Geometric Investigation of Al-Wind Dam Reservoir Northeastern Iraq, using Digital Elevation Models and Spatial Analyses System

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Abstract

Geometric analysis of Al-Wind dam reservoir in Diyala discussed in this paper as necessary and strategic subject, spatial analysis systems were used to extract the area of Al-Wind dam reservoir from the digital elevations model (DEM), at 26 selected water levels in the reservoir with one meter interval, from 195 up to 219.5 m.a.s.l., the geometric criteria used to extract the essential negative geometric elements represented by the Negative Volume (NV) Negative Planner Area (NPA) and Negative Surface Area (NSA), the perimeter of water body, the depth of water column and the shape factor of the reservoir, as well as for the positive geometric elements as Positive Volume (PV), Positive Planner Area (PPA) and Positive Surface Area (PSA) of the islands within the perimeter of the reservoir.

The elements above are basics in geometric studies, which are used to design the procedure of reservoir operating, as the control on storage, and releases from the gates of the dam in the different operating conditions, it is control the changes that will occur on the land uses after beginning the storage at each level, as well as the changing on the outcrops of geological formations that would be inundated with changing in water level, accordingly, the secure operation level were determine to avoid the hazards on the dam, and decrease the wastage in the land use and the stored water, and decrease the immersed areas, the mathematical relationship between the inundated areas and the capacity of the reservoir were derived to use it in the future for the operation and routing of the reservoirs, determine the surface area of the reservoir as well as predict the capacity of the reservoir at each level.

The current analysis reflect that the maximum operational safe level is 215 m.a.s.l., that equivalent to the capacity of 54,308,822 m³, while the preliminary study of the dam, which was conducted using conventional methods to the survey indicated that the storage capacity at the same level is 37,820,000 m³.

Digital elevations models for each selected level was exported as digital images of same scale for the purpose of visual comparison between the extensions and forms of the reservoir at different levels.

This analysis useful to management of the dam used by the administration of the dam in the selection of suitable operational policy for the reservoir.

Introduction

The crisis in Iraq and the decline of Iraq’s share of water by aggravation the problem of drought in all areas of Iraq and the world, it is characterized by its occurrence in the arid and semi-arid regions with hot summer and relatively cold winter, the temperature varies significantly and rainfall rates from the far south to the north, which in recent years significant decline in their know rates, as well as the lack of Iraq’s share of the water obtained from the rivers shared with Turkey, Syria and Iran, because of the
control and storage projects established and assessed by these countries [1], all calls for thinking rational way to manage water resources, and to know that dams is one of the most important solutions for the regulation and rationalization these resources.

The project Al-wind dam is the strategic project in the city of khanaqin in northeastern Iraq and classified this dam within the middle dams and completed this dam by Iraqi hands company and specifications world of dams, and considered the first dam in Iraq and the Middle East was implemented using a plastic barrier to reduce the seepage under the dam.

In order, the geometric elements of the reservoir and analyze spatial variables of geomorphological phenomena at selected levels of the reservoir, and analysis of the relations of geometric elements such as storage volume, planner area of water body, wetted area and depth of the water column at different locations of the reservoir and contraindication of the reservoir, and to know the changes that occur on the uses of the surrounding lands at each level, and determine the relationship between discharge of the river and the capacity of the lake, in order to reach the differentiation between the different levels to choose the optimum one.

Traditional topographical surveys are usually used for these investigations, which is usually limited to the volume of the storage. In this case, the results are often in accurate due to lack of survey points and topographical complexity.

The use of digital elevation models has made a big jump in dams reservoirs studies, because of the facilities and accuracy that can be obtained due to the large number of survey points relative to the traditional land survey, the digital elevation models was adopted in the derivation of the reservoir area at (26) selected level, where the methodology included several steps and used software packages specialized in GIS and remote sensing.

The study area is located in northeastern Iraq on the Wind River in Diyala province, 7Km southeast of Khanaqin city and 6 Km from the Iraqi – Iranian border. The study area is shown in figure (1). By the coordinates of the dam body are determine by two points as in table (1).

| Table (1) represents the coordinates of the study located (dam body) |
|-----------------|-----------------|-----------------|
| Point | Easting | Northing |
| A | 540940 | 3797320 |
| B | 540613 | 3796029 |
| UTM Zone 38 | DATUM=WGS84 |

Figure (1) location of the Al-wind dam reservoir within boundaries of Diyala/ Iraq at the level 219.5 m above of sea level

Geology of the Study Area:
The reservoir is flooded different geological formation outcrops at different levels, so it is of stratigraphic importance in the region; the differences of geological formations that have been submerged with the beginning of storage are Mokdadiya
formation (Upper Miocene-Pliocene) which is one of the oldest geological Formations in the region, as shown in the geological map figure (2).

