Using 3D Analysis of GIS and Remote Sensing for Modeling Erbil Water Flow and Sewerage Network

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Abstract

Objective of this paper is to show the logical development of digital technologies that explain and show the movement of water in two- and three-dimensions (2D and 3D) as observed **in nature.** Flow of water is a special case of fluid flow in porous media, and is governed by **the** laws of physics, in particular the laws of fluid mechanics. Fluid mechanics deals with the motion of fluids and with the forces The purpose of this paper is to obtain 3D digital map of flow that enable to interprets the state variables of water(superficial and ground water) in each point of the flow domain and if necessary also in time. The improper disposal of sewage is one of the major factors threatening the health and comfort of individuals in areas where satisfactory municipal, on-site, or individual facilities are not available. This paper not only shows the impact of water flow and its relationship with landuse but also illustrate the areas that out of service of sewerage network in Erbil city (study area). Modeling flow let us see how water or other materials move from a source point (or points) through a network or over a surface with aiding of GIS and remote sensing thus help in analyzing water sources in Erbil city and understand how these water sources used . The final 3D digital map contains all necessary information for users and designers to reach to the best decision.

Keywords: GIS, DEM, Landuse, Remote Sensing and Flow of Water

استخدام نظام المعلومات الجغرافية والتحسس النائي لانتاج نموذج ثلاثي الابعاد يبين تدفق المياه والصرف الصحي في مدينة أربيل

الخلاصة

الهدف من هذا البحث هو لإظهار التطور المنطقي للتقنيات الرقمية التي تفسر وتوضح حركة المياه في بعدين وثلاثة أبعاد كما في الطبيعة. تدفق المياه هو حالة خاصة من تدفق السوائل في الاوساط المختلفة ويخضع لقوانين الفيزياء ، لا سيما قوانين ميكانيكا الموائع. ميكانيكا الموائع تتعامل مع حركة الموائع ومع القوى الحاكمة وان الغرض من هذا البحث هو الحصول على خريطة رقمية ثلاثية الابعاد التي تفسر متغيرات حالة المياه (السطحية والمياه الجوفية) في كل نقطة من المجال المتدفق وكذلك بمرور الوقت. التخلص غير السليم من مياه الصرف الصحي هو احد العوامل الرئيسية التي تهدد صحة وراحة الأفراد في المناطق حيث انعدام الوسائل الفردية او البلدية الجديدة. هذا البحث لا يظهر أثر تدفق المياه وعلاقتها مع استخدام الأراضي فحسب ولكن أيضا يبين المناطق المحرومة من خدمة شبكة الصرف الصحي في مدينة أربيل. نموذج التدفق يبين كيفية تحرك الماء و المواد الاخرى من موقع الى موقع خلال الشبكة بمساعدة التحسس النائي و انظمة المعلومات الجغرافية. وبالتالي تساعد في تحليل مصادر المياه في مدينة أربيل ، وفهم كيفية استخدام هذه المصادر المائية. أخيرا الخارطة ثلاثية الابعاد لمنتجة تحوي كل المعلومات الضرورية للمستخدمين و المصممين لأتخاذ القرار الامثل.

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1. Introduction

The 3d GIS is useful to interpret the difference in flood peak resulting from land use change during the decade. Peak flows are altered as agricultural or irrigated lands and other areas with high infiltration rates are converted to uses with lower infiltration rates. Common sense and the literature consistently demonstrate that land use change is a one-way street. It always reduces infiltration and increases runoff. The need for 3D information is rapidly increasing. Currently, many human activities, i.e. urban planning, cadastre, environmental monitoring, telecommunications, public rescue operations, landscape planning, transportation monitoring, real-estate market, hydrographical activities, utility management, military applications, make steps toward third dimension[1]. Although water is a renewable resource and it be used little more than 10% of the total precipitation surplus for public water-supply, irrigation, and industrial processes, its availability is restricted through an uneven distribution, both in time and space. In this respect, there is no essential difference between ancient times and the present day; society has always experienced problems with water too little, too much, too variable, too polluted. Over more than 6000 years mankind has tried to manage these water problems by intervening in its natural courses through redistribution, storage, and regulation, to accommodate their requirements for irrigation, drainage, flood protection, drinking water, sanitation, and power generation [2]. 3D visualization within 3D GIS requires appropriate means to visualize 3D spatial analysis, tools to effortlessly explore and navigate through large models in real time. Observations on the demand for 3D City models show user preferences for photo-true texturing. Trading photo-true texture brings up necessities to store parameters for mapping onto the geometry. The 3D GIS is very important in monitoring large city such as Erbil city it can be made use of its facilities easily. Raster surfaces represent phenomena that have values at every point across their extent. Different interpolation techniques can produce different output surfaces from the same input data, although the broad pattern will be similar [3]. The specific parameter choices will influence the results. A particular technique may be suited to particular data or applications. They are created from values sampled at a limited set of locations, such as surveyed height values (for an elevation surface), or temperatures collected at weather stations (for a temperature surface). GIS includes tools for interpolating values between the sampled locations to create a continuous surface. Another type of surface created from sample point's

shows concentration per unit area (density).
The objectives in this research can be summarized as following:

