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Purposeful scientific research is a basic pillar for the advancement of Iraq

DEM-GIS Based Geometric Analyses of Kufri Dam, northeastern, Iraq

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ABSTRACT

The geometric analyses for each reservoir area represent an important database to aid dam's designers. New Innovated methodology used the Digital Elevation Model of Kufri dam reservoir area to extract the geometric characteristics of the reservoir depending to the analyses of volume-area-level relations of the reservoir depression.

The area that surrounded within the borders of maximum contour line for the reservoir which represent 279 m a.s.l. according to the design of dam, was extracted and exported as a global mapper package file. Then this data file used to extract the elevation data for the hypothetical levels from 258 m a.s.l which represent the minimum operation level, to maximum 279 m a.s.l. with 0.15 m interval, these data was exported as SURFER grid files to derive the geometric elements.

Ten geometric elements were suggested and derived in this proposed methodology, which are the positive volume (for islands), negative volume (for reservoir), positive planar area, negative planar area, positive surface area, negative surface area, residual capacity, average island thickness, and average depth for each corresponding level, in addition to dead storage.

The relationships of the geometric parameters of storage volume, submerged area, surface area, and positive elements were constructed against hypothetical levels and then statistically processed.

The optimum operation and flood levels for the reservoir were selected dependence on the geometric parameters. Also, the dead storage map and the depth maps for selected water levels were derived, plotted and analyzed.

Keywords: dam; reservoir; DEM; GIS; geometric analysis; dead storage; depth map

Introduction

In several semiarid areas in the world, surface water provides a major source of water supply. Storage of surface water is an essential strategy in guaranteeing water supply in these regions. River runoff which occurring during the rainy seasons is stored in surface reservoirs to sustain human, agricultural and industrial water use during the dry seasons (Guntner, et.al. 2004).

The authorities in the sector of water resources, politicians, decision makers, and the media, complain from water shortage in Iraq, while the actual disaster practiced in Iraq, is the crisis of water management, where no concern in the sector of water resources.

The dams are the most important projects in the sector of water management, they used to store irrigation water during the wet period, and reuse it when the dry, in addition to other benefits in the fields of power generation, tourism, reducing flood risks, and fish farming.

Human has known the importance of dams since ancient eras, so, the construction of dams on the valleys in order to best use of flood water and protect the risk of devastating floods, and the keenness often to live around these dams to take advantage of the water that collects in lakes, therefore, to design the dams according to the accurate standards and regulations have a great importance in the protection of life and safe the possessions.

Kufri dam is located in the northeast of Iraq, 3.5 km apart to the northeast of Kufri town's center, At the maximum level, the reservoir of the dam is capable of storing 21 million cubic meters of water. The geographical coordinates of the dam reservoir are situated within the longitudinal range of 34° 43' to 34° 44' and the latitudinal range of 44° 58' to 44° 56'. and the location on the map is shown in Figure 1.

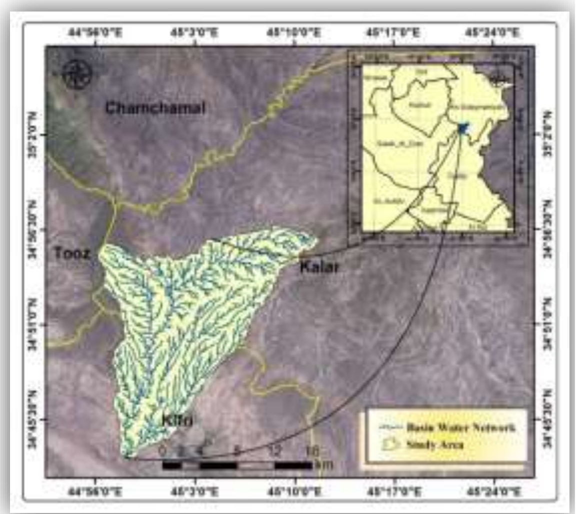

Fig. 1: shows the location of the reservoir, at the maximum level

Injana fm. (Upper Miocene) is the oldest outcropped formation in the northeast of Kufri River watershed area, it consist of sequence of sandstone, siltstone, and claystone, to southwestern part of watershed Mukdadiya Formation (Upper Miocene) was outcropped, this formation consists coarse gravel, and the foundations of the dam are installed on these outcrops. The Mukdadiya formation underlies the dam reservoir. The southern part of the dam reservoir is located on the outcrops of this formation, while the northern part of the reservoir is located on Injana. The Mukdadia formation, characterized by coarse gravel, and the Injana formation, comprising sandstone, siltstone, and claystone, provide an appropriate foundation for the reservoir in terms of water quality. This suitability arises from the absence of salt-bearing rocks, such as gypsum, in these formations.

Structurally, the area is located on the southwestern of a syncline, oriented south-east-northwest. The area of the dam is also bounded from the south by an anticline oriented to the same direction.

The study area is located between the foot hill zone and high folded zone as a basin surrounded by the highlands from all sides, the derivation of the drainage system of Kufri dam watershed reflect the presence of longitudinal and transverse valleys, Figure 2.

There is another transverse valley perpendicular to the anticline axis, and parallel to the dip direction, the other valleys are longitudinal parallel to the axis of the fold; the shape of the basin is longitudinal to the northeast.

The study of geometrical elements, which represented by the capacity (negative volume) of the reservoir, the surface area (area evaporation), an area of the bottom of reservoir (wetted area), shape factor, areas and volumes of islands and bays corresponding to the levels of reservoir, dead storage, and depth maps represents the most important information and database upon which determine the optimum level to operate the reservoir, This study presents an operation database for the operators responsible for managing the dam and its associated structures. The information and insights provided in this study can aid in effective decision-making during the operational phase of the dam. (Al-Shaheri, 2015).

