Phosphogypsum disposal in Greece

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EMRAS 2006

Greek Atomic Energy Commission

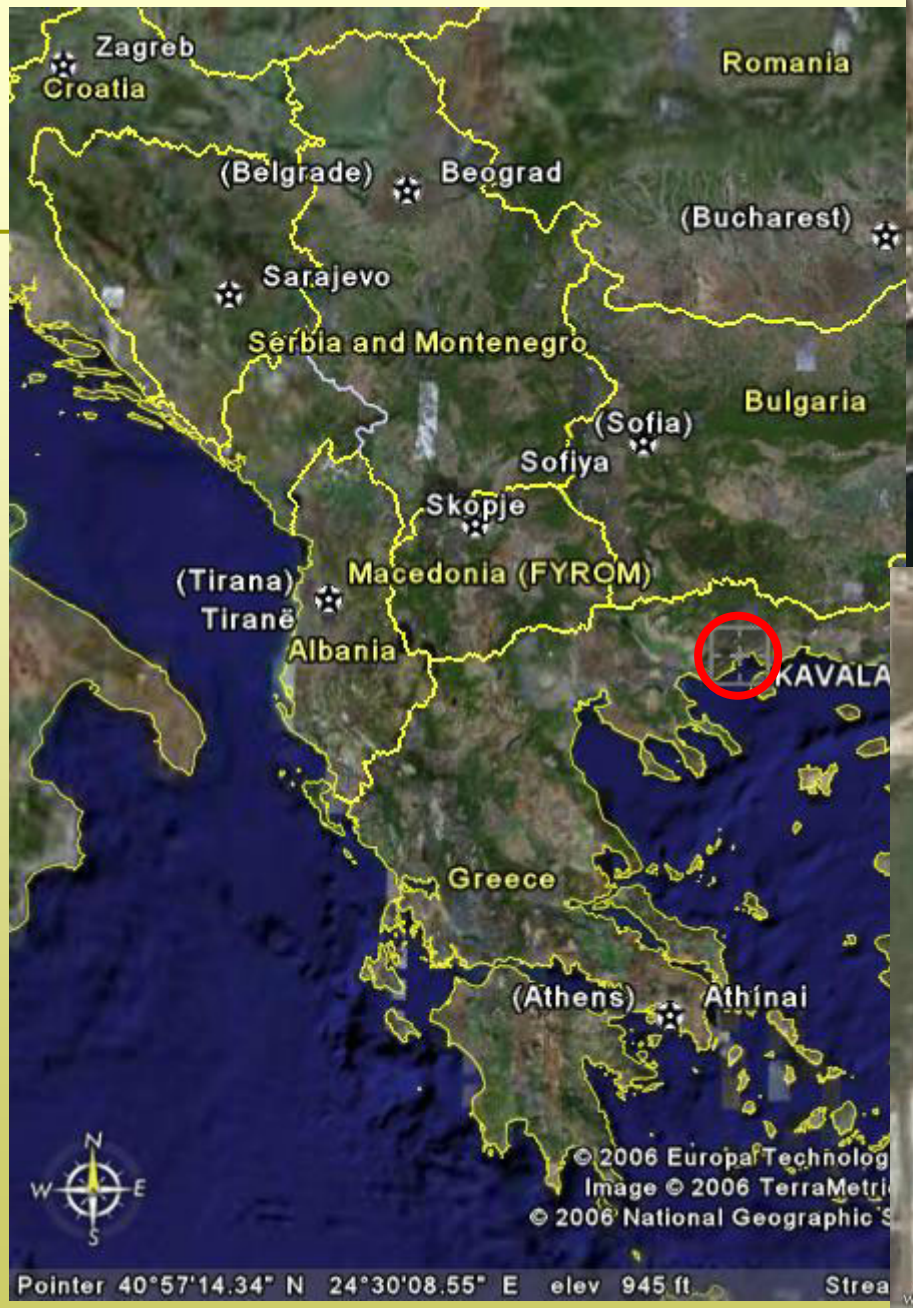
Existing situation

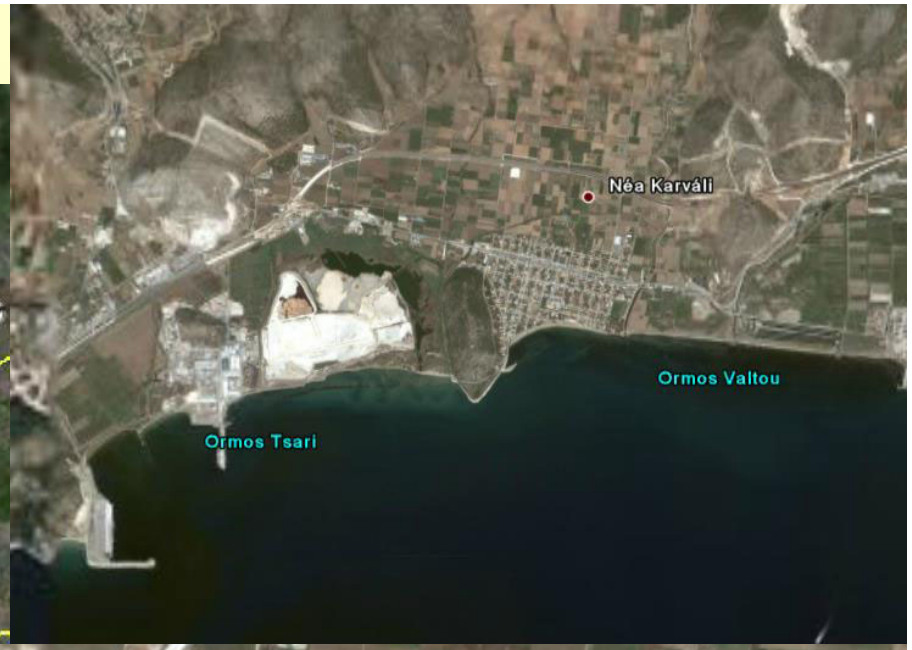
- **The fertilizer industry is in operation since 1965**
- **Location: north Greece, by the sea**
- **According to Greek legislation for waste disposal, each industry has to submit to the local authorities an environmental study that has to include:**

  detailed description of the geological and hydrological situation at the disposal site

  proposed measures to prevent pollution

- **GAEC has to give an expert opinion on the radioactivity issues**


Zagreb
Croatia
Romania
(Belgrade)
Beograd
(Bucharest)
Sarajevo
Serbia and Montenegro
Bulgaria
(Sofia)
Sofiya
Skopje
Macedonia (FYROM)
(Tirana)
Tiranë
Albania
KAVALA
Greece
(Athens)
Athínai
© 2006 Europa Technolog
Image © 2006 TerraMetri
© 2006 National Geographic
Pointer 40°57'14.34" N 24°30'08.55" E elev 945 ft
Strea


