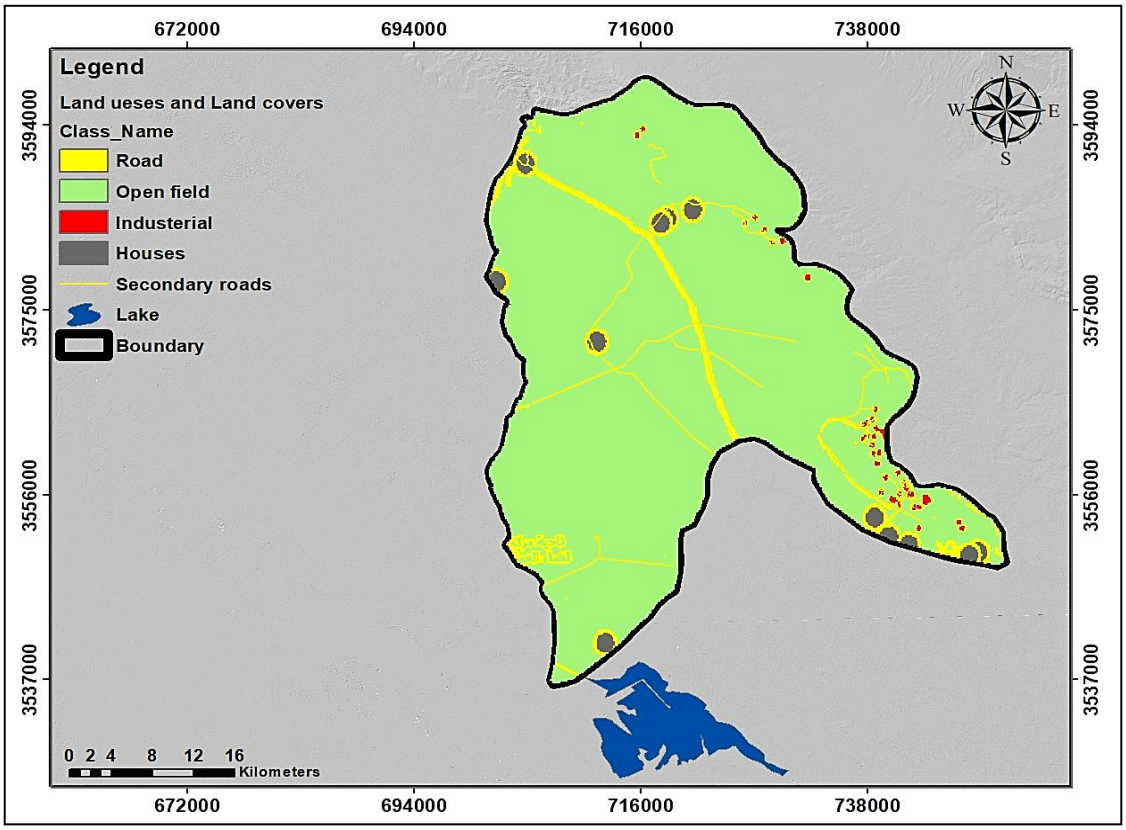

Fig. 5. Land use and Land covers map of the up Al-Sanaf Marsh sub-basin.

