A Technical Analysis of Fuerte Mocorón, Honduras, For Tropical Testing of Army Materiel, Equipment and Systems

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ABSTRACT *(Maximum 200 words)*

This report presents the findings of a scientific panel assembled by the U.S. Army Research Office (ARO) at the request of the Technical Director, U.S. Army Yuma Proving Ground (YPG), for the purpose of evaluating the suitability of one area in the nation of Honduras for tropical testing for the Army. The evaluation panel addressed this tasking through the utilization of an ideal tropic test site model and hierarchical decision tree process to prioritize critical environmental parameters developed in previous studies in Puerto Rico, Hawai'i, Queensland, Australia, Suriname and Panama.

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A Technical Analysis of Fuerte Mocorón, Honduras for Tropical Testing of Army Materiel, Equipment and Systems

This analysis was conducted by a scientific panel assembled by the Army Research Office and Yuma Proving Ground of the U.S. Army Developmental Test Command.

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Mr. Rod Peralta of Yuma Proving Ground's liaison officer to US Southern Command was the project manager for this survey. None of this work would have been possible without his hard work and professionalism in managing with meticulous detail the myriad of requirements necessary to move the team to this remote location, provide all the logistical support, and get the team home safely while accomplishing the mission. Further, his regional expertise was invaluable in many aspects of the technical component of this project. Mr. Peralta is commended for his exemplary performance of duty in supporting this mission.

EXECUTIVE SUMMARY

History has taught the United States Army the significance of military operations in wet tropical climates. First, conflicts will continue to occur in these geographic areas; since 1960 more than 75 % of regional conflicts have had their roots in countries located within the tropics. Secondly, successful operations require troops and equipment capable of sustained operations in the stifling heat, humidity, and variable environmental conditions presented by wet tropical landscapes. To achieve operational success, military equipment must be tested in harsh tropical conditions and Soldiers must be trained within this demanding environment. The United States Army had a long history of testing and training within the tropics at sites located in Panama. However, under the terms of the Carter-Torrijos Treaty of 1977, the military mission in Panama was required to vacate the country by December 31, 1999. The U.S. Army lost important capabilities with the closure of both the Army tropic testing facilities and Jungle Operations Training Center (JOTC) in Panama. To mitigate this loss, the Army Test and Evaluation Command (ATEC), through its sub-element at Army Yuma Proving Ground (YPG), is developing a suite of alternative sites to support the tropical testing mission. This approach has been taken because no single location that can support the variety of testing needs has been developed to date. Though not a specific task of this study, it must be noted that the Army has not replaced the capability to conduct individual and collective training in the tropics lost with the closure of the JOTC.

In 1998, YPG requested the assistance of the U.S. Army Research Office (ARO) to convene an expert panel to undertake two related studies. The first study, "A Technical Analysis to Identify Ideal Geographic Locations for Tropical Testing of Army Materiel and Systems" (King et al., 1998), examined the Army's tropical test mission to define the conditions that best provide the environmental challenges needed for tropical testing, at that time and into the 21st century. This study identified the climatic, physical, and biological characteristics defining the ideal tropical test environment and identified regions of the world that best fit the composite specifications of an ideal tropical test environment. Sixteen regions were identified that provide the requisite conditions of an ideal environment for tropical testing and training. None of these sites were readily accessible for Army use. Based on these initial findings, the tropic test study panel previously concluded that a suite of sites having different but complementary testing attributes would offer the best technical approach to replace the testing capacity lost with the closure of testing facilities in Panama (King et al., 1998, 1999, 2001, 2006). The work of developing a suite of tropical test sites continues with this examination of locations in Honduras.

This study evaluates three sites located within Fuerte Mocorón, Honduras, garrison and training areas of the 5th Infantry Battalion (Pumas) of the Honduran Army. Geographically, it is located within the Caribbean coastal lowlands near the border with Nicaragua. The climate is classically tropical with ample heat, humidity, and rainfall to fully meet the ideal climate conditions for a tropical testing and training site. The land cover of the site is dominated by the pine forests common to the lowland coastal savannah. The only tropical evergreen forests within the training area are located within the floodplains along the streams and rivers. These riparian forests range from widths of only a few meters on each side of the stream to areas ranging several hundred meters away from the water course.

These two vegetation types also reflect a basic difference in soil texture with generally sandy soils in the pine forests, while higher clay and silt content is found in the riparian forest soils. From a testing and training standpoint, having two different biomes in close proximity is useful. A limiting factor for this site is a lack of relief and significant slopes. A major plus for this site is its isolation from cultural inferences, particularly electromagnetic signals. This is of value in many types of electronics tests including communications and remote sensing technologies.

Overall, the Mocorón locality adds to the Army's ability to test materiel and systems in a demanding tropical environment. The site does not represent the harshest of tropical conditions, but is representative of the challenges presented by a significant percentage of the tropical areas in the world. Its strengths as a test site include: 1) its isolation and the many benefits that this affords testers, 2) its location on an existing military installation and the value that offers such as the ability to fire small caliber weapons, 3) its ideal tropical climate, 4) its clean RF environment, and 5) its 1390m airstrip. The site would not be a capable of supporting large caliber weapons firings, nor would it be a good choice for most vehicle tests. The existence of a suite of sensor targets within the two primary biomes is also a strength of its use to test remote sensing systems.

CHAPTER I

BACKGROUND HISTORICAL REVIEW

I.1. Introduction.

The major military powers of the world recognize the need for field testing of materiel and equipment in the wet tropics. U.S. experience in the Pacific in World War II and in Southeast Asia during the Vietnam War clearly demonstrated the need to test the performance of new equipment in the harsh environmental conditions of the wet tropics. Since 1960, some 75% of all international and internal conflicts have been in countries whose borders are totally or partially within the wet tropical environment. Researchers examining past conflicts to better understand the security threats of the future have reached the conclusion that the countries lying within the tropics are the most likely locations for future conflicts (e.g., Lee, 1999; Barnett, 2004). Further, studies examining the sources of insecurity posed by global environmental degradation regard the tropical regions of Africa, Asia, and the Americas as the most likely locations of instability in the future (King, 2000). Recent operations in Somalia, Rwanda, Haiti, Panama, East Timor, and elsewhere have only reinforced the need to be prepared for tropical conditions. Clearly, the Army must be prepared to deploy and operate successfully in the tropical environment.

As prescribed by AR 70-38 (U.S. Army, 1979a), and guided by requirements in numerous performance standards (MIL STDs), environmental conditions and their effects are to be given realistic consideration in the research, development, test, and evaluation (RDT&E) process for materiel used in combat by the Army. As a result, testing and evaluation in the tropical environment of material, equipment, and systems, as well as human performance, is well established and has a long history. The U.S. and several of its military allies operate testing and/or training facilities in the hot, humid tropics (e.g., the U.K. in Belize, France in French Guiana, and Australia in its state of Queensland). The mission of testing in extreme natural environments for the Army (U.S. Army, 1979b) resides with the Army Test and Evaluation Command (ATEC) and is vested with Yuma Proving Ground (YPG). Presently, this mission is accomplished at desert, arctic, and sub-tropical test facilities in the United States (arctic at Fort Greeley, AK (CRTC); desert at Yuma Proving Ground, AZ (YTC), and sub-tropic at Schofield Barracks, HI (TRTC). Temperate environment testing is the responsibility of the Aberdeen Test Center (Aberdeen Proving Ground, MD).

I.2. Study Panel Tasking.

Army testing of materiel, equipment and systems, together with human performance evaluation under tropical conditions took place in the Canal Zone area of the Republic of Panama as far back as WWI. This mission evolved into the Tropic Test Center (TTC) in 1962, which supported specific Army test functions in response to evolving military needs through the 1990s. Under the terms of the Carter-Torrijos Treaty of 1977, the military mission in Panama was required to relocate from the country by December 31, 1999.

In 1998, at the request of Yuma Proving Ground (YPG), the Army Research Laboratory's Army Research Office (ARO) convened an expert panel to undertake a study to identify the general areas across the globe that could satisfy the test environment that was being lost as a result of departure from Panama.

That study - *A Technical Analysis to Identify Ideal Geographic Locations for Tropical Testing of Army Materiel and Systems* (King et al., 1998) examined the Army tropical test mission to define the conditions that best provide the environmental challenges needed for tropical testing, today and into the 21st century. The 1998 study defined the climatic, physical, and biological characteristics of the "ideal tropical test environment" and identified regions of the world that best provided the combined parameters for such an ideal location. The analysis was based solely on critical environmental parameters defined by the panel, without constraining the analysis by the numerous important, but non-scientific considerations that would impact any final site selection. To support any follow-on locational efforts, a decision tree was constructed based upon a prioritization of the critical environmental parameters. Although some 15% of the earth's land surface is tropical in general character (Veregin, 2005), very little of this area is considered ideal for tropical testing. Worldwide, 16 areas were identified in the 1998 study (King et al., 1998; 2004) as suitable localities for Army tropical testing (Figure 1). The first group of six geographic areas, ordered in terms of their relative proximity to the continental U.S., included: northern Honduras, the Isthmus of Panama, French Guiana/coastal northeastern Brazil (adjacent to Suriname), the southwestern New Guinea lowlands, low-moderate altitude areas of the East Indies in east-central Java and southeastern Borneo, and the Isthmus of Kra in Malaysia. The premier localities in this group for tropical testing were the Isthmus of Panama and the Isthmus of Kra because both areas offer a spectrum of tropical conditions and environments within a compact geographic area. A second group of 10 locations were identified that exhibited the general physiographic and biotic character, but failed to provide one or more of the other important elements considered requisite of the ideal tropical environment for Army testing. This group consisted of coastal Belize, Puerto Rico, southeastern Costa Rica, northwestern Colombia, portions of the Hawai'ian Islands and the Fiji Islands, the Philippines, New Britain-New Ireland, the coastal region of northern Queensland in Australia, and the Bangkok area of coastal Thailand.

In late 1998, guidance was issued to relocate the Army tropic test mission to a U.S. controlled site. In response to this directive, a second study panel was convened in the early part of 1999 to evaluate sites in Hawai'i and Puerto Rico for their capability to support tropical testing. The report, *A Technical Analysis of Hawai'i and Puerto Rico for Tropical Testing of Army Materiel and Systems* (King et al., 1999), contained a number of findings, including the fact that Schofield Barracks on the island of Oahu could…."adequately accommodate up to about 80% of the volume of the current TRTC test mission". As a result, YPG-TRTC has focused on the development of test capabilities in Hawai'i, specifically toward the creation of a Soldier systems jungle test area at Schofield Barracks. Additionally, the second report recommended that additional test facilities should be developed as a part of a 'suite of sites' that would enhance the tropical testing capabilities, particularly since the Schofield Barracks site was not suitable for certain testing missions.

In the next phase of the work, YPG requested that an ARO expert panel evaluate specific sites in the northern Queensland area of Australia, an area where the Australian Army operated tropical testing and training facilities.

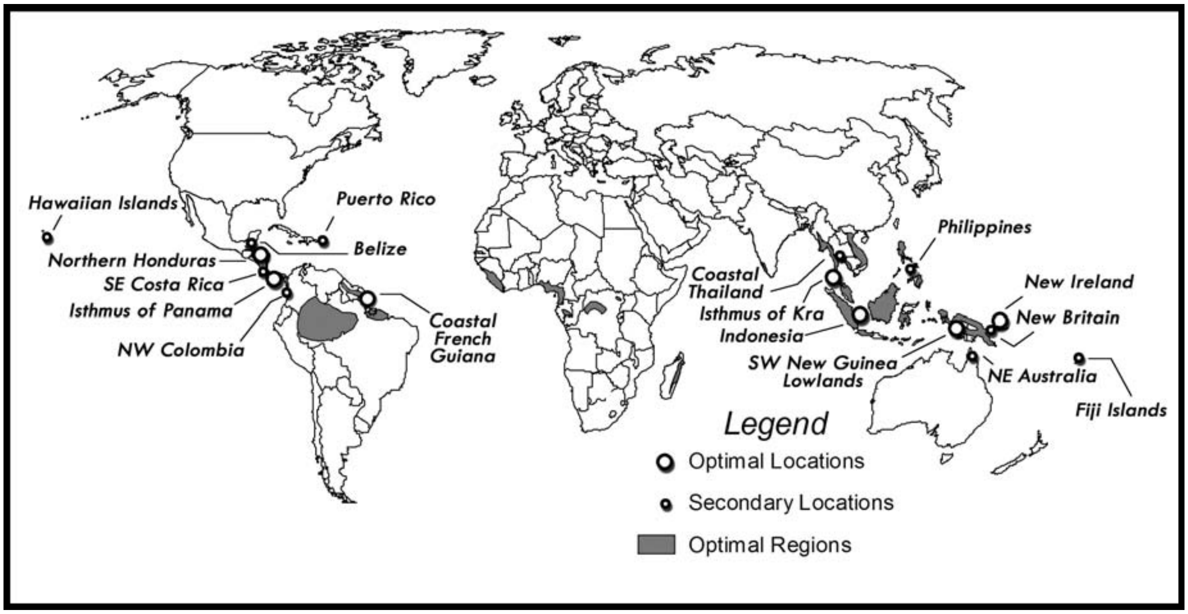

Figure 1. Optimal locations for developmental and operational tropical testing of military equipment, vehicles, and weapon systems (from King et al., 1998; 2004)

In 2007, the Army is engaged in tropical testing, now employing a suite of sites that has evolved from the results and recommendations of previous panel work. Sites include locations in Hawai'i and limited capability to use sites within Panama.

The purpose for this research is to conduct an environmental characterization one military training area within the Republic of Honduras to determine its suitability to host various types of military systems tests. The site will be referred to as Fuerte Mocorón, the Spanish name for the military reservation. This characterization compares the basic physical, biotic, and climate parameters with the ideal conditions for tropical testing and training, which had been defined in previous research (King et al, 1999). The membership of the study panel assembled by ARO, together with a brief statement of qualification for each member, is listed in Appendix 1.

