Expansion of the Enrique A. Jimenez International Airport:

Evaluating the extent and environmental impact

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List of Abbreviations

ANAM – Autoridad nacional del ambiente de Panamá

AAC – Autoridad Aeronáutica Civil de Panamá

STRI – Smithsonian Tropical Research Institute

CFZ – Colon Free Trade Zone

ICAO- International Civil Aviation Organization

1.0 INTERNSHIP COMPONENTS

1.1 Number of days spent on project

	Panama City	Punta Galeta	Total
Days per person	27	10	31
Total days	54	20	74
Total man hours	432	160	592

1.2 Contact Information

Host Institution

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1.3 Host institution

Our host institution was the Smithsonian Tropical Research Institute (STRI), a sister organization of the Smithsonian Institute in Washington, DC, USA. STRI was founded in 1923 on Barro Colorado Island. Since then, it has grown to encompass five affiliated research stations throughout the country of Panama. Each station is home to various scientific staff and

researchers conducting biological and anthropological research. Our internship was conducted at Punta Galeta, one of STRI's marine laboratories located on the Caribbean coast. Most of the research conducted here is on marine organisms and mangrove ecosystems.

1.4 Study Site

The location of Punta Galeta is illustrated in Figure 1. It is located on the Caribbean coast of Panama, 8km northeast of the city of Colon. Punta Galeta is surrounded by an intact mangrove ecosystem. Just southwest of these mangroves in the Colon Free Trade Zone and the small residential community of Coco Solo.

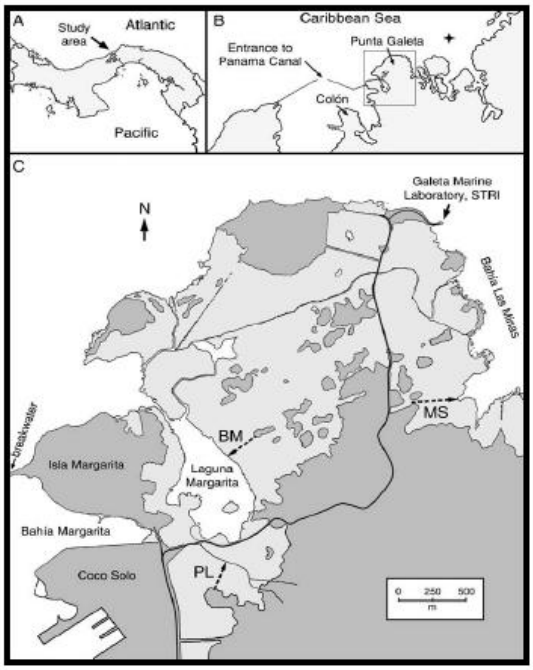


Figure 1 (A) Location of study area within Panama; (B) Location of Punta Galeta and entrance to Panama Canal; (C) Enlargement of Punta Galeta Marine Laboratory area, light grey shading indicates mangrove forest and dark grey shading indicates upland forest and developed areas (Sousa et al., 2007).

1.5 Acknowledgements

The completion of this project would not have been possible without the help from various institutions and people. First of all, thank you to the STRI for facilitating our stay here in Panama and providing ongoing administrative support. We would like to formally thank our supervisor Dr. Stanley Heckadon for his help and guidance throughout the investigation. We would also like to thank all the scientific staff at Galeta for their hospitality and help, in particular Jorge Morales,

Alfredo Lanzua, Illia Grenald and Gabriel Thomas. We would like to thank the Policia Nacional de Panama for their support and escorting us to the airport.

We would also like to thank all the academics and professionals we interviewed throughout the course of our internship including Hector Guzman, Thomas Meredith, Milagros Hernandez, Ricardo Castillano and Vittorio Williams. We would like to show appreciation towards all the people that assisted us in obtaining data for our research including Cecilia Jaramillo from the AAC, Steve Patton and Milton Solano from STRI and Deena Yanofsky from the McGill Geographic Information Center. Finally, thank you to our professors, Roberto Ibanez, Raphael Samudio and Kecia Kerr for their ongoing guidance and advice.

2.0 INTERNSHIP BACKGROUND AND INITIATION

2.1 Introduction

In the mid 20th century the United States military maintained a base of strategic value in the area surrounding the Panama Canal. Located at the Atlantic end of this base, inside area known as France Field, was an airport that was used for military supply and restocking. In 1964, the Smithsonian Tropical Research Institute (STRI) received a concession to establish a marine laboratory at Punta Galeta approximately 3km north of this airport. What attracted scientists there was not any military value, but the biological and ecological value of marine ecosystems.

Nowadays devoid of military presence, Punta Galeta remains open for marine research and environmental education. It is home to the longest monitoring research station in the Caribbean (McKinley, 2007). The Autoridad Nacional del Ambiente de Panama (ANAM) works with STRI to protect the region and maintains a permanent office within the confines of Punta Galeta. According to ANAM this area is classified as a "protected landscape"; an area that is managed for aesthetic value, biodiversity and conservation (ANAM, 2011). Surrounding Galeta is an intact mangrove ecosystem that covers an area of 750 acres (Triana, 2011). The mangroves work to stabilize land in the event of rising sea levels, cycle nutrients, trap sediment, process pollutants and provide habitat for both terrestrial and marine organisms (Alder, 2005). Their healthy functioning is vital for the operation of Galeta and protection of human communities from high tides, flooding and extreme weather events.

Throughout the 20th century, the area south of Galeta experienced expansive industrial growth with the establishment of the Colon Free Trade Zone (CFZ). This zone is a place of international imports and exports and receives over 250,000 international visitors each year

(Business Panama, 2007). The above mentioned airport changed with this changing landscape and began to host the arrival of domestic flights. Recently, as a part of a government economic expansion plan, the Civil Aeronautic Authority of Panama (AAC) has been given $250 million to invest in Panama's airports (Racero, 2010). $58.3 million of this has been allocated to the Costa Rican based contractor MECO for the expansion of the Colon airport into an international airport (Racero, 2010). Construction began in January 2011 to expand the runway and infrastructure in order to support international cargo and passenger arrivals and departures entering the CFZ. It will also be used to as a tool for increasing tourism in the province of Colon (Racero, 2010).

Due to the geographical proximity between the airport and the marine laboratory, STRI holds concern about the environmental consequences of the expansion. The decision to move forward with the project was made at a governmental level with little public consent and information. The staff who work at Galeta station were given no information regarding the project and thus are eagerly trying to determine what its effects will be for them and the marine ecosystem they work to protect.

2.2 Objectives and goals

The objective our internship was to determine the components of the airport expansion and what it means for Punta Galeta. Through this, we aimed to determine the economic, physical and social components of the expansion. We gave explicit focus on trying to understand the environmental impact the expansion will have on the mangrove ecosystem of the region. Within this investigation, the overarching goal was to determine opportunities for mitigation and our final objective was to make contact with groups or individuals involved in the project. We hoped

to organize a meeting to discuss possible mitigation measures that will reduce harmful environmental impacts on Galeta.

2.3 Methods

The main methods used to complete our objectives were an extensive literature review and a series of interviews. Literature was obtained from a variety of sources including scientific journals, newspaper articles, environmental impact assessments, government documents, institutional documents, reports and websites. The first step of the literature review was to develop a general understanding of our study area and the driving economic forces behind the changes occurring to it. The next phase of our literature review consisted of examining environmental impact assessments for this project and past proposals to understand the physical extent of the project. Since the EIA did not explain what the environmental impacts will be during operation, the next phase of our research focused on attempting to discover what these impacts will be. We focused on emissions, the hydrological cycle, noise and biotic impacts. The final phase of our literature review consisted of looking for opportunities and recommendations for mitigation and management.

Interviews were conducted with scientific experts in areas of environmental management and coastal biology. We also conducted various interviews with people involved in the expansion of the project including airport employees, lead engineers, members of the AAC and ANAM officials. Furthermore, informal discussions were held with Galeta staff and researchers. Over the course of the investigation we also visited the airport site twice to talk with on-site representatives and to obtain GPS points of important expansion locations.

To illustrate the extent of the expansion and understand the impact on the hydrological cycle we used GIS mapping methods. Using personally collected GPS points and spatial data obtained both from STRI and the McGill University archives we were able to produce two maps that showed the impact and extent of the expansion. A full description of the GIS methods is available in appendix 7.1.

2.4 Limitations

Throughout our course of study we encountered various limitations that prevented us from obtaining the full results we initially hoped for. We had planned to do GIS modelling to model noise dispersion and drainage networks. However, we were unable to obtain a software licence with Spatial Analyst – a part of the ArcGIS program that allows you to analyze raster data sets. Since most of the data required for these analyses is raster, it was impossible to complete them. Another limitation we faced was through encounters with people. We found it hard to get in contact with various government officials and once we did get in contact with them, they would not have the information we needed and would direct us to someone who we were unable to get a hold of. Unfortunately, we were unable to complete our third objective of organizing a meeting due to lack of time and inability to get in contact with enough people in charge of the project. However, we do have a list of contact information that we will be presenting to Galeta.

2.5 Ethical Considerations

Since a large portion of our research required formal and informal discussions with human subjects, we strictly followed the McGill Code of Ethics. All interview participants were informed of our status as interns for STRI as well as our status as students at McGill University.

All participants were informed of our project objectives and intended goals for the results of the interviews. Participants were asked if their names could be published and those wishing to remain anonymous are not listed in our report.

3.0 RESULTS

3.1 Components of the Expansion

3.1.1 Economic

The driving force behind the expansion of the airport has been the national Government of Panama. As part of President Martinelli's campaign to increase tourism and commerce in the country, he ordered that the land surrounding the old airport (owned by CEMIS) be given to the government. The land was then transferred to the ownership of the AAC along with $60 million to fund the expansion of the airport (Prensa, 2009).