![Geological map of the studied area](image)

**Figure (2) Geological map of the studied area**

The investigation consist of sequence of claystone, sandstone and limestone, which contains varying proportions of gravel, these sediments are located on the banks of the original river, sometimes covered with recent sediments and sediments of the quaternary period, sometimes interspersed with secondary gypsum sediments. As in the geological cross section, fig (3).

![Geological cross section along the axis of the dam](image)

**Fig(3) Geological cross section along the axis of the dam**

The outcrops of Al-Mokdadiya Formation in the area of the reservoir cover the oldest sediments represented by the layers of Injana Formation (Upper Miocene- Lower Miocene). As in the right bank of the river, there are Quaternary sediments represented by the river terraces, which consist of the siltstone that is interspersed with lenses of gravel and sand, also polygenetic deposits of Quaternary sediments present on the right bank of the river. There are recent sediments filled the depressions in study area, and inconsistent sediments in the narrow flood plain that does not exceed tens meters along the course of the river, these deposits are submerged at the beginning of the storage and after submersion of flood plains.

The structural elements in the area are that the anticline surrounded the reservoir from the south, and the thrust fault extends along the fold towards south-west, this fold is one of the determinants of the extension and shape of the reservoir [2].

Geomorphologically, the reservoir area contains a group of geomorphological features that give the final shape of the reservoir and its extension. The study area is located in the eastern part of the transition zone between the foot hills and the high folded zones. Topographically the elevation of the area ranges between 195m above sea level near the site of the dam, to 220m above sea level, which represents the highest rise in the outer perimeter of the reservoir, in some depressions within the lake may be less than 195, representing the pool as a part of the dead storage. When the drainage system is derived from the digital elevation model of the reservoir (before storage), notice the presence of longitudinal and transverse valleys, which intersect the site and form a drainage pattern as shown in Figure (4), these valleys especially the transverse ones, appear as bays after the storage.

The area of the reservoir is divided into two parts by a geological barrier; these parts are then connected.
near the body of the dam, as shown in 3D model of the water reservoir Figure (5), each part of the reservoir is interspersed by barriers separating the transverse valley.

![Figure (4) Drainage system of the reservoir at level 219.5 m](image)

![Figure (5) 3D model of the wind dam reservoir (high exaggeration factor used to explain the shape of the reservoir)](image)

**Materials and method**

1- The digital elevation models with resolution 23*23m was called by Global Mapper V.13, then the digital model of the reservoir was seperated at (26) elected level, from (195)m to the top of the dam (219.5)m, and was exported as (Global Mapper package file) as shown in Figure (6).

2- Locate the two ends of the dam in the field as well as the deviation in the body them on the digital elevation model, represented in point (A), the beginning of the dam from the right, and (TP) is a deviation point in the dam body, and (B) the end of the dam from the left, as in the table (2):

<table>
<thead>
<tr>
<th>Name</th>
<th>Easting</th>
<th>Northing</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>540940</td>
<td>3797320</td>
</tr>
<tr>
<td>B</td>
<td>540613</td>
<td>3796029</td>
</tr>
<tr>
<td>TP</td>
<td>540664</td>
<td>3796564</td>
</tr>
</tbody>
</table>

**Table (2) the coordinates of study site**

UTM Zone 38  DATUM=WGS84
3- Generate the contour line, which represents the height of (219.5) m above the sea level, and cut the limits of this line east of the body of the dam along the course of Al-Wind river, the line represent the highest level of the reservoir in emergency conditions, as shown in the figure (7).

4- generate the contour lines for the earth surface elevations for each hypothetical level to extract the DEM for these levels, to determine the values of geometric elements, the contour interval (1m) used for the levels from the lowest (195m), to highest (219m) as shown in figure (8).

1- The digital elevation data was re-isolated using Digitizing tool of Global Mapper 13, at each contour line of (26) elected levels.

2- Digital elevation model for each level was saved in a Global Mapper Package File, and then requisition the data again to the program (Global Mapper), to draw the topographic sections of reservoir by (path profile/ LOS- line of sight).

