Mediterranean Quarry Rehabilitation Manual

Learning from the Holcim Experience

INTERNATIONAL UNION FOR CONSERVATION OF NATURE

National Council for Scientific Research

AFDC

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Credits

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Table of Contents

List of Figures

List of Tables

List of Acronyms

QRD	Quarry Rehabilitation Directive
IUCN	International Union for Conservation of Nature
ROWA	Regional Office for West Asia
CNRS	National Council for Scientific Research
AFDC	Association for Forest Development and Conservation
AFC	Abou-Chacra and Frangieh Contracting
IDAF	Instituto de Defesa Agropecuária e Florestal do ES
HQS	Holcim Quarry Site
DEM	Digital Elevation Model
BOQ	Bill of Quantities
CSR	Corporate Social Responsibility

I. QUARRY REHABILITATION: AN imPOSSIBLE MISSION

I. Quarry Rehabilitation: an imPOSSIBLE mission

a. Importance and impacts of quarries

Quarrying activities are crucial components of socioeconomic development, as they provide the key material required for building and infrastructure, as well as decent incomes through numerous job opportunities.. However, although these activities constitute an important pillar of economic sustainability, quarrying is a short-term action with long term impacts affecting soil, water, and other natural resources, not to mention the negative.. effects on human health.

Throughout the last decades, Lebanon faced intense quarrying activities resulting in severe degradation of its ecosystems, illustrated by alterations of the vegetation cover, landform modifications and natural resources' depletion (Khater *et al*., 2011a; 2011b). The number of quarries in Lebanon increased from 784 to 1278 between 1989 and 2005, and quarried areas almost doubled since then (Darwish *et al.,* 2011).
A recent study by the National Center for Scientific Research- Lebanon (Delpeuch, 2010) identifies the environmental impacts of quarrying on the environmental, social and economic levels as the:

- Destruction of natural resources and habitats
- Pollution of ground water and surface water
- Soil degradation (erosion and landslides)
- Emission of dust, noise and vibration
- Air pollution
- Landscape alteration
- Degradation of large tracts of productive lands

In Lebanon there are six different types of quarrying operations: rock quarries, sand quarries, mosaic quarries, decorative stone quarries, cement quarries and crushers without quarries (Ministry of environment 2006-1997). Spread across Lebanon, quarrying industries are clustered around selected types of rocks such as marble, limestone, slate or gypsum. Moreover, abandoned or non-operational quarries are widely distributed (Darwish *et al*. 2010). Generally, there are two main reasons behind quarry abandonment: either the quarry has reached the property limits, or it was operating with no license and was consequently shut down by the government..

Lebanon has several environmental laws dating as far back as the 1930s.. lacking implementation, enforcement, clarity and consistency. A number of institutions in Lebanon are directly or indirectly involved in the management of degraded environments. Before 2002, quarries faced political interference and conflict of prerogatives (Delpeuche 2010). The exploitation of more than 700 quarries with little consideration of landscape values has resulted in the degradation of major ecosystems and the subsequent development of a large number of human settlements. In an attempt to regulate quarrying activities, the government ratified several decrees which imposed the signature of a contract between ...the operator of a quarry/crusher and experts (Ministry of the environment, municipalities, engineer or architects) in order to establish a quarterly review of operations. One of the decrees states that no new license will be assigned to quarries unless they previously provide a rehabilitation plan abiding to national and international standards. Other laws charge the quarries with taxes according to the excavated area and period of excavation. Several decrees and acts impose a certain deposit on quarries to pay once they get the permit, to guarantee the rehabilitation process after quarrying. The money is returned back to the operator once a rehabilitation plan is submitted and implemented.

b. Quarries: a promising scar

Quarrying activities trigger the progressive demise of the excavated sites, which slowly degrade causing habitat fragmentation, loss of biodiversity and resources depletion (El-Fadel *et al.,* 2001; Khater *et al.*, 2003; Groom *et al*., 2006). After the completion of excavation activities, if the site is solely left for natural recovery, natural dynamics processes are only able to reinstate the prior prevailing conditions and ecological functions after . a period which might... exceed 25 years (Khater, 2010).

While quarrying activity is a crucial economic activity serving the needs of social and urban development, it has major negative impacts on the environment. Quarries represent extreme cases of degradation characterized by complete removal of vegetation cover and profound landform modifications (Khater & Martin, 2007). Quarrying activities can intensely modify preexisting ecosystems by perturbing the biogeochemical cycles and regimes; altering soil characteristics, landscape patterns and integrity; destroying natural habitats; and interrupting species natural dynamics and genetic flows. By the end of the excavation operations, and in the absence of any rehabilitation, quarries are left to undergo sustained degradation towards increased ecosystem deterioration, surface runoff, accelerated erosion and reduced natural recharge (Atallah *et al*., 2003 ; Darwish *et al*., 2010; Khater, 2010).

In a global trend aiming at sustainable development , quarry rehabilitation is considered a pioneering stepping stone towards the fulfillment of the social, ecological and economic requirements in view of the increased demand on natural resources exploitation. Reconciling ecological concerns and socioeconomic priorities, becomes a challenging task in a complex context of environmental and socioeconomic realities, aiming at mainstreaming science into the design and restoration of degraded ecosystems in a holistic sustainability perspective'.

The overall interest lies in restoring habitats and ecosystem functions in order to develop ecologically sustainable areas (Suding, *et al*. 2004). Restoration is a process which assists the ecosystem to recover to its former state. Yet, a restored ecosystem will not necessarily fully recover, since contemporary constraints and conditions might reorient its evolution along an altered trajectory.

Ecological engineering is an emerging field integrating ecology and engineering concerned with the design, monitoring and construction of ecosystems (Mitsch & Jorgensen, 1989). According to Mitsch (1996) "the design of sustainable ecosystems intends to integrate human society with its natural environment for the benefit of both".

Hence, ecological engineering involves the manipulation of natural material, living organisms and the physical-chemical environment to achieve specific human goals and solve technical problems (SER, 2004).

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER, 2002; Khater, 2010). An ecosystem is considered recovered and restored when it contains sufficient biotic and abiotic resources to continue its development without further assistance or subsidy and it can sustain itselfstructurally and functionally. Furthermore, it must demonstrate and must be ...resilient to normal ranges of environmental stress and disturbance and it will interact with contiguous ecosystems in terms of biotic and abiotic flows and cultural interactions (SER, 2002). Ecological restoration is the practice of restoring ecosystems as performed by practitioners at specific project sites, whereas restoration ecology is the science upon which the practice is based (SER, 2004). Ideally, restoration ecology provides clear concepts, models, methodologies and tools for practitioners to support their practice .

The practice of restoration ecology, when dealing with a degraded ecosystem, offers three ways for accelerating and orienting the natural processes (Khater *et al*., 2011b). Aronson *et al*. (1993), Aronson and Le Floc'h (1995), Martin *et al*. (2002), SER (2002), and Khater and Martin (2007) offer an exhaustive review of these three main concepts' definitions which could be restated as:

1) Restoration: relying on spontaneous natural processes/dynamics and assisting the recovery of the pre-existing ecosystem (closer to what it was before the anthropic disturbance).
2) Reallocation: adopting strong technical measures aiming to orient the future use of the site.
3) Rehabilitation: Assisting the restoration/rehabilitation through the adaption of technical measures to orient natural/ spontaneous succession due to a limitedin time intervention.

Briefly, restoration/rehabilitation initiatives aim at:

- Favoring landscape integration within the surrounding area;
- Targeting site naturality (appearance and functionality);
- Restoring the native vegetation cover;
- Limiting soil erosion;
- Improving biodiversity onsite through habitat creation and management;
- Increasing biomass;
- Serving for educational .and research purposes;
- Minimizing adverse long-term environmental, social and economic impacts after quarry closure;
- Returning land to a beneficial post-quarrying use, balancing environmental, social and economic factors;
- Making the site safe and stable for future land use.

c. Holcim Lebanon: an experimental platform

Complying with its commitment to sustainable development and biodiversity management and abiding by its Quarry Rehabilitation Directive (QRD) issued under its corporate Environmental Policy in 2011, Holcim Group is committed to the effective ... management and rehabilitation of operating quarries, in order to:

- Reintegrate the exhausted parts of a quarry into the surrounding natural landscape;
- Make the site safe and stable for future land use;
- Return land to a beneficial post-quarrying use, balancing environmental, social and economic factors;
- Minimize adverse long-term environmental, social and economic impacts after quarry closure.

In this context, concluding excavation activities in one of its quarry sites in Chekka North Lebanon extending over an area of approximately 5 ha, Holcim Lebanon mandated a team of experts gathered from different institutions to design an ecological restoration scheme for the latter in the frame of a mutual collaboration between Holcim Lebanon and IUCN's regional office for West Asia (ROWA).

This pioneer initiative prioritizes ecological concerns and aims at reinstating, to the highest extent possible, the original ecological characteristics of the site well before quarrying activities took place, with the least possible recurring interventions.

Built on close and long term collaboration between IUCN and Holcim, this project involves several partners: the National Council for Scientific Research (CNRS-L), the Association for Forests Development and Conservation (AFDC) and Abou-Chacra and Frangieh Contracting (AFC). The assigned team consists of experts with different knowledge and backgrounds:

1. IUCN expert: Eng. Mufleh Al Alaween Abbadi

2. CNRS-L experts:
- Carla Khater, PhD (Ecological restoration): CNRS project manager
- Chadi Abdallah, PhD (GIS and Geo-hazards)
- Talal Darwish, PhD (Soil science)
- Rita El Hajj (Ecology: Research Assistant)
- Karine Baz (Graphic design and technical assistance)
- Christine Maksoud (Landscape engineer)
- Ali Alyan and Rawane Alaily (Topographers - as part of their Master thesis)

3. AFDC experts:
- Sawsan Bou Fakhereddine
- Hisham Salman
- Elias Chnais
- Miguel Angel Navarrete (IDAF-Spain)

4. AFC experts:
- Rachid Abou Chacra
- Joe Abou Chacra
- Boulos Frangieh

5. Eco-Med experts:
- Alexandre Cluchier (Ecological engineer)
- Christophe Coton (Ecological restoration)
- Julien Viglione (Ecologist)
- Paolo Varese (Flora and ecological restoration)

This report comes as a third step after a first phase (January 2012 - August 2012) focused on initial assessments (Arab Resources Development, 2003; Alomari and Abbadi, 2012; Chnais and Poyatos, 2012), and a second phase (September 2012 - November 2012) concerned by the design of the rehabilitation scheme (CNRS/AFDC 2012). It covers the last implementation, supervision and documentation stage of the project (May 2013 - April 2014).

Building on the experience of Holcim Lebanon in rehabilitating one of its degraded quarries after excavation activities, this report will provide guidelines for rehabilitation practices in Lebanon and the Mediterranean. It will suggest milestones towards a successful rehabilitation process and discuss the challenges and constraints facing restoration initiatives while highlighting the main elements and lessons learned for future rehabilitation attempts in limestone quarries.

II. THE CHEKKA QUARRY: FOLLOWING HOLCIM LEBANON'S STEPS

II. The Chekka quarry: following Holcim Lebanon's steps

1. The Chekka sketch

The study site is a former active quarry owned by Holcim Lebanon, one of the leading cement companies in Lebanon. Located on the edge of the coastal plain of El Heri in the Caza Batroun (North Lebanon governorate) at the center of Chekka Bay, the quarry lies on the northern foothills of the Chekka formation and extends on one of the Holcim quarry sites spreading over the parcels 625 ,624 ,623 over an area of 4,62 ha. This abandoned and degraded site was made available by Holcim Lebanon for ecological restoration purposes (Figure1).

Figure 1. Geographical location of the Holcim quarry site in Chekka

The site is surrounded by typical Mediterranean scrubland areas and stands at an altitude ranging between 60 and 110 meters above sea level on a slope gradient from south to north ranging from 15 to %20. The HQS is identified as a limestone quarry with the existence of gravel, and represents approximately %10 of the total excavated quarried area in the surrounding region. In 2006, excavation activities were concluded and the site was left to natural dynamics processes. However, uncontrolled grazing activities, as well as climatic and edaphic constraints have limited natural regeneration capacity. In 2009, a rehabilitation initiative within the site was undertaken through the plantation of stone pine stands (Pinus pinea). Yet, due to environmental incompatibility and inability to adapt to the site's abiotic conditions, the planted trees did not grow successfully and the spot was colonized by spontaneous herbaceous vegetation.

This rehabilitation initiative supports Holcim Lebanon's credibility towards the local communities in dealing with the environmental challenges of its activities and commitment to mitigate the impact. Furthermost, this initiative is presented as a pilot project to serve as a model that can be replicated in Lebanon and the region.