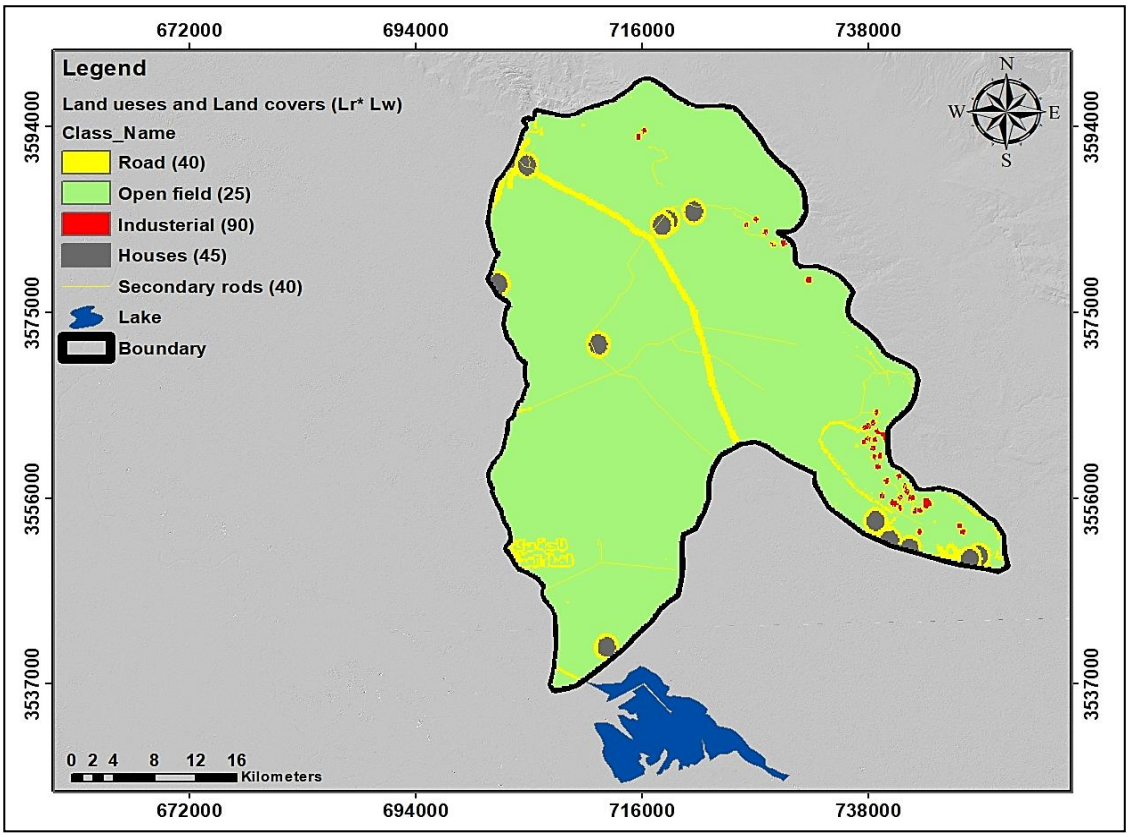

Fig. 6. Land use and Land covers value map of the up Al-Sanaf Marsh sub-basin.

4.3. Groundwater Risk Map

The production of a groundwater risk map is the result of several scientific studies or research accurate practical at the same time including:

- The included hydrogeological studies (pumping test, measuring groundwater depths, and groundwater recharge).
- The geological studies (lithology or geological formations and topography).
- The nature of land use and land cover. The Vulnerability maps, land use and land cover combined in the Arc GIS software (V 10.4). Equation:

Risk map = Vulnerability map or Drastic system + Land uses and land covers (2)

The results of the risk map range from 117 to 218 low to very high. The up Al-Sanaf sub-basin is divided to four zones (Fig. 7).

