SOIL REHABILITATION IN THE MUNICIPALITY OF LAVRION: A CASE STUDY

NATO/CCMS PILOT STUDY MEETING

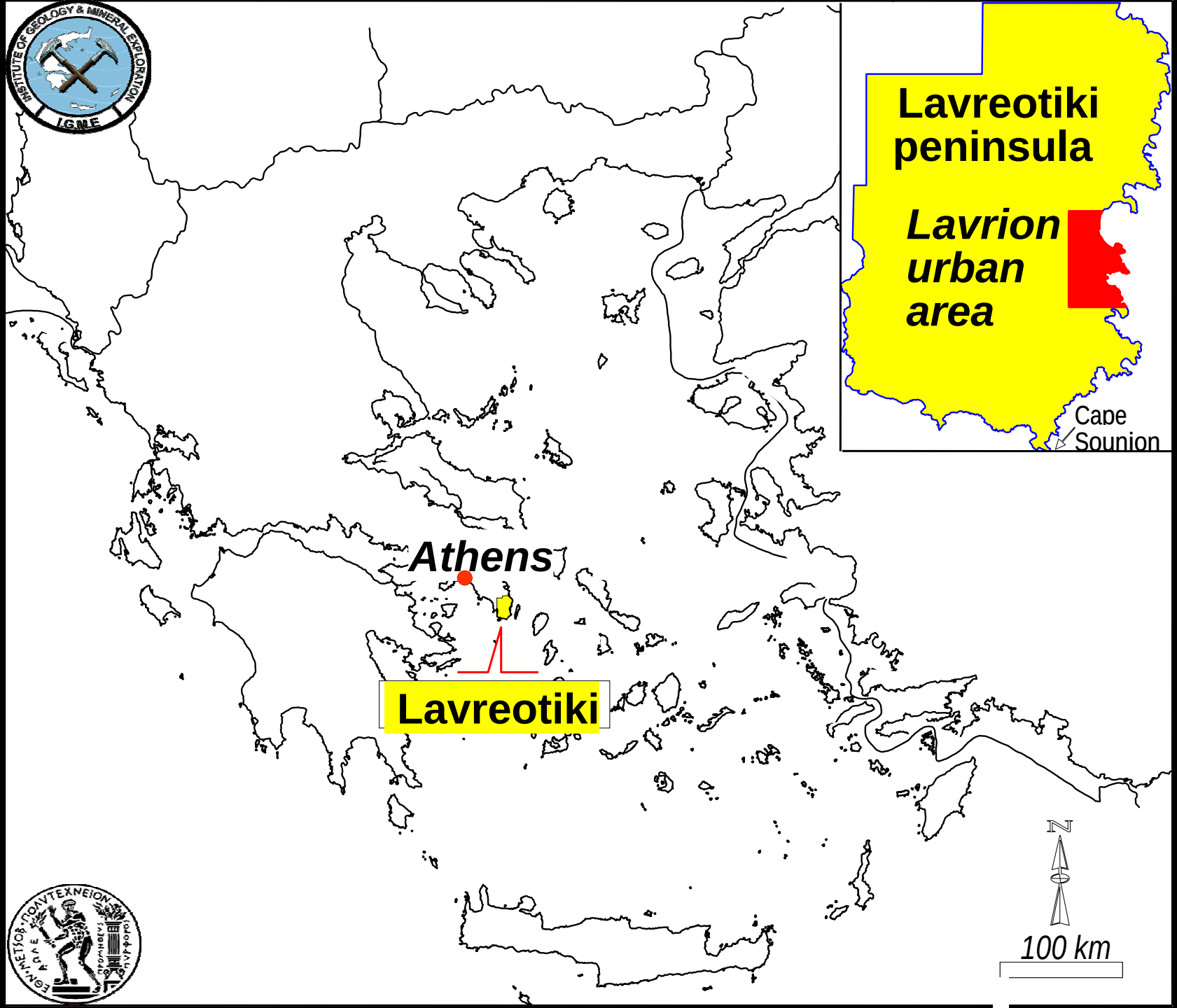
Athens, Greece, 5-7 June 2006

Alecos Demetriades

Institute of Geology and Mineral Exploration (I.G.M.E.)

Nymfodora Papassiopi

National Technical University of Athens (N.T.U.A.)


Lavreotiki peninsula
Lavrion urban area
Cape Sounion
Athens
Lavreotiki
N
100 km

attiki
Athina
Pireas
Elefsina
Nea Makri
Rafina
Porto Rafti
Glyfada
Varkiza
Vouliagmeni
Lagonissi
Lavrio
Sounio
Megara
Mandra
Aspropyrgos
Fili
Marathonas
Spata
Peania
Koropi
Markopoulo
Keratea
Kalyvia
Anavissos
Saronida
Artemis
Parnitha
Pendeli
Ymittos
Pateras
Makri Oros

SOIL REHABILITATION IN THE MUNICIPALITY OF LAVRION
LIFE Programme Contract No.: 93/GR/A14/GR/4576

Municipality of Lavrion

PRISMA

I.G.M.E.

N.T.U.A.

- British Geological Survey
- Imperial College (Univ. London)
- Lavrion Medical Centre
- Aachen Technical University
- Connecticut University, U.S.A.

Knight, Piesold & Partners, U.K

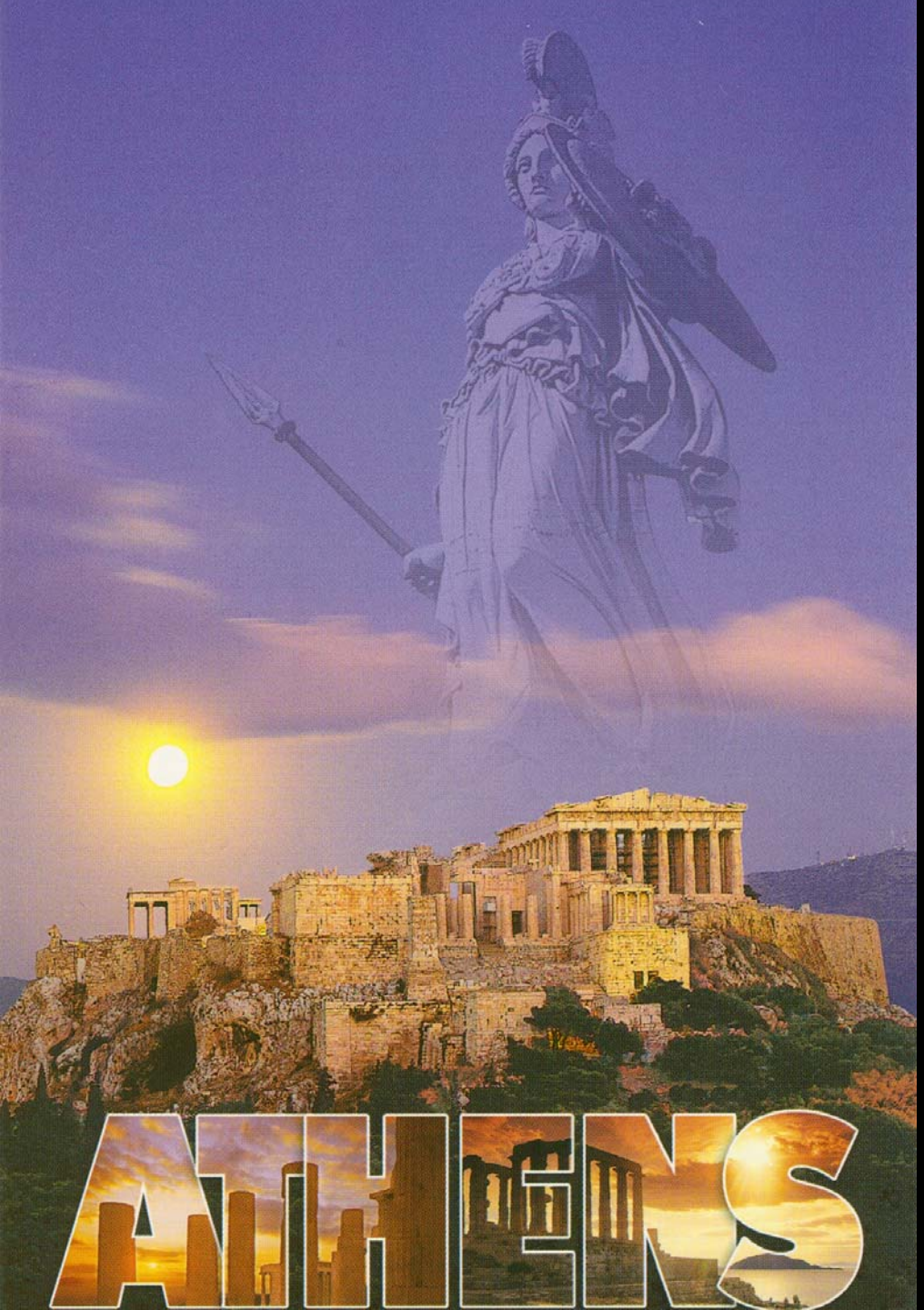
The main objectives of the project were:

- To determine the current state of environmental pollution in the greater Lavrion area, focusing mainly on soil contamination, with respect to lead and other toxic elements.
- To define the main sources of contamination.
- To select and apply methods, which will hinder the further contamination of soil by applying preventive measures at the contamination sources.
- To select and apply remedial measures for the rehabilitation or neutralisation of contaminated land, and
- To develop an integrated environmental management scheme for the greater Lavrion urban area.

