A Study on Restoration Plans of Jeju Hanon Maar Crater

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Abstract

Hanon Crater is the largest crater with a diameter of more than 1km and the only maar type crater in the Korean Peninsula. It is like a ‘time capsule of the Earth’s environment’, preserving the invaluable scientific information that reveals the process of the Earth’s climatic and ecological environmental changes over the past 5 million years. However, the value of the crater has been unattended and the crater itself has been damaged and neglected. About 550 years ago, as people tore down the wall of the crater to use the crater as farmland, the crater lake disappeared. In recent years, damage has been done to the crater under the threat of development without thought for the environment. This study verifies the climate and environmental value of Hanon Crater and the value of the maar lake sedimentary layers of the crater as a key national asset and the necessity of its reatoration as presented in the recommendations of the 2012 WCC and provides supportable reasons for making the restoration project as a national one in conjunction with IUCN and the international community. In particular, this study, in which the Commission on Ecosystem Management of IUCN also participated, suggests the objectives, strategies and alternatives in restoring the crater wall, lake, and vegetation based on Ecological Restoration for Protected Areas: Principles, Guidelines and Best Practices (Keenleyside et al., 2012) and ways to utilize the crater as a national resource after the restoration such as establishing a center for studying ancient organisms and climate and setting up a maar museum."

Key words: Hanon, Crater, maar, Korean, Peninsula, time, capsule, Earth’s, environment
Chapter 1 Background of the Study

Hanon Crater is the largest crater with a diameter of more than 1km and the only maar type crater in the Korean Peninsula. It is like a ‘time capsule of the Earth’s environment’, preserving the invaluable scientific information that reveals the process of the Earth’s climatic and ecological environmental changes over the past 5 million years. However, the value of the crater has been unattended and the crater itself has been damaged and neglected.

About 550 years ago, as people tore down the wall of the crater to use the crater as farmland, the crater lake disappeared. In recent years, damage has been done to the crater under the threat of development without thought for the environment.

The turning point came when the plan of constructing a baseball training camp on Hanon Crater was announced by Seogwipo City in 2002. Meanwhile, civil environmental organizations were against this plan and the research results of the Asian Lake Drilling Programme team issued in 1998 came into the spotlight. Since then, through numerous international forums and symposiums, many scholars have showed keen interest in the crater and this has led to continuously highlighting the necessity of restoring Hanon Crater in order to preserve the environmental and ecological value of the crater and let the future generation use the crater renewably.

Above all things, we have a difficult task to restore the crater and the lake in order to turn Hanon Crater into a world class volcanic, geological, ecological, and landscape resource. The participants of the 2012 WCC sympathized with the value of Hanon Crater and the necessity of its restoration and advised the Korean government to carry out the restoring project as a national one.

Thus, the purpose of this study is to create an international standard model of restoring damaged environmental assets through making the restoration of the crater, lake, and natural vegetation a top priority as well as turning the crater into a model for studying climate change in the future through the research on the maar lake sedimentary layers and ancient climate and vegetation.

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environmental value of Hanon Crater and the value of the maar lake sedimentary layers of the crater as a key national asset and the necessity of its restoration as presented in the recommendations of the 2012 WCC and provides supportable reasons for making the restoration project as a national one in conjunction with IUCN and the international community.

In particular, this study, in which the Commission on Ecosystem Management of IUCN also participated, suggests the objectives, strategies and alternatives in restoring the crater wall, lake, and vegetation based on *Ecological Restoration for Protected Areas: Principles, Guidelines and Best Practices* (Keenleyside et al., 2012) and ways to utilize the crater as a national resource after the restoration such as establishing a center for studying ancient organisms and climate and setting up a maar museum, etc.

Chapter 2 Analysis of the Current Situation

Part 1 General Status

1. Location and Size

Hanon Crater is located in the central area of Seogwipo City, which is located in the southern part of Jeju Island. The crater is near the coastal lowlands where the range of Mt. Hallasan drops sharply away from the top to the south and meets the sea passing through the mid-mountainous area.

The center of the crater (968-1 Seoheung-dong, Seogwipo City) is 12.4km away from Baekrokdam, the summit of Mt. Hallasan and 1.25km away from Oedolgae Rock, south to Sammaebong (oreum). (See Figure 1)

The center of the crater is located at 33 degrees 15 minutes north latitude and 126 degrees and 32 minutes east longitude. According to the administrative district, it sits in the boundary area between Hogeun-dong and Seoheung-dong in Seogwipo City and joins along Local Road 1132 on the north. The crater’s total area is 1,266,825㎡.
2. Topography

(1) General Outline

Hanon Volcano was formed in the late Pleistocene Epoch and has been generally categorized as a tuff ring, a maar or a tuff ring with a maar crater. (Park Seung-pil, 1985, 2003; Yoon Seok-hun, 2004, 2006; Sohn and Park, 2005).

There are volcanic hills, lowlands, and valleys and waterfalls around the volcano so it is difficult to demarcate the exact outer boundary of Hanon Volcano. However, considering the current distribution patterns of tuff layers erupted from the crater, it can be said that the diameter of Hanon Volcano is about 1.8 km from east to west and 1.3 km from north to south. Its circumference is 3,774 m and its area is about 1,266,825 m². (See Figure 2)

With regard to the height of the volcano, its southwest part is the highest (143.3m above sea level) and its east part is the lowest (60m above sea level). Most of the west wall of the volcano is above 100m but the east wall is below 80m, making the volcano asymmetric with its higher western part and lower eastern part. The base of the volcano inclines gently towards the south-southeast and the highest point is 63m (relative height). The base faces the northwest slope of Sammaebong Cinder Cone to the southeast. Most of the slope of the volcano is gentle (below 10°) but some part of its southwest slope is with a gradient of more than 20°.

A circular crater is formed at the central part of the volcano and inside the crater; there are cinder cones of scoria.

![Figure 2. Torpographic Map of Hanon Crater and Its Surroundings](image-url)
(2) Crater

The circular crater ring which encompasses the crater is 1,000-1,150m in diameter and the height from the base to the top is 750-850m and the area of the base is about 216,000㎡. The inside slope of the crater is very steep. Most part of the inside slope is with a gradient of more than 10° and to the maximum 50°. The slope of the eastern part of the crater is the steepest where the height of the crater is the lowest. The inside of the crater inclines gently from south to north and its height is 53m-65m above sea level. The two parts of the base of the crater is relatively clearly divided with the 55m contour line. In the southern part of the base, there are cinder cones and, in the northern part of the base, there are wetlands. The flat area of the northern part of the base is 53-55m above sea level and it is maximum 90m below from the top of the crater ring and maximum 60m below from the surface of the earth outside the volcano before the volcanic eruption.

(3) Cinder Cones

There are two conical cinder cones in the center and the southern part of the inside of the crater as well as many hill-type cinder cones. The width of the conical cinder cones is 100-180m and the relative height is 20-25m. Irregular hilly cinder cones located in the southern part of the crater are 5-15m high with low and gentle slopes.

Part 2 Natural Environment

1. Weather Conditions

Jeju is located in the southernmost tip of the Korean Peninsula and sits in the transition zone from a subtropical climate zone to a temperate climate zone. The island is mainly under influence of the maritime tropical air mass and the continental tropical air mass. In winter, Jeju Island is under the influence of a corrupted cold air mass, which is made from the northwest continental air mass when the air mass changes and weakens while passing through the sea. In spring and fall, Jeju is regularly affected by a pressure trough and a migratory anticyclone from the southeastern part of China. Jeju is also the first area which is under influence of the southwest monsoon. With regard to the distribution of the continent and the ocean around the island, it is located at the edge of the northwest Pacific Ocean and affected by the humid ocean due to its long distance from the Asian Continent. The warm Kuroshio Current, which flows from the southwest year-round, also affects the weather in Jeju.

According to meteorological data for the last 30 years (1981-2010) analyzed by the Korea Meteorological Administration, the average temperature for the year in Korea ranges from 6.6-16.6℃ and that of Seogwipo is 16.6℃, making the city the warmest place in Korea. The average daily maximum temperature and the average daily minimum temperature for the year in Seogwipo are 20.2℃ and 13.5℃ respectively, also the highest records in Korea. While the average precipitation rate for the year in Korea ranges from 825.6~2,007.3mm, the average rainfall in Seogwipo is 1,923mm, the third highest record in Korea next to Geoje in Gyeongsangnamdo (2,007.3mm) and Seongsan in Jeju (1966.8mm). Over the past 50 years, in Seogwipo, the average temperature has steadily increased and the average precipitation rate has remained at the same level.

Hanon Crater, located in the southern part of Seogwipo City, is a crater with the altitude difference between 53m and 143.4m. In winter, the chilly air stays longer inside the crater so the temperature in the crater becomes different from that in other flat areas. In particular, the slope of the crater has the different amount of sunshine, wind, and the different level of humidity according to its location and gradient. This also seems to influence the environment of Hanon Crater.

2. Water System
(1) Current Conditions of Streams

Because of the geological features, the water system of Jeju Island spreads out like the spokes of a wheel, with Mt. Hallasan as the hub. The water system of Seogwipo City starts from Mt. Hallasan and flows to the south into the sea. There are 34 local streams in the Seogwipo area and, among them, 32 rivers except for Dosuncheon Stream, and Akgeuncheon Stream, which are dry streams that have flowing water only when it is raining. Streams around Hanon Crater are Yeonoecheon Stream, Hogeuncheon Stream, Wonjecheon Stream, Seohongcheon Stream, and Saengsucheon Stream. Among them, the main stream is Yeonoecheon Stream whose length and basin area are 9.06km and 18.65㎢, respectively. The end point of this stream is the seaside of Cheonjiyeon Waterfall.

(2) Spring Water in Hanon Crater

The earth of Jeju Island mainly consists of basalt volcanic ash soil which has high water permeability. Therefore, the amount of underground water made from rainfall in Jeju is much larger than that in the mainland. There are two types of spring water in Jeju. One is high-level ground water and the other is pressed ground water. High-level ground water happens when the rainwater seeps underground through high water permeability strata and then returns to the surface of the earth after facing impermeability layers. Pressed ground water occurs when the rainwater goes underground and flows through strata formed hydrogeologically to the seaside and then spouts after facing the sea level.

On Hanon Crater, there are three springs called ‘Molmangsu’, ‘Dongeonsaemi’, and ‘Seoteonsaemi’, respectively. Molmangsu is a spring located in the eastern part of the crater base and the daily amount of water from this spring is maximum 1,000-5,000m³. Molmangsu plays an important role as a source of water supply, providing rice paddies (59,000m²) inside the crater with water through grid-shaped waterways. Dongeonsaemi is located in the northern slope of the crater and its daily amount of water is 5-100m³. This spring is used to provide water to orchards around the spring and rice paddies inside the crater. The last one, Seoteonsaemi is located in the western part of the crater wall and its daily amount of water is 50-250m³. This spring water is used as drinking water at a Buddhist temple (Bongrimsa Temple) and as agricultural water for orchards and rice paddies around the spring.

