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GIS, REMOTE SENSING AND CARTOGRAPHY FOR MAPPING AND MANAGING QUARRIES AND MINES IN CYPRUS

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Abstract

Integration of remote sensing, geographic information system (GIS) and cartography can provide a means to find and update information about the location of quarries and mines, type of quarrying material, quarrying zone and mapping data in the Cyprus area for better management and planning. Indeed, the authors provide a description of their proposed methodology which is based on the integration of field data, satellite remotely sensed data, GIS platform and system, auxiliary data such as cadastral maps and sheets. Such tools have been used to develop the proposed system which gives the following information

- ***Quarries locations in reference to populated areas***
- ***Geological formations***
- ***Complete database for quarries and mines such as locational data, quarry zone, owner information etc.***

The detection of old quarries using archived and up to date satellite imagery through the application of classification and change detection algorithms show the potential of the proposed method. Positional accuracy assessment between the cadastral sheets, the maps (produced from field data) and the high resolution satellite images of each quarry and mine area was also performed.

1. INTRODUCTION

The Cyprus Geological Survey Department has been already prepared a strategy for the Sustainable Quarrying and Mining Development of Cyprus 2001-2025. The project has been divided in several phases that include: (a) an intensive programme of data. A GIS system and other appropriate databases were established to record the acquired data. (b) The impacts of mineral extraction and processing on the environment, the built heritage, public health and local communities. (c) Recommendations on the future of the mining and quarrying industry in Cyprus (d) formulating specific recommendations for new government policies and strategies for the further development of the mineral wealth of Cyprus (Themistokleous, 2003)

The existing project is set up to assist the currently designed project, described above so as to contribute to the Sustainable Quarrying and Mining Development of Cyprus 2001-2025, using both GIS, cartography and earth observation techniques. The overall methodology of this proposed project is described below:

- Use of satellite remote sensing for tracking the location and spectral characteristics of the quarries
- Use of cartography: cadastral sheets / land-survey maps for each quarry area.
- Develop a GIS database to include all the required information
- Check the positional accuracy between the location data between the cadastral sheets, survey maps and high-resolution satellite imagery.

2. CYPRUS STATUS

In Cyprus, about 250 quarries were in operation in the last few years producing aggregates, building stone, clay, gypsum and sand and gravel. Limestone and clays were won for cement production for the domestic construction industry and for export. Bentonite, gypsum, umber and minor quantities of dimension stone were also mined for export. Minerals for the construction industry account for the major proportion of the minerals won in Cyprus. Crushed aggregates are primarily obtained from diabase and reef limestones with a lesser quantity of fine aggregate (sand) obtained from crushed calcarenites.

3. IMPORTANCE OF THE PROJECT: BENEFITS

The use of satellite remote sensing, cartography and GIS techniques in this project will assist the Geological Survey Department in Cyprus to meet the following objectives:-

- To formulate a Strategic Plan for the sustainable and rational development of the quarrying industry of Cyprus;
- To ensure that the environmental impacts caused by mineral operations and the transport of minerals are kept, as far as possible, to acceptable standards;
- To encourage sensitive working, restoration and aftercare practices so as to preserve the overall quality of the environment;
- To establish spectral signature records for different quarry materials (aggregates, havara, sand etc) so as to provide continuous support in the image-processing of up-to-date satellite images;
- To protect areas of designated landscape or nature conservation value from development, other than in exceptional circumstances and where it has been demonstrated that development is in the public interest (Themistokleous, 2003)

4. PROPOSED GIS SYSTEM

A Geographical Information System (GIS) and a Microsoft Access database were set up, for storing and analysing data such as those obtained from the Geological Survey Department (GSD) and the Mines Service, were searched. Operational and closed mines and quarries were visited and topic papers on the mineral resources of Cyprus were prepared.

A programme of site visits was undertaken and many of the major operational sites were visited, observations were made on the site conditions and operators were interviewed. Some typical abandoned mines and quarries were also visited. The results of the field surveys were recorded in the GIS and Access database. Individual records were prepared for each operational site, covering key technical and environmental features and similar records were prepared for each of the abandoned mines and quarries visited. In parallel with the other data gathering exercise, topic papers comprising a synopsis of each mineral product were prepared from published and archive data.