I.3. The Ideal Tropical Test Site.

The expert panel began its tasking by implementing the analysis model developed during the previous studies of Puerto Rico, the Hawai'ian Islands, Panama, Suriname, and Australia (King et al., 1999; 2001, 2004, and 2006).

The requisite characteristics of the ideal environment for a tropical test facility are derived from complex interrelationships among the key factors of climate, terrain, and vegetation.

Climate is the defining characteristic of a tropical region, whereas physiography and geologic factors are closely associated, and the biologic manifestations (land cover/vegetation type) are a direct function of the combination of climate, physiography, and geology within a given region. The criteria identified as defining the ideal tropical test environment from a scientific basis (King et al., 1998) are summarized in Table 1.

I.3.A. Climate Requirements.

Climatic criteria for the humid tropics are defined in Army Regulation, AR 70-38 (U.S. Army, 1979a), which broadly classifies world climates into four "basic climatic design types." Each of these design types is characterized by one or more daily weather cycles. Two daily cycles in the 'basic climatic type' represent the humid tropics (Table 2).

The ideal setting for a tropical test facility would lie in a hot and humid tropical climate regime to provide extremes of high relative humidity (RH) in a very high rainfall and near-constant high temperature environment. As such, the area encompassing the site should have annual precipitation in excess of 2,000 mm, monthly-averaged minimum temperature and RH in excess of 18-20°C and 60%, respectively, and mean monthly temperatures and RH of at least 25°C and 75%, respectively. Average rainfall would not fall below 100 mm in any single month, nor exceed 6,000 mm per year. These precipitation requirements address a desire for minimal seasonal variability (i.e., a preference for no absolute dry season). Regions experiencing tropical cyclone (hurricane or typhoon) activity should be avoided, unless all other physical factors indicate the site to be an optimal location. Ideally, a relatively compact area would exhibit variable conditions of climate (e.g., frequency/distribution of precipitation and temperature) across the spatial domain encompassing a landscape varying from coastal lowlands to steep montane relief.

I.3.B. Physical Considerations.

The requirements defined in the ideal test environment are best met in terms of an area of sufficient size to contain the test mission, significant variations in slope and relief across the site, surface streams that can support a variety of tests, surrounding land use that is compatible with the testing mission, and the absence of cultural/historical resources or conservation pressures that could infringe on testing. The area should not be a high-risk zone in terms of frequency of natural hazards (e.g. tropical storms, volcanic activity, earthquakes, landslides, flooding, etc.). Also, it should not be affected by significant adverse anthropogenic activities (e.g. high adjacent population density, upstream pollution from urban, industrial, and/or farming activities). Soils need not be a specific type, but must be of sufficient thickness and health to support a diverse suite of lush tropical vegetation and offer significant challenges to the mobility of troops and vehicles.

I.3.C. Biological Considerations.

Given the specific climatic, topographic and geographic constraints listed above, the major biological considerations for a tropical testing site are specific tropical vegetation characteristics and the presence of a diverse community of above- and below-ground organisms. In the past, military interest in tropical vegetation was primarily based on the latter's structure and distribution in both horizontal and vertical dimensions as challenges to vision, mobility, and performance of personnel and equipment. For other organisms, especially microbes, concerns focus primarily on sufficient density to produce high rates of the metabolic processes and by-products that foul materiel and interfere with equipment and systems. Military testing at present and in the future requires much greater detail and understanding of the structure, function, and interrelationships of species in complex tropical ecosystems.

Table 1. Criteria for an Ideal Tropical Test Area (King et al., 1998).

I. Climate	
Precipitation:	2 to 6 meters (m) per year, > 0.1 m in driest month
Temperature (^oC):	18 minimum average, 25 to 40 average daily
Relative Humidity (%):	Mean = 75, range = 75 to 90
II. Physical Setting	
Relief:	Elevation = Sea level to 1500 m, Site relief = 150 m minimum, Slope = 0 to 60 %, coastal location with lowlands.
Surface water:	Perennial small (1 to 2 m) to medium (up to 20m) width streams, with nominal velocities (<2.0m/s).
Soils:	Oxisols, ultisols, inceptisols, minimum depth in the range of 10m
III. Biological Considerations	
Vegetation Structure: Secondary tropical rainforest with undisturbed growth for 25 years. Closed canopy forest cover. Minimum, 70 to 95% of stems <10cm dbh with remaining stems >20cm dbh, basal area 20 to 70m^2/hectare, established understory growth. Microbiology: Diverse fauna and decomposer populations	

I.4. Study Methodology.

Because of complex feedback mechanisms, land cover also influences local/regional climate. Therefore, in a tropic test suitability analysis, the hierarchical ranking of factors in Table 1 (climatic, physiographic/geologic, and biologic factors) provides a simple and direct means for comparative site evaluation. The decision tree developed by the study panel (Table 3) took into consideration the three primary parameters of climate, physical setting, and biological characteristics, weighed from highest to lowest priority according to the criteria listed in Table 1. To implement this ideal test center model in the panel's optimization studies, a set of 14 environmental parameters were developed to summarize the environmental conditions of a specific location.

Table 2. Description of AR 70-38 humid tropical climate types (U.S. Army, 1979a)

Operational Conditions for Storage and Transit

Climate Parameter	B1 Constant High Humidity	B2 Variable High Humidity
Ambient air temperature (^oC)	Nearly constant at 24	26 to 35
Solar radiation (BTU/ft^2/hr)	Negligible	0 to 307
Ambient relative humidity (%)	95 to 100	74 to 100
Induced air temperature (^oC)	Nearly constant at 27	30 to 36
Induced relative humidity (%)	95 to 100	19 to 75

The 'Constant High Humidity Cycle' corresponds to conditions under the jungle canopy, and the 'Variable High Humidity Cycle' corresponds to conditions in open areas. These conditions occur throughout the year with little or no seasonal variation. Other important characteristics are rainfall, a double canopy of vegetation, a dense understory, and varying degrees of topographic relief. The limits indicated in Table 2 represent the minimum recommended environmental conditions necessary to evaluate the effects of a jungle environment on personnel and equipment.

Table 3 - Decision tree structure utilized in this study (after King et al., 1999).

Essential tropical parameters include:
Diurnal and annual temperature (mean and ranges)
Annual and monthly precipitation level (mean and ranges)
Relative humidity
Physiography (relief, slope, elevation range)
Biotic communities (vegetation structure)
Characteristics deemed highly desirable, but not critical, include:
Minimal effects of tropical cyclone (hurricane or typhoon) activity
Seasonality (minimal dry season preferred)
Range of vegetation types (rainforest, wetlands, savannah)
Range of landscape types (sea coast, coastal wetland, coastal plain, upland)
Well-developed and variable soil profiles (oxisols, ultisols, inceptisols, entisols)
Range of stream sizes and flow regimes
Screening criteria resulting in elimination of otherwise acceptable locations include:
Intensive geologic hazards (active volcanism, seismic activity, landslides)
High tsunami/storm surge susceptibility
Presence of extensive karst topography (limestone)
Frequent or large-scale disturbance of vegetation (natural and/or anthropogenic)
Presence of high levels of disease vectors
Excessive monthly or annual precipitation
Impacts of farming, industry or urbanization
Land use restrictions

Table 4. Environmental factors required for specific tropical testing missions (King et al., 1999).

Mission	**Environmental Factors**
Equipment Development Testing:	
1) Communication & electronics	***Understory, canopy, temperature***, humidity, relief, fauna
2) Ground & air sensors	***Canopy, understory***, temperature, humidity, rainfall
3) Chemical & biological defense	***Fauna, understory,*** temperature, relief
4) Environmental exposure	***Humidity, rainfall, fauna, temperature,*** canopy
Operational and Human Performance Testing:	
1) Individual soldier systems	***Temperature, humidity, canopy, understory, rainfall, relief,*** slope, soils
2) Communication and electronics systems	***Canopy, understory, fauna, temperature, humidity***, ***relief,*** rainfall
3) Ground and air sensors	**Canopy,** ***understory***, temperature, humidity, relief, soils
4) Chemical and biological defense	***Understory, fauna, temperature, humidity,*** relief, canopy
Small Caliber Munitions:	
1) Exposure testing	***Land use, temperature, humidity, fauna,*** rainfall**,** canopy
2) Operational testing and firing	***Land use ,area, adjacent land use***, temperature, humidity
3) Smoke and obscurants	***Understory, temperature, humidity,*** relief, canopy
Large Caliber Munitions:	
1) Exposure testing	***Land use, temperature, humidity, fauna, rainfall***, canopy
2) Operational testing and firing	***Land use ,area, adjacent land use,*** temperature, humidity,
3) Smoke & obscurants	***Understory***, temperature, humidity, relief, canopy
Vehicle Mobility Testing	***Soils, slope, relief, rainfall, streams***, understory, humidity

Note: The environmental criteria are listed in general order of importance. Criteria presented in bold and italics are considered essential elements for that testing mission.

These 14 criteria are: temperature, rainfall, humidity, soils, area size, slopes, relief, surface streams, understory, forest canopy, forest floor fauna, land use/ownership, adjacent land use, and cultural/historical features. Any candidate site can be characterized by its ability to fulfill these environmental parameters.

Because the panel recognized that it would be difficult for a site to achieve a perfect match, rather than employing a simple "YES" or "NO" analysis, a 4-tiered rating scale was developed to assess the relative compliance with each specific environmental criterion (A "0" rating denotes a situation that fails to provide the required setting; a "1" rating denotes a marginal condition that places severe limits on testing; a "2" rating denotes a good setting that meets all critical and most desired criteria; and a "3" rating denotes an excellent setting that is fully capable of supporting the requirement)**.**

The concluding step in the analysis requires the grading of each site for its overall ability to support each component of the testing mission. To accomplish this task, one additional grading scale was developed to evaluate the ability to conduct a specific type of test in a given location, a scale that analyzes only the essential or important environmental conditions required for a specific test, as listed in Table 4. An overall grade (see Table 5) is derived that reflects the capability of that site to support a specific testing mission based on only the environmental factors that are important to that test.

I.5. Summary.

The overall procedure that was utilized in this study of two sites in Panama implemented the model developed and proven in the course of the previous work by this panel. The methodology is founded on two primary products from the initial study, (i) a characterization of the ideal test environment (Table 1), and (ii) a decision tree to evaluate areas on a regional basis (Table 3). Candidate sites can then be characterized by their ability to comply with the environmental requirements for the specific test activities listed in Table 4.

Table 5. Environmental factor ratings (after King et al., 1999).

Grade	Environmental Ranking	Site Evaluation Description
A	All 3'and 2’s, mostly 3’s	Acceptable testing capability
B	Mostly 2's	Adequate with some limitations
C	2's and 1's	Marginally useful for testing
D	Mostly 1's	Undesirable, limited utility for testing (with 0 for non-essential elements)
F	0’s for critical elements	Completely unacceptable

CHAPTER II

THE TESTING MISSION

II.1. Overview of the Testing Process.

The testing and evaluation of equipment and systems in the natural environment is conducted using accepted scientific protocols and established engineering practices. This assures repeatability, experimental control, and validity of test results. Many aspects of the testing process are conducted over long periods of time and, therefore, a fundamental requirement for a test location is the constant presence of tropical conditions that meet the needs of the item undergoing testing. Testing also requires a well-characterized and understood suite of tropical field sites that provide environments that are fully representative of those in which soldiers, systems, and materiel may be fielded during combat.

The test and evaluation of equipment and systems is a complex continuum that begins with basic proof of concept, then develops an understanding of how environmental effects impact equipment throughout its life cycle, and finally tests systems with Soldier operators. The test continuum is a participative, iterative process among developers, test personnel, and Soldiers, during the RDT&E process in multiple test phases. Each phase focuses on maturing the item and furthering it along for inclusion in the Army inventory. Any number of very specific test facilities and capabilities are required to meet various needs during the course of the overall testing process. Natural environment developmental testing (DT) addresses technical issues and criteria that require realistic, calibrated test sites and courses where repeatability and control can be ensured over time and events. Operational Testing (OT) addresses force-on-force system effectiveness issues. Both types of testing require representative, natural environments. These facilities and capabilities are summarized in the following section.

The wet tropical environment is the most diverse and complex natural environment in the world and, consequently, is one of the most challenging for Soldiers, equipment, and systems. Modern sophisticated technology, with complex integrated electronic circuitry, is more critically affected by tropical factors than the simpler electromechanical systems of the past. The effects of heat, humidity, direct insolation, and biological degradation by organisms such as bacteria and fungus, coupled with a dense cover of a multi-canopy jungle, not only attack and deteriorate equipment, but also create a most hostile natural environment in which the soldier must successfully wield the technology to accomplish the military mission.

II.2. Types of Testing.

Current environmental testing by the Army can be divided into five broad categories: (i) equipment and system development testing [30% workload]; (ii) equipment and system operational and human performance testing [50%]; (iii) munitions testing including long term storage [15%]; (iv) specialized testing [3%], and (v) vehicle mobility testing [2%]. This testing is encompassed and described by a matrix of six test categories or groups that have common environmental test requirements as described below.

II.2.A. Developmental Testing.

Developmental testing typically encompasses the prototype testing of new equipment. It focuses on all types of equipment, systems and materials with current emphasis on communications systems and electronics, ground and air sensor systems, and chemical-biological detection systems. Exposure and wear testing of equipment under both open and jungle conditions is an integral component of this activity. Sites for tropic developmental testing should have "robust" environmental characteristics that provide climatic conditions close to those described in AR 70-38, so as to provide the maximum tropical environmental challenge to the performance envelope of these items. These include (i) a dense jungle canopy for obscuring ground-placed targets to airborne sensors, (ii) a well-developed soil profile (iii) a dense vegetative understory, (iv) topography for challenging line-of-sight communication, and (v) a hot humid jungle environment with abundant biologic decomposition to produce the volatile compounds that challenge chemical-biological detection equipment. An intense tropical environment includes a diverse suite of biological degraders consisting of bacteria, fungus, and insects to challenge long-term material integrity.

