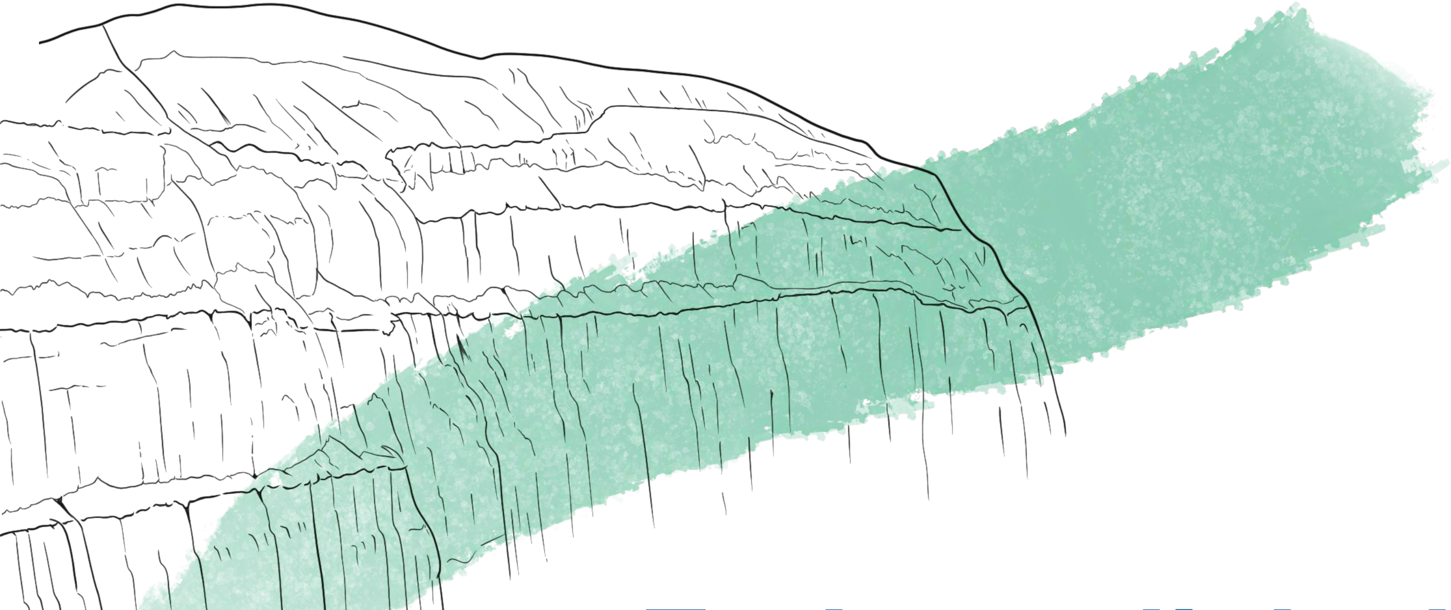

Life RIBERMINE
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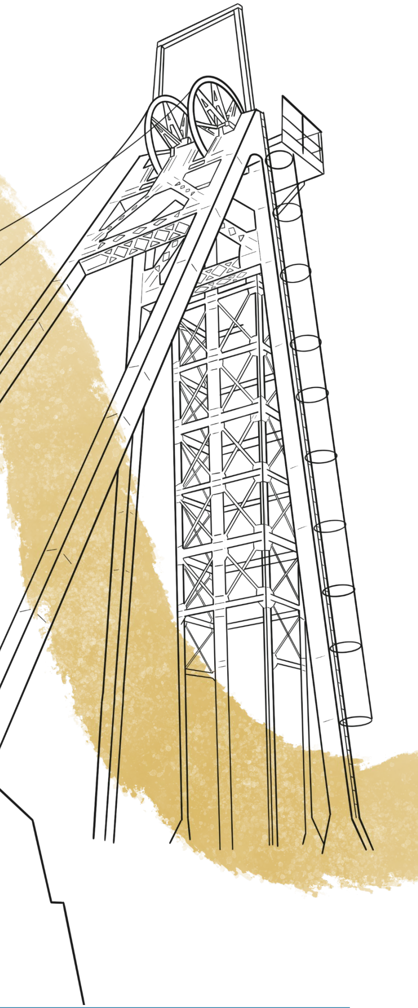
Technosoil design and geochemical remediation in Lousal



Javier Lillo

TECHNICAL CONFERENCE: Mining Restoration and Remediation Techniques. Dynamization of the LIFE RIBERMINE Project | Lousal | 20-21 February 2024

Disclaimer
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Universidad Rey Juan Carlos