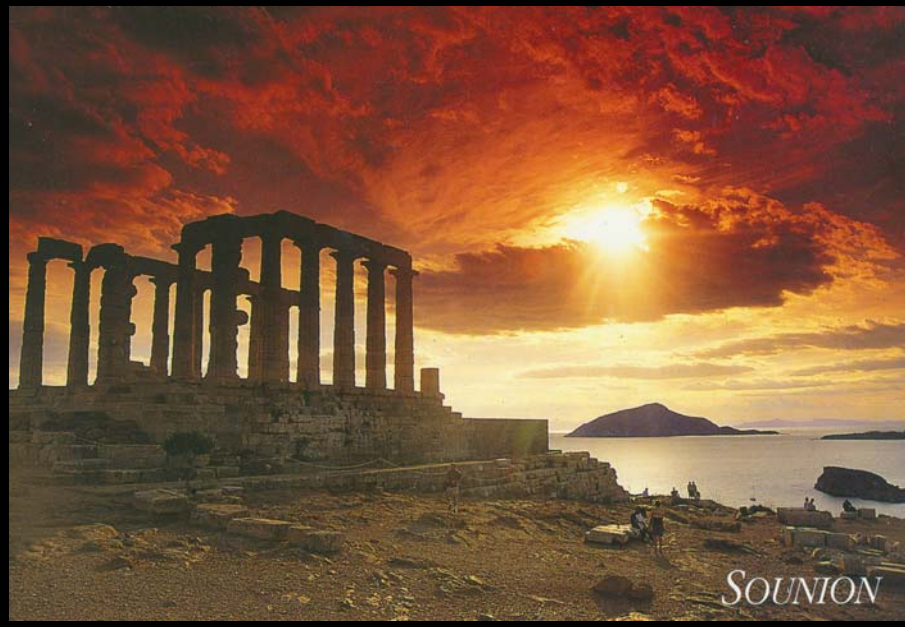
HISTORY

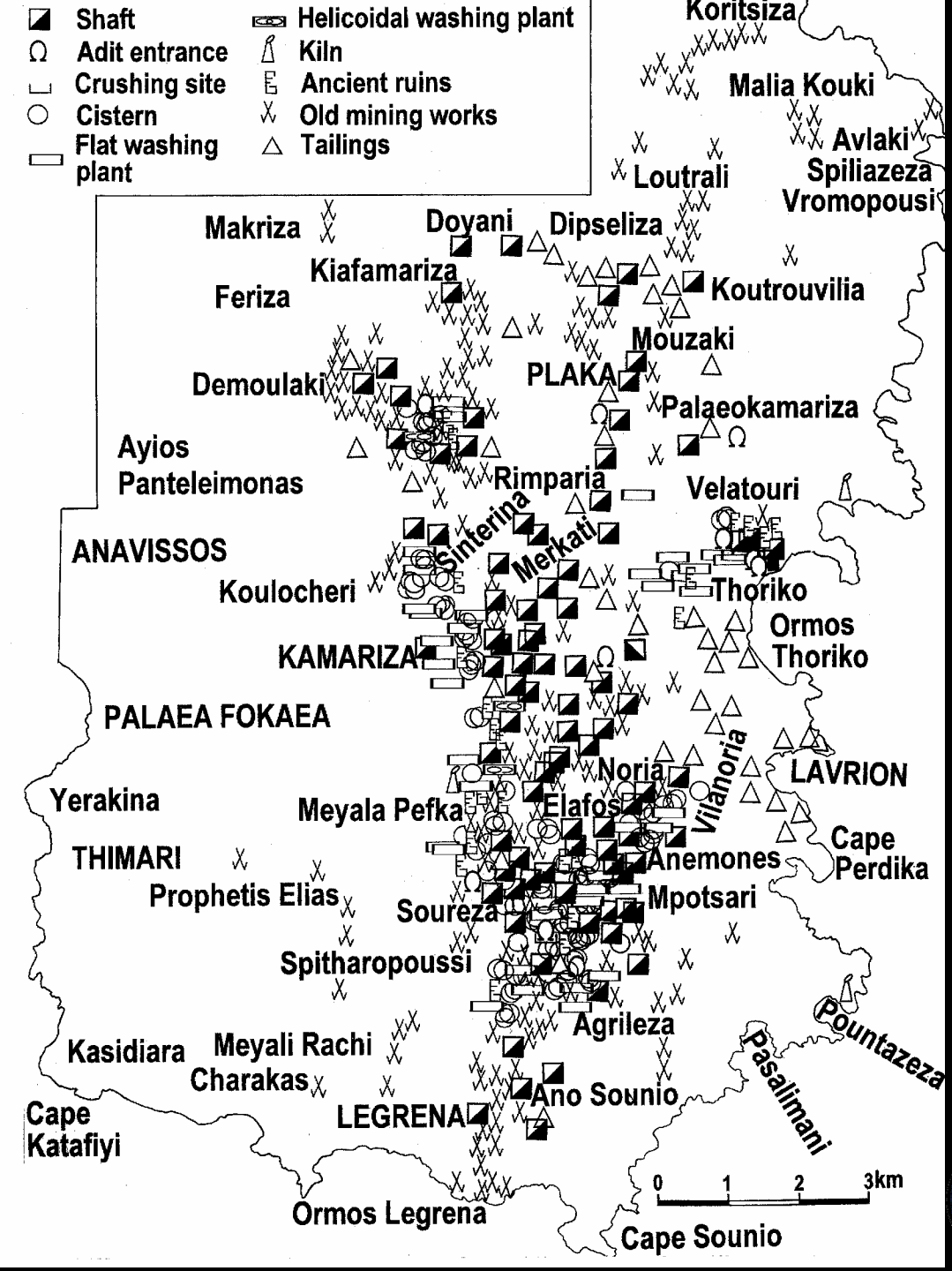
- 3500 B.C. (?) – Earliest record of mining and ore processing of argentiferous galena.

- 7th to 4th century B.C. mining peak
- 3rd to 1st century B.C. waning down of mining with the opening of Au mines in Macedonia and Thrace, and final closure. By the 1st century A.D. Lavrion is completely forgotten.
- 1864 to 1977 A.D. Closure of mines
- 1989 A.D. Closure of ore beneficiation and metallurgical plant



The Golden Age of Athens in the 5th century B.C. depended on the revenues from the Lavrion Ag-Pb mines





Ancient and recent mining activities & metallurgical installations and wastes

[from Conophagos (1980) & IGME work]

C. Conophagos, 1980. Le Laurium antique et la technique Grecque de la production deo l'argent. National Technical University of Athens, 458 pp.

Calcite

[$CaCO_3$]

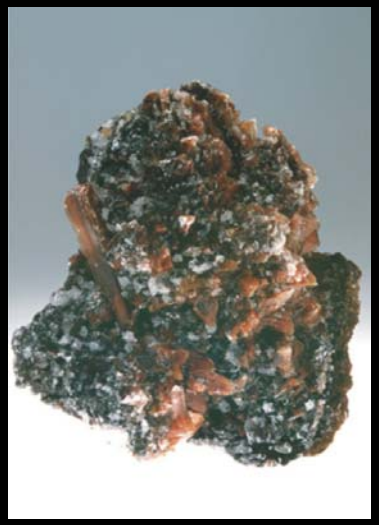
Galena

[PbS]

Calcite

[$CaCO_3$]

Aragonite
[$CaCO_3$]



Gypsum
[$CaSO_4.2H_2O$]

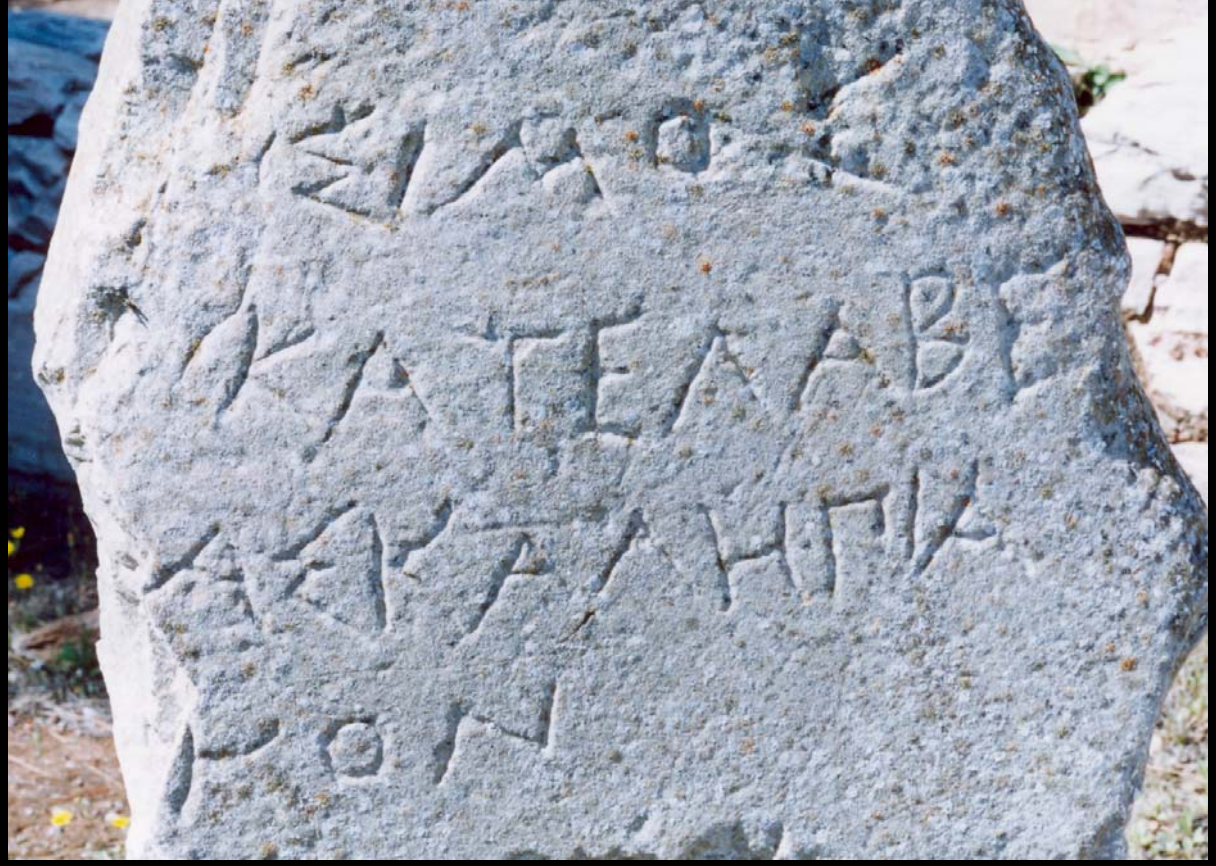
Azurite
[Cu3(OH)2(CO3)2]
Malachite
[$Cu_2CO_3(OH)_2$]

Barite
[$BaSO_4$]

Ancient adits & wastes

INSTITUTE OF GEOLOGY & MINERAL EXPLORATION
IGME

Ancient washing plants for separation & beneficiation of ore



ΣΙΜΟΝ ΚΑΤΕΛΑΒΕ ΑΣΚΛΗΠΙΑΚΟΝ

SIMON LEASED ASKLIPIAKON

Recent exploitation/Wastes & Installations of French Co.


INSTITUTE OF GEOLOGY & MINERAL EXPLORATION
I.G.M.E.


INSTITUTE OF GEOLOGY & MINERAL EXPLORATION
IGME

The result of this intense mining and metallurgical activity is

soil contamination

Over the whole Lavreotiki peninsula (130 out of 170 sq. km. investigated), with the greater intensity in the Lavrion urban area of 7 sq. km.

In the EU the LIFE project the Institute of Geology and Mineral Exploration was responsible for:

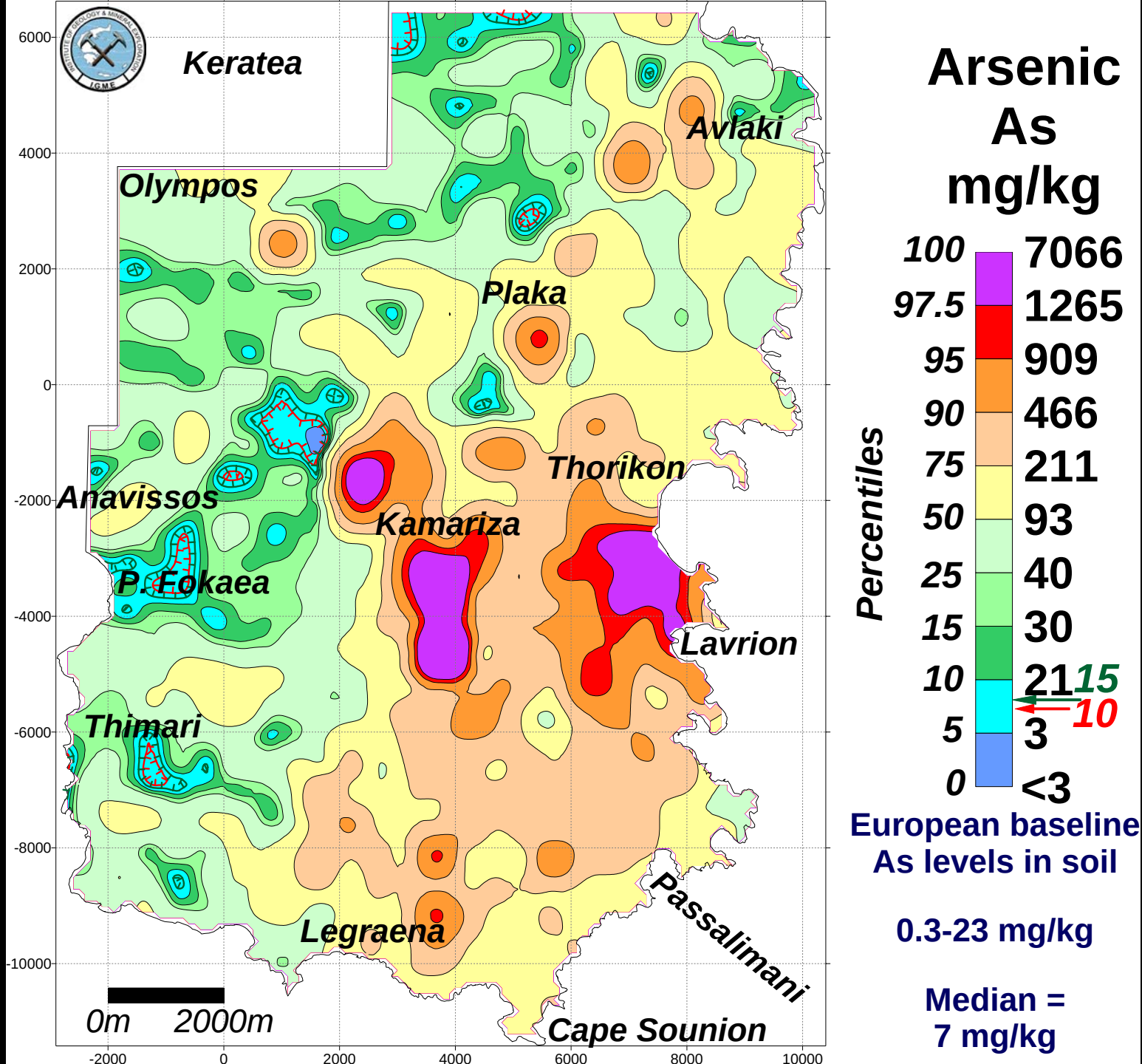
- Geochemical mapping of soil (overburden), house dust, parent rocks and mining wastes;
- Groundwater geochemistry;
- Mapping of wastes & contaminated overburden;
- Mapping of parent rocks (lithology);
- Logging of drill holes;
- Land use mapping;
- Property mapping;
- Risk assessment and management;
- Environmental planning (in collaboration with NTUA);
- Processing of all data by G.I.S., and
- Report presentation

