Faculty of Engineering and Technology

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An integrated Vulnerability Assessment DRASTIC model and Landuse for Yatta aquifer.

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Palestine – Hebron

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Based on the instructions of PhD. Nabeel Al-Joulani and Dr. Itisam Abu Eazeiahand the approval of all members of the committee, this project was introduced to the department of Civil Engineering and Architecture in the Collage of Engineering and Technology for partial fulfillment of the requirements for The Bachelor Degree.

Supervisors signature

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Head of the department signature

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May 2109

Chapter One:

Concept of the project

1.1 Introduction

Hebron district with about an area of 1036 km^2 , based on the existence of 170 springs and dug wells and of about 30 % of its area is used for cropping [1], it became a highly valuable agricultural land and highly sensitive area . The area suffers from scarcity of water supply due to many reasons including; limited clean water resources, Israeli occupation which controls most of the water resources in Palestine, increasing of water demands due to population growth, and human activities keep on contamination the water resources. For that, increasing stress continues to be placed on the available water resources thus generating a need to environmental assessment to restrict these activities. [2]

Up to 90% of all water supplies are provided by groundwater in the West Bank and Gaza Strip. The main aquifer systems can be divided into four distinct units; the Western Aquifer Basin, the North-eastern Aquifer Basin and the Eastern Aquifer Basin for the West Bank. [2]

Ground water contamination by oils, chemical waste, leachate from landfills, and fertilizers are all line sources of pollution. Methods for assessing the degree of vulnerability of the aquifers are very helpful to provide protection from this contamination. [3]

Water observation is one way of solving the problem, to anticipate how and when water is affordable and when it is not. This is possible by different methods of geospatial analysis which allow for data analysis, data mapping and data storage, therefore, groundwater vulnerability maps are becoming a valuable tool in the environmental management.

1.2 literature review

The world has been facing the ever-increasing environmental challenges since 18th century when many heavy industries came in force, thus many pollutants were emitted to our atmosphere, and sank into our oceans, affected our land and caused various types of diseases.

Water is not excluded from this crisis, it’s the most vulnerable to pollution regarding the output effluents of all types of industries that are not free of pollutants; which change water’s physical, chemical and biological characteristics thus making it non-potable, or not usable by humans.

Surface and ground water are of the same importance to human beings, since water is the cause of our existence, threatening this resource is a direct threat to our presence on earth.

The current situation carries responsibilities for those in charge of making change, such that problems get solved, and earth is saved. There’s a stage prior to solving any problem, which is preventing it’s occurrence as a prediction process.

This stage requires researchers to do their pre-studying and observation of the target, new technologies has been developed and is being developed in order to track problems’ source and control them. It is both economic and environmentally effective trend to follow.

In the case of groundwater, there have been real attempts to estimate how much danger is out there. The term vulnerability describes the likelihood of any environmental system to be harmed by different hazardous sources.

Vulnerability is a concept introduced in hydrogeology in terms of possibility of contamination groundwater system encounters, which reduces its quality. It was first introduced in France by the end of 1960s to spread awareness about groundwater contamination. [4]

As a definition, the National Research Council (1993) defined vulnerability of groundwater as; the tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer.

Groundwater vulnerability could be either, intrinsic or specific. Intrinsic vulnerability accounts for physical characteristics in describing the sensitivity of groundwater, while the specific type accounts for the transport properties of a particular type of contaminants or a group of contaminants through the subsurface. Approaches for groundwater vulnerability assessment can be categorized into three groups: [5]

1- Overlay and index methods;
2- Methods employing process-based simulation models;
3- Statistical methods.

In the first method, parameters that control movement and dispersion of pollutants from the ground surface into the saturated zone (e.g., geology, soil, impact of vadose zone, etc.) are mapped according to existing or derived data.

Numerical values (weights) are then assigned to each factor based on its significance in controlling pollutants movement. The rated maps are then linearly combined to produce the final vulnerability map of an area.

Evaluation of groundwater vulnerability using this method is qualitative and relative. What gives preference of such method is the ability of evaluation of some controlling factors over a large area, which enables researchers to do regional scale assessment.

1.3 Problem statement

Groundwater is the most important source of drinking water and human use, so it must be protected from the risk of contamination or completion. However, the increasing human consumption of groundwater, human activities and natural factors have led to contamination of chemical, physical and biological contaminants، and put it at risk of shortages. Which adversely affects human health and the environment, also the discharge of wastewater over land leads to pollution and deterioration of groundwater quality.

Therefore, there was a way to detect the probability of contamination of groundwater as a result of human activities and geological factors of the nature of the region. This method was to conduct an assessment of the sensitivity of groundwater and its representation in models like DRASTIC Model that helps to understand the situation and decision-making.

1.4.1Research objectives

The general objective of this research is to estimate the risk potential for the study area of Yatta by developing a vulnerability map then classify the area into hazardous levels, and recommend a future land use limitation after assessing the impact on the socio-economic situation in the study area.

1.4.2 Specific objectives

The specific objectives of this research are:

1- Determining the geological and hydrological characteristic including: rainfall, contour maps, water tables, etc.

2- Defining the land use risk categories of Yatta point of source.

1.5 Importance of the study

Yatta city encounters different environmental and service-related problems. For most of the population, water's accessibility and availability is a critical issue due to certain political, social and resources' scarcity. Since the major reliance of the city is on groundwater as water resource; it is substantial to study the current characteristics, and the future state of this resource. Observation and prediction of groundwater vulnerability to pollution is part of the solution, to anticipate how and when this resource is affordable and when it is not.

This is possible through different methods of remote sensing which enable researchers to deduce accurate and reliable results, for further progress in solving or even avoiding certain problems. DRASTIC model is one of several applications to assess vulnerability of groundwater to pollution, as the first step in creating better, stable and comfortable life for people of Yatta.

This research will benefit Yatta Municipality, Ministry Of Local Governorate, land use planners and water managers, it will help decision makers to identify areas where there's potential risk of groundwater pollution.

1.6 Methodology

Thus the preparation of aquifer vulnerability map is a key consideration and becomes a forecasting tool. Via the planning processes, it also acts as a prevention tool and an identifier of action priority list. Vulnerability mapping has been carried out in many countries in recent years and examination of these maps and descriptions of vulnerability in the scientific literature shows considerable variation from different perspectives. DRASTIC is one of the assessment and mapping methods based on GIS supported weighting and ranking of the component factors relevant to groundwater pollution according to their relative importance. [3]

The DRASTIC model, which is an overlay and index method, easy to implement and provides a good assessment of groundwater vulnerability to contamination. The DRASTIC model is based on seven parameters (depth of groundwater, net recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity) used to calculate the index number who can be obtained according to the following equation: [6]

$$DI = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw \quad \ldots\ldots..(1)$$

where D, R, A, S, T, I, and C are the seven factors of the DRASTIC method and subscripts R and W represent, respectively, the rating and weight of the factors. The higher the value of the DRASTIC index, the greater is the vulnerability to pollution of that part of the aquifer. [6] The incorporated use of a Geographic Information System (GIS) is shown in figure 1.1.

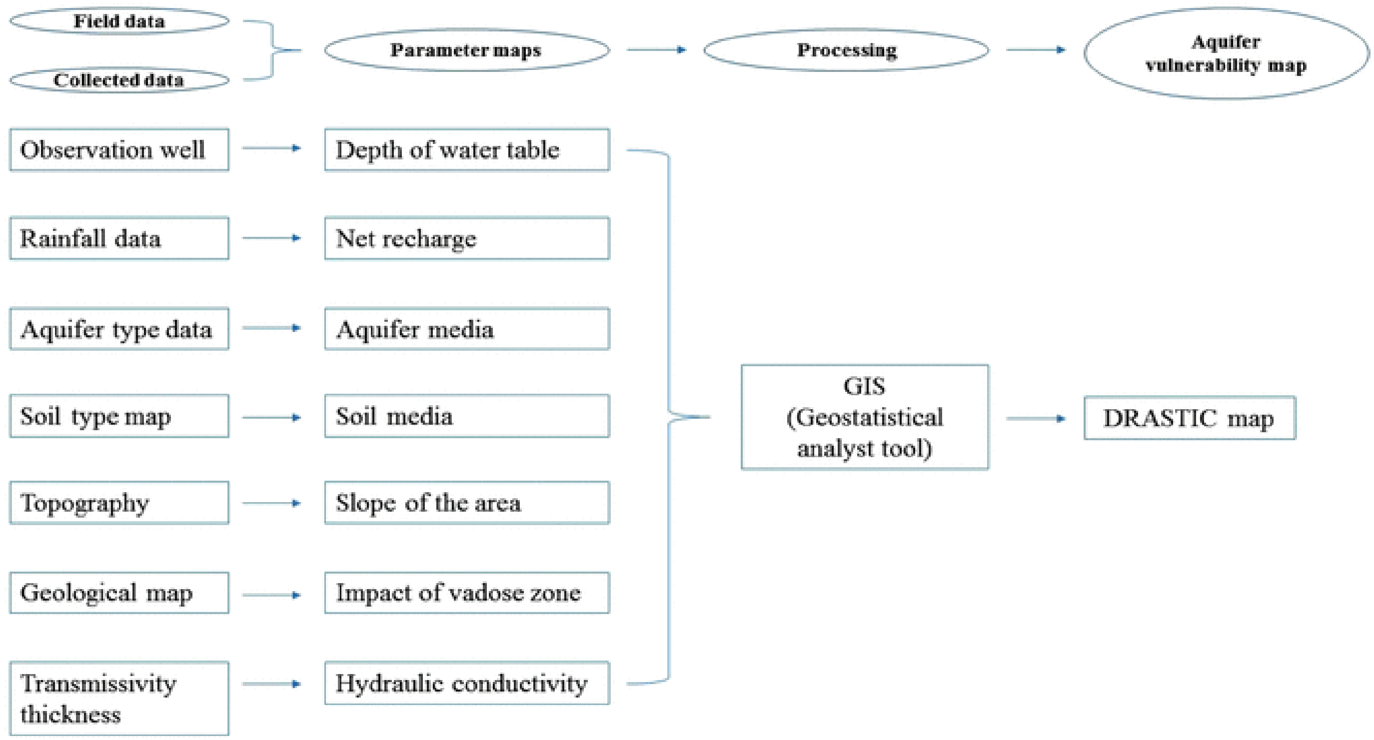

Figure.1.1: The Flow Chart of DRASTIC Method. *[7]*

1.7 Limitations

1. Lack of information about Yatta Governorate due to its recent independence as another governorate separation from Hebron governorate.
2. Difficulty in collecting representative samples from wells in the study area due its random distribution.
3. The location of the study area in "C" zone, under Israeli control.

1.8 Action plan

Table 1.1 : Action plan for the first semester

September to December- 2018

TASKS	1^{st} Month				2^{nd} Month				3^{rd} Month				4^{th} Month			
	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4
Identification of Project Idea																
Literature Review																
Data collection																
Field visits																
Data preparation																
Analysis																
Documentation																
Discussion																

Table 1.2 : Action plan for the second semester

February to May- 2019

TASKS	1st Month				2nd Month				3rd Month				4th Month			
	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4
Data collection																
Studying the method																
Map preparation																
Field visits																
Wells tests																
Analysis																
Documentation																
Presentation																

Chapter Two

Literature review

2.1 Background

2.1.1 Groundwater pollution

Both surface and ground water are natural renewable resources, but groundwater is harder to manage because of the natural time lag in its formation [8]

Groundwater is more than a supplying source for human's need of water, it also contributes to feeding rivers, either as base flow or springs. Discharge of groundwater into rivers could be permanent or seasonal; according to the height of water-table within the aquifer. Water-table which is the height of water in the aquifer separates the unsaturated zone comprising the rock from the saturated zone. It is measured by determining the level of water in boreholes and wells. [8]

The water-table' height fluctuates over a wide area depending on topography and climate change. Over abstraction of groundwater or drought cause water level in the aquifer to decrease, since rainfall replenishes or recharges the water lost. [8]

Groundwater is the only water source feeding rivers in case of severe drought, thus if the water-table falls below some certain level called critical level, the river would dry up completely. [8]

Aquifers could be either confined or unconfined. Figure 2.1 shows the groundwater flow paths from recharge to discharge areas. The confined aquifer is the one that is recharged where the porous rock is covered by an impervious layer of soil or rock. [8]

In confined aquifers, all the porous rocks are saturated with water as it is below water-table level; and thus there's no oxygen. Because confined aquifers are bounded by two impermeable layers, the water is under hydraulic pressure, i.e. artesian pressure; so it will rise in borehole and wells under its own pressure. [8]

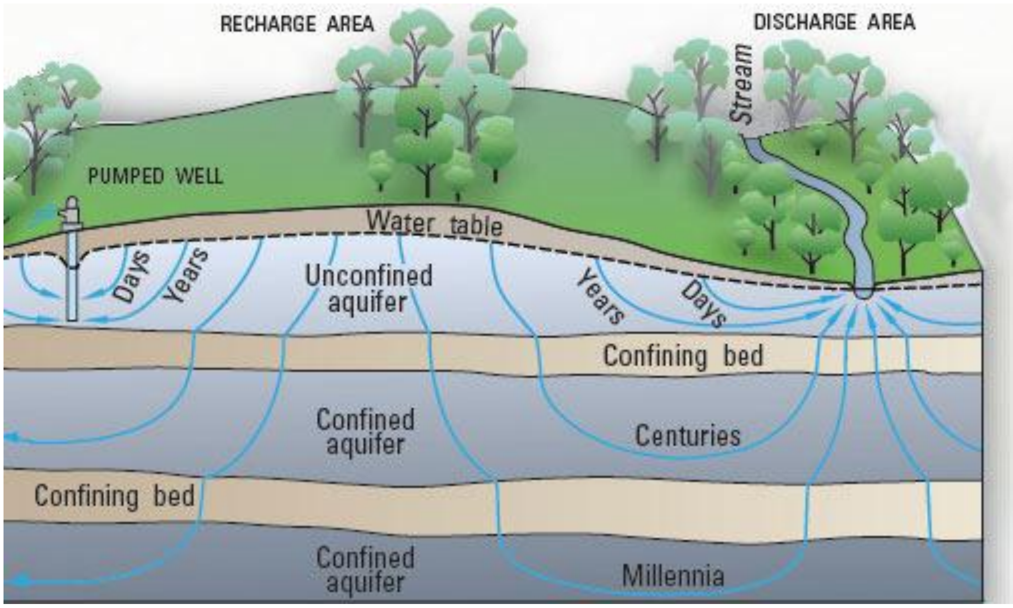

Figure 2.1: Cross section showing groundwater flow paths from recharge to discharge areas. [8]

The majority of groundwater supplies are abstracted from unconfined aquifers, specifically from the saturated zone which originate mainly from rainfall, so it is particularly vulnerable to pollution. [8]

The unsaturated zone in confined aquifers which is situated between the land surface and the water-table of the aquifer, allows for elimination of some pollutants, while it has the great effect of hindering the movement of pollutants, in such a way, their occurrence in groundwater supplies is concealed for long periods. [8]

2.1.2 Origins of groundwater pollution

Groundwater pollution is referred to four main sources: industrial, domestic, agricultural, and environmental pollution, each category is divided into continuous and accidental types: [8]

1- Industrial pollution is transmitted to groundwater by:
   a. Wastewater with high content of chemical compounds and heavy metals, or at high temperature. Radioactive material from nuclear plants.

b. Rain infiltration through waste disposal.
c. Accidental damage of pipes.