Geometric analysis studies are very limited in Iraq, but there are some studies in the world such as the study of Laurence Cload, (2007), which use the traditional techniques to analyzed the geometric properties of Mokihinui dam reservoir to predict the probable landslide engineering effects on the dam and reservoir (Al-Kraei et. al. 2015).

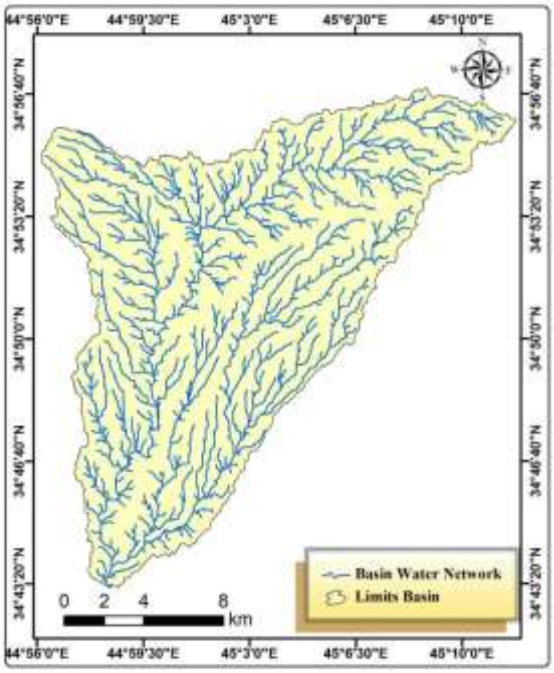

Fig. 2: Drainage system of the Kufri dam watershed

Haghiabi, et al., 2013, used the plotting of reservoir depth against reservoir capacity (negative volume) on a log-log paper, to estimate the shape factor which is the most important geometric characteristics of a dam's reservoir, that equal to the reciprocal of the slope of a line obtained by this plotting.

Sawunyama, T., (2005), estimate the small reservoir storage capacities in Limpopo river basin, using remotely sensed surface areas.

Saleh, (2014), studied Makhoul dam reservoir - hydrologic and geometric study for optimum level selection. Geometric analysis of the reservoir was performed at the levels from 140 to 156 meters above sea level, and then discussed the relations between the geometric elements with the different levels, and relations between the elements with others.

Al-Hawaiz, (2014), conducted a bathemetric study on Tigris River sections at the industrial establishment's water intakes and assesses the sediments in their settlement basins, in Baiji city and conducted a geometrical analysis of each section of the river at these inlets in order to reach the optimum state.

Al-Shaheri (2015) studied the flood routing of Tigris River in Baiji and Makhal dam reservoir in northern Iraq, by a hypothetical operation of the dam. Among his attention was the geometrical analysis of the reservoir, which is one of the basic requirements for routing, therefore, the storage capacity can be calculated with the variation of input and output discharge and the resulting storage difference, and the corresponding water level.

Saleh, et al. (2017) analyzed the reservoir of Wind dam in the east of Iraq. They chose the optimum level and the corresponding capacity for this level, compared with the calculated capacity in the traditional way; the operational procedures of the reservoir have been developed on this basis.

The construction of the dam, would lead to control the water surplus in the river and will raise the water level in the river, and thus change the submerged areas, volumes of storage, land uses, and get morphological changes in the basin storage, for example dry valleys changed to bays, and hills to islands. The extent of storage leads to an increase in the surface area of the water, which increases the amount of evaporation that causes water salinization, and leakage, which leads to increase the groundwater recharge.

A field trip was conducted to identify the geology of the area and its stratigraphic, morphological and topographical characteristics. Information on the coordinates of the dam site was obtained by UTM system. Some of the phenomena were documented in photographs as evidence of the validity of the facts presented in the research, as shown in Figure 3.

Fig. 3: Photographs of the dam during the collection of information, the right photo shows the body and shape of the dam, while the left photo shows the dam reservoir.

The study aims to analyze the spatial variations of geomorphological features, for selected levels of the reservoir, and analysis of geometric elements such as storage volume, the surface area of the reservoir, the circumference, the wetted area, the depth of the water column and the shape factor. As well as changes that occur on land uses at every level, and then compare different elevations to choose the optimal level.

Methodology

The geometric criterion which depends on the relation between geometric elements and water level and with each other, used to optimize the water levels in the dam and select the optimal.

1. Digital elevation models DEMs, E44_N34, E45_N34, E44_N35, and E45_N34, with resolution of 14X14 m have been used to extract the geometric elements.

2. The coordinates of the dam were determined in the field using Global Positioning System (GPS) and projected on digital elevation models to locate the two ends of the dam (the right end A and the left end C) in the field as well as the bending point (B) in the body of the dam, Figure 4. and Table 1.