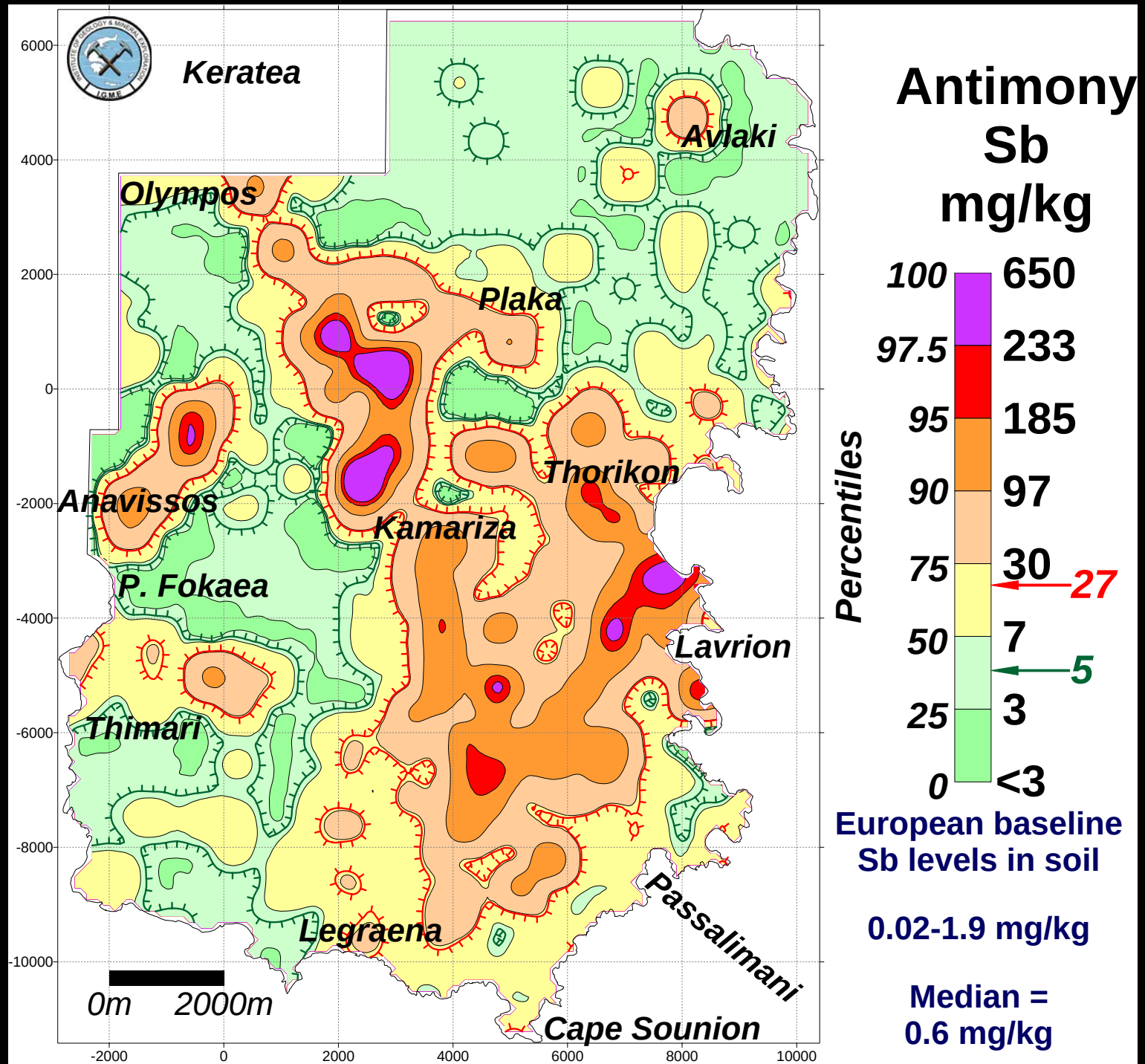
The National Technical University of Athens was responsible for:

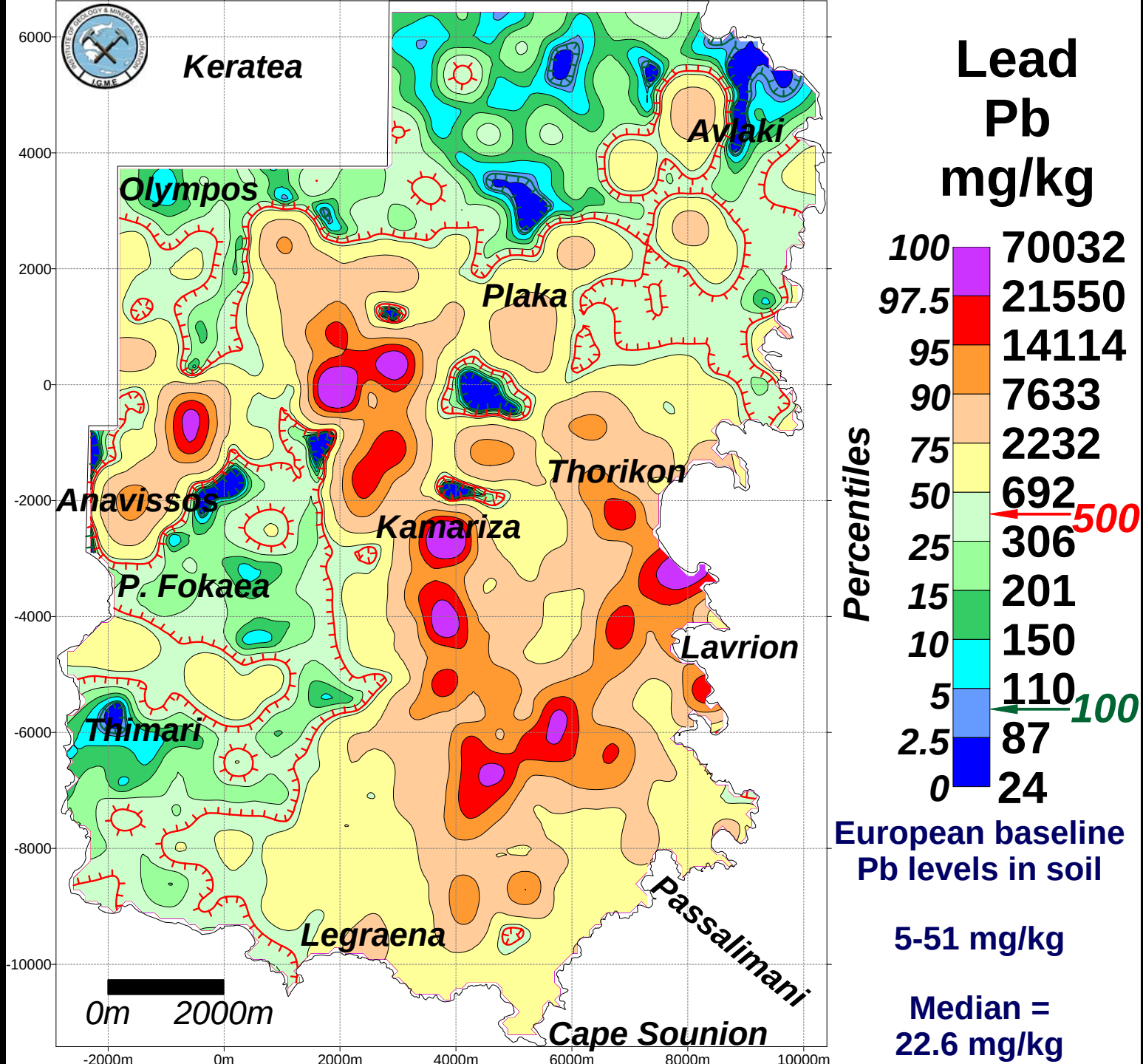
- **Chemical characterisation of mining wastes;**
- **Testing of different rehabilitation technologies in the laboratory;**
- **Drilling operations for assessing the depth of pollution;**
- **Demonstration scale application of rehabilitation technologies;**
- **Monitoring of demonstration scale rehabilitation technologies;**
- **Environmental planning (in collaboration with IGME);**

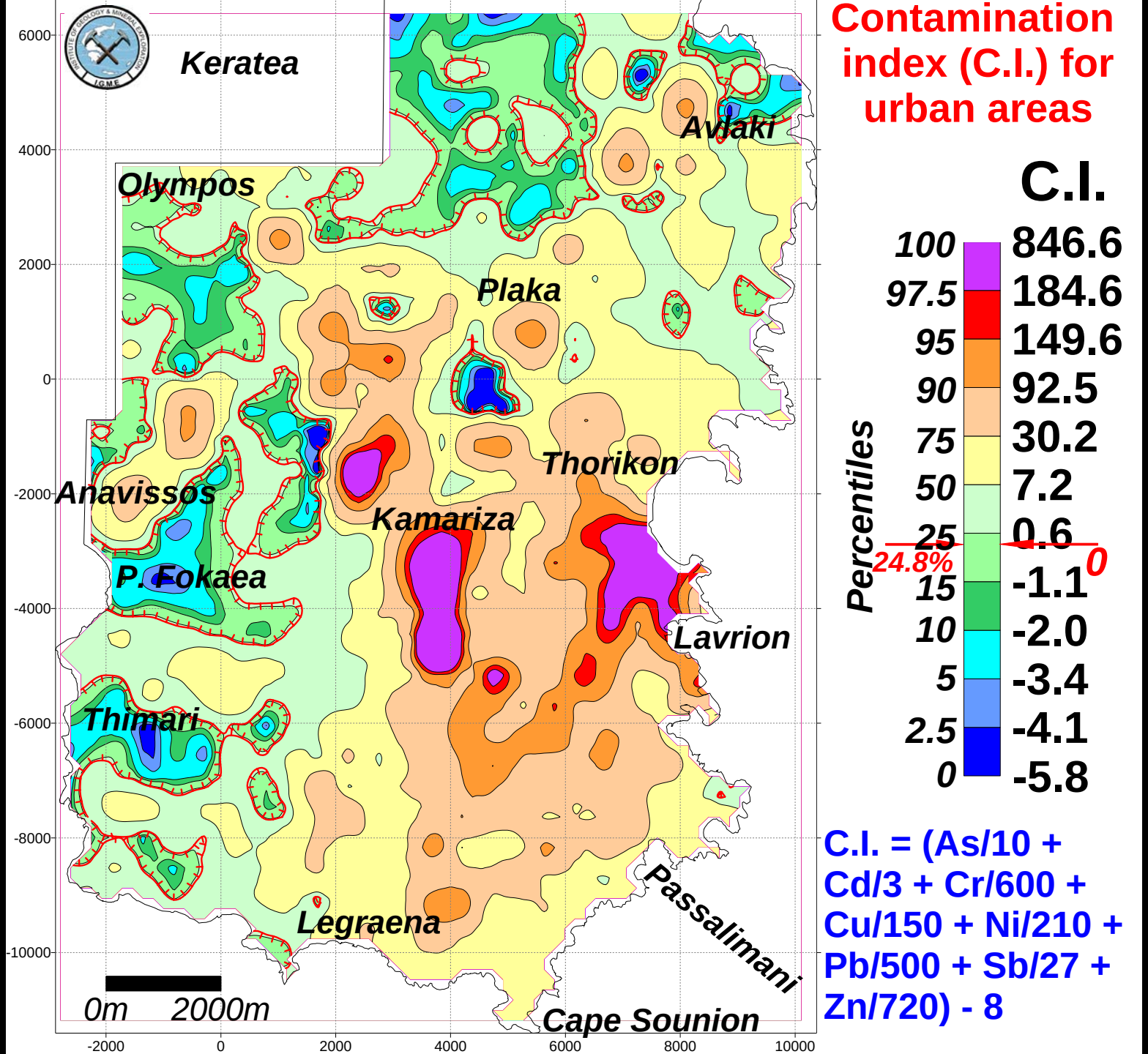
The Institute of Geology and Mineral Exploration also investigated the whole Lavreotiki peninsula with financial support from the EU Structural Funds programme and the Hellenic Ministry of Finance.