2- Domestic pollutants are transmitted by:
   a. Rain infiltration through landfills.
   b. Accidental damage of septic tank.
3- Agricultural pollution is due to irrigation water or fertilizers, salts, minerals, pesticide and herbicides.
4- Environmental pollution such as; seawater intrusion in coastal aquifers.

Each type could be contaminated by groups of dissolved inorganic and organic compounds that could be observed by pollution indicators listed in Table 3.

Table 2.1: list of main groundwater pollutants and pollution indicators [8]

COD (Chemical Oxygen demand)	Bicarbonates HCO3	Zinc
BOD (Biological Oxygen Demand)	Iron Fe2+	Lead
Ammonium	Nitrites (NO2-)	Nitrates (NO3-)
Conductivity	Calcium	Fluoride
Detergents	Redox	pH
Temperature	Potassium	H2S
Sulfates (SO42-)	Phenol	Manganese
Arsenic	Copper	Total hardness

2.2 Study cases.

Case study I: Kerman plain, Iran [9]

According to Neshat, et al. 2014 who used an improved DRASTIC (AHP) method in GIS; further improvements on the vulnerability assessment methods provide greater opportunities for conserving aquifers or plains from contamination.

The study was conducted on the southeast part of Iran, the area suffered scarcity in surface water, so relied mainly on groundwater, and agriculture was the major activity in the study area, and thus an extensive use of fertilizers took place.

The extent of groundwater contamination was analyzed by treating a DRASTIC index and developing the seven map layers of the DRASTIC model by the committee of the United States Environmental Protection Agency to obtain the intrinsic groundwater vulnerability.

Given that the DRASTIC model is an easy target for criticism, many researchers have recommended the optimization of the DRASTIC model. In this study, the AHP method revealed the modification based on local hydrogeological setting provides better and more accurate results.

The modified DRASTIC-AHP can be applied in areas with extensive concentrations of nitrates for modifying the rates of DRASTIC which could be used for groundwater vulnerability assessment of nitrate pollution.

The type of modifications applied in the DRASTIC model is determined by the condition of the area. Numerous methods can be used in association with the DRASTIC rates and weights, which varies accordingly.

Case study II: Evaluation of vulnerability of aquifers by improved fuzzy DRASTIC method [10]

As the previously mentioned case in Iran, more researchers improved the DRASTIC method by some modifications; this one is also in Iran in Kochefsahan plain.

As justified in their study, the reason why to use advanced or modified methods; it's because of the limitations that typical DRASTIC comprises; like assuming equal values for range and weight of parameters for the entire region of the field studied, while AHP method is upgraded to overcome this problem, but the latter has already its own defects, so the fuzzy method is used in this study based on application of unfuzziness of decision making, and does not take into account uncertainties of individual judgements.

Hence the classical AHP method is unable to get accurate results for the modeling of uncertainties, and fuzzy theory by comparisons of adjacent pair elements the analytical hierarchal processes, which is helpful for decision makers to get more accurate results.

It is possible to combine this method and GIS technique in multi-objective decision making in vast dimension by a great accuracy. Literature survey showed that some studies were conducted on fuzziness of DRASTIC method for accurate evaluation of pollution potential of groundwater.

The vulnerability was investigated by fuzziness of the different layers. Fuzziness is a function assigned to each value of the DRASTIC index. The used fuzzy functions are non-linear and symmetrical, and that values of each factor are in some range. The critical ranges of values of these factors, were selected as an index for the rate of influence of that factor in groundwater pollution.

As compared in the study; in fuzzy DRASTIC model most of the northern regions of the plain were marked by moderate to high vulnerability, and in the southern region the vulnerability was low to moderate. In standard DRASTIC model only the small location in the northern region was calculated by high vulnerability. Fuzzy DRASTIC model compared to standard DRASTIC model showed more adaptability to this plain.

Case study III: Melaka State in Malaysia [11]

Another research has been conducted and four assumption have been considered for the model:

1- The contaminant is introduced at the ground surface;
2- The contaminant is flushed into the groundwater by precipitation;
3- The contaminant has the mobility of water and
4- The area being evaluated by DRASTIC is 0.4 km^2 or larger.

The set of variables were grouped into three categories: land surface factors, unsaturated zone factors and aquifer or saturated zone factors which are the important considerations for the DRASTIC model.

A risk map was also developed for the study area which evaluates the potential risk of groundwater based on the land use activities combining with the DRASTIC map. The risk map was created using the additional parameter (land use), combined with the conventional DRASTIC method. This combination has been called the modified DRASTIC method. Agricultural, industrial and urbanization impacts on the groundwater vulnerability are of great concern in the risk map, and are deeply studied through the risk map.

The water quality parameters used for validation of study are, nitrate and chloride; nitrate is not present in groundwater naturally. Therefore, its presence in groundwater system indicates groundwater contamination, in which contaminants transport by infiltration water through ground surface into the groundwater system.

Nitrate and chloride concentration values are used to develop the correlations with the values of conventional DRASTIC index (DI) and modified DRASTIC index (MDI). Correlation is a technique for investigating the relationship between two quantitative, continuous variables.

Case study IV: guidelines to groundwater vulnerability mapping for Sub-Saharan Africa [12]

This paper reviews an approach to solving the challenges encountered in groundwater vulnerability assessment in Sub-Saharan African countries. Groundwater is an important source for drinking, livestock and irrigation water in those countries. It is of vital importance to meeting the target of the Millennium Development goal (MDGs) of all people having access to clean water, as most of rural Africa, and a considerable part of the urban Africa, are supplied by groundwater.

The study categorized groundwater vulnerability assessment into three different approaches:

1- The assumption that groundwater vulnerability is related to the response of the system to impacts from natural processes and human activities.
2- The consideration that vulnerability is an intrinsic (natural) property of the groundwater system without considering the properties of the contaminants impacting on the system.

3- Those that synthesize complex hydro-geologic information into a useable form for planners, decision makers and policymakers, geoscientists and the public.

Factors needed to be taken into consideration.

1- The effective travel time through the system.
2- The quantity of contaminants that reach the target because not all contaminants that the leave the surface catchment infiltrate into the aquifer, some leaves as surface run-off.
3- The physical reduction of the contaminant as it travels through the system such as dispersion or dilution.

Concluded from this paper, the challenges of mapping groundwater vulnerability in Sub-Saharan African countries:

1- Lack of comprehensive hydrogeological data.

2- Limitations of established vulnerability assessment methods.
3- Political and social challenges.
4- Scarcity of skilled hydrogeologists.
5- Lack of funding, poor policies and legal tools.

Examples of the mainly successful approaches applied to SSA can be subdivided into the following and are hereby recommended to be used on a country-wide application:

1- Travel time approach.
2- Parametric approach.
3- Numerical approach.

Case study V: Oued Righ,Valley Algeria [13]

According to Messaoud Hacinib who compared results from two different methods of vulnerability assessment to pollution; DRASTIC and GOD methods, in order to preserve the quality of groundwater of the Mio-Plio-Quaternary, in Oued Righ Valley, the areas that are vulnerable to pollution in the region were mapped in order to determine the best method that assesses this vulnerability.

Kendall test, The Kendall coefficient (W) is a statistical index that measures the degree of conformity between two or more parameters, who are supposed to judge the same phenomenon this factor has a variation margin extending from 0 to 1. The degree of conformity increases as the value of the coefficient W approaches 1. The calculations of Kendall's coefficient shows that this test is reliable, since the coefficient W is found positive, and is therefore interpretable (W=0.703).

Based on the test, showed that the two methods present moderate agreement. The statistical analysis of different vulnerability classes revealed that vulnerability assessment, using DRASTIC method, may be represented by four classes: "very low", "low", "medium" and "high", with a dominance of class "medium" (74.3%). The GOD method resulted in vulnerability that sits between two classes, "low" and 'medium", with a noted domination of class "low" (70%).

From the geological perspective, the study area consists of:

- Paleozoic formations that outcrop south of the study area.
- Mesozoic and Cenozoic formations which are outcrops of the borders.
- Tertiary and Quaternary continental deposits that occupy the center of the basin.

The hand study (annual area rainfall as a hyper-arid of 63.34 mm) climate, and the Saharan thermal type, amplitudes. It is characterized on the other by (annual low and mean erratic temperature rainfall of the 23.38 one ˚C.

Comparison of the two vulnerability maps obtained from the DRASTIC and GOD methods reveals that the DRASTIC method has better representation for the distribution of degrees of vulnerability to pollution in the aquifer of the Mio-Plio-Quaternary.

The use of these two methods required collecting and processing a set of numerical and cartographic data, on the study area, which were provided by the National Agency for Water Resources, in Ouargla. These data were processed and analyzed using the GIS software. Then they were developd in digital format and then distributed between meshes. Subsequently, the final results were converted in the form of maps representing the aquifer vulnerability to pollution.

Case study VI: Application of DRASTIC method on alluvial aquifer: north east of Algeria [6]

The study area classified as semi-arid, Morsott, Boukhadra and El Aouinet region, north east of Algeria, an alluvial area that has suffered of increasing salinity toward the northern part of the basin.

The known seven environmental parameters of the DRASTIC method were used to represent the natural hydrogeological settings of the aquifer.What makes the area of interest is its geological nature; where the plio-quaternary terrains occupy the central part; they consist of actual and recent alluvial deposits, conglomerates, gravels and sandstones.

Three aquiferous formations are present in the stratigraphic column of the study area, among them the formation of Plio-quaternary one. The aquifer being studied covers the major part of the tectonic basin. It consists of various deposits such as, alluvial fans, silts, calcareous crust, conglomerates and gravels. This aquifer is considered a major supplier of drinking water for residents of the region. The authors described the intrinsic vulnerability assessment as an effective tool for describing innate features of specific hydrogeological conditions that provide some degree of protection from external contamination. The DRASTIC vulnerability index was computed and values were reclassified into three classes (low, medium, high), occupying 56%, 35% and 90% respectively.

Concluded from the study, that groundwater vulnerability map can be a useful tool for land use planners, hydrogeologists and water managers. It enabled researchers to identify the areas where there is potential risk of groundwater pollution.

Case study VII: groundwater vulnerability assessment in vicinity of dumpsite, Lagos, Nigeria [14]

The study area in this paper is of a special case, near an active dumpsite; to assess groundwater vulnerability to pollution from the dumping site using a modified DRASTIC method.

This dumpsite is the largest in Nigeria of about 18 meters deep and covers an area of roughly 42 hectares, with a life span of 35 years. 40 water samples were collected from 20 different dug wells for two consecutive years and have been analyzed by physiochemical tests.

The modification of DRASTIC was for the peculiarity of the dumpsite, which results in the formation of six hydro-geologic parameters based model, DRALTIC; where L stands for distance from well to dumpsite. Each parameter was assigned a weight according to its significance and influence in the pollution potential.

To validate the effectiveness of the DRALTIC model; nitrate concentration was used as an indicator for its efficiency, and that showed a high efficiency, because there was a similarity between groundwater vulnerability index, and the pattern of spatial distribution of nitrate concentration in water.

Chapter three

GIS application on Groundwater Assessment

3.1: Introduction

A geographic information system (GIS) is a set of computer-based tools for storing, processing, combining, manipulating, analysing and displaying data which are spatially referenced to the earth. Thus, GIS is a special case of data management and analysis dealing specifically with spatial or geographical data. [15]

A geographic information system is comprised of people, computer hardware and software, and data. The system users, system operators, GIS suppliers, the data supplier, application developers and GIS systems analysts are people who are interface GIS. Computer hardware and Software including computer devices, workstations, networks and computer's toolboxes such as X-Windows or MOTIF, Microsoft Windows. GIS data can be categorized as graphic and nongraphic. [15]

Graphic data is often viewed as a series of layers, figure 3.1 shows the data base for a GIS for an urban area might include layers representing: topographic contours, soils, streets, utilities, land ownership parcels, zoning districts, and municipal boundaries. For the soils layer, nongraphic attributes might include soil type, moisture content, and erosion parameters. For the utility layer, nongraphic attributes might include the size, material, and year installed for each water line. For a land ownership parcel, nongraphic attributes might include owner name, parcel size, land use, and market value of property. [15]

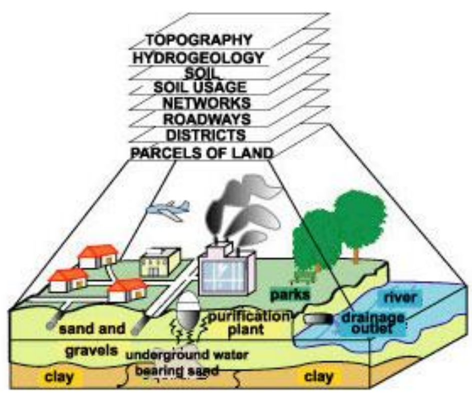

Figure 3.1 : Organizing spatial data base for an urban area in GIS System

[15]

has different applications and hence is of high interest in various fields of study. The need for a systematic approach for modeling, analyzing and/or present huge amounts of data (spatially and temporally distributed) could be answered by GIS. Water Resources Engineering as a multidisciplinary field requires modeling and analysing spatially distributed data with different spatial resolutions. Therefore, GIS is indeed a suitable tool for solving water resources problems. [16]

3.2: GIS Application for Groundwater

Groundwater contamination is an increasing water resource problem on a global scale. Many programs are in place to remediate polluted groundwater and to develop new clean-up technologies for groundwater. [17]

Various groundwater vulnerability mapping methods have developed such as DRASTIC method, GOD method and Aquifer Vulnerability Index, those methods depend on dividing the into many areas which can be assigned concentration of groundwater pollution vulnerability, from low to high, based on hydrological and geographic parameters which analysed by geographic information system GIS . [17]

3.3: DRASTIC Model

This method was developed in the 1980 by the National Water Well Association, in order to assess the risks of groundwater pollution. It was developed by the Environmental Protection Agency (EPA) in the United States in 1985, to estimate the groundwater pollution potential. [13]

DRASTIC model of groundwater vulnerability is one of the most commonly used methods. The DRASTIC model is used to prepare a vulnerability map for the area of study. The name DRASTIC is taken from initial letters of seven environmental parameters, used to evaluate vulnerability of aquifer systems. These seven parameters are: [18]

1) **Depth (D) to water table**: the more depth to water, the chance for the contaminant to reach is less as compared with shallow water table.

