Horizon 2020
TO DE-POLLUTE THE MEDITERRANEAN BY THE YEAR 2020

Training on mercury management and remediation of contaminated sites

"La Soterraña" mercury mine characterization and restoration design.

Almadén (Spain) 18-19th November 2015

Raúl López

emgrisa

UNEP

MAP

Site location

- ✓North of Spain
- ✓Principado Asturias.
- ✓Cantabrian mountain range.
- ✓Historical mining area.

The Site- La Soterraña

- ✓Underground mine.
- ✓ Surface (facilities and dumps): 2.4 ha.
- ✓ Mine waste dumps: 220.000 m^3.
- ✓ Small village at 500 m SW.

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History and mineralogy

1844: Starting mining activity.

1879: Fábrica de Mieres.

1948: Minas Soterraña society.

1974: Cessation of operations.

Industrial process:

Cinnabar ore roasting (~ 600º C) + Hg vapour condensation.

Cinnabar (HgS)

Realgar (AsS)

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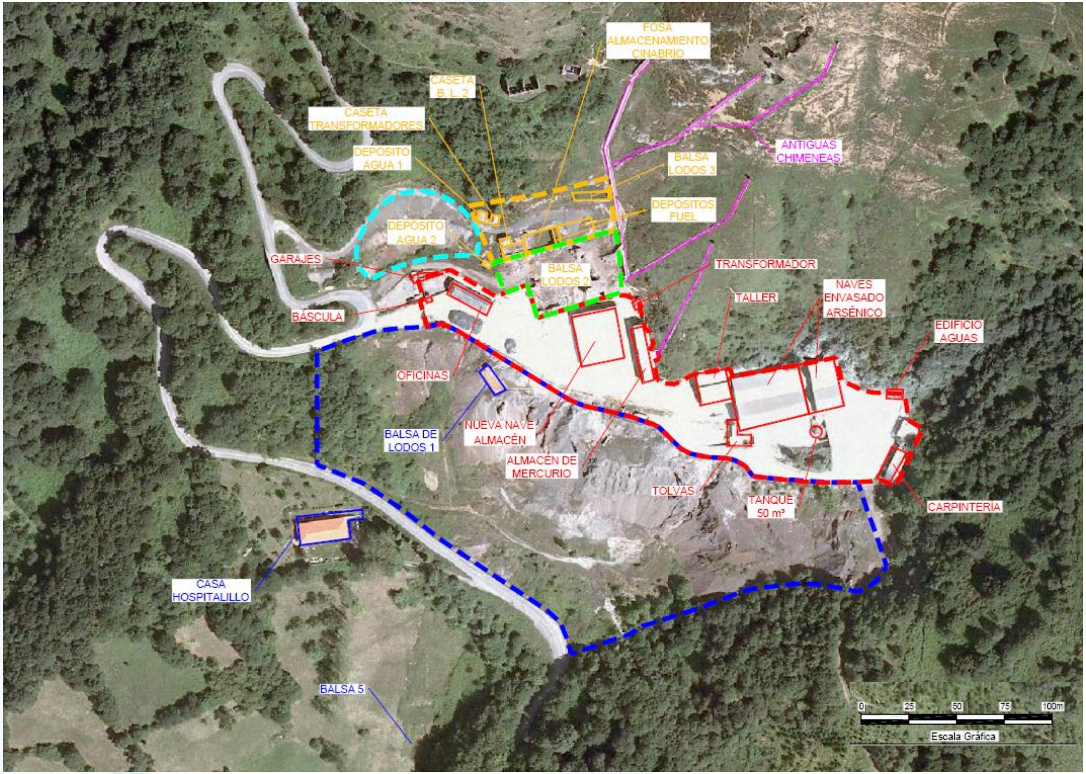
Main facilities



Previous works

- ✓ Detailed Topography.
- ✓ Physical & environment study (rinfall, Tª, wind…).
- ✓ Geological and geotechnical study.
- ✓ Mine waste dump stability survey.
- ✓ Environmental survey (3 phases).

	FIEL WORK / MATRIX SAMPLED	Units	Max. depth (m.b.g.l.)
	BOREHOLES (101mm; DR)	16	15
	PITS (excavator)	5	5
	SURFACE MANUAL SAMPLES	56	0,3
	PIEZOMETERS (DN50)	9	14
SAMPLES	SURFACE (MANUAL)	56	0,3
SAMPLES	DEEP SOIL (From Noreholes and Pits)	46	several
SAMPLES	GROUNDWATER (from piezometers)	9	several
SAMPLES	SURFACE WATER SAMPLES	11	-
SAMPLES	STREAM SEDIMENT SAMPLES	5	0,2
SAMPLES	MINE SLUDGE	6	0,5
	INCLINOMETERS (70mm)	2	14.5

Current environmental situation.

1) High concentration of Hg (up to 54,000 mg/kg) and As (603,000 mg/kg) in waste, mostly in ore processing facilities (muffles, rotary kinl, condesators, chimneys, etc.)
2) High concentrations of As and Hg in soil with concentrations of 48.000 mg/kg and 1.200 mg/kg respectively.
3) Impact in surface and sub-surface water (no aquifer) and sediments by As (mainly) and Hg also.
4) Main waste dump landslide (small cracks in road located at 30 m from the dump front).
5) Pollution dispersion:
   - ✓ Erosion of waste dump and sedimentation downstream.
   - ✓ Spreading by runoff.