3. Flora and Fauna

3.1. Fauna

The Fauna of Hanon Crater consists of 47 species including birds, fish, amphibians, a reptile, and mammals. With regard to birds, there are 37 species in the crater such as 23 species of resident birds, 9 species of summer migratory birds, 3 species of winter migratory birds, and 2 species of passage migrant birds. Among them, one species of a hawk is an endangered one and four species such as hen harriers, hawks, kestrels, and sparrow hawks are designated as national monuments. The three species of fish are the Chinese minnow, crucian carp, and Chinese muddy loach. With regard to amphibians, two kinds of frogs such as black-spotted pond frogs and tree frogs are found in the crater. The only reptile inhabiting the crater is a red-sided water snake. Siberian weasels, birdlike noctules, Norway rats, and greater horseshoe bats are mammals that can be found in Hanon Crater.

3.2. Flora

(1) Flora

Tracheophytes which are found in Hanon Crater are 371 species and one variant (total of 372 species) under 284 generes and 108 families. Among them, fern is composed of 21 species under 16 generes and seven families. Gymnosperm consists of 11 species under 10 generes and seven families. While dicotyledoneae consists of 252
species under 194 genuses and 76 families, monocotyledonous plant is composed of 87 species and one variant under 64 genuses and 18 families.

According to an analysis based on the Raunkiaer system, in Hanon Crater, therophytes account for 82 species (22.0%), the highest share, and geophytes account for 41 species (13.1%). Hemicryptophytes have 49 species (13.1%) under its wing, while 22 species (5.9%) belong to chamaephytes. Other kinds of plants and their percentages are as follows: Nanophanerophytes (46 species, 12.4%), Microphanerophytes (33 species, 8.9%), Megaphanerophytes (46 species, 12.4%), Hygrophytes (52 species, 14.0%), and Epiphyte (one species, 0.3%). Among them, 35 species are invasive species (9.4%) and 85 species (22.8%) are planted and cultivated species.

Given annual plants are the most in the crater and the percentages of planted and cultivated species are high, it seems that artificial factors such as continuous cultivation have affected the fauna and flora of Hanon Crater.

(2) Hydrophytes

Hydrophytes in Hanon Crater appear mainly in the waterways on the base or around the rice paddies. According to analysis based on growth characteristics, there are tree species of free-floating hydrophytes including Spirodela polyrhiza (L.), three species of floating-leaved hydrophytes including Nymphaea tetragona Georgi and Potamogeton cristatus Regel & Maack, four species of submerged hydrophytes, and 17 species of emergent hyrophytes including Zizania caduciflora C(Turcz.ex Trin.) Hand.-Mazz., Lobelia chinensis Lour., Scirpus triangulatus Roxb. To sum up, there are 27 species of Hydrophytes in Hanon Crater.

3.3. Vegetation

There are three types of vegetation in Hanon Crater. The first and second ones are Japanese black pines and bushes on the slope of the crater and Aloreum. The third one is wetland plant communities found in the waterways and some fallow ground. Farmland accounts for 55.9% (663,840m³) and vegetation areas such as black fine forests, orchards, and fallow rice paddies account for 10.1% (119,876m³).

Like this, most of the base of the crater has been used as farmland and artificial interference such as buildings and other facilities has continuously endured. Natural vegetation covers only a small portion of the total vegetation of Hanon Crater.

3.4. Inference of Original Vegetation

The current vegetation of Hanon Crater, which consists of tangerine orchards, rice paddies, bamboo forests, and black pine forests, was formed by human interference. Therefore, the original vegetation can be inferred through vegetation in neighboring areas.

Vegetation which is considered as interfered least by human is Cheonjiyeon Waterfall. According to a study on the vegetation around the waterfall (Kim Chan-su, et al., 2002), evergreen broad-leaved trees, which is considered as original vegetation, include Castanopsis cuspidata var. sieboldii Nut, Quercus glauca, elaeocarpus sylvestris var. ellipticus, Neolitsea sericea (Blume) Koidz, Litsea japonica, and Machilus thunbergii, etc. Shrub vegetation consists of Eurya japonica, Viburnum odoratissimum var. awabuki, Camellia japonica, Elaeagnus glabra, Pittosporum tobira, and Daphniphyllum teijsmannii Zoll. Ex Kurz, etc. Thus, it is desirable to restore the vegetation of Hanon Crater based on the above vegetation of the neighboring areas.

3.5. Paleovegetation from Hanon Maar Sedimentary Layers

(1) Current Conditions of Paleovegetation Samples
When the core sample was collected and analyzed from the surface layer to the layers located 5m below from the surface, a large amount of spores and pollen such as spores of Pteridophyta and pollen of gymnosperms and angiosperms were found. (See Figure 3)

Spores of Pteridophyta were mainly found from the samples collected between the surface and the layers located at 195cm below ground. The representative spores are from Crypsinus hastatus, Osmunda and Ceratopteris with y-shaped trilete apertures.

The representative kinds of pollen of gymnosperms in the crater are pollen of conifer such as Pinus, Abies, Picea and that of Taxodiaceae, Cupressaceae, Texaceae, and Ephedra. Among them, pollen of bola cypress is abundant, accounting for about 10% of all the pollen found in the samples collected between the surface and the sedimentary layers 195cm below ground. In the samples collected from sedimentary layers located deeper than 195cm from the surface, the portion of the pollen of bola cypress decreases.

The most various and abundant types of pollen come from angiosperms. However, the appearance patterns of woody plants and herbaceous plants are different. Pollen of woody plants appears in the all the samples, even though its appearance frequency is not high. On the other hand, pollen of herbaceous plants appears mainly in the samples collected deeper than 195cm from the surface. The representative types of pollen of woody plants which are frequently found in the samples are from Quercus, Castanea/Castanopsis, Alnus, Betula, Carpinus, Ulmus/Zelkova, and etc. They have 5-15% of the production frequency. With regard to the pollen from Herbaceous plants, the dominant types of pollen come from Graminaceae/Poaceae, Compositae/Asteraceae, Persicaria, Cyperaceae, Myriophyllum, Rumex, Nymphoides, Caryophyllaceae, Chenopodiaceae-Amaranthaceae, and etc. Among them, pollen of Compositae/Asteraceae is the most dominant in the samples deeper than 195cm from the surface and its share is 30-50%.

On the whole, the most dominant kinds of pollen are from Crypsinus hastatus, broad-leaf trees, and herbaceous plants. The apperance patterns clearly differ from the above and the below of the 195cm line. In the samples collected from the upper part of the 195 cm line, pollen of Crypsinus hastatus, Taxodiaceae-Cupressaceae-Taxaceae, Quercus, and Ulmus/Zelkova is dominant. However, below the 195cm line, pollen of herbaceous plants (Artemisia is the representative one) is dormant.
(2) Ecological features of spores and pollen from Hanon Crater

It turned out that most of the donor plants of the spores and pollen of Hanon Crater are mainly temperate zone plants. They have ecological features which enable them to inhabit wider climate zones but there are also some plants which clearly prefer some climate conditions to other climate ones.

Crypsinus hastatus, which is the representative kind of Pteridophyta, is distributed relatively over large areas and is known for its inhabitation in warm and humid temperate zones (Barnett, 1989; Berglund, 1986; Davis et al., 1980; Hopkins, 1969). Coniogramme intermedia is distributed in forests or watersides in temperate or tropical zones but it can also be found in chilly temperate zones due to its resistance to cold. Currently, water fern is a tropical or subtropical plant which inhabits the southern part of the Korean Peninsula in areas such as Yeosu. Taxodiaceae-Cupressaceae-Taxaceae mainly inhabit humid lowland in warm temperate zones.

Pinaceae such as Pinus, Picea, and Abies have been found in various environments around the world after the Tertiary Period. However, they are found most abundantly in alpine regions in chilly temperate zones.

Betula, Carpinus, Ulmus)/Zelkova, and Quercus whose pollen frequently appears in Hanon Crater are forest trees or shrubs. They mainly form a colony on slopes of mountains in chilly temperate zones. Evergreen broad-leaved trees such as Castanopsis, Magnolia, and Elaeagnus are plants which inhabit warm temperate or subtropical zones. The pollen of these plants dominantly appear in the sample collected from the surface to the sedimentary layers 195cm below from the surface.

Potamogeton, Myriophyllum, and Nymphoides appears in most of the samples even though their yields are small. They are aquatic plants found in ponds, lakesides, and riversides. Their share in the samples collected deeper than 195cm under the ground is 50% on average. It is known that herbaceous plants, which appear abundantly in Hanon Crater, appear on earth for the first time in the Oligocene Epoch and flourished rapidly after the Miocene Epoch. They now inhabit various areas around the world in very different environments. But also they are known to like a chilly and dry climate and can be influenced by local climates and physiographic factors.

In particular, Artemisia, Gramineae/Poaceae, and Chenopodiaceae-Amaranthaceae, which dominantly appeared in this analysis, are well known to be representative plants in the glacial period. (Ager & Brubaker, 1985; Bryant & Hall, 1993; Tsukada et al., 1986)

(3) Characteristics of Paleoclimate

The reason why the appearance patterns are different between the upper part and the lower part of the depth of 195cm underground is that they were influenced by the climate change at the transition period from the glacial period to the Holocene Epoch. In the sample collected deeper than 195cm underground, herbaceous plants are dominant and Crypsinus hastatus, and Taxodiaceae-Cupressaceae-Taxaceae decrease rapidly. This seems to be caused by the influence of the climate coldness which is related with the glacial period (Adam, 1988; Berglund, 1986; Davis et al., 1980; Delcourt and Delcourt, 1989; Whitlock and Bartlein, 1997). In other words, the sedimentary layers above the depth of 195cm show the vegetation of the Holocene Epoch whose climate was very similar to that of the present, which is warm and humid. The sedimentary layers below the depth of 195cm show the vegetation of the glacial period whose climate was cold and dry.

The vegetation under the depth of 195cm seems to be similar to the vegetation of the mountainous areas of the upper-middle part of the Korean Peninsula in the present (Lee & Lim, 1978; Lee et al., 1985). The climate of this region is a chilly temperate climate or subarctic one. The annual average temperature is around 10℃. Therefore, it
seems that the vegetation of the sedimentary layers under the depth of 195cm in Seogwipo was formed in a climate whose annual average temperature was lower than that in the present day in Seogwipo (16.6°C from 1981 to 2010, Korea Meteorological Administration) by more than 5°C at least.

Part 3 Human and Social Environment

1. History of Agriculture in Hanon Crater

The fact that people tore down the wall of Hanon Crater in order to do rice farming in the Joseon Dynasty appears in a renowned geographic book, Shin-dongguk-yeoji-seungnam and Tamra-ji which was published by then Jeju Governor Lee Won-jin.

In Shin-dongguk-yeoji-seungnam, there is a description on Sammaebong and Hanon Crater such as “Sammaebong is located 11.8km away to the west of Jeonguighyeon (administrative district). Around Sammaebong, there are a number of fields and rice paddies. The name of area in which these fields and rice paddies are located is ‘Keun Mot (meaning ‘big pond’ in Korean)”.