Néa Karváli
Ormos Valtou
Ormos Tsari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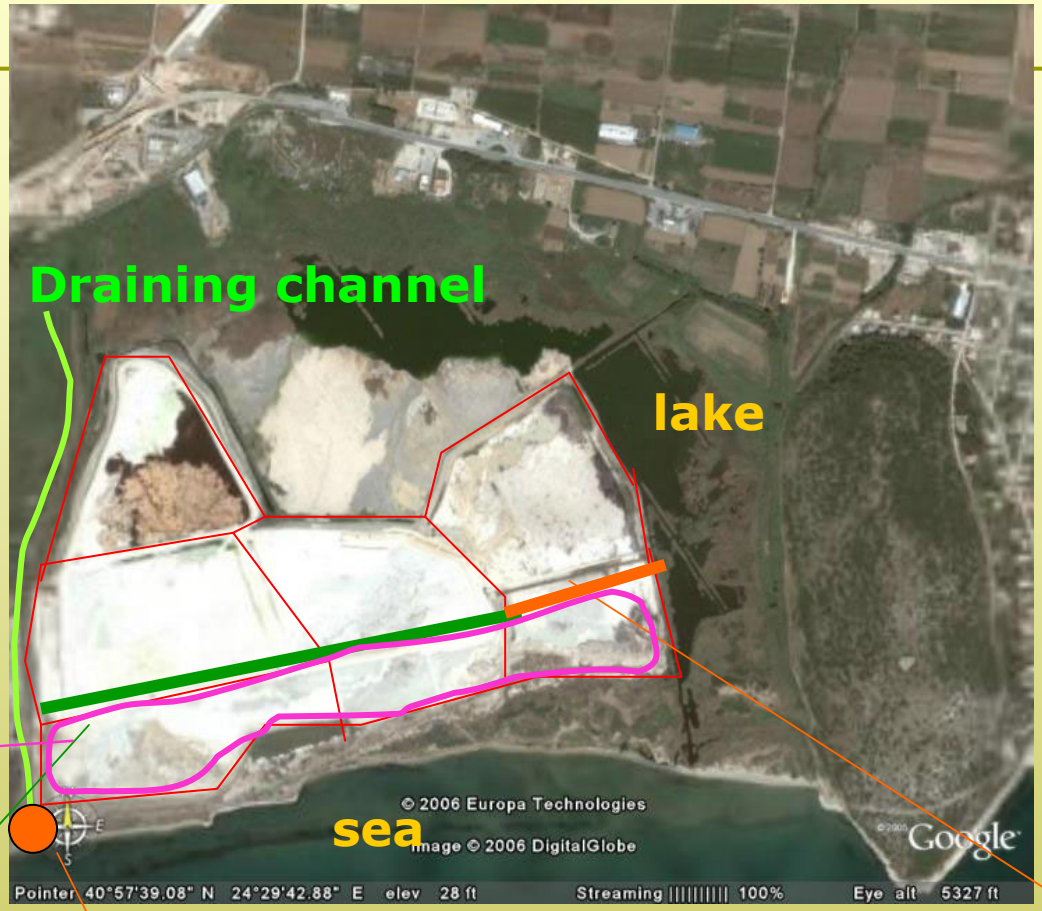
Google
Pointer 40°57'39.08" N 24°29'42.88" E elev 28 ft
Streaming 100%
Eye alt 5327 ft

- **145 m^3/h phosphogypsum (wet production) 30% b.w**
- **563240 m^3**

- **6 basins (height: 2 -12m)**
- **underground water: sea water, phosphogypsum water, underground fresh water**
- **Underground water flux: 20 -30 m^3/h**
- **phosphogypsum k_f: 2.85 10^{-8} m/s - 1.65 10^{-7} m/s (low or very low water permeability) --→ ideal $K_f < 1\ 10^{-9}$ m/s (waste management regulations)**
- **Total surface water runoff = 57.5 m^3/h**
- **underground water runoff: -25m^3/h**
- **rainfall= + 25.8 m^3/h**
- **Total water balance +/- 145.8 m^3/h**
- **underground water conductivity: 20 -25 mS/cm**

Existing situation

(563.240m²)



Inactive site

Pump for surface water

Clay dyke

Phosphogypsum dyke

Environmental data

North: clay layer at 3.5m from east – 5.5-6.0 m center, water: 0.8-2.4m → underground runoff of the pg drainage to N

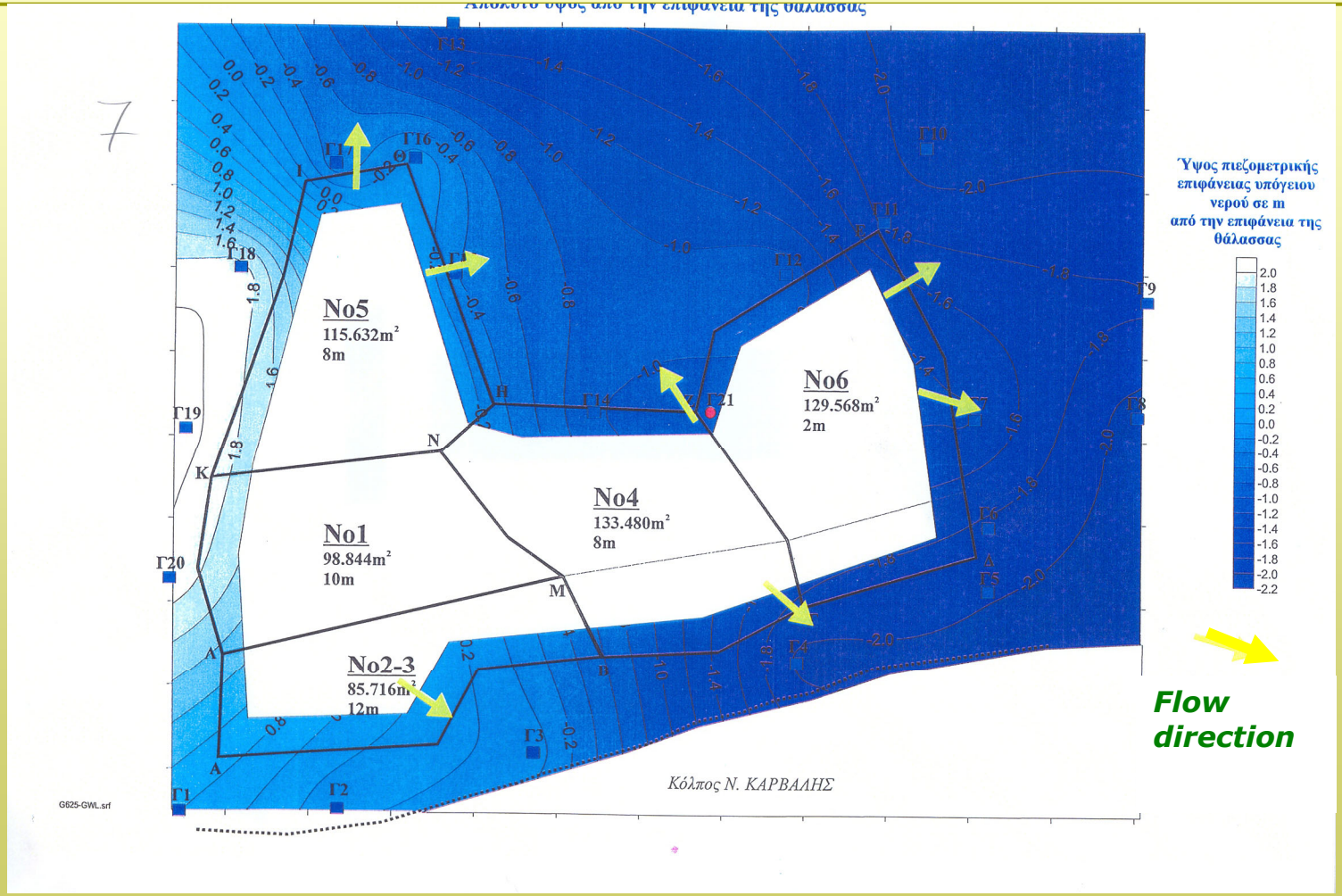
West: clay layer at 2, water: 0.8-2m (sub pressure)-→ no underground runoff

