

# Application of the Folchi Method in the Limestone Quarry to Quantify the Environmental Impact: (Case Study)

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**Abstract:** *The application of the FOLCHI method it is depicts in this paper to quantify the environmental impact of mining activities in a limestone quarry. The affected environment surrounding the pit was broken down into the eleven components such as Human health and immunity, Surface water, Air quality, Noise, Landscape etc. The effect of ten impacting factors, both directly and indirectly, from the mining activities was then calculated for each Environmental Component. Firstly, using the Magnitude ranges, where each Impacting Factor for the proposed mining activity was assessed and its Magnitude chosen. A matrix of the Impacting Factors against the Environmental Components was then drawn up, with the chosen Magnitude weighted using the numeric values given. Then the overall effect on each Environmental Component was calculated by summing the weighted magnitudes of all the Impacting Factors. It was then possible to summarize the Environmental Impact Statement for the proposed mining activity as a simple graphical representation. The method, which is outlined here in a schematic form, was originally developed for a mining operation in Kruja District, Albania, but it can successfully be used for limestone quarry ventures and more general mining and other industrial activities in accordance to environmental regulations and laws.*

**Keywords:** Folchi Method; environment; impact factor, quarry, mining operation

## 1. Introduction

The environment affected by exploitation was embedded in a number of components, such as; public health and safety in society, social relations, air quality and water, flora and fauna. The effect of the impact of different mining activities on both direct and indirect factors is then calculated for each environmental component. To do this, each affecting factor is given for the first time a magnitude, a number based solely on the range of possible scenarios for the impact factor. A matrix of measurement factors was then systematically extracted the quantitative effects of each factor and the normalization, affecting each component of the environment. The overall impact on each individual environmental component is calculated for all factors influencing it by collecting then the areas of weighted sizes.

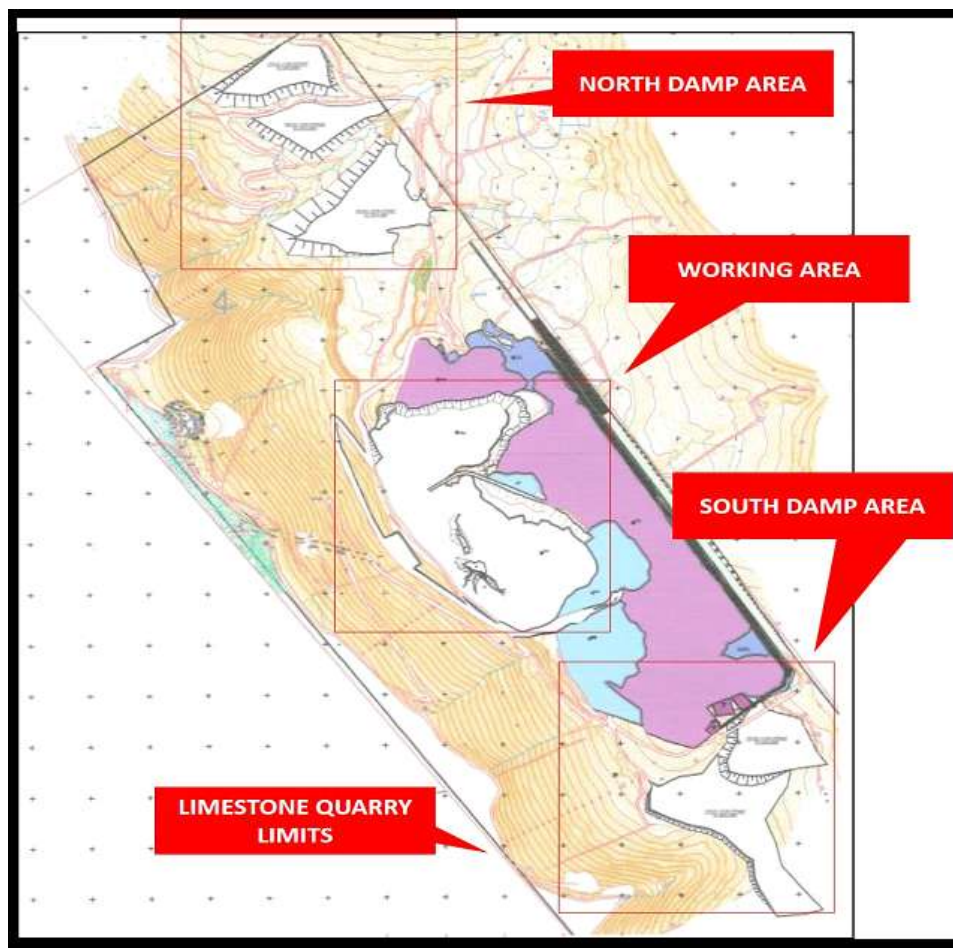
The method, which is described here in a schematic form, was originally developed for mining operations in Sardinia, Italy. It has subsequently been successfully used for mining and other mining businesses and many general industrial activities, such as dump waste, recycling and power generation.

