

# **DIGITAL ELEVATION DATA AND THE USE OF ARCHYDRO TO LOCATE PLACES FOR CREATION OF SMALL DAMS IN THE NORTH EAST PART OF THE GREEK ISLAND OF NAXOS.**

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## **ABSTRACT**

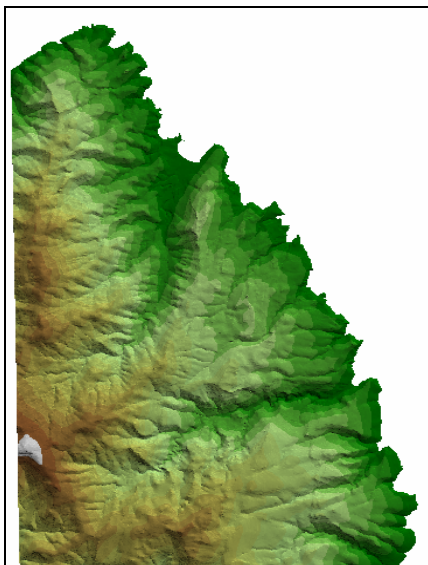
This work deals with application of surface hydrology modeling data to locate places for the creation of small dams in the North East part of the Greek island of Naxos. Modern GIS systems such as Arc-Gis together with hydrological modeling extensions such as the ArcHydro are used to perform a better management of run off water during rainfall. The work includes digitization of contour lines of maps 1:5000 and contour interval 4.00 m, to create a digital elevation model and then processing through the Hydrological model to create surface hydrology data. Based on such data the locations for creating small dams are determined. Consequently, the bearing capacity of all small dams is computed and the total ability to hold part of the run off water is analyzed.

**Key words:** Gis, Hydrology, ArcHydro, Small dams, Naxos

## 1. INTRODUCTION

Small dams have already been constructed in the area of Apeiranthos of Naxos and they have been reported by Glezos Manolis, 1993. The great success of such work has given the idea for the investigation that follows.

Precipitation surface water in the Greek islands in the Aegean Sea is very valuable and the main source of water supplies in such areas. People since thousand years ago used to gather such water from the roofs of the buildings and store it in small reservoirs located in the basement of the house. Although this process helped people to cover part of their needs in water supplies, only a small portion of surface water was saved, and the rest will go down to the sea. Modern technologies such as GIS can help us to make a better water resources management so that to minimise the amount of water that goes to the sea. The idea is to locate places to build small dams which could hold a minimal amount of water (for example, 50 m<sup>3</sup>). They can be constructed by local material such as rocks which is adopted better to the environment and try to hold as much water as possible so that to enrich the ground water aquifer and to reduce erosion and flooding.



**Figure 1:** Triangulated Irregular Network (TIN) of North Eastern part of the island of Naxos

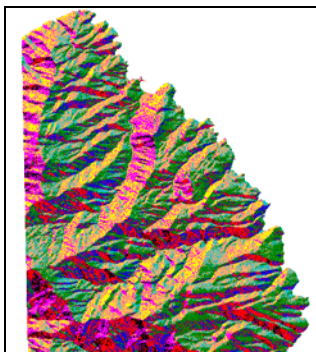
The basin of the North East part of the island of Naxos which starts from Apollon village and ends up over Komiaki village was chosen to make the experimental testing. Such testing is limited presently at study level in order to provide evidence of using Gis technology to identify locations for small dam structures.

## 2. DIGITALISATION OF MAPS TO CREATE DTM (TIN AND GRID)

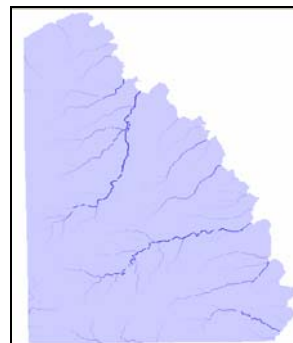
A total of 8 maps having scale 1:5000 of North Eastern part of the island of Naxos were digitized via the ESRI ArcView 3.2 software. Creation of TIN was based on digitization of 4 meter contour line interval stored in a single shapefile. Elevation points for more precise depiction of ground surface together with coastal line were also changed from linear to polygon feature (with the help of xtools) in order to enclose the region of study. Creation of Grid with cell size of 2 meter was generated using ArcGis software. The generated TIN is given in Figure 1.