2) **Net (R) recharge:** it represents the total quantity of water that reaches the water table. It is the process through which the contaminants are transported to the aquifer. The more recharge, the more vulnerable the aquifer.
3) **Aquifer (A) media:** it represents the geological characteristic of the aquifer material determining the mobility of the contaminants through the aquifer material. For example, the larger the grain size is higher the permeability, and thus vulnerability of the aquifer.
4) **Soil (S) media:** it represents the texture of soil of different types have differing water holding capacity and so influence the travel time of the contaminants.
5) **Topography (T):** it refers to the slope of the land surface. High degree of slope increase runoff and erosion which is composed of the contaminants.
6) **Impact (I) of vadose zone:** it represents the texture of the vadose zone (it is the unsaturated zone above the water table). The texture determines the time of travel of the contaminants through it.
7) **Hydraulic conductivity (C):** it refers to the ability of an aquifer to transmit water. With a higher hydraulic conductivity, there exists a greater potential for contamination because contaminants can move easily through the aquifer.

This model produces a numerical value called DRASTIC INDEX which is resulted from the rating and weights assigned to the parameters have evaluated the potential of groundwater contamination. [18]

Weights: a relative parameter value ranging from 1 to 5, where each weight determines the relative significance with respect to pollution potential. Table 3.1 represents the least significant factor and five represents the most significant factor. [18]

Ratings: each of the DRASTIC parameters is assigned a rating from 1 to 10 based on a range of values, and based on its relative effect on the aquifer vulnerability. Ratings depend on the physical character of the parameters which are more or less constant. [18]

Table 3.1: Weights of DRASTIC parameters [18]

Parameters	DRASTIC weight
Depth to water table	5
Net recharge	4
Aquifer media	3
Soil media	2
Topography	1
Impact of vadose zone	5
Hydraulic conductivity	3

Determination of the DRASTIC INDEX (DI) value (pollution potential) for a given Area involves multiplying each factor rating by its weight and adding together the resulting values. The total impact factor score of the DRASTIC INDEX can be calculated as: [18]

$$DI = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw \quad \ldots\ldots..(1)$$

Where: **D, R, A, S, T, I**, and **C** are the seven hydrogeologic parameters.

r is the rating for the area being evaluated (1–10).

w is the weight for the parameter (1–5).

The resulting DRASTIC index represents a relative measure of groundwater vulnerability. The higher the DRASTIC index means the greater the vulnerability of the aquifer to contamination. A site with a low DRASTIC index is not free from groundwater contamination, but it is less susceptible to contamination compared with the sites with high DRASTIC indices. The DRASTIC index can be converted into qualitative risk categories of low, moderate, high, and very high. [18]

3.4: Benefits of GIS Application in DRASTIC Model

As a tool, GIS is very powerful for addressing groundwater resources issues such as ground water quality, ground water movement, ground water contamination. On a local, regional, national or even global scale. It could be used for different approaches such as analyzing the current situation, modeling and stimulating different scenarios for predicting the future, projecting new information, and enhancing decision making and groundwater management. [16]

Chapter Four

Study area

4.1 Yatta profile

4.1.1 Location and population

Yatta is one of the largest cities in the Hebron governorate in Palestine, lies 12 km south of Hebron along the mountains of Palestine and the north of the Negev to the south , the study area is located on coordinated of [31.447778 N , 35.09 E] map 4.1 shows location map of Yatta. [19].

Yatta is located on a mountain about 750 meters to 820 meters above the sea level, with a mean rainfall 303 mm, an average annual temperature of 18 °C, average annual humidity at 61%. [20]

Yatta is bordered by Zif and Khallet al Maiyya to the East, Ar Rihiya, Al Fawwar Camp and Wadi as Sada to the North, Beit 'Amra to the West, and As Samu' to the South [21] .The total area of Yatta is approximately 270 km² classified depending on different land uses that are shown in table 4.1. The population is about 63511 Ca and Population per km^2 is 0.48 with a population growth rate of 3.8%. [20]

Table 4.1: Classification of Yatta land use. [21]

Land use	Area
Agricultural	115 km^2
Built up	14 km^2
Forests, uncultivated, or public land	141 km^2
Total	270 km^2

4.1.2 Climate

Yatta climate is characterized by the Mediterranean climate, so it is hot and dry in the summer, cold during the winter. Spring begins at the end of March, whilst the hottest month is July, when max temperature is about 34 C°. Usually the fifth week is the hottest. The coldest month is January. In this month temperature could be even 11 C° at night. Map 4.2 shows average monthly precipitation for Yatta city. [21]

The period between October and April has more precipitation, with a mean rainfall about 370 mm, figure 4.1 shows average monthly temperature and precipitation year 2017 for Yatta area, while the average humidity ratio equals 61%. [21]

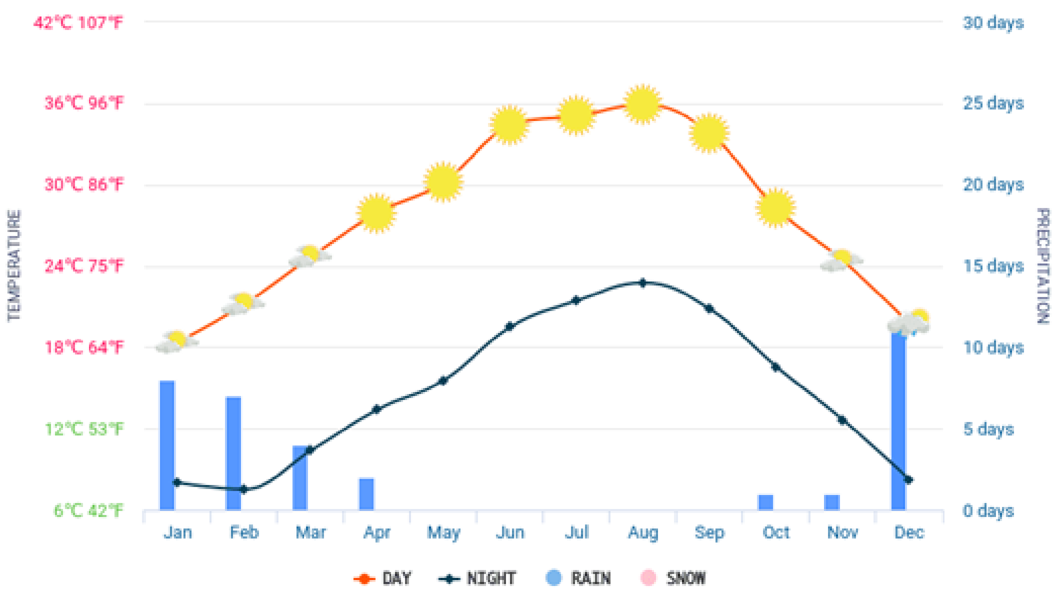

Figure 4.1: Average monthly temperature and precipitation for Yatta city. [21]

4.1.3 Topography

Yatta area is a mountainous area. Map 4.3 shows the elevations of Yatta area, where the average elevation of Yatta area is about 800 m above sea. [1]

4.1.4 Soil

Yatta watershed is mostly hilly and rocky, and soils are often shallow. There are four main types of soil which are: Loam, Clay, Sand, and Silt. Other types of soil are a mixture between the main types such as: sandy clay loam, silt clay loam, sandy loam, etc [1]. Map 4.4 shows the soil types and their formulas in Yatta area.

4.1.5 Hydrogeology

Yatta is located on the south-eastern unconfined part of the Western Mountain Aquifer Basin (WMAB).The part of the basin lie in Yatta boundaries classified as recharge areas for the aquifer.

The WMAB has a general thickness of 600 - 1000 meters consist of limestone and dolomite with thicknesses ranging between 250 and 400 m each .It is divided to layers; the lower (Beit Kahel formation) and the upper (Jerusalem, Bethlehem and Hebron formations) permeable layers, these two layer form lower and upper sub-aquifers. Yatta Formation is characterized by chalky limestone, chalk and marl with thickness of 80 - 120 m makes the layer behaves as a semi-permeable layer. Figure 4.2 shows a typical schematic cross section for the WMAB showing the flow mechanisms between the aquifer layers. [3]

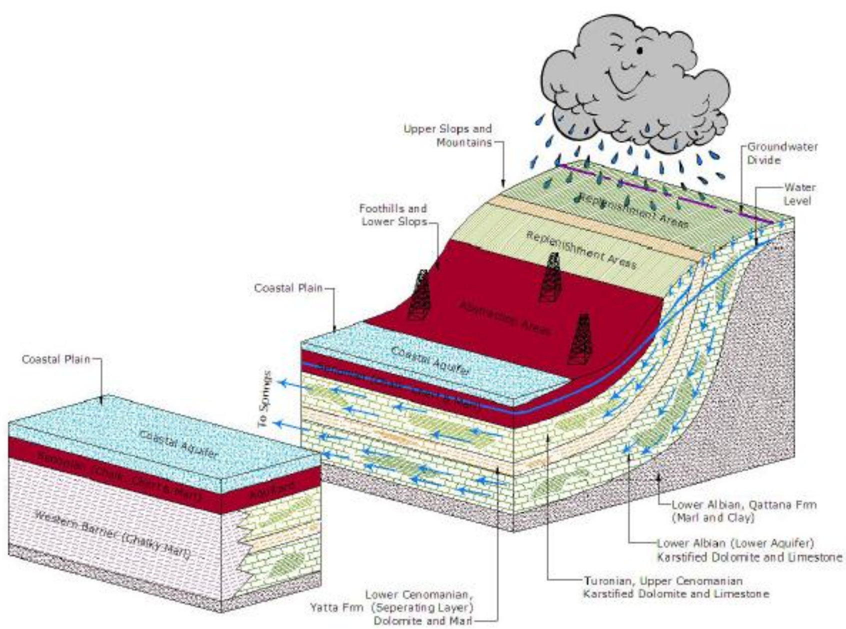

Figure 4.2 : The typical schematic cross section for the WMAB showing the flow mechanisms between the aquifer layers. [3]

4.2 East yatta catchment area

East yatta catchment area is 214.4 m^2 characterized by 14 springs and wells shown in table 4.2 of daily discharge of 85.9 m^3, part of Bani na`im is located at Yatta boundary. [1]

Table 4.2 : spring and wells data profile of east Yatta catchment area. [1]

Common name	Type	Discharge (m^3/d)	Saturated thickness(m)	Depth of water table (m)
al karmel/alberkeh	Spring	10	0	0
al Twaneh	dug well	5	2.5	5
abo Ekraeim	Spring	2	0	0
abo Shabban	dug well	30	2	10
aldeiart al tahtani	dug well	4	2	10
aldeiart al foqani	dug well	6	1	4.4
Albeideh	spring	2.2	0	0
Erfaeyeh	spring	8	0	0
Al shahhaneieh	dug well	1.5	0.6	5.5
Om rokba	Dug well	2	2.6	2
Jaheer albalad	Dug well	closed	2	9
Abu kashabeh	Dug well	4	5.8	5.2
Om alshennar	Spring	7.2	0	0
Beirein	Dug well	4	5.7	1.3

Jaheer ALbalad well that is located within bani na`im area built in was closed and used as a septic tank, further more Beirein is located 2.5 km south to Bani na`im is in danger of pollution as it used by the Bedouins for animal breeding, Erfaaeye and albeidah springs the only sources for arifa`iye village, are polluted by human activities, the same with aldeirat altahtani and alfoqani wells. [1] Figure 4.3 for Erfaeyeh spring is shown below.

Figure 4.3: Erfaeyeh spring / ar-Rifa'ye village. [1]

Alkarmel spring shown in figure 4.4 below feeds an area with a historical importance by open concert pool, abo shabban spring is located in wadi floor near umm Lasfa village, a near concert tank was built for storage. [1]

Alsahhaneieh and om rokbeh dug wells both are used for manure and wadi food , For tuwani village shown in figure 4.5 , altwaneh and abo ekraeim dug wells , both of them are under pollutiim from animal breeding and human activities. [1]

Figure 4.4 : AL-Karmel / Al-Berkeh spring /AL-Karmel village. [1]

Figure 4.5 : Abo EHraeim dug well / Tuwani village. [1]

4.3 Geology of Yatta formation (lower middle cenomanian)

The Lower Yatta Formation is a deep confined aquifer across most the West Bank. This aquifer consists of upper and lower Beit Kahil, kobar and Yatta geologic formations. Figure 4.6 shows that this aquifer is 385-630 meters in thickness and it consisits of yellowish and brown fine to medium crystalline composed mainly of limestone, dolomite, chalky limestone, marl, and massive dolomite. The presence of chalks bed at bottom with thickness 30 – 150 meter prevent movement of water and allow the springs to emerge that formed Yatta local perched aquifer. [1]

The Lower Yatta Formation hydraulically separates the two regional aquifers (Upper and Lower Aquifers) across most of the West Bank, although to the north, the presence of Yatta limestone gives rise to minor springs and seepage. Water levels (heads) in the Upper Aquifer are generally higher than in the Lower Aquifer. [22]

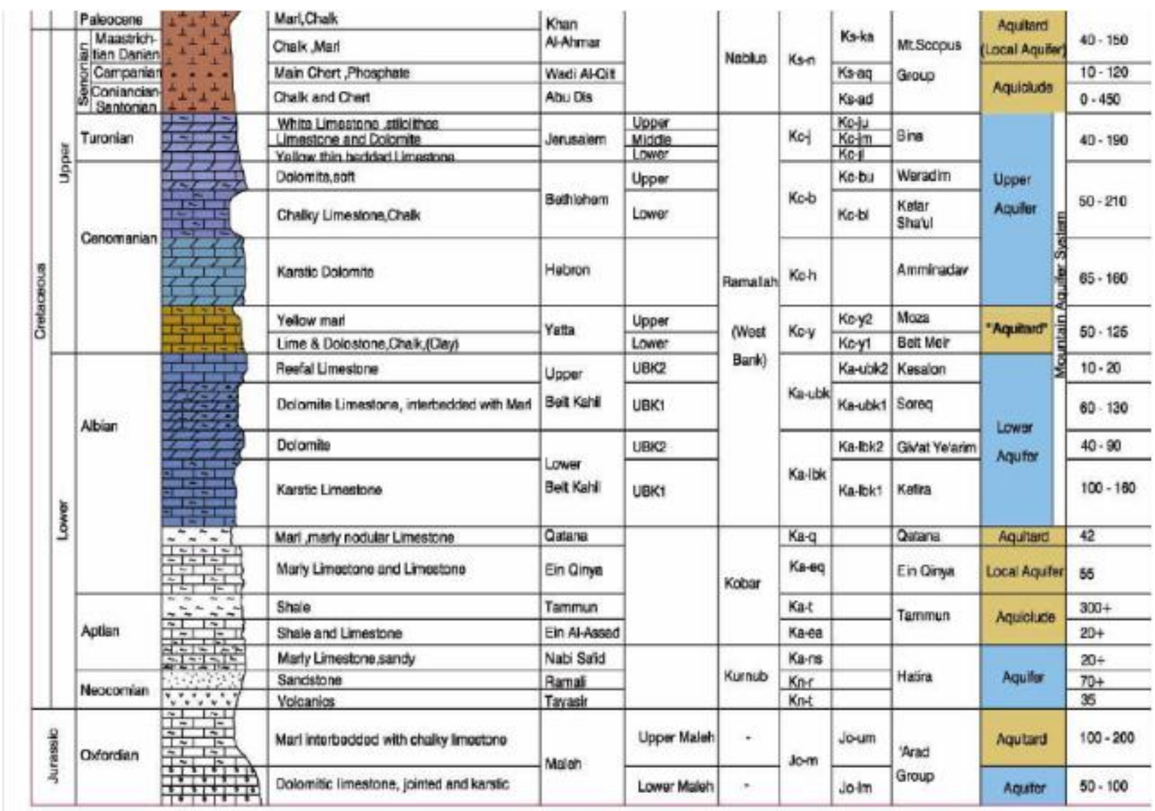

Figure 4.6 : Stratigraphical columnar Section of the West Bank basin. [1]

The aquifer is a regional source of drinking water across the West Bank with discharge range from 150-450 m^3/hr. Well depths vary from 500 to 850 m. Most of the basin area lies inside Israel 81% or 7453 Km^2.The high water bearing capacity and productivity is owed to the great thickness of dolomitic limestone and limestone. Most of the West Bank is an area with high hydrological vulnerability of groundwater to pollution. [3]

4.3.1 Yatta city and water history

The city of Yatta has been connected to the water network since 1974 and is the source of the Israeli water company (Makrout), about 85% of the housing units are connected to the network, but this network is outdated and inconsistent [20]

Between 25% and 30% of the city's neighborhoods are not connected to the water network, creating a heavy load on tanks, which is of lower quality and costs more than 400% of the cost of piped water, as a result most of families of Yatta city and villages live on rainwater harvesting wells, which are also contaminated by the presence of septic tanks as there is no sewer systems. [20] Map 4.5 shows the distribution of septic tanks in Yatta.

