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# Engineering Geology and the Environment

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# Management of geoenvironmental hazards: Flood risk assessment and emergency planning at Halandri City, Athens, Greece

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**ABSTRACT:** Flash floods that caused extensive damages have repeatedly struck Halandri City the last few years. The main causes for these phenomena are of both natural - geological nature (morphology, drainage, climate, hydrogeology, etc.) and anthropogenic nature (changes of the natural drainage network, uncontrolled housing, insufficient protective works, reduction of forests, etc.). In order to face the problem effectively it is necessary to design an emergency action plan that will be applied by local authorities focusing on protection, emergency action and rehabilitation.

## 1 INTRODUCTION

One of the most destructive natural hazards that has affected Greece over the last few years, with increasingly large consequences on everyday life and production processes, is without doubt flooding. Attica is no exception to the rule and was introduced to the destructive power of floods with several casualties, apart from damages and other environmental impact. As with other natural disasters floods were followed by a period of unstable economy and social structure. This period varied in time according to the level of preparedness.

In this paper flood hazard at Halandri City is analysed with the help of environmental (climate, geology) and man induced parameters (changes of the drainage network, uncontrolled housing, insufficient protective works, reduction of forests). The expected environmental impact, along with the damages of infrastructure and human resources, are also assessed. Finally, a preliminary emergency organisation plan, aiming to increase public awareness and preparedness, is suggested. This plan was compiled especially for Halandri City, which has been severely damaged by flash floods a number of times during the last few years.

## 2 GEOMORPHOLOGY - DRAINAGE

Halandri City is situated at the north-west foot of

Pendeli Mountain. Slopes dip gently towards north-west at the east part (Fig. 1). At the central and west parts, as with most of the city, slope angles are less than 1%. A thin zone at the west and east suburbs has slopes around 3% and only at the east edges of the city towards the mountain there are slopes steeper than 10%.

Slopes steeper than 10%, that can exceed 100%, are also found along Halandri stream, which flows through the north-west part of Halandri City (Fig. 2). In general terms topography is gentle, and the only striking relief feature is Halandri stream (a seasonal torrent), and a quick increase of slope angle at the east. This is particularly important since Halandri lies between Athens basin and Pendeli mountain and it is essential to quickly reduce the velocity of

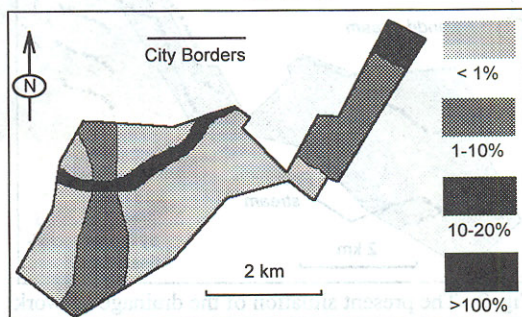


Fig. 1. Slope angle map (%).

drained rain-water over a short distance in order to protect the capital.

Two streams oriented east - west flow through Halandri City (Fig. 2, 3) and join outside the city border forming a tributary to Kifissos River, which also flows along an east - west striking axis. One of the torrents is a tributary to Podoniftis Stream and drains a relatively large area including north - north-west Hymmitos mountain and a small part of north-west Pendeli mountain. This torrent is covered by constructions, mostly houses and industrial buildings. The stream flows freely only at its springs north-west of Halandri and is covered totally along the rest of its length. However, some works that divert the stream into a culvert and drain rain-water have already been done.

The valley of the other torrent, known as Halandri Stream, is unaltered and varies from 10 - 100 m length and 10 - 40 m depth. The basin of this torrent is also relatively large: draining a significant part of Mt. Pendeli which extends from the main watershed of the ridge towards north-west. The cumulative length of all streams that ultimately meet with Halandri stream is higher than the cumulative length of other torrent tributaries suggesting that it discharges a higher amount of rain-water.

