

Utilities of GIS and Remote Sensing Data in the Spatial Analysis of the Radioactive Contamination Site in Nineveh Province

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Abstract: The destruction of the Iraq's nuclear facilities through the wars (1991, 2003) led to create many sources of radioactive waste and contamination. These sources are distributed in different parts of Iraq. One of these parts are in Nineveh Province (390 km to the north of Baghdad). The present study addresses two of the radioactive waste and contamination sites which are called Al-Jezira (or Al-Rayhania) and Addaya. The two sites located in the northwestern of Mosul city. Al-Rayhania site is one of the sites that were part of Iraq's past nuclear program, it was destroyed by the inspection committees that came to inspect and monitor Iraqi weapons programs during the previous nineties. The present study depends on QuickBird satellite image acquired at 2007, Enhancement Thematic Mapper (ETM) data of Landsat7 acquired at 2002 and Digital Elevation Model (DEM) with spatial resolution of (30m) to study the effect of the surface terrain of the study site on the spread of radioactive waste. ArcGIS9.3 Desktop, Erdas9.1, and Global Mapper11.0, RiverTools3.0 package software have been used to complete the research methodology to produce the final maps (Contour map, Slope map, Aspect map and drainage pattern map) of the study site. Through study and analysis of these maps, it can found the ways to curb the spread and the effect of the radioactive contamination on the water resources.

1. Introduction

Radioactive wastes are produced from civil and military nuclear applications – nuclear power generation, nuclear weapons production and other uses of nuclear materials [1]. The level of radioactivity and duration varies – some waste will remain radioactive for hundreds of thousands of years. The radioactive waste is accompanied by the emission of one or more types of radiation, such as alpha particles, beta particles and gamma rays, which can damage DNA, potentially causing cancer or hereditary defects, and threatening humans, animals and plants. Radioactive wastes are generated in a number of different kinds of facilities and arise in a wide range of concentrations of radioactive materials and in a variety of physical and chemical forms. There is also a variety of alternatives for treatment and conditioning of the wastes prior to disposal. Likewise, there are a number of alternatives for safe disposal of these wastes, ranging from geological disposal to near surface disposal and direct discharge to the environment [2].

The destruction of the Iraq's nuclear facilities during the 1991 aggression and the second aggression in 2003 led to create many sources of radioactive waste and contamination. In Mosul City, the investigation of existing radioactive contamination shows a slightly higher radioactivity in and around the destroyed targets [3]. Also there are another sources of these contamination resulted from the destroyed of the Mosul Production Facility called Al-Jezira Facility (also known as Al-Rayhania site). Landsat imagery taken in January (2004) shows the local reflection anomalies throughout the environmental studies in the southern and northern limbs of Allan and Atshan respectively [4]. This anomaly in the reflectivity was evident at Al-Rayhania site and around regions that are expected to contain contaminated materials and equipments which were stolen from the site after 2003. Surely, all of these sites require decommissioning and remediation in order to ensure radiological safety.

The use of remote sensing and Geographic Information System (GIS) in preparing thematic and topographic maps has become an useful and widespread tool for environmental protection. Integration between GIS software packages with different satellite imagery and Global Positioning System (GPS) dataset have been applied in this research to study the effect of terrain on the prevalence or the possibility of reducing the spread of radioactive contaminants and their impact on the environment. Identify the study area in terms of slope, aspect, contour, watershed based on the Digital elevation Model (DEM) have been done by using the Spatial analyst extension in ArcGIS9.3. Based on these maps as a database, the terrain variation characteristics could be realized on a detailed understanding of its natural surface features that including hills, valleys, drainage, village, basin ...etc.

The applied geodetic system of the used remote sensing data and the output resulted maps was defined according to UTM_WGS84_Zone38N projected system.



2. Study area

2.1 Location

The study area lies in the Nineveh Province (north region in Iraq) and located in the northwestern of Mosul city between Lat. $36^{\circ} 07' 14.84''$ and $36^{\circ} 27' 33.43''$ N and Long. $42^{\circ} 32' 58.92''$ and $43^{\circ} 01' 29.79''$ E., as shown in figure(1). Two contamination sites are covered by the study area: Al- Jezira (or Al-Rayhania) factory (30 km from Mosul center) and Addaya site (40km form Mosul center).