## 3. APPLICATION OF ARC HYDRO IN THE REGION OF STUDY

The application of Arc Hydro requires specific tools in ArcEditor / ArcInfo and Spatial Analyst which were used. In present work operations **Flow Direction** and **Flow Accumulation** were used.



**Figure 2 :** Flow Direction Grid



**Figure 3 :** Flow Accumulation Grid

The operation Flow Accumulation as shown in Figure 3, calculates the flow accumulation grid which includes the accumulated number of cells that flow in a particular cell. Opening the table Properties in Accumulation Grid and selecting Source, one may observe how many cells exist in the mesh, the cell size, the highest accumulation of flow expressed in number of cells and in which draining region corresponds (Maidment and Robayo, 2002).

#### 4. HYDROLOGICAL CONSIDERATIONS

Rainfall water **P** has three possible paths to follow and are given by the equation:

$$P = I + R + E$$

Where: **P** is precipitation, **I** is water infiltrated to the ground (ground water), **R** is water rolling over the ground (surface water) and **E** is water from evaporation and evapotranspiration

This equation represents the hydrologic budget which is characteristic for each region and determines the aquatic economy of the region. The elements of equation that are also called phases of hydrologic budget can be expressed either as volume ( $m^3$ ), or, as precipitation height (mm). The precipitation height (water height) results from the volume when it is divided by the area of region in which is referred, which means that we assume a uniform distribution over the entire region in question, therefore this value would express a layer of water with thickness equal to the precipitation height in mm (G. Soulios, 1996).

Factors that play significant role in the determination of hydrologic budget in a basin are:

Topography of basin, Morphology and geological composition of basin, Amount and intensity of rain, Temperature, Humidity, Land cover. Basin topography influences the flow. It is obvious that the steeper the slopes of a basin, the bigger the speed of water. So water remains on the ground for a short time and the degree of evaporation and infiltration is reduced. Because ground slope is steeper in higher elevations of basin, we can say that the factor of flow grows as one moves from plains to the mountains.

The shape of basin influences the flow since it grows or minimizes the length of water path. Thus it is obvious that in a basin with circular shape the flow is faster as compared to a basin with elongated shape. As a consequence, of this, the factor of flow in a circular shaped basin is bigger, since water remains less time over the ground. The geographic location of basin has also an influence because the direction of mountain ranges, in combination with the direction of winds creates intense rainfalls in certain slopes while in opposite slopes creates small rain heights. Geological composition such as permeability, influences the flow because a part of rain can infiltrate into the ground, therefore the flow factor is decreased. When the basin is composed from impermeable layers then all volume of water rises and the factor of flow is big. A rain which continues without interruption, causes an increase of value of factor of flow, because it is obvious that the evaporation is decreased considerably, since air is saturated, the soil does not absorb water and the plants have retained the highest quantity in the leaves and in their trunk. The continuity of rain causes a reduction in the air temperature, which influences considerably the evaporation. Agriculture and basin vegetation, affect considerably the flow and the shaping of streams. It is obvious that under similar conditions, in bare grounds arises bigger quantity of rain than in covered grounds by plants and forests (C. Tsogas, 1999).

