EMRAS I (NORM) SUMMARY

(Detailed information is in the main EMRAS I NORM working group report)

Outline

- Previous programs
- Aims of EMRAS
- Review of NORM situation
  - Characteristics of NORM
  - NORM industries
  - Models
  - Datasets
- Hypothetical scenarios
- Real scenarios

Previous Programs

- BIOMOVS, BIOMOVS II, BIOMASS, VAMP
- Nearly all triggered by Chernobyl and the need for international cooperation and harmonization
- Concentrated on anthropogenic radionuclides, particularly those associated with the nuclear fuel cycle

Aims of EMRAS

- To develop, verify and validate models for simulating the transfer of radionuclides in the environment
- To establish scenarios for testing and intercomparison of models
- To collect, evaluate and update data on transfer parameters for use in environmental models, particularly for tropical, desert and arctic environments

Characteristics and relevance of NORM

- Products, wastes and residues that contain radionuclides that occur in the natural environment are collectively known as NORM
- Radionuclides include the members of the primordial decay chains from ^{238}U, ^{235}U and ^{232}Th, plus long-lived individual radionuclides such as ^{40}K, ^{87}Rb and ^{115}In
- NORM is ubiquitous
- After medical exposures, the presence of NORM in the environment delivers the largest dose to the population

General features that distinguish NORM from anthropogenic radionuclides

- Large number of radionuclides in decay chains: therefore a wide range in chemical properties, particularly solubility
- Extremely wide range of radioactive half-lives
- A range of physical forms
- Frequently have very large volumes of material
- (Re)-use of residues in landfill, roadfill, building materials, etc
  - Projected land use
- Regulatory issues – shift in emphasis from limitation to optimisation and acceptable risk

Summary of occurrence of NORM in industry

Industry	Environment	Products	Form of Wastes or Residues	NORM wastes or residues
Mining and milling	Everywhere	Mineral	Liquids and solids	Tailings, process water
Mineral processing	Everywhere	Metal	Scales, sludges, volatiles	Residues, tailings
Phosphate	Everywhere	Fertiliser, phosphoric acid	Liquids and solids	Phosphogypsum, scales
Power generation (fossil fuels)	Everywhere	Electricity	Solids and gases	Ash, mine water
Oil & gas production	Marine & on-shore	Oil, gas	Liquids and solids	Scales, sludges, process water
Water treatment	Everywhere	Potable water	Liquids and solids	Sludges, bio-solids

In the Beginning……..

- No consistent approach to modelling requirements
- No ‘standard’ approach on guidance documentation and verification and validation reporting
- Very few models available
- Very few comprehensive, validated data sets available

Modelling issues

- Potential exposure pathways to NORM can be influenced by
  - solubility
  - physical form
  - volatility
  - environmental factors (soil and rock types, rainfall,…)
- In ideal conditions secular equilibrium exists, but in many environmental situations the decay-chain sequence is interrupted and introduces dis-equilibrium

Causes of dis-equilibrium

- Differences in solubility or volatility of different radionuclides, followed by:
  - Atmospheric dispersion (hours to days)
  - Surface water transport (hours to weeks)
  - Groundwater transport (many years)

Dis-equilibrium can be important when assessing the potential impact of NORM on the environment and human health

Other issues with NORM

- Until recently, there was little awareness of NORM being a potential environmental and human health issue
  - No regulation of practices and/or
  - No radiological assessment performed/required

- Major implications
  - Many countries have problems relating to legacy wastes particularly from mining and mineral processing
  - For many legacy sites, the currently available data (if any) do not provide a good basis for modelling studies
  - Monitoring of the sites was not required in the past - therefore no historical data available