### 3 CLIMATE

Unfortunately there is no published climatic evidence concerning Halandri or even Attica for long time - periods. However, historical evidence and meteorological data of the last few decades support that:

- Parameters that influence the climate of a par-

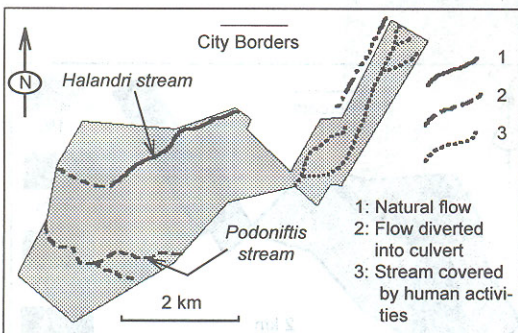


Fig. 2. The present situation of the drainage network of Halandri City

ticular area are not stable but keep changing periodically.

- There are both long and short periods of climatic changes. According to relevant models, supported by a large part of the scientific community, "short period" climatic change is 100 - 120 years long.

- Historic records show that extensive drought struck during Holocene following the last glacial period. More specifically, such droughts are known that struck during the 8<sup>th</sup> century BC (Agora Drought), the 2<sup>nd</sup> century AD (Roman Drought) and the 12<sup>th</sup> century AD (Acominate Drought).

- Droughts are most often followed by intense storms, but the reasons for this phenomenon are not known in detail.

- Sahel Drought is currently active and, according to some researchers, it will last until the year 2010 - 2020, setting apart from annual diversification and fluctuations.

- During the present century there has been observed a connection between rainstorms that lead to floods and solar activity. Floods are confined within an 11-year period which either commences immediately after the abnormal solar activity or within the following 5 years.

- In 1995 the 5-year period, after intense solar activity observed in 1989 expired and therefore the 11-year rain-period is expected to commence.

- Total rainfall for the years 1990 - 1995 is indeed considerably lower than earlier 5-year long periods leading to the conclusion that drought and floods will be repeated in the future.

### 4 GEOLOGY

Geological conditions are not directly related to floods but quite often influence their generation, evolution and magnitude of impact. Geology and hydrogeology determine permeability which in turn influences run - off and subsequently floods.

Halandri City is covered by Neogene and Quaternary deposits which involve impermeable clay seams. Bedrock is made of "Athens Schist" and marble of the relative autochthonous unit and is exposed at the east part of the basins of both torrents. Schist dominates marble and therefore run off is maximum. The small fraction of infiltrating water moves towards the plains and forms an unconfined aquifer in the permeable strata of neogene deposits. Perched aquifers are also formed over the clay lay-

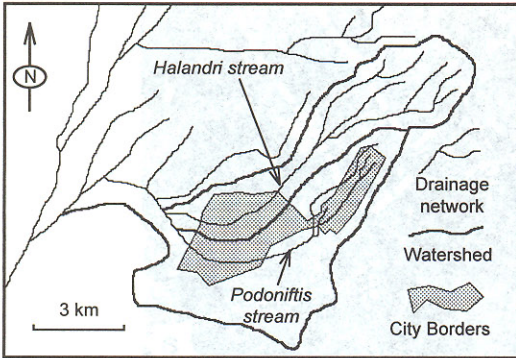


Fig. 3. Basins of "Halandri" & "Podoniftis" streams.

ers. The depth of the water table is lower than 10 m at the west part of the city, about 10 - 15 m at the central part and greater than 20 m at the east part.

Halandri Stream involves not only recent loose sand and gravel but also tertiary, post-alpine orogeny clays and sandy clays. The low - strength - nature of these deposits combined with steep slopes, intense rainfall and downcutting of the torrent result in landslides along the banks. A secondary effect of landsliding in this case is that the valley widths reduced and flowing water is not efficiently discharged (Fig. 4).



Fig. 4. Human activities at "Halandri" stream area have caused the reduction of the valley width (a) and secondary phenomena such as landslides (b).

