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May 2, 2007

Sr. Fernando Lloveras, Executive Director
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Dear Sr. Lloveras,

Enclosed is our report entitled Sustainable Development at the San Cristóbal Canyon. It was written for the use of the Fideicomiso de Conservación de Puerto Rico at their San Juan location between January 11, and May 2, 2007. Preliminary research was done in Worcester, Massachusetts, prior to our arrival in San Juan, Puerto Rico. Copies of this report are being simultaneously submitted to Professors Arthur Gerstenfeld and Susan Vernon-Gerstenfeld. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We appreciate the time that you and the Conservation Trust of Puerto Rico have devoted to us.

Sincerely,

Samantha Cote
Kevin Cox
Marcos Rivera

Report Submitted to:
Dr. Susan Vernon-Gerstenfeld
Assistant Advisor: Dr. Arthur Gerstenfeld
Puerto Rico, Project Center

By

Kevin Cox _____
Samantha Cote _____
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In Cooperation With:
Juan Rodríguez
And the
Fideicomiso de Conservación de Puerto Rico

Sustainable Development at the San Cristóbal Canyon

May 2, 2007

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EXECUTIVE SUMMARY

Puerto Rico is a small island in the Caribbean with a fixed amount of natural resources and areas of natural beauty. The San Cristóbal Canyon, located within the municipalities of Aibonito and Barranquitas, contains ecological and geological features found nowhere else on the island. The Conservation Trust of Puerto Rico requested that our group investigate ways to foster sustainability in the development of the San Cristóbal Canyon protected area. Our report presents our research and recommendations to develop trails in the canyon for fully accessible use for potential visitors, to create an informational native tree exhibit, and to promote community cooperation in the conservation of the canyon.

The Conservation Trust proposed four trails for our group to examine in order to determine which ones could be developed and for what purposes. Our first objective was to provide recommendations that will allow the trails to be accessible for as many people as possible, including those with physical disabilities.

Our recommendations for the trails in the canyon required proof of functionality and adaptation to the local climate. We gathered ideas for possible recommendations by visiting other protected areas that operate in a similar manner to the San Cristóbal Canyon protected area. The next step was to examine those ideas in order to adapt them to the weather conditions of the canyon. We conducted research to ensure that our recommended construction materials and methods are environmentally-friendly and resistant to erosion.

It was essential for our group to provide specific locations of important aspects of each proposed trail, such as where safety features were needed, the locations of excessive

amounts of vegetation that would require clearing, and where erosion may be an issue. Using a GPS receiver, we recorded steep locations and areas bordering cliffs. We also recorded various turning points along the trails. We combined and plotted those coordinates to create the only known maps of the proposed trails for the area.

Through our research, investigations, and field surveys, we determined that two of the four trails were able to be constructed for complete handicapped accessibility. Those trails run through the nursery and the previous dump site. Those trails should be constructed of concrete with grooves in the surface as we witnessed first hand at Las Cavernas de Río Camuy. The concrete has a high initial cost, but requires less maintenance than alternatives such as asphalt or gravel. The grooves cut into the concrete serve to provide traction when the ground is wet, which often occurs in the canyon region. The trails should also follow regularly accepted guidelines for firmness, stability, steepness and width (Rathke and Baughman, 2007; National Center on Accessibility, 2002). Fencing should be implemented in areas with excessive slope. The construction of those two fully accessible trails will allow more visitors to appreciate what the canyon has to offer.

The remaining two trails, one leading to the proposed lookout tower, and the other running through a trial reforestation area, are not feasible to develop for complete accessibility. The lookout tower trail can, however, be constructed for general hiking by people with no major physical disabilities. We recommend that the trail be constructed with complete fencing on both sides due to its steep grade throughout. The surface of the trail should be constructed of concrete the same way as in the accessible trails. However,

this trail should have stairs instead of ramps due to its steep grade and expected use by people without major disabilities.

The trail through the trial reforestation area travels through a section of land that is currently not owned by the Conservation Trust. We are recommending that trail not be developed until the land can be acquired or a contractual agreement be made with the current owner.

The second objective of our project was to educate the potential visitors of the canyon about the local native flora that exists in the area. In order to accomplish that objective, we hiked the proposed trails with a GPS receiver and recorded the location of the best examples of native flora we could find. We also took pictures of each of those specific plants. We researched each of the plants and created summaries of them in both English and Spanish. The information about each plant was compiled from Spanish as well as English sources. In order to make the information presented to visitors more interactive, we created an example checklist for visitors to fill out as they travel the trails. The checklist consists of a series of leaf images and a brief description of the plants. The potential visitor is then encouraged to fill in the names of the plants that have those leaves when they find them.

The final objective of our project was to provide the information necessary to establish the San Cristóbal Canyon area as a biosphere reserve. To accomplish that objective, we researched the purpose of biosphere reserves and examples of already established reserves on the United Nations website and in scholarly articles. The concept of a biosphere reserve was created by the Man and Biosphere Program established by the United Nations in 1974. The biosphere reserve program was designed to create a

network of protected, characteristic ecosystems throughout the world for sustainable use and development. The purpose of a biosphere reserve is to combine conservation with sustainable land use. The characteristic difference between a biosphere reserve and a national park is that people are directly involved in the conservation of the protected area.

In order to help the Trust develop positive relations with its neighbors, we investigated possible solutions to damaging practices by inhabitants. An example of such damaging practices is the dumping of waste by local poultry farms into the Aibonito River. We researched more environmentally-friendly means for the disposal of poultry waste because those farms are the largest point sources of pollution of the Aibonito River, which runs directly into and through the canyon.

Through our research, we concluded that establishing the canyon as a biosphere reserve may help foster positive relations with the surrounding communities. Furthermore, we determined the Conservation Trust of Puerto Rico has the ability to fulfill the criteria, as suggested by the United Nations Statutory Framework, for the San Cristóbal Canyon protected area to be designated as a biosphere reserve. To this end, and to achieve the Trust's goal of connecting the area's history with its conservation, we recommend that the Trust pursue the establishment of the San Cristóbal Canyon as a biosphere reserve.

Our project report provides necessary recommendations and background information to achieve the sustainable development of the San Cristóbal Canyon. Our study has the potential to directly impact the roughly 57,024 residents of Aibonito and Barranquitas (U.S. Census Bureau, 2000), Puerto Rico through increased tourism and cooperation between the Trust and the residents surrounding the canyon. It will also

impact an unpredictable number of visitors to the canyon. As the population of Puerto Rico continues to grow, the concepts that we researched in our project will need to be practiced in order to assure the survival of its natural resources for future generations.

ABSTRACT

The Conservation Trust of Puerto Rico requested the assistance of our group to create a planning document to outline sustainable development of the San Cristóbal Canyon. This process included investigating the process of establishing a biosphere reserve in the canyon. Through research and data collection, we have provided sufficient information in the form of pictures, maps, and documents, to outline specific areas of concern along the trails. We provided the information necessary to develop two trails for handicap access. Our group recommended that the Trust create an interactive tree exhibit using the information that we provided, in order to educate the public. With all of that information, the Trust should be able to achieve sustainability in the development of the San Cristóbal Canyon.

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CHAPTER ONE: INTRODUCTION

The sustainable utilization of natural resources should be a worldwide concern. As the world's population increases, so does the strain on those resources. The middle of the twentieth century provided a huge increase in the world population with a jump from three billion to six billion people in the years 1949-1989 (U.S. Census Bureau, 2006). As of January 23, 2007, the U.S. Census Bureau estimated the world's population at over 6.57 billion. These staggering numbers contribute to the heightened demand for expansion of towns and cities, in addition to the destruction of forests world wide for agricultural land and other uses.

According to Cropper and Griffiths (1994), deforestation in tropical regions is caused by the need for lumber, fuel wood, and pasture or cropland. Furthermore, they assert that those increased needs are caused by population growth resulting in deforestation in these regions. About thirteen million hectares of forest are lost each year. However, that figure is decreasing as more countries implement better reforestation plans (Food and Agricultural Organization of the United Nations [FAO], 2007).

Puerto Rico is a small island and, therefore, self-sustainability is very difficult. With a growing population, the stress on Puerto Rico's limited resources is becoming more apparent in highly populated areas, such as San Juan. Urban development of potential conservation land in Puerto Rico should be a major concern for its inhabitants. Between 1977 and 1994 a loss of 6 percent of potential agricultural land was calculated (Lopez, Aide and Thomlinson, 2001). If that trend continues, the history and beauty of those lands will be lost forever to the citizens of Puerto Rico.

An issue that will directly inhibit the economic success of areas such as Puerto Rico is the rapidly increasing world and local population. The current population of Puerto Rico is 3.95 million, while the island is only 3,514 square miles in total size. That large population of people in a small area results in having over 1,124 people per square mile. In 2010, only a few years away, the population of Puerto Rico is expected to reach 4.44 million; therefore, the population per square mile will be 1,262. Furthermore, the total population is expected to double in the next eighty eight years, starting in the year 2002 (Puerto Rico, 2007). That drastic increase will raise pressure to develop remaining undeveloped lands. Alarmingly, only 7 percent of all the land in Puerto Rico is protected against development according to our liaison, Juan Rodríguez. With such a small percentage of protected land and a huge demand for space, precious lands will be lost to development if conservation efforts are not strengthened.

Urban growth and deforestation are directly linked to the extinction of plant and animal species in Puerto Rico. In the most recent survey of the area, there were approximately seventy-eight species of plants and animals that were federally listed as endangered or threatened in this country (U.S. Fish and Wildlife Service, n.d.). Fifty of the species on that list are plants. Fifty-six out of the seventy-eight total species are native to Puerto Rico and cannot be found anywhere else in the world. Many, if not all of those species, will be directly threatened if these conditions are not carefully monitored and changes are not made (Silander, 1998).

The Conservation Trust of Puerto Rico is researching the possibility of developing the San Cristóbal Canyon protected area for sustainable use, conservation of its valuable resources, as well as educating the public of the rich history in the area. The

organization requested that our group investigate certain areas of the San Cristóbal Canyon and make recommendations as to how to make the trails accessible and safe for the public.

The investigation involved the collection and interpretation of data in order to plan the implementation of low impact nature trails for sustainable use of the San Cristóbal Canyon protected area. The first challenge that was presented was the competition between several interests groups (Bojorquez, de la Cueva & Diaz, 2004). For example, private landowners in the surrounding towns of Aibonito and Barranquitas are hesitant to sell their lands to the Trust. Many of those landowners are farmers or industries that have been established for decades.

In addition to the requests made by the Conservation Trust, we provided the information necessary to create a native tree exhibit for the opening of the canyon to visitors. The exhibit should include signs describing native trees that are found in the canyon. First, the visitors should be shown an example of the tree in the nursery and then they should be instructed to find those trees along the trails. There should be signs constructed near good specimens of the trees throughout the trails in the San Cristóbal Canyon. Visitors will also be equipped with a checklist showing pictures of the tree leaves along with a brief description of the tree. The potential visitor will then be encouraged to fill in the name of the tree corresponding to the leaf and its description as he or she hikes the proposed trails. The purpose of this exhibit will be to educate the visitors to appreciate the beauty and value of the San Cristóbal Canyon Nature Reserve.

In order to determine the environmental and geological suitability of the trails in the San Cristóbal Canyon protected area, our group acquired essential information

through academic journals, articles, and related past projects. Interviews with experts in related fields and surveys of the reserve provided valuable data. Through the analysis of that data, the group made recommendations for improving the safety and accessibility of existing trails. Our group provided the results of our analysis to the Conservation Trust so that they will be able to better manage and develop the San Cristóbal Canyon for its sustainable use.

CHAPTER TWO: BACKGROUND

The United Nations Environment Program (2003) makes clear the importance of sustainability, and they define sustainability as the effective management of protected areas for tourism while maintaining the attractions of the areas for future generations. Bossel (1999) defines sustainable development as "the kind of human activity that nourishes and perpetuates the historical fulfillment of the whole community of life on earth." We are adopting that as our working definition of sustainable development.

Biosphere reserves have been developed by the United Nations Man and Biosphere Program (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2007) in order to achieve the objectives of sustainable development for the world's rare and complex ecosystems. The purpose of a biosphere reserve is to facilitate a relationship between humans and the area designated for conservation (UNESCO, 2006). Establishing a biosphere reserves requires research of the region's geography, geology, complex ecosystem and climate. This chapter will provide a review of each topic required to plan a sustainable biosphere reserve.

HISTORY OF TOBACCO IN THE CANYON

The following history of tobacco in Puerto Rico is adapted from the work of Sanchez-Carlo (2005). Tobacco production has played an important role in the history of Puerto Rico. Most of that tobacco was grown within thirty-nine municipalities in the eastern section of Puerto Rico's central mountain range. Aibonito and Barranquitas, within which the San Cristóbal Canyon is located, were among the most important tobacco producing municipalities on the island. They were important because of their

large amount of tobacco leaf production and cultivation area. Due to the mountainous nature of those towns and the need for land clearing for tobacco production, there were continuous problems with erosion and soil depletion. Those problems constantly hindered production, and reduced yield.

Tobacco production peaked in Puerto Rico from the mid 1800's to the mid 1900's. During the 19th century, tobacco produced on the island was mainly used for local cigar and cigarette manufacturing. During the 20th century, the focus of tobacco sales shifted from local manufacturing to exporting to the United States. After 1950, the importance of tobacco production waned and large numbers of people migrated away from tobacco producing areas.

The cultivation of tobacco left much of the San Cristóbal Canyon cleared of trees, sparing only the most inaccessible areas. Tobacco requires a large area of cleared land for proper growth. The only trees allowed to stand among the tobacco were the Puerto Rican royal palms. Those trees were left standing due to their importance to the local people. The trunks of the trees were used for their wood while the fronds were used as roofing material. The fronds were also used for religious purposes. They would be blessed by a priest and then weaved into a cross which would then be hung within the home. Those practices led to a great change in the ecology of the canyon, diminished biodiversity and eliminated some species entirely. Much of the land remains cleared. The Conservation Trust of Puerto Rico is currently working to restore the canyon to its former state by planting native trees and encouraging biodiversity.

FLORA AND FAUNA OF THE CANYON

According to the bioclimatic classification by Holdridge (1967), the San Cristóbal Canyon is located in a subtropical rain forest. Francis, Alemañy, Liogier, and Proctor (1998) found the San Cristóbal Canyon to consist of five types of ecological areas: 1) Agriculturalist lands; 2) Older forests with trees of at least twenty years of age; 3) Moderately younger forests with very tall trees that form a canopy; 4) Vegetation that includes the areas around the rivers; 5) Unstable areas that include cliffs and flora in covered slopes by vegetation adapted to less than ideal conditions.

The canyon is the habitat of 677 plant species (548 native and 129 exotic). Some of these species are able to survive only in the unique habitats that the canyon provides: 1) upland slopes and hills, 2) swales and draws within the uplands, 3) rocky cliffs with many variations in microhabitat, 4) side slopes with south-facing aspects and north-facing aspects, and 5) a riparian zone with many variations in microhabitat (Francis *et al*, 1998). A survey of all the species in the canyon by Francis *et al* (1998) shows that there are twenty-two species that are on the Department of Natural Resources of Puerto Rico's threatened or endangered species list. A rare specie of grass, the Somulus parviflorus, was discovered during that same survey. It is not native to Puerto Rico, but the canyon is its only habitat in Puerto Rico. That exotic specie can be found in Cuba and Hispañola, although it was previously not known to be located in Puerto Rico. It is found in the borders of the canyon and on the banks of the Rio Usabón.

The Rio Usabón is the main river that passes through the canyon. It is the habitat of various species of shellfish, fish, reptiles, insects and amphibians. Some known native

species of the river are the coquí de yerbas and the guppy Poecilia reticulata (Ortiz and Quevedo, 1986). Many of the species of fauna, such as the spider Nephila clavipes, can only exist in areas of higher humidity, such as the canyon. Without the unique combinations of habitats provided by the reserve, the hundreds of species mentioned above would have no place to live and thrive (Francis *et al*, 1998).

Termites

Termite protection is a possible requirement for the structures to be built at the canyon due to the large population of termites within that region. Termites are small ant-like insects that have existed for millions of years. They are a burden to the majority of humanity because their food sources are anything made of wood, paper, or cotton. Termites are found in most places of the world that have mild to warm climates (All Around the House, n.d.). The primary way to protect any building site in a termite zone was to use a chemical soil treatment; however, due to regulations becoming stricter over the past twenty years, a different technique must be used. The idea of the barrier method includes placing a metal or sand substance in between the soil and the bottom of the structure or house. According to Day (1996), that method is successful because termites most commonly attack wood that is touching or very close to the ground. Unless the infestation is allowed to remain for an extended period of time, wood that is supported above the ground is typically safe. Another method to prevent wooden structures from being damaged by termites is to chemically treat the wood. A final solution is to use wood that contains natural protective substances. However, those types of wood are not typically used for large scale construction. For outdoor use, wood treated with chemicals

such as chromated copper arsenate, ammoniacal copper quat, and copper azole are commonly used (Forintek, 2002).

SUSTAINABLE DEVELOPMENT

UNESCO (2007) explains the concept of sustainable development. Sustainable development can be closely linked to the sustainability of humankind. In the past, sustainability was not a criterion in human societies when areas of land were considered for development. However, the concept of sustainability of human life was actually an implicit goal, since no society would ever purposefully pursue its own destruction over time. Only more recently, people have focused on sustainability explicitly because population growth and increasing consumption have put increased pressure on all of the world's ecosystems.

With today's technology and knowledge, humans realize that the world's resources are finite and need to be conserved. However, conservation efforts can be impeded by several factors: lack of cooperation from local communities, insufficient education of the importance of conservation, and urban development, among others. According to Brunkhorst (2001), society is struggling to resolve problems with depletion of the land, its resources, and failing ecosystems. Governments are also facing challenges to assist with sustainable development due to lack of resources. In order to resolve those limitations, UNESCO created the Man and Biosphere Program in 1974. UNESCO is the United Nations Educational, Scientific and Cultural Organization. It was founded in 1945 with the idea of promoting international cooperation for the conservation of the world's rare and unique ecosystems (UNESCO, 2007). Although no examples of a

biosphere reserve failure were encountered, there are several factors that would cause the deterioration of a biosphere. For example, lack of cooperation from local communities could pose a threat to conservation efforts by allowing negative edge effects to harm the designated core area. If allowed to continue, the biosphere reserve would fail due to its inability to accomplish its objectives of sustainability and promoting community cooperation.

Biological Conservation and its Conflicts

The increasing demand for natural resources generated by the needs of the growing population of Puerto Rico has created opposition to already established nature reserves and the creation of new ones (Tapia, Cueva & Diaz, 2004). Biological conservation competes with other categories of land use such as forestry, agriculture, recreation, and urban and infrastructure development (Margules and Usher, 1981). The economic, social and cultural needs of Puerto Rico pose a challenge in conservation efforts, which can possibly make it difficult for conservationists to justify the money, time, and effort, needed to conserve the San Cristóbal Canyon. Puerto Rico's per capita income is only about half that of the poorest U.S. state and a majority of its residents live below the U.S. poverty line (Soto Class, n.d.). Although the Fideicomiso is a privately-owned organization, its conservation efforts directly affect the citizens of Puerto Rico.

According to Crowfoot and Windolleck (1990), the competition between conservation and development is one generated from opposing values of different economic sectors such as forestry, recreation, and urban development. For example, in Namibia, the competition exists between human development and wildlife habitats.

According to O'Donnell-Rodwell and Rodwell (2000), increased elephant densities in the Caprivi region have created greater tensions between humans and elephants. The resulting negative attitudes towards wildlife have the potential to undermine conservation efforts in that region.

In the San Cristóbal Canyon area, there is economic pressure from private land owners to develop the area in close proximity to conservation lands. There are also poultry farms that heavily pollute the local waters with the waste and carcasses of the poultry. Development of that land will create not only legal issues, but it will have a detrimental affect on community cooperation in the near future. Furthermore, continued pollution of the river from poultry waste will compromise the aesthetic value of the canyon. That failure to cooperate will also compromise the potential ecotourism business for the surrounding municipalities.

Poultry Farms

According to Cartwright (2006), many poultry farms are not following acceptable, environmentally sustainable disposal methods for chicken waste and carcasses. Currently, the majority of poultry farms use landfills and offal pits to dispose of waste. Poor practices for disposal of waste products on the farms can contribute significantly to increased numbers of chicken deaths as well as the spread of dangerous diseases such as the Avian Flu. Poultry waste also provides a health risk to water sources such as rivers and reservoirs through the spread of Salmonella and other dangerous organisms. The chicken waste can also cause a foul odor and is a breeding site for harmful insects and pests.

In order to protect against harmful environmental and health effects, farmers need to have an acceptable animal waste management system. There are some cost-effective options available, such as aerobic and anaerobic lagoons, and composting. Hairsten and Stribling (1995) describe two common practices for the disposition of poultry waste. Lagoons are the most common method for treating poultry wastes. Anaerobic lagoons break down waste material without oxygen or aeration and can handle all poultry wastes. Aerobic lagoons break down waste material with oxygen and aeration. Composting is a process that biologically breaks down organic matter, which usually results in a useful soil-like end product.

The major issue; however, is the carcasses of dead poultry that need to be disposed. Typical practice is to dump carcasses in a landfill, which is not only a health hazard, but it can create odor issues. Brodie and Carr (n.d.) argue that composting is an efficient alternative for carcass disposal. The only ingredients needed for composting are air, water, nutrients, and carbon. Carbon can be found in everyday materials such as sawdust, straw, paper, cornstalks, and similar fibrous materials. Several benefits of composting dead poultry include easy management, no odor if the process within the compost is maintained properly, and the high temperatures of the composting kills most pathogens that may exist in the carcasses. Those sort of environmentally-friendly practices need to be implemented in the areas surrounding the San Cristóbal Canyon if it is established a biosphere reserve.

Biosphere Reserves

The definition of a biosphere reserve, according to the UNESCO (2007), is an area of one or more protected lands, with the objective of combining both conservation

and sustainable use of natural resources. There are several characteristics that define a biosphere: 1) it conserves examples of characteristic ecosystems in a natural region of the world, 2) it is an area where people in the surrounding areas play a large role in its conservation, 3) it serves as a center for research, monitoring, education and training, 4) it is a place where scientists, managers, and people of the surrounding communities cooperate in developing a program for managing land and water sources to meet human needs while conserving these sources, and finally, 5) biosphere reserves serve as an area for voluntary cooperation to manage and conserve its resources.

The biosphere reserve program was founded in 1974 under the Man and Biosphere Program [MAB] by UNESCO (See Appendix E). The purpose of the MAB program was to facilitate a relationship between people and the environment for the purpose of sustainable development and conservation of the world's natural resources. The objective of the international network of biospheres was to provide opportunities for long-term monitoring and research into the ecological, social and economic aspects of conservation and sustainable development.

According to UNESCO (2007), biosphere reserves are similar to laboratories where nature and human activity can be observed. They are designed to perform three inter-connected functions: conservation, development, and logistic support. Conservation concerns the preservation of landscapes, ecosystems, and species variation. The development function deals with economic, human, and cultural development. Finally, logistic support is concerned with the research, monitoring, and environmental education and training of faculty.

The difference between national parks and protected areas is that people are an integral part of the process in the development and maintenance of a biosphere reserve (Taylor, 2004). According to Batisse (1997), each biosphere reserve includes three distinct territorial components: the core area, buffer zone and transition area. The core area is the protected area in which no one lives. The buffer zone is the area where there are heavy regulations imposed by the owners of the designated core area on the businesses and homeowners within this area in order to prevent activity that compromise conservation efforts. The transition area is where non-conservation activities are permitted with consent of the owners of the reserve (UNESCO, 2007). The ten major objectives of a biosphere are: (Brunckhorst, 2001):

1. Local Community Participation
2. Integrated Resource Planning and Management
3. Conservation and Restoration
4. Research
5. Monitoring of Flora and Fauna
6. Regional Planning and Development
7. Environmental Education and Training
8. Ecologically Sustainable Development
9. Information and Communication
10. Developing an International Framework

In order to be sustainable and enduring, land use must be multi-functional across municipalities, human communities, and economies (Brunckhorst, 2001). Economic systems rely on five types of capital: natural, social, human, physical, and financial (Brunckhorst 1998):

1. Natural: Food, wood, water regulation and supply, climate regulation, wildlife habitats, and recreation
2. Social: The cohesiveness of surrounding communities
3. Human: Status of individuals-health, nutrition, education, skills, access to schools and medical care
4. Physical: Local infrastructure
5. Financial: Money and savings

These five types of capital can produce economic growth and sustainable use of natural resources. In an article by the non-profit group Europaworld (2004), West African Environment Ministers were promoting biospheres in that region of the world to fight against environmental degradation and poverty. The four year project called for the development of six biosphere reserves in West Africa. The project planned to increase income in those regions through the development of ecotourism in that area. In that case, all five types of capital would be enhanced through completion of its objectives.

Another example of that type of project is the Cape West Coast Biosphere in Capetown, South Africa, which is operated under the West Coast Environmental Cooperative. Their vision for the biosphere seeks to improve the economic, environmental, and social areas in that region of South Africa. The cooperative would like to improve the local economy by generating income for local communities through enhancing ecotourism. The environmental aspect involves working towards the enhancement of the natural beauty of the area and increasing the amount of space available to control storm water runoff. Finally, the cooperative is striving to provide programs to encourage environmental awareness within the local communities, which will facilitate a positive working relationship between those communities and the environment. The overall concept of that biosphere reserve is designed to strengthen all

five types of capital in the surrounding communities by accomplishing the ten major objectives as stated by Brunckhorst (2001).