The city has 5 water tanks with a total capacity of 6,700 m^3 and another two in the villages of Yatta with a capacity of 500 m^3 each as follows: [20]

1) Kharaj tank : It was built in the center of the city during the Jordanian government since the sixties of the last century, with a capacity of 250 m^3, rising from the ground 12 meters, and from the sea surface 846 meters. The reservoir is in poor condition and need to be removed and a new reservoir with sufficient capacity (500 m^3) well be instead. It is used only in cases of extreme necessity for filling water tanks in the summer.
2) Tank AL- aroosa: a high reservoir, it was found in 1992 with a capacity of 500 m^3, rising 20 meters above the ground, 856 meters above sea level.
3) Metref tank: a circular tank with a capacity of 2000 m^3, rising 845 meters above sea level. It was created in 2005 with the support of the United States Agency for International Development (USAID) and under the supervision of RAFEED.

4) Hrez tank : a circular tank with a capacity of 4000 m^3, rising 840 meters above sea level. It was found in 2011 with support from the United States Agency for International Development (USAID).

5) Yatta Municipality Stadium Reservoir: A water tank 1300 m^3 below stadium, was created in 2002 with the aim of irrigation, it is not connected to the water distribution system. It was used to store rain water for the purpose of constructing municipal projects, and sometimes from water networks to supply water to schools and institutions by tanker.

4.3.2 Water Sources: [2]

1) Mekorot water line (Israeli company): a Water line with 8 inch in diameter coming from wells Taqoa with a flow rate of 50 m / h and decreases in summer to 25 m/h. However, 30 % of all municipal water supplies available to Palestinians were distributed to 60% on the West Bank and 4% in the Gaza Strip.
2) Bani Na'im wells: there are three wells in Bani Na'im, with a capacity of 5,000 m^3/d, supplies Hebron, Bani Naim, and Yatta with a discharge to Yatta Municipality does not exceed 1000 m^3/d.
3) Dura tank (Abu Ashosh): water is supplied to Yatta via a 20-inch pipe or about 3500 m^3/w, or only 580 m^3/d.
4) Al-Riyihiya: With a capacity of 48 m^3/hr , water is pumped into the Beit Umra and Al-Riyihiya areas.

Only the Palestinian authority is allowed to manage these resources is the Palestinian Water Authority and the West Bank Water Service. [2] The most important public issues and problems in the city water network can be summarized as follows [20]

1) A deficit in the quantities of water coming from the multiple sources of water such as Bani Naim aquifer , Khana Dura, Makrout line, Yatta well , where the daily average does not exceed 20 l/ca.

2) the scarcity of water and the water crisis in the summer , leading to the division of the city to about 30 distribution area, and often the water is not supplied for 6 months.

3) Water pollution: The population relies mainly on the collection wells in water storage, so that 85% Of town houses contain these wells, and because of the existence of a septic tank for each home, most of the well water is contaminated.

4) The network's inability to meet the needs of the citizens : 40% of the neighborhoods have no water networks .

5) The networks are damaged due to their long life and the rust caused by the absence of water for periods.

6) high percentage of losses in internal networks and main lines as a result of pipe erosion.

4.4 Waste water problem

The city of Yatta suffers from lacks of sewerage system, and its wastewater is disposed of by cesspits or through open channels. The number of cesspits within the city is estimated to be more than 6,000 cesspits and these are discharged in the adjacent valleys without any regard for the environment [20]

Hebron Station and Deir Samet Station are wastewater treatment units of Hebron district [21].However, these units are of low efficiency and are currently not functioning. Thus, the wastewater from the population flows into the nearby valleys without any treatment, which leads to soil pollution and degradation of natural resources, especially groundwater. [1]

The main wastewater stream in Hebron flows into Wadi al-Saman as shown in figure 4.7 . This valley starts from the Hilla area north of Yatta and extends through the Valley of Sada and the Valley of Abu Faul until the Al-Dhahiriya and then the Negev. About 2,300,00 m^3 / year of wastewater is discharged through the main line of Hebron in Wadi Al-Saman. [23]

Figure 4.7 : Open wastewater flow in Wadi-Samen catchment area. [23]

The problem of wastewater flow from the Palestinian communities through Wadi Samman without any treatment gets worse by the random disposal of wastewater from the Israeli settlements and their factories nearby Hebron at towards the lands of Hebron and Bani Na'im, to Yatta, through Wadi al-Saman . In addition, the wastewater from the settlement of Atna'el flows through several areas to reach and pour into Wadi Samman to increase the flow of wastewater in this valley. [23]

Chapter Five

Ground Water Vulnerability Assessment

5.1 Introduction

5.1.1 The aim of Vulnerability Assessment

The concept of groundwater vulnerability is based on the assumption that the physical environment provides some natural protection to groundwater against human impacts, especially with regard to contaminants entering the subsurface environment. The aim of vulnerability assessment is providing information for decision making concerning management of water resources and land use as related to groundwater quality control. [3]

Groundwater vulnerability assessment approaches qualitative and quantitative approaches, that depending on local conditions and available data. Each of these approaches requires data that affect groundwater vulnerability, such as soil properties, hydraulic properties, precipitation patterns, depth to groundwater, and use and land cover, and other characteristics of the area to be assessed. [3]

5.1.2 Overview of Yatta Catchment

The importance of Yatta catchment springs and wells emerges from the fact that currently most of these springs and wells are the unique water supply source of the inhabitants. As a consequence, tankered-water access was mostly not possible and this put the available springs and dug wells under more pressure, which means that people tried to use every liter of the water for domestic use. [1]

There were 8 springs and dugs in Yatta, table 5.1 shows nitrate level exceeding the standard value, of which two of them show also the highest chloride level (Al-Karmel and Al-Twaneh) indicating pollution taking place mainly by mixing groundwater with sewage water. [1]

Table 5.1:The parameters for springs and wells of Yatta Catchment [1]

Name	Locality	pH	EC µS/cm	Turbidity NTU	DO mg/l	Saturation %	Hardness mg/l	Salinity %	TDS mg/l	TSS mg/l	TS mg/l	COD mg/l
Beirein*	Bani Naim	8	749	21	6.3	60	320	0.4	365	93	458	10
Al-Sahhaneieh*	Bani Naim	8.3	466	2.3	5.8	54.9	184.2	0.2	225	59	284	10
Om Rokbeh*	Bani Naim	7.9	511	1.1	5.8	55.8	184.2	0.2	247	73	320	10
Abu Khashabeh*	Bani Naim	8.3	446	1.4	52.6	49.3	184.2	0.2	215	13	228	10
Om Al-Shennar**	Bani Naim	8.3	427	4.7	5.5	52.6	164.9	0.2	206	100.67	306.7	17
AlKarmel/AlBerkeh**	Yatta	7.9	1142	1	7.2	73.3	455.8	0.6	562	472	1034	10
Al-Twaneh*	Yatta	8.3	982	1.4	7.1	6.9	358.8	0.5	482	390	872	4
Abo Ekraeim**	Yatta	8.3	391	5.1	8.4	85.4	223	0.2	195	151	346	56
Abo Shabban*	Yatta	8.2	625	1.4	7.7	77.7	242.4	0.3	304	209.33	513.3	49
Al-Deirat Al-Tehtani*	Yatta	7.9	538	1.5	6.3	62.1	203.6	0.3	261	152.33	413.3	56
Al-Deirat Al-Foqani*	Yatta	8.2	561	1.6	6.7	68.2	193.9	0.3	272	281.33	553.3	27
Al-Beidah**	Yatta	8.6	485	1.2	6.3	64.6	193.9	0.2	234	166	400	20
Erfaeyeh**	Yatta	8.9	642	3.1	6.4	66.6	281.2	0.3	312	228	540	10
Name	**Locality**	**Na+K mg/l**	**Ca mg/l**	**Mg mg/l**	**NH4 mg/l**	**NH4_N mg/l**	**Cl mg/l**	**HCO3 mg/l**	**NO3 mg/l**	**NO3_N mg/l**	**SO4 mg/l**	**TC coliforms/100ml**
Beirein*	Bani Naim	31.3	97.2	18.8	2.9	2.2	68	215.6	114	25.8	38	27
Al-Sahhaneieh*	Bani Naim	51.2	38.9	21.2	0.4	0.3	65	185.7	34	7.6	25	3
Om Rokbeh*	Bani Naim	41.5	58.3	9.4	0.9	0.7	49	201.7	17	3.9	26	2
Abu Khashabeh*	Bani Naim	38.7	64.1	5.9	1.1	0.8	37	236	4	0.8	15	303
Om Al-Shennar**	Bani Naim	33.3	52.5	8.2	0.4	0.3	47	152.1	30	6.8	25	0
AlKarmel/AlBerkeh**	Yatta	43.1	117	40	0	0	148	173.9	223	50.4	48	5
Al-Twaneh*	Yatta	51.1	101	25.9	0.1	0.1	122	142.7	174	39.3	59	80
Abo Ekraeim**	Yatta	41.2	73.8	9.4	0.1	0.1	39	274.7	4	0.9	22	300
Abo Shabban*	Yatta	29.1	66.1	18.8	0.1	0.1	86	137	74	16.8	23	45
Al-Deirat Al-Tehtani*	Yatta	24.9	60.2	12.9	0.1	0.1	60	147.5	38	8.6	25	100
Al-Deirat Al-Foqani*	Yatta	39	60.2	10.6	0.3	0.2	59	123.7	101	22.8	25	10
Al-Beidah**	Yatta	23.2	60.2	10.6	0.1	0.1	52	150.8	30	6.8	26	120
Erfaeyeh**	Yatta	24.7	81.6	18.8	0.2	0.1	59	211.4	66	15	34	20

*Dug Well **Spring

The other 3 wells and springs (which are also nitrate contaminated) are mainly contaminated by manure pollution distributed over their recharge areas especially that their chloride level is the same and is low. [1]

In comparison with Al-Arroub and Dura Catchments, this catchment springs and wells show lower hardness and TDS (salinity) probably due to the nature of the aquifer type and rock formations and to their less polluted recharge areas. [1]

5.1.3 Water classification for springs and dug wells in Yatta Catchment

There are four types for water based on organic dissolved compounds: [1]

1) Earth alkaline water with bicarbonate and chloride. 5 wells and springs demonstrated this type.
2) Earth alkaline water with prevailing chloride and is demonstrated by 1 well.
3) Earth alkaline water with increased portion of alkalis and with prevailing bicarbonate. 5 springs and wells demonstrated this water type.
4) Earth alkaline water with increased portion of alkalis and with prevailing sulphate and chloride. This type of water is demonstrated by 2 springs.

Table 5.2 defines the different water types with different types of rock formation [1]

Table 5.2: Water types of springs and wells in Yatta Catchment [1]

Name	Water Type	Emergent Formation	Aquifer
Beirein	Ca-Mg-HCO3-Cl	Yatta	Yatta local perched aquifer
Al-Sahhaneieh	Na-Ca-Mg-HCO3-Cl	Alluvial	Eocene-Alluvial aquifer
Om Rokbeh	Ca-Na-HCO3-Cl	Yatta	Yatta local perched aquifer
Abu Khashabeh	Ca-Na-HCO3	Yatta	Yatta local perched aquifer
Om Al-Shennar	Ca-Na-HCO3-Cl	Yatta	Yatta local perched aquifer
Al-Karmel/Al-Berkeh	Ca-Mg-Cl-NO3-HCO3	Alluvial	Eocene-Alluvial aquifer
Al-Twaneh	Ca-Mg-Na-Cl-HCO3-NO3	Yatta	Yatta local perched aquifer
AboEkraeim (Ekraymeh)	Ca-Na-HCO3	Yatta	Yatta local perched aquifer
Abo Shabban	Ca-Mg-Cl-HCO3	Yatta	Yatta local perched aquifer
Al-Deirat Al-Tehtani	Ca-Mg-HCO3-Cl	Yatta	Yatta local perched aquifer
Al-Deirat Al-Foqani	Ca-Na-HCO3-Cl-NO3	Yatta	Yatta local perched aquifer
Al-Beidah	Ca-HCO3-Cl	Alluvial	Eocene-Alluvial aquifer
Erfaeyeh	Ca-Mg-HCO3-Cl	Alluvial	Eocene-Alluvial aquifer

5.2 Pollution sources

Since springs or dug wells are draining water from the shallow water table aquifer, they are more susceptible of pollution. The study area hydrogeologic features facilitate even the springs/dug wells vulnerability to contamination attack. Karstic aquifers are extremely vulnerable to pollution due to their high porosity and permeability, due to the cracking, jointing, faulting, solution channels and fractures that dominate the calcareous rock formation. [1]

Springs or dug wells have water table depth ranging from 0 to 30 m, with an average of 5 m, below ground surface. It should be mentioned that most of the dug wells are Romans-built with stone casing from the inside allowing sufficient interstitial voids or spaces. Deep groundwater aquifers are more protected due to deeper rock beds barriers (high profile depth) that adsorb many contaminants and filter-off the percolating water to a certain degree due to longer traveling time of the recharge water. [1]

Both point and non-point sources of pollution are distinguished in the study area as shown in Map 5.1. These are consequences of the mismanagement in the land use or unavailability of urbanization sound planning and control. Eutrophication (excessive algal growth due to nutrients availability) was observed in many wells and springs. [1]