LIFE RIBERMINE LIFE18 ENV/ES/000181

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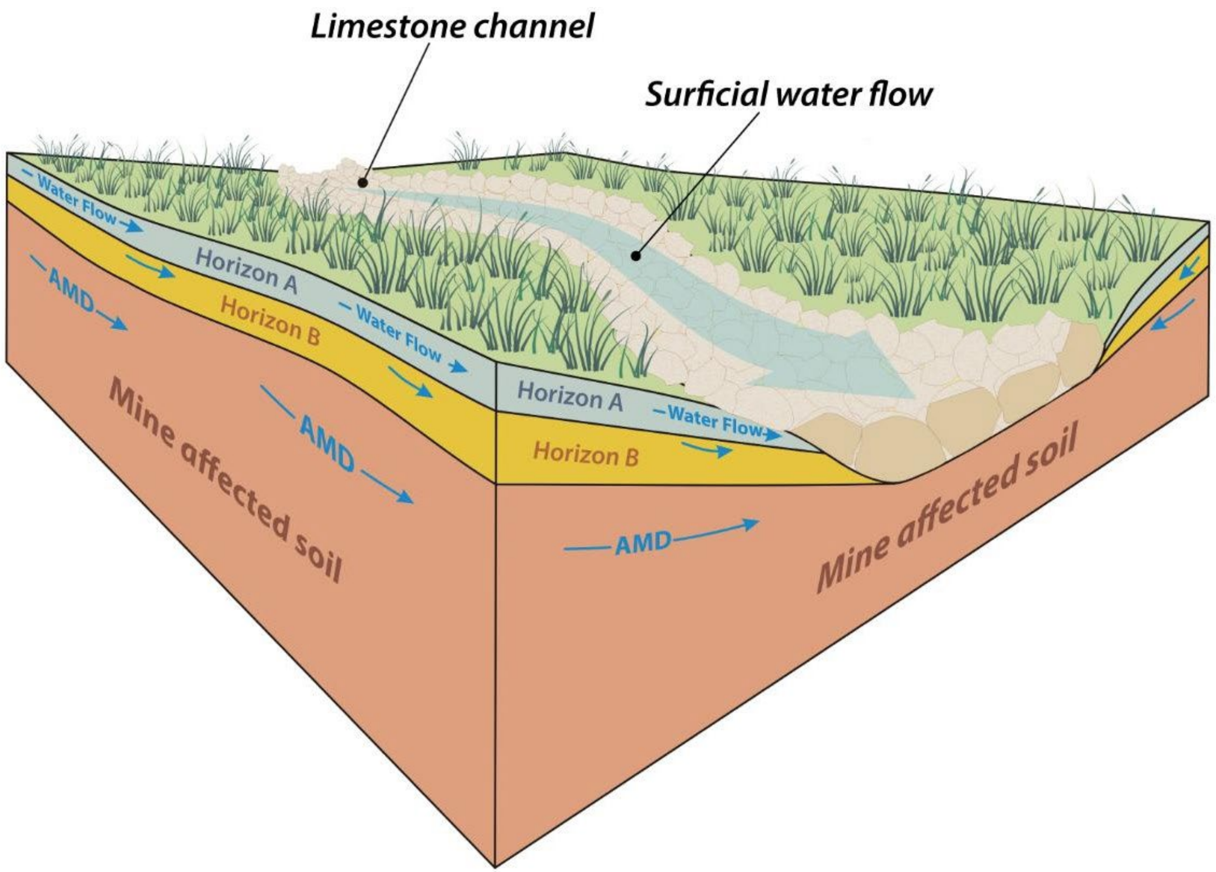

(Source: Sánchez Donoso et al., 2023. https://doi.org/10.1080/17480930.2023.2247698/)

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Justification

Main problem

- Dispersion of metals to water and soil
- Acidification of water and soil

→ **Acid Mine Drainage (AMD)**

Origin of the problem: Existence of deposits of pyrite and their weathering

Water as the main factor

- Water is involved in weathering
- Water is the main dispersion agent for metals (which can be mobilized in the liquid and solid phase) and acid

Justification

To address the problem, it is key to understand how water works

Acid Mine Drainage (AMD): Acid waters are formed by oxidative dissolution of pyrite

$$4FeS_{2(s)} + 14O_{2(g)} + 4H_2O_{(l)} \longrightarrow 4Fe^{2+}_{(aq)} + 8SO_4^{2-}{}_{(aq)} + 8H^+_{(aq)}$$

$$4Fe^{2+}_{(aq)} + O_{2(g)} + 4H^+_{(aq)} \longrightarrow 4Fe^{3+}_{(aq)} + 2H_2O_{(l)}$$

$$4Fe^{2+}_{(aq))} + 12H_2O_{(l)} \longrightarrow 4Fe(OH)_{3(s)} + 12H^+_{(aq)} \quad \text{(ferrihydrite)}$$

$$FeS_{2(s)} + 14Fe^{3+}_{(aq)} + 8H_2O_{(l)} \longrightarrow 15Fe^{2+}_{(aq)} + 2SO_4^{2-}{}_{(aq)} + 16H^+_{(aq)}$$