It can be deduced from the record that there were many fields and rice paddies in the Hanon Crater area and the crater’s old name was “Dae Ji (大池, meaning ‘big pond’ in Chinese character)” then later the name changed into “Dae Dap (大沓, meaning ‘great rice paddies’ in Chinese characters)” after rice farming began and many rice paddies appeared in the crater. This record is an important clue as to when rice farming began in Hanon Crater.

In Tamra-ji published in 1653, there is also another record of Sammaebong and Mulmangso (spring on the base of Hanon Crater) saying, “Sammaebong is 29.5km away to the west of the hyeon (Jeonguighyeon). The central part of Sammaebong is flat and wide and there are dozens of rice paddies there. ‘Joyeon (Mulmangso)” is on Sammaebong and its name comes from the fact that there are many duckweeds on the surface of the spring water. Later, people torn down the eastern part of Sammaebong and turned the area into fields and rice paddies using the water inside Sammaebong.” From this record, it can be deduced that, in the past, the name “Sammaebong” refers to Sammaebong and Hanon Crater together and people pulled down the wall of the crater and drained off water to do rice farming and dry-field farming a long time ago.

On Jihyeong-do, a topographic map published in 1915, Hanon Crater appears as a rice paddy field with the name of “Dae Dap” and in Tamra-Sunryeok-do, a picture book on Jeju Island of 1702, Hanon Crater appears as a big circle and is named as “Dae Dap”.

According to Jejudo-ji (History of Jeju Island) written by Park Yeong-hu in 1976, in 1428, King Sejong exempted people on Jeju Island from taxation because the soil of Jeju was barren and there weren’t many rice paddies on the island. However, in 1521, under the ruling of King Jungjong, then Jeju Governor Lee Un introduced a tax on produce from rice paddies after he obtained approval from the royal court.

According to a folk tale, in the past, it was very difficult to do rice farming on Hanon Crater because the rice paddies on the crater were all wetted rice paddies. But, one day, a feng shui expert, who was passing by the village, suggested that the residents break down the wall of the crater and make a waterway. The expert said that if the village people did what he told them to do, they would able to do rice-farming more conveniently. As the residents followed his advice, the rice-farming became much easier than before.

According to Sejong-Silrok-Jiri-ji, a geographical book published in 1454, there is no record of rice paddies in Jeonguithyeon where Hanon Crater is located. Considering all the related records, it seems that people tore down the wall of the crater and drained off water around the year 1500, almost 500 years ago.
2. Current Conditions of Land Use and Buildings and Facilities

With regard to the current conditions of the land use in Hanon Crater, the total area of the land subjected to the restoration project is 1,236,114m$^2$ (1,246 lots). The area of the state-owned and public-owned land is 122,271m$^2$ (61 lots) and that of the private-owned land is 1,113,843m$^2$ (1,185 lots). The private-owned land accounts for 90.11% of the total area of the targeted land. Regarding the classification of the land, 75.5% (933,787m$^2$) of the land is farmland such as fields, rice paddies and orchards. Among the land subjected to the restoration project, 1,188,413m$^2$ of the land will be included to the planned district of the restoration project (96.14% of the total land subjected to the restoration project).

Facilities on the targeted land are 184 artificial facilities such as houses, warehouses, and discarded buildings, 15 houses for farming, and 89 graves. They lie scattered around the crater basin.

The targeted land for the restoration project faces a local road (Local Road 1132) to the north and a municipal road (Taepyeong-ro) to the south. The total length of the roads on the targeted land is 4.7km. Most of the roads are concrete-paved and around 2m wide. There are some unpaved roads for passing between orchards.

3. Current Conditions of Geological and Ecological Resources around Hanon Crater

Geological and ecological resources around Hanon Crater are Sammaebong, Oedolgae Rock, Cheonjiyeon Waterfall, Seogwipo Shellfish Fossil Mound, and Geolmae Ecological Park. Hanon Crater sits in the central axis from which all the above ecological sites can be connected.

Chapter 3 Geological, Ecological, and Environmental Value of Hanon Crater

Part 1 The Value of the Only Maar Type Crater and Sedimentary Layers of the Korean Peninsula

1. Generation Process of Maar Type Crater

(1) On the way from the ground, magma during the initial period of a volcanic eruption (2) comes in contact with layers of underground water and causes explosive eruptions of volcanic ashes (3). A tuff tephra ring is formed by volcanic ashes and a deep crater lake is often created due to layers of underground water when volcanic activities stop. The Hanon Crater is one example of such an event (See Figure 4. For more details, refer to Part 2 ‘Geological Value of Hanon Vocano’).

![Figure 4. Generation Process of a Maar Type Crater](source: Martin Koziol (2010))
2. Generation Process of Sedimentary Layers in Hanon Maar Crater

Since the Hanon maar crater, a closed underwater environment developed on top of a volcano, has a low energy environment with less influence of water flow, its sediment deposits are mainly under the influence of climate that can affect the ecosystem and the wind, and the biological, geological, and topological environment. Therefore, it plays an important role as an indicator of paleoenvironment.

The clastic deposits accumulated in the Hanon crater can be classified into self-origin and external origin. The sediments of self-origin are the weathered particles of tuff and igneous rocks that are distributed on the crater ring and within the crater, brought in by slope landslide, rainwater, or wind. Externally originated sediments are composed of dust particles, yellow sand, and tephra, mostly brought in by wind while floating in the atmosphere. Organic deposits are the product of aquatic microorganism, such as planktons in the lake, the flora and fauna, and the wildlife species inhabiting the surrounding area of the crater, including pollen and spores in the air. Chemical sediments occur when the components of dissolved rock of the crater and the elements dissolved in the water while organisms secrete or decompose after death undergo some aquatic chemical changes.

3. Seasonal Changes of the Sediments of Hanon Crater

The sediments of maar craters show layer structure accumulated on a yearly basis. The sediment layers of maar contain the yellow sand and dust of dry winters and as the season changes into summer, the size and the amount of particles become larger, forming varve, which is the clock of nature. Maar crater sediment is not only a tool to measure archaeological dates but also a tool that retains the records of the environmental changes.

4. The Environment of the Sediments of Hanon Crater

In general, in most maar craters, the temperature at the bottom is low and has low oxygen contents, and despite the seasonal influence, it shows a strong thermocline layer.

Since the water at the bottom of the crater is anaerobic, the sediments are not disturbed by epibenthic species. That’s why the paleoenvironmental record of long periods of time is preserved in the maar sediments. As the temperature, oxygen, and the intensity of illumination become drastically low at the bottom, it has the same effect as putting canned goods in the refrigerator. Hence, the paleoclimatic and paleobio information has been well-preserved without disturbance, with which we can interpret the changes of global environment for tens of thousands of years including the ice age.

5. Changes in vegetation in the sediments

The result of the analysis of the Hanon sediments based on the biomiozation categorized by climate conditions reveals that the vegetation has changed from those of khingan fir and birch genus, currently growing in Mt. Baekdu area and above, to those of indeciduate oaks (Japanese Evergreen Oak, Blue Japanese Oak etc.). That is, as the climate changed, the shifts in plant species dominating the crater also took place in the order of frigid mixed forest, temperate deciduous forest, frigid mixed forest, temperate forest, frigid coniferous forest, frigid mixed forest, warm temperate forest, temperate deciduous forest, and warm temperate forest. (Figure 5)
6. Chronological Mean Temperature Changes in the Hanon Sediments

According to the analysis of the sediments, the mean temperature from 12,000 years ago to the present is 14°C, which is similar to the climate of Seogwipo. During the period before 18,000 years ago, the annual mean temperature was 3°C. This indicates that the temperature rise that initiated from this period resulted in the retreat of the Ice Age, and that it occurred 2,000-3,000 years earlier compared to other northern hemispheric regions. It is presumed that the reason Jeju Island responded the quickest to the changes in the surface temperature of the west Pacific Ocean was due to the influence of Kuroshio Warm Current.
Part 2. Geological Values of the Hanon Volcano

1. The Only Maar Crater on the Korean Peninsula

With Cheonjiyeon trachyandesite, Gaksubawi trachyandesite, and Beopjeongdong trachybasalt as its base rock, the geology of the Hanon volcano is made up of, from the bottom, hanon tuff, hanon basalt and scoria layer, and hanon lacustrine deposit. As the volcano is comprised of a crater which was formed when the surface indented to the level before the explosion, and a tuff ring that surrounds the crater, it is classified as a maar according to the definitions of Fisher and Schmincke (1984), Cas and Wright (1987), and Vespermann and Schmincke (2000). According to Wohletz and Sheridand (1983), it is categorized as a tuff ring with a maar crater. Judging from the fact that the crater was filled with water after its volcanic formation and lacustrine sedimentation occurred until recently, it is classified as maar that fits the definition by Bardintzeff and McBirney (2000).

Maar is a crater formed when the surface is deeply caved in due to a steam-magmatic eruption of basaltic magma. It is distinctively different from a caldera formed by sinkage of a volcano from rhyolitic or quartz andecitic magma in the types of magma, the types of volcanic eruption, and the basin formation mechanisms. Unlike calderas formed when underground magma collapses immediately after volcanic eruption, such as Cheonji of Mt. Baekdu, Nari Basin of Uleungdo Island, and Sangumburi crater of Jeju Island, the Hanon volcano is the only maar crater on the Korean peninsula.

2. Formation of Cinder Cones and a Crater Lake

The Hanon tuff, containing accretionary lapilli and structures such as parallel lamination, wavy bedding, and bomb sack, can be interpreted as deposits of pyroclastic surge generated by hydrovolcanism and its fall accompanying the volcanic activity. (Moore, 1967; Waters and Fisher, 1971; Kienle et al., 1980; Sohn, 1996)

Around 34,000 years ago, which is presumed to be the time of the eruption, since it is reported that the sea level at the time was 65 meters lower than the current one (Chappell and Shackleton, 1986), and Gaksubawi trachyandesite, the base rock of the Hanon volcano, appears within the crater at 65~85 meters above sea level, it can be interpreted that the eruption occurred in inland environment which was 130~150 meters above sea level. (Yun Seokhun et al., 2006) Therefore, it is assumed that the hydrovolcanic eruption that formed the Hanon volcano happened when the deep underground water came into contact with magma. (Yun Seokhun et al., 2006)

Since the Hanon volcano developed immediately over the Gaksubawi trachyandesite aged about 76,000 years old (Bak Gihwa et al., 2000), the eruption is presumed to have occurred after this period. Given that the sediment layers are accumulated approximately 30 ~ 40 centimeters in depth in 1,000 years, to date the Hanon maar sediment as high as 15 meters suggests that it has been piled for about 50,000 years. There are, however, differences in the period ranging from 34,000 to 70,000 years among researchers, necessitating the scientific measurement through detailed survey including geological investigation and sediment drilling.