East: clay layer at 4.5m NE, water: 2.1-2.9m, lack of clay layer → underground runoff of the pg drainage to S

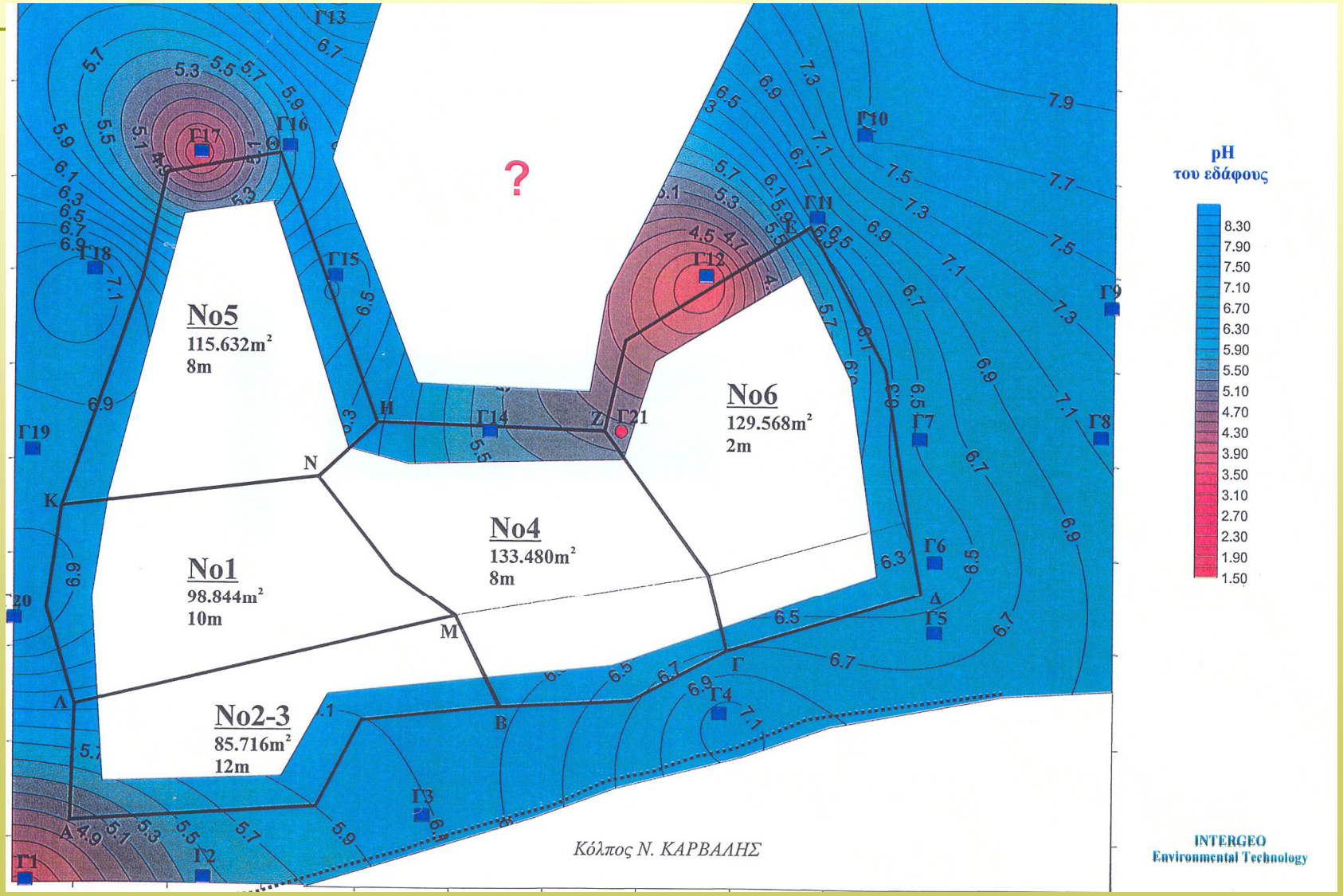
South: sand up to 7m, water: 2-5 m→ underground runoff of the pg drainage the sea

sand, gravel | phosphogypsum | sand, gravel, pg | clay | c, s, g | clay, mud | c,s