Point	Easting	Northing
A	497684	3841974
B	497514	3842064
C	497520	3842084

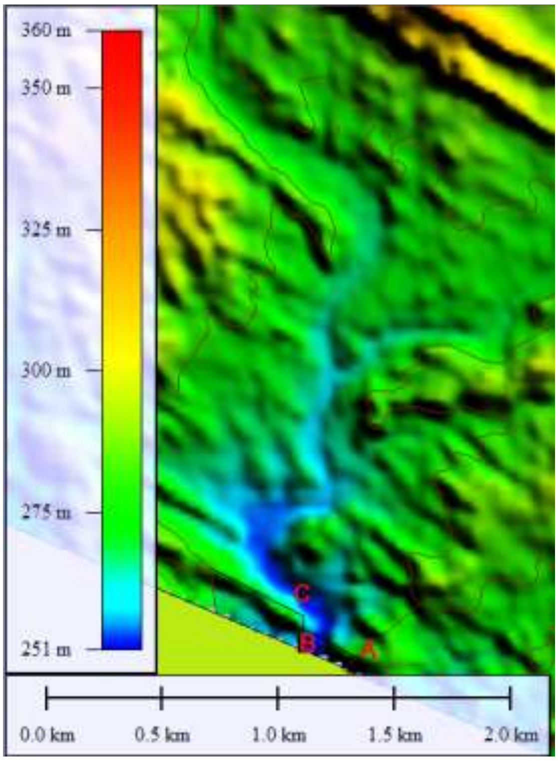

Fig. 4: Shows the projection of the dam points and the maximum limits of the reservoir

3. then, the contour line which represents the elevation 279m above sea level were generated, and thus, the DEM separated along this line around the stream of Kufri river, so, the line of 276 m.a.s.l. represents the outside boundaries of the reservoir area, which owned as the dam establishments, it is also represents the highest hypothetical level, for the reservoir in emergency conditions, Figure. 5.

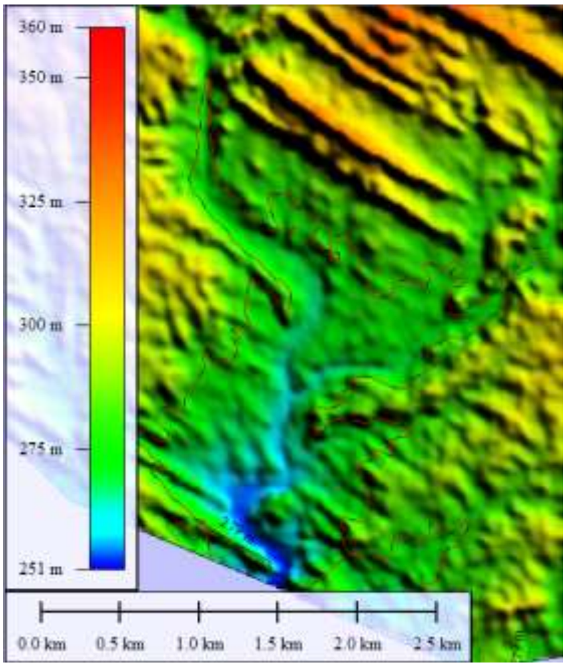

Fig. 5: the reservoir's extensions and shape at the contour line 279.

4. Contour lines of the heights have been regenerated within the area surrounded by the contour line 279 m (a.s.l.) using Digitizing Tool of Global Mapper 16, with contour interval (0.15m), from the height 258 m, which represent the lowest operating level, to 279 m (a.s.l.), and then re-separate the digital elevation data, for 144 selected levels, Figure 6.

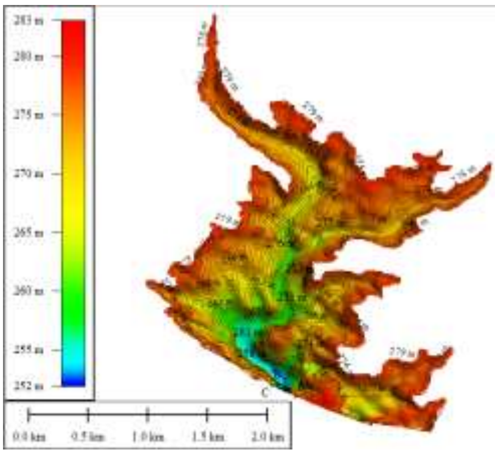

Fig. 6: The contour map of the reservoir

5. The digital elevation data for each level have been exported as Global Mapper Package file, then called up again to the Global Mapper, to plot the selected topographical sections for the bottom of the reservoir by Path Profile/Line of Sight.

6. Digital data file has been re-exported as an image of JPG-file, for later processing using ArcGIS, as well as, exported as SURFER grid files, to be used in the software SURFER ver. 13, to extract the longitudinal, areal, and volumetric geometric elements.

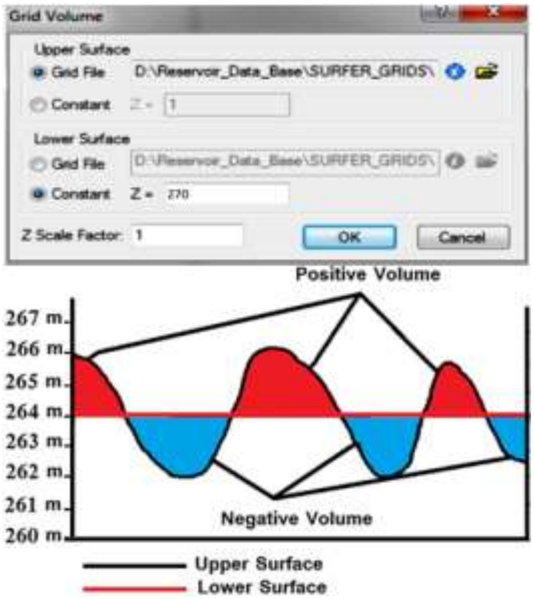

Fig. 7: Grid-Volume box, the upper surface is taken from the grid file representing the earth surface, and the lower surface represents the surface of the water in the reservoir and inserted as a hypothetical selected level.

7. The software Global Mapper is being used to call the layers of all levels to regulate and export them as images files in the same scale, for the comparison between shape and horizontal extensions of the reservoir at each level.

8. Tabulation of geometric elements data that derived as datasheet.

9. The relations between these elements were represented, to determine the optimal water level This corresponds to the optimal storage of water..