Quarrying activities in the HQS have resulted in serious environmental damages. The main site specificities resulting from the accrued excavation misdeeds can be briefly summarized as:

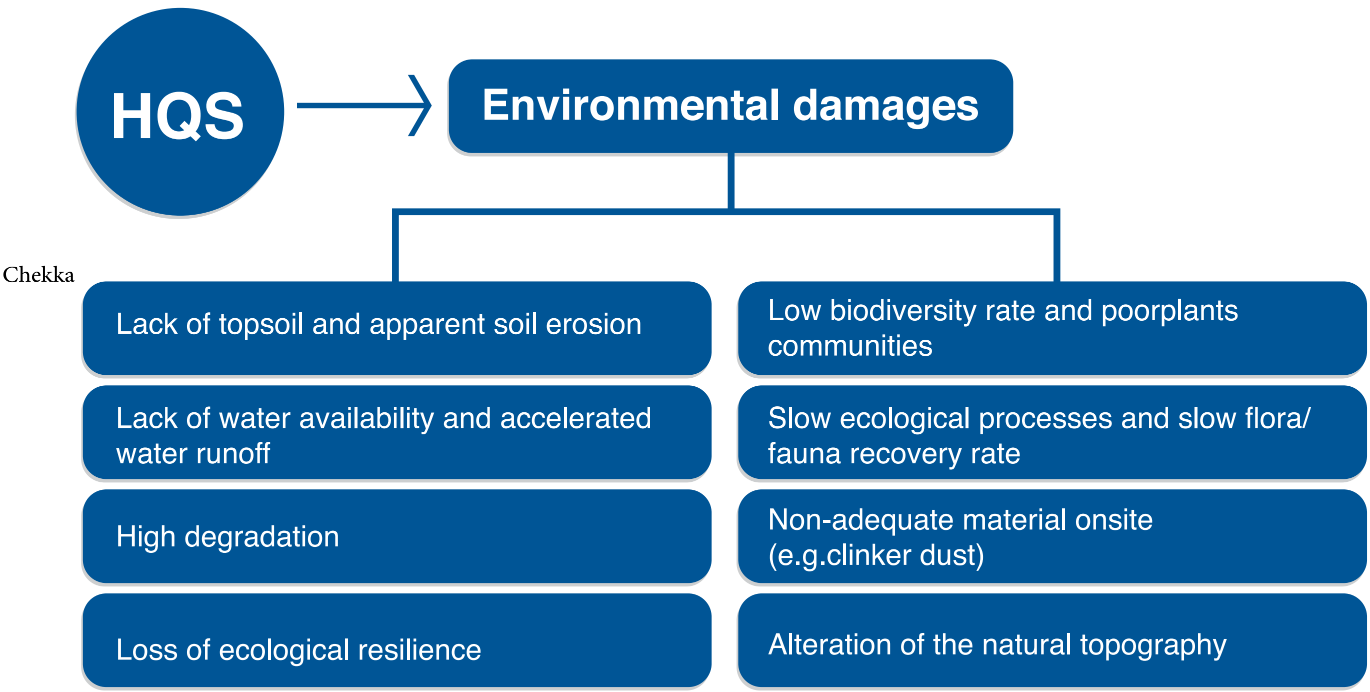

Figure 2. HQS Environmental Damages

2. The rehabilitation process

In view of the current status and the environmental damages it underwent the main objectives of the HQS rehabilitation project were set as following:

- Limit soil erosion and water runoff while reducing water speed through improved water harvesting and increased rainwater infiltration.
- Promote landscape integration within the surrounding zone through the restoration of the natural floristic composition of the area and the use of native flora species.
- Target site naturality (appearance and functionality) to improve biodiversity onsite.
- Restore and keep the site as similar as possible to its natural state by restoring native vegetation cover.
- Serve for educational and research purposes.
- Develop management guidelines and ensure annual monitoring and follow-up.

Set realistic objectives in view of the site's status and environment.

3. From scratch to closure

The HQS rehabilitation process should follow four steps from initiation to monitoring:

- Step 1: Benchmarking: "initiation" phase of the project (baseline surveys);
- Step 2: Rehabilitation scheme conception: "planning" stage of the project;
- Step 3: Implementation: "execution" step of the project along with "supervision and documentation" of the implantation milestones;
- Step 4: Monitoring: "monitoring the rehabilitation" phase of the project.

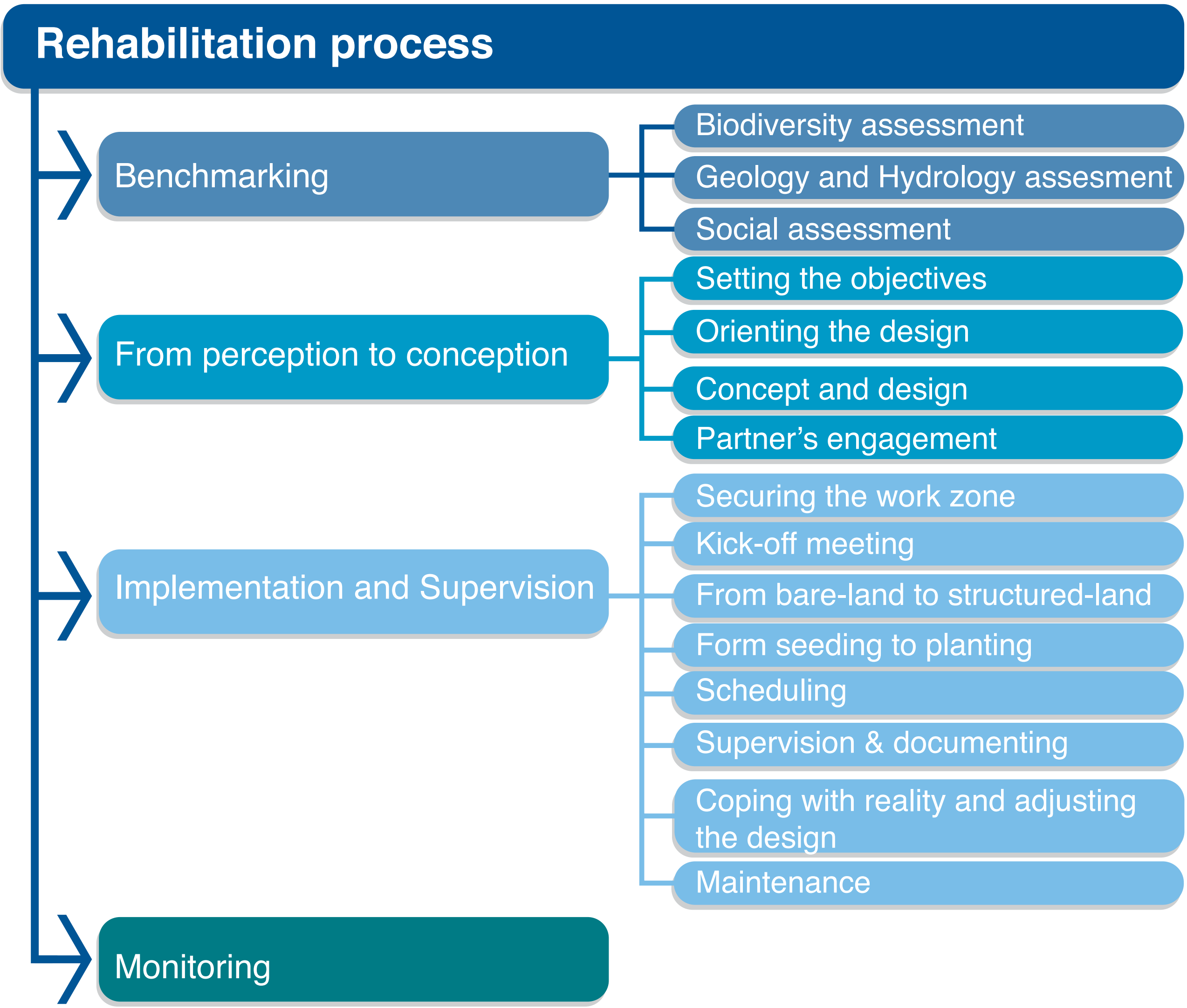

Figure 3. The four key steps from scratch to monitoring

This adopted approach, along with its corresponding milestones, can be easily replicated in comparable sites (characterized by similar conditions to the HQS site) across Lebanon and the Mediterranean.

The following steps are suggested guidelines for practitioners aiming at orienting quarry rehabilitation processes.

a. Step 1: Benchmarking

The project benchmarking is the official launch of the project's design/implementation process. It is based on the identification of the project needs including assessments, expenses, risks, resources allocation, etc. This step is considered an investigation phase through which different systematic observations are carried out to identify the site's potentials which will guide the future phases of rehabilitation.

a.1. Biodiversity assessment

Biodiversity assessment consist of collecting information (inventories) on the fauna and flora species present in a given area.

As confirmed by the IUCN guide to biodiversity released in April 2000 ("Assessing the status and trends of biodiversity is essential for sustainable development strategies at all levels"), performing a biodiversity assessment is one of the main components of a rehabilitation process. It allows the determination of the floristic composition, the abundance and density of the main species, and the diversity of species; it defines the bio-geographical and bio-climatic features of the site; it sets the recommendations for the most suitable species for restoration; and it proposes actions to optimize vegetation reinstatement in the quarry.

Biodiversity assessments performed before excavation activities can serve as reference to orient rehabilitation processes and evaluate their success.

Developing environmental* indicators *based on biodiversity assessment is an essential step towards the initiation of a monitoring plan for the site.

The period of assessment is a key element, as Otherwise, it will be of a limited success.

The optimal periods of biodiversity assessment are usually related to season and climate

A proper biodiversity assessment is usually performed over a period of approximately three to nine months. It may sometimes require a longer time-scale (an entire year or more) to ensure that it covers all the species' life cycles. The period of assessment can be however reduced, in other cases, if sufficient data is available for the site/area.

In Mediterranean environments such as Lebanon, biodiversity assessment is ideally undertaken in Spring (February - April) and/or Fall (September - November).

In the HQS, the biodiversity assessment, including floristic composition, abundance, percent cover, diversity, ecological resilience of the identified plant communities and grazing impacts, was conducted in late Spring (during the period of 2012/5/23-21), (Chnais and Poyatos, 2012). Some of the identified species were Inula viscosa, Calicotome villosa, Sacropoterium spinosum, Onionis pubescens and Capparis spinosa.

Taking into consideration the current state of the quarry and the weak ecosystem dynamics prevailing within its plant communities, several species were proposed for restoration.

As for the fauna, only the red fox, vulpes was recorded during the assessment. No rodents were found onsite due to the complete removal of topsoil. A low number of birds were identified, with the presence of disturbance-resistant birds such as: Falco tinnunculus, Galerida cristata, Prinia gracilis, Oenanthe oenanthe, Corvus cornix, Passer domesticus, Oenanthe hispanica, Oenanthe isabellina, Monticola solitaries (Alomari and Abbadi, 2012) with the exception of disturbance. Turtles such as Testudo terrestris, known to be vulnerable species, were spotted in the direct site surroundings. Finally, Laudakia stellio and Cyrtopodion kotschyi, were the only species of reptiles identified onsite.

a.2. Geology and Hydrology assessments

These assessments aim at identifying the site's geological features including terrain stability, as well as the state of the existing water network/flow (adjacent water courses and streams). Large exposed bedrock with lack of topsoil and fine material and a highly deformed topography are detected.

Geology and Hydrology assessments are crucial for identifying the site's geological features, terrain stability and state water flow.

This area is mainly occupied by the Sannine - Maameltain formation (C5), which is composed of massive gray to white limestone belonging to the Cenomanian Turonian. The Chekka formation (C6) of Senonian formation and the Quaternary formation (Q) can also be found in this area (Arab Resources Development, 2003)

The hydrology assessment revealed that the closest major river is the Jouz River that has related water courses most of which are seasonal and active only during the rainy season. Field surveys showed that the Asfour stream is the major seasonal watercourse in the area. A seasonal "wadi" is present on the north eastern side of the site (Dalton, 2012).

a.3. Social assessment

This assessment aims at identifying the major stakeholders involved in the quarry rehabilitation process, their roles, responsibilities, influence and degree of intervention. Interviews with concerned stakeholders are an important element guiding the concept of a successful rehabilitation scheme.

Stakeholders are the persons directly or indirectly:
- Affected by the quarry activity
- Involved in the exploitation and management of the quarry site
- Benefiting from the rehabilitation of the quarry site

Quarrying activities have a direct impact on surrounding communities. Consultation meetings with neighboring villages will thus highlight their main concerns and assess their opinion regarding the quarried site. This step is of major importance in orienting the quarry rehabilitation design with respect to locals' needs (recreational, touristic, educational or social values anticipated from the project), fears and expectations.

A participatory planning based on consultation meetings with stakeholders is a strategic approach which highlights the main challenges, fears and expectations of communities and other stakeholders involved in the management of the site. It plays a key role in orienting decision making processes.

Taking into consideration the current state of the quarry and the weak ecosystem dynamics prevailing within its plant communities, several species were proposed for restoration.

The Holcim rehabilitation project did not consider the social aspect as part of the assessments, so no social surveys were performed. The decision making processes were exclusively kept to the Holcim representatives as they are the sole owners, investors, and only beneficiaries of the project.

Scientific assessments and baseline surveys are key elements of a successful rehabilitation process. They highlight the main socio-ecological aspects of a given site and therefore enable a better orientation of rehabilitation objectives and schemes.

Table 1 summarizes the key issues of concern encountered onsite based on the survey's results, and highlights the corresponding rehabilitation objectives and recommended actions in view of the site's constraints and specificities. This table was developed upon the review of the flora, fauna and hydrological assessments performed during the first phase of the design.