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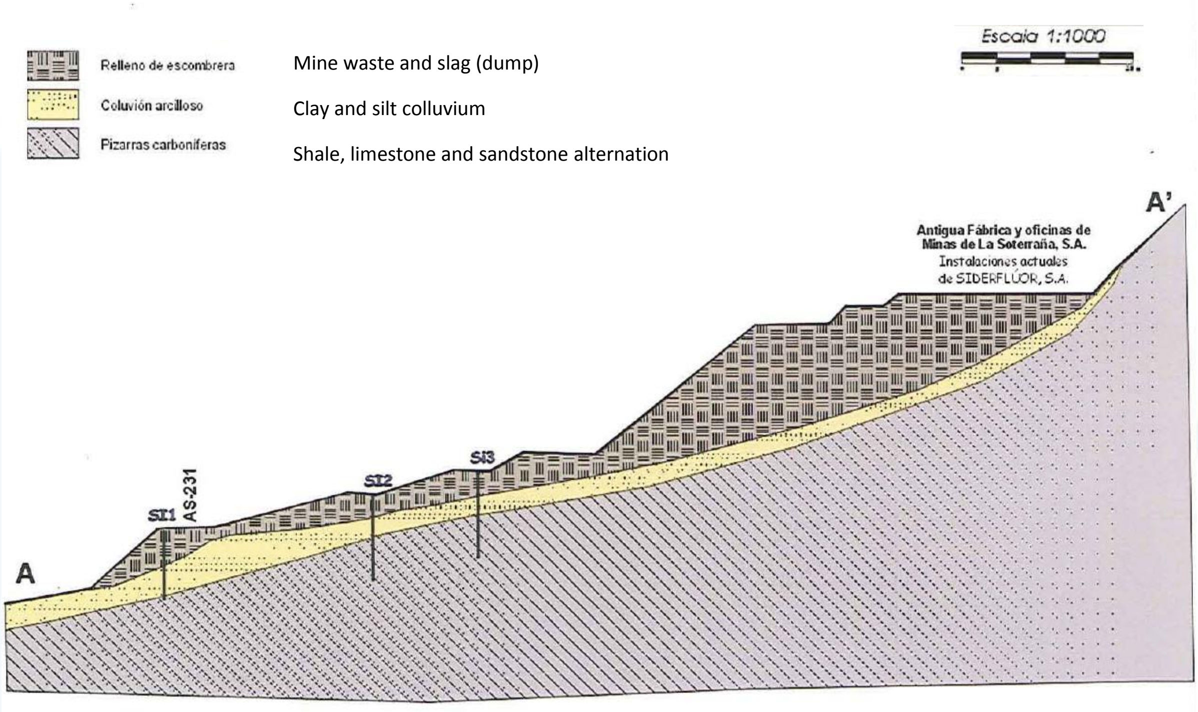
Lythological Cross Section



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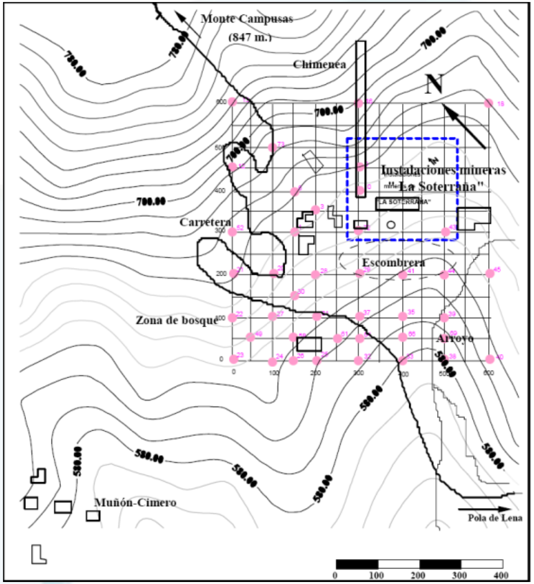
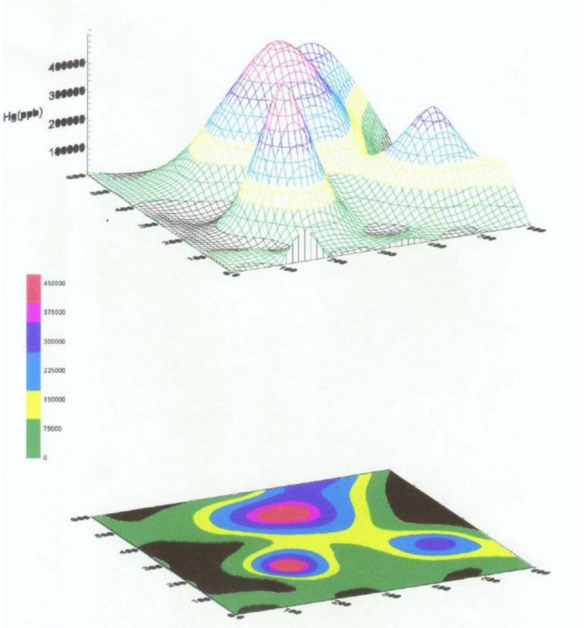
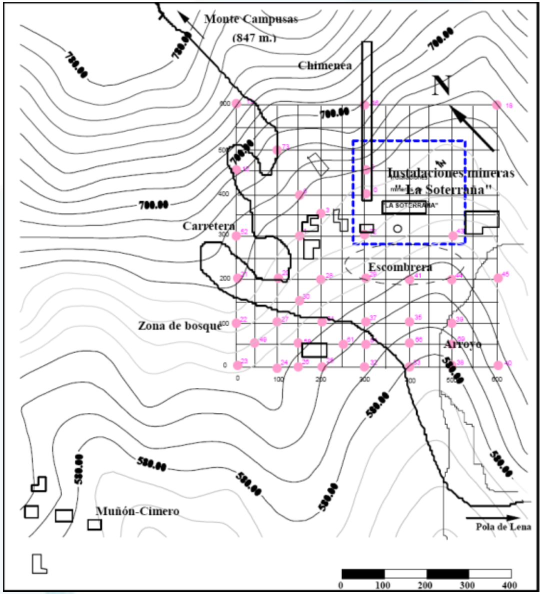
Hg in surface soils (µg/kg)