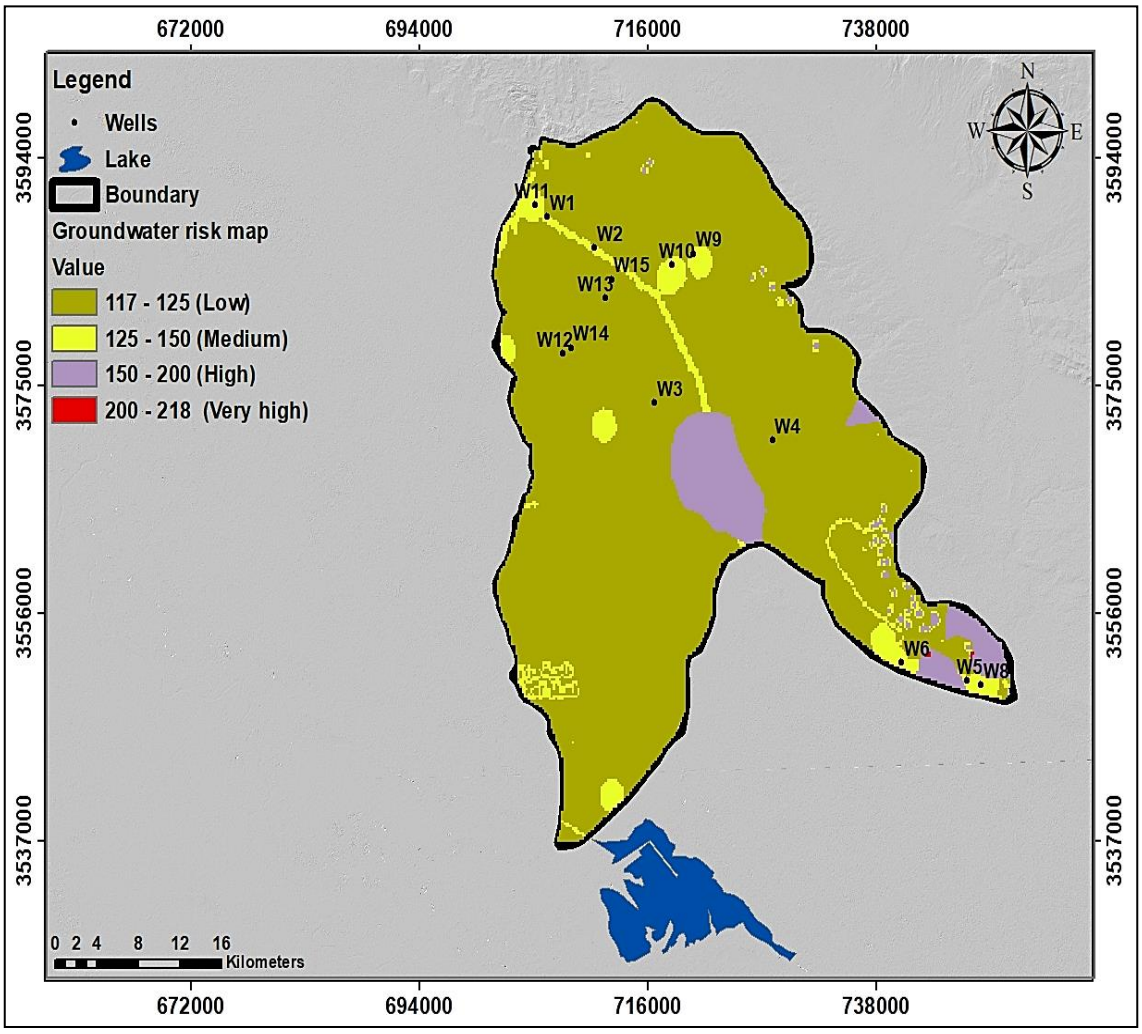

Fig. 7. Groundwater risk map of the up Al-Sanaf Marsh sub-basin

Risk map assessment of contamination consists of two parts; the possibility of pollution (Vulnerability) and impact potential (Baalousha, 2006). In the case of probability and the impact of high pollutants show high risk, but the possibility of pollution is high and the impact of pollutants low, it will show low risk (Fig. 8) (Baalousha, 2011) (Figs. 9 and 10).