II.2.B. Human Factors (HF) Performance Testing

This testing is directed toward the operation of equipment and systems in the manner employed during use by the Army. It allows for testing of both the functionality of the equipment, as well as for the performance of the individual Soldier. High temperature and humidity stress the Soldiers, thus lessening the ability to move quickly, work long hours, and successfully manipulate complex equipment and systems. The tropical environmental characteristics required are high humidity, high temperature, a well-developed understory and canopy, and appropriate geomorphic features such as relief, streams, and soils. In actual combat conditions, all of these factors combine to create a dark and foreboding atmosphere that can affect Soldiers' attitudes and senses of well-being, and thus their ability to accomplish their mission.

II.2.C. Long-Term Exposure and Testing of Munitions

This activity is focused on the long-term exposure of munitions and testing of small ($\leq$40 mm) and large (>40 mm) weapon systems in tropical environments, in both open and jungle settings. Munitions of all types, particularly larger caliber, are stored for protracted periods to evaluate their stability when subjected to tropical conditions. The testing of munitions generates military unique test requirements and, as such, the military infrastructure requirements of established ranges and approved storage areas for munitions must overlay, or be in close proximity to, the environmental test areas. Small caliber munitions involved in operational testing require a similar military-unique infrastructure, as well as the usual environmental characteristics of high heat and humidity identified in AR 70-38. Large caliber weapon systems must be subjected to both exposure and operational testing within the tropical environment. Ultimately, all munitions firing must be conducted on ranges approved for all safety standards. Testing of smokes and obscurants requires a relatively flat area in areas of restricted access.

II.2.D. Vehicle Mobility

This testing is directed toward evaluating mobility performance of wheeled, tracked, and towed vehicles. It includes the testing of trucks, tanks, towed weapons, trailers, and any other types of vehicular system that must move on wheels or tracks. The environmental requirements include a variety of tropical soils capable of yielding mud, slopes up to 60%, varied vegetation in stem size and density, and surface water features that are representative of conditions found in tropical settings worldwide. Continued long-term access to the same mobility courses is a requirement, so that comparative analysis over the same set of slopes, soils, terrain, and environmental conditions can be utilized as new test requirements emerge.

II.3. Other Considerations.

II.3.A. Operational Testing

Operational Testing is the final end testing of an item or system before it enters into the Army inventory. Typically, the system is provided to the soldiers who are conducting normal field exercises, force on force activities, or field support activities, depending on the item and its projected use. Realistic scenarios are required including the battlefield environment and associated maneuver facilities. Movement is relatively unconstrained at this point and the geographic constraints associated with Developmental Testing sites are no longer applied. It is not uncommon that elements of Developmental Testing will be embedded within or combined into Operational Testing, a trend likely to continue in the future.

II.3.B. New Technologies

In addition to the ongoing testing requirements described above, a vision for future requirements includes the need to test new technologies being developed for the Objective Force and the Future Combat System. This testing would include: sensors (airborne/space-born and man-portable systems); information, data networking, and communication technologies based on electromagnetic transfer; cloaking, and reduced signature technologies; and product improvements of existing systems (as a cost-saving measure to replacement systems). For example, use of hyperspectral image data has been successfully employed worldwide in recent counter drug operations. With all objects reflecting, absorbing, or emitting electromagnetic radiation based on their composition, hyperspectral sensors using reflected solar radiation (0.4 micrometers - 2.5 micrometers wavelength range), capture unique spectra, or the 'spectral signature' of an object. Using a procedure called BandMax™, spectral characteristics of targets are compared to background signatures. This enables significant spectral features indicative of spectral target material to be exploited, whereby atmospheric effects are avoided and ultimately “false alarms” from similar objects are reduced. This approach provides a ‘yes/no’ answer to the question of whether or not an object is present, with a statistically high degree of confidence (SORC, 2005). Plastics and some other unique materials required in running drug labs do not naturally occur in the natural landscapes of the tropics and are, therefore, frequently selected as target material (see Figure 2).

Demonstrating this differentiation technique, the spectral radiance of a chemical pit is compared with that of drying coca plants in Figure 3. In addition to these sensor techniques, new information and communication systems, such as Land Warrior, spearheaded by PM Soldier, will provide the individual Soldiers with advanced technologies and weapons for the battlefield of the 21st century. There will be an increased focus on dual-use or multi-use technologies that have high payback, such as environmental technologies for unexploded ordnance (UXO) detection/location and similar applications. All of these technologies are highly sophisticated and complex. As such, test and evaluation of such new technology and related methods will require a thorough understanding of the environmental factors affecting their technical performance, as well as the synergistic environmental effects that challenge equipment operability and reliability.

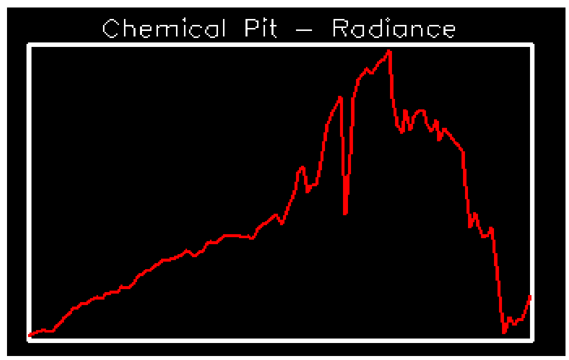

Figure 2. Chemical Pits return a unique spectra to a Hyperspectral Sensor (GalileoGrp,2005)

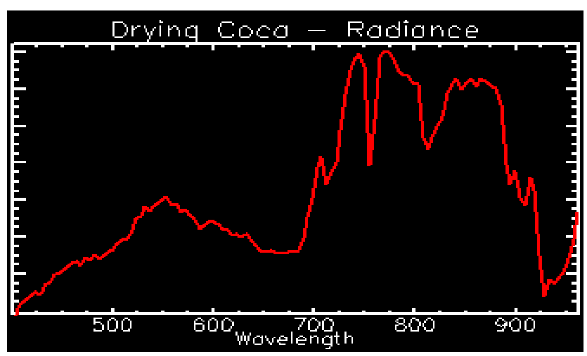

Figure 3. Drying Coca Leaf Spectra Gathered from Airborne Data and Applied to Airborne Data Comparison Profiles (GalileoGrp,2005)

CHAPTER III

CHARACTERIZATION OF TEST SITE

III.1. Geographic Overview of Honduras

III.1.A. Location and Population. The country of Honduras is centered on 15°00' north latitude and 86°30' west longitude and is situated on the widest section of the Central American landbridge. The country is home to 7.2 million inhabitants, based on data from the United Nations and the Population Reference Bureau (BBC, 2005; PRB, 2005). Nearly 90% of the people are Mestizo (a mixture of Native American Indian and Hispanic), and about 7% are Indian (Gecko, 2005). The indigenous people are predominantly Mayan descendents (Tomaselli-Moschovitis, 1995).

III.1.B. Areal Extent and Relative Location. Honduras is the second largest of the Central American Republics, occupying an area of 43,267 sq mi (112,090 sq km), an areal extent larger than the US state of Tennessee (Goodwin, 2007). The Country has 888 km of coastline that includes 153 km along the Golfo de Fonseca and 735 km along the Caribbean Sea (Library of Congress, 1989). Honduras shares land borders with Guatemala (256 km) in the northwest, El Salvador (342 km) in the southwest, and Nicaragua in the south and southeast (922 km) (CIA, 2005; Figure 4).

III.1.C. Physiographic Regions. Geographers generally divide Honduras into three geographic regions; the Caribbean Lowlands, the Pacific Lowlands, and the Interior Highlands. The Pacific Lowlands constitute the smallest physiograhic region, averaging less than twenty-five kms in width along the coast of the Golfo de Fonseca and comprised of mangrove swamps and narrow, alluvial coastal and river plains (Library of Congress, 1989; West and Augelli, 1989).

The Interior Highlands account for about 70% of the country's area. The mountainous interior includes elevations approaching 3000 m and is home to the majority of the country's population, where most subsist via the cultivation of foodstuffs on small plots made possible by relatively fertile volcanic soils found in highland basins between 1,000 and 3,000 meters (West and Augelli, 1989). The Interior Highlands also support extensive stands of oak and pine forest, although most recent trends have witnessed extensive de-forestation.

The Caribbean Lowlands extend along the entire coast from the border with Guatemala in the west to the Rio Coco, which serves as the boundary with Nicaragua in the east. Heavy year-round precipitation in this region produces patches of tropical rain forest, especially in the 'La Mosquitia' area where average annual rainfall exceeds 2400 mm (Library of Congress, 1989). The balance of the region includes savannah, alluvial river valleys, coastal plains, and mangrove swamps. The site under study is situated in the 'La Mosquitia' region of Honduras and this report focuses specifically on environmental conditions in the Mocorón area of La Mosquitia, approximately 50 km inland from the Caribbean Coast (Laguna de Caratasca).

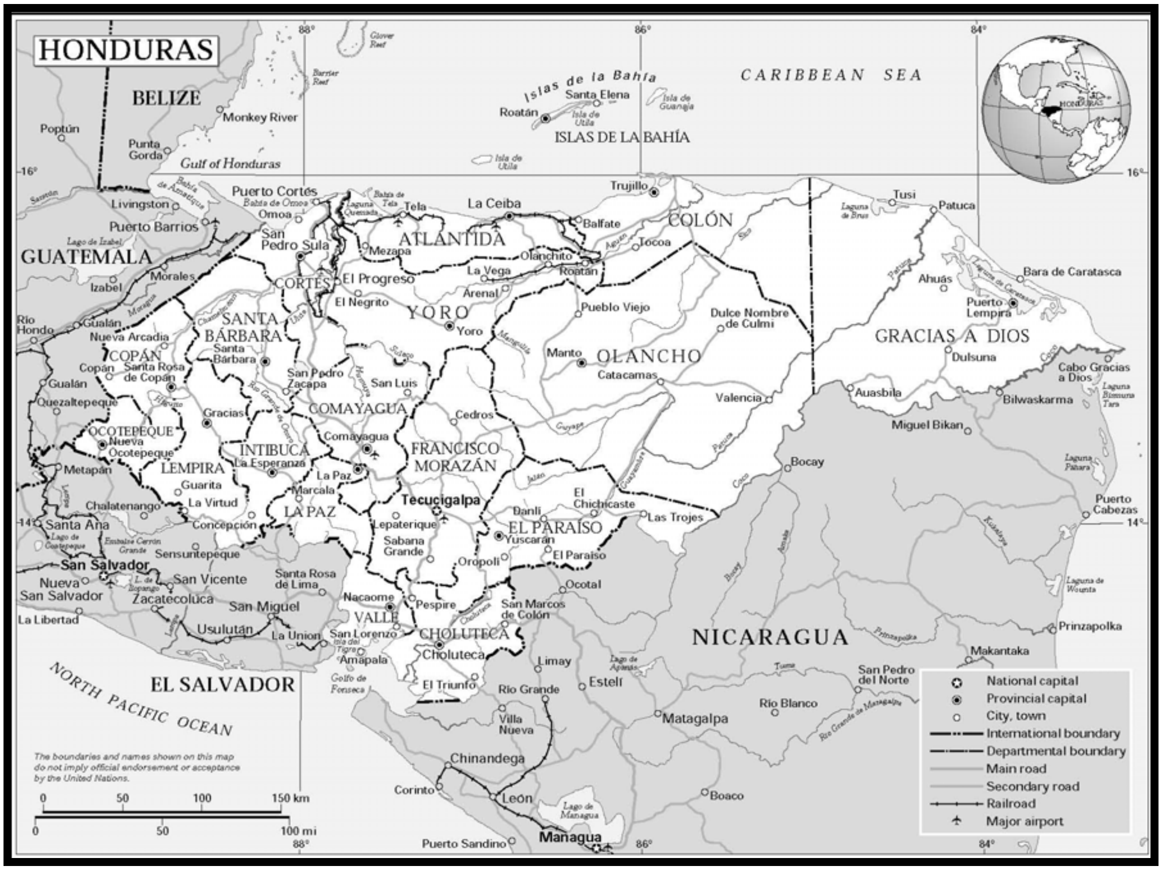

Figure 4: Political map of Honduras (after United Nations, 1994)

III.1.D. Relief. Some estimates characterize 70% of Honduras as being mountainous (Global Connections, 2000). Elevations within the country vary from sea level to almost 3000 m. Cerro Las Minas, located in the south eastern part of the country is the highest point at 2849 m. Principal mountain ranges run generally in an east-west direction and include the Merendon, Cordillera Nombre de Dios, Esperanza, Agalta, Colon, and Entre Rios mountains. The Opalaca, Montecillos, and Comayaguar mountains run northwest-southeast in the western half of the country and are the most dominant ranges in Honduras (Figure 5). Lowlands prevail along both the Caribbean and Pacific coasts, with elevations ranging from sea level to a couple of hundred feet. Honduras' southwestern boundary lies only a few kilometers to the north of the Central America volcanic axis. The limit of an old volcanic surface extends inland about 50-75 km from the border with El Salvador, but lacks the recent volcanic ash covering, which would otherwise contribute to more fertile soils (West and Augelli, 1989).

III.1.E. Natural Hazards. Any geographic overview of Honduras (or any Central American country) should mention the significant natural hazards that have historically plagued the country. Honduras is vulnerable to three distinct hazards: volcanoes, earthquakes, and hurricanes or tropical storms. The Central American volcanic axis skirts the southern part of the country (Figure 6).

With the exception of a single volcano that erupted several hundred years ago in the north central part of the country, the volcanic activity is concentrated along the boundary between the Pacific Lowland and the Highland Interior. Earthquake activity strongly correlates with plate boundaries within the region. As such, the earthquake hazard is also concentrated along the country's southern periphery, although a couple of quakes have occurred along the country's northwestern boundary (Figure 7). Like volcanoes and earthquakes, hurricanes and tropical storms present additional hazards to Central American countries. Honduras is most vulnerable along its eastern and northern coast (Caribbean coast), which are exposed to annual hurricane tracks (Figure 8).