In the following paragraphs, the main sources of pollution presents in the area are discussed:

5.2.1 Wastewater

The results of laboratory tests for water samples taken by the Applied Research Institute - Jerusalem (ARIJ) 2007 showed that their biological load (BOD) exceeded 624 mg / L which is higher than the percentage Oxygen in the developed countries as well as Israel. Table 5.3 shows The Characteristics of Waste water in Wadi Al-Saman threatens the nature and the ecosystem and causes health and environmental damage and the emission of unpleasant odors, as well as providing an environment for breeding insects and the spread of epidemics and diseases. [21]

Table 5.3: Characteristics of Waste water in Wadi Al-Saman [21]

PH	Zn ppm	Pb ppm	Cr ppm	Cd ppm	Ni ppm	$NO3^-$ ppm	Cl^- ppm	TSS ppm	BOD ppm
7.82	0.339	0.000	1,278	0.030	0.041	2.27	575	1,370	624

It was also found that the concentration of nitrates in wells close to Wadi al-Saman is high compared to the recommended rate globally, due to the mixing of wastewater with well water. It is worth mentioning here that seven sewage pumping stations have been established in Wadi Al-Samman. These stations are expected to pump wastewater from Wadi Al-Saman to the eastern part of Yatta . However, for several reasons, these stations have not yet operated. [21]

The environmental impacts of the discharge of wastewater into the environment through Wadi al-Saman do not stop at the borders of the city of Yatta, south of the city of Hebron, but rather the whole of Hebron. The negative effects of wastewater flow through Wadi Al-Saman are the emission of unpleasant odors and the spread of harmful insects as well as the expected effects on the soil and its ecosystem through the accumulation of salts and solids in the soil. [21]

Where wastewater affects soil fertility by disrupting its components. The area of land affected by wastewater flowing into Wadi al-Saman is estimated at 500 dunums. Olive trees account for 90% of the affected crops, while almonds and vegetables make up 10% of these crops. It is worth mentioning that the phenomenon of irrigating the cultivated wastewater from the wadis is spread in the city of Yatta and the areas adjacent to Wadi al-Saman, which poses a threat to public health. In addition to the above mentioned Wadi Al-Samman is located above an area of operation that feeds the Eastern Basin. This is of great importance and seriousness. The discharge of wastewater over this area leads to pollution and deterioration of groundwater quality in this basin. The risks of untreated wastewater can be summarized in the Palestinian environment and public health: [21]

1) Drain water sources.
2) Deterioration of water quality.
3) Degradation of nature and biodiversity.
4) Distort the scene and aesthetic values.
5) Localization of insects and unpleasant odors.
6) Spread of epidemics and population exposure to disease.

In the field of solid waste management, the main landfill in the Hebron governorate, which is estimated to be about 200 dunums, is 9 km from the city of Yatta. The landfill is currently being used by most areas of southern Hebron as well as areas in Bethlehem governorate and settlements around Yatta. The wastes are randomly received inside the landfill so that they remain exposed to the surrounding atmosphere, causing the multiplication of flies, harmful insects and rats, as well as the unpleasant odors that are emitted, and then be disposed of by burning them completely, which causes the air pollution of smoke and gases. This has an impact on human and environmental health. [21]

The main problems in the town of Yatta are the Israeli forces' confiscation of the lands of Yatta, the bulldozing and the uprooting of its trees. The isolation of agricultural land behind the wall leads to the deterioration of agricultural land as a result of the lack of access to and access to these lands. In addition, the problem of the flow of wastewater in Wadi Al-Saman as shown in figure 5.1 poses a great danger as it threatens the public health and the environment in the town. Wastewater pools are a breeding ground for insects and the spread of diseases borne by these waters, adding to the bad smell caused by the dangers of irrigation of plants with such water. [21]

Figure 5.1 : Sewage flow from Hebron city. *[1]*

5.2.2 Agricultural sources: manure, fertilizers and plant residues

Pesticide use in the Yatta has been highlighted in some reports as a potential environmental problem. According to the EQA, more than 120 pesticides are in use by Palestinian farmers, and several are banned internationally (e.g., DDT). Methyl bromide is still also used by farmers for soil sterilization, although significant efforts have been made to eliminate it use by Palestinian organizations. EQA has reported that more than 1,500 (metric) tons of methyl bromide is used annually in the Yatta, mostly in the latter. [24]

Fertilizer use is reported as excessive. Both organic and inorganic (e.g., "super-phosphate) fertilizers are used, on the order of 30,000 tons annually in the West Bank and Gaza Strip. The governorates of Tulkarm, Jericho and Jenin represent the major users and generators of agricultural waste products in the West Bank. [24]

Uncontrolled use of pesticides and fertilizers are particularly problematic from an aquifer protection point of view, and if the agricultural sector grows according to forecasts (in line with availability of treated wastewater), then quantities are also expected to grow. [24]

The quantities of manure of animals are collected, stored and applied to the land in improper methods as shown in figure 5.2. The distribution of manure over the arable lands exceeds the plant nutrient requirement for Nitrate and Phosphate. Heaps of manure allows nutrient wash out to the water bearing layers. In some areas of the study catchments manure heaps are washed by storm water from the up-stream to stay close to springs sites at the downstream. [1]

Figure 5.2: Manure accumulation at up-stream. [1]

5.2.3 Solid Waste

Solid waste disposal practices in Yatta are potentially a major contributor to aquifer pollution. Lack of management and collection services, uncontrolled dumping, and open burning are the norm. There is no separation of waste, and historically, dumping sites have been started out of necessity and without specific concern for groundwater quality. During interviews, several municipalities report that attempts have been made to obtain necessary permits to construct sanitary landfills, but because these mostly fall within C Areas, permits have been difficult to obtain. [24]

Dumping sites are believed to be more localized “point” sources of potential groundwater pollution, but there are no suitable monitoring systems in place to measure any chemicals or metals that may periodically leach to the underlying aquifers. [24]

There are no engineered sanitary landfills in operation in the West Bank, however, projects for sanitary landfills are underway in Jenin (at Zahrat Finjan), Ramallah/Al-Bireh (near Deir Dibwan), and Hebron (in Yatta) under World Bank financed initiatives. [24]

5.2.4 Industrial and Hazardous Waste

While the Palestinian industrial sector in the West Bank is considered small, and there is a general lack of heavy industries, there are nevertheless industries and industrial areas that use hazardous raw materials. There is currently no inventory kept of raw materials used – hence, there is no detailed (even basic) understanding of the types and quantities of chemicals used and handled. [24]

Several Israeli industrial zones have been established within the West Bank (e.g., Atarot, Mishor Adumim, Barkan, Nizzane Shalom, Karnei Shomron, Kedumim). It is estimated that Israeli industries include manufacturers of pesticides and fertilizers, glass fiber, flammable gas, textiles, and plastics industries.[21] Some of this information has been verified by this assessment, but details on Israeli industries are required to draw definitive conclusions about their nature and potential impacts. [24]

Chapter six:

On ground points of source; Results and analyses

6.1 Introduction

Yatta in total has 14 springs and dug wells as mentioned in previous chapters with a totally discharge estimated in a study held by (PHG) in 2005 to be $90m^3$. Recently, the municipal boundaries were limited, and so the study area was chosen to be within the scope of the municipality. Among all the tanks that feed Yatta, Hrez tank shown in figure 6.1, is the main source that still works in a safe condition controlled by the municipality. Al-Riyihiya well is considered as a second main source, but only the Palestinian water authority in Hebron is allowed to manage it [20]. Alkarmel spring, shown in figure 6.2, despite its contamination mainly by manure pollution distributed over their recharge areas especially that their chloride and Nitrate levels are high, it is an open source and a few people still take it as a supply source. [1].Aziz well , shown in figure 6.3 is found to be polluted by highly nitrate level , it used to be a drinking source to all families near it and they has been told the last three years to not use it again.

Figure 6.1: Hrez tank- yatta

Figure 6.2: Alkarmel spring-yatta

Figure 6.3: Aziz well - yatta

6.2 Field visit

In Feb 2019, a visit to the study area was planned to collect samples of Yatta main sources to study and observe ON GROUND POINT OF SOURCES where the coordinates were recorded by GPS test plus phone application, and to track problems source and control them by mitigation of industrial and population daily activities in Yatta. It has been found that families tend to use drinking wells mixed the water come from municipality with rainwater. Several studies showed cases of contamination in these wells from soil and environment polluted by septic tanks that exists in every house in Yatta. [21]

Based on previous circumstances, samples of Al-Riyihiya well, Hrez tank, Alkarmel spring and Aziz well were taking to be tested, map 6.1 shows the location of the four main sources and how Al-Riyihiya well is out of municipality control. Another 20 random samples of home drinking wells were collected. Map 6.2 shows the distribution of the samples collected in the study area.

Nitrate and chloride were chosen to be tested under climate and seasonal changes, so the next visit was in April 2019, where rain effect on these concentrations was considered. Figures (6.4 to 6.7) show the water samples collected for testing. Chloride tests weren't available so the study was limited on Nitrate.

Figure 6.4 : sample collected for Hrez tank in April 2019.

Figure 6.5: sample collected for a random home drinking well in April 2019.

Figure 6.6 : sample collected for a random home drinking well Feb 2019 .

Figure 6.7: sample collected for Alkarmel spring in Feb 2019.

6.3 Testing program

The tests were done with the corporation of Water Quality Laboratory - Hebron Municipality using Cadmium Reduction Method. It’s a colorimetric method that involves Cadmium metal (powder) reduces nitrate in the sample to nitrite. The salt couples form a red colored solution. The red color is then measured by electronic spectrophotometer that measures the amount of light absorbed by the treated sample at 500 nm wavelengths for spectrophotometers or 520 nm for colorimeters. The absorbance value is then converted to the equivalent concentration of nitrate. Figures (6.8 to 6.15) show the testing procedure.

Figure 6.8: samples were prepared to be tested.

Figure 6.9: the red colored of the wells samples after adding the powder to measure the absorbance.

Figure 6.10: samples were put in cuvettes.

Figure 6.11: samples of expected high conc. were diluted.

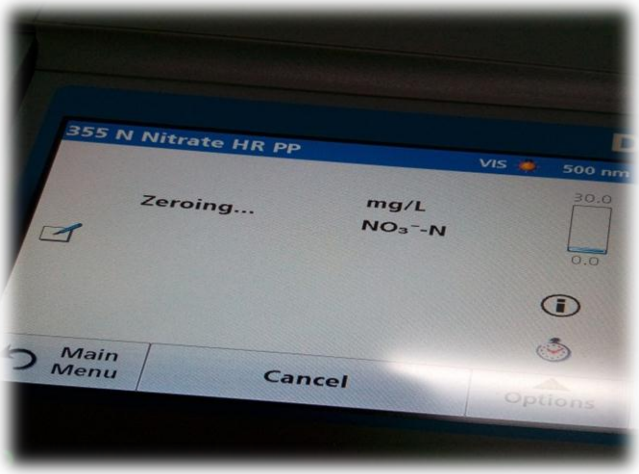

Figure 6.12: spectrophotometer was zeroed by a blank every sample.

Figure 6.13: the cuvettes were put in the spectrophotometer to be tested

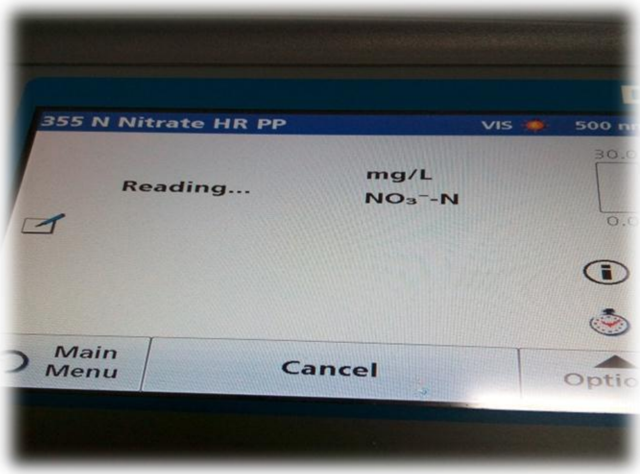

Figure 6.14: absorbance of samples was measured.

Figure 6.15: the concentration of a measured sample.

6.4 Results and analysis

The standard value for nitrate is 50 mg/l according to (WHO). This value is based on epidemiological evidence for methemoglobinemia in infants (WHO), which results from short-term exposure. According to (PSI), the standard value for nitrate is 50 mg/l and it's allowed to be 70 mg/l in emergencies. It's obvious from tables 6.1 and table 6.2 that the nitrate concentrations of the homes wells are within public health safe values of nitrate. However, table 6.3 and table 6.4 show that Al-Riyihiya well and Hrez tank have an acceptable concentration, whereas Alkarmel spring and Aziz well have high nitrate concentrations that reveals a highly contamination characterized by livestock, Poultry farms, fertilizers and septic tanks, since springs or dug wells are draining water from the shallow water table aquifer, they are more susceptible of pollution. Map 6.3 shows some of the pollution sources almost around every taken sample classified into agricultural like greenhouses and olives farms, industrial like stonecutting and chemical factory and finally infrastructure that includes fuel station and car washing, etc.

In addition to the limited possibilities of treatment and maintenance allowed in Yatta , discharges of wastewater from septic tanks as well as the intensive and uncontrolled use of chemical fertilizer in agriculture, overgrazing and transhumance form in total a burden on water sources and its safety along years ago. Nitrates in West Bank wells monitored by PWA in 2012 shown in figure 6.16 below. The sensitivity of the Karst aquifers to pollution enlarges the problem.