Results

The values of geometric elements data of the reservoir, which acquired from SURFER grid volumetric data reports, were tabulated as EXCEL datasheet, and the relationships among these elements were graphically represented, to formulate the mathematical equations of these relations, and thus, determine the optimal water level, Table 2.

The JPG files, for 140 hypothetical levels, from 258 to 279 m (a.s.l.) with contour interval 0.15m, were export from Global Mapper in the same scale as JPG files, for reasonable visually comparison of reservoir extension of each water levels with others. Because of the large number of these image files (144 image file), six levels were selected for display and visual comparison in this article, these levels were selected where there a dramatic changes in the shape and properties of the reservoir as in Figures 8.

Table 2: The different geometric elements and their relation to water level in the reservoir in Metric units

Elevation M.A.S.L	Positive Volume (m^3)	Negative Volume (m^3)	Residual Capacity (m^3)	Positive Planar Area (m^2)	Negative Planar Area (m^2)	Average Island Thickness (m)	Average Depth (m)	Positive Surface Area (m^2)	Negative Surface Area (m^2)
258	12,981	269,151	21,615,291	1,490	82,100	8.7	3.28	1,520	82,331
258.15	11,766	286,352	21,598,090	1,346	85,480	8.74	3.35	1,376	85,730
258.3	10,697	306,272	21,578,170	1,227	87,486	8.72	3.50	1,257	87,755
258.45	9,393	326,141	21,558,301	1,178	94,547	7.98	3.45	1,207	94,840
258.6	8,856	345,751	21,538,691	855	94,600	10.36	3.65	871	94,893
258.75	8,150	361,189	21,523,253	1,283	98,216	6.35	3.68	1,310	98,511
258.9	10,145	379,785	21,504,657	1,068	99,780	9.50	3.81	1,085	100,071
259.05	8,653	401,129	21,483,313	1,334	104,098	6.49	3.85	1,348	104,446
259.2	6,039	418,143	21,466,299	546	109,739	11.06	3.81	556	110,096
259.35	9,758	438,407	21,446,035	961	113,908	10.15	3.85	982	114,267
259.5	4,911	471,114	21,413,328	824	118,629	5.96	3.97	842	119,038
259.65	9,126	489,717	21,394,725	1,002	118,721	9.11	4.12	1,037	119,159
259.8	4,504	508,622	21,375,820	891	123,146	5.06	4.13	907	123,567
259.95	4,270	525,960	21,358,482	559	129,411	7.64	4.06	570	129,835
↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓
277.2	1,901	17,589,075	4,295,367	1,999	2,057,016	0.95	8.55	2,008	2,063,573
277.35	4,934	17,982,498	3,901,944	3,874	2,075,634	1.27	8.66	3,898	2,082,827
277.5	2,882	18,268,359	3,616,083	1,339	2,103,246	2.15	8.69	1,349	2,110,056
277.65	2,697	18,627,783	3,256,659	1,290	2,124,058	2.09	8.77	1,300	2,131,189
277.8	5,762	19,024,381	2,860,061	3,277	2,145,800	1.76	8.87	3,300	2,153,637
277.95	5,894	19,363,124	2,521,318	3,285	2,167,903	1.79	8.93	3,309	2,175,812
278.1	6,516	19,720,332	2,164,110	5,945	2,202,184	1.10	8.95	5,985	2,210,211
278.25	9,225	20,102,292	1,782,150	6,704	2,226,772	1.38	9.03	6,752	2,235,268
278.4	4,750	20,403,231	1,481,211	4,790	2,243,247	0.99	9.10	4,816	2,251,121
278.55	5,287	20,775,610	1,108,832	4,771	2,274,814	1.11	9.13	4,803	2,283,063
278.7	1,225	21,101,788	782,654	1,580	2,304,161	0.78	9.16	1,586	2,311,624
278.85	3,464	21,524,603	359,839	2,960	2,327,319	1.17	9.25	2,981	2,335,500
279	6,631	21,884,442	0	6,306	2,365,228	1.05	9.25	6,339	2,373,774

↓ The table was shortened because it is long, and substituted by graphs in next paragraphs.

The cross-sectional and longitudinal topographic sections of the reservoir are very important in the study of geometric characteristics of the reservoir. The cross sections give an idea of the reservoir's expansions and depth variation in comparison with the banks. The longitudinal section gives an idea about the variation of depth and slope between the river upstream and the dam (Salih, 2014), the cross-sectional and longitudinal sections are explained in Table 3.