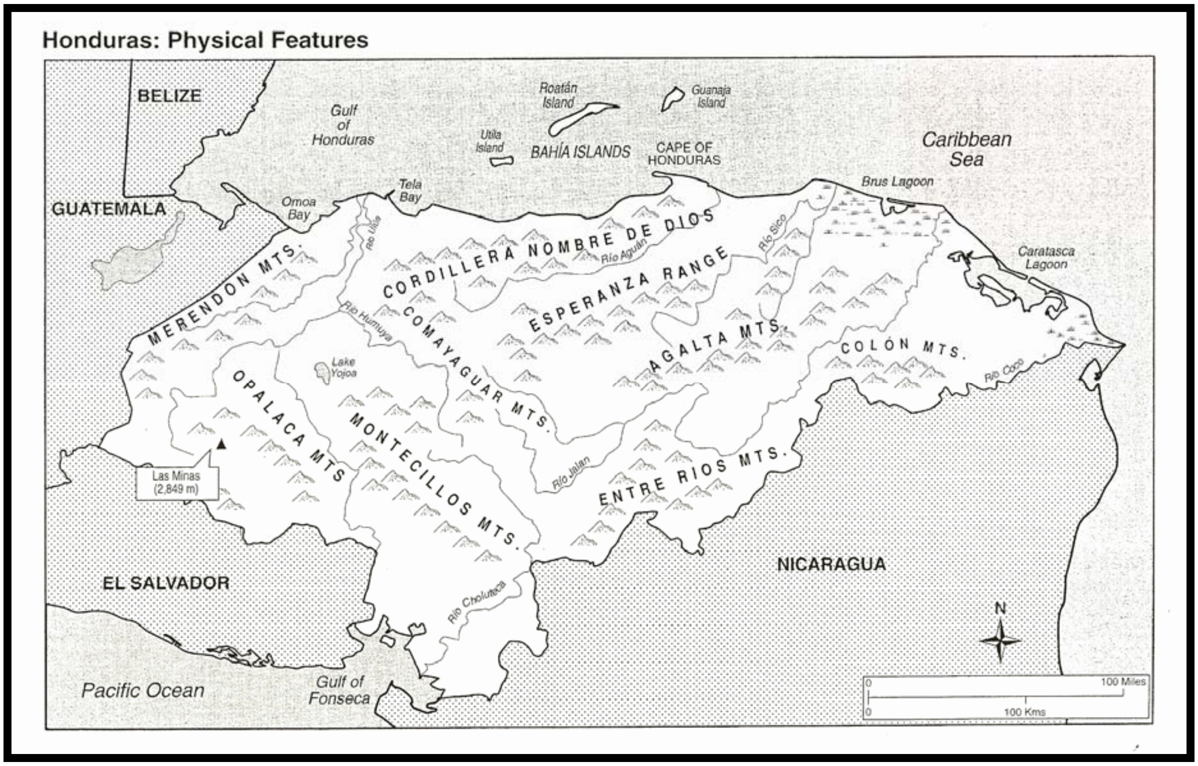

Figure 5: Honduras Relief (from Tomaselli-Moschovitis, 1995)

Of the three hazards mentioned above, hurricanes and tropical storms are the only threats to the La Mosquita region of the country, within which this study is based. The latter, however, present a serious threat, as evidenced by the recent hurricane record (Hurricane Francelia in 1969, Hurricane Fifi in 1974, Tropical Storm Alleta in 1982, and Hurricane Mitch in 1998), which collectively caused billions of dollars of damage to infrastructure, destroyed millions of acres of crops, and resulted in tremendous loss of life. Particularly destructive 20th Century hurricanes include: Francelia (1969), Fifi (1974; 8,000 people killed), and Mitch (1998; 6,000-10,000 killed).

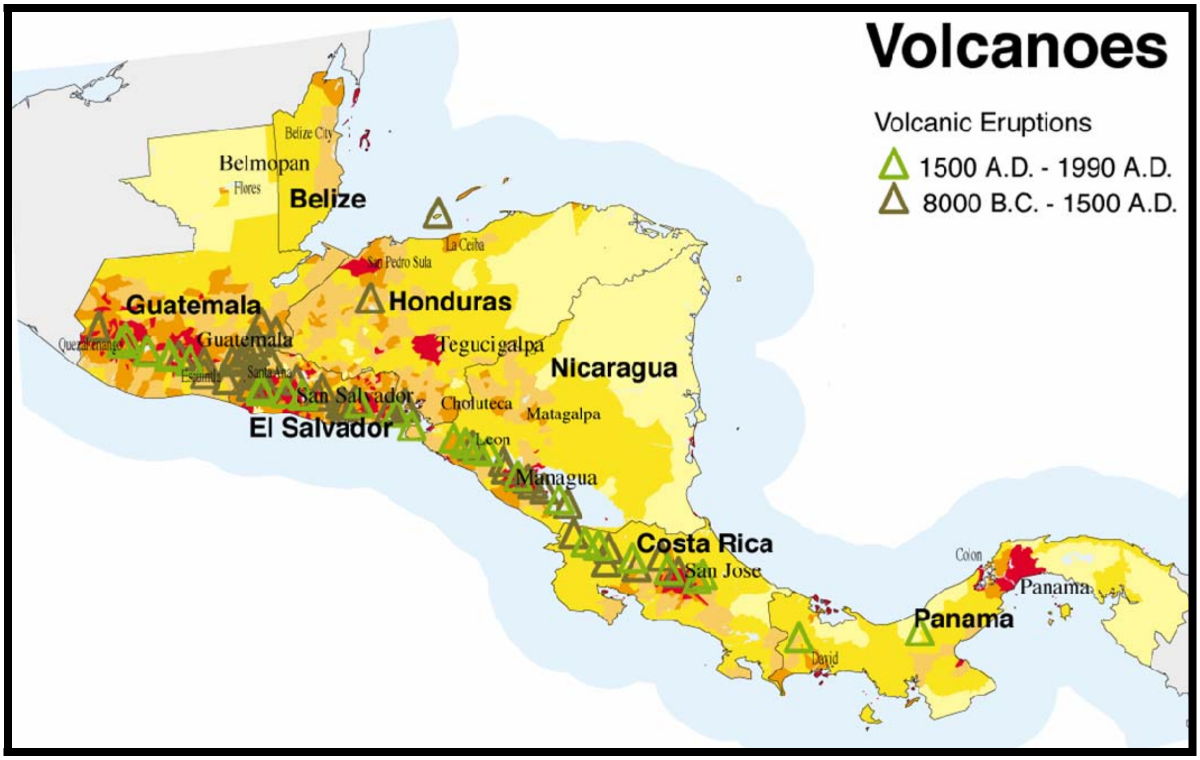

Figure 6: Distribution of volcanoes in Central America (Smithsonian Institution, Global Volcanism Program)

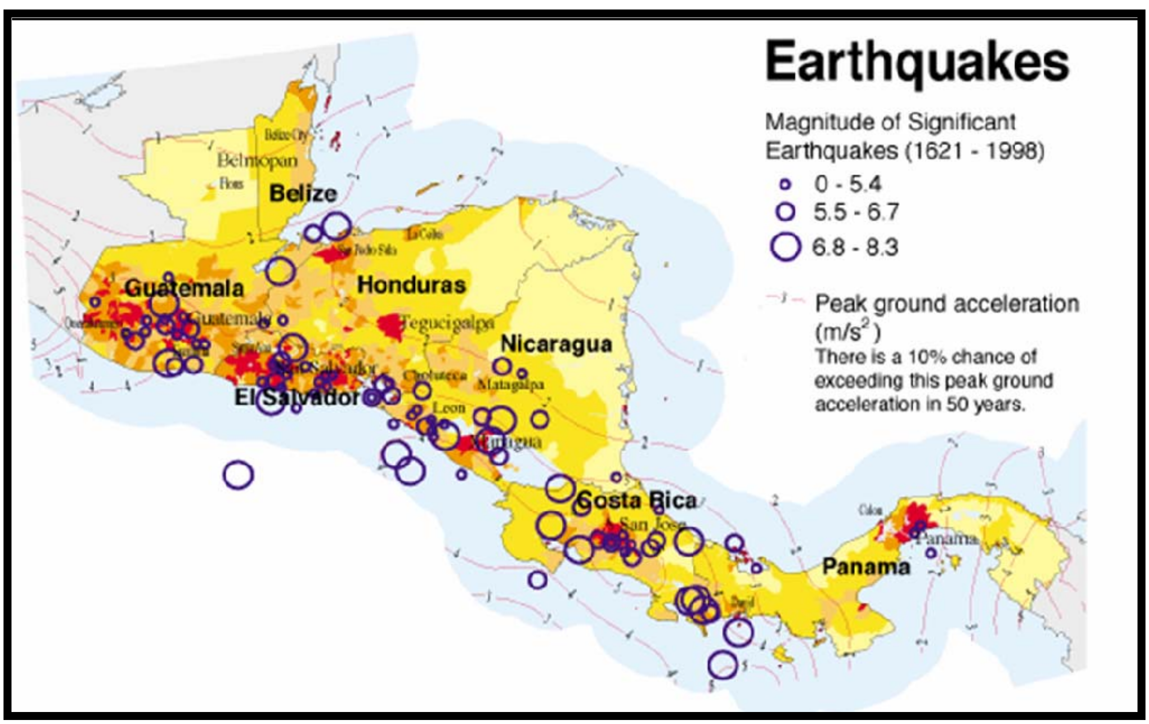

Figure 7: Earthquake hazards in Central America (Shedlock, 1998).

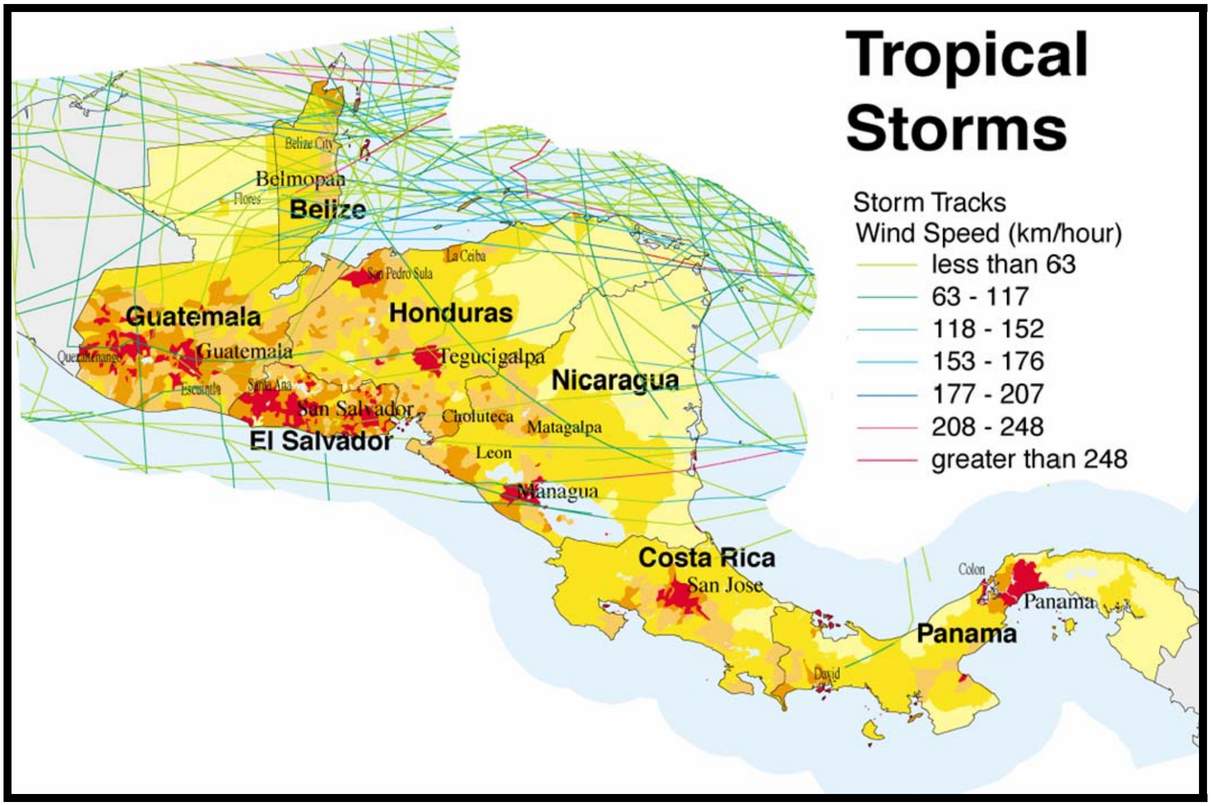

Figure 8: Tropical Storm track in Central America (Colorado State University and NOAA Tropical Prediction Center)

III.1.F. Surface Water and Drainage Patterns. With abundant precipitation and significant relief, water is plentiful. The Rio Ulúa, located near the border with Guatemala, is more than 400 km in length before it reaches the Caribbean Sea, and is considered the most important river in Honduras. The Rio Coco is regionally significant and constitutes about half of the border with Nicaragua. Many other rivers drain the Interior Highlands and flow into the Caribbean Sea (Figures 9 and 10). Most are important as sources of water, some are navigable via small boats, and all have deposited sediments and contributed to fertile, alluvial valleys. Despite the numerous rivers and abundant rainfall, however, Lago de Yojoa, located in west-central Honduras, is the country's only natural lake.

III.1.G. Climate. The eastern, Atlantic coast of Honduras (centered at 15^{o}N) and adjacent Nicaragua, known as 'La Mosquitia', is characterized by a classic humid tropical climate (*tierra caliente*), under the influence of year-round, moisture laden trade winds from the Caribbean. On large scale global climate maps, 'La Mosquitia' is typically depicted as exhibiting a continuously wet or marginally winter-dry, humid tropical climate (either ***Af*** or ***Aw*** in the widely used Koppen climate classification system).