## 5 HUMAN ACTIVITIES

Human activities are the most probable cause for maximisation of the impact of natural disasters. Human activities that are introduced into a physical system require readjustments by the system which often are not to our benefit. Human activities, as defined here, include:

- Building on natural valleys and levelling of river beds.
- Partial river diversion into the sewage system that cannot always discharge flood waters.
- Reduction of natural valley width that obstructs run off (Fig. 4)
- Defective and not - maintained sewage systems. In some cases the sewage system is not sufficient whereas in others it is not even existent.
- Forest extinction within hydrologic basins reduces infiltration and evapotranspiration in favour of surface run-off which is a flood-aggravating factor.

The map shown in Fig. 3 illustrates the present situation of the drainage network. According to the "percentage" of human intervention there are three possible cases:

- The natural river valley is still free regardless of any reduction in width by human activities (filling) or landslides.
- The stream is at least partly diverted into underground culvert regardless of its diameter and its capability to discharge flood waters.
- Constructions (buildings, roads) cover the river bed itself without any flood protection measures (surface or underground).

The study of old topographic maps and sequential takes of aerial photographs shows a gradual decrease and in some instances disappearance of streams and torrents resulting in inadequate rain-water discharge. For example in the air photographs taken in 1945, 1960 and 1988 (Fig. 5) one can follow the gradual disappearance of river beds and the simultaneous "generation" of roads and other structures. From 1960 onwards, when the building