Meanwhile, at the time of volcanic activity, a strong hydrovolcanic eruption occurred between magma and underground water deep under the inland area at the altitude of 130~150 meters above sea level, a crater was formed below the surface level, and volcanic material piled up around the crater to form a maar. As the underground water was exhausted or blocked from entering into the crater, the eruption turned into Strombolian or Hawaiian type to form cinder cones...
and a crater lake in the center of the crater. Immediately after the volcanic activities finished, a crater lake began to form inside the crater and as high as 15 meters of maar sediment layers developed up until relatively recently.

Part 3 Geopolitical Values

The weather pattern in East Asia is dominated by summer and winter monsoon system; warm humid oceanic atmosphere blows towards the continent in summer and cold dry air blows out of the Asian continent. (Korea Ocean Research and Development Institute, 2004)

Jeju Island is geopolitically situated in the center of Far East including the Korean peninsula, China, and Japan, a very important region. Located in the middle of the East China Sea, facing Kyushu to the east, the mainland China to the west, and the Korean peninsula to the north in between the South Sea, Jeju has distinct weather patterns both continental and oceanic depending on the season.

For this reason, it is under the influence of maritime tropical air mass and continental tropical air mass. In spring and fall, Jeju is periodically affected by troughs of low pressure and migratory anticyclones coming from southeastern China, while in summer, as the first hit by southwest monsoon in the country, it is on the route of summer monsoons and typhoons. When the cold and humid Okhotsk sea air mass and the hot and humid North Pacific air mass collide, the seasonal rain front moves northward from the south of Jeju Island, during which the Westerly jet in the upper atmosphere moves southward, causing torrential rain, and otherwise, the Okhotsk sea air mass is strengthened, causing drought to last longer. In winter, as Jeju is rather influenced by the cold air mass weakened and denatured while passing the ocean than the directly influenced by the northwestern continental air mass. Due to the influence of the warm Kuroshio Current, Jeju is also the region that responds fastest to the changes of the sea-surface temperature in the western Pacific.

Therefore, having a host of environmental factors the Hanon crater of Jeju Island, having a host of environmental factors, is a key to dating and interpreting the sedimentary environment in the northeast Asian region, provides detailed accounts of the climate change process in the East Asian region for the past 50,000 years by analyzing the paleoclimate, and can be used as a model to predict the future climate.

Chapter 4 Restoration Goals and Directions

Part 1 The Progress of the Restoration Promotion of the Hanon Crater

1. Promotion Process

While the Hanon area was long abandoned, part of the crater was damaged and the crater lake disappeared as it began to be used as a rice field about 500 years ago. More recently, it was faced with threats of thoughtless development. In 2002, Seogwipo city set up plans to utilize the Hanon crater as off-season baseball training ground, causing a strong resistance. The pressure of development continued as the landowners of the crater raised insistence that a tourism and entertainment complex with a park, arts and sports facilities, and shopping be built.

Hanon began to receive attention in 2002, when Seogwipo city announced the plans to build a baseball training facility. While the civic environmentalist group was responding to the issue, new light was shed on the result of Japanese research team ALDP (Asian Lake Drilling Programme) in 1998. Afterwards, through several international symposiums, a number of scientists have shown keen interest, the need for restoration of the Hanon crater has been steadily raised in order to preserve its global, environmental values and utilize
it for the future generations in a sustainable way.

In 2004, Seogwipo city began to promote the restoration project as the first administrative body by establishing the master plan for the Hanon Ecological Forest Restoration Project. International symposiums were held in 2004, 2006, 2010, and 2011 under the theme of restoration and preservation of Hanon crater attended by experts in volcano, geology, and ecology from Germany, Poland, Japan, China and Korea, which were a catalyst to discuss the values of the crater and form international consensus. (Table 1)

More concrete activities for restoration and preservation have been developed in administrative and private levels since 2011. The National Promotion Committee for Hanon Crater Restoration (chairpeople: Go Chungseok, Seo Yeongbae) was launched on the third of August 2012, after one and a half years of preparation, with its 578 members representing academia, culture and art community, environmental specialists, local residents, and had the restoration, conservation agenda adopted at the World Conservation Congress 2012 organized by the IUCN.

The initiative of ‘Hanon Crater Restoration and Conservation’ prepared by Seogwipo City and the National Promotion Committee for Hanon Crater Restoration and proposed by Jeju Speical Self-Governing Province, was placed on the IUCN Congress on September 12, 2012, passed with overwhelming majority votes in favor (99.3%) and adopted as a Recommendation. It served as momentum to elicit support and consensus from home and abroad, and made a breakthrough in driving the Hanon restoration project into an important national policy task. (Figure 7)

With 2012 WCC as momentum, the values of the Hanon crater and the need for its restoration rose to international prominence, Jeju Special Self-Governing Province and Seogwipo City undertook preparation work to establish ‘Hanon Crater Restoration Master Plan’ in 2013.

In August 2013, in order to make the breakthrough for the restoration project through cooperation with international environmental groups such as the IUCN, the delegation of National Promotion Committee for Restoring Hanon Crater paid a visit to the IUCN headquarters in Geneva, Switzerland, had a meeting with Julia Marton-Lefevre, IUCN Secretary General, Enrique Lahmann, Global Director, and other high officials. Through an official document for cooperation dating August 26, it was decided that CEM, Commission on Ecosystem Management, an IUCN-affiliated expert group, would join the restoration project, a desired outcome to proceed the project in collaboration with a world-class international expert group and international cooperation at the level of IUCN headquarters.

Table 1. Foreign Scholars’ Opinion on Jeju Hanon Crater

| Prof. Hitoshi Fukusawa | “Since there are a lot of paleoclimatic and paleontological materials in Hanon, Jeju Island is the most important place for studying paleoclimate and predicting future climate and climate models.” |
| Prof. Miroslaw Makohonienko | “The Hanon crater is a perfect archive to demonstrate the history of local paleoecology and paleoenvironment as well as that of natural heritage of Jeju Island and the entire region. The climate changes, vegetation changes, biodiversity, and the history of human activities of East Asia can be identified at Hanon.” |
| Prof. Hiroyuki Kitagawa | “Due to its important geopolitical location, the Hanon Maar, as an archive of the East Asian climate changes of the past, will be a critical key to predicting regional and global climate changes.” |
## Assessment and Implications of Restoration Activities

Started as an opposition to the plan to use the Hanon crater as a baseball training ground in 2002, and undergoing multiple international symposiums and national promotion committee for restoring Hanon crater, the issue has induced an international awareness of the values of the Hanon crater and consensus on the need for restoration. This remarkable result was led to develop as an international issue when the motion for restoration and conservation of the Hanon crater was introduced at the WCC 2012 and the recommendation was adopted by IUCN member organizations by overwhelming votes in favor (99.3%).

The positive outcomes of the restoration promotion activities include a wide range of study and international consensus on the values and importance of the Hanon crater, strong support and interests from geology, ecology, and environment experts around the globe, growing interests and participation from academia, culture and art community, civil environment groups, and local residents, changes in the awareness of the central government and local administrative agencies that were indifferent, negative or

<table>
<thead>
<tr>
<th>Dr. Achim Brauer</th>
<th>“The maar lake sediments accumulated year by year is an ideal recorder of the past climate and environmental changes.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Jörg F.W. Negendank</td>
<td>“Hanon needs to avoid thoughtless development, preserve its original state and reproduce the lake in the crater.”</td>
</tr>
<tr>
<td>Prof. Yoshinori Yasuda</td>
<td>“The restoration of the maar lake and the sediment conservation project is a miraculous event and a very interesting proposal, and if the lake can be reproduced, permanent conservation of its environment will be possible.”</td>
</tr>
</tbody>
</table>

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### IUCN Recommendations at WCC 2012 (Sep.12, 2012)

- Request the six IUCN Commissions (Commission on Ecosystem Management, Commission on Education and Communication, Commission on Environmental, Economic and Social Policy, Commission on Environmental Law, World Commission on Protected Area, Species Survival Commission) to monitor and help with the Hanon crater restoration and conservation project so that the initiatives for recovery project can be disseminated to other States, regions and throughout the world.
- Recommends that governments of the Republic of Korea establish and execute a comprehensive plan for restoration of the natural environment of the Hanon crater.
- Recommends establishment of an international academic research network that can contribute to the provision of predictions on climate change.

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Figure 7. 2012 WCC IUCN Recommendations
had lukewarm attitudes, and international recognition of the values and the importance of restoration at WCC 2012, which later became an international agenda.

The problems to point out were the lack of communication, in the process of the promotion activities, with the administration, civil environmental groups, and the local residents including the property owners, the lack of understanding the values of the Hanon crater by the promoters themselves, and insufficient goal setting coherent to the restoration project.

Despite these achievements up to this point, there still remain tasks to make the restoration work reflected in national policies and transform it into a national project carried out by the central government itself.

To this end, it is urgent to establish the values of the crater and secure logical legitimacy of its restoration so that the government will take interest and fulfill its duty to restore its natural environment. As a separate body from the National Promotion Committee for Restoring the Hanon Crater, an organization exclusive to promoting national projects needs to be organized to negotiate between the central government and the committee. The organization can be made up of members of the National Assembly, members of the provincial assembly, Jeju Special Self-Governing Province, National Promotion Committee, related specialists, and representatives of the local residents. At the same time, a mechanism for close cooperation and support is also needed with the departments concerned, such as governments (central and municipal), related organizations, and the IUCN, in which duties and projects of each participating party are to be reestablished and the roadmap for promoting a national project is to be made so that the restoration work is carried out organizationally, systematically and extensively.

In particular, it is urgent to inform the public in order to induce nationwide support and interest in the restoration project of the Hanon crater, and it is necessary to help the landowners and the residents to fully understand and agree on the recovery work.

Part 2 The Status of the Hanon Crater and the Grounds for Promoting a National Project

1. Status of the Hanon Crater

The Hanon crater contains the paleoenvironmental data of geology, climate, ecology, etc., for 50,000 years since the Ice Era. It is the living museum of the Earth, a natural time capsule and the Earth’s most precious asset that can contribute to providing predictions for climate change, as well as the history of ancient organisms and climate of East Asia. As the largest crater in size in the Korean peninsula, unlike the other calderas, or collapse craters such as Cheonjji of Mt. Baekdu and Nari of Uleungdo Island, it is also the only maar crater formed by an explosion when the magma came into contact with underground water.

In the early stage of the explosion, when magma came into contact with underground water, explosive tephra was launched into the air and the pyroclastic flow eventually formed a tuff crater ring. As the volcanic activity continued, when underground water was exhausted, molten lava, instead of tephra, erupted to create four cinder cones in the center of the crater and a lava pond was formed in the low lying ground within the crater. At the bottom of the crater lake created after the volcanic activity was completed, 15 meters of sediment was accumulated for tens of thousands of years, which is an invaluable record of climatic and biological information of East Asia.

The Hanon crater is the only resource in Korea to study maar in line with geology and volcanic activity. Storing paleontological and paleoclimatic information in the sediments piled for 50,000 years, the crater has high scientific value in terms of geology and environment. By unveiling the history of natural heritage, such as the climate changes,
vegetation changes, and biodiversity in East Asia, it is invaluable as an absolute asset that can contribute to the humanity, academically and policy wise.