TABLE 1

Objectives and techniques of the design

Site specificities	Site surroundings specificities	Sensitive key issues onsite	Rehabilitation objectives	Recommended actions
High degradation of quarry site, and loss of ecological resilience, lack of capacity for natural regeneration in short to medium term. Alteration of the natural topography. Lack of topsoil, low biodiversity and slow recovery rate. Partial elimination of the native flora cover. Floristic composition: *Inula viscosa, Calicotome villosa, Sarcopoterium spinosum, Ononis pubescens, Capparis spinosa, Scolymus hispanicus, Lavatera punctata, Echinops viscosus , Spartium junceum, Helichrysum sanguineum, and Micromeria sp.* Little or no soil present due to excavation activities. no rodents found on site since the topsoil is completely removed. Low number of birds. Presence of disturbance resistant birds such as Common Kestrel, Crested Lark, Graceful Warbler, Wheatear, Hooded Crow, House Sparrow, Black-eared Wheatear, Isabelline Wheatear, Blue Rock-Thrush.	Shrubby layers composed of cosmopolitan species belonging to the *Lamiaceae* and *Compositae* families dominate the natural landscape. Dominant species are *Quercus calliprinos, Calycotome villosa, Sarcopoterium spinosum*. Seasonal water availability and mild climatic condition. Improved drainage conditions. Floristic composition: *Inula viscosa, Calicotome villosa, Ononis pubescens, Teucrium polium, Sarcopoterium spinosum, Thymbra spicata, Spartium junceum, Eryngium creticum, Teucrium divarticum, Micromeria sp.* A seasonal "wadi" is present on the north-east side of the site, divided into a lower area and a higher area. The higher area drains a larger, steeper catchment area. The lower area drains a small catchment area, and receives supplemental flow from a channel which joins the "wadi" directly behind the rehabilitation-site. High sediment loads and high pH of the water draining into the soil affecting water reservoirs. Presence of rodents such as Lesser Mole Rat Spalax *ehrinbergi*. Carnivores such as Red Fox, Feral Dogs, Hyena *Hyena hyena*, Wolf Canis lupus, Golden Jackal *Canis aureus*, and the Common Badger Meles *meles exist*.	Slow ecological succession. Few possibilities to store water in soil or natural depressions. Thus, rainfall will either evaporate, run-off, or drain quickly into cracks in the limestone. The natural "wadi" is the main water source. Uncontrolled grazing onsite has an impact on flora cover (over 30%), and perturbation of the fauna life cycle. Turtles *Testudo terrestris* are vulnerable species spotted in the direct site surroundings and potentially present onsite. Possible hunting activities onsite. Poor vegetative cover and high disturbance affected food availability and shelter for birds . Reptiles' preference to rocks like *Laudakia* stellio and *Cyrtopodion kotschyi* are the only species to occur.	Limit soil erosion and reduce water runoff. Promote landscape integration within the surrounding, and icrease site capacity for ecological functionality. Restore and keep the site as close as possible to natural state. Model for restoration in the region. Serve for educational and research purposes. Improve fauna presence and use onsite through habitat creation and management.	1. Improve water availability onsite. 2. Adjust timing, shaping, and sizing of the rehabilitation with respect to fauna and flora life cycles. 3. Substitution of early successional species with later successional species to accelerate ecological succession. 4. Enrichment of mature community species to increase the density of their populations and stabilize the system. 5. Reduce soil introduction to limit risk of ruderal-in vasive species potentially present in the seed bank. 6. Soil can be mixed with organic compost, gravels and rocks to respect site naturality. 7. Privilege, when possible, transport topsoil from neighboring reference ecosystem in the site. 8. Benefit from direct seed sowing and seedling transplants. 9. Plan timing considering rainfall periods and large events, to provide soil moisture for seed germination and natural regeneration. 10. Take into account the wider landscape functions. 11. Suggest long term monitoring scheme based on rapid assessment of key species. 12. Use hard machinery from Holcim in the rehabilita-tion execution. 13. Orient choice of species to be used with respect of existing species. 14. Promote habitat creation for fauna species.

b. Step 2: From perception to conception

Good planning is required to determine in which direction a project is leaning. An interactive planning process draws a clear and concise path which orients the project's activities and provides a clear understanding of the final results, while highlighting milestones and major phases towards the fulfillment of the set objectives.

Several "ingredients" contribute to the success of a project, mainly:

- The team efficiency and dedication;
- The definition of clear and concise objectives;
- The diligence in implementation and pertinent follow-up;
- The flexibility of the implementing party.

Following the identification of the main challenges and constraints related to the HQS through a comprehensive analysis of collected data, objectives' definition becomes a first step towards the identification of the project goals. Once targets are well defined, the search for the answers starts through the conception of schemes and designs adapted to site realities and the expectations of the stakeholders. These schemes are then put into action and concretely implemented, supervised and monitored over a period of time to ensure an optimal long-term achievement of the set objectives.

Project milestones:
- Gather the data (baseline surveys);
- Set the objectives;
- Search for a solution (concept);
- Illustrate with a design;
- Execute and supervise;
- Monitor the project's evolution over a given period of time.

b.1. Objectives

Defining the rehabilitation "objectives" is one of the key components of the project. No matter how wide the ambitions are, setting clear objectives will help guiding the project's activities into tangible results.

The rehabilitation objectives guide the project's activities into tangible results.

Knowing that the HQS site is characterized by serious environmental damages resulting from the excessive excavation activities, the main objectives of the rehabilitation project were set as follow:

a. Re-integrate the quarry in its surrounding landscape.
b. Make the site safe and stable for frequentation.
c. Make the land functional after accrued usage and inquest a balance between environmental, social and economic factors.
d. Reduce the long-term negative impacts on the environmental, social and economic levels.

b.2. Orienting the design

During the design phase of the rehabilitation scheme, aspects related to the season of intervention, the ecological functionalities of the site, the integrated energy design, the landscape context, the site features, the water availability onsite, the choice of plants, the available substrates (rocks, clinker, etc.), the natural dynamic zones, the technical tools to be used, the budget, the project timeline, and the expected technical outputs, should be thoroughly considered in order to achieve a successful rehabilitation plan.

b.2.1. Season of intervention

It is recommended to avoid working during peak nesting and reproduction seasons.

The biodiversity assessment highlighted the major ecological sensitivities of the HQS. In view of the achieved results, rehabilitation activities were planned with respect to the identified species biological cycles. However, as HQS did not exhibit any major ecological sensitive species',before the season of intervention was scheduled before end of summer in order to plan for the plantation process in line with the next rainy season.

b.2.2. Ecological continuities

From an ecological point of view, a site is perceived as a series of corridors and biological reservoirs. The reservoirs are identified as the “non-disturbed” spots still acting as a refuge and/or shelter for biodiversity, whereas corridors are perceived as functional sectors used by species to perform their biological cycles (reproduction, hunting, feeding, movement, etc.)

Once biological reservoirs are identified, the purpose is to orient the design in a way to restore or strengthen their role as refuges or shelters and to enhance their connectivity through the creation or restoration of corridors.

In the case of the HQS, as the site is located in the direct vicinity of the “wadi”, the main ecological concerns are thus focused on this “wadi” as being a temporary water flow system and a permanent biological corridor for species movements and hunting (mainly for birds, reptiles and small mammals).

The biological reservoirs in the HQS were carefully identified in order to preserve existing spots (existing S-structures, spots in the embankments and quarry edges) and to improve their connectivity (creation of new S-structures and water flow canals).

b.2.3. Integrated energy design

An integrated energy design is a method which highly considers energy performance in such a way as to reduce to reduce to the best possible extent the consumption of non-renewable resources and produce minimum negative impacts on the ecosystem’s assets. Such a design is a prerequisite to:

- Achieve optimal implementation performance with low energy consumption;
- Reduce operating costs;
- Lessen negative impact’s on natural resources.

> ***Integrating sustainability into the project will guarantee a long-term lifecycle and promote a better site performance.***

b.2.4. Landscape context

The understanding of prevailing large-scale ecological processes helps orienting rehabilitation design and reintroducing life into the site. Landscape ecological principles aim at integrating a degraded site into its surrounding physical, biological and cultural features, while striving to achieve an original combination of science and art targeting impact mitigation and aesthetic ends.

> ***A rehabilitation scheme has to target the integration of the site with its natural surroundings in order to create a robust environment based on ecologically sound principles.***

b.2.5. Site features

Cliffs are considered as potential microhabitats for wildlife, as they serve as shelters for reproduction, nesting and perching for several fauna (lizards, birds, snacks, spiders, etc.) and flora (lichens and mosses) species. The conservation of cliff areas protects the fragile ecological communities already disturbed by the quarrying activities.

> ***Site heterogeneity induces significant variations in landform which generates unique microhabitats under various conditions (temperature, moisture, wind, light exposure, etc…) promoting microclimate differentiation at a smaller scale, and therefore, higher biodiversity potentialities.***

In the HQS, several cliffs bearing many cervices resulting from the quarrying operations occur. Given their importance in supporting the natural development of plants and animals species, these areas are highly valorized and included throughout the design of the rehabilitation scheme in order to re-establish topographic heterogeneity and target geomorphologic diversities and varied exposures (bench levels, steep cliffs and platforms).

b.2.6. Water availability onsite

The HQS is described as a dry environment as it falls in the thermo-Mediterranean bioclimatic level characterized by four months of cold and very wet winters (with high amounts of precipitation) followed by eight months of very hot and dry summer.

Water availability onsite was proven to be an important factor to be considered during the rehabilitation process. The fair amount of yearly precipitation supports the potential creation of wet areas (ponds) which in turn play an important role as shelters for a large number of animals, insects and plants. On the other hand, the rugged topography of the site supports on another hand a specific water flow that can be pertinently redirected in order to optimize water availability.

Water is an important component to consider in the design of a rehabilitation scheme. The creation of ponds induces several ecological processes while boosting the lifecycle of a large number of fauna and flora species and improving landscape quality and value.

Wet areas encompass several microhabitats (surface habitat, shore habitat, etc.) serving as different niches for diverse fauna and flora communities. Ponds are thus temporary water structures created in order to promote and boost the life cycles of particular species, while improving landscape aesthetics and enhancing the site's ecological functionalities

b.2.7. Choice of plants

The success of plantation operations is strictly related to the choice of species with respect to the concepts of biological integrity, local competitiveness and seed availability and adaptability (Khater *et al*., 2003; Khater and Martin, 2007).

- Why re-vegetating a degraded area?

Vegetation is the best prevention against soil erosion. To re-vegetate holds many benefits such as conserving and enriching native plant communities and improving wildlife habitats. It reduces soil erosion and water loss, and provides shelter and shade while increasing soil fertility.

- What species to select?

As long as an intervention is planned (planting or seeding), the major constraint is to make sure plant species are adapted to the harsh conditions of the site. Hence, it is recommended to select those from the list of species present in reference ecosystems (being either neighboring ecosystems to the site, or similar degraded sites in comparable environments).

The choice of plants species to be used in the restoration scheme should conform to two basic principles: availability and adaptability.

Non-native plants might sometimes act as invasive species (competition with other plants over nutrients and water). The use of native indigenous plants conserves the authenticity of the existing natural environment and contributes to maintaining the unique character of the landscape. Native plants are more resilient and have a better ability to regenerate after disturbance.

- What should be the source of the plants or seeds?

As plant growth follows specific biological cycles, seeds are not readily available throughout the year. The chosen species are meant to replicate a natural Mediterranean coastal ecosystem as common in the quarry area. It would be however impossible to grow all the species occurring within the site's proximity. However, with time, these species will colonize the site again as the soil conditions and the ecosystem functions are restored.

The source of plants can be either from direct seed collection from natural populations or from transplanted plants from stands or cuttings raised in nurseries.

Plant stocks and seeds used for the rehabilitation of a degraded area are rarely available in nurseries. However, local councils and land-care groups run nurseries specialized in indigenous plants and sometimes keep stocks of local plants, or might be able to collect seeds and grow the required plants.

Stands, cuttings or even seeds of native species are not commonly found in nurseries.

The suggested list of species for plantation in the HQS is presented in Table 2.

TABLE (2)

Demographic Make-up of Maan Governorate

Seeds	Seedlings	
Calicotome villosa	Quercus calliprinos	Pistacia palaestina
Salvia triloba	Olea europaea	Pistacia lentiscus
Oreganum syriacum	Ceratonia siliqua	Spartium junceum
Thymbra spicata	Pinus brutia	Thymbra spicata
	Ficus carica	

b.2.8. Creating masses of plants

The variability of a stand's structure is an important factor triggering higher ecological performance of a site. Tree patches feature unique habitats with high rates of species diversity which generate higher small-scale habitat heterogeneity compared to conventional plantation styles (Benayas *et al*., 2008)

Creating a mosaic structure of plants using different shapes and levels and a mixture of deciduous and perennial plants breaks the topography of a degraded site and revives the landscape. Such structures support species diversity, reinstate a variety of microhabitats, and retain the substrate's cohesion and humidity. Irregular mosaics of vegetation patches alternately distributed with barren rocky lands enhance fauna frequentation and biodiversity, especially birds. Ward and Anderson (1988) confirm that in a location where vertical and horizontal vegetation structures are homogeneous, bird species diversity is usually low.

Along the HQS, mosaics of vegetated and non-vegetated patches were created not only through plantations but also through the installation of merlon-like structures (structures composed of rocks, gravels and topsoil). This assortment creates a variety of habitats privileged by a wide number of species. The green patches include a palette of plant species selected from those listed in Table 2.

> ***Green patches with different plants' size and shapes contribute to a wider, hence richer, species composition and microhabitats diversity.***

b.2.9. Rocks

The presence of rocks, stones and boulders highly contributes in breaking the monotonous aspects of a degraded site, while creating safe microhabitats for particular fauna species (such as reptiles).
Different types of stones can be used in rehabilitation activities. However, the perfect choice would target rocks with related value to the local landscape of the site in order to conserve its naturality.

If natural rocks already exist in or around the previously quarried site, their use would bring an added value to the rehabilitation process as the reuse of these "leftovers" would not only valorize their presence onsite, but also contribute to achieving the ecological rehabilitation targets.
The HQS rehabilitation design includes planted merlon-like structures, which would improve the landscape and serve as shelters for plants and animals.

> ***Make use of the onsite aggregates left after the excavation processes!***
> ***Use onsite rocks to conserve site naturality , to reduce costs, and to improve landscape. Rocks are privileged habitats for several fauna species.***

b.2.10. Natural dynamic zones

"Nature tends to grow in complexity and richness by taking advantage of all possibilities allowed by the environment" (Cantore, 1977).

A rehabilitation initiative is not only meant to restore and conserve a degraded site through time-bonded interventions, but is also keen on preserving the ability of nature to evolve at its own pace over time.

Natural dynamics zones serve as "experimental" areas for the study of natural dynamics and successions in degraded sites with no human intervention for restoration. These areas have to be regularly observed and monitored in order to understand nature's potentials and compare (over time) the difference between the results achieved in rehabilitated sectors to those reached in patches where nature was left to evolve on its own.

Hence, aiming to at understanding the natural processes involved in the normal evolution of the landscape, some areas within the HQS were left with no intervention for monitoring and scientific research purposes. These areas will further serve as a reference to determine whether the suggested rehabilitation scheme succeeded in complying with nature's trajectory.