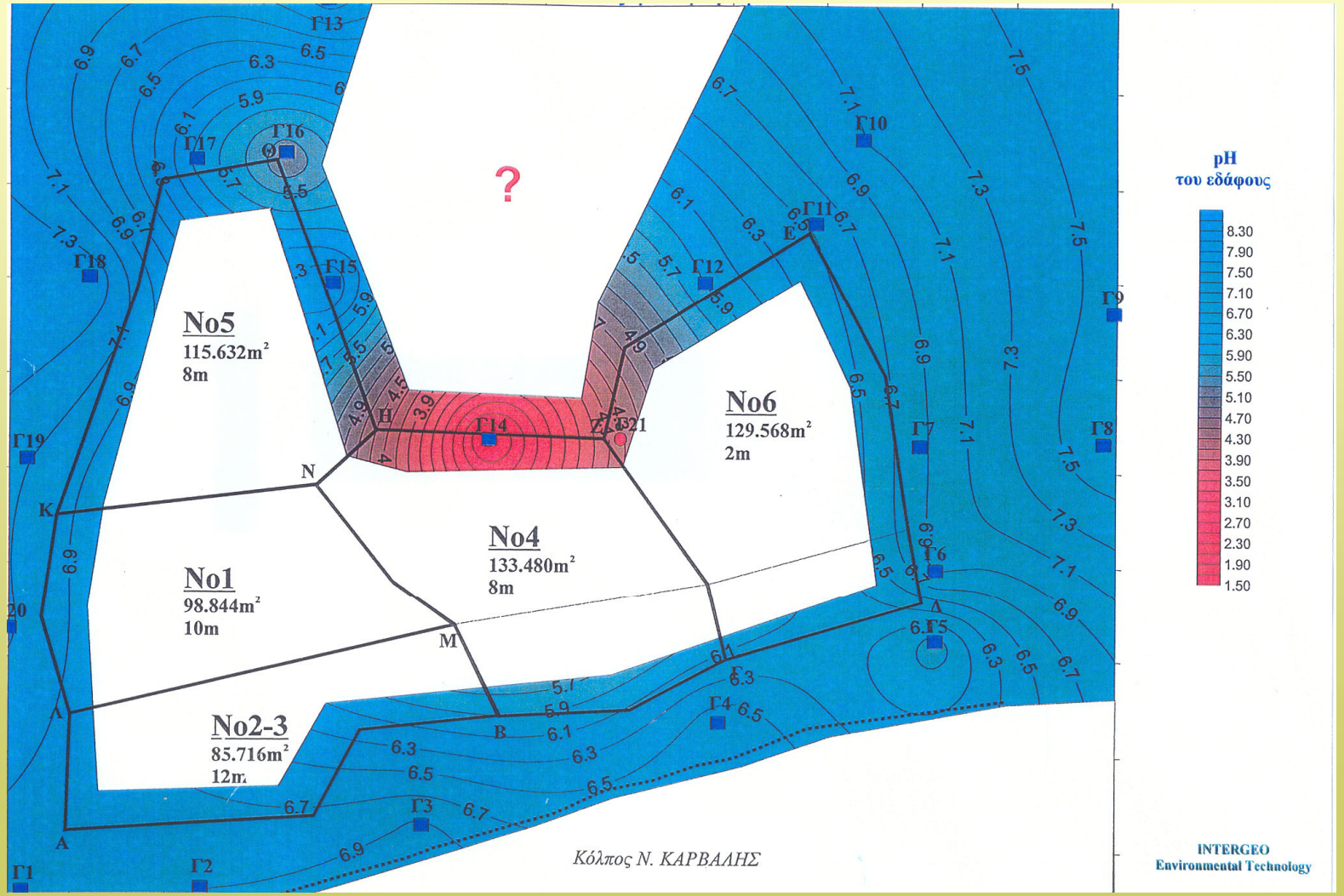
Distribution of piezoelectric level of the underground water



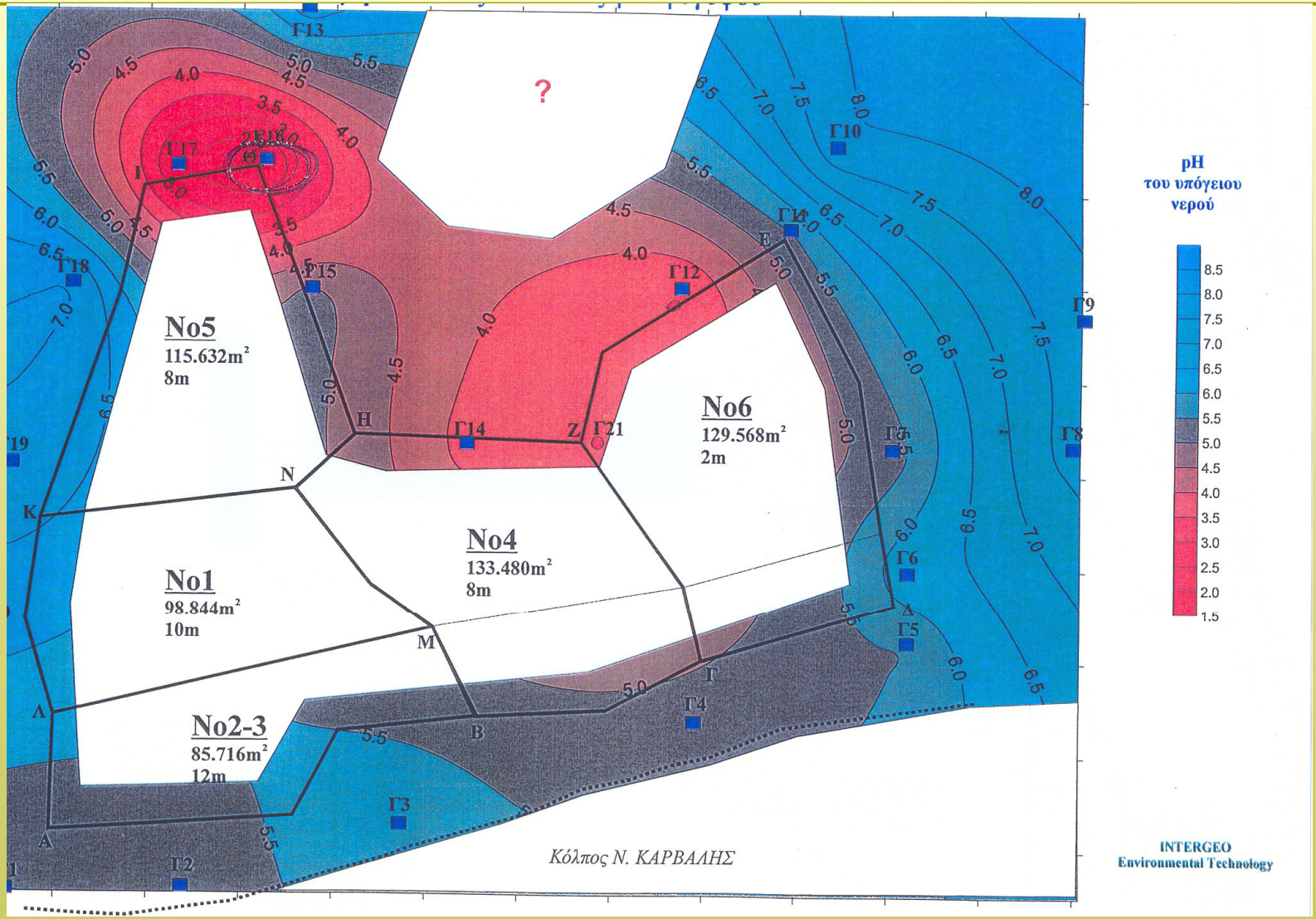
pH distribution for the unsaturated soil layer