Types of models and criteria for use

TYPES

1. Screening
2. Compliance
3. Detailed assessment

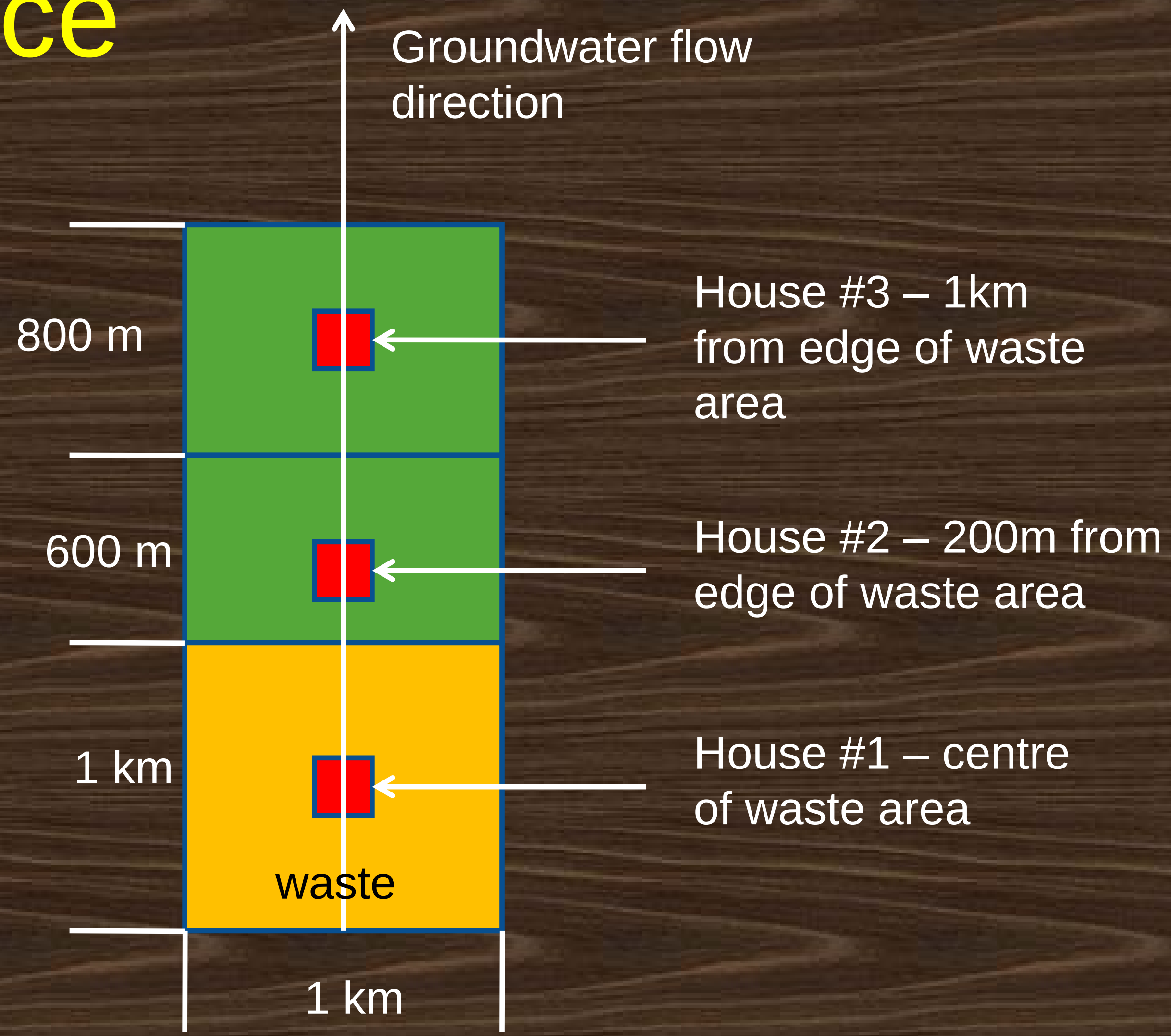
CRITERIA FOR USE

1. Easy to use
2. Readily available
3. Well documented
4. Supported
5. Tested – verified and validated

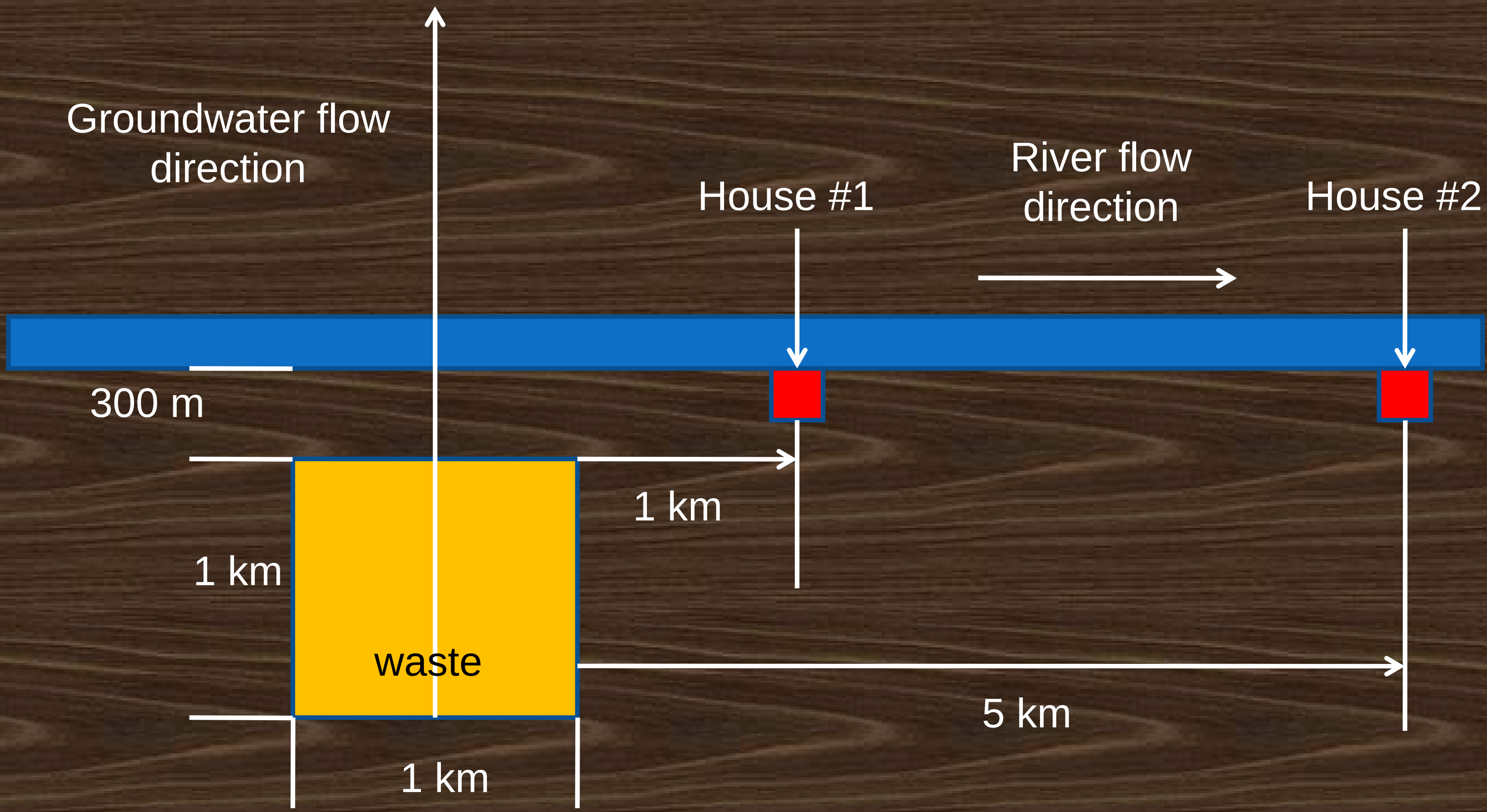
Hypothetical scenarios

- Because there are/were very few models and very few comprehensive, validated data sets available, it was decided to begin by developing some hypothetical ‘standard’ scenarios that would assist in model intercomparison and development
- Three scenarios were set up
  - Point source
  - Area source
  - Area source + river
- These scenarios were characterised by simple geometry, uniform source terms and discharge rates, constant rainfall, etc.

Area source


Groundwater flow
direction
800 m
600 m
1 km
waste
1 km
House #3 – 1km
from edge of waste
area
House #2 – 200m from
edge of waste area
House #1 – centre
of waste area

Area source + river



Models used

Scenario	Detailed Model	Screening Model
Point source	PC-CREAM	CROM COMPLY
Area source	RESRAD-OFFSITE DOSDIM (+ HYDRUS) AMBER	PRESTO
Area source plus river	RESRAD-OFFSITE (AMBER)	

Summary

- 3 hypothetical scenarios
  - Point source (2 models, 3 modellers)
  - Area source (2 models, 6 modellers)
  - Area source + river (1 model, 2 modellers)
- 4 real scenarios
  - Lignite power plant – multiple point source (1 model, 1 modeller)
  - Phosphogypsum stack – wet – area source (no modelling)
  - Phosphogypsum stack – dry – area source (no modelling)
  - Gas mantle plant – highly heterogeneous – screening model (no modelling by WG)

Real scenarios

- Lignite power plant complex – several power stations – city to south east - modelled
- Camden – urban area – abandoned thorium processing plant and gas mantle fabrication plant – modelled (screening) before EMRAS
- Phosphogypsum #1 – disposal in "tailings dam" type structure – not modelled
- Phosphogypsum #2 – disposal in "dry" stack – retaining wall – leachate re-circulated – not modelled

Lignite power plant scenario

- Several discharge points
  - data on surface ^{226}Ra concentration;
  - data on ^{226}Ra in airborne dust;
  - limited meteorological data

- Models used
  - PC-CREAM (detailed), COMPLY, CROM (screening)

- PC-CREAM calculations give quite good agreement with measured radionuclide concentrations

