The United Nations University

GEOTHERMAL TRAINING PROGRAMME
Orkustofnun, Grensásvegur 9,
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Reports 2005
Number 13

GEOTHERMAL TOURIST PARK IN BERLÍN FIELD, EL SALVADOR, ASSESSMENT ON THE USE OF GEOTHERMAL BRINE FOR BATHING AND SPA

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ABSTRACT

Geothermal manifestations have become attractive destinations in the tourism industry. Therefore, the idea of developing a geothermal tourist park in the Berlín geothermal field is not surprising. The Berlín field is surrounded by an amazing landscape and located in a natural environment among coffee plantations and native forest. The combination of the geothermal phenomena, rural tourism and the possibility that weather conditions would allow visitors all year around, should point towards this place as an interesting tourist destination.

In the search of a unique characteristic that may help to put the Berlín field on the tourism map, this report introduces a preliminary assessment on the use of the geothermal brine in Berlín for bathing and a spa.

1. INTRODUCTION

Geothermal resources in El Salvador have been under exploitation since 1975 for electricity generation only, although some potential for other direct uses has been identified. The idea of developing a Tourist Park using the geothermal manifestations as main attractions should become a starting point for the direct utilization of geothermal resources in El Salvador.

This report has been prepared as part of the Geothermal Training Programme of the United Nations University in 2005 and includes a review of tourism and some of the possibilities that have been developed elsewhere until now in geothermal areas regarding tourism. The report also reviews some examples of utilization of thermal waters for balneology around the world, in order to provide a convenient summary of information for the development of a tourist park and the assessment of opportunities for developing bathing facilities as part of this park.

Balneology and the utilization of thermal water have been done since ancient times as direct uses of geothermal manifestations; this report includes the study of the Blue Lagoon in Iceland, which has become a famous destination for tourists as well as for curing skin ailments.

2. BACKGROUND AND GENERAL INFORMATION

Initial uses of natural heat and its by-products probably date back to ancient times, perhaps the Palaeolithic; however, concrete evidence dates from 8,000 to 10,000 years ago. The first time that man used heat from earth was for thermal bathing. After that, humans started to settle around thermal waters; since then, people have learned the different effects of thermal waters and its applications. With time, surrounded by abundant vegetation and thermal springs, these places became an attraction for hunters and a visiting place for residents of nearby areas looking for relaxing warm baths during the winter, eventually becoming a kind of open-air resort, our ancestors' first thermal spa (Cataldi, 1999).

FIGURE 1: Yellowstone National Park (modified from Uhler, 2005)

Nowadays, hydrothermal phenomena such as hot springs, geysers, as well as other surface evidences of geothermal activity are tourist attractions. The world's first national park – Yellowstone in the United States (Figure 1), was established in 1872 to protect, preserve and provide proper tourist access to natural hydrothermal phenomena. Today, geothermal energy plays many different functions in tourism, such as: 1) heating hotels and resort facilities; 2) the use of geothermal waters in recreational and therapeutic pools; 3) for curative and therapeutic procedures. This growth in geothermal utilization facilitates "sustainable tourism" and the ecological development of many regions and countries (Kepinska, 2003). In Iceland, geothermal phenomena like geysers, fumaroles, hot springs and the most famous geothermal lagoon in the world are included as part of the attractions offered to people visiting the country.

2.1 Tourism – definition and importance

The benefits of tourism are indeed an important tool in the development of countries. Tourism offers opportunities for sustainable employment to well-trained people, as well as jobs for people with little formal training or education (Roest, 2004). In developing countries, where the work force does not always include people with high standards of education, this is definitely an opportunity for growth and the development of new skills.

Tourism (Figure 2) has become an important aspect of the world's economies. In developed countries it is considered an important industry, while developing countries are trying to invest in tourism and

FIGURE 2: Tourism

bet on it as an element that will help to improve their economies. There has been a lot of discussion and work done around tourism and even more in sustainable tourism. This report includes some of the definitions that have been pointed out by different authors.

Tourism is generally defined as the activities of individuals who, for leisure, business or other purposes, travel to and stay in places outside their normal environment for less than a year. Today, tourism represents a genuinely global phenomenon and one of the fastest growing sectors of the world economy. It plays a very significant role in the socio-economic development of advanced, as well as of a growing number of developing, countries. It is an increasingly important source of income, employment and wealth in many countries. Domestic Tourism basically involves a regional distribution of national incomes, while international tourism has now become the world's largest source of foreign exchange receipts (Neto, 2003; Roest, 2004; WTO-OTM, 2002)

Sustainable tourism development refers to a broad range of recreational activities occurring within the context of a natural environment. The World Commission on Environment and Development defines sustainable development as the one that meets the needs of the present without compromising the ability of future generations to meet their own needs. It is a way to increase the benefits from tourism resources for host communities while maintaining the cultural and environmental integrity of these destinations. It also helps to enhance the protection of ecologically sensitive areas and natural heritages (Neto, 2003; UN, 2002; Eagles, 1995).

2.1.1 Tourism and its impacts

The impacts of tourism have been a subject of debate for a while. Tourism plays an important and positive role in the socio-economic and political development of many countries. It contributes to cultural exchange and is often a tool in a positive evolution of international relations through better knowledge of each other's cultures and ways of life acquired during this exchange. The impacts are often difficult to pinpoint and measure. Many tourist destinations experience negative impacts upon the environment, culture and society (Roest, 2004). Accordingly, when planning a tourist area the designer and people involved must be proactive, aware of any possible negative impacts in advance in order to avoid or alleviate them.

Probably the two main areas of environmental impact of tourism are: pressure on natural resources and damage to ecosystems. Intensive tourism development can threaten natural landscapes, notably through deforestation, loss of wetlands and soil erosion. Besides the consumption of large amounts of natural resources, the tourism industry also generates considerable waste and pollution. Tourism activities can also cause the severe disruption of wildlife habitats and increase pressure on endangered species, when not properly managed and monitored (Neto, 2003).

With the aim of reducing negative impacts that accompany tourism, several mechanisms can be developed in order to make tourism a sustainable industry. Among these we can count the economic benefits of tourism and use them to contribute in protecting the environment and practice the sustainable use of natural resources. Income from tourism can help in financing protected areas and safeguarding sensitive regions against environmental damage (Neto, 2003; Roest, 2004). Impacts on the natural landscape and scenery can be avoided by designing buildings and facilities that are adapted to the location; its incorporation into the surrounding environment eliminates a visual impact.

A successful management and planning of the tourist market can also lead to positive impacts in the host community. Benefits can be obtained in a way that creates new sources of employment to help satisfy the needs of the communities in the surrounding areas of a tourist development.

If we think of positive effects, we cannot forget that the development of tourism as a whole is usually accompanied by considerable investments in the infrastructure, such as roads, water and sewerage facilities, telecommunications and other public utilities. These infrastructural improvements not only

generate comfort for tourists, it also contributes to improving the living conditions of local populations.

Well planned tourism can provide many benefits to local communities in such a way that an improvement in their economies can be achieved. According to Ashley et al. (2001), this can be obtained in different situations: (a) when local employment strategies result in a high proportion of jobs going to local people; (b) when considerable training and skill transfers take place for unskilled people; (c) when goods and services required by the tourism industry are produced and supplied locally, leading to micro-enterprise development.

Benefits are not only to be found in the economic level of a society; there are also benefits in the mitigation of environmental impacts, when a strategic plan considers the management of the natural resources and avoids degradation. In addition, social and cultural impacts are avoided by controlling the number of visitors minimizing not only cultural intrusion into local communities but the devastation of natural resources as well. By avoiding cultural intrusion, the preservation of the original way of life in a host community is maintained, sustaining particular differences in cultures and habits, and forming a unique attraction for visiting tourists.

2.1.2 Tourism possibilities in geothermal areas

Geothermal areas are used as tourist attractions in several countries around the world. This constitutes not only income resulting from local tourists but also international tourist interest. The so-called Thermal centres or Integral health spa's boom around the world is very remarkable. The success achieved is indeed generating an outstanding increase in resource direct use. The framework of thermal demand is constantly growing and provinces motivate tourism industry based on geothermal fluids as a main attraction (Pesce, 2005).

After the social and economical crisis in Argentina (2001-2002), tourism turned into a significant industry in the country, being considered an important tool for generating real income and creating new jobs, urgently needed. Thermal complexes and health tourism have experienced significant development over the last five years, providing a new economic alternative that contributes to the development of regional and local economies (Miranda, 2005).

FIGURE 3: Larderello´s geothermal attractions (mod. from Geothermie, 2005, and Enel, 2005)

Hungary is considered a country where tourists look for the enjoyment of thermal baths and the cure of ailments at the same time. Larderello in Italy (Figure 3), the first geothermal power station built in the world is nowadays not only a local museum of geothermal industry, it is a great tourist attraction which includes the hot springs, visits to the power station and geothermal souvenirs among others. Larderello region belongs to the most important of the World's tourist destinations.

We can say that a new sector of tourism includes geothermal balneotherapy and spas as basic elements of therapeutic tourism, which has become very popular in nowadays. Healing purposes can be acquired through various forms of tourism (spas, weekend tours, general healing tours, healing tours dedicated to specific diseases, etc.). Spa therapy has become one of the most used ways of reducing stress, promoting leisure, healing and biological rejuvenation (Kepinska, 2003).

2.1.3 Tourism in El Salvador

El Salvador, strategically located in Central America (Figure 4), has many possibilities as a tourist destination. Since the signing of peace in 1992, the country has been under constant improvement and modernization. A small country (21,040 km^2), El Salvador gives the chance to experience different sceneries in a short time trip around the country. The road system that crosses the country from west to east, forms part of the main regional road system reaching from Mexico to Panama; several road systems from north to south connect the main cities of the country and the ports with this regional road. The international airport is located at only 40 km from the capital city San Salvador, and it is considered one of the most modern airports in Latin America, with daily direct flights to and from some of the major cities in the United States of America, all of the Central American airports, and other countries such as Mexico, and Canada. It also provides convenient connecting flights to Europe, Asia and the rest of the world. The statistics of the main tourist markets and the incomes for tourism in the period between the years 2000 and 2004 are given in Table 1.

FIGURE 4: Location map of El Salvador

TABLE 1: Main tourist markets in the period 2000-2004 (Ministry of Tourism, 2005)

Main tourist markets	**2000**	**2001**	**2002**	**2003**	**2004**
Central America	538,750	490,781	670,728	578,602	637,570
North America	176,932	160,331	201,269	212,570	263,687
South America	3,450	1,222	577	19,539	19,853
Europe	27,012	21,371	26,523	34,782	32,147
Rest of the world	48,534	60,562	51,500	11,885	13,159
Total of tourists	**794,678**	**734,627**	**950,597**	**857,378**	**966,416**

El Salvador has many tourist attractions. Several cities and towns around the country are examples of the colonial architecture. Tourists can find beautiful churches with traditional Spanish colonial facades, crafts, traditional food and amazing natural environments. El Salvador has several ancient archaeological sites dating from the Mayan civilization, among them Joya de Cerén, Tazumal, Casablanca and San Andrés Ruins, as well as the pre-Columbian village of Quelepa in the Eastern part of the country.

The country has a breathtaking landscape formed by two parallel volcanic chains, 307 km of coastline (CIA, 2005), the country's most important ecological reserve "El Imposible National Park", and other natural resources which offer tourists a unique experience for trekking and hiking expeditions and wildlife observation. El Salvador's southern border is the Pacific Ocean; the beaches are bathed with warm waters, where water sports like surfing and sport fishing are counted among the most famous attractions. Canoeing and white-water rafting are possible in some of the rivers.

The Government of El Salvador has identified tourism as a new possibility for the development of the country, an option for economic growth in the future, as identified in the recent formation of the Ministry of Tourism in 2004. In the website of the Ministry of Tourism (2005) we can find some of the local and national efforts made to-date to develop tourist attractions in the country (Figure 5). Among them are the so-called "Flowers Route", which includes a visit to five cities located in the Apaneca mountain chain; "The Craft Route", in the northern part of the country, on this route tourists can find hand-painted crafts made famous by the Salvadoran painter Fernando Llort; "The Peace Route" goes through some of the main cities that were located in the middle of the so-called War Zone during twelve years of civil war in the country. Finally, but of no less importance, is "The Archaeological Route" which includes visits to the main archaeological sites of the Mayan culture in El Salvador.

FIGURE 5: El Salvador, tourist attractions (modified from Ministry of Tourism, 2005)

El Salvador can reinforce the development of tourism, while participating in a regional strategy with other countries. This has been done with the formation of the Mesoamerican Tourism Alliance, where Salvanatura, one of the main organization links of the Ministry of Tourism in El Salvador is represented. This initiative will bring more opportunities for growth in the future of tourism in the country. The Mesoamerican Ecotourism Alliance (MEA) is an alliance of local organizations committed to the development and promotion of sustainable tourism as a means for supporting conservation efforts in Mesoamerica. MEA operates in Honduras, Belize, Guatemala, El Salvador and two Mexican destinations, Chiapas and Yucatán (MEA, 2005).

2.2 Examples of utilization of thermal waters for balneology around the world

2.2.1 China

Chinese traditions of geothermal water usage date back to at least 3,000 BC, such waters were used for watering cultures, washing, cooking and for therapeutic purposes (Kepinska, 2003). Although early people used hot springs for irrigation and domestic purposes, most hot spring use has focused on disease treatments and recreation.

Examples of these places where people have used geothermal water for bathing and curing diseases since ancient times are: the “Fairy Spring”, located northwest of Lishan Mountain near Xi’ an City, considered a magical spring which treated almost every kind of disease; another magical spring was found in Zhejiang Province, during the Tang Dynasty; and a third magical spring on Lushan Mountain in Jiangxi Province, among others (Wang Ji-Yang, 1995). Nowadays, hot spring bathing plus hot spring health care and hot spring entertainment represent the 65.2% of the total capacity of geothermal direct use in China (Zheng, 2004).

2.2.2 Japan

Vestiges of geothermal bathing utilization in Japan have been discovered near hot spring sites that are still in use. These sites include Yuda hot spring, Iwate Prefecture (used during the pre-pottery period before 11,000 BC); Oyu hot spring, Akita Prefecture, Kaminodan hot spring, Nagano Prefecture (used during the Jomon period from 11,000 BC to 300 BC); and Kokonoe hot spring, Shimane Prefecture, and Kamanokuchi hot spring, Ehime Prefecture (during the Yayoi period from BC to 300 AD (Sekioka, 1995).

