Guyana Research Park Development Project

A Major Qualifying Project submitted to the Faculty of Worcester Polytechnic Institute in fulfillment of the requirements for the Bachelor of Science Degree in Civil Engineering and Bachelor of Arts Degree in Environmental and Sustainability Studies

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Abstract

Climate change in coastal Guyana can critically impact local livelihoods. There is also a desire for development efforts to be Guyanese led, breaking dependency from Global North. The goal of this project is to design a research park that enables universities and professionals to study coastal ecosystems, natural resources, the impacts of climate change, and to design strategies for climate mitigation, adaptation, and resilience. The park will create educational opportunities to train the next generation of Guyanese innovators. Qualitative and quantitative data was collected through interviews, analysis of government reports and scholarly articles, and maps. The deliverables for this project include a site plan for the research park, amenities list, and an educational plan.

Executive Summary

The goal of this project was to design a site plan for a research park near the East Demerara Water Conservancy in Guyana. The park will support the study of local natural resources, ecosystems, the impacts of climate change, and create educational opportunities to train the next generation of scientists and engineers in Guyana.

Postcolonial Guyana has faced and continues to face many challenges around economic development, maintaining effective flood infrastructure, and harnessing local leadership. With the added threat of climate change, communities are faced with the additional challenge of adapting development, infrastructure, and leadership in rapidly changing environments. Using semi-structured interviews with local experts and community members, including members of my family, I have identified four main problems that the proposed research park could help to address.

Problems & Objectives

First, STEM graduates in Guyana often leave to pursue careers in the Global North, particularly the United States, Canada, and the United Kingdom (2019. Ministry of Finance). This leaves communities with fewer people to aid in the development of the country. Second, flooding in urban and residential coastal areas has increased due to poor maintenance of canals that are meant to move water away from these areas. There is also an outdated and inefficient flood water pump infrastructure that requires more frequent maintenance (DRR team Guyana 2016). The third critical issue that the research park aims to address is the need to increase high quality STEM education for all types of learners. This would help to create the intellectual foundation needed for the next generation of scientists and engineers in Guyana, including those who can contribute to community-led development. The fourth and final critical issue that the center aims to address is lack of local 1) knowledge, such as expertise in hydrology, sustainable design, and appropriate research methodology; 2) data, such as ecosystem data - for example, how does sugarcane farming impact the local ecosystem?; and 3) tools, such as indoor and outdoor laboratories, and potentially a lack of research equipment (Ministry of Finance, 2019). The lack of these resources is critically linked to the first three problems and having such resources could help to retain STEM graduates, provide critical knowledge needed to address flood management, and create opportunities for high impact STEM education.

To design this park, I focused on four objectives that would allow for an effective design in this unique remote coastal environment. The first objective was to develop an understanding of the roles of engineers and scientists in Guyana, and how they interact with the community. By examining the role of professional and academic engineers and scientists, my goal was to understand the context where these people work, and the opportunities that are currently available in Guyana. The second objective was to investigate existing research parks around the world to understand how these spaces operate and develop the best usage for the land available. By researching parks from around the world, my goal was to understand steps that

each park took during the beginning stages and implementation process, as well as the history, usage, and any contestation or conflict associated with these of research parks. I applied this knowledge to the site area selected in Guyana to create a usable park for the community and to help identify potential sources of conflict. The third objective was to understand the current conditions of the site and its current uses. The last objective was to develop plans for the site to aid future development of the site. At the completion of this research project, the site plan will be evaluated by local community groups, organizations, and stakeholders to get feedback from these key constituencies who provided input in earlier phases of the project.

Methods

To collect data, I used both primary and secondary sources, including semi- structured interviews, maps, GIS data, academic scholarship, and governmental and non-governmental organization reports focused on other local infrastructure development projects. I conducted interviews with 4 number of people in the areas of education, research, engineering in Guyana, and site conditions. Each interview candidate was asked a set of questions depending on their background to make sure the information given was deeper than what could be found through an internet search.

To analyze data, interviews were transcribed, and themes were developed to aid in creating deliverables for the next steps in development. Themes included: education; science, technology, engineering and math culture; research, and a miscellaneous category for themes that arose through discussions.

Some of the specific infrastructure development reports that influenced research were: the DRR-Team Mission Report, which documented the Dutch government's research into the drainage infrastructure in Georgetown, and the surrounding area; Managing Flood Risk in Guyana-The Conservancy Adaptation Project, a study meant to "reduce the likelihood of catastrophic flooding along Guyana's low lying coastal areas"; and the Water Resources Assessment of Guyana by the US Army Corps of Engineers.

I preformed research on five different parks that aim to achieve similar goals of my proposed development. The parks I researched were the Houston Arboretum, Tampines Eco green, Jurong Lake Gardens, Iguaçu National Park, and Kruger National Park. Each of these parks aim to educate the public about their natural environment in different ways. To analyze the research park data, I compared them thematically using a chart tabulated for effective comparisons.