Buffer Zones

The definition of a buffer zone is an area of land surrounding a protected core in order to filter out potentially dangerous edge effects (Reid and Miller, 1989). Examples of edge effects include invading cattle, noise pollution, and human activity. The pressures around the canyon include pollution from local poultry farms, invading cattle, and housing developments. According to Shafer (1999), the need for a buffer zone arises from the fact that these edge effects do not stop directly at the park boundary.

In their initial design, UNESCO (1974) proposed a buffer zone for biosphere reserves. The mode core/buffer configuration (see Appendix D) would allow people to live in the buffer zone and keep recreation and tourism away from the core area. Presently, the model biosphere reserve design is uncertain. Countries have created their own versions of the ideal model to meet social and political needs. For example, the United States attempted to pass legislation in the 1990's to ban buffer zones due to the pressure by private landowners. Whether or not a country follows an optimal model depends on nature conservation laws and the society and politics of that country.

The requirement for these lands was to create a specific set of regulations regarding land use (UNESCO, 2007). The Statutory Framework for biosphere reserves (see Appendix E) serves as the basis for the governments to create any additional laws to protect biosphere reserves. In most countries it has not been necessary to create special legislation for biosphere reserves because existing nature protection laws are applicable.

Currently, there are an increasing number of countries creating specific legislation for biosphere reserves to eliminate any confusion with legal issues.

Shafer (1999) argues that in order to protect the core of a biosphere, community cooperation is essential in the areas designated as buffer zones. In many cases, community cooperation is hindered due to the resistance of private landowners. That resistance is in response to the common association of the term buffer zone with zoning and private land-use regulation. In the United States, thirty-four million landowners control 3.2 billion hectares of land. That fact alone causes the fear of the government controlling the use of private lands.

Other countries have opposing views regarding government control of private lands. The governments of those foreign countries recognize the importance of protecting ecosystems. In southern Australia, a private landowner must get permission to clear native vegetation. If the vegetation is considered ecologically valuable, then permission will be denied. Denmark follows a similar practice that requires permission to be granted in order to disturb ecologically important habitats and ecosystems.

In Aibonito and Barranquitas, the acquisition of lands for buffer zones is complicated due to the resistance of private land owners. In Aibonito, landowners have been hesitant to sell their lands to the Conservation Trust of Puerto Rico because they are afraid that the development of the San Cristóbal Canyon will bring too many tourists to the area. According to Shafer (1999), that problem can be resolved through direct acquisition, purchase of easements, tax incentives, state and county zoning and regulation, cluster development and persuasion. If the Conservation Trust can offer incentives to those resistant landowners, they may enhance cooperation with those

neighbors. That cooperation is needed by the Conservation Trust in order to achieve sustainability in the development of the San Cristóbal Canyon.

GEOGRAPHY AND CLIMATE

Puerto Rico is located between the Caribbean Sea and the North Atlantic Ocean, directly south east of Florida. The island is within the tropical climate zone, which extends from approximately 30˚ N to 30˚ S. The main island occupies 8740 square kilometers. The geographic location of the island in the tropic zone plays a significant role in determining and understanding the local climate and geology (Daly, Helmer and Quiñones, 2003).

The geography of Puerto Rico contributes significantly to the variety of different weather conditions that may be experienced at different places on the island. The biggest contributor to this is the mountain range La Cordillera Central. The range spreads from as far east as Aibonito, to the west in Maricao (Please refer to Appendix B, Map 5, for a map of Puerto Rico showing elevation). That mountain range serves as a divider for the island of Puerto Rico. To the north, there are far more moist conditions than to the south of the island, with significantly more rainfall. To the south, dryer, more arid conditions are usually present (Geography, 1998).

The highest point in Puerto Rico, Cerro La Puntita, is located on this mountain range between Villalba and Adjuntas. The San Cristóbal Canyon is located among that mountainous area, at the far eastern end of the range, in Aibonito and Barranquitas. Included in Appendix B, Map 4 is a map that shows examples of the dry and moist

regions in Puerto Rico. Appendix C, Table 2 and 3 are charts that show how rainfall varies throughout the year in both Barranquitas and Aibonito (Ewel and Whitmore, 1973).

During the winter months of November through April, the island often experiences cold fronts that travel through the United States and across the island from northwest to southeast, bringing several days of rain. Rainfall is also provided by typical thunderstorms on hot, humid days when the land is heated up more quickly during the day than the water (National Weather Service, 2003). Those storms occur all year round, but are more frequent during the rainy season.

Vulnerability to Landslides

The soil properties of the San Cristóbal Canyon are essential in order to evaluate the fitness of the land for interpretive trails. In a study by Weaver, Birdsey & Lugo (1987) of the soils in Puerto Rico, the densities of tropical soils are lower than those of drier climates. The lighter properties of the tropical soil, combined with the properties of the rocks in the reserve area, are not ideal in the climate of Puerto Rico. The properties of the soil along with the geographic properties of the rocks result in a greater risk of landslides (Geological Information, 2001).

GEOLOGY

In order for the reader to understand the geological issues of the San Cristóbal Canyon, a basic understanding of the geology of Puerto Rico and the surrounding areas of the canyon is required. The island is located on the Caribbean tectonic plate, which was once moving northward in contrast to the North American plate, which was sliding

southwards. As a result, the North American plate was pushed under the Caribbean plate. The force of that tectonic movement actually pushed up the islands of what are now Puerto Rico and the Dominican Republic (Geological Information, 2001).

As typical with many islands, Puerto Rico was formed from volcanic and plutonic activity. The oldest part of the island is in the center, with the rocks decreasing in age as one gets closer to the edges of the island. A diagram depicting the ages of the rocks in Puerto Rico may be found in Appendix C, Table 1. The lava and ash from the volcanic activity eventually formed sedimentary rocks. Those high folded, faulted, and eroded rocks now form the basis of the Cordillera Central. The Cordillera Central is an east-west chain of mountains that runs from Luquillo and Cayey on the east coast to above Rincon on the west coast (Refer to Appendix B, Map 5). The San Cristóbal Canyon project site is located in that area of Puerto Rico; where the jagged peaks and steep slopes make it prone to landslides (Yale University, 2007).

Although volcanic rocks dominate the geology of Puerto Rico, other types of rock can be found on the island. When the North American plate was being pushed underneath the Caribbean plate as described previously, material from the ocean floor was brought up on top of the Caribbean plate. According to geophysicist Declan De Paor of Worcester Polytechnic Institute, those rocks and sediments from the ocean floor, after a long period of time, metamorphosed into the amphibolites, gneiss, and serpintinite that are located in the southwestern part of the island today (See Glossary). In the San Cristóbal Canyon, the rocks are mainly plutonic igneous rocks and volcanic rocks that form the core of the island, as depicted in the rock diagram in Appendix D, Figure 1.

According to Professor De Paor, the most unique feature about the geology of Puerto Rico is the limestone deposits formed after volcanic activity ceased. Limestone was deposited in the shallow areas around the islands where the coral reefs are located today. As tectonic forces pushed up the island, this limestone was exposed to rainwater and began to dissolve. When the heavy rains stopped, the dissolved limestone precipitated out of the water to form a case rock that is resistant to both chemical and physical weathering. These rocks can be found along the northern coast of the island.

When planning and designing a biosphere reserve, it is important to understand and recognize geological features for safety reasons and recreational purposes. For example, if a trail is prone to physical weathering, proper security measures need to be implemented to avoid any possible danger to visitors and staff. In addition, the important geological features need to be properly indicated and easily visible.

TRAIL DESIGN

Creating a reserve with interpretive trails requires knowledge about how to design the trails. Basic strategies for trail design are well documented (Rathke and Baughman, 2007; Long and Todd-Bockarie, 1994; National Park Service [NPS], 2006; Hultsman and Hultsman, 2001). While the presentation of the design strategy is different, the actual process outlined in the various documents remains virtually the same. Rathke and Baughman break down the process of designing a nature trail into the following steps (2007):

1. Decide the trail's purpose
2. Inventory the property
3. Design the trail
4. Scout the trail corridor

5. Clear the tail
6. Construct the trail tread
7. Mark the trail

The first step requires determining for what the trail will be used. Whether the trail will be used for motor vehicles or pedestrian traffic will have a large effect on its ultimate design (Rathke and Baughman, 2007; Long and Todd-Bockarie, 1994; Hultsman and Hultsman, 2001).

Step two requires locating key features in the property that would be enjoyable for visitors as well as those areas that might lessen their experience. This step also incorporates the locating of regions within the property that may be fragile and should be avoided (Rathke and Baughman, 2007; Long and Todd-Bockarie, 1994).

Step three contains the bulk of the actual design process. In this step, the areas of interest that are found in the second step need to be physically connected. This is done by reviewing the areas between points of interest and determining the safest and most appropriate route. Rathke and Baughman (2007) suggest that trails should be designed in closed loops that start and end at the same point. This design prevents backtracking of trails. A short, straight, and level route should be used to access these trails (Rathke and Baughman, 2007; Long and Todd-Bockarie, 1994; Hultsman and Hultsman, 2001).

The grade of a trail is an important consideration during the design process. For a table of different trail grades, see Appendix C, Table 6. Rathke and Baughman (2007) suggest designing a trail in the following way: "one-third level, one-third uphill, and one-third downhill" (Rathke and Baughman, 2007; Long and Todd-Bockarie, 1994).

To allow easy passage through trails, as well as to prevent excessive overgrowth, hiking trails should be cleared (Rathke and Baughman, 2007; Long and Todd-Bockarie,

1994). Rathke and Baughman (2007) suggest an overhead clearance of eight feet and a width of four to six feet. See Appendix D, Figure 3, for a visual description of clearance.

Areas that come in contact with water need protection from erosion. Rathke and Baughman (2007) suggest that trails near water should be placed above the normal high water line and that there should be an area of vegetation, called a filter strip, between the trail and the water's edge. See Appendix C, Table 7, for filter strip guidelines. Long and Todd-Bockarie (1994) argue that trails should stay at least thirty-five feet from stream banks. Rathke and Baughman (2007) and others (Long and Todd-Bockarie, 1994) argue that stream crossings should be avoided wherever possible to prevent damage to the aquatic environment. When crossing a stream is necessary, it is better to have two trail loops with one stream crossing than to have two separate stream crossings (Rathke and Baughman, 2007).

Water drainage is largely affected by different soil types. Soil also has an effect on the likelihood of erosion. According to Rathke and Baughman (2007) and others (Hultsman and Hultsman, 2001), trails should be placed where the soil is adequately drained to prevent excessive water build up on traversed ground. A method to determine if soil is adequately drained is if the soil is one continuous color. If the soil has many spots of varying color, then it is likely that the drainage is poor and the ground is unsuitable for trail placement (Rathke and Baughman, 2007; Hultsman and Hultsman, 2001).

Rathke and Baughman (2007) argue that trails should avoid clay or silt as they have a high tendency to compact and erode, especially on an incline. Avoiding sand is also important as the large grain size makes the ground unstable. See Appendix C, Table

8, for more details on soil textures. If it is impossible to choose suitable ground, certain fixes such as the use of boardwalks or the embedding of gravel into the trail can help preserve the trail and extend its lifespan (Rathke and Baughman, 2007; Long and Todd-Bockarie, 1994).

Step four is simply scouting the proposed trail to find any problems before clearing begins. This includes searching for slopes that are too steep, areas with poor drainage, and other potential obstacles. Areas that show signs of previous landslides should be avoided, especially in earthquake prone regions, to lower the required amount of future trail maintenance. According to Rathke and Baughman (2007) and others (Hultsman and Hultsman, 2001), the trail should be aesthetically pleasing, enjoyable, and should disturb the natural environment as little as possible. For more information on recommended trail standards, see Appendix C, Table 11.

Step five requires clearing the trail. This step is simply removing and flattening anything within the proposed trail corridor. This leaves the trail ready for surfacing and construction (Rathke and Baughman, 2007; Long and Todd-Bockarie, 1994).

Step six requires constructing the actual trail tread (Rathke and Baughman, 2007). There are several different options for trail surfacing. Some types of trail surfaces include compacted natural ground, gravel, packed gravel, asphalt, concrete, and wood. For the purpose of an accessible trail, compacted ground and gravel would not be viable options due to the variability in the ground surface. Flatter, more permanent structures are needed for full access. Asphalt may appear foreign to the natural environment and should be avoided where possible. Compacted gravel is a good alternative that better fits with the natural environment without compromising accessibility. Raised wooden

structures can be used in areas where the ground is often saturated with water. The final choice should be practical and accomplish all requirements set for the trail system (U.S. Department of Transportation - Federal Highway Administration, n.d.; National Center on Accessibility, 2001).

The last step is to mark the trail. On smaller, natural trails, this can be important to ensure that people know where the trail is and how to exit the trail (Rathke and Baughman, 2007). Trail marking can also be used to provide valuable data such as information about local flora and fauna.

Accessibility

One concern of trail design is ensuring that as many people as possible can enjoy the trails. The topography of the San Cristóbal Canyon has made it inaccessible to the public; however, if we developed a sustainable plan, everyone could enjoy the reserve despite varying physical capabilities and personal interests. Development of accessible trails requires knowledge about the Americans with Disabilities Act (ADA) and methods to ensure that persons with disabilities can gain the same benefits from natural settings as people without disabilities. The ADA mainly deals with buildings, roads, sidewalks, and other highly controlled settings. Nature trails, however, are not highly controlled man made areas. Trails ideally move with the landscape, changing as little of the natural setting as possible. Because of this reasoning, the United States Forest Service has recognized the impossibility of creating all trails to accessible standards. They outline four "Conditions of Departure" from ADA rules as follows (Forest Service, 2006):

1. Where compliance would cause substantial harm to cultural, historic, religious, or significant natural features or characteristics.
2. Where compliance would substantially change the physical or recreation setting or the trail class, designed use, or managed use of a trail or trail segment or would not be consistent with the applicable land management plan.
3. Where compliance would require construction methods or materials that are prohibited by federal, state, or local law, other than state or local law whose sole purpose is to prohibit use by persons with disabilities.
4. Where compliance would be impractical due to terrain or prevailing construction practices.

The Forest Service Trail Accessibility Guidelines describe how to implement these rules to ensure compliance with ADA rules whenever possible while recognizing that full compliance with ADA rules would have a negative affect on the intent of the trails and the environment (Forest Service, 2006).

Even with the numerous obstacles associated with designing accessible trails, there are many examples of their successful use in national parks. The Minute Man National Historic Park in Massachusetts (National Park Service [NPS], 2002), Asan Bay Overlook at the War in the Pacific National Historical Park in Guam (NPS, 2001), and the Indiana Dunes National Lakeshore (NPS, 2000) are all award winning and highly accessible parks. Following the Forest Service Trail Accessibility Guidelines and keeping accessibility in mind during the initial design phase of a trail system can result in a trail layout that lends itself to high accessibility and overall user enjoyment.

Impact Indicators

Choosing the appropriate indicators is a task that is vital to developing standards (Kim, Lee and Shelby, 2003). Indicators identify what conditions will be measured and monitored, while standards indicate when these conditions are acceptable or not (Whittaker and Shelby, 1992). According to Stankey (1985), the criteria for those indicators should appear in management frameworks to erase any confusion and discrepancies that could arise when problems with a trail are brought to attention. Some researchers have suggested specific indicators to consider during the planning process (Stankey, 1985, Kuss, 1990), while others (Whittaker and Shelby, 1992) suggest guidelines for selecting indicators. The latter researchers suggest that indicators should be specific, measurable, and able to adapt to change, in line with management policies, and have significance to faculty and visitors of the site.

Written survey methods are used by managers and researchers to identify important impact indicators. However, in a study by Kim (2003), this method was found to have some drawbacks due to the burden of providing a detailed response from those asked to take a written survey and the possibility of some important indicators being omitted from the list. The validity of the questions being asked may also be called into question; resulting in misinterpretation of the question. In consequence, the results of the written survey method may be inaccurate.

A possible solution to the disadvantages of this survey method, as posed by Kim (2003), is to use photos in the indicator selection process. Instead of having the respondent to the survey imagine the conditions of the trail, he or she is able to visualize the trail or trails in question. However, it is impossible for photos to capture the non-

visual impact indicators such as odors and sounds. A study performed by Kim on 661 subjects within the Mudeung-Mountain Provincial Park in Kwang-ju, Korea found that the photo survey methods can be a useful tool for selecting impact indicators. A different study conducted by Kim and Shelby (2006) found that the written survey method to be a heavy burden on the park visitors due to repetitive questions in the survey; causing the process to be long and tedious. There are no generally accepted solutions to that issue; however, Kim (2003) argues that the photo survey method can reduce the burden that appears to characteristic of the written survey method.

In a study of the Mount Everest National Park in Nepal by Nepal and Nepal (2004), a Geographic Information System (GIS) was used to identify patterns of trail degradations. In addition, that study used a four-class rating system for trail conditions. GIS was used to digitize topographical, water drainage, and land use information to map out current trail conditions based upon this rating system. The Geographical Information System is a collection of computer hardware, software, and geographic data used for managing and analyzing geographic information. GIS is a powerful problem-solving tool used widely for many purposes such as creating databases, maps, and models (Your Internet Guide to GIS, 2007).

The information in this literature review will allow us to make justifiable recommendations. Without adequate background information, scientific conclusions could not be made about the results.

CHAPTER THREE: METHODOLOGY

PROVIDING RECOMMENDATIONS FOR TRAIL SAFETY AND ACCESSIBILITY

In order to provide recommendations for trail safety and accessibility, our group acquired information to make recommendations so that the Conservation Trust can improve the safety and accessibility of the four proposed trails in the San Cristóbal Canyon protected area.

Field Survey

Our group performed an extensive field survey of each of the proposed trails in order to give the Conservation Trust exact coordinates for each of our recommended safety features. We hiked four proposed trails to determine whether or not they could be developed in the near future. We considered the possibility of each trail being fully accessible. We hiked the proposed trails with a GPS to determine where the Trust needs to put safety features. Finally, we obtained all the coordinates along the trails. With those coordinates, we developed a map, using Google Earth, which the Conservation Trust can use to develop the proposed trails.

The materials used for construction of the trail greatly affect the hiking experience as well as determine the level of trail accessibility. To select proper materials for construction of the trails we researched options that were recommended by various professionals. We researched specific aspects of possible trail surfaces such as cost of installation, maintenance, and aesthetic value. The trail surfaces that we researched were also chosen based upon their levels of accessibility.

Geology and Geography

In order to make recommendations to ensure the safety of visitors on the proposed hiking trails, our group researched the geology and geography of the canyon. We learned about the geology of the canyon through an interview with geophysicist Declan De Paor, a professor at Worcester Polytechnic Institute. Additional information about the geology of the canyon was obtained from the United States Geological Service website.

Visits to Other Conservation Trust Sites

In order to see other examples of safe, accessible trails, our group visited other sites developed by the Trust to see how those trails are designed. We visited Hacienda Buena Vista in Ponce, El Faro in Fajardo, and Hacienda la Esperanza in Manatí. As we hiked the trails at each site, we made note of the safety features that were used and the reason that they were needed. Those visits helped us see what safety options were available and consider which ones could be used at certain points along the proposed trails of the canyon.

PROVIDING INFORMATION FOR THE CREATION OF AN INTERACTIVE TREE EXHIBIT

In order to provide the information to create an informational native tree exhibit, we generated a list of native trees and shrubs by collaborating with our liaison in the Conservation Trust, Juan Rodríguez. We found examples of those trees along the proposed trails, took pictures of them, and recorded their coordinates using our GPS device. After we compiled the list, we used books describing native trees of Puerto Rico

to create short, interesting descriptions about each one of them in both English and Spanish.

Visits to Other Conservation Trust Sites

We visited Hacienda Buena Vista in Ponce, El Faro in Fajardo, and Hacienda la Esperanza in Manatí so that we could examine other successful exhibits that the Conservation Trust provides to its visitors. It was important to make our exhibit interactive because the exhibits at the other Conservation Trust sites encourage visitor interaction.

DETERMINING THE IMPACT OF ESTABLISHING THE CANYON AS A BIOSPHERE RESEREVE

We researched the framework of a biosphere reserve because it is a program that coincides with the goal of our project of combining conservation with sustainable land use. We studied the objectives of biosphere reserves on the United Nations website and in academic journals so that we could see how the objectives could be applied to the canyon.

In order to fully understand the management of biosphere reserves, we studied examples of previously established biosphere reserves throughout the world. In order to determine if the San Cristóbal Canyon could be established as a biosphere reserve, we studied Article Four of The Statutory Framework of the World Network of Biosphere Reserves (UNESCO, 2007), which describes the seven criteria that an area should fulfill in order to be considered for establishment as a biosphere reserve.

Our group also investigated the process for the San Cristóbal Canyon protected area to become designated as a biosphere reserve, because the Conservation Trust has not designated any of their other sites as a biosphere reserve. Additionally, we investigated the process of participating in the World Network of Biosphere Reserves. We researched the information for the process of application to be designated as a biosphere reserve and participation in the world network in Articles Five and Seven in the Statutory Framework of Biosphere Reserves (2006).

Promoting Community Cooperation

One of the issues that our group discovered concerning sustainable development was when conservation efforts conflict with the interests of others. We researched those issues regarding sustainable development in scholarly articles because Juan Rodríguez informed our group of currently pending lawsuits against private developers who are developing areas in close proximity to the Trust's lands. We researched that issue because development of those properties jeopardizes community cooperation and presents potential harm to the flora and fauna that the Trust desires to conserve. Without community cooperation, people are not involved in the conservation of the core area. That will jeopardize the success of a biosphere reserve.

Another problem that the Conservation Trust faces is the pollution of the Aibonito River by local poultry farms. In order to encourage cooperation with those neighbors, our group researched alternative waste disposal methods for the poultry industry. We investigated two methods: Anaerobic and aerobic lagoons and composting. Both of those methods were investigated for environmental advantage and economic feasibility so that

the farmers will be encouraged to invest in more environmentally-friendly practices instead of continuing to dump their waste into the Aibonito River.

History and Culture of the Canyon

The goal of the Conservation Trust of Puerto Rico is to connect the history and culture of the San Cristóbal Canyon and its surrounding areas to its conservation efforts. Since there is little documentation about the history and culture of the canyon, our group interviewed local people who have done primary research on this subject.

Influence of Tobacco, Coffee and Sugar Cane Industries

In order to gather information about the history and culture of the San Cristóbal Canyon, we interviewed Carlos Dominguez, a historian for the United States National Forest Service. We interviewed him because he is one of the only experts on that subject. Mr. Dominguez was able to give our group information about the impacts of the tobacco, coffee and sugar cane industries on the vegetation in the area of the canyon in addition to their impacts on the economics of Aibonito and Barranquitas. We used this information in order to connect the cultural history of the area to the conservation efforts of the Fideicomiso. Finally, we visited the tobacco museum in Caguas to gain more information about the tobacco industry in Puerto Rico.

CHAPTER FOUR: RESULTS AND ANALYSIS

SUSTAINABLE DEVELOPMENT OF THE SAN CRISTÓBAL CANYON

Proposed San Cristóbal Canyon Biosphere Reserve

In order to be designated as a biosphere reserve, the San Cristóbal Canyon protected area should match the general criteria as set forth by the United Nations Statutory Framework of the World Network of Biosphere Reserves. The canyon meets the first and second criteria in Article Four because it serves as the habitat of many characteristic ecosystems that are representative of the mountainous region of Puerto Rico. In addition, it is also the habitat of rare and endangered species of native and exotic flora and fauna. The fact that the San Cristóbal Canyon is the only canyon on the island proves that the habitat created by that area cannot exist anywhere else in Puerto Rico.

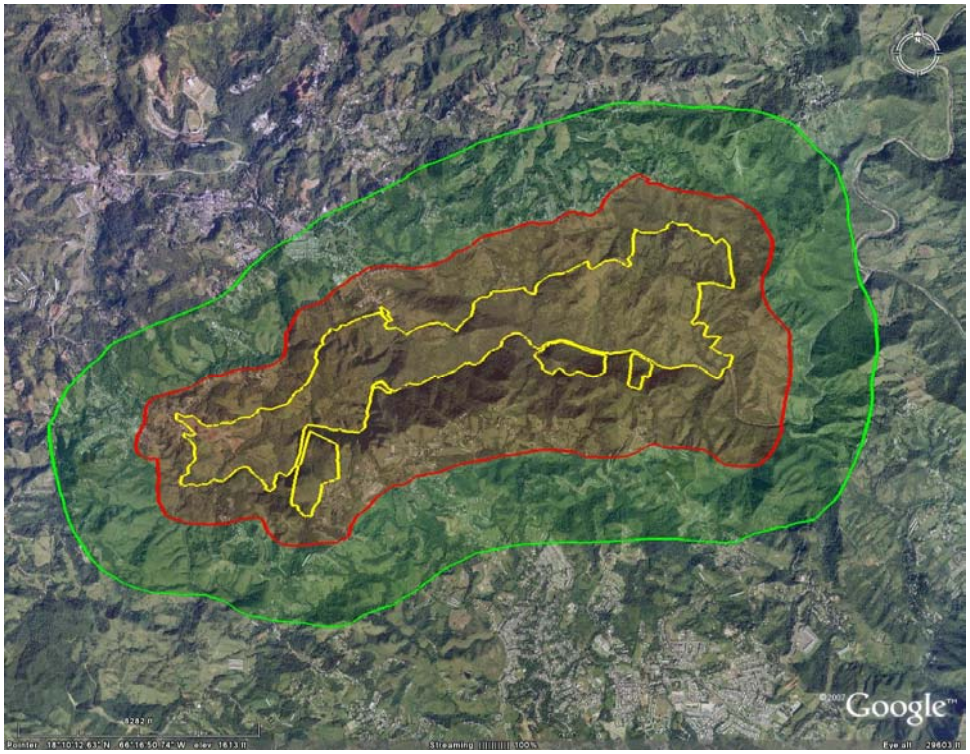
The canyon fulfills the third criterion of the framework because it provides central Puerto Rico with a unique opportunity to explore approaches to achieving sustainable development. The fourth criterion is questionable because the size of the potential buffer and transition zones depends on the negotiation efforts on behalf of the Conservation Trust. The fifth criterion depends, once again, on the success of community cooperation facilitated by the Conservation Trust. The three defined zone layers of the proposed biosphere reserve would be designated based upon how the Trust can best protect the designated core area. The last two criteria of the Statutory Framework can be fulfilled if the Conservation Trust creates a management framework for an established biosphere

reserve that includes the involvement of local authorities, local communities, and private businesses.