Rainfall over this region is derived largely from periodic low pressure disturbances (easterly waves) embedded in this prevailing north-east and easterly trade wind flow. Additionally, localized, heavy rainfall is typically associated with thermally driven, convectional instability during periods when the inter-tropical convergence (ITC) lies near Honduras (May-November). The region is consequently subject to periodic, large scale flooding of the low-lying coastal plain during the extended wet season (May-November). The 'La Mosquitia' region is also the area of Honduras most susceptible to the impact of Atlantic hurricanes (July to November hurricane season). Over the past 40 years, hurricanes and other severe tropical storms have caused devastating economic impact and loss of life in Honduras.

Figure 9. Major Rivers of Honduras (CIA, 1985).

III.1.H. Vegetation of the 'La Mosquitia' Lowlands. Major vegetation associations in the low-lying Mosquitia region are largely controlled by edaphic and hydrologic factors. In near-coastal areas subject to marine tidal inundation or estuarine mixing of saltwater and fresh water, extensive mangrove forests (*Rhizophora mangle*) dominate the littoral zone. Further inland, narrow, evergreen tropical gallery (riparian) forests of moderate stature (25-40 m canopy height) occupy the floodplains of numerous perennial rivers and streams that extensively dissect the coastal and interior lowlands. As many as 6000 native vascular plant species are known to occur in the region, with many additional species yet to be scientifically described. This riparian evergreen forest is dominated by such species as *Albizia carbonaria, Calophyllum brasiliense,* and *Cecropia* sp. (Nelson, 1986).

Between meandering stream courses, slightly more elevated (5-30 m) interfluves areas are characterized by nutrient deficient soil (dominated by quartz sand/gravels of late tertiary age) that support a distinctive Honduran pine savannah ecosystem (*Pinus caribaea* var. *hondurensis*). The pines (20-25 m maximum height) are moderately to widely spaced, intermixed with scattered, low stature palm thickets (*Acoelorrape wrightii*) and extensive grasslands. The dominant herbaceous species include: *Paspalum pulchellum, Rhynchospora* sp. *Tonina fluviatilis* and *Fimbristylis paradoxa.* During prolonged heavy rains even these pine savannahs may be covered by shallow, standing water.

Over the past several centuries this regional mosaic of natural vegetation has been substantially impacted by anthropogenic factors. Selective commercial logging of valuable Honduran tropical hardwood (particularly Mahogany), accessible along the Caribbean coast, began as early as 1750, and intentional burning of the pine savannah for both swiden agriculture and to improve pasture for cattle is now widespread throughout the 'La Mosquitia' lowlands (West and Augelli, 1989). The area is also subject natural disturbance cycles (vegetation succession) associated with periodic hurricanes.

III.1.I. Geology, Geomorphology, and Soils. The landscape of northeastern Honduras reflects the geological history and diversity of geological process that have affected this region of Central America. The Mocorón site at 15^{o}03' N and 84.27' W lies on the Chortis block of the Caribbean Plate. This ancient continental terrane became a part of the present Central American landmass about 20 million years ago as a result of plate tectonic movements that resulted in the collision of the Chortis block with the Mayan block of continental North America in southern Mexico and the Costa Rica-Panama volcanic arc. Geological mapping of the region has been done by Mills and Hughes (1974), Finch and Ritchie (1985), Kozuch (1991), and Rogers and O'Conner (1993). The lithology of the region is complex, representing the entire pre- and post-assembly geologic history of the Chortis block and consists of (i) Paleozoic metamorphic basement consisting of gneisses, schists, phyllites, meta-intrusive rocks, and marbles (Horne et al., 1976); (ii) Jurassis to Cretaceous sedimentary rock consisting of conglomerates, sandstones, shales, and carbonates (Fitch and Ritchie, 1985; Donnelly et al, 1992; Rogers, 1992); (iii) late Cretaceous terrestrial continental deposits, i.e. 'redbeds', and overlying marine carbonates (Finch, 1981; Rogers and O'Conner, 1993), to (iv) Tertiary-Quaternary volcanic deposits derived from the modern Central American volcanic arc (Mills and Hughes, 1974).

The geology of the 'La Mosquiita' region immediate west of the Mocorón area has been described by Rogers (1995). Metamorphic basement of phyllite, slate, schist, and quartzite of the Jurassic-Cretaceous Honduras Group form the northeast trending highlands to the northwest. The overlying fine-grained limestones of the Cretaceous Atima Formation forms the Montañas de Colón south of the Río Patuca in the Mocoron area. Thinly-bedded shale, clastic sedimentary rocks, and redbeds of sandstone and conglomerate that contain isolated basalt and andesite lava flows of the Upper Cretaceous Valle de Angeles Group are exposed in the Río Patuca lowlands. The redbeds grade upward to the thick cobble and boulder breccia of the Paleocene Tabacón beds that flank the southeast side of the metamorphic highlands. This suite of lithologies comprises the gravel bedload present in the streams of the Mocoron area. Quaternary alluvium consisting of unconsolidated silt, and, and gravel covers the entire land surface Mocoron area.

III.2. Fuerte Mocorón Site Evaluation

III.2.A. General. This report focuses specifically on environmental conditions in the Mocorón area of 'La Mosquitia', approximately 50 km inland from the Atlantic Coast (Laguna de Caratasca and Puerto Lempira, see Figure 10). The terrain exists exclusively within the lowland coastal plain characterized by an absence of hills and steep slopes only in the immediate area of drainage systems. The exact area of the fort cannot be establishes because boundaries are not documented but are included in the area shown in the map shown in Figure 11 and the image presented in Figure 12. The battalion trains over extensive acreage adjacent to the post cantonment area. This cantonment area includes barracks, dining, headquarters, and logistics support facilities for a battalion of infantry soldiers. The post does maintain a primitive airport with a gravel- surfaced 1390 meter runway. There is limited electrical power or running water. Appendix 2 presents photos of the terrain and vegetation, while Appendix 3 adds addition views of the area with a special focus on the soils.

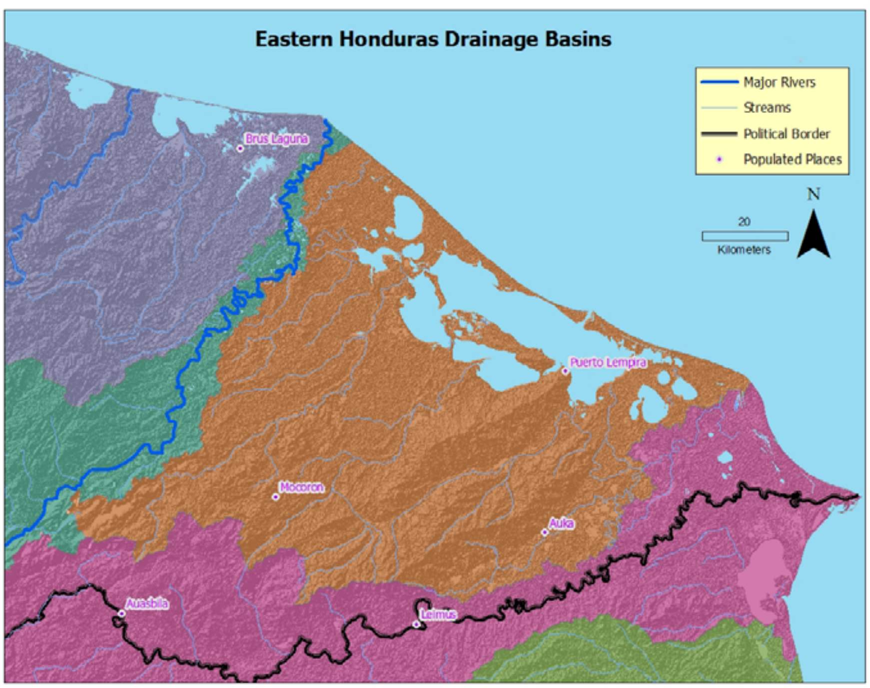

Figure 10. Drainage and Relief in the Area of Mocorón, Honduras
Source: MAJ Ian Irmischer, 2007.

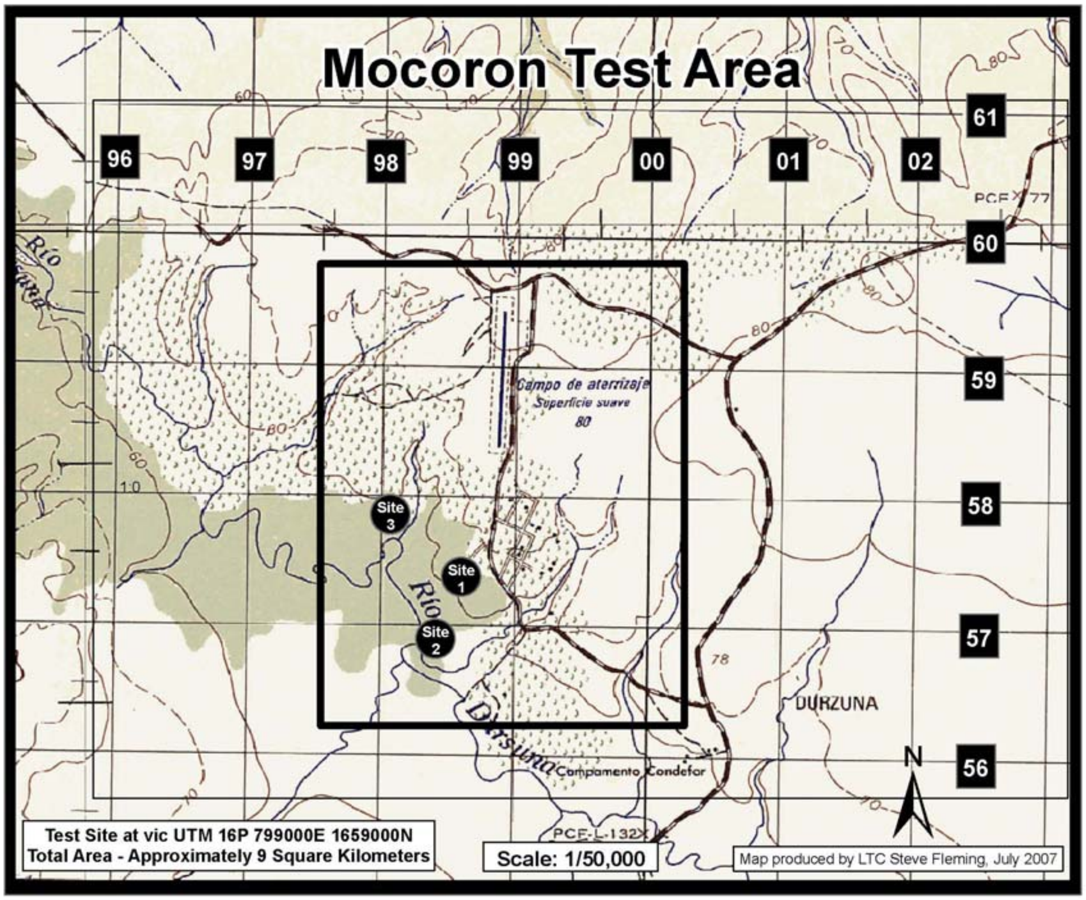

Figure 11. Area Map of Fuerte Mocorón, Honduras

III.2.B Soils at Fuerte Mocorón. The soils at the site reflect the alluvial nature of the geology and exhibit a wide range of textures from very coarse to very fine. Terraced river valleys have been incised into the redbeds of conglomerates. The streams generally have low gradients, but steeper gradients do occur at transitions from one terrace to another. Where the gradients are low the streams tend to meander and as a result soil textures will vary from fine to coarse; deposits of coarse sands and gravel are encountered at steeper gradients. The soils are young and do not show distinct horizons except for **A** horizons with accumulations of organic matter close to the soil surface.

Four characteristic soil profiles have been sampled in the area. Profiles I-III (Tables 6-9, and App 3- Figures 3-6) are typical for the lower lying areas next to the streams. Here soil textures vary from sandy to clay with a high spatial variability. Therefore, dielectric coefficients and attenuation of radar signals in the soils, as well as vehicle and personnel mobility can vary over short distances. Soil Profile I (Table 6 and App 3- Figure 3) consists of fine textured soil wheras Soil Profile III (Table 8 and App 3- Figure 5) has a coarser texture with more sand. Soil Profile II (Table 7, App 3- Figure 4) contains a whitish horizon (> 45 cm) whose origin is not clear. It could be a strongly leached horizon or a volcanic ash layer.

This horizon is typical for areas surrounding volcanoes, but is not found in the other soil profiles due to the active nature of alluvial soils where layers are eroded and deposited due to stream dynamics.

Figure 12. Remote Image of Fuerte Mocorón

Soil Profile IV (Table 9, App 3-Figure 6) is typical for higher locations in the landscape. This profile consists of coarse sand with gravel layers at the bottom. This profile exhibits some slight horizon features that are typical for a podzol. At the surface a dark **A** horizon is located (0–7 cm); the light yellow horizon (7–30 cm) below it suggest that materials have leached out of it which led to some accumulation in the darker yellow horizon (30–75 cm). The lowest horizons show redish oxidation spots. The bottom layer (90–100) contains gravel with finer textured materials that will cause the hydraulic permeability to reduce. Attenuation of radar signals in this soil is expected to be low. Mobility will be good under most weather conditions, but flooding of these soils has been observed after heavy rainfall. The coarse texture of this soil leads to a low water holding capacity of about 50 mm in a 100 cm deep profile and, thus, water stress for the vegetation during months with a water deficit. In March and April, the average precipitation is, respectively, 60 and 75 mm while the potential evapotranspiration is about 150 mm.

Table 6. Soil Profile I (UTM 16 P 0798462, 1657021), with deciduous vegetation.

Depth	Sample #	Texture
Litter layer 1-2 cm		
0 – 10	S3	Clay loam
10 – 20	S4	Clay loam
20 – 30	S5	Clay loam
30 – 40	S6	Clay loam
40 -50	S7	Clay loam
50 – 60	S8	Sandy loam
60 – 70	S9	Clay loam

Table 7. Soil Profile II (UTM 16 P 0798423, 1657740) with deciduous vegetation.