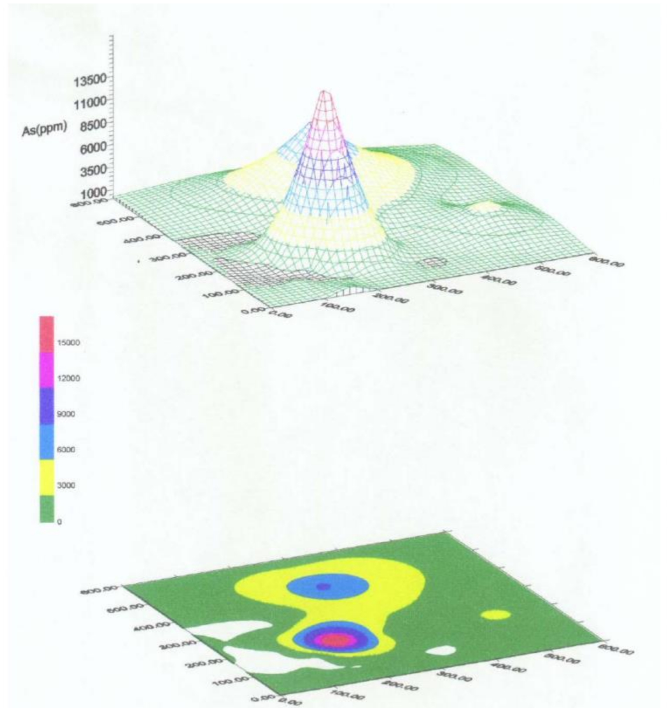
Systematic - orientated sampling grid.



As in surface soils (mg/kg)

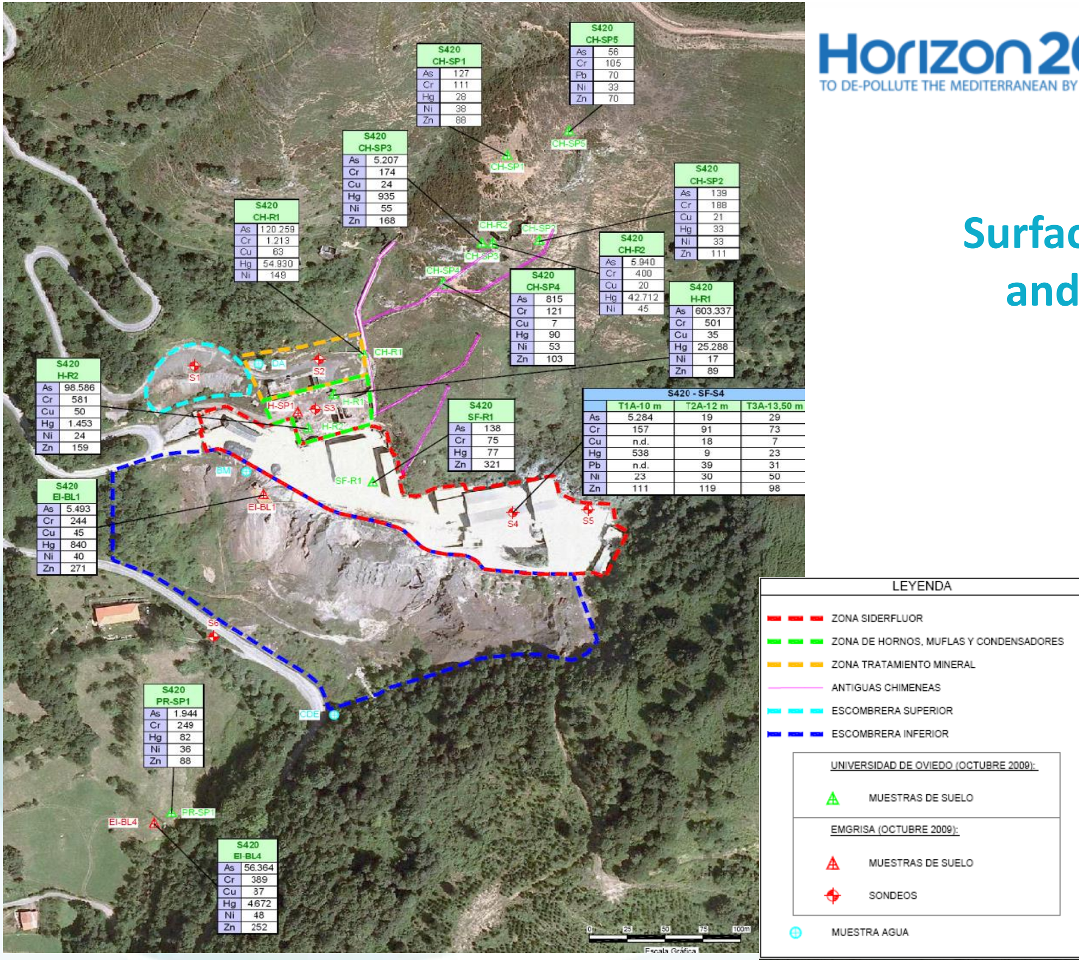


Systematic - orientated sampling grid.



Surface soils and waste

UNOVI (mg/kg)