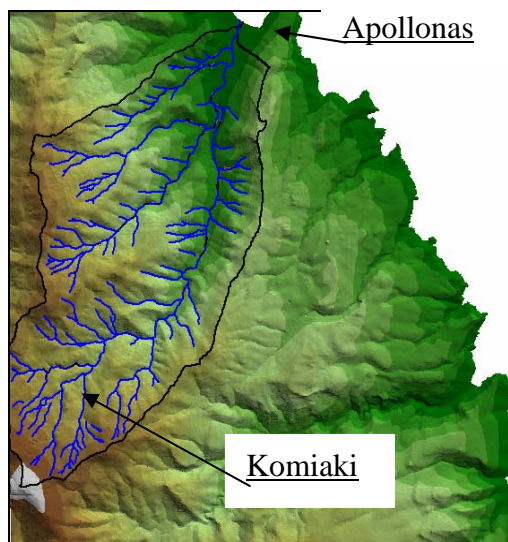
#### 5. PROCESS TO SEARCH FOR LOCATIONS TO CREATE SMALL DAMS

Results from application of the Arc Hydro model and data from digitalisation of various characteristics of landscape of Naxos were utilized to identify suitable locations for the creation of small dams. This way of study helps to reduce the time of research in the field. The study area was selected in the region of Apollo Komiaki basin of the island of Naxos as shown in Figure 4.

Cyclades islands in Central Aegean are characterized by low annual rainfalls and each effort of withholding the rain waters before their discharge at sea are judged of great importance. Such water retained in small dams can be used to feed ground water aquifer. Moreover, in the islands of Cyclades floods are seldom and if they happen, they usually take place in near the coast flat regions. For this reason with the creation of small dams from territorial materials (in the form

instructive or protective dykes) the time of withholding of water is increased and the speed of water flow and the erosion is decreased.

Furthermore, in the test area, it was utilized the following data: (a) Triangular Irregular Network (TIN) which represents the ground surface, (b) the polygon characteristic "Catchments" representing the sub basin regions, (c) the linear characteristic of hydrographic network that determines the location of streams over the ground surface, (d) contour lines used to locate and design dam locations and (e) the mesh of accumulation of flow that shows the accumulated flow in each cell.



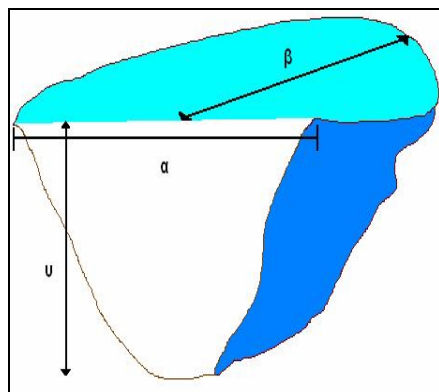
The following specifications were placed to search for the location of small dams (see Figure 5):

1. Height ( $u$ ) of dam face to be less or equal to 2m.
2. Width ( $\alpha$ ) of dam face to be less or equal to 12m having direction perpendicular to water flow direction.
3. Ratio of depth over width ( $\beta/\alpha$ ) be greater than one.
4. Volume of water in the dam be greater than 50m

Assumptions to hydrology parameters to estimate run off water were as follows:

1. Rainfall in the basin is uniform at all points.
2. Typical mean monthly rainfall height was selected the one measured in year 2001 (see table 2).
3. Flow coefficient is constant at all points in the basin.
4. Volume of water collected in each dam is considered to have a geometric shape of pyramid (see Fig. 5).
5. All volume of water comes from a rainfall.

**Figure 4** : Illustration of basin of water flow in the Apollonas Komiaki region.



To facilitate the location searching process, there was a densification of contour line interval to 2 meters. Moreover, using the tool of distance measurement in ArcView, the desired width and depth of dam was measured as shown in Figure 5.

An effort was initially attempted to estimate the run off water according to Iskovski formula:

$$Q = K * H * E$$

Where:  $Q$  = maximum capacity in [ $m^3$ /month]

$E$  = Area of basin in [ $m^2$ ]

$H$  = mean monthly rainfall height [m]

$K = \alpha * \tau$  Where:  $\alpha$  is coefficient of topography and  $\tau$  is coefficient depended on the size of watershed

**Figure 5** : Typical representation and dimensions of a pyramid shaped small dam.

Factor  $\tau$  was estimated as 9,5 because the area of basin is about 10  $Km^2$  and factor  $\alpha$  was estimated as 0,070 because from the geological map of region of study was found that the rocks in the basin are mainly marbles, slates and gneiss that are considered soil of regular composition and the terrain of basin is hilly. Such geology is being considered by hydrogeology enough impervious because they have not suffered chemical or tectonic alteration.