The Trust currently owns over 1,000 acres of land in the area of the canyon, which can be legally designated as the protected core area, as shown in yellow on the map below of our proposed biosphere reserve. The Trust bought the property in order to protect it against former harmful activities that once damaged the canyon. Currently, harmful edge effects are a problem for the protected area. An example of these edge effects are the cattle from neighboring farms that are invading the land currently owned by the Trust, as shown in the picture below.

This picture was taken on the San Cristobal Canyon Protected Area property

This picture shows the need for a buffer zone in order to protect against edge effects, such as invading cattle. According to Juan Rodríguez, poultry farmers surrounding the canyon properties are dumping poultry waste into the Aibonito River, which runs directly through the canyon. That waste dumping is an additional example of a harmful edge effect that is currently posing a problem for conservation efforts. With those two facts, we created the buffer zone, in red below, to include local poultry and cattle farms, as well as nearby residential housing. The residential housing was included in the buffer zone because it would help fulfill criteria six and seven in the Article Four of the Statutory Framework.



As mentioned before, local poultry farmers who would be included in the proposed buffer zone are not following practices that would be permissible for that area according to the framework as set forth by the United Nations MAB Program. Dumping

poultry waste into the Aibonito River directly harms the proposed core area. More environmentally friendly waste removal methods are needed for those farms in order to protect the proposed San Cristóbal Canyon Biosphere Reserve. We gathered information about composting, and the results are shown below.

Composting for Poultry Farms

Composting of Dead Poultry

Table 1. Composition of dead poultry compost*

Analysis	Amount
Moisture, percent	46.10 +/- 2.19
Nitrogen, percent	2.20 +/- 0.19
Phosphorus (P2O5), percent	3.27 +/- 0.23
Potash (K2O), percent	2.39 +/- 0.13
Calcium, percent	1.33 +/- 0.15
Magnesium, percent	0.82 +/- 0.10
Sulfur, percent	0.40 +/- 0.02
Manganese, parts per million	122.00 +/- 18.00
Zinc, parts per million	245.00 +/- 32.00
Copper, parts per million	197.00 +/- 28.00

Table 2: Typical recipe for composting dead poultry

Ingredient	Parts by Weight
Caked litter or manure	1.5 to 3
Dead birds	1
Straw*	0.1
Water (added sparingly)**	0 to 0.5

* University of Maryland, 1991.

* Other carbon sources may also be used such as peanut hulls, sawdust, or shredded cellulose paper. However, straw has been shown to be an excellent material for this purpose.

** The requirement for water will vary depending on moisture content of straw, litter, and other factors. Too little moisture or too much moisture may adversely affect composting. The mixture should be damp, in the range of 40-60 percent moisture. If moisture is required, it should be added to each element during the layering process while building the compost stack.

Chemical Composition of Cow Manure

Organic fertilizers	Organic matter (%)	N (%)	P (%)	K (%)
Compost	11.7	0.65	0.3	0. 5
Fish flour	86.50	10.25	2.22	1.17
Cow manure	73.77	2.95	1.32	1.27
Red crab flour	70.52	6.27	1.25	1.10
Soil	0.4	0.04	0.8	7.72

Courtesy of: Murillo-Amador et al. (2006)

A good fertilizer needs to be high in nitrogen content as well as other nutrients. As one can see from these tables, the nitrogen content in both the cow manure and chicken compost is comparable, within 1 percent. The nutrient content of the chicken compost is higher than that of cow manure by 2 percent. These findings indicate that chicken compost has similar, if not better, fertilizer qualities than cow manure. This finding will be attractive to poultry farmers because it is a potential new source of income, and they could also use the fertilizer produced from a composting unit on their own farms. The Conservation Trust should present this information to the farmers in order to facilitate community cooperation if the Trust pursues establishing the canyon as a biosphere reserve.

Type of Composter Needed

Type of Compost Needed	Weight of Dead Poultry (lbs per day)
Minicomposter	<30
Two Stage System	30<weight<300

Courtesy of: Brodie and Carr (n.d.)

From this chart, one can see that the type of compost machine needed for a farm depends on the weight of poultry and waste that needs to be composted on a daily basis. If the poultry farm processes thirty pounds or less, then a minicomposter is sufficient to meet those needs. If a farm needs to process more than thirty pounds up until three hundred pounds, then a two stage composter is needed.

INTERACTIVE TREE EXHIBIT

Our group provided the Conservation Trust information about fourteen native trees and shrubs so that an interactive exhibit can be created in both English and Spanish. The intended use of the gathered information will be to present it on a plaque which will be posted near the tree and shrubs of interest along the proposed trails. The picture shown below the description of each tree and shrub are actual specimens that will be pointed out along the trail.

Cupey - Clusia rosea

English:

- Origin: E. Australia
- Common Name: Monkey apple
- Identification: Tree 6-15 m high. Shining, oval leaves, to around 120 mm, very aromatic when crushed. Flowers are whitish during Oct-Jan. Fruit is a large conspicuous berry pink-mauve or white in bunches.
- Forest, damp shrub lands. Capable of invading lowland forests including secondary forests dominated by kanuka, manuka or podocarps. Locally common. Very common hedging plant in gardens.

Spanish:

- Origen: E. Australia
- Identificación: Árbol 6-15 metros de alto. Brillando, hojas ovales, a alrededor 120 milímetros, muy de aromático cuando está machacado. Florece Octubre-Enero blanquecino. La fruta es una baya visible grande rosada-de color de malva o blanco en manojos.
- Bosque, shrublands húmedos. Capaz de invadir bosques de la tierra baja incluyendo bosques secundarios dominó por kanuka, manuka o los podocarps. Localmente campo común. Planta que cerca muy común en jardines

Picture of Leaf:

Actual Specimen along Trail:

Camasey - Miconia prasina

English:

- The camasey is always a green tree that reaches 25 feet in height and 4 inches in diameter.
- The bark is straight, gray and thin. The interior bark is chestnut –yellow and bitter.
- The little branches are a mulatto color and have fine rings in the nodes and when new ones form they are in the form of a star.

Spanish:

- El camasey es siempre un árbol verde que alcanza 25 pies en altura y 4 pulgadas de diámetro
- La corteza es recta, gris y fina. La corteza interior es castaña - amarilla y amarga
- Los pequeños ramas son un color del mulato y tienen anillos finos en los nodos y cuando los nuevos forman están en la forma de una estrella

Hoja Menuda - Eugenia rhombea

English:

- Common Name: Red Stopper
- Habitat: South Florida and Puerto Rico and any sunny locations
- Very hard, heavy wood, related to Guava and Eucalyptus
- From the lower part of the tree forming a multiple trunked tree
- Leaves are small and nearly diamond-shaped

Spanish:

- Nombre Común: Red Stopper
- Habitat: La Florida y Puerto Rico del sur y cualquieres localizaciones asoleadas
- Muy difícilmente, madera pesada, relacionada con la guayaba y el eucalipto
- Hay troncos multibles
- Las hojas son pequeñas y casi de forma diamantada

Close-up Picture of Tree:

Actual Specimen along Trail:

Tintillo - Randia aculeate

English

- Common Name: White Indigo Berry
- Shrub or small tree from 2 to 6 meters in height
- It is spiny and may have one to several stems
- White
- Indigo berry has smooth to slightly fissured gray bark, opposite, often horizontal, branches, a thin crown, and rough appearance
- In Puerto Rico, the species grows in dry and moist forests, more commonly over limestone rocks, but also over igneous rocks and ultramafics (serpentine)

Spanish

- Nombre Común: White Indigo Berry
- Arbusto o árbol pequeño a partir del 2 a 6 metros en altura
- Es espinoso y puede tener uno a vástagos multiples
- Blanco
- En Puerto Rico, la especie crece en seco y los bosques húmedos, piedra caliza del excedente oscilan más comunmente, pero también las rocas ígneas del excedente

Picture of Leaf:

Actual Specimen along Trail:

Guasábara - Eugenia domingensis

English

- Grows in mountainous forests
- Gray to whitish bark
- White flowers
- Dark purple berries that are round or elliptical and are rumored to be edible
- Grows 30-60 feet in height and 8-18 inches in diameter in the trunk
- Interior bark is a chestnut color

Spanish

- Crece en bosques montañosos
- Gris a la corteza blanquecina
- Flores blancas
- Bayas púrpuras oscuras que son redondas o elípticas y se rumorean para ser comestibles
- La corteza interior es un color de la castaña

Puerto Rican Royal Palm - Roystonea borinquena

English

- Grows 10-30 meters tall
- Widely used for decorative purposes
- Considered by many to be the most beautiful palm in the world
- Intolerant of cold weather: they will show cold damage at 31°F and are killed at 25°F
- Played an important role in the tobacco history of Puerto Rico

Spanish

- Crece 10-30 metros de alto
- Utilizado extensamente para los propósitos decorativos
- Considerado por muchos para ser la palma más hermosa del mundo
- Intolerante del tiempo frío: demostrarán daño frío en 31°F y se matan en 25°F
- Desempeñó un papel importante en la historia del tabaco de Puerto Rico

Maga - Thespesia grandiflora

English

- Native tree to Puerto Rico
- Grown for timber and an ornamental tree
- Its flower is the official national flower of Puerto Rico
- Grows up to 15 meters tall
- Closely related to a hibiscus, but the maga is a tree

Spanish

- Un árbol nativo a Puerto Rico
- Crecido para la madera y un árbol ornamental
- Su flor es la flor nacional oficial de Puerto Rico
- Crece hasta 15 metros de alto
- Se relaciona de cerca con un hibisco, pero el maga un árbol

Picture of Flower and Leaf:

Actual Specimen along Trail:

Malagueta (Bay Rum Tree) - Pimenta raemosa

English

- Very tall - can grow up to 80 feet in height
- As the tree matures, the outer layer of bark peels off leaving the trunk smooth and shiny and with a blend of brown and tan colors
- Leaves are 6 inches long and two inches wide and are shiny and blue-green in color
- Leaves are very aromatic

Spanish

- Muy alto-puede crecer hasta 80 pies en altura
- Mientras que el árbol se madura, la capa externa de la corteza pela de dejar el tronco liso y brillante y con una mezcla del marrón y de los colores del tan
- Las hojas tienen 6 pulgadas de largo y dos pulgadas de ancho y son brillantes y azulverdes en color
- Las hojas son muy aromáticas

Picture of Leaf:

Actual Specimen along Trail:

Palo de Jazmin - Styrax portoricensis

English

- Native species to Puerto Rico
- Listed as an endangered specie
- Evergreen tree that reaches up to 20 meters in height
- Leaves are shiny dark green above, pale green below, hairless
- Fruits are about 1 centimeter in diameter, densely covered with scales

Spanish

- Especie nativa a Puerto Rico
- Mencionado como specie puesto en peligro
- Árbol imperecedero que alcanza hasta 20 metros en altura
- Las hojas son verde antedicho, pálido verde oscuro brillante abajo, sin pelo
- Las frutas son cerca de 1 centímetro de diámetro, cubierto denso con las escalas

Picture of Leaf:

Actual Specimen along Trail:

Ausubo - Manilkara Bidentata

English

- Native to Puerto Rico
- Fruits are edible and eaten fresh
- More common use of the tree is as a commercial timber
- Wood is very hard, strong, fine textured, and heavy
- Flowering and fruiting can occur year-round
- In Puerto Rico, ausubo is native to the moist coastal and limestone forests, and to lower mountain forests.

Spanish

- Natural a Puerto Rico
- Las frutas están frescas comestible y comido
- Un uso más común del árbol está como madera commercial
- La madera es muy dura, fuerte, tecturada muy bien, y pesado
- Floreciente y el dar fruto puede ocurrir a lo largo de todo el año
- En Puerto Rico, el ausubo es nativo a los bosques costeros y de la piedra caliza húmedos, y a bosques más bajos de la montaña

Picture of the leaves:

Actual specimen on trail:

Cojoba - Phitecelobium arboretum

English

- Small to medium size tree, occasionally grows over 10 meters tall
- Flowers are small whitish balls of stamen at the leaf axils. Fruits are scarlet, twisted pods.
- Trunk often leaning and branched near the ground

Spanish

- El árbol pequeño-medio del tamaño, crece de vez en cuando sobre 10 metros de alto
- Las flores son bolas blanquecinas pequeñas del estambre en los axils de la hoja. Las frutas son escarlata, vainas torcidas
- Tronco que se inclina y ramificado a menudo cerca de la tierra

Picture of Leaves:

Actual Tree along Trail:

Eucalyptus - Eucalyptus robusta

English

- More than 700 species of eucalyptus, mostly native to Australia
- Nearly all eucalypts are evergreen but some tropical species lose their leaves at the end of the dry season
- Flowers have numerous fluffy stamens, which may be white
- The appearance of eucalypt bark will vary with the age of the plant, the manner of bark shed, the length of the bark fibers, the degree of furrowing, the thickness, the hardness and the color: cream, yellow, pink or red

Spanish

- Más de 700 especies del eucalipto, sobre todo nativas a Australia
- Casi todos los eucaliptos son imperecederos pero un ciertas especies tropicales pierden sus hojas en el final de la estación seca
- Las flores tienen estambres mullidos numerosos, que pueden ser blancos
- El aspecto de la corteza del eucalipto variará con la edad de la planta, la manera de la vertiente de la corteza, la longitud de los fibres de la corteza, el grado de surco, el grueso, la dureza y la crema del color, el amarillo, el color de rosa o el rojo

Picture of Leaves:

Actual Specimen along Trail:

Maya

English

- Large pineapple-like plant with dark green sword shaped leaves
- Classified as a perennial because it has a woody core at its base and fibrous leaves
- Plants grow 1-2 meters in height and 2-3 meters wide in 2-3 years
- Historically used as a hedge or living fence to protect fields and homesteads
- Its fruit is a yellow elliptical berry

Spanish

- Grande piña-como la planta con la espada verde oscuro formó las hojas
- Clasificado como perennial porque tiene una base arbolada en su base y hojas fibrosas
- Las plantas crecen 1-2 metros en altura y 2-3 metros de ancho en 2-3 años
- Utilizado históricamente como un cercar o cerca viva proteger campos y granjas
- Su fruta es una baya elíptica amarilla

Guava

English

- Low evergreen or shrub 6 to 25 feet high
- The leaves are oblong or oval and blunt, 3 to 6 inches long, and feather-veined
- Guava is used to produce jams, jellies, and juices commercially
- Guava may be eaten raw or cooked. Guavas are an excellent source of vitamin C and also contain iron calcium, and phosphorus
- The flowers are an inch or more across, bell-shaped and splitting irregularly, the four to six petals are white
- The fruit is yellow and lemon-shaped. Some fruits may be brownish yellow. The inside of the fruit has pink or cream-colored pulp and small hard seeds

Spanish

- Árbol de hoja perenne o arbusto bajo 6 a 25 pies de alto
- Las hojas tienen pulgadas oblongas u ovales y blunt, 3 a 6 largas, y pluma-vetearon
- La guayaba se utiliza para producir los atascos, los jellys, y los jugos comercialmente
- La guayaba puede ser cruda comido o cocinado. Las guayabas son una fuente excelente de la vitamina C y también contienen el calcio del hierro, y el fósforo
- Las flores son una pulgada o más a través, acampanadas y que parten irregular, los cuatro a seis pétalos son blancos
- La fruta es amarillo y limo'n-formado. Algunas frutas pueden ser amarillo pardusco. El interior de la fruta tiene color de rosa o semillas duras crema-coloreadas del pulpa y pequeñas

Picture of Leaf:

Actual Specimen along Trail:

Those native trees, as described above, have been translated from Spanish sources for the purposes of providing an English version of the interactive tree exhibit. The facts found in this section are basic, interesting facts, suited for a potential visitor to the canyon. This list was generated from collaboration with Juan Rodríguez, who indicated these trees as we hiked the proposed trails.

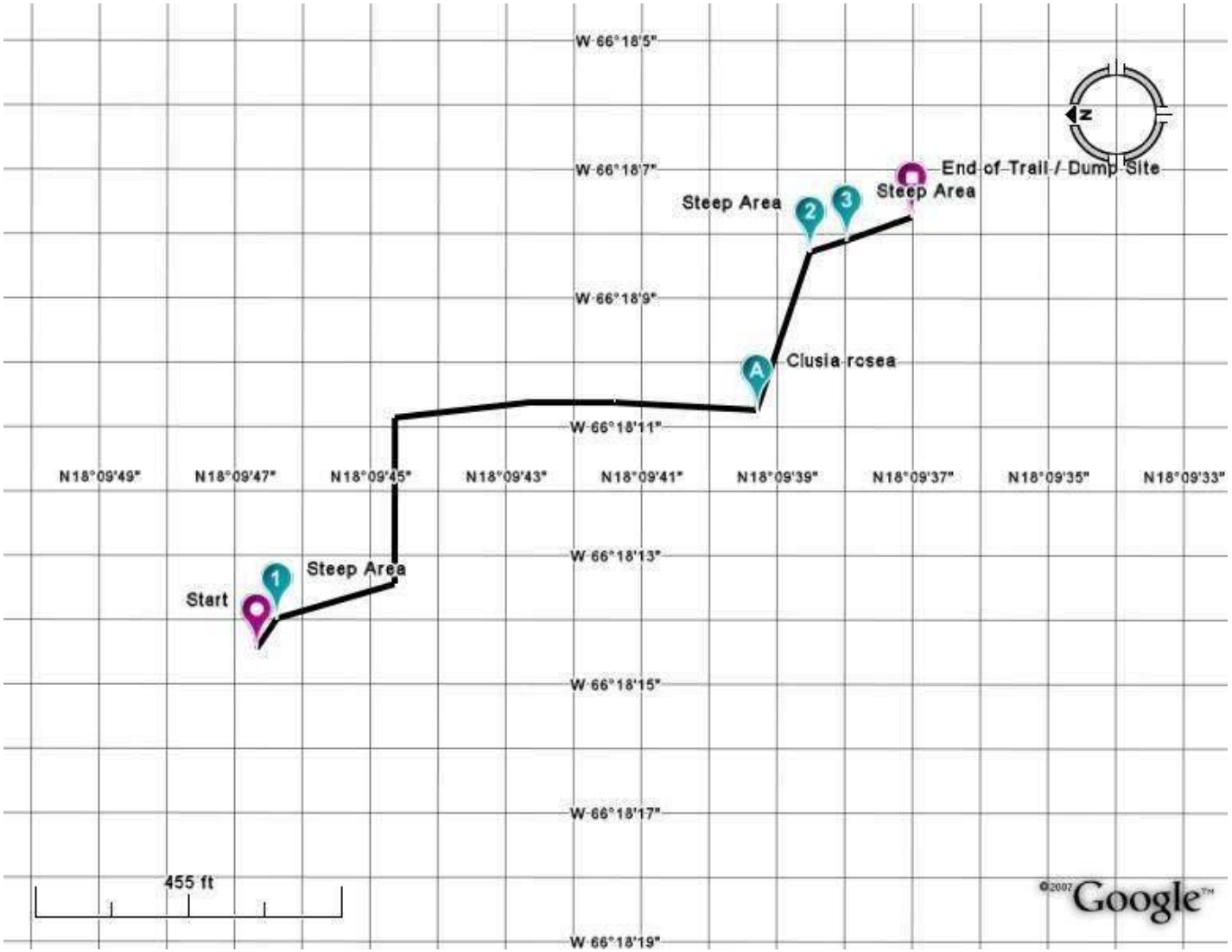
TRAIL DESIGN

The data gathered for the design of the proposed trails was primarily in the form of GPS coordinates and photographs. The coordinates were used in the Google Earth program to create the maps below. The recommendations for trail surface materials were determined by a cost analysis for installation and maintenance.

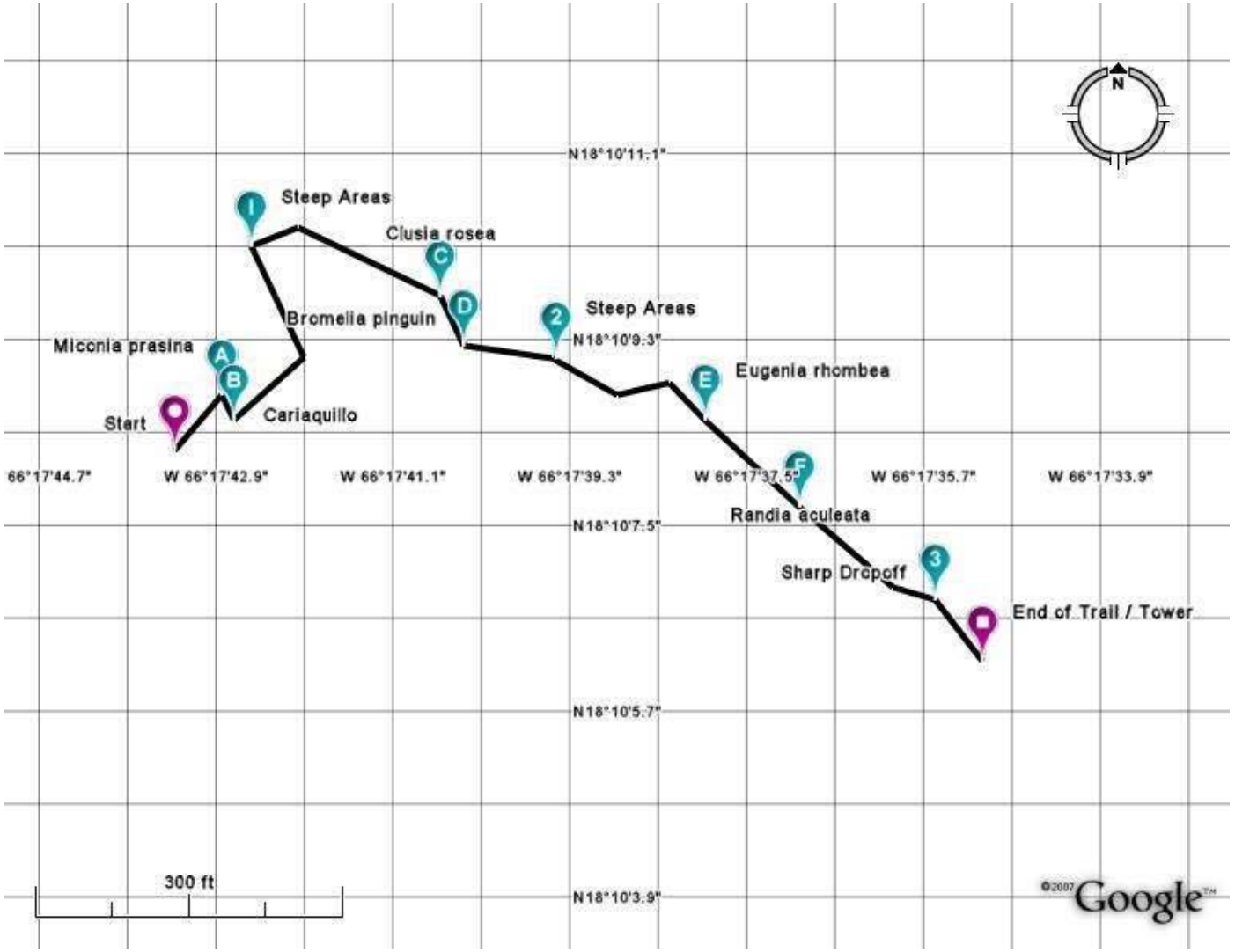
Maps

Following are maps of the four trails proposed for development. Steep areas that may need modification are indicated on the maps with numbers. Also included are the locations of prime examples of flora, indicated by letters, for the purpose of marking with plaques. The GPS data for trail one may be unreliable due to heavy cloud cover and rain interfering with the GPS signal during data collection. As a result, the map for trail one may be inaccurate. Data for the remaining trails were collected with little cloud cover, providing an accuracy of within fifteen feet.

