A STUDY ON THE ASSESSMENT OF BATHYMETRIC CHANGES VIA GIS: ALTINAPA DAM (KONYA) EXAMPLE

Ayhan CEYLAN and Ilke EKİZOGLU, Turkey

Key words: Hydrographic surveying, RTK-GPS, Water management, GIS.

SUMMARY

The main objective of water policies is to appreciate the value of present waters and water springs, use them in the most efficient way and gain maximum benefit. In order to store more water in dams, lakes and ponds, prevent water pollution, protect water sources and extend the service life of these facilities, it is important for users (Municipalities, DSHW, Irrigation Unions, etc.) to know the current topographic conditions and any changes in the capacities of these facilities, data about their geological structure, plant cover and water resources etc. and environmental elements and physical and chemical characteristics of the water.

Computer assisted data analysis currently plays an important role in the protection, development and management of water resources. Geographical Information Systems (GIS) are commonly used in efficient and effective data management for hydrographic data.

This study aimed to identify the updated topographic and bathymetric data required for the efficient management and usage of Altınapa reservoir, changes in surface area and volume of the facility, and to form a Dam Information System (DIS).

Two digital elevation models, from 2009 and 1984, were used to determine changes in the storage capacity of the reservoir. The calculations indicated that, within this 25-year period, the storage capacity of the reservoir decreased by 12.7% due to sedimentation.

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1. INTRODUCTION

Hydrographic maps are used to determine topographical features, researching water springs, producing navigation maps, establishing surface platforms, and subsea pipelines, etc. Turkey is surrounded by three seas and has hundreds of lakes of various sizes, ponds and dams, and therefore has strategic and geopolitical importance. Including the sea area within the continental shelf, Turkey has approximately 26 million ha of usable waters, 95% of which consists of seas, 1.3% of which consists of dammed reservoirs, 3.5% of which consists of natural lakes and approximately 0.1% of which consists of ponds (Kalkan and Alkan, 2005; Kalkan, 2009).

The main objective of water policies is to appreciate the value of present waters and water springs, use them in the most efficient way and gain maximum benefit. In order to store more water in reservoir, lakes and ponds, prevent water pollution, protect water sources and extend the service life of these facilities, it is important for users (Municipalities, DSHW, Irrigation Unions, etc.) to know the current topographic conditions and any changes in the capacities of these facilities, data about their geological structure, plant cover and water resources etc. and environmental elements and physical and chemical characteristics of the water.

Computer assisted data analysis currently plays an important role in the protection, development and management of water resources. Geographical Information Systems (GIS) are commonly used in efficient and effective data management for hydrographic data (Millett and Evans, 2009).

This study identified changes in water volume of the Altınapa reservoir, as a result of sedimentation over a 25-year period, by comparing topographic and bathymetric data from 1984 and 2009. The study also aimed to present the Dam Information System (DIS) for use by relevant institutions, involving data on the geological structure, plant cover, physical and chemical features of the water of Altınapa Dam and its surrounding area, and updated topographical and bathymetric information of the dam.

2. MATERIAL AND METHOD

2.1 Geographical Information System

A geographical information system (GIS) is an information system for the acquisition, preservation, analysis and presentation of graphical and non-graphical data based on locational operations (Yomralıoğlu, 2005).

These characteristics geographical information systems mean they are used for data analysis in a wide range of applications.

Data acquisition is the one of the most important phases, requiring the greatest time and cost, in realizing geographical information systems. During this stage, the efficient operation of the system way requires regular data flow to the system. Data acquisition operations can be realized by various disciplines, depending on current technological developments (Yomralıoğlu, 2005).

2.2 Study Area

The study area is Altınapa Dam, located in the Meram district of Konya province, Turkey. Altınapa Dam is located between 37^{0}54’32’’ and 37^{0}52’34’’ northern latitudes and 32^{0}17’00’’ and 32^{0}18’45’’ eastern longitudes. Altınapa Dam is 20 km from the western part of Konya province (Figure 1).

Altınapa Dam is a rock-fill dam built for potable water, flood control and irrigation, which has been operational since 1967. The normal operational water level of the dam is 1253.40 m, normal operational volume at this level is $32.7x10^{6}$ m^{3}, maximum water level is 1254.80 m and maximum reservoir volume is $37.6x10^{6}$ m^{3} (Küçüktığlı, 2002).

Figure 1. General View of Altınapa Dam

2.3 Topographical and Bathymetric Measurements

Hydrography is the study of the topographic status of the water-covered areas of the earth. The facts that approximately 71% of the planet’s surface is covered with water and that the seas are as rich and productive as the land in terms of food and transport, increase the importance of hydrographic measurements (Erkaya and Hoşbaş, 1998; Ozgen and Algul, 1977).