As with any assessment, the method requires an element of subjective assessment but it does not at least give transparency in the process used to assess the environmental impact. The method can be used to ensure the consistency of the approach needed to allow the real comparison to be made between the design of different solutions mitigation measures.

In a wider sphere, for example a mining provincial neighborhood, it can be used to provide a consistent means of comparing environmental impacts due to different mining locations.

The volume of rock extracted, and the waste deposit area, are located within the mining area. The physiography was fierce, with steep slopes and narrow valleys, all covered with wood and Mediterranean bush. The rock mass, consisting of limestone, generally had good geo-mechanical characteristics.

The open pit is dimensioned for an annual supply of 1 200,000 tons per year of limestone. The mines were planned in three groups with parallel progression, vertical holes in the quarry ladder; loading with right bucket excavators and Dumper truck transport, see *Figure 1*.



**Figure 1:** The area for the limestone quarry

Therefore, the Environmental Impact Statement had only to consider the mining activity itself and the study was conducted in the following manner:

- 1) Characterizing the pre-existing environmental context in terms of geology, geotechnics, hydrology, weather, economy, etc.
- 2) Identifying the IMPACTING FACTORS, namely those factors, that during mining, could modify the pre-existing environmental conditions
- 3) Defining the possible ranges for the MAGNITUDE of the variation caused by each IMPACTING FACTOR
- 4) Singling out the ENVIRONMENTAL COMPONENTS whose pre-existing condition could be modified as a result of the mining
- 5) Correlating each IMPACTING FACTOR and each ENVIRONMENTAL COMPONENT
- 6) Estimating the specific MAGNITUDE for each IMPACT FACTOR, using the already defined ranges
- 6) Calculating the weighted sum of the environmental impact induced from the IMPACTING FACTORS on each ENVIRONMENTAL COMPONENT.

As with any assessment, the method requires an element of subjective assessment but it does not at least give transparency in the process used to assess the environmental impact. The method can be used to ensure the consistency of the approach needed to allow real-world comparison between the design of different solutions and mitigation measures.

## 2. Pre-existing Environmental Context

The area for the open pit mining was located in the mountains, about 1.5 km away from the nearest town and 10 km away from the sea.

The geological and geotechnical surveys that had been undertaken for the design of the dam were used for the study. Weather and economic data were obtained from existing databases. Seventy percent of the surrounding area was covered with wood and Mediterranean bushes. The remaining thirty percent was dedicated to meadow-pasture with a small area containing olive trees, vineyards, domestic vegetable gardens and to a much lesser extent, stock-raising. For the meteorological characterization, data was obtained from the Italian Institute of Statistics.

## 3. Impacting factors

The following ten IMPACTING FACTORS were taken into account:

### 3.1 Alteration of the area's potential resources

The exploited development quarry and the waste disposal site were in the area that was covered with wood, no activity of any kind, took place in that area. Also, the area was expropriated for quarry construction and will be within the licensed surface quarries.

### 3.2 Exposition, visibility of the limestone quarry

The quarry and waste disposal site will be visible from the nearest town (Fushë Krujë and the surrounding villages) and from the Tirane-Shkoder national road and local ones up to 3 km away (Figure 2). However, all the roads in this area have been a bit more rural without covering the asphalt, and consequently, the volume of traffic is low, less than 1000 vehicle passages per day.