In a news article, Geovanni Ferrari, the president of the CFZ stated that the purpose of the airport will be to increase safety for investors doing business in the CFZ, facilitate the movement of cargo, increase the number of tourists using cruise ships and act as a back up in the case of emergency at Tocumen (Prensa, 2009). The project is also meant to help stimulate growth in the province of Colon, which currently only contributes to 12% of GDP (Prensa, 2009). However, after multiple interviews with on and off site personal involved in the construction, it has become apparent that the airport is being constructed with no clear plan or projections of what it will be used for. In interviews with both the head engineer and tower controller, it was stated that they do not know how many planes will be coming, where they will be arriving from, where they will be going, or the proportion of cargo to passenger flights expected (Hernandez, Personal Communication, March 17 2011; Williams, Personal Communication, March 17 2011).

There is also some speculation that airport construction across Panama is linked to the development of the mining industry. There are currently three airport expansion projects in Bocas del Toro, Cocle and Colon. These expansions can be linked to the nearby copper or gold

deposits in Cocle and Chiriqui. The development of airports will help facilitate national GDP growth by allowing easy international mineral exports.

Based on literature review, there are some indications that the construction of the airport will be beneficial and used to full capacity. There is a strong relationship between airport construction and economic growth (Upham, 2003). Between 2007 and 2008 the number of international flights landing in Panama increased by 14.6% (Memoria, 2009). Of the 250,000 international visitors to the CFZ, most are from countries that can easily be accessed with only one flight, such as Haiti, Jamaica, Costa Rica, Venezuela, Colombia, United States and Ecuador. Additionally, 83% of cargo exports go to nearby countries such as Venezuela, Guatemala, Ecuador, Costa Rica, Dominican Republic, the United States, Chile, Cuba, Honduras, Peru, Brazil, Nicaragua and El Salvador (Business Panama, 2007). Overall, the airport is being constructed with justified far-sighted intentions of stimulating commerce and tourism but with unknown projections for capacity and use.

3.1.2 Physical

The physical extent of the project is explained in the Environmental Impact Assessment completed by the AAC in December 2010. Construction was scheduled in two phases, the first phase will require 87ha and the second will require 201ha. Upon our first visit to the airport in January 2011, the first phase was well underway. The second phase started in March 2011 and by the end of March all deforestation was complete. Table 1 summarizes the size and extent of the expansion.

Table 1 Size and Extent of Expansion (Cardenas, 2010)

	Total Area
Project area	288.5 ha
Deforestation	50.9 ha
Secondary forest	60% - 30.5 ha
Primary forest	40% - 20.4 ha

Historically, the airport had two runways to handle incoming and outgoing domestic flights. A north-south runway was used for takeoff and landing and an east-west runway was used for parking planes. The only infrastructure present was a small air traffic control tower located at the southwest corner of the runway intersection. However, to accommodate large international passenger and cargo planes, the north-south runway is being extended north 1125m to the edge of Galeta Road (see Map 1). The runway will be expanded to a width of 45m and 7m will be allocated to shoulders and 2.5m for taxis. The east-west runway is not being expanded. In this region, wind direction is north during the entire year with variations in strength and wind speed (Arden, 2001). The runway must be extended in the north-south direction because extension in the east-west direction will use more fuel for takeoff and landing. Due to heavy industrial development to the south the runway cannot be extended in this direction. The runway must therefore be extended north, ending exactly on the boundary of Punta Galeta.

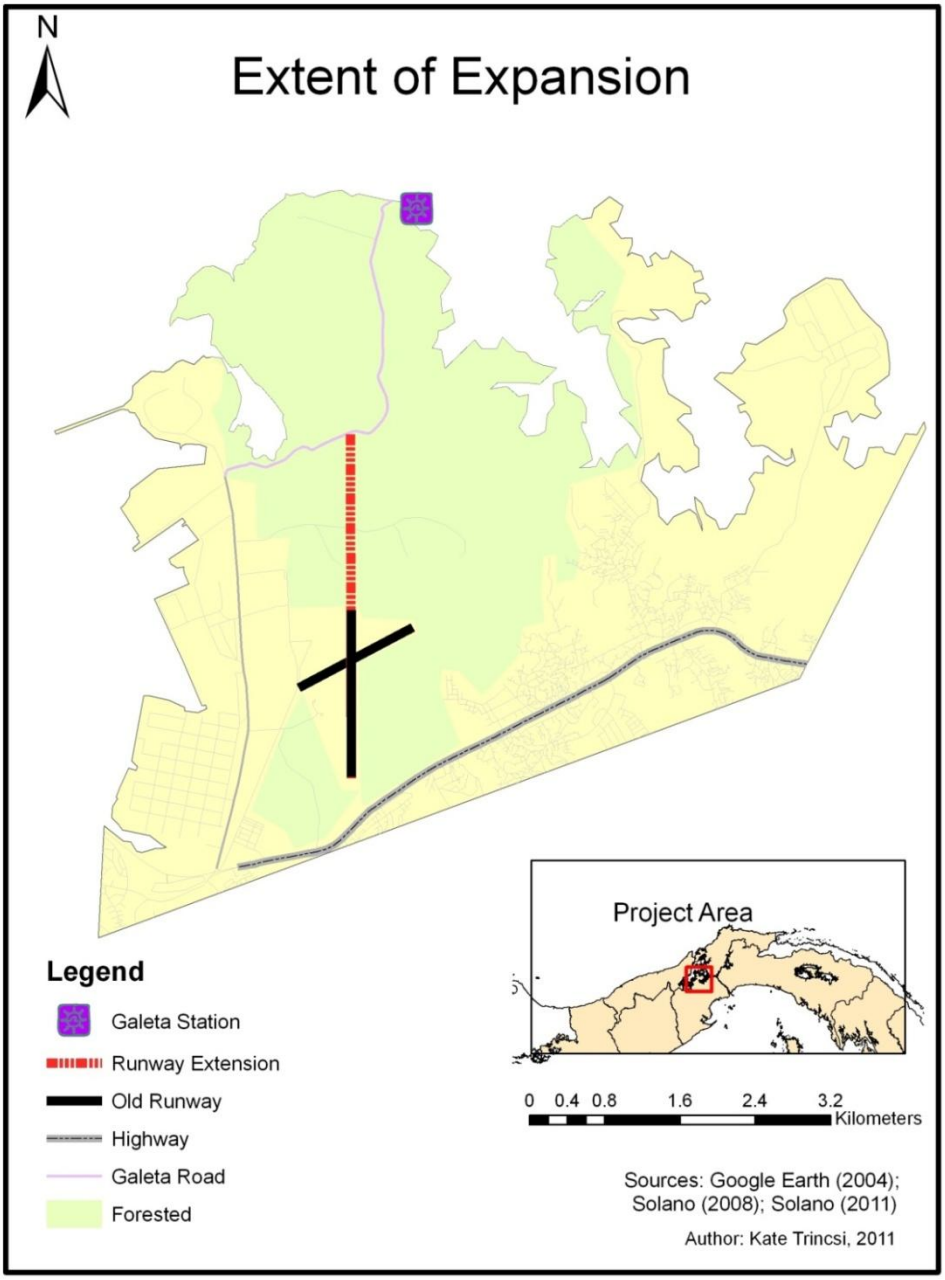
To accommodate the new international airport, various infrastructures will be installed to host 500 incoming and 500 outgoing passengers at one time, all 24 hours of the day (Hernandez, Personal Communication, March 17 2011). To accommodate passengers a large terminal complex and parking lot will be built. They will also install an electric plant for emergencies, 800m long road for public access, a water treatment plant, a new tower control system and a small incinerator. The full MECO infrastructure construction plans can be seen in appendix 7.2.

Maintenance for newly constructed infrastructure will be provided by various external companies. The full list of services is outlined in table 2.

Table 2 Colon Airport Services (Cardenas, 2010)

	During Construction	**During Operation**
Organic and Inorganic waste	Transported twice a week by tucks to Monte Esperanza	
Domestic waste	Stored in garbage bags to be transported to Monte Esperanza by the service of AGUASEO	
Water supply	Administered by IDAAN	
Liquid Waste	Removed by Latinzel	Treated by treatment plant then deposited into Rio Coco Solo
Energy	Elektra Noreste	
Access Road	Via Randolph	
Public Access	Via Randolph	Carretera Transistmica

Map 1 GIS construct of the extent of the expansion



***Forest cover is based on 2004 estimates

3.1.3 Social

The EIA discusses the importance of public participation and outreach throughout the phases of construction. The stakeholders that need to be considered by the development project are:

- ANAM who maintains a permanent office in Punta Galeta
- Scientific staff and community of Isla Galeta who rely on a healthy ecosystem for research and environmental educational programs
- Construction company MECO
- Residents of Coco Solo: an impoverished neighbourhood located less than 1km away from the planned expansion
- Panamanian government and AAC who commissioned the expansion
- Businesses within the CFZ who will use the facilities for passenger and cargo imports and exports

There were two meetings with the community that took place on November 15 and November 23, 2010. It is unstated how many people attended these meetings but the EIA claims that there was an overall consensus of acceptance for the project. The AAC also conducted an interview with similar accepting results. However, this particular survey only evaluated the opinion of 13 people. It is important to note that not all stakeholders were consulted in these processes, evident in the fact that Galeta had received no information regarding the project or the dates of consultation meetings.

The city of Colon is one marked by poverty. The expansion of the airport will provide benefits through social services to the area of Colon. Directly, 150 jobs will created during the construction phase and 100 during operation. However, most of the high paying jobs will be

given to people commuting from Panama City, not the residents of Colon. On the other hand, a lot of jobs will indirectly be created in Colon if the airport succeeds in stimulating local tourism.