Even if the application area of hydrographic measurements is limited to the coastline, to

establish the connection between hydrographic maps and land, the coastline and some of its characteristics should be measured. Classical terrestrial techniques, Global Navigation Satellite System (GNSS), photogrammetric and remote-sensing methods are used for these measurements.
In this study, measurements were made using Topcon Precision GPS Hyperpro GPS receivers (RTK-GPS) and Topcon GPT 3007 electronic tachymeter.
In bathymetric measurements, depth and location measurements should be conducted simultaneously to detect the location of the point in both horizontal and vertical planes. The updated method used in horizontal location measurements are Time Kinematic (RTK-GPS) or Differential GPS (DGPS). Acoustic methods are generally applied in depth measurements.

Since the sea floor is not directly visible, bathymetric measurements are conducted according to a previously determined direction, and at certain time intervals, and the resulting data is related to the water level at the time of measurement.

A double- frequency Matrix GPS 97 Humminbird Echo Sounder was used in depth measurements of Altınapa reservoir. Horizontal location information of the depth measurement points was acquired by an RTK-GPS with Topcon Precision GPS Hyperpro receiver. One of the GPS receivers was established on reference point while the other was mobile and used on the hydrography boat. Bathymetric measurements were conducted on 2650 points. Topographic and bathymetric measurement points are shown in Fig. 2.

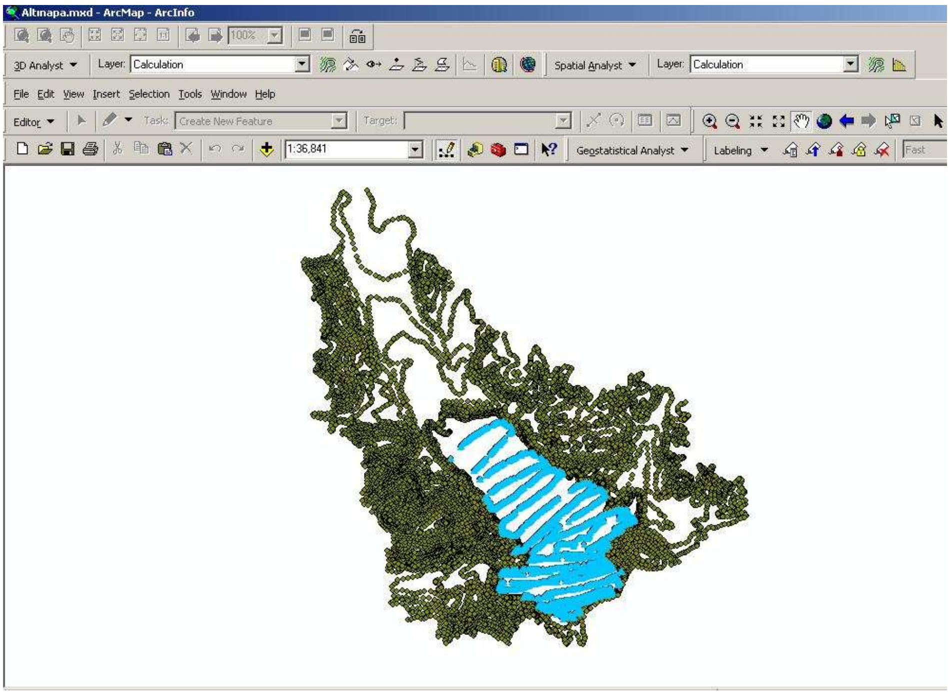


Figure 2. Locations of the topographic and bathymetric points

The elevation of the water surface on the day of measurement was taken from the mareograph station of State Hydraulic Works (SHW) the 4 th. Regional Directorate. Water floor elevations were calculated by reducing the corrected depths according to average water surface elevation.

2.4 Gathering Attribute Information

Attribute information of Altınapa such as meteorological, plant cover, geological and forest features was gathered from the institutions shown in Table 2.

Table 2. Institutions and attribution data (Ekizoğlu, 2011)

Institutions	**Received Information**
SHW 4th Regional Directorate	Bathymetric map from 1984, average water level values, water supply values of Meram stream, vaporization values of the dam, precipitation
Konya Special Provincial Administration	1:25.000 scale map of Konya and transportation roads of the dam
Konya Water and Sewage Administration	Basin border map of the dam
Central Anatolian 2nd District Office of Mineral Research and Exploration	Geological map of the region of the dam and geological information
Konya Regional Directorate of Forestry	Forestry maps and information about plant cover
Konya Provincial Department of Environment and Forestry	Information about trees in the region
Konya Directorate of Meteorological Service	Meteorological values of Konya province