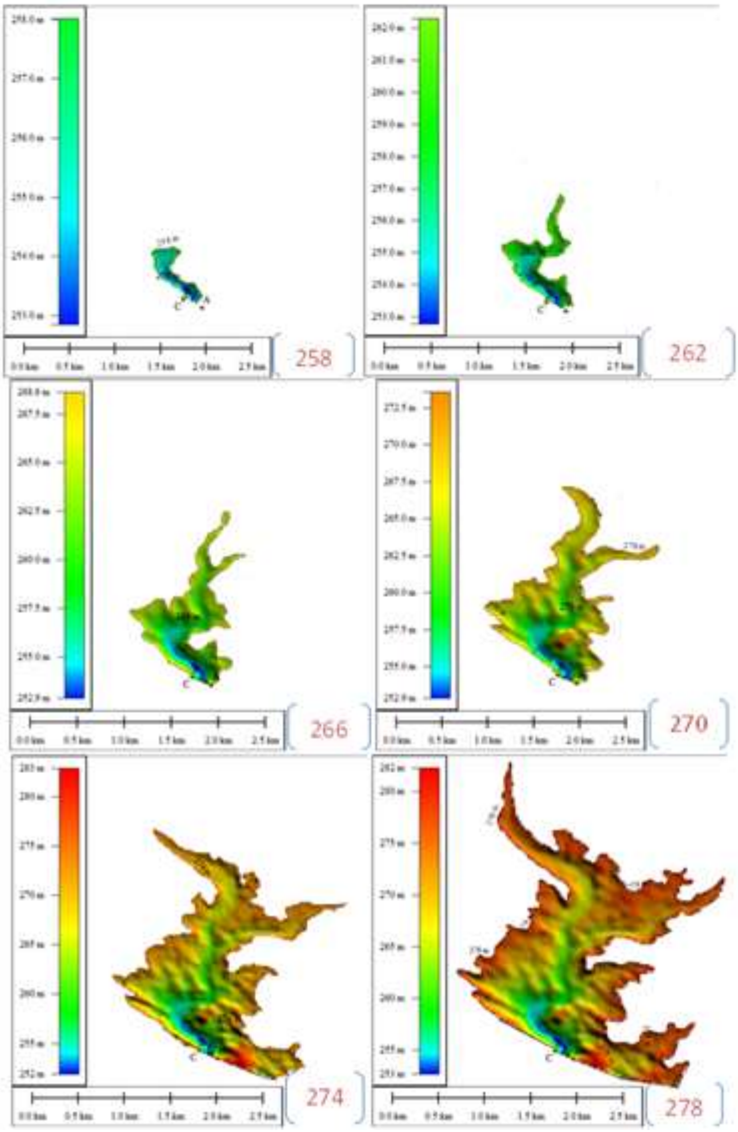

Fig. 8: The comparison of extension and shape of the reservoir on four selected levels 158, 162, 164, 166, 170, 174, and 178 m.a. s.l.

Topographic sections were drawn from the digital elevation model of the level 179 m (a.s.l.), because the sections for this level could give an idea for another lowest levels in the same geographical location, the traverse section A-A' was located 573m east of the dam and represents the part of the reservoir near the body of the dam, it is perpendicular to the original stream of the river, the traverses sections B-B' is located 1151m east of the dam body in the middle of the reservoir, it is also perpendicular on the original stream of the river, C-C' section is located 1593m east of the dam in the far part of the reservoir, and it is perpendicular to the original stream of the river, while the section E-E' is located along the original stream of the river, and passes along sinuous line on the deepest points inside the reservoir, the length of the section reaches 2225 m at the level of water 279m

Table 3: The data of cross sections and longitudinal section data

Section	Start	End	Lowest Elevation of bottom (m)	Distance from the dam (m)	Section Length (m)
A-A'	X=496953	X=497959	257.905	573	1196
	Y=3843058	Y=3842386			
B-B'	X=497388	X=497911	262.136	1151	630
	Y=3843636	Y=3843126			
C-C'	X=497666	X=498074	265.59	1593	694
	Y=3843806	Y=3843317			
E-E'	X=497741	X= 497592	252.602	0.0	2225
	Y=3843921	Y=3842121			

Discussion

The importance of this work is to Assessment the geometric characteristics of the reservoir; it is useful for route the reservoir and designs the operating procedures and scenarios (Al-Shaheri and Saleh, 2015).

The morphology, size, and depth of the reservoir play a crucial role in facilitating navigation and tourist boat transportation within the reservoir. and distribution of fixed tourism sites.

The length of reservoir will be around 2.25km, with an average width 0.75km, when the water level in the reservoir reaches 279 m (a.s.l.) figure 3.

From the visual comparison of the reservoir body extensions of 144 selected water levels, with the interval of 15.15 meters, the reservoir body is undivided in its part near the dam. However, as we move towards the upstream of reservoir, the bays will appearance, which represent the estuary of the valleys.

It was observed that the changes in the form of the reservoir and its extensions at high levels, especially near the body of the dam, and this may reduce the seismic hazard

The comparison between the lateral extensions of the reservoir area and different water levels, reveals to gradually growth of reservoir body, with the growth of level. there are no sudden changes in the shape of reservoir with the changes of levels, except some simple changes Figure 3, and this is in harmony with the topographic reality, that the river banks rising gradually between levels 258 to 279 m (a.s.l.), with some minor exceptions.

Level-Volume-Area relationships:

The relations between the geometric elements, especially among level, volume and area, are the basic of geometric studies, these relations used to design the future operational policy of the reservoir, which specifies the changes that will occur on land use after starting the storage at each level. Accordingly, the level will be ensures safe operation, to meet the less harmful in the use of lands, less immersed areas, in addition to avoid the environmental problems and disasters.

Area-capacity curves are usually used for reservoir flood routing, determination of water surface area, capacity corresponding to each water level, and reservoir classification (Mohammadzadeh, et. al., 2009). These curves are revealing to the most important physical characteristics of dam reservoirs(including but not limited to size, shape , height , capacity and depth). These curves are used for reservoir operation, prediction of sediment distribution in reservoirs, etc., (Haghiabi, et.al., 2013).

The relationships between these hypothetical water levels in the reservoir on the X-axis, are plotted versus the corresponding volumetric and areal geometric elements on the Y-axis, table 2.

The first of these relationships was between positive volumes (PV) and water Level, (PV) was fluctuated with increasing of water level, especially at 267 m (a.s.l.) where the positive volume increased significantly, followed by a general decrease in volume with simple fluctuation. The reason for this fluctuation is the appearance of new islands and the disappearance of other islands within the limits of the reservoir with the increase of these levels as a result of the addition of new land to the body of the tank, as in Figure 9.