3.2 International Guidelines

An essential requirement for our internship was to determine if there are international airport guidelines that this expansion would have to adhere to. Through intensive research we found that there are guidelines produced by two different international organizations. The first set we looked at were the International Finance Corporation's, a tributary of the World Bank, Environmental Health and Safety (EHS) guidelines for commercial airports. The guidelines are available online for public viewing. However, after examining them we found that they are more suggestions and recommendations than strict numeric guidelines. For example, the guidelines on emissions are to "minimize fugitive air emissions from jet kerosene" and "optimize ground service infrastructure to reduce aircraft and ground vehicle movements on taxiways" (International Finance Corporation, 2007). Nowhere in the document does it list strict international guidelines that require ongoing regulation.

The second set we referenced were guidelines created by and organization affiliated with the United Nations, the International Civil Aviation Organization (ICAO). The guidelines were obtained from binders available at the AAC library located in Albrook. Similar to the EHS guidelines, there were few definite rules pertaining to the environment. Most of the guidelines are recommendations. However, these guidelines served as excellent information sources of how airports operate. Of some importance is the CO_2 standard the ICAO is currently in the process of developing (Hupe, 2010). We suggest that if CO_2 emissions are causing problems in the future, the Galeta staff follow up on the results of this project.

3.3 Environmental Impact

After conducting literature a review of the environmental impacts caused by the operation of large-scale international airports, we determined that the following four factors will have the largest site-specific impact in Colon and thus required analysis.

3.3.1 Emissions

Concerns for emissions take place in two separate manners: operation of airplanes and operation of ground equipment. Emissions vary with fuel type, craft type, engine type, engine load, distance travelled and flying altitude. The two planes expected to use the newly internationalized runway are the Boeing 767 and Boeing 757 (Racero, 2010). This will result in a shift from gasoline fuelled engines used for the old airport to kerosene fuelled engines used in these larger planes (Rydpal, 2000). Using the table in appendix 7.3 we determined that these two planes both emit carbon dioxide, methane, nitrogen oxides, nitrous oxides, carbon monoxide, volatile organic compounds and sulphur dioxide. However, of particular concern for Galeta are the chemicals emitted during the takeoff/landing cycle of airplanes, since cruising is likely to be done too far away to directly impact this area. The line dividing landing/takeoff from cruising is approximately 1000m (Rydpal, 2000). Flight paths for both taking off and landing planes will involve circulation around Galeta. Table 3 outlines the typical emissions for one model of a Boeing 757. It can be extrapolated that a 767 releases similar emissions (Boeing, 2011).

Table 3 Boeing 757 emissions at various flight stages (ICAO, 2007)

Mode	Fuel Flow kg/s	Emission indices (g/kg)		
		Hydrocarbon	Carbon Monoxide	Nitrogen Oxide
Take-off	1.761	0.05	0.4	31.1
Climb-out	1.4448	0.06	0.41	24.8
Approach	0.493	0.21	2.3	10.3
Idle	0.155	2.26	23.1	4.4
Number of tests		3	3	3
Number of engines		1	1	1

The chemicals that will be released in greatest quantities at these takeoff and landing stages of flight are hydrocarbons, carbon monoxide and nitrogen oxide. These chemicals pose certain risks to humans living in the neighbourhood of Coco Solo, as well as the people who work every day in the CFZ and Galeta. Carbon monoxide, nitric oxide, nitrous oxide, ozone, unburned hydrocarbons, polyaromatic hydrocarbons and sulphur dioxide are harmful when inhaled. Respiratory problems and cancer can be associated with these gases. In addition, nitrogen oxides and sulphur dioxide react with water to produce various acids, namely nitric acid (HNO_3) and sulphuric acid (H_2SO_4). These compounds are not only dangerous to breathe in; they are the causes of acid rain. Consequences of acidic precipitation include damage to limestone or marble structures, accelerated oxidization of metals, harm to vegetation, and acidification of soil and water – with subsequent effects on aquatic animals. As previously stated, predominant seasonal wind direction is north in the direction of Galeta. Depending on where the chemicals are emitted there is a chance that they will be blown north into the Caribbean away from the station before becoming deposited on the ground.

In conclusion, it is important to keep in mind that all of these emissions will be dispersed over an unknown volume of atmosphere. Flight paths, winds at different altitude and traffic density are unknown factors to keep in mind. Potential harmful impacts are human health concerns, an increase in primary production from carbon dioxide increase and an increase in acid rain.

3.3.2 Hydrology

Background information

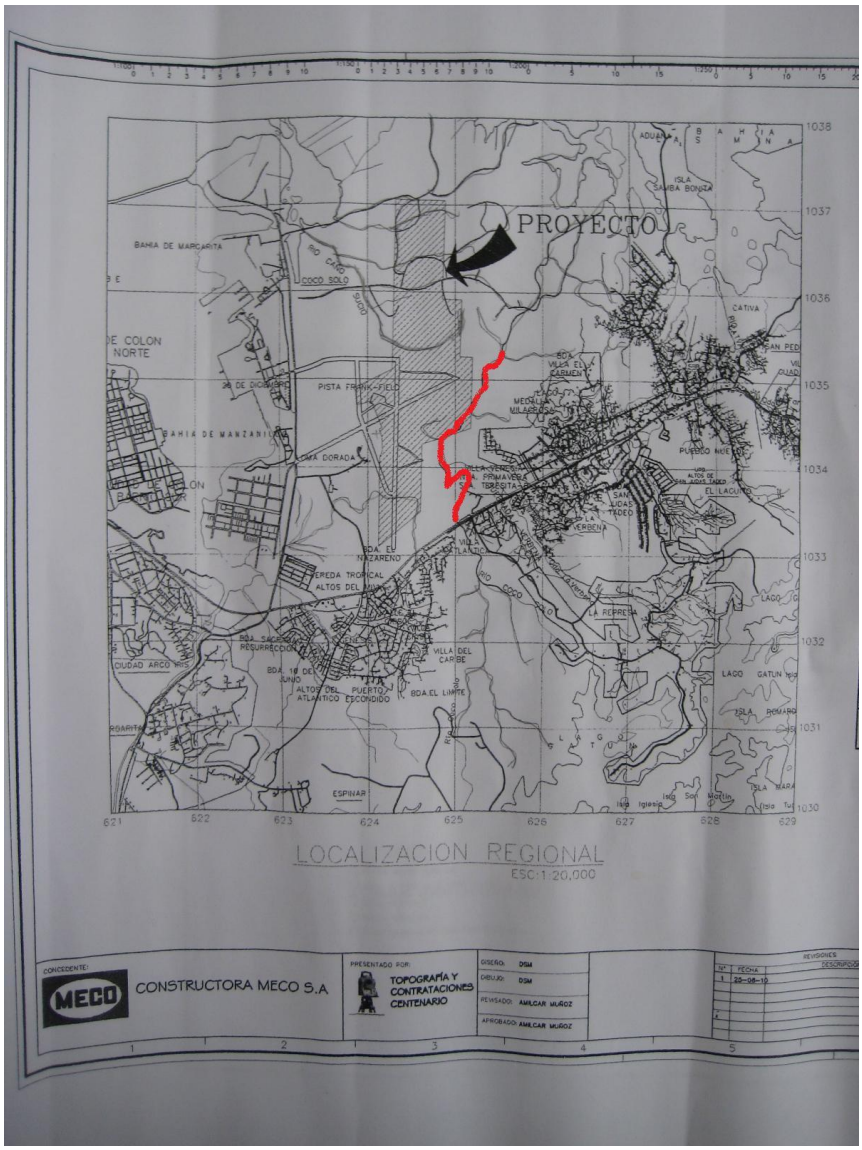
Another physical aspect of the environment that will be greatly affected by the construction and operation of the airport is the hydrological cycle. There are three streams that pass through the project area: Cano Sucio, Majagual and Rio Coco Solo. The size of each stream is classified based on a classification system developed by Horton and Strahler in 1964. The larger the order of the stream, the more water it contains and the more regular the flow (see appendix 7.4). Table 4 outlines the characteristics of each stream and map 2 shows their location relative to the airport. It is important to note that MECO will be diverting a tributary of Rio Coco Solo (highlighted in red) that passes where planned infrastructure is going. Overall, the rivers in this region are not in a healthy state and are saturated in industrial runoff and chemicals (Hernandez, Personal Communication, March 17 2011).

Table 4 Streams located within project area (Arden, 2001).

River	Location relative to airport	Order	Characteristics	Drainage area	Length
Cano Sucio	Northwest	2	Good vegetation, secondary forest, low velocity	360ha	1800m

Majagual	Southeast, ends in bahia de manzanillo (in France field sector)	2	Poor vegetation, poor drainage, lots of pavement	570ha	1998m
Coco Solo	Southeast	3	Moderate secondary vegetation, low-moderate velocity	1360ha	5494m

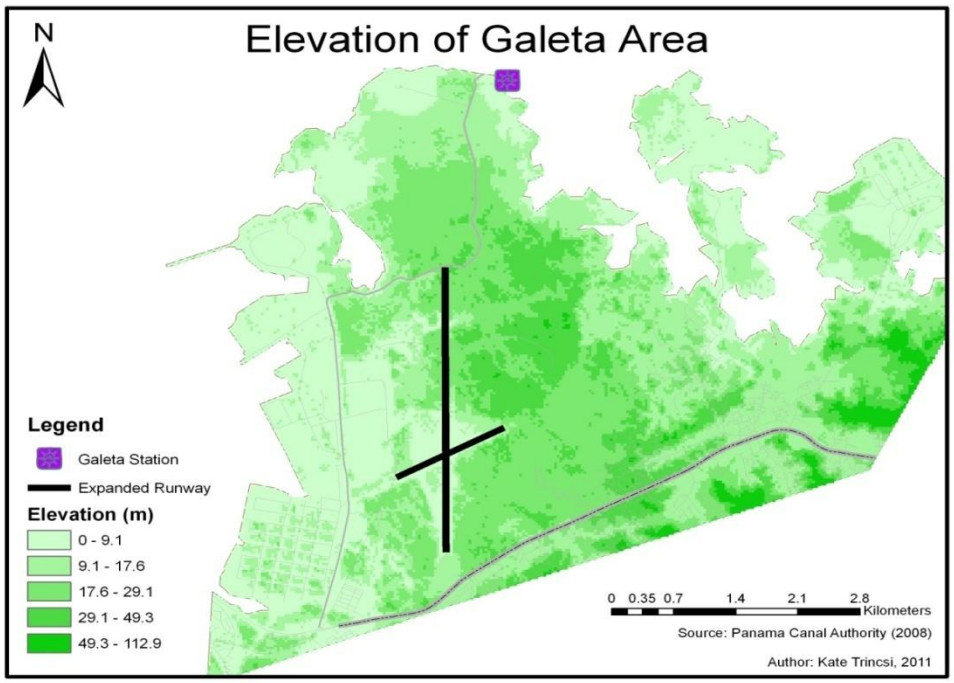
Map 2 MECO map of stream location. The tributary highlighted in red will be diverted further eastward to avoid confrontation with expanding infrastructure (Cardenas, 2010)