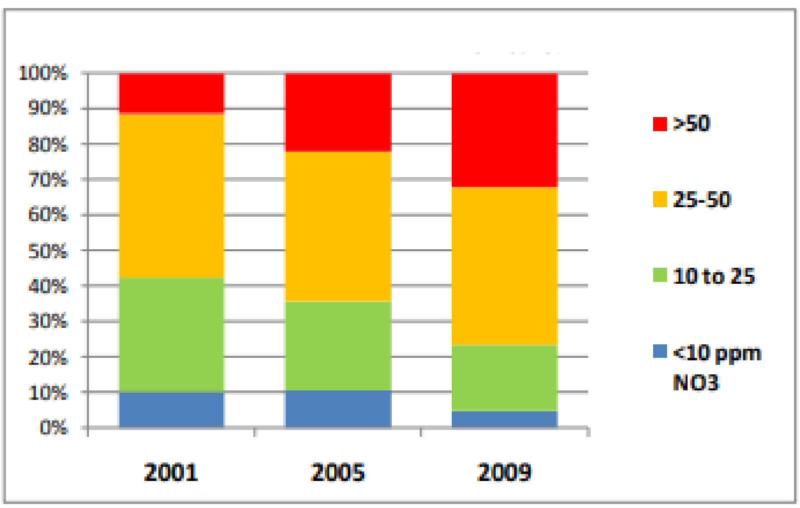

Figure 6.16: nitrates in West Bank wells monitored by PWA in 2012

Table 6.1: Test results of the main sources collected in Feb 2019

name	Longitude(x)	Latitude(y)	Ph	TDS (mg/l)	Conductivity (μs)	NO3-con (mg\l)
Hrez tank	35°7'21.623"E	31°28'21.734"N	7.55	147.2	247	2.6
			7.69	150.1	242	2.8
Karmel spring	35°8'6.282"E	31°25'26.818"N	7.44	744	925	124
			7.51	953	1585	119.5
Aziz well	35°5'14.58"E	31°25'41.436"N	7.7	462	811	46.5
			7.68	489	799	45.5
Al-Rayhia tank	35°4'33.683"E	31°27'24.605"N	7.55	371	619	3.1
			7.53	372	622	2.7

Table 6.2: Test results of the main sources collected in April 2019

name	Longitude(x)	Latitude(y)	Ph	TDS (mg/l)	Conductivity (μs)	NO3-con (mg\l)
Hrez tank	35°7'21.623"E	31°28'21.734"N	8.22	218	452	2.6
			8.5	223	450	2.8
Karmel spring	35°8'6.282"E	31°25'26.818"N	7.78	895	1.81(ms)	126.5
			7.68	900	1.56(ms)	124.2
Aziz well	35°5'14.58"E	31°25'41.436"N	8.09	398	828	36.5
			8.1	380	830	35.2
Al-Rayhia tank	35°4'33.683"E	31°27'24.605"N	7.5	351	615	3
			7.65	365	620	2.5

Table 6.3: Test results of the samples collected in Feb 2019

name	Longitude(x)	Latitude(y)	Ph	TDS (mg/l)	Conductivity (µs)	NO3- con (mg\l)
محمد حسين الطحان	35°5'45.863"E	31°26'36.046"N	7.68	309	516	3
مؤنس عيسى جبارين	35°6'8.578"E	31°26'51.172"N	7.52	367	616	6
مدرسة ذكور ابن تيمية	35°6'54.583"E	31°27'29.22"N	7.66	347	584	3.4
دار العزب	35°6'56.986"E	31°27'55.497"N	7.66	313	513	1.9
احمد محمد مخامرة	35°7'4.855"E	31°28'0.359"N	8.5	294	490	2.6
راغب محمد الشواهين	35°4'29.206"E	31°27'23.665"N	8.15	291	489	3.3
ملحمة المدينة المنورة	35°4'42.253"E	31°26'46.998"N	8.178	368	610	1.6
نافذ ابو زهرة	35°4'33.683"E	31°27'24.605"N	8.09	264	442	2.6
محمود أبو علي	35°5'15.102"E	31°26'35.345"N	8.06	140	232	2.3
بدر الهدار	35°5'53.389"E	31°26'0"N	7.9	334	558	7.5
موسى محمد منصور	35°5'51.068"E	31°27'11.607"N	8.02	397	656	2.9
محمد محمود حوشية	35°5'44.765"E	31°27'21.79"N	8.25	279	463	5.4
عيسى يوسف	35°5'38.448"E	31°27'4.04"N	7.89	3.86	6.44	2.5
اسماعيل محمد عبد ربه	35°5'44.765"E	31°27'21.646"N	7.99	146.3	244	3.5
خزان البلدية	35°5'22.874"E	31°26'53.686"N	7.98	354	593	1.9
الحجة- الخضر	35°5'23.394"E	31°26'53.274"N	7.81	340	563	5.8
محمد حسين اليمني	35°5'24.193"E	31°26'53.96"N	8.11	322	543	2.7
ملحمة ابو سمرة	35°5'33.82"E	31°26'47.053"N	7.8	326	541	2.6
عيسى ابو عزيز	35°5'48.39"E	31°26'23.219"N	7.56	288	482	2.6

Table 6.4: Test results of the samples collected in April 2019

name	Longitude (x)	Latitude(y)	Ph	TDS (mg/l)	Conductivity (µs)	NO3- con (mg\l)
محمد حسين الطحان	35°5'45.863"E	31°26'36.046"N	8.42	283	498	3
مؤنس عيسى جبارين	35°6'8.578"E	31°26'51.172"N	8.07	245	512	3
مدرسة ذكور ابن تيمية	35°6'54.583"E	31°27'29.22"N	8.35	256	514	1.7
دار العزب	35°6'56.986"E	31°27'55.497"N	8.26	144	301	2.3
احمد محمد مخامرة	35°7'4.855"E	31°28'0.359"N	8.02	183.6	384	3.4
راغب محمد الشواهين	35°4'29.206"E	31°27'23.665"N	8.53	275	577	3.1
ملحمة المدينة المنورة	35°4'42.253"E	31°26'46.998"N	8.16	312	657	7.1
نافذ ابو زهرة	35°4'33.683"E	31°27'24.605"N	8.5	253	586	2.6
محمود أبو علي	35°5'15.102"E	31°26'35.345"N	8.65	245	565	3.5
بدر الهدار	35°5'53.389"E	31°26'0"N	8.35	162	475	2.7
موسى محمد منصور	35°5'51.068"E	31°27'11.607"N	8.46	224	491	3.2
محمد محمود حوشية	35°5'44.765"E	31°27'21.79"N	8.31	163	382	2.5
عيسى يوسف	35°5'38.448"E	31°27'4.04"N	8.6	186	387	3.9
اسماعيل محمد عبد ربه	35°5'44.765"E	31°27'21.646"N	7.98	296	617	2.9
خزان البلدية	35°5'22.874"E	31°26'53.686"N	8.23	252	523	3.2
الحجة- الخضر	35°5'23.394"E	31°26'53.274"N	8.37	244	513	2.7
محمد حسين اليمني	35°5'24.193"E	31°26'53.96"N	8.11	283	595	5.7
ملحمة ابو سمرة	35°5'33.82"E	31°26'47.053"N	8.1	236	328	3
عيسى ابو عزيز	35°5'48.39"E	31°26'23.219"N	8.16	191	404	2.5

Comparing the results of the two periods of sampling, it seems that the concentrations decreased by percentages range from 5% to 60 % of its primary values. The expected explanation of this decrease is mainly due to quantities of rain collected due harvesting, this must give an indication that families in Yatta rely mainly on rain water. Figure 6.17 and figure 6.18 show how nitrate concentrations in the main sources and the collected samples, respectively vary with time

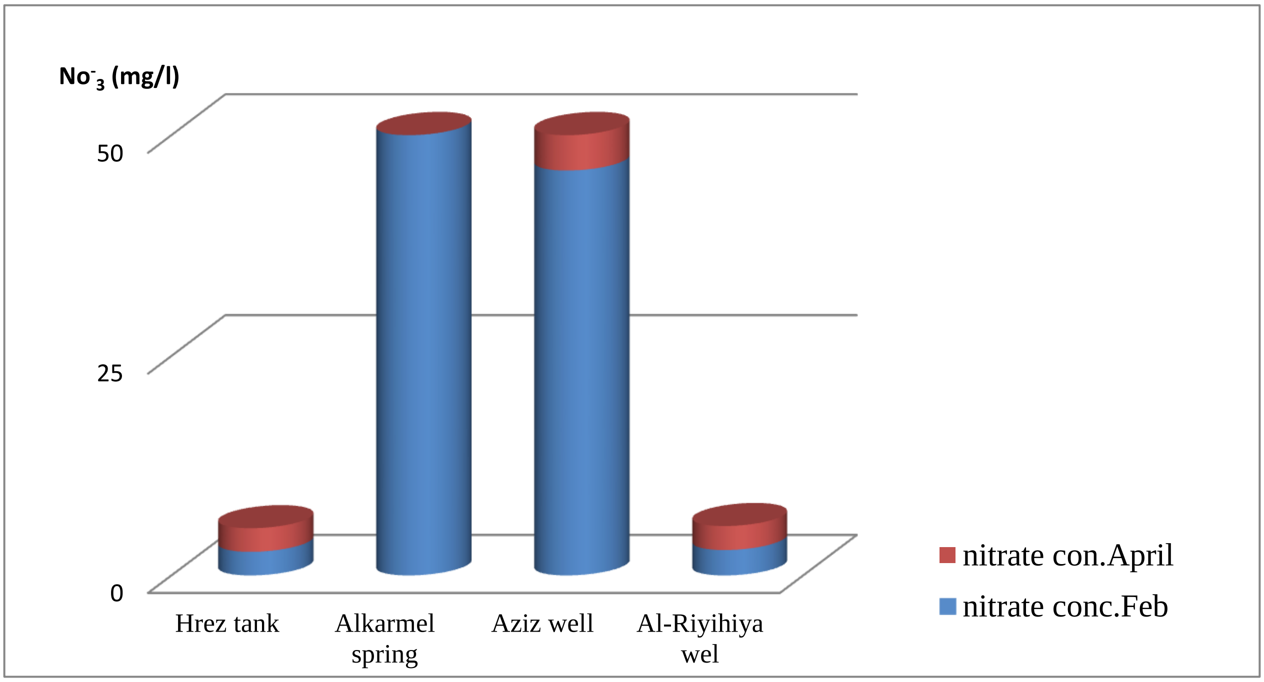

Figure 6.17: variation of Nitrate concentration of main sources with time.

As the massive use of fertilizers and the human and animal excreta contamination leached by septic tanks or farms and live stocks, nitrate can reach both surface water and ground water [25]. Nitrate has been one of the dominant forms of increased Nitrogen loading since the 1970s [26]. Nitrogen in surface waters has a variety of sources including atmosphere deposition and dust in rainwater that has been observed to have a concentration of nitrate up to 5 mg/l [25].

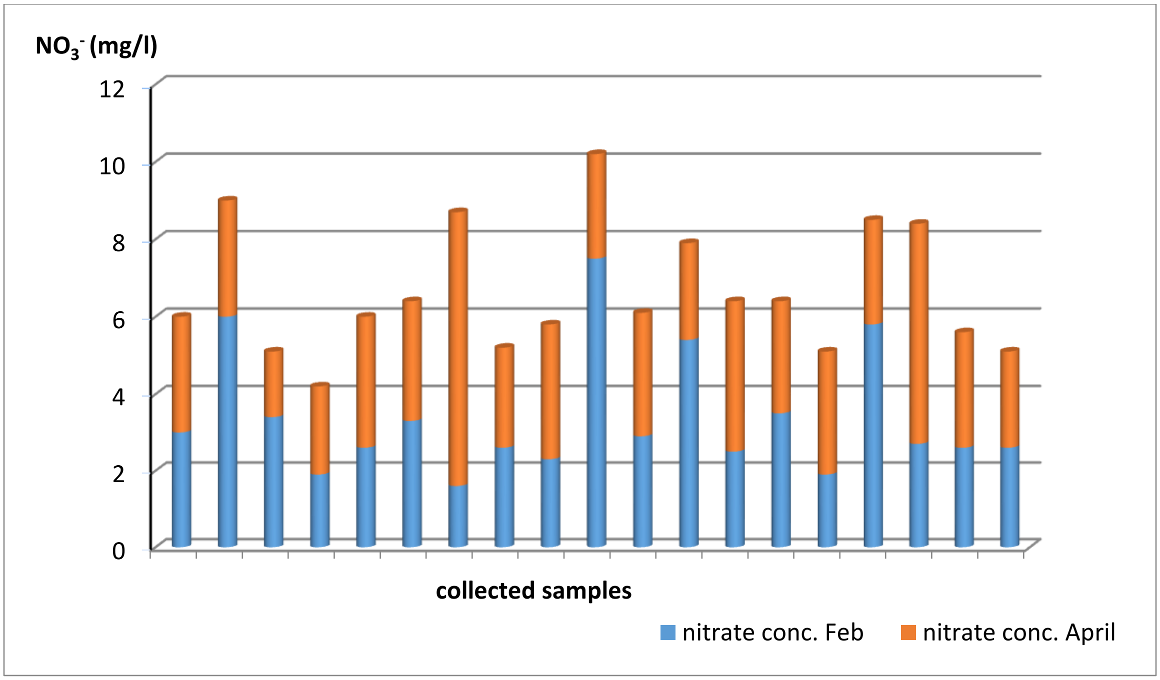

Figure 6.18: variation of Nitrate concentration of collected samples with time.

It should be mentioned that 1 pound of nitrogen per 1000 $ft.^2$ indicates that there is no leaching, the rate of fertilizers releasing to the ground water, the plants nitrogen uptake, irrigation practices and soil texture control the nitrate leaching to the groundwater as climate conditions do [27]. Temperature and precipitation are both important environmental co-factors affect the nitrate leaching. Higher average temperatures result in lower nitrate contamination of groundwater, possibly due to increased evapotranspiration. Higher average precipitation dilutes nitrates in the soil, further reducing groundwater nitrate concentration [28].

Chapter seven:

Vulnerability assessment using DRASTIC method

7.1 Method of assessment using DRASTIC model:

As previously mentioned in chapter three, DRASTIC model is based on assigning weights and ratings for each of the seven parameters of the DRASTIC equation, refer to table 3.1.

The DRASTIC index equation sums the effects of weight and rating of each parameter as follows:

$$DI = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw \quad \ldots\ldots\text{(1)}$$

Where;

D_R	rating of depth to water factor
D_W	weight of the depth to water factor
A_R	rating of net recharge factor
A_W	weight of net recharge factor
S_R	rating of soil media factor
S_W	weight of soil media factor
T_R	rating of topology factor
T_W	weight of topology factor
I_R	rating of impact of vadose zone factor
I_W	weight of impact of vadose zone factor
C_R	rating of hydraulic conductivity factor
C_W	weight of hydraulic conductivity factor

7.2 DRASTIC parameters

DRASTIC factors represent measurable parameters for which data are generally available from a variety of sources without a detailed reconnaissance. [29]

The most important mappable factors that control the groundwater pollution potential were determined to be: topography, soil media, aquifer media, net recharge, depth to water table, hydraulic conductivity and the impact of the vadose zone. [29]

1- *Depth to water table (D):*

It is an important factor in vulnerability assessment, because this depth affects the dispersion of pollutants from surface to underground, it is the thickness the pollutant travels from surface to groundwater aquifer.The depth is inversely proportional to vulnerability, the shallower the water table is, the more vulnerable the aquifer. There is a greater chance for attenuation to occur with increase in depth because deeper water level means longer travel time. [30]

The depth to water table for the study area was calculated by subtracting the water level elevation from ground surface elevations , the depth ranges from 15 to 205 (m). Table (7.1) shows the ratings for different depth ranges

Table 7.1: Ratings of Depth to Water Table [30]

Range (feet)	Rating
0-5	10
5-10	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1

Map (7.1) shows the distribution of ranges of depth across the study area.