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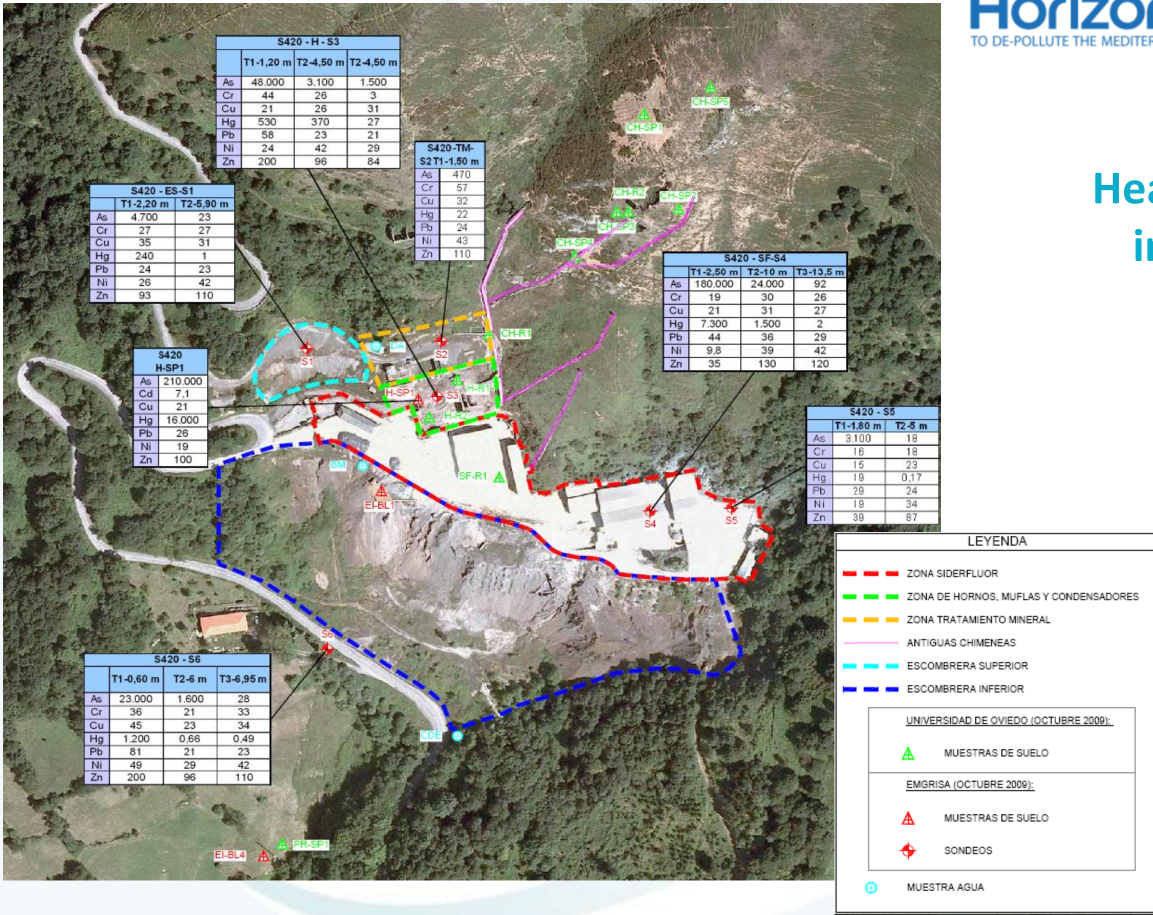
Heavy metals in deep soil (mg/kg)



S420 - H - S3

	T1-1,20 m	T2-4,50 m	T2-4,50 m
As	48.000	3.100	1.500
Cr	44	26	3
Cu	21	26	31
Hg	530	370	27
Pb	58	23	21
Ni	24	42	29
Zn	200	96	84

S420-TM-S2 T1-1,50 m

As	470
Cr	57
Cu	32
Hg	22
Pb	24
Ni	43
Zn	110

S420 - ES-S1

	T1-2,20 m	T2-5,90 m
As	4.700	23
Cr	27	27
Cu	35	31
Hg	240	1
Pb	24	23
Ni	26	42
Zn	93	110

S420 - SF-S4

	T1-2,50 m	T2-10 m	T3-13,5 m
As	180.000	24.000	92
Cr	19	30	26
Cu	21	31	27
Hg	7.300	1.500	2
Pb	44	36	29
Ni	9,8	39	42
Zn	35	130	120

S420 H-SP1

As	210.000
Cd	7,1
Cu	21
Hg	16.000
Pb	26
Ni	19
Zn	100

S420 - S5

	T1-1,80 m	T2-5 m
As	3.100	18
Cr	16	18
Cu	15	23
Hg	19	0,17
Pb	29	24
Ni	19	34
Zn	39	87

S420 - S6

	T1-0,60 m	T2-6 m	T3-6,95 m
As	23.000	1.600	28
Cr	36	21	33
Cu	45	23	34
Hg	1.200	0,66	0,49
Pb	81	21	23
Ni	49	29	42
Zn	200	96	110

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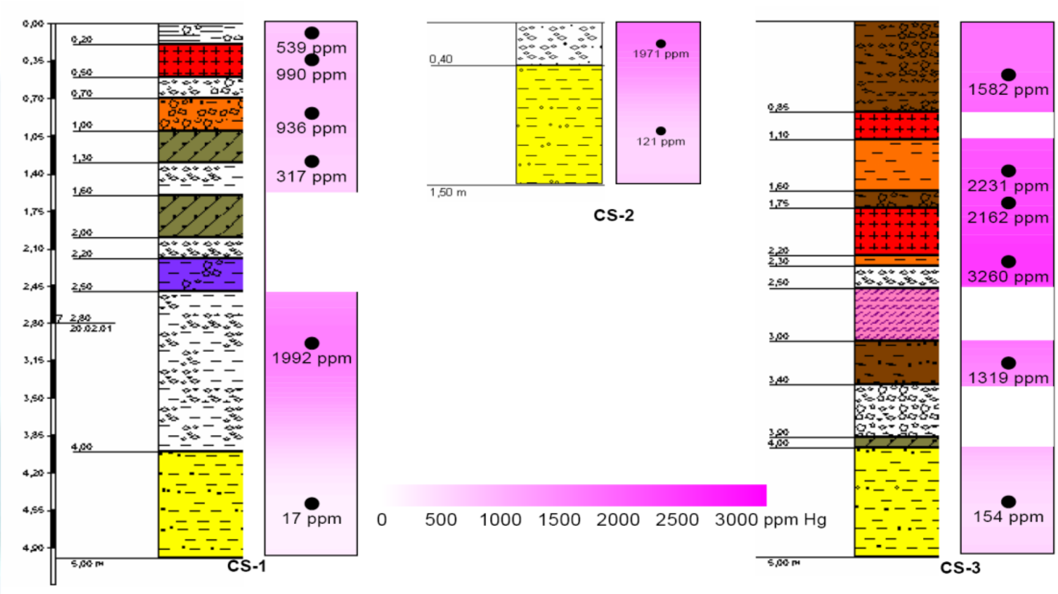
Vertical pollution percolation