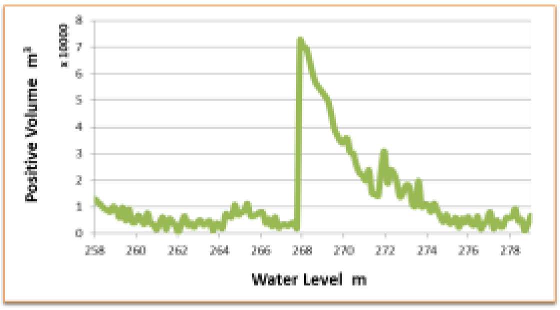

Fig. 9: The relation between water level (m) with the positive volume m^3 of the reservoir

The second relationship between the negative volume m^3 with the water level, which showed increasing of negative volume with the increase in water level in general, the trend of this relationship divided to two main stages separated by a transition one, First stage start with the beginning of storage and end at level 265 m, the increase in the volume of storage with the increase of level (the blue line in Figure 10) lowest than next stages, then followed by transitional stage between the levels 265 m to 274 m, most of the islands submersed and the storage moving from the floodplain of the river to the first river terrace, then the increase in volume is sharpest after the level 274m up to maximum level 279m. The reservoir would be more broadly along the reservoir within the borders of river terrace (red line in figure 10), the maximum negative volume (reservoir capacity) reached to 21884442 m^3 corresponding to maximum level.

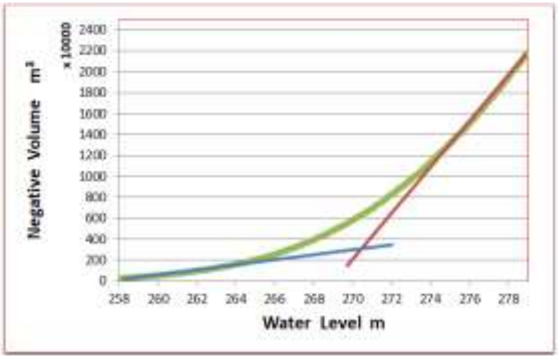

Fig. 10: The relation between water level (m) with the negative volume m^3 of the reservoir

The PSA decreases overall, excluding some exceptions which corresponding to the exceptions in the case of PV; the reason for these exceptions is the appearance of new islands during the (hypothetical) increasing of water levels. This is compatible to PPA, which have similar behavior to PSA, because their curves are perfectly matched. This convergence indicates that the surfaces of islands are flat, so, undulating surface areas are approximately equal to the projections areas figure 11.

The positive surface area (PSA), which represents the uneven area of the islands, is generally low in the low levels to 262 m.a.s.l., as the reservoir boundary is still in the original stream of the river, but this area increases immediately after the level (267) and then began to fluctuate because of the roughness of the shoulders of the stream, which makes the islands appear sometimes and disappear again with the increase due to the addition of new land to the body of the reservoir, as in Figure 11.

This is compatible to PPA, which have similar behavior to PSA, because their curves are perfectly matched. This convergence indicates the low roughness of islands because the low resolution of DEMs, Figure 12.

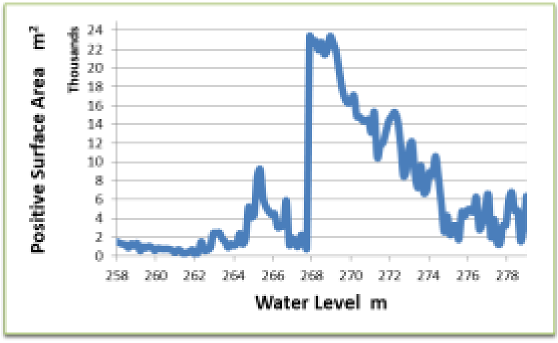

Fig. 11: The relation between water level and Positive Surface area of Kufri reservoir

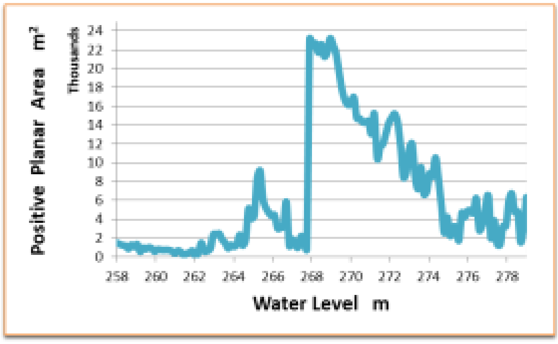

Fig. 12: The relation between water level and Positive Planner Area of Kufri reservoir

The negative surface area (NSA), which represents the uneven area of the reservoir bottom (submerged area); it is continuously increased and not fluctuated with the increasing of water levels. The slope of the increase curve is low when low levels, but it was increased significantly above the level 266 m.a.s.l., due to exit of the reservoir body out of the original valley cliff as in Figure 13.

The increase of NSA and Negative Planner Area NPA with the increase of water level should be exactly matched, their tabulated values converged due to low roughness of the terrain of reservoir bottom, or low resolution of the DEMs, So, all terrains those less than one pixel area, disappears (the area of one pixel in this study is 14 x 14 meters). Therefore, the surface area approximates very close to the flat area, Figure 14.