Japanese treat baths and leisure in geothermal utilities as a very popular and common way of spending time. This is a part of Japanese rites, culture and lifestyle. Tourism in Japan is closely connected with geothermal, hydrodynamic and volcanic phenomena, e.g. Fuji, which is a sacred mountain, a symbol of the country and a place of numerous pilgrimages (Kepinska, 2003). Among all the attractions that this country offers to the tourist, geothermal phenomena have played an important part in tourism development.

2.2.3 Italy

Thermal balneology has been used in Italy since the time of the Roman Empire. It was developed systematically by the Romans from the 2nd century BC on. The use of spas spread throughout the territory under Roman domination. At the beginning, balneotherapy was an exclusive practice of the elite class living in localities with natural hot springs. However, this attitude changed during the second half of the 2nd century BC; with an increase in the interest of all society sectors in the Roman Empire, the first public baths (*balnea and thermae)* appeared (Cataldi and Burgassi, 1999).

Nowadays, the spa business employs some 70,000 people, generating over 300 million Euro reaching 2,140 million Euro if dedicated suppliers are also included. Spa treatment covers the largest share of geothermal heat in Italy, with two prevailing resort areas: The Albano district (Euganei Hills) and Ischia island. In the first of these, some 120 hotels are heated and sanitary water is provided; in Ischia Island, 80 hotels have geothermal wells and cure facilities. As part of new developments, a small leisure and sport facility vas recently installed in Rodigo (Lombardy) (Borghetti et al., 2005).

2.2.4 Turkey

Anatolia, the Asian part of Turkey, is located in a zone of intense volcanic and tectonic activity, rich with geothermal manifestations such as hot springs, fumaroles, mud pools, and mineral resources. People have made use of these natural phenomena since prehistoric times. However, vestiges of this application in Turkey's history date from the time of the Roman Empire. Today, the Turkish bath is well known all over the world. Romans greatly contributed to the Turkish baths, both architecturally and socially. Some of them are in use today in Turkey. Baths of varying standards can be found in most Turkish cities where water from springs or geothermal wells is employed; the biggest and best known spa is Izmir Balcova (Özgüller and Kasap, 1999; Kepinska, 2003).

Currently, several facilities use geothermal water for heating and curing purposes; among these we can count Afyon Gazligol (68°C water); Orucoglu Thermal Resort (48°C water); Cankiri-Cavundur Thermal Facility (56°C) and Bolu-Karacasu Thermal Facilities (44°C) (Mertoglu et al., 2003). At the moment 195 spas in Turkey are used for balneological purposes. Additional to the existing spa utilization in Kursunlu geothermal field, a big thermal facility complex (aqua parks, curing centres, etc.) is being planned (Simsek et al., 2005).

2.2.5 Greece

Unlike Turkey, in Greece there are archaeological findings that prove the use of thermal waters for bathing and healing purposes in mythological times before the birth of Rome. Apart from Gods and mythical heroes, ancient Greeks frequented all known thermal localities for curative purposes. Depending, of course, on the nature of the water in each locality and on the thermo-mineral mud associated with it, one or more diseases could be treated: alphosis, psoriasis, alopecia and eye infections among external diseases; and rheumatism, gout and respiratory system infirmities among internal diseases. Of the many thermal localities frequented for cures by ancient Greeks, Aedipsos, Loutraki, Epidaurus and Thermopylae deserve specific mention for their historical importance (Fytikas et al., 1999).

Many interesting applications and developments have taken place in Greece during the last years including heating a hotel in the neighbourhood of Nea Apollonia hot springs (Macedonia) and a spa complex in Rhodes Island (Fytikas et al., 2000). Exploitation of geothermal energy for balneology and bathing pools can be found in the fields of Nigrita, Sidirokastro and Agistro (Karydakis et al., 2005).

2.2.6 Hungary

Since prehistoric times, hot springs have been thought of as fonts of life and health, divine and sacred gifts in Hungary. Although there are not any archaeological findings that proved this theory, it is well known that many Neolithic people settled near thermal springs. These became more important in Central Europe during the Roman Empire; however thermal balneology was a local tradition long before the arrival of the Romans. However, the Romans built the famous Spa "Aquincum" (Cohut and Árpási, 1999).

At present, there are 260 public baths and spas in operation in Hungary. According to the characteristics of the water and its use, 89 of them are considered medicinal and 140 as mineral (Ákoshegyi and Árpási, 2005).

2.2.7 United States of America

According to Lund (1993), the use of natural springs, especially geothermal ones in the United States, has gone through three stages of development: first used by Indians as a sacred place, then developed by European settlers and finally, as a place of relaxation and fitness. The Indians used every hot spring in the Americas, and most were considered sacred places. Records of these uses go back for over 10,000 years (Lund, 2005) Ojo Caliente "Hot Springs", in New Mexico, may be one of the oldest health resorts in North America, once considered sacred by the ancestors of today's Tewa Tribes. It is known that the Spaniards, in their quest for gold and the fountain of youth, also discovered the springs. In 1535, explorer Cabeza de Vaca wrote: "the greatest treasure that I found these strange people to possess are some hot springs which burst out of the foot of a mountain... so powerful are the chemicals contained in this water that the inhabitants have a belief that they were given to them by their gods. These springs, I have named Ojo Caliente" (Witcher, 2002; Ojo Caliente, 2005).

Nowadays, health spas and resorts represent a major part of the health and fitness industry in the country and have grown in popularity and offer high investment potential; therefore, the development of spas has increased. Unlike European spas where medical cures of specific ailments are more important, US spas give more importance to exercise, reducing stress, lifting depression and losing weight. Of recent interest is the development of "health conservancies" to preserve natural areas for health and fitness activities (Lund, 1993; Lund, 2005). In spite of the differences in the main reasons for going to a spa in Europe and the United States, this industry is growing on both continents.

2.2.8 Latin America

Vapour baths, cooking in steam at fumaroles or on naturally hot rocks, crop irrigation, and therapeutic applications were all ways that the Earth's natural heat was used in Mesoamerica. This region, particularly rich in active geothermal manifestations, allows intense contacts between mankind and geothermal forces. Geothermal resources, in the widest sense of the word, deeply influenced the material, spiritual and cosmic development of the Mesoamerican people. From time immemorial, American people took vapour baths by throwing cold water on hot rocks taken from the mouths of hydrothermal manifestations; they socialized, enjoying the vapours.

Temazcal, a dome constructed with volcanic stone and mortar, was warmed from the outside by showering cold water on piled rocks, heated by fire. Thermal baths were used widely in Mesoamerica (Suarez et al., 1999). In Náhuatl, Temazcal is formed by two words: *temas*, which means bath and *calli,* meaning house. Nowadays, the experience of taking Temazcal baths like the Mayans and the Toltec is offered in several modern spas in Mexico.

Before the Spanish Conquest, El Salvador was populated primarily by Indians of the Pipil tribe. Vestiges of Pre-Columbian history have shown that bathing and relaxing in thermal waters was part of the life of the Pipils.

Joya de Cerén was a pre-Hispanic farming community that was buried under a volcanic eruption 1,400 years ago. Because of the exceptional condition of the vestiges, they provide an insight into the daily lives of the Central American populations who worked the land at the time. Joya de Cerén has been classified under the UNESCO World Heritage list. This place is considered an archaeologically unique site in the New World, comparable only to the famous buried sites of Pompeii and Herculanaeum in Italy. The wealth of information that Joya de Cerén has yielded about the everyday life in a Late Preclassic Maya Period Mesoamerican settlement, means that it is without parallel in the Western Hemisphere (UNESCO, 2005). Many sites of the Mesoamerican cultures have been excavated, however there had only been found religious and ceremonial sites until the discovery of Joya de Cerén.

One of the most amazing discoveries found in Joya de Cerén, classified as a special structure, is a sweat bath (Figure 6). This is a structure with a large domed architecture in a Classic period village in southern Mesoamerica. It is believed that this place served a neighbourhood or the community rather than just a family. In the interior of the structure 10 people could sit on a *laja* (flat slab of andesite) covered bench that ran around a central firebox. This place is believed to have been used for physical as well as spiritual and medicinal cleansing. Previous to finding this, it was believed that domed architecture was brought to the New World by the Spanish (Cerén, 2005).

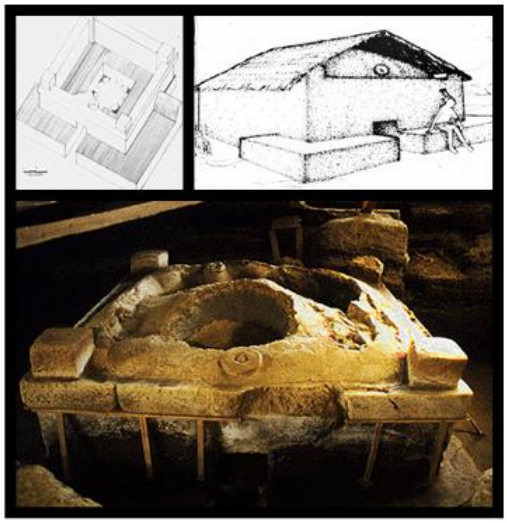

FIGURE 6: Picture of the sweatbath structure in Joya de Cerén; drawings by Karen Kievits's (Cerén, 2005)

Recent reports of direct use of geothermal waters for bathing and spa in Latin America include projects in Cordoba Province (Huerta Grande, La Falda, Valle Hermoso); Buenos Aires (Carhue); Entre Ríos (Nogoya, Basavilbaso, Diamante and San José) and Santa Fé (Carlos Pelligrini), where thermal fluids are directed to thermal spa and balneology, a remarkable trend in economical development in Argentina (Pesce, 2005).

Costa Rica is one of the Central American countries that produces electricity from geothermal resources. The direct use of geothermal resources in low-temperature fields is limited to some mountain hotel pools dedicated to ecological tourism (Mainieri, 2005). One of the most known places in Costa Rica is Tabacon Hot Springs Resort and Spa, in which bathing in thermal springs and the enjoinment of the rainforest's natural beauty can be experienced.

2.3 Main characteristics of geothermal spas

A spa can be defined as a place where people go looking for relaxation, wellness and for fitness purposes. The word SPA, known and used since Roman times, is a Latin expression meaning Salud Per Aqua (Health trough water), and is also thought to have its origin from the name of a town in southern Belgium, where a health resort named ESPA was founded (Lund, 1996).

With the recent increase in people's interest for going to spas, new trends and more specialization have been developed. According to ISPA, (2005), nowadays we can find different concepts of spa services such as those shown in Figure 7: facilities such as club spas, cruise ship spas, day spas, medical spas, mineral spring spas, resort/hotel spas and destination spas (those whose purpose is to provide lifestyle improvement and health enhancement through professionally administered spa services, physical fitness, educational programming and on site accommodations).

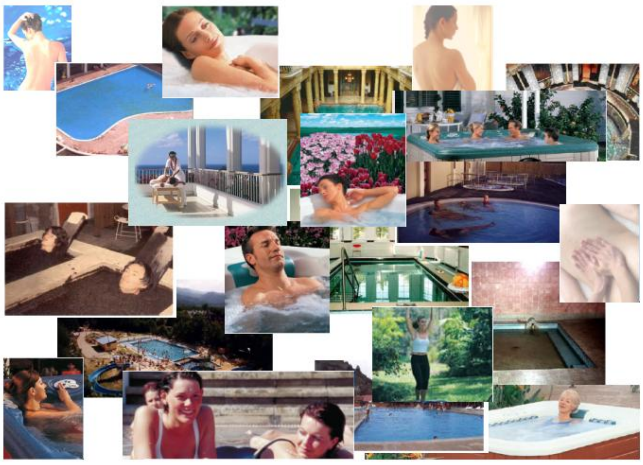

FIGURE 7: Different spa services

A geothermal spa is supplied with mineral thermal waters that may flow to the surface in springs or may be produced from wells. These natural groundwaters containing a blend of minerals may also have some healing effects, although this mineral content may not be suitable for drink (GeothermEx Inc, 2000). In some places where thermal water baths can be enjoyed, the use of any metal jewelry is not recommended, especially copper or silver, which can be damaged during contact with some of the minerals in the water.

According to professor J. Paul DeVierville, director and founder of the Alamo Plaza Spa, in order to be successful, a spa must have: hygiene; service and a unique attraction, such as scenery, special water, special mud, special cure, special food, unique location, unique facility, etc. (Lund, 2005).

When planning the development of a spa/resort, the designer must have in mind that the main features are a favourable climate and a wide range of recreational activities. Resort activities are generally developed for the outdoors and take advantage of the climate and natural surroundings. Some of the recreational activities that can be expected in a world class resort are: spa, cultural tours, beaches, hiking, nature tours, golf and a water complex and others.

As resorts provide many recreational and cultural activities, they are also expected to provide the guests with the services to participate in these activities. Full service resorts assist people with these services. In a resort with a specific attributes such as geothermal resources, these assistants will be expected to know and explain about the wonders of this natural and renewable source of energy.

The first step in building up a balneology industry is to define the resource, physically and socially. This entails the classification of geothermal waters, checking the availability of mineral water as well as the available medical services and recreation. The next steps are to make market analyses and then to define business projects based on the results from those two primary steps. A part of a resource definition as well as the definition of a business project is to designate the kind of balneotherapy possible for the type of waters and other resources accessible (Kristmannsdóttir and Björnsson, 2003).

3. BALNEOLOGICAL UTILIZATION AND GEOTHERMAL TOURIST ATTRACTIONS IN ICELAND

There is a long tradition in Iceland in the use of geothermal baths for entertainment, relaxation and also for rehabilitation and curing rheumatism and other illnesses (Kristmannsdóttir and Björnsson, 2003). Balneology in Iceland has been practiced for a long time; evidence of this is many in the country. One of the most famous spots that remains from old times is the very well known "*Snorralaug pool*" (Figure 8) in Reykholt, the place where Snorri Sturluson (1179-1241), one of the greatest writers in the history of Iceland, established his

FIGURE 8: Snorralaug pool

home. Here he built a warm pool, with water coming from a nearby hot spring. It is considered one of the first places in Iceland that used geothermal resources for heating purposes.