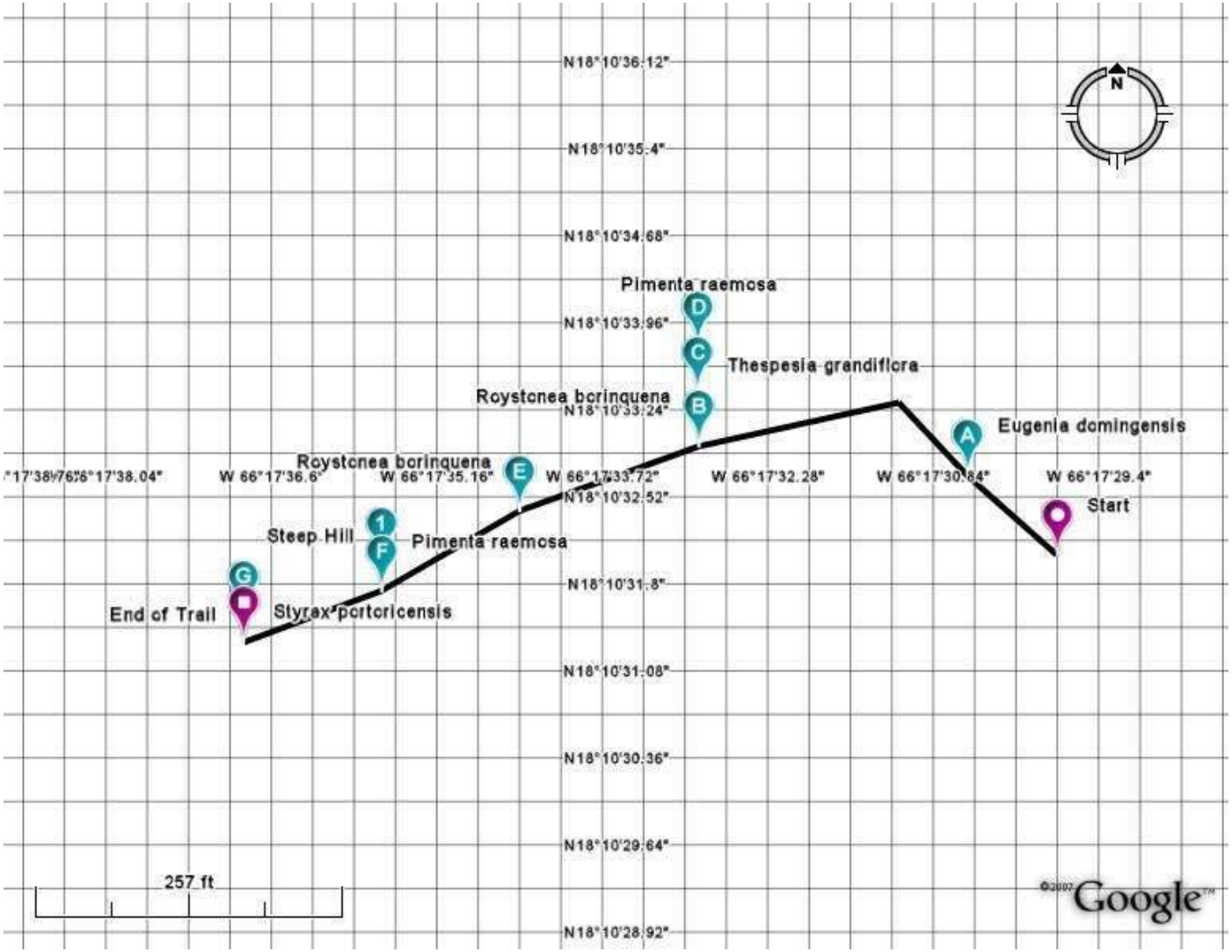
Trail One:


W 66°18'5"
W 66°18'7"
W 66°18'9"
W 66°18'11"
W 66°18'13"
W 66°18'15"
W 66°18'17"
W 66°18'19"
N18°09'49"
N18°09'47"
N18°09'45"
N18°09'43"
N18°09'41"
N18°09'39"
N18°09'37"
N18°09'35"
N18°09'33"
Start
Steep Area
Steep Area
Steep Area
End of Trail / Dump Site
Clusia rosea
1
2
3
A
455 ft
©2007 Google

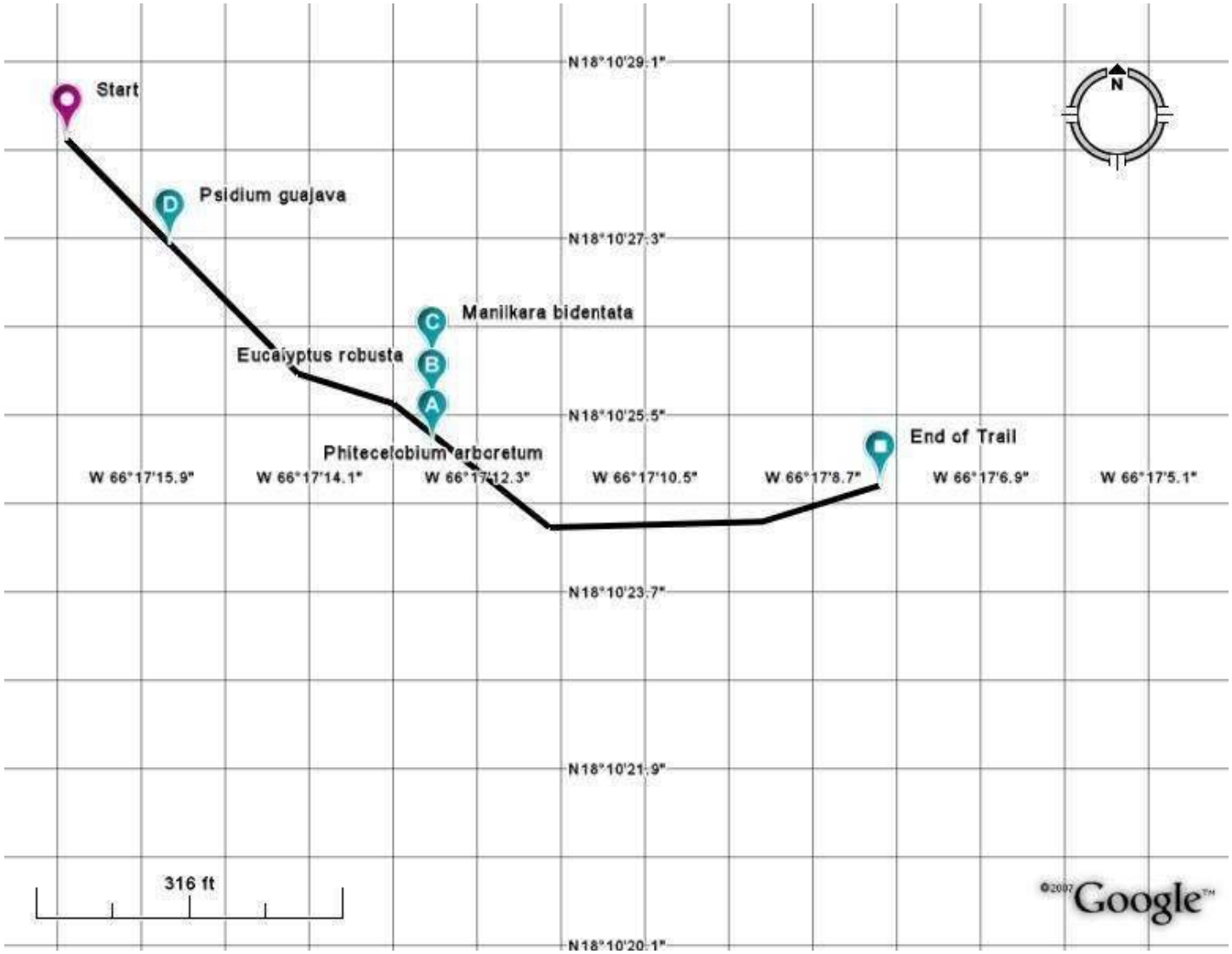
Trail Two:


N
N18°10'11.1"
1
Steep Areas
Clusia rosea
C
D
Bromelia pinguin
2
Steep Areas
N18°10'9.3"
Miconia prasina
A
B
Start
Cariaquillo
E
Eugenia rhombea
F
Randia aculeata
3
Sharp Dropoff
End of Trail / Tower
66°17'44.7"
W 66°17'42.9"
W 66°17'41.1"
W 66°17'39.3"
W 66°17'37.5"
W 66°17'35.7"
W 66°17'33.9"
N18°10'7.5"
N18°10'5.7"
N18°10'3.9"
300 ft
©2007 Google

Trail Three:


N18°10'36.12"
N18°10'35.4"
N18°10'34.68"
N18°10'33.96"
N18°10'33.24"
N18°10'32.52"
N18°10'31.8"
N18°10'31.08"
N18°10'30.36"
N18°10'29.64"
N18°10'28.92"
N
Pimenta raemosa
D
C
Thespesia grandiflora
Roystonea borinquena
B
Eugenia domingensis
A
Roystonea borinquena
E
W 66°17'36.6"
W 66°17'35.16"
W 66°17'33.72"
W 66°17'32.28"
W 66°17'30.84"
W 66°17'29.4"
Start
1
Steep Hill
F
Pimenta raemosa
G
End of Trail
Styrax portoricensis
257 ft
©2007 Google

Trail four:


Start
Psidium guajava
Eucalyptus robusta
Manilkara bidentata
Phitecelobium arboretum
End of Trail
N18°10'29.1"
N18°10'27.3"
N18°10'25.5"
N18°10'23.7"
N18°10'21.9"
N18°10'20.1"
W 66°17'15.9"
W 66°17'14.1"
W 66°17'12.3"
W 66°17'10.5"
W 66°17'8.7"
W 66°17'6.9"
W 66°17'5.1"
N
316 ft
©2007 Google

COST COMPARISON OF TRAIL SURFACE MATERIALS

The table below was acquired from the Northwestern Indiana Regional Planning Commission. It was included in a document by the Ped & Pedal organization, which provides guidelines for pedestrian and bicycle transportation. The table can be used as a method to estimate the cost differences between asphalt surfacing and concrete. Both substances require the same granular sub base for the entirety of the trail, and therefore the high cost of concrete, more then double, is obvious (Northwestern Indiana Regional Planning Commission [NIRPC], 2005).

Construction cost per unit for Trail Elements

Trail Element	Unit	Price per unit (year 2000 Construction)
Clearing and grubbing	Acre	$2,000.00
Grading for hard-surfaced trails	Mile	$3,000.00
Grading for natural-surfaced trails	Mile	$2,500.00
Granular surfacing	Sq. ft.	$.40
Granular subbase	Sq. ft.	$.40
Asphalt surfacing	Sq. ft.	$1.00
Concrete	Sq. ft.	$2.25
Wood chips	Sq. ft.	$.40
Seeding/mulching	Acre	$1,600.00
Other costs (drainage, signage, and support services)	Mile	10% of trail cost
Planning	Mile	2% of trail cost
Preliminary design	Mile	2% of trail cost
Construction documents	Mile	5% of trail cost
Construction services	Mile	5% of trail cost
Administration	Mile	5% of trail cost

The cost difference can also be clearly seen in the report entitled Estimates of Cost & Return. In this report the cost of a twelve-foot-wide, multi-purpose, asphalt paved trail is $300,000 per mile. The cost for the same trail to be paved with concrete is

approximately $500,000. Additionally, the costs for engineering design and development are estimated in this report to be an additional 10 to 15 percent of the cost of the entire trail. For comparison, this report also estimates the cost of a six foot wide, bare earth hiking trail, to be $40,000 per mile (NIRPC, 2005).

Both concrete and asphalt have similar maintenance life spans when properly prepared with a base gravel layer underneath the pavement. According to Peterson of the Colorado Asphalt Pavement Association (Peterson, 2007), the best method to determine which type of pavement to be used is to consider the opinion of those who will be using the trail. McGee (n.d.) states that the trails in El Yunque, the Carribbean National Forest, that are made of rock and concrete are very slippery in places where they run along the rivers or during the rain. Furthermore the concrete paved trails Mina Falls and Big Three Trails are considered to by high impact, with numerous long, winding concrete staircases (Legends of Puerto Rico, 2007).

Traction Issues with Concrete

Several different sources have identified that concrete becomes slippery when wet. Slip Industries has created a product that is used to cut grooves into concrete before it dries. It has been commonly used to cut a herringbone pattern into concrete boat ramps to increase traction for the trucks (Balogh, n.d.)

A similar method was observed by our group during a visit to Las Cavernas de Rio Camuy, in Camuy, Puerto Rico. All of the trails leading into the caverns as well as the trails within the cavern are made of concrete. Due to the high level of humidity within these caves, the concrete trails are always wet. To help prevent slipping, all of the concrete has a grid of grooves cut into it.

Low-impact paving

The Clean Air Counts Organization (n.d.) offers an alternative to asphalt paving known as low-impact paving. Low-impact paving is a method of paving that does not use crude oil products in its recipe. Therefore, that method emits lower quantities of harmful volatile organic compounds or VOCs. The technique has been used to replace ordinary asphalt paving in a variety of different applications. By following this practice the company claims possible lower construction costs, maintenance costs, as well as possible aesthetic improvement for the project. The technique has been put to the test in several cases, for example a Dominican University in River Forest paved a parking lot with low-impact paving. The initial cost of the paving was higher, at $1.5 million compared to $1.25 million of ordinary asphalt. However, the gravel-pavement method requires no drainage system and can be laid around obstacles such as large trees. Due to this, overall project costs were decreased, as compared to general asphalt paving (Clean Air Counts, n.d.)

Trail Materials Regarding Accessibility

The National Center on Accessibility asserts that the trail surface is a critical aspect regarding accessibility. They state that the surface must be firm and stable so that the users who suffer from disabilities are not required to spend unnecessary energy trying to enjoy the trail. They define firmness and stability as the distance that a foot or wheel sinks into the surface. These levels are outlined as very firm/stable, moderately firm/stable and not firm/stable. Trails of lengths greater than half a mile, requiring accessibility, should fall into the very firm/stable category. Similarly trails of lengths less than half a mile should reside in the moderately firm/stable category. The following

chart from the National Center on Accessibility is included to clarify the specifications for these terms (National Center on Accessiblity [NCA], 2001).

ANSI/RESNA Standards for Firmness & Stability			
	Very Firm/Stable	**Moderately Firm/Stable**	**Not Firm/Stable**
Firmness	0.3 inch or less	>0.3 £ <0.5 inch	>.5 inch
Stability	0.5 inch or less	>0.5 £ <1.0 inch	>1.0 inch

Maintenance of Trail Surface Materials

According to The National Center on Accessibility, maintenance is an important aspect to consider concerning budget constraints. They conclude that, if a large one time sum of money is available, concrete is the most cost effective material to use for accessible trails. It has far less maintenance requirements than a compacted gravel surface, despite a greater initial cost (NCA, 2001).

Available do-it-yourself Products

Quikrete 40lb bag - Commetial Grade Resurfacer - $21.16 –

- Just add water
- Used for sidewalks, pool decks, patios
- Yields 90 square feet at 1/16 thick.

Quikrete 94 lb bag – Type I cement $7.97

- Must be mixed with gravel and sand.
- Requires a mixer.

Quikrete Gravel 50lb bag - $3.62

Quikrete Sand 50lb bag – $5.07

Monarch BigCat Utility Mixer - $257.00

- 1/3 HP electric mixer motor
- 220 lb capacity
- completely portable

For a general estimate, a trail that is one mile long, eight feet wide, with a six inch layer of concrete for the trail surface will be used. To construct that trail with concrete would require 21,120 cubic feet of concrete. If the mixer method was used, with the Type I cement, gravel, and sand mixture, approximately 940 bags of each material would be required. The estimated cost for this extremely labor intensive method is approximately $16,000 for just the concrete (Lowe's, 2007).

SHORE EXCURSIONS

Item	**Cost**	**Notes**
Shuttle Bus (one)	~60,000$	Brand new, 25 passenger shuttle bus
Gasoline per trip	~30$	Approximately 10 gallons per trip
Driver Salary	~200$	Approximately 10 hour day at 20$ per hour
TOTAL COSTS	Approx 60,000$ start-up Approx 250$ per day to operate	Operation costs easily covered with a reasonable visitation fee

The estimated cost of the shuttle bus is from www.nationsbus.com (Nations Bus, 2007) and the offered vehicle is a 25 passenger Ford E450 passenger truck. The daily operation costs are a generous estimate for gas mileage of the vehicle and salary of the driver. The gas mileage estimate came from Ford's website. It is also possible to lease a bus or busses in order to lower maintenance costs.

Cost Analysis

Cost Return Analysis

Years	Customer Cost to Pay Off Bus Purchase (includes daily costs)			
1	$58.00	$77.33	$116.00	$232.00
2	$34.00	$45.33	$68.00	$136.00
3	$26.00	$34.67	$52.00	$104.00
4	$22.00	$29.33	$44.00	$88.00
5	$19.60	$26.13	$39.20	$78.40
	100% full bus	**75% full bus**	**50% full bus**	**25% full bus**
Passengers per year	*1250*	*938*	*625*	*313*
Base price to cover daily costs	$10.00	$13.33	$20.00	$40.00

Passengers per trip = 25 max	Cost of bus = $60000
Cost per day (gas + driver) = $250	Trips per year = 50
Year total for daily costs = $12500	

We created the spreadsheet above to show different ticket prices for the shore excursions to the canyon and how long it would take to pay off the purchase of a bus for this trip. The left column is the number of years to pay off the bus. The respective prices shown are the cost of the ticket, including daily costs. If the trip is only offered once a week, therefore fifty weeks per year, the daily costs to operate the bus are estimated at $12,500 per year. The number of passengers is estimated for four different bus capacities. In our recommendation, since there are only fifty trips per year, we estimated that capacity will be 75 percent to 100 percent for the shuttle bus. With those capacities, the bus could easily be paid off in two or three years, with very low cost for the ticket. However, these prices only reflect the cost to cover the finance the transportation part of the tours, admission costs will need to be set by the Conservation Trust in the future.

We consider the box highlighted in red to be the ideal choice. It will pay off the bus at a reasonable rate without charging the visitors an unreasonable price. This number is similar to the cost of a guided and narrated tour of El Yunque through the services of

Princess Cruises. They offer what would be a similar trip for $39 to adults and $31 to children.

CHAPTER FIVE: RECOMMENDATIONS AND CONCLUSIONS

By analyzing the large amount of data that has been collected about the San Cristóbal Canyon, our group has provided several major recommendations. Our recommendations are intended to provide options which the Conservation Trust could use to sustainably develop the canyon and make the area accessible to potential visitors. Many of these recommendation were developed from information gathered at historical sites that the Conservation Trust owns that have already been established and opened for public visiting.

SUSTAINABLE DEVELOPMENT OF THE SAN CRISTÓBAL CANYON

Biosphere Reserve Recommendations

In order to fully protect the canyon from pollution and fulfill the objectives set forth by the Conservation Trust, our team recommends that the San Cristobal Canyon be designated as a biosphere reserve with UNESCO. By working with that United Nations Program, the San Cristóbal Canyon would join a large network of protected ecosystems throughout the world. It would also ensure the sustainable development of the canyon for its conservation.

The core area should be the land that is currently owned by the Conservation Trust. That is the area where there is the largest amount of restrictions on land use. No business or residential development is to take place in the core area, nor any grazing. No cattle should be allowed in the core area because of potential risks to tourists and faculty. As a result, it would be beneficial to have secure fences put in place on neighboring

farms. Any development of the core area for private businesses and residential homes would be prohibited under law. The core area is the area where scientists can conduct their research, where visitors can be monitored, and where the Conservation Trust faculty can maintain the reserve.

The buffer zone is needed for a biosphere to exclude edge affects that pose threats to the designated core area. The buffer zone needs to include local point sources known to cause water pollution in the canyon. It also should contain residential areas and businesses close to the core area that could produce possible edge affects such as noise pollution, animal invasions, and illegal waste dumping. In particular, we made sure that the poultry farms were included in the buffer zone because they are the greatest point source of pollution to the canyon.

For the transition area, we recommend that it encompass adequate area outside the buffer zone so that community cooperation can be facilitated. The purpose of UNESCO's biosphere program is to conserve ecosystems by engaging local communities in its sustainable development. Having the transition area include Aibonito and Barranquitas is necessary to accomplish that objective of a biosphere reserve. The Conservation Trust needs to enforce the regulations that are set forth for a transition area so that conservation efforts are not compromised. Since residents and businesses need to be granted permission to engage in any activity against conservation interests, the Trust needs to be accessible to the municipalities so that applications for those activities can be processed immediately. In addition, a transition area provides further protection for the core area against any harmful edge effects.

The Conservation Trust needs to consider a multi-year project to fulfill the criteria to be designated a biosphere reserve. That needs to be accomplished through extensive scientific research of the property and negotiation with neighbors and local communities. Cooperation and communication with local citizens is necessary to encourage compliance with regulations and encouraging expansion of a potential ecotourism economy. The Trust should consider offering neighbors incentives to use or purchase their land so that future trails can be developed. Some of those incentives could be to offer an adequate amount of money so that the owner can relocate or to create a deal with these owners in which the Trust can use their land for a certain price per timely basis that is negotiated between the Trust and the landowner.

Composting Poultry Waste

Local poultry farmers near the canyon serve as the largest point sources of pollution in the canyon. If the canyon is designated as a biosphere reserve, those farmers will be forced to abandon the practice of dumping poultry waste into the rivers that run through the canyon since they exist in the proposed buffer zone. As such, we recommend that the Trust discuss with those farmers more environmentally-friendly practices of removing waste, such as composting.

A practical solution for disposing of poultry waste and carcasses is to compost them directly on the farm. The result of composting is a black soil-like product with high-fertilizer capabilities. That soil can be used directly on the farm, or it can be sold for profit. The fertilizer produced from the compost can help offset the initial capital costs of the composting device. According to a study by the University of Maryland

(Brodie and Carr, n.d.), the quality of fertilizer produced by dead poultry should be equal to, if not better than the quality of fertilizer produced by other composted materials.

The size of the compost needed depends on the farm capacity and projected mortality of the poultry. If the farm needs to process up to thirty pounds of waste and mortalities per day, then a minicomposter is appropriate. If the farm needs to compost more than thirty pounds up until three hundred pounds, then a two-stage composting device is recommended.

In both a minicomposter and a two stage system, the operating temperature of the compost needs to be in the range of 130-150 degrees Fahrenheit. Operating at this temperature kills most pathogens that exist in dead poultry and proper maintenance will ensure no odors and protection from flies. Monitoring the temperature will help the operator ensure that the system is working properly. Composting for poultry farms is a safe and environmentally-friendly means for disposing of poultry waste and mortalities. It is also an intelligent economic solution.

Connecting History with Conservation

The history of the Canyon's use in the past is of great interest and should be made available to potential visitors. We recommend that in the future, more trails be developed in areas where tobacco or coffee plantation houses used to exist. By using the map that shows land usage in the Canyon in 1950 along with a global positioning system, it would be easy to locate those historical sites. It is also recommend that future trails should be created along the tree lines that marked the division between land owners many years ago.

These are both very appealing things to visit, and they would add to the relevance of the tobacco history exhibit that will be at the visitor center.

INFORMATION OF THE INTERACTIVE NATIVE TREE EXHIBIT

With the information gathered about the native local trees and shrubs along the proposed trails, we recommend that the Conservation Trust create an interactive checklist, as exemplified below in both English and Spanish.

Example of Native Tree Exhibit Checklist (English)

Picture of Leaf/Shrub	Description	Name (to be filled in by visitor)
	Tree 6-15 m high. Shining, oval leaves, to around 120 mm, very aromatic when crushed. Flowers whitish Oct-Jan. Fruit a large conspicuous berry pink-mauve or white in bunches.	(Cupey)
	Always a green tree that reaches 25 feet in height The bark is straight, gray and thin. The interior bark is chestnut –yellow and bitter	(Camasey)
	Very hard, heavy wood, related to Guava and Eucalyptus Leaves are small and nearly diamond-shaped	(Hoja Menuda)
	Shrub or small tree from 2 to 6 meters in height It is spiny and may have one to several stems	(Tintillo)
	Gray to whitish bark White flowers Dark purple berries that are round or elliptical and are rumored to be edible	Guasábara

	Widely used for decorative purposes Intolerant of cold weather: they will show cold damage at 31°F and are killed at 25°F	(Puerto Rican Royal Palm)
	Its flower is the official national flower of Puerto Rico Closely related to a hibiscus, but the it is a tree	(Maga)
	Very tall-can grow up to 80 feet in height Leaves are very aromatic Leaves are 6 inches long and two inches wide and are shiny and blue-green in color	(Malagueta)
	Listed as an endangered specie Evergreen tree that reaches up to 20 meters in height Leaves are shiny dark green above, pale green below, hairless	(Palo de Jazmin)
	Fruits are edible and eaten fresh More common use of the tree is as a commercial timber Wood is very hard, strong, fine textured, and heavy	(Ausubo)

	Small to medium size tree, occasionally grows over 10 meters tall Trunk often leaning and branched near the ground	(Cojoba)
	Nearly all species of this tree are evergreen but some tropical species lose their leaves at the end of the dry season Flowers have numerous fluffy stamens, which may be white	(Eucalyptus)
	Large pineapple-like plant with dark green sword shaped leaves Its fruit is a yellow elliptical berry	(Maya)
	Low evergreen or shrub 6 to 25 feet high The leaves are oblong or oval and blunt, 3 to 6 inches long, and feather-veined	(Guava)

Example of Native Tree Exhibit Checklist (Spanish)

Foto del Hoja	Descripción	Nombre (escribirá por el viajero)
	Árbol 6-15 metros de alto. Brillando, hojas muy de aromático cuando está machacado. La fruta es una baya visible grande rosado-de color de malva o blanco en manojos.	(Cupey)
	El camasey es siempre un árbol verde que alcanza 25 pies en altura y 4 pulgadas de diámetro La corteza es recta, gris y fina. La corteza interior es castaña - amarilla y amarga	(Camasey)
	Muy difícilmente, madera pesada, relacionada con la guayaba y el eucalipto Las hojas son pequeñas y casi de forma diamantada	(Hoja Menuda)
	Arbusto o árbol pequeño a partir del 2 a 6 metros en altura Es espinoso y puede tener uno a vástagos multiples	(Tintillo)

	Gris a la corteza blanquecina Flores blancas Bayas púrpuras oscuras que son redondas o elípticas y se rumorean para ser comestibles	Guasábara
	Utilizado extensamente para los propósitos decorativos Intolerante del tiempo frío: demostrarán daño frío en 31°F y se matan en 25°F	(Puerto Rican Royal Palm)
	Su flor es la flor nacional oficial de Puerto Rico Se relaciona de cerca con un hibisco, pero el maga un árbol	(Maga)
	Muy alto-puede crecer hasta 80 pies en altura Las hojas son muy aromáticas Las hojas tienen 6 pulgadas de largo y dos pulgadas de ancho y son brillantes y azulverdes en color	(Malagueta)
	Mencionado como specie puesto en peligro Árbol imperecedero que alcanza hasta 20 metros en altura Las hojas son verde antedicho, pálido verde oscuro brillante abajo, sin pelo	(Palo de Jazmin)

	Las frutas están frescas comestible y comido La madera es muy dura, fuerte, tecturada muy bien, y pesado	(Ausubo)
	El árbol pequeño-medio del tamaño, crece de vez en cuando sobre 10 metros de alto Las flores son bolas blanquecinas pequeñas del estambre en los axils de la hoja.	(Cojoba)
	Casi todos son imperecederos pero un ciertas especies tropicales pierden sus hojas en el final de la estación seca Las flores tienen estambres mullidos numerosos, que pueden ser blancos	(Eucalyptus)
	Grande piña-como la planta con la espada verde oscuro formó las hojas Clasificado como perennial porque tiene una base arbolada en su base y hojas fibrosas	(Maya)
	Árbol de hoja perenne o arbusto bajo 6 a 25 pies de alto Las hojas tienen pulgadas oblongas u ovales y blunt, 3 a 6 largas, y pluma-vetearon	(Guava)

In the left column, there is a picture of the leaf or close-up of the native tree or shrub. The middle column contains a brief description of the plant in the corresponding row. The right column is intended to be left blank so that the potential visitor may fill it in as he or she finds the tree or shrub along the trail. The checklists in this report are examples, and may be adjusted.