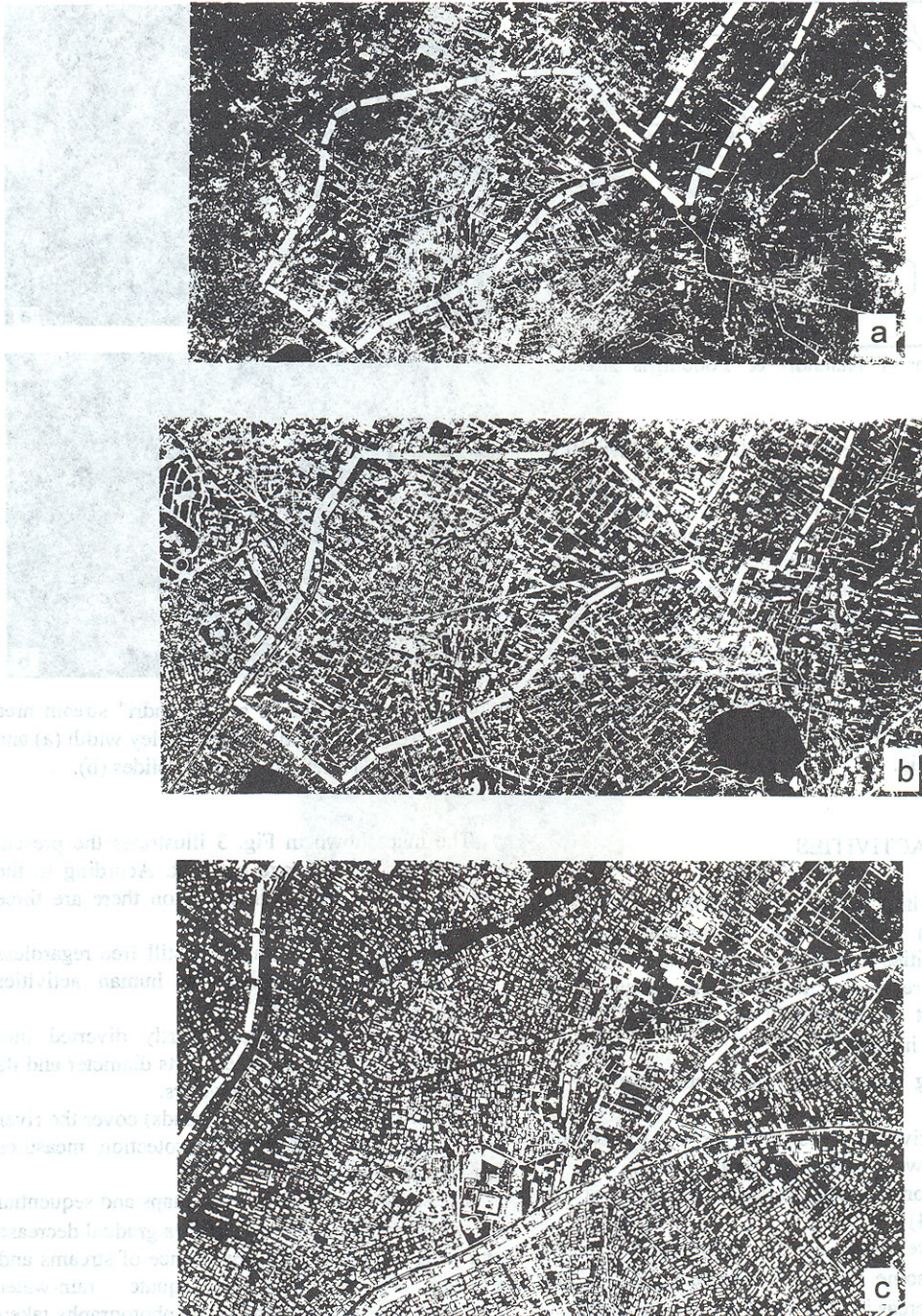


Fig. 5. Three generations of airphotographs (a:1940, b:1960, c:1988) showing the magnitude of human influence on the environment of Haladri City.

boom commenced, there is a marked increase of residential housing that created the present infrastructure and densely populated blocks. The aftermath of this situation is that future floods are expected to have an incremental increase in their magnitude of impact.

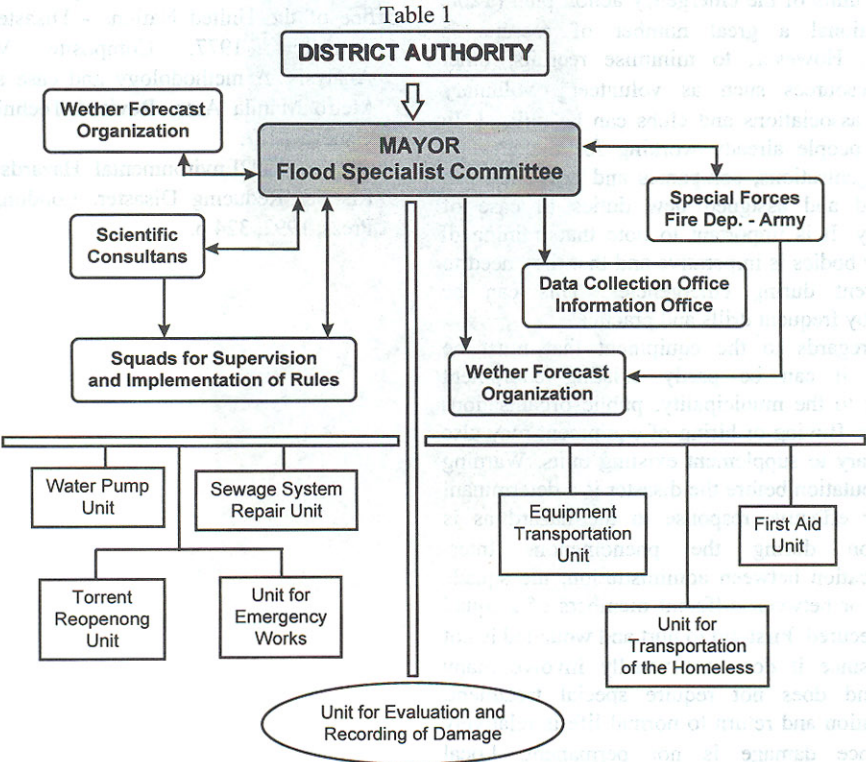
### 6 ORGANISATION PLANNING

Based on the above physico - geological characteristics, and with given human intervention, adverse effects are anticipated. Subsequently, a flow chart for emergency organisation planning was compiled aiming to minimise the impact of floods through effective hazard management by the local authorities. The key points of this emergency plan are protection, emergency action and rehabilitation.