2.5 Water Quality Measurements

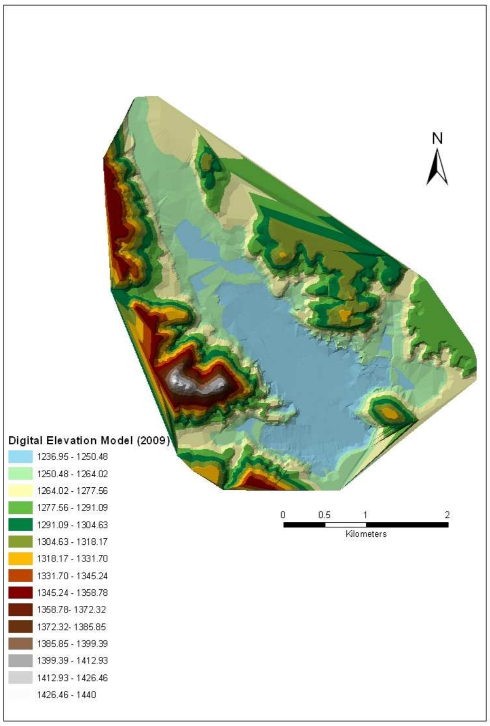
Water quality measurements were conducted in conjunction with bathymetric measurements. Samples from 31 points gave pH, turbidity, dissolved oxygen and temperature values of water. A WTW 340i multi-parameter device and a 30 cm diameter Secchi disc were used in measurements.

2.6 Digitalizing of Present Maps

A geological map provided by the Regional Directorate of Mineral Research and Exploration, forest map provided by the Directorates of Forestry and bathymetric maps from 1984 provided by the SHW 4th Regional Directorate were scanned at 300 dpi resolution and converted to TIFF (Tagged Image File Format) format. Then, maps in TIFF format were converted to vector maps with the Affin transformation routine within Netcad software.

2.7 Integration of Data to GIS Medium

Location and attribute data of the study area was integrated into ArcGIS 9.2 software., Firstly, vectorial data (X, Y, H) was exported to ArcGIS 9.2 software in ESRI shape format. Then, a digital elevation model of the study area was obtained with the TIN (Triangulated Irregular Network) method using the 3D Analyst module (Figure 3). Digital land model data were converted to GRID data with TIN to raster module of 3D Analyst module.



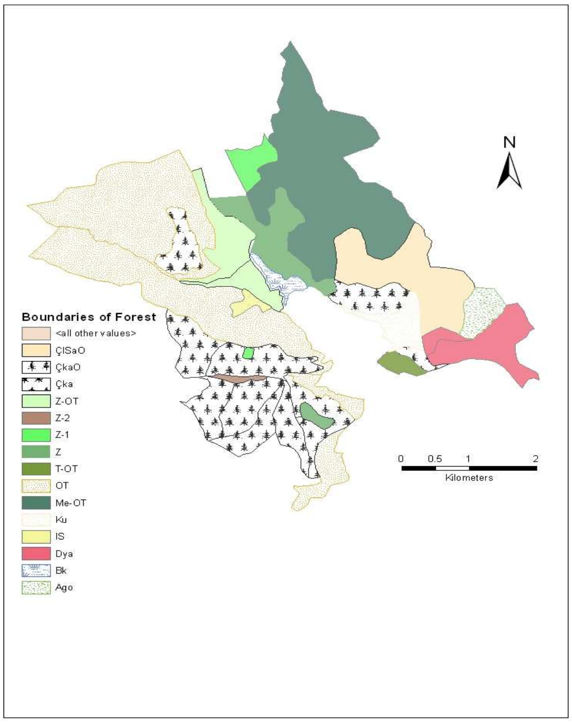


Figure 3. Digital elevation model map of 2009 Figure 4. Forest map

A forestry map of tree species, features and regions was produced with Add XY Data within the Tools module of ArcGIS 9.2 software (Figure 4); the geological map was similarly transferred to ArcGIS. The layers in the study area, their symbols and formation times were integrated into the program.

Physical and chemical features (pH, dissolved oxygen, temperature and turbidity data) of lake water were transferred to ArcGIS as point data.

Average water level of the reservoir, water supply data of Meram stream, evaporation values and precipitation data of the dam were added as GIS data layers.

Plant species in the study area added to the GIS system as points. The elevation of the plants, their Latin names, local names, the elements they belong to and their locations were transferred to the GIS.

3. RESULTS AND DISCUSSION

Within the scope of this study, digital land models and bathymetric maps of Altınapa Reservoir for the years 1984 and 2009 were obtained using ArcGIS 9.2 software (Figure 5).

The surface and volume changes of different water levels of Altınapa Reservoir were examined using GRID data of digital elevation models of 1984 and 2009 Surface area and volume changes of the reservoir are shown in Figures 6 to 8.