Natural dynamic zones left with no intervention allow the observation and monitoring of nature's evolution and dynamics over time on a degraded site.

b.2.11.Technical tools

Several tools were used to orient the rehabilitation scheme of the HQS: a digital elevation model (DEM), topographic maps and a water flow model.

The DEM thoroughly assesses the topography of the site. It highlights the variability in terrain elevations over a specific area and for exact spatial intervals (2.5m).

The DEM facilitated the production of a rainfall-runoff hydro model, which facilitated the analysis of the site's hydrology in order to better orient water management onsite. Flow direction, flow accumulation and stream networks were assessed through Arc Hydro.

The results exhibited a highly irregular terrain with narrow drainage paths, and detected areas where water is mostly collected.

The DEM study facilitates the development of an in-situ rainfall-runoff hydro model. It gives a clear location of water drainage paths and collection areas.

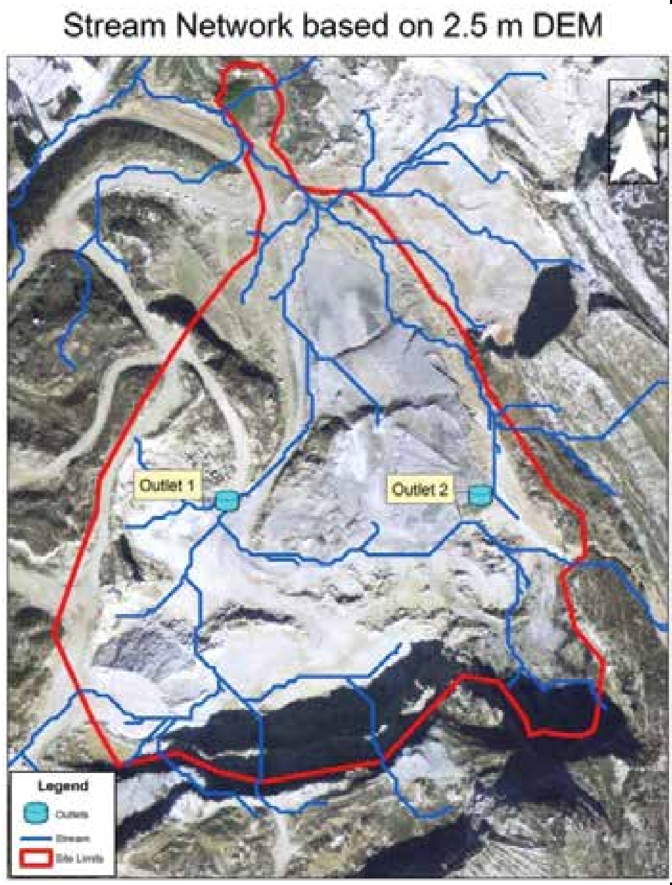

Figure 4. The Stream Network based on the 2.5m DEM along with the location of the two

b.2.12.Project timeline

The project implementation timeline is a schedule which sets for each activity:

- The time for execution;
- The duration for achievement;
- The responsible party for implementation.

The contractor has a fixed time interval to achieve execution. Some tasks cannot be completed until others are finished, while other activities can be accomplished in parallel. Some labor requires the skills of a single individual, while other tasks require the collaboration of several persons to lighten the load.

Progress charts have to be presented by each organization (or partner involved in the project) to display the expected timing/duration of each activity and foresee accordingly the overall approximate period for implementation. These charts present the phases of the project and the sequence in which the associated activities shall be carried out, with an estimate for the extent of time required for each activity. This schedule, also known as "Gantt chart", illustrates the activities which can be executed in parallel to reduce the overall timeline, and those which have to be accomplished sequentially. The schedule should take into consideration the hours during which the employees are available, their vacations, and the company's holidays.

The project should also have a fixed deadline for completion. Once the deliverables satisfy the project's funders, beneficiaries, and end-users, the project is considered achieved. At this stage, post-closure agreements including post-delivery support, warranties, inspections and payments should be carried out.

The key to a successful project implementation is scheduling the priorities and optimizing time use.

Throughout the Holcim experience, schedules were submitted before work initiation (Appendix 1).

b.2.13. Budget and investment

A project has to be set along with a budget which quantitatively reflects the cost of execution. The budget exhibits the expenses or financial liabilities which will allow implementing the related project activities.

The budget thoroughly includes all the financial requirements needed for an optimal achievement of the project's objectives.

Budgeting is a crucial step in the design of a project. It predicts and calculates all the costs related to implementation including labor, material, expertise, field expenses, etc. along specific budget lines.

Throughout the Holcim experience, time and money were invested to achieve quality end results.
Most of the material used for rehabilitation were already found onsite which reduced the expenses related to the purchase of rocks (considering that Holcim is the only funder of this project).
With respect to a budget envelop of 255.000 USD set by Holcim Lebanon, bills of quantity (BOQ) including plantation, labor work (terrain preparation), irrigation, material purchase, removal of existing material, and cost of maintenance and management of the site over two years were developed.

b.2.14. Technical outputs

Many tools are available to facilitate the design of the rehabilitation scheme:

- Sketches: freehand drawings executed to develop and graphically demonstrate a concept. Sketches can be considered as preliminary draft outputs of the rehabilitation schemes.
- Software products: computer programs which illustrate the technical detailed design along with the visual aspects.

The following technical outputs were attained in the process of the quarry restoration design using Autocad, GIS and Photoshop:

Start from scratch then push your concept beyond with technical plans.

- A digital elevation model (DEM);
- A 3D fly-over of the quarry site;
- Technical AutoCAD drawings of the final restoration design and subunits, along with site panoramas.

Set your goals, envision your concept, illustrate with a coherent design with site's specificities, adjust and amend according to site constraints, and end-up with a success story!

<u>b.3. Concept and Design</u>

Rehabilitation design conception is a critical phase which has to abide to a specific method, taking into account all the site features, specificities, constraints, as well as spatial, temporal and human resources challenges related to execution. The concept must respect the predefined goals of the project.

Being the on-site key issue of concern, water availability is considered to be the prime core of the whole new HQS restoration scheme. The concept of the rehabilitation design is defined as: "A Hidden Loop across a Dryland".

"Hidden" for a long period across the year a crucial component triggering natural dynamic processes, water is the primary "loop" of the final suggested design, sustaining long-term ecological dynamics across the quarry site "dry" environment.

This design is oriented towards creating a "water web" inside the quarry site to act as a network to slow down water runoff and temporarily increase its availability onsite. The importance accorded to water availability makes the latter the core intervention of the final adopted restoration scheme. This approach secures a pertinent future ecological reinstatement of the site by owing it with a complex network of water ponds that will support fauna and flora development.

The rehabilitation scheme divides the quarry site into four main subunits: Highland, Cliffland, Coreland and Lowland according to the main concept of the design aiming at creating coherently structured subunits respecting the key principles of ecological restoration and providing a fair space for education and scientific research purposes (Table 3 and Figures 4 and 5).

The rehabilitation scheme divides the quarry site into 4 main subunits: Highland, Cliffland, Coreland and Lowland according to the main concept of the design aiming to create coherently structured subunits respecting the key principles of ecological restoration and providing a fair space for education and scientific research purposes (Table 3 and Figures 4 and 5).

TABLE (3)

Objectives and techniques of the design

Subunit	Objectives	Techniques
Highland	- Break the visual impact of excavation scars. - Increase biomass on the terraces. - Create an adequate habitat attracting small fauna species. - Respect natural dynamics occurring on the head of the quarry wall boasting rock-adapted (rupicolous) flora and faunaspecies, and create a space for research and monitoring purposes.	Consider 2 sections within the terrace: - The first using planted gabions located at 0.5m from the edge of the terrace, while keeping the space behind the latter clear/open for monitoring. In these gabions, place a coconut blanket topped with an approximate volume of 2 m3 of soil. - The second section using unplanted gabions located at 0.5m from the edge of the terrace to retain the backward topsoil which will be added and planted with native shrubs. Add a geotextile behind the non-planted gabions to retain the soil's fine materials.
Cliffland	Create a Mediterranean-type mosaic mesophilic habitat, aiming at: - Creating an adequate habitat for Testudo terrestris. - Enhancing reptiles' presence onsite by creating a mixed formation of rocks and shrubs.	- Cover the area with an irregular layer of topsoil and plant it with native species and shrubs. - Make use of and expand the natural landform as an "impluvium" (catchment basin) to retain soil. - Install internal gabion structures (close and parallel to the existing impluvium) to serve as a second defense line.
Coreland	Create a "water web" throughout the quarry site composed of a network of three ponds aiming at: - Slowing down water run-off. - Guiding water across the site. - Creating temporary water retaining structures providing humidity to the site. - Creating a network of sub-humid habitats in an overall dry environment. - Improving amphibians and insects frequentation. - Boosting overall site visual appearance	- Create 3 ponds by land excavation: • The bulldozer will dig a sloping pond up to 30cm in P1 and P3 and 50cm in P2 opposite to the site's slope. • On the shallow side of the 2nd pond, an overflow at 10cm from surface is planned. The overflow shall pour from P2 into a created 1m width and 30cm depth overflow canal on the western roadside to ensure water evacuation outside the site. • Add a 10cm layer of clay at the bottom of each pond and compact it to ensure water repellency. - Level the terrain towards P2 to avoid water accumulation around the pond and ensure overall water flow towards the pond. - Ensure terrain leveling up to 1m to facilitate smooth water flow across the site. - Create merlon-like-structures planting units (referred as "S structures") (rocks, gravels and topsoil mixed with organic compost) and plant/seed them with a variety of native species. - Add topsoil and install merlon-like-structures around P3.
Lowland	Create a "demonstration" area composed of adapted plant species used in the site's restoration, aiming to serve as "panel" area for the whole quarry site.	- Use the clinker pile available next to the suggested P3 for ground leveling within the low-land. - Build a stone/retaining wall of 100 cm on the northern and eastern sides of the existing clinker in order to retain soil and stabilize the structure, and mount 2 traditional stone walls of 100 cm height within the clinker along with small terraces of 20-25 cm height to improve visual integration. - Install a 20cm bed of gravels on top of the clinker to improve water drainage. - Add approximately 80 cm of topsoil layer. - Plant with the panel of species (trees and shrubs) used in the restoration of the quarry site.

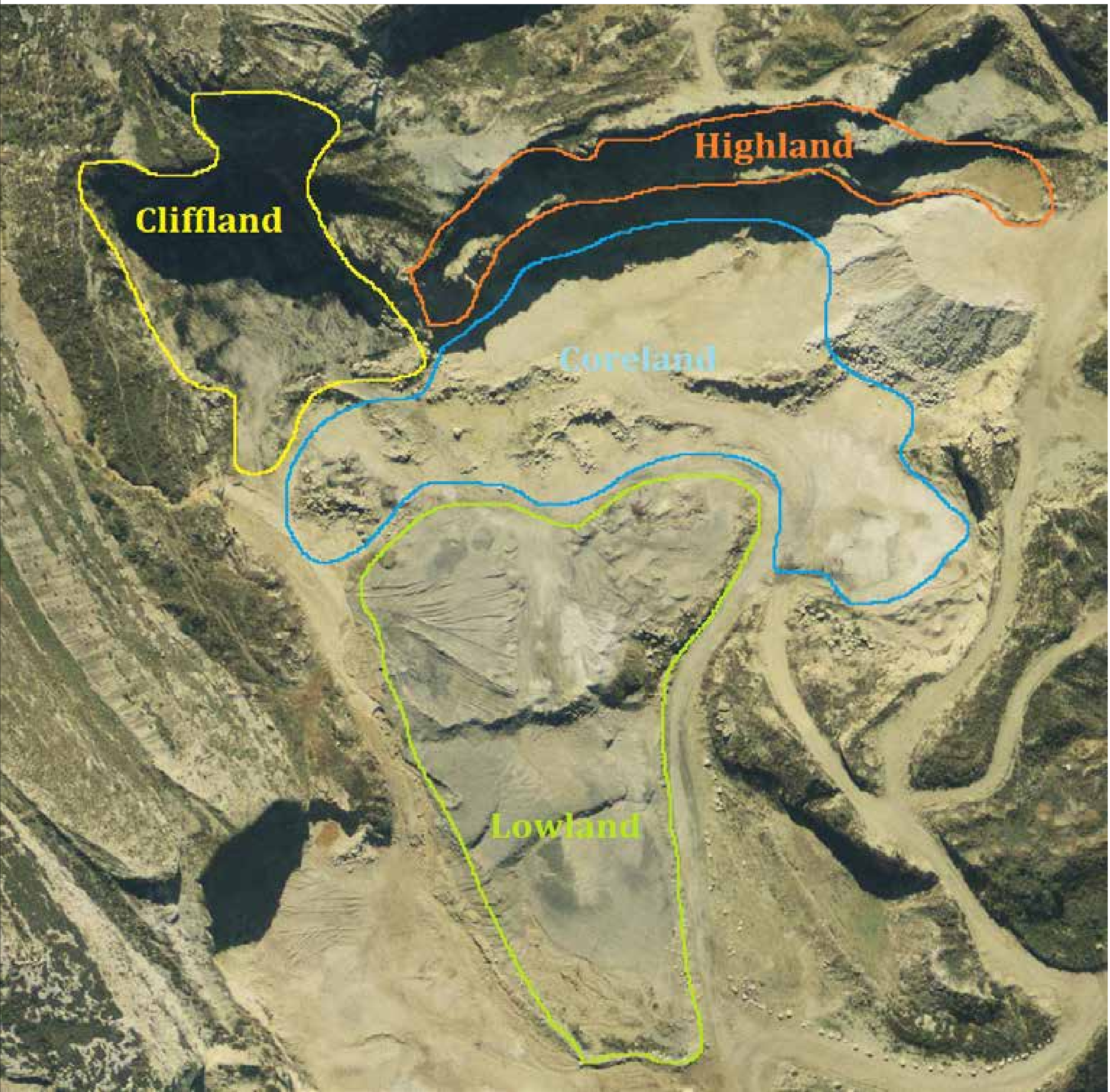

Figure 5. Satellite image of the HQS displaying the four suggested subunits

Figure 6. Initial rehabilitation design of the HQS (before and after site panoramas)
(This design was amended during implementation to cope with unexpected site constraints)

b.4. Partners' engagement

Team work is a key component for a project's success. Choosing the right experts is a major chapter in any given project.