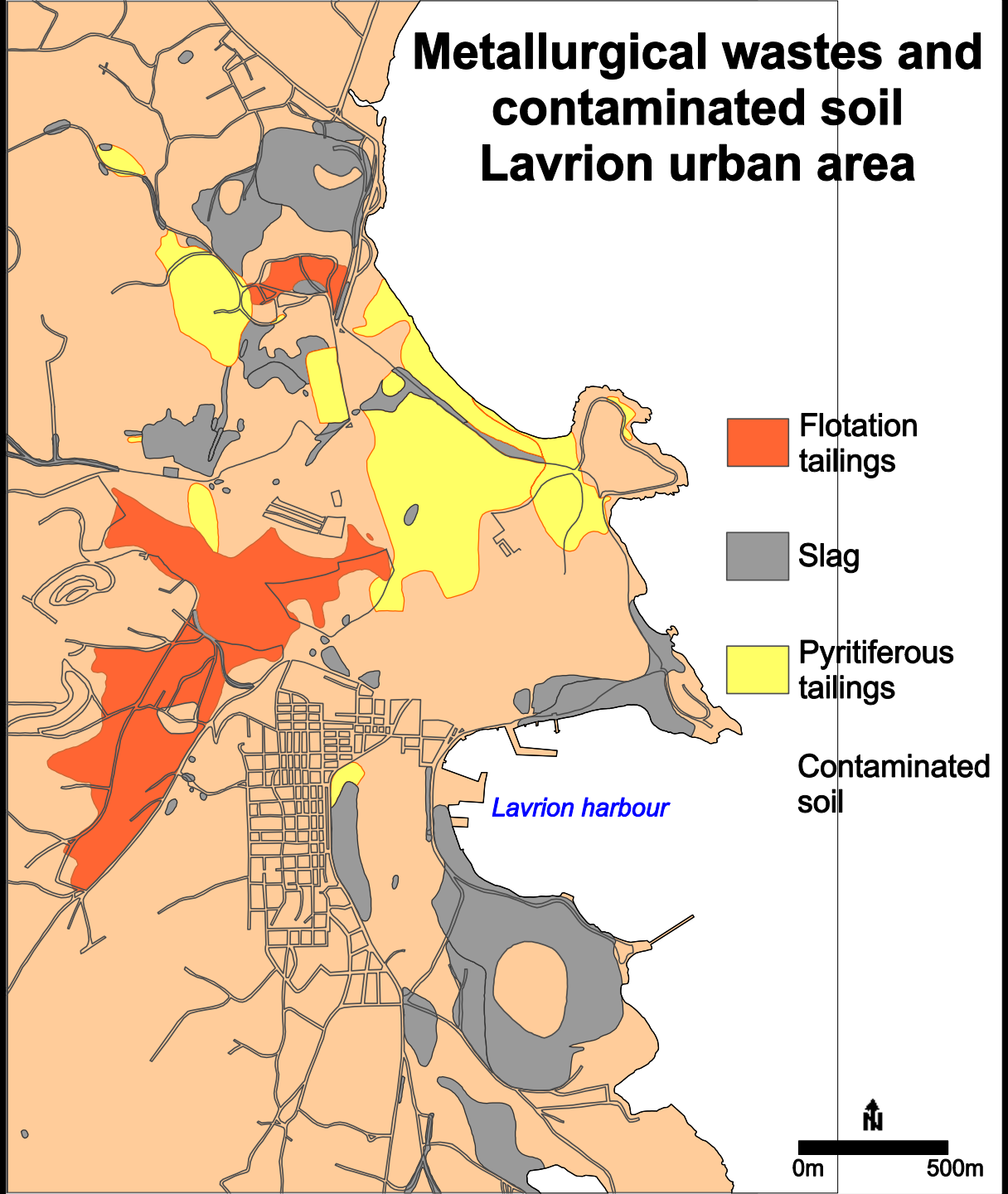
Attiki Region project No: 202.088.00

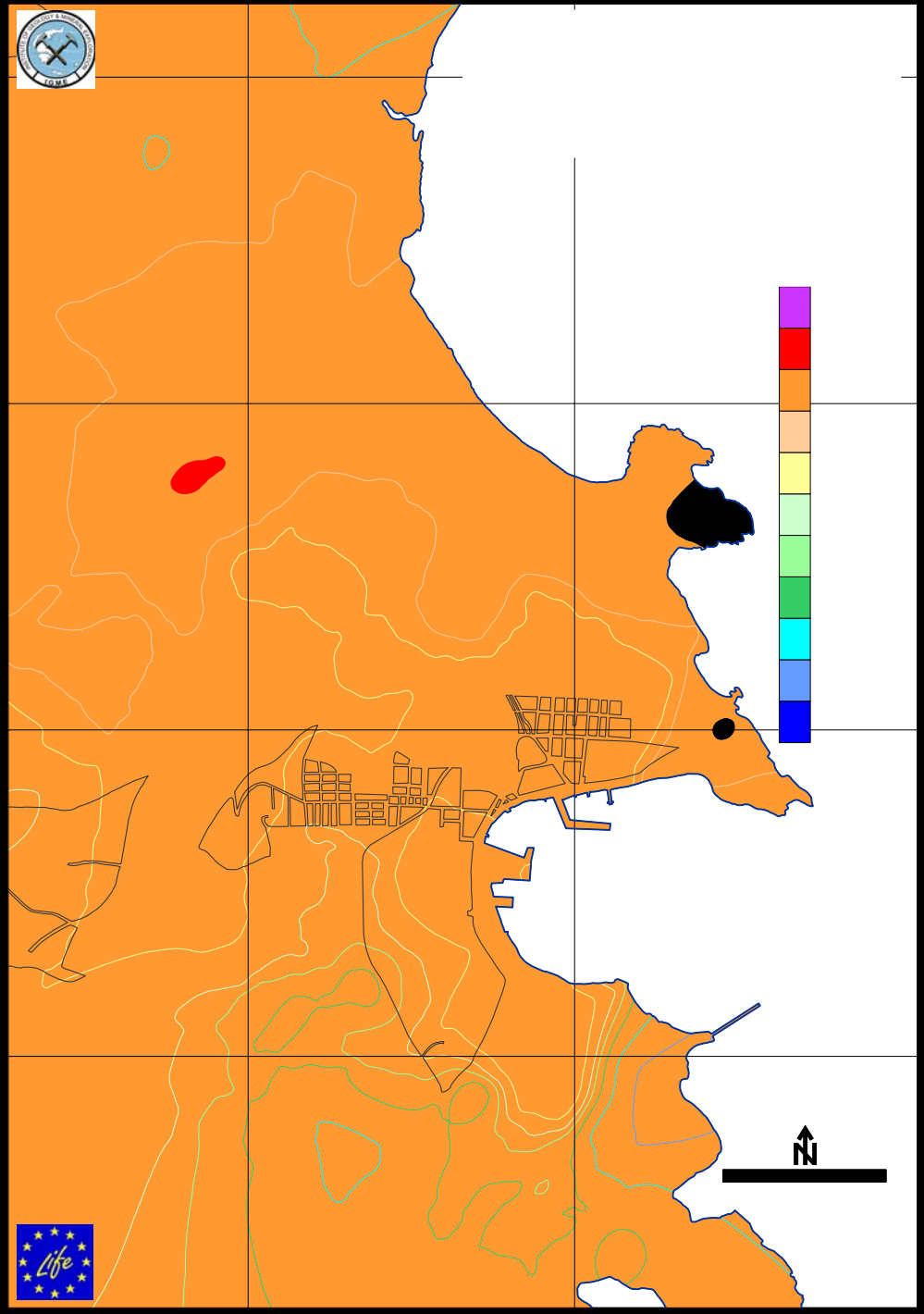

Keratea
Avlaki
Olympos
Plaka
Thorikon
Anavissos
Kamariza
P. Fokaea
Lavrion
Thimari
Legraena
Passalimani
Cape Sounion
0m 2000m
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-2000
0
2000
4000
6000
8000
10000
Arsenic
As
mg/kg
Percentiles
100 7066
97.5 1265
95 909
90 466
75 211
50 93
25 40
15 30
10 21
5 3
0 <3
15
10
European baseline
As levels in soil
0.3-23 mg/kg
Median =
7 mg/kg

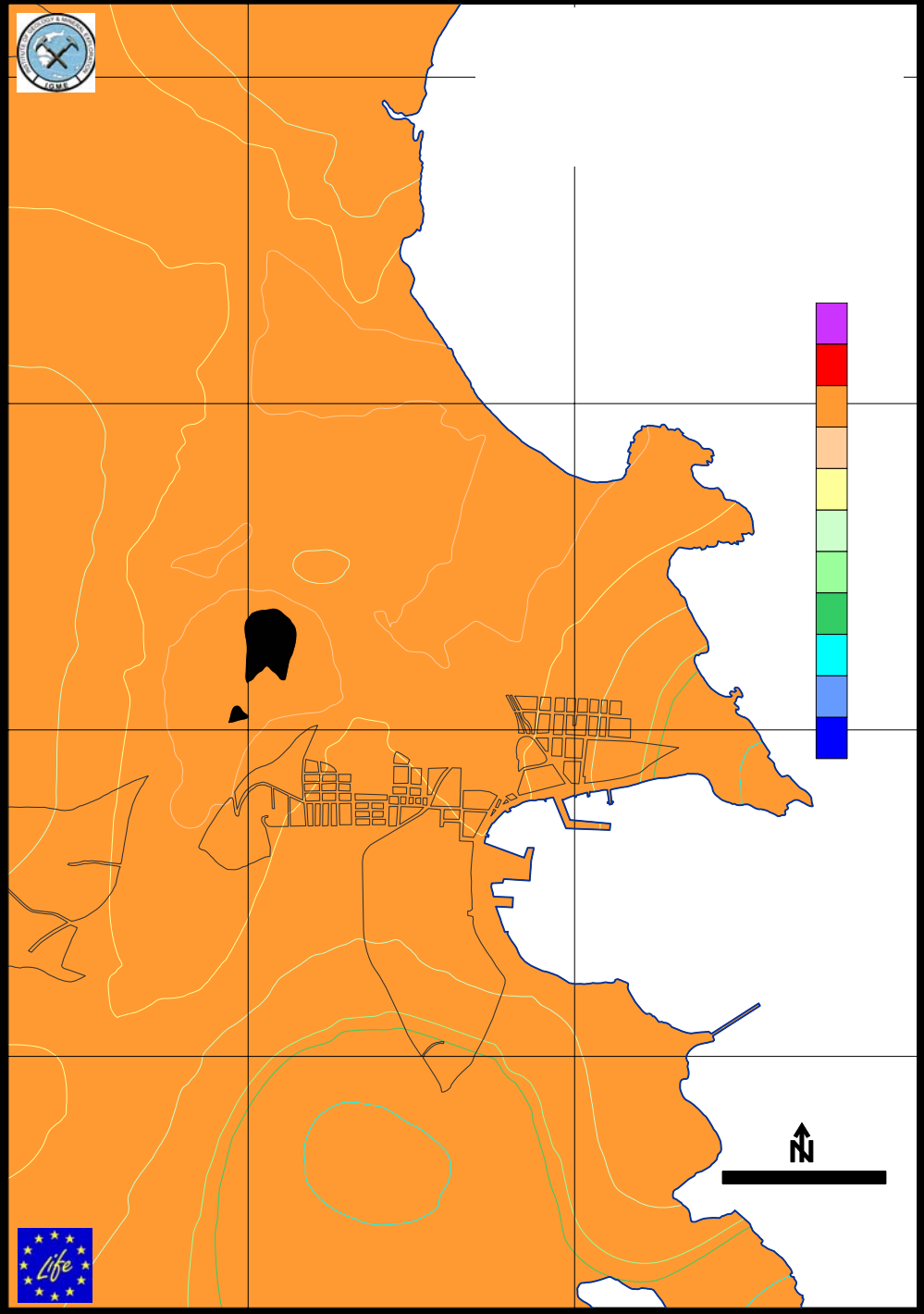

Keratea
Avlaki
Olympos
Plaka
Thorikon
Anavissos
Kamariza
P. Fokaea
Lavrion
Thimari
Legraena
Passalimani
Cape Sounion
0m
2000m
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-2000
0
2000
4000
6000
8000
10000
Antimony
Sb
mg/kg
Percentiles
100
97.5
95
90
75
50
25
0
650
233
185
97
30
27
7
5
3
<3
European baseline
Sb levels in soil
0.02-1.9 mg/kg
Median =
0.6 mg/kg

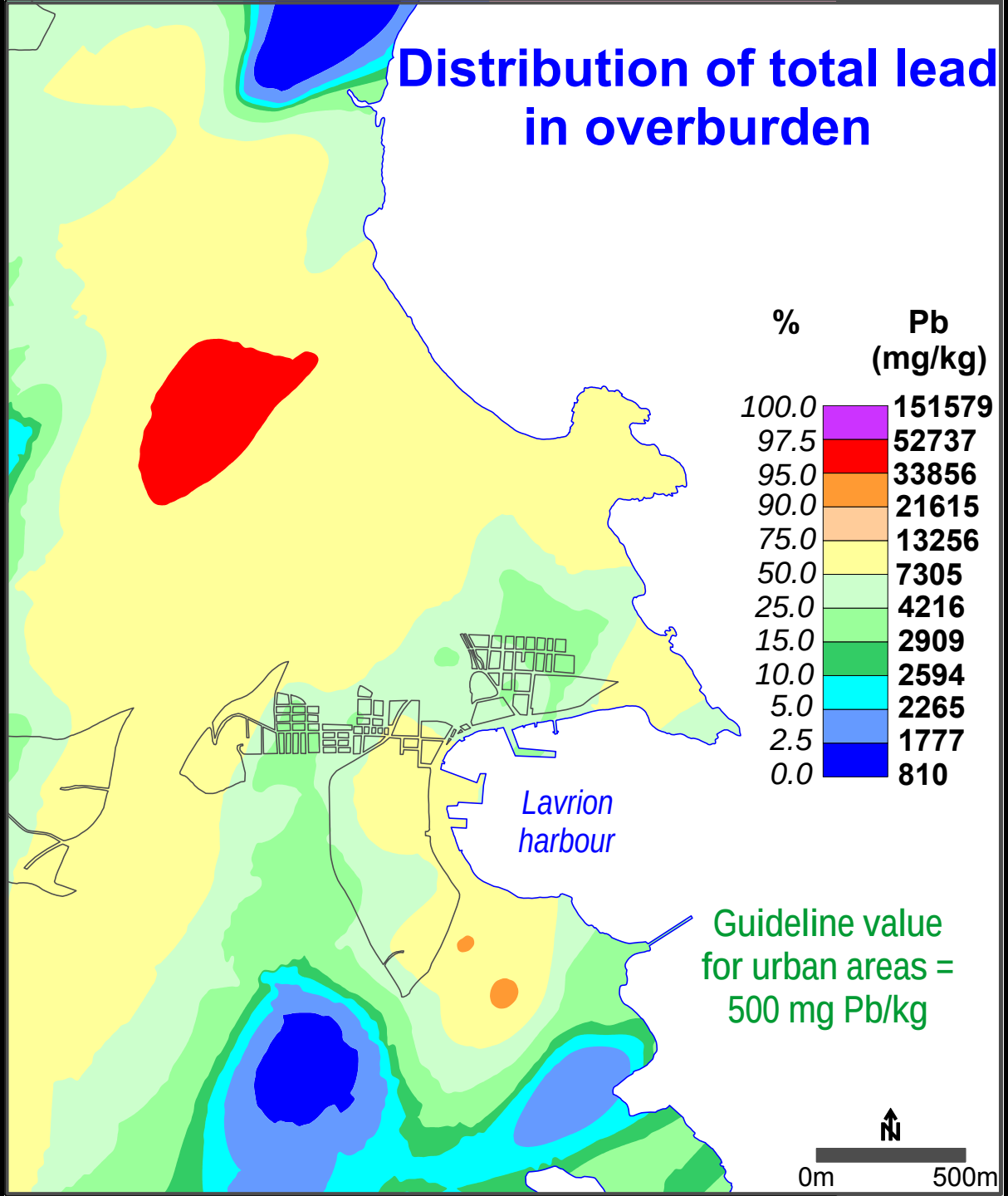

Keratea
Avlaki
Olympos
Plaka
Thorikon
Anavissos
Kamariza
P. Fokaea
Lavrion
Thimari
Legraena
Passalimani
Cape Sounion
0m 2000m
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-2000m
0m
2000m
4000m
6000m
8000m
10000m
Lead
Pb
mg/kg
Percentiles
100 70032
97.5 21550
95 14114
90 7633
75 2232
50 692
500
25 306
15 201
10 150
5 110
100
2.5 87
0 24
European baseline
Pb levels in soil
5-51 mg/kg
Median =
22.6 mg/kg