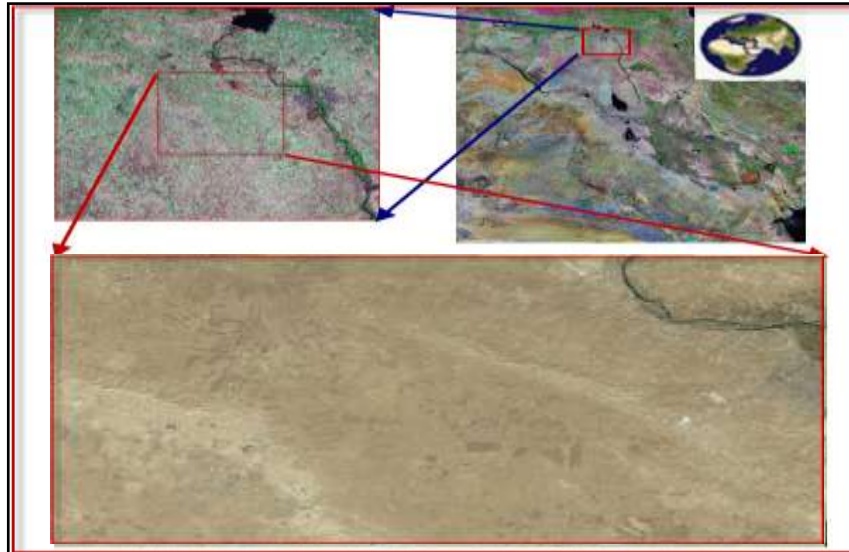


Figure (1): the location of the study area

2.2 Background

Al-Jezira facility (Al-Rayhania site) was designed to receive yellowcake and produced Uranium dioxide (UO_2) and Uranium tetrachloride (UCl_4). There are three main nuclear material handling locations; the UO_2 plant (called site 000), the UCl_4 plant (called site 400) and three large concrete waste tanks as shown in figure (2) [5]. This facility was heavily damaged by American bombing during the Gulf War at 1991. The destroyed equipments, concrete rubble and miscellaneous solid wastes were trucked to a burial site near the village of Addaya about 35km west of Al-Jezira as shown in figure (3). The material was dumped into excavations in the soil and subsequently covered. After the events of 2003, the Addaya site have been facing to tampering and sabotage operations and stealing some of the contaminated materials and equipment to unknown places, which certainly led to the spread of radioactive contamination in the area of the region.