### 3.3 Interference with the above-ground water system

The limestone quarry would take place at a short distance from a river. The surrounding terrain was impermeable and trough valleys conveyed water directly to the river. The location of the quarry and its supporting infrastructure, such as ramps, paths and yards, were all designed to minimize any interference with the above-ground water courses. The presence of the pit was minimal, compared to the existing river basin, and would not cause any significant perturbations in the above-ground water system.

### 3.4 Interference with the underground water system

The permeability of the surrounding rock mass was so low that no underground water system existed.

### 3.5 Increase in vehicular traffic

Access to the pit area, for personnel, supply of materials, spare parts and explosives, would take place via the existing public roads. Transportation of the blasted and crushed rock would take place the unpaved interior roads of the area between the career and the break-up plant without any need to enter public roads (Figure 3).

### 3.6 Atmospheric release of gas and dust

Emissions into the atmosphere, together with acoustic emissions and ground vibration, can be one of the most significant IMPACTING FACTORS for open pit mining with explosives. Drilling and blasting both produce a fine dust that contains silica. Due to a strong, yearlong round wind, and the dust could be distributed over a wide area and at some considerable distance from the limestone quarry. A similar fine dust is also produced from haulage using “push and accumulation” into a dejection cone, a system which is frequently used in Albanian quarries. Haulage was planned to take place at the toe of the bench, with no push and accumulation in a cone. Drilling would be performed dry but the machines would be equipped with filters and paths and yards would be kept wet, to dampen down the dust. All these precautions, taken to provide an effective means of reducing the risk of silicosis, also significantly reduce any spread of the dust outside of the working area. Gases such as, CO, CO<sub>2</sub>, SO<sub>2</sub> and NO<sub>x</sub> would be produced by vehicles, compressors and detonation of the explosives.



**Figure 2:** The process of exploding in the career and the benefit of the broken limestone  
[Source: Photo from authors, Fushë Krujë].



**Figure 3:** Loading equipment and truckloads on a career scale  
[Source: Photo from authors, Fushë Krujë].

### 3.7 Fly-rock

A controlled blast was planned for optimization of explosives consumption and rock fragmentation. Drilling and blasting operations would be conducted by experienced personnel. These measures would ensure that fly-rock would be confined within a safety zone inside the pit yard. Besides, there were no public streets or any sort of facility close to the benches.

### 3.8 Noise

Trucks, excavators and crushing plants produce low amplitude, low frequency, persistent acoustical impact. The blasting, once every couple of days, produces a high amplitude and frequency pulse acoustical impact.

The effects of acoustical impact on fauna are not well known. Past experience suggests that, following the initial desertion from the affected area, a tolerance is acquired and the abandoned territories are gradually re-inhabited. The time needed for this re-occupation ranges from weeks to months. The impacted area was expected to be extended by about 1 km (0.625 miles).

Conversely, the effects of acoustical impact on humans are well known. However, experience has shown that not exceeding “nuisance” threshold values is not a guarantee of freedom from complaints and law suits.

### 3.8 Ground vibration

Rock blasting produces seismic waves with related ground vibration that can be felt at large distances away from the

source of the blasting. This is usually the biggest cause of hostility from the surrounding neighbors, resulting in complaints and law suits. In the past, complaints have also been received as a result of induced vibration at levels well below the “no-damage” reference values given in standards such as DIN 4150-3 and UNI 9916.

Ground vibration due to the blast, often equated to the effect of a catastrophic event such as an earthquake, is the most frequent cause of litigation in Italy. Also, people living nearby sometimes confuse the air overpressure, which may be amplified by the rattling caused by loose glass panels in the window frames, as ground vibration and the basis of a complaint for “structural damage”.

Dust and noise can often be reasonable causes for complaint but even if they are at levels higher than those given by law, they are not usually cited in law suits. In the last 10 years, there has been an increasing trend towards litigation based not on property damage but on “biological damage” to the inhabitants, due to the fears caused by ground vibration. This approach has been somewhat encouraged by Court sentences.

For the pit in question, the blast would be planned with a large ignition sequence, to maximize fragmentation. This would also drastically reduce the ground vibration impact.

### 3.9 Employment of local work force

Kruja is a region with high unemployment and the new mining activity itself would bring new job opportunities to the nearby town and also increased trade for the service industries, hotels and restaurants.