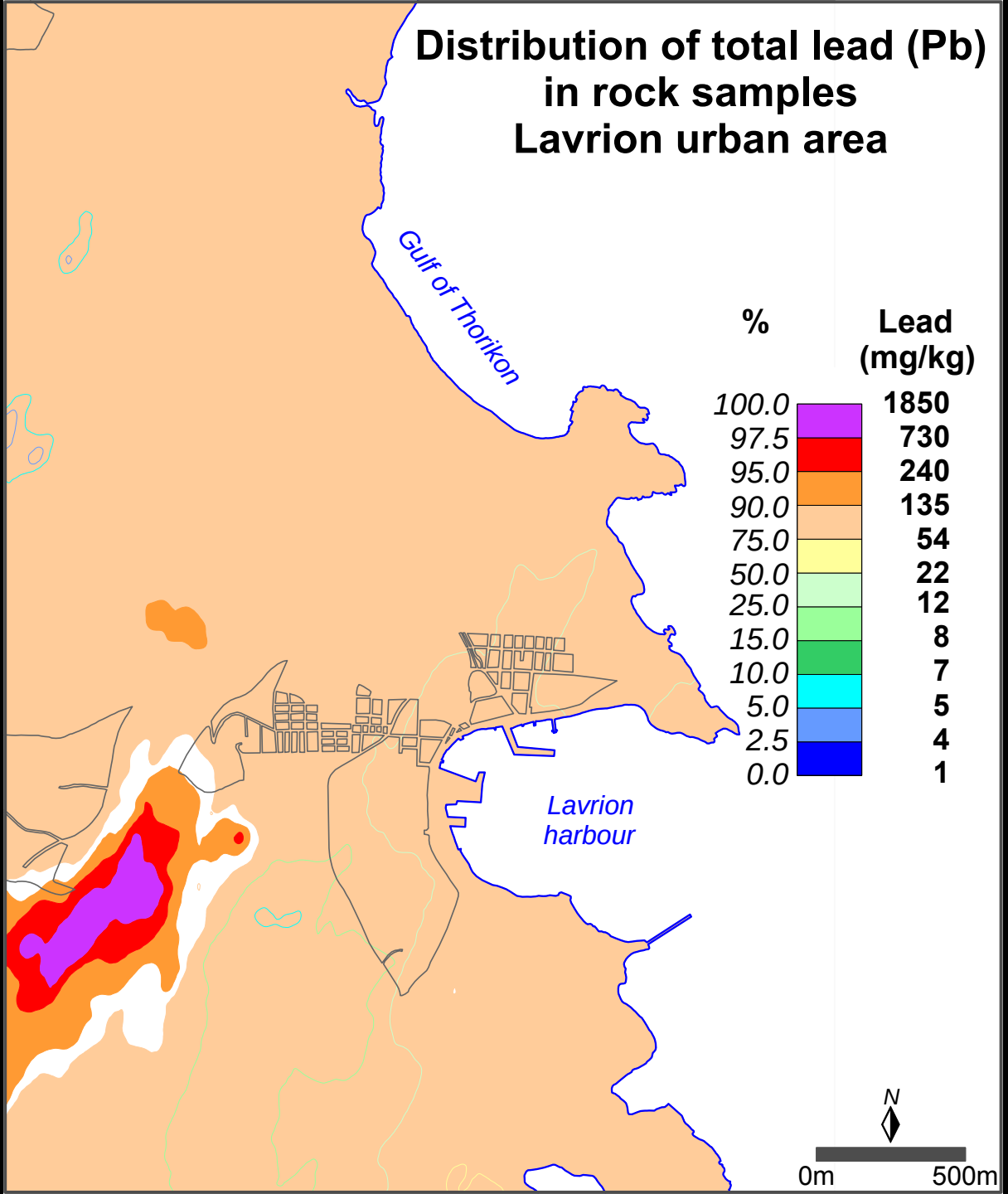

Contamination index (C.I.) for urban areas
C.I.
Percentiles
100 846.6
97.5 184.6
95 149.6
90 92.5
75 30.2
50 7.2
25 0.6
24.8% 0
15 -1.1
10 -2.0
5 -3.4
2.5 -4.1
0 -5.8
C.I. = (As/10 + Cd/3 + Cr/600 + Cu/150 + Ni/210 + Pb/500 + Sb/27 + Zn/720) - 8
Keratea
Avlaki
Olympos
Plaka
Thorikon
Anavissos
Kamariza
P. Fokaea
Lavrion
Thimari
Legraena
Passalimani
Cape Sounion
0m 2000m
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-2000
0
2000
4000
6000
8000
10000

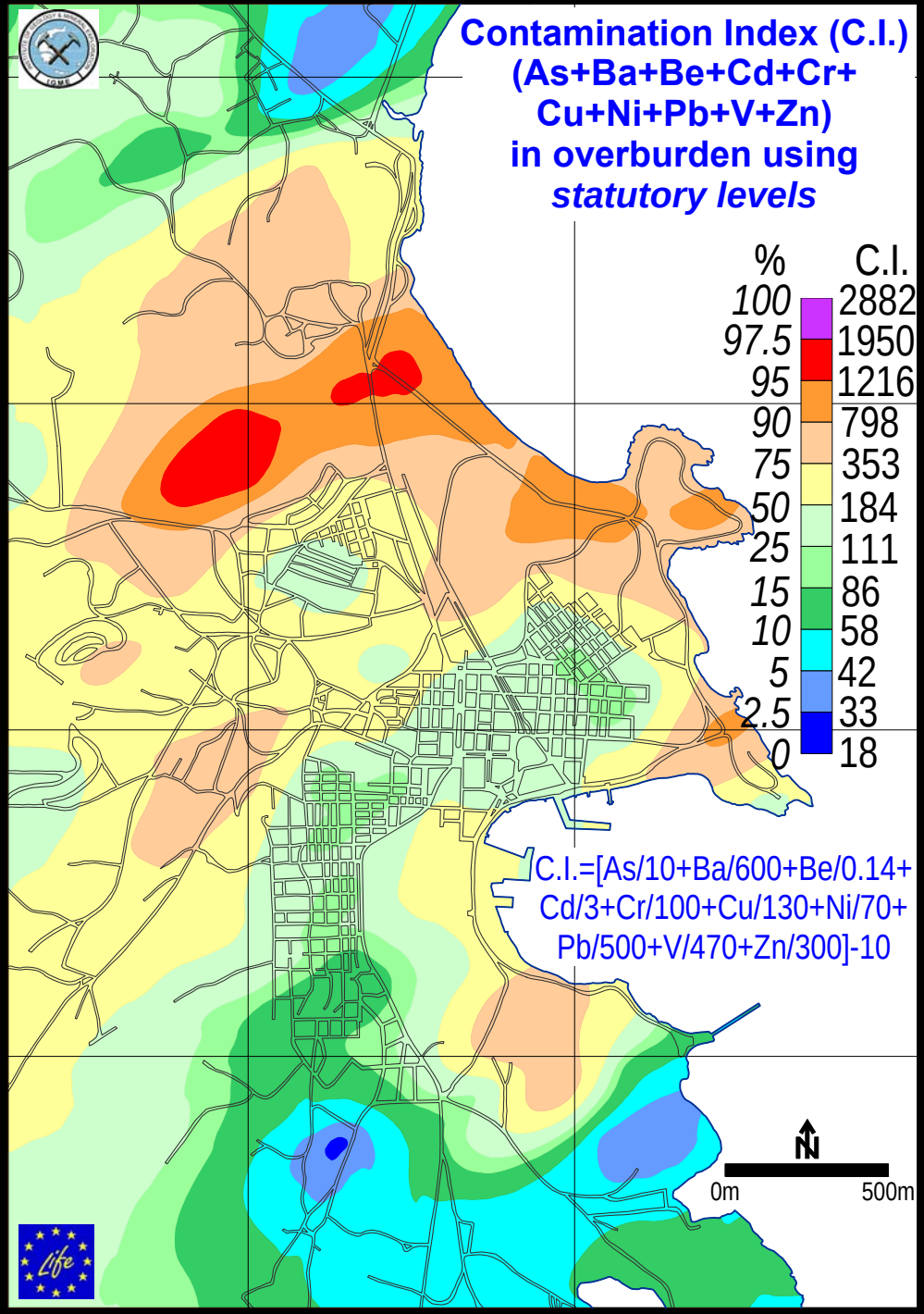

Metallurgical wastes and contaminated soil Lavrion urban area
Flotation tailings
Slag
Pyritiferous tailings
Contaminated soil
Lavrion harbour
N
0m
500m