Camden

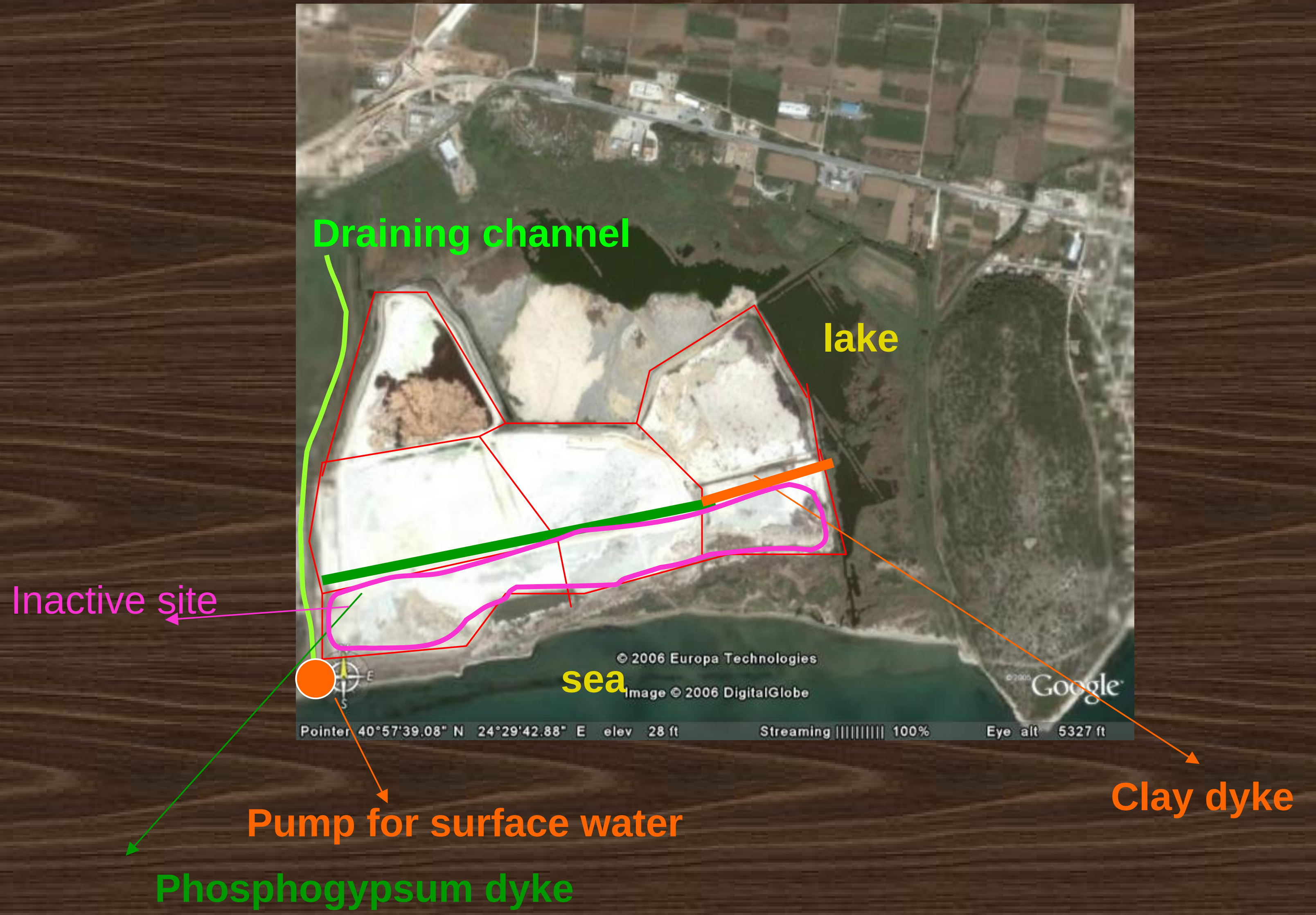
- Legacy site
  - thorium processing plant
  - thorium gas mantle fabrication plant
  - one large waste area and many small scattered pockets of waste
  - many houses built over small pockets of waste after the plants ceased operation
- Screening approach most appropriate (FRAMES package) – detailed study already conducted
- Some remedial work carried out

Phosphogypsum scenarios #1 and #2

- Scenario #1
  - lake - complex geometry and groundwater flow – data available on pH and radionuclide concentrations in groundwater
  - Preliminary modelling carried out with the AMBER package
- Scenario #2
  - stack – complex geometry
  - retaining wall to inhibit leaching
  - recirculation of leachate wells from down-gradient side

Existing situation

(563.240m²)



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

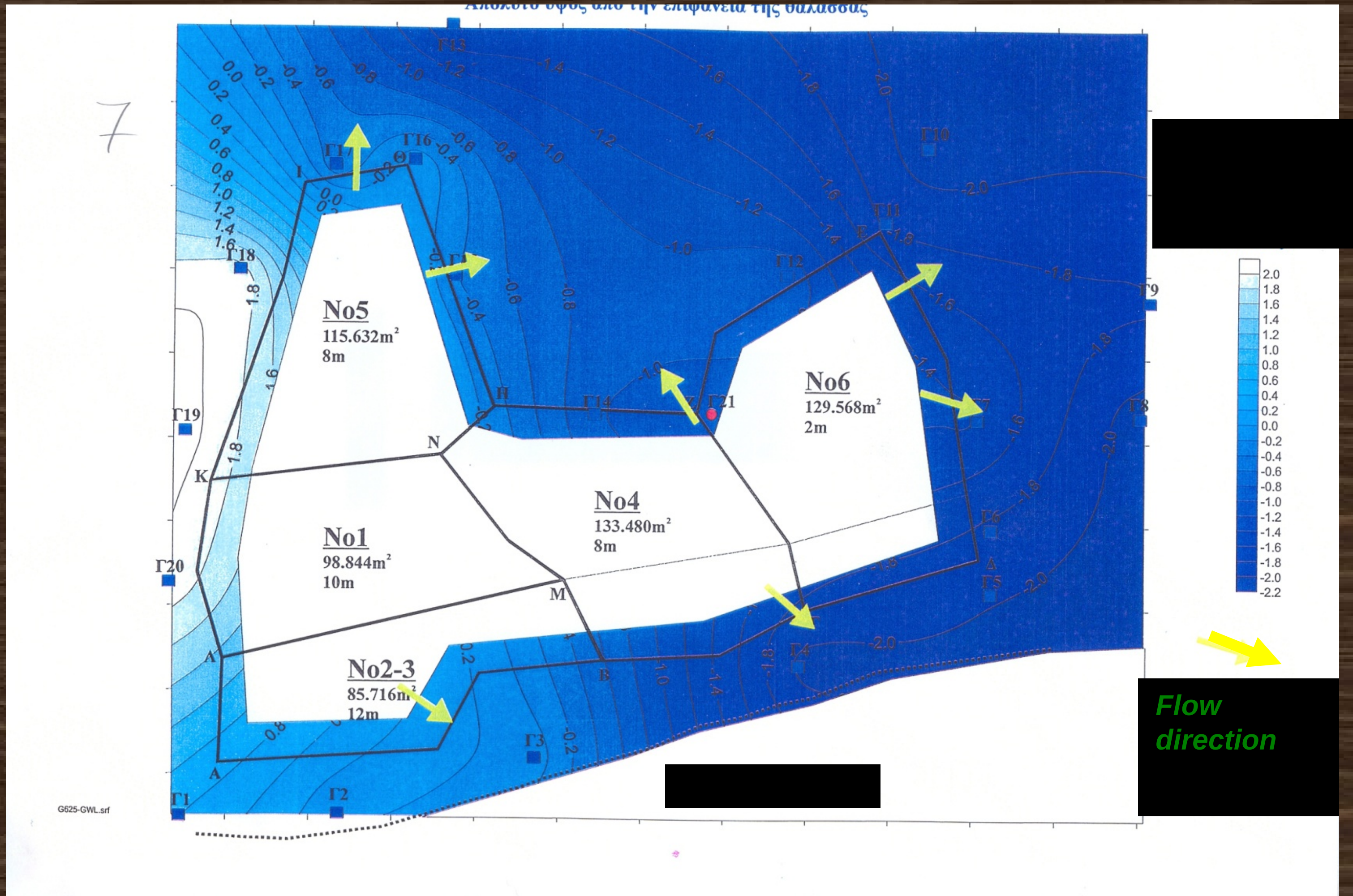
sand, gravel | phosphogypsum | sand, gravel, pg | clay | c, s, g | y, mud | ,s