During the Holcim project, a partnership with a group of national experts sharing the same passion and interest in quarry rehabilitation was established. This pool of experts is involved in advising and assisting the team in achieving an optimal rehabilitation design and producing high quality outputs.

Led by Holcim and IUCN and jointly executed by CNRS and AFDC, this HQS rehabilitation initiative has enabled the design of the first restoration scheme for a quarry in Lebanon. This design has been conceived to serve as a pilot example which can be readapted and replicated in other sites in Lebanon and throughout the Mediterranean basin and shall be put at the disposal of the scientific community for future monitoring and research purposes. After setting the objectives, the concept and the design, the implementation was allocated (assigned) among partners so that every party, according to its expertise, takes responsibility of a specific part of the work.

By implementing this project, Holcim would have not only abided by its environmental charter, but also extended its Corporate Social Responsibility (CSR) to include a national NGO (AFDC), an international organization (IUCN) as well as a National Research Center (CNRS).

Take advantage of experts' knowledge and skills. Put the right person in the right place where their performance is at its best!

c. Step 3: Implementation and Supervision

"Execution is the ability to mesh strategy with reality, align people with goals, and achieve the promised results" (Larry Bossidy, 2002)

This step is the heart of the project. It is about shaping the project concepts into visible outputs. Execution of activities is usually assigned to specific agencies (contractors). In the current project, AFC (Abou-Chacra and Frangieh Contracting) was the contractor in charge of implementing the rehabilitation scheme.

Implementation requires planning and structured execution.

c.1. Securing the working area

Site stabilization is a crucial step towards its protection from eventual external disturbances which might affect rehabilitation activities' progress. Therefore, it is highly recommended to establish at a first stage (before activities launching) well-controlled physical boundaries limiting site access during project implementation in order to create a suitable environment in which the rehabilitation activities can be successfully implemented.
The site must be prepared to support a productive environment and the required infrastructure should be ready in place to be used during the implementation.

During the Holcim rehabilitation process, the contractor respected and applied all the security measures related to the site and personnel. Delineating the site perimeter protected it from inadvertently accesses. Fencing was not possible, but a gate helped controlling unauthorized access to the site. Onsite labor force (workers, subcontractors and contractors) was equipped with all compulsory safety/security measures (hard helmets, safety glasses, reflective vests, and safety boots). Emergency and rescue procedures were also planned in case of any accident or injury.

Ready for implementation?
Safety comes first!
Delimit your work zone, use the convenient equipment and signs, and secure your terrain to ensure a safe workspace.

c.2. Kick-off meeting

Before launching site activities, the kick-off session associates all the teams involved in the project execution including the owner of the project, the pool of experts who conceived the rehabilitation design, and the implementation agents. This meeting aims at:

- Agreeing on the project timeline;
- Identifying the expectations and fears of every partner;
- Validating the project's strategies and the involvement of every partner in the implementation process;
- Defining the next steps for work execution (workflow,workplan and deliverables).

Kick-start the project with a meeting to assign responsibilities to the team members and agree on the project's timeline.

c.3. From bare-land to structured-land

The implementation process of the quarry rehabilitation scheme is detailed in Appendix 2, which thoroughly presents the workers involved in the execution of each activity, the duration of work, and the detailed quantities for execution. Appendix 2 served as basis for the analysis provided in this section.

To achieve successful rehabilitation of the HQS, the site requires the installation of a number of structures in order to shape the suggested design and to convert the existing bare-land into a productive structured-land: stone walls, gabions walls, merlon-like structures, open excavated ponds, and topsoil addition.

c.3.1. Stone walls construction

Stone walls are a main component of the HQS rehabilitation design (Figure 6). Their construction consumed a great amount of time and work effort, as walls are generally composed of several parts: foundation, footing, lifts, hearting and stones.

The "foundation" is the surface on which the wall is built (Figure 7). Sometimes walls are built over a bed of crushed stone or a bed of concrete. Walling over the bedrock is one of the best options, as this substrate is the most solid foundation for construction (case of the HQS). In some cases (such as in the third level of the Lowland where clinker dust have greater depth variation) walls were built over a foundation of barren soil surface. This method was adopted to avoid the use of concrete and given that constructed walls were not meant to be large enough to require a solid foundation.

Stone wall construction has been practiced in Chekka-Lebanon and the Mediterranean region for centuries. Calcareous stones are locally available in Holcim Lebanon quarries, which further lowered the implementation expenses. Stone is a hard material which is not affected by decay. Irregular stones were used during the construction to give a random shape for the wall.

While selecting stones, it is recommended to pick those with at least one or more sides roughly angled at °90 to the other sides, as acute or obtuse angled stones are much harder to manipulate and would require extra handwork to adjust sides.

Select the stones which have at least one or more sides roughly angled at °90 to the other sides; otherwise it would require extra handwork to adjust sides.
Careful when scheduling stone walls construction as it is a time consuming task which requires hard labor effort (i.e. 15-12m of stone walls require 9 workers/day if stones are available onsite and are already shaped).

"Footing" is the bottom layer of stones which supports the wall. These rocks are called the foundation stones, since they are usually the largest in the wall. As shown in figure 5, the walls across the quarry site have only one "lift" and are topped with the "cope" which serves to add additional height and capping to the wall. The gaps between face stones are filled with small stones generally called "hearting". A solid structure is built when gaps between rocks are tightly filled with few large hearting stones placed individually and not randomly.

Finally, walls have a batter, which is the angle of the face of the wall. This angle is created by the difference of depth and every wall should have a narrower top than the bottom. The HQS walls are battered by °5 every 1m, as illustrated in figure 8.

Figure 7. Stones used for walls construction

Figure 8. HQS walls features

Figure 9. Angle of the walls' batter

Batter the wall! And reinforce the wall with an angle of °5 every 1m.
Trees and walls don't fit together, roots are free spirited, they don't like boundaries and they push walls away.

c.3.2. Gabion walls construction

Purchasing gabion baskets is better than manufacturing them from scratch as it is a time consuming job which requires a high level of expertise.

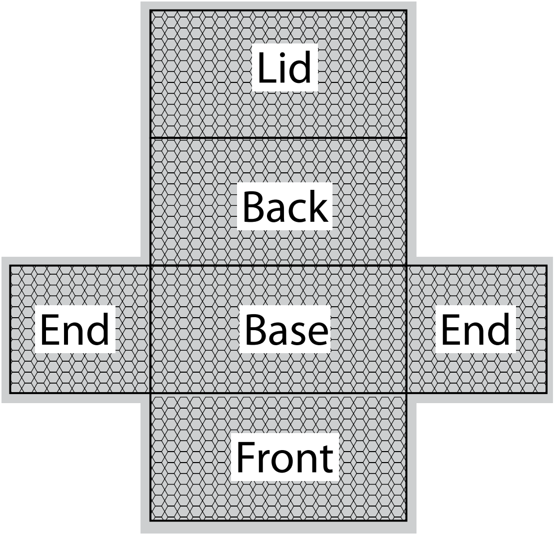

Figure 10 . Gabion basket purchased from the supplier for assembly

Gabion baskets can also serve as tools to stabilize eroded areas as well as planting containers.

To determine the width and height of the gabions to be purchased as well as the number of gabion rows needed, the first step is to measure the area desired to the area which will host the wall. The baskets are available in the market in different sizes and styles and only require onsite assembly (Figure 7).
After leveling and smoothing the foundation with a backhoe, gabions can be installed and basket edges wrapped together with wires to ensure stability.
Stones must be evenly distributed in the basket to minimize voids and provide an aesthetic appearance. Rocks diameters must be bigger than mesh perforations to prevent stones from washing out through wires' mesh.

In the HQS, gabions were used in two sections: the Highland and the Cliffland, and in both cases, baskets had uniform dimensions [1m*2m*1m (length*width*height)]. The use of gabions in the HQS rehabilitation scheme is meant to stabilize the added topsoil and prevent its erosion. As shown by the design, gabions baskets were split into two categories: one where gabions are filled with rocks and backfilled with planted topsoil (in the Cliffland and in a part of the Highland: Figure 8), and one where gabions are filled with topsoil and planted (in a small section of the Highland intended for research purposes to enable the monitoring of natural recovery of the degraded area without human intervention).

An additional coating of the back face of the baskets with geotextile blankets extending for an additional 1 meter under the topsoil allows adequate water drainage and prevents soil erosion.

In planted gabion walls, baskets are tailored to be used as containers filled with rocks and topsoil and planted with small shrubs (Figure 10). The installation of appropriate sized geotextile fabric in the baskets prevents soil percolation and loss through gabion holes. Planted gabions further improve the aesthetic features of the rehabilitated Highland.

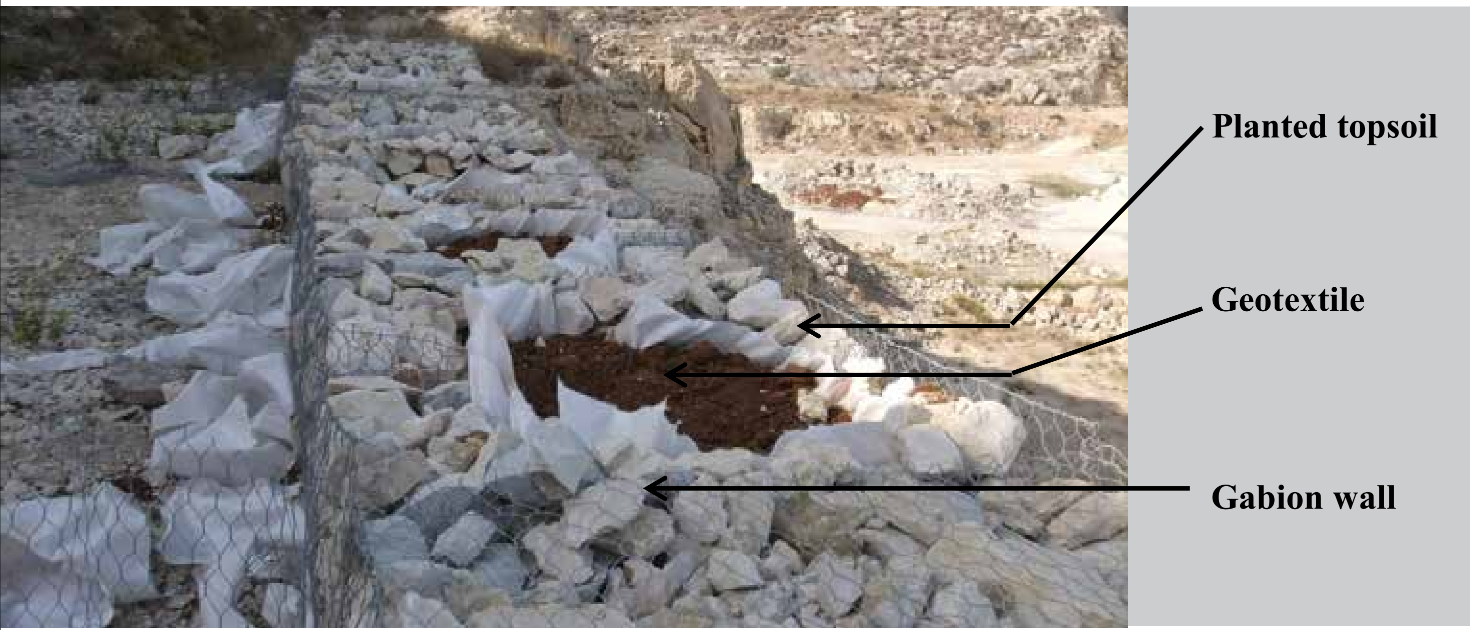

Figure 11. Gabion Wall

c.3.3. Substrate structures and embankment structures

Rocks and rock piles are important structural elements of landscape, as they constitute a privileged habitat for many reptiles, birds and insects species. An embankment structure also called merlon (referred to in the design as impluvium: Figure 11) is a massive elevated rock structure operating as a defensive obstacle that withstands the impacts of sliding rocky masses.

The geometric and functional characteristics of such structures widely varies. In the HQS, an existing impluvium already surrounds the Cliffland area and protects it from soil erosion incidents.

Another form of merlon was introduced in the HQS, referred to in the design as S-structures. Smaller than the existing impluvium (1.5m height and 4-2.5m length), these structures are made of the same types of rocks used in constructed walls disposed in a random but reasonable way (Figure 12).

Figure 12. Existing impluvium structure in the Cliffland

Piles of rocks are useless to humans but are highly valuable for small wild creatures! Keeping these structures is a must! And if not present try introducing some.

The construction of rock piles isn't usually a time consuming task as it can be mechanically performed with an excavator. However, although these structures are easy to compile, it remains crucial to respect the order of their different layers. From inside to outside, the S-structures are made of large rocks overlaid with topsoil and planted with native flora species (to reduce visual impact).

After several visits to the HQS, it was observed that these rock piles were immediately vegetated. Snakes were also detected.

Figure 14. Dust

c.3.4. Open excavated ponds

Excavation work generally implies the removal of soil and/or bare rocks from a site to create an open hole or cavity using tools, machinery and/or explosives. During removal activities, dust should be controlled and kept to a minimum by spraying the area with water (Figure 13).

A wide range of equipment can be used for excavation activities. Choosing the right equipment should take into consideration access restrictions, ground conditions, type and depth of the desired pond and volume of soil/rocks to be excavated.

Ponds in the HQS were created by digging a pit in a nearly leveled area. Long narrow ponds yield more water than square ponds. However, rectangular shapes remain the most convenient for excavation equipment.