AMD in Lousal

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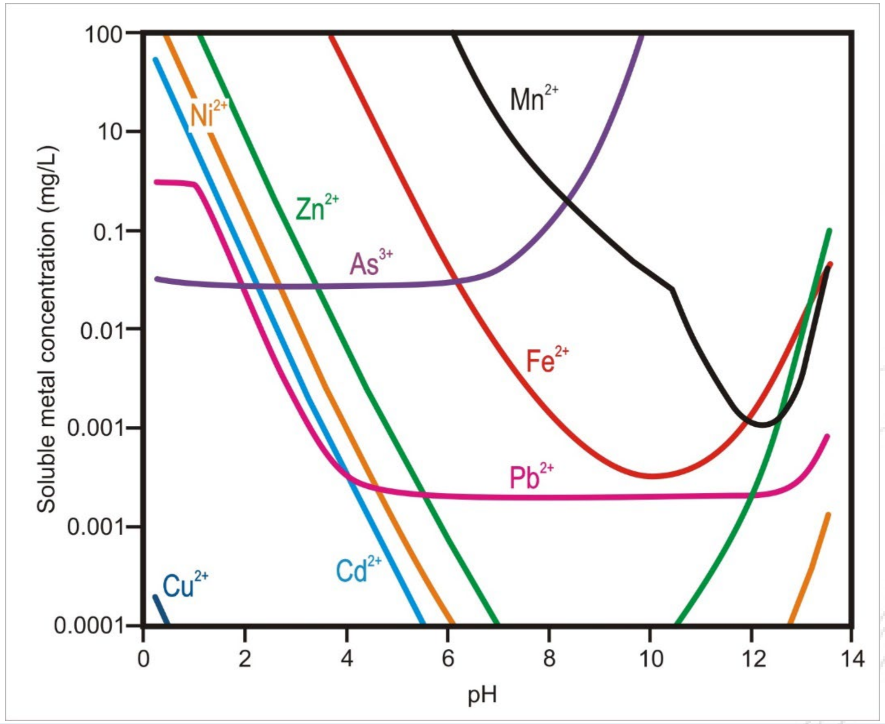
Justification

To address the problem, it is key to understand how water works:

Acid Mine Drainage (AMD): With decreasing pH, the solubility of metals increases (there are some exceptions), and therefore their mobility when transported by acidic water



Variation of metal concentration in solution as a function of pH

(Adapted from: Lewis, 2010 https://doi.org/10.1016/j.hydromet.2010.06.010)

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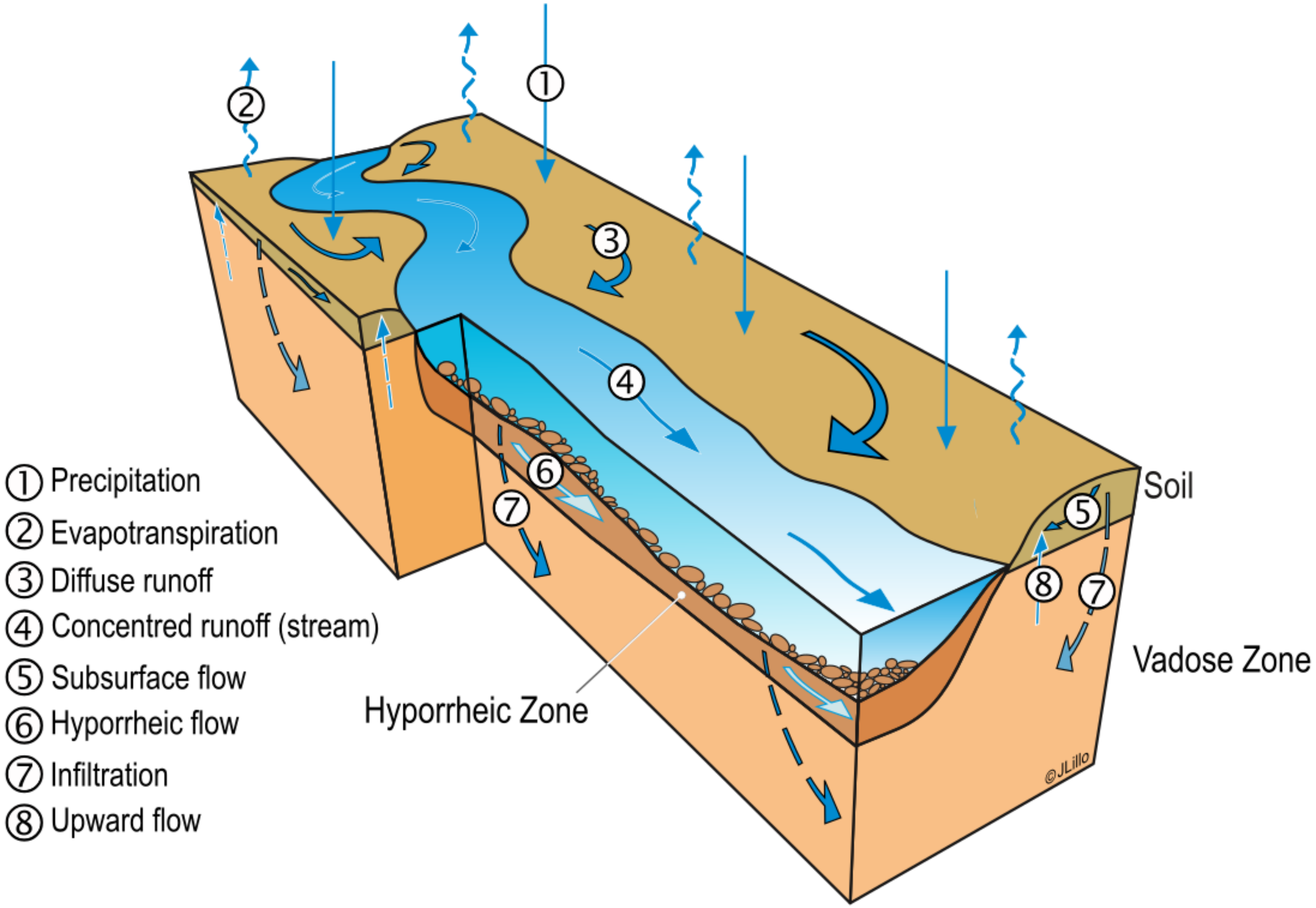
Justification