Findings & Results

From my research I found that multi- use, modular amenities (chapter 4.2.1) are effective during the beginning stages of developing a research park. With this information I created a custom list of amenities for the specific site that aid in achieving its goal of developing a park will support the study of local natural resources, ecosystems, the impacts of climate change,

and create educational opportunities to train the next generation of scientists and engineers in Guyana.

To make sure that the park can be used to add to and enhance high impact STEM education opportunities for students of multiple age groups, I developed an educational plan that lists out relevant guidelines for educational activities at the park, as well as a short list of example activities.

Lastly, I developed a conceptual site plan that maps out the different amenities for the site, as well as existing conditions that would affect development on the site. These deliverables will be evaluated by different stakeholders of the research park. Long term, my goal is for these site plans to be further developed via academic research projects with students and faculty from the University of Guyana. Then, the students, faculty, community members, NGOs, and STEM professionals will provide input and expertise and identify funding sources for these research projects in order to physically develop a research park that can accomplish the objectives identified through this Master Qualifying Project.

Capstone Design Statement

This project is personal for me because of my family connections to Guyana and my desire to continue the work that has been going on to improve the country as a whole. This project was initially inspired by my grandfather, a retired professor, who wished to solve Guyana's hydrology infrastructure problem. Even though the academic institutions of the area produce high performing talent as far as engineers, scientists and other professions, many of those who would create and improve infrastructure leave the country for other opportunities. Developing this park could be an opportunity to increase the number of scientists who actively work in and around the community. Having this representation can be critical in really changing the mindset of the communities we serve. Providing a community with empowering tools to teach themselves, especially in an ecologically rich, but sensitive landscape, are great not only for the community and the country of Guyana, but for the individuals who use the space.

To complete this capstone design project "Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating appropriate engineering standards and multiple realistic constraints'' (ABET 2017) These constraints include economic, social, political, environmental, ethical, health and safety, constructability, and sustainability.

Economic
Cost is a crucial aspect to any engineering design. Even though there is not a specific cost for the development of this Research park, costs were taken into account when selecting amenities for the park's initial development. Because Guyana is a foreign country the exchange for currency is also taken into account for these amenities as well. The design process requires for reiteration and continued analysis before final cost calculations are made to make sure the development of this park is cost effective

Socio-Political
Guyana's sociopolitical framework operates differently than that of the United States, but by interviewing different members of the Guyanese community an informal understanding of this framework was acquired. Along with these interviews the goals of this project and the park align with many of Guyana's future development goals.

Environmental
Civil engineering must take into account the environment very heavily, because of the immense changes that the projects can cause on the natural environment. Environmental impact was assessed throughout the each of the recommendations of the park. The main focus of the proposed site plan is to be as low impact as possible because of the sensitive watershed area that the site interacts with. Many amenities also aim to research different ways that infrastructure, i.e. conservancy dams and bioswales, could positively impact the natural environment. It is also important that the educational activities of the park take time to educate others on the environment and how to be better stewards of it.

Ethics

Ethics is a priority in all aspects of Civil Engineering design projects. Engineers in Guyana have more recently pushed for administrative efforts to guide the ethics of engineers and engineering companies. In the past the Guyana Association of Professional Engineers or GAPE formed as a collective of Guyanese engineers to ensure that projects are ethically sound. (KaiteurNews, 2017) As future recommendations and feedback occur for this project GAPE will be a major partner for developing this research park.

Health & Safety

Health and safety were considered from mainly the accessibility consideration because the site is far from the main Guyanese population. Creating an easily accessible site for construction workers researchers and the general public is the first step in creating a safe workplace in Guyana. Most of Guyanese health and safety standards focus on workplace safety, while the other main focus is on roads(Gov of Guyana 2018).

Constructability

The development of this park happens in stages with modular amenities, which allows for a step-by-step construction plan to be used for the park. Because accessibility to the site area could be an issue, these modular steps plus a more specific construction schedule will help streamline construction of the park.

Sustainability

This development addresses both environmental and social sustainability through different methods. Through the research of local natural resources, ecosystems, the impacts of climate change environmental sustainability will be uplifted through the operations of the park. The park will also provide an educational resource to the community which will allow them to tackle problems with equitable knowledge through park operations and employment opportunities. Visitors and employees of the park will be immersed in an environment where they can learn about how to be stewards for the natural environment, as well as use resources effectively. These efforts will hopefully be reciprocated away from the park space in their home communities.

Professional Licensure

Civil Engineering projects impact the livelihoods of people around the world. Civil engineers work on large and small scale projects like the construction of public works, such as roads, bridges, dams, tunnels, buildings, airports, water and sewage systems, and other infrastructure projects. Because these projects affect so many lives, to be a professional Civil Engineer you must acquire a professional license.

To earn a Professional Licensure in the field of engineering is a great achievement. It shows employers and clients that one is not only prepared, but well qualified to take on higher level tasks. Earning one's Professional Licensure signifies the readiness to combine specialized skills with a high standard for ethics, professionalism, and quality of work to complete a project.