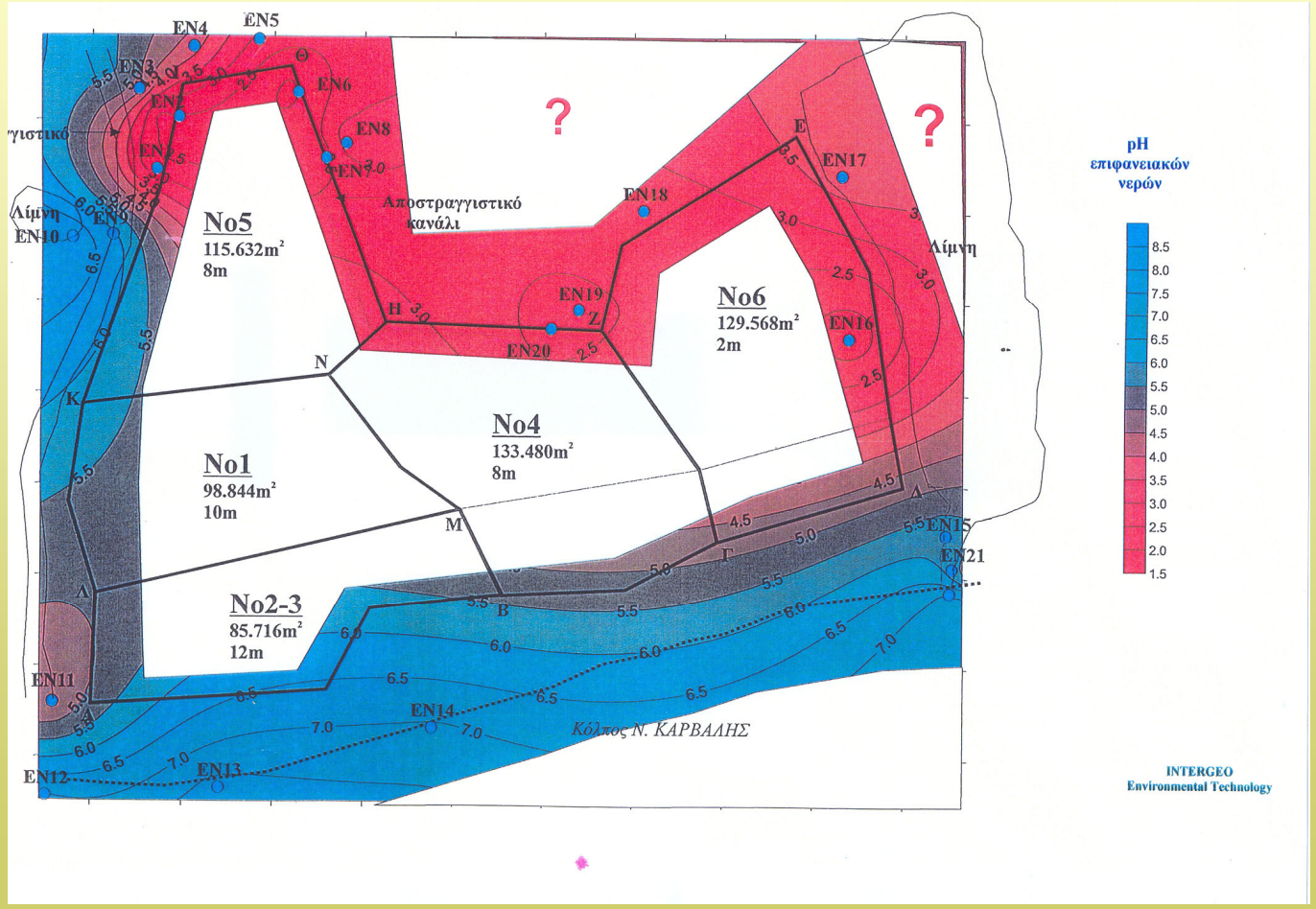
pH distribution for the saturated soil layer