The main preparation and compilation of the GIS (using Autodesk Map 3D and MapInfo software) database was also undertaken. Other auxiliary data such as copies of plans and licence details of all 250 operational sites were obtained from the GSD and digitised into the GIS together with quarry zones and planning zone data obtained from the Department of Town Planning.

The methodology for identifying new Quarry Zones needs to be logical, verifiable and transparent. In this way all interested parties will be able to see and understand the process used to arrive at the identification of new sites. Thus, even if strong objections are raised to a New Quarry Zone, the decision makers will be able to choose an option that is based on sound planning and environmental principles and which has been developed through a transparent and open process.

The traditional approach to identifying acceptable sites for mineral working is through a procedure known as “sieve analysis”, which is used to identify areas or sites of potential mineral extraction. This process is ideally suited to GIS manipulation. Using GIS as the principle analysis tool, areas with the least environmental or other constraints can be identified. These areas can then be subject to more detailed site assessments to establish the potential for future mineral development.

There are two main classes of constraints that determine whether or not mineral development is potentially acceptable at any particular location. *Absolute constraints* relate to land that is designated or has properties that effectively prohibit mineral extraction; an obvious absolute constraint would be the development boundaries of towns or villages within the resource area. Partial constraints are locations where mineral working would be undesirable but not prohibited. Interrogating the GIS database will identify absolute and partial environmental constraints to potential minerals development within the study area. Additional data would need to be gathered following discussion with other relevant authorities and follow-up fieldwork, which would then be entered into the GIS database. Layers of information that relate to a whole range of environmental designations and constraints will include amongst others: -

- Settlements
- Industrial and commercial development
- Major roads
- Rivers and watercourses
- Internationally protected sites including:
    - Ramsar sites
    - Special Protection Areas
    - Special Areas of Conservation
    - Natura 2000 Sites
- Nationally important sites including:
    - Coastal protection areas
    - Most valuable forestry areas
    - Tourist zones
    - Most valued habitats
    - Irrigation/high value agricultural areas
    - Sites of archaeological importance

These constraints can either prohibit mineral development entirely or constrain the extent or the manner in which quarry development could be achieved.

5. DATA COLLECTION

The Autodesk Map 3D and MapInfo Geographical Information System (GIS) have been adopted as a recognised software standard for storing, manipulating and displaying geographically related data.

Data has been acquired from various government sources and stored on the GIS and in particular the geological map base-data, topographical data (supplied by the Geological Survey Department including elevation, roads and villages etc.) and data from the Forestry Department particularly the boundaries of the Forest Areas and surface soil thematic maps. The locations and boundaries of each mine/quarry unit have also been digitised into the system at a scale of 1:5000 for ease of future reference copies of each licence application submission and accompanying plan are stored as facsimiles within the GIS. Photographic records of each site are also accessible directly from the system.

Several methods of cross-checking the accuracy of the data have been adopted including *inter alia* overlaying the GIS data with the main geological map, Town Planning Zone maps and satellite imagery.

Since the Geological Surveys Department did not have any data digitized from the quarries and mines, the researchers had to collect all the paper maps that were available from the licensing applications and map them in the GIS system by correcting their location (latitude/longitude and scale). In order to do this, the Lands and Surveys Cadastral maps were overlaid onto the scanned maps in order to correct the scale and position of the maps. Satellite images of the quarries and mines areas, photographs and other related data were collected, which is detailed below.

Maps

- Raster/Vector Data of 250 quarries and 40 mines
- Cadastral maps
- Field maps
- Infrastructure and road maps
- Natura areas
- Geological identification areas
- Archeological areas
- Planning and zoning maps

Data

- Field information
- Pictures
- Environmental info
- Planning and zoning info

Figure 1. Photo taken from an existing quarry included in the database.