Depth	Sample #	Texture
Litter layer 1-2 cm		
0 – 10	S15	Clay
10 – 20	S16	Clay loam
> 45	S17	Clay loam

Table 8. Soil Profile III (UTM 16 P 0798347, 1657754) with deciduous vegetation.

Depth	Sample #	Texture
Litter layer 1-2 cm		
0 – 10	S18	Sandy loam
20 – 30	S19	Sandy loam
40 – 50	S20	Sandy loam

Table 9. Soil Profile IV TM 16 P 0798886, 1657256), with pine tree vegetation.

Depth	Sample #	Texture
Litter layer 1-2 cm		
0 – 5	S21	Loamy sand
10 – 20	S22	Sand
20 – 30	S23	Sand
30 – 40	S24	Sand
40 -50	S25	Gravelly sand
50 – 60	S26	Gravelly sand
60 – 70	S27	Gravelly sand
70 – 80	S28	Gravelly sand
80 – 90	S29	Gravelly sand
90 – 100	S30	Gravelly sand

After taking the soil water holding capacity of 50 mm into account, the net water deficit is estimated as about 150 – 60 – 50 = 40 mm per month. Therefore, drought tolerant Pine trees dominate the vegetation on these sites while tropical evergreen vegetation dominates the lower lying areas with finer textured soils that have a higher water holding capacity and often are underlain by shallow groundwater tables. Pine trees are often removed for cattle grazing the and, as a consequence, large areas of grass vegetation are present in the study area. The combination of soil physical characteristics, climate, and anthropogenic factors (cutting trees, burning) lead to a mosaic of three major vegetation types: tropical evergreens with dense vegetation cover, savannah like vegetation of grass cover with pine trees, and grass lands (App 3 - Figures 7-8). This feature makes the site attractive for the testing of different remote sensing sensors.

III.2.C. Climate.

Rainfall. Although an automated meteorological station has recently been installed at Fuerte Mocorón (*pers. comm.* R. Peralta, July, 2007), no specific, long term rainfall records are currently available for the immediate area. A review of rainfall records (www.worldclimate.com) from other nearby Atlantic coast areas of Honduras and adjacent Nicaragua (e.g., from La Cieba to Puerto Lempira, Honduras and Bonanza and Puerto Cabezas in Nicaragua) indicate that average annual rainfall over the 'La Mosquitia' lowlands is within the range of 2400-3400 mm/year. A minor 'dry season' typically occurs between February and April when cooler northern air flow and strong trade winds combine to reduce convective instability over the region. Even during this short dry season monthly rainfall at all stations reviewed was never below 60-75 mm/month. The meteorological station nearest Fuerte Mocorón with long term rainfall records is at Puerto Lempira (15^{o}01' N; 84^{o}16' W; located 57 km east of Mocorón). These data can be reasonably extrapolated to the subject site since both locations are comparable lowland areas under the influence of prevailing north-east trade winds from the adjacent Caribbean Sea. Figure 15 illustrates mean monthly rainfall patterns for Puerto Lempira. Mean annual rainfall is 3328 mm/year, with an extended 8-9 month wet season (May-December) where rainfall exceeds 200-400 mm/month. Only 2 months (March-April) receive less than 100 mm/month, but even here, this 'dry season' period, on average receives rainfall of 70-80 mm/month.

From the perspective of ‘ideal’ tropic test criteria (see page 5), the extrapolated rainfall at Mocorón well exceeds the specific requirement of >2,000 mm/year, although the additional requirement for ‘continually wet’ conditions (>100 mm/month) is marginally missed during the February-March period. In comparison with previous Panamanian (Cerro-Tigre and Altos de Pacora) and Suriname (Moengo) site evaluations (King, et.al 2006a; 2006b), Mocorón has higher annual rainfall (3300 mm vs. 2100-2700 mm) with a ‘dry season’ (2 months), equal to Suriname and significantly less extreme than Panama (3-4 months). From a tropical rainfall perspective, Mocorón more closely meets ideal tropic test conditions than other previously evaluated sites.

Air temperature. As with rainfall, no specific long term temperature data exists for the immediate area of Fuerte Mocorón, and proxy temperature data from nearby Puerto Lempira was used for site characterization. Because local temperature variation in the tropics varies largely as a function of elevation, the fact that both Puerto Lempira and Mocoron are in the coastal lowlands (elevation 5-5 0m) justifies extrapolation to the subject site. Temperature data for Puerto Lempira is shown in Figure 13. The mean annual temperature is 27.2°C, which meets the ideal tropical testing criteria (>27.0°C). During the four winter months November through February, means monthly temperature drop slightly below 27°C (i.e., 26-26.5 °C). Maximum daytime and minimum nighttime temperatures throughout the year average 29.5 °C and 24 °C respectively. During field work (0900-1000h, local time, July 14, 2007), several random, instantaneous temperature measurements under the gallery (riparian) forest canopy at Site 2 averaged 27.8-28.3 °C, compared to 28.9-29.4 °C under adjacent, open pine savannah (Site 1) or open riverbanks locations.

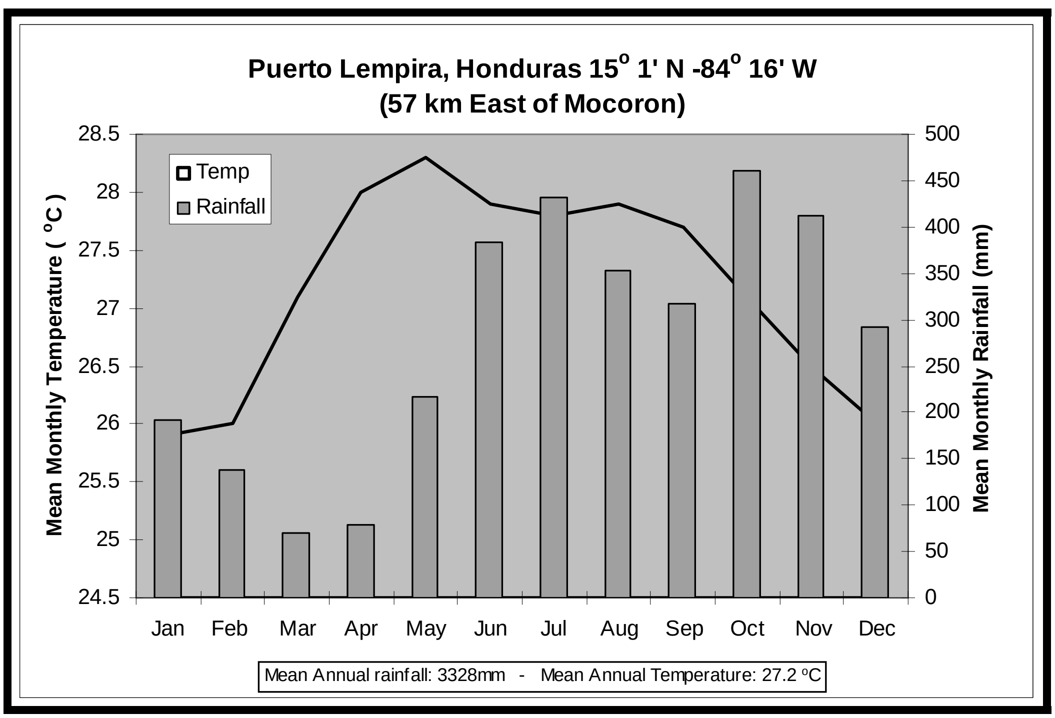

Figure 13. Climagraph of Puerto Lempira, Honduras

Relative Humidity. Year-round, high humidity is characteristic of the Mocorón region. Limited data for 1996 from Puerto Lempira indicates an annual average relative humidity of 83% (mean nighttime 90%; mean daytime 75%). This annual average is slightly higher than that for previously evaluated Panamanian and Suriname sites (80.8% and 81.4% respectively; see King *et.al* 2006a, 2006b). During field work (0900-1000h, local time, July 14, 2007, no rain occurring), several random, instantaneous humidity measurements under the gallery (riparian) forest averaged 99.2-99.8%. Relative humidity in open pine forest and open river-bank locations averaged 96%. All recorded values substantially exceed 'ideal' tropic test criteria for mean relative humidity <75% (range 60-90%).

Evapo-transpiration and Water Balance. No measured pan evaporation data are available for the 'La Mosquitia' region. Based on local meteorological conditions which are quite similar for much of the surrounding *tierra caliente* Caribbean lowlands, it is safe to estimate an annual evapo-transpiration rate of about 1500 mm/year. When this value is compared with annual rainfall over the region (2400-3300 mm/year) a substantial annual moisture surplus is indicated, typical of humid tropical locations. Only during March and April, when monthly rainfall drops slightly (30-50 mm/month) below estimated monthly evapo-transpiration, would soil moisture depletion and plant water stress be expected. Even though this moisture stress period is comparatively minor, anthropogenic fires during this short season can have significant impact on the regional vegetation and related biological processes.

III.2.D. Vegetation site characterizations of Fuerte Mocorón. Vegetation characterization was undertaken for three existing tropic test sites at Fuerte Mocoron. In past vegetation site characterizations for other tropical forests areas in Panama and Suriname (King, et al. 2006a; 2006b), emphasis was focused on documenting the size and canopy characteristics of very large forest trees (DBH >50 cm) that dominated the high canopy (35-50 m). At Mocorón, the generally disturbed (secondary forest) nature of the site with significantly smaller trees necessitated a modification in sampling methodology. At this site all woody tree stems with DBH >5.0 cm were sampled in forest plots.

Pine Forest - Site 1. This site, composed of several mock remote sensing 'target' structures, occurs generally within the open pine savannah, but immediately abutting riparian evergreen forest. A randomly positioned 200 m^2 sampling plot was located immediately adjacent to the structures at this site. A survey of all woody stems with DBH >5.0 cm, yielded only the single pine species (*Pinus caribaea* var. *hondurensis*) with a mean DBH of 17.6 cm and density of 95 trees/ha. The canopy was very open with an average tree height of 19 m (range 17-26 m). All trees showed evidence of past minor fire damage to lower trunks. A distinctive canopy understory was largely absent, with the exception of a few small pine saplings. Due to this general lack of developed understory, horizontal visibility was characteristically >75 m. The ground was almost completely covered by native savannah grasses and other herbaceous species.

Gallery Forest - Site 2. This site, composed of several mock remote sensing 'target' structures, occurs exclusively within the largely closed canopy, tropical evergreen gallery forest.

Two vegetation sampling plots were established near separate structure clusters within the forest. Quantitative results for tree density, DBH, understory, and visibility measurements from both plots (totaling 333 m^2) were nearly identical (differences not statistically significant), so the data from both plots were combined for site characterization. A survey of all woody stems with DBH >5.0 cm yielded a mean tree DBH of 15.2 cm (range 5-51 cm) and a density of 1,861 trees/ha. Canopy height averaged 23-27 m). Selective measurements for 6 other large trees in the immediate area (but outside the sampling plots) had an average DBH of 50.2 cm (range 47-55 cm) and an average tree height of 34 m (range 26-42 m). With a mean tree DBH of only 15.2 cm and no trees with DBH >55 cm, vegetation development at this site clearly represents disturbed, secondary forest, rather than true primary rainforest. The area was likely subjected to earlier logging and possible hurricane disturbance. Much larger trees and better developed, multi-layered canopies were documented for previously surveyed Panama and Suriname tropical forest sites (King et al. *2*006a, 2006b). The forest understory at this site was generally well developed and dense, with as mean understory height of 2.5 m. Palms and saplings of canopy species dominated the understory. Repeated (n = 20) horizontal visibility measurement (maximum distance from observer to point where standing man in camouflage clothing is no longer visible in the undergrowth) yielded an average of 13.0 m. This value is significantly less than similar measurements recorded for forest understories at previously surveyed Panamanian and Suriname sites where visibility was 15.4-25 m (King et al. *2*006a, 2006b).

Gallery Forest in Wetland - Site 3. This site, also composed of several mock remote sensing targets, is closer to the Rio Dursuna than the other two sites. Unlike the Site 2 site this location is characterized by more low-lying topography and may carry significant standing water during the extended wet season. An enumeration of all woody stems (DBH >5.0 cm) yielded a mean Tree DBH of 15.6 cm (range 5-46 cm) and a tree density of 2636 stems/ha. Canopy height averaged 20-31 m. Two additional large trees (in the immediate area but outside the sampling plot) had DBHs of 50 and 102 cm respectively (tree height 25-30 m). As with the other sites, the comparatively small mean DBH (15.6 cm) confirms the secondary forest nature of vegetation at this site. The forest understory at this site was somewhat less developed than at site 2, perhaps a consequence of seasonal flooding and a topographic position nearer the Rio Dursuna (115 m). Small palms and saplings of canopy species dominated the understory, with an average height of 1.2 m, and horizontal visibility averaged 16.1 m (n = 5), significantly higher than at site 2.

CHAPTER IV

EVALUATION OF TESTING CAPACITY

IV.1 Site Ratings

The analysis process begins by grading each of the three sites under study for their ability to support 14 different testing missions listed in Table 4 and described in Chapter II. The first step in this process is to assign utility rating values to each of the 14 environmental criteria that characterize the two candidate test environments. These ratings depict how well the local conditions within each environment match the ideal criteria presented in Table 1. These rating are produced through deliberations by the expert panel based on a review of literature information together with an on-site assessment. The panel includes both scientists knowledgeable in different aspects of environmental sciences and test engineers expert in the conduct of natural environmental testing. Applying these combined experiences produces results that are both scientifically justified and also practical with regard to identifying the true needs for environmental testing. This approach does not reduce the value of the science, but enhances the study goals because it enables the analysis to directly assess the value of specific sites or areas for different test missions. Further, this scientific team included members with experience in the four previous studies, which supported comparative analyses between the 'Ideal Tropic Test Site Model' of King et al. (1998), current provisional U.S. Army test sites in Hawai'i and Panama, plus the other sites in Puerto Rico, Hawai'i, northeast Queensland, Australia, and Suriname that were investigated in previous studies (King et al., 1999; 2001; 2006).