## 4. Magnitude of the impacting factors

The possible scenarios for each IMPACTING FACTOR were then considered and a numerical value, or MAGNITUDE, was given to each scenario. For simplicity, the value chosen for each scenario was between 1 and 10, the number chosen being indicative of the severity of the environmental impact, with 10 being the most severe. The various scenarios and their related MAGNITUDE are shown for each IMPACTING FACTOR in *Table 1*.

**Table 1: Ranges of Magnitude for impacting factors**

<i>Impacting Factors</i>	<i>Scenario</i>	<i>Magnitude</i>
1. Alteration of area's potential resources	Parks, protected areas	8-10
	Urban area	6 - 8
	Agricultural area, wood	3 - 6
	Industrial area	1 - 3
2. Exposition, visibility of the pit	Can be seen from inhabited areas	6 - 10
	Can be seen from main roads	2 - 6
	Not visible	1 - 2
3. Interference with above-ground water	Interference with lakes and rivers	6 - 10
	Interferences with non-relevant water system	3 - 6
	No interference	1 - 3
4. Interference with underground water	Water table superficial and permeable grounds	5 - 10
	Water table deep and permeable grounds	2 - 5
	Water table deep and un-permeable grounds	1 - 2
5. Increase in vehicular traffic	Increase of 200%	6 - 10
	Increase of 100%	3 - 6
	No interference	1 - 3
6. Atmospheric Release of Gas and Dust	Free emissions in the atmosphere	7 - 10
	Emissions around the given reference values	2 - 7
	Emission well below the given reference values	1 - 2
7. Fly-rock	No blast design and no clearance procedures	9-10
	Blast design and no clearance procedures	4-9
	Blast design and clearance procedures	1 - 4
8. Noise	Peak air overpressure at 1km distance	
	<141 dB	8 - 10
	<131 dB	4 - 8
	<121 dB	1 - 4
9. Ground vibration	Cosmetic damage, above threshold	7 - 10
	Tolerability threshold	3 - 7
	Values under tolerability threshold	1 - 3
10. Employment of local work force	Job opportunities	High 7 - 10 Medium 3 - 6 Low 1 - 2

### 4.1 Environmental components involved

The environment surrounding the pit was broken down into the following eleven components:

- |  |   |
|--|---|
| 1) Human health and safety                 | 3) Water quality  |
| 2) Social relationship and quality of life | 4) Air quality  |
|  | 5) Use of territory, as naturalistic resources, socio-cultural and economical |
|  | 6) Flora and fauna  |
|  | 7) Above ground   |

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- 8) Underground
- 9) Landscape
- 10) Noise
- 11) Economy

#### 4.2 Weighted influence of each impacting factor on environmental component

An IMPACTING FACTOR will modify the pre-existing state of equilibrium of an ENVIRONMENTAL COMPONENT in a way that can vary from having no effect at all through to a severe impact. Four levels of perturbation,

namely nil, minimum, medium and maximum, were chosen to describe the effect that an IMPACTING FACTOR has on an ENVIRONMENTAL COMPONENT. The maximum perturbation level was numerically defined as double the medium perturbation level and similarly, the medium perturbation level was defined as double the value of the minimum level. The sum of all the perturbation levels for each ENVIRONMENTAL COMPONENT was normalized by imposing the sum equal to 10. *Table 2* shows the perturbation level of the IMPACTING FACTORS for each ENVIRONMENTAL COMPONENT and the related numeric weighting factors calculated as described above.

**Table 2:** Correlation matrix with values of the weighted influence of each Impacting Factor on each Environmental Component