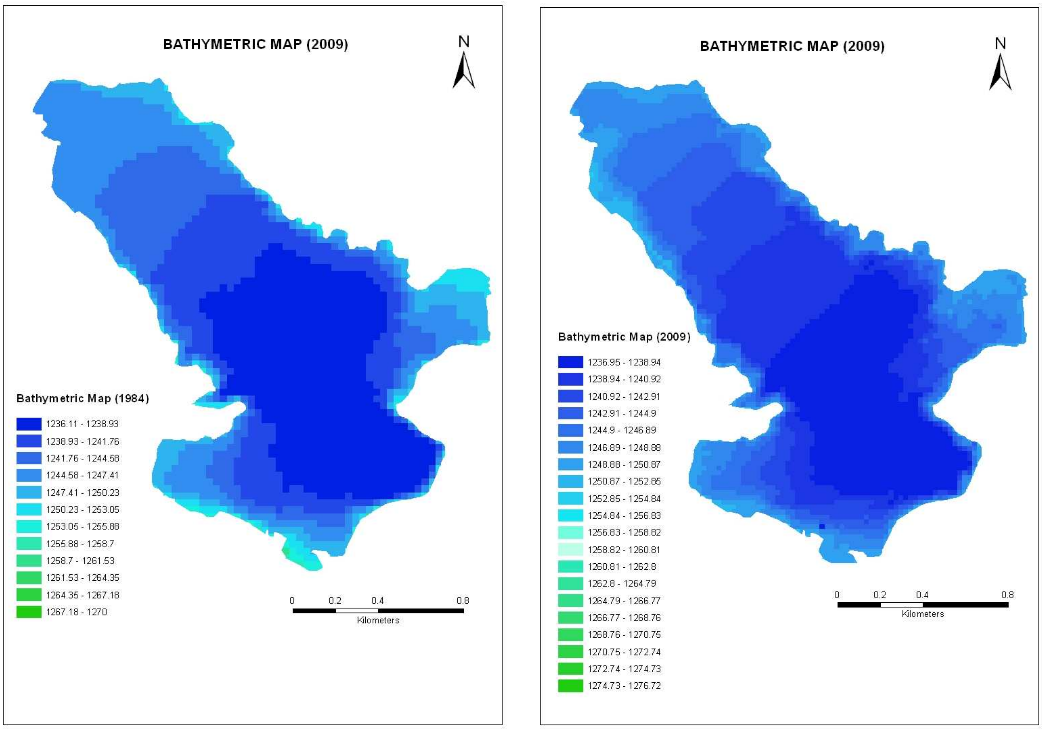


Figure 5. Maps of bathymetric in 1984 and 2009

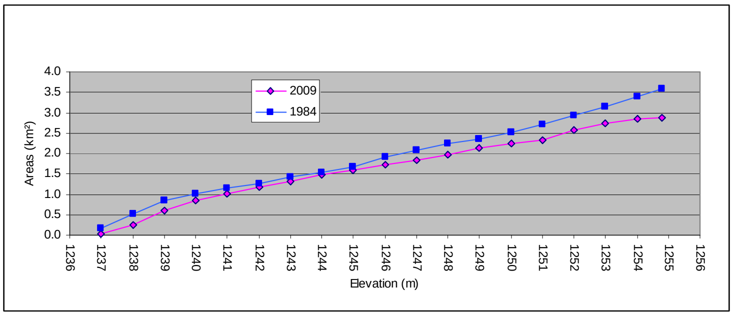


Figure 6. Changes in the surface area

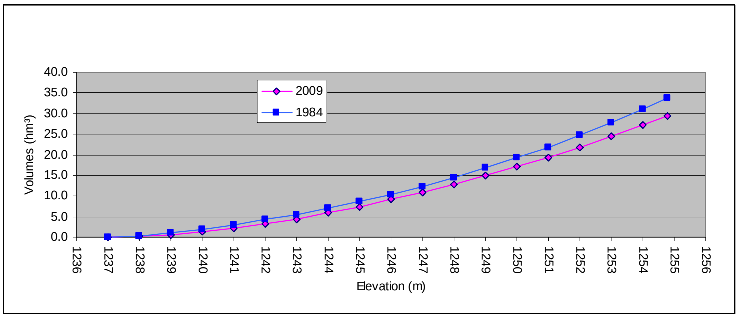


Figure 7. Changes in the volume

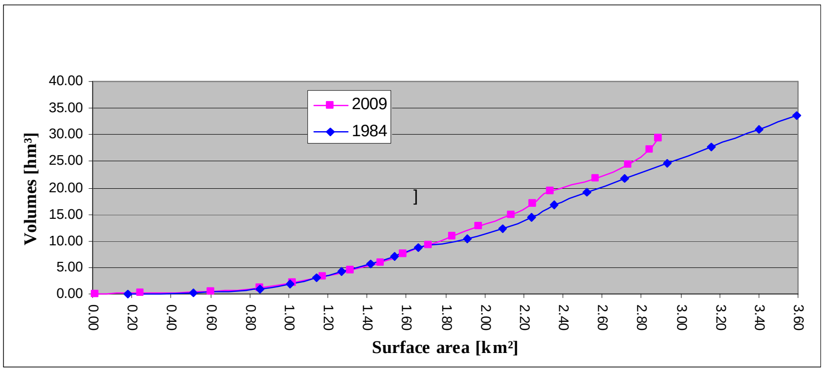


Figure 8. Changes of the area versus volume

In this study, these results represent a reduction in volume of 12% according to normal water level and 12.7% according to maximum water level. The capacity of the reservoir (normal water level) was found to have decreased by an average of 171215.75 m³/ year (or 0.51%).