2- Net recharge (R)

It is the amount of water per unit area of land penetrating the ground surface annually, thus it affects vulnerability proportionally, the more recharge there is per year, the greater the chance of contaminants to be transported to the aquifer [31].Recharge values and ratings are shown in table (7.2)

Table 7.2: Ratings of Net Recharge [30]

Range (inches)	Rating
0-2	1
2-4	3
4-7	6
7-10	8
10+	9

Map (7.2) shows the distribution of ranges of recharge across the study area

3- Aquifer media (A)

Aquifer media refers to the consolidated or unconsolidated medium which serves as an aquifer, an aquifer is the medium that yield sufficient water for use. Thus, the larger the grain size, and the more fractures and openings within the aquifers, the higher the permeability and consequently, the greater the pollution potential [30].

The rate of movement of pollutant depend on the geological formation of the aquifer, the aquifer has three types of formations as follows:

1- Senonian: consist of Marl, Chalk, Limestone and Chert rocks.
2- Turonian:consists of, Dolomite and limestone with often thin plated and with slight Marl intercalations.
3- Upper Cenomanian, which is mostly a white massive Limestone with Stilolites, Dolomite and thin bedded Limestone.

The rating for each type is shown in table (7.3).

Table 7.3: Ratings of Aquifer Media [30]

Range	Rating	Typical rating
Massive Shale	1-3	2
Metamorphic/ Igneous	2-5	3
Weathered Metamorphic/ Igneous Thin Bedded Sandstone	3-5	4
Limestone, Shale Sequences	5-9	6
Massive Sandstone	4-9	6
Massive Limestone	4-9	6
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	9-10	10

Map (7.3) shows the distribution of ranges of aquifer media across the study area

4- *Soil media (S)*

Soil media is the upper layer of the vadose zone characterized by high biological activity.The travelling time of pollutants is affected by the thickness and type of soil layer, the pollution potential depends on the type of clay and its shrinkage and swelling properties; the less the ability of clay to shrink and swells, and the smaller the grain size, the less the pollution potential. [30]

The soil types of the study area are shown in table (7.4) and the rating for each type is shown in table (7.5).

Table 7.4: Characteristics and classification of soil types of the study area. [32]

Soil Type	Soil American Classification	General Characteristics
Brown & Pale Rendzina	Xerorthents and Haploxerolls	Texture is loamy or clay, about 30% is stony. Parent material is soft chalk and marl.
Dark Brown Soil T a	Xerorthents and Haploxerolls	Coarse textured residual dark brown soil. Parent rocks are Aeolian sediments, calcareous sandstone and medium to fine textured alluvial deposits, sandy loam.
Terra Rosa	Xerorthents	Reddish clay to silty clay texture. Parent material, limestone and dolomite.
Dark Rendzina, Bright Rendzina	Xerorthents	Clay texture.
Terra Rosa, Rendzina	Xerorthents and Haploxerolls	Terra Rosa: parent material, dolomite and hard limestone

Table 7.5: Ratings of Soil Media [30]

Range	Rating
Thin or Absent	10
Gravel	10
Sand	9
Shrinking and /or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay or Loam	3
Non-shrinking and non-aggregated clay	1

Map (7.4) shows the distribution of ranges of soil media across the study area.

5- *Topography(T)*

Refers to slope and slope variability of the land surface, the topography influences the time a pollutant will remain on surface, thus the infiltration into groundwater, the lower the slope the higher the infiltration and the higher pollution potential. [30] The rating for each type is shown in table (7.6).

Table 7.6: Ratings of Topography [30]

Range	Rating
0-2	10
2-6	9
6-12	5
12-18	3
18+	1

Map (7.5) shows the distribution of ranges of slope across the study area.

6- *Impact of vadose zone(I)*

The vadose zone is the unsaturated zone above the water table, type of media affects the length of path and routing, thus affects time available for attenuation to occur. [30] The rating for each type is shown in table (7.7).

Table 7.7: Ratings of Impact of Vadose Zone [30]

Range	Rating	Typical rating
Silt/ Clay	1-2	1
Shale	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Bedded limestone, sandstone, shale	4-8	6
Sand and gravel with significant silt and clay	4-8	6
Metamorphic/ igneous	2-8	4
Sand and gravel	6-9	8
Basalt	2-10	9
Karst limestone	8-10	10

Map (7.6) shows the distribution of ranges of vadose zone across the study area.

7- *Hydraulic Conductivity (C):*

Refers to the ability of the aquifer material to transmit water, which in turn controls the rate at which groundwater will flow under a given hydraulic gradient, thus controlling the rate of movement of a contaminant [30].Higher hydraulic conductivities will allow pollutants to move at higher rate from the point it's introduced in the aquifer, thus higher pollution potential. The rating for each type is shown in table (7.8).

Table 7.8: Ratings of Hydraulic Conductivity [30]

Range (GPD/ft^2)	Rating
1-100	1
100-300	2
300-700	4
700-1000	6
1000-2000	8
2000+	10

Where; GDP= gallon per day.

Map (7.7) shows the distribution of ranges of hydraulic conductivity across the study area.

7.3 GIS method in developing the model

- All maps were derived from earlier study for the same study area, whereby a vulnerability map that combined factors related to DRASTIC factors was developed, using a different model to produce the map.
- In ArcMap, weight and rating fields were added to the attribute table or each map, and then multiplied in another field = weight *rate, using field calculator tool.
- Each resulting map was then converted into raster form.
- The raster layers were combined into one layer that has the DRASTIC index values using "Raster Calculator" tool from the Arc Tool Box as shown in figure (7.1)

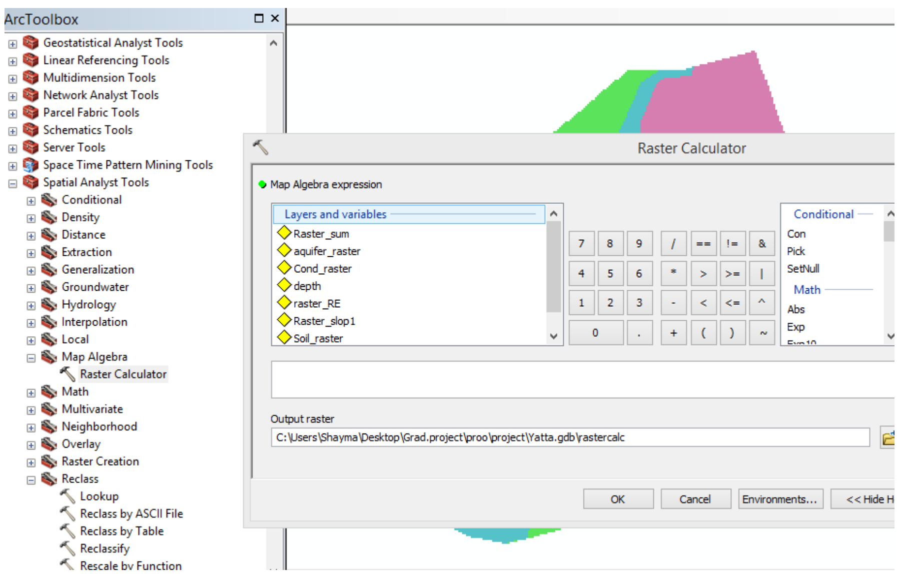

Figure 7.1 Combining the raster maps using Raster Calculator

- The value of the DRASTIC index in final layer was reclassified into 5 classes using "Reclassify" tool from the Arc Tool Box as shown in figure 7.2

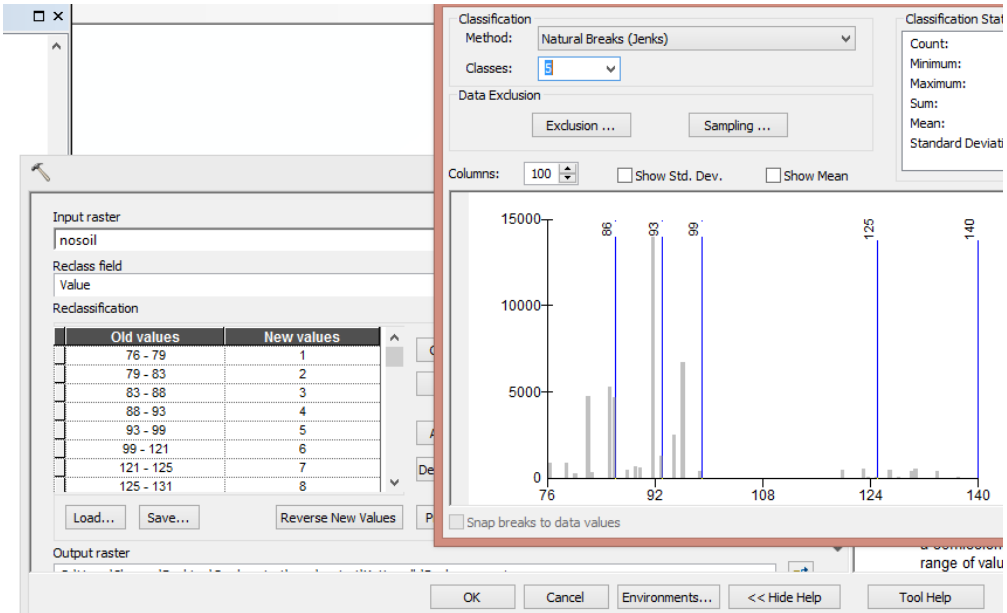

Figure 7.2: Classification of DRASTIC index values into five classes

- The classification is based on the range of values compared to previous studies with the same or similar ranges, and that vulnerability potential increases with higher DI values. [33]

- Range of DRASTIC index was from 78 to 151.

Map (7.8) is the DRASTIC vulnerability map with DI ranges.

7.4 Results and Analysis

The final results as shown in table (7.9) indicate that 30% of Yatta Aquifer lies in the very low vulnerable area, while 50% of the lies has low vulnerability to pollution, and 18% of the aquifer has moderate vulnerability to groundwater pollution and finally, 3% and 4% of the aquifer are of high and very high vulnerability of groundwater to pollution respectively.

Table 7.9 Final results of DRASTIC index classification

Range DI	Class Description
78-92	Very low
92-102	Low
102-119	Moderate
119-135	High
135-151	Very high

- Then to compare the effect of each factor with the others; a parametric study was conducted by eliminating each parameter from the final raster map interchangeably, and re-combine the other remaining factors, which resulted in 7 maps with different DI values as follows:

1) *Elimination of Depth To Water factor:*

   Map (7.9) shows the DI values and vulnerability map resulting after removal of D factor; whereas the values decreased, the minimum DI is 66, and the maximum is 104 while when including the D factor, the minimum was 78, which indicates that the D parameter has significant impact on the vulnerability of the aquifer, as theoretically expected, whereby, adding the depth factor will increase the DI value and thus vulnerability.

2) *Elimination of Net Recharge factor:*

   Map (7.10) shows the DI values resulting from removal of the R factor, whereas the values decreased by less magnitude, the minimum DI is 66 and the maximum is 139, while when including the R factor, the minimum was 78, and the maximum was 151, this indicates that recharge has less effect on vulnerability than depth to water table.

3) *Elimination of Aquifer media factor:*

Map (7.11) shows the DI values resulting from removal of the A factor, whereas the values decreased by higher magnitude than both depth and recharge, such that the range of values has shifted substantially, the minimum DI is 48 and the maximum is 127, while when including the A factor, the minimum was 78, and the maximum was 151; which indicates that aquifer media is a limiting factor and has significant effect on vulnerability and its removal will neglect a whole range of vulnerability of the study area.

4) *Elimination of Soil media factor:*

Map (7.12) shows the DI values resulting from removal of the S factor, where there's slight difference in DI values, the minimum DI is 76 and the maximum is 140, while when including the S factor, the minimum was 78, and the maximum was 151; this indicates that soil media has less effect on vulnerability than previous factors and may be negligible.

5) *Elimination of Topology factor*

Map (7.13) shows the DI values resulting from removal of the T factor, where DI values decreased almost by magnitude close to the (D) factor, but range closer the whole vulnerability DI range. The minimum DI is 66 and the maximum is 147, while when including the T factor, the minimum was 78, and the maximum was 151; this indicates that topology has less effect on vulnerability but may not be negligible.

6) *Elimination of Impact of Vadose zone factor:*

Map (7.14) shows the DI values resulting from removal of the I factor, where there's similar difference in DI values to the effect of removing T factor, the minimum DI is 62 and the maximum is 132, while when including the I factor, the minimum was 78, and the maximum was 151; which indicates that I factor has less effect on vulnerability but may not be negligible.

7) *Elimination of Hydraulic Conductivity factor:*

   Map (7.15) shows the DI values resulting from removal of the C factor, where there's similar difference in DI values to the effect of removing T and I factors, the minimum DI is 60 and the maximum is 130, while when including the C factor, the minimum was 78, and the maximum was 151; which indicates that I factor has less effect on vulnerability but may not be negligible.

Comparing the results shown in table 7.10 of a vulnerability assessment from the study area derived from the DRASTIC with PI method [3], it has been found the variation of percentages of risk levels is based on the used factor in each model.

There is a noticeable increase in areas that lie in the low and moderate level of risk due to the increase in the buildup areas, which create a heavy burden as the use of septic tank and the daily activities that may pollute the surrounded environment.

An increase have been found in the high and very high areas that lie at the boundaries of the study area due to the olives trees that result in high contamination because of the increased use of pesticides.

Table 7.10: Final results of DRASTIC index classification

Risk level	PI method	Drastic model 2018
very low	52.6%	30 %
Low	12.8%	50%
Moderate	33.5%	18 %
High	0.9%	3%
Very high	0.2%	4%

Chapter Eight:

Landuse Analysis

8.1 Introduction

Land is definitely one of the most important natural resources, since life and developmental activities are based on it. Land use refers to the way in which land has been used by humans and their habitat, usually for economic activities [34]. It also refers to evaluation of the land with respect to various natural characteristics. [35]

The land use of a region is a conclusion of natural and socio-economic factors and their consumption by man in time and space. Land use data are essential for planners, decision makers and those concerned with land resources management. Monitoring and analysis of the urban environment make use of up-to-date Landuse information, for proficient and sustainable management of urban areas. [35]

The advent of geographic information system (GIS) has made it possible to integrate multisource and multidate data for the generation of landuse changes involving such information as the trend, rate, nature, location and magnitude of the changes. [35]

8.2 Landuse Mapping Methodology

1. Georeferencing

Georeferencing of raster images is a very vital procedure and has a unique aim of building a more direct association between the biophysical phenomena on the ground and the acquired data [36]. The image was geometrically co-registered using four ground control points into Palestine Grid 1923 projection as shown in figure 8.1. The ground control points (GCPs) are known ground points whose positions can be accurately located on the digital imagery. Such features include road intersections, corners of open field or lawns. [35]

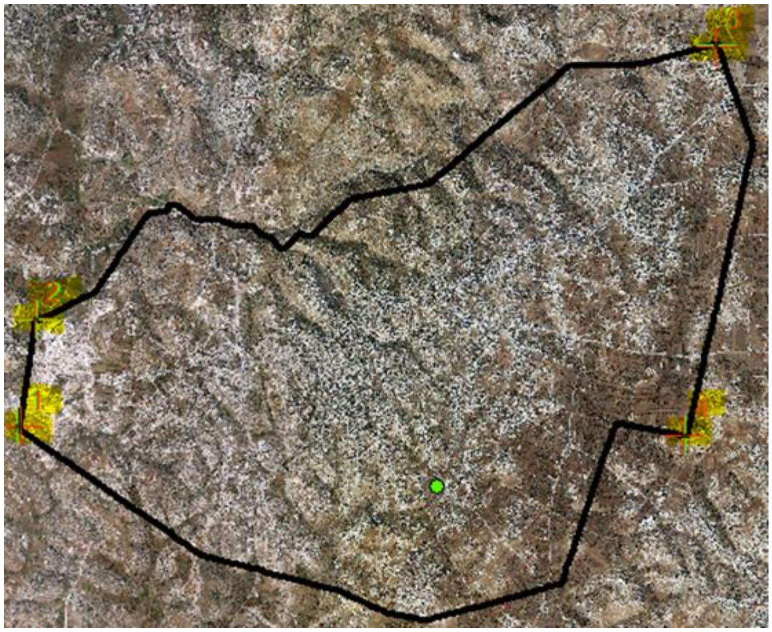

Figure 8.1:Ground Control Points (GCPs)

The Georeferencing toolbar is used to georeference raster as shown in figure 8.2.