Available data

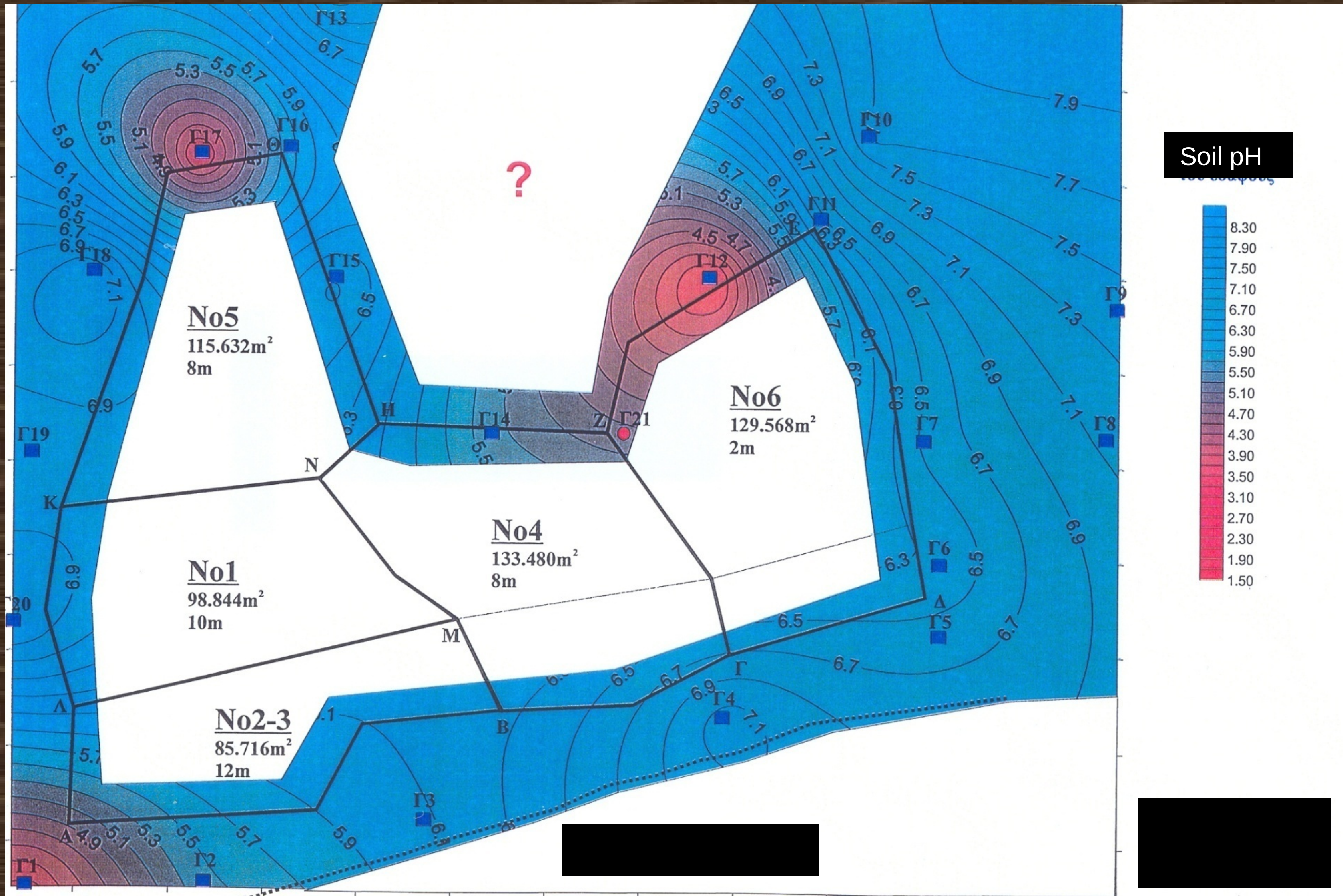
- Stratigraphic data
- Piezoelectric levels in groundwater
- pH levels for the unsaturated soil layer
- pH levels for the saturated soil layer
- pH levels in groundwater
- pH levels in surface water
- Water budget
  - Rainfall
  - Evaporation
  - Runoff

- More details in main report

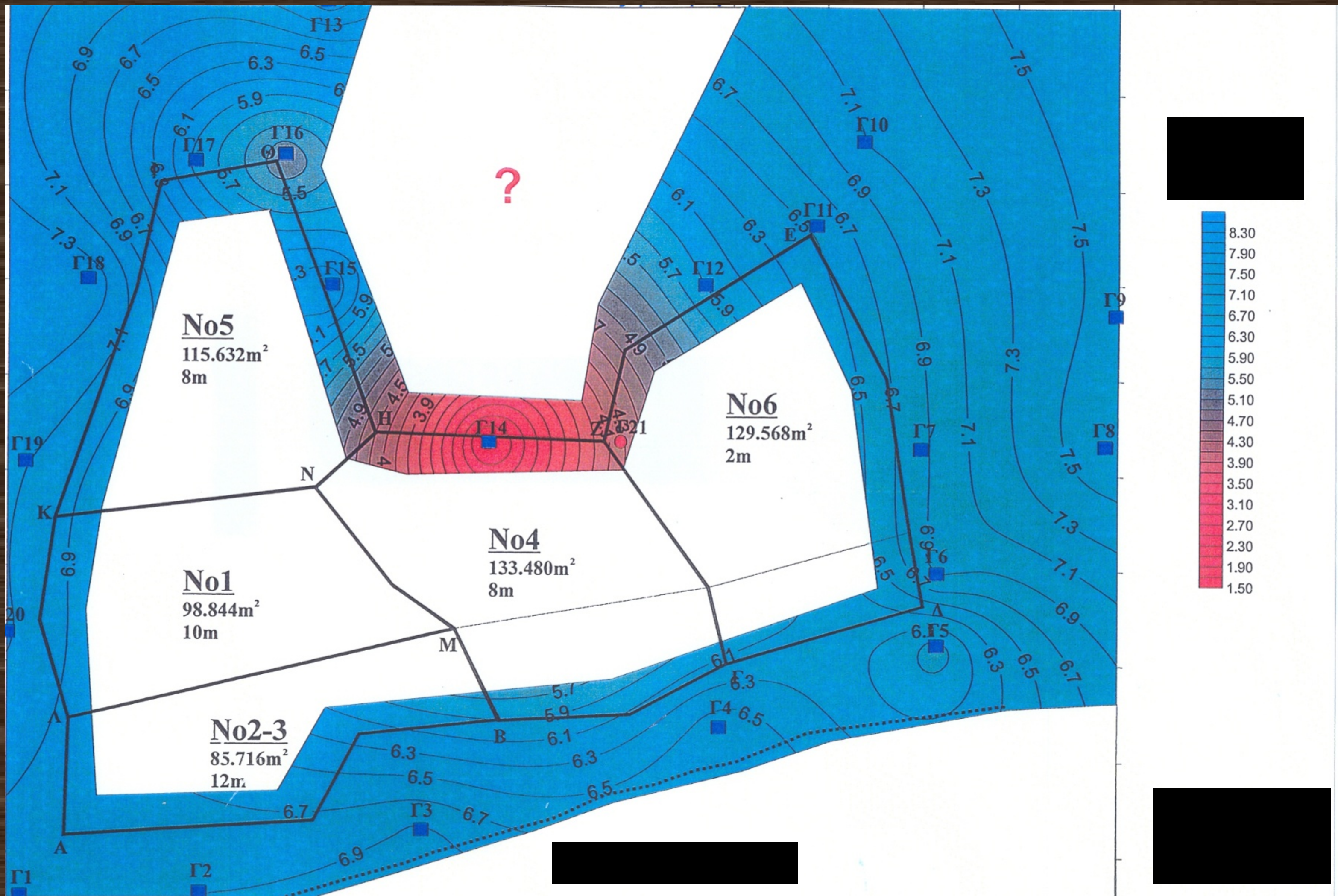
Distribution of piezoelectric level of the underground water