To address the problem, it is key to understand how water works

Hydrological processes related to pollution generation and mobilization



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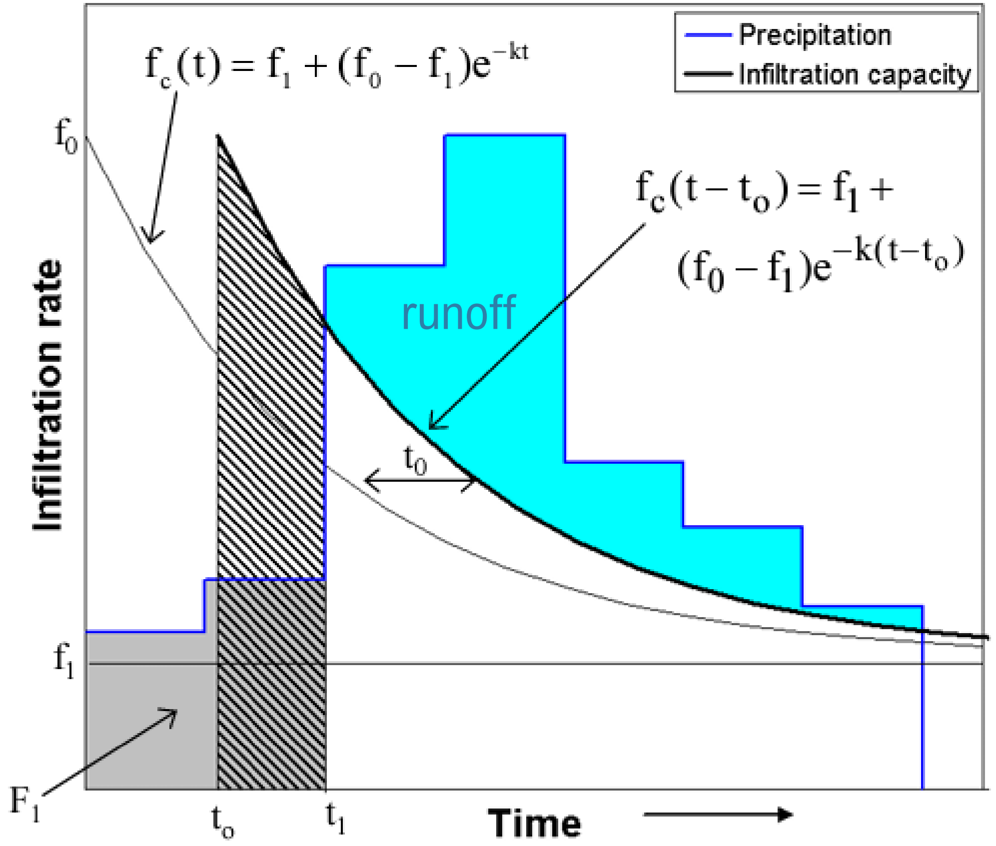
Justification

Runoff vs. Infiltration: When it rains, water that does not infiltrate becomes runoff, but…

runoff → erosion

So, encapsulation of the reactive material is not the appropriate way to correct the problem



Partition of surface water input into infiltration and runoff using the Horton infiltration equation

(Source: Tarboton, D.G. 2003. https://hydrology.usu.edu/rrp/)

Objectives

- To protect against erosion by diffuse runoff (physical)
- To serve as substrate and support for plants (physical and geochemical)
- To neutralize acid drainage (DAM)
- To immobilize metals in DAM

} geochemical

To be fulfilled by the constructed soil:

- Water and nutrient supplier for plants
- Physical stabilization of materials
- Buffer and neutralizer of acidity
- Pollutant retainer

Methodology

Aspects to consider:

- Geochemical processes to promote
- Water level and hydrogeological conditions (initial)
- Revegetation to be implanted
- Geomorphological restoration design and application area
- Materials required: quantity, cost and local availability. Application procedures

Methodology

Geochemical processes to promote:

- Neutralization (by calcite)

$$CaCO_{3(s)} + 2H^{+}_{(aq)} \leftrightarrow Ca_{2}^{+}{}_{(aq)} + H_2CO_{3(aq)} \qquad pH < 6.3$$