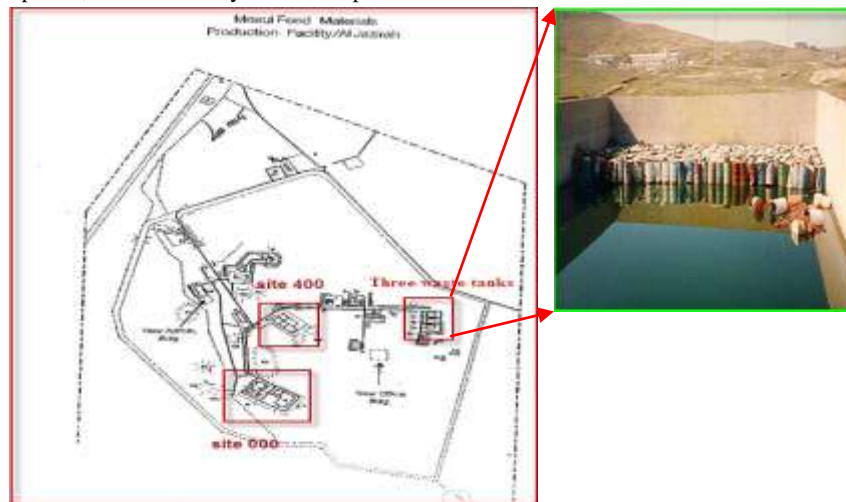


Figure (2): The layout of Al-Jezira buildings



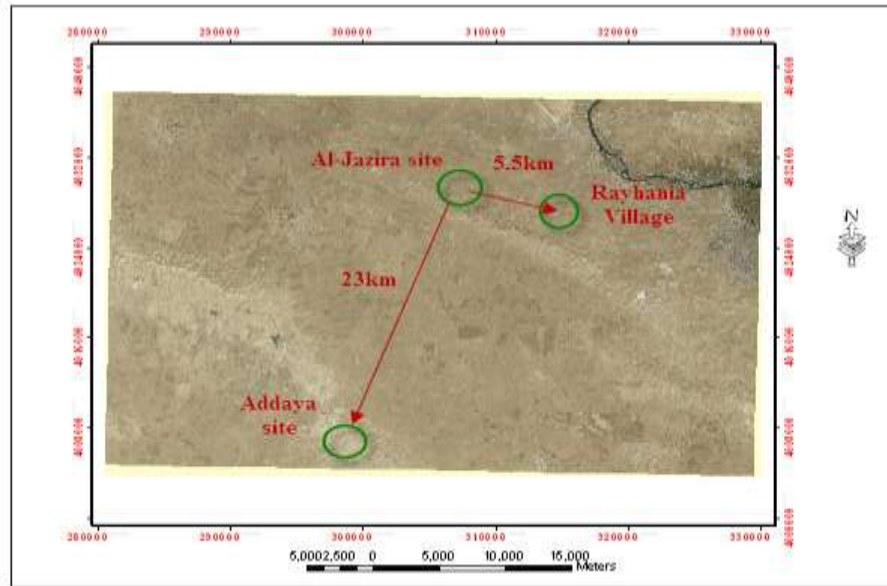


Figure (3): The location of Al-Rayhanah and Addaya sites

2.3 Geological setting

The brief geological setting describe here is related only to the anticlines near the radioactive contamination sites adopted in the present study. As shown from the geological map in figure (4) below, the dominant and the highest structure in the study area is the Atshan anticline trending NW-SE. It is a broad, open, doubly plunging asymmetric fold, approximately (30km) long, more than (4.5km) wide as measured by the applied geological map and the GIS package software. The northeastern limb is steeper than the southwestern one and locally overturned. The oldest rocks that out crop in the core of the Atshan anticline are of the Early-Middle Miocene age (Euphrates Formation) consist of Limestone, dolostone and marl. The stratigraphic sequence exposed in the study area surrounding Atshan anticlinal structures is Middle Miocene (Fat'ha Formation) consist of green marl, limestone, and gypsum (lower member (Mio2f1)). The syncline between Atshan and Addaya anticlines further south occupy a broad topographic low plains covered with thick Quaternary sediments. The general elevation of the plain is between (230m) and (280m) above sea level, Jebel Atshan, at (470m) is the highest point of the structure. In other side, Addaya anticline is asymmetrical and also double plunging anticline. It consist of two domes. The southeastern one is locally called Haddaya [6]. The main out crop of Addaya anticline (Fat'ha Formation) which consist of red claystone, marl, limestone, gypsum and siltstone (upper member (Mio2f2)). The anticline has a length of (8.4 km) and width of (1.7km) . Its highest elevation is a bout (400m) .

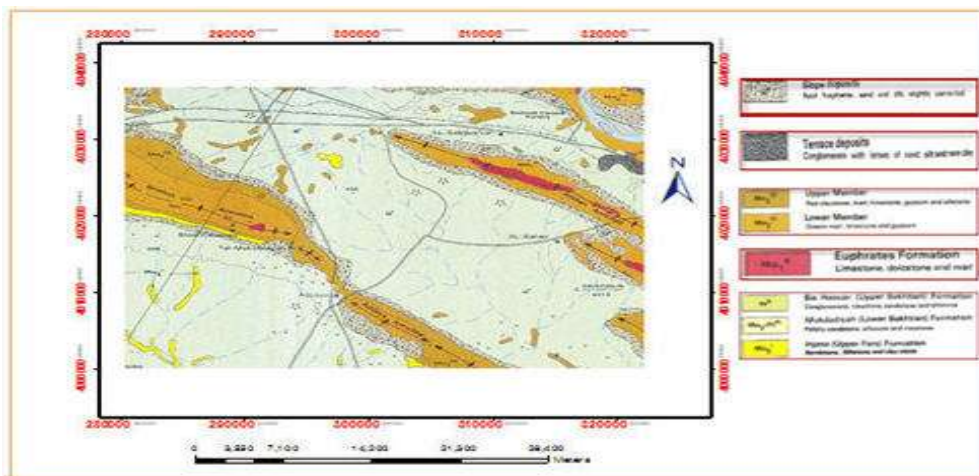


Figure (4): The geological map of the study area (after Varoujan et al, 1995)



3. Dataset Used

Different kind of the available satellite imageries and diverse ancillary data have been collated for the purpose of spatial analysis and image processing in order to come up with the required result efficiently about the study area. Table (1) lists the specifications of the data used.

Table (1): The specifications of the used data

Remote sensing dataset	Bands	Resolution(m)	Date
Landsat7, ETM+	3,2,1	14.25	10/09/2007
QuickBird	1, 2, 3	0.6	2007
Google Earth image	1, 2, 3	10	29/12/2004
DEM		30	2003
Maps	Index	Scale	Date
Geological Map of Al-Mosul Quadrangle[11]	NJ-38-13	1:250000	1995

4. Software used

Nowadays, the GIS and digital image processing software combination can provide significant advantages for analyzing, geoprocessing, mapping, placing data in common scale and overlaying different types of information of the study area. In the present study, the used GIS package softwares are:

- a. ArcGIS9.3 with spatial analyst extension- This was used for the displaying of the georeferencing images and extracting the required terrain maps from the DEM file, as well as the related subsequent processing.
- b. Global Mapper10.0- This was used to identify the study area from the satellite image and DEM file, georeferencing process and GPS dataset acquired.
- c. ERDAS Imagine 9.1- This was used for the enhancement and classification process.
- d. RiverTools3.0- This was used also for working with DEM file to extract the hydrologic information the study area.

5. Measurement of Radioactivity wastes

Radioactive elements decay over time. The process of radioactive decay transforms an atom to more a stable element through the release of radiation — alpha particles (two protons and two neutrons), charged beta particles (positive or negative electrons), or gamma rays (electromagnetic radiation). Radioactivity is expressed in units of curies — the equivalent of 37 billion (37 x 10⁹) atoms disintegrating per second. The rate of radioactive decay is expressed as half-life — the time it takes for half the atoms in a given amount of radioactive material to disintegrate. Radioactive elements with shorter half-lives therefore decay more quickly [7]. The International System of Units (SI) for radiation measurement is now the official system of measurement and uses the "gray" (Gy) and "sievert" (Sv) for absorbed dose (the amount of energy deposited in a unit mass in human tissue or other media) and equivalent dose respectively. For equivalent dose, the unit corresponding to rads is the rem (Roentgen equivalent man). The equivalent dose reflects the fact that the biological damage caused by a particle depends not only on the total energy deposited but also on the rate of energy loss per unit distance traversed by the particle. Conversions are as follows[8]:



- 1 Gy = 100 rad
- 1 mGy = 100 mrad
- 1 Sv = 100 rem
- 1 mSv = 100 mrem

When handheld radiation survey instruments is used for contamination measurements , the common readout units are roentgens per hour (R/hr), milliroentgens per hour (mR/hr), rem per hour (rem/hr), millirem per hour (mrem/hr), and counts per minute (cpm).