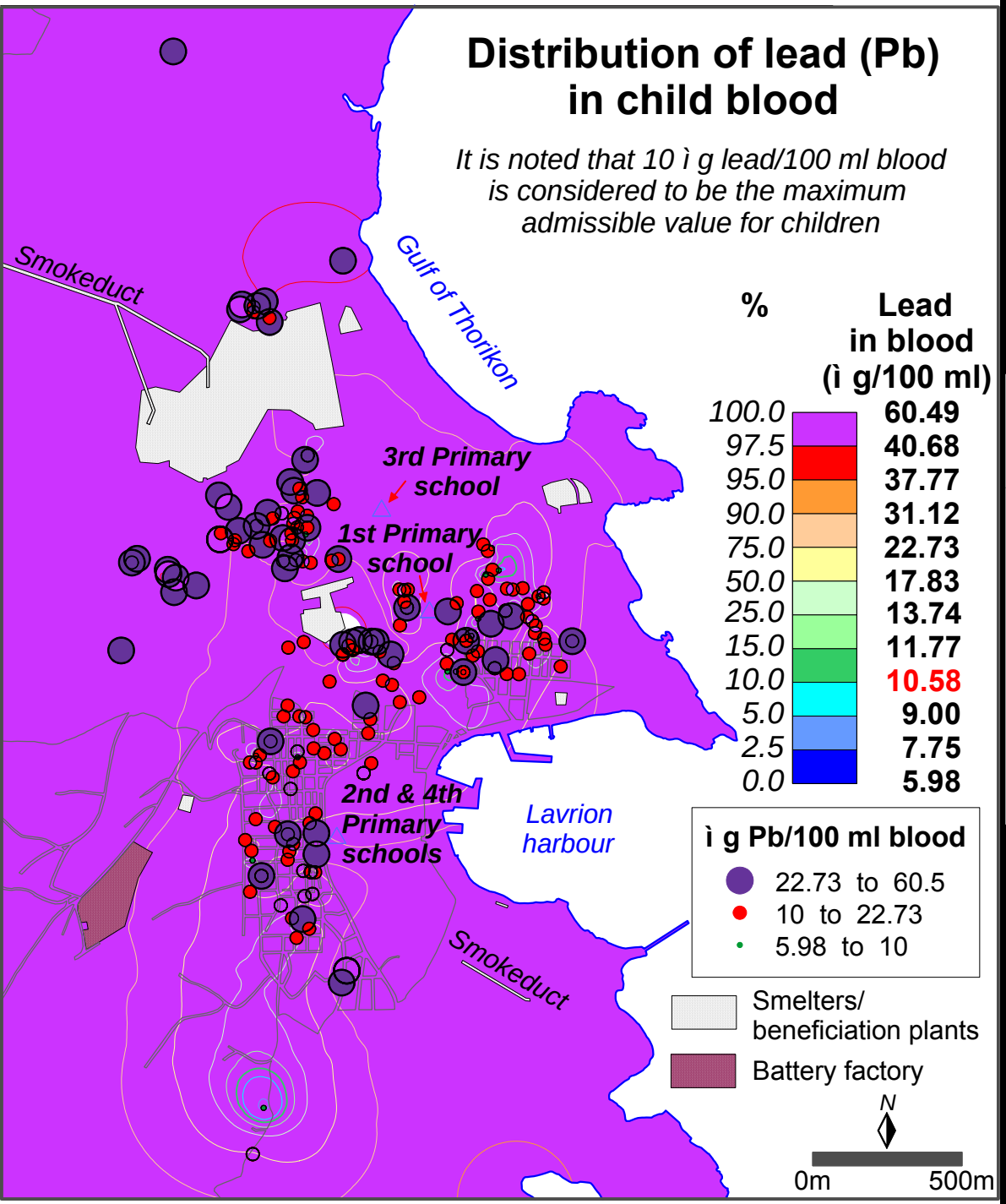

N

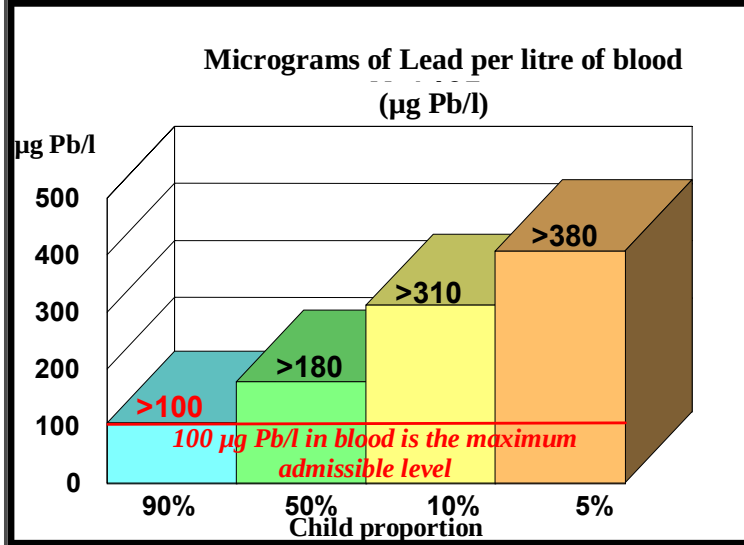

Distribution of total lead in overburden
%
Pb (mg/kg)
100.0 151579
97.5 52737
95.0 33856
90.0 21615
75.0 13256
50.0 7305
25.0 4216
15.0 2909
10.0 2594
5.0 2265
2.5 1777
0.0 810
Lavrion harbour
Guideline value for urban areas = 500 mg Pb/kg
N
0m
500m


Distribution of total lead (Pb)
in rock samples
Lavrion urban area
Gulf of Thorikon
Lavrion
harbour
%
Lead
(mg/kg)
100.0 1850
97.5 730
95.0 240
90.0 135
75.0 54
50.0 22
25.0 12
15.0 8
10.0 7
5.0 5
2.5 4
0.0 1
N
0m
500m


Contamination Index (C.I.)
(As+Ba+Be+Cd+Cr+
Cu+Ni+Pb+V+Zn)
in overburden using
statutory levels
% C.I.
100 2882
97.5 1950
95 1216
90 798
75 353
50 184
25 111
15 86
10 58
5 42
2.5 33
0 18
C.I.=[As/10+Ba/600+Be/0.14+
Cd/3+Cr/100+Cu/130+Ni/70+
Pb/500+V/470+Zn/300]-10
N
0m
500m
Life

Plant type	*Lead (mg/kg) in produce/fruit*	*Lead (mg/kg) in leaves*
Olive trees	**5.6**	**386**
Vines	**8.7**	**175**
EU Directive	**0.1**	**0.3**


Distribution of lead (Pb) in child blood
It is noted that 10 ì g lead/100 ml blood is considered to be the maximum admissible value for children
Smokeduct
Gulf of Thorikon
3rd Primary school
1st Primary school
2nd & 4th Primary schools
Lavrion harbour
Smokeduct
% Lead in blood (ì g/100 ml)
100.0 60.49
97.5 40.68
95.0 37.77
90.0 31.12
75.0 22.73
50.0 17.83
25.0 13.74
15.0 11.77
10.0 10.58
5.0 9.00
2.5 7.75
0.0 5.98
ì g Pb/100 ml blood
22.73 to 60.5
10 to 22.73
5.98 to 10
Smelters/ beneficiation plants
Battery factory
N
0m
500m


Micrograms of Lead per litre of blood
(µg Pb/l)
µg Pb/l
500
400
300
200
100
0
>100
>180
>310
>380
100 µg Pb/l in blood is the maximum admissible level
90%
50%
10%
5%
Child proportion

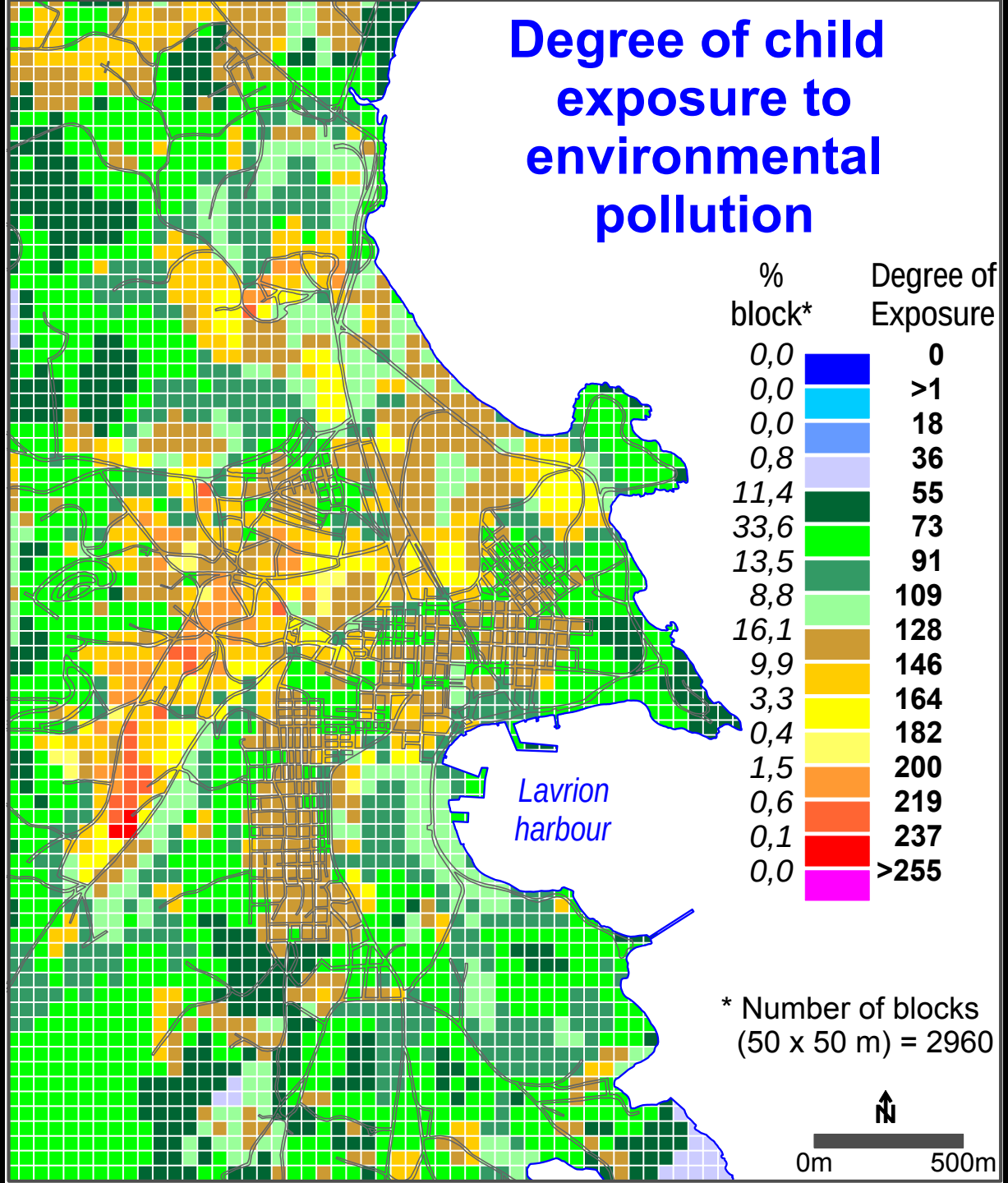
Eight factors and two constraints are considered in a multi-criteria Exposure Assessment Model, including Pb concentrations in overburden/soil, *i.e.*,

(a) Factors:

(1) Lead (Pb) concentration in overburden/soil;
(2) Degree of dustiness of the metallurgical waste;
(3) Proximity to metallurgical wastes;
(4) Proximity to current or previous stacks;
(5) Proximity to roads;
(6) Proximity to rivers;
(7) Proximity to Pb-industry;
(8) Degree of exposure.

(b) Constraints:

(9) Area with metal-related industry, and
(10) Area over Quaternary deposits.


Degree of child exposure to environmental pollution
% block*
Degree of Exposure
0,0 0
0,0 >1
0,0 18
0,8 36
11,4 55
33,6 73
13,5 91
8,8 109
16,1 128
9,9 146
3,3 164
0,4 182
1,5 200
0,6 219
0,1 237
0,0 >255
Lavrion harbour
* Number of blocks (50 x 50 m) = 2960
N
0m
500m

Seven factors and two constraints are considered in this multi-criteria Risk Assessment Model, including Pb concentrations in overburden/soil, *i.e.*,

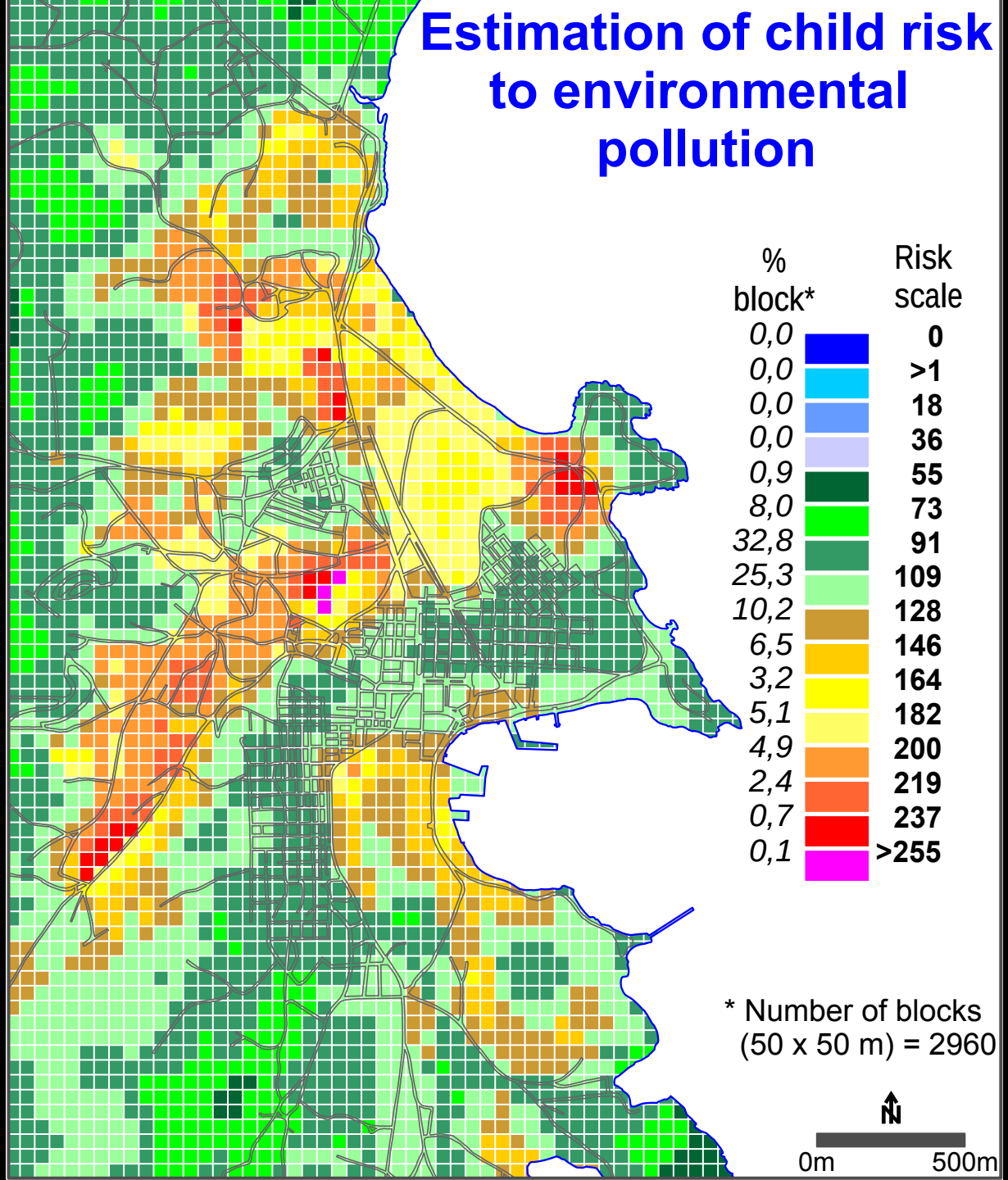
(a) Factors:

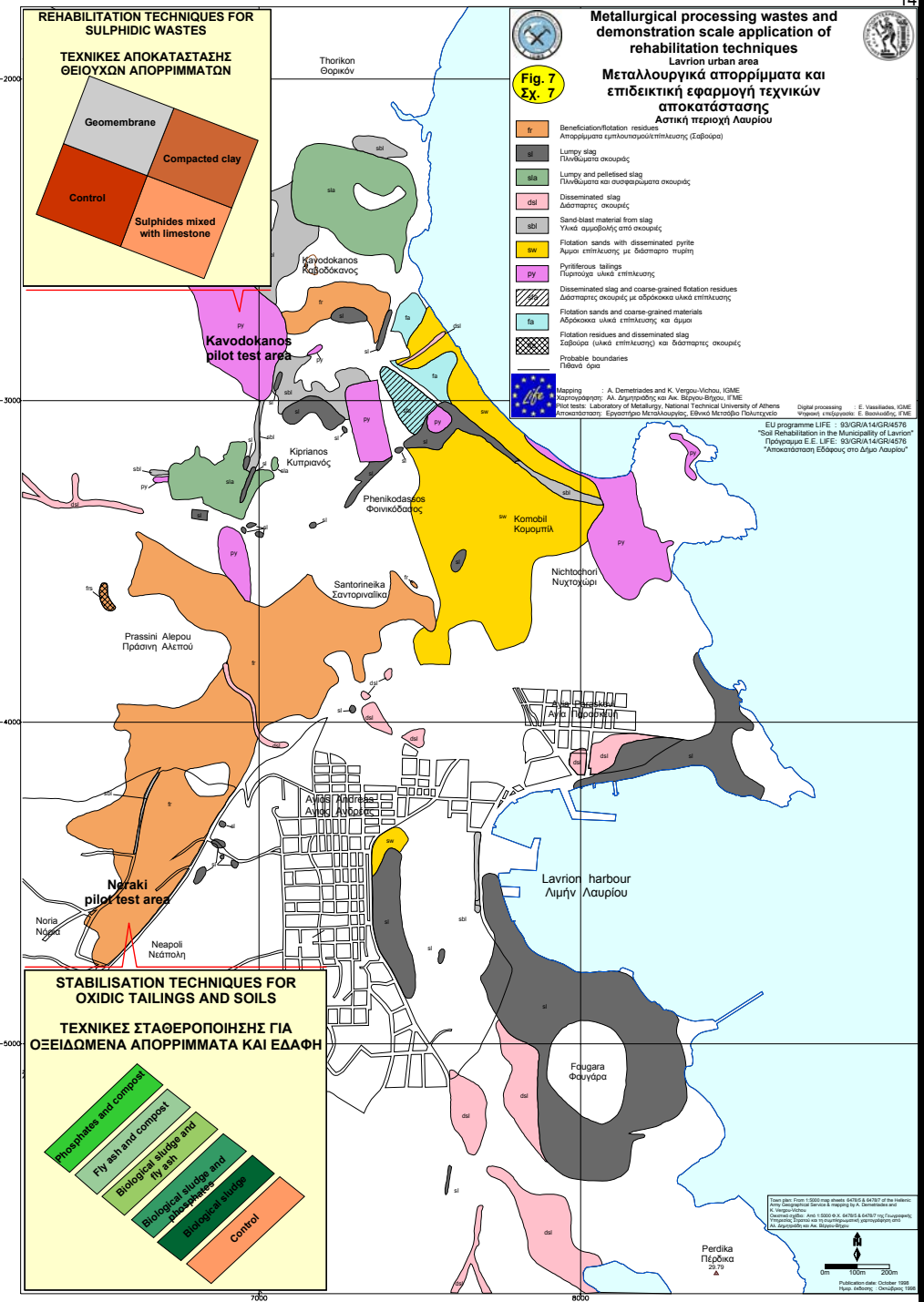
(1) Lead (Pb) concentration in overburden/soil;
(2) Degree of dustiness of the metallurgical waste;
(3) Proximity to metallurgical wastes;
(4) Proximity to current or previous stacks;
(5) Proximity to roads;
(6) Proximity to rivers;
(7) Proximity to Pb-industry.

(b) Constraints:

(8) Area with metal-related industry, and
(9) Area over Quaternary deposits.

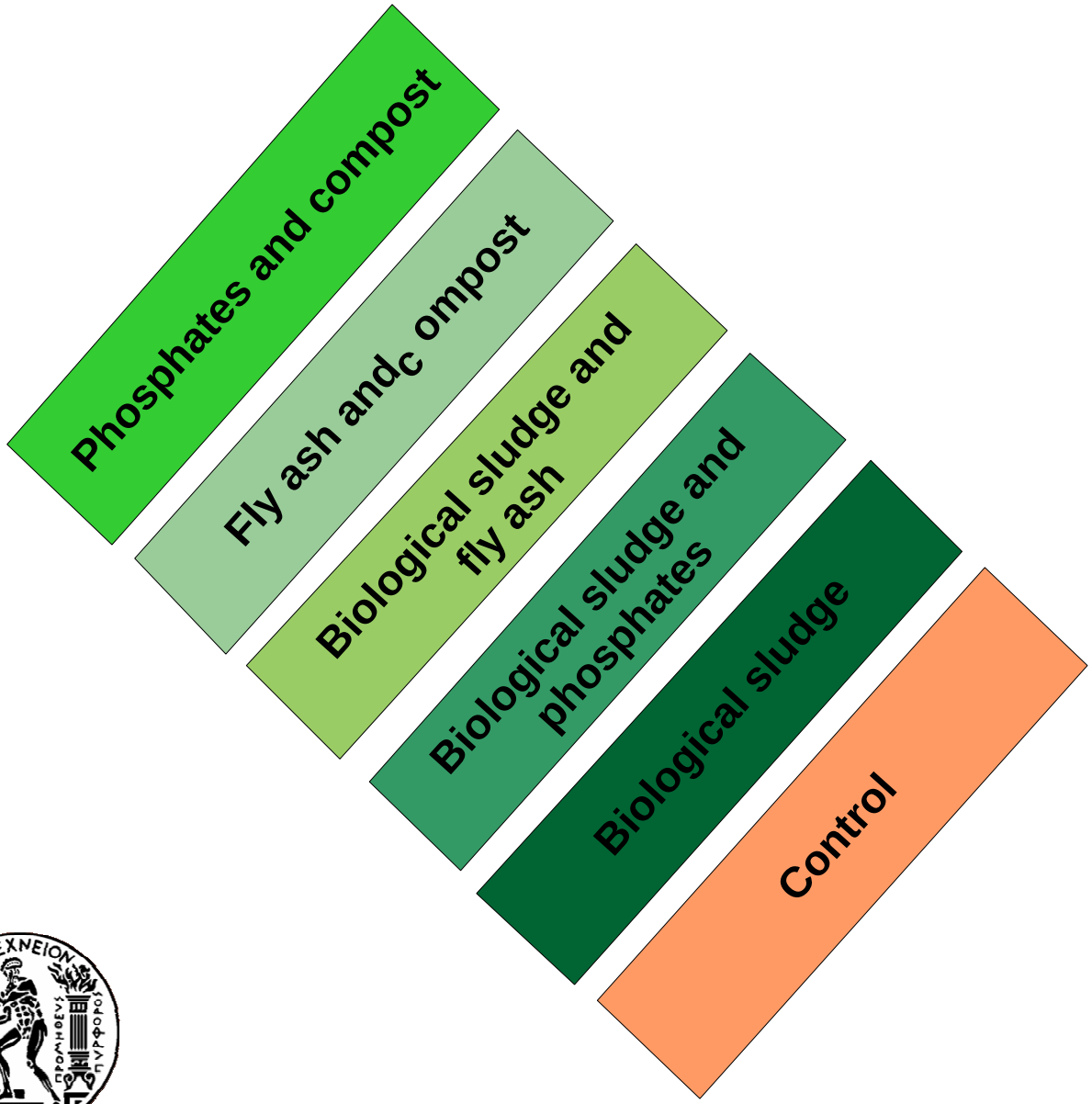
Estimation of child risk to environmental pollution