TRAIL SAFETY AND ACCESSIBILITY

Recommendations for the Proposed Trails

We have been informed that there are four separate proposed trails within the property owned by the Fideicomiso de Conservación at the San Cristóbal Canyon. Of the four trails, two are located nearby to the proposed site of the visitor center. One of these trails brings you to the site that was used in the past as a dumping point for the local communities. That trail will be referred to as Trail 1, and the dumping site can be seen on the map at the end of the trail. The other trail in this location brings you to the area where a lookout tower or deck will be built. The lookout tower trail is Trail 2, and the tower's location is marked on the map at the end of the trail. The final two trails, Trail 3 and Trail 4, begin at the nursery. Trail 3 is a shorter trail that heads through the nursery and Trail 4 travels the opposite direction through an area that was used as a trial for reforestation. Our group will provide recommendations for all aspects of the development of those trails.

First, we are recommending that all the trails that continue into the development stages be constructed of concrete. Concrete has a higher initial installation cost, however low maintenance costs and high levels of accessibility make it ultimately more affordable

and least impact option for the trail surface. As seen in our results and analysis section, it meets all of the needs of an accessible trail surface material.

Trail 1, which leads to the dumping site, has the possibility to be developed for complete accessibility, including those confined to a wheel chair. To accommodate persons of all physical limitation, we are recommending that this trail be paved with some type of concrete, which is more visually appealing and less harmful to the environment than asphalt. The trail should follow the guidelines for accessibility that are specified in Appendix C. The green numbers on our map mark specific areas that require attention. In this case, the only obstacles to overcome are several sections that are steep hills, where ramps would need to be constructed to achieve the recommended slope guidelines. The actual site where the dumping took place is located at the very end of the trail, and should be completely surrounded by fencing. For the entirety of the accessible trails, any section that achieves a slope of 12.5 percent or greater should be fenced on both sides.

We also recommend that Trail 3, leading through the nursery be paved and constructed in a similar manner to Trail 1. Both of those trails have the possibility to be completely accessible. This trail though the nursery would only require minor modification to provide a level trail surface. There is one particular area that is a small hill that will need to be leveled. That area can be seen on our map at Point 1. We also recommend that a small, completely fenced, viewing platform or deck be constructed at the end of the trail for safety and to provide a better view of the waterfall. The end point of Trail 3 can be seen on our map.

The two remaining trails, Trail 2 and Trail 4, are located on terrain that is not reasonable to develop for complete accessibility. However, Trail 2, which leads to the location of the proposed lookout tower, should be developed for general, limited accessibility, hiking purposes. Again the trail would be paved, but it would include concrete stairs or steps wherever the steepness of the trail is too great. The trail should have complete fencing on both sides of the entire trail for safety. The end of the trail is the proposed location of the lookout tower and it should be entirely fenced as well. The fencing should be similar to the trails at Hacienda Buena Vista, in Ponce due to its low impact aspects, and its structural support for safety. There are many particular areas along this trail that should be considered for the steepness of the terrain. For example, Point 3 on the map of Trail 2 is a steep drop off right before the trail ends. We recommend the construction of stairs with drainage systems at those points to prevent the erosion of the soil, and provide easier access to the lookout tower location.

The final trail, Trail 4, is the one that goes through a section of property that is not owned by the Conservation Trust. It also travels through an area that was used for experimental reforestation. This area can be seen on our map where points A, B, and C are located. We are recommending that the development of this trail be delayed until the section of un-owned land can be acquired. If that land can be acquired or if a contractual relationship can be developed with the owner, we would recommend that this trail be developed for limited accessibility hiking, the same as the trail to the primary lookout tower.

There is a system of dirt roads that connect the dumping site and lookout tower trails to the proposed visitor center location. Those roads are currently only accessible by

a truck or off-road vehicle. We are recommending that all of those dirt roads within the property be properly prepped, with a layer of gravel, and then paved with asphalt and constructed with proper run-off drainage systems. That will allow for a trolley or similar vehicle to travel the roads and transport visitors to the starting point of the lookout tower trail as well as the trail to the dumping site. That trolley should be exactly similar to the trolley that operates at El Faro in Fajardo.

Security

It is recommended that the Conservation Trust employ either a volunteer or a paid security or park ranger staff. An example of a system of volunteers has been developed by the East Bay Regional Park District. That organization uses several different types of volunteer patrol groups to manage the risks involved with providing a nature park to the public. The five types of groups that they use are horse mounted patrol, bicycle patrol, companion dog patrol, hiking patrol, and a marine safety unit. The volunteers provide educational information and safety regulations to the visitors of the park. The goal of that organization is to provide for the safety of the public within the park as well as to preserve the park's nature and historical resources. The volunteers are required to attend monthly training and informational meetings to keep their knowledge of the park up to date. They also are required to provide a minimum of 100 hours of patrol time in the park per year. The volunteer patrol units are equipped with two-way radios as well as person cell phones in case of emergencies (http://www.ebparks.org/Police/volco.htm). This description of a currently functioning park patrol group is provided as an example which could be used or modified to fit the specific needs of the Conservation Trust. If

more dedicated patrol members are required, this plan could be easily converted to provide similar functionality with a smaller staff on a salary.

ADDITIONAL RECOMMENDATIONS

Shore Excursions

Attracting groups of visitors to travel to the canyon is an essential task. A resource for this that could be easily exploited is the huge influx of tourists from cruise ships coming to port in Old San Juan. Many of them would likely be interested in participating in an adventure that is different from just shopping and walking around the city. Spending the day hiking the San Cristóbal Canyon is a perfect alternative. The only obstacle is transportation to and from the canyon. Currently, there are escort services offered as a part of an all inclusive day trip for things such as snorkeling or hiking in the rain forest. Known as shore excursions, cruise lines offer numerous options for day trips while the ship is at port. Guests of the cruise can sign up for these trips in advance, and partake in unique experiences while visiting the island (Princess Cruises, 2007). For example, there are already guided tours of El Yunque offered to cruise ships that come to Puerto Rico. There is a bus that arrives in the morning and picks up the patrons, brings them to the site, and then brings them back to the ship in the afternoon. Establishing an excursion similar to this would provide a captured audience of visitors for the San Cristóbal Canyon nature reserve, as well as an interesting alternative place for spending a day in Puerto Rico. A detailed cost estimate and analysis for establishing a shuttle bus escort for this purpose is included in our results.

APPENDIX A: INFORMATION ABOUT OUR SPONSER

MISSION

The Fideicomiso is a private non-profit organization dedicated to the protection of Puerto Rico's natural resources. This is accomplished through donations of lands that contain great ecological, aesthetic, historical, and cultural value. The Trust has developed programs to educate the population of Puerto Rico the significance of protecting these lands. Through its program Árboles…más árboles (A+A), the Trust produces and distributes native tree species in order to encourage Island's biological diversity.

ORIGINS

The end of the 1960's brought a time of drastic change to the economy of Puerto Rico. Heightened urbanization and modernization had a detrimental affect on the natural surroundings. This prompted the government to create several agencies such as the Department of Natural and Environmental Resources and the Puerto Rico Environmental Quality Board. In 1970, the US and Puerto Rican governments formed the Conservation Trust of Puerto Rico to achieve the mission stated above. During its first ten years, the Trust received funds from U.S. tariffs from petrochemical companies located on the island. Soon, the Trust began to accumulate income through private transactions with companies operating under Section 936 of the U.S. Internal Revenue Code. Once this could not generate any more funds for the Trust, it began to invest in stocks and bonds in order to receive a portion of the rum tax returns from the federal government. The funds generated from this tactic have enabled the Trust to acquire lands of high importance.

FUNDING

In addition to receiving tax refunds for its income, the Trust also receives land and cash donations from its AMIGOS. These individuals and corporations are committed to the same ideals of the Trust-to the preservation and conservation of the natural resources of Puerto Rico.

HISTORY

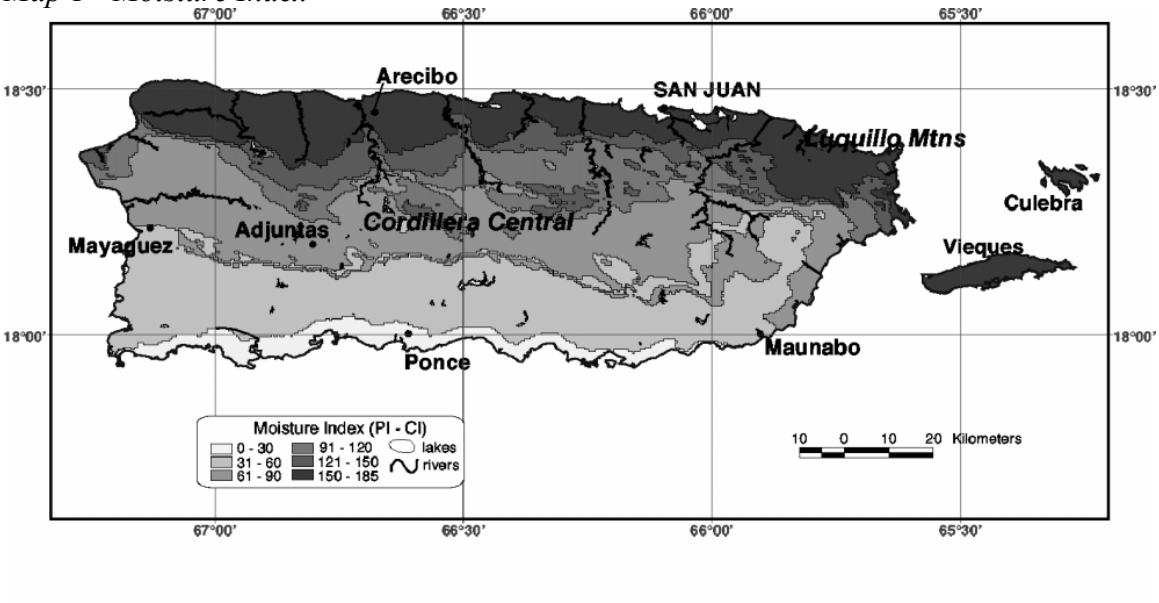
In the first thirty-three years, under leader Francisco Javier Blanco, the Trust protected over 16,000 acres of land. These included lands at Parguera in Lajas, Las Cabezas de San Juan in Fajardo, Hacienda Buena Vista in Ponce, San Cristóbal Canyon, Haciena La Esperanza in Manatí and Punta Guanaquilla in Cabo Rojo. For its outstanding restoration and preservation accomplishments, the Trust has received important recognitions. Furthermore, Mr. Blanco has managed to establish mechanisms for the conservation of land in the Caribbean region, such as debt-for-nature swaps in the Domincan Republic

and Jamaica. Mr. Blanco retired in December of 2002 with lawyer Fernando Lloveras San Miguel as his replacement. Since his installation, Mr. Lloveras has obtained over 2,000 acres of land.

Source: The information for this Appendix was taken directly from the Fideicomiso website; http://www.fideicomiso.org/enter.htm

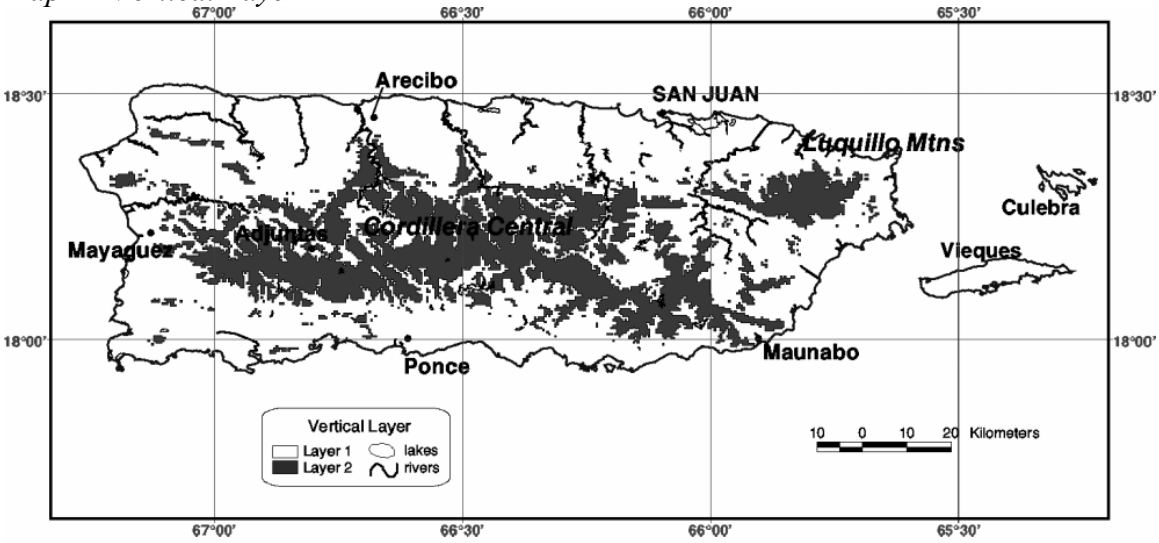
APPENDIX B: MAPS

Map 1 - Moisture Index



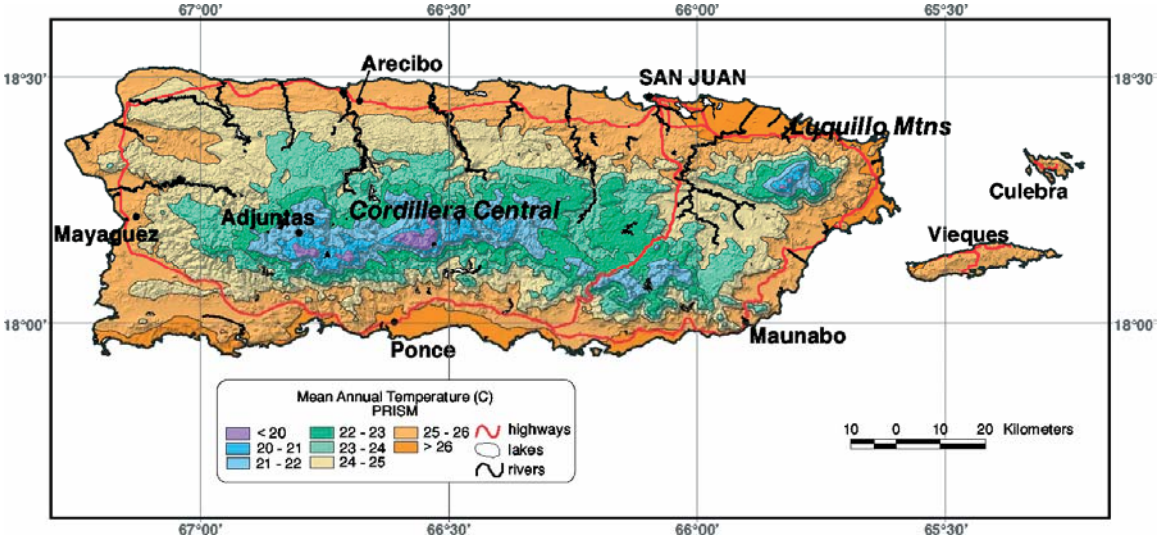
Source: http://www3.interscience.wiley.com/cgi-bin/fulltext/104551280/PDFSTART?CRETRY=1&SRETRY=0

Map 2 - Vertical Layer



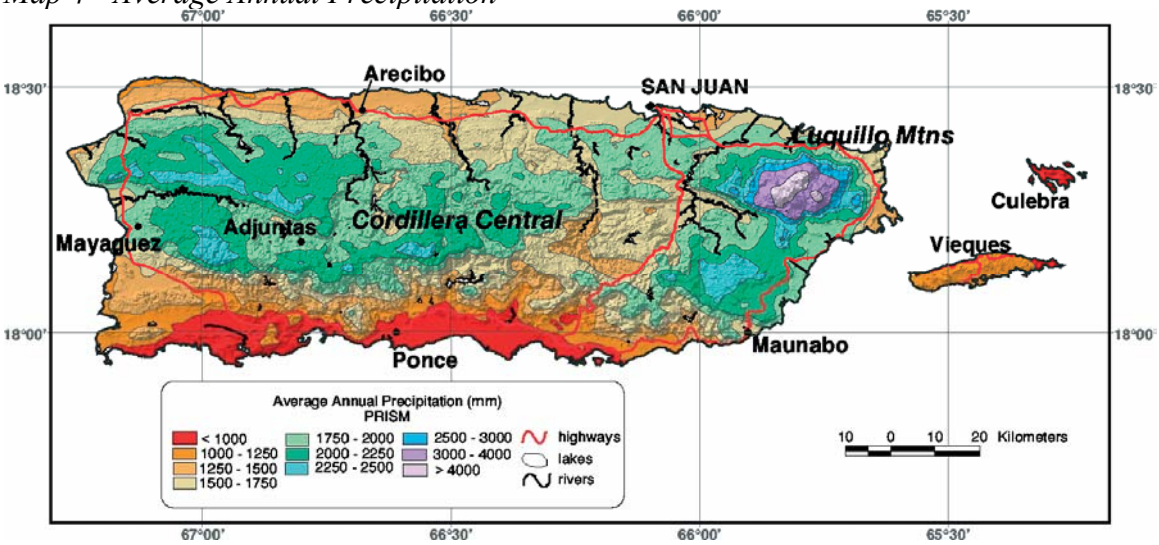
Source: http://www3.interscience.wiley.com/cgi-bin/fulltext/104551280/PDFSTART?CRETRY=1&SRETRY=0

Map 3 - Average Annual Temperature



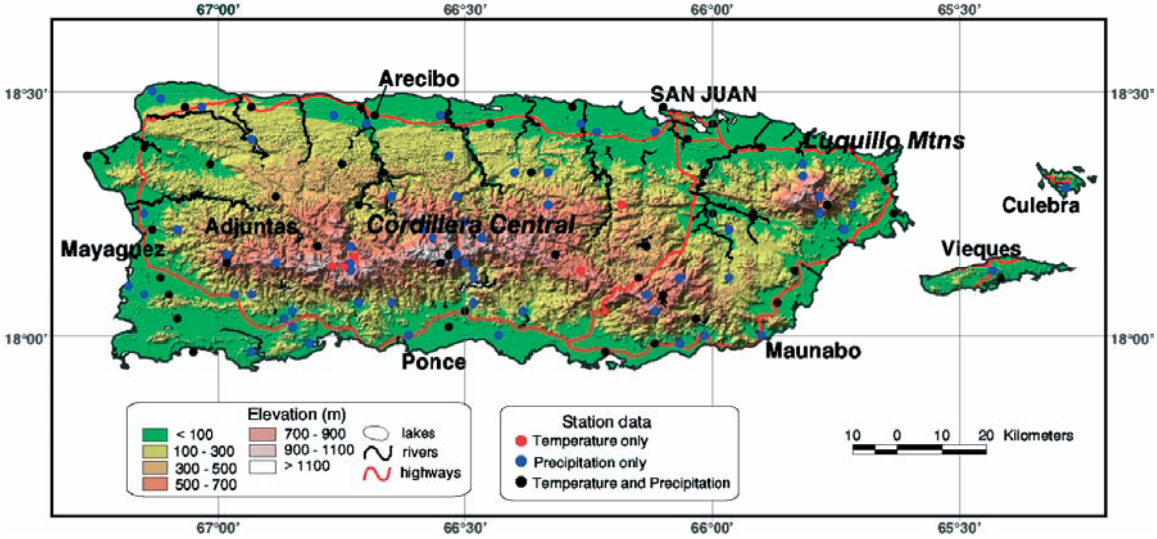
Source: http://www3.interscience.wiley.com/cgi-bin/fulltext/104551280/PDFSTART?CRETRY=1&SRETRY=0

Map 4 - Average Annual Precipitation



Source: http://www3.interscience.wiley.com/cgi-bin/fulltext/104551280/PDFSTART?CRETRY=1&SRETRY=0

Map 5 – Elevation

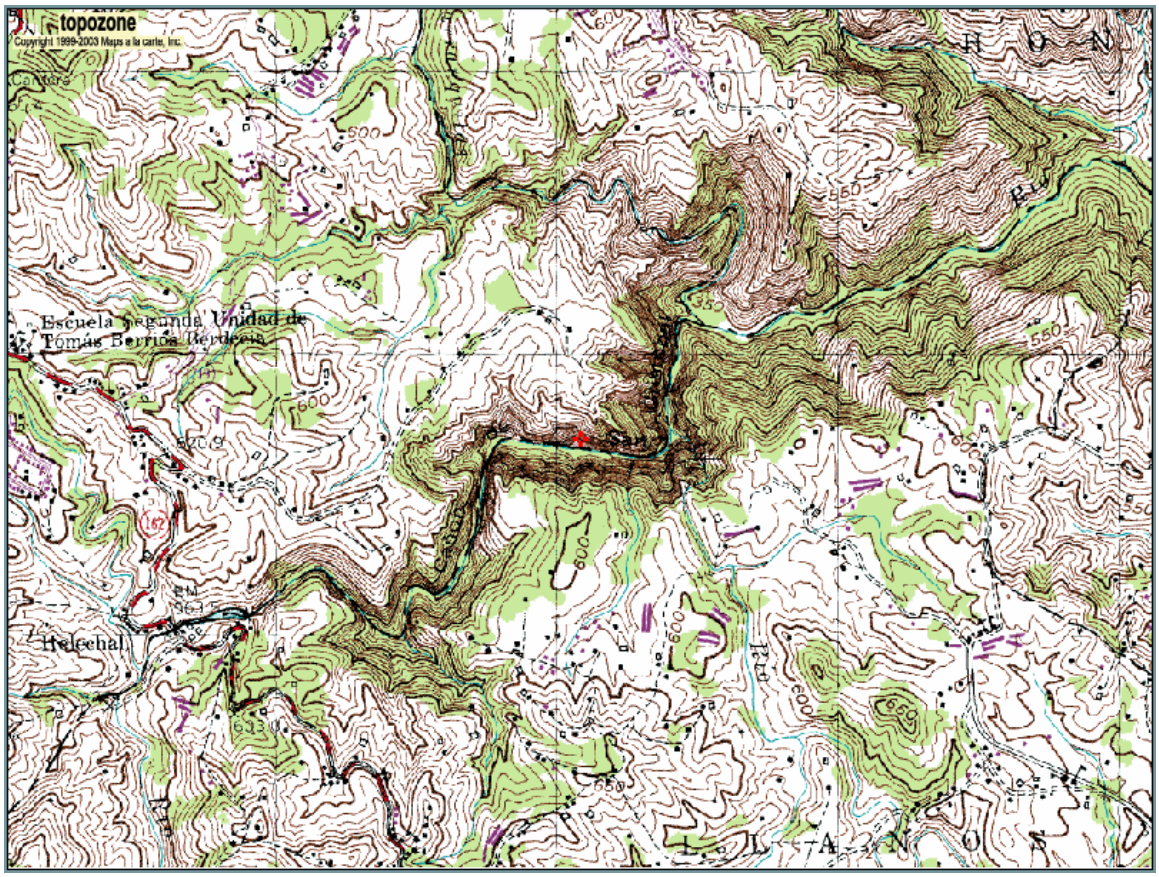


http://www3.interscience.wiley.com/cgi-bin/fulltext/104551280/PDFSTART?CRETRY=1&SRETRY=0