6. Spatial Analysis Methodology

Several field measurements was done by using Garmin GPSMAP76SCx unit to identify the main locations of the radioactive contamination in the two site (i.e., Al-Jezira and Addaya) and other locations. The height of each locations was measured from the DEM file of the study area. All the acquired coordinates from the GPS unit were referred to the UTM_WGS84_Zone38N projected system. Table (2) listed the total measuring locations by the GPS unit. The yellow rows referred to the radioactive contamination locations inside the study area. Figure (5) shows the overlapping of the measuring locations with the DEM layer. The adopted DEM was acquired by the Shuttle Radar Topography Mission (SRTM) aboard the Space Shuttle Endeavour, launched in 2003. The SRTM DEM is a high quality product with a horizontal ground resolution of 30 meters. The DEM in figure (5) shows the variables in the terrain and elevation of the study area and it is excellent visual description of the landscape.

Table (2): The measuring coordinates of the contaminated locations

Locations no.	UTM coordinates		Height (m)
	Easting (m)	Northing (m)	
1	305565	4029325	347.5
2	305517	4020335	346.0
3	305515	4029431	343.1
4	305567	4029439	343.3
5	404963	4029092	374.6
6	304988	4029384	358.6
7	310502	4028919	297.8
8	298738	4007212	352.5
9	298706	4007025	338.5
10	298798	4008632	376.7
11	297867	4008654	348.0
12	298686	4007102	351.3
13	311133	4031141	266.7



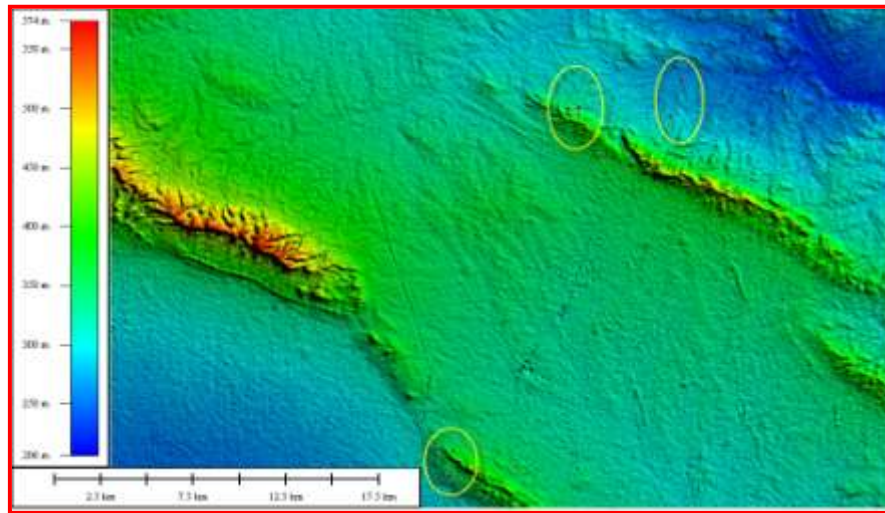


Figure (5): Overlapping of GPS measuring locations with the DEM layer as display by GM10.0 windows

By using the ArcGIS9.3 / 3D Analyst tools, the contour map which describe the underlying topography of the study area was created from the DEM. Figure (6) shows the contour map with interval of (10m).

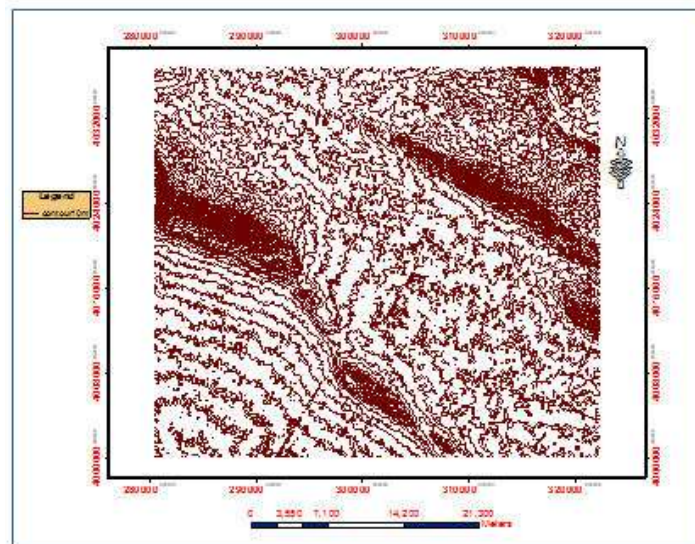


Figure (6): contour map of (10m) interval

Also, because the DEM confirm to the surface of the study area, it can be used to calculate the degree of slope and aspect (direction characteristics) of the land. Slope and aspect are both measured of the shape, or morphology, of a surface. Slope is the change in Z value over distance (or steepness) through a cell and aspect is the direction of the steepness path through the cell relative to north or to orientation of the cell [9]. According to the classifications given by [10] and listed in table (3), figure (7) shows the percentage categories of the slop. The direction characteristics of the steepness path was shown in figure (8).