The drainage of the CFZ and project area is very poor with a widely recognized flooding problem. The airport is located less than 3km from the Caribbean Sea in a region with a slope of 15% and elevations ranging from below sea level to 50m (Arden, 2001). Most of the city of Colon and Punta Galeta remain less than 9m above sea level. The mangrove forest that traditionally occupies this area is especially adapted to these poor drainage conditions and naturally prevents flooding. However, since the industrial expansion began in the CFZ, deforestation, paving and landfilling has significantly compromised the ability of this natural water removal system. Currently, the main method for water removal near the airport site is a large drainage ditch dug along the east side of Via Randolph. This system is inadequate in the rainy season and often overflows onto nearby roads (Bragg, 2008).

Using a satellite obtained Digital Elevation Model of the region from 2008, it is possible to see high and low points in the study region and suggest possible directions of drainage (see map 3). However, this is only a preliminary assessment and for more concrete results it is necessary to delineate drainage paths using a more advanced version of ArcGIS. Prior to the expansion, runway water would drain eastward towards the mega development projects of the CFZ and end in the above mentioned drainage ditch. By expanding the runway north into a region of lower elevation, it is possible that some of the future runway water will drain north into Galeta.

Map 3 Elevation of study site



As a result of the deforestation and operation of the airport, two main hydrological problems will occur. The first of these problems is an increase in sediment and toxins in runoff from the project site. The runoff will be washed into the three nearby streams as well as the drainage ditch in various severities depending on the elevation gradient from the origin of the pollutant source.

Runoff during construction

Deforestation causes increases in sediment transport, higher runoff and erosion from bare soil and roads (Moore, 2009). As 50ha of primary and secondary forest are cut down, nutrients previously tied up in the biomass will be washed away with rainwater. Nutrients will be released in various degrees of ease depending on how their cation exchange capacity works with the soil

of the region. Nitrogen is released the easiest followed by potassium, calcium than phosphorus (Moore, 2009). In the clay majority (40%) soils of the region phosphorus is tightly bonded. However, as outlined in table 5, there are high concentrations of calcium and medium concentration of potassium which will easily be released into the hydrological cycle during precipitation events. This can lead to changes in nearby stream properties such as thermal regime, sediment concentration and nutrient loading (Moore, 2009).

Table 5 Physical-chemical analysis of soil at project site (Arden, 2001)

Parameter	Result	Observation
Texture	Sand 38% Silt 22% Clay 40%	Clay loam
pH	5.11	Acidic
Phosphorous	3.8ppm	Low
Potassium	98ppm	Medium
Calcium	4.98meq/100g	High
Magnesium	1.98meq/100g	High
Acidity	0.50meq/100g	Low
Aluminum	0.30meq/100g	low
Organic content	3.12%	Medium
Iron	68ppm	Medium
Copper	1.90ppm	Low
Magnesium	40ppm	Medium
Zinc	5ppm	Medium

Runoff during operation

During operation, chemicals deposited during takeoff and landing on the tarmac are expected to be washed away into the hydrological cycle of the region. This is especially exasperated by the wet tropical climate in this region. There is on average 3300mm of precipitation annually. The precipitation in Colon is orographic due to the nearby Cordillera. As a result of this, in the wet season rain falls all day and is equally probably and intense (Bragg,

2008). The high frequency and intensity (table 6) of rainstorms means that water will wash away chemicals relatively quickly after they've been deposited on the tarmac, not leaving them enough time to convert to gaseous forms.

Table 6 Frequency and intensity of rainstorms (Arden, 2001)

Duration	Quantity (mm)
5 minutes	17
10 minutes	30
60 minutes	131
24 hours	343

The second hydrological problem that will be accelerated by the deforestation is an increase in flooding. By removing trees there will be a reduction in local interception and evapotranspiration. By removing approximately 20ha of primary forest the ability of the mangroves to naturally drain water will also decrease. It is expected that the drainage ditch that flows to the east of Via Randolph will have a larger quantity of water, leading to more flooding in the CFZ. In conclusion, it is expected that there will be a huge nutrient and chemical release into the hydrological cycle over the life of the expansion. It is also expected that there will be a slight increase in flooding. However, these results are preliminary and we recommend that a more detailed study on the hydrological cycle be conducting using ArcGIS and field data.

3.3.3 Noise

A third environmental concern is increased noise levels in the area because of increased plane size and increased flight frequency. The noise situation at the surface caused by airplanes varies on "the types of aircraft used at the airport, the overall number of take-offs and landings, operating conditions, the time of day those aircraft operation occur, the runways that are used,

weather conditions, and airport-specific flight procedures" (ICAO, 2004). As sound travels, it loses intensity. In theory, attenuation is a function of the square of the distance in air, but in practice, environmental factors also affect this. They include "altitude of the source, temperature, humidity, terrain, wind conditions, and vegetation" (Bowles, 1995). Since the flight direction is north, sound will diffuse over Galeta. Given that the park does not have permanent human occupancy, the largest concern is whether or not the frequencies and the intensities of the frequencies will disrupt animals living within the confines of Punta Galeta. Meaningful sounds are used by many animal species to "communicate, navigate, avoid dangers, and find food" (Bowles, 1995). These sounds have to be detected from background noise. Thus, anthropogenic sounds are harmful to animals, notably "by harming their health or altering reproduction, survivorship, habitat use, distribution, abundance, or genetic composition" (Bowles, 1995). Overall, similar to the impact of emissions and hydrology, the exact impact of noise can only be speculated. The exact frequencies of the airplanes, intensity of sound and frequencies used by animals inhabiting the region will have to be researched to determine the extent of noise impacts.

3.3.4 Biotic Impacts

Reaching a Threshold

Since the CFZ opened and development began in Colon, there has been increasingly less forest and mangroves available for biotic habitats. According to Hector Guzman, the entire region north of the Carretera Transistmica was covered in mangrove forest in 1980 (Personal Communication, March 24 2011). A 1994 study published by Duke et al. uncovered that there were 1232ha of mangrove forest in the coastal area east of Colon city. They study estimates that only 73ha remained within the CFZ. Since 1994 this number has only decreased as a result of

expanding infrastructure and megaprojects. The expansion of the airport is removing an additional 50ha of forest, approximately 20ha of which can be classified as primary forest.

As a result of this ongoing deforestation and expansion over the last 30 years, all animals that normally reside in the region have been pushed back into the remaining small fragment of forest (Guzman, Personal Communication, March 24 2011). Almost all remaining forest is within the confines of Galeta protected area. This is extremely dangerous to both the flora and the fauna residing in the region. As more animals are pushed back the carrying capacity of the forest becomes closer and closer to being exceeded. Once this happens, there will be mortality in fauna and a decreased functionality of the flora. This phenomenon was already observed at the end of January when multiple dead sloths were found just off of Galeta Road. Eventually the ecosystem will reach a threshold where it will be unable to support itself and collapse.

Additionally, since the Caribbean Sea is only 3km away from the airport, there is the chance that runoff or chemical deposition will affect the reef that lines the coast. However, according to Hector Guzman, this expansion will probably not affect the reef system since this little piece of reef exhibits low diversity and does not sustain the entire Caribbean coast (Guzman, Personal Communication, March 24 2011).

Wildlife Collisions

There are three possibilities for wildlife collisions: during construction, in the air and on the runway. In an article published in the Journal of Management in Engineering by Khalafallah (2006), it is demonstrated that the construction of the airport itself can pose a hazard for the biota of the area: “the presence of construction activities and temporary facilities near airport operations can attract more wildlife and further increase the risk of wildlife-aircraft collisions”.

Since the construction site is located directly next to forest and is expected to be active for two years, some possible attractions are trash left by construction workers, ponded water and unprotected temporary construction facilities that attract the formation of bird nests.

In order to regulate and monitor bird collisions in Panama wildlife control programs are established at international airports through *Bird Hazard Committees.* It is therefore expected that some form of wildlife control system will be set up at the expanding Colon airport. The project are has at least eight species of birds, not including migratory birds. However, in Panama 70.6% of bird collisions are not reported and there is no mention of bird collisions or mitigation measures in the EIA (Godinez, 2005). It is especially important that this be monitored due to the proximity of a protected landscape and the wet climate of Colon since most collisions occur during rain events near airports (Godinez, 2005).

A third aspect of wildlife collisions is collisions with mammals. A full range of mammals present in the project area is listed in appendix 7.5. Collisions can occur during airplane take off and landing, but are most likely to occur with on the ground vehicles. Overall, as a result of the rich animal diversity in Punta Galeta, it is expected that there will be animal confrontations with activities associated with airport operation.