Based on Iskovski's formula, the surface run off water was computed for each cell. The area of the watershed was measured using X-tools (Delaune Mike, 1999) and was found to be  $E = 12.172.540 m^2$ . The mean monthly rainfall height measured in year 2001 (see Table 1) was found to be  $H = 0,02341 m$ . Then assuming  $K = 0,665$  the capacity is given as follows:

$$Q = K * H * E = 189498 m^3/ month$$

**Table 1** : Monthly rainfall height measured in mm (Source: National Meteorological Service of Greece)

Month / Year	2000	2001	2002	2003
January	16,6	43,7	70,6	78,9
February	18,5	30,1	24,2	148
March	43,1	0,2	66,3	99,8
April	2,3	13,5	9,9	76,7
May	0,9	7,4	21,1	16,8
June	-	-	-	-
July	-	-	1,1	-
August	-	-	-	-
September	-	-	39,9	0,4
October	46,6	-	39,2	16,8
November	46,5	68,0	98,4	37,8
December	45,9	118,0	93,7	95,2
<b>mean monthly height</b>	<b>18,37</b>	<b>23,41</b>	<b>38,7</b>	<b>47,53</b>
Notice: Symbol (-) means there was no rain.				

Taking into consideration that the grid cell dimensions are **2x2 meters**, then the total number of cells in the entire watershed area is **12.172.540 m<sup>2</sup> / (2x2) = 3.043.135**. Thus the **monthly surface flow in m<sup>3</sup> / cell is equal with 0,062**. Consequently, knowing from the mesh of accumulation of flow and the accumulation in a cell located over and under the stream, then the volume of water in the dam can be computed as well as the sum that will flow further below. In this way it can be decided whether or not it is necessary to create successive dams so as to avoid a great loss of rain water.

In order to compute the volume of water in each small dam, the volume of pyramid is used. The area of dam (**A<sub>d</sub>**) is the pyramid base and the height of the dam face (**u**) is the height of the pyramid and the volume is as follows:

$$V = (1/3)(A_d)(u)$$

The area (**A<sub>d</sub>**) is measured using X-tools, the height is taken **u = 2 meters**. Dams are located along creeks and the volume of water in a dam is subtracted from accumulated flow below the dam, in this way the volume of water reaching the sea can be calculated. Throughout this experiment spots for **107 small dams** were located (see Figure 6) and a volume of **9786 m<sup>3</sup>** of rain water is anticipated to be held in these dams or **5.16%** of the total monthly rainfall (see Table 2). Table 2 shows Dam ID, Area, Volume, Accumulated volume upwards the dam, and Accumulated volume downwards the dam.

The minimal mean monthly rainfall capable of filling up 100% of dams is about **1,2 [mm]** of rain. The climatic data for 2001, which represent mean rainfall values for the Cyclades islands, indicate that rainfall takes place about six months per year and thus within this time interval the small dams will be filled up to the top by runoff water. However, during the months with lower than 1,2 [mm] height of rainfall water level in the dams may not fill them up to the top. Comparing with rainfall data of drier years one concludes that the rate of withholding of water concerning total flow in proposed places is still at maximum. Thus proposed locations (to all the extent of basin) lead to a water storage system of small dams which is active for several months per year.

## 6. CONCLUSIONS

This work is a further investigation over the management of water resources in the Cyclades islands where such resources are minimal. The use of advances in technology such as GIS and Hydrologic modeling helped to study locations for small dam construction to withhold water from rainfall which in turn can feed local aquifers and at the same time is reducing the impact of erosion and flooding.