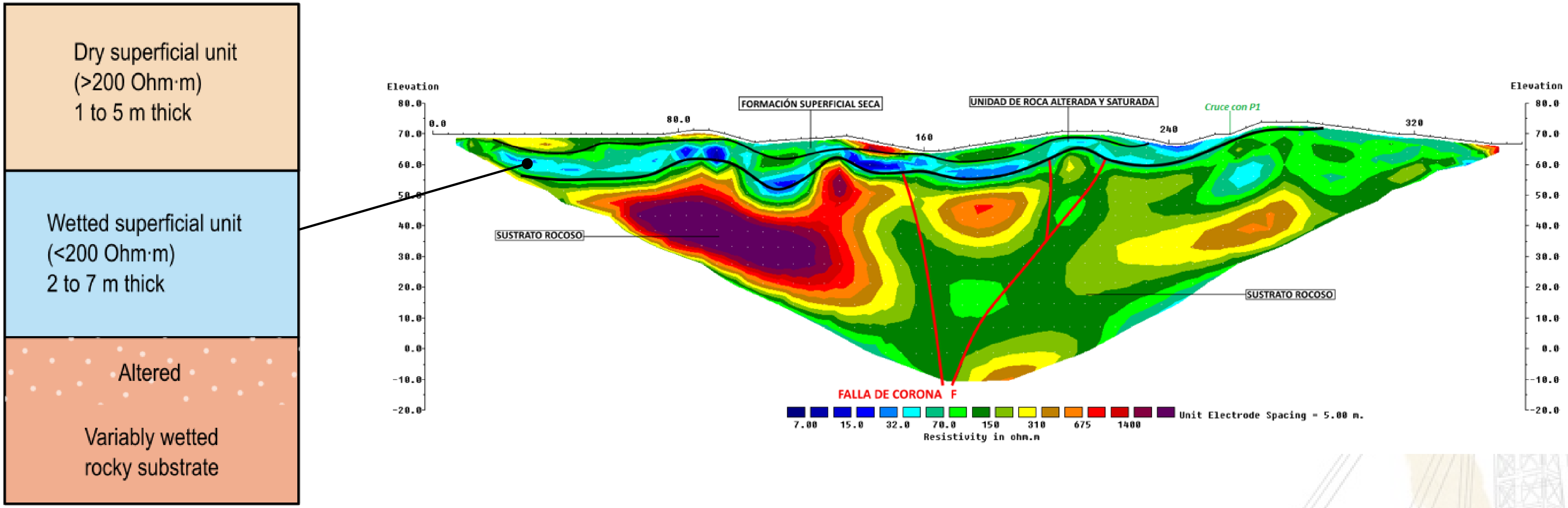
$$CaCO_{3(s)} + H^{+}_{(aq)} \leftrightarrow Ca_{2}^{+}{}_{(aq)} + HCO_{3}^{-}{}_{(aq)} \qquad pH > 6.3$$

- Adsortion (by clays and Organic Matter)

- Coprecipitación (mainly as oxyhydroxides, sulfates and carbonates, NOT ALWAYS CONVENIENT, as it causes clogging with loss of porosity and reactive surfaces)

Methodology

Water level and hydrogeological conditions (initial)



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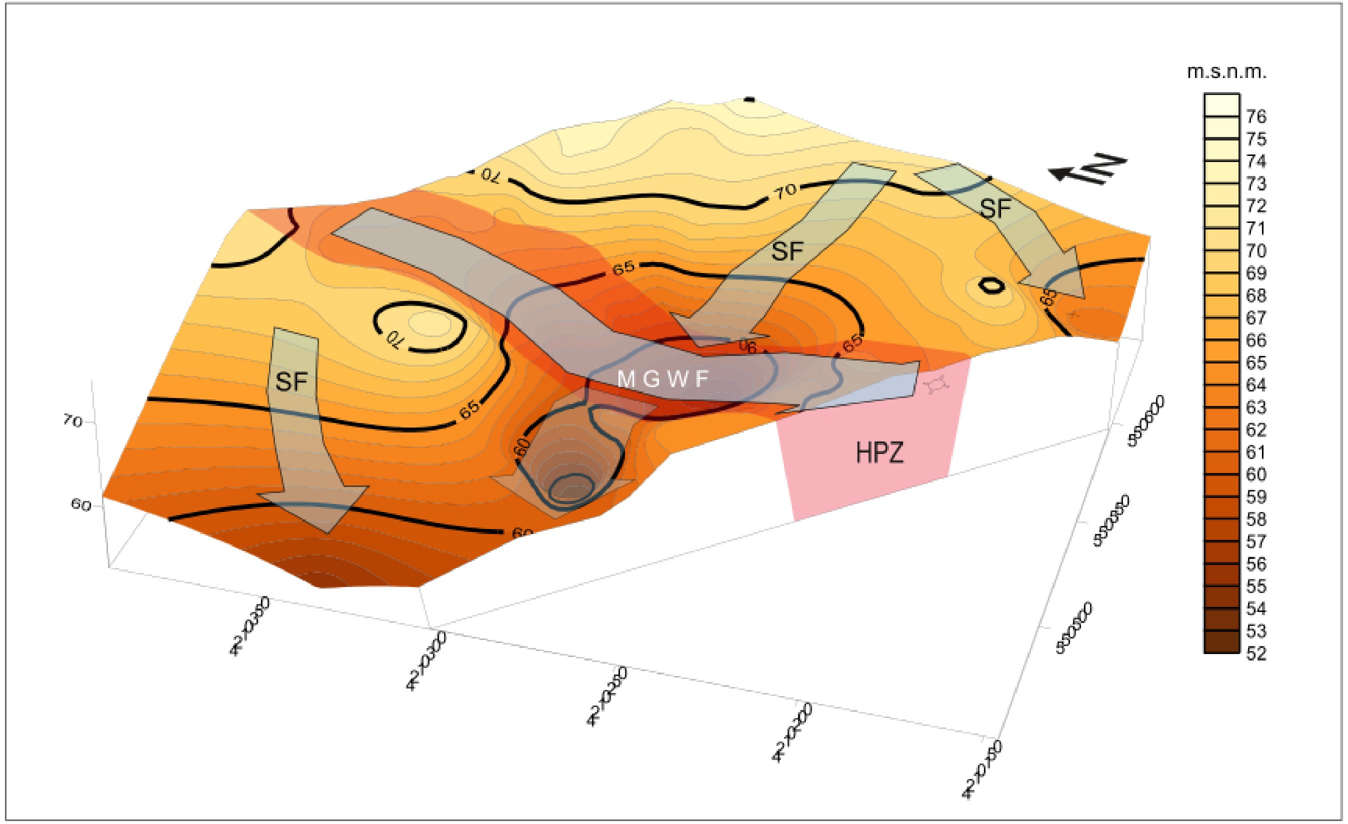
Methodology

