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Best Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries

in accordance with Directive 2006/21/EC

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4.3.2.1.4 Landscaping and geomorphic reclamation

1. Description

Landscaping and geomorphic reclamation are techniques used to recreate the shapes and functionality of the natural landscapes. They are used to reduce the visual impact and emissions to surface water and groundwater, but also to control wind erosion and noise emissions, as the slopes of the extractive waste deposition areas (including EWFs) are reshaped to simulate natural heaps while optimising the extent of re-engineering works.

2. Technical description

This BAT candidate is relevant for ponds, dams and heaps and for excavation voids where extractive waste is placed back.

The landscaping technique may consist of constructing heaps by first creating their outer slope and then transfer ramps and working benches into the heap's inner area. The EWF slopes are then reshaped to simulate a natural landform while optimising the extent of re-engineering works. It may also serve for wind erosion prevention and noise reduction (see Section 4.4.1).

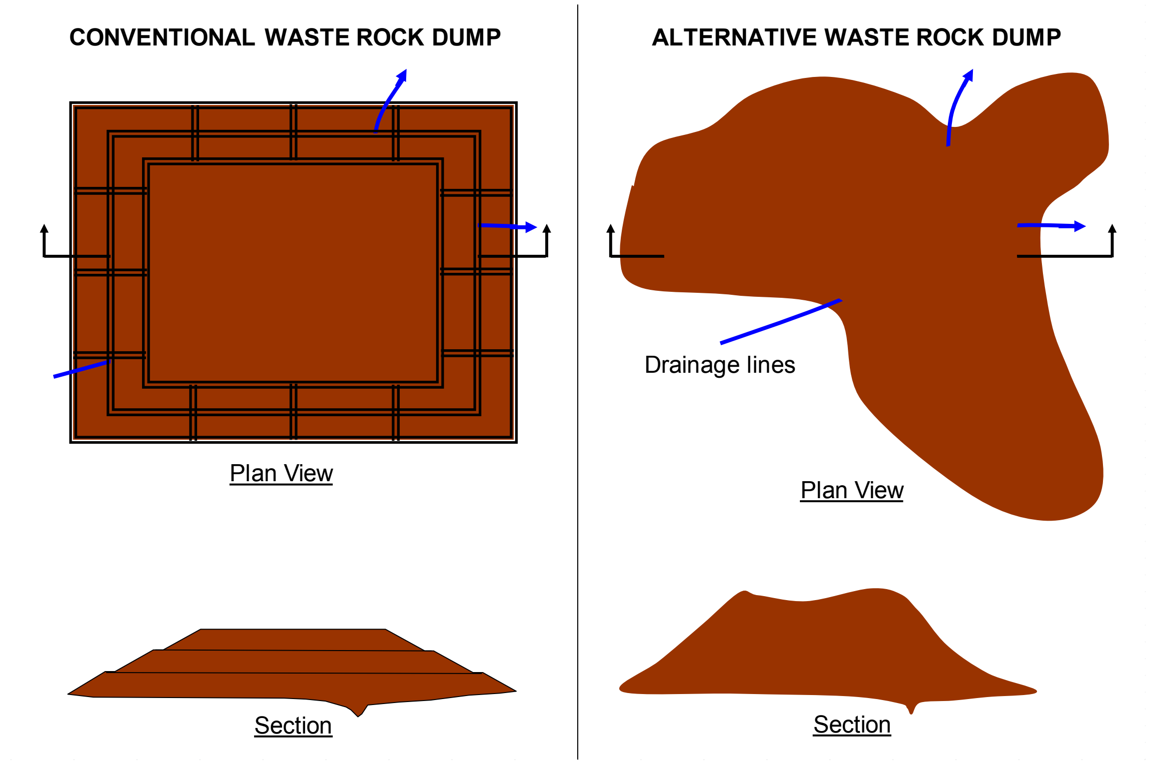
Any landscaping and geomorphic reclamation is designed in such a way that any confining function is not impaired and that short- and long-term geotechnical stability is not reduced (see Section 4.2.1.3.6.1 and Section 4.2.1.3.6.2).

For geomorphic reclamation, excavation and rehabilitation processes are integrated, which offers maximum earth movement savings. Thus, placement of the generated extractive waste is planned to coincide with the geomorphic reclamation landforms, i.e. valleys or ridges, according to the geomorphic design and following progressive rehabilitation. Therefore, a general reclamation landform shape emerges as the excavation process progresses.

Landscaping and geomorphic reclamation are used to reduce the visual impact, but furthermore they increase the physical stability, provide a natural hydrological function, minimise erosion from storm water and snowmelt run-off, provide a natural landform variety that promotes ecological diversity for vegetation and wildlife communities, and minimise construction and short- and long-term maintenance and repair costs.