MERCURIO



Clay and silt colluvion play the role of vertical barrier (K = 10^{-7} to 10^{-9} m/s)

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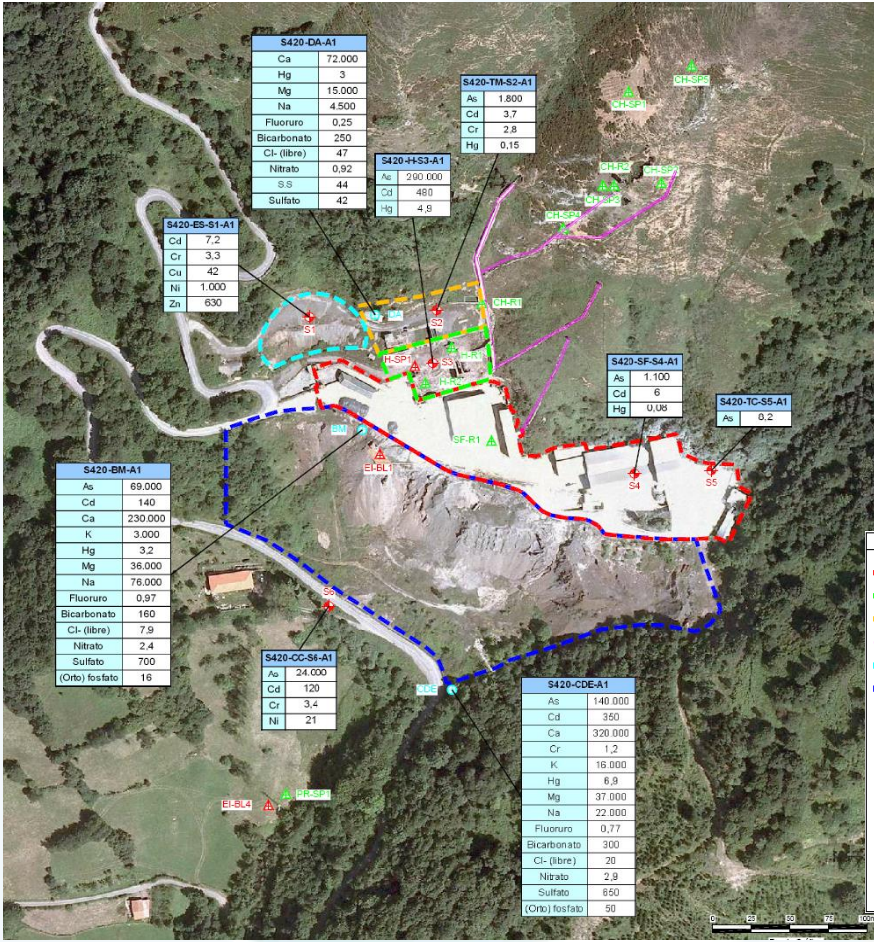
Metals in surface and sub-surface water (µg/L)



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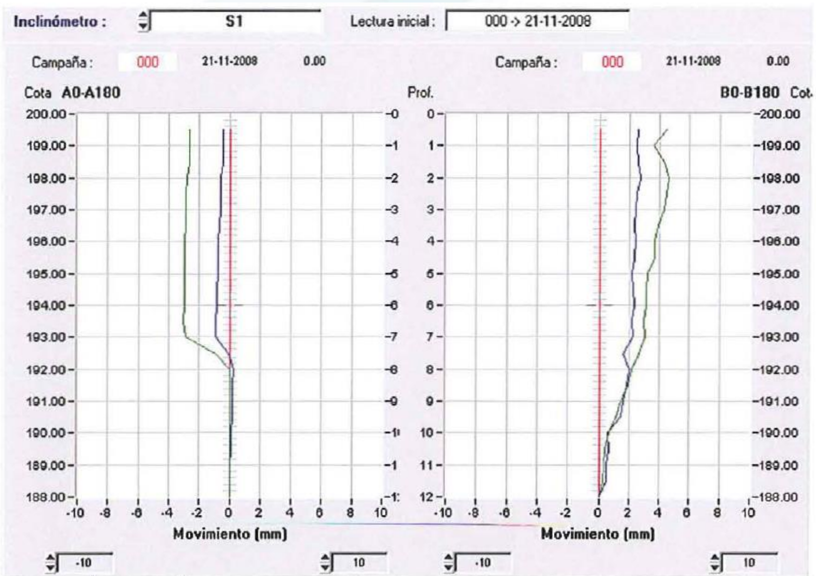
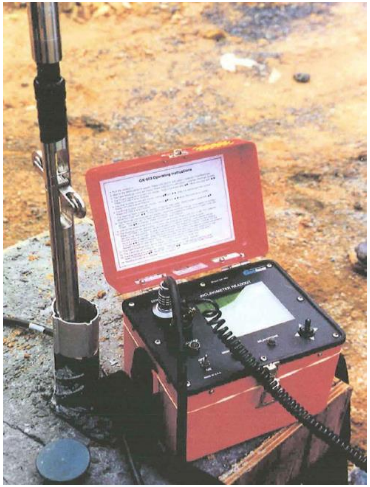
Dump mechanical estability



Fecha de medida.

1	red	21-nov-08
2	blue	27-nov-08
3	green	5-dic-08

- ✓Inclinometer campaings
- ✓Slide plane at 6-8 m under mine waste dump front.



Inclinometer probe

Site environmental needs

- ✓ To eliminate mining waste with high concentrations of As and Hg (high leachate capacity), as well as hazardous waste present from industrial activity.
- ✓ To eliminate or confine mining waste and soil polluted with moderate concentrations of As and Hg.
- ✓ To ensure waste dump mechanical stability avoiding collapse, damages to public infractructures
- ✓ To avoid pollution dispersion by soil erosion and runoff (water and sediments).

ENVIRONMENTAL INTEGRAL RESTORATION

Solution. Alternatives study

FEASIBILITY ALTERNATIVE ANALYSIS:

1.- Waste transportation, stabilization and disposal in hazardous waste landfill (COGERSA at 34 Km from the site).