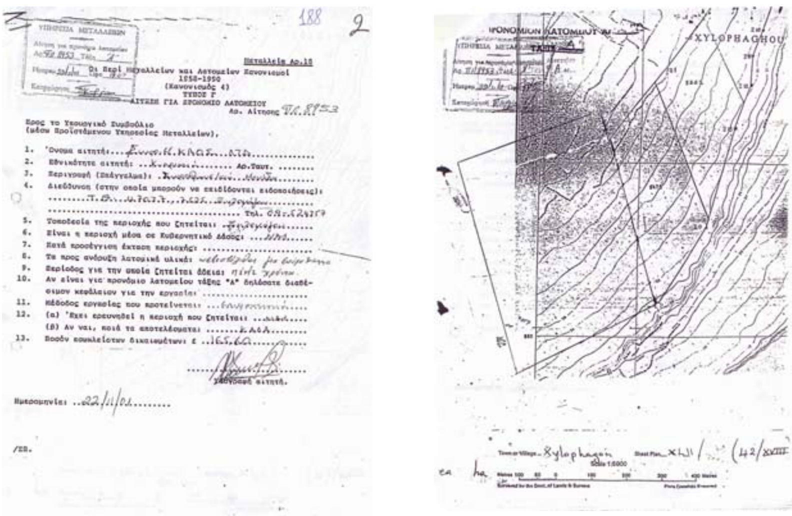

Figure 2. Application forms and Cadastral maps were collected and scanned.

6. POSITIONAL ACCURACY

Position and accuracy was one of the main goals in this project in order to get the results needed for this project. The cartography data collected needed to be geographically corrected and correlated with existing data.

For position and accuracy, the following methods were used:

1. After scanning the maps and identifying their locations, their scale was corrected.
2. Maps were entered into a GIS sytems and their location was corrected in terms of latitude and longitude.
3. The scanned maps were overlaid on the Lands and Surveys Cadastral maps in order to correlate the scale and position.
4. GPS data collected from site visits were used to verify the location of the quarries and mines.
5. Satellite images were overlaid on the quarries and mines maps to verify their position.
6. All the identified quarries and mines were vectorised in order to linked the GIS data.

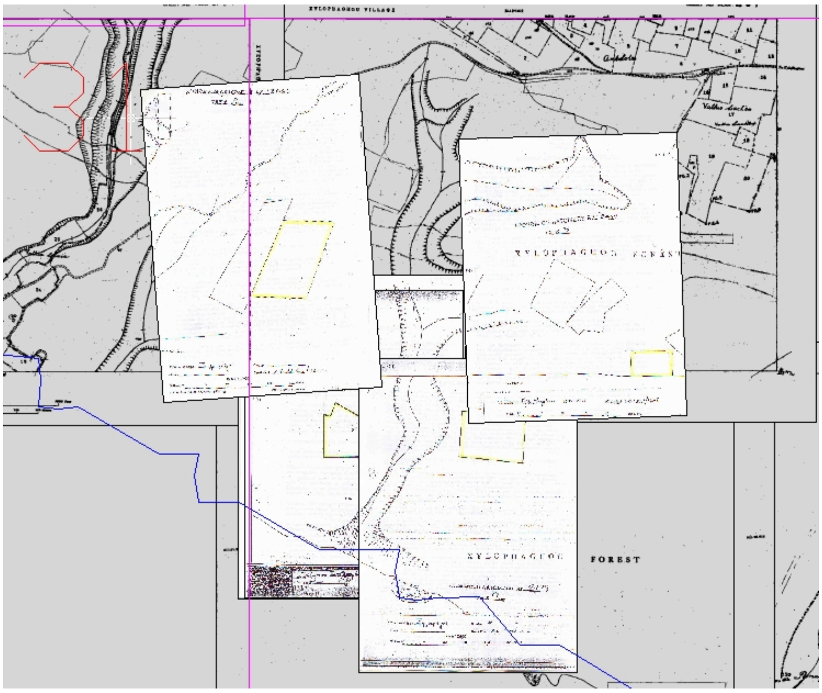

Figure 3. Overlay of scanned maps on the Lands and Surveys Cadastral maps in order to correct the scale and position.