2. Justification for Promoting the National Project

The study on the sediments of the Hanon crater accumulated for about 50,000 years and the characteristics of its geopolitical location will enable the analysis of the history of the ancient East Asian organisms and climate and can provide predictions for climate changes.

The restoration of the Hanon crater will contribute to producing academic materials highly applicable not only to the concerned area but also the State and the entire globe. A case in point is Vulcaneifel, a maar crater in Germany, where an international research network has been established with France, Russia, and Asian countries, including the CDMP, Chinese Maar Drilling Program, with the Chinese government since 1995.

As it was recommended by the IUCN at WCC 2012 to implement a national restoration and conservation project for the Hanon crater, its geological and environmental values have been recognized and international consensus on the need for restoration and conservation has been created.

The crater can be used as a space for ecology and environment education, and bring economic effect to the community when used as a resource for education and tourism. Vulcaneifel in Germany, for instance, since a geotourism program related to the maar crater began to operate, has been visited by more than 1.5 million people annually from home and abroad.

As the world is showing high interest in natural ecological restoration, promoting the Hanon crater restoration project will be an exemplary case of national environmental policy. Being the world’s first example of restoring a maar crater, the project will ultimately enhance the national status.

Not only that, by demonstrating the will to comply with the WCC’s recommendation at the national level, the Republic of Korea will secure international credibility on its environmental policies and show its position as an environmentally-developed country. In addition, the restoration of the crater will raise the nation’s awareness on the values and conservation of ecological and environmental resources, which will be able to induce compliance with national environment policies.

3. Grounds for a National Project

As a set of laws based on the Article 10 and the Section 1 of the Article 35 of the Constitution, including the Framework Act on Environmental Policy, the Natural Environment Conservation Act, and the Framework Act on Science and Technology, stipulate that restoring the natural ecology and conserving the natural environment is a national responsibility, the restoration and conservation of the Hanon crater accords with the higher law in that it contributes to improving the quality of life of the people of the country and to realizing their dignity.

With regards to the main implementer of the restoration work, considering its symbolic representation as a national resource, the characteristics of the resource, the scale of the project, the time required, the technology for restoring natural environment, and the international cooperation, it is appropriate to proceed it as a national project, for there exist limits for municipalities to carry out the plans.

Part 3 Master Plan for Restoration

1. Visions and Goals of Restoration

(1) Visions

The purpose to restore the Hanon crater is to permanently conserve the maar sediments
containing biological information from tens of thousands of years ago, utilize it as a place for ex situ conservation of rare and endangered marshy vegetation, and maximize its values as an educational resource of ecology and environment and a resource of geology, ecology, and climate change prediction. The ultimate grand vision of this project is, through the restoration and sustainable conservation and utilization of the crater, to realize the life value of good quality for the future generations of the country and the humanity.

(2) Objectives

Restoration objectives are, while systematically implementing the ‘IUCN recommendations for ‘restoration and conservation of the Hanon crater of Jeju’ adopted at WCC 2012, to restore the Hanon crater, damaged about 500 years ago, to its original state and then conserve and use in a sustainable way; through this restoration work, to induce the designation of the crater as a Biosphere Reserve linked with UNESCO’s Jeju Island Biosphere Reserve; to establish the foundation for its Biosphere Reserve designation by preparing an integrated conservation plans of the Hanon crater area through the restoration of the damaged periphery area; and to build a historical and cultural resource base by reconstructing the crater 500 years ago, the changes and its current state through the restoration.

2. The area subject to restoration

The planned area subject to restoration is 1,188,413 square meters in total, of which the actual restoration area is 989,300 square meters, and facility area is 199,113 square meters.

3. Setting directions of restoration

Figure 8. Restoration Framework

In principle, the Biosphere Model of UNESCO MAB (Man and the Biosphere Programme) will be applied in deciding the area subject to restoration. The most desirable alternative is to determine the core area around the water system within the Hanon crater which needs special protection, 200 meters from the core area a buffer area considering the travel distance of wild animals such as birds, and outside the buffer area a transition area. However, the current state of the land usage will be taken into account in determining the boundary of the subject area within the scope in which the ecology of the Hanon crater will be preserved in a sustainable way. The direction of restoration is, in terms of the crater wall, the lake and the natural vegetation, to reconstruct the crater to its predisturbance state before it was drained to make a rice field about 500 years ago.
4. Source of the Restoration Framework

The restoration framework in this Ecological Restoration Master Plan is adapted from the restoration process outlined in the IUCN document “Ecological Restoration for Protected Areas, Principles, Guidelines and Best Practices” (Keenleyside et al. 2012). The framework is presented schematically in Figure 8. The framework presented here is designed to be compatible with an adaptive management approach, which is described in detail in Phase 7.

4.1. Restoration Problem and Stakeholder Engagement (Phase 1)

Restoring the Hanon Maar Crater is a project that has support among a wide group of interested parties, but to build political will and secure funding for the implementation, several additional factors need to be in place. The project must have 1) a concise and compelling rationale, 2) a coherent implementation plan, 3) a justified cost estimate and timeframe, 3) demonstrated community support, 4) clearly delineated leadership and 5) a plan to ensure transparency and sharing of information.

4.2. Problem Assessment (Phase 2)

(1) Current Conditions (Phase 2.1)

Because of the paleological climate record in the crater floor and as a result of the sustained efforts of various scientists from the Republic of Korea and elsewhere, there is already a body of knowledge that partially characterizes the project site. However, additional information requirements are identified.

A full site assessment will be required to gather the necessary information required to prepare a restoration design. It is composed of two distinct steps. The first is simply gathering information and collecting field data. The second is the analysis and synthesis of this data, which will help determine which restoration approach is the most desirable and feasible.

(2) Reference Ecosystems (Phase 2.2)

Reference areas are a tool commonly used in the science of restoration ecology to help guide the restoration of disturbed or impacted natural communities. In general, reference site flora and fauna are useful templates for restoration because they are less disturbed and contain a relatively high level of ecological function, diversity and structure.

The reference ecosystem sites selected for the project provide a basis for comparison for important attributes of the Hanon Maar Crater such as altitude, topography, vegetation community types, hydrology, soil types and soil moisture regime. They both include mature stands of native vegetation.

Accordingly, sites that have similar physical characteristics and still contain vegetation communities reminiscent of the predisturbance Hanon Maar Crater vegetation community may serve as reference sites (ex. Cheonjiyeon Waterfall or Sangumburi Crater) and be used as important data in restoring the natural vegetation of Hanon Crater.

It is anticipated that information on the types of native flora and fauna associated with lakes on Jeju Island is available and can be used for guidance in restoring the lake and its shoreline vegetation. Other data including soil series, litter layer depth, dead snags, aspect, surface hydrology, apparent wetland hydrology or soil moisture regime and historical information or collections in universities, herbariums or museums may also serve as a useful source of information about the historical conditions of the crater.

(3) Environmental and Social Impact Assessment (Phase 2.3)

Applicable laws and international guidelines will dictate the precise nature
of the environmental and social impact assessments required. An environmental impact assessment may be needed to determine if there will be any environmental damage (temporary or permanent) to the site or surrounding areas if the project is implemented. The benefits of the project need to be identified along with potential negative impacts. Socio/economic impacts will be similarly assessed, to determine the social or economic impacts if the project is implemented. These could include positive examples such as stimulation of the local economy by increased tourism or opportunities for eco-guides and negative impacts such as lost agricultural revenues or displaced inhabitants.

(4) Information Management System (Phase 2.4)

A great deal of information regarding the site will need to be collected, stored and managed. Information management and archiving is essential in executing a successful ecological restoration project, particularly because the project and the adaptive management of it, will be occurring over a long timeline. Documentation of initial activities preserves information that may be very useful decades later, and detailed information can also help to ensure the success of future projects. Plans for managing data will be described and agreed upon early in the project life, and information management will be planned for an extended period into the future.

4.3. Ecological Restoration Goals (Phase 3)

The overarching project goal is to restore the Hanon Maar Crater in order to protect the historical fidelity of the only maar crater on the Korean peninsula, preserve the paleoclimatic and paleontological history of Jeju Island and the Korean peninsula for academic research, serve as a natural history destination for domestic and foreign tourists, and demonstrate the Republic of Korea’s commitment to ecological stewardship.

4.4. Ecological Restoration Objectives and Monitoring Plan (Phase 4)

(1) Restoration Objectives (Phase 4.1)

The objectives for ecological restoration process are to restore the damaged crater wall to accommodate the full predisturbance historical extent of the crater lake, restore the lake to its predisturbance historical size, depth and quality to support indigenous flora and fauna, revegetate the crater rim, walls and floor with indigenous plants representative of predisturbance vegetation communities and modified by current climatic trends, provide for an equitable and just transition for the inhabitants of Hanon Maar Crater, provide for an open and transparent restoration process, incorporate opportunities for community engagement throughout the restoration process, and integrate recreational, educational and tourism opportunities into restoration outcomes.

(2) Preliminary Monitoring Design (Phase 4.2)

Both adaptive management and measuring project success through time require relevant and accurate monitoring information and monitoring should be considered earlier in the process as well. Monitoring is an important component in overall project success; however, it must be accommodated in the project budget.

4.5. Ecological Restoration Approach (Phase 5)

4.5.1. Strategies and Alternatives (Phase 5.1)

(1) Objective 1: Restore the damaged crater wall

In order to restore the full pre-disturbance historical extent of the crater lake, the crater wall must be reestablished or an artificial
A dam must be constructed to retain the water originating from the springs within the crater. An artificial dam consisting of concrete, stone, or other material would meet the objectives of restoring the crater lake, but would not meet the goal of preserving the historical fidelity of the crater. In order to retain the historical fidelity of Hanon Maar Crater, reestablishment of the damaged crater wall using locally sourced natural materials is the recommended approach. The exact extent and shape of the crater wall prior to it being excavated over 500 years ago is not known, but analyzing the landforms, exposed rock scars and soils may provide evidence of its general shape and footprint. Implicit with this approach is the need to engineer an earthen dam capable of retaining the lake water given the existing geotechnical conditions of the in-situ soils, surrounding slopes and hydrologic conditions. Identified below are five strategies that must be considered in restoring the crater wall sufficient to retaining the predisturbance lake and reestablishing the historical fidelity of the Hanon Maar Crater.

■ Strategy 1.1: Restore the crater wall

In order to maintain the historical fidelity of the crater wall and meet dam safety regulation for creating the crater lake by impounding water up to six meters in depth, the three alternatives for restoration are identified below. (See Figure 9)

1. Alternative 1.1A - Earthen Dam – This alternative would consist of building an earthen dam sufficient to impound 6 meters of water. It would use the least amount of material of the three alternatives but would not recreate a historically accurate shape and footprint for the crater wall.

2. Alternative 1.1B - Partial Terra-forming – Partial Terra-forming would consist of building an earthen dam consistent with Alternative 1.1A to impound 6 meters of water with the addition of fill material on the walls of the dam to achieve greater historical fidelity to the original crater wall’s shape and footprint.