3.1 Swimming pools

Reykjavik, the capital of Iceland is advertised in several tourist websites as the "*Spa City*". This is due to the high number of swimming pools, naturally heated with geothermal water in the city. Figure 9 is a collage that shows some of these facilities. The water is used directly in the pool or it is used to heat fresh cold water. Swimming pools offer the experience of bathing in hot thermal water outdoors all year around. Icelanders enjoy going to the swimming pools and this activity has become very popular among tourists too. Most of the towns and villages have outdoor and indoor pools and there are many high quality pools in Iceland.

FIGURE 9: Swimming pools in Iceland

Swimming pools in Reykjavik have long opening hours. People can visit one of these facilities from early in the morning 6:30 am, when long lines of Icelanders wait to go in, and remain open until around 22:30.

Nowadays, average Icelanders and tourists use the swimming pools for everyday recreation and relaxation enjoying more numerous swimming pools per capita than in other countries. Spa treatment, however, is not as popular and is even less common in Iceland than in many European and Asian countries (Kristmannsdóttir and Björnsson, 2003).

3.2 Geothermal tourist attractions

Iceland, located on the Mid Atlantic Ridge, has abundant geothermal resources. Features such as hot springs, fumaroles, mud pots and geysers are common in the country. People have made use of these resources for a long time and one of the main uses, after heating utilization, is balneology. Iceland has magnificent facilities for bathing and balneotherapy and one the most famous tourist attractions in Iceland is the Blue Lagoon, which will be properly described later in this report. Another place where people enjoy healthy baths in the hot geothermal springs is the new facility opened in the northern region of the country: "*Mývatn Nature Baths*" (Figure 10), the newest of Iceland's geothermal spas.

FIGURE 10: Mývatn Nature Baths

Opened on the 30th of June in 2004, Mývatn Nature Baths offer the experience of natural

baths with a sensation of wellbeing. This place includes, such facilities as a reception desk, cafeteria, changing rooms and showers, natural steam baths, and a geothermal bathing pool maintained at a constant temperature of approximately 38°C. The water comes from a high-temperature well and the inlet temperature is 130°C, so it has to be cooled down before it enters the lagoon. It runs into a pond constructed for this purpose. The lagoon constructed with a sand and gravel covered bottom so it gives the feeling of being in a natural formation (Mývatn Nature Baths, 2004).

FIGURE 11: Geothermal tourist attractions in Iceland

Tourist attractions in Iceland are not limited to bathing spaces; there are a lot of possibilities for the development of tourist destinations in several places where hot springs, geysers, mud pools and fumaroles are considered the main attraction. Figure 11 shows a collage of several places visited during the training programme where one can observe the different approaches of utilization of these magnificent geothermal phenomena.

4. BLUE LAGOON GEOTHERMAL SPA

The Blue Lagoon in Iceland (Figure 12) has become a popular spot in the eyes of the world; this year it was on the cover of "The Washington Post Magazine" (July); "The New York Times Travel" (January); "Elle Magazine" (January) and several other articles about it have been in important magazines around the world during 2003 and 2004. Taking a bath in the famous Blue Lagoon in Iceland has been classified as one of the "99 things to do before you die" included in travelchannel.com under the category mysterious places.

It was voted in the year 2004 as "*The Best Medical and Thermal Spa in the World*" by the readers of "Condè Nast Traveller", in a list that includes other well-known spas like Royal Park Evian in France and Clinique La Prairie in Switzerland. It was visited by several famous people in 2005, such as the Czech President, Vaclav Klaus in August; the Rock bands Foo Fighters and Duran Duran in July, and the world's most respected tenor, Placido Domingo, in March.

Blue Lagoon Ltd. is the company that runs the facilities. This leading Company has received several awards and recognitions for its work, among them: "The President of Iceland's Award for Export Achievement" in 2004; "Marketing Firm of the Year" in 2002; "Environmental Award" granted by the Icelandic Tourist Board in 1999; and the "Blue Flag" in 2003, 2004 and 2005, granted to beaches that have made an extra effort to improve the standard of beaches, marinas, and the environment (Blue Lagoon, 2005).

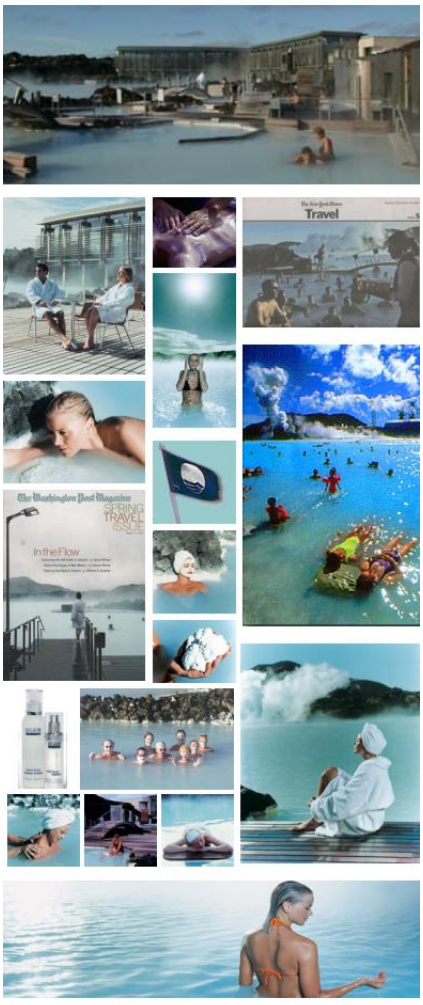

FIGURE 12: Blue Lagoon (Blue Lagoon, 2005)

This amazing place is located in The Reykjanes Peninsula, in SW-Iceland. Getting to the Blue Lagoon is very easy; the distance to the capital city, Reykjavík, is approximately 48 km and to the International Airport 23 km. This man-made lagoon was formed in the Svartsengi lava field which dates back to 1226. The water is the effluent water of the Svartsengi power station. The bedrock of the Svartsengi geothermal reservoir is primarily composed of porous and fractured lavas, allowing seawater to slowly seep into the reservoir. The temperature in the reservoir is about 240°C and the fluid is a mixture of 65% sea water and 35% fresh water. The chemical composition of the reservoir fluid is changed by reactions between the bedrock and the fluid, causing e.g. the silica to increase drastically (Ólafsson et al., 1994; Ólafsson and Sigurgeirsson, 1998; Ólafsson and Sigurgeirsson, 2003).

The water for the lagoon is supplied from the Svartsengi geothermal plant, a combined heat and power plant. In this power plant, cold groundwater is heated by the geothermal brine for space heating purposes. The total installed capacity for electricity production is 46.4 MWe (Thórólfsson, 2005). After being used in the power plant, the geothermal seawater is piped directly from the original source to the Blue Lagoon.

The idea of bathing in the Blue Lagoon started by accident, when one of the employees from the power plant started bathing in the pond and surprisingly he had an improvement in his psoriasis problems. After that, people started coming to the lagoon for bathing. Several studies on these effects have been carried out and the effectiveness of the brine in curing psoriasis has been medically proven with positive results. A secured bathing zone was developed and improvements on the facilities have been constant since then.

4.1 Design considerations

This chapter is prepared with valuable information obtained from Sigrídur Sigthórsdóttir, head designer of the facilities, Blue Lagoon Company's staff employees, chemical data from ÍSOR - Iceland Geosurvey, and online information available in the company's internet website.

4.1.1 Architecture

The geothermal spa building at the Blue Lagoon is the first phase in a building complex that houses health and tourist services. The design emphasizes the contrast between modern technology and the unique natural surroundings, befriended by nature and inspired by its force and mystique.

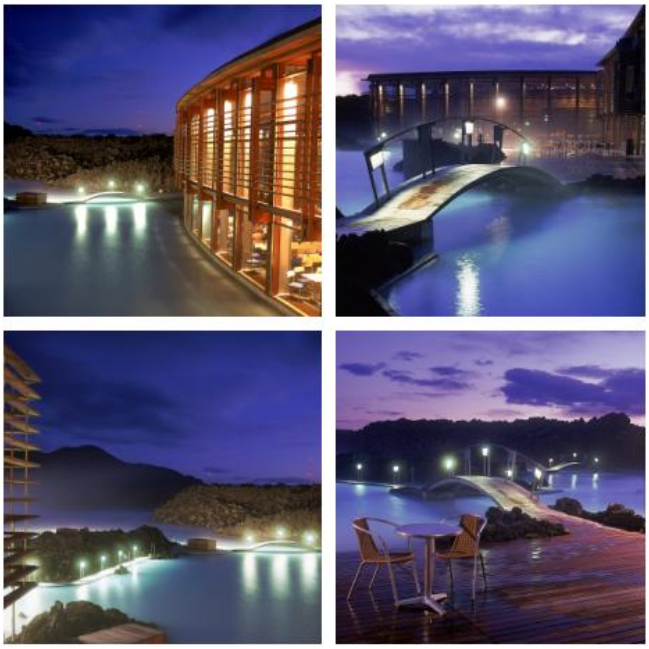

FIGURE 13: Blue Lagoon's lighting design (Blue Lagoon, 2005)

In the design process, the team was inspired by nature: the special northern lighting conditions are a defining part of the unique characteristics of the Icelandic natural context; the bright summer nights, when the sun lingers on the horizon illuminating the sky with a subtle glow and producing elongated shadows; the long winter nights with northern lights, snowfall, or just dense darkness. The design team attempted to grasp these singular moments in the building by subtly separating the light-glazed public areas from the dense service areas. This way the light always connects the inside-outside atmosphere (Figure 13).

FIGURE 14: Blue Lagoon and the geothermal spa facilities, designed in harmony with its surroundings

The building is nestled in a natural lava berm which shelters and defines the lagoon. The rock-clad walls create continuity with the natural context and also serve as orientation, guiding the guests through the building. The massive concrete parts of the building lean towards the lava. The light glazed parts open towards the lagoon and the sun.

FIGURE 15: Brick-lava wall, architectural element used in the Blue Lagoon complex

Inside, the concrete masses are of smooth in-situ appearance, insulated on the outside and rendered with mortar that resembles the silica in the water. The building rises out of the water and becomes stained by the silica residue. Thus, the man-made contribution is clearly defined from the natural environment while remaining harmonious by virtue of form, materials and "weathering" (Figure 14). The light building masses have an internally exposed steel structure and are largely glazed with framing, cladding and bis-soleil of Brazilian Jatoba hardwood. These building parts lightly touch the rock wall and the separation of the building masses is underlined by light flooding through the glazed gap.

The building is set on the fringe of the "*Illahraun*" lava field. The 200 m long pathway from the parking area to the main entrance leads the guests into a gully and through a lava barrier. Inside the building the gully is continued by a man-made lava wall, made of 64,000 lava bricks (Figure 15), which leads through the entry hall, restaurant area and onward out onto a terrace at the water's edge. At this point the man-made wall again becomes the natural rim which surrounds the lagoon. The entry hall serves as access to the changing rooms and bathing area, the restaurant and conference area, and the tourist shop. The bathing area, which is approx. 5,000 m^2, is visible through the glass wall of the entry hall and restaurant. The building itself is approx. 2,700 m^2. Table 2 contains the architectural programme for the Spa facilities.

Future phases of the building complex will include the expansion of the Blue Lagoon shop and administrative offices; private changing rooms; conference and restaurant facilities; a five star hotel with an exclusive separate new lagoon and wellness centre; and further recreational and leisure facilities. Later phases will not interrupt existing functions and each facility will operate as an independent entity (S. Sigthórsdóttir, pers. comm.).

TABLE 2: Blue Lagoon spa, architectural programme

Room	**Size (m^2)**
Entre, lobby	139
Wintergarden, restaur.	298
Bistro services	110
Shop	62
Changing rooms	412
Indoor pool area	192
Kitchen, restrooms	503
Technical rooms	130
Administration	172
Staff	72
Conference room	123
Area	**2,213**
Total surface	**2,700**

4.2 Characteristics of the geothermal brine

The geothermal brine in the Blue Lagoon is, for the most part, an effluent solution from the Svartsengi power plant, diluted by a small amount of condensed steam. Samples of the water have been collected annually from all producing wells and twice a year from selected wells. The results of the monitoring demonstrate that the composition of the geothermal fluid in Svartsengi is very homogenous (i.e., different wells produce fluids with very similar compositions) and stable (i.e., the fluid composition of a given well does not change over time) (Thórhallsson, 2005).

In 1996 and 2003 the major and trace element concentrations were analysed, confirming the stability of the chemical composition. The total dissolved solids changed by less than 3% and observed concentrations for most major elements did not vary by more than 5%. Trace element concentrations generally did not change by more than a factor of 2. The most important exception is that silica concentration was 17% lower in 2003 than in 1996; this difference can be explained by variable degrees of amorphous-silica precipitation from the solution, possibly due to different flow rates through the outlet-pool where the samples were collected or the fact that the samples were probably not collected at exactly the same location in the pool. The composition of the brine flowing into the Blue Lagoon is expected to be stable considering the very stable nature of the geothermal fluids utilized in the Svartsengi power plant (Fridriksson, 2003).

4.3 Maintenance and operation

The geothermal effluent water is supplied from the Svartsengi power plant. The temperature of the supplied water is 150°C; this is done to avoid silica scaling in the pipeline. The water is not cooled by mixing with cold water because the aim is to keep the lagoon as natural as possible; instead, control valves that are controlled by sensors in the lagoon are used.

Maintenance requires a lot of work and is expensive. The pipes are tested regularly; the valves have to be changed periodically and so on. The lagoon area is 5,000 m^2 and it takes about six-million litres of water which is pumped and renewed in about 40 hours (H. Kárason, pers. comm.).

4.4 Other products and services

The main attraction of the Blue Lagoon's operation is definitely the geothermal spa. Here, the guests enjoy bathing and relaxing in the geothermal seawater. This experience combines healing power, wellness and beauty while being in the middle of a unique landscape of unspoiled nature (the white bluish colour of the geothermal seawater plus the dark and green lava fields through their eyes).

Besides bathing in the lagoon, guests can choose between a complete range of options such as a sauna with a view of the lagoon; a steam bath with white walls (resembling the silica mud); a cosy steam bath carved into a lava cave; an amazing waterfall that provides an energizing massage and of course the silica mud is available in special boxes while bathing in the lagoon.

The geothermal spa is not the only service provided in this amazing complex. The Blue Lagoon Ltd Company has developed a distinct concept of products and services based on the geothermal seawater and its active ingredients: the silica mud, mineral salts and a blue green algae (Blue Lagoon, 2005). Appendix I shows the main characteristics of these natural ingredients.