Table (3): slop categories according to [9]

Relief Unit	Slop Steep (%)	Relative Height Different (m)
Flat	0-2	2-5
Undulating / gently	3-7	5-50
Undulating / rolling	8-13	25-75
Rolling –hilly	14-20	50-200
Hilly – steeply	21-55	200-500
Steeply	56-140	500-1000
Mountain	>140	>1000

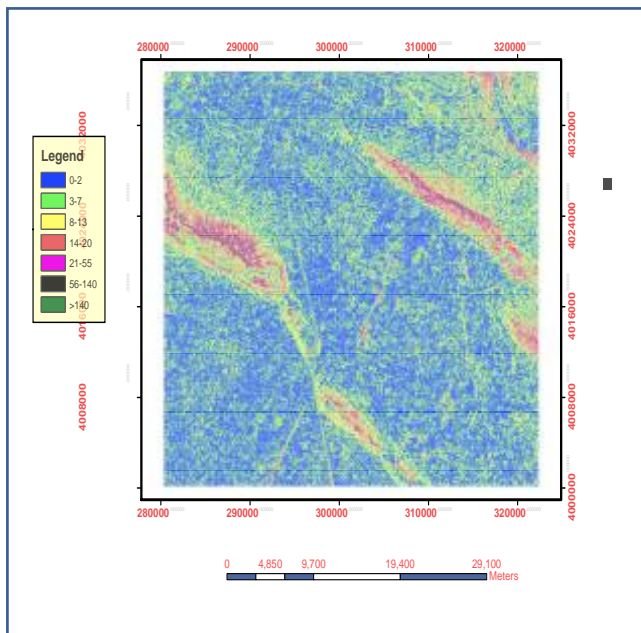


Figure (7): Slope map of the study area

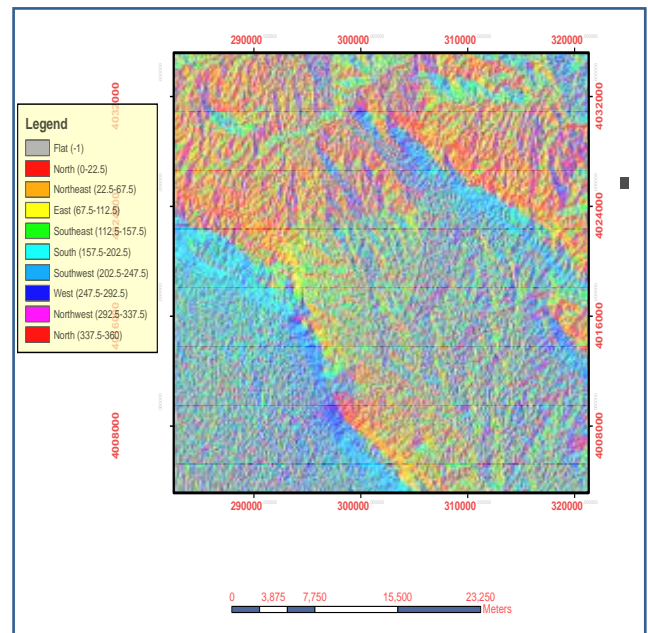


Figure (8): Aspect map of the study area

The analysis of the slop characteristics of the study area is very important to identify the surface of rainfall and flow direction, reveals the area where rainfall is changing and also reveals the speed of that change (i.e.; the steeper slops are change faster).

Based on the topographic terrain steepness characteristics, the general drainage pattern of the study area as derivative from DEM by using RiverTools3.0 package software was shown in figure (9) below.