Map 6 - Towns and Cities

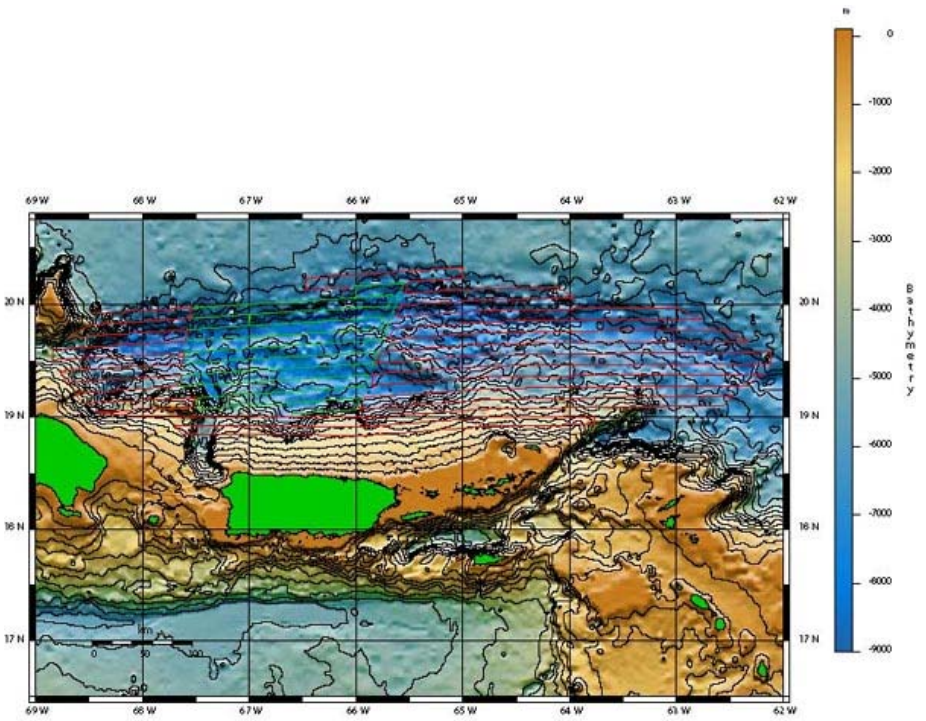
http://www.ccsu.edu/caribstudy/images/pr-municipalities.gif

Map 7 – Topographic Map of the San Cristobal Canyon



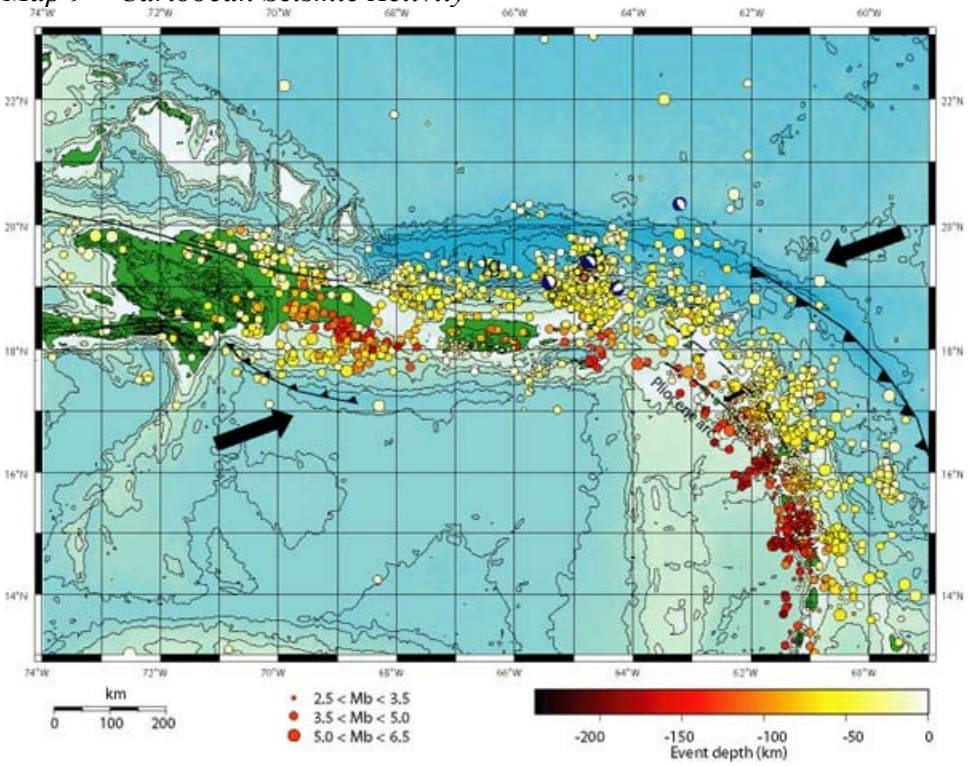
http://www.topozone.com/map.asp?lat=18.1711&lon=-66.2919&datum=nad27&u=4&layer=DRG&size=l&s=50

Map 8 – Under water depths



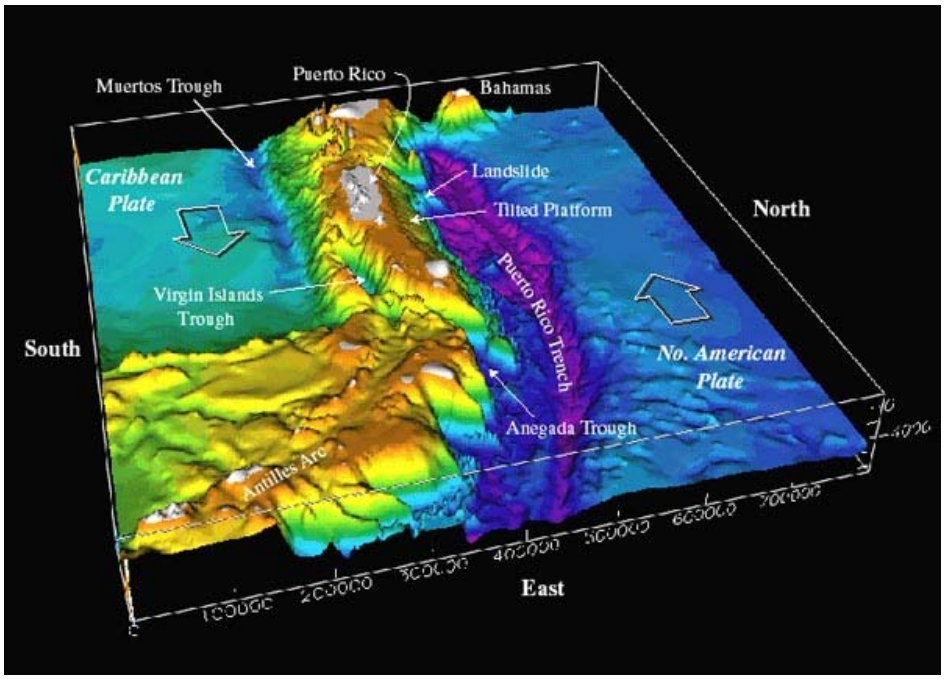
Courtesy of Declan De Paor

Map 9 – Caribbean Seismic Activity



Courtesy of Declan De Paor

Map 10 – Plate Tectonics in the Caribbean



Courtesy of Declan DePaor

APPENDIX C: TABLES

Table 1: Geological Time Sequence

Introduction to Geology | Navigating our Geology Wing

(mya = million years ago)

Phanerozoic Eon (543 mya to present)	Cenozoic Era (65 mya to today)	Quaternary (1.8 mya to today) Holocene (10,000 years to today) Pleistocene (1.8 mya to 10,000 yrs) Tertiary (65 to 1.8 mya) Pliocene (5.3 to 1.8 mya) Miocene (23.8 to 5.3 mya) Oligocene (33.7 to 23.8 mya) Eocene (54.8 to 33.7 mya) Paleocene (65 to 54.8 mya)
	Mesozoic Era (248 to 65 mya)	Cretaceous (144 to 65 mya) Jurassic (206 to 144 mya) Triassic (248 to 206 mya)
	Paleozoic Era (543 to 248 mya)	Permian (290 to 248 mya) Carboniferous (354 to 290 mya) Pennsylvanian (323 to 290 mya) Mississippian (354 to 323 mya) Devonian (417 to 354 mya) Silurian (443 to 417 mya) Ordovician (490 to 443 mya) Cambrian (543 to 490 mya) Tommotian (530 to 527 mya)
Precambrian Time (4,500 to 543 mya)	Proterozoic Era (2500 to 543 mya)	Neoproterozoic (900 to 543 mya) Vendian (650 to 543 mya) Mesoproterozoic (1600 to 900 mya) Paleoproterozoic (2500 to 1600 mya)
	Archaean (3800 to 2500 mya)	
	Hadean (4500 to 3800 mya)	

authors © help

Courtesy of: http://www.ucmp.berkeley.edu/help/timeform.html

Table 2: Monthly Precipitation in Aibonito, Puerto Rico

AIBONITO, PUERTO RICO

Monthly Total Precipitation (inches)

(660158)

File last updated on Jul 28,
*** Note *** Provisional Data *** After Year/Month 200603
a = 1 day missing, b = 2 days missing, c = 3 days, ..etc..,
z = 26 or more days missing, A = Accumulations present
Long-term means based on columns; thus, the monthly row may not
sum (or average) to the long-term annual value.
MAXIMUM ALLOWABLE NUMBER OF MISSING DAYS : 5
Individual Months not used for annual or monthly statistics if more than 5 days are missing.
Individual Years not used for annual statistics if any month in that year has more than 5 days missing.

YEAR(S)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1948	1.76	4.40	5.02	5.82	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	17.00
1949	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1950	2.46	3.39	1.01	3.93	2.01	3.00	2.35	5.91	3.30	7.72	7.80	2.13	45.01
1951	2.13	0.50	0.32	1.85	5.58	3.65	5.11	3.56	5.72	0.00 z	0.00 z	0.00 z	28.42
1952	4.16	3.63	2.36	4.61	6.03	2.73 S	2.08	0.00 z	12.12	5.69	2.47	1.91	47.79
1953	1.40	1.23	1.38	2.93	1.82	3.80	4.06	7.45	0.00 z	0.00 z	4.46	0.00 z	28.53
1954	1.98	4.54	1.06	4.99	4.07	5.56	4.92	3.77	8.75	10.62	7.66	1.69	59.61
1955	2.90	2.38	2.11	3.29	3.84	3.15	6.21	6.19	6.88	3.33	5.64	4.00	49.92
1956	1.72	3.91	1.55	3.96	6.02	8.82	1.69	0.00 z	2.43	6.11	4.74	3.45	44.40
1957	0.93	1.54	0.58	2.14	1.20	4.28	2.09	0.00 z	11.27	3.03	6.54	3.96	37.56
1958	2.82	1.17	1.12	6.34	6.12	5.64	1.85	3.17	0.00 z	5.70	1.93	1.55	37.41
1959	1.66	2.39	1.08	4.42	3.52	0.94	4.64	4.70	3.11	2.37	1.64	3.10	33.57
1960	2.57	2.09	1.83	7.91	5.40	3.00	5.21	6.31	21.50	2.95	4.70	5.89	69.36
1961	1.91	2.02	3.20	5.16	4.19	5.05	2.90	6.95	4.95	5.04	3.54	2.23	47.14
1962	3.04	1.83 i	0.55 a	3.50	6.79	0.00 z	3.27	5.74	7.51	11.14	2.66	3.54	47.74
1963	3.52	3.04 a	1.05	8.61	8.80 g	0.00 z	2.17 e	0.00 z	4.82	7.17	3.95	0.681	34.33
1964	1.05 g	1.83	1.74 d	3.39 e	1.90	1.75	4.19	2.36	3.63	4.50	1.18	0.00 z	26.47
1965	0.98 k	2.11	1.41	2.79	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	6.31
1966	3.40	1.83	3.06	3.11	4.39	1.82	0.00 z	0.00 z	3.11	2.30	3.24	3.71	29.97
1967	2.21	3.45	1.22	1.57	2.97	1.14	0.63	1.23	2.48	3.35	3.16	1.11	24.52
1968	0.00 z	1.63	1.69	2.05	5.20	4.86	3.11	3.61	2.54	1.15	5.42	2.75	34.01
1969	3.52	0.00 z	1.75	9.28	8.32	3.52	3.56	3.50	7.35	6.41	12.49	2.74	62.44
1970	2.82	1.66	1.42	0.13	7.46	8.36	5.33	13.97	3.97	38.08	11.69	9.61	104.50
1971	4.33	2.43	3.14	13.30	4.95	0.97	1.35	5.10	2.68	8.01	4.49	3.34	54.09
1972	4.05	0.00 z	5.53	0.00 z	1.35	1.06	1.74	4.68	6.11	7.86	2.60	0.00 z	34.98
1973	1.01	4.37	3.77	1.12	1.70	0.00 z	0.69	5.60	1.55	4.03	0.00 z	0.00 z	23.84
1974	1.75	1.90	1.71	1.11	0.79	1.00	1.12	2.19	4.80	7.82	6.98	3.65	34.82
1975	3.49	1.09	3.36	3.80	3.20	0.24	5.69	2.96	10.09	4.54	7.25	7.37	53.08
1976	2.02	4.39	3.22	3.90	1.86	2.19	1.25	5.47	4.76	8.51	2.94	2.96	43.47
1977	1.55	1.58	1.70	2.55	2.04	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	9.42
1978	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1979	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1980	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1981	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1982	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1983	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1984	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1985	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1986	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1987	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1988	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1989	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1990	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1991	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1992	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00
1993	0.00 z	0.00 z	0.00 z	0.00 z	5.07	5.01	6.30	4.77	6.66	2.62	3.93	2.55	36.91
1994	1.92	1.47	2.82	3.17	0.64	0.93	1.01	1.94	3.93	5.98	1.25	1.74	26.80
1995	1.81	4.53	1.42	1.65	8.90	2.42	3.57	1.93	13.23	6.27	2.25	2.77	50.75
1996	5.20	1.11	2.08	3.93	3.37	4.97	5.98	3.65	18.27	3.80	4.94	2.49	59.79
1997	3.82	3.25	2.13	1.89	2.99	0.63	1.72	1.86	1.86	13.90	4.34	0.50	38.89
1998	4.68	8.27	1.90	4.52	6.69	1.62	2.45	15.20	23.58	8.68	0.00 z	8.12	85.71
1999	3.39	1.64	2.48	3.82	3.73	6.76	4.77	3.86	9.01	4.01	17.84	6.96	68.27
2000	4.04	2.86	1.33	1.73	4.22	3.13	1.05	10.46	6.21	7.51	4.39	3.55	50.48
2001	3.28	3.58	2.68	4.11	8.00	1.67	3.44	8.28	4.31	5.27	10.93	5.25	60.80
2002	3.55	2.36	2.43	9.60	3.41	4.15	1.36	2.00	8.34	1.14	0.34	3.47	42.15
2003	2.49	4.64	1.92	14.16	4.06	1.51	6.26	5.93 a	8.72	7.75	25.43	8.41	91.28
2004	2.75	3.41	4.04	3.24	10.04	1.47	3.84	2.22	24.26	7.37	14.94	5.78	83.36
2005	9.23	0.70	0.35	2.67	7.55	3.45	0.00 z	0.00 z	8.15	0.00 z	5.30 a	2.61	40.01
2006	7.50	1.41	11.28	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	20.19
Period of Record Statistics													
MEAN	3.05	2.66	2.28	4.30	4.39	3.17	3.22	5.05	7.62	6.71	5.97	3.78	54.17
S.D.	1.63	1.51	1.83	3.07	2.39	2.13	1.79	3.23	5.87	6.08	5.13	2.22	19.99
SKEW	1.84	1.36	3.03	1.64	0.42	0.88	0.28	1.60	1.58	3.94	2.04	1.07	0.85
MAX	9.23	8.27	11.28	14.16	10.04	8.82	6.30	15.20	24.26	38.08	25.43	9.61	104.50
MIN	0.93	0.50	0.32	0.13	0.64	0.24	0.63	1.23	1.55	1.14	0.34	0.50	24.52
NO YRS	39	39	42	40	39	36	37	33	37	36	36	33	22

Table 3: Monthly Precipitation in Barranquitas, Puerto Rico

BARRANQUITAS, PUERTO RICO

Monthly Total Precipitation (inches)

(660736)

File last updated on Jul 28,
*** Note *** Provisional Data *** After Year/Month 199112
a = 1 day missing, b = 2 days missing, c = 3 days, ..etc..,
z = 26 or more days missing, A = Accumulations present
Long-term means based on columns; thus, the monthly row may not
sum (or average) to the long-term annual value.
MAXIMUM ALLOWABLE NUMBER OF MISSING DAYS : 5
Individual Months not used for annual or monthly statistics if more than 5 days are missing.
Individual Years not used for annual statistics if any month in that year has more than 5 days missing.

YEAR(S)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1955	3.35	2.63	2.43	3.13	3.41	3.78	3.89	12.41	14.26	4.07	5.91	3.69	62.96
1956	3.40	4.51	1.49	4.38	7.37	7.96	2.08	9.24	3.15	9.93	5.77	4.35	63.63
1957	2.12	1.37	1.59	3.23	1.78	4.46	2.41	3.89	8.02	3.55	6.45	5.23	44.10
1958	6.98	0.69	1.55	3.70	8.39	5.89	7.59	5.53	7.57	7.63	3.36	3.17	62.05
1959	2.38	3.35	0.91	6.56	7.98	1.42	6.65	4.81	3.78	3.38	3.19	3.04	47.45
1960	3.68	3.89	2.18	6.43	5.34	3.53	4.99	3.91	19.00	5.37	4.55	9.95	72.82
1961	2.24	2.08	3.26	4.74	2.45	2.81	0.00 z	0.00 z	0.00 z	0.00 z	6.16	6.87	30.61
1962	3.93	1.63	2.66	8.33	10.75	4.06	3.13	6.66	8.85	5.68	1.82	3.02	60.52
1963	4.40	2.94	0.00 z	7.13	10.14	2.02	3.76	7.85	7.22	7.73	6.00	1.49	60.68
1964	2.52	1.07	1.85	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	5.44
1965	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	3.72	4.79	3.71	3.08	3.28	11.58	30.16
1966	2.79	1.44	4.59	4.24	4.67	2.85	4.78	4.47	5.78	7.14	6.21	4.96	53.92
1967	3.00	3.73	1.80	2.95	2.05	2.72	4.19	2.64	3.71	7.26	7.67	1.40	43.12
1968	3.90	2.13	3.56	2.35	5.66	6.47	2.84	3.84	3.65	0.00 z	12.19	2.73	49.32
1969	9.24	2.40	6.12	9.14	15.46	3.41	3.85	3.17	8.93	6.01	10.33	2.76	80.82
1970	3.60	1.44	1.89	2.14	12.78	7.62	6.61	10.88	6.34	36.19	11.58	10.29	111.36
1971	3.94	3.73	2.28	12.17	0.00 z	0.00 z	0.56 p	6.66	3.52	7.48	4.74	2.78	47.30
1972	3.00	1.12	0.00 z	0.00 z	0.00 z	1.36	2.27	0.00 z	5.70	4.54	2.06	2.44	22.49
1973	0.80	2.32	2.33	1.88	2.59	1.78	1.41	4.61	3.13	6.23	1.27	2.40	30.75
1974	5.75	2.14	2.15	2.73	2.73	2.03	1.60	5.11	5.71	10.49	11.08	3.48	55.00
1975	4.14	0.75	1.75	2.84	1.85	0.00	4.05	3.21	11.49	4.24	1.52	8.88	44.72
1976	1.06	3.25	2.56	2.83	2.22	1.30	0.95	4.20	4.04	7.78	1.18	2.73	34.10
1977	1.86	1.95	1.69	2.05	2.52	0.00	1.84	5.04	5.10	0.00 z	5.53	2.13	29.71
1978	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	1.39	3.66	5.87	12.14	2.97	1.20	27.23
1979	4.96	0.26	0.00 z	0.00 z	0.00 z	10.70	10.42	13.06	0.00 z	0.00 z	0.00 z	0.00 z	39.40
1980	0.00 z	0.00 z	3.24	7.24	7.21	1.13	2.12	2.84	10.44	9.40	1.20	4.25	49.07
1981	5.93	2.67	5.28	0.00 z	0.00 z	4.82	3.26	3.51	6.86 j	12.95	3.69	7.24	49.35
1982	1.05	3.20	0.95	1.19	7.41	1.31	3.93	1.41	9.44	6.61	5.77	4.71	46.98
1983	1.74	0.32	4.31	7.81	5.19	8.24	2.60	4.48	1.20	6.26	4.17	1.48	47.80
1984	2.72	1.95	0.62	3.53	2.89	3.09	4.18	2.94	11.17	5.55	14.88	0.00 z	53.52
1985	0.64	2.60	0.97	5.69	9.36	1.53	2.36	5.11	5.53	29.63	5.94	1.88	71.24
1986	1.57	0.70	1.52	7.84	14.28	13.49	1.97	3.51	2.06	1.93	7.83	0.16	56.86
1987	0.67 c	0.00 z	0.00 z	10.72	0.00 z	0.00 z	0.33	4.05	1.42 k	1.62	12.77	8.49	38.65
1988	3.14	1.22	1.53	0.00 z	1.60	0.00 z	2.05	5.32	0.00 z	0.00 z	4.69	1.18	20.73
1989	1.07	0.34	0.92	0.95	3.30	0.20	1.41	1.14	0.00 z	0.32	0.00 z	0.00 z	9.65
1990	3.28	0.00 z	1.27	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	4.75	9.30
1991	1.20	5.15	4.73	2.85 d	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	0.00 z	3.58	1.02 a	18.53
Period of Record Statistics													
MEAN	3.12	2.16	2.39	4.85	5.98	3.79	3.39	5.12	6.73	8.08	5.74	4.11	57.38
S.D.	1.90	1.26	1.39	2.94	4.06	3.27	2.12	2.82	3.96	7.54	3.61	2.95	18.41
SKEW	1.14	0.42	1.10	0.79	0.83	1.27	1.40	1.44	1.24	2.62	0.87	1.05	1.24
MAX	9.24	5.15	6.12	12.17	15.46	13.49	10.42	13.06	19.00	36.19	14.88	11.58	111.36
MIN	0.64	0.26	0.62	0.95	1.60	0.00	0.33	1.14	1.20	0.32	1.18	0.16	30.75
NO YRS	34	32	31	29	27	29	32	32	28	29	33	33	19

Table 4: Table of Soils in Puerto Rico

TABLE 1. *Summary of environmental data for the soil survey of timberland[a] in Puerto Rico by forest class. All data are expressed as percent of 130,500 ha (Birdsey and Weaver 1982).*

Environmental parameter	All forest classes combined	Secondary forest	Coffee shade		Nonstocked[b] areas
			Abandoned	Active	
Subtropical moist forest					
Deep volcanic soils	6.7	3.7	1.5	0.8	0.8
Shallow volcanic soils	16.3	9.6	3.4	0	3.4
Granitic soils	7.4	6.2	1.1	0	0
Limestone soils	15.9	9.5	2.1	1.1	3.2
Subtotal	46.3	29.0	8.1	1.9	7.4
Subtropical wet forest					
Deep volcanic soils	39.2	11.0	15.0	12.3	0.8
Shallow volcanic soils	7.0	0.9	4.4	1.8	0
Granitic soils	6.9	3.8	1.7	0.5	0.8
Limestone soils	0.6	0.6	0	0	0
Subtotal	53.7	16.3	21.1	14.6	1.6
Total	100.0	45.3	29.2	16.5	9.0
Stand age					
<30 yr	66.1	32.3	12.9	12.0	9.0
>30 yr	29.1	11.4	13.8	3.8	0
Mixed	4.8	1.6	2.5	0.7	0
Total	100.0	45.3	29.2	16.5	9.0
Timber volume class					
<25 m^3/ha	40.4	20.8	4.0	6.6	9.0
25–75 m^3/ha	42.6	14.1	19.3	9.2	0
>75 m^3/ha	17.0	10.4	5.9	0.7	0
Total	100.0	45.3	29.2	16.5	9.0

[a] Forest land capable of producing crops of industrial wood and not withdrawn from that use.
[b] Commercial forest land <10% stocked with trees that have commercial potential; early secondary forest in many instances.

http://www.jstor.org (2007)

Table 5: Description of Different Trail Grades

Table 1. Description of Different Trail Grades.

Percent Grade	Description
0 to 2	Nearly level
3 to 6	Gently sloping
7 to 12	Moderately sloping
13 to 18	Moderately steep
19 to 25	Steep
26 and greater	Very steep

Courtesy of Rathke and Baughman, (2007)

Table 6: Filter Strip Width Guide for Trails

Table 2. Filter Strip Width Guide for Trails.

Land Grade Between Trail and Body of Water (percent)	Recommended Filter Strip Width (feet)
0 to 1	25
2 to 10	30 to 50
11 to 20	51 to 70
21 to 40	71 to 110
41 to 70	111 to 170

Courtesy of Rathke and Baughman, (2007)

Table 7: Soil Textural Classes

Table 3. Soil Textural Classes.

Soil Texture	Identification
Sand	Loose and gritty. Will not form a ball.
Loam	Smooth (flour-like), but slightly gritty. Forms a ball, but ribbon usually breaks easily.
Silt	Smooth like flour, no grittiness. Forms ribbon that breaks under its own weight.
Clay	Smooth and sticky when wet. Forms ribbon that is long and pliable.
Organic (peat, muck)	High amount of decomposed material and water. Black to brown color. Wetlands, low areas.

Courtesy of Rathke and Baughman, (2007)

Table 8: Results of study by Sang-Oh Kim

Table 4. Waterbar Spacing for Trails.