4.4.1 The medical centre

The medical centre offers natural geothermal treatments of psoriasis in cooperation with the Icelandic health authorities. The Icelandic social insurance covers the treatment of Icelandic patients. This

treatment also attracts psoriasis patients from different corners of the world. In addition to being recognized by the Icelandic health authorities, the treatment is also recognised in Denmark and in the Faroe Islands.

The Blue Lagoon's natural treatment involves a combination of bathing in the geothermal seawater and UVA/UVB light therapy. In addition, the climate, fresh air, healthy food and the relaxing atmosphere are integral parts of the treatment.

FIGURE 16: Blue Lagoon's medical centre facilities

A new Dermatology Clinic opened in the summer of 2005. A modern look and practical solutions characterize its design. The lagoon area is designed with the needs of the clinic in mind and includes a 50 m^2 indoor pool and a 350 m^2 outdoor lagoon (Figure 16).

The clinic includes a specially designed room for guests to relax in after bathing and light therapy. A massage room and rooms for medical examinations and doctor's appointments are at the site. Spacious changing rooms and a private area for the disabled and patients with special needs is available.

The accommodation features 15 double rooms that fulfil all standard requirements for clinics and hospitals. The rooms are well designed and spacious with a private bathroom and a porch. A dining room, living area, and fitness room are also on the site (Blue Lagoon, 2005).

4.4.2 The skin care products

Initially these products were developed to fulfil the needs of the psoriasis patients; the use of these products is an important part of the treatment. In addition, a complete range of face and body geothermal spa products is available; spa accessories complement the geothermal skin care products and enhance the spa experience. The Blue Lagoon skin care range is divided into face care, body cleansing, body nourishing, body relaxing and accessories. These products are developed with special blends of the natural active ingredients of the geothermal seawater from the Blue Lagoon. These products are developed in cooperation with dermatologists, pharmacists and French cosmetologists (Blue Lagoon, 2005).

The ingredients are harvested and produced by Blue Lagoon Ltd in Iceland (Figure 17); the Blue Lagoon raw materials are sent abroad to production subcontractors. The final production of the skin care products is also done by subcontractors abroad. The development of the products is directed by Blue Lagoon Ltd. with assistance from specialists in product development (Á. Brynjólfsdóttir, pers. comm.).

4.4.3 Treatments and massage

FIGURE 17: Harvesting and production of raw materials for skin care products

The spa treatments take place in the lagoon on a specially designed wooden bench; massage takes place on a mattress in the lagoon and they are based on its natural ingredients. Being outdoors, the natural environment and fresh air make these a unique experience.

A complete range of massages is available in Blue Lagoon, including a Blue Lagoon in-water massage; a relaxing massage; a silica massage; pregnancy massage; silica massage for the feet; silica back massage; and a massage for children between six and eleven years old. The treatments available are: a salt glow treatment; a nourishing and relaxing algae treatment; water retention and cleansing treatment; firming treatment and a facial treatment (Blue Lagoon, 2005).

4.4.4 Eldborg - Gjáin

Eldborg is a reception and conference centre located 800 meters (only five minutes drive) from the Blue Lagoon. It includes large meeting and conference rooms that can accommodate up to 400 guests. This facility provides guests with an impressive view of the rugged nature through its floor-to-ceiling windows.

Gjáin "The Rift" is a geological information centre in Eldborg, which provides a dramatic exhibition of world geology with an emphasis on Icelandic geology, geothermal heat and conservation of energy resources. This facility, with modern technology (pictures, video clips, a magnificent sound system), has a unique environment which allows guests to have an interactive experience to learn about geological wonders. Gjáin features natural rock walls creating an atmosphere that easily transfers guests into the centre of the earth.

In addition, The Geothermal Spa has a conference facility located on the second floor. Providing a magnificent view of the lagoon it is a favourite meeting site for a number of domestic and international firms - the perfect combination of meetings and relaxation, providing the energy needed to achieve a successful meeting (Blue Lagoon, 2005).

4.4.5 Restaurant

Blue Lagoon also includes a modern restaurant with 7 m high glass walls with a spectacular view over the lagoon, creating a comfortable atmosphere while enjoying a meal. This facility accommodates 300 people in sitting receptions and 450 people in standing receptions and is the place where many companies hold their annual balls while it is also a convenient place for weddings, gala dinners, anniversaries and different events (Blue Lagoon, 2005).

4.4.6 Leisure activities

The experience at Blue Lagoon is supported by a whole range of leisure activities, both for people visiting the geothermal spa or patients of the medical centre. This keeps the people around the area for longer which is the aim when considering the next step for the Blue Lagoon Complex, i.e. a five star hotel.

Blue Lagoon has a fitness room in the medical centre, equipped with cardiovascular equipment and weight lifting stations. Also, it is possible to hire a personal trainer for those who are into the fitness experience. Taking a walk and enjoying Iceland's fresh air is also an excellent choice; easy walkways are located in the complex. Renting a bike is another option available here.

If the aim is to explore more of the natural and local attractions, the area has easy access to the Reykjanes peninsula where people can enjoy the scenic beauty of the Atlantic shores while walking along its beaches; the Reykjanes light house is a popular bird watching site.

Charming fishing villages such as Grindavík (Blue Lagoon's home town) and Sandgerdi are close enough to offer the experience of learning a little bit more about the fishing culture. A visit to the famous bridge between the continents is something not to be missed, the whole experience of crossing from Europe to America in a matter of minutes in the only place in the world where the spread of the continental plates can be observed above sea level. The contact with the nature can be experienced by taking a whale watching boat; this breathtaking experience offers the possibility of seeing whales and dolphins in their own natural environment.

When talking about culture there is a must see visit to the Viking-ship, an Icelandic replica of an old Viking ship called the "Gaukstad-ship". The Viking ship made a historic journey to Greenland and America to celebrate the millennium of Leif Eriksson's journey to the New World; it is located in Reykjanesbaer. The Duus Cultural Centre, the local folk museum at Gerdahreppur and the lighthouse at Gardskagi, erected in 1897 and the latest lighthouse built in 1944, are also there to be experienced.

For sport and adventure there is the Go-Kart route and four golf courses located in the area. All these activities and many more are available, including the Golden Circle tour to: Gullfoss (Iceland's most famous waterfall), Geysir (the world-famous geothermal area); and Thingvellir (the national park, and site of the old parliament of Iceland), are of importance for local tourism.. In every tourist booklet available at the airport, shops, hotels and restaurants, visits to the Blue lagoon are advertised in combination with one of these famous tourist attractions and activities like horse riding on pure-bred Icelandic horse.

5. DESIGN REQUIREMENTS OF GEOTHERMAL SPAS

5.1 Characteristics of the buildings

Design is a complex process in which, concept character, shape and function interact in such a way that none of these elements are more relevant than the others. According to Lund (1996), there are many types of designs for spas, depending upon the local culture, the unique character of the location, and what the developer is trying to achieve in terms of atmosphere, service and type of clientele.

Concept is a synthesis that in advance guides the design process and at the end gives a meaning to the building. *Character* refers to all those visual aspects and physical features that form the appearance of a building. If we want to make a list of the elements that define the Character of a building we can count the shape, materials, interior spaces, the site and the environment among others.

The characteristics of a site (topography, breathtaking views, immediate sights and so on) influence the shape of the building; the cultural context in the surroundings is reflected in the architectural design and gives the buildings a sense of belonging to the site.

In 1908, Frank Lloyd Wright introduced the world "organic" in architecture. For him this was an attempt to integrate the spaces into a whole unit that reflects coherence. Site, structure and context are related in the design process, as was point out by Wright. Wright brought into architecture a whole

new group of ideas and principles, like the existence of a relationship between human scale and landscape that he also applied and introduced into his designs, using materials such as glass and steel in an attempt to include open spaces and transparencies. The development of the architectural character of buildings was definitely part of his work. It must be pointed out that Wright considered form and function as one. Wright considered Japan a place where everything has a strong relation and is properly integrated in such a way that the entire civilization is reflected as a unit. This is not possible if the achievement of a concept is not thought through in advance.

All these concepts of character, site, environment, and so on, are important tools when planning a new building, helping to avoid negative visual impact, and the result can be the acceptance and integration into the surroundings. Once more when talking about architecture, the famous expression "Location, Location, Location" becomes relevant. In this report a brief review is included on some geothermal spas, their locations and context in an attempt to show how integration and acceptance can be obtained in perfect harmony with the environment.

5.1.1 Ojo Caliente mineral springs - architectural concept

Ojo Caliente mineral springs, New Mexico in southwestern United States is a perfect example of Santa Fe Style architecture (Figure 18). This style is derived from native American architecture, typified by soft organic lines; rounded corners and parapets (low walls extending above the roof line); and the use of materials such as *adobe* (sun dried mud bricks) and a final cement coat (stucco) plastered on the walls. The use of natural materials in this architectural style allows a perfect match with the high dessert landscape in the surroundings, giving these facilities the visual aspect of buildings that belong perfectly to the site.

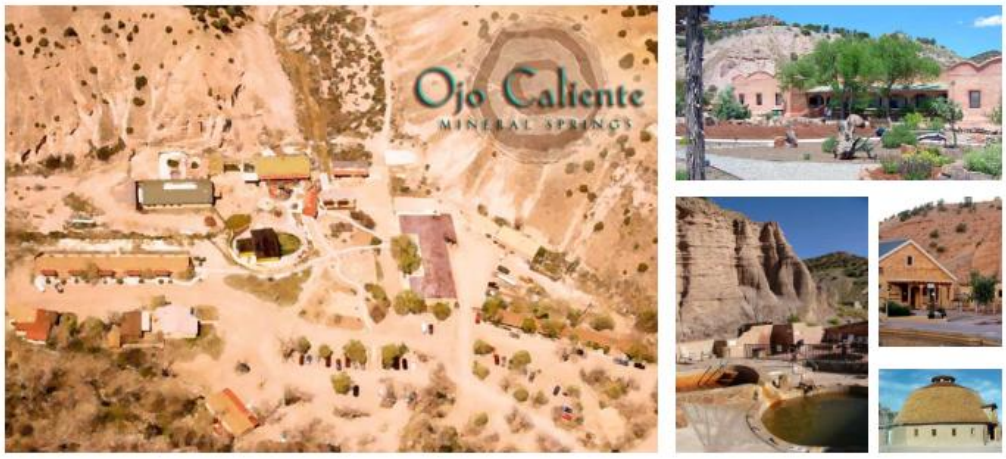

FIGURE 18: Ojo Caliente mineral springs (Ojo Caliente, 2005)

5.1.2 Jiuhua Spa and Resort - architectural concept

These facilities, located in Beijing, China, are a perfect match with the location and surroundings. Traditional Chinese architecture with breathtaking roofs that are painted in detail with buildings based on the principle of balance and symmetry.

There is a deep relationship between architecture and culture in China, and this can easily be observed in these facilities. People in the interior of this amazing place can not only feel the sensation of wellness from the massages and treatments, but the architecture of the interiors gives them the sensation of being in a mystical country. The gardens are based on a combination of natural scenes and man-made landscapes as show in Figure 19.

FIGURE 19: Jiuhua Spa & Resort (Kepinska, 2003; Jiuhua, 2005)

5.2 Temperature of water for bathing and swimming

The temperature of the water in swimming pools and bathing facilities varies according to the use that it is aimed at. A pool for Olympic competitions will have a different temperature requirement than a therapeutic pool. This report gives some of the desirable temperatures of water based on different uses.

In USA Swimming (2005) are published some of the general guidelines for temperature requirements according to specific purposes. These establish that 27°C or lower temperatures are suitable for competitive swimming team training, adult aerobic lap swimming and high intensity vertical water exercise; 30-31°C waters are suitable for learning to swim, moderate vertical water exercise and water walking, younger age (10 and under) swimming training, low-intensity lap swimming, synchronised swimming, diving and recreational swimming; 32-33°C waters are suitable for aquatic therapy, Ai-Chi, learning to swim for children and diving; 35°C water is suitable for Aquatic therapy, WATSU (Water Shiatsu), Ai-Chi and for preschool children learning to swim.

In Lund (2000) several considerations based on ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) standards from the Application handbook 1999 are listed. According to these, the desirable temperature for swimming pools is 27°C; however, this may vary from culture to culture by as much as 5°C. It establishes also that the maximum temperature that can be tolerated by the human body (for short periods of time) is 43°C and several other recommendations such as the ones listed in Table 3.

TABLE 3: Temperature design conditions in typical natatoriums (Lund, 2000)

Type of pool	Water temperature (°C)
Recreational	24 to 29
Therapeutic	29 to 35
Competition	24 to 28
Diving	27 to 32
Whirlpool/Spa	36 to 40

Appendix II shows the characteristics of selected US spas supplied by thermal or mineral water; this table is extracted from GeothermEx Inc. (2000) and is based on research they made on several data sources. This serves as a reference of the different temperatures of water used in some facilities, and the different services provided in these.

5.3 Heat loss considerations

This report includes the heat loss considerations for an outdoor pool. This chapter is based on Svavarsson (1990), Lund (2000), Jalili-Nasrabadi (2004) and the lecture on swimming pools, included in the course on Geothermal Utilization in UNU-GTP. Heat losses will mainly be due to convection *(Q_C)*, evaporation *(Q_E)*, radiation *(Q_R)*, conduction *(Q_L)* and rain *(Q_p)*.

According to Lund (2000), based on ASHRAE 1999 standards and Rafferti (1998), conduction losses are through the pool walls, convection from the pool surface, radiation and evaporation from the pool surface. The formulas that must be used to estimate the heat losses follow below in this section (definitions are in Nomenclature) and must be applied for the detailed design of thermal pools.

Heat Convection (Q_C): Convection losses depend on the temperature differences between the pool water and the surrounding air and the wind speed (Lund, 2000):

$$Q_C = h_c (T_w - T_a) \tag{1}$$

The Rimsha-Doncenko formula gives the relationship for the heat transfer coefficient (h_c) and the wind speed.