Impacting Factors	Environmental Components										
	Human health and safety	Social relations hip	Water quality	Air quality	Use of territory	Flora and fauna	Above ground	underground	landscape	noise	economy
1. Alteration of area's potential resources	Med 0.80	Min 0.77	Nil 0	Nil 0	Max 5.71	Min 0.63	Nil 0	Nil 0	Max 2.86	Nil 0	Nil 0
2. Exposition, visibility of the pit	Nil 0	Min 0.77	Nil 0	Nil 0	Med 2.86	Nil 0	Nil 0	Nil 0	Max 2.86	Min 2.00	Nil 0
3. Interference with above-ground water	Max 1.60	Nil 0	Max 4.44	Nil 0	Nil 0	Max 2.50	Med 6.67	Nil 0	Max 2.86	Nil 0	Nil 0
4. Interference with under-ground water	Min 0.40	Nil 0	Max 4.44	Nil 0	Nil 0	Nil 0	Nil 0	Med 6.67	Nil 0	Nil 0	Nil 0
5.increase in vehicular traffic	Max 1.60	Max 3.08	Nil 0	Nil 0	Min 1.43	Max 2.50	Nil 0	Nil 0	Min 0.71	Nil 0	Nil 0
6. Atmospheric Release of Gas and Dust	Max 1.60	Min 0.77	Min 1.11	Max 10.00	Nil 0	Max 2.50	Min 3.33	Nil 0	Min 0.71	Nil 0	Nil 0
7. Fly-tock	Max 1.60	Nil 0	Nil 0	Nil 0	Nil 0	Med 1.25	Nil 0	Nil 0	Nil 0	Nil 0	Nil 0
8.noise	Med 0.80	Max 3.08	Nil 0	Nil 0	Nil 0	Min 0.63	Nil 0	Nil 0	Nil 0	Max 8.00	Nil 0
9.ground vibration	Max 1.60	Med 1.54	Nil 0	Nil 0	Nil 0	Nil 0	Nil 0	Min 3.33	Nil 0	Nil 0	Nil 0
10.employment of local work force	Nil 0	Nil 0	Nil 0	Nil 0	Nil 0	Nil 0	Nil 0	Nil 0	Nil 0	Nil 0	Max 10.00
<b>T o t a l</b>	10	10	10	10	10	10	10	10	10	10	10

#### 4.3 Calculation of the impact on each environmental component

Firstly, using the MAGNITUDE ranges defined in *Table 1*, each IMPACTING FACTOR for the proposed mining activity was assessed and its MAGNITUDE chosen, as shown in *Table 3*.

**Table 3:** MAGNITUDE of IMPACTING FACTORS for the limestone quarry

Impacting Factors	Scenario	Magnitude
1. Alteration of area's potential resources	The mining of the quarry would have permanently modified the potential resources of the area. Although this aspect would not be relevant after the mining phase after the flooding of the lake, it had to be taken into account during mining activity.	6
2. Exposition, visibility of the pit	The limestone quarry would have modified a landscape characterized by woods and meadows. Harsh physiography will help to absorb visual impact.	4
3. Interference with above-ground water	The limestone quarry was placed to avoid interference with the river and to minimize alteration of the hydraulic basin.	3
4. Interference with underground water	Because of the very low permeability of the rock mass and consequent lack of an underground water system, no real interference was foreseen.	1
5. Increase in vehicular traffic	Transportation would take place in internal paths. No relevant traffic increase would be apparent on public roads.	1
6. Atmospheric release of gas and dust	Dust and gas emissions would be kept below given threshold values: filters for drilling equipment, paths and yards kept wet. Negligible gas pollution from machinery and blast.	2
7. Fly-tock	The blast would be planned to keep rock throw distance within the quarry area. Haulage at the bench toe, without push and stocking in a dejection cone, reduces the quantity of fines and minimize the quantity of dust.	1
8. Noise	The blast will keep air overpressure much below the tolerability levels. Physiography will keep machinery noise to tolerable levels for nearby housing.	4

9. Ground vibration	To maximize fragmentation, the total explosive charge would be detonated in a high number delay sequence, thus reducing induced vibrations. Also the low productivity required, 150,000 m <sup>3</sup> / y, would mean low levels of vibration.	2
10. Employment of local work force	For the limestone quarries, it would be necessary to hire non-qualified local workforce and some truck drivers. Also related economical activities, gas stations, small hardware stores, hotel, restaurants, etc. would benefit.	3

A matrix of the IMPACTING FACTORS against the Environmental Components was then drawn up, with the chosen MAGNITUDE weighted using the numeric values