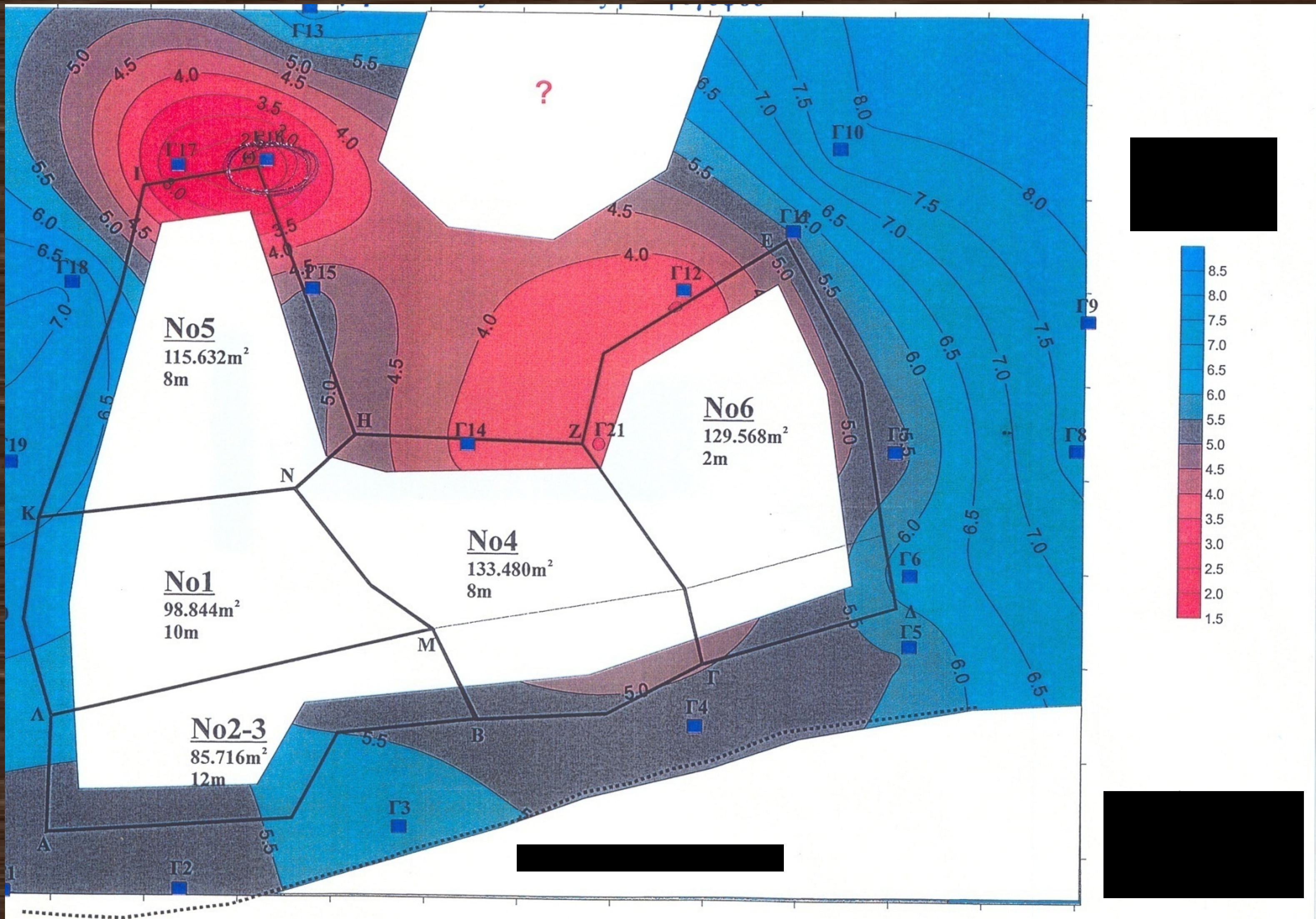
pH distribution for the unsaturated soil layer



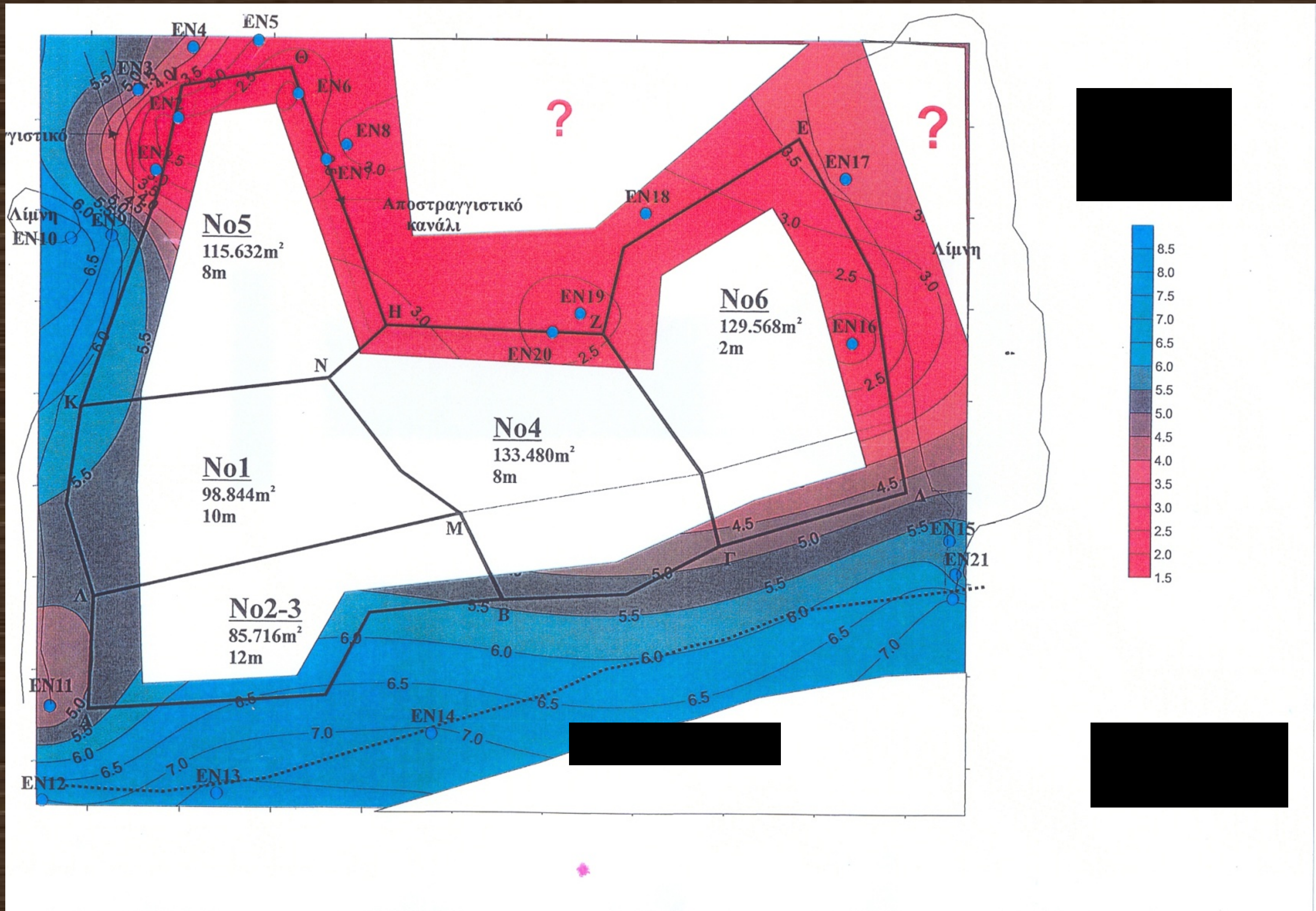
pH distribution for the saturated soil layer