Previous studies on this issue reported that the capacity of the McConaughy Reservoir (USA) decreased by 0.03%/year, Overholser reservoir (USA) decreased by 0.29%/year, Seyhan reservoir (Turkey) decreased by 0.71%/year, and Sille reservoir (Turkey) decreased by 0.48%/year (Childs et al., 2003; Kress et al., 2005; Body and Ganske, 2005; David et al., 2005; El-Sersawy, 2005; Güvel, 2007; Ceylan et al. 2010; Ceylan et al., 2011) . Based on these values, it can be suggested that sedimentation is a serious threat to the continued operation of Turkey's dams.

To determine changes in the lake floor due to sedimentation, five distinct sections were taken from the reservoir (Figure 9). The changes in the lake floor are shown in Figure 10. Maximum sediment thickness, average sediment thickness and standard deviation are shown in Table 3.

Plant species found at the dam and its surrounding area, geological data and forestry coverage and composition were presented to users in GIS medium (ArcGIS 9.2 software).

Attribute values of the dam and its surrounding area were spatially referenced within the GIS and made available for examination. For example, users are able to investigate questions such as "Which tree species are present? What is the age structure of the stand? Where are the borders of tree species? What is the elevation of tree species? What is the location of tree species? What kinds of formations are observed? What are the formation years of these formations?" (Figures 11 to 13). In addition, GIS data layers were produced, allowing the examination of reservoir water quality data (temperature, dissolved oxygen, Secchi disc, pH) (Figure 14, 15, 16, 17).

Figure 14-17 shows the spatial distribution of pH, Secchi Disk Depth (SDD), Dissolved Oxygen (DO) and Temperature over the reservoir.

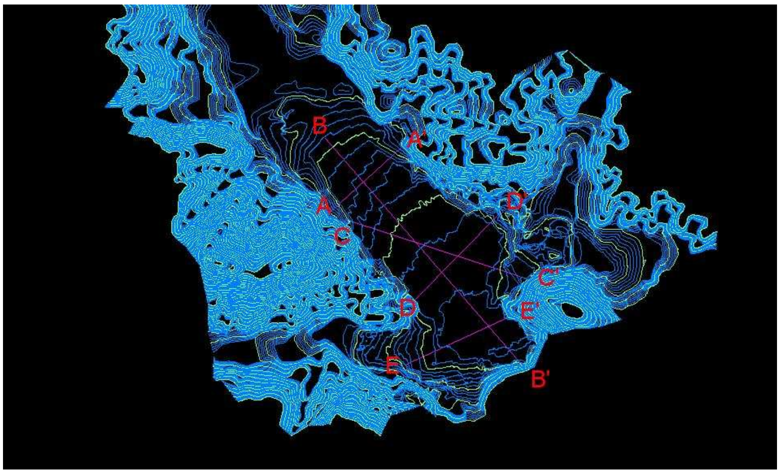


Figure 9. View of cross-section lines

Table 3. Standard deviations and sediment thickness on the cross-sections

Cross-sections	Max. sediment thickness (m)	mean sediment thickness	Standard deviations
A-A’	4.23	0.95	±1.15
B-B’	0.97	0.65	±0.20
C-C’	3.24	1.07	±0.63
D-D’	1.61	0.69	±0.37
E-E’	3.53	0.74	±0.77

4. CONCLUSIONS

For effective management of water sources, first, water that is not used should be stored in environments such as dams or ponds, wherever possible. In addition, prevention of water pollution, up-to-date topographic and bathymetric information on reservoirs, changes in reservoir storage capacities due to erosion and sedimentation are given priority. In this context, this study was carried out to determine the current topographic and bathymetric situation, and the changes in the surface areas and volume due to sedimentation and erosion, in Altınapa reservoir. The study also aimed to present the Dam Information System (DIS) for use by relevant institutions, involving data on the geological structure, plant cover, physical and chemical features of the water of Altınapa Dam.

Calculations were made on ArcGIS software using digital elevation models of the lake based on date from the years 1984 and 2009. The data indicated that, over the 25-year period between the two datasets, the storage capacity of the lake decreased to 4280393.75m^3, a reduction of 12.7 %.The capacity of the lake therefore decreased by 171215.75 m^3/ year (or 0.51%) on average. This value is consistent with the results of previous studies and is much greater than global and European averages.