The next step in the analysis is to develop an overall grade for each site for each test mission. Step 1 produced values of 0 to 3 for each of the 14 environmental criteria for each land unit evaluated (Tables 11 - 13). In Step 2, each test mission is evaluated for its suitability at each site according to the important environmental factors for that particular test (Tables 14 - 16). A summary explanation of the analysis process and the location of the results are presented in Table 10.

The final step of the evaluation process is to establish grades for each site for each type of testing mission. Grades are assigned as **A** to **F** as described in Table 13, a scale that is familiar to most students.

Table 10. Analytical model for tropical test site evaluation.

Process Goal	Study Activity	Location of Results
Define test mission	The testing community defines their mission requirements in quantifiable environmental criteria.	Section II
Define environmental requirements	Select the climate, physical, and biologic conditions necessary to achieve mission	Table 1
Select a hierarchy for analysis	Determine the importance of each environmental parameter to be used in analysis	Table 3
Select geographic region	Apply screening tools to a regional analysis.	Figure 4 and 9
Select environmental parameters	The mission is analyzed to identify environmental parameters that apply to the needs of the mission.	14 parameters in Table 4
Select sites	Scientific and practical considerations are applied to select candidate sites from selected regions	
Rate sites for compliance with environmental criteria	Used to characterize the environment at each site visited	Analysis in Tables 7 to 10
Grade sites by testing mission	Critical criteria from Table 4 used to grade (Table 5) each site versus each component of the test mission, a rating of testing capability is made.	Table 11

IV.2. Discussion of the sites.

IV.2.A.- Site 1 (Pine Forest). This site is representative of much of the land cover of Fuerte Mocorón. The trees are sparse relative to the riparian forest areas and grasses are common because of the open canopy. Further, most of the pine forest areas are on very flat terrain. The battalion does have areas of this terrain type where they live fire with small caliber ammunition.

IV.2.B - Site 2 (Gallery Forest). This site is a strip of riparian forest adjacent to the river and further dissected by smaller streams. It has value for static tests and tests not requiring large areas, but would not be suitable weapons firing that would have to be contained inside the forest. Using adjacent pine forest for safety fan areas might allow some weapons and live fire testing inside the riparian forest. The area lacks climax stage rainforest vegetation and a fully developed canopy system. It is likely that the larger trees have been routinely removed for lumber. There is also the possibility that forest development has been impacted by tropical storms. This forest is characteristic of many of the tropical forests in the world where human activity has impacted the forest.

IV.2.C. - Site 3 (Lowland Gallery Forest). The only difference between Sites 2 and 3 is the frequent presence of surface water in this area because it is in a low-lying area of the post. The vegetation does not indicate that this area has constantly saturated soil which would classify it as a wetland.

Table 11 - Environmental Evaluation of: Fuerte Mocorón Test Site 2a

Evaluation Criteria	**Rating**
Temperature	3
Rainfall	3
Humidity	3
Soils	1
Area size	2/0*
Slopes	1
Relief	1
Surface streams	1
Understory	1
Forest Canopy	1
Forest floor fauna	1
Land use/Ownership	3/0*
Adjacent land use	3
Cultural/Historical	3
TOTAL	**27/22**

Evaluation rating scale: 0=unacceptable; 1=marginal; 2=good; 3=ideal

Site 1 is located within Fuerte Mocoron, Honduras. Primary use of the overall facility is to house and train the 5th Infantry battalion. The site exists in the savannah pine forest area which covers most of the fort. The area resides within a large area of public land. The site includes a series of 5 building which serve as aerial remote sensing targets.

* Size of the area and land use restrictions exclude the use of the site for vehicle testing and firing of large caliber weapons.

Positive Physical Attributes

Constant high temperature, humidity, and rainfall
Security and controlled access for testing activities
Well isolated from cultural interference
Easy access from the fort
Available support personnel from the soldiers of the battalion

Limiting Factors

Very flat
Only limited canopy
Soil not suitable for most testing

Table 12 - Environmental Evaluation of: Fuerte Mocorón Test Site 2b

Evaluation Criteria	Rating
Temperature	3
Rainfall	3
Humidity	3
Soils	2
Area size	2/0*
Slopes	2
Relief	1
Surface streams	3
Understory	2
Forest Canopy	2
Forest floor fauna	3
Land use/Ownership	3/0*
Adjacent land use	3
Cultural/Historical	3
TOTAL	**35/30**

Evaluation rating scale: 0=unacceptable; 1=marginal; 2=good; 3=ideal

Site 2 is also located within Fuerte Mocoron, Honduras adjacent to Site 2a. Primary use of the overall facility is to house and train the 5th Infantry battalion. The site exists within the gallery (riparian) forest area of the fort. The overall area of the fort resides within a large area of public lands. The site includes a series of 6 building which serve as aerial remote sensing targets.

* Size of the area and adjacent civilian uses exclude the use of the site for vehicle testing and firing of large caliber weapons.

Positive Physical Attributes

Constant high temperature, humidity, and rainfall
Security and controlled access for testing activities
Well isolated from cultural interference
Adequate canopy for most testing
Excellent access to small to medium streams

Limiting Factors

Relatively flat and no extensive slopes
Relatively small areas of continuous gallery forest

Table 13 - Environmental Evaluation of: Fuerte Mocorón Test Site 3

Evaluation Criteria	**Rating**
Temperature	3
Rainfall	3
Humidity	3
Soils	2
Area size	2/0*
Slopes	1
Relief	1
Surface streams	3
Understory	2
Forest Canopy	2
Forest floor fauna	3
Land use/Ownership	3/0*
Adjacent land use	3
Cultural/Historical	3
TOTAL	**34/29**

Evaluation rating scale: 0=unacceptable; 1=marginal; 2=good; 3=ideal

Site 3 is located within Fuerte Mocoron, Honduras. Primary use of the overall facility is to house and train the 5th Infantry battalion. The site exists in the pine forest uplands area of the fort. The area resides within a large area of public lands. The site includes a series of 5 building which serve as aerial remote sensing targets.

* Size of the area and adjacent civilian uses exclude the use of the site for vehicle testing and firing of large caliber weapons.

Positive Physical Attributes

Constant high temperature, humidity, and rainfall
Security and controlled access for testing activities
Well isolated from cultural interference
Adequate canopy for most testing
Excellent access to small to medium streams
Contained within a lowland wet area different from other sites on the Fort

Limiting Factors

No extensive slopes
Relatively small areas of continuous gallery forest
Difficult to access

Table 14. Rating of compliance with environmental criteria for all testing missions at Site 1.

TESTING MISSION	*ENVIRONMENTAL FACTORS*	*RATINGS*
Equipment Development Testing:		
1) Communication & Electronics	***Understory, canopy, temperature***, ***humidity***, relief, fauna	**1, 1, 3, 3,** 1,1
2) Ground & air sensors	***Canopy, understory***, ***humidity***, temperature, rainfall	**1, 1, 3**, 3, 3
3) Chemical & biological defense	***Fauna, understory, humidity*** temperature, relief	**1, 1, 3,** 3, 1
4) Environmental exposure [*]	***Humidity, rainfall, fauna, temperature,*** canopy	**3, 3, 1, 3,** 1
Operational and Human Performance Testing:		
1) Individual soldier systems [**]	***Temperature, humidity, canopy, understory, rainfall, relief,*** slope, soils	**3, 3, 1, 1, 3, 1,** 1, 1
2) Communication and electronics	***Canopy, understory, fauna, temperature, humidity***, ***relief,*** rainfall	**1, 1, 1, 3, 3, 1,** 3
3) Ground and air sensors	**Canopy,** ***understory***, ***humidity,*** temperature, relief, soils	**1, 1, 3**, 3, 1, 1
4) Chemical and biological defense	***Understory, fauna, temperature, humidity,*** relief, canopy	**1, 1, 3, 3,** 1, 1
Small Caliber Munitions:		
1) Exposure testing	***Land use, temperature, humidity, fauna,*** rainfall**,** canopy	**3, 3, 3, 1,** 3, 1
2) Operational testing and firing	***Land use, area, adjacent land use***, temperature, humidity	**3, 2, 3,** 3, 3
3) Smoke and obscurants	***Understory, temperature, humidity,*** relief, canopy	**1, 3, 3,** 1, 1
Large Caliber Munitions:		
1) Exposure testing	***Land use, area, temperature, humidity, fauna,*** rainfall, canopy	**3, 0, 3, 3, 1,** 3, 1
2) Operational testing and firing	***Land use, area, adjacent land use,*** temperature, humidity,	**3, 0, 3,** 3, 3
3) Smoke & obscurants	***Understory***, temperature, humidity, relief, canopy	**1,** 3, 3, 1, 1
Vehicle Mobility Testing[*]	***Land use, area, soils, slope, relief, rainfall, streams***, understory, humidity	**0, 0, 1, 1, 1, 3, 1**, 1, 3

Notes:
[*] The site lacks the space for large scale vehicle testing. There are no current areas for this type of testing and whether large scale vehicle tests would be allowed is unknown.
[**] Solar radiation is a significant factor affecting human performance in tropical environments.
The environmental criteria are listed in general order of importance. Criteria presented in bold and italics are considered essential elements for that testing mission.

Table 15. Rating of compliance with environmental criteria for all testing missions at Site 2.

TESTING MISSION	*ENVIRONMENTAL FACTORS*	*RATINGS*
Equipment Development Testing:		
1) Communication & Electronics	***Understory, canopy, temperature***, ***humidity***, relief, fauna	**2, 2, 3, 3,** 1, 3
2) Ground & air sensors	***Canopy, understory***, ***humidity***, temperature, rainfall	**2, 2, 3**, 3, 3
3) Chemical & biological defense	***Fauna, understory, humidity*** temperature, relief	**3, 2, 3,** 3, 3
4) Environmental exposure *	***Humidity, rainfall, fauna, temperature,*** canopy	**3, 3, 3, 3,** 2
Operational and Human Performance Testing:		
1) Individual soldier systems **	***Temperature, humidity, canopy, understory, rainfall, relief,*** slope, soils	**3, 3, 2, 2, 3, 1,** 2, 2
2) Communication and electronics	***Canopy, understory, fauna, temperature, humidity***, ***relief,*** rainfall	**2, 2, 3, 3, 3, 1,** 3
3) Ground and air sensors	**Canopy,** ***understory***, ***humidity,*** temperature, relief, soils	**2, 2, 3**, 3, 1, 2
4) Chemical and biological defense	***Understory, fauna, temperature, humidity,*** relief, canopy	**2, 3, 3, 3,** 1, 2
Small Caliber Munitions:		
1) Exposure testing	***Land use, temperature, humidity, fauna,*** rainfall**,** canopy	**3, 3, 3, 3,** 3, 2
2) Operational testing and firing	***Land use, area, adjacent land use***, temperature, humidity	**3, 0, 3,** 3, 3
3) Smoke and obscurants	***Understory, temperature, humidity,*** relief, canopy	**2, 3, 3,** 1, 2
Large Caliber Munitions:		
1) Exposure testing	***Land use, area, temperature, humidity, fauna,*** rainfall, canopy	**0, 0, 3, 3, 3,** 3, 2
2) Operational testing and firing	***Land use, area, adjacent land use,*** temperature, humidity,	**0, 0, 3,** 3, 3
3) Smoke & obscurants	***Understory***, temperature, humidity, relief, canopy	**2,** 3, 3, 1, 2
Vehicle Mobility Testing*	***Land use, area, soils, slope, relief, rainfall, streams***, understory, humidity	**0, 0, 2, 2, 1, 3, 3**, 2, 3

Notes:
* The site lacks the space for large scale vehicle testing. There are no current areas for this type of testing and whether large scale vehicle tests would be allowed is unknown.
** Solar radiation is a significant factor affecting human performance in tropical environments.
The environmental criteria are listed in general order of importance. Criteria presented in bold and italics are considered essential elements for that testing mission.

Table 16. Rating of compliance with environmental criteria for all testing missions at Site 3.

TESTING MISSION	*ENVIRONMENTAL FACTORS*	*RATINGS*
Equipment Development Testing:		
1) Communication & Electronics	***Understory, canopy, temperature***, ***humidity***, relief, fauna	**2, 2, 3, 3,** 1, 3
2) Ground & air sensors	***Canopy, understory***, ***humidity***, temperature, rainfall	**2, 2, 3**, 3, 3
3) Chemical & biological defense	***Fauna, understory, humidity*** temperature, relief	**3, 2, 3,** 3, 1
4) Environmental exposure *	***Humidity, rainfall, fauna, temperature,*** canopy	**3, 3, 3, 3,** 2
Operational and Human Performance Testing:		
1) Individual soldier systems **	***Temperature, humidity, canopy, understory, rainfall, relief,*** slope, soils	**3, 3, 2, 2, 3, 1,** 1, 2
2) Communication and electronics	***Canopy, understory, fauna, temperature, humidity***, ***relief,*** rainfall	**2, 2, 3, 3, 3, 1,** 3
3) Ground and air sensors	**Canopy,** ***understory***, ***humidity,*** temperature, relief, soils	**2, 2, 3**, 3, 1, 2
4) Chemical and biological defense	***Understory, fauna, temperature, humidity,*** relief, canopy	**2, 3, 3, 3,** 1, 2
Small Caliber Munitions:		
1) Exposure testing	***Land use, temperature, humidity, fauna,*** rainfall**,** canopy	**3, 3, 3, 3,** 3, 2
2) Operational testing and firing	***Land use, area, adjacent land use***, temperature, humidity	**3,0, 3,** 3, 3
3) Smoke and obscurants	***Understory, temperature, humidity,*** relief, canopy	**2, 3, 3,** 1, 2
Large Caliber Munitions:		
1) Exposure testing	***Land use, area, temperature, humidity, fauna,*** rainfall, canopy	**0, 0, 3, 3, 3,** 3, 2
2) Operational testing and firing	***Land use, area, adjacent land use,*** temperature, humidity,	**0, 0, 3,** 3, 3
3) Smoke & obscurants	***Understory***, temperature, humidity, relief, canopy	**2,** 3, 3, 1, 2
Vehicle Mobility Testing*	***Land use, area, soils, slope, relief, rainfall, streams***, understory, humidity	**0, 0, 2, 1, 1, 3, 3**, 2, 3

Notes:
* The site lacks the space for large scale vehicle testing. There are no current areas for this type of testing and whether large scale vehicle tests would be allowed is unknown.
** Solar radiation is a significant factor affecting human performance in tropical environments.
The environmental criteria are listed in general order of importance. Criteria presented in bold and italics are considered essential elements for that testing mission.