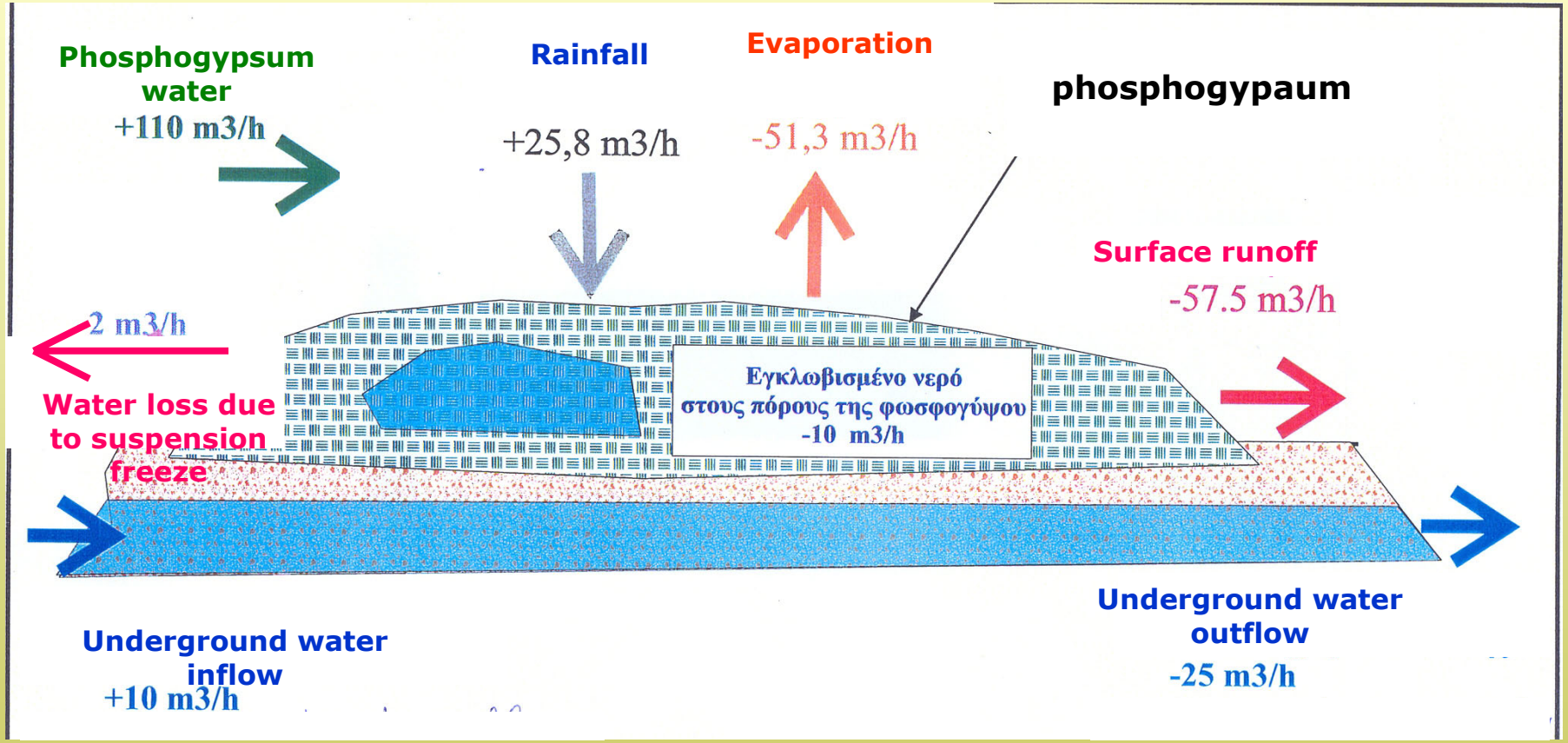
Underground water: pH distribution



Surface water: pH distribution



Water balance



Conclusions

- The underground water pH is significantly low (min= 1.93), specially at the north.
- The low pH values are correlated with increased SO_4 & P_2O_5 concentrations.
- The underground water pollution is mainly due to underground phosphogypsum drainage water runoffs (10-20 m^3/h), mainly at north, east and south:
    - lower to the east
    - the clay layer presents a significant incline to E-NE
    - at the N, E & S site existence of water permeable layers at the underground water level.

Proposed measures

- Construction of new perimetric drainage channels with maximum depth of 2m. The water will be collected and guided with a special pump at the existing draining channel and then back to the phosphoric production unit.
- The proposed system satisfactory solves the surface water drainage problem, but it does not take into account the underground water runoff (<2m)
- The underground clay layer is not consistent. Moreover, it has a grade and it some areas it disappears, so the vertical discharge is favored
- At the south site (sea), phospogypsum is no longer disposed, but measures must be taken in order to avoid sea pollution due to underground water runoff (according to the geological characterization, there is a water permeable sand layer at the south).
- At the west site, the existing channel, the very low permeable layer (clay), the non- existence of a leakage point (based on piezoelectric measurements) and the direction (west to east) of the underground water flow, prevent the surface and underground runoff.

• The main problem is the underground runoffs specially at the north and east site.

Proposed solutions:

1. Construction of a deep channel down to clay layer
2. injection of special insulating material
3. Hydraulic retention of underground drainage

Option	Difficulties	Efficiency	Installation Cost	Maintenance	Operation cost
1	Very big	Moderate	Big	Minor	Moderate
2	Big	Moderate	Very big	Moderate	Low
3	Minimum	moderate	Moderate-low	moderate	moderate

Proposed measures

Inactive site

Phosphogypsum dyke

Proposed draining channel

Pump for surface water

Proposed well

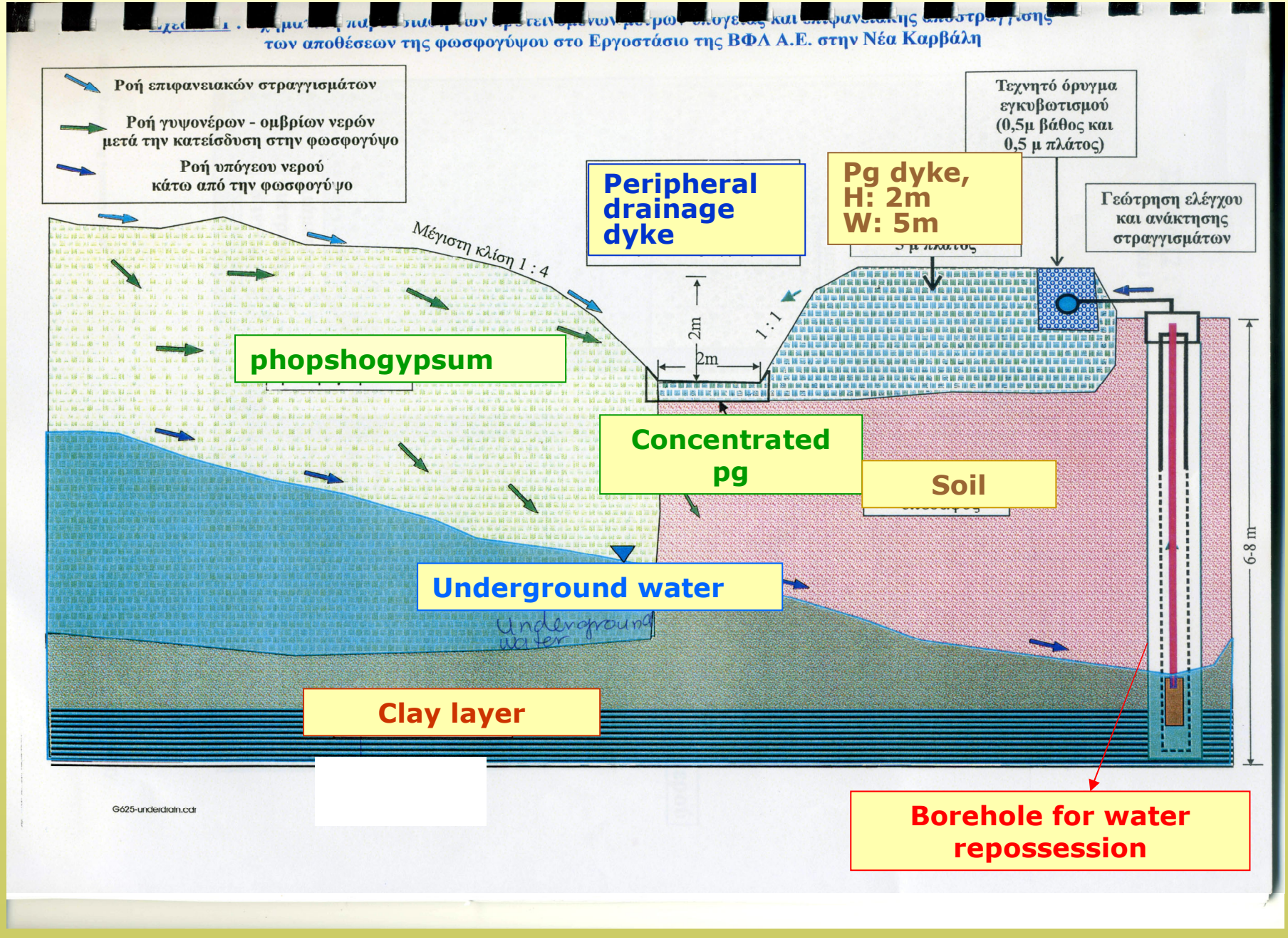
Clay dyke

Transport channels for underground draining water

Direction of surface water flow at the transport channel

Borehole for water repossession

Proposed system



QUESTION to GAEC:

Are the proposed measures suitable also for the radionuclides?