3. Alternative 1.1C - Full Terra-forming – Full Terra-forming would consist of building an earthen dam consistent with Alternative 1.1A to impound 6 meters of water with the addition of fill material on the walls and top of the dam to create the most historically accurate shape and footprint for the crater wall.

For comparison, Table “Basic characterization of the three impoundment options” (See Figure 9) summarizes the three alternatives with the estimated amount of earthen fill required, the final elevation of the top of the wall in meters above sea level, the surface area of the wall above the water line, and the width at the base and top of the wall.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Fill Required</th>
<th>Final Elevation</th>
<th>Area above</th>
<th>Width at Base</th>
<th>Width at Top</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthen Dam (1.1A)</td>
<td>15,000 m$^3$</td>
<td>61 m</td>
<td>0.6 ha</td>
<td>41m x 5m</td>
<td></td>
</tr>
<tr>
<td>Partial Terra-forming (1.1B)</td>
<td>46,000 m$^3$</td>
<td>61 m</td>
<td>2.6 ha</td>
<td>135m x 15m</td>
<td></td>
</tr>
<tr>
<td>Full Terra-forming (1.1C)</td>
<td>119,000 m$^3$</td>
<td>64 m</td>
<td>3.8 ha</td>
<td>150m x 16m</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9. (A) Alternative 1.1A, Earthen Dam, (B) Alternative 1.1B, Partial Terra-forming, (C) Alternative 1.1C, Full Terra-forming
Strategy 1.2: Install Water Control Structure

A water control structure is needed to serve three primary purposes: 1) manage water levels to accommodate storm flows; 2) manage water levels to improve water quality; and 3) manage water levels to enhance habitat for aquatic species and waterfowl. The water control structure would be engineered to include an inlet structure, ideally placed at or near the bottom of the lake with the capability of regulating the amount and rate of flow; an outflow pipe that conveys the discharge through the reconstructed crater wall; and an outlet structure designed to safely discharge the flows into a receiving body of water.

Strategy 1.3: Remove Infrastructure and Restore the Morphology and Hydrology of the Creater Wall

Restoring the full historical fidelity of the crater walls and the lake would require the complete removal of about 150 structures within and around the the interior rim of the crater. Regrading the crater walls to replicate the natural morphology and surface hydrology patterns of the land prior to disturbance, reestablishing a native woodland plant community in accordance with the final revegetation design is also needed.

Objective 2: Restore the lake to its predisturbance historical size, depth and quality to support indigenous flora and fauna

The restored lake is the keystone of the Hanon Maar Crater restoration. The final lake surface elevation will determine the amount of water that will be stored in the lake, drive the requirements for the impoundment, and affect the ecology of the lake habitat. It will also influence the type and extent of aquatic habitat and vegetation that will be restored. A full restoration of the Hanon Maar Crater to its predisturbance condition will require a lake of approximately 6m in depth, as estimated based on current morphological features of the crater wall.

Strategy 2.1: Restore the Lake to Its Original Water Level

Alternative 2.1A: Fill the lake on a delayed schedule

Soils on the crater floor and side slopes up to 6 meters from the crater floor may contain high levels of nutrients (N and P) and pesticide residues. Since the construction of the crater wall will take a number of years, it may be advantageous to employ passive remediation that relies on natural processes to reduce nutrients and pesticide residues before the lake is fully reestablished. While the specific remediation strategies would be contingent on the results of a comprehensive evaluation of soil contaminants, there are several remediation techniques that are commonly employed to contain, degrade or eliminate soil pollutants. A range of treatments could be applied to the lake bed under a delayed filling schedule.

Alternative 2.1B: Fill the crater incrementally

The limnology of the completely restored crater lake can be modeled based on similar lakes and impoundment projects, but the exact hydrological dynamics of the site will depend on a complex interaction of drivers such as water temperature, precipitation and flow rates. Filling the crater incrementally would provide an opportunity to evaluate some of these key drivers and address the mobilization of contaminants or excess nutrients from the lake bed as the lake fills. This would allow the project to better manage the lake water quality and reduce the risk of eutrophication before committing to the full 6 m lake restoration.

Alternative 2.1C: Fill the crater completely

This alternative would forgo both preparation of the lake bed and an incremental filling and simply allow the lake to fill once the crater wall is restored and can support a 6 m lake. Such an approach would be the least expensive method of filling the lake, especially if the soil testing reveals few contaminants of concern.
Strategy 2.2: Ensure Appropriate Water Quality of the Reconstructed Lake

In addition to managing the quality of the water as the lake fills, a program to manage the quality of the water on an annual basis would need to be developed and employed as part of the final restoration design. During the first years, this may include a recurring threat of eutrophication and algal blooms (see Strategy 1.2). This program would set water quality metrics for dissolved oxygen, excess nutrients, fecal coliform, sedimentation, etc., develop a monitoring and evaluation protocol and employ remediation strategies to address water quality issues. It would also serve to guide the habitat management goals for in-lake aquatic habitat as well as waterfowl and shorebirds.

(3) Objective 3: Restore Native Vegetation on the Crater Wall

Restoring native vegetation on the crater walls is a central component of the overall restoration of the Hanon Maar Crater. Successful vegetation restoration involves a number of inter-related site activities, including amending the soil to offset contamination or compaction problems if necessary, assessing the presence of invasive plant species and developing a plan for their control, controlling and/or eradicating and removing non-native non-invasive species potentially, and establishing native vegetation that reflects the reference area composition based on plant species, diversity, density and physical characteristics recorded in the reference areas.

Regardless of the restoration options that are ultimately employed, there are two necessary considerations that are long-term in nature and must be addressed.

Firstly, monitoring vegetation survival and growth using systematic sampling techniques over an extended period of time (decades) is an important part of the adaptive management of vegetation, to aid survival and plant vigor after vegetation is established and to ensure that plant diversity is maintained over time. Monitoring is also necessary for controlling invasive plant species over time.

Secondly, using the vegetation monitoring data and climate data, plant community structure should be examined periodically and assessed based on future climate change, with the goal of maintaining as much vegetative diversity and vigor as possible.

This second point is critical because shifts in vegetation based on climate change have been predicted for the future. Native vegetation restoration at the Hanon Maar Crater may present an excellent opportunity to experiment, if desired, with present and potential future plantings based on predicted climate shifts for the area. If the decision is made to pursue this, information gathered could help to better understand how the warming climate will affect plant species’ native ranges and vigor at the Crater site and in other similar areas.

Strategy 3.1 Access and Manage Soils

A well-balanced soil is crucial to the establishment of healthy native vegetation, and soils should be amended, if necessary before vegetation restoration is attempted. Soil erosion will need to be controlled throughout the restoration process. The construction of the crater wall should include a robust soil erosion plan. Other areas within the crater that are currently experiencing soil erosion or have the potential to experience soil erosion during the restoration process need to be addressed.

Strategy 3.2: Manage Exotic and Invasive Plant Species

Exotic plants are defined as plants that are not a component of the targeted native vegetation community for the restoration of Hanon Maar Crater, and generally include agricultural and possibly horticultural species. Invasive species are exotic plants that have the ability to displace native vegetation and negatively affect natural ecological processes. As part of the restoration of native plant
communities for the Hanon Maar Crater, a comprehensive exotic and invasive species management program will need to be developed.

- Strategy 3.3: Re-establish Native Vegetation

Restoring the crater to its predisturbance condition requires restoring native vegetation communities in areas that have been altered for human purposes over centuries. Excavation of the crater wall to drain the lake and the clearing of vegetation for agriculture, roads, houses and other buildings has removed most of the native vegetation from the Hanon Maar Crater. Based on the current land use land cover data, approximately 6% of the crater area is currently in forest cover, and 94% has been converted to other uses. Restoring native vegetation to the disturbed areas will create a diverse and robust forest cover that provides habitat to native wildlife, builds soil, and improves the quality of the water flowing into nearby water sources. The restored plant communities will grow vigorously, naturally replace senescing native species and resist invasive species. The restored vegetation will reflect the reference area’s plant species composition, structure and diversity and closely resemble the predisturbance forest cover.

There are three alternatives for re-establishing native vegetation where exotics exist, 1) planting native species in the available space (interplanting); 2) partially controlling exotic species and then revegetating; or 3) fully controlling exotic vegetation and revegetating.

Based on current information, there are four discrete vegetation zones at the Hanon Maar Crater site. They are the crater walls and rim, the restored crater wall, the floating cone areas, and the wetland fringe of the lake shore. (See Figure 10)

Figure 10. Basic Plan Drawing for Restoring Hanon Crater
The walls and rim of the Hanon Maar Crater are predominantly cultivated land of orchards and residential gardens. They range in elevation from approximately 55 m to approximately 145 m above sea level. Restoring native vegetation to the crater walls and rim can begin contingent upon the removal of existing infrastructure, the completion of any actions specified by the invasive species management plan and any necessary soil amendments, especially to the sites where infrastructure was recently removed. Given sufficient time for the propagation of native plants as necessary, the revegetation efforts on the walls can begin well before the completion of the crater wall and the filling of the lake.

Alternative 3.3A: Interplant Native Species in Existing Open Space

The current plant cover contains few native species. If alternative 3.3A Interplanting is chosen, native trees will be planted among the existing exotics, and as the exotics senesce, they will be replaced by natural recruitment of native species. A fully native forest is expected to be established after about 30 years.

If the regeneration of non-native species and invasive species is managed and controlled, then native species will eventually replace non-native species. The benefit to this alternative is that initial costs for native vegetation stock are low, and over time, natural regeneration occurs, cancelling the need to purchase additional stock, thus lowering overall cost.

However, this strategy will require an extended period of time before the non-native vegetation is replaced by native vegetation. This strategy is less expensive (estimated 50% less planting expenses than Alternative 3.3C), but requires patience in achieving the full restoration of native vegetation.

Alternative 3.3B: Partial Non-native Control and Revegetation

With this alternative, the non-native vegetation is cut, left to die and decompose where it falls without removing it, and native species are then planted in all open spaces and where infrastructure has been removed. As stated previously, this work occurs after invasive species have been controlled if necessary. This strategy requires an intermediate amount of site preparation and incurs costs associated with site preparation, purchasing planting stock, and planting (estimated planting costs are 75% of those for 3.3.C). As with Alternative 3.3A, the ability to mechanically cultivate the soil before planting native vegetation will be drastically limited or non-existent, due to the lack of large open spaces in which to operate cultivation equipment.

The benefits of this alternative are intermediate costs and an accelerated schedule for restoration of native vegetation, compared to Alternative 3.3.A. The challenges are that it will take several years before the non-native vegetation decomposes, and the aesthetics of the site will be affected by the presence of downed non-native vegetation for several years.