- Viewing the topography, cities, easily
- To view entire Erbil city in 3D by draping the required vector (sewerage network) & raster layers on the DEM
- Modeling the flow of water over an elevation surface

2. Classification of Erbil Satellite Image

Maximum likelihood classification is supervised classification. It first determines the distributions of the DN (digital number) values in each band for each class. Each unknown pixel is then assigned to a class based upon Gaussian probability. If a pixel satisfies a certain set of criteria, the pixel is assigned to the class that corresponds to those criteria. This process is also referred to as image segmentation. An example of a classified image is a land cover map, showing vegetation, bare land, pasture, urban, etc. [4]. Pattern recognition is the science—and art—of finding meaningful patterns in data, which can be extracted through classification. By spatially and spectrally enhancing an image, pattern recognition can be performed with the human eye; the human brain automatically sorts certain textures and colors into categories. In a computer system, spectral pattern recognition can be more scientific. Statistics are derived from the spectral characteristics of all pixels in an image. Then, the pixels are sorted based on mathematical criteria. The classification process breaks down into two parts: training and classifying (using a decision rule) [5]. Maximum likelihood classification is supervised classification. It

$$q_x = -K\frac{\partial h}{\partial x} \qquad ...(1)$$

$$q_y = -K\frac{\partial h}{\partial y} \qquad ...(2)$$

$$q_z = -K\frac{\partial h}{\partial z} \qquad ...(3)$$

In addition to heterogeneity, that is, porosity and conductivity variations from point to point, a dependence on direction is possible. That is the case for so-called anisotropy porous media, where due to some direction-related properties,
as preferential lining of fractures, stratifications, or layering, the conductivity changes depending upon direction. Such situations can be

$$\underline{\underline{K}} = \begin{bmatrix} K_{xx} & K_{xy} & K_{xz} \\ K_{xy} & K_{yy} & K_{yz} \\ K_{xz} & K_{yz} & K_{zz} \end{bmatrix}$$

described by an extension of previous equations, where the conductivity becomes a symmetrical matrix, K, with following components [8].

First determines the distributions of the DN (digital number) values in each band for each class. Each unknown pixel is then assigned to a class based upon Gaussian probability. This method should produce better results than the previous two methods. Although it is expensive, modern computers allow it to be widely used [6]. Figs. 1a-b shows the satellite image and classified image respectively**3.**

Mathematical concepts

Darcy's law, like the momentum equation, is a vector relationship. When the flow is 3D, a Darcy's law can be written for each of the directions. For instance, in case of an isotropic porous medium, the conductivity matrix, K, becomes a scalar resulting in three Darcy equations where h represents the groundwater potential, the space position is denoted by Cartesian coordinates x, y, z, and time is represented by the symbol t ; x, y, z, and t are independent variables, while other variables, as h, are *considered dependent, that is, with each set of values (x, y, z, t) variables can be associated, as H(x, y, z, t) [7].* In Cartesian coordinates, Darcy's law becomes

$$q_x = -K_{xx}\frac{\partial h}{\partial x} - K_{xy}\frac{\partial h}{\partial y} - K_{xz}\frac{\partial h}{\partial z} \quad (5)$$

$$q_y = -K_{yx}\frac{\partial h}{\partial x} - K_{yy}\frac{\partial h}{\partial y} - K_{yz}\frac{\partial h}{\partial z} \quad (6)$$

$$q_z = -K_{zx}\frac{\partial h}{\partial x} - K_{zy}\frac{\partial h}{\partial y} - K_{zz}\frac{\partial h}{\partial z} \quad (7)$$

4. Construction of DEM from Contour Map

A Digital Elevation Models (DEMs) are collections of elevation points for an area. Arcgis 9.3 software can display Digital Elevation Models to show the terrain surface in three dimensions and from a choice of viewpoints. There are currently two methods that are being used to gather elevation coordinates: the systematic grid pattern (regular grid) and stratified method of data