Measurements performed:

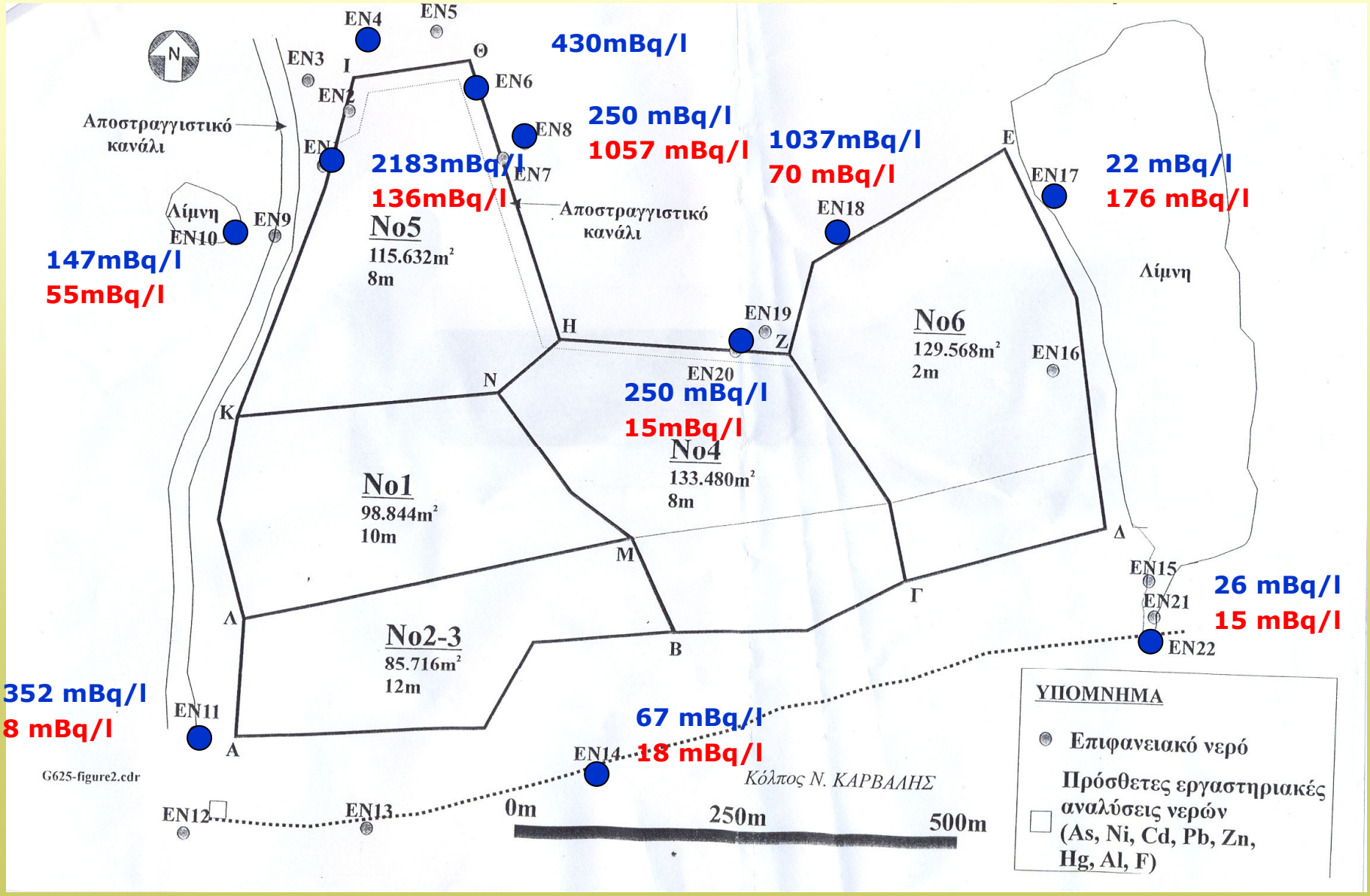
- phosphogypsum (gamma spectroscopy)
- underground and surface water (U-238 & Ra-226 with a-spectroscopy)
- leaching experiments

Phosphogypsum samples

Bq/kg	Ra-226	U-238	Pb-210	Th-228	K-40
Min – max	118 –598	12 –84	111 – 485	3 –58	4 – 730
Mean	381	38	321	14	155
sd	134	18	112	13	282