Evaporation (Q_E): Evaporation losses constitute the greatest heat loss from pools. The evaporation occurs as a function of air velocity and pressure differences between the pool water and the water vapour in the air or vapour pressure difference (Lund, 2000):

$$Q_E = (1.56 \cdot K + 0.7 \cdot V_2)(e_w - e_a) \tag{2}$$

where

$$h_c = K + 0.45 \cdot V_2 \tag{3}$$

$$K = 0.93 + 0.004(T_w - T_a) \tag{4}$$

Radiation (Q_R): Radiation losses are greater at night, especially in outdoor pools; however, during the daytime there will be solar gains. These may offset each other (Lund, 2000):

$$Q_R = 4.186\left(\left(13.18 \cdot 10^{-9} \cdot T_a^4 \left(0.46 - 0.06 \cdot e_a^{0.5}\right) - G_0 \cdot (1-a)\right) \cdot \left(1 - 0.012 \cdot N^2\right) + 13.18 \cdot 10^{-9}\left(T_w^4 - T_a^4\right)\right) \tag{5}$$

Heat conduction (Q_L): This is the least significant contribution unless the pool is above ground or in contact with cold groundwater (Lund, 2000). Heat loss due to conduction is very small, due to good insulation in the pool building materials (Jalili-Nasrabadi, 2004). Heat conduction must be calculated in a similar way as heat losses through the walls of a building.

Rain (Q_p): Heat loss due to rain occurs because the rain needs to be heated to the pool water temperature. One mm of rain is about 1 kg/m^2 (Svavarsson, 1990). The following formula is applied, assuming that the water temperature is 27°C and that 1 mm of rain falls evenly during 24 hrs.

$$Q_p = \frac{(1\,kg \cdot 4200\,kJ/kg\,°C \cdot 27\,°C)}{(24 \cdot 3600)} = 1.5\,W/m^2\ mm\ \ rain \tag{6}$$

If we consider different values of rain fall, like for example rain fall of 57 mm in 24 hrs, then:

$$Q_p = 1.5 \cdot 57 = 86 \tag{7}$$

According to Jalili-Nasrabadi (2004), the main heat losses from the swimming pool occur by convection and evaporation. Based on previous research and analyses, heat losses due to radiation,

conduction and rain can be estimated to be equal to 10% of total heat loss due to convection and evaporation.

5.4 Maintenance and operation

5.4.1 Water requirements and renewal of water

In heated water pools, the international regulations establish that certain renewal of the water must be carried out and in addition some chemical treatments must be applied to the water in order to avoid the creation of bacteria and certain pathogens that are harmful to human health. This may include a list of equipment for chloride addition and the chemical treatment of the water.

However, when pools and spas are supplied either from springs or wells, facilities do not chemically treat the water, generally relying on once-through flow (no recirculation) and also through a monitoring system by taking samples to check possible contaminants to maintain water quality. Alternately, individual pools may be drained and re-filled after each use (GeothermEx, 2000). Other facilities change the water every 24 or 27 hours. Appropriate disposal of the water after use sometimes includes reinjection, especially in places where the reinjection of geothermal water is required by law.

5.4.2 Cleansing requirements and equipment

Cleansing equipment for swimming pools are offered on the market. However, before choosing the appropriate one, some design calculations must be done, As this report's aim is not the detailed design of a swimming pool, only a brief review on the equipments will be done.

According to Svavarsson (1990), new pools almost solely use closed sand filters to clean the water from the pool:

- *The filtration equipment* can be a plastic tank, painted steel or stainless steel. This equipment uses sand as a filter for the water. The water must be pumped to the tank at a certain speed and then while passing through the sand, all the impurities are left (Svavarsson, 1990).
- *The coarse filtration* must be done before the water goes through the pump on its way to the filtration tank (Svavarsson, 1990).
- *The pumps* can be selected based on the maximum flow rate and pressure drop in the water circulation system (Jalili-Nasrabadi, 2004).

5.5 The pipe system

According to Svavarsson (1990) the piping system is divided into inflow and outflow pipes. The material for these pipes must be selected carefully according to the water temperature and the chemicals in the water.

The inflow pipes: a new system is used for the layout of the pipes; wide pipes are put in the bottom of the pool before it is cemented. Special preparation is needed around the distributors so they can be connected and packed later.

The outflow pipes: Drainage pipes are in the overflow case of the pool which is all around it. When this is not working properly or is not sufficient, a pipeline installed in the bottom will let the water run to the pumps. These will not work in dry conditions, which may cause damage to the pumping system.

6. BERLÍN GEOTHERMAL FIELD – DESCRIPTION

6.1 Location

The Berlin geothermal field is located in the eastern part of the country, approximately 100 km from the capital city San Salvador (Figure 20). The field is located in an area of high seismic activity. This is mainly because the country forms part of the Pacific "Ring of Fire" within the subduction zone of two intersecting tectonic plates (Cocos and Caribbean).

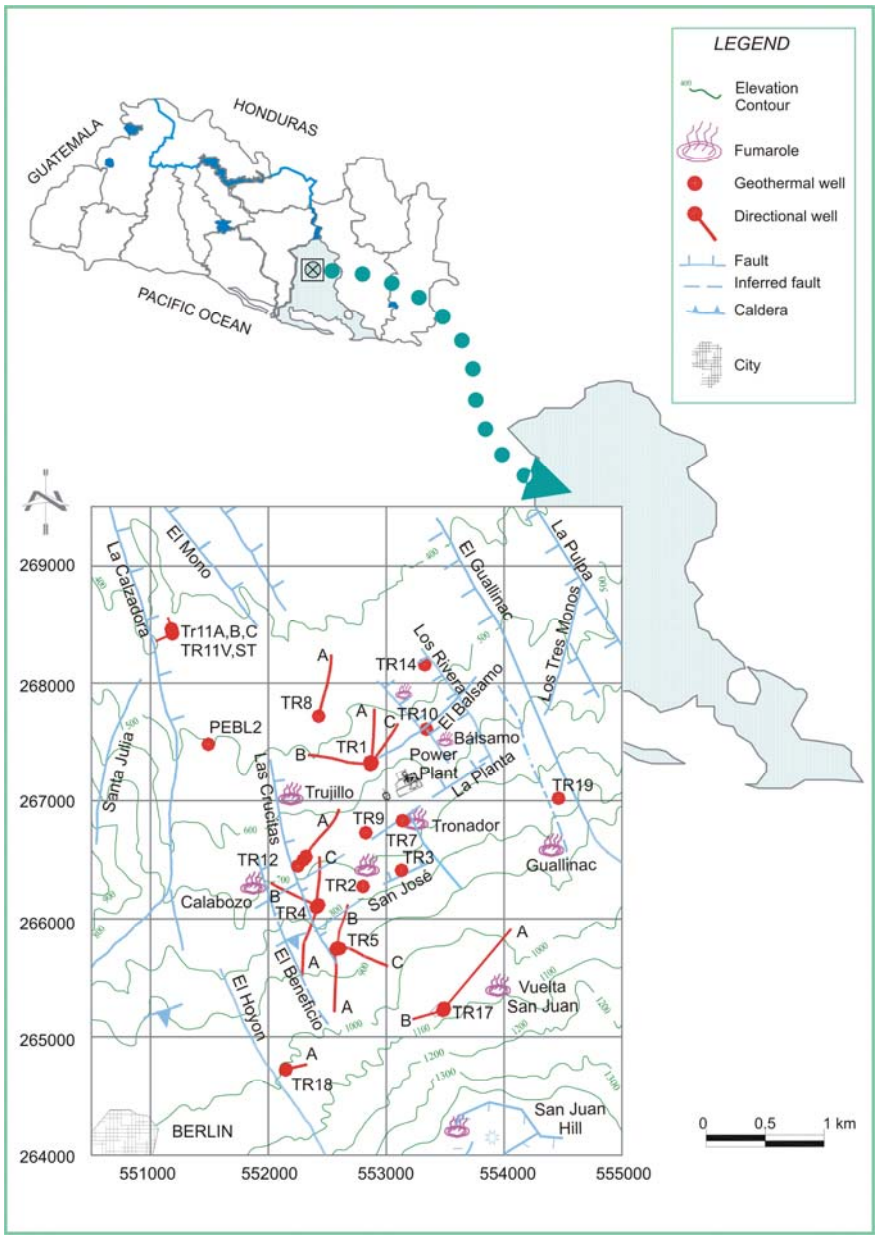

FIGURE 20: Location map of the Berlín geothermal field

The subduction zone is the main source of the geothermal potential. Geothermal fields can be found in the volcanic areas and the heat sources are the magma chambers. The structures are calderas or grabens associated with volcanic activity, and the reservoirs are formed by infiltration of rainwater into the high part of the volcanic craters (Rodríguez and Herrera, 2005). The Berlín field occupies one part of the northwestern flank of the Berlín-Tecapa volcanic complex, where the main geological feature is a major caldera, largely filled with volcanic material (Renderos, 2002).

6.2 Geology

The subduction of the Cocos and Caribbean plates has formed a tectonic graben that runs in an E-W direction through El Salvador. The centre of the Berlín volcano appears to be where the regional northwest trending fault system intersects the southern margin of the E-W trending fault system, forming the 5 km wide Berlín graben.

The geology of the field has been divided into annular faults formed by a caldera collapse, a regional fault system with a NE-SW orientation, probably related to a central graben, and a transverse fault with NNW-SSE orientation, believed to be related to the caldera collapse (Magaña, 1999).

6.3 Hydrogeochemistry

The geothermal field of Berlin is characterised as liquid-dominated and the temperature of the fluid in the southern production zone is approximately 300°C. The discharged fluids have been classified as sodium-chloride type and the chloride content has been estimated in a range between 3,000 and 7,000 ppm; pH values are between 5 and 8 and salinity between 7,000 and 20,000 ppm.

The groundwater of the field can be classified into three main groups: a) Neutral sodium-bicarbonate water of shallow meteoric origin; b) Sulphate water of surface origin and low pH due to oxidation of H_2S; c) NaCl-type with high SO_4 concentration (Renderos, 2002). Table 4 shows the three geothermal aquifers identified with the results obtained from chemical analysis.

TABLE 4: Berlin's geothermal aquifers (Magaña, 1999)

Aquifers	Depth
Low-salinity shallow aquifer (1600 ppm)	200-300 m a.s.l.
Intermediate-salinity aquifer (6600 ppm)	~sea level
Deeper saline aquifer (8000-12000 ppm)	-800 to -1200 m a.s.l.

The chloride concentration of the well discharge water is between 2,500 and 8,000 ppm. With reference to the relative abundance of chloride, sulphate and bicarbonate in the water of the geothermal wells, the water is classified as of sodium-chloride type with relatively low sulphate and bicarbonate content, typical of high-temperature systems associated with andesitic and rhyolitic magmatism (Magaña, 1999; Renderos, 2002).

6.4 Main characteristics of the geothermal field

The Berlín geothermal field is located in one of the most affected zones of the country during the civil war (Arévalo, 1998). This area was affected economically and most of the people living in the area had to move to other cities or abroad (mainly to the United States). The area influenced by the field extends to several small towns that belong to three municipalities: Alegría, the main production field and where the power plant is located, Berlín, and Mercedes Umaña.

6.4.1 Infrastructure

24 km of roads were paved and repaired during construction of the project "First condensing development of Berlín geothermal field" in the period between 1997 and 1999, by CEL (Comisión Ejecutiva Hidroeléctrica del Rio Lempa), the national electric utility company, with secured financing from the InterAmerican Development Bank (Arévalo, 1998).

The geothermal field at the moment is under the responsibility of LaGeo S.A. de C.V., the company in charge of the maintenance and operation of the power plant and the geothermal installations in the field. One of the duties is the annual maintenance program on the roads and infrastructure to facilitate the mobilization of personal in the field. The main road surface materials in the field are asphalt, stone paving and gravel bed, among others.

LaGeo's strategic partner, Enel Green Power, a subsidiary of Enel S.p.A. of Italy (Rodríguez and Herrera, 2005), has been in charge of the construction of new well pads in the field. This has led to more improvements on existing access roads and the construction of several new ones.

6.4.2 Population

The total population of the neighbour communities is estimated to be 10,000 people, with an average household size of 5 persons (S. Arévalo, pers. comm.). These estimations were established for the influence area of the geothermal field formed by six small towns distributed in the three municipalities mentioned in Section 6.4.

6.4.3 Economic activity

The main economic activities in this area are the typical rural activities in the country: agriculture and cattle farming. This part of the country was one of the production fields for coffee plantations, one of the main export products of the country in the past. However, with the decrease in international prices, this activity has started to be replaced.

The main agricultural products are maize, beans and *maicillo*. In the township El Recreo in the influenced area of the field, some of the farmers are cultivating oranges, bananas and other fruits. The area has been part of a pilot project for irrigation with condense water from the power plant during the dry season (November-April). During the past years El Salvador has done well with the income from economical aid sent by people living abroad to their families living mainly in the rural areas; the Berlín field area is not an exception of this phenomenon.

Some of the people in the area are carpenters, bricklayers, or receive income from small groceries, and 0.01% of the total population has administrative and technical jobs in the power station (Arévalo, 1998). During the construction periods of new projects and or maintenance duties, some of the people in communal organizations are hired as a work force (mainly unskilled workers). Alegría, Berlín and Mercedes Umaña have received some economical benefits since the commission of the power plant and the operation of the field, not only from the constant improvement of the infrastructure, but also from new facilities such as small restaurants, cafeterias and grocery stores to provide services to the workers and employees of the power plant. This area has also received the aid of some non-governmental organizations, among them a foundation for social development called FUNDABERLIN (Foundation for the development of Berlín). This organization is formed mainly by local people and their families living in San Salvador and its aim is to improve the living conditions of the area.

6.4.4 Culture-custom and traditions

Alegría, Berlín and Mercedes Umaña are predominantly Roman Catholic towns and most of the holidays and customs have religious origins. One of the main festivities is celebrated in honour of San Michelangelo, the patron saint, spiritual protector of the area. This event includes a fair, several parades, the crowning of a queen, fireworks and traditional food and candies.

Other main celebrations are held during Christmas and Easter. During the latter, the passion, death and resurrection of Jesus Christ are celebrated with colourful carpets made of sawdust, sand, colour dust and flowers (Arévalo, 1998).

6.4.5 Legends and myths

Rural areas in El Salvador are the cradle of many myths and legends and the region of the geothermal field is no exception. Here the people believe that the Lagoon of Alegría is a place where at night several ghosts and spirits wander. The Lagoon is also the cradle of several legends. One of them tells the story about the formation of this lagoon. According to this legend, before Spanish conquest, this area was the settlement of a Lenca Tribe that was invaded by the Tecolucas-Nonualcos tribe. Here lived a beautiful young woman named Xiri, meaning Star in the Lenca's language. A warlock accompanying the invaders fell in love with her beauty but she never looked at him in the same way.