Landscaping and geomorphic reclamation of a waste-rock deposit is aimed at reconstructing a similar distribution of slope angles and lengths, drainage patterns and density, surface textures and vegetation patterns to those that either existed before the EWF construction or that replicate a suitable shape similar to the local environment. Outside their upper convex shapes, most of the length of natural slope profiles is typically concave, as this is the profile for long slopes with less erosion. If the waste-rock has been deposited in layers with benches between lifts, a concave slope can be readily constructed in the after-closure phase. Final deposit landforms can better match natural landforms if this consideration has been included in the design since the planning phase.

Natural landscapes are a 3D arrangement of drainage networks and convex/concave slopes.
Figure 4.40 shows schematically the contrast between a conventional waste-rock deposit layout and an alternative layout that takes into account the pre-existing drainage lines and natural shapes (Williams 2014).

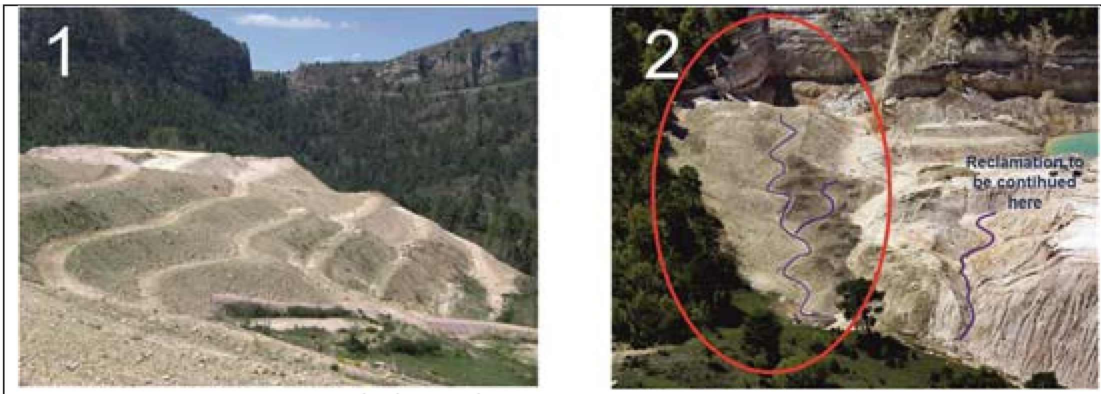


Source: (Williams 2014) with permission of Prof. Williams

Figure 4.40: Scheme of a conventional layout and example of an alternative layout for waste-rock deposit rehabilitation

Specific patented methods of landform design based on fluvial geomorphic concepts as well as soil erosion and landscape evolution models are available worldwide for obtaining an optimum and stable landform design.

Extractive waste heaps reclaimed with this technique can become functional watershed systems like the ones that develop spontaneously in nature. The drainage patterns of undisturbed lands are reproduced. Instead of the uniform terraces and linear slopes, geomorphic landforms provide complex surfaces, with ridges and valleys, and S-shaped slopes. Small drainage paths are created and they converge to natural-looking meandering channels.

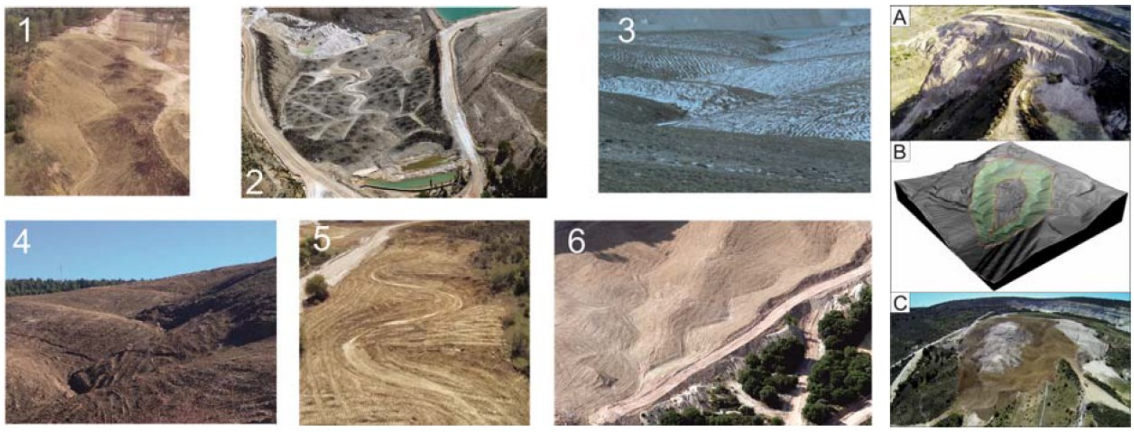


NB: 1 and 2 El Machorro mine, CAOBAR (Spain)
Source: Provided by the TWG

Figure 4.41: (1) Conventional terraced reclamation; (2) Geomorphic reclamation tying into the existing topography of the surroundings

A typical geomorphic reclamation project for stabilising and rehabilitating an EWF includes the following phases:

- locating stable natural landforms in earth materials similar to the extractive waste as field input;
- designing the area with the help of computer tools such as computer-aided design (CAD) software;
- making a geomorphic reclamation model of the site;
- validating the stability and the performance;
- building the designed landforms;
- monitoring the hydrological and erosive-sedimentary production of the geomorphic reclamation.