4.0 DISCUSSIONS

4.1 Evaluation of the Environmental Impact Assessment

The majority of information regarding the physical extent of the project and the launch point of our investigation was obtained from an environmental impact assessment (EIA) conducted by the AAC in December of 2010. However, after thoroughly reviewing this investigation we determined that it was inadequate. It was performed by a government agency and potentially subjected to corruption. For example, the EIA examines the potential environmental impacts of the construction itself but does not address anywhere what the environmental consequences of operation will be. The EIA was classified as category 2 when it should have been classified as category 3 (Guzman, Personal Communication, March 24 2011). Category II EIAs do small assessments when the negative impacts and mitigation measures are well known. On the other hand, category III assessments are done when there is likely to be a significant range of negative impacts whose full range and extent is not understood (SEA, n.d).

We also obtained an EIA for the same project that was conducted in 2001 by an external agency, Arden and Price Consulting. This project did not succeed due to corruption and scandal within the government of Panama. However, this external EIA was about twice the size of the 2010 EIA and extremely thorough. It was category III and examined many things at a scientific level. It is hard to extrapolate the results of this EIA to the current project because this particular proposal was for a slightly larger airport. However, we were able to use a significant proportion of data obtained by this assessment such as soil type, climate classification and stream dynamics.

4.2 Pertinence to Galeta

The vast expanse of this project and its position directly beside Punta Galeta has caused some serious concern among staff and researchers about the environmental effects this project will have on the ecosystem. The runway is being extended to the edge of Galeta Road with no buffer. Takeoff will be directly over Galeta and flights will circulate around the entire region of Punta Galeta. In order to understand how results obtained in section 3 will affect this protected landscape, it is imperative to understand how the ecosystem functions and why it is important to maintain the health, vitality and resilience of the environment.

4.2.1 Description of ecosystem

The mangrove forest that surrounds the airport and Punta Galeta mainly contains three species of mangrove: Avicennia germinans (Avicenniaceae), Laguncularia racemosa (Combretaceae) and Phizophora mangle (Rhizophoraceae) (Sousa, 2007). Apart from these three species, the forest maintains a high biodiversity of both aquatic and terrestrial organisms. Mangroves provide habitat, nursery grounds, food for reef species and necessary spawning grounds for migrating birds (Alder, 2005). In a study performed by Mumby (2004), it was proven that the relationship between mangroves and fish is particularly strong in the Caribbean. Mangroves significantly increase survivorship rates of young fish that rely on these forests for protection from predators. The study also proved that deforestation of mangroves significantly affects this relationship. The tables in appendix 7.4 illustrate the rich diversity of organisms occupying only the secondary forest. However these tables do not touch on the rich diversity of organisms that live in the mangroves and nearby seagrass and coral reef ecosystems.

Mangrove forests also provide other ecological benefits such as nutrient cycling and atmospheric regulation. They have a high net primary production and represent a significant global carbon store (Alder, 2005). They aid in disease control, which is of particular interest since flooding in the CFZ has been linked to disease outbreaks in the region (Bragg, 2008). Furthermore, mangrove forests protect against coastal erosion and storms by "obstructing waves with roots and trunks" (Othman, 1994). Using a table adopted from the World Resource Institute, we are able to show the relative importance of the mangroves in the Punta Galeta forest. The highlighted parts represent what we know about the Galeta forest from observation and informal interviews with staff and researchers. It is evident that the majority of factors provide a high level of coastal protection.

Figure 2 (WRI, 2009)

Table 1 - Coastal Protection Factors
Source: Institute of Marine Affairs (IMA) and WRI, adapted for Belize

Factor	Level Of Coastal Protection				
	Very High 4	High 3	Medium 2	Low 1	None 0
Coastal Geomorphology	Rocky, Cliffed Coastline Or Sea Wall	Soft (Limestone) Cliffs or Low Bluffs	Mangroves	Beaches	N/A
Coastal Geology	Igneous and/or Volcanic	Metamorphic	Sedimentary	Unconsolidated Sediments	N/A
Coastal Protection Structures	Significantly protected by a large atoll or 2 prominent headlands	Protected by atoll, or by headlands	Slightly protected by atoll	Protected by one or two small headlands	No protection by atoll or headlands
Coral Reef Index (sum of 3 factors / 10 N)					
Reef Type	Emergent Reef (barrier or windward side of atoll)	Fringing and Leeward side of atoll	Patch	--	No reef present
Reef Distribution	---	---	Continuous	Discontinuous	No reef present
Reef Distance Offshore (m)	< 250 m / 250 – 500m	5 – 1 km / 1 - 2 km	2 – 4 km / 4 – 8 km	8 – 16 km / > 16 km	No reef present
Wave Energy (~ Max. Wave Height)	< 25 cm	25 – 50 cm	50 – 100 cm	1 – 2 m	> 2 m
Storm/Hurricane Events	Affected by at least a category 1 every 25 years	Affected by at least a category 2 every 25 years	Affected by at least a category 3 every 25 years	2 or more category 3 or higher expected every 25 years	N/A
Coastal Elevation (m)	> 12	9 - 12	2 - 9	0 - 1	< 0 (N/A) **
Coastal Vegetation) Type	Mangroves	Forest / Coastal Woodlands	Shrub and Thicket	Savannah and Wetlands	None
Coastal Anthropogenic Activities	No sand mining, coastal development, etc.	Misc. Other Activities	Either sand mining or coastal development	Sand mining and coastal development	N/A

The most significant role the mangroves of Punta Galeta perform is waste processing. Located downstream from the Colon Free Trade Zone, the hydrological cycle of this region is saturated in toxic runoff (Hernandez, Personal Communication, March 17 2011). Heavy metals are easily removed from water by mangrove trees and incorporated into plant tissue (Yin, 1999). As demonstrated in the section on hydrology, harmful chemicals will be washed from the runway downhill towards Galeta. It is extremely important that this "low-cost wastewater treatment system [that] has a large capacity in retaining heavy metals and nutrients from wastewater" be kept viable, large, and healthy (Yin, 1999).

4.2.2 Effect on ecosystem

As we have previously stated, the exact effect on the ecosystem is unknown. What we do know is this ecosystem is extremely important for the proper functioning of the STRI station. Our results section on the environmental impacts is only speculation based on literature review and preliminary GIS analysis. However, we expect that there will be a significant decline in local air quality, nutrient overloading from deforestation leading to changed habitat, increased noise that will possibly affect animal communication and health, an increase in wildlife collisions, and a stress being placed on the carrying capacity of the forest which can lead to the crossing of an ecological threshold. We highly recommend that, if possible, further studies be done by the AAC to determine magnitude of these effects.

4.3 Recommendations

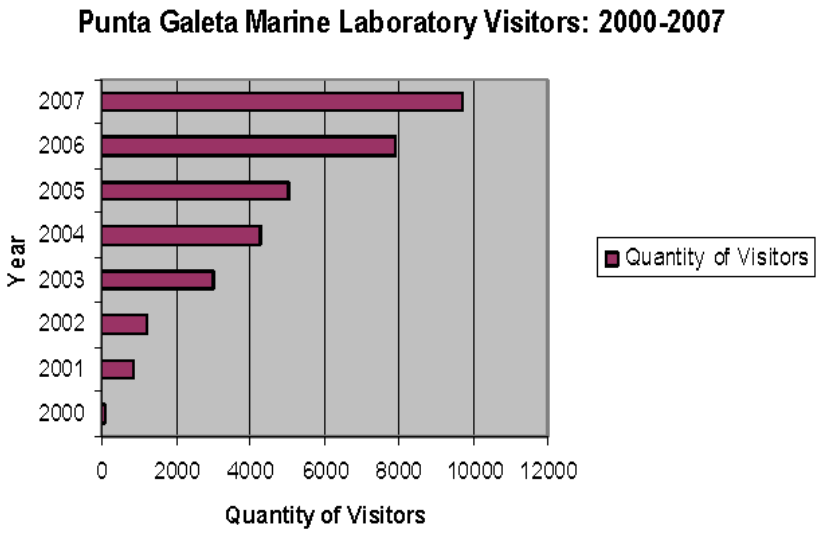
The recommendations we have produced for Galeta can be classified as either regulatory or technical. Regulatory recommendations will involve stakeholder participation and cooperation across groups. Technical recommendations are measures that should be incorporated during the

construction of the airport and thus we recommend that facilitation begin as soon as possible before the airport becomes fully operational.

4.3.1 Regulatory recommendations

One of the main reasons for the airport expansion is to stimulate tourism in the province of Colon. One of the main tourist attractions is Punta Galeta as is evident by the increasing number of visitors (figure 3). If tourism really is important to the government, than the maintenance of the health of this ecosystem is vital. This can be used as a launch point to encourage investment in the further protection of the mangrove ecosystem.

Figure 3 Increasing Visitors to Punta Galeta (Bragg, 2008)



In an interview with Thomas Meredith (April 5, 2011), he suggested one way to encourage this regulation is to have the government give a certain percentage of the total cost of the airport to continuous monitoring and ecological improvement programs. With a projected project cost of $58.3 million, even a very small percentage will be a significant contribution. In the Journal of Air Transport and Management it is suggested that operators “invest sufficient

resources in environmental management and mitigation to ensure future capacity. Anecdotal evidence suggests that around 10% of the total capital cost of a project is typically associated with such measures" (Upham, 2003).

Through extensive literature review, it has been observed that the key to successful development projects is stakeholder participation. Stakeholder participation is defined as "the process where individuals, groups and organizations choose to take an active role in making decisions that affect them" (Reed, 2008). Since the airport is obviously going to have a direct effect on Punta Galeta, some form of consultation and collective participation should occur. Using ecosystem knowledge from the scientific staff of Galeta, the construction and operation of the airport can minimize its environmental impact. It is also imperative that the members of the community be made aware of the declining size and status of the mangrove forest. According to Hector Guzman, the people of Colon are interested in preserving Galeta but they are not motivated to do anything about it (Personal Communication, March 24 2011). We therefore suggest that public interest and opinion be generated. The AAC should be held socially accountable to the effects of the airport since "in addition to minimizing the adverse effects it is also important that airports develop strategies which seek to maximize the social and economic benefits of their continuing growth and target these towards areas of greatest need or areas worst affected by their operation" (Upham, 2003).