Alternative 3.3C: Full Non-native Control and Revegetation

This strategy alternative entails cutting all cultivated and non-native vegetation and removing it. Then native species are planted in all open spaces and where infrastructure has been removed. This strategy has the advantages of re-establishing full occupancy of native vegetation immediately and the removal of the non-native vegetation debris. The complete restoration of native vegetation is achieved more quickly, and the unsightly debris is minimal. However, there is the added expense involved in the removal of the non-native plant debris, site preparation and in the need for additional planting stock to fill in more open space, compared to Alternatives 3.3A and 3.3B. Therefore, this strategy alternative is the most expensive of the three.

Other Things to Consider

The restoration of the vegetation on the crater wall depends on the alternative chosen (1.1 A, B or C) for its reconstruction, though erosion control will be of utmost importance for each alternative, and planting must
therefore begin as soon as possible.

The vegetation of Boroni has been partially protected by the topography, and there is already a relatively natural forest occupying the north slope of it. The dominant species is reported to be Japanese black pine, *Pinus thunbergii*. The existing forest on Boroni may be allowed to mature naturally, without any intervention, unless invasive species are present. The existing orchards on the southern slopes of Boroni may be restored using the same alternative as that selected for the crater walls and rim.

Emergent wetland vegetation may be established where the lake is shallow (< 1 m) and there is very little wave action. These areas are designated as wetland fringe. It is assumed that native emergent wetland vegetation will naturally create wetland fringe habitat in the shallow areas around the lake. Additional species may be planted in these areas to add color or aesthetic appeal.

4.5.2. Develop an implementation plan (Phase 5.2)

The implementation plan should include the following components such as implementation funding and cost estimates, stakeholder engagement plan, engineering and ecological assessments, design documents, land use transition plan, invasive species management plan, plant material procurement plan, restoration services procurement plan, adaptive management framework and monitoring plan, implementation schedule, and implementation oversight plan.

4.5.3. Ecological Restoration Timeline (Phase 5.3)

The following timeline is an example of a schedule for the restoration process, which is a subcomponent of the overall implementation plan (See Figure 11).

![Figure 11. Ecological restoration timetable](image-url)
4.5.4. Development Performance Standards and Monitoring Plan (Phase 5.4).

Performance standards are criteria used to evaluate the results of a project and assist in ensuring that appropriate remedial measures are implemented if project metrics are not being met. Performance standards need to be tied to the Objectives; accurately measurable; appropriate to the temporal and spatial scale of the ecosystem, and cost-effective. They should be developed for restored lake water quality, vegetation restoration implementation, vegetation restoration results, erosion control, and exotics/Invasive species removal/treatment.

Once the performance standards are established, the monitoring plan will address progress toward those standards and provide additional information about the project. Monitoring is a critical component of ensuring that performance standards are being met. Monitoring methods must be both feasible and meaningful and be based on project-specific methods based on the performance standards. Monitoring can be both qualitative (photo monitoring) and quantitative (plant species richness, percent cover). Monitoring methods should be described in detail in a monitoring plan and include who is responsible for monitoring as well as how the results will be presented, e.g., monitoring report.

Monitoring should be directly integrated into the design of the restoration project, ensuring that all stakeholders understand and agree upon indicators that reflect their concerns (Estrella & Gaventa, 1998).

4.6. Implement Ecological Restoration Approach (Phase 6)

At this point in the project, implementation plans have been carefully developed and reviewed by all the respective stakeholders. Project implementation, and its success, is a function of the quality of the planning that went into it and the contractors who are selected to perform the work outlined in the implementation plans. Project implementation should include periodic assessments of progress, accompanied by opportunities for adjustments and corrections if necessary (adaptive management). It is important to maintain open communication between the restoration team and the respective contractors and subcontractors throughout the construction process, so that changes in the approach, when deemed necessary, are carried out smoothly and without undue expense. Project progress updates to stakeholders are key elements in project implementation.

4.7. Implement Adaptive Management (Phase 7)

Adaptive management is used to increase project implementation success in attaining restoration goals and objectives when faced with the uncertainty that is inevitable with natural ecosystem behavior. Adaptive management is also used to increase project implementation efficiency. It involves monitoring the restoration implementation process, assessing the monitoring data to determine if project objectives are being met, and adjusting the implementation process accordingly, to either continue with the process being used, or adapt the process and change it, based on strategic data from the project itself.

Adaptive management is not a trial and error process. It uses the implementation plan as a basis, and then refines it as necessary throughout the implementation process, based on project monitoring data. The type of data that is acquired through monitoring and then analyzed is carefully and strategically planned.

Part 4 Management and Utilizing Plan

1. Operation Plan of Education and Research Facilities
(1) Maar Dome (Hanon Maar Museum)

Maar Dome (Hanon Maar Museum) will exhibit displays showing the history, fossils, and paeloclimatic characteristics of Hanon Crater and play a role of educating, promoting, displaying and preserving the process and meaning of the restoration. As a museum, Maar Dome will be a key facility and play a central role of conserving valuable fossils from Maar volcanoes around the world.

Maar Dome will give an opportunity to experience the past through reproducing the paleontologic ecology and learn the process and differentiation of evolution through exhibitions and education. Research facilities annexed to Maar Dome will dedicate to the three objectives such as exhibition, education and research. There will be an exhibition hall called “World Exhibition Hall” for displaying the history of Maar Craters in the world, fossils and paleoclimate, extinction and evolution of ancient animals and plants. Another exhibition hall called “Hanon Restoration Exhibition Hall” dedicated to displaying the history, process, and effect of Hanon Crater Restoration. The third exhibition hall will show the core samples of Hanon Crater and supply researchers with data for studying paleontologic taxonomy, morphology, ecology, and meteorology. The last exhibition hall will be dedicated to education and promotion such as Scanning Electron Mircoscopy of pollen, education of image design, production of pollen model, education of age dating, paleoclimate and evolution of ancient animals and plants.

(2) Research Center for Studying Fossils and Paleoclimate

A research center for studying fossils and paleoclimate can be established near Hanon Crater. The center will be a complex research facilities for predicting the future change of the ecosystem of the Korean Peninsula and ways to deal with climate changes through researching species, distribution, evolution, and ecology of ancient animals and plants and paleoclimate.

The center will provide related information to IPCC (the International Panel on Climate Change) and exhibit key samples of fossils, and sedimentary layers and other geological data. The center will improve a country image by presenting demonstration models of restoring natural assets by human from reckless damage to nature.

The center will collect core samples of strata from Mt. Hallasan to Mt. Beakdusan and conduct research of paleonologic taxonomy, evolution and extinction of ancient animals and plants, change in ecosystem, change of paleoclimate, and conservation of future ecosystem, restoration of craters and ecology, and collection and multiplication of plants. Also, the center will manage database of samples and other materials and operate an exhibition hall of specimens.

2. Designation of Protected Area

A protected areas can be defined broadly as a concept which include preservation areas and districts, national territorial management areas, and greenbelt districts (Jeon, 2007). The Korea Research Institute for Human Settlements defines a protected area as an ‘area which is under regulation by law for conserving and maintaining biodiversity, ecosystems, valuable habitats, natural environment, and cultural assets’. In other words, protected areas are geographical space which is effectively designated, managed and limited for improving biodiversity, conserving natural environment, cultural value and ecosystems.

Currently, protected areas in Korea are designated and managed by the Ministry of Environment, the Korea Forest Service, the Cultural Heritage Administration of Korea, and the Ministry of Land, Infrastructure and Transport. According to the jurisdiction of management, ecosystem in ecological scenery conservation areas and wetland conservation areas are managed by the Ministry of Environment and the coastal areas are controlled by the Ministry of Land,
Infrastructure and Transport.

Because protected areas in Korea are designated and protected by related laws and regulations relevant to each district and area, it is necessary for Hanon Crater to be designated and managed by the nature conservation law. Also enacting a new law for restoring and conserving geological assets such as Hanon Crater can be considered as an alternative. When a new law is enacted or the existing laws are revised, a term ‘Maar and Wetland Conservation Area’ is needed to be reflected in the names of the laws.

3. Management Plan affiliating with International Institutions or National Institutions

3.1. Current Conditions of International and National Institutions

International or national institutions which are able to be connected to the Hanon Crater restoration plan can be environment conservation institutions and environment research institutions. Representative international institutions which are dedicated to environment conservation are UNESCO, IUCN, and WCPA. Representative domestic institutions of environment studies are the Korea Environmental Preservation Association, the Korea Preservation Areas Forum, the Korea Institute of Geoscience and Mineral Resources, and related academic societies (the Ecological Society of Korea, the Korea Society of Environmental Restoration Technology). Building a close relationship with these institutions will contribute to form a bond of sympathy and make known the appropriateness of the restoration and conservation of Hanon Crater.

3.2. Management Plan for Affiliation

(1) Building Cooperative Systems and Promoting Cooperation Activities

In order for Hanon Crater to be positioned as a world environmental asset through the restoration and conservation project, it is essential to build multilateral cooperative relationships between international institutions and domestic institutions. It may be difficult to attempt to build direct relationships with international institutions and organizations. Therefore, as an initial step, it is desirable to build a strategic partnership with NGOs and academic circles which play a role of executive bodies of international institutions through carrying out education and promotional projects with them.

Based on experience of making IUCN adopt a initiative of restoring and conserving Hanon Crater as its recommendation and attracting the attention of the international society, it is advisable to make the restoration of the crater mentioned as an environmental agenda. Currently, the Commission on Ecosystem Management of IUCN, an expert penal of IUCN, is participating in developing basic plans for the restoration of the crater and this can be an opportunity to expand cooperative partnerships with other institutions. A concrete and detailed case study of other similar international cooperative projects on environment conservation will help build a cooperative framework at private and government levels.

(2) Conducting Joint Scientific Research

Hanon Crater is the only Maar type volcano in the Korean Peninsula and academic circles pay a keen attention to the geological value of the sedimentary layers of the crater. Analyzing the sedimentary layers, paleovegetation, geological features will give scholars a chance to be led to academic achievement in paleontology, geology, and ecology.

Before the restoration project, related research institutions should work out cooperative plans to do joint research which encompasses an academic scope of Hanon Crater. After the restoration and conservation project becomes concrete, confirming related research institutions’ intention of participation.
(3) Revising Plans to jointly Develop Environment Restoration Technology

As the seriousness of ecological destruction comes to the fore, the necessity of restoration as well as conservation of natural environment attracts the notice of people. In Korea, many technologies and methods in civil engineering, landscaping, forestry, and horticulture have been applied to restoring ecosystems. However, there have been comments on their problems such as not fully reflecting the objectives of restoration (Ministry of Environment, 2002).

Later, when the restoration project of Hanon Crater begins, environment restoration technologies which encompass many related academic fields can be utilized. This will contribute to taking a major step forward with related sciences so, plans to jointly and multilaterally develop environment restoration technologies at national level should be prepared.

4. Establishing and Affiliating with a World Environment Graduate School

It is necessary to establish a world environment graduate school which is operated jointly by UN, the central government, and Jeju Special Self-Governing Province. The graduate school will have status as a world-class environment graduate school officially established by UN in order to research and solve environmental problems, cultivate people of talent, realize environment justice, and share information.

Maurice Strong, former UN deputy secretary general and chair professor at Jeju National University, officially made a proposal of establishing a world environment graduate school affiliating with the Hanon Crater restoration project at the 2011 Jeju Forum.