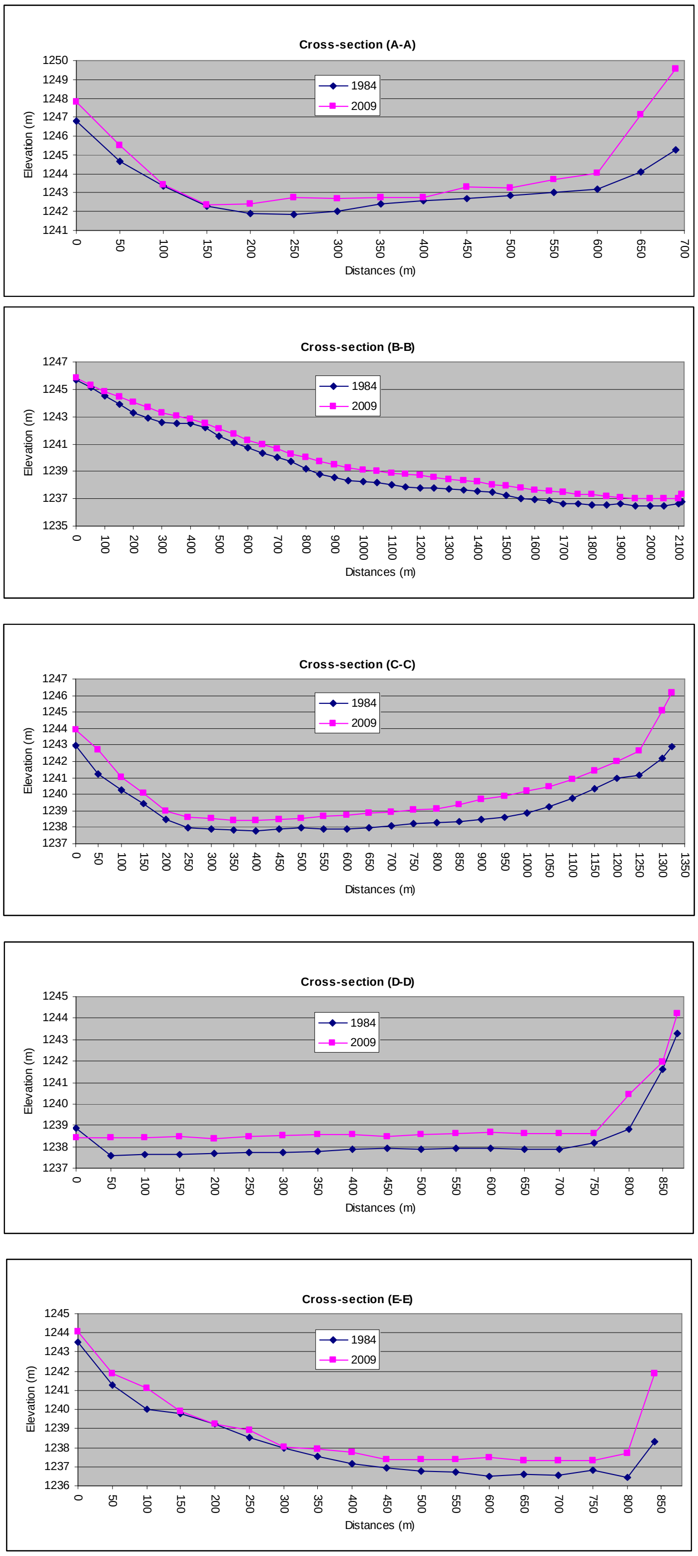


Figure 10. The changes in the lake bottom on the cross-sections

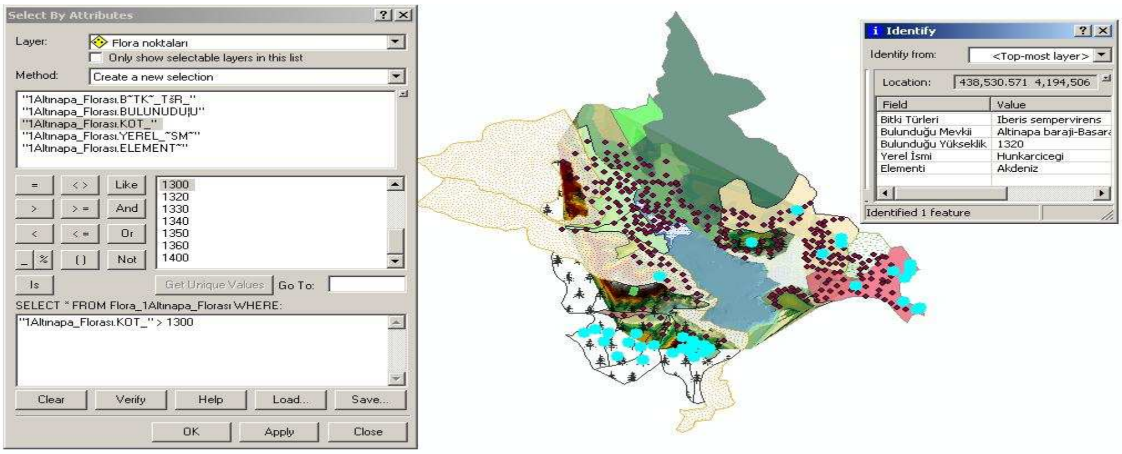


Figure 11. Screenshot for plant query

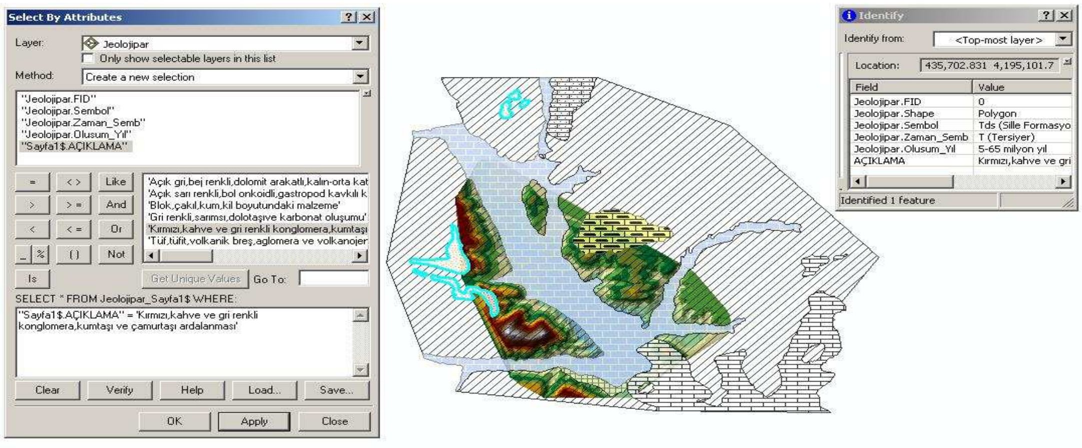


Figure 12. Screenshot for geological features query

A series of 5 cross-sections were taken from the reservoir, to analyze bathymetric changes in the lake floor. The data indicated that, in coastal sections of the lake, the depth was reduced by between 0.97 and 4.23 m, inner sections of the lake, where the lake floor is lower, there were changes of between 0.15 and 0.95m. The mean sediment thickness was obtained to be 0.82m.