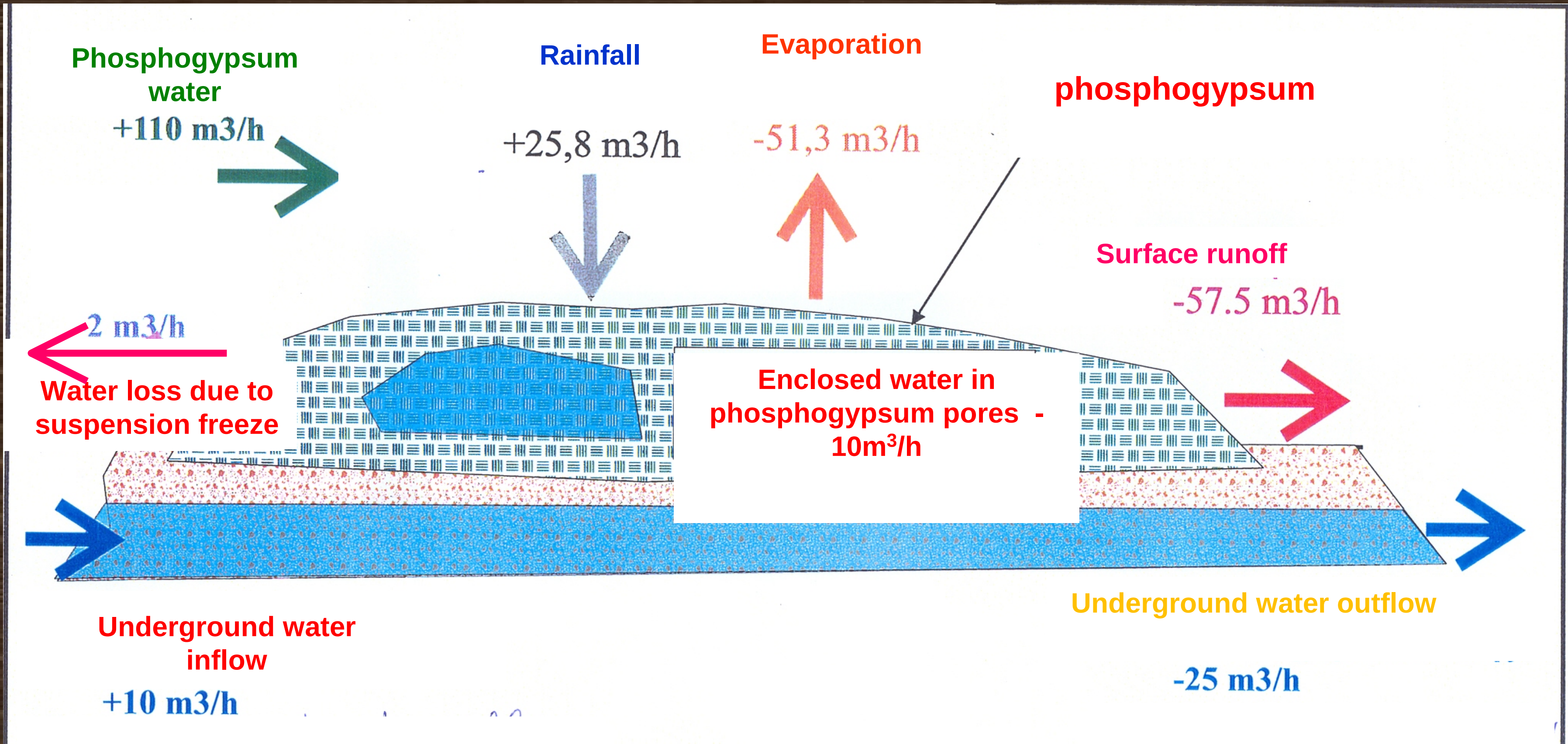
Underground water: pH distribution



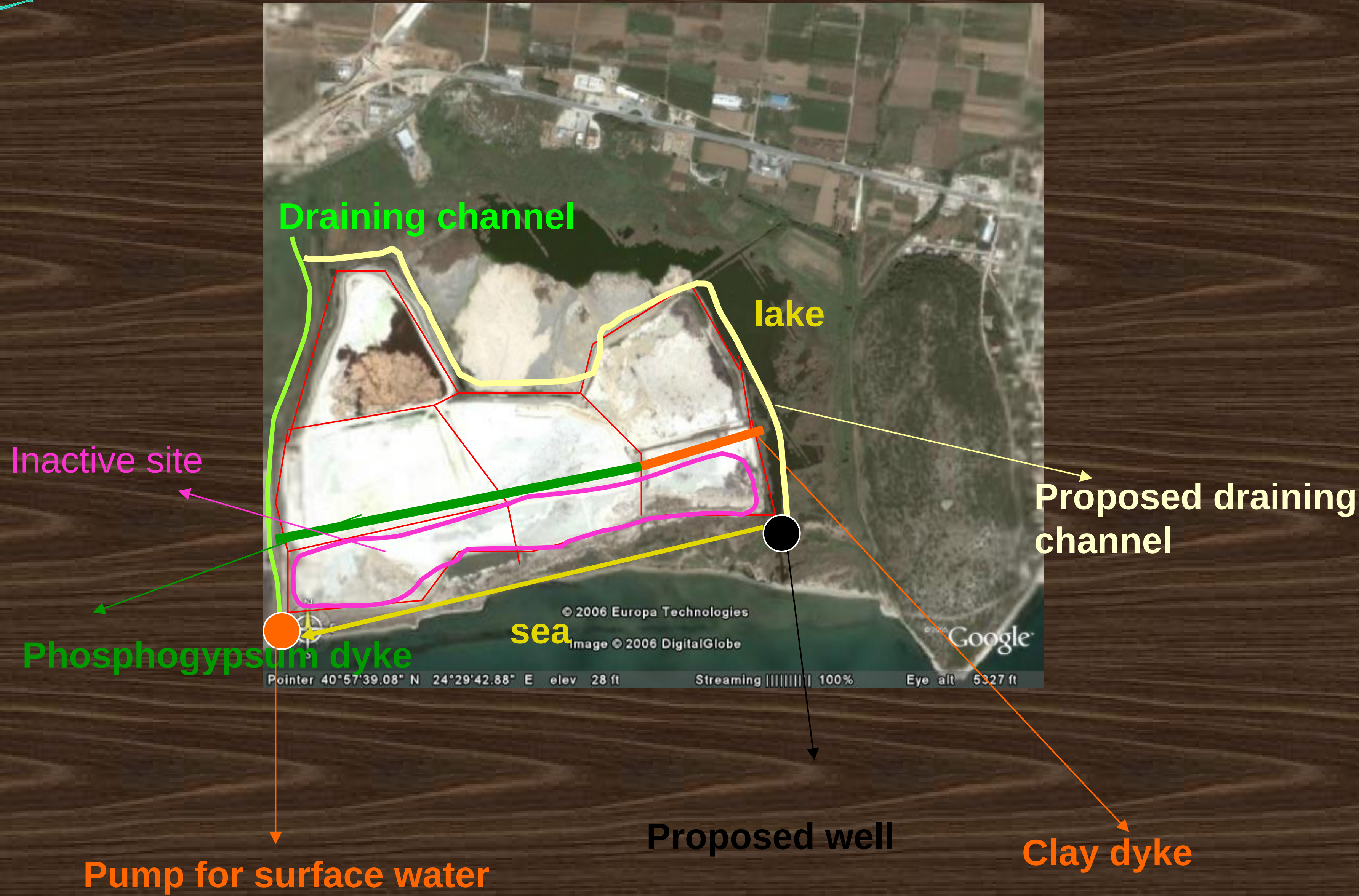
Surface water: pH distribution

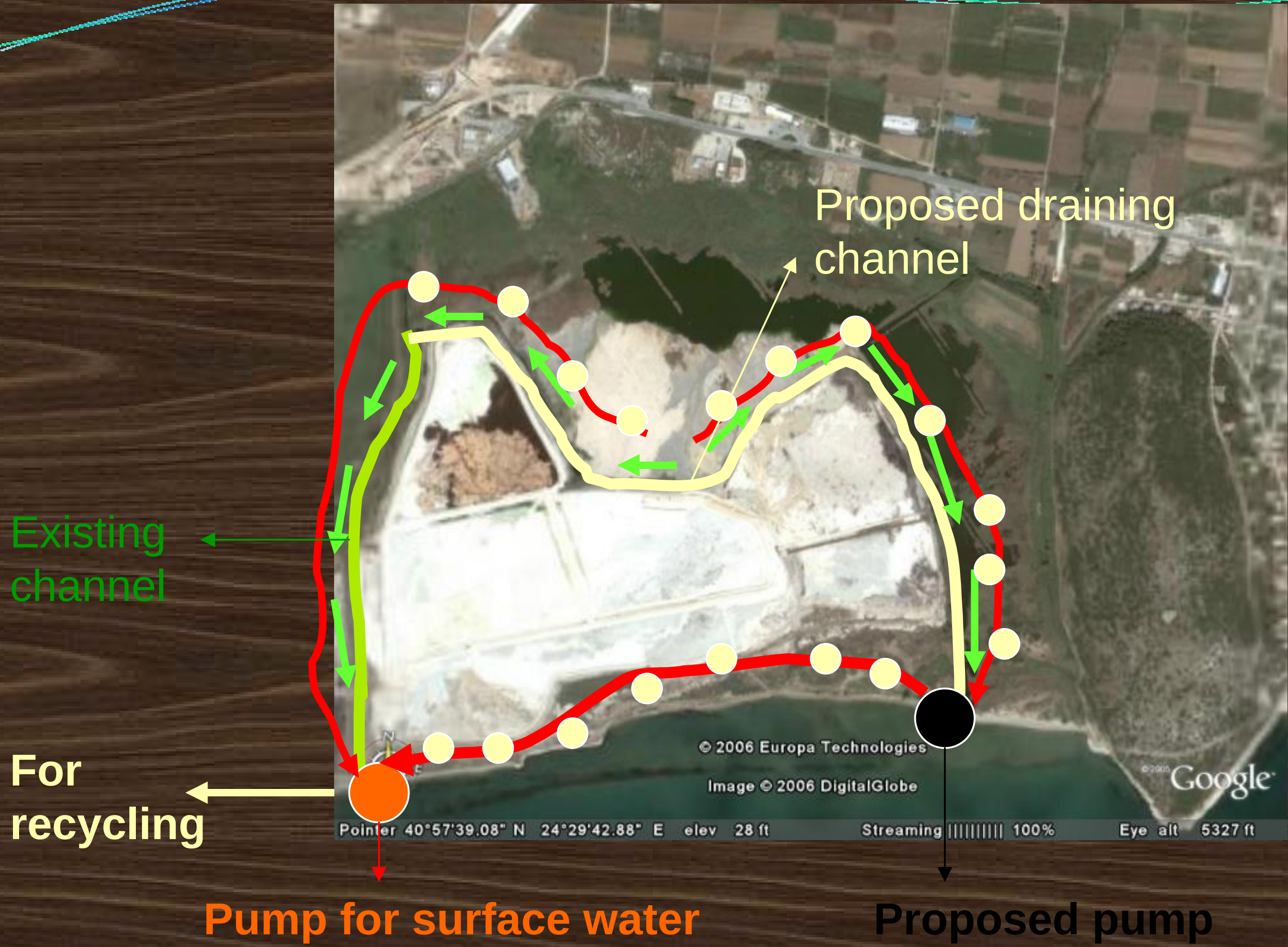


Water balance



Proposed measures



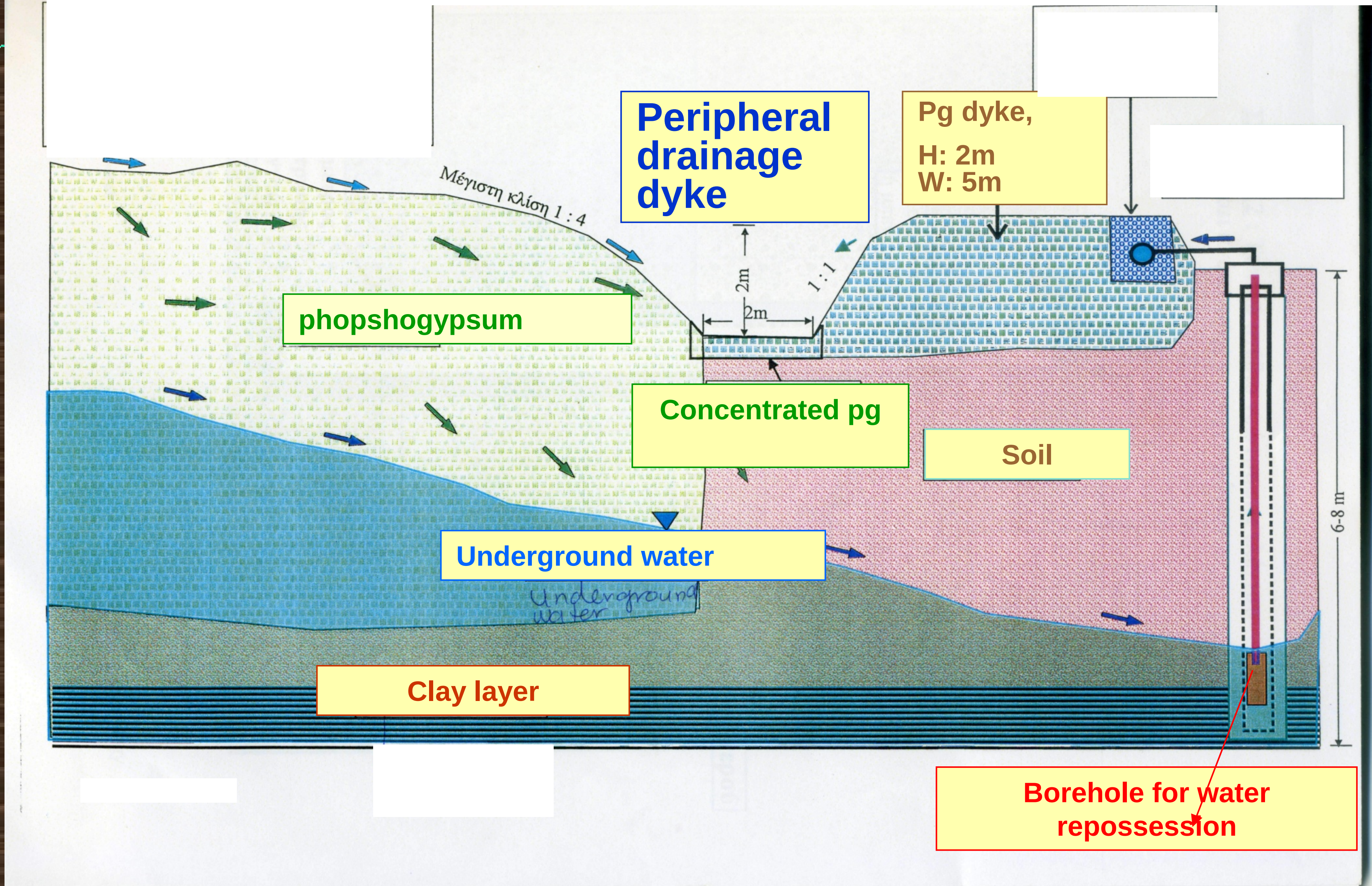


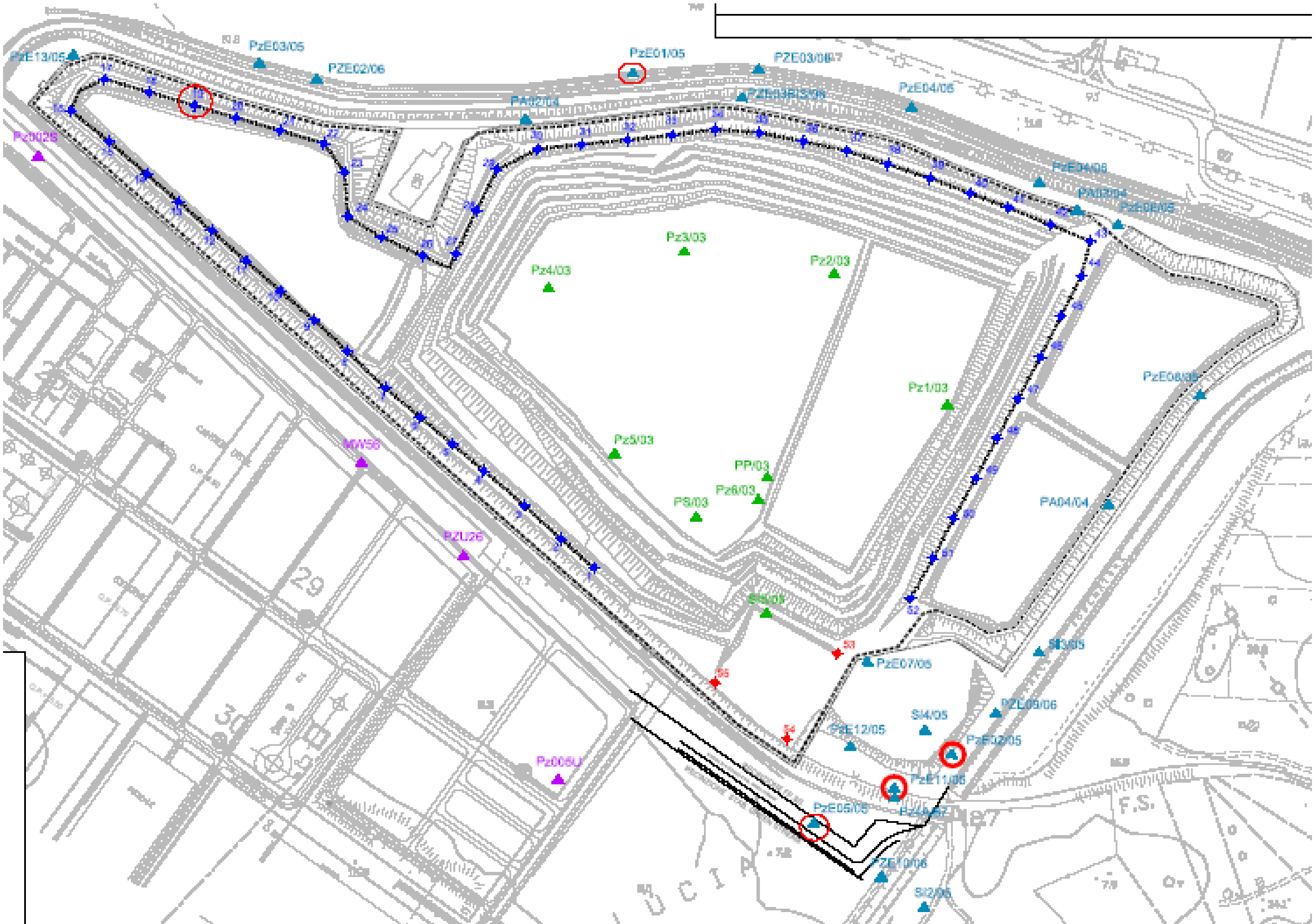
Transport channels for underground draining water

Direction of surface water flow at the transport channel

Borehole for water repossession

Proposed system




PzE13/05
PzE03/05
PZE02/06
PzE01/05
PZE03/06
PzE04/05
PA02/04
Pz002S
PzE04/08
PA03/04
PzE06/05
Pz3/03
Pz2/03
Pz4/03
Pz1/03
PzE08/05
Pz5/03
MW56
PP/03
Pz6/03
PS/03
PA04/04
PZU26
PzE07/05
SI3/05
PZE09/06
SI4/05
PzE12/05
PzE02/05
Pz005U
PzE11/05
PzE05/05
PZE10/06
SI2/05
29
30

Features and available data

- Sampling points shown in colour
- Stack surrounded by a concrete retaining wall
- Leachate returned to the top of the stack
- Groundwater flow NW to SE

- Measured concentrations of ^{234}U and ^{238}U in ground water and percolate for 2006 and 2007.
- Measured concentrations of radionuclides in phosphogypsum and phosphorites
- Stratigraphic and hydrological data
- More details in main WG report