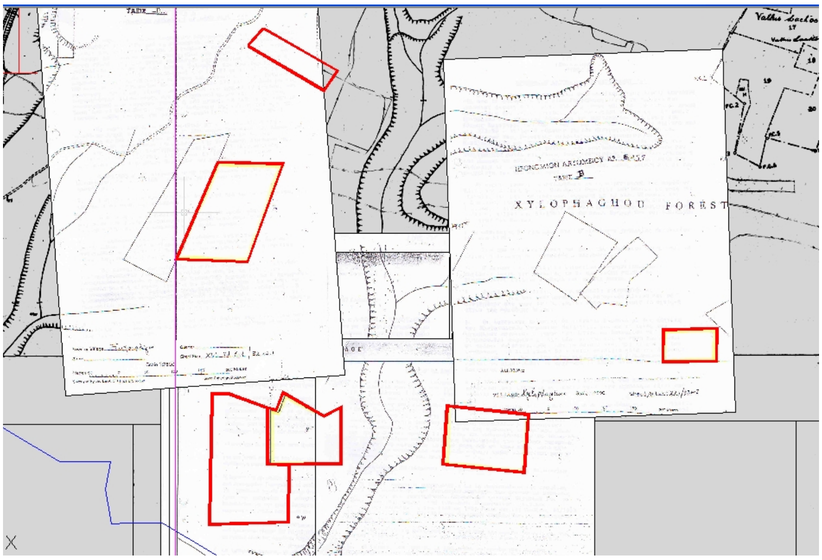

Figure 4. Digitization of all quarries and mines from scanned images.

Figure 5. Overlay of high resolution satellite images to verify quarry locations.

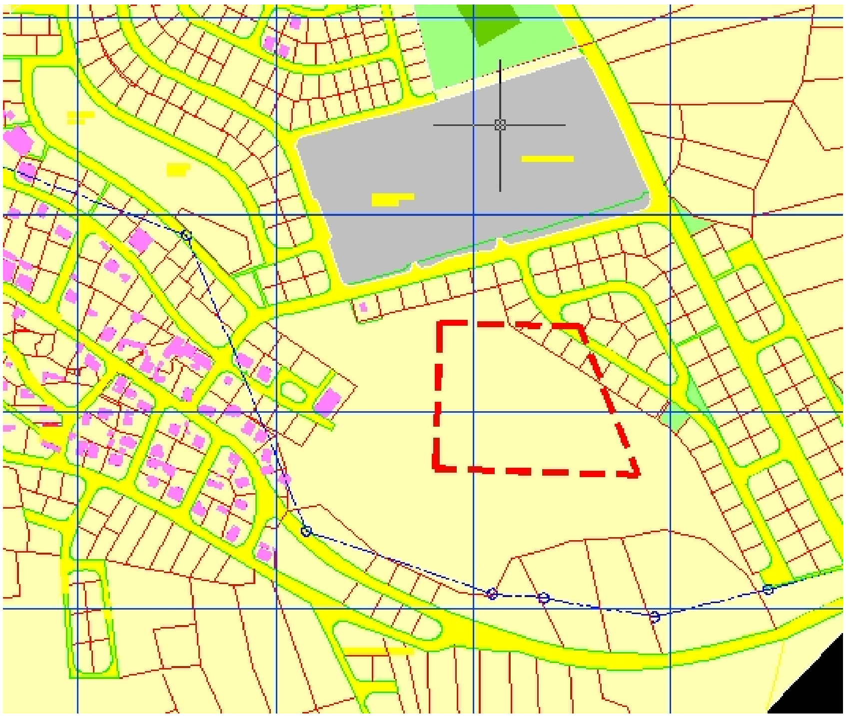

Figure 6. Lands and surveys Cadastral maps and GPS data were used to identify quarry location.