U-238, Ra-226

Surface water



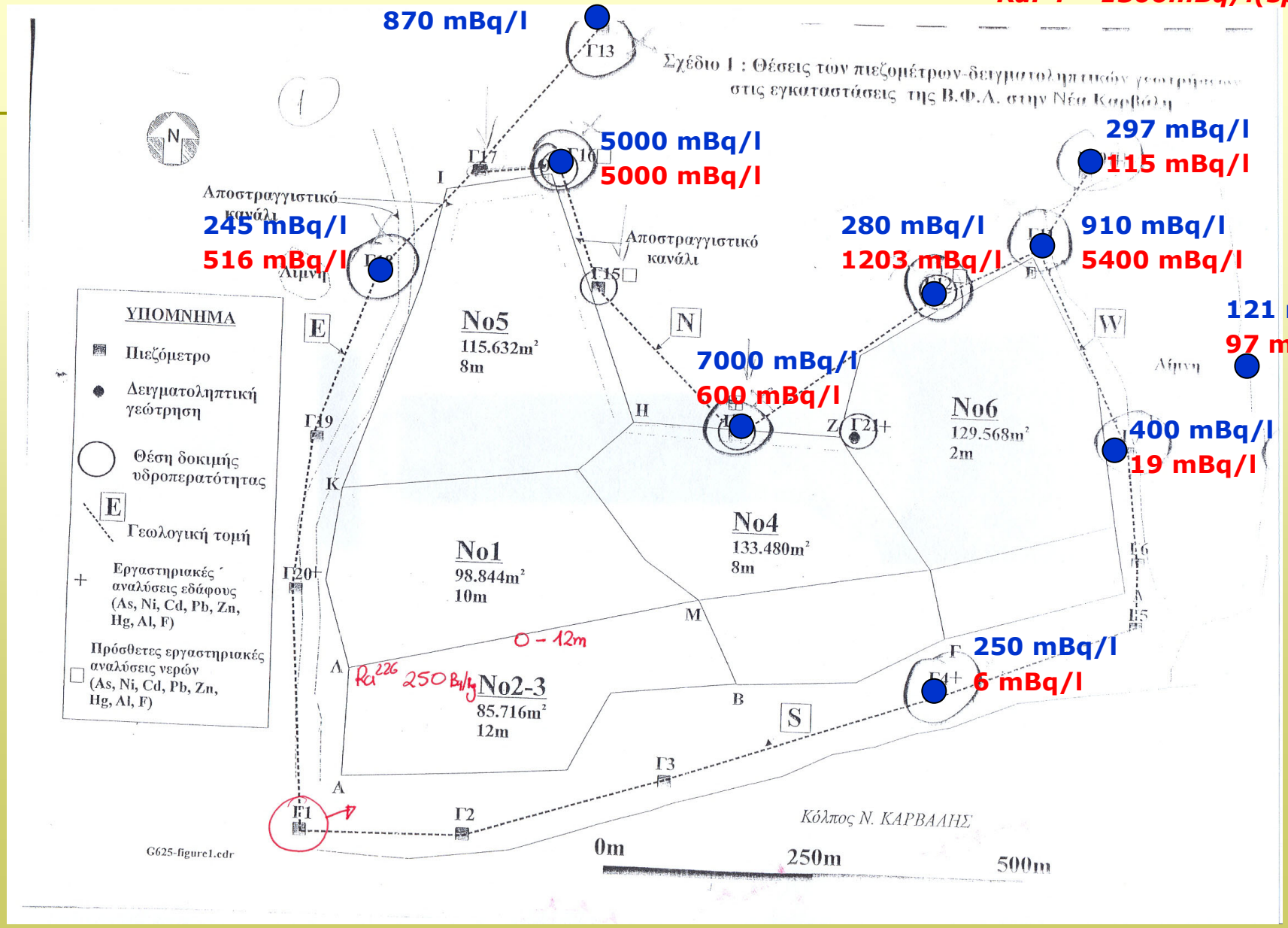
U-238, Ra-226

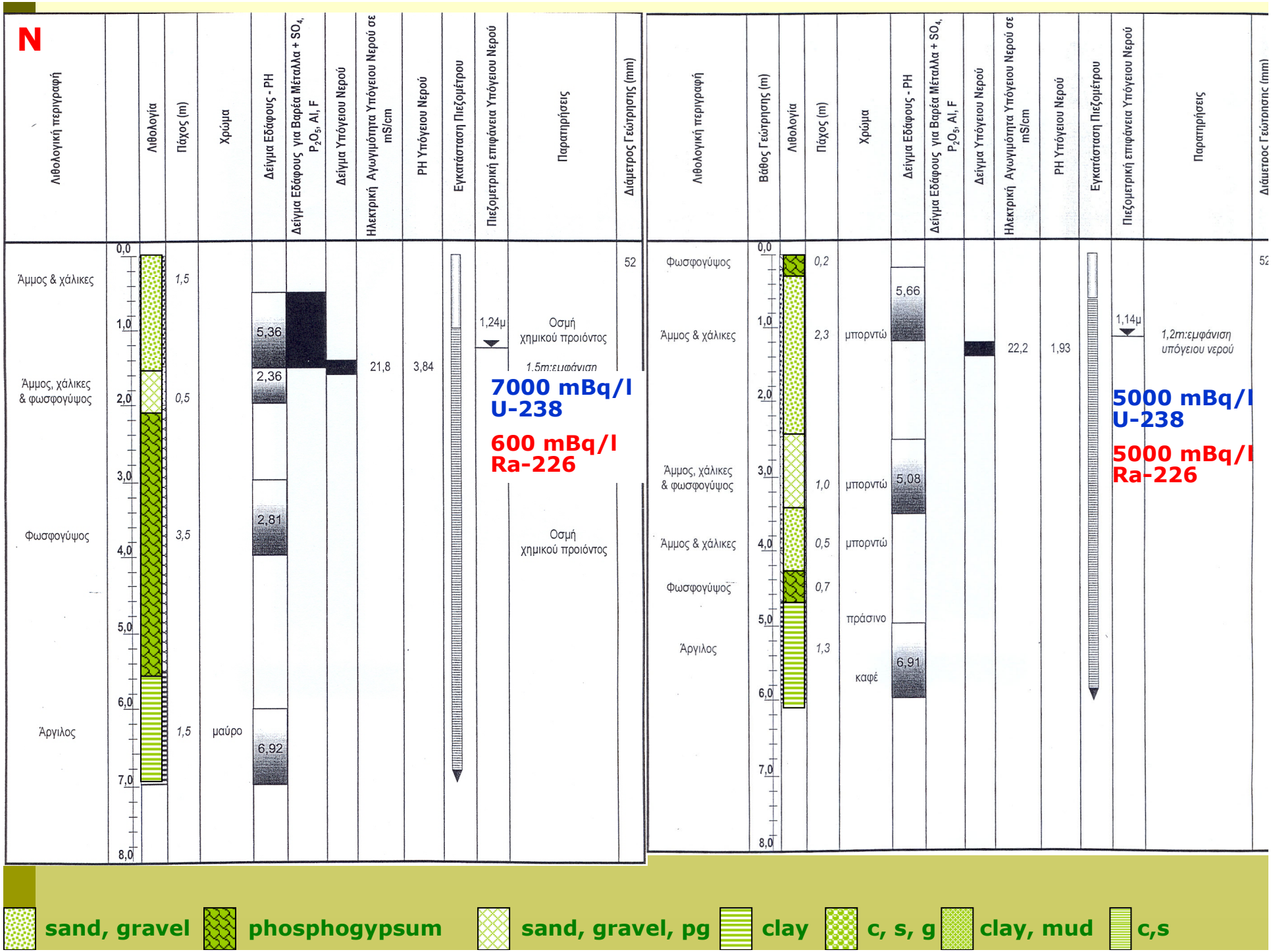
Underground water

Typical values:

U: 3 – 65mBq/l

Ra: 4 – 1500mBq/l(spas)




N
Λιθολογική περιγραφή
Λιθολογία
Πάχος (m)
Χρώμα
Δείγμα Εδάφους - PH
Δείγμα Εδάφους για Βαρέα Μέταλλα + SO4, P2O5, Al, F
Δείγμα Υπόγειου Νερού
Ηλεκτρική Αγωγιμότητα Υπόγειου Νερού σε mS/cm
PH Υπόγειου Νερού
Εγκατάσταση Πιεζομέτρου
Πιεζομετρική επιφάνεια Υπόγειου Νερού
Παρατηρήσεις
Διάμετρος Γεώτρησης (mm)
Άμμος & χάλικες
Άμμος, χάλικες & φωσφογύψος
Φωσφογύψος
Άργιλος
1,5
0,5
3,5
1,5
μαύρο
5,36
2,36
2,81
6,92
21,8
3,84
1,24μ
Οσμή χημικού προιόντος
1.5m:εμφάνιση
7000 mBq/l U-238
600 mBq/l Ra-226
52
Βάθος Γεώτρησης (m)
Φωσφογύψος
Άμμος & χάλικες
Άμμος, χάλικες & φωσφογύψος
Άμμος & χάλικες
Φωσφογύψος
Άργιλος
0,2
2,3
1,0
0,5
0,7
1,3
μπορντώ
μπορντώ
μπορντώ
πράσινο
καφέ
5,66
5,08
6,91
22,2
1,93
1,14μ
1,2m:εμφάνιση υπόγειου νερού
5000 mBq/l U-238
5000 mBq/l Ra-226
sand, gravel
phosphogypsum
sand, gravel, pg
clay
c, s, g
clay, mud
c,s