3- Digital elevation data for each level was exported to a JPG image file for visual comparison.

4- The software (SURFER) used to extract the geometric elements, where the extracted digital elevation models exported by Global Mapper as (Surfer Grid File) to process the resulting file with (Surfer13) (Global Software, Inc., 2013), to calculate the geometric elements (volumetric, spatial and longitudinal data) the (Grid- volume) command adopted for this purpose, each of these files is used to define the values of the bottom of the reservoir at the selected level. The file name is entered in the upper surface field, while the hypothetical water surface of the reservoir at the concerned level is inserted into the lower surface field in the dialog box as in figure (9):
Figure (8) contour lines for the earth surface high level

Figure (9) the dialog box (Grid - volume) to illustrate the upper and lower surface

The command above executed and the report of geometrical calculation issued and includes:
1. Positive Surface Area, (PSA)
2. Negative Surface Area, (NSA)
3. Positive Planner Area, (PPA)
4. Negative Planner Area, (NPA)
5. Negative Volume, (NV)
6. Positive Volume, (PV)

Result
The positive surface area that represents the uneven area of the islands within the boundaries of the reservoir, and negative surface area represents the uneven wetted surface of the bottom of the reservoir, while the negative volume represents the volume between the bottom of the reservoir and water surface, and the positive volume represents the volume of the islands within the perimeter of reservoir at concerned level, fig (10).

Figure (10) the concept of positive volume, positive surface area, negative volume, negative surface area and upper and lower surface when water surface is (210m) above sea level.

The planner area are calculated after the projection of positive and negative surface area on the horizontal level and calculating the area of the projection, the positive planner area represents the flat area of the islands inside the reservoir, while the negative planner area represents the flat area of the water body, fig (11):
Digital elevation models exported as Global Mapper Package files at each level, and re-exported as surface elevation Grid file, the processing report includes the values of the geometric elements (PV, NV, PSA, NAP) corresponding to the selected levels, the values of these elements are tabulated in the table (3).

(Arc. GIS- 93) used to call all image layers of the levels for final reorganization. And export them as JPG files of standard scale for objective visual comparison between the horizontal extensions of the reservoir and the reservoir area at each level, as in figure (12).

Calculating the volume of the storage

The basic method to extract the digital elevation model at each level is the automatic method in which the area is isolated after the conversion of the contour line which represents a line feature to areal feature which surrounded the isolated area. Since the body of the dam was not straight the calculating of the volume of the reservoir was carried out in two stages:

The first stage uses the automatic method that depends on closing the contour line as areal feature, and then exports it as in the steps of methodology.

In the second stage the triangle (A),(TP), (B), adjacent to the dam body was manually extracted from digital elevation models at each level, as shown in fig (13), and export this part to (Grid file) and then calculate the volume in same steps of methodology to calculate this additional volume and insert its value in column 4 in table (3), and then add the volume of storage (negative volume) at each level to additional volume to find the total negative volume at each level.

Discussion:

The study of geometric elements represented by reservoir volume, surface area (evaporation area), the depth of the water column, areas of islands and bays corresponding to each level of reservoir dam, that represent important information that depends to...
determine the optimum safe operating policy, that signifies a data base for designers to returned to when designing the dam and its structures, especially in the proposed new dams, it support a decision on the construction of the dam.

Fig. (12): The variation of the shape, area, and the extension of the reservoir with the selected levels of the reservoir
The geometric analysis aims to illustrate the relationship between geometric elements with level of water in the reservoir and between these elements with others, and analysis the changes on land uses on each level. The first relationship illustrate the changes of positive volume with the water level, the relationship shows the fluctuation of positive volume with increasing water level in general, especially at level (206, 210, 216, 217)m above sea level, and observe sharp increase at the levels (215m) and (216m) above sea level, accompanied by a decrease of volume at levels (217, 218)m above sea level, the cause of this extraordinary increase that appearance of new islands within the body of reservoir with the increase of levels, that led to additional areas, at last lead to increase the positive volume, this is an important determinant of future land uses, especially the areas of islands that will appear at these levels, which may be important in tourism uses as shown in fig (14).