Percent Grade	Spacing Between Waterbars (feet)
2	250
5	130
10	80
15	50
25+	40

Courtesy of Rathke and Baughman, (2007)

Table 9: Backslope Cut Ratios by Soil Type

Table 5. Backslope Cut Ratios by Soil Type.

Soil Type	Backslope Cut Ratio (horizontal:vertical)
Sand	3 or 4 : 1
Moist clay	2 or 3 : 1
Loose, gravelly soil or organic	1.5 or 2 : 1
Loose rock	0.5 : 1
Stable rock	0.25 : 1

Courtesy of Rathke and Baughman, (2007)

Table 10: Recommended Trail Standards

Hiking

- **Trail Layout**
  Trail patterns vary depending on the expectations of the trail user. Day users tend to favor a loop or a series of loops. Design trails to cover a variety of vegetation, land forms, and sights. Frequently occurring curves and grade changes will add interest. Short spur trails may be used to access waterways and summits.
- **Length**
  Hikers travel at 1 to 3 miles per hour depending on the terrain and their ability. Hiking trails should be long enough to afford a meaningful recreational experience and short enough to suit a hiker's ability. Internal connector trails and cutoffs can be used to offer different trail lengths.

Day use: 1/4 to 5 miles (1/2 day)
5 to 15 miles (full day)

Backpacking: 25 or more miles

- **Clearing Width**
  Vary clearing widths to avoid the tunnel effect and promote a variety of trail environments such as woodland flowers, meadow openings, and woodland edges. Trails generally should narrow on steep slopes to a minimum width of 3 feet.

  Light use: 4 to 6 feet (one-way traffic)

  Heavy use: 7 to 10 feet (two-way traffic)

- **Clearing Height**
  8 feet. Additional clearance may be needed to compensate for extended backpacks and branches drooping with heavy rain or snow.
- **Tread Width**

  Light use: 2 to 3 feet (one-way traffic)

  Heavy use: 4 to 6 feet (two-way traffic)

- **Trail Surface**

  Light use: Natural with gravel or corduroy used in wet areas

  Heavy use: Natural if possible; woodchips or gravel

- **Turning Radius**
  Turning radius is not critical; however, gentle curves are aesthetically pleasing and easier to maintain. Shortcut trails often will develop prior to sharp-angled turns. Straight sections usually should not exceed 100 feet.
- **Percent Grade**
  Grades exceeding 10 percent are difficult for hikers to sustain and, without additional protection, erosion problems often will develop. Steps, switchbacks, or water bars may be needed on slopes over 25 percent. Occasional grade changes and dips should be incorporated into the trail layout to promote user interest and facilitate natural drainage.

  Desired: 0 to 5%

Maximum: 15% (sustained)
40% (shorter than 50 yards)

Outslope: 4% (maximum)

- **Sight Distance**
  Sight distances are not especially critical on hiking trails. However, motorized road crossings must be carefully located and designed to ensure that trail users and vehicle drivers have good sight distances in all directions.
- **Water Crossings**
  Structures for crossing water depend on the flow and length of the crossing and expectations of the hiker - almost all methods will accommodate foot traffic.

Bridges: Must be located above ordinary high water mark or cabled at one end to prevent washout.

Width:

2 to 4 feet (light use)
5 to 6 feet (heavy use)
8 feet or more (maintenance vehicles)

Weight capacity:

Variable depending on maintenance equipment, bridge length, and alternative trail uses

Fords: Slow moving water less than 24 inches in depth may be forded. Rocks and stepping stones may be used to assist hikers.

- **Compatible Uses (with additional trail design standards)**

Winter: Snowshoeing, ski touring, or snowmobiling

Summer: Horseback riding (low use), or accessibility trails for persons with disabilities

- **Facilities**
  Parking area, picnic area, resting areas, overlooks, campsites, water, information board, signs

Courtesy of Rathke and Baughman, (2007)

Table 11: Recommended Accessible Trail Standards

	Access Route (ADAAG)	Outdoor Access Route	Trail
Surface	Stable, firm, Slip resistant	Firm and Stable	Firm and Stable *Exception**
Max Running Slope	1: 12	1: 20 (for any distance) 1: 12 (for max 50 ft) 1: 10 (for max 30 ft)	1: 20 (for any distance) 1: 12 (for max 200 ft) 1: 10 (for max 30 ft) 1: 8 (for max 10 ft) *Exception- 1: 7 (for 5 ft max for open drainage structures)* *Exception**
Max Cross Slope	1: 50	1: 33 *Exception- 1: 20 (for drainage purposes)*	1: 20 *Exception- 1: 10 (at the bottom of an open drain where clear tread width is a min of 42 inches)*
Min Clear Tread Width	36 inches 32 inches (for no more than 24 inches)	36 inches *Exception- 32 inches when * applies*	36 inches for any distance *Exception- 32 inches when * applies.*
Edge Protection	Where provided, min of 2 inches.	Where provided, min of 3 inches.	Where provided, 3 inches min.
Tread Obstacles	(Changes in Level) 1/4 inch (no beveled edge) 1/4 - 1/2 inch must have a beveled edge with a max slope of 1: 2. Over 1/2 inch= ramp.	1 inch high max *Exception- 2 inches high max (where beveled with a slope no greater than 1: 2 and where * applies.)*	2 inches high max *Exception- 3 inches max (where running and cross slopes are 1: 20 or less)* *Exception**
Passing Space	Every 200 feet where clear tread width is less than 60 inches, a minimum 60 X 60 inch space, or a t-shaped intersection of two walks or corridors with arms and stem extending min of 48 inches.	Every 200 feet where clear tread width is less than 60 inches, a minimum 60 X 60 inch space, or a t-shaped intersection of two walking surfaces with arms and stem extending min of 48 inches. *Exception- every 300 feet where * applies.*	Every 1000 feet where clear tread width is less than 60 inches, a 60 X 60 inch min passing space or a t-shaped intersection of two walking surfaces with arms and stem extending min of 48 inches. *Exception**
Resting Intervals	(Landings) 60 inch min length, min width as wide as the ramp run leading to it, if change in direction occurs, must have 60 X 60 inch space.	60 inches min length, width at least as wide as the widest portion of the trail segment leading to the resting interval and a max slope of 1: 33 *Exception- a max slope of 1: 20 is allowed for drainage purposes.*	60 inches min length, width at least as wide as the widest portion of the trail segment leading to the resting interval and a maximum slope of 1: 20. *Exception**

* (16.1.1 Conditions for Departure) The provision may not apply if it cannot be provided because compliance would cause substantial harm to cultural, historic, religious or significant natural features or characteristics; substantially alter the nature of the setting or purpose of the facility; require construction methods or materials that are prohibited by Federal, state or local regulations or statutes; or would not be feasible due to terrain or the prevailing construction practices.

Courtesy of the National Center on Accessibility, (2002)

APPENDIX D: FIGURES

Figure 1: Life Zones and Soil Types

The life zones and soil types are significant in our consideration for the trail surfaces to be recommended for the proposed trails in the canyon.

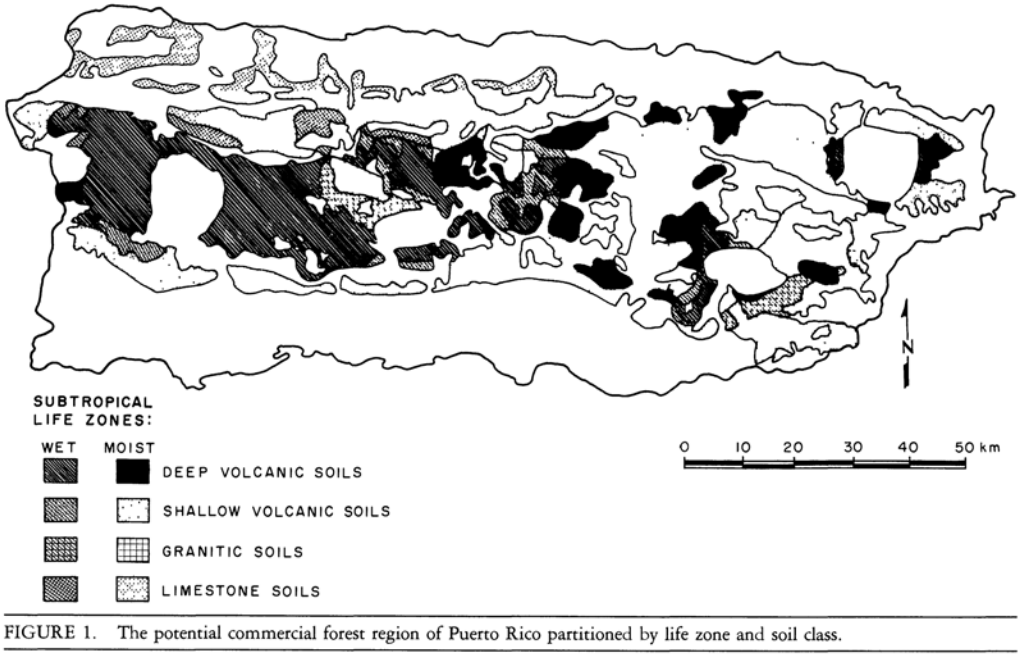


FIGURE 1. The potential commercial forest region of Puerto Rico partitioned by life zone and soil class.

Taken from: Weaver, Birdsey & Lugo, 1987

Figure 2: Trail Clearance Image

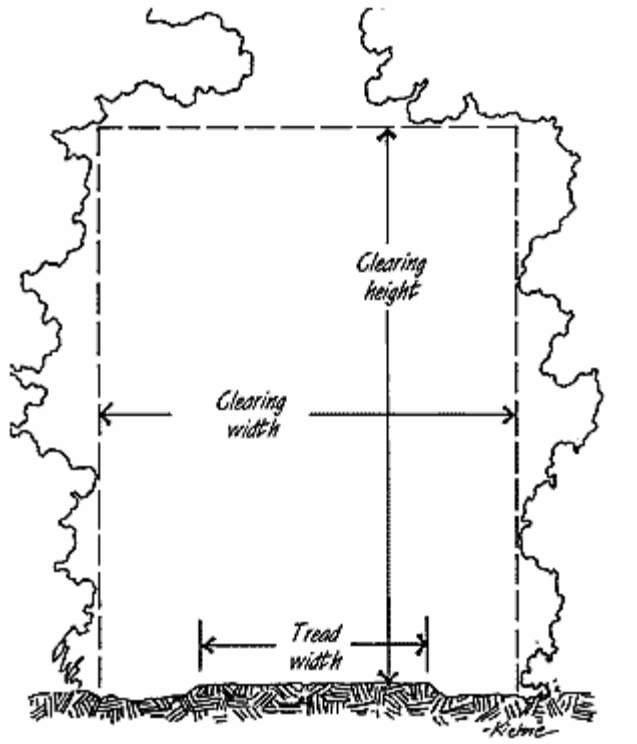
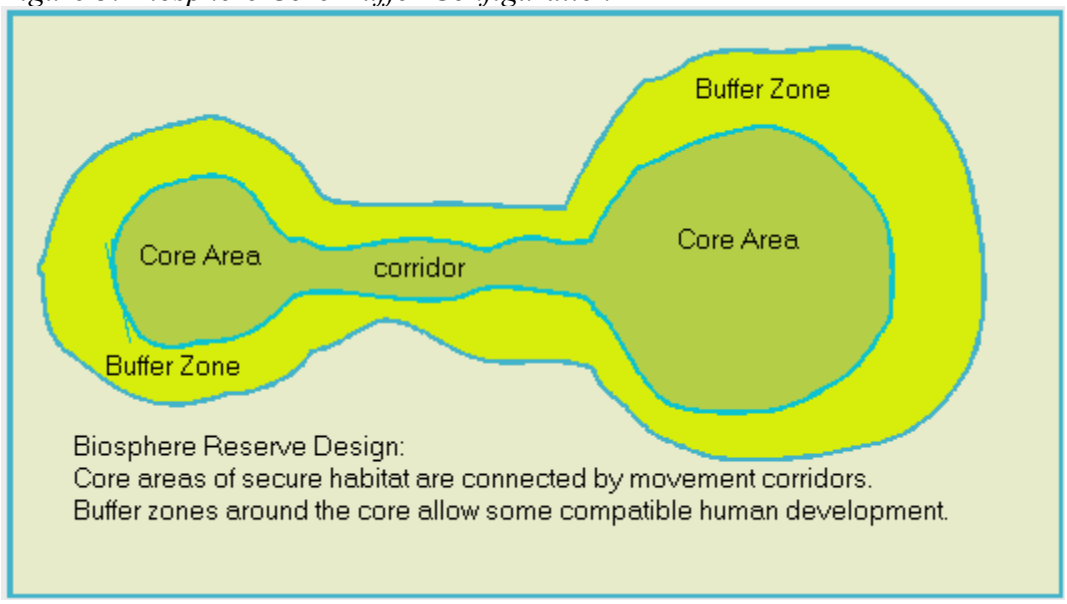


Figure 4. A trail corridor normally is cleared to a minimum height of 8 feet and a width of 4 to 6 feet.

Figure 3: Biosphere Core-Buffer Configuration



Courtesy of www.wildlands.org/corridor/reserve.html

APPENDIX E: GENERAL INFORMATION

GEOGRAPHY OF THE PUERTO RICAN ISLANDS

Two islands that belong to Puerto Rico can be found off the coast, to the east. They are Vieques, which is approximately 125 square kilometers, and Culebra, which is much smaller, approximately twenty-five square kilometers.

VOLANIC AND PLUTONIC ACTIVITY OF PUERTO RICO

The volcanic and plutonic activity on the island changed at the end of the Middle Eocene era, about forty-five million years ago. The motion of the Caribbean plate shifted to the east. The sea floor spreading occurring in this zone is pushing the Caribbean plate to the east to where the western part of the North American plate is being subducted. The subduction that once took place along the north border of the Caribbean plate has been replaced by a strike-slip motion of the two tectonic plates. This strike-slip motion is the source of many earthquakes in Puerto Rico (Refer to Appendix A for a chart of earthquake frequencies in Puerto Rico). The majority of these earthquakes cannot be felt; however, there are some earthquakes that do reach a magnitude of four or five on the Richter scale.

PUERTO RICO GENERAL TEMPERATURES

Puerto Rico's average temperatures have very little variation throughout the year. The island is located within the topical zone of the world globe. In the coldest months, January and February, the average temperature is around seventy-five degrees, with the warmest month, typically August, averaging around eighty degrees. Puerto Rico does not

experience freezing temperatures, and coastal regions experience significantly less variation in temperature throughout the year (The Climate of Puerto Rico, n.d.).

PUERTO RICO GENERAL GEOLOGICAL INFORMATION

The geology of Puerto Rico is a very unique but a relatively simple one. The island is approximately 135 million years old, which is considered young geologically. The two islands were actually one piece of land; however the sea level covers the shallow areas of this land. During the middle ages when the sea levels were significantly lower, the islands were one island above sea level. The Puerto Rico trench is located along the northern border. That trench is the deepest point in the Atlantic Ocean at 8,516 meters deep (Geological Information, 2001).

LAND SUITABILITY ASSESSMENT

The process that is required to determine exactly where the trails should be is a land suitability assessment, or LSA. A LSA is a technique use to determine the suitability of land for the purposes set forth by the stakeholder, in our case, the Conservation Trust of Puerto Rico. The whole purpose of a land suitability assessment is to demonstrate how to best utilize the reserve.

LAND SUITABILITY

Suitability can be defined as the fitness of a particular area for a defined use (Steiner, 1983). There are five basic suitability classes that can be used to describe the fitness of the reserve (Food and Agricultural Organization of the United Nations, n.d.):

Very Suitable (VS) - 80 percent or more of the land is completely suitable for the trails

Suitable (S) - 60 percent to less than 80 percent of the land is completely suitable for the trails

Moderately Suitable (MS) - 40 percent to less than 60 percent of the land is completely suitable for the trails

Marginally Suitable (mS) - 20 percent to less than 60 percent

Not Suitable (NS) - less than 20 percent of the land is usable.

The maximum attainable yield is the best possible suitability in that particular area. The results of a land suitability assessment will allow the Conservation Trust to protect the most delicate features of the Reserve, allow access to the most important geological and ecological features and designate areas that are not suitable and/or dangerous for a trail.

PARK MANAGEMENT

Planning a sustainable nature reserve requires a long-term approach during the design phase. This requires building a foundation for future analysis and park management. Understanding some of the basics of park management can help during the initial planning. One of these basic elements is the concept of carrying capacity and the effect it has on sustainability.

Carrying capacity has many complications, including its definition. In the past, carrying capacity has been defined as a set number of visitors that, once exceeded, will result in the inevitable degradation of conditions within the park (Prato, 2001). The notion of a 'magic number' for visitor traffic has come into question by many authors (McCool and Lime, 2001; Prato, 2001; Manning, 2002). McCool and Lime (2001) argue that the concept of a fixed number carrying capacity is flawed, and that, depending on the objectives defined, an area may have many different carrying capacities. Prato (2001) suggests that, instead of searching for a magic number, park managers and designers need

to decide on a set of objectives for various aspects of the park. According to Prato (2001) and others (Clivaz, Hausser and Michelet, n.d.), these aspects include the acceptable amount of change to the ecosystem, amount of tourism traffic before visitors experience negative effects due to overcrowding, income required for park operation, and any other variables that managers feel need to be controlled for the sustainability of the reserve. Failure to consider all variables can result in an inadequate management plan. This is shown by the Yosemite National Park's failure to consider user capacity as described later in this section (Bacon, Roche, Elliot, and Nicholas, 2006).

The Forest and Rangeland Renewable Resources Planning Act of 1974 (Forest Service, 1974) requires every national park in the United States to create a resource management plan to help control and maintain its resources. According to Schmoldt and Peterson (2001), those parks often fail to analyze the various needs of the park, resulting in an inadequate resource management plan that does not properly control resources and maintain the integrity of the environment. An example where park management failed was in Yellowstone National Park. Local communities who were dependant on tourism prevented the closing of damaging facilities such as ski slopes and snowmobile trails resulting in degradation and fragmentation of the natural environment (Goldstein, 1992).

To manage time and resources, Schmoldt and Peterson suggest using an analytic hierarchy process to determine the importance of specific onsite projects. Saaty describes the analytic hierarchy process in the following steps (Saaty, 1990),

1. Structure a problem with a model that shows the problem's key elements and their relationships.
2. Elicit judgments that reflect knowledge, feelings, or emotions.

3. Represent those judgments with meaningful numbers.
4. Use these numbers to calculate the priorities of the elements of the hierarchy.
5. Synthesize these results to determine an overall outcome.
6. Analyze sensitivity to changes in judgment.

Schmoldt and Peterson (2001) argue that applying these steps within a park can help analytically prioritize the needs of the park and allow more efficient budgeting and design to accommodate those needs. To test this theory, Schmoldt and Peterson (2001) completed a study at Olympic National Park where they used the analytic hierarchy process to prioritize eight local projects. It should be noted that those projects represented only a small sample of the 147 that actually existed in the park. Using different weighting schemes, Schmoldt and Peterson (2001) were able to devise theoretical priority and funding strategies and compare them to the actual funding received by the official resource management plan produced for the park. From this research, Schmoldt and Peterson (2001) concluded that the use of the analytic hierarchy process could more productively prioritize the various needs of the park than the commonly used, less rigorous approach.

Other authors have proposed different methods for controlling park resources. Prato (2001) suggests the use of an ex post adaptive ecosystem management model followed by an ex ante multiple attribute scoring test of capacity. The adaptive ecosystem management model uses data collected from the park to determine its condition and the level of compliance that various sections of the park have with management goals. If areas of the park are not in compliance, the ex ante multiple attribute scoring test of capacity is used to quantitatively determine the best management

strategies to bring these areas into compliance Prato (2001). While this method seems promising, we have not been able to find an instance where this method has been tested under real world conditions.

One other method of park management is the Visitor Experience and Resource Protection as described by Manning (2002). This method is outlined in the following nine steps:

1. Assemble an Interdisciplinary Project Team
2. Develop a Public Involvement Strategy
3. Develop statements of Park Purpose, Significance, and Primary Interpretive Themes
4. Analyze Park Resources and Existing Visitor Use
5. Describe a Potential Range of Visitor Experience and Resource Conditions (Potential Prescriptive Zones)
6. Allocate the Potential Zones to Specific Locations in the Park (Prescriptive Management Zoning)
7. Select Indicators and Specify Standards for Each Zone; Develop a Monitoring Plan
8. Monitor Resource and Social Indicators
9. Take Management Action

Visitor Experience and Resource Protection was originally used in Arches National Park, Utah for the purpose of testing and refinement. The purpose of the Visitor Experience and Resource Protection framework was to act as a model for the rest of the national park system. The National Park Service has adopted the Visitor Experience and Resource Protection framework, using it in several national parks, and has developed a Visitor Experience and Resource Protection handbook and workbook (Manning, 2002). While the Visitor Experience and Resource Protection handbook, provided on the National Park Service website, has not been updated since 1997 (National Park Service, 1997), the Visitor Experience and Resource Protection framework has been extensively and recently used in parks such as Yosemite National Park. In 2000, a management plan

for the Merced River in Yosemite was completed. After resulting public criticism and legal actions, it was realized that the park had not properly planned for user capacity. It was later decided to use the Visitor Experience and Resource Protection framework to better manage the Merced Wild and Scenic River Corridor (Bacon *et al*., 2006). This process started with the identification of desired conditions followed by management zoning. The three zones used were wilderness, diverse visitor experience, and developed. Ten indicator variables were established with each having standards of quality determined by professional practice and scientific research. Methods for continuous monitoring of these indicators were developed. The information provided by the indicators was used to take management action when these data showed deviation from desired conditions. The entire process used for the Merced River is continuously monitored and refined in an iterative process for the purpose of approaching an optimal management plan (Bacon *et al*., 2006).

STATUTORY FRAMWORK FOR BIOSPHERE RESERVES

The Statutory Framework of the World Network of Biosphere Reserves

- Introduction
- Article 1 - Definition
- Article 2 - World Network of Biosphere Reserves
- Article 3 - Functions
- Article 4 - Criteria
- Article 5 - Designation procedure
- Article 6 - Publicity
- Article 7 - Participation in the Network
- Article 8 - Regional and thematic subnetworks
- Article 9 - Periodic review
- Article 10 - Secretariat

Introduction

Within UNESCO's Man and the Biosphere (MAB) programme, biosphere reserves are established to promote and demonstrate a balanced relationship between humans and the biosphere. Biosphere reserves are designated by the International Co-ordinating Council of the MAB Programme, at the request of the State concerned. Biosphere reserves, each of which remains under the sole sovereignty of the State where it is situated and thereby submitted to State legislation only, form a World Network in which participation by the States is voluntary.

The present Statutory Framework of the World Network of Biosphere Reserves has been formulated with the objectives of enhancing the effectiveness of individual biosphere reserves and strengthening common understanding, communication and co-operation at regional and international levels.

This Statutory Framework is intended to contribute to the widespread recognition of biosphere reserves and to encourage and promote good working examples. The delisting procedure foreseen should be considered as an exception to this basically positive approach, and should be applied only after careful examination, paying due respect to the cultural and socio-economic situation of the country, and after consulting the government concerned.

The text provides for the designation, support and promotion of biosphere reserves, while taking account of the diversity of national and local situations. States are encouraged to elaborate and implement national criteria for biosphere reserves which take into account the special conditions of the State concerned.

Article 1 - Definition

Biosphere reserves are areas of terrestrial and coastal/marine ecosystems or a combination thereof, which are internationally recognized within the framework of UNESCO's programme on Man and the Biosphere (MAB), in accordance with the present Statutory Framework.

Article 2 - World Network of Biosphere Reserves

1. Biosphere reserves form a worldwide network, known as the World Network of Biosphere Reserves, hereafter called the Network.
2. The Network constitutes a tool for the conservation of biological diversity and the sustainable use of its components, thus contributing to the objectives of the Convention on Biological Diversity and other pertinent conventions and instruments.
3. Individual biosphere reserves remain under the sovereign jurisdiction of the States where they are situated. Under the present Statutory Framework, States take the measures which they deem necessary according to their national legislation.

Article 3 - Functions

In combining the three functions below, biosphere reserves should strive to be sites of excellence to explore and demonstrate approaches to conservation and sustainable development on a regional scale:

(i) conservation - contribute to the conservation of landscapes, ecosystems, species and genetic variation;

(ii) development - foster economic and human development which is socio-culturally and ecologically sustainable;

(iii) logistic support - support for demonstration projects, environmental education and training, research and monitoring related to local, regional, national and global issues of conservation and sustainable development.

Article 4 - Criteria

General criteria for an area to be qualified for designation as a biosphere reserve:

1. It should encompass a mosaic of ecological systems representative of major biogeographic regions, including a gradation of human interventions.
2. It should be of significance for biological diversity conservation.
3. It should provide an opportunity to explore and demonstrate approaches to sustainable development on a regional scale.

4. It should have an appropriate size to serve the three functions of biosphere reserves, as set out in Article 3.
5. It should include these functions, through appropriate zonation, recognizing:
(a) a legally constituted core area or areas devoted to longterm protection, according to the conservation objectives of the biosphere reserve, and of sufficient size to meet these objectives;
(b) a buffer zone or zones clearly identified and surrounding or contiguous to the core area or areas, where only activities

compatible with the conservation objectives can take place;
(c) an outer transition area where sustainable resource management practices are promoted and developed.
6. Organizational arrangements should be provided for the involvement and participation of a suitable range of inter alia public authorities, local communities and private interests in the design and carrying out the functions of a biosphere reserve.
7. In addition, provisions should be made for:
(a) mechanisms to manage human use and activities in the buffer zone or zones;
(b) a management policy or plan for the area as a biosphere reserve;
(c) a designated authority or mechanism to implement this policy or plan;
(d) programmes for research, monitoring, education and training.