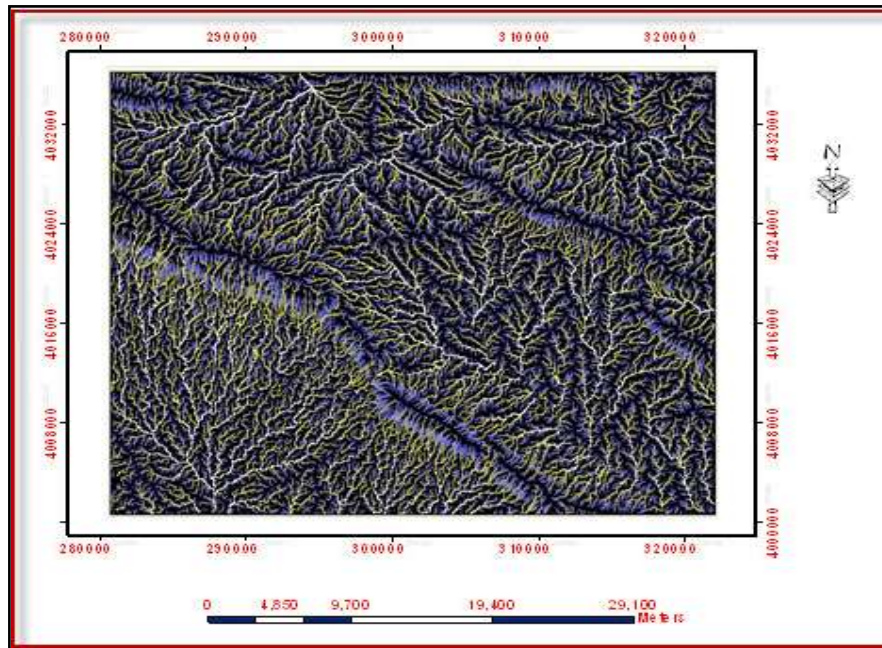


Figure (9): Drainage pattern of the study area

All of the above produced thematic maps will be useful tools for the purpose of best management for the radioactive contamination monitoring and removing from the study area.

Results and Discussion

Due to the security situation at both contaminated sites in the study area, which are difficult to conduct field survey and measurements to determine the intensity level of the radioactive contamination. So, the data collection are depended on three sources of data concerning the locations and the levels of the radioactive contamination in the study area: Committees formed by the Ministry of Science and Technology, Directorate of Environment of Nineveh Province and the Internet webs.

According to the radiological measurements that have been taken by the Ministry of Science and Technology [11], it was found that the average levels of the radioactive contamination at the two sites were as follows:

1. Measurements of contaminated equipments at Al-Jezira site indicates average contamination level of :
 $0.5\text{-}8\text{mr/h} = 0.5 \times 10^{-2} - 8 \times 10^{-2} \text{msv/h} = 1500\text{-}2500 \text{imp/min}$.
 These measurements include the locations of building (000), (400) and three large concrete waste tanks.
2. Measurements of contaminated equipments at Addaya site indicates a radioactive contamination level of:
 $0.5\text{-}7\text{mr/h} = 0.5 \times 10^{-2} - 7 \times 10^{-2} \text{msv/h} = 1500\text{-}2100 \text{imp/min}$.
 These measurements has been done on the drums and containers contaminated with uranium.



Figure (10) shows the 3d view of the study area with the locations of the two sites

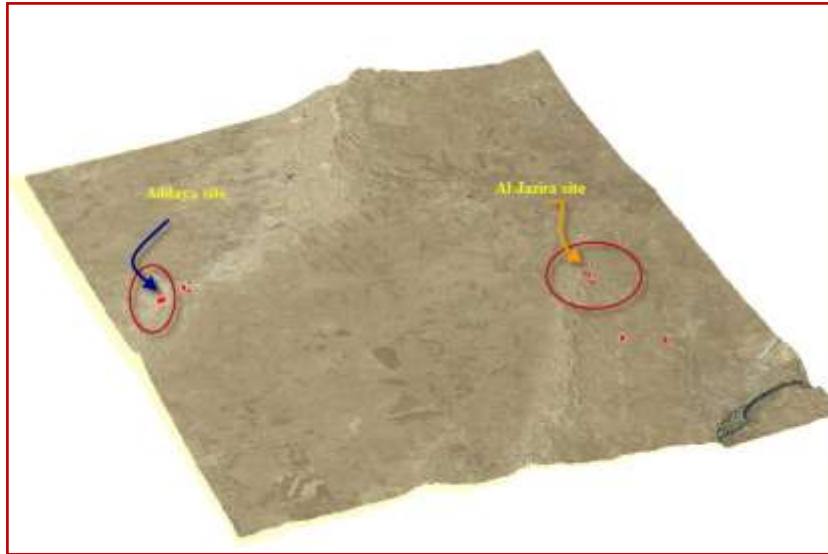


Figure (10): the location of the two site with respect to the study area

Addaya site has been used in 1991 as a landfill for the destructive equipments, apparatus and containers loaded with uranium from Al-Jezira. The burial of the contaminated materials have been done by using trenches below the surface of the earth up to 2-3 meters. This method could be the best one at that time relative to the available feasibilities, but it didn't take into account the negative effects on the agricultures and groundwater to the surrounding areas.

By overlapping the locations of the burial with the geological map of the study area as shown in figure (11), it can be seen that the locations were inside the slope deposits. This area characterized by rock fragments (seem to be irregular different and with size ranging from more than 2mm to couple or even to block sizes), silt, sand, and loose materials slightly cemented. Area with this specifications may bare relatively high permeability and porosity, this led to form easily paths to groundwater persist in the area. Consequently it led to negative effects on human health and activities.