4.1Methodology

There are several methods to create DEM. One method is the conversion of printed contour lines in which we scan existing plates used for printing maps. The raster is then vectorized and edited. Then these contours are tagged with elevations. Additional elevation data are created from the hydrography layer. Finally, an algorithm include least square method is used at every grid point from the contour data to interpolate elevations. Another method is using photogrammetry that can be done manually or automatically. The elevation contours on the topographic map must be converted to xyz data in order to create a DEM from a topographic map. The raster elevation contours must be first convertedto Collection (irregular grid). A regular grid has equally spaced points regardless of the terrains shape while an irregular grid uses points of larger percentage in areas where there are more relief variation like mountains and valleys. The accuracy of a DEM is greatly affected by the spacing and density of the elevation points. The model's accuracy depends on the density of the recorded elevation points. Survey or elevation collection can be done using traditional surveying methods or Global Positioning System (GPS) [9]. However, in most cases, the elevations are being calculated from

contour lines on pre-existing maps. Recently, DEMs are created directly from photographs. These DEMs are later used to create contours. Selecting points is a major issue in building a DEM. Very dense matrix of points may be needed to capture the land surface with variations. The figure below gives a comparison between a 2-Dimentional Topographic Map and a 3-Dimentional DEM. It can be observed that a DEM offers a clearer and more accurate view of the terrain.

vectors. The corresponding elevation values must be tagged to the elevation values. Using an interpolation algorithm, the tagged data is transferred to a superimposed grid. The gridded elevation values are then, converted into GIS format for it to be used by other applications.

A topographic map with a suitable color raster image must be obtained. The layers must be separated. It is necessary to use image-processing techniques to achieve this. The image must be filtered to separate the elevation contours from unwanted raster data. Now, the vectors must be inspected for correctness. When the repairs are completed, the contours must be tagged. Once the contours are tagged, the next step is to convert it to a DEM file.

By using ERDAS9, ArcGIS 9.3 and topographic map (1/25000) scale for Erbil city the DEM is built Fig.2

5. **Models**

The word model has so many definitions and is so overused that it is sometimes difficult to discern its meaning. A model is perhaps most simply defined as an approximate representation of a real system or process. A conceptual model is a hypothesis for how a system or process operates. This hypothesis can be expressed quantitatively as a mathematical model. Mathematical models are abstractions that represent processes as equations, physical properties as constants or coefficients in the equations, and measures of state or potential in the system as variables [10].

Most groundwater models in use today are deterministic mathematical models. Deterministic models are based on conservation of mass, momentum, and energy and describe cause and effect relations. The underlying assumption is that given a high degree of understanding of the processes by which stresses on a system produce subsequent responses, the response of the system to any set of stresses can be predetermined, even if the magnitude of the new stresses falls outside the historically observed range.

Deterministic groundwater models generally require the solution of partial differential equations. Exact solutions can often be obtained analytically, but analytical models require that the parameters and boundaries be highly idealized. Some deterministic models treat the properties of porous media as lumped parameters (essentially, as a black box), but this precludes explicit representation of heterogeneous hydraulic properties in the model. Heterogeneity, or variability in aquifer properties, is characteristic of all geologic systems and is recognized as important in affecting groundwater flow and solute transport. Utility networks are represented in ArcGIS 9.3 using geometric network datasets.

Once it would be built a geometric network, it can be traced the flow over the network from one or more source points. You can find connected features, find closed loops, trace upstream or downstream, and so on. To do this, it uses the Utility Network Analyst toolbar in ArcGIS 9.3.The model used in this research to describe the movement of flow in Erbil city with help of the GIS, the surface water, ground water and sewerage network of Erbil city are built using ArcGIS 9.3 software depending on large amount of maps that describe the study area (see Figs.3a-b) that illustrate huge information about water resources and sewerage network.

6. 3D GIS

As shown in section 4 that contain the stages of DEM construction of Erbil city the DEM draped with satellite image to produce 3D visualization.