Either the second relationship between negative volume with water level that shown continuous increase in negative volume with water level, in general the direction of this relationship is divided into three stages separated by two transitional stages. The first stage begin from the level (203)m above sea level, which has the capacity of the reservoir (2045605m³), and ends at level (211)m above sea level, that has the capacity of the reservoir (29667889m³) where low increase in the capacity of the reservoir, the second stage between the level of (211) m and the level (215)m above sea level, that corresponding to the capacity of reservoir (54308822m³), where the increase gradually more accurate than the first stage. The final stage begins from the level (215)m, to the level (219.5)m where the capacity of reservoir is about (99641673m³). Where the increase in the negative volume is dramatically with the increase in the level and more sharply than the two previous stages, the transition from first stage to second is caused by the exit of the storage from the original river channel to the flood plain. While the transition from the second stage to final one because the exit of the storage from the flood plain to the river terraces, either the stage preceding the level (203m) represents the dead storage, fig. (15).

The positive surface area which represents the uneven area of the islands, it is relatively low when the low levels below (205m) where the reservoir boundary is still within original stream channel (within the limits of the valley cliff), but this area increase immediately after this level and then begins to fluctuate due to the roughness of the valley banks. The increase of the volume of islands is due to the addition of new islands to the reservoir. So that the area of the islands as high as possible at the level of (216 m) as in fig (16).
The positive planner area which represents the flat area of islands have a similar behavior to the positive surface area, as they are relatively low in to the levels below (205 m), where the boundary of the reservoir is still within the original channel of the (within the limits of the valley cliff), but this area increase directly above this level, after which it fluctuates due to the roughness of the valley banks, the islands appear and disappear with the increase in the level due to the addition of new island to the body the reservoir, as in figure (18). The high similarly in the behavior of the positive surface area with the positive planner area is due to two reasons:

First: the low roughness of the topography, so that the flat area is roughly equal to the uneven area. However, the second reason is the low accuracy of the digital elevation model so that all topography less than the area of the cell unit (one pixel size in the digital model used 23*23 meters) disappears, so the undulated area is very close to the flat area, as in fig (18).

The negative planner area which represents the flat area of water body have a similar behaves to the negative surface area, as their value increase continuously and does not fluctuate with increasing levels, the slope of the increasing curve is low in low levels, but the increase significantly mentioned above the level (198)m for the same reason mentioned in previous paragraph because the body of the reservoir exit out of the original valley cliff, the large symmetry of the negative surface area and negative planner surface is due to two reasons:

The first is the low roughness of the topography of the bottom, so that the flat area of water body is roughly equal to the uneven area of bottom. However, the second reason is the same reason that low accuracy of the digital elevation model so that all topography less than the area of the cell unit (one pixel size in the digital model used 23*23 meters) disappears, so the undulated bottom is very close to the flat area of water body, as in fig (19).

When comparing the variety of Negative Planner Area and the total negative volume, the increase in the flat area of water body (evaporation area) is relatively small compared to the large increase in storage volume, as in figure (20), its noticed that a relatively large increase in the volume of storage especially when this volume (527684m$^3$) corresponding to level (198 m), as the increase after this level is relatively greater than before, as in figure (20), which turns out to be at the beginning of the figure, any increase in the volume of storage is accompanied by a large increase in negative planner area. This means that the bottom of the reservoir in this area is of a planner nature.

Dead Storage:

It is defined as the volume of storage at the lower level of lower gate of the dam, at this level; at this level the storage cannot exist from the gates, and therefore metaphorically called dead storage. Which is under the level (203 m), as shown in the figure (25), as the lowest level of the gates of Al-Wind dam is (203 m), through the geometric analysis in the table (3), the volume the dead storage equal (4011813 m$^3$), dead storage usually reduced over time due to the accumulation of the deposits in the area below the level of gates, as shown as in the figure (21).
The percentage of the dead storage (which reached to 54308822 m³, at the operational level 215m) to total storage is (7.4%), which is acceptable for the total volume of the reservoir.

**Conclusions**

Through the geometric analysis results of number of important geometric elements of the reservoir, the following conclusions can be reached:

1. The innovated method of geometrical analysis in this study, that supported by the digital elevation models and spatial analysis system are an excellent, accurate and effective method, but its accuracy increased with the increasing of accuracy of digital elevation models.

2. The innovative method has developed a method of integration between the different spatial analysis software that exports the data to each other.

3. The relationship between the levels and the negative geometric elements, such as negative volume, negative planner area and negative surface area are non-linear covariant relations, in which there are more than one direction and transitional stage, these directions and stages are due to the increasing of storage and submerge areas, as a result of the exit of the reservoir from the original stream of the river to the flood plain, then from the flood plain to the river terraces.