According to the water-flow model, the capacity of the HQS ponds doesn't exceed 50cm in depth. Capacity estimations are made to ensure that enough water is stored in the pond to satisfy the intended water uses.
Once excavated, P2 was topped with a layer of compacted clay to improve impermeability and reduce water leakage. Silt can also be used as a substitute of clay to create an impermeable layer.

Based on the results of the water flow model, which highlighted the areas where water mainly collects in the HQS after rain events, three ponds were conceived in the Coreland section to collect rain water and reduce runoff. Different dimensions were required with variable depths according to the outcomes of the water flow model. The ponds took 10 days to be dug and finalized. Located over the bed-rock, P1 was successfully installed and immediately started to collect water (Figure 14). No clay layer was added to P1. P2 formed a mud-hole as the clay aggregated with the substrate beneath. Accordingly, it was relocated to a nearby position on a bed-rock substrate where water indeed collected during a rain event and further enlarged to convey a greater capacity. P3 had to be cancelled and filled with S-structures as it did not collect water.

Figure 15. Water collected in P1 located in front of the Cliffland

Stop water leakage! Add an impermeable clay or silt layer to reduce seepage. Always shape your pond structure to actual water collection capacity.

Topsoil or productive soil, was largely used in the rehabilitation process of the HQS (Figure 15).
In the Lowland, topsoil was added to cover the clinker dust which resulted from previous quarrying activities. In other subunits, topsoil was added to be later planted in order to accelerate natural recovery processes.
As the site was heavily disturbed, no topsoil was available. Hence, soil was extracted from neighboring undisturbed areas and thoroughly analyzed to validate its suitability for plantation (Appendix 3).

Adding topsoil over the toxic quarry waste (clinker dust) of the Lowland promotes a nontoxic environment for plants' growth. Yet, since clinker is a very toxic material, it was recommended to add a thick layer of gravels (20cm depth) before topsoil addition to prevent roots getting in direct contact with clinker. This method was indeed expensive, especially that gravels had to be transported from a long distance.

Compaction ruins the soil and affects rooting and hinders growth.

c.3.6. Compacted soil

Soil structure consists of organic matter, air holes and particles of sand, silt and clay. A good structure is lost by compaction, tillage or erosion. Compaction is the consolidation of the soil by an applied force that destroys the structure, reduces porosity and limits water and air percolation. A compacted soil hinders root penetration and limits areas for seed germination.

Figure 16. Topsoil added in the HQS subunits

Wet clay soils are highly compatible as clay material form water bonds which act as lubricants that bring together the soil particles.

Due to the heavy machinery used on the HQS, the clay soil slightly compacted. Therefore, it was important to improve soil structure through conventional scarifying or plowing of the compacted soil layer in order to create a favorable seedbed for germination. Plowing to a depth of 30-20 cm was enough to break the aggregates and ruts of the upper soil layer and prevent invasive weed development. The chisel plowing method is moderately inexpensive, it consists of raking the soil surface with ripper shanks pulled behind a tractor (Figure 16).

c.3.7. Soil amendment

Results of the topsoil analysis exhibited that all soil samples were composed of heavy clay requiring effective enrichment prior to plantation in order to improve soil fertility and functions, create a suitable environment for plant growth, and reduce alkalinity. Soil amendment was performed through the addition of fertilizers and organic matter (the addition of small stones might help creating a better structure). The added soil mix was made of 0.5kg/m2 of compost along with 340l/100m2 of peat moss.

Figure 17. Plowing and ripping compacted topsoil

Figure 18. Organic compost and peat moss amendments added to the topsoil

c.4. From nursery to site: planting and sowing

Once the site's structural interventions are accomplished, plantation activities can be launched.
This phase concerns the soft, living elements of the implementation which require more care and maintenance until plants are ready-to-be-transplanted as autonomous individuals.

c.4.1. Plant establishment

Collecting and storing seeds

After the flowering period, the matured fruits of plants selected from the surrounding area of the HQS and from the AFDC nursery are collected. Once seeds are extracted, they are placed in the shade to dry then stored in the refrigerator in clean airtight containers or paper bags, labeled with the name of the species and the date. Unlike plastic bags, paper bags allow the moisture to escape from the seed, which lowers the risks of rotting. The cool temperature slows seeds' natural respiration. Storage period differs depending on the species and the quality of the seed.
Seeds must be planted within the next year or within the two to three coming seasons as their germination capacity increases with time. Once germination initiates, young seedlings are very vulnerable to environmental stresses (mainly water, temperature and light availability).

Moisture and warmth are the stored seeds' worst enemies!
Storage period differs depending on the species.

Sowing period is scheduled according to the season with the best germination conditions.

Seedlings

Rooted seedlings or nursery-raised plants can be both used for re-vegetation (Figures 18 and 19). These alternatives are yet more expensive than seed sowing, as well as more time consuming. However, the use of seedlings or plants ensures higher rates of survival. When raised in nurseries, seedlings are relatively under protected conditions. Once established, they are gradually exposed to stress to start adapting the future plants to the tough field conditions. This process is called hardening. Nursery operations must be scheduled before the adequate timing for plantation on field. In the case of the HQS, this period was planned in the rainy season.

In HQS, all species were either planted as seedlings or directly sown as seeds. Seedlings were grown out of seeds collected on site or from mother-plants existing in the AFDC nursery in Ramlieh.

Figure 19. Seedlings grown in the AFDC nursery in Ramliyeh

Figure 20. Plant seedlings

Plant preparation

Quercus calliprinos seeds were collected during autumn 2012 (October) from stands located in Ramlieh prepared in AFDC nursery in winter 2012 (December). They were stored in the chiller without any ventilation for a month and a half. Sowing process initiated in late January 2013 and ended in late February. Pinus brutia seeds were collected and prepared in November 2012. The seeds geographic origin is Nabeh el Safa. Seeds were then stored in the shed for 4 months and sowing process was accomplished during two days in early April 2013.

Ceratonia siliqua, Pistacia palaestina, Spartium junceum, Salvia triloba, Origanum syriacum and Thymbra spicata seeds were collected from areas close to Ramlieh and planted in AFDC's nurseries.
Olea europea, Rhus coriaria, were purchased from several local nurseries.

During the transplanting process, the substrate used in the nursery was cocopeat and peatmoss; a substrate which reduces weeds development risks. Slow fertilizer release was applied for 6 months before sowing to regulate the pH level. Yet in nurseries, fertilizers aren't needed unless they are used to boost the development of the rooting system and foliage.

Plantation

Lack of rain delayed the first phases of the plantation process in the HQS. Plantations were then initiated in December 2013. The entire plantation of a total number of 1533 seedlings took approximately 8 days (6 hours and 5 workers per day) (Appendix 4).

The seedlings plantation followed the steps hereafter:

- All the equipment and plants needed in the plantation process were prepared and made easily reachable to the workers.
- Plantation holes were prepared: 40*40*40cm, 5 liters of peat moss and 15g/plant of slow fertilizer release.
- Added material (peat moss and fertilizer) were then well mixed with soil until the medium is homogenized.
- The seedlings were placed in the plantation holes, which were then filled with soil. The soil must be firm around the seedling to make sure that the roots are fully covered with topsoil.

No mulching was needed during the HQS rehabilitation. Optional additions of mats for weed control and shelters against grazing can be performed. Tall plants such as Olea europea required stacking during the first year (Figures 20 and 21).

Figure 21. Stacking applied for Olea

While planting the HQS minor challenges occurred:

- The Olea europea trees were bought in metal containers, so it was a time consuming process to remove containers before plantation.
- Lack of rain delayed the plantation process which required further irrigation of the already planted seedlings.

After re-vegetating the HQS, reducing weed competition was necessary. Hence, manual plowing was applied once all the plants were established to remove all the weeds around the stand.

A formal launching of the plantation was held in the rehabilitated site in Chekka. The representatives of each partner inaugurated the plantation by planting an *Olea europea* tree and a *Quercus calliprinos* tree in the Lowland section. The ceremony was attended by all the stakeholders. The partners stressed on the fact that collective effort is the key to achieving successful results (Figure 22).

<u>Sowing</u>
As prepared by the AFDC team, team, the seeds were weed free and good quality. Certification guarantees that the seeds have the potential to have a well performance on field.

Complying with the suggestions of the rehabilitation design, seeding was performed in patches not over the whole plots. For each section of the HQS the seed quantity was measured separately in grams, then seeds of all the added species were mixed together with peat moss. The seeded patches were delineated by wood sticks to mark and avoid future plowing. Topsoil was raked before sowing to destroy existing weeds and loosen and soften the compacted surface. Seeds were randomly manually spread over the topsoil, and then lightly covered with soil at a preset depth using a spading fork to insure good soil/seed contact (Figure 23).
Seeds need a moist soil to germinate. Hence, watering is needed in the first few months.

Figure 22. Steps to complete seedlings plantation

Figure 23. Partners' contribution in plantation

Figure 24. Seed spreading onsite

c.5. Supervising and documenting

Supervision is a process which ensures that the work is being accurately executed by the team with respect to the project timeline. The supervision party takes responsibility of following-up on the implementation process and reporting/coordinating with the different partners in case of complications, punctual problems, issues, or risks, where the implementation schedule can be eventually readapted and corrective actions suggested by the different teams.
Documentation consists of a step by step reporting of all undertaken activities' milestones, progress, constraints, etc. Documenting work's evolution along with all the technical details related to actual execution enables all partners to learn from the experience and identify challenges to address in future similar initiatives.

Supervision and documentation help identifying the obstacles affecting the project implementation such as financial constraints, technical limitations, and management difficulties. However, it also highlights partners' commitment and beneficiaries' involvement in the whole process and detects gaps.

Supervision and documentation highlight successes, challenges and lessons to be learned.

c.6. Coping with reality and adjusting the design

After careful planning and designing of the project, unexpected complications can occur during the implementation phase. These types of situations are very common, as one cannot predict unforeseen constraints unless the action is in the execution process. In such cases, flexibility is the answer. Readapting the proposed technical design to cope with reality is the best solution to overcome such circumstances provided that adaptive measures still comply with the overall set objectives and defined concepts. Appropriate alternative interventions (fitting in the defined project budget envelop) can be suggested to address the technical constraints and ensure a successful flow of the project. Readapting the workplan and the previously planned interventions might however affect the implementation process.
During the HQS rehabilitation process, the contractor was flexible enough to abide by all the changes suggested in the design.

Several changes were made to the original design:

Unexpected technical complications occur! Coping with reality and readapting the design is the only way out. It's all about being flexible and creative! After all, restoration is the art of the possible…

- The walls of the Lowland section were adapted to the existing topography. Four walls amongst which one was double leveled were thus built instead of three. This adjustment was made due to the instability of the clinker dust deposited over this area. Between the two additional walls a small road was left for small trucks to access the area (Figure 24).

- Few adjustments were done in the Highland section which was initially devided into two parts: one with unplanted gabions and another with planted gabions. The adjustment was made between these two sections due to a leveling problem, as a deep sector was left as a physical split between the two parts. This amendment resulted in the use of a reduced number of gabion baskets and the additional construction of a stone wall and another gabion wall to close both sections and avoid substrate loss (Figure 25).

- The Coreland adjustment was based on a trial and error experiment. The first rain events were considered as the base of the changes made to this section.

* Pond (P3) did not succeed to collect rain water. Therefore, partners decided to cover this pond with S-structures.
* Pond (P2) collected rain water but it had impermeability problems. P2 formed a mud-hole as the clay aggregated with the substrate beneath. Accordingly, it was relocated to a nearby position on a bed-rock substrate where water was collected during a rain event and further enlarged to convey a greater capacity.

- The last changes tackled plantations. As presented before, the recommended method of plantation was the creation of patches with masses of plants. However, during execution, workers only created unequally linear aspects with the vegetation (Figure 26).

Figure 25. Lowland adjustment, double wall constructed over two levels

Figure 26. Gap in Highland section

Figure 27. Plantation pattern in the Lowland

c.7. Maintenance

Maintenance operations promote maximum performance of the site and increase the chances of its endurance. They include frequent routine actions which ensure the proper establishment of the project elements in order to prevent eventual failures. This activity, through which broken material is replaced, adjusted or repaired to save its intended functional conditions, tests the sustainability of the project's units.

Maintenance operations promote maximum performance of the site and increase the chances of its endurance. They include frequent routine actions which ensure the proper establishment of the project elements in order to prevent eventual failures. This activity, through which broken materials are replaced, adjusted or repaired to save their intended functional conditions, tests the sustainability of the project's units.

Two main types of maintenance can be performed: preventive maintenance (which prevents the failure of equipment); and corrective maintenance (when equipment fails and requires elimination and replacement).

A successful project doesn't happen by itself, it needs dedication, motivation, perseverance and maintenance.

d. Step 4: Monitoring the rehabilitation

Monitoring activities consist of the systematic collection of data enabling the follow-up of the restoration progress according to the targeted criteria and the performance standards which indicate that ecological objectives were achieved. Collected data over a minimum period of 5 to 20 years are parameters used to provide general indicators which support assessing the evolution of the landscape, the ecosystems, the communities, the populations and the species. These criteria help in understanding the ongoing dynamics, determine whether the system is able to autonomously sustain and self-regulate itself, and suggest remedial actions in case dynamics showed regressive trajectories directing the site away from the conceived rehabilitation scheme.

Hence, evaluating the success of the restoration operations should be taken into account at every stage of the development through the definition of standards and indicators of success such as the presence of certain species or the reinstatement of particular processes.

Projects don't have a middle or an end anymore, they only have a beginning that never stops beginning..

d.1. Fauna indicators

Fauna surveys assess the number and types of species frequenting the site after rehabilitation.
Comparing these surveys to those performed before the rehabilitation processes took place, highlights the impact of restoration interventions in reinstating life into the site through the creation of privileged environments and microhabitats for species.