After building the surface water, ground water, sewerage network and DEM of Erbil city the next step is to visualize all these information in 3D scene in order to control all the variables and analyzes them. Raster surfaces represent phenomena that have values at every point across their extent. They are created from values sampled at a limited set of locations, A TIN, or triangulated irregular network, is a surface data structure composed of triangular facets defined by nodes and edges. They are usually used to represent terrain. The terrain heights are derived from spot elevations that are used as initial nodes in the triangulation. The shape of the TIN surface is controlled by the triangulation of these spot elevations. TINs capture the variation in a surface better than do rasters—the spot elevations can be irregularly distributed to accommodate areas of high variability in the surface and their values and exact positions are retained as nodes in the TIN. This makes TINs well suited to engineering applications (such as calculating cut and fill). When creating the TIN it can be included other features, such as streams or ridge lines, to refine the TIN surface (these become break lines that define the edges of triangular facets)[11]. Polygons, such as lakes, can be included to create flat planes in the surface. TIN surfaces are created using the 3D Analyst extension of Arc GIS 9.3. GIS model is a Watershed Modeling System based on the Soil Conservation Services Most of the inputs such as slope, length and area can be derived from GIS data products. All those techniques are exported to 3D GIS to view all the result at 3D vision to monitoring water resources, landuse and sewerage network then connected by flow model describe the movement of water (Figs.4a-d)

7. **Conclusions**

- The use of 3D GIS fixed huge areas of Erbil city and classified it according to the groundwater then shows the sewerage network and water sources in 3D vision that give good information to make best decision
- The power in a GIS to manipulate and analyze spatial data is significant. This paper has demonstrated a number of techniques for applying this technology to explain and show the movement of water in 2 and 3 dimensions. Overlays, distance functions, classifications, and using weighting scales are some of the easiest and most common and were demonstrated in the monitoring water resources and land use analysis studies.
- The hydrology in the Spatial Analyst is useful for modeling the flow of water over an elevation surface. It can be defined hydrologic basins, identify stream channels, and calculate the distance along a flow path.
- This research shows that there are huge urban areas out of service of sewerage network
- The use of 3D GIS gives accurate measurements depend on the accuracy of the digital elevation model (DEM)

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Figure (1a) Satellite Image of Erbil City (LANDSAT 7ETM+) 2004,4M resolution

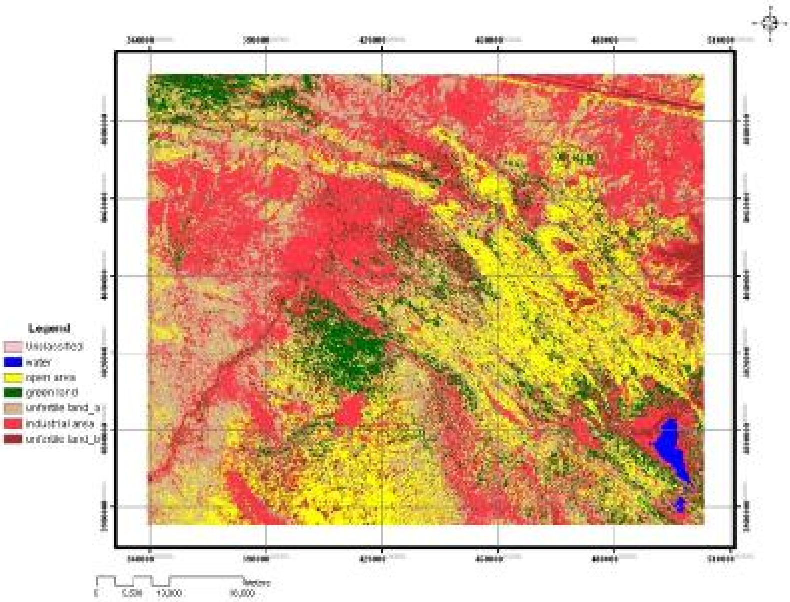

Figure (1b) Supervised classification _ Maximum likelihood method for Erbil Satellite Image