4. The relationship between the levels and the positive geometric elements such as positive volume, positive surface area and positive planner area, is generally fluctuated relationship, if the increase of the level companied by the expansion of the reservoir to a new land with the appearance of new islands, the positive volume will increased, either if the raising of the level is not companied by appear of new island, the positive volume will be decrease as a result of the submerge of an islands gradually with the increasing of the level.

5. The increasing of the positive volume at a number of levels will has a great importance in determining the optimal use of these islands, especially for tourism.

6. The similarity in the behavior of positive planner and surface geometric relationships with the level reveal to that there are no topographic complexities, but this is probably due to the lack of accuracy of digital elevation models adopted in the analysis

**Recommendations**

1. Adopt the results of this geometric analysis in suggest the operation scenarios of the dam reservoir, that related to storage, release and control the storage.

2. Use the most accurate digital elevation models in the future studies of reservoirs, by the same procedure and methodology

3. Achieve studies of reality of groundwater in terms of levels, movement, recharge, type of aquifers and hydrochemical characteristic, and then develop mathematical models to simulate the groundwater conditions surrounding the dam reservoir.

**References**


التحليل الجيومتري لخزان سد الوند في شمال شرق العراق باستخدام نماذج الارتفاعات الرقمية ونظام التحليل المكاني
صنبر عبدالله صالح، اكفاءة طه عبد القادر، أمين موقع إبراهيم، هدى مزهر حسين
قسم علوم الأرض التطبيقية، كلية العلوم، جامعة تكريت، تكريت، العراق

الملخص
ناقش هذه الورقة موضوع حيوي واستراتيجي، وهو التحليل الهندسي لخزان سد الوند في ديالى، إذ استخدمت نظم التحليل المكاني لاشتقاق موقع خزان سد الوند من نماذج الارتفاعات الرقمية، عند 26 منسوب منتبخ ابتداء من 195 وحتى 219.5 متر فوق مستوى سطح البحر، وفاصلة قدرها متر واحد، واختمت المعايير الجيومتري استخلاص قيم العناصر الجيومترية السالبة الأساسية ممثلة بحجم الخزين (السالب) (Negative volume) (NV) والمساحة المستوية (السالبة) (Negative Planner Area) (NPA) والمساحة المحيطة (المثبتة) (Planner Area Positive) (PPA) والمحيط (المثبت) (Planner Surface Area) (PSA) للمحيط المائي وحجم الشكل للخزان، وكذلك الحال بالنسبة للعناصر الجيومترية الموجبة الحجمية (Positive volume) (PV) (Positive Planner Area Positive) (PPA) والمحيط المائي وحجم الشكل للخزان، العناصر المذكورة أساسًا في الدراسات الجيومتريّة، إذ على أساسها تصمم سياقات تشغيل الخزان، كالتغذية والاستغلال من بيوت السد في ظروف التشغيل المختلفة، وهي التي تحدد التغيرات التي ستتعرض عليها استخدامات الأرض بعد بدء التخزين عند كل منسوب، وكذلك تغيرات المكانيات الجيولوجية التي ستعرض للتغير مع تغذية المنصب، وبناء عليه تم تحديد المنصب الذي يضم تغييرات آمنة للخزان بما يلي: منصب الابعاد المحدد عن السد، وأقل هدر في استخدامات الأرض وأقل مساحة مغمورة، وأقل هدر في الخزين الأساسي، كما تم وضع العلاقة الرياضية بين مساحة وسعة الخزان لاستعداد الفيضانات في الخزانات، وتكون المساحة الم цельة للخزان كذلك التنبؤ بسعة الخزان عند أي مستوى للماء، وكذلك تصنيف الخزان.

انظر التحليل الحالي أن المنصب التشغيلي الأمثل هو (215) م فوق مستوى سطح البحر الذي بلغ عند حجم الخزين (54308822) م³ (1) في حين اتشرت الدراسة الأولية للسد التي أجريت بالطرق التقليدية للمسح أن حجم الخزين عند نفس المنصب هو (37820000) م³ (2).

صارت نماذج الارتفاعات الرقمية لكل منصب منتبخ على شكل صور رقمية مفيدة، رغم موجد لمغرض المقارنة البصرية بين امتدادات وشكل الخزان عند المنصب المختلط، إن هذا التحليل مفيد لأدراة السد في وضع السياسة التشغيلية للخزان.