Currently, the project of establishing a world environment graduate school is included in ‘the Plans for Realizing World Environment Capital by 2020’. It is important to realize the establishment of the school as a connected project to the restoration and conservation project of Hanon Crater. If the school is established, the footing of ecological education and accumulation of restoration technologies will be prepared.

5. Plan for Promoting Ecotourism through Geotourism

Geotourism can be defined as tourism that maintains and strengthen an identity of a local region considering its geological, environmental, cultural, and aesthetic aspects and its heritage and local residents’ happiness. The name ‘geotourism’ comes from ‘geology’ and ‘tourism’ but its scope is beyond a simple concept of ‘geological tourism’. Geotourism here includes observation of geological characteristics, geotracking, enjoying views from observatories, guided tours, and activities related with geology, and utilizing tourists’ centers. The presentative example of geotourism is Grand Canyon tour in the USA, volcano sightseeing, and hot spring tours (Farsani et al., 2011).

Geotourism of Hanon Crater should be designed and carried in combination with local residents and concerned people’s participatin utilizing elements like geological attractions, clean environment, ecosystems, nature, view of farming villages, history, culture, and art.

To put it concretely, there should be a tourist information center, tour programs with commentators, handicrafts using the concept of the crater, goecafes and georestaurants. Also some education programs need to be developed based on academic data accumulated during the restoration process. In addition, in order to utilize restored Hanon Crater as a tourism attraction, plans
to associate the crater with other attractions around it need to be designed.

6. Plan for Affiliating with Local Residents

A precondition for successful running of the restoration and conservation project of Hanon Crater is local residents’ active participation. Especially, it is very important to make the owners of the lands on the crater understand the project and participate in it.

(1) Introduction of Transfer of Development Rights System

Transfer of Development Rights system is a system which separate development rights of land from ownership of land and let it transferred to others. This system is for compensating for the loss from limiting use of land.

If the restoration and conservation project of Hanon Crater is carried out as a national project, the introduction of transfer of development right system at government level needs to be considered.

In order to establish a legal basis for the system, a new law can be enacted or the existing laws can be revised by various agents such as the central or local governments, or the Ministry of Land, Infrastructure and Transport.

For the implementation of transfer of development rights system, designation of districts of transferring development rights, ways of transferring rights, designation of districts of using transferred development rights, and additional ways to further development should be regulated and coded.

(2) Plan for Inducing Local Residents’ Active Participation

For making the project successful, it is necessary for the project to contribute to vitalizing a local economy within the framework of renewable development.

Local residents should be a part of the manpower for the project and geotourism programs which is based on local communities and solve local problems by introducing business-like methods. In this case, the programs will be a business of residents’ initiative and be operated in tandem with the exiting community-based businesses.

Plans for the residents’ participation will be like training geotourism commentators and employing them, shareholding of geo and eco-tourism businesses, operating tourism infrastructure such as accommodations, employing local residents in protecting and conserving ecological and cultural resources, shareholding of businesses of developing and manufacturing geotourism souvenirs, giving preferential right to local residents in lotting out shops, and commissioning the operation of the programs to local organizations which are willing to participate in.

In case that local residents invest in manufacturing souvenirs or operating facilities, corporative associations will be a means to attract participation. Corporative associations have the merit of contributing to the advancement of communities’ interests through being jointly shared and democratically operated by people who want to meet communities’ economic, social, cultural needs (Ministry of Strategy and Finance).

Part 5 Financial Investment Plan

For carrying out the restoration and conservation project of Hanon Crater, it is necessary to explore various ways of financing (National or local finance, private investment, etc.), but this study focuses on the national funding of the project. Investment plans and estimated expenses for each phase are as follows (Table 2).

The total amount of money for the project is 262.2 billion won (about 256.5 million dollar). In the first phase of the project, 144.4 billion won (55.5% of the total amount of money) will be spent on the launching of the project.
Out of the money assigned to the 1st phase, 128.1 billion won (48.8%) will go to purchase the land and 78 billion won (29.7%) will be spent on restoring the crater wall, lake and vegetation. The construction expenses which will be assigned for building a Maar museum and etc. are 20.2 billion won (7.7%).

Table 2. Details of Total Working Expenses

<table>
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<th>Div.</th>
<th>Phase</th>
<th>Main Contents</th>
<th>Estimated Cost (won)</th>
<th>Portion (%)</th>
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<tr>
<td>1st</td>
<td>Launching Project</td>
<td>Designation of Land for Purchasing, Developing a Basic Plan, Basic and Execution Designing, Purchasing Land, Removal of Facilities and Compensation</td>
<td>1,444</td>
<td>55.0</td>
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</tbody>
</table>
| 2nd  | Launching Restoration Process | · Infrastructure  
· Restoration of Crater, Crater wall, Crater lake and Vegetation  
· Constructing Center for Research of Fossils and Paleoclimate, and Maar Museum  
· Observatory/Eco Trails, Observatory Decks, Other Landscaping  
· Establishing Mangement and Guide System  
· Building Tourist Center, Ticket Office and Additional Facilities and Amenities | 1,182                | 45.0        |
|      | Total                  |                                                                               | 2,626                | 100         |

Part 6 Expected Effect for Restoration

So far the necessity of restoring and conserving the geological and environmental value of Hanon Crater has been emphasized at various symposiums and conferences. Especially, as the recommendation of restoring the crater was adopted at the 2012 IUCN general assembly with the overwhelming support from the members (99.3% of the members were in favor of the recommendation), the restoration and conservation project earned the support and bond of sympathy from the international communities. The expected effects of the successful restoration and conservation of the crater will be as follows.

First, it will be a model case of other nations in which a large-scale restoration project of nature and environment is successfully completed. This also lay the foundation for raising an international brand image of Hanon Crater and strengthening its status.

Second, the successful restoration of the crater will be an exemplary case of nation’s environment policy and boost Korea’s image as an environment-concerned nation and gives some leverage in environmental diplomacy. This will be considered as fulfillment of IUCN’s recommendation so, Korea’s sovereign ratings and brand image are also improved.

Third, these days restoration and conservation projects usually lead to expansion and accumulation of base and technology. The restoration project will give a chance to give opportunities for new business and contribute to a national economic growth.

Fourth, the restoration and conservation of Hanon Crater is a representative project for making Jeju ‘World Environment Capital’. The success of this project will help form Jeju’s brand identity of having and desirably
conserving a world environment treasure in the international communities.

Fifth, the project will make Hanon Crater a center for researching paleoclimate and paleovegetatio and predicting the future climate through research on its sedimentary layers. This will also lay the foundation for Jeju’s becoming a ‘World Environmental Capital’ where global environmental issues are discussed through building international research networks.

Sixth, through renewable restoration and conservation of Hanon Crater, the crater will serve as a center for sightseeing, visit, international conferences and research exchange. Hanon Crater will serve as a momentum for setting a new paradigm of tourism and environment industry.

Lastly, the restoration and conservation project will be the cornerstone of finding a future growth engine through realizing harmonious coexistence between the future generation, environment and ecosystem.

Chapter 5 Policy Proposal

The restoration of Hanon Crater is the first of its kind and a very important natural environment restoration project which recover the lost value of nature and environment. Therefore, in order to restore the crater perfectly through international cooperation, the Korean government’s role is essential. We suggest that the Korean government launch the restoration of Hanon Crater as a national project.

Especially, the restoration of Hanon Crater will be the touchstone of the Jeju government’s commitment to its pledge of putting the value of environment before anything else in reestablishing Jeju’s value. The restoration project will also be a barometer of the current Jeju Governor’s ability to fulfill his election pleges. We are sure that the Jeju government will carry out the restoration and conservation project of Hanon Crater wisely with an understanding of the project’s importance to human kind and the future generations.

As a result of this study, we put forward our recommendations for the restoration project such as conducting comprehensive academic research, building an administrative, and systematic footing for the restoration, establishing cooperative networks with international institutions like IUCN, forming a task force for the project, and preparing temporary conserving plans before the restoration project.

(1) Comprehensive Academic Research

For a close investigation and scientific research, comprehensive scientific research on Hanon Crater should be conducted annually and the database of the research should be established for later uses. The history, human and social environment, weather, topography, water system, geological features, landscape, and ecosystem of the crater should be the subjects of the research.

Especially for the restoration of the original vegetation of Hanon Crater, investigations into vegetation which hasn’t been disturbed by human activities should be conducted and a mimetic diagram reflecting the ecosystem of Hanon Crater should be drawn and utilized for the restoration project.

(2) Building an Administrative, and Systematic Footing for the Restoration

Base on the results of the funded research project on a basic plan of restoring Hanon Crater, the local government (Jeju Special Self-Governing Province) should develop an administrative plan for restoring Hanon Crater as a national project which will attract
the central government’s attention and help the central government fulfill its duty of protecting and restoring nature.

Also, given that the restoration and conservation project of Hanon Crater has legal basis provided by the basic environment law, the natural environment conservation act, and the national land planning and utilization act which stipulate that the central government should protect and conserve nature and environment, the local government should include the restoration and conservation project of Hanon Crater to its official policies and revise related laws and regulations to prepare measures of protecting and conserving maar craters, crater lakes, and maar sedimentary layers.

Jeju Special Self-Governing Province has to show its willingness to put the restoration of Hanon Crater at the top of its agenda and play a leading role in minimizing conflicts between various interest groups and reaching an agreement with local residents and forming a consensus of the restoration project.

Jeju Special Self-Governing Province should also form a task force which exclusively deals with the restoration project. The task force will perform various work such as planning, securing a legal footing, negotiating with the central government, holding and attending international conferences and seminars, promoting the project, mediating conflicts between interest groups, carrying out temporary protective measures, and etc.

(3) Establishing Cooperative Networks with International Institutions such as IUCN

Establishing cooperative networks with international institutions such as IUCN and local players like academic societies focusing on geology, environment, ecology and climate, environment organizations, the media, and religious groups is very important. This can work as a channel through which social demands of making the restoration of Hanon Crater as a national project can be delivered to the central government. Therefore, it is necessary to actively build those networks.

In addition, establishing an international research network for predicting the future climate change which was one of the recommendations for restoring Hanon Crater at the 2012 World Conservation Congress will be important. This can attract attention on the restoration of Hanon Crater from international communities.

(4) Forming a Task Force for the National Project

A temporary task force consisting of members of the National Assembly, the Jeju Provincial Council, the National Promotion Committee for Restoring Hanon Crater, and related field experts, and representatives of local residents should be established. The task force will play a leading role in carrying out the national project such as negotiating and compromising with the central government, and etc.

(5) Temporary Conserving Plans before the Restoration

Before the restoration of Hanon Crater is decided, it is necessary for the administration to prepare legal and institutional measures to protect the crater from reckless development activities. Without the infringement of property rights, the administration needs to come up with different measures to curb reckless development activities towards Hanon Crater (One possible measure is to designate the crater as a possible candidate for the core zone of the UNESCO Biosphere Reserve).

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