Then an enormous volcanic eruption started and this warlock pretending to read the future, led the people to believe that the sacrifice of a young girl was needed to stop it and that Xiri was the chosen one. The story tells that the girl possessed a bird, which being a witness of her sacrifice, started singing in such a special way that the eruption stopped and no more stones, lava or steam came out of it. Then it started to cry and the teardrops formed the Lagoon in the volcanic crater.

7. TOURIST PARK IN BERLIN GEOTHERMAL FIELD - DESCRIPTION

Geothermal resources in El Salvador have been under exploitation since 1975 for electricity generation. In the geothermal field of Berlin this has been done since 1992 when two backpressure units of 5 MWe each were used to produce electricity. In 1999 two single flash condensing units of 28 MWe each were commissioned. The current geothermal development in the field includes the upgrading of the power plant to obtain an increase in generation for 40 or 45 MWe more, and the commissioning of a binary cycle plant.

The disposal of the brine is made by injection into wells at temperatures in the range 100-180°C, although during this process heat and chemical contents are lost in large quantities. LaGeo has been considering the use of the brine for alternative applications and for obtaining additional benefits. The alternatives under analysis are additional heat extraction; industrial uses; chemical recovery and a tourist area.

The Berlín area is in a volcanic landscape covered by coffee farms. The whole area has a high potential for ecotourism. Suitable additions for this purpose are a swimming pool, a geothermal museum, and walking areas and so on (Monterrosa, 2003). The Tourist Park would be located in the Berlín geothermal field, near well pads TR5 and TR7, as shown in Figure 21.

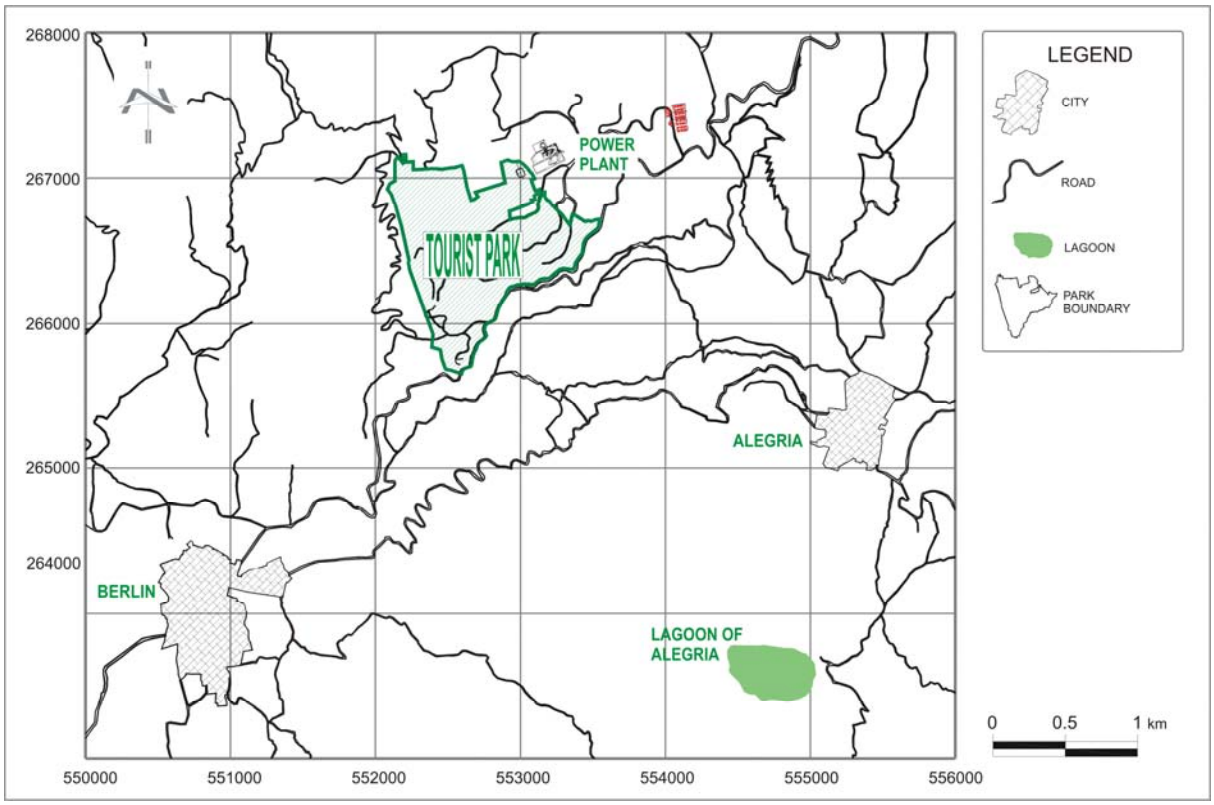

FIGURE 21: Location map of the tourist park

7.1 Marketing considerations

When planning the development of new facilities, one of the first things to study is the available market. This chapter includes a review of some of the newest marketing trends that are affecting the tourism industry as well as new spa trends. This information will be useful when deciding the main characteristics for the Tourist Park and its components.

If we look in a dictionary for the definition of "Trend", we will find that this is "*a general direction or tendency" or "the current general movement in fashion and taste"*. According to this we can consider a trend an external agent responsible for the creation of opportunities but also as a warning system that can lead people in the tourism business to look for innovations and creativity while offering a destination. The relevance of a trend is that it allows planners of new developments to choose from a number of tourist segments which are desirable and will continue to be so for a long time; the success of a destination is directly related. In addition, it becomes relevant to establish a differentiation between the aims for the domestic tourism market and the international market. These markets have different interests and priorities. The domestic tourists may desire shorter trips; they travel at specific periods such as weekends and national holidays. Meanwhile, international tourists enjoy longer stays at a destination, looking for places that offer an extensive range of activities that enhance their experience. Another difference between these two markets is that the International market has a bigger budget for spending and also looks for a cultural exchange.

Some of the new world's tourism market trends are *rural tourism*, associated with comfort in a relaxed atmosphere and a healthy natural lifestyle; *ecotourism*, the main interest is to travel to natural areas with a concern in preserving the environment and *cultural and heritage tourism*, where the trend is focussed on direct contact with the history, culture and heritage of a destination.

One trend that has been gaining popularity is the interest in natural mineral waters. With this trend, a whole range of specializations has been developed in the spa industry (GeothermEx, 2000). When talking about spa trends we can list a large number of reasons for going to a spa: while some guests look for pampering and relaxation, there is another group looking for health improvement, to lose some weight and fitness. The latter has become an important element available at modern facilities. Many of these modern spas combine ancient traditions with modern innovations and complementary techniques for health promotion, rehabilitation, stress management and wellness.

It is not surprising to find that the number of men going to spas is increasing. If we consider that the range of services in these facilities has become more versatile, we realise that more expectations for spa goers are fulfilled. Therefore, when planning a new spa, all tendencies must be present in the mind of the designer.

Appendix III shows the number of tourists visiting El Salvador per month and nationality during the year 2004. In the table, we can observe that the highest number of tourists comes from the Central American countries (66.0%), followed by the North American market (27.3%), while the number of tourist from South America (2.1%), Europe (3.3%) and the rest of the world (1.4%) continues to be quite low in comparison with the two main markets. From these we can also remark that the highest number of tourists comes to the country in the months of April, July and December during the main holidays (Easter, summer and Christmas time), although during the lowest period of arrivals, these are still up to 65,000 tourists. This leads us to think that the number of tourists throughout the year justifies an investment on tourism development.

Table 5 shows the tourist arrival distribution during the year 2004. From this table we can observe that the highest number of people visiting the country is formed by foreign tourists, while Salvadorans living abroad represent 21%. The main reasons for visiting the country seem to be to visit family and friends (30.8%), spend vacations in El Salvador (25.2%) and business (19.7%). Although there is a category named other reasons (21.3%), this data must be analysed deeply, mainly because these results

come from a survey made from tourists visiting the country; when no data was obtained it was classified as "other", which probably could increase the number of tourists under the other categories.

TABLE 5: El Salvador's tourist arrivals during the year 2004 (Ministry of Tourism, 2005)

Type of tourist	**January-December**	**%**
Salvadorean living abroad	202,947	21
Foreign tourist	763,469	79
Total	**966,416**	**100**
Most common reasons for visiting the country	**January-December**	**%**
Vacation	243,537	25.2
To visit family and friends	297,656	30.8
Business	190,384	19.7
Conference/seminar/convention	18,362	1.9
Health treatment	10,631	1.1
Other reasons	205,847	21.3
Total	**966,416**	**100**

Even with a long tradition in medical use of thermal waters, Macedonia does not have active thermal spas. An analysis of the situation, experience, problems, benefits of use and perspective leads one to think that the approach to this economic sector should be generally changed in order to reach possible benefits. Orientation towards an introduction of recreational activities looks to be a feasible and economically justified solution (Gorgieva and Popovski, 2001).

The combination of the geothermal phenomena, rural tourism and amazing landscape is the main idea for the development of a Tourist Park in Berlín field; it will be further supported by the construction of a hotel and mineral pools. This is a place which has the ability to host visitors all year around which will provide wider market opportunities.

7.2 Character of the park

The Park has been visualised as a geothermal tourist park that merges facilities for the hosting, relaxation, physical and psychological recuperation in a place that offers many possibilities such as spending a few days of peace and rest in a natural environment, riding and observation tours, sports programme fitness, cultural activities and enjoyment of outdoor activities and so on. Components of the park include the geothermal manifestations and the facilities of the geothermal field, and it is located in a natural environment with elements such as coffee plantations and native forests, among others. The area for the project is at a close distance from the power plant, surrounded by a magnificent landscape and views.

It has been thought that the park should include forest hikes and horse-back riding tours, thermal sauna facilities, steam baths, hot pools, canopy tour, the construction of a geothermal museum including the history of the villages and towns of the surroundings is also included.

The investment that these ideas may require and a primary analysis of the market, lead us to think in different phases of development. The idea is to start off with a domestic tourism market, which will include most of the geothermal attractions available, such as walking tours in the fumaroles' areas; tours that include the observation of geothermal wells and reinjection ponds; riding tours; a botanical garden; and a canopy tour, among others. The next step will be to focus on the international market, including the design and construction of a hotel and spa facilities.

7.3 Formal concept and main influences of the surroundings

This chapter is based on a previous formal analysis made by the Civil Work Department of LaGeo S.A. de C.V., during the conceptualization phase of the Tourist Park.

The main idea for the project is to promote rural tourism by establishing equilibrium with nature; including sports and recreation while taking advantage of the natural resources available in the geothermal area.

The horizontal distribution of the facilities needs to be flexible, dynamic and organic. The project will emphasise the most representative elements of the architecture from the surrounding cities of Berlín and Alegría, providing a cultural enrichment for the project. The elements to be included in the design of the facilities are listed below and shown in Figure 22.

- *Columns*: One of the most repetitive elements in the architecture of Alegría is the use of columns in the corners of doors and windows.

- *Portals and entrance halls*: These elements, characterize colonial architecture and are used in most of the buildings and houses in Berlín and Alegría.

- *Kiln-burnt tile roofs*: Very common and the most picturesque roofs in both cities.

- *Wooden windows*: Wood is a frequently observed material for windows and doors.

- *Wrought-iron*: This material stands out as a colonial element in balconies and front doors in both cities.

FIGURE 22: Architectural elements in the nearby cities

Other elements such as pergolas and square paths can be included. As for materials to be used, the main emphasis must be on those that are environmentally friendly, allowing permeability into the ground; and at the same time be decorative and produce pleasant sensations in the guests. Among these materials we can list: volcanic stones; kiln-burnt tiles and bricks; wood, wrought-iron and so on.

7.4 Natural resources in the field and surroundings

There is no doubt that the main natural attraction in the area is the geothermal resource. The geothermal phenomena include ten fumaroles and six areas of hydrothermal alteration (36 km^2 in extent). A hydrological system, a part of which is considered an ecologically protected area, is listed below.

- *La Cascada*: A waterfall in Alegría, located 3.5 km southeast of the power station.

- *La Laguna de Alegría* (Lagoon of Alegría): Small natural crater lake with high sulphur concentration and estimated to be the main recharge for the geothermal field. It is located 2.1 km south of the power station. The beauty of this natural resource caused the Chilean poet, Gabriela Mistral, to name it "The Emerald of America", due to the emerald green colour of the water.

- *La Sabana and El Plan de Quimela*: Forest area with centenary species such as cedro, conacaste and laurel.

- *Las Piscinas*: Called "La Reventazón", area formed by five cold springs with extensive vegetation, native wildlife and wild animals under protection. It is located only 1.5 km north of the power plant (Arévalo, 1998).

The success of a tourist destination most of the time depends on the diversity of activities offered to the guests. The natural resources and all the geothermal manifestations available in the Berlín field provide a large number of possibilities for recreation; among these we can count some of the activities listed below and that have been thought to be included as part of the Tourist Park in Berlín.

Recreation and extreme sport: A canopy tour, offering the tourists a unique opportunity to observe the native forest from the treetops while enjoying a breathtaking adventure. The construction of platforms, bridges between trees, zip lines and observation towers. All these can be developed in a way of having a minimal impact on the native forest. A climbing wall is another activity that can be included as part of the attractions.

Ecological tourism: A botanical garden, hiking and horse riding tours along the geothermal manifestations and native forest, and visits to some of the boreholes and geothermal facilities, are some of the activities that can be developed for this aim. These tours, in combination with selected viewpoints, will provide the guests with special spots for the enjoinment of amazing sceneries and landscapes.

Cultural and rural tourism: This field can relate to the civil war in the country (1980-1992), such as military facilities used during the conflict for protection of the area. These can be arranged and used as viewpoints. The construction of a geothermal museum with a permanent exhibition of the geothermal phenomena, geology, and so on, as well as the history and culture of the townships in the surroundings, cradle of legends, myths and important people for the history of the country, e.g. Alegría, where the former President of El Salvador, Dr. Manuel Enrique Araujo and the master poet Alberto Masferrer, among other important people, is planned. A craft market should also be included in the cultural area.