A particularly weak point in the EIA is that in its list of mitigation measures it states that they will monitor air, water, flora and fauna quality. A full list of mitigation measures can be found in appendix 7.6. However, there is no description of how the airport plans to do this – what tools they will use, who will be responsible, how own measurements will occur, who will interpret results, or a threshold upon which the results no longer become acceptable. We

therefore strongly suggest that these mitigation measures be discussed with MECO and the AAC so they are fully developed, consolidated and operational by the time operation begins.

We also recommend that an environmental baseline be developed to monitor positive or negative changes induced by the airport, but also to monitor changes that will occur in the future due to rapid industrial development in Colon. A final recommendation is to ensure that the legal status of Punta Galeta is fully recognized with ANAM and the Panamanian government. There is supposed to be a buffer around Galeta road to protect against developments. However, as seen in figure 4 the airport construction stops less than 2m from Galeta road and this buffer was not honoured. A huge risk with internationalizing the airport is possible expansion. If the airport becomes successful and used for a significant proportion of CFZ cargo exports, it is possible that further expansion of the airport will be desired to have more runways and to accommodate larger planes. This will require deforesting inside of the boundaries of Punta Galeta.

Figure 4 Airport site as seen from Galeta Road (Personal Photo, March 2011).

4.3.2 Technical recommendations

The technical recommendations listed below are recommendations presented by various literature sources discussing airport construction and management:

- Wildlife control strategies such as habitat modification, exclusion, repelling and harassment to prevent collisions
- Establishment of berm to filter runoff from the tarmac
- Place the water filtration plant on Cano Sucio since this river is already saturated with industrial runoff from CFZ
- SWAT (Soil and Water Assessment Tool) modelling to determine water movement in the CFZ
- Develop a noise baseline using either a measuring stick technique or a noise index (ICAO, 2004) to determine how much sound is being added to the region and whether or not the frequencies are ample enough to affect animals
- Noise insulation programmes to reduce interior noise levels for nearby buildings, especially ones with high human occupancy such as the nearby hospital

Additionally, there are a number of initiatives being undertaken at international airports to address and reduce environmental impacts. If Panama wishes to internationalize and compete at global standards, it is in the best interest for public relations and ecosystem health to adopt some of the following programs: emissions reduction, noise abatement programmes, use of alternative energy supplies, energy efficient terminals, mass transit options to and from the airport, improved waste management, wildlife preservation and employee transport incentives (McGinley, 2007).

5.0 FINAL REMARKS

5.1 Benefits versus consequences

Overall it is evident that various economic benefits will come from this project, at the expense of ecological deterioration. Table 7 summarizes the list of positive and negative effects resulting from the expansion. In the end, the question of benefits versus consequences comes down to tradeoffs. How much environmental damage is the government willing to cause to facilitate economic growth? Tocumen International Airport is located 40 minutes away and can be accessed by boat, railway or a highway. The remaining mangrove ecosystem on the other hand is irreplaceable and has no alternatives.

Table 7 EIA list of positive and negative impacts (Cardenas, 2010)

Negative Effects	Positive Effects
• Dust and gases released during hydrocarbon combustion • Soil contamination • Affected habitat of permanent and migratory species • Landscape change • Elimination of forest cover • Sediment erosion during rainfall • Generation of organic and inorganic wastes • Increased noise levels	• Change landscape in a way that supports commercial and tourism development nationally and internationally • Increase commercial activity of the area • Generate employment • Stimulate local economy by using local companies • Increase tax revenues on local and national level

5.2 Conclusion

Throughout the report we have placed a very large emphasis on the negative environmental impacts because we feel that there is an opportunity for mitigation. Although the results of our report are preliminary, it will provide the staff of Galeta with a launch point and information on areas that need most attention for mitigation measures. Although the expansion of

the airport cannot be stopped, there are still opportunities. We firmly believe that through proper stakeholder interaction and persistence, STRI has the ability to alter the way this project is developed. There is limited time left before the airport becomes fully operational in 2012 so we therefore suggest rapid action and pressure from Galeta.

On a larger scale, the proximity of Galeta to the CFZ places STRI in a vulnerable position. As Panama continues to seek economic growth and internationalize, it puts priority on development over environment resulting in an increasing pressure on its remaining environmental resources. A common fallacy is a separation of economy from environment. Solutions to global environmental problems will be made at the local level not the national or international level. The fate of the mangroves of Galeta lies in the ability of locals to raise awareness and ensure developers understand the environmental tradeoffs of their projects. As soon as this occurs, economic development will coexist sustainably with conservation.