2.- Building a new and specific hazardous lanfdill near the mine (Lena municipality).

Both alternatives are economic unfeasible, and involve a significant environmental impact.

3.- In situ mine waste sealing and mechanical dump stabilization.
Removal, and external treatment and disposal of hazardous waste.
Landscape restoration.

This is the best option from an econcomic and environmental point of view.

Avoiding great mine waste excavation and transport outside.

Required a long term monitoring plan (>30 years) and leachate management.

Design of solution

1) **DECOMMISSION OF MINING FACILITIES.**
    a) ZONE 1. - Former chimneys, rests of muffles, rotary kiln, condensator, tailing ponds, etc.
    b) ZONE 2. – Buildings from mine square.
2) **EXTERNAL TREATMENT AND DISPOSAL.**

    Mining waste with higher concentracion of As and Hg (leaching), transformer (PCBs) and fuel-oil (UST), asbestos, etc.

    Phase 1 and 2 will be executed in parallel way
3) **MECHANICAL STABILIZATION OF MAIN WASTE DUMP.**
    a) Modification of waste dump slope profile (berms, etc.).
    b) Slide stabilization on the dump base front.
4) **SEALING AND IMPLEMENTING A DRAINAGE SYSTEM.**
5) **CREATING A VEGETATION COVER -** (LANDSCAPE INTEGRATION).

Phase 1- Decommission of mining facilities

✓Demolition of hillside and vertical chimney.

Inside particles and surroundings soils with high concentrations of Hg and As.

Phase 1 -Decommision of mining facilities and buildings



✓Demolition and waste segregation (construction waste, industrial, etc.), valorization of iron structures.

Phase 2 -Hazardous waste management

Transformer (PCBs).

Tailing/sludge pond.

Fuel-oil in UST.

Fuel-oil filtrations in retaining wall.

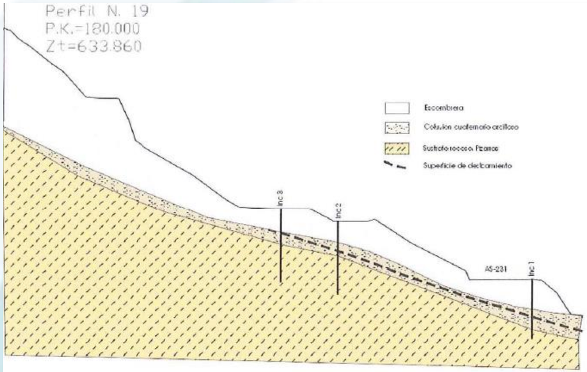
Hazardous waste removal and external elimination.

Decommision and waste management

Unit	Waste (inert)	Quantity
t	Metal structures	150
m^2	Brick buildings	3,150
m^3	Croncrete buildings	10,175

Unit	Waste (hazardous)	Quantity
t	Polluted residues from demolition	500
	Fuel-oil from underground tank	800
	Other (asbestos, oil with PCBs, etc.)	100

Phase 3 – Main waste dump stabilization



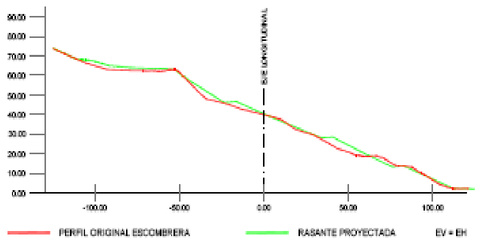
Main goals:

✓Safety.
To avoid collapses and affectation to local road (AS231)

✓Environmental.
To prevent dispersion by creeping of dump material downstream .

Phase 3 – Main waste dump stabilization

- ✓ Modification of dump slope profile and instalaltion berms.
- ✓ Installation of sustainment structures .
- ✓ Soil anchorage mechanisms.



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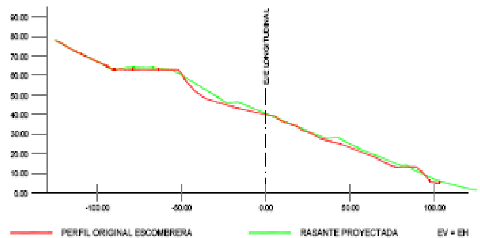

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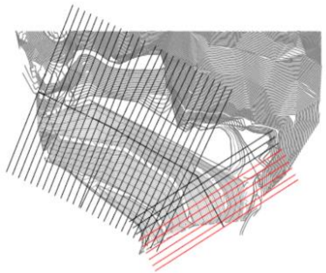
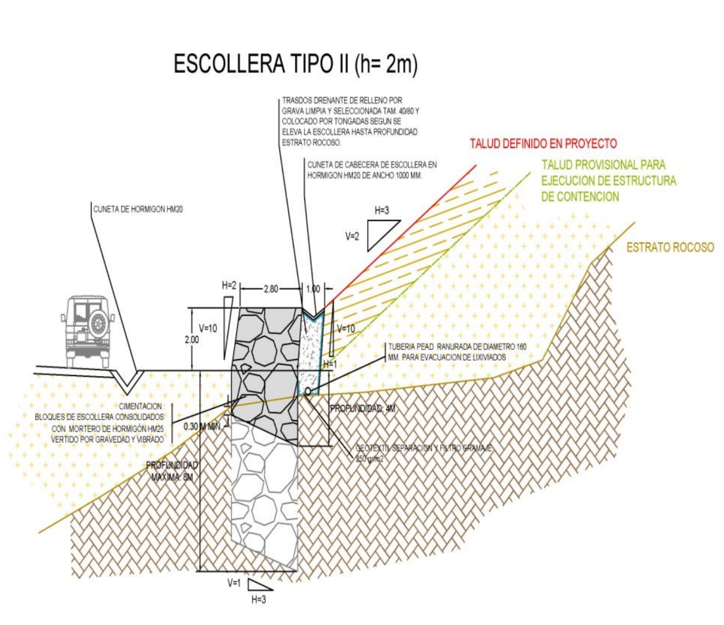


SITUACIÓN DE PERFILES 1:4000

Phase 3 – Main waste dump stabilization

- ✓ Installation of sustain structures: rock-concret riprap.