7.5 Hotel characteristics

The hotel will be located inside the boundaries of the tourist park, designed to attract tourists who will spend a few days of leisure and rest in a rural area, learn about the cultural life of the surroundings and get involved in magnificent landscapes and the extensive range of possibilities with the enjoinment of the geothermal phenomena and natural resources of the region.

Nowadays, according to Claus Sendliger, CEO and president of Design Hotels (a successful network of independently-owned hotels), guests in a hotel are looking for a place that feels personal and geographically specific. In other words, they want to know where they are at any moment. An example of this can be seen in the Nordic Light Hotel in Stockholm designed by Jan Söder and Lars Pihl, the lighting designed by light architect Kai Piippo. No one can forget where they are when at every moment and place there is a spectacular lighting show on the walls or special screens which remind them that they are staying at the Nordic Light Hotel (Figure 23), which provides them with a unique Scandinavian experience: the northern lights (Aurora Borealis).

The designer must have in mind that site planning, landscape and infrastructure create quality, identity and "sense of place". Therefore, the design must be driven by the idea of belonging to its particular location. In the Berlín field, surrounded by the remains of colonial architecture and magnificent scenery and landscape, the interior design must be strongly related with the exterior views, providing breathtaking experiences while turning the eyes and looking through the windows at fantastic views of the native forest and coffee plantations.

FIGURE 23: Nordic Light Hotel's lighting displays
(Nordic Light Hotel, 2005)

In the search for success when designing a new hotel the elements not to be forgotten are individuality, personalization, recognition and sustainability. Every detail must be thought through in advance and with extreme care: lighting, furniture, sound system, etc. Design becomes relevant because it is a part of the unique experience and it is not just a matter of fancy chairs in the lobby area, it is about providing a special atmosphere by including the local surroundings, finding the desire of its clients and offering an extraordinary service with the right staff at hand.

The definition of sustainability has many variations, however, it is commonly described as the balance between environmental concerns, economics and social awareness. Sustainability in a hotel means that quality, service, management, operation, product, price, atmosphere and location are important elements of a whole concept. For sustainability, the hotel must be attractive the whole year and help put the Berlín field on the tourism map.

With the increase in the world's interest in the preservation of the environment, sustainability has become relevant. Nowadays, hotels are promoting their environmental and social responsibility. In particular, hotels have in place environmental management systems. They hire a staff person responsible for environmental matters, have an environmental plan, sort waste and so on. All these have a positive effect on the image and reputation of a hotel and also require space in the hotel area.

One important element in the success of a hotel is to fulfil all the desires and expectations of the clients. That is why this place must be prepared to provide the guest with facilities for booking available tours (hiking, horse riding, etc), extreme sport activities, guided tours to the geothermal facilities and manifestations, spa services and so on. All these can be done by designing a special space in the hotel where the guests can get all the necessary information for each activity. Whether this is included at the front desk and reception space or not; it must have a specific area assigned.

A table containing a basic architectural programme is shown in Appendix IV. It contains a list of spaces to be included in the hotel, divided by category of use and function: guests, services, staff and outdoors.

8. ASSESSMENT ON THE USE OF THE BRINE FOR BATHING AND SPA

The purpose of this section is to identify the chemical composition of the geothermal water from the Berlín field in terms of concentrations of major and minor elements and to establish a comparison with the water in the Blue Lagoon, other geothermal spas, water quality standards and seawater, in order to assess the use of the brine for bathing.

Curative characteristics are commonly associated with thermal and mineral water. Further studies must be done on the curative properties of the geothermal brine in the Berlín field in order to determine the healing effects bathing. According to Kristmannsdóttir and Björnsson (2003), this requires a close cooperation of specialists from different fields, such as geoscientists, medical doctors and so on.

Some of the curative thermal effects of the water summarised in Skapare (2001) are: vasodilation increase in the veins of the skin, thereby, the acceleration of metabolic processes in the cells of the skin; in addition the mechanical force caused by the motion of water molecules, which provides a micro massage and an improvement in capillary dilation and blood circulation; waters of high mineral salt content have diverse beneficial chemical effects on diseases through the absorption of a certain quantity of the dissolved materials via the skin; health benefits due to thermal effects of balneological water can be quite significant, the pulse rate and cardiac output begin to increase once the temperature reaches 38°C or higher. The use of thermal water in hot pots is, thus, useful for relaxation and the treatment of some nervous disorders.

The Blue Lagoon water's effect on psoriasis has been studied. Research conducted on the curative effects of the lagoon has shown that bathing in this water is an effective treatment for psoriasis. Three different studies were carried out and at the end of the first one, it was proven that scales disappeared quickly and lesions were greatly reduced in thickness in only two weeks. The second and third analyses combined bathing in the lagoon with UVB light treatments and proved that results could be enhanced by using this treatment combination.

Analyses of the chemical composition of the water in the Blue Lagoon revealed that the water contains no substances that are known to cure psoriasis. The silicon mud is, of course, significant and doubtless the reason for the rapid disappearance of patients' scales. The results lead the experts to believe that the mud is the best option possible for descaling treatment. However, what makes the Blue Lagoon special is the organisms that grow in it, the algae (*Lyngbya estuaria var. thermalis*) and the bacterium (*silicibacter lacuscaerulensis*). Experts believe that these organisms may produce some sort of substance that is effective against psoriasis (Ólafsson and Sigurgeirsson, 1998; Ólafsson and Sigurgeirsson, 2003).

An international definition of mineral water has not been accepted yet. However, there are some commonly used definitions that establish mineral waters as natural water obtained from natural springs or drilled wells. For water, to be classified as mineral, it must contain at least 1,000 mg/kg total dissolved solids (TDS) or more than 250 mg/kg of carbon dioxide (Skapare, 2001).

8.1 Comparison between chemical composition of water in Berlín, Blue Lagoon, other spas, water quality standards and seawater

The aim for the comparison table in Appendix V is to obtain an indication of the potential use of water for bathing by comparison with other places with similar chemical concentrations. The comparison shown in Appendix V includes data from well H0-01 in the Stykkishólmur geothermal field, West Iceland. In this field the outbuilding of a health resort has been planned and the water has been used successfully for the treatment of psoriasis and is claimed to be appropriate for health cures by drinking as well as for bathing therapy for rheumatism. The water has been classified as calcium-sodium

chloride. The data from the Blue Lagoon in Appendix V includes the results of chemical analyses of samples taken in 2003 from the outlet in Svartsengi, the therapy pool (used for the psoriasis treatment) and the bathing facilities; these results show the concentration of the major elements in the water. The data from Baden-Baden and seawater are obtained from Skapare (2001), and are a part of a comparison table used in the report with collected data from different sources. Baden-Baden is considered one of the most prestigious and historic thermal spas in Germany and a top place for balneological treatment.

Bathing in mineral water has some effects on healthy skin. In the Blue Lagoon it has been observed that skin can become dry after protracted bathing. Yet bathing in Blue Lagoon has an even more pronounced drying effect on skin, i.e. causing the shedding of dead skin cells. The skin softens but becomes dry at the same time. Therefore, it is necessary to use moisturizing cream copiously after bathing in the lagoon. Hair strands become coated with silicon crystals. As a result, the hair stiffens and may be difficult to control for several days afterwards. To prevent this, it is advisable to apply hair nutrients before entering the water (Ólafsson and Sigurgeirsson, 2003).

The recreational uses of water include activities such as swimming, wading, boating and fishing. Often insufficient data exist on the human health effects of physical and chemical pollutants, including most toxic, to make a determination of criteria for recreational uses. However, as a general guideline, recreational waters that contain chemicals in toxic concentrations or that are otherwise harmful to man if ingested, or irritating to the skin or mucous membranes of the human body upon brief immersion, should be avoided (EPA, 1994).

The results obtained from recent analyses on the reinjection water and other sources in the Berlín field indicate that very high values of arsenic concentration make the reinjection water not suitable for developing bathing facilities. However, the results obtained from other domestic sources have values that are in the range of possible uses like those shown in Appendix V for springs 79, 80 and 81.

9. CONCLUSIONS AND RECOMMENDATIONS

Prospects for building a geothermal tourist park in the Berlín field are very promising and will become a very relevant kick start point for direct utilization of geothermal resources in El Salvador and will definitely help to put the Berlín field on the country's tourism map.

The development of the tourist park in the Berlín field will help to improve the economic situation of the nearby area. The benefits will result in a high number of job opportunities going to local people; considerable training and skill will be transferred to unskilled. The goods and services required for the tourism development will be produced and supplied locally, improving the economy of the surrounding communities.

The region will benefit as the park can become part of a regional tourism corridor, such as the flowers route in the western part of the country, by including tours and activities in some villages and cities grouped in a tourism cluster.

As for the bathing facilities, the high values of the concentrations of arsenic in the reinjection water indicate that a more specialised and detailed assessment must be done in the near future in order to look for a different source of mineral water. The possibility of finding other sources can be determined based on the results from the domestics springs (S-79, S-80 and S-81) shown in Appendix V, which shows more suitable mineral water for this aim. The values of mineral concentration obtained from these selected springs, indicates that it might be feasible to find other mineral water sources in the field.

The fact that the geothermal tourist park development will be done in several steps will allow the necessary time to do a detailed assessment of other water sources for bathing. Additional studies on use of steam and silica mud must be done in order to look for other geothermal attractions for the park.

AKNOWLEDGEMENTS

My deepest gratitude to the UNU staff, Dr. Ingvar B. Fridleifsson, Mr. Lúdvík S. Georgsson and Mrs. Gudrún Bjarnadóttir for their care, generous help, advice and assistance. I am much obliged to the UNU, the Government of Iceland and LaGeo S.A. de C.V. for granting me this opportunity to improve my knowledge and skills and for giving me the opportunity to attend the UNU Geothermal Programme in Iceland,.

I would like to express my special and deepest thanks to Sigrídur Sigthórsdóttir; it has been an honour to be under her guidance and advice during the preparation of the report. I am very grateful to Magnús Ólafsson for his help with assessing the chemical analysis. Thanks to all the lecturers and staff members at Orkustofnun for their presentations and willingness to share their experience and knowledge. Thanks to my UNU fellows for mutual support and unforgettable friendship.

My entire gratitude is for David López, Rosy Escobar and my colleagues at the civil work department in LaGeo for their help, support and effort during this time. Thanks to all those who have provided me the necessary information for my project and to the Blue Lagoon company for granting me the permission to use their data. Special thanks to Ana Silvia de Arévalo, Ricardo Escobar, Roberto Renderos and the people from LaGeo's laboratory who helped me very much with information and by making new analyses on the reinjection water, the Lagoon in Alegría and selected springs which data have been very useful for the assessment made in the report.

My heartfelt thankfulness to Almighty God, my beloved parents Mario and Haydee, my siblings Mario, Gerardo, Roxana, Iliana and Edgard, my sweet nieces Raquel, Rocío and Fatima and the rest of my family and friends; their support, encouragement and unconditional love helped me through these six months.

Finally, some photos used in composite figures (e.g. Figures 2, 7 and 9) were taken from various tourism and spa websites, that have not been referred to. Here, my thanks are acknowledged.

NOMENCLATURE

a = Natural reflection of water
e_a = Partial pressure of steam in air (mbar);
e_w = Partial pressure of steam at surface (mbar);
G_0 = Sun radiation in clear weather (Wm^2);
h_c = Heat transfer coefficient (W/m²°C);
K = Empirical coefficient (W/m²°C);
N = Cloudiness (1-8)
Q_C = Heat convection (W/m²);
Q_E = Evaporation (W/m²);
Q_L = Heat conduction (W/m²);
Q_p = Heat loss due to rain (W/m²);
Q_R = Radiation (W/m²);
T_a = Air temperature (°C);
T_w = Water temperature (°C);
V_2 = Wind speed 2 m above the ground (m/s);

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APPENDIX I: Properties of the geothermal seawater ingredients in Blue Lagoon
(Bluelagoon, 2005)

Active ingredients	Properties	Effects
SILICA 	Oil absorbing Cleansing Exfoliation/peeling Bacteriostatic Sebum regulation Tissue restructuring	Cleansing Softening Smoothing Rejuvenating Nourishing Energizing
MINERAL SALTS 	Remineralization Osmotic force Enzymatic reaction catalyst Tissue restructuring	Revitalising Softening Tonifying Nourishing Balancing
BLUE GREEN ALGAE 	Regulates the sebum cretion Antioxidant Moisturizing Strengthens the defence System of the skin	Protecting Moisturizing Softening Nourishing

APPENDIX II: Characteristics of selected spas in the USA supplied by thermal or mineral water
(GeothermEx, 2000)

Facilities		Temperature of produced water (°C)	Comments
Calistoga, California	Six private spa resorts with mineral baths, steam baths and mud baths; 1 public mineral-water swimming pool	77-93	Supplied by wells about 60 feet deep. Produced water is cooled to 27-40°C for use in pools and baths. Water is also bottled as mineral water for drinking
Hot Springs, Arkansas	National Park, incl. 1 spa resort and 1 medical facility; 3 spa resorts and 1 arthritis hospital outside the park with soaking tubs and swimming pools	60-62	Supplied by surface springs. A portion of spring water is cooled by heat exchangers to 32°C, then mixed with uncooled water to temperatures in the range of 32-40°C
Hot Springs, Virginia	1 private resort (The Homestead) with 700 rooms. Sauna, steam baths and mineral baths, mineral water swimming pool	39-41	Supplied by surface springs.
Hot Sulphur Springs, Colorado	Private resort with private mineral baths and 10 mineral water pools	40-44	Supplied by surface springs. Water is not re-circulated in pools. No chemicals added
Saratoga Springs, New York	Saratoga Spa is New York state park, with 2 bath houses, a hotel/convention centre and 2 swimming pool complexes. Private resort in city of Saratoga Springs offers mineral baths	6-13	Supplied by surface springs. At state-run bath-houses, mineral water is heated to 37°C. At private resort, mineral water is mixed with tap water to reach desired temperature. Mineral water is bottled for drinking
Thermopolis, Wyoming	Hot Springs State Park, incl. bath house with private baths and central pool; boarding home and physical rehabilitation centre. Private RV park with large mineral pool. Private greenhouse	22-57	State Park facilities are supplied by Big Horn Spring (120 l/s). Private facilities are supplied by Sacajawea well (flow rate 60 l/s), depth not reported
Warm Springs, Georgia	Rehabilitation centre operated by state, with 21 m × 27 m therapy pool	31	Water is heated to 34-35°C for therapy pool
White Sulphur Springs, West Virginia	Private health resort (The Greenbriar) with indoor and outdoor thermal mineral pools	17	Water for mineral pool is heated to desired temperature