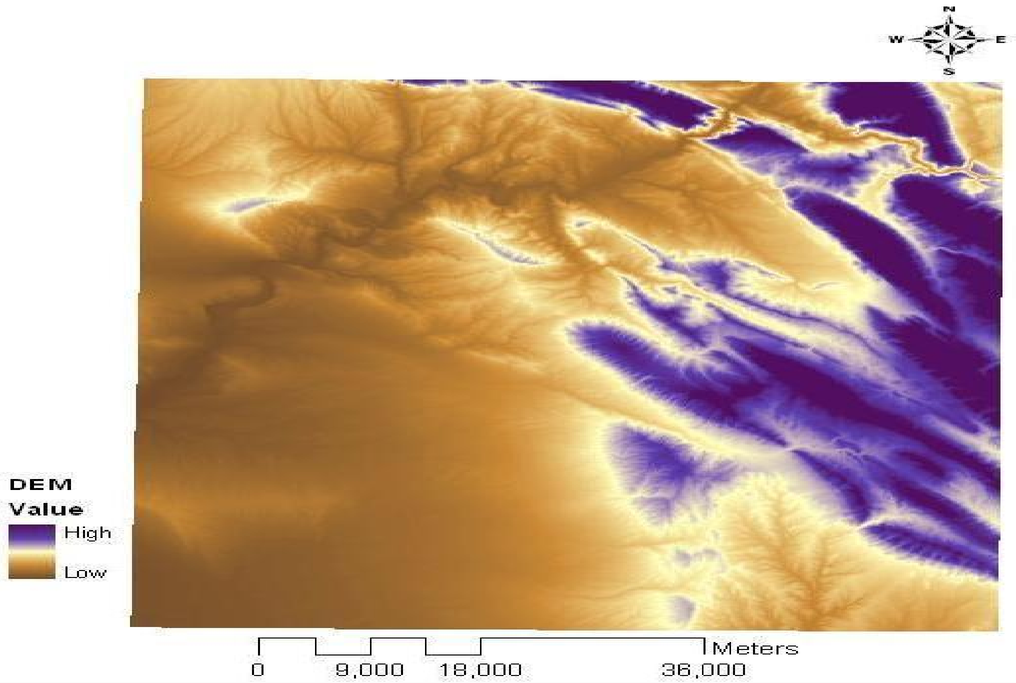

Figure (2) Digital Elevation Model (DEM) of Erbil City

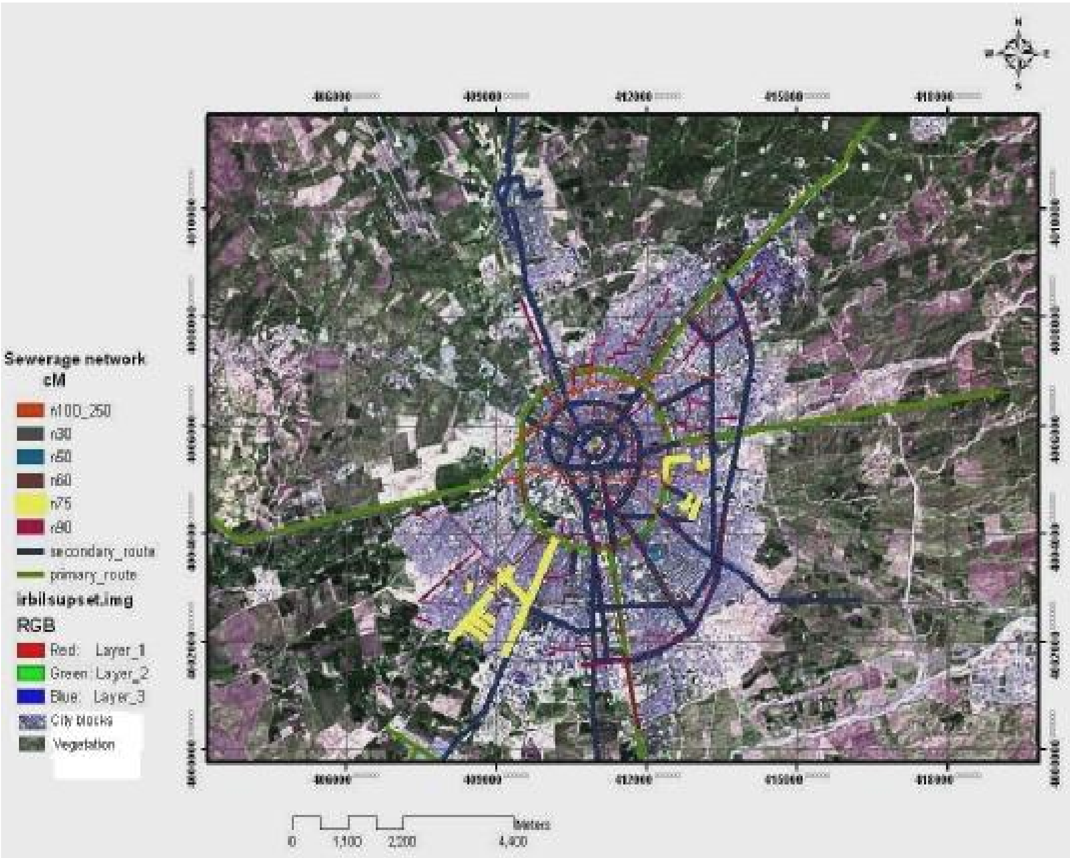

Figure (3a) Sewerage network and blocks of Erbil City t

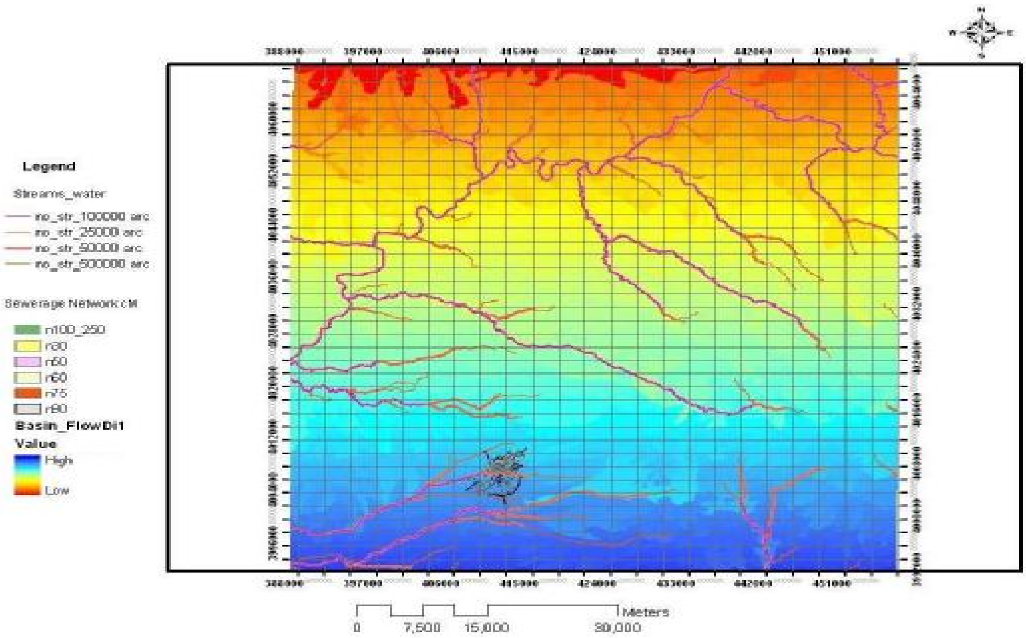