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7.0 APPENDICES

7.1 GIS Methodologies

Figure 5 Methodology to create extent map

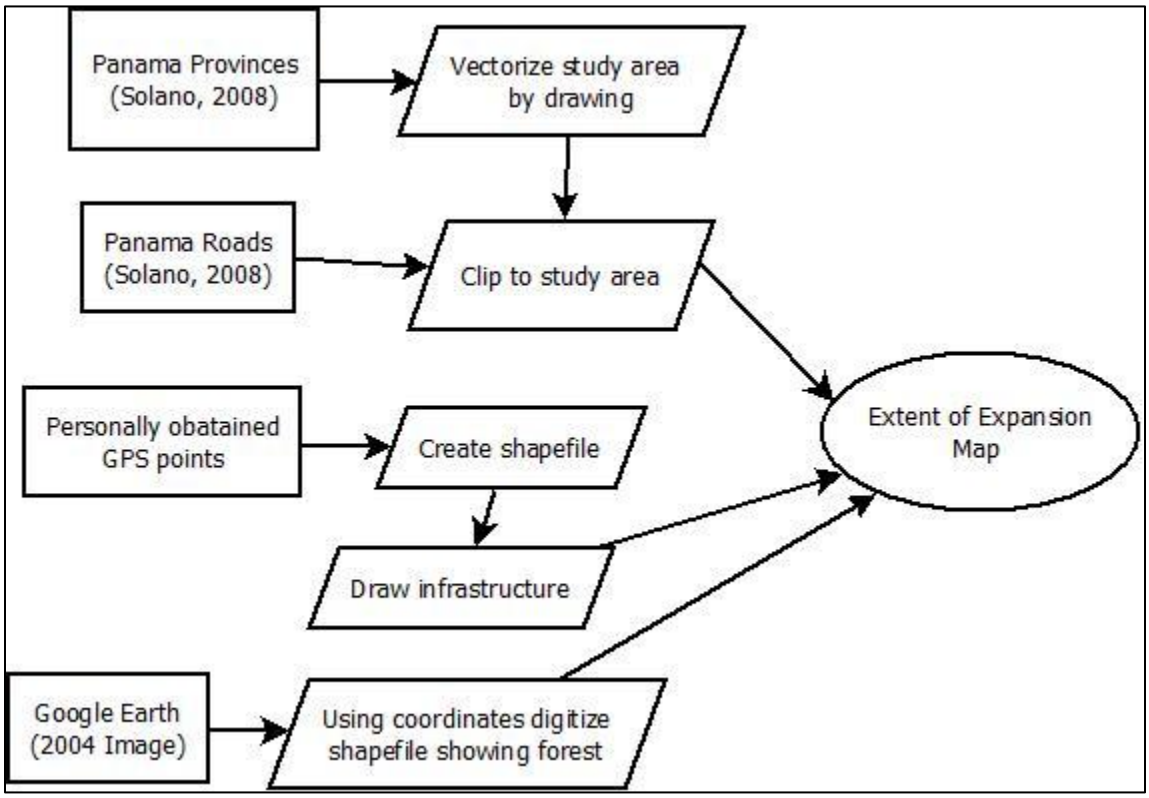


Figure 6 Methodology to create elevation map

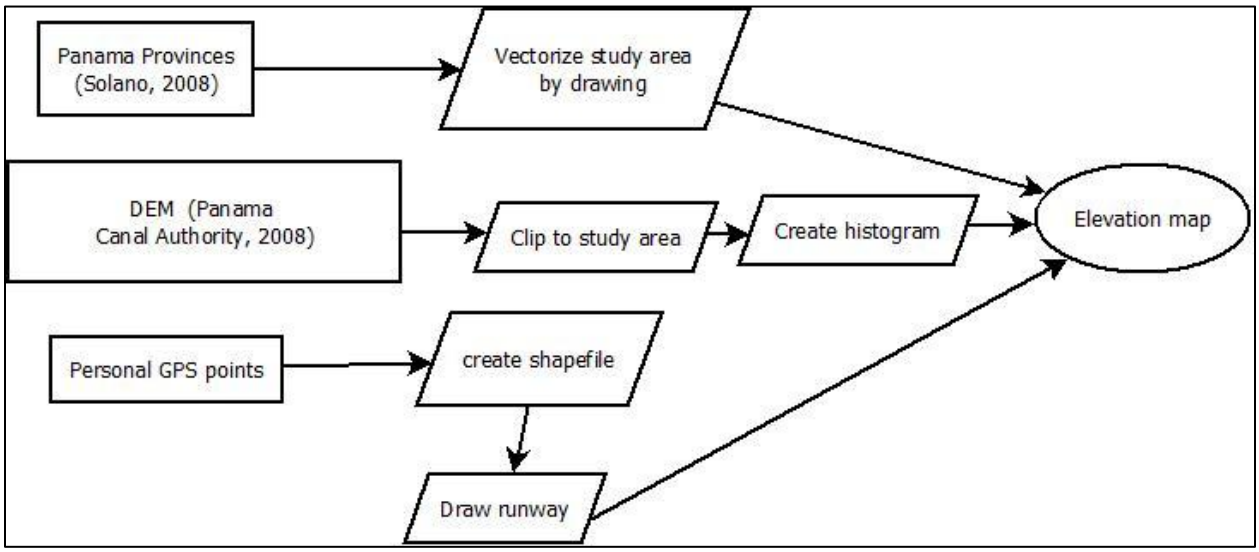
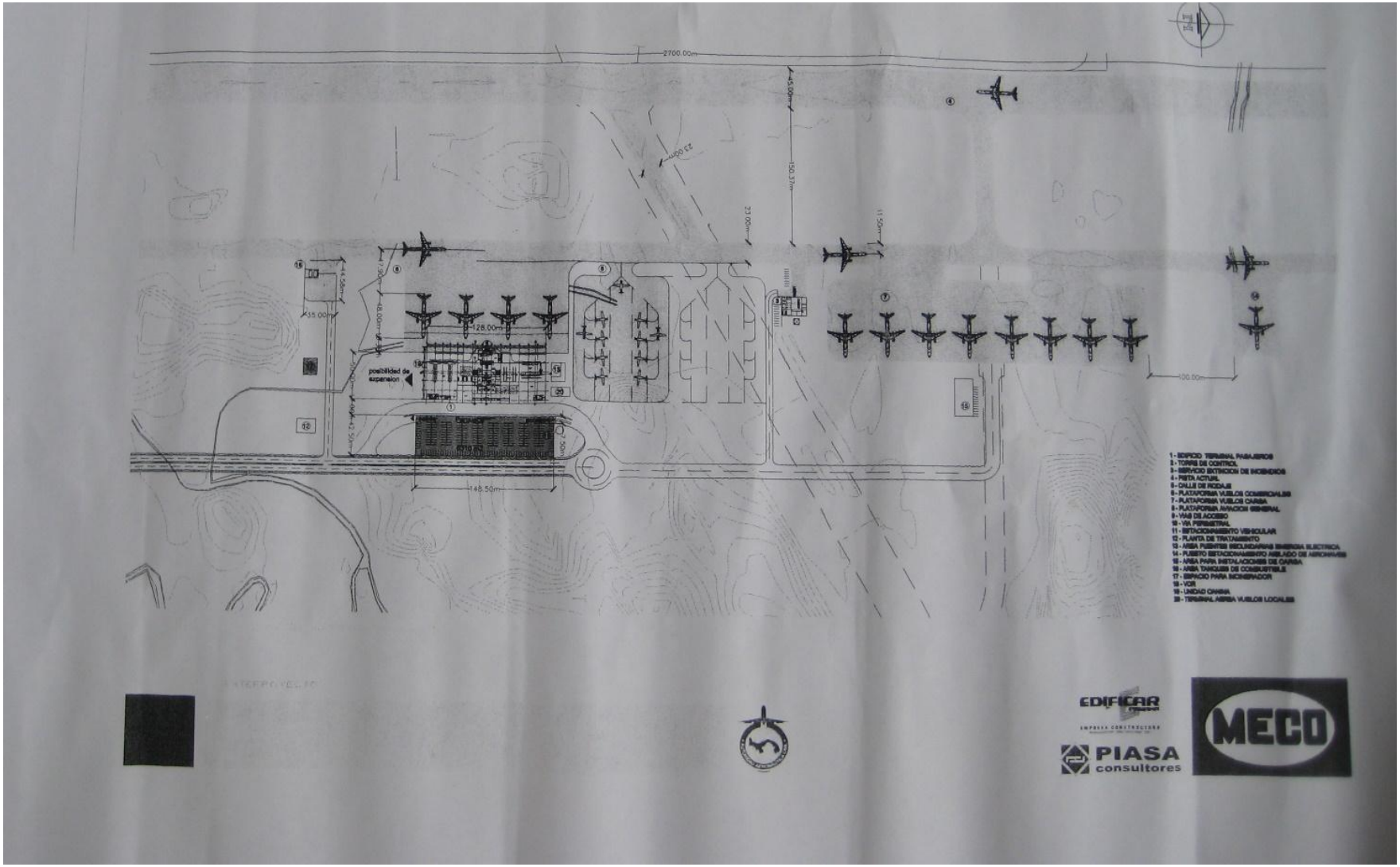
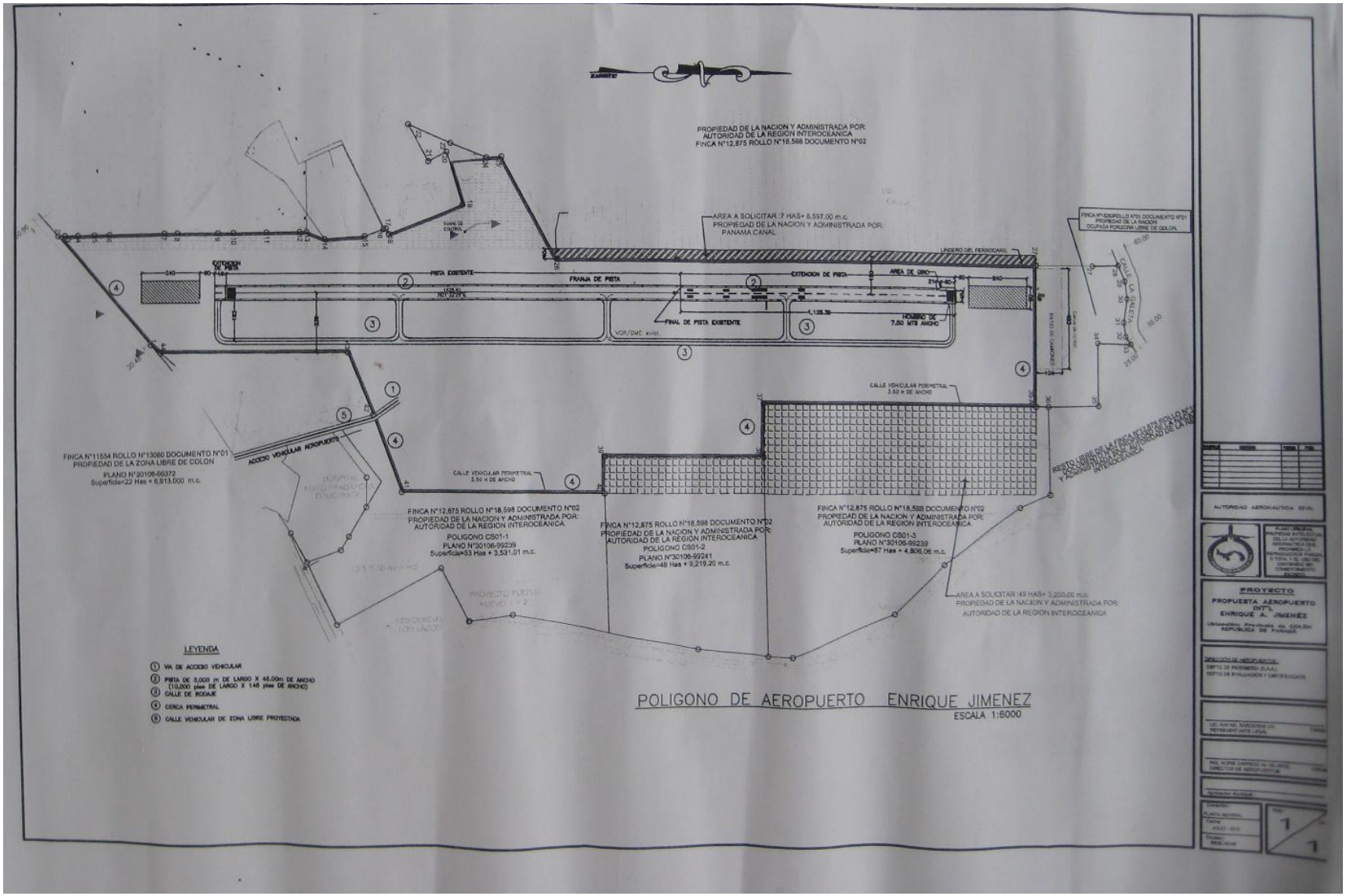


Table 8 GPS Coordinates. Latitude longitude format and projected in a WGS84 datum

Point #	N	W	Description
1	09 21 31	79 52 02	N-S runway
2	09 21 22	79 52 00	offices
3	09 21 28	79 52 01	N-S runway
4	09 21 34	79 52 01	Intersection
5	09 21 42	79 52 47	edge of deforestation
6	09 21 46	79 52 41	E end of runway
7	09 21 08	79 52 02	N-S runway
8	09 20 54	79 52 03	S end of runway
9	09 20 40	79 51 59	access road hits highway
10	09 20 35	79 52 46	Via randolph
11	09 20 51	79 52 43	Via randolph
12	09 21 19	79 52 39	Via randolph
13	09 21 43	79 52 38	Rio Cano Sucio
14	09 22 53	79 52 03	Galeta road
15	09 24 11	79 51 39	Galeta