Table 17 - Evaluation of capability to conduct military testing at sites in Honduras.

	Equipment Development				Human Factors Testing				MUNITIONS TESTING Small caliber			MUNITIONS TESTING Large caliber			Other Tests
SITE	CSE	GASS	CBD	EE	ISSHF	CSE	GASS	CBD	EE	FT	SO	EE	SO	FT	VM
1	C	C	C	B	C	C	C	C	B	B	C	F	F	F	F
2	B	B	**A**	**A**	B	B	B	B	**A**	F	B	F	F	F	F
3	B	B	**A**	**A**	B	B	B	B	**A**	F	B	F	F	F	F

* A/D – The A rating is for open exposure. The D rating indicates a lack of canopy for forest exposure.

Legend:

Grade	**Site Evaluation Description**
A	Fully acceptable testing capability
B	Adequate with some limitations
C	Marginally useful for testing
D	Undesirable, limited utility for testing (with 0 for non-essential elements)
F	Completely unacceptable

Sites: 1 – Pine Forest 2- Riparian Galley Forest adjacent to 2° 3- Lowland Gallery Forest	CSE = Communications Systems & Electronics GASS = Ground & Air Sensor Systems CBD = Chemical/Biological Defense Equipment ISSHF = Individual Soldier System & Human Factors Performance EE = Environmental Exposure SO = Smokes & Obscurants FT = Firing Tests CE = Coastal Exposure VM = Vehicle Mobility

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS.

V.1. Conclusions. This study has successfully characterized the environmental setting of Fuerte Mocorón, Honduras, and evaluated its ability to support a variety of tropical testing missions. Three specific sites within the fort were characterized in detail, two within the gallery tropical evergreen forest and one that was representative of the savannah pine forest, the dominant landscape of the area. Overall, the climate of Morocoń is ideal for all types of tropical testing and training. The flat terrain and lack of relief may reduce the utility of the site for certain tests. In general, both the gallery forest and adjacent pine savannah do not conform to ideal tropic test conditions for tropical rainforest vegetation, due both to inadequate tree diameters and canopy height and complexity. However, where test missions may require secondary tropical forest environments or a complex mosaic of abutting vegetations types (i.e. adjacent open pine forest and grasslands) Fuerte Mocorón may provide very acceptable environmental conditions. The entire area of the fort is too small for any type of large caliber weapons testing.

Though not a specific task of the study panel, it is important to comment on this site and its ability to support military training. Army doctrine requires that the Army train for full spectrum operations conducted in the contemporary operating environment, which absolutely includes the tropical environment. The panel judges that Fuerte Mocorón is a good to excellent location for tropical training of infantry and special operations forces up to company sized units. Established small arms ranges, space for maneuver, and the isolated location all add to the training value of the site. The ability to conduct joint training with an excellent battalion of the Honduran Army makes the site even more promising.

Specific conclusions concerning each site are as follows:

Site 1 (Pine Forest) - This site represents most of the land cover type on Fuerte Mocorón. The overall assessment for this area was that it was only marginally useful for most tropical testing missions.

Site 2 (Riparian Gallery Forest) - These forests are representative of a highly disturbed secondary tropical forest, which is common throughout the tropics because of the level of human disturbance now seen in many tropical forests around the world. It is representative of small strips of forest crossing Fuerte Mocorón adjacent to the surface streams. The gallery forest rates as fully acceptable to adequate for most types of testing not requiring large areas.

Site 3 (Lowland Gallery Forest) - This site ranks the same as site 2b, but adds the ability to test with wetter soils or standing water present.

The presence of a variety of vegetation and soil types within the fort adds value to the site for testing, particularly for all types of sensor testing. The battalion located at Fuerte Mocorón has proven valuable in the execution of tests on the site. A primitive airport with a useable 1390 m runway adds value to Fuerte Mocorón as a test site.

The isolation of the location from civilian activity is a two edged sword for testing. Testing activities must be conducted mostly independently, bringing in all the resources needed to accomplish each test. The battalion at Fuerte Mocorón is very supportive, but they live in a very austere manner with limited potable water, electricity, fuels and other supplies.

V.2. Recommendations.

(i) Fuerte Mocorón should be included as an important addition to the suite of sites available for tropical testing. It offers certain features, both environmental and infrastructure, that do not exist at other sites examined to date.

(ii) The site can be used for tests that requires tropical climate and can utilize disturbed secondary growth vegetation.

(iii) Collecting and analyzing weather date would add value to the location as a test site.

(iv) The site is best suited for tests where climatic variables are most important.

(v) Units visiting the site should plan to be self-sufficient. The C-130 capable airstrip enables users to arrive with a significant logistical package or to arrange for resupply.

REFERENCES

Barnett, T.P.M, 2004, *The Pentagon's New Map: War amd Peace in the Twenty-First Century:* G.P. Putnam & Sons, New York.

BBC News. 2005. Country Profile: Honduras. 22 November 2005. http: //news.bbc.co.uk/go/pr/fr/-/hi/world/americas/country-profiles/1225416.stm

Donnelly T.M., Horne, G.S., Finch, R.C., and López Ramos, E., 1991, Northern Central America: The Maya and Chortis Blocks: in *The Geology of North America, H: The Caribbean Region*, (Dengo, G. and J.E. Case, eds.), Geological Society of America, Boulder, Colorado, USA: 37-76.

Finch R.C. 1981, Mesozoic Stratigraphy of Central Honduras: AAPG Bulletin, 65: 1320-1333.

Finch R.C. and Ritchie, A.W., 1985, Mapa Geológico de Honduras, Danlí sheet, scale 1:50,000, Instituto Geográfico Nacional, Tegucigalpa, Honduras.

Galileo Group, 2005, SORC Counter Drug Presentation, Colorado Springs, CO.

Goodwin, Paul B. 2007. *Global Studies: Latin America, 12e*. Dubuque, Iowa: McGraw -Hill.

Gecko's Crossroads Adventures, 2005. Country Notes: Honduras. http: //www.geckos.com.au/latin_america/country_notes.asp?country=116

Horne G.S., Clark, S.G., and Pushkar, P., 1976, Pre-Cretaceous rocks of northwestern Honduras: Basement terrane in Sierra de Omoa: AAPG Bulletin., 60: 566-583.

King, W. Christopher, 2000, *Understanding International Environmental Security: A Strategic Military Perspective,* Army Environmental Policy Institute (Atlanta).

King, W. C., Harmon, R.S., Bullard, T., Dement, W., Doe, W., Evans, J., Larsen, M.C., Lawrence, W., McDonald, K., and Morrill, V., 1998, A Technical Analysis to Identify Ideal Geographic Locations for Tropical Testing of Army Materiel and Systems, Army Research Office Report to Yuma Proving Ground, July 1998, 47p.

King, W.C., Harmon, R.S., Bullard, T., Evans, J., Juvik, J.O., Johnson, R., and Larsen, M.C., 1999, A Technical Analysis of Hawai'i and Puerto Rico for Tropical Testing of Army Materiels and Systems. Army Research Office Report to Yuma Proving Ground, April 1999, 74p.

King, W. Chris; Palka, Eugene J.; Harmon, Russell S.; Juvik, James; and Hendrickx, Jan M. H. 2001. *A Technical Analysis of Australia for Tropical Testing of Army Materiel and Systems*. Research Triangle Park, NC: United States Army Research Office.

King, Wendell C., Palka, Eugene J., and Harmon, Russell S. 2004. Identifying Optimum Locations for Tropical Testing of United States Army Materiel and Systems. *Singapore Journal of Tropical Geography* 25 (1): 92-108.

King, W. Chris; Harmon, Russell S.; Juvik, James; Hendrickx, Jan M. H., and Palka, Eugene J. 2006. *A Technical Analysis of Suriname for Tropical Testing of Army Materiel and Systems*. Research Triangle Park, NC: United States Army Research Office.

King, W. Chris; Harmon, Russell S.; Juvik, James; Palka, Eugene J.; Hendrickx, Jan M. H.; and Fleming, Steven D. 2006. *A Technical Analysis of Cerro Tigre and Altos de Pacora, Panama for Tropical Testing of Army Materiel and Systems*. Research Triangle Park, NC: United States Army Research Office.

Kozuch M.J. 1991, Mapa Geológico de la República de Honduras, scale 1:500,000, Instituto Geográfico Nacional, Tegucigalpa, Honduras.

Mills R.A. and K.E. Hughes 1974, Reconnaissance Geologic Map of Mosquitia Region, Honduras and Nicaragua Caribbean Coast, AAPG Bulletin., 58: 189-207.

National Geospatial-Intelligence Agency (NGA), 2006. Image obtained from commercial satellite image library (CSIL), IKONOS (IK010007 pan), collected 19 Jul 2003, Bethesda, MD.

Nelson, C. 1986. *Planta Comunes de Honduras, 2 vols*. Universidad Nacional Autonoma de Honduras Tegucigalpa, 922 pp.

Population Reference Bureau. 2005. PRB Country Profiles: Honduras. http://www.prb.org/TemplateTop.cfm?Section=PRB_Country_Profiles&templates

Rogers R.D., 1992, Geology of the Valle de Jamastrán Quadrangle, open file report, 56 pp., Instituto Geográfico Nacional, Tegucigalpa, Honduras.

Rogers, R.D., 1995, Geology along the Río Ratuca and Río Wampú, La Mosquita, Honduras: Open File Report, Instituto Geográfico Nacional, Tegucigalpa, Honduras.

Rogers R.D. and O'Conner, E.A., 1993, Mapa Geológico de Honduras, Tegucigalpa sheet, (2nd ed) scale 1:50,000, Instituto Geográfico Nacional, Tegucigalpa, Honduras.

Spectral Operations Resource Center (SORC), 2005, SORC Counter Drug Presentation, Colorado Springs, CO.

Tomaselli-Moschovitis, V, ed., 1995, *Latin America on File*: Facts on File Inc., New York, NY.

U.S. Army Regulation 70-38, 1979a, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.

US Army Tropic Test Center Report 790401. 1979b. Materiel Testing in the Tropics. DTIC AD NO: A072434. 269p.

Veregin, H., 2005. *Goode's World Atlas*, 21st Edition, Rand-McNally, New York.

West, R. G. and Augelli, J.P.,1989. *Middle America - Its Lands and Peoples* (3rd edition), Prentice Hall, Englewood Cliffs, New Jersey.

APPENDIX 1 – Study Panel Membership

The Scientific Peer Panel for the Tropic Test Center Relocation Study is made up of those individuals listed below. A statement of qualification is included.

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APPENDIX 2
Photos of Fuerte Mocorón

Figure 1. Welcome Sign

Figure 2. Site 1 – Savannah Pine Forest

Figure 3. Pine Forest, Target Set and Gallery Forest in Background

Figure 4. Gallery Riparian Forest Canopy

Figure 5. Gallery Forest in Wetland Area – Site 3

Figure 6. Gallery Forest Understory at Site 2

Figure 7. Wetland Forest Understory (site 3)

APPENDIX 3 Photos from Soil Study

Figure 1. Río Dursana with meanders.

Figure 2. Mining gravel for construction in Rió Dursana.

Figure 3. Soil Profile I; example of fine textured alluvial soil profile. The pencil is inserted at depth 60 cm.

Figure 4. Soil Profile II; example of alluvial soil profile with volcanic ash layer. The water level in the pit is at about 60 cm depth. The water accumulated in the pit due to the low permeability of the fine textured volcanic ash layer.

Figure 5. Soil Profile III; example of alluvial soil profile. The pit is about 60 cm deep; texture is sandy.

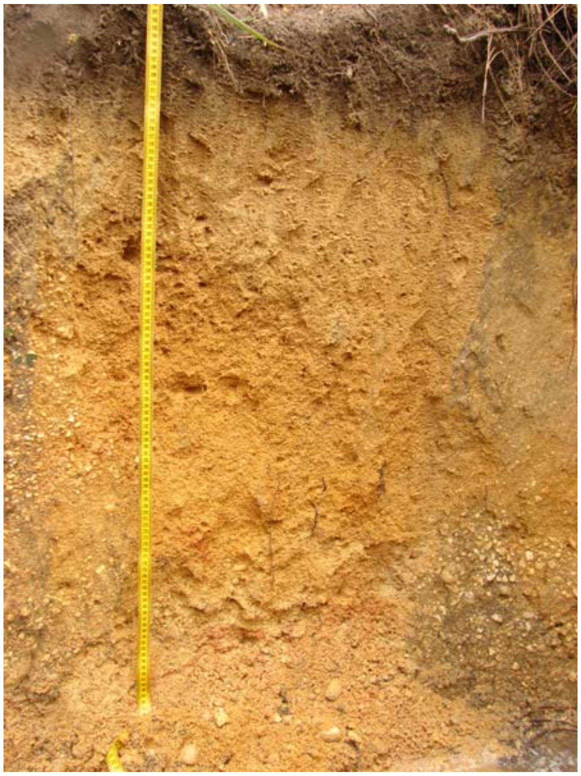

Figure 6. Soil Profile IV; example of alluvial soil profile in sandy soil under Pines. The depth of the pit is 100 cm.

Figure 7. Tropical evergreen vegetation on the lower locations in the landscape; Pine trees (foreground of picture) on the higher locations with coarser soils.

Figure 8. Pine trees and grass lands on the coarser soils close to the Morocón site.