In this study we tried to construct a Dam Information System by collecting data on water level changes in Altınapa Dam, physical and chemical properties of dam water, topographic and bathymetric data of the dam and its surrounding, plant species, geology and forest maps etc. within a single database, using ArcGIS 9.2 software. The system aimed to allow users to conduct spatial inquiries and analyses.

The General Directorate of State Hydraulic Works, which is the only authority regulating all functions related to dams in Turkey, has important roles in operating and conserving the dams. In this respect, State Hydraulic Works should perform the following activities to create a Dam Information System, similar to those in Western countries and the USA

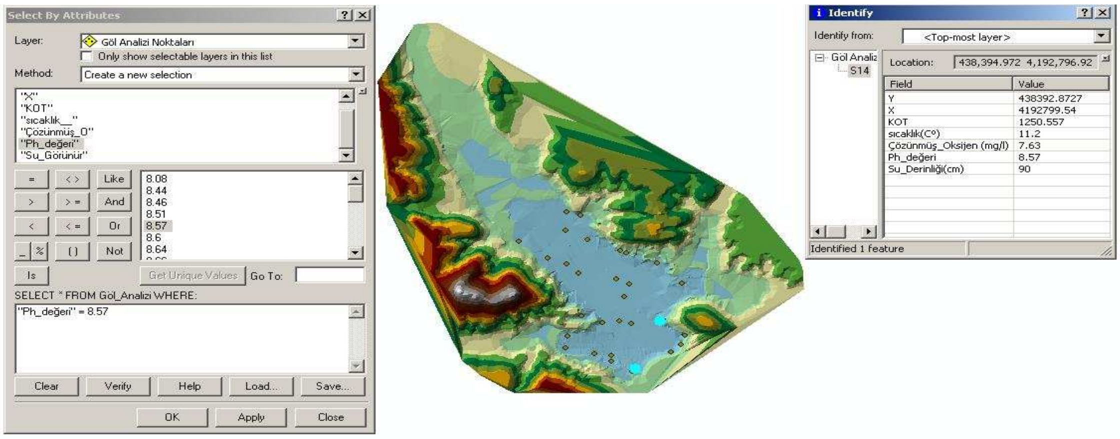
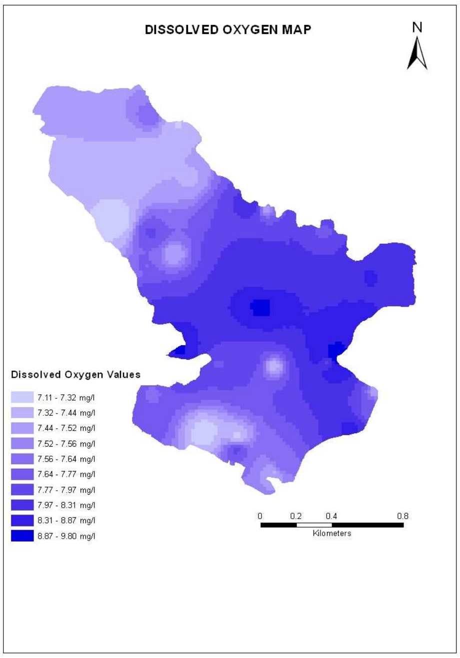