Figure (3b) Flow Model of water illustrates surface water & the basin (The more saturated areas) over an elevation surface

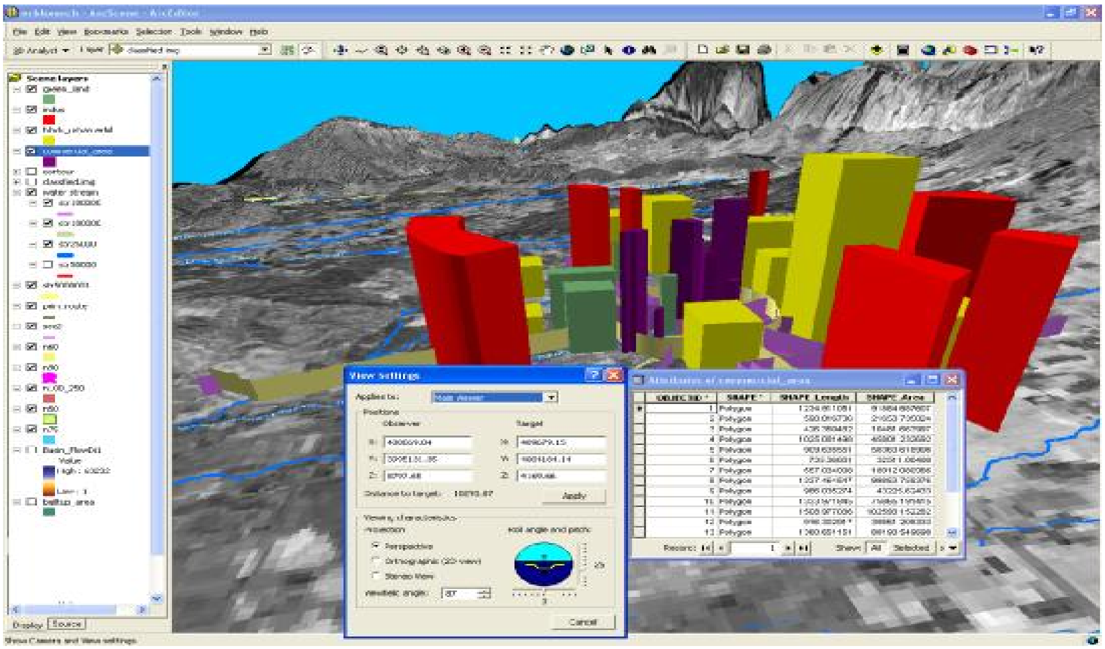

Figure (4a) 3D Visualization of Erbil City represents urban areas and their attributes