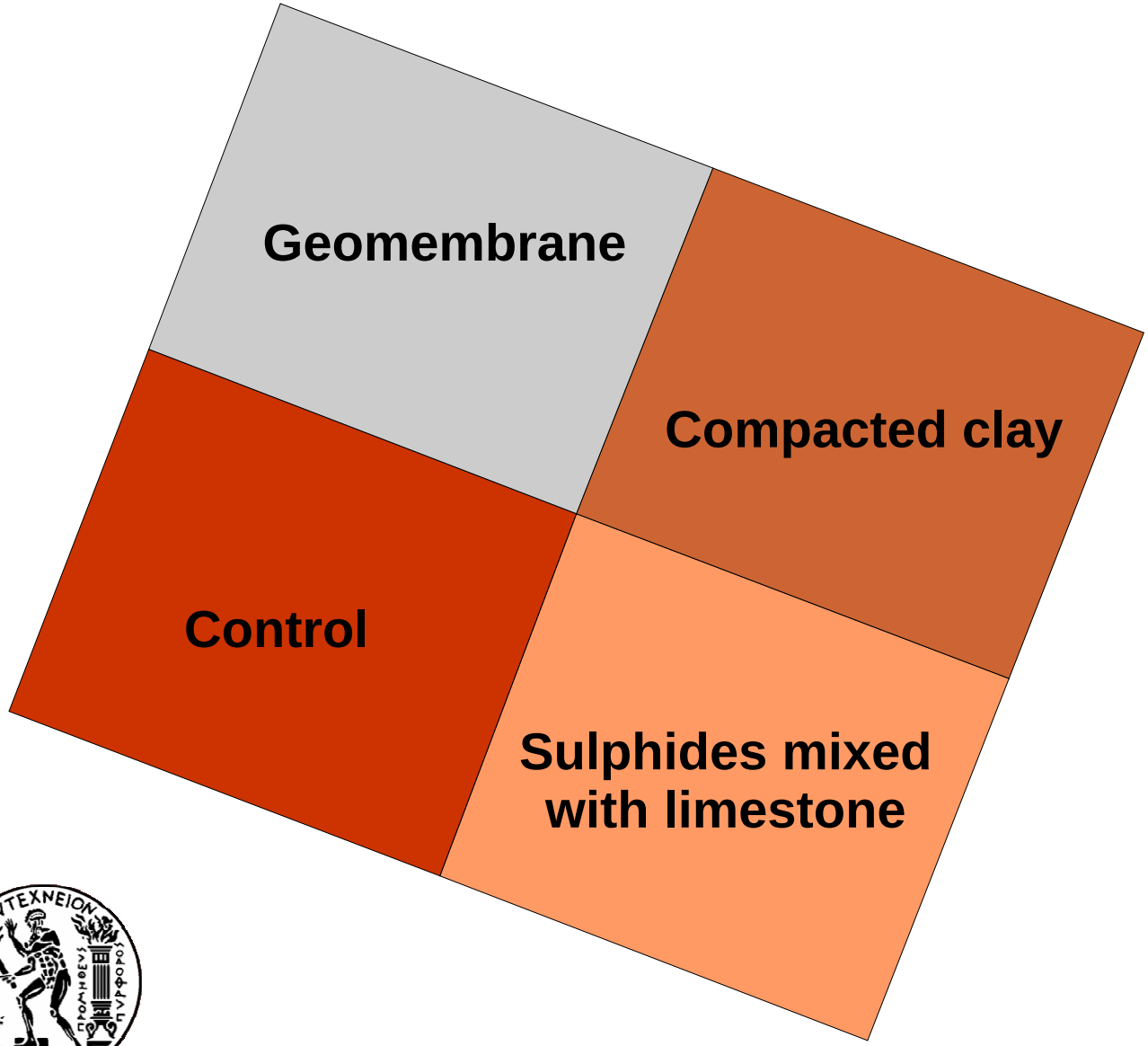


Pilot project areas

STABILISATION TECHNIQUES FOR OXIDIC TAILINGS AND SOILS



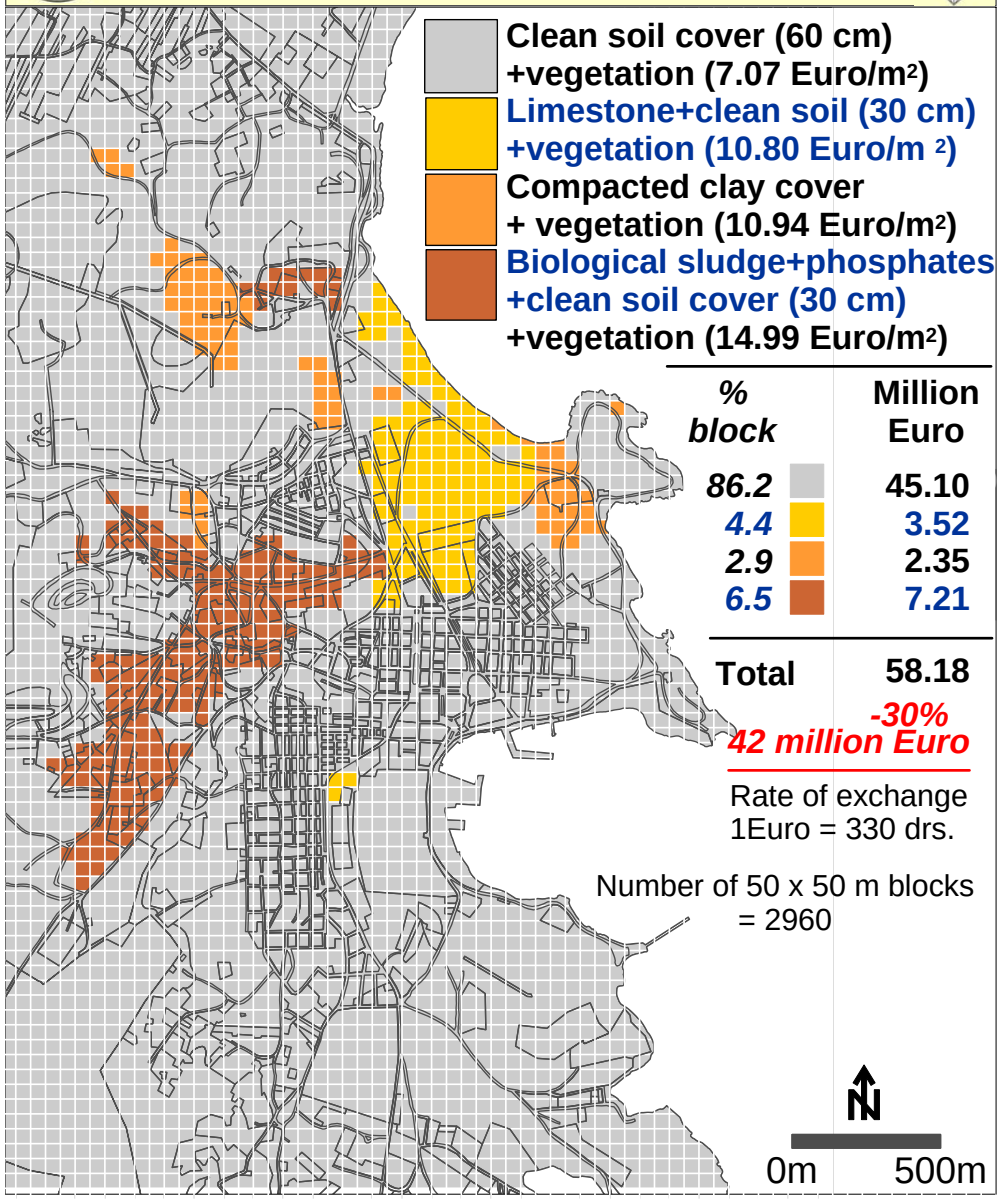
REHABILITATION TECHNIQUES FOR SULPHIDIC WASTES



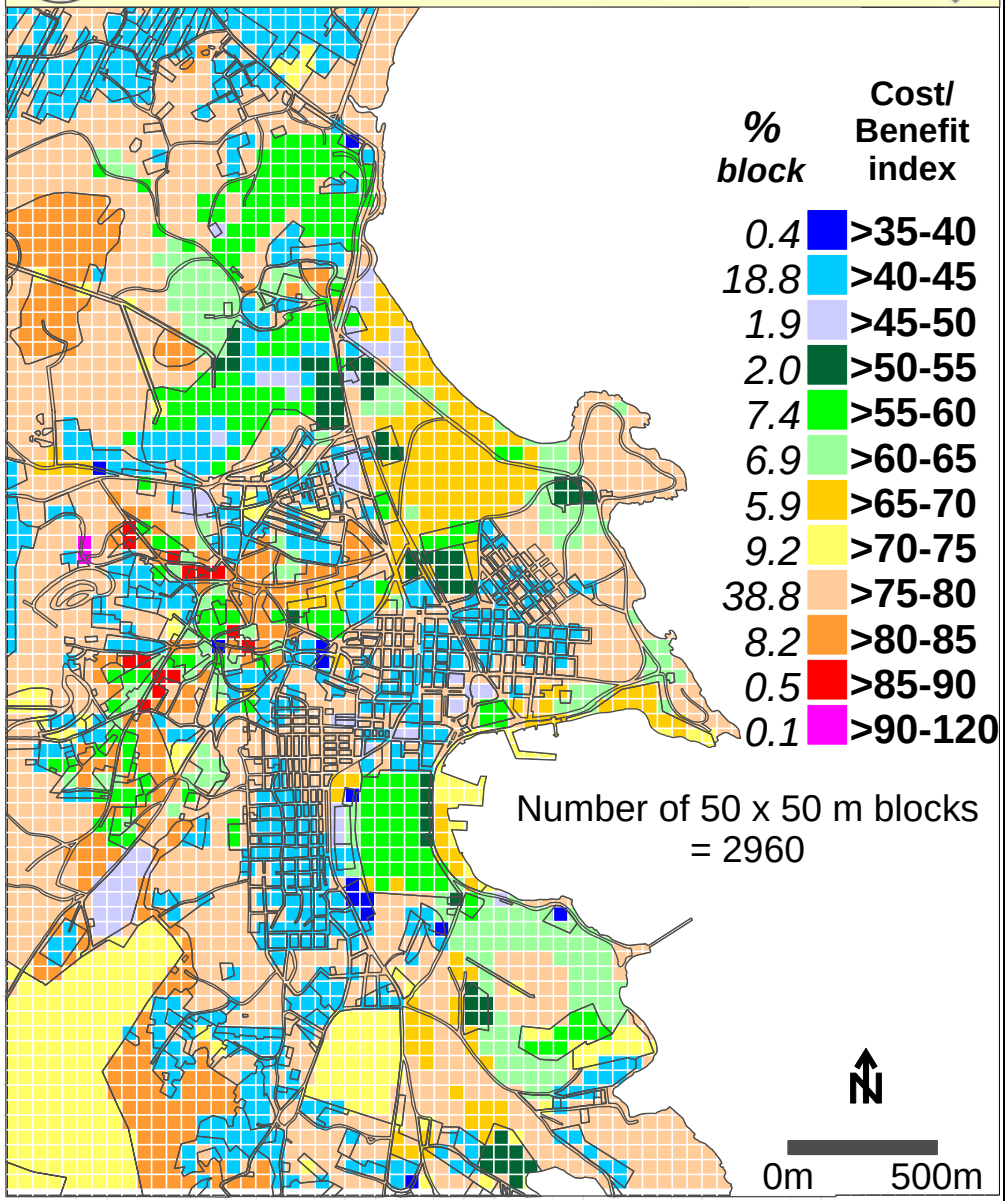

25 9'97


STEYR

Least cost technologies for the rehabilitation of overburden materials in the Lavrion urban area



Cost/Benefit index of the methods for the rehabilitation of the Lavrion urban area



Having as aim the quality of life of the inhabitants and especially children, the results of this study should be used for:

- taking protective measures (*short term aim*);
- the rational land use management (*medium term aim*), and
- improvement of living conditions (*long term aim, provided if this action is possible*).

Otherwise other solutions should be found, including the resettlement of all inhabitants.

All agricultural and animal rearing activities must stopped (*short term aim*)

The inhabitants must be informed immediately in order to change their way of life (*short term aim*)

Children must not play with beach sand and with soil (*short term aim*)

QUALITY OF LIFE

It is indeed reasonable to ask the question:

Can quality of life exist in such a highly contaminated environment?

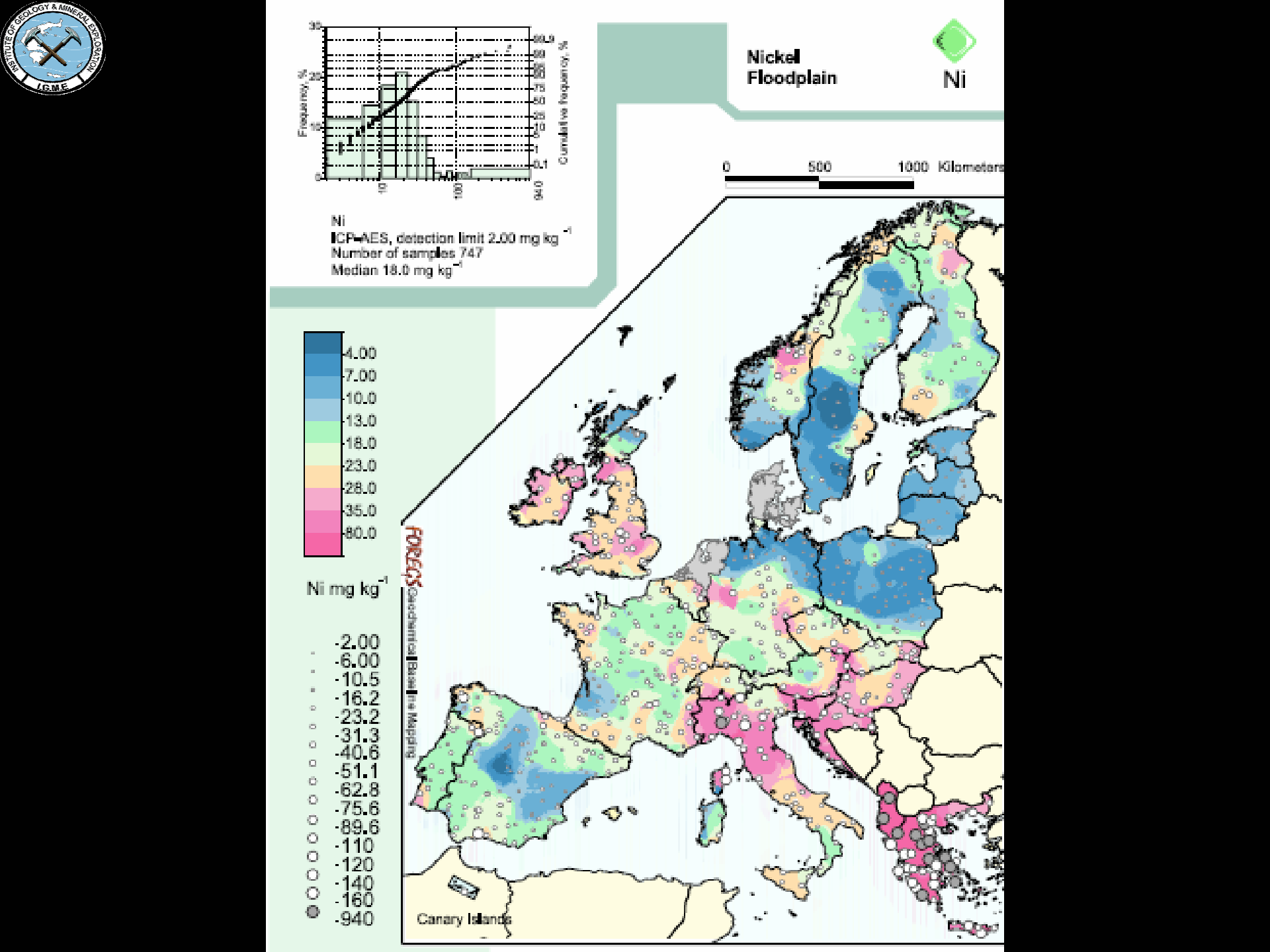
For geochemical baseline data in Europe lock in to: http://www.gtk.fi/publ/foregsatlas/

FOREGS

- Frontpage
- Articles
- Statistics
- Maps
- Compare Maps
- Photographs

A contribution to IUGS/IAGC Global Geochemical Baselines

EuroGeoSurveys


Nickel
Floodplain
Ni
0 500 1000 Kilometers
Frequency, %
Cumulative frequency, %
Ni
ICP-AES, detection limit 2.00 mg kg-1
Number of samples 747
Median 18.0 mg kg-1
4.00
7.00
10.0
13.0
18.0
23.0
28.0
35.0
80.0
Ni mg kg-1
-2.00
-6.00
-10.5
-16.2
-23.2
-31.3
-40.6
-51.1
-62.8
-75.6
-89.6
-110
-120
-140
-160
-940
FOREGS Geochemical Baseline Mapping
Canary Islands

Thank you for your attention

For more information contact:

Alecos Demetriades – E-mail: ademetriades@igme.gr

Nymfodora Papassiopi – E-mail: papasiop@metal.ntua.gr

Soil Rehabilitation in the Municipality of Lavrion"
Contract No.: 93/GR/A14/GR/4576:

Date of publication 1999

Demetriades, A. (Editor), **Volume 1** – Explanatory text: Geochemical Atlas of the Lavrion Urban Area for Environmental Protection and Planning. Institute of Geology and Mineral Exploration, Athens, Greece.

Demetriades, A. (Editor), **Volume 2:** Geochemical Atlas of the Lavrion Urban Area for Environmental Protection and Planning. Institute of Geology and Mineral Exploration, Athens, Greece.

Demetriades, A. (Editor), **Volume 1A** – Figures and Tables: Geochemical Atlas of the Lavrion Urban Area for Environmental Protection and Planning. Institute of Geology and Mineral Exploration, Athens, Greece.

Demetriades, A. (Editor), **Volume 1B** – Appendix reports: Geochemical Atlas of the Lavrion Urban Area for Environmental Protection and Planning. Institute of Geology and Mineral Exploration, Athens, Greece.

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