NB: Left: 1, El Machorro active mine; 2 and 3, María José active mine; 4 and 5, Nuria abandoned mine; 6, Somolinos abandoned mine. Right: Nuria abandoned mine (A, active landslide; B, landform design; C, built reclamation.
Source: Provided by the TWG

Figure 4.42: Geomorphic reclamation carried out by CAOBAR in Spain

Landscaping and geomorphic reclamation are planned in the design phase and are usually implemented in the closure phase.

- *Planning and design phase*
  Planning and design of the landscaping or geomorphic reclamation.
- *Operational (construction, management and maintenance) phase*
  Landscaping and geomorphic reclamation is implemented, while applying management systems.
- *Closure and after-closure phase*
  The technique described in the operational phase is adapted to the specifics of the closure phase and implemented.
  The technique described in the operational phase is adapted to the specifics of the after-closure phase and implemented, for as long as may be necessary, taking into account the nature and duration of the residual risks and hazards.

3. Achieved environmental benefits

- Prevention or minimisation of surface water status deterioration by:
  - preventing or minimising the EWIW generation.
- Prevention or minimisation of groundwater status deterioration and soil pollution by:
  - preventing or reducing the formation of polluted seepage due to inappropriate water collection.
- Helping to ensure the chemical stability of extractive waste by:
  - preventing or minimising the self-ignition of extractive waste.

- Helping to ensure the long-term and short-term physical stability of the extractive waste deposition area (including the EWF) by:
    - minimising soil erosion.
- Prevention or minimisation of air pollution by:
    - preventing or reducing wind erosion and dusting from exposed surfaces of the extractive waste.
- Prevention or minimisation of noise and vibration emissions from the management of extractive waste.
- Prevention or minimisation of visual and footprint impacts from the management of extractive waste by:
    - providing a natural channel morphology that conveys water and sediment discharge in hydrological balance;
    - improving vegetation and habitat values; the landscape designs provide a broader range of post-extraction land use alternatives.

4. Environmental performance and operational data

- At the El Machorro mine, landscaping has been incorporated into the operation plans since 2012. The geomorphic reclamation is carried out as a progressive rehabilitation process in slope or contour mines. After four years, the surfaces are stable in geomorphic terms and maintenance is not needed. The concave shape of the base of the watershed slopes plays a key role in terms of geomorphic stability and promotion of ecosystems development.

An example of the management of the active slag heaps in the Ruhr area is reported in Annex 4.

5. Cross-media effects

- Land availability for extractive waste placement, associated with lowering the average slope angles. Compared with traditional steep slopes, geomorphic reclaimed landscapes may need a larger area (footprint) than cone-shaped heaps.

6. Technical considerations relevant to applicability

- The characteristics of the waste material and specific local conditions, amongst others, have to be taken into account.
- The applicability may be restricted by land availability on existing operational sites.
- The technique is applicable in combination with BAT on structural stability (see Section 4.2.1.3.6.1, Section 4.2.1.3.6.2 and Section 4.2.1.3.6.4), ARD prevention or minimisation (see Section 4.2.2.2.2) and self-ignition prevention or minimisation (see Section 4.2.2.2.3).
- This technique cannot be applied to slurried extractive waste from mineral processing and extractive waste from mineral processing accumulated upstream in dams. It is applicable to dry extractive waste encapsulated with inert materials, provided that the landform regrade does not affect the core of the encapsulated extractive waste.
- Geomorphic reclamation provides physical stabilisation of the extractive waste heaps.
- Geomorphic reclamation needs to be carried out either with GPS-guided machines or by survey stakeout (with differential GPS), whereas conventional approaches do not usually require this.

7. Economics

- High capital costs (CAPEX) are related to the relevant amount of land available. These can be later compensated by savings in maintenance.

- At the El Machorro mine, economic savings of EUR 55 000 per year by applying geomorphic restoration compared to the costs of cleaning and maintaining a settling pond have been estimated.
- According to the information provided in the questionnaire by users of the geomorphic restoration method, cost savings range from revenue-neutral up to 37 % when compared to traditional rehabilitation methods. Most of the economic benefits are derived from the absence of containment structures and the reduction of maintenance operations.