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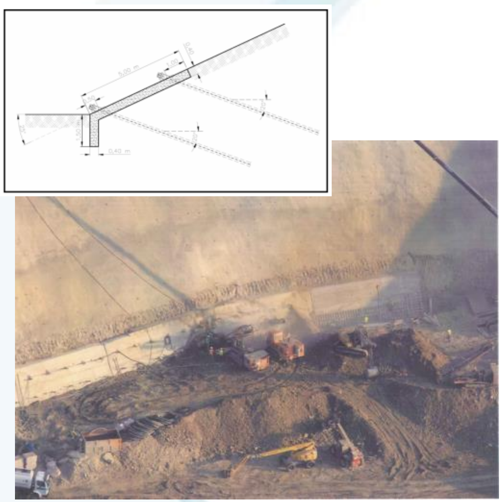
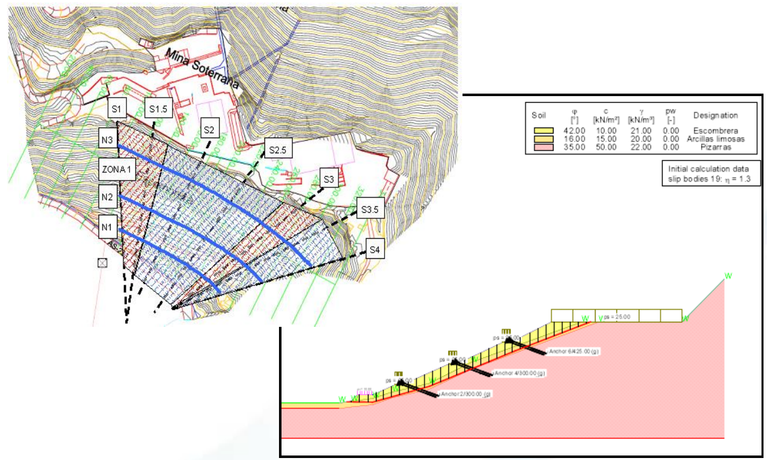
Phase 3 – Main waste dump stabilization

✓ Soil anchorage (bulbs) with rection plinths.



Reaction plinths



Anchorage structures (Ø 70 mm; 40º ; 14 m length)

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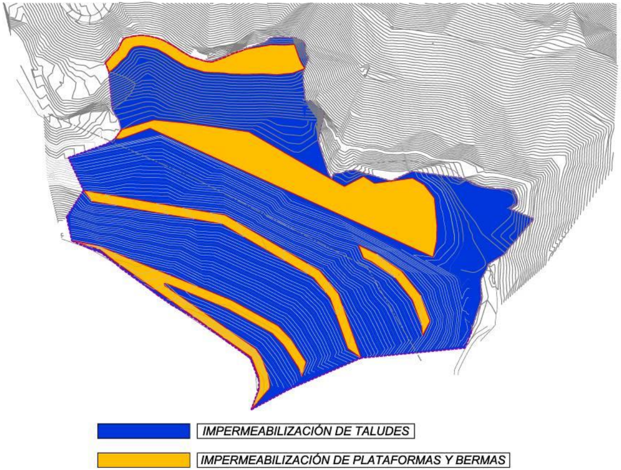
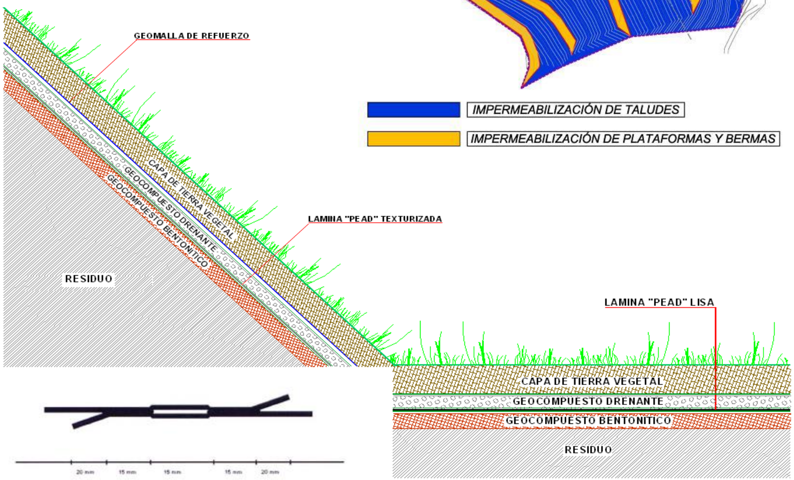
Phase 4 – Sealing



Sealing layers:

- ✓ Bentonitic geocomposite.
- ✓ HDPE sheet.
- ✓ Drainage composite .
- ✓ Geogrid of reinforment

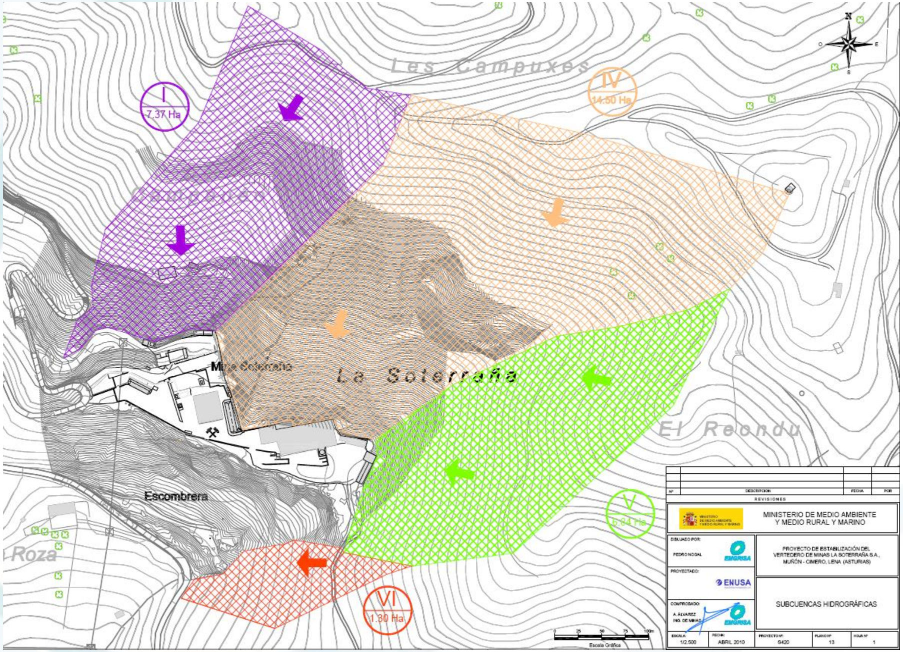
Vegetation cover .