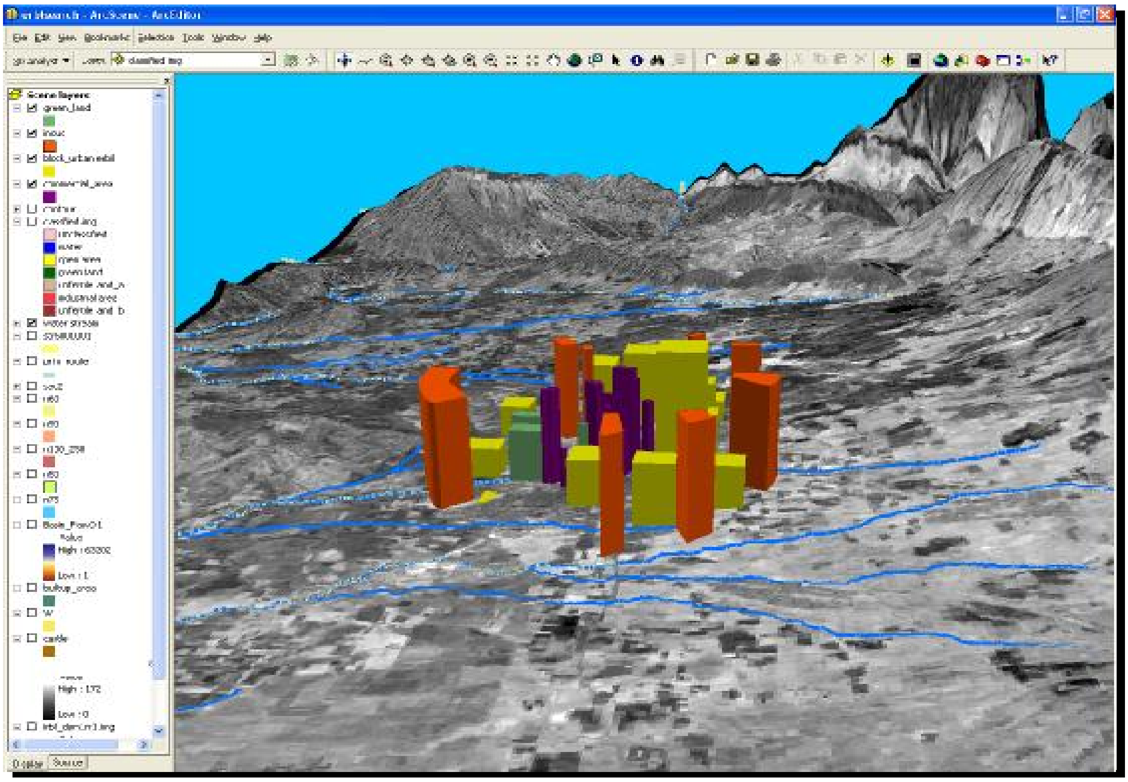

Figure (4b) 3D Visualization of Erbil City represents streams of water

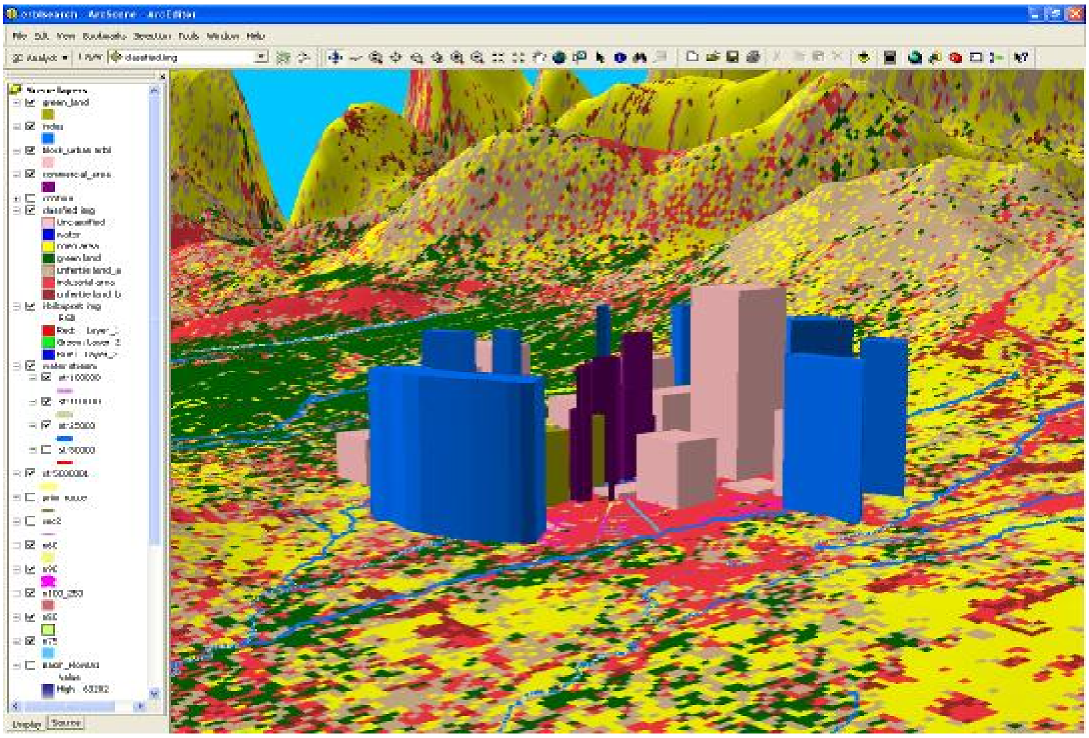