Water level and hydrogeological conditions (initial)

- Subsurface flow, controlled by substrate morphology and cover thickness

- Deeper (regional) flow, structurally controlled (Corona fault)



Methodology

Revegetation to be implanted

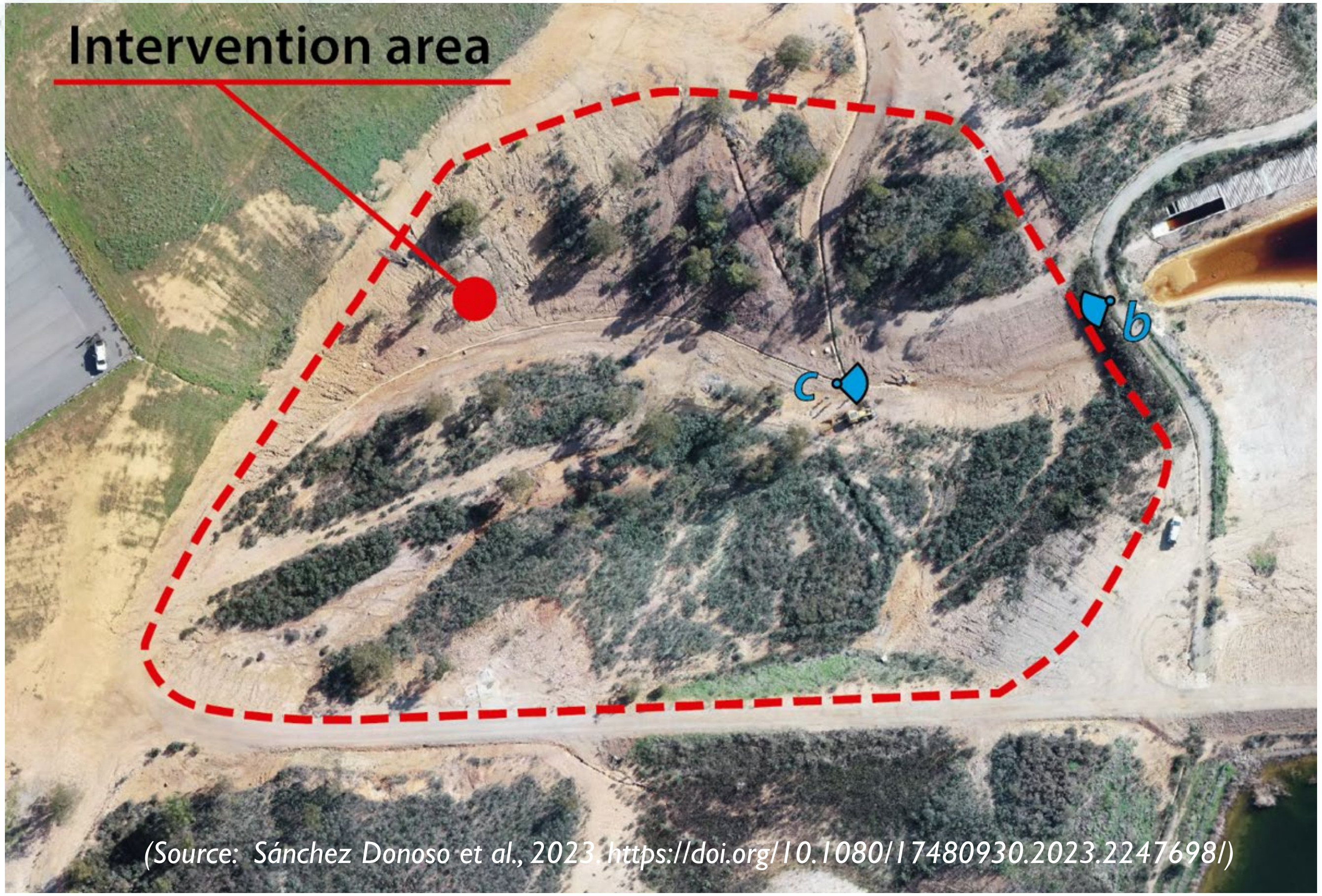
- Pioneer/autochthonous species, capable of surviving in different environmental and substrate conditions