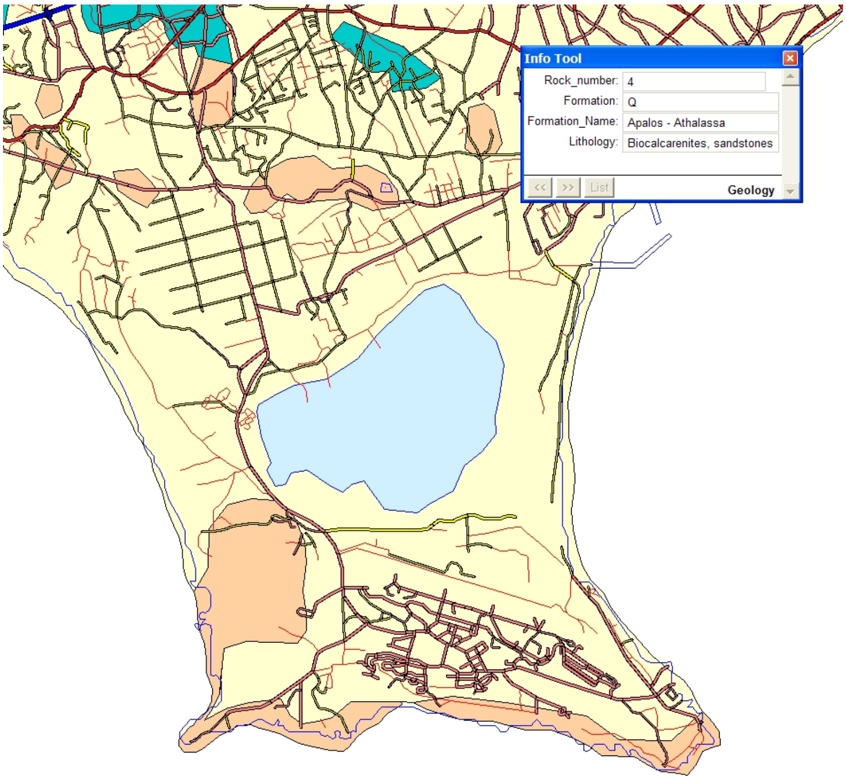

Figure 7. Overlay of quarries and mines with infrastructure and geographical data.

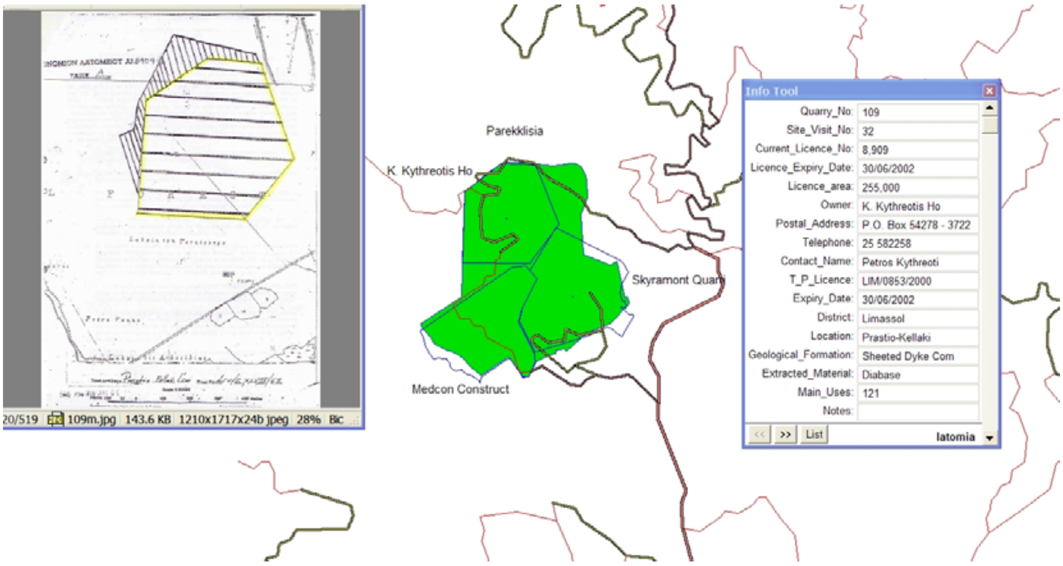

Figure 8. All the quarries and mines were linked to the GIS data.