Fauna indicators include among other the detection of:

* Carnivores: the only carnivorous species observed is the red fox (Vulpes vulpes) and other carnivore species were reported by the locals. Monitoring programs will inspect whether the population of this species is increasing and will also determine if individuals are frequenting the site as it matures and heals.
* Rodents: which can highly benefit from the upper soil layers of the added topsoil in the various parts of the quarry. Close monitoring and detection of the lesser mole rat specie (Spalax ehrinbergi) can be a strong evidence of site's healing as this species used to exist onsite prior to quarrying activities.
* Birds: monitoring should take into consideration bird species frequenting the site, especially those using it for breeding or nesting as the site matures.
* Reptiles: species benefiting from the ecological restoration will use the soil, rocks, and brush cover as habitats. Their presence onsite is a good indicator of rehabilitation success.

d.2. Flora indicators

Few indicators can be suggested to assess the flora status onsite after rehabilitation:

* Canopy cover: it is an indirect indicator to be evaluated after 6 ,3 and 10 years (if possible) to assess the success of the vegetation cover establishment.
* Floristic composition: assess after 6 ,3 and 10 years (if possible) the evolution of species composition while comparing the floristic composition onsite to that of the surrounding environment in order to determine whether the restoration model was properly designed. This indicator highlights the populations' progression, regression or stability, and assesses species loss in the quarry.
* Vertical and horizontal vegetation structure: assessment of the vegetation structure during the first 10 years after the restoration: vertically (herbaceous strata, shrubs and trees) and horizontally (between plants groups in the site). This criterion highlights the diversity of established habitats for fauna in the restored quarry.
* Landscape integration with surrounding areas.
* Representativeness: assess whether the established vegetation is comparable to the mature ecosystems in surrounding areas.

Monitoring activities will also highlight the need to replace plants in case of low survival rates of planted species. Therefore, plants will be closely monitored during the first couple of months to avoid water stress and suggest supplemental irrigation if deemed needed.

d.3. Hydrology indicators

Monitoring the functioning of the site's hydrological regime and the characteristics of the hydro-morphological processes established after the restoration is an important aspect to address in the HQS. In this regard, a couple of criteria/indicators can be assessed:

* Status of the natural and artificial drainage network;
* Ecological connection/sealing/functioning of the ponds;
* Stream profile: monitoring the modifications in the stream and its aquatic integrity in the surrounding area;
* Water quality: monitoring this factor by collecting water samples and focusing on chemical (oxygen, nutrients and metals) and physical parameters (pH and temperature) of the integrated ponds is a must. Hydrology monitoring programs can also identify the source of pollution if present;
* Aquatic habitat quality: habitat evaluation determines the potential of the ponds to sustain aquatically healthy systems, and might include the identification of factors which affect or improve the establishment of the aquatic biodiversity (sediment embedment, water stability, riparian habitats, etc.).

III. CONCLUSION AND LESSONS LEARNED

III. Conclusion and Lessons learned

One of the pioneer initiatives in Lebanon and the Mediterranean, the Holcim experience has proven the success of adopting a scientific-based approach for quarry rehabilitation, integrating both social and ecological aspects. Throughout the rehabilitation process, several challenges and constraints were confronted. Coping with these realities is a must to achieve a successful rehabilitation scheme.

Many lessons arise from this experience. Learning from these lessons will definitely facilitate the orientation for future similar rehabilitation initiatives in Lebanon and the Mediterranean.

- ✓ The main purpose of a rehabilitation process is to reduce the gap between what existed before the perturbation (initial state) and the post-rehabilitation status. It is mandatory to either perform exhaustive biodiversity assessments before any activity is planned on a site or (in case this is impossible), to perform these assessments in neighboring similar ecosystems.
- ✓ It is important to consider any restoration intervention as a “medical transplant” on a degraded ecosystem. The main challenge resides in succeeding at integrating this transplant. They key to success is to therefore identify, within the biodiversity assessments, key species to serve as indicator targets for the restoration. The more key indicator species to orient the rehabilitation design the more the chances of success are.
- ✓ The key step to ensure the achievement of a self-sustained restored ecosystem supporting clear onsite ecological functions and efficiently connected to neighboring ecosystems is to escort the rehabilitation process far beyond the intervention period. Clear successful results can only be observed after 4 to 5 years in Mediterranean environment, and monitoring this progress is a key component of evaluating the success.
- ✓ Keeping an emergency budget in the planning in order to be able to adapt to sudden difficulties is crucial.
- ✓ Flexibility in implementation is key to success. Nothing is perfect. Sometimes, actual onsite rehabilitation might not achieve to execute the conceived design per se. Being flexible and creative helps better adapting/coping with constraints.
- ✓ Setting clear and concise objectives and goals from the beginning of the project, respecting the project timeline and in case of complications, adapting to reality while always considering time priorities are basic elements to achieve a successful implementation.
- ✓ Team collaboration, dedication and constant follow-up are key to efficient achievements.

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APPENDIX 1: IMPLEMENTATION SCHEDULE

This workplan displays the dates of the field visits performed by the three partners to the HQS

		CNRS		AFDC		IUCN
Activity	Sub-activity	Date of the visit		Report	Report	
Mobilization and Site Preparation	1. Site visit and safety kickoff meeting			First week of March		
	2. Delimitate overall site boundaries					
	4. Install access and safety signage					
	5. Define and delimitate work sub-zones	7-May				7-May
	6. Mobilize needed equipment					
	7. Prepare internal access roads				30-May	
	8. Prepare stock areas					
	9. Remove any obstacles from work areas					
Low-land	1. Level the base of the 3 stone walls	20-May				
	2. Construct of the 1st wall					
	3. Construct of the 2nd wall					
	4. Construction of the 3rd wall	10-Jun				
	5. Place a 20cm layer of gravel		11-Jun			
	6. Place 80cm + 100cm layer of topsoil+strip of rocks					14-Jun
Core-land	1. Establish ponds	8-Jul				
	2. Place 10cm layer of clay + compaction					
	3. Ensure waterflows as per design	19-Jul				
	4. Establish connecting canals	21-Jul	23-Jul			25-Jul
	5. Add topsoil around pond					
	6. Construct merlon-like structures	4-Aug				
Cliff-land	1. Level the base for the gabion baskets					
	2. Establish impluvium like aspect of the landform	16-Aug				
	3. Construct Gabion walls	22-Aug	3-Sep			5-Sep
	4. Add topsoil behind Gabions					
Highland	1. Level the base for the gabion baskets					
	2. Construct planted gabion wall	23-Sep				
	3. Construct unplanted gabion wall	29-Sep				
	4. Place geotextile and topsoil behind unplanted gabions		15-Oct			

Activity	Description					
Site visit	Pre-planting site visit assessment			15 -Oct.		
Planting	Soil preparation					
	Planting of subunits:					
	· Low-land					
	· Core-land					
	· High-land	7-Nov				
	· Cliff-land				30-Oct	
	· Rest-land	12-Nov	26-Nov			28 - nov.
	Planting and species distribution per subunit will be done according to the already agreed upon design.		7-Jan	1-14 Nov.	30-Nov.	
Maintenance visit	Maintenance visit for weeding and inspection of growth	First week of March 2014	18-Mar	First week of March		20-May
Maintenance visit	Maintenance visit for growth and mortality inspection. This visit is weather dependent, i.e. if rain stopped early in the season, the visit will be scheduled earlier	Late April 2014	1 April - 13 May 2014	Mid June	30-Jun	17-May
Maintenance visit	Maintenance visit for growth and mortality inspection	Mid June	24-Jun			

APPENDIX 2: TECHNICAL IMPLEMENTATION SHEET (HARD WORK)

List of Subsection	Subunits	Dimension						Materiel		Equipment and Machinery	Schedule					
		As per design			As per execution			As per design	As per execution		Provided		Effective	Worker title	Nb. of workers	Effort / worker
		Height	Length	Depth	Height	Length	Depth				Start	End	period			
Site Preparation	Site visit										1-May	2-May				
	Delineate the site boundaries										3-May	4-May	2 days	1 Topographer 1 Worker	2 workers	1. 1st day : reference points (30 minutes) 2. 2nd day : locating the points onsite
	Install signage				0.8	0.3	0.9			Pick-up	5-May	6-May	2 days	3 Workers	3 workers	5 signs/day
	Delineate work subzone															
	Mobilization of equipment (Prefab offices + Furn + electricity, etc.)								2 prefab offices + furniture +water tank + generator+ light tower	Truck, crane and wheel loader	10-May	13-May	4days	1 Electrician 1 Plumber 3 Workers 1 Site engineer	6 workers	1 bought and second existed +Electric connection
	Access road preparation									Loader	12-May	13-May	2 days	Eng + 2 workers	3 workers	Loader work
	Preparation of stock areas									Loader	14-May	15-May	2 days	1 driver 1 worker	2 workers	Loader work
	Removal of obstacles									Loader + Truck	16-May	17-May	1 day	Eng + worker	2 workers	Loader + truck

Lowland	Level the base of the 3 walls									Excavator	18-May	23-May	5 days	1 Driver 1 worker	2 workers	
	Rocks needed for construction	165 m3			270 m3				Rocks							
	Construction of 1st wall	1.25 m	300 m	0.45 m	1 m	300 m	0.80 m	Rock Stone		Excavator + Truck + Loader	24-May	3-Jun	9-10 days	3 Masons Teams	18 workers	30-35 m / day
	Construction of 2nd wall	1.25 m	72 m	0.45 m	1.25 m	72 m	0.60 m	Rock Stone		Excavator + Truck + Loader	4-Jun	9-Jun	5-6 days	2 Masons Teams	9 workers	12-15 m / day
	Construction of 3d wall	1.25 m	112 m	0.45 m	2 m	112 m	0.75 m	Rock Stone		Excavator + Truck + Loader	10-Jun	15-Jun	5-6 days	3 Masons Teams	18 workers	20-25 m / day
	Construction of 4th wall				2 m	112 m	0.75 m	Rock Stone		Excavator + Truck + Loader	10-Jun	15-Jun	5-6 days	3 Masons Teams	18 workers	20-25 m / day
	Construction of 5th wall				2.2 m	112 m	0.75 m	Rock Stone		Excavator + Truck + Loader	10-Jun	15-Jun	5-6 days	3 Masons Teams	18 workers	20-25 m / day
	Construction of 6th wall				0.80 m	85 m	0.75 m	Rock Stone		Excavator + Truck + Loader	15-Sep	20-Sep	5-6 days	2 Masons Teams	9 workers	12-15 m / day
	Place gravel layer	1381 m3		0.2 m	1826 m3		0.2m		Crushed limestone	Loader, Truck, Crusher, Grader	16-Jun	21-Jun	5-6 days	2 Drivers 1 Worker	3 workers	12 - 15 trucks / day
	Place topsoil and strip of rocks	8351.7 m3		0.8 m	9470 m3			Calcisol + Organic matter	Clay soil + amendments	Trucks, Loader	22-Jun	30-Jul	35 - 40 days	3 Drivers 2 workers	5 workers	12-15 trucks / day

Core-land	Ponds deliniation										1-May	2-May	1 day	Topographer	1 worker	
	Pond 1		35 m	0.5 m	5	7	0.6			Excavator+Truck +Loader	8-Jul	15-Jul	7 days	1 driver 1 worker	2 workers	
	Pond 2		62 m	0.5 m	6	6	0.5			Excavator+Truck +Loader	8-Jul	15-Jul	7 days	1 driver 1 worker	2 workers	
	Pond 3		35 m		9	5	0.4			Excavator+Truck +Loader	8-Jul	15-Jul	7 days	1 driver 1 worker	2 workers	
	Place imperme-able layer + compaction			0.1 m					Clay	Compactor	16-Jul	18-Jul	3 days		4 workers	
	Ensure waterflows as per design										19-Jul	20-Jul				
	Establish connecting Cannals	95 m	1 m	0.1 m	75	1	0.25			Excavator	21-Jul	28-Jul	8 days	1 Driver	1 worker	
	Add topsoil around pond	1785 m3			1834 m3			Calcisol + Organic matter	Calcisol + Organic matter	Trucks + Loader	29-Jul	3-Aug	7 days	2 Drivers + 1 worker	3 workers	
	Construct merlon-like structures							Rocks (195m3) + Gravel (39m3) Calcisol (143m3) and organic matter (15.6kg)		Small Loader/ JCB	4-Aug	11-Aug	7 - 8 days	3 Drivers + 3 worker	6 workers	

Cliff-Land	Level the base for gabion basket									Small Loader/ JCB	12-Aug	15-Aug	3 -4 days	1 Driver	1 worker	
	Impluvium structure									Small Loader/ JCB	16-Aug	21-Aug	4- 5 days	1 Driver	1 worker	
	Place the gabion Walls	1 m	82 m	2 m	1	89	2	Metal structure + Rocks	Gabion structure + limestone rocks	Truck + loader	22-Aug	6-Sep	14 - 15 days	3 Drivers + 3 worker	5-6 worker / day	5-6 Gabion / day
	Merlon like structures construction	1.5 m	4 m		existing	exist- ing	existing	Rocks (195 m3) + Gravel (39 m3) Calcisol (143 m3) and organic matter (15.6 kg)	Rocks + Gravel + Clay soil + amendment	Loader			existing			Clean ups only
	Topsoil behind Gabions	5.460 m3			5560 m3			Calcisol and organic matter	Clay soil + amendments	Loader	7-Sep	2-Oct	25 - 27 days	3 Drivers 3 workers	6 workers	10-12 trucks / day
HighLand	Base of Gabion Baskets leveling									Small Loader/ JCB	25-Aug	28-Aug	3 -4 days	1 Driver	1 worker	
	Planted Gabion Wall	1 m	82 m	2 m	1	18	2			Loader	29-Aug	4-Sep	4- 5 days	7 workers	7 workers	3-4 Gabions / day
	Unplanted Gabion Wall	1 m	82 m	2 m	1	165	2			Loader	5-Sep	1-Oct	25 - 27 days	7 workers	7 workers	5-6 Gabions / day
	Topsoil in the planted Gabions	2 m3			4 m3					Manual	2-Oct	4-Oct	2 days	5 workers	5 workers	
	Coconut blancket	2.8 m	1.4 m		2.8 m	1.4 m				Manual	5-Oct	6-Oct	1 days	4 workers	4 workers	
	Geotextile behind unplanted gabions	3.6 m			1 m	165 m				Manual	7-Oct	9-Oct	2 days	2 workers	2 workers	70 - 80 m / day
	Topsoil behind unplanted gabions	2346.75 m3			2125 m3			Calcisol and organic matter	Clay soil + amendments	Loader	10-Oct	30-Oct	20 days	1 Driver 1 worker	2 workers	4-5 trucks / day
RestLand	Cover the housing facility with rocks							Rocks								
	Toilets implementation	2.11 m	1.15 m					Rocks + concrete								
	Banches	0.6 m	2 m	0.5 m				Concrete								