- No exceptional nutrient and moisture needs

(Source: Sánchez Donoso et al., 2023. https://doi.org/10.1080/17480930.2023.2247698/)

Methodology

Geomorphological restoration design and application area



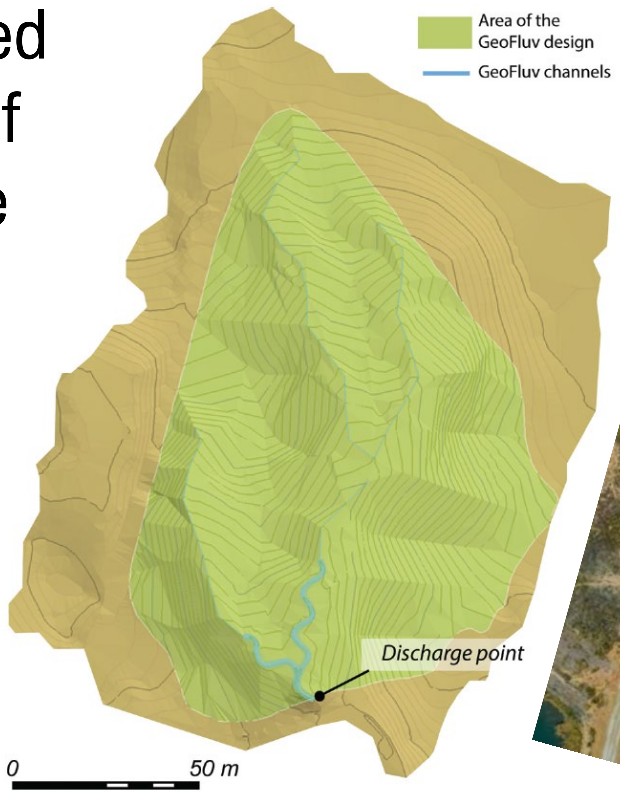
Methodology

Geomorphological restoration design and application area

- Geomorphological restoration is based on a single catchment with an area of approximately 1.7 hectares and three main fluvial channels and smaller micro-catchments

- The slope allows the materials to be applicated

- Three main fluvial channels are potential AMD collectors



(Source: Sánchez Donoso et al., 2023. https://doi.org/10.1080/17480930.2023.2247698/)

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Methodology

Materials required: quantity, cost and local availability. Application procedures

- The area of application significantly affects the volume of material used (one square meter with a thickness of 10 cm results in one cubic meter)
- The cost of materials and application activities may increase during the execution of the restoration
- Local supply of materials is limited
- The geometry of the design is conditioned by the application procedure

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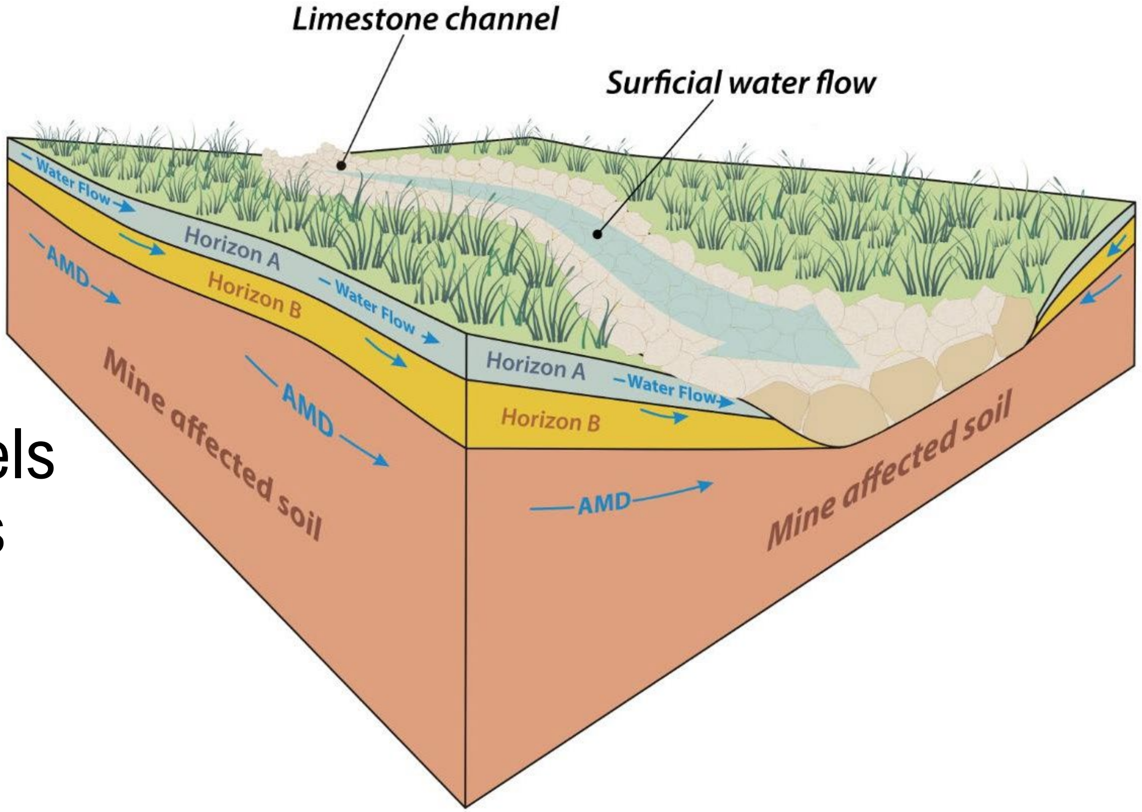
Design and execution