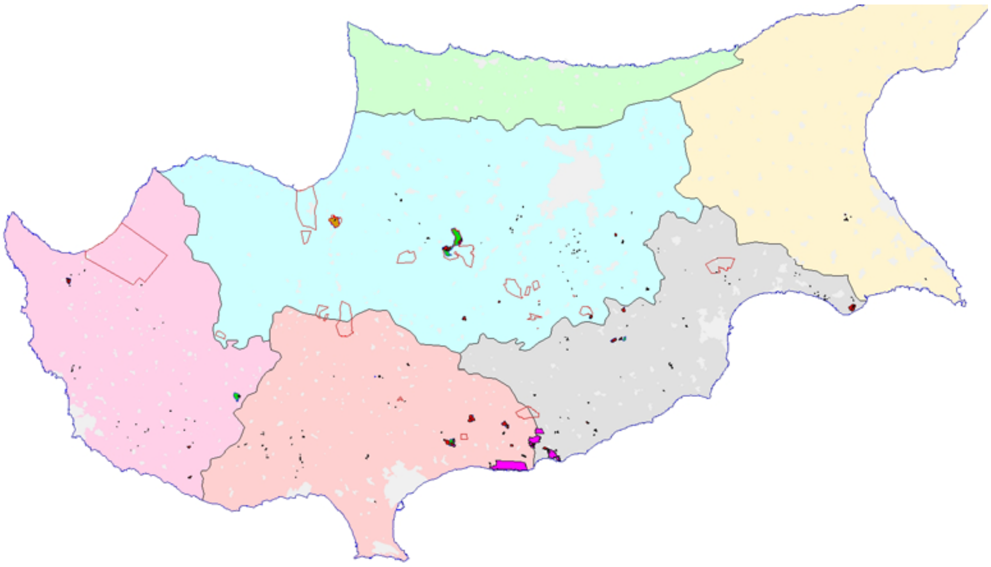

Figure 9. Quarry location in reference to populated areas.

7. CONCLUSIONS

All the “Quarry Zones” identified from this process would then be individually examined to determine if there are any constraints that are not identified on published mapping, or otherwise documented, but which need to be taken into account. This would include consultation with other Departments, by appraising the framework of existing mineral planning policies and through field survey. The areas identified could be further assessed in the field by applying an Environmental Capacity Framework Assessment to each area. This will determine the effect of development with respect of the following aspects:

- Potential Visual Impacts
- Topography and Vegetation Structure

- Biodiversity – this assesses at a broad level the conservation status and habitats present and,
- Potential impacts on the historic environment.

These data could be recorded in a Strategic Search Area Database within the GIS system. It will include sufficient information to enable areas to be prioritised for mineral development based on the results of consultations with Government Departments, the framework of existing mineral planning policies and field assessments.

The following conclusions were identifying using the GIS database collected for this project:

- There are substantial resources of essential minerals to meet the development requirements in the long term
- In the short term there will be a shortfall in reserves of clay for brick manufacture
- In the short to medium term there will be a shortfall of aggregate reserves to meet demand in the Paphos and Larnaca areas (limestone)
- In the medium term additional reserves will need to be identified and released (i.e., granted permits) within the timeframe of the project (up to 2025)
- For distance over 40 to 50 km the cost of transport exceeds the cost of the product
- There are evident advantages in developing new quarries near to markets (the proximity principle), which accords with sustainability principles
- Sustainability means reducing unnecessary costs or other impacts on the environment

8. REFERENCES

CLARK, R.N., KING, T.V.V., KLEJWA, M., SWAYZE, G.A, and VERGO, N., 1990, High spectral resolution reflectance spectroscopy of minerals, *Journal of Geophysical Research*, 95, 12653-12680

HADJIMITSIS, D.G., CLAYTON C.R.I., and HOPE, V.S., 2000a, The Importance of Accounting for Atmospheric Effects in Satellite Remote Sensing: A Case Study from the Lower Thames Valley Area, UK, *Space and Robotics 2000* (ed. S.Johnson, K.Ghua, R.Galloway, P.Richter), February 2000, New Mexico, USA, sponsored by the ASCE and co-sponsored by NASA and SANDIA National Laboratories, 194-201.

HADJIMITSIS, D.G., CLAYTON C.R.I., RETALIS A. and SPANOS K., 2000b, Investigating the potential of using satellite remote sensing for the assessment of water quality in large dams, and irrigation demand, in Cyprus, *Proceedings of the 26th Annual Conference and Exhibition of the Remote Sensing Society, RSS2000*, University of Leicester.