Figure 13. Screenshot for pH values query



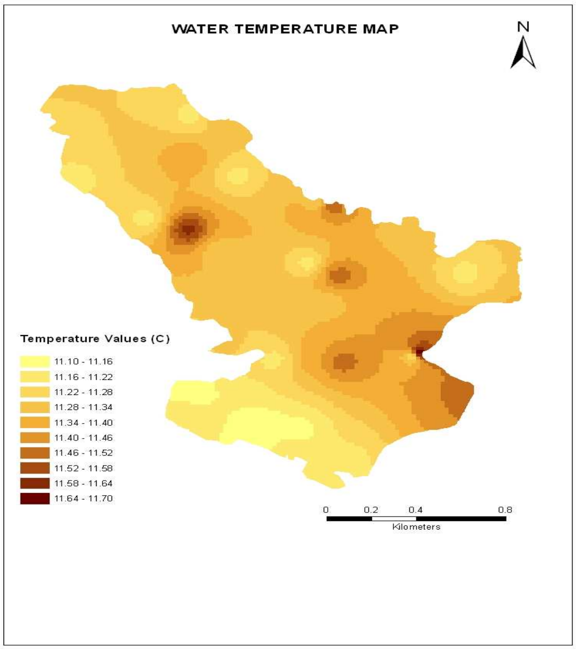


Figure 14. Dissolved oxygen map

Figure 15. Water temperature map

- Topographic and bathymetric measurements of each reservoir and its surrounding should be renewed at five year intervals. The storage capacity of a reservoir can be determined by evaluating these measurements.
- Deformations occurring in the dam embankment due to underground tectonic movements should be monitored. These deformations should be analyzed to determine whether they threaten dam safety.
- Measurements should be made to determine the amount of sweeping material carried by the rivers and creeks that supply water to the dams. The degree and quality of the threat to the dam caused by sedimentation should be determined and dam improvement activities should be conducted.

- Physical and chemical properties of dam water, water quality measurements, climate, plant species and environmental factors should be determined. Evaluation of these data will contribute significantly to prevention of water pollution; conserve and increase the biodiversity in and around the dam lake; and allow people involved in fishery activities to make better use of the lake.

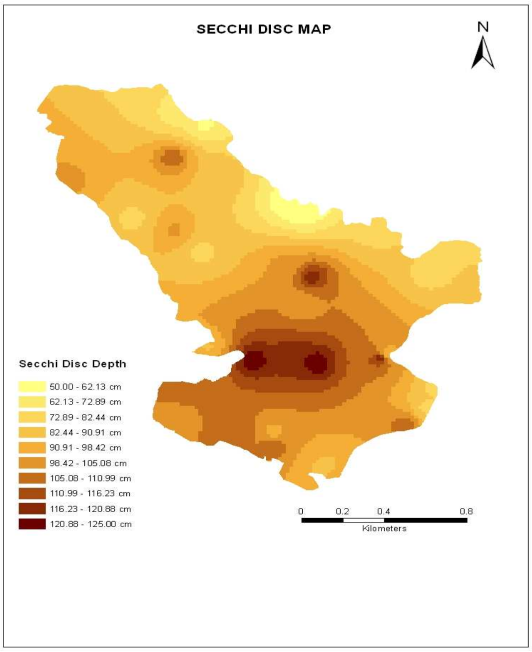


Figure 16. Secchi disc map

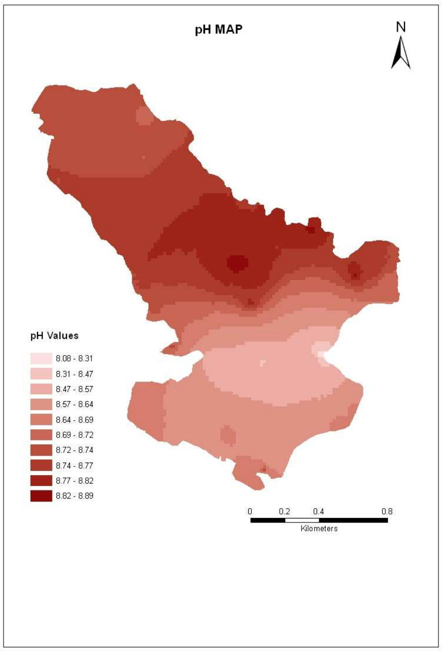


Figure 17. pH map

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BIOGRAPHICAL NOTES

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