What makes a Professional Engineer different from an engineer who did not earn Professional Licensure is the ability to prepare, sign, seal, and submit engineering plans for public approval and for clients. An individual must complete the following to become a licensed Professional Engineer (PE): receive a four year degree from an Accreditation Board for Engineering and Technology (ABET) accredited engineering program; pass the Fundamentals of Engineering (FE) exam to become an Engineer in Training (EIT); complete four years of progressive engineering experience under the direction of a PE; and pass the Principles and Practices of Engineering (PE) exam. Since Professional Licensure first started in the state of Wyoming in 1907, every state in the USA made their own additional requirements for Professional Licensure.

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Chapter 1: Introduction

Guyana, or “the land of many waters” is an English-speaking country on the northern coast of South America. The country shares a border with Brazil Suriname and Venezuela and has a land area approximately the size of Idaho. Guyana is divided into four main geographical regions: the hilly sand & clay region, the Hinterland Forest, the Rupununi savannas and the low coastal plains or coastal lowlands (FIG 1). Most of the country lives along the Coastal lowlands, which is almost entirely below sea level. Because of the elevation of this area there have been a few key infrastructure improvements to combat the high-water table. Some of the tools used to protect these coastal lowlands are large ”water storage impoundments,'' seawalls, canals, pumping stations and more. An example of one of these impoundments is the East Demerara Water Conservancy, or EDWC. Even with these tools, the coastline is extremely susceptible to flooding because of lack of maintenance and increased effects of weather due to climate change.

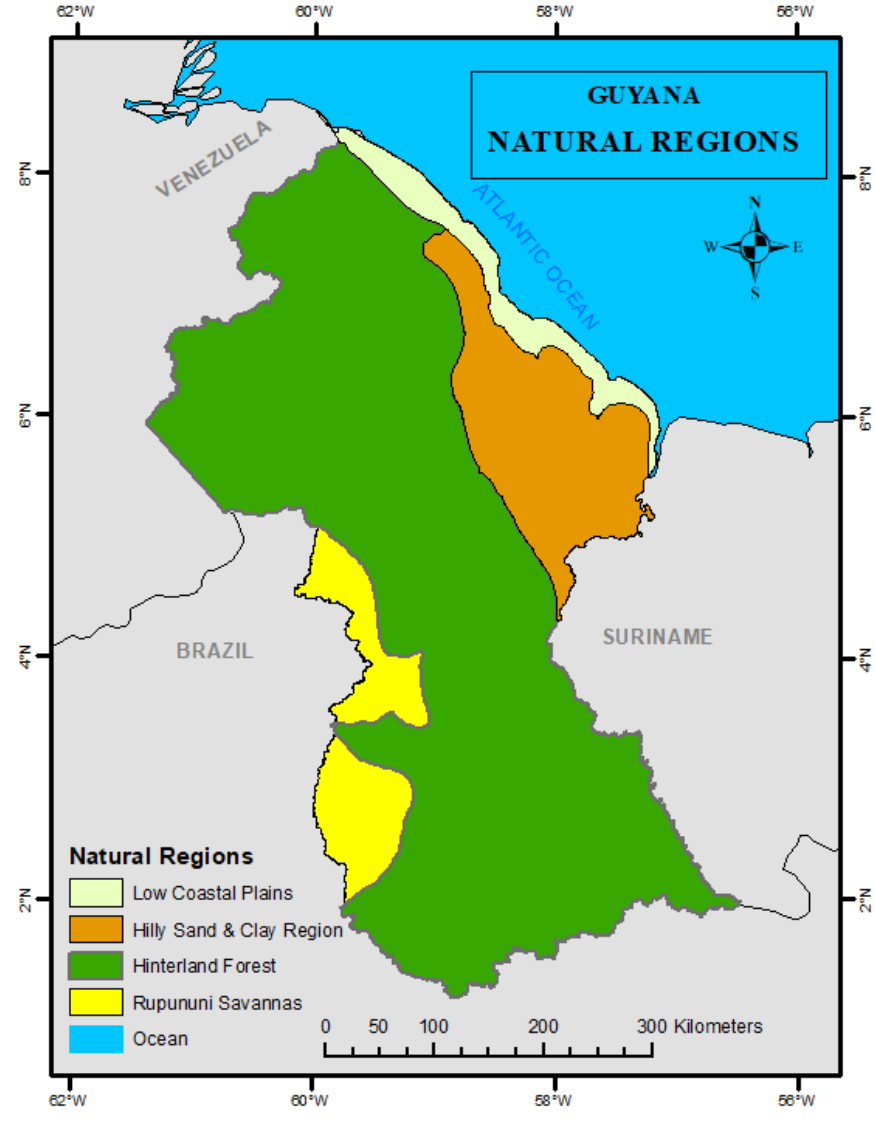


Figure 1 Map of Guyana's Natural regions (Guyana Lands and Surveys Commission. n.d.)

Guyana has