7.2 MECO project site maps (Cardenas, 2010)




PROPIEDAD DE LA NACION Y ADMINISTRADA POR:
AUTORIDAD DE LA REGION INTEROCEANICA
FINCA N°12,875 ROLLO N°18,598 DOCUMENTO N°02
AREA A SOLICITAR :7 HAS+ 8,597.00 m.c.
PROPIEDAD DE LA NACION Y ADMINISTRADA POR:
PANAMA CANAL
FINCA N°11554 ROLLO N°13080 DOCUMENTO N°01
PROPIEDAD DE LA ZONA LIBRE DE COLON
PLANO N°30106-66372
Superficie=22 Has + 6,913.000 m.c.
ACCESO VEHICULAR AEROPUERTO
CALLE VEHICULAR PERIMETRAL
3.50 M DE ANCHO
FINCA N°12,875 ROLLO N°18,598 DOCUMENTO N°02
PROPIEDAD DE LA NACION Y ADMINISTRADA POR:
AUTORIDAD DE LA REGION INTEROCEANICA
POLIGONO CS01-1
PLANO N°30106-99239
Superficie=53 Has + 3,531.01 m.c.
FINCA N°12,875 ROLLO N°18,598 DOCUMENTO N°02
PROPIEDAD DE LA NACION Y ADMINISTRADA POR:
AUTORIDAD DE LA REGION INTEROCEANICA
POLIGONO CS01-2
PLANO N°30106-99241
Superficie=48 Has + 9,219.20 m.c.
FINCA N°12,875 ROLLO N°18,598 DOCUMENTO N°02
PROPIEDAD DE LA NACION Y ADMINISTRADA POR:
AUTORIDAD DE LA REGION INTEROCEANICA
POLIGONO CS01-3
PLANO N°30106-99239
Superficie=87 Has + 4,806.06 m.c.
AREA A SOLICITAR :48 HAS+ 3,200.00 m.c.
PROPIEDAD DE LA NACION Y ADMINISTRADA POR:
AUTORIDAD DE LA REGION INTEROCEANICA
FINCA N°:DISPERSO,LLO N°01 DOCUMENTO N°01
PROPIEDAD DE LA NACION
OCUPADA POR ZONA LIBRE DE COLON
LINDERO DEL FERROCARRIL
EXTENSION DE PISTA
PISTA EXISTENTE
FRANJA DE PISTA
AREA DE GIRO
FINAL DE PISTA EXISTENTE
HOMBRO DE
7.50 MTS ANCHO
VOR/DME
TORRE DE CONTROL
RESTO LIBRE DE LA FINCA N°12,875 ROLLO N°18,598 DOCUMENTO N°02
PROPIEDAD DE LA NACION Y ADMINISTRADA POR:
AUTORIDAD DE LA REGION INTEROCEANICA
LEYENDA
1 VIA DE ACCESO VEHICULAR
2 PISTA DE 3,000 m DE LARGO X 45.00m DE ANCHO
(10,000 pies DE LARGO X 148 pies DE ANCHO)
3 CALLE DE RODAJE
4 CERCA PERIMETRAL
5 CALLE VEHICULAR DE ZONA LIBRE PROYECTADA
POLIGONO DE AEROPUERTO ENRIQUE JIMENEZ
ESCALA 1:6000
AUTORIDAD AERONAUTICA CIVIL
PROYECTO
PROPUESTA AEROPUERTO
INT'L
ENRIQUE A. JIMENEZ
Ubicación: Provincia de COLON
REPUBLICA DE PANAMA
DIRECCION DE AEROPUERTOS
DEPTO DE INGENIERIA (D.A.A.)
DEPTO DE EVALUACION Y CERTIFICACION
LIC. RAFAEL MARCHENA DR.
REPRESENTANTE LEGAL
ING. NORIS CARRILLO DE VILLARS
DIRECTOR DE AEROPUERTOS
Propietario: Nacional
Contenido:
PLANTA GENERAL
Fecha:
JULIO - 2010
Escala:
INDICADA
Hoja
1
1

7.3 Aircraft Landing/Take-Off Emissions. LTO stands for Landing/Take-off. Emissions are given in terms of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), and sulphur dioxide (SO_2). The Fuel column represents fuel used **(Rydpal, 2000).**

TABLE 1

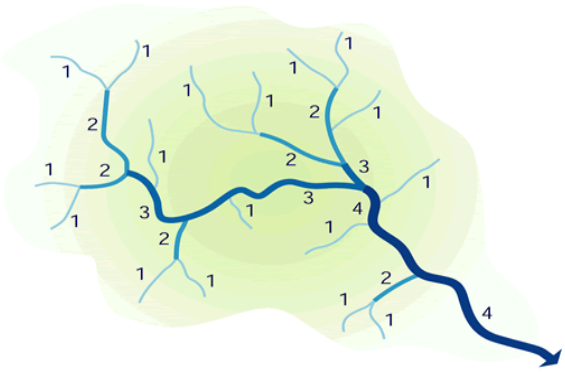
DEFAULT FUEL USE AND EMISSION FACTORS FOR SOME AIRCRAFT TYPES FOR LTO CYCLE, KG/LTO

Aircraft type[a)]	CO_2	CH_4[b)]	N_2O[c)]	NO_x	CO	NMVOCs	SO_2[d)]	Fuel
A300	5470	1.0	0.2	27.21	34.4	9.3	1.7	1730
A310	4900	0.4	0.2	22.7	19.6	3.4	1.5	1550
A320	2560	0.04	0.1	11.0	5.3	0.4	0.8	810
BAC1-11	2150	6.8	0.1	4.9	67.8	61.6	0.7	680
BAe 146	1800	0.16	0.1	4.2	11.2	1.2	0.6	570
B707*	5880	9.8	0.2	10.8	92.4	87.8	1.9	1860
B727	4455	0.3	0.1	12.6	9.1	3.0	1.4	1410
B727*	3980	0.7	0.1	9.2	24.5	6.3	1.3	1260
B737-300	2905	0.2	0.1	8.0	6.2	2.0	0.9	920
B737*	2750	0.5	0.1	6.7	16.0	4.0	0.9	870
B737-400	2625	0.08	0.1	8.2	12.2	0.6	0.8	830
B747-200	10680	3.6	0.3	53.2	91.0	32.0	3.4	3380
B747*	10145	4.8	0.3	49.2	115	43.6	3.2	3210
B747-400	10710	1.2	0.3	56.5	45.0	10.8	3.4	3390
B757	4110	0.1	0.1	21.6	10.6	0.8	1.3	1300
B767	5405	0.4	0.2	26.7	20.3	3.2	1.7	1710
Caravelle*	2655	0.5	0.1	3.2	16.3	4.1	0.8	840
DC8	5890	5.8	0.2	14.8	65.2	52.2	1.9	1860
DC9	2780	0.8	0.1	7.2	7.3	7.4	0.9	880
DC10	7460	2.1	0.2	41.0	59.3	19.2	2.4	2360
F28	2115	5.5	0.1	5.3	54.8	49.3	0.7	670
F100	2340	0.2	0.1	5.7	13.0	1.2	0.7	740
L1011*	8025	7.3	0.3	29.7	112	65.4	2.5	2540
SAAB 340	945	1.4(E)	0.03(E)	0.3(E)	22.1(E)	12.7(E)	0.3(E)	300 (E)
Tupolev 154	6920	8.3	0.2	14.0	116.81	75.9	2.2	2190
Concorde	20290	10.7	0.6	35.2	385	96	6.4	6420
GAjet	2150	0.1	0.1	5.6	8.5	1.2	0.7	680

Source: *IPCC Guidelines* on National Greenhouse Gas Inventories. Reference Manual, page 1.96.

*The emission factors for domestic aviation have been derived from an average of a number of typical aircraft. For domestic aircraft, the average fleet is represented by Airbus A320, Boeing 727, Boeing 737-400, Mc Donell Douglas DC9 and MD 80 aircraft. The old fleet is represented by Boeing B737 and Mc Donell Douglas DC9. For international traffic the average fleet is represented by Airbus A300, Boeing 767, B747 and Mc Donell Douglas DC10, whilst the old fleet is represented by the Boeing B707, Boeing 747 and Mc Donell Douglas DC8. Sulphur content of the fuel is assumed to be 0.05% S for both LTO and cruise activities

7.4 Stream Orders Using Horton and Strahler Classification (FISRWG, n.d.)



7.5 Species affected by deforestation (Cardenas, 2010)

Note: these reference tables do not include all species in the area, only the species within the 290ha project site

Table 9 Insect species

Family Name
Mosquito (Culicidae family)
Aedes Aegyptis
Culex pipens
Sand fly (Cerotopogonidae family)

Table 10 Mammals, Amphibians and Reptiles

Common Name	Scientific Name
Snake	Bothrops sp
Iguana	Iguana iguana sp.
Vine Snake	Oxybelis sp.
Nine-banded Armadillo	Dasypus novemcinctus
Brown-throated Sloth	Bradypus variegatus
Anteater	Tamandua mexicana
Central American Agouti	Dasyprocta punctata
Lizard	Anolis sp.

Table 11 Birds

Common Name	Scientific Name
Tropical Kingbird	Tyrannus melancholicus
Grey Hawk	Buteo nitidus
Black-cheeked Woodpecker	Melanerpes pucherani
Blue-gray Tanager	Thraupis episcopus cona
Green Violetear	Colibri thalassinus
Ruddy Ground Dove	Columbina talpacoti
Black-chested Jay	Cyanorax affinis

7.6 List of mitigation measures stated by the AAC (Cardenas, 2010)

- Stop operations during rain
- Trucks must use fabric/tarp/canvas during transport
- Establish permanent communication with transit authority
- Maintain direct communication with the residents of Gold Hill
- All employees must wear PPE
- Monitor air, water, flora, fauna – how?
- Supervise the relocation and final deposition of solid wastes
- Supervise areas of cutting, filling, grading and infrastructure construction

7.7 Ecological importance of mangroves (Alder, 2005)

Table 19.2. Summary of Ecosystem Services and Their Relative Magnitude Provided by Different Coastal System Subtypes. The larger circles represent higher relative magnitude.

Direct and Indirect Services	Estuaries and Marshes	Mangroves	Lagoons and Salt Ponds	Intertidal	Kelp	Rock and Shell Reefs	Seagrass	Coral Reefs
Food	●	●	•	●	•	●	•	●
Fiber, timber, fuel	●	⬤	●					
Medicines, other	•	•	•		●			•
Biodiversity	●	●	●	⬤	●	⬤	●	⬤
Biological regulation	●	⬤	●	•		•		●
Freshwater storage and retention	•		•					
Biochemical	•	•			•			•
Nutrient cycling and fertility	●	●	●	•	•	•		●
Hydrological	•		•					
Atmospheric and climate regulation	●	●	●	•		•	•	●
Human disease control	●	●	●	●		•	•	•
Waste processing	⬤	⬤	●			•	●	•
Flood/storm protection	●	●	•	•	•	●	●	⬤
Erosion control	●	⬤	•				•	•
Cultural and amenity	⬤	•	●	⬤	•	●	●	⬤
Recreational	⬤	•	•	⬤	•			⬤
Aesthetics	●	•	●	●				⬤