The responsible for prognosis (prediction) are not of course the local authorities but the National Weather Forecast Organisation. However, local authorities must be on line with the NWFO for information about the progress of the phenomenon and to raise the alarm in case of sudden weather

changes. This will provide the emergency action units the time necessary for setting up (usually a 24 hour warning is available). The factors that local authorities need to know are the intensity and the duration of rainfall and the time lag of flood.

Local authorities (districts or municipalities) should at first create a special board (Flood Specialist Committee) that will be under the mayor and will report directly to him. The role of this committee is to: (i) form, propose and inspect the enforcement of laws and directives (focusing on protection), (ii) decide about the necessity, time, place, manner and type of emergency action needed, (iii) take all appropriate measures, co-ordinate and establish a course of action for rehabilitation of structures and victims. The flood specialist committee should be in contact with scientific consultants who will analyse and evaluate the reliability of the prediction and the emergency action measures. Scientific consultants are also expected to make their suggestions to the Flood Specialist Committee. The FSC should also co-operate with state forces such as the Fire Department, Army and Police. If all these bodies act jointly they can



produce a very coherent and effective disaster minimisation scheme.

Protection against floods is defined as all necessary measures and technical works aimed at the minimisation of a flood and its impact. Protective measures can be taken on: (i) the natural drainage network i.e. into the valleys, (ii) the sewage system and the man-made drainage system and (iii) selected areas that are known to suffer from floods. With regards to the natural drainage network, i.e. along the section of Halandri Stream where flow is free and along some small torrents to the east, the following mitigation measures are suggested: (i) restoration of the river bed to the former (natural) conditions, (ii) opening of the river bed where debris or human activities (filling) have formed barriers, (iii) removal of structures and waste that prevent water from flowing downstream especially during intense rainfalls, (iv) engineering of all slopes prone to landsliding and construction of support schemes against slope erosion and undercutting (this is both for environmental reasons and the protection of buildings) and (v) maintenance of public works and surveillance to avoid new unauthorised buildings and earth fill or other waste fill into the river bed. To make the units of the emergency action plan (Table 1) operational a great number of recruits is necessary. However, to minimise recruits, other human resources such as volunteers, voluntary societies, associations and clubs can be utilised. In addition, people already working for the city (in public organisations, companies and hospitals) can be trained and assigned new duties in case of emergency. It is important to note that training of these new bodies is imperative and that they need to be coherent during emergencies. This can be achieved by frequent drills and practice.

With regards to the equipment that must be available, it can be partly existing equipment belonging to the municipality, public organisations or citizens. Buying or hiring of equipment may also be necessary to supplement existing units. Warning of the population before the disaster is a determinant factor for effective response to the hazard as is information during the phenomenon. Inter-communication between administration, the squads involved, or between different members of a squad must be secured. First-aid to hurt and wounded is not difficult since it does not usually involve many people and does not require special treatment. Rehabilitation and return to normal life is relatively quick since damage is not permanent. Local

authorities however should act to guarantee (i) transportation of homeless, (ii) food and services, (iii) medical care and (iv) recording of damages by civil engineers and specialist advice for the works required. Special care for the lower classes is usually required since it has been observed that most people suffering from floods belong to low economic classes or are elderly people living at sub-standard quarters.

## REFERENCES

- Alexander, D. 1993. Natural disasters. UCL Press, 1993, 632 p.
- Keller, A.E. 1988. Environmental Geology. Merrill Press, 1988, 540 p.
- Lekkas, E. 1955. Environmental Geology. Univ. of Athens, 242 p.
- Lekkas, E. 1996. Natural and Technological Disasters. Access Soft Publ., Athens, 278 p.
- Lekkas, E., Lozios, S. & Holevas, K. 1984. Natural and Technological Disasters at Halandri City. Planning, Organization and Protection. Research Project, Univ. of Athens, 232 p.
- Office of the United Nations - Disaster relief co-ordinator. 1977. Composite Vulnerability Analysis. A methodology and case study of the Metro Manila Area. Revised Technical Report, Geneva 1977.
- Smith, K. 1992 Environmental Hazards. Assessing Risk & Reducing Disaster. London, Routledge Press, 1992, 324 p.

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