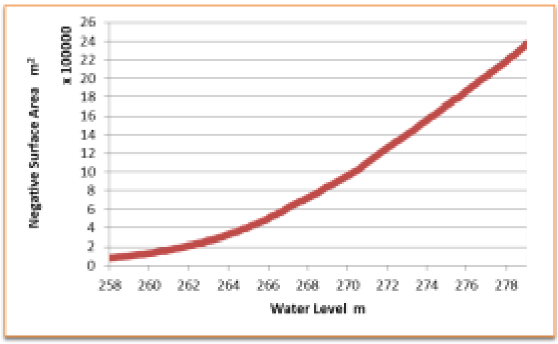

Fig. 13: Shows the relationship between the water level and the negative surface area

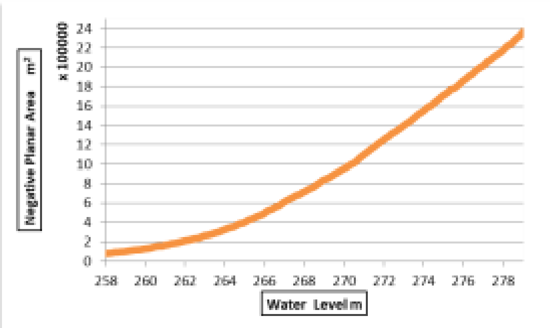

Fig. 14: Shows the relationship between the water level and the negative planner area

The relation between the Negative Planner Area (NPA) and the Negative Volume of the reservoir (NV), reflect that the increase of flat area of water body (evaporation area) is semi-linear with the increase in the volume of the reservoirs, Figure 15 reflects the nature of the reservoir resulting from the geological background of the selected site.

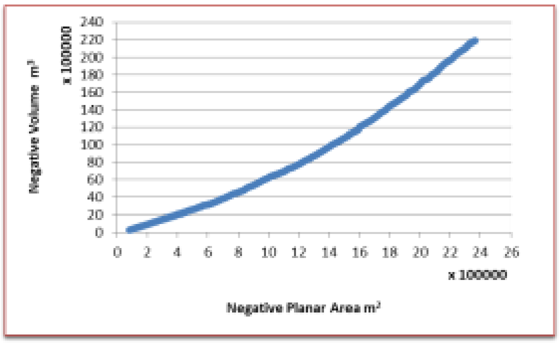

Fig. 15: The relation between Negative Planner Area (m^2) and the Negative Volume (m^3) of the Kufri reservoir

The cross and longitudinal topographic sections to the bottom of the reservoir, are very important in the study of geometric properties of the reservoir, the cross sections give a clear vision for the places of breadth of the reservoir, and variations of depths along these sections, either longitudinal sections are give a vision for heterogeneity of depths between the upstream and the dam, and the slope of the river bed along these sections.

The cross section (A-A`) is located 573m east of the dam, it is perpendicular to the original stream of the river, it represents the part of the reservoir near the dam, Figure 16, the length of the section is 1196m, when water level 279 m.a.s.l, the deepest point in the section is about 23m in the stream of the original river, it is away from point A at the distance 800m , then the depth begins to decrease until it reaches point A`.

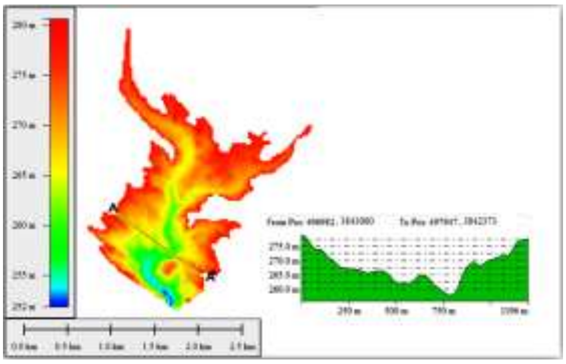

Fig. 16: Cross section A-A` in Kufri dam reservoir

The cross section (B-B`) is located 115 m east of the dam in the mid of the reservoir, it is perpendicular to the original stream of the river as shown in Figure 17. The length of the section is about 630m at the water level 279 m.a.s.l., the highest depth of water 19m, which is 425m away the point B.

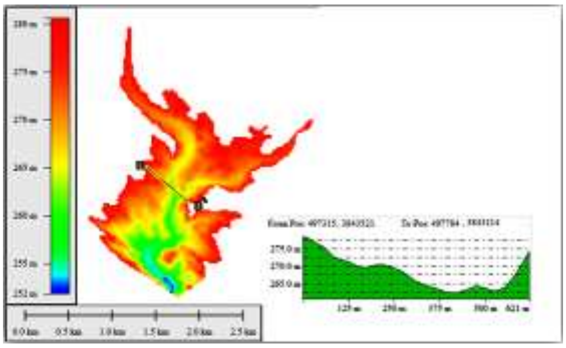

Fig. 17: Cross section B-B` in Kufri dam reservoir

The cross section C-C` is located 1593m east of the dam in the far part of the reservoir, and vertical on the original stream of the river as shown in Figure 18. The length of the section is 694m when the water level is 279 m.a.s.l., the highest depth of water in the section is 15m, 200 m away from the point C, and then the depth begins to decrease to the point C`.

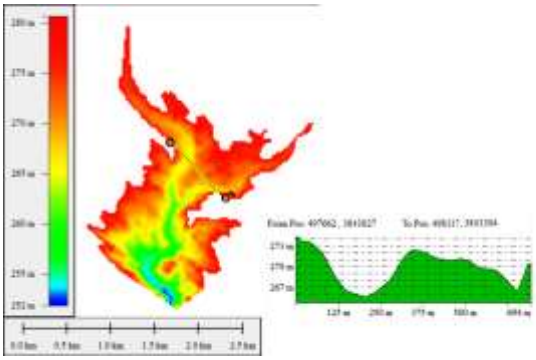

Fig. 18: Cross section C-C` in Kufri dam reservoir.