Appendix 3: Topsoil analysis

الجمهورية اللبنانية
وزارة الزراعية
مصلحة الأبحاث العلمية الزراعية
مختبر تل العمارة

شهادة تحليل تربة

المرسل : AF comtructing قبلان فرنجية	مختبر التربة والمياة تل عمارة
العنوان : شكا	
الزراعة : فحص روتيني	

رقم العينة كما وزد		حفرية السويف	القيم المرغوب حسب قوام التربة وحاجة الزراعة	التقدير
العمق سم				
رقم العينة المتسلسلة		197		
رقم غليظ	%	15		
رمل دقيق	%	12		
سلت غليظ	%	8		
سلت دقيق	%	10		
طين	%	55		
مادة عضوية	%	0.7	2.5	
يدس pH	(2:5)	8.4	8	
موصلية	(2:5)	0.13	0.4	
كلس كلي	%	39		
كلس نشط	%	14		
ازوت متاح	كلغ/مكتار	20	70	
فوسفور أولسن	ppm	2.1	15	
بوتاس متاح	ppm	50	400	
مغنزيوم متبادل	ppm	230	100	
كالسيوم متبادل	ppm	561	250	
حديد متبادل	ppm	7925	3500	
حديد متاح	pmm	1.3	10	
سمة التبادل	%		20	

التقدير 197 تربة طينية كلسية غينة بالكلسيوم والمغنزيوم فقيرة بالحديد والبوتاس والمادة العضوية الازوت والفوسفور

ملاحظة:- المصلحة مسؤولية فقط عن نتيجة التحليل المشار إلية أعلاه للعينة التي تم فحصها في مختبر تل العمارة

تل العمارة في 6/11 / 2013

رئيس مختبر التربة والمياه
المهندس نصير ملاعب

الجمهورية اللبنانية
وزارة الزراعية
مصلحة الأبحاث العلمية الزراعية
مختبر تل العمارة

شهادة تحليل تربة

المرسل : AF comtructing قبلان فرنجية	مختبر التربة والمياه تل عمارة
العنوان : شكا	
الزراعة : فحص روتيني	

رقم العينة كما وزد		حفرية السويف	القيم المرغوب حسب قوام التربة وحاجة الزراعة	التقدير
العمق سم				
رقم العينة المتسلسلة		198		
رقم غليظ	%	11		
رمل دقيق	%	8		
سلت غليظ	%	12		
سلت دقيق	%	10		
طين	%	59		
مادة عضوية	%	0.3	2.5	
pH يدس	(2:5)	8.3	8	
موصلية	(2:5)	0.21	0.4	
كلس كلي	%	5		
كلس نشط	%	2		
ازوت متاح	كلغ/مكتار	11	70	
فوسفور أولسن	ppm	8.3	15	
بوتاس متاح	ppm	100	400	
مغنزيوم متبادل	ppm	320	100	
كالسيوم متبادل	ppm	591	250	
حديد متبادل	ppm	5690	3500	
حديد متاح	pmm	3.3	10	
سمة التبادل	%		20	

التقدير 198 تربة طينية كلسية غنية بالكلسيوم والمغنزيوم فقيرة بالحديد والبوتاس والمادة العضوية الازوت والفوسفور

ملاحظة:- المصلحة مسؤولية فقط عن نتيجة التحليل المشار إلية أعلاه للعينة التي تم فحصها في مختبر تل العمارة

تل العمارة في 6/11 / 2013

رئيس مختبر التربة والمياه
المهندس نصير ملاعب

الجمهورية اللبنانية
وزارة الزراعية
مصلحة الأبحاث العلمية الزراعية
مختبر تل العمارة

شهادة تحليل تربة

المرسل : AF comtructing قبلان فرنجية
العنوان : شكا
الزراعة : فحص روتيني

مختبر التربة والمياة
تل عمارة

رقم العينة كما وزد		حفرية السويف	القيم المرغوب حسب قوام التربة وحاجة الزراعة	التقدير
العمق سم				
رقم العينة المتسلسلة		199		
رقم غليظ	%	11		
رمل دقيق	%	8		
سلت غليظ	%	16		
سلت دقيق	%	14		
طين	%	51		
مادة عضوية	%	0.5	2.5	
يدس pH	(2:5)	8	8	
موصلية	(2:5)	0.33	0.4	
كلس كلي	%	5		
كلس نشط	%	2		
ازوت متاح	كلغ/مكتار	15	70	
فوسفور أولسن	ppm	7.9	15	
بوتاس متاح	ppm	80	400	
مغنزيوم متبادل	ppm	320	100	
كالسيوم متبادل	ppm	566	250	
حديد متبادل	ppm	5971	3500	
حديد متاح	pmm	3.6	10	
سمة التبادل	%		20	

التقدير 199 تربة طينية كلسية غينة بالكلسيوم والمغنزيوم فقيرة بالحديد والبوتاس والمادة العضوية الازوت والفوسفور

ملاحظة:- المصلحة مسؤولية فقط عن نتيجة التحليل المشار إلية أعلاه للعينة التي تم فحصها في مختبر تل العمارة

تل العمارة في 6/11 / 2013

رئيس مختبر التربة والمياه
المهندس نصير ملاعب

APPENDIX 4: TECHNICAL PLANTATION SHEET

				Quercus calliprinos	*Olea europea*	*Ceratonia siliqua*	*Pinus brutia*	*Tamarix sp.*	*Pistacia palaestina*	*Calicotome villosa*	*Spartium junceum*	*Salvia triloba*	*Oreganum syriacum*	*Rhus coriaria*	*Ficus carica*	*Thymbra spicata*
Seed preparation	Seed supplier	Purchased				Nov-12		not suc-cessful	September through October 2012		Aug-11	June	August			July-August
		Collected		Oct-12			Nov-12									
		Prepared in nurseries		Dec-12		Mar-13	Nov-12		Oct-12		Sep-11					
	Seed geographic origin			Ramlieh		Chouaifet	Nabe3 I Safa		Ammatour		Ramlieh	Damour	Ramlieh			Ramlieh
	Seed extraction			cleaning and floating		None	Drying of cones		Removal of pulp under running water		drying and removal from pods	Separa-tion through water	Removal of twigs and leaves			Removal of twigs and leaves
	Seed storage	Location of storage		chiller		Storage shed	Storage shed		chiller		storage shed	storage shed	storage shed			storage shed
		Condition of storage	Temperature	2+ - 4+		from 5 -25	from 5-25		from 2 to 4		from 5 - 25	from 5-25	from 5-25			from 5-25
			Relative humidity	around 85		Dry condi-tions	Dry condi-tions		around 85		dry condi-tions	dry condi-tions	dry condi-tions			dry conditions
			Ventillation	None		Natural air circula-tion	Natural air cirulation		none		natural air circula-tion	natural air circula-tion	natural air circula-tion			natural air circula-tion
		Time of storage before sowing		1.5 months	Purchased	4 months	3 months		4 months		1 year and 4 months	one year and 4 months	6 months		Purchased	one year and 4 months
	Treatment stratifica-tion, scarifica-tion...)	Type of treatment		No treatment		soaking in running water	cold stratifica-tion		cold stratification		cold stratifi-cation					
		Location of treatment				in nursery	chiller		chiller		Chiller					
		Soaking in water: period				48 h	24 h		24 h		24 h	24 h				
		Temperature of treatment				in chiller +2 +4 (4 weeks)	2 to 4		2 to 4		2 to 4	2 to 4				
		Quantity of seeds treated				12,000 seeds	10000 seeds		15000		600	400	200			200
	Seedbed and sowing preparation	Seedbed dimensions	Width													40 x 25 styro-foam boxes
			Row per bed													

Sowing	Sowing date	From	31/1/2013	Purchased	25-Apr-13	10-Apr		3-Mar		2-Mar	15-May	15-May		Purchased	20-Apr
		To	27/2/2013		1-May-13	12-Apr									
	Sowing depth		max 2 cm		max 1 cm	max 1 cm		surface sowing		0.5 cm	surface sowing	surface sowing			surface sowing
	Mulch	Type	perlite		perlite	perlite		perlite		perlite	perlite	perlite			perlite
		Depth	0.5 cm		0.5 cm	0.5 cm		0.5 cm		0.5 cm	0.5 cm	0.5 cm			0.5 cm
	Losses of seeds		20%		50%	20%		30%		10%					
	Challenges		Palatable to rodents		removing broken seeds	birds and rodents like the seeds		none		none	none	cleaning the debris from the seeds			cleaning the debris from the seeds
	Sowing machines or manually	Work load	1 day		1 day	1 day		1 day		1 day	1 day	1 day			1 day
		Nbr. of workers or machines	1 worker		3 workers	8		1 worker		1 worker	1 worker	1 worker			1 worker
		Machine type	none		none	none		none		none	none	none			none
	Irrigation	Type	sprinkler		sprinkler	sprinkler		sprinkler		sprinkler	sprinkler	sprinkler			sprinkler
		Frequency	varies, on average 4 days		varies, on average every 3 days	varies, on average 4 days		varies, on average 4 days		varies, on average 4 days	varies, on average 4 days	varies, on average 4 days			varies, on average 4 days
	Type of soil used + compost		cocopeat + peatmoss		cocopeat + peat-moss	cocopeat + peat-moss		cocopeat + peatmoss		cocopeat + peat-moss	cocopeat + peat-moss	cocopeat + peat-moss			cocopeat + peat-moss
	Pesticides	Type	Fungicide once, insecticide once		None	None		None		None	None	None			None
		Purpose	Powdery mildew, insect attack												
	Pots and trays	Type	650 cc containers		130 cc styro-foam	D27 (475 ml)		300 cc		300 cc	300 cc	300 cc			300 cc
		Density	20 cells per container/172 seedlings per m sq.		91 cells per contain-er	20 cells per container		50 cells per container		50 cells per contain-er	50 cells per contain-er	50 cells per contain-er			50 cells per contain-er
		Dimensions	38 cm x 30 cm x 28 c		35 cm x60 cm	38 x 30cm		43x31 cm		43 x 31 cm	43 x 31 cm	43 x 31 cm			43 x 31 cm
	Germina-tion %		60%		45%	75%		65%		90%	80%	50%			50%
	Period from seedling (or seed) to emergence		first emergence after 25 days		first emer-gence after 15 days	first emer-gence after 20 days		first emer-gence after 3 weeks		first emer-gence after one week	first emer-gence after one week	first emer-gence after 3 weeks			first emer-gence after 3 weeks
	Period to transfer to another pot		none		none	none		none		none	none	none			none

Fertilisation	Before sowing		Slow release (6 months)		slow release (6 months)	slow release (6 months)		slow release (6 months)		slow release (6 months)	slow release (6 months)	slow release (6 months)			slow release (6 months)
	In nursery		None so far		none so far	none so far		none so far		none so far	none so far	none so far			none so far
	Time of application														
	Amount applied														
	Type of fertilizer														
	Purpose of application														
Weeding (the use of cocopeat and peat moss greatly reduces weed problems	Application timing (pre-seed-ing)														
	Handweed-ing	Worker	one permanent and two seasonal		one permanent and two seasonal	one permanent and two seasonal		one permanent and two seasonal		one permanent and two seasonal	one permanent and two seasonal	one permanent and two season-al			one perma-nent and two season-al
		Herbicide used	2 applications	Purchased	None so far	None so far		None so far						Purchased	
		Amount													
		Purpose													
Pesticides	Diseases		Damping off, mildew, insect attack		insect foraging			None		None	None	None			None
	Stage of species attacked (seed, germina-tion, roots…)		roots for damping off, mildew on leaves, insects on leaves and some on seeds		leaves										
	Method of control (fumigation, seed treatment, drench or spray…)		seed treatment in insecti-cides and fungicides		none, limited attack										
	Type of pesticide		Insecti and Fungi/cides												
	Purpose (preventive)		preventive and curative												
	Time of the year		Before sowing and whenever symptoms appear												

Equipment	Seed processing			None	Purchased	none			sieves		none	none	none		Purchased	none
	Seed storage and handling			chiller		chiller			chiller		chiller	chiller	chiller			chiller
	Sowing			manual		manual			manual		manual	manual	manual			manual
	irrigation			sprinklers		sprinklers			sprinklers		sprinklers	sprinklers	sprinklers			sprinklers
	Fertilization			slow release mixes		slow release mixes			slow release mixes		slow release mixes	slow release mixes	slow release mixes			slow release mixes
	Pruning			Shears												
	Herbicide and insecticide spraying			Sprayers												
	Frost protection			Greenhouse												
	Transplant-ing			None		None	None				None	None	None			Hand picking
From seeding to plantation	Period			11 months		7 months	8 months		9 months		9 months	7 months	7 months			8 months
	Photos															
Quantities	Section	Highland	As per design	31	27	9	22		39		29		5			5
			As per execution	31	27	9	22		60	40	32	40	40			20
		Cliffland	As per design	62	52	20	62		62		83				10	
			As per execution	62	52	20	62		103	40	83	40	40		10	20
		Coreland	As per design	62	30	10	17	165	40		63					
			As per execution	62	30	10	17		52	20	73	20	20			10
		Lowland	As per design	149	149	74			101		149					
			As per execution	149	149	74			185	60	149	60	60			30

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