KAUFMANN, H., 1988, Mineral exploration along the Aqaba-Levant structure by use of TM/ data; Concepts, processing and results, *International Journal of Remote Sensing*, 9, 1639-1658

KONTOES, C., and STAKENBORG, J., 1990, Availability of cloud-free Landsat images for operational projects, The analysis of cloud-cover figures over the countries of the European Community, *International Journal of Remote Sensing*, 11(9), 1599-1608.

MATHER, P., 1999, *Computer Processing of Remotely-Sensed Images*, John Wiley.

ROWAN, L.C., GOETZ, F.H., and ASHLEY, R.P., 1977, Discrimination of hydro thermally altered and unaltered rocks in visible and near infrared multispectral images, *Geophysics*, 42, 522-535.

TEILLET, P.M., 1986, Image correction for radiometric effects in remote sensing, *International Journal of Remote Sensing*, 7(12), 1637-1651.

THEMISTOKLEOUS, K., 2003, Personal Communication, Limassol, Cyprus.

TOWNSEND, T.E., 1987, Discrimination of iron alteration minerals in visible and near-infrared reflectance data, *Journal of Geophysical Research*, 92, 1441-1454.

BIOGRAPHIES

Dr. Diofantos Hadjimitsis-Assistant Professor

Dr. Diofantos Hadjimitsis is an Assistant Professor in the Department of Civil Engineering of the Cyprus University of Technology. He undertook his PhD and MPhil in the field of Satellite Remote Sensing intended for environmental applications (water quality surveillance and air pollution monitoring) from the University of Surrey, Department of Civil Engineering (UK).He obtained a First Class BEng. (Honours) Degree in Civil Engineering. Diofantos obtained a distinction MSc award in Real Estate and Property Management, from the University of Salford in the UK. Dr Hadjimitsis was working in the construction industry on managing and supervising various town-planning projects (road-works) in Cyprus with construction cost of more than CYP.15 MILLIONS. He worked also as a managing director of a consultancy company working in the fields of remote sensing and GIS. He has been appointed as a Consultant by governmental departments in the fields of remote sensing, GIS and construction of town-planning projects. Diofantos has more than 65 publications in fields of remote sensing and GIS.

Kyriacos Themistocleous - Special Scientist

Kyriacos Themistocleous is a special scientist at the Department of Civil Engineering. He teaches Design using Computer-Aided Design Technology. He graduated in the United States with a 5 year Bachelor's degree in Architecture form the University of Louisiana, USA and a 2 year Master's degree of Architecture in Urban Planning and Design from the University of Oklahoma, USA. Mr. Themistocleous is the principal and Director of Themistocleous & Associates, where he provides architecture, urban planning, and GIS services. He possesses over 20 years experience in teaching Computer-Aided Design (CAD) and Geographical Information Systems (GIS) in both private offices and corporations in the United States and Cyprus, as well as in private colleges and universities. He also has a great deal of experience in Architecture, design and GIS systems. Mr. Themistocleous has worked as an architect on a large number of architectural and urban planning projects, as well as developed GIS projects in the private and public sectors in both Cyprus and abroad. He has more than 10 publications in fields of remote sensing and GIS.

Dr. Toula Onoufriou - Professor

Toula Onoufriou is a Professor in the department of Civil Engineering. She is a top graduate of the Civil Engineering Department (BEng, First Class Honours) of City University London, UK) and she was awarded the Renie Prize. She has a PhD in offshore structures and DIC in Structural Engineering from Imperial College London (London, UK). She joined the offshore oil industry and worked as Senior Consultant and Deputy Head of the Analysis and Development Department of Brown & Root. She played a leading role in developing and establishing the department and lead several projects providing services to external clients and to Brown&Root worldwide. In 1995 she joined the University of Surrey as Reader in Structural Engineering and served as Director of Research for the Civil Engineering Department. She established and led the Infrastructure Reliability and Management Research Centre IRMAC at the University of Surrey . She has served as a member of various national and international committees on structural safety and reliability and she is the author of several publications in the se areas. She was awarded the Stanley Gray Award by the Institute of Marine Engineers UK for the best paper in Marine Technology.