Article 5 - Designation procedure

1. Biosphere reserves are designated for inclusion in the Network by the International Co-ordinating Council (ICC) of the MAB programme in accordance with the following procedure:
(a) States, through National MAB Committees where appropriate, forward nominations with supporting documentation to the secretariat after having reviewed potential sites, taking into account the criteria as defined in Article 4;
(b) the secretariat verifies the content and supporting documentation: in the case of incomplete nomination, the secretariat requests the missing information from the nominating State;
(c) nominations will be considered by the Advisory Committee for Biosphere Reserves for recommendation to ICC;
(d) ICC of the MAB programme takes a decision on nominations for designation. The Director-General of UNESCO notifies the State concerned of the decision of ICC.
2. States are encouraged to examine and improve the adequacy of any existing biosphere reserve, and to propose extension as appropriate, to enable it to function fully within the Network. Proposals for extension follow the same procedure as described above for new designations.
3. Biosphere reserves which have been designated before the adoption of the present Statutory Framework are considered to be

already part of the Network. The provisions of the Statutory Framework therefore apply to them.

Article 6 - Publicity

1. The designation of an area as a biosphere reserve should be given appropriate publicity by the State and authorities concerned, including commemorative plaques and dissemination of information material.
2. Biosphere reserves within the Network, as well as the objectives, should be given appropriate and continuing promotion.

Article 7 - Participation in the Network

1. States participate in or facilitate co-operative activities of the Network, including scientific research and monitoring, at the global, regional and subregional levels.
2. The appropriate authorities should make available the results of research, associated publications and other data, taking into account intellectual property rights, in order to ensure the proper functioning of the Network and maximize the benefits from information exchanges.
3. States and appropriate authorities should promote environmental education and training, as well as the development of human resources, in co-operation with other biosphere reserves in the Network.

Article 8 - Regional and thematic subnetworks

States should encourage the constitution and co-operative operation of regional and/or thematic subnetworks of biosphere reserves, and promote development of information exchanges, including electronic information, within the framework of these subnetworks.

Article 9 - Periodic review

1. The status of each biosphere reserve should be subject to a periodic review every ten years, based on a report prepared by the concerned authority, on the basis of the criteria of Article 4, and forwarded to the secretariat by the State concerned.
2. The report will be considered by the Advisory Committee for Biosphere Reserves for recommendation to ICC.
3. ICC will examine the periodic reports from States concerned.
4. If ICC considers that the status or management of the biosphere reserve is satisfactory, or has improved since designation or the last review, this will be formally recognized by ICC.
5. If ICC considers that the biosphere reserve no longer satisfies the criteria contained in Article 4, it may recommend that the State concerned take measures to ensure conformity with the provisions of Article 4, taking into account the cultural and socio-economic context of the State concerned. ICC indicates to the secretariat actions that it should take to assist the State concerned in the implementation of such measures.
6. Should ICC find that the biosphere reserve in question still does not satisfy the criteria contained in Article 4, within a reasonable period, the area will no longer be referred to as a biosphere reserve which is part of the Network.

7. The Director-General of UNESCO notifies the State concerned of the decision of ICC.
8. Should a State wish to remove a biosphere reserve under its jurisdiction from the Network, it notifies the secretariat. This notification shall be transmitted to ICC for information. The area will then no longer be referred to as a biosphere reserve which is part of the Network.

Article 10 - Secretariat

1. UNESCO shall act as the secretariat of the Network and be responsible for its functioning and promotion. The secretariat shall facilitate communication and interaction among individual biosphere reserves and among experts. UNESCO shall also develop and maintain a worldwide accessible information system on biosphere reserves, to be linked to other relevant initiatives.
2. In order to reinforce individual biosphere reserves and the functioning of the Network and subnetworks, UNESCO shall seek financial support from bilateral and multilateral sources.
3. The list of biosphere reserves forming part of the Network, their objectives and descriptive details, shall be updated, published and distributed by the secretariat periodically.

GLOSSARY

ROCK DEFINITIONS

- **Amphibolite:** A metamorphic rock that contains mostly ferro-magnesium silicates. Its most distinctive property is the ability to cleave along two directions.
- **Basalt:** An ingneous rock characteristically black, dense, and massive. It is the most abundant extrusive volcanic rock and constitutes most of the oceanic crust.
- **Faults:** A fracture along which significant movement has occured.
- **Gneiss:** A metamorphic rock in which foliation results from layers of different mineral groups. The foliation may range from semi-continuous layers of light and dark minerals to highly contorted, well-defined layers.
- **Igneous:** Rock fromed from cooling and solidification of magma that has not been changed appreciably since its formation.
- **Limestone** Sedimentary rock that contains more than 50% calcium carbonate. The calcite may precipitated chemically (hot springs) or organically (microogranisms) or may be of detrital origin (shell fragments).
- **Magma** Molten rock.
- **Mantle** The inner layer below the outer crust of the earth.
- **Metamorphic:** Rock derived from pre-existing rocks but differ from them in physical, chemical, or mineralogical properties as the result of natural geologic processes, principally heat and pressure, originating from within the earth.
- **Pangea:** The hypothetical single continent that split into fragments and began to drift apart during the Jurassic Period.
- **Tectonic or Continental Plates:** Relatively strong, brittle outer rigid blocks or plates that make up the crust of the earth and that move relative to each other ovar a more plastic inner mantle.
- **Trench:** A narrow, elongate depression on the deep sea floor parallelling the trend of an island arc or continental margin.
- **Sedimentary:** Rock derived from erosional debris and precipitates of other rocks deposited at the earth's surface at normal pressures and temperatures. the major processes involved in the formation of sedimentary rocks are: 1) physical and chemical weathering of parent rock material; 2) transportation of the weathered products by running water, wind, gravity, or ice; 3) deposition in a sedimentary basin or platform; 4) compaction and cementation of the sediment into rock.
- **Serpintinite** A metamorphic rock derived from the alteration of magnesium rich silicate minerals in water rich environments under low temperature.
- **Volcanic** Igneous rocks formed from magma that erupts at the surface, cools, and solidifies.
- Zone of Subduction A zone where one continental or tectonic plate is pulled down underneath another.

Courtesy of: http://cgsc.biology.yale.edu/geodef.html (2007)

REFERENCES

All Around the House. (n.d.). *Termites.* Retrieved April, 12, 2007, from http://www.electrospec.ca/lib.stu.t3.htm

Australian Government. (2007). *Department of the Environment and Water Resources.* Retrieved April 30, 2007, from http://www.environment.gov.au/

Bacon, J., Roche, J., Elliot, C., & Nicholas, N. (2006). VERP: Putting principles into practice in yosemite national park. [Electronic version]. *The George Wright Forum, 23*(2), 73-83. Retrieved February 23, 2007

Balogh, A. (n.d.). *Slip Industries Makes Finishing Tools that Last, and Last...and Last.* Retrieved April, 30, 2007, from http://www.concretenetwork.com/anne_balogh/slip_industries.htm

Batisse, M. (1982). The Biosphere Reserve: A Tool for Environmental Conservation and Management. *Environmental Conservation, 9*(2), 101-111.

Batisse, M. (1997). Biosphere Reserves: A Challenge for Biodiversity Conservation & Regional Development. *Environment*, April 30, 2007 from http://findarticles.com/p/articles/mi_m1076/is_n5_v39/ai_20036719

Biosphere reserves: Reconciling the Conservation of Biodiversity with Economic Development. Retrieved April, 12, 2007, from http://www.capebiosphere.co.za

Bojorquez, T., Luis, A., de la Cueva, H., Diaz, S., Melgarejo, D., & Alcanzar, G., et al. (2004). Environmental Conflicts and Nature Reserves: Redesigning Sierra San Pedro Mártir National Park, Mexico. Biological Conservation, 117, 111-126.

Bojorquez-Tapia. (2004). Building consensus in environmental impact assessment through multicriteria modeling and sensitivity analysis. *Journal of Environmental Management, 36*(3), 469-481.

Boonyanuphap, J., Wattanachaiyingcharoen, D., & Sakurai, K. (2004). GIS-Based Land Suitability Assessment for Musa (ABB group) Plantation [electronic version]. J. Appl. Hort, 6(1), 3-10.

Bossel, H. (1999). Indicators for Sustainable Development: Theory, Method, Applications. Canada: International Institute for Sustainable Development.

Bottomley, B. R. (1998). Mapping Rural Land Use & Land Cover Change in Carroll County, Arkansas Utilizing Multi-Temporal Landsat Thematic Mapper Satellite Imagery. University of Arkansas: Center for Advanced Spatial Technologies:

Brodie, H. L., & Carr, L. E. *Composting Animal Mortalities on the Farm*. University of Maryland, College Park: Department of Biological Resources Engineering.

Brunckhorst, D. (1998). Creating Institutions to Ensure Sustainable use of Resources. [Electronic version]. *Habitat International, 22*(3), 347-354.

Brunckhorst, D. (2001). Building Capital Through Bioregional Planning and Biospheres. *Ethics in Science and Environmental Politics,* 19-32.

Burr, S. W. (1995). What Research Says About Sustainable Tourism Development. Parks & Recreation, 1/30/2007

Bydekerke, L., Van Ranst, E., Vanmechelen, L., & Groenemans, R. (1998). Land Suitability Assessment for Cherimoya in Southern Ecuador Using Expert Knowledge and GIS [electronic version]. Agriculture, Ecosystems and Environment, 69, 89-98.

Cartwright, G. (2006). Composting Dead Poultry. Paper presented at the *Proceedings of the NZ Poultry Industry Conference,* Massey University, Palmerston North, New Zealand*, 8* 141-146. from http://www.eggfarmers.co.nz/uploads/8E738_Composting_Dead_Poultry.pdf

Christiansen. (1996). The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. *Ecological Applications, 6*, 665-691.

Clean Air Counts. (n.d.). *Low Impact Paving.* Retrieved April 30, 2007, from http://www.cleanaircounts.org/lowimpactpaving.shtml

The Climate of Puerto Rico. Retrieved 1/30, 2007, from http://cgsc.biology.yale.edu/prclim.html

Clivaz, C., Hausser, Y., & Michelet, J. Tourism Monitoring System Based on the Concept of Carrying Capacity–The Case of the Regional Natural Park Pfyn-Finges (Switzerland). [Electronic version].

Cropper, M., & Griffiths, C. (1994). The Interaction of Population Growth and Environmental Quality. [Electronic version]. *The American Economic Review, 84*(2), 250-254.

Crowfoot, & Wondolleck. (1990). *Environmental Disputes. Community Involvement in Conflict Resolution.* Washington DC: Island Press.

Daly, C., Helmer, E. H., & Quiñones, M. (2003). Mapping the Climate of Puerto Rico, Vieques and Culebra. [Electronic version]. International Journal of Climatology, 23, 1359-1381.

Day, E. (1996). *Termite.* Retrieved April, 12, 2007, from http://www.ext.vt.edu/departments/entomology/factsheets/eastterm.html

Dictionary.com unabridged (v 1.1). (n.d.). Sustain. Retrieved February 09, 2007, from http://dictionary.reference.com/browse/sustain

Europaworld: Biosphere Reserves for Sustainable Development. (2004). Retrieved April, 12, 2007, from http://www.europaworld.org/week162/biosphere30104.htm

Ewel, & Whitmore. (1973). Climate chart. Retrieved 1/30, 2007, from http://cgsc.biology.yale.edu/climchar.html

Food and Agricultural Organization of the United Nations. Retrieved 1/23, 2007, from http://www.fao.org

Forest Service, Department of Agriculture. (1974). Forest and Rangeland Renewable Resources Act of 1974, 2. Retrieved February 13, 2007, from http://www.fs.fed.us/emc/nfma/includes/range74.pdf

Forest Service, Department of Agriculture. (2006). *Trail accessibility guidelines,* from http://www.fs.fed.us/recreation/programs/accessibility/FSTAG.pdf

Forintek Canada Corp. and Canada Mortgage and Housing Corporation. (2002). *Combating Termites*

Francis. (1993). *The flora of canon de san cristóbal*US Department of Agriculture, Forest service, International Institute of Tropical Forestry.

Francis, J. K., Alemañy, S., Liogier, H. A., & Proctor, G. R. (1998). *The Flora of Cañón de San Cristóbal, Puerto Rico* (General Technical No. 4) International Institute of Tropical Forestry.

Geography of Puerto Rico. (1998). Retrieved 1/30, 2007, from http://www.solboricua.com/geogr1.htm

Geological Information about Puerto Rico and the Virgin Islands. (2001). Retrieved January 22, 2007, from http://geology.er.usgs.gov/states/pr_vi.html

*The Geological Society of America.*http://geosociety.org

Goldstein, B. (1992). The Struggle Over Ecosystem Management at Yellowstone. [Electronic version]. *Bioscience, 42*(3), 183-187.

Götmark, F., Söderlundh, H., & Thorell, M. (2000). Buffer Zones for Forest Reserves: Opinions of Land Owners and Conservation Value of their Forest Around Nature

Reserves in Southern Sweden. [Electronic version]. *Biodiversity and Conservation, 9*(10), 1377-1390.

Hairston, J., & Stribling, L. (1995). Animal Waste Management to Protect Water Quality. *Agriculture and Natural Resources Water Quality: Controlling Nonpaint Source (NPS) Pollution, 1-5*

Holdridge. (1967). *Documento para la Designacion de la Reserva Natural Cañón de San Cristóbal*

HotRot Composting Systems Ltd. (n.d.). *Composting of Poultry Farm and Poultry Processing Wastes,* from http://www.hotrotsystems.com/content/library/poultry_wastes_HCS.pdf

Hultsman, W., & Hultsman, J. (2001). Pathways for people: Trail designs to minimize environmental damage and enhance user enjoyment (FNR-121). [Electronic version]. *West Lafayette, IN: Purdue University, Cooperative Extension Service, 5*

Kassam, A. H., van Velthuizen, H. T., Fischer, G. W., & Shah, M. M. (1993). Agro-ecological Land Resources Assessment for Agricultural Development Planning - A Case Study of Kenya-technical annex 3 No. T0741/E

Keeney, & Raiffa. (1976). *Decisions With Multiple Objectives*. New York: Wiley.

Kim, Lee, & Shelby. (2003). Utilization of Photographs for Determining Impact Indicators for Trail Management. Environemtnal Management

Kim, & Shelby. (2005). Developing Standards for Trail Conditions Using Image Capture Technology. *Leisure Sciences, 27*(3), 279-295.

Krohn. Landslide Mitigation Using Horizontal Drains, Pacific Palisades Area, Los Angeles, California. In J. E. Slosson, A. G. Keene & J. A. Johnson (Eds.), (pp. 63-68)Geological Society of America.

Kuss. (1990). *Visitor Impact Managements: A Review of Research*. Washington DC: National Parks and Conservation Association.

Legends of Puerto Rico, Inc. (2007). *Yunque Rainforest Tour - High Impact Trail.* Retrieved April 30, 2007, from http://www.legendsofpr.com/yunque.htm

Long, A., & Todd-Bockarie. (1994). A. *Trails, Bridges and Boardwalks.* Retrieved February, 22, 2007, from http://www.sfrc.ufl.edu/Extension/pubtxt/Framefor5.htm

Lopez, Aide, & Thomlinson. (2005). Land Use Dynamics in a Post-Agricultural Puerto Rican Landscape (1936-1988). *Biotropica, 28*(4)

Lowe's. (2007). *Lowe's Home Improvement.* Retrieved April 30, 2007, from http://www.lowes.com/lowes/lkn?action=home

Maddock, & Samways. (2000). Planning for Biodiversity Conservation Based on the Knowledge of Biologists. *Biodiversity and Conservation, 9*(8)

Manning, R. E. (2002). How Much is Too Much? Carrying Capacity of National Parks and Protected Areas. [Electronic version]. ARNBERGER Arne et al, 306-313.

Margules, & Usher. (1981). Criteria Used in Assessing Wildlife Conservation Potential: A Review. *Biological Conservation, 21*(2), 79-109.

Martino, D. (2001). Buffer Zones Around Protected Areas: A Brief Literature Review. [Electronic version]. *Electronic Green Journal, 15*, 1076-7075.

McCool, S. F., & Lime, D. W. (2001). Tourism Carrying Capacity: Tempting Fantasy or Useful Reality? [Electronic version]. Journal of Sustainable Tourism, 9(5), 372-388.

McGee, J. (n.d.). *El Yunque Rainforest.* Retrieved April 30, 2007, from http://www.vividlight.com/articles/1711.htm

Mitchell, C. C., Donald, J. O. & Martin, J. (n.d.). *The Value and Use of Poultry Waste as Fertilizer.* Retrieved March, 30, 2007, from http://hubcap.clemson.edu/~blpprt/Aub-244.html

National Center on Accessibility. (2001). *Trail Surfaces: What do I Need to Know Now?* Retrieved April, 12, 2007, from http://www.ncaonline.org/monographs/1trail-surfaces.shtml

National Center on Accessibility. (2002). *What is an Accessible Trail?* Retrieved April 30, 2007, from http://www.ncaonline.org/monographs/8accessible-trails.shtml

National Park Service. (1997). *The Visitor Experience and Resource Protection Framework* from http://planning.nps.gov/document/verphandbook.pdf

National Park Service. (2000). *Accessible Design Achievement in Architecture, 2000 Award Winners.* Retrieved February, 14, 2007, from http://www.nps.gov/access/awards/architectural/2000.htm

National Park Service. (2001). *Accessible Design Achievement in Architecture, 2001 Award Winners.* Retrieved February, 14, 2007, from http://www.nps.gov/access/awards/architectural/dsc_pac.htm

National Park Service. (2002). *Accessible Design Achievement in Architecture, 2002 Award Winners.* Retrieved February, 14, 2007, from http://www.nps.gov/access/awards/architectural/2002.htm

National Park Service. (2006). *Trail Layout.* Retrieved February/22, 2007, from http://www.nps.gov/noco/parkmgmt/upload/NCT_CH3.pdf

National Weather Service. (2003). *Puerto Rico and U.S. Virgin Islands Severe Rainfall.* Retrieved April 30, 2007, from http://www.srh.noaa.gov/sju/FloodEventNov2003.htm

Nations Bus. (2007). *New Bus & Used Mini Buses for Sale, Shuttle Limousine & Trolley Bus Sales.* Retrieved April 30, 2007, from http://www.nationsbus.com/

Nepal, S. K., & Nepal, S. A. (2004). Visitor Impacts on Trails in the Sagarmatha (Mt. Everest) National Park, Nepal. *A Journal of Human Environment, 33*(6), 334-340.

New Project Leader Named for Puerto Rican Parrot Recovery. (2001). Retrieved 1/30, 2007, from http://www.fws.gov/southeast/news/2001/r01-103.html

Northwestern Indiana Regional Planning Commission. (2005). *Northwest Indiana Pedestrian & Bicycle Transportation Plan of 2005*. Portage, Indiana: Ped & Pedal. Retrieved April 30, 2007, from http://www.nirpc.org/pdf/PPTableofContents.pdf

O'Donnell-Rodwell, C., & Rodwell. (2000). Living with Modern Conservation Paradigm: Can Agricultural Communities Co-Exist with Elephants? A five-year case study in east caprivi, africa. *Biological Conservation,* (93), 381-391.

Ortiz, & Quevedo. (1986). *Datos de Flora y Fauna del Cañón de San Cristóbal.* Departamento de Recursos Naturales y Ambientales.

Peterson, T. (2007). *Trail Design and Construction.* Retrieved April 30, 2007, from http://www.americantrails.org/resources/trailbuilding/BuildAsphaltCloserLook.html

Prato, T. (2001). Modeling Carrying Capacity for National Parks. [Electronic version]. Ecological Economics, 39(3), 321-331.

Princess Cruises. (2007). *Princess Cruises, Escape Completely.* Retrieved April 30, 2007, from http://www.princess.com/

Puerto Rico. (2007). Retrieved January 23, 2007, from https://www.cia.gov/cia/publications/factbook/geos/rq.html

Rathke, D. M., & Baughman, M. J. (2007). Recreational Trail Design and Construction. Retrieved 2/6, 2007, from http://www.extension.umn.edu/distribution/naturalresources/DD6371.html

Reid, W. V., & Miller, K. R. (1989). Keeping Options Alive: The Scientific Basis for Conserving Biodiversity. *World Resources Institute, Washington, DC,* 128.

Rivera, M. (2007). Puerto Rico Economy. Retrieved 1/30, 2007, from http://welcome.topuertorico.org/economy.shtml

Saaty, T. L. (1990). How to Make a Decision: The Analytic Hierarchy Process. [Electronic version]. European Journal of Operational Research, 48(1), 9-26.

Sanchez-Carlo. (2005). *Tobacco History of Puerto Rico.* Fideicomiso de Conservación de Puerto Rico.

Schmoldt, D. L., & Peterson, D. L. (2001). Strategic and Tactiocal Planning for Managing National Park Resources. [Electronic version]. The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making.Boston: Kluwer Academic Publishers, 67-69.

School of Forest Resources & Conservation. Trail Design. Retrieved 2/6, 2007, from http://www.sfrc.ufl.edu/Extension/pubtxt/for5b.htm

Shafer, C. L. (1999). U.S. National Park Buffer Zones: Historical, Scientific, Social and Legal Aspects. *Environmental Management, 23*(1), 49-73.

Shrader-Frechette, & McCoy. *Methods in Ecology: Strategies for Conservation.* University of South Florida.

Silander, S. (1998). Biodiversity in Puerto Rico. Retrieved January 23, 2007, from http://www.findarticles.com/p/articles/mi_m0ASV/is_6_23/ai_54061826

Soto Class. *Puerto Rico's Economic Challenge.* Retrieved February 25, 2007, from http://www.brookings.edu/comm/events/20060525.htm

Southeast Regional Climate Center. Aibonito, Puerto Rico - Climate Summary. Retrieved 1/30, 2007, from http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMAIN.pl?pr0158

Southeast Regional Climate Center. Barranquitas, Puerto Rico - Climate Summary. Retrieved 1/30, 2007, from http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMAIN.pl?pr0736

Stankey. (1985). *The Limits of Acceptable Change (LAC) System for Wilderness Planning* No. INT-176). Ogden, Utah: USDA Forest Service.

Stapen, C. H, Puerto Rico: Top Attractions. Retrieved 2/22, 2007, from http://away.com/stores/travel-guides/puerto-rico-attractions.html

Steiner. (1983). *Journal of Environmental Management, 7*(5), 401-420.

Stevens, T. (2002). Sustainable Tourism in National Parks and Protected Areas: An Overview No. AH(NC04)010299)

Tapia. (1994). Multivariate Approach for Suitability Assessment and Environmental Conflict Resolution. Journal of Environmental

Tapia, Cueva, & Diaz. (2004). Environmental Conflicts and Nature Reserves: Redesigning Sierra San Pedro Martir National Park, Mexico. *Journal of Geographic Information Science,* (15), 111-126.

Taylor, P. (2004). Biosphere Reserves in Canada: Exploring Ideals and Experience. *Environments, 32*(3)

U.S. Census Bureau. (2000). *Estimates of the Population of Puerto Rico Municipios.* Retrieved April 30, 2007, from http://www.census.gov/population/estimates/puerto-rico/prmunnet.txt

U.S. Census Bureau. (2006). *World population information.* Retrieved January 23, 2007, from http://www.census.gov/ipc/www/world.html

U.S. Department of Transportation - Federal Highway Administration. (n.d.). *Designing Sidewalks and Trails for Access.* Retrieved April, 12, 2007, from http://www.fhwa.dot.gov/environment/sidewalks/chap5a.htm

U.S. Fish & Wildlife Service. Threatened and Endangered Species System. Retrieved 1/30, 2007, from http://ecos.fws.gov/tess_public/StateListingAndOccurrence.do?state=PR

United Nations Educational Scientific and Cultural Organization. (2007). *United Nations Educational Scientific and Cultural Organization.* Retrieved April 30, 2007, from http://portal.unesco.org/en/ev.php-URL_ID=29008&URL_DO=DO_TOPIC&URL_SECTION=201.html

United Nations Educational, Scientific and Cultural Organization. (2006). *The Statutory Framework of the World Network of Biosphere Reserves*. Retrieved April 30, 2007, from http://www.unesco.org/mab/doc/statframe.pdf

United Nations Educational, Scientific and Cultural Organization. (2007). *UNESCO's Man and the Biosphere Programme.* Retrieved April 30, 2007, from http://www.unesco.org/mab/mabProg.shtml

United Nations Educational, Scientific and Cultural Organization. (2007). *The World Network of Biosphere Reserves.* Retrieved April 30, 2007, from http://www.unesco.org/mab/wnbrs.shtml

United Nations Environment Programme. (2003). Sustainable Tourism in Protected Areas. Retrieved 1/30, 2007, from http://www.uneptie.org/pc/tourism/library/sust_prot_areas.htm

Weaver, Birdsey, & Lugo. (1987). Soil Organic Matter in Secondary Forests of Puerto Rico. J Stor

Whittaker, & Shelby. (1992). *Selecting Indicators: Which Impacts Matter More?*. Fort Collins, Colorado: USDA, Forest Service, Pacific Northwest Research Station.

Yale University. (n.d.). *Yale department of geology and geophysics.* Retrieved April 30, 2007, from http://www.yale.edu/geology/

Your Internet Guide to GIS. (2007). Retrieved April, 12, 2007, from http://www.gis.com