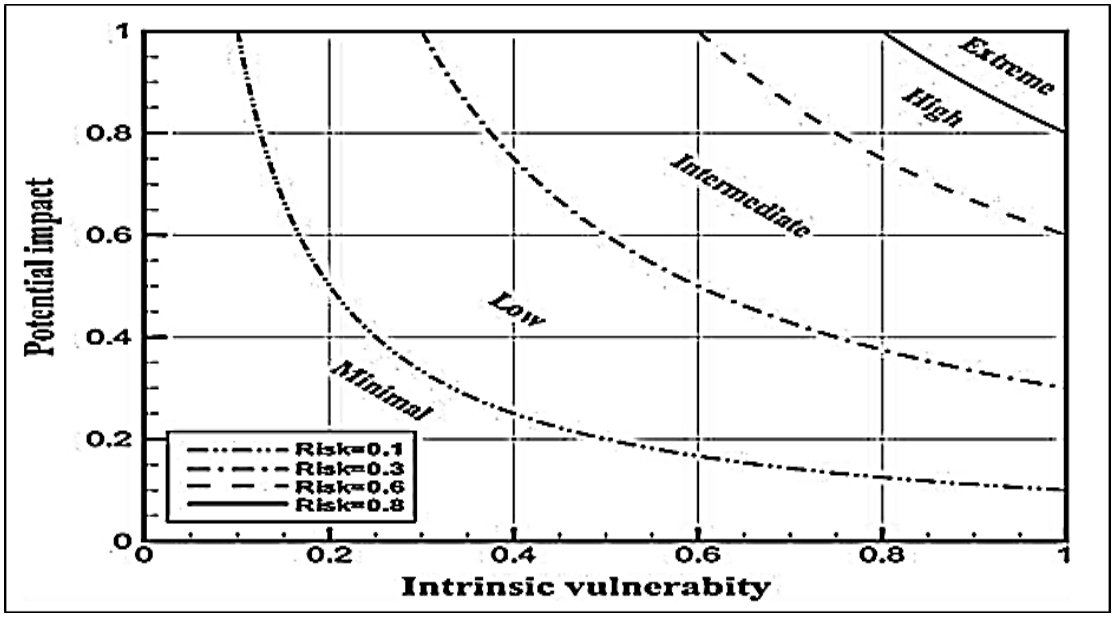

Fig. 8. The concept of groundwater contamination risk mapping according to (Baalousha, 2011)