APPENDIX III: El Salvador’s tourist arrivals by nationality in the year 2004

Country/ month	January	February	March	April	May	June	July	August	September	October	November	December	Total	%
Central America	**55,841**	**54,352**	**55,654**	**62,016**	**45,286**	**47,131**	**45,372**	**44,311**	**50,882**	**57,582**	**57,806**	**61,337**	**637,570**	**65.97**
Guatemala	27,549	25,993	28,085	32,453	25,949	26,995	25,413	24,618	23,851	28,639	24,576	32,316	326,437	
Honduras	9,556	11,048	11,748	9,719	7,831	7,958	9,158	8,720	11,276	12,616	13,214	15,475	128,319	
Nicaragua	15,343	13,853	12,535	16,180	8,522	9,073	7,154	7,653	12,472	13,112	16,112	9,618	141,627	
Costa Rica	2,457	2,450	2,325	2,720	2,188	2,336	2,608	2,264	2,370	2,377	2,658	2,652	29,405	
Panama	808	849	819	609	634	641	744	750	704	665	1,020	830	9,073	
Belize	128	159	142	335	162	128	295	306	209	173	226	446	2,709	
North America	**21,302**	**16,391**	**19,853**	**19,059**	**15,770**	**26,157**	**35,459**	**24,596**	**12,853**	**16,403**	**20,033**	**35,811**	**263,687**	**27.29**
USA	18,588	13,675	16,978	15,991	13,230	23,628	31,014	21,602	10,658	13,626	16,725	30,195	225,910	
Mexico	1,580	1,630	1,670	1,901	1,687	1,616	2,761	1,805	1,628	1,891	2,123	2,681	22,973	
Canada	1,134	1,086	1,205	1,167	853	913	1,684	1,189	567	886	1,185	2,935	14,804	
South America	**1,472**	**1,714**	**1,728**	**1,661**	**1,812**	**1,625**	**1,822**	**1,590**	**1,528**	**1,699**	**1,842**	**1,360**	**19,853**	**2.05**
Argentina	289	299	309	291	341	324	384	329	332	378	316	291	3,883	
Brazil	124	157	180	121	163	119	198	222	178	227	245	135	2,069	
Colombia	340	428	416	415	449	426	379	330	296	349	419	360	4,607	
Chile	257	275	221	203	261	202	212	202	207	222	230	177	2,669	
Peru	117	169	152	179	161	144	190	147	166	137	181	121	1,864	
Venezuela	129	134	189	178	196	177	150	140	120	144	189	121	1,867	
Others	216	252	261	274	241	233	309	220	229	242	262	155	2,894	
The Caribbean	**117**	**107**	**146**	**159**	**147**	**126**	**211**	**157**	**270**	**199**	**225**	**153**	**2,017**	**0.21**
Cuba	18	19	24	26	32	27	17	16	15	37	26	33	290	
Dom. Republ.	72	69	71	83	84	71	116	96	70	121	178	81	1,112	
Others	27	19	51	50	31	28	78	45	185	41	21	39	615	

Country/ month	January	February	March	April	May	June	July	August	September	October	November	December	Total	%
Europe	**2,814**	**2,973**	**2,969**	**2,923**	**2,262**	**2,350**	**3,063**	**3,039**	**2,042**	**2,372**	**2,833**	**2,507**	**32,147**	**3.33**
Germany	461	456	493	481	341	312	317	515	345	456	341	292	4,810	
Spain	707	814	699	810	640	682	1,101	1,043	629	671	817	658	9,271	
France	176	237	207	211	118	102	117	120	81	68	122	110	1,669	
Holland	122	140	119	127	120	105	161	97	82	102	125	125	1,425	
Italy	341	353	466	297	250	259	414	434	276	274	373	385	4,122	
Norway	106	118	57	40	42	43	45	26	14	38	59	33	621	
England	316	281	304	335	273	266	270	309	214	242	219	225	3,254	
Sweden	139	127	129	142	109	191	165	91	98	135	228	245	1,799	
Switzerland	147	110	134	123	91	87	102	89	80	84	119	87	1,253	
Others	299	337	361	357	278	303	371	315	223	302	430	347	3,923	
Africa	**35**	**25**	**47**	**37**	**43**	**39**	**59**	**41**	**34**	**71**	**72**	**79**	**582**	**0.06**
South Africa	13	11	32	18	21	23	33	20	20	22	29	35	277	
Others	22	14	15	19	22	16	26	21	14	49	43	44	305	
Asia	**674**	**734**	**695**	**760**	**719**	**551**	**770**	**696**	**615**	**642**	**712**	**691**	**8,259**	**0.85**
Israel	75	77	92	82	86	80	76	81	63	69	79	46	906	
Japan	189	263	240	178	159	132	196	193	200	179	164	222	2,315	
Korea	198	127	161	202	192	188	229	185	177	200	175	177	2,211	
Taiwan	148	138	114	174	216	80	152	137	116	100	229	132	1,736	
Others	64	129	88	124	66	71	117	100	59	94	65	114	1,091	
Oceania	**166**	**128**	**155**	**144**	**126**	**146**	**109**	**120**	**172**	**148**	**361**	**526**	**2,301**	**0.24**
Australia	144	113	135	126	95	124	94	94	140	127	328	480	2,000	
Others	22	15	20	18	31	22	15	26	32	21	33	46	301	
Total	**82,421**	**76,424**	**81,247**	**86,759**	**66,165**	**78,125**	**86,865**	**74,550**	**68,396**	**79,116**	**83,884**	**102,464**	**966,416**	**100**

Source: General Direction of Migration of El Salvador (Ministry of Tourism, 2005)

APPENDIX IV: Hotel's architectural programme

ID	AREA / ROOM
1.	**ROOMS / HOUSEKEEPING**
1.1	**Rooms**
1.1.1	Double / Twin
1.1.2	Suites
1.2	**Housekeeping**
1.2.1	Cleaning and housekeeping office
1.2.2	Storage (linen and towels)
1.2.3	Dressing room maids and uniforms storage
1.2.4	WC
1.2.5	Laundry
1.2.6	Cleaning storage
2.	**FRONT DESK / ADMINISTRATION**
2.1	**Front desk / Reception**
2.1.2	Reception staff
2.1.3	Activities booking staff
2.1.4	Back office
2.1.5	Luggage storage
2.2	**Administration**
2.2.1	Hotel manager
2.2.2	Secretary
2.2.3	Hotel marketing / public relations and sales
2.2.4	Hotel finance, booking and accounting
2.2.5	Restaurant manager
2.2.6	Wellness manager
2.2.7	Technical manager
2.2.8	Security office
2.2.9	Computer network expert
2.2.10	Computer room
2.2.11	Meeting room
2.2.12	Coffee station / lounge
2.2.13	Restrooms male
2.2.14	Restrooms female
3.	**FOOD AND BEVERAGE**
3.1	**Restaurants and Bars**
3.1.1	Restaurant
3.1.2	Bar / Lounge
3.1.3	Gourmet coffee
3.2	**Operating area F&B**
3.2.1	Cooling storage drinks
3.2.2	Wines and liquors storage
3.2.3	Storage

ID	AREA / ROOM
3.	**FOOD AND BEVERAGE**
3.3	**Staff Restaurant**
3.3.1	Staff lunch area (close to kitchen)
3.4	**Kitchen**
3.4.1	Food preparation
3.4.2	Cold kitchen salads, appetizers
3.4.3	Cooking
3.4.4	Stewarding
3.4.5	Cooling storage food
3.4.6	Dry food storage
3.5	**Delivery and waste disposal**
3.5.1	Delivery
3.5.2	Dish washing
3.5.3	Waste disposal glass
3.5.4	Waste disposal paper
3.5.5	Waste disposal plastic
3.5.6	Waste disposal others
3.6	**Outside**
3.6.1	Waste disposal
4.	**SHOPS AND PUBLIC AREA**
4.1	**Shops**
4.1.1	Shop gifts / crafts, souvenirs, maps, etc
4.2	**Public**
4.2.1	Lobby
4.2.2	Restrooms male
4.2.3	Restrooms female
4.2.4	Restrooms handicapped
4.2.5	Emergency room (24 hours)
4.3	**Game rooms**
4.3.1	Game room / ping pong, chess, billiard, etc.
5.	**TECHNICAL ROOMS AND MAINTENANCE**
5.1	**Maintenance shops**
5.1.1	Air conditioning
5.1.2	Electricity distribution frame
5.1.3	Pool equipment
5.1.4	Maintenance shop & tools storage
5.1.5	Landscaping and grounds keeping shop & storage
5.1.6	Paintings and inflammable materials storage

ID	AREA / ROOM
5.	**TECHNICAL ROOMS AND MAINTENANCE**
5.2	**Parking (Outside)**
5.2.1	Guests parking lots
5.2.2	Staff parking lots
6.	**STAFF**
6.1	**Social rooms**
6.1.1	Employees recreation
6.1.2	Changing rooms/lockers male
6.1.3	Changing rooms/lockers female
6.1.4	Restrooms
6.2	**Sleeping rooms**
6.2.1	Manager on duty
6.2.2	Doctor on duty
7.	**WELLNESS**
7.1	**Bathing (outdoors)**
7.1.1	Thermal pool
7.1.2	Private pools / Jacuzzi cabins
7.1.3	Private whirlpools (integrated in suites)
7.1.4	In water massage
7.2	**Wellness**
7.2.1	Reception / lobby
7.2.2	Showers and changing rooms/lockers, restrooms male
7.2.3	Showers and changing rooms/lockers female
7.2.4	Massage compartments
7.2.5	Mud treatment
7.2.6	Sauna male
7.2.7	Sauna female
7.3	**Beauty**
7.3.1	Facial and skin care treatments
7.3.2	Manicure spa
7.3.3	Pedicure spa
7.4	**Fitness**
7.4.1	Fitness room
7.4.2	Aerobic active room
7.4.3	Yoga, Pilates, relaxing

APPENDIX V: Comparison table of fluid chemical composition, concentration in ppm

Element	Berlín field[1]					Blue Lagoon[2]			Spas		Water Quality Standards for priority pollutants[5]		
	Reinjection Pond (TR9)	Spring- 79	Spring-80	Spring-81	Lagoon of Alegría	Svartsengi (outlet)	Therapy pool	New bath. Place	Stykkis-hólmur[3]	Baden-Baden[4]	Fresh water	Salt water	Human health for consumpt.
°C	64	58	35	50	25	82	30.4	37.1	86.6				
SiO_2	855.6	152.9	149.4	151.8		529	272	251	71.7				
pH/°C	7.09	7.97	8.14	8.27	1.88	7.68/22.6	7.42/23	7.22/22.6	8.4/17	8.2			
CO_2						0	9.1	11.4	4.4				
Na	4115	49.8	46.4	45.3	48.1	8,890	6,875	7,643	740	851			
K	858.6	13.6	14.5	14.7	18.7	1,353	1,046	1,177	14.5	32.9			
Mg	0	3.9	4.5	4.9	11.2	0.69	0.59	0.6	0.5	58			
Ca	83.9	14.4	16.1	17	80.6	1,475	1,129	1,274	1,170	144			
Li*	13.76	0.05	0.05	0.05	0.05	3.55	2.8	2.99					
SO_4	28.56	43.7	45.65	43.05	1570	35.5	28	31.8	315	209			
Cl	7,396	5.03	6.05	5.96	41.65	18,540	14,250	15,740	2,960	1,442			
F						0.21	0.16	0.18	1.23				
Al*	0.276				84	0.0276	0.0109	0.00339	0.02				
Cr*	<0.05				<0.05	0.0003	0.000207	0.000201	0.000035		0.016	1.1	
Fe	<0.01				39.47	0.0309	0.014	0.0081	0.023				
Zn*	<0.02				<0.02	0.0127	0.00904	0.0144			0.12	0.09	7.4
Pb*	0.0138				<0.005	0.000802	0.000389	0.00433	0.00005		0.065	0.21	
V*						0.000581	0.00157	0.00194					
B	140.8	1.3	1.2	1.4		10.7	8.69	9.6	0.08				
Mn*						0.193	0.162	0.172	0.023				
As*	11.04	0.0091	0.0096	0.0092	0.45	0.119	0.098	0.104	0.0006		0.34	0.069	0.00018
Mo*						0.0293	0.00594	0.00601					
Se*						0.000217	0.000228	0.000141	0.00003			0.29	0.17
Cu*						0.00181	0.00113	0.00211	<0.000005		0.013	0.0048	
Ni*						0.00712	0.00129	0.00252			0.47	0.074	0.61

Element	Berlín field[1]					Blue Lagoon[2]			Spas		Water Quality Standards for priority pollutants[5]		
	Reinjection Pond (TR9)	Spring-79	Spring-80	Spring-81	Lagoon of Alegría	Svartsengi (outlet)	Therapy pool	New bath. place	Stykkis-hólmur[3]	Baden-Baden[4]	Fresh water	Salt water	Human health for consumption
Ag*						<0.0005	<0.0005	<0.0005			0.0032	0.0019	
Cd*	<0.025				<0.025	0.000161	0.000108	0.000184	0.000003				
Sb*						0.000938	0.00116	0.00107					0.0056
Hg*	<0.0005				<0.0005	0.0000059	0.000005	0.0000087	0.000007		0.0014	0.0018	
Ba*						2.36	1.9	2.03					
Co*						<0.00005	<0.00005	<0.00005					
P*						<0.04	<0.04	<0.04					
Br						60	46.2	50.3	9.7	1.6			
I									0.6				
Sr*						9.45	7.27	7.94	5.3				
H_2S									0.07				
NH_4						0.42	1.36	1.05					
Si										167			
NH_3									2.2				
NO_3		19.26	22	21.17					<0.1				
NO_2									0.04				
PO_4									0.08				
Ti									0.00006				
Rb													
Cs													
HCO_3	3.5	127.9	135.3	143.5	0								
TDS	13,700				3,515	30,670	23,560	25,800	5,430	3,100			
Cond µg/s	20,770	295.4	305	314	5,245				(25°C) 8,750				

*: Blue Lagoon's water analysed at Analytica Sweden 1: LaGeo's laboratory 2: Hardardóttir, 2003 3: Kristmannsdóttir et al., 2005 4: Skapare, 2001 5: EPA, 2004