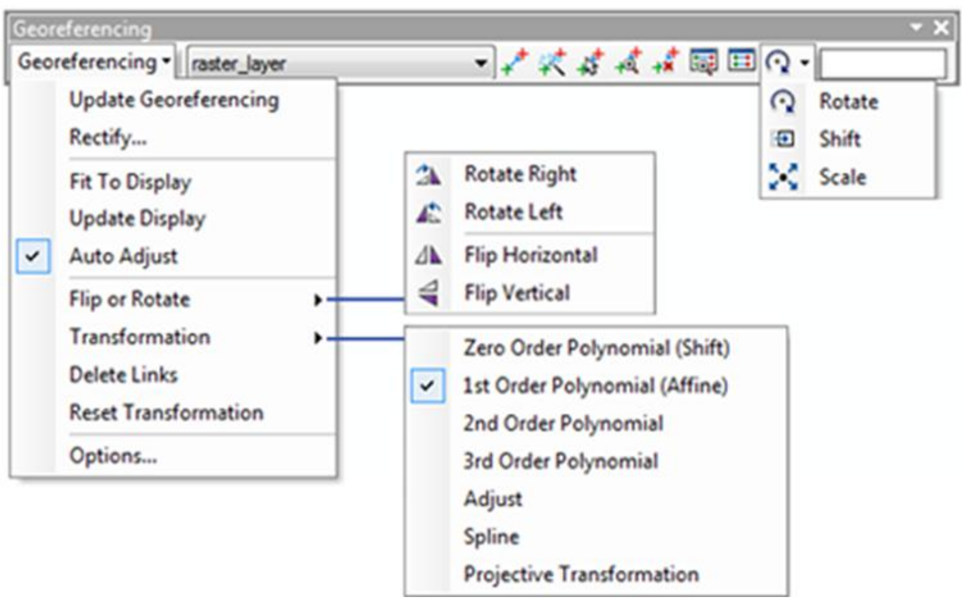

Figure 8. 2:The Georeferencing toolbar

2. Classification by Editing

Classification was carried out for the year 2011, and 2018 was produced for the study area by geographical information system Editing. GIS allows you to create and edit several kinds of data using the Editing toolbar as shown in figure 8.3. It can be edit feature data stored in shape files and geodatabases, as well as various tabular formats as shown in figure 8.4. This includes points, lines, polygons, text (annotations and dimensions), multipatches, and multipoints. You can also edit shared edges and coincident geometry using topologies and geometric networks.

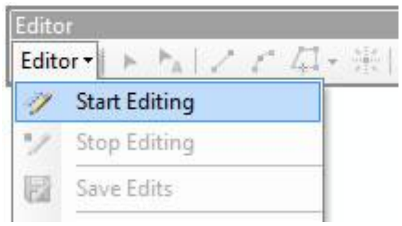

Figure 8.3: The Editing toolbar

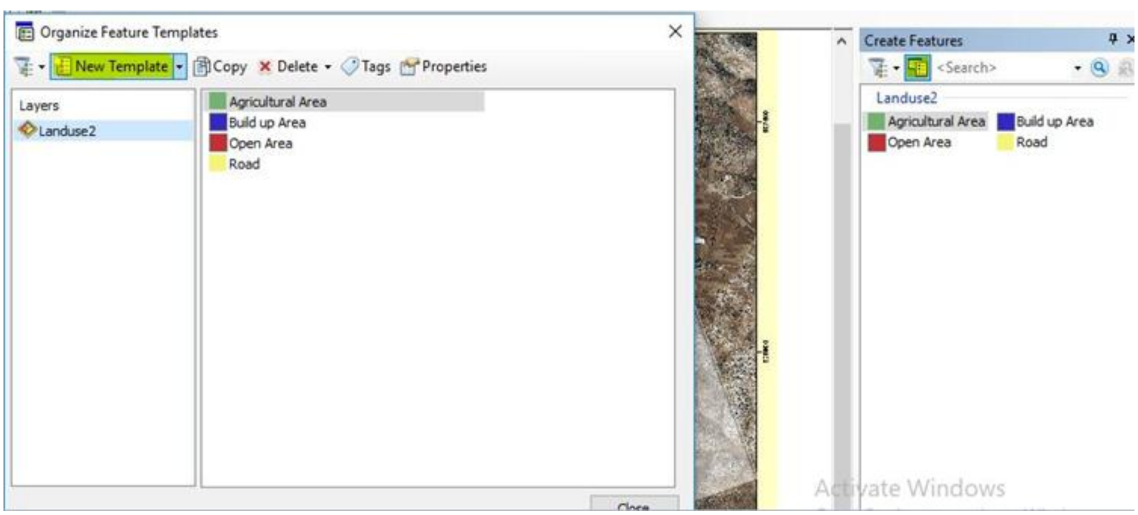

Figure 8.4: Organize Feature Templates

Four major landuse classes were mapped see Table 8.1 for more details: Built-up areas, Open lands, Agricultural Areas including the Rainy and irrigated land and Road; to be able to detect possible details. [35]

Table 8.1: Four major landuse classes

No.	Landuse Type	Description	Colour Assigned
1	Built-up areas	This class includes continuous and discontinuous urban fabric, industrial, commercial and other related built-up areas.	Brown
2	Open Areas	Sand plains, unpaved roads, excavation site, are considered as bare lands.	Pink
3	Agricultural Areas	This comprises green urban areas, non-irrigated arable (Rainy) land, irrigated land, scrubs and forest cover.	Green
4	Road	Transportation areas, Streets and Alleys.	Blue

3. Change Detection

Change detection has been applied in different application areas ranging from monitoring general land use change using multi-temporal imageries to detection. One of the most common applications of change detection is determining urban and agricultural land use change and assessing urban spread with agricultural Shrinking. This would assist urban planners and decision makers to implement sound solution for environmental management. A number of approaches have emerged and applied in various studies to determine the spatial extent of landuse changes. [35]

Change trajectory of classification comparison was used to map the patterns and extents of landuse in the study area as well as determine the magnitude of changes between the years of interest 2011 and 2018. [35]

8.3 Results and Discussion

8.3.1 Landuse map

The outcome of the image editing was presented in form of digital maps, layout and attribute tables. The area covered by the four-class landuse map of 2018 shown in map 8.1.

8.3.2 Change Detection

In Landuse mapping, the comparison technique is the only method that resulted in a change detection. Landuse map of 2011 was derived from Dr. Muath Abu Saada study as shown in map 8.2.

The landuse changes were computed between 2011 and 2018, table 8.2 represents what happen between 2011 and 2018, and the capability of the resampled topographic map was assessed from the results of editing raster images. The overall result of change detection shows that Build up Areas and Road are increasing, the agricultural lands and Open Areas are decreasing as shown in figure 8.5.

Table 8.2: Change Detection of Area

Landuse Type	2011		2018		Change Area	
	Area in Km^2	Area in %	Area in Km^2	Area in %	Area in Km^2	Area in %
Build up	8.7	35	10.1	41	1.4	5.7
Agricultural	8.3	34	7.9	32	-1.2	-4.9
Open Areas	7.3	30	6.1	25	-0.4	-1.6
Road	0.4	2	0.6	2	0.2	0.8

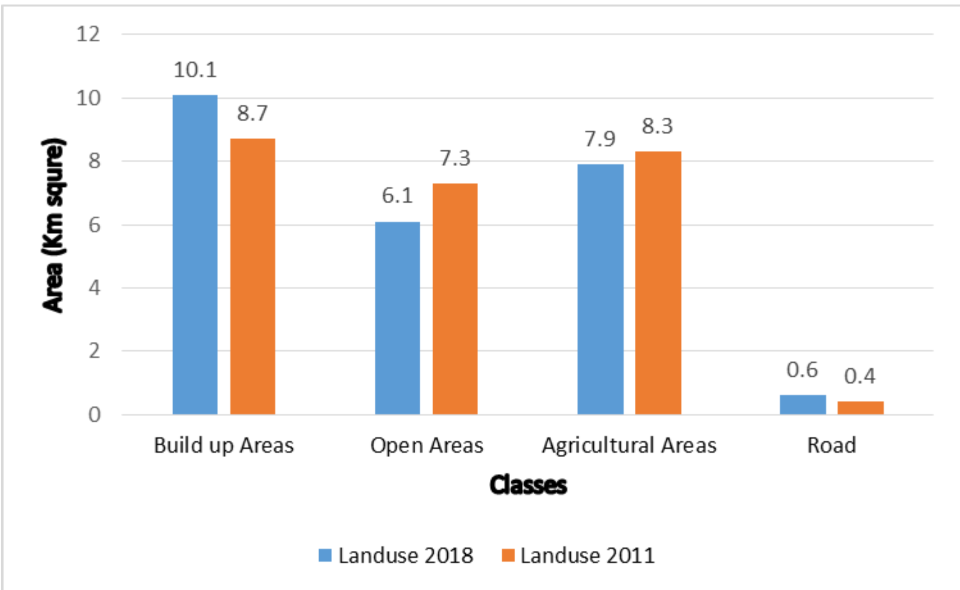

Figure 8.5: The overall result of change detection

8.3.3 Landuse Analysis with DRASTIC Model

The results of vulnerability map show that 98% of the Yatta Aquifer lies in the very low, low and moderate vulnerable areas that covered by Build-up areas and Road, while 7% of the aquifer are high and very high vulnerability of groundwater to pollution, which covered by Agricultural and Open areas.

8.3.4 Discussion

- There are several factors that include directly and indirectly caused changes to Yatta Landuse such as population increase is a major one. Colonization for employment and better living opportunities is another factor that has contributed in increasing urban growth.
- High and very high vulnerability of groundwater to pollution, which covered by Agricultural and Open areas. Due to Uncontrolled use of pesticides and fertilizers, and the distribution of manure over the arable lands exceeds the plant nutrient requirement for Nitrogen and Phosphate. Heaps of manure allows nutrient wash out to the water bearing layers are particularly problematic from an aquifer protection point of view.

Conclusion and Recommendation

There is deficit in the quantities of water coming from the multiple sources of water and the daily average does not exceed 20 l/ca in Yatta. Between 25% and 30% of most families of Yatta city and villages live on water tanks. The majority of families rely on water harvesting that was indicated through the dilution of nitrate concentration in drinking wells samples.

The final results of vulnerability assessment indicates that 30% of Yatta Aquifer lies in the very low vulnerable area, while 50% of the lies has low vulnerability to pollution, and 18% of the aquifer has moderate vulnerability to groundwater pollution and finally, 3% and 4% of the aquifer are of high and very high vulnerability of groundwater to pollution respectively.

High and very high vulnerability of groundwater to pollution, which covered by Agricultural and Open areas. Due to pollution sources, such as use of pesticides and fertilizers, and the distribution of manure over the arable lands exceeds the plant nutrient requirement for Nitrogen and Phosphate. As a final recommendation, the following strategic points could be suggested:

- Protecting the quality of water resources has become a very important issue in this area.
- Reducing the risk resulting from the wastewater generated from the urban and industrial sectors.
- Control the quantities of fertilizers and pesticides used in the agricultural sector. Also, reducing the runoff generated from the farms by establishing woody buffers, storm water wetlands, terraces, etc.
- Minimizing the number of pollution point sources especially the solid waste disposal points by establishing a main isolated dumping site in the study area.
- Finally, it is recommended to conduct a regular monitoring survey for all domestic wells (e. g.on a monthly basis), try to design simple sewer system in the study area to make sure that no contaminants reach the aquifer.

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Dedication

"Say: 'Allah will see your works and so will His Messenger and the believers; then you shall be returned to the Knower of the unseen and the visible ،and He will inform you of what you were doing. '"[9.105]

For all friends of the environment,

For all enemies of war and destruction,

For whoever is trying to construct rather than destruct,

For whoever is trying to improve rather than worsen,

For whoever is leaving good impacts on their surroundings,

For whoever is working for a better world, better environment and a better future,

We dedicate our work!

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GIS	Geographic Information System
HEC	Hydro- Engineering Consultancy
AHP	Analytical Hierarchy Process
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DI	DRASTIC Index
MDI	Modified DRASTIC Index
MDGs	Millennium Development Goals
EPA	Environmental Protection Agency
WMAB	Western Mountain Aquifer Basin
USAID	United States Agency for International Development
ARIJ	Applied Research Institute - Jerusalem
SSA	Sub-Saharan Africa
GOD	Groundwater occurrence, Overall aquifer class and Depth of water table
EQA	Environmental Quality Authority
DDT	Dichlorodiphenyltrichloroethane
WHO	World Health ORganization
GCPS	Ground Control Points

Abstract

This project aims to study the vulnerability assessment of Western Aquifer Basin; Yatta aquifer in Hebron City. This is the largest basin and the most important one among the West Bank Aquifer basins. In first stage our project aims to pre-study and observe ON GROUND POINT OF SOURCES to mitigate industrial and human activities of groundwater pollution as to track problems ‘source and control them.

The net concentration of nitrate in water has just been found after collection and testing of water samples from 4 main source and 20 sub-source in the study area with an average of 44.5mg/l with max of 128.5 mg/l and a 3.735mg/l with max of 7.5mg/l, respectively.

The strategy followed by economic and environmentally effective real attempts to estimate how much danger is out there. A vulnerability assessment was developed by applying The DRASTIC model, representing distribution of degrees of vulnerability from vary low to very high with ranges 30% , 50% , 18% 4% and 3% , respectively.

The overall result of change detection between land use 2011 and 2018 shows that Build up Areas and Road are increasing by 5.7% and 0.8 %, respectively , whereas the agricultural lands and Open Areas are decreasing by 4.9 % and 1.6% respectively.

Key words:

Ground Water, Vulnerability risk assessment, DRASTIC model, Yatta lower aquifer.