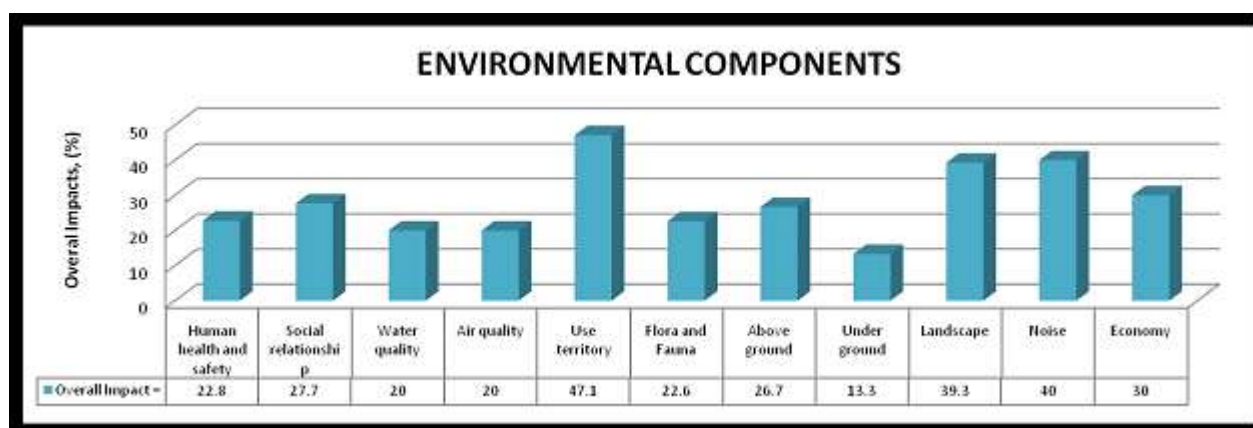
given in **Table 2**. Mean time **Table 4** shows the resultant matrix.

**Table 4:** Matrix of weighted Magnitudes for each Impacting Factor on each Environmental Component

Impacting factors	Environmental Component										
	Human health and safety	Social relationship	Water quality	Air quality	Use of territory	Flora and fauna	Above ground	Underground	landscape	Noise	Economy
1. Alteration of area's potential resources	4.8	4.6	0.0	0.0	34.3	3.8	0.0	0.0	17.2	0.0	0.0
2. Exposition, visibility of the pit	0.0	3.1	0.0	11.4	0.0	0.0	0.0	0.0	11.4	0.0	0.0
3. Interference with above-ground water	4.8	0.0	13.3	0.0	0.0	7.5	20.0	0.0	8.6	8.6	0.0
4. Interference with underground water	0.4	0.0	4.4	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0
5. Increase in vehicular traffic	1.6	3.1	0.0	0.0	1.4	2.5	0.0	0.0	0.7	0.0	0.0
6. Atmospheric release of gas and Dust	3.2	1.5	2.2	20.0	0.0	5.0	6.7	0.0	1.4	0.0	0.0
7. Fly-tock	1.6	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
8. Noise	3.2	12.3	0.0	0.0	0.0	2.5	0.0	0.0	0.0	32.0	0.0
9. Ground vibration	3.2	3.1	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0
10. Employment of local work force	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
<b>Overall impact</b>	<b>22.8</b>	<b>27.7</b>	<b>20.0</b>	<b>20.0</b>	<b>47.1</b>	<b>22.6</b>	<b>26.7</b>	<b>13.3</b>	<b>39.3</b>	<b>40.0</b>	<b>30.0</b>

Then the overall effect on each ENVIRONMENTAL COMPONENT was calculated by summing the weighted magnitudes of all the IMPACTING FACTORS. It was then possible to summarize the Environmental Impact Statement

for the proposed mining activity as a simple graphical representation as shown in **Figure 4**.



**Figure 4:** Quantitative Environmental Impact Statement

## 5. Conclusions

1) As can be seen from **Figure 4**, the most significant impacts were on three ENVIRONMENTAL COMPONENTS, namely "Use of Territory", "Noise" and "Landscape". However, a major impact would have an Overall Impact value of 100 on any of the ENVIRONMENTAL COMPONENTS and therefore, the actual impacts on these three ENVIRONMENTAL COMPONENTS are low.

2) The Overall Impacts on the other ENVIRONMENTAL COMPONENTS, "Public Safety", "Social Relationships", "Water Quality", "Air Quality", "Flora and Fauna", "Above Ground" and "Underground" were considered to be insignificant.

3) This quantitative analysis provided a neat method for demonstrating that the proposed mining activity would not cause any relevant alteration to the surrounding environment. Something that was to be expected since the activity would only last two years and

take place in a confined area, which would subsequently be covered by the lake produced by the dam.

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