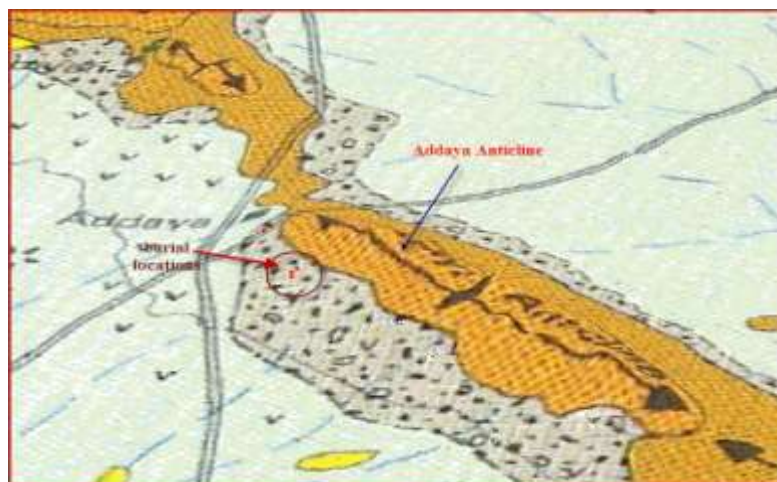


Figure (11): The 3d view of the burial locations in Addaya anticline

It is worth noting that the areas surrounding the landfill site is a major agriculture that supports crops such as wheat, barely, vegetable and large scale livestock operation. Figure (12) shows the landuse of the study area as resulted from the multispectral supervised classification on the ETM+ layers of (3, 2, 1). This classification supported by the results undertaken by [12].



It should be noted that the style of the irrigation water for these agricultural areas depends mainly on rainfall.

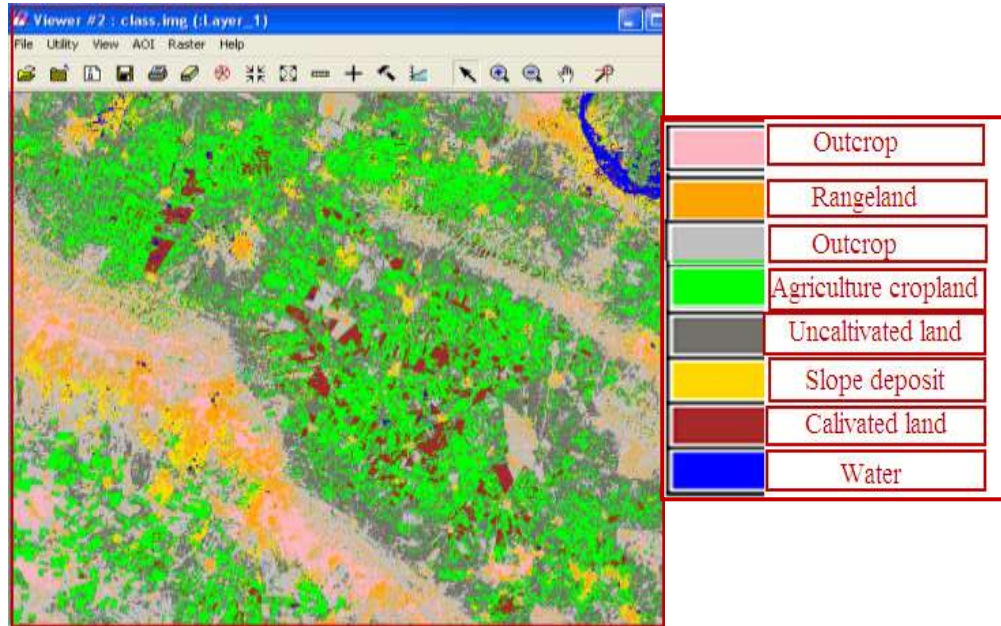


Figure (12): The landuse of the study area

Based on the DEM and the derivative contour map of the study area, the hydrological analysis of the two contaminated sites identified an effectively drainage patterns for rainfall that discharge into the agricultural areas in the region surrounding the sites. Certainly, these drainage patterns will be significantly contributing in the contaminated of the agricultural areas with the radioactive waste resulting from the decay of the contaminated materials. ArcGIS 9.3/ Arc Hydro Tools was used for the extracting and delineated the rainfall drainage patterns and catchments area of the two sites. The average calculated catchment area for Al-Jezira site is (86.1km²), while for Addaya site is (26.5km²). Figure (13) shows the expected effects of the contaminated materials on the agriculture areas through the drainage patterns in the two sites.