- Based on the construction of a technosoil composed by two horizons:
  - Horizon A, a surface organic horizon
  - Horizon B, a subsurface mineral horizon

- In addition, the main geomorphic channels are configured as neutralization channels



(Source: Sánchez Donoso et al., 2023. https://doi.org/10.1080/17480930.2023.2247698/)

Design and execution

Horizon A, the surface organic horizon :

- 5 -10 cm thickness. 486.67 m^3 total volume
- Homogeneous mixture of poultry and horse manure (220 m^3, 45% of total Horizon A volume), together with topsoil (266.67 m^3, 55% of total Horizon A volume)
- Functions:
  - to provide nutrients and water retention for plants
  - to develop adsorption complexes for metal retention
  - to promote soil structure (erosion protection)

Design and execution

Horizon B, the subsurface mineral horizon :

- 10-15 cm thickness.1866.77 m^3 total volume
- Mixture of clay (<10% smectite; 750 m^3, 40% of total Horizon B volume) and limestone gravel (12/20 mm Ø, 1116.77 m^3, 60% of total Horizon B volume)
- Functions:
  - to serve for pH neutralization and buffer
  - to facilitate subsurface water flow
  - to provide nutrients and water retention for plants
  - to develop adsorption complexes for metal retention
  - to promote soil structure (erosion protection)

Design and execution

Neutralization channels:

- ´A´ to ´Aa+´ type channels (upstream). Design is based in a limestone lining 50 cm wide and 20 cm high
- ´Cb´ type meandering channels (downstream). Design is based in a limestone lining 200 cm wide and 20 cm high
- Functions: to serve for pH neutralization and buffer of DAM of surface concentrated runoff

Construction of neutralization channels

(Source: Sánchez Donoso et al., 2023. https://doi.org/10.1080/17480930.2023.2247698/)

Design and execution

Implementation operations:

- Preparation of soil layer materials using heavy machinery for batch mixing
- Mechanical spreading of the soil material by backhoe and manual labor, where required
- Lining of limestone neutralization channels using both heavy machinery and manual labour

Preparation of soil layer materials

(Source: Sánchez Donoso et al., 2023. https://doi.org/10.1080/17480930.2023.2247698/)

Design and execution

Implementation operations:

- Thickened horizon B where AMD was anticipated
- Thickened horizon A to cope with rain, wind and gravity sedimentation in the headwaters

(Source: Sánchez Donoso et al., 2023. https://doi.org/10.1080/17480930.2023.2247698/)

Remarks

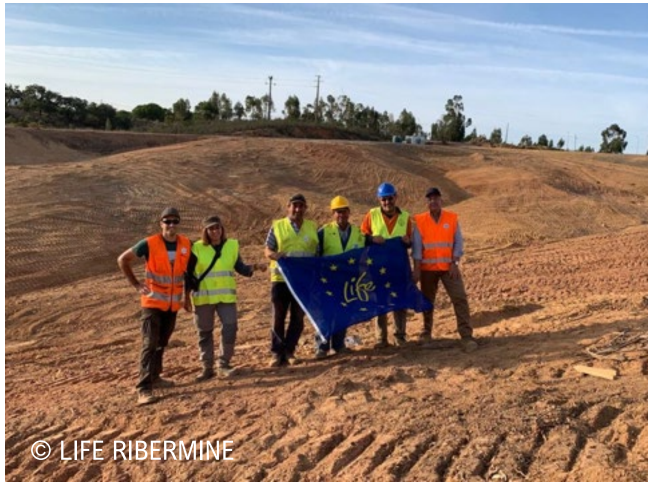
Some challenges:

- The planning and construction of the edaphic cover is subject to ongoing adjustments throughout the execution phase of the project
- Some contingencies are arising from the supply of material
- Heavy rainfall causes some erosion of soil materials during or immediately after execution

(Source: Sánchez Donoso et al., 2023. https://doi.org/10.1080/17480930.2023.2247698/)

Acknowledgments:

- To the team of Centro Ciência Viva do Lousal
- To the Geomorphological Restoration Group at UCM
- To the team of AGS



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