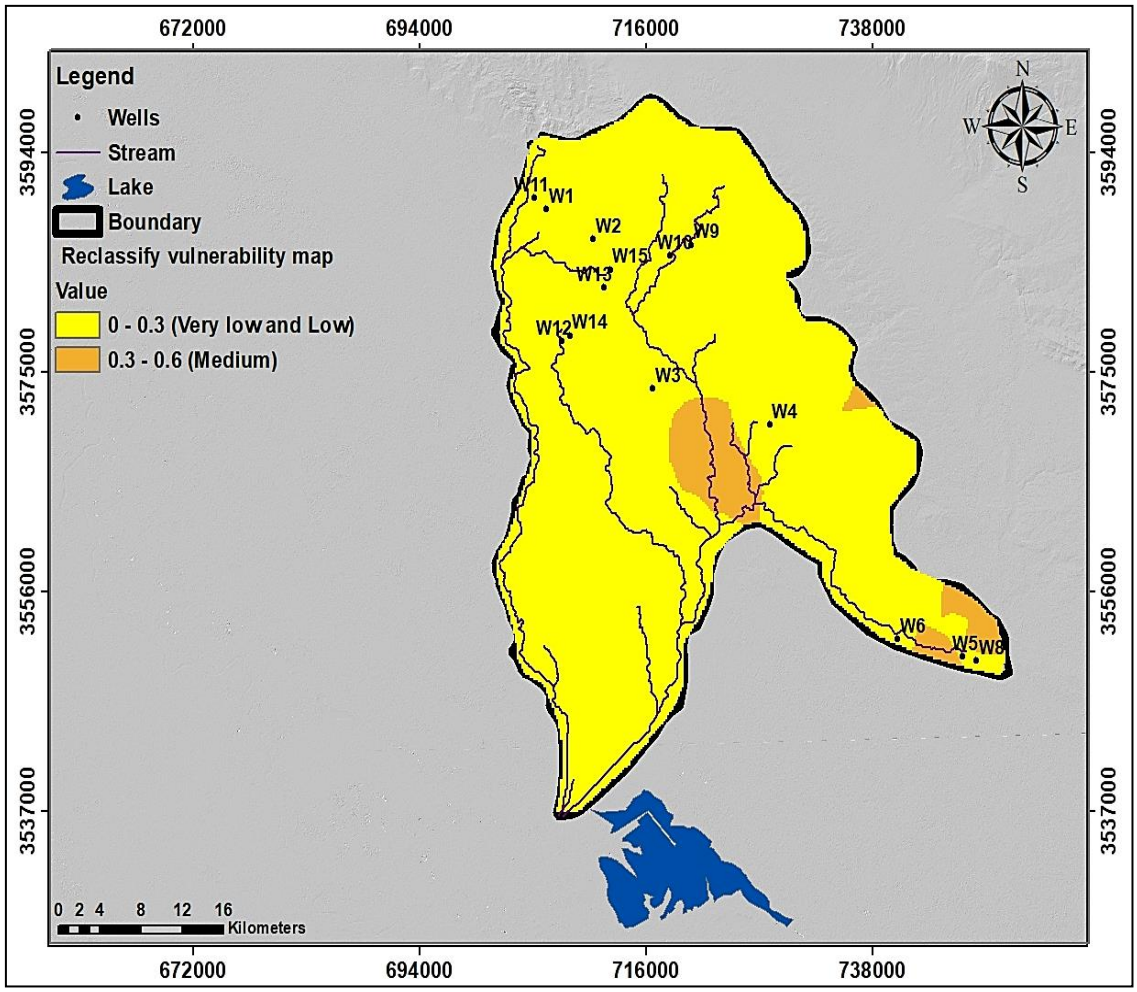

Fig. 9. Intrinsic vulnerability map of the up Al-Sanaf Marsh sub-basin

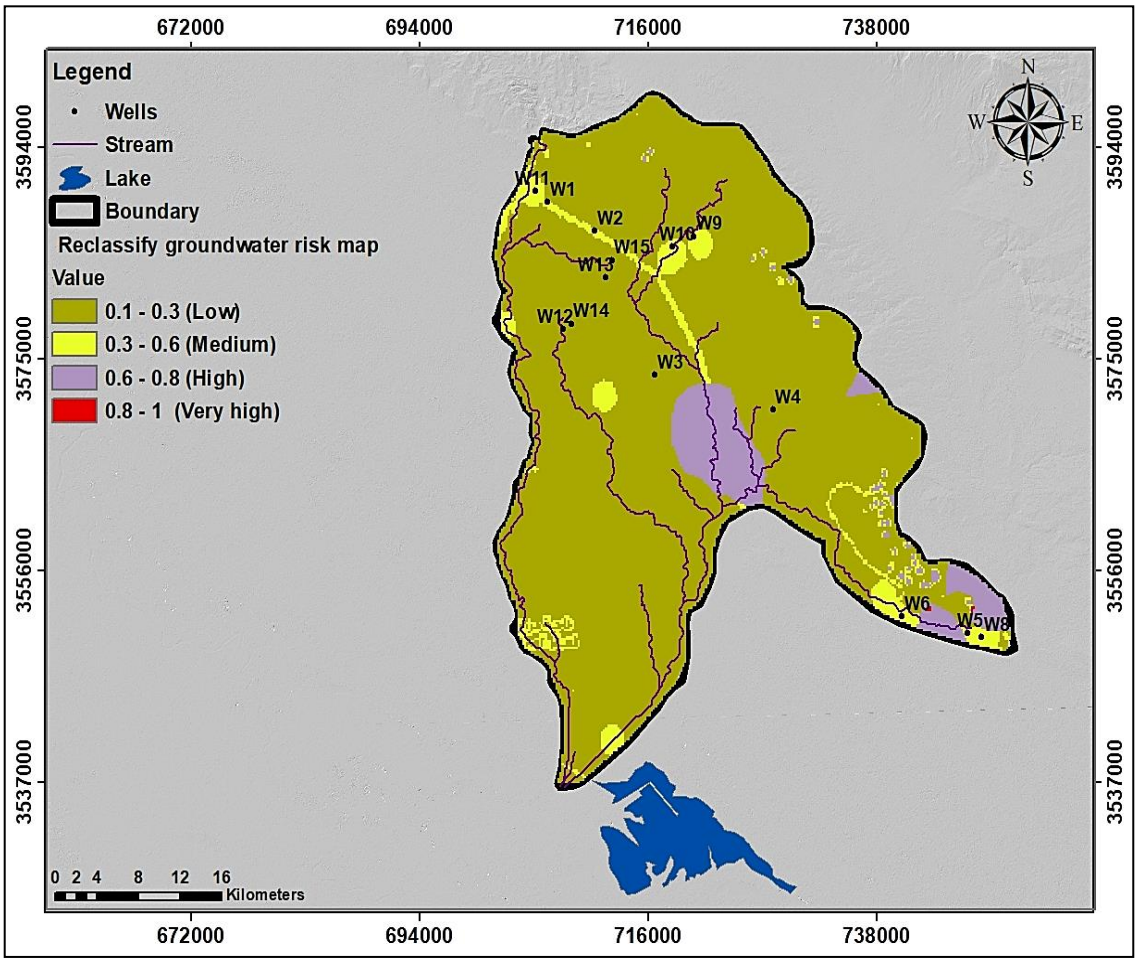

Fig. 10. Potential impact map of the up Al-Sanaf Marsh sub-basin

5. Validation

Nitrates are considered one of the most important pollutants to validate the application of the risk map model for groundwater (Salih and Al-Manmi, 2021). The groundwater nitrate concentration of the wells located within the sub-basin was compared with the groundwater risk map to verify the accuracy of the work results. Therefore, the results were identical, meaning that the groundwater wells had nitrate harmless concentrations matching with the non-risk locations of the groundwater risk map.

6. Conclusions

The application of this study is very important and represents modern applications in understanding the effects of the risks of the aquifers. This application depends on many factors, including hydrogeology, geological nature, and potential areas of groundwater pollution. The use of the QGIS software (V 3.12) contributes to obtaining the available information from land use and land covers, as well as the use of Arc GIS software (V 10.4) in the preparation of the map, classification, reclassification, some calculations, and mathematical equations to produce the final map. The highest elevations are located in the northern, northeastern, and some eastern parts, while the lowest are southern, southeastern, and southwestern. The results show most of the up AL-Sanaf Marsh sub-basin area is an open field. In addition to some villages (houses) in the northern, northwestern, western, southwestern, western, and southeastern parts. The industrial use is in the eastern, southeastern, and northern parts, which have weight in terms of negative effects of the groundwater. The sites of pollution that negatively affect the groundwater are located in the southern and southeastern parts of the up AL-Sanaf Marsh sub-basin range (high, very high). While some small sites are at risk to groundwater

ranging from high to very high, but they affect the aquifer by infiltrating in the northern and eastern parts of the sub-basin. Most of the rest parts range from low-medium which covers a few areas that cannot negatively affect the groundwater, especially in the western, southwestern, and northwestern parts and the center of the sub-basin. The risk sites with high and very high impacts on the groundwater are all located in the Bai-Hassan Formation.

Acknowledgements

The authors are very grateful to the reviewers, Editor in Chief Prof. Dr. Salih M. Awadh, the Secretary of Journal Mr. Samir R. Hijab, and the Technical Editors for their great efforts and valuable comments. The authors thank Prof. Dr. Alaa M. Al-Abadi for making the vulnerability map of study area.

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