The E-E` longitudinal section is located along the stream of the original river, and passes on a meandering line on the deepest points within the reservoir and the length of the section about (2225) m at 279m water level, the section shows the slope of reservoir in the original riverbed as shown in Figure 19. The highest depth of water is26m near the dam, and then the depth gradually decreases to a few meters at the point E.

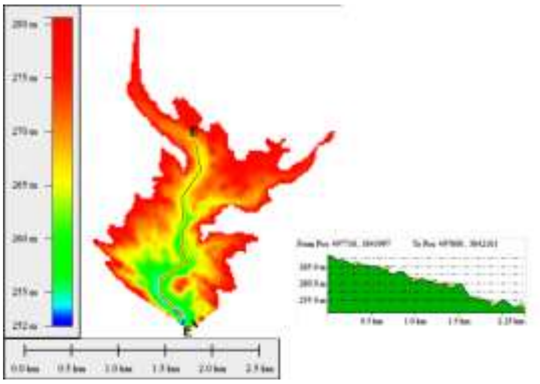

Fig. 19: Longitudinal section E-E` in Kufri dam reservoir.

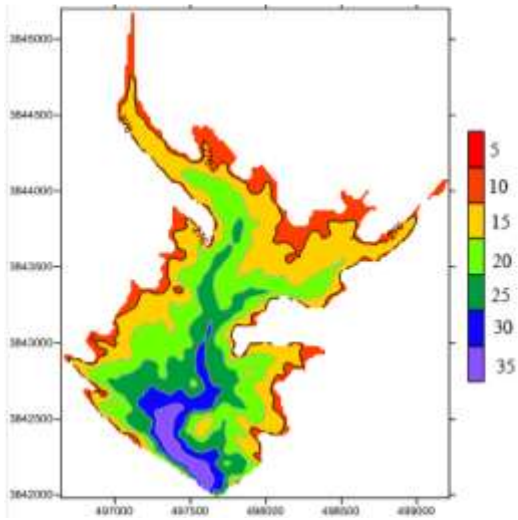

Fig. 20: Map of water depths at the maximum level.

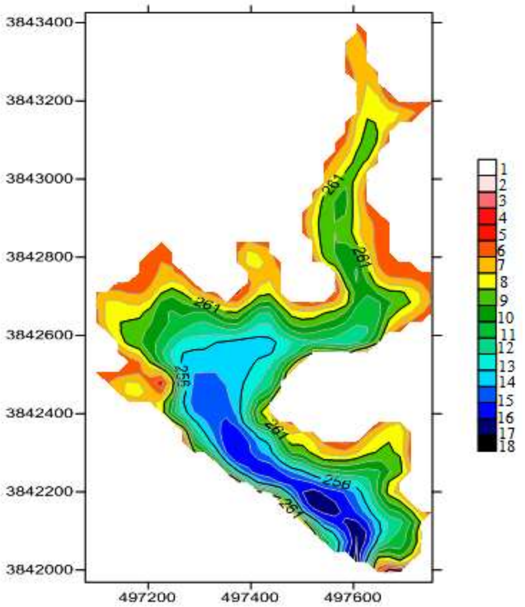

Fig. 21: A map of the depths of the reservoir under dead storage.

The water depth map at the maximum level of the reservoir reflected that the shallow areas represent a narrow strip on the outer borders of the reservoir, the depth gradually increased towards inside of the reservoir and areas near the dam, this confirms the appropriate choice of the location of the reservoir, and can be adopted this form in the choice of routes of mobile and fixed tourism facilities, and in the operating scenarios of the reservoir Figure 20. Demonstrate that the maximum depth of the water body, at the highest water level, attained a value of 35 m, which gradually decrease towards the edges.

Dead storage is defined as the size of the reservoir at the lowest level of the lower discharge gates outside the dam. At this level, the reservoirs cannot exit the gates. This is called dead storage, which is under the volume (264) m, as shown in Figure 21. The lowest level of the gates of the Kafri Dam is 264 m above sea level. In geometric analysis in Table 2, the dead storage volume is 1606495 m`. Accumulation of deposits in the area below the levels of gates.

Conclusions: The visual comparison between the extensions of 144 selected level for Kufri dam reservoir, reveal to that the reservoir body is undivided in the part near the dam. However, when move towards the upstream of reservoir, the bays will appearance, which represent the estuary of the valleys.

1. The comparisons between the extensions of the selected levels reflect that there are no significant changes in the width and shape near the dam.
2. The water depth map at the maximum level of the reservoir reflected that the shallow areas represent a narrow strip on the outer borders of the reservoir, the depth gradually increased towards inside of the reservoir and areas near the dam
3. The relationship between PV, PPA, and PSA with water level, showed low fluctuation of these geometric elements with the increase in water level in general, and a sharp increase in the level of 267.9m, this exceptional increase due to the appearance of new islands within the reservoir. This is an important factor in the future uses of the land, especially islands areas that will appear on these levels.
4. The NV raised with the level, this relationship divided to two main stages, the first started with the beginning of storage and ended at the level 265m, the growth of volume is lowest than next stages, then followed by intermediate stage between levels 265 m to 274 m, most of the islands covered and the storage moved from the floodplain of the river to the river terraces, then the increase in volume sharpest after the level 274 meters, and the reservoir would be more extensive along the reservoir within the river terrace.
5. The direct relationship between the NPA and NV, reveal to clear relative increase in the volume of storage compared with the flat surface area, especially when the water level of 267.9m, the increase of NV above this level, relatively larger than before this water level.

Recommendations

1. Application the method used in this study on other reservoirs.
2. Use the high resolution digital elevation data in future, especially in small reservoirs.
3. Dependence of geometric data analysis by the dam's designers.

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