Figure (4c) A Classified Satellite image of Erbil City has been draped over the terrain DEM

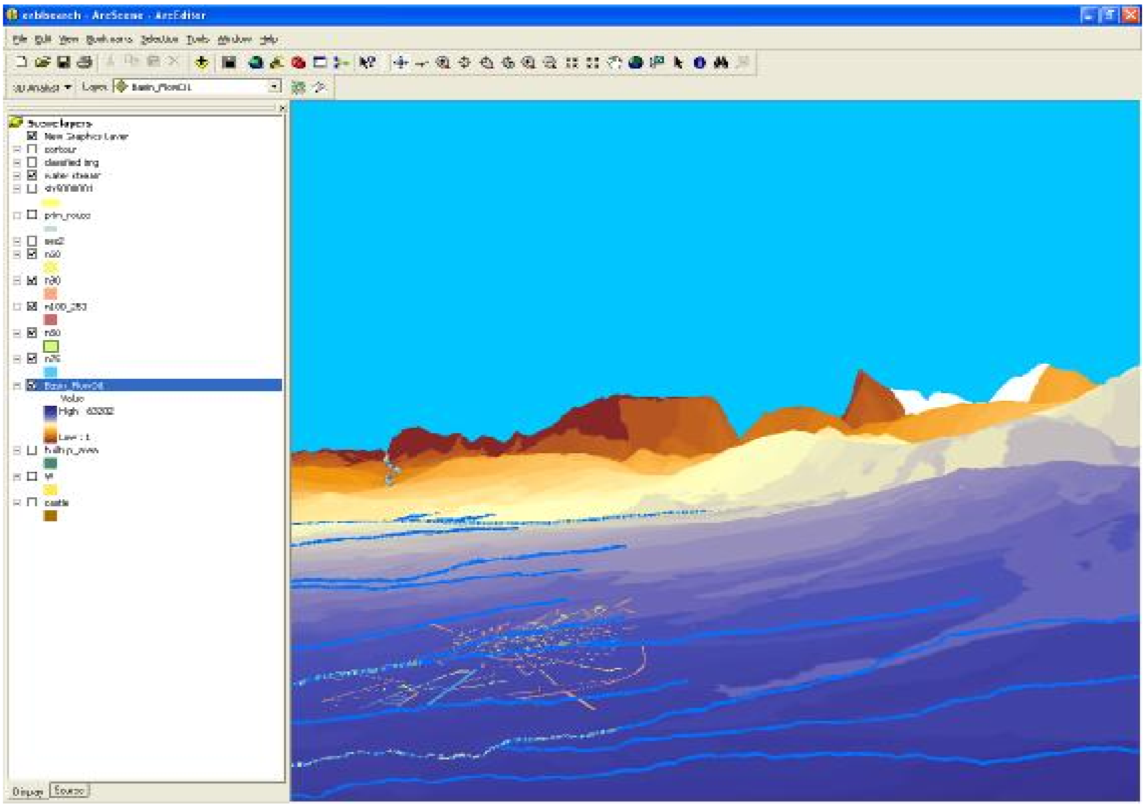

Figure (4d) A Flow basin of Erbil City has been draped over the terrain DEM