Detail section of HDPE sheet joints

Phase 4 – Drainage design

Local water sub-basins anaylisis to design differents drainage an re-direction infracturtures.



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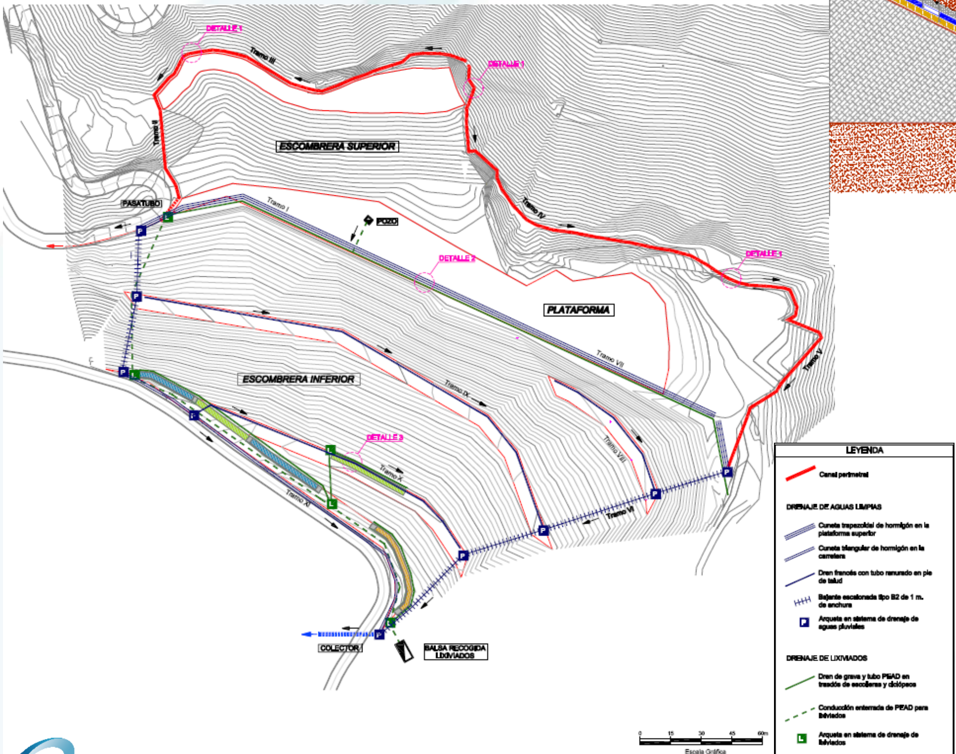
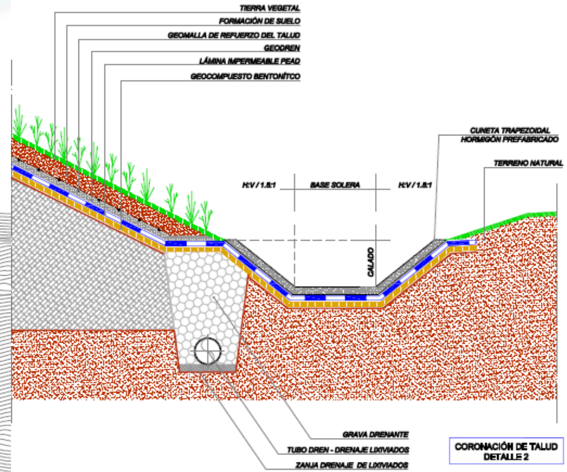
Phase 4 – Drainage infraestructures





- ✓ Upstream runoff re-direction channel (red).
- ✓ Rainwater channel (blue).
- ✓ Leachate drainage (green).

Phase 5 -Landscape restoration

Targets:

- ✓ Miniminaze landscape visual alterations. Integration.
- ✓ Erosion protection.

HYDROSEEDING: High pressure application of homogeneus suspension (water + seeds + nutrients + stabilizing agents).

Local plant species will be used. Ecology and adaptation.

Uranium mine restoration, Ciudad Rodrigo (Salamanca, Spain)

Monitoring

Focus on:

- ✓ Dump geotechnical stability.
- ✓ Correct drainage of sealed surface.
- ✓ Leachate monitoring: chemical and quantification.
- ✓ Surface water quality (streams).
- ✓ Visualize erosion process and vegation cover effectiveness.

Spanish Regulation: R.D 1481/2001

Monitoring Post-closure Plan ≥ 30 años.

General project information

Client:	Ministerio de Medioambiente Medio Rural y Marino
	(actual Ministry of Agriculture, Food and Environment).
Date:	April 2010 (adenda 2011).
Budget:	5.7 M €.
Project phases and schedule:	Decommision (P1) and waste management (P2) - 13 weeks.
	Implementation of stability measurements (P3) - 47 weeks.
	Sealing and drainage infrestructures (P4) - 29 weeks.
	Lanscape restoration – vegetation cover (P5) – 3 weeks.
Monitoring:	30 years.

Aspects **to improve:**

Before undertaking the project, to assess better the sub-surface runoff (rate and flow) to implement adittional sealing measurements that minimize water inputs and therefore mine leachate.

THANK YOU VERY MUCH

FOR YOUR ATTENTION !!!!

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