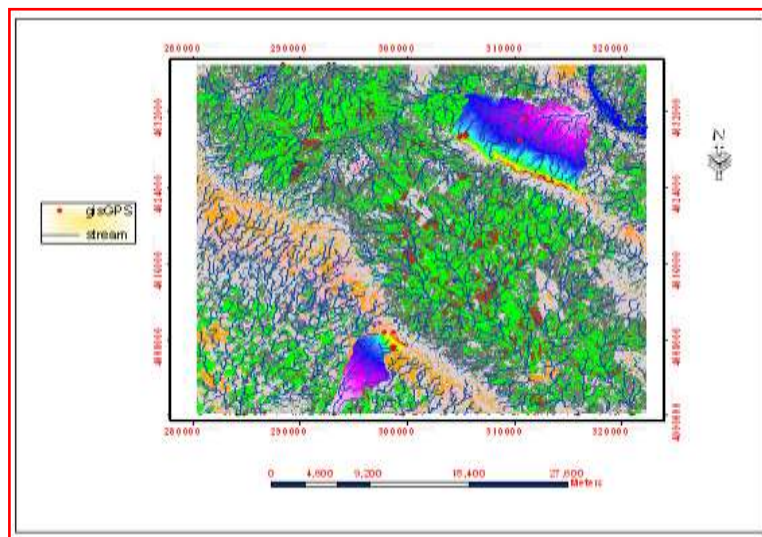


Figure (13): The catchment areas and the drainage patterns of the two sites



This hydrological analysis done by the present study strengthen the proposals suggested by [4] for Al-Jezira site to construct dams or barrier to prevent the spread of radioactive waste in region as shown in figure (14). The output results also confirm the importance of establishing the same barrier for the Addaya site as shown in figure (15). There is another important method for the disposal of waste is landfilled in the geological repository which can be built depending on the severity of the radioactive materials. Such a repository has to be built in a stable geological environment ensuring that the isolation of the stored radioactive waste will not affecting the surrounding environment such as groundwater and soil.

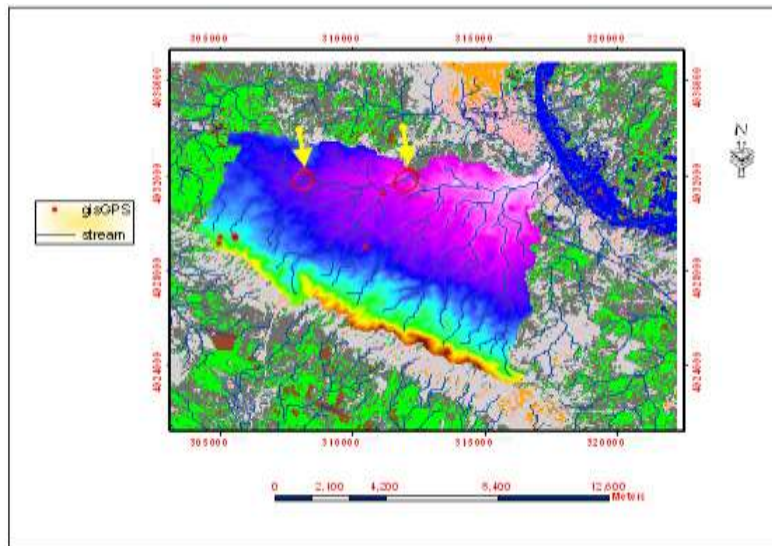


Figure (14): Suggested dam or barrier in Al-Jezira site

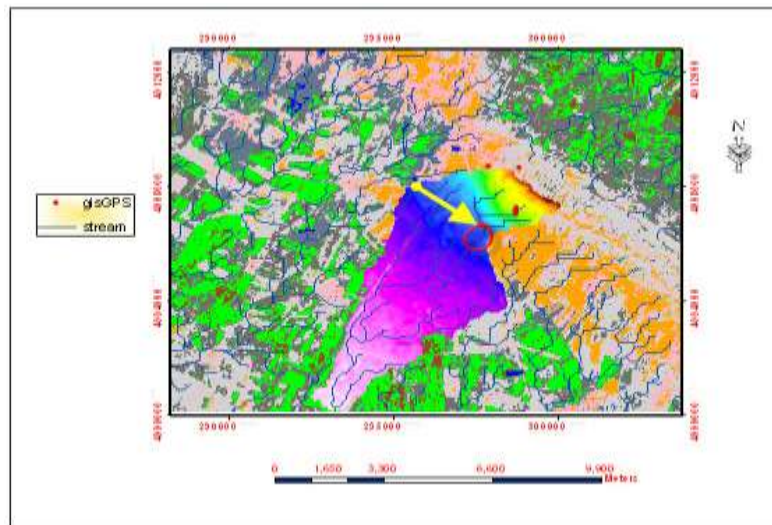


Figure (15): Suggested dam or barrier in Addaya site

All of the thematic maps that obtained from the study will be as spatial database for assisting the management process to choose the optimum methods to prevent the risk and impact of radioactive waste from the sites under study. This environmental problem can be treated by the cooperation between the environmental community with the local and central government.



Conclusion

Satellite remote sensing and GIS is a powerful tool for identifying the spatial relationship between maps required in identifying the locations of the radioactive waste. These maps will provide an affective database for assisting the management process to choose the optimum methods to prevent the risk and impact of radioactive waste from the Al-Jezira and Addaya sites. The present study reveals that the radioactive waste in Addaya site was buried in a slope deposit layer which could affecting the surrounding environment such as groundwater and agricultures through the hydrological system of the region. The study suggests some methods to prevent the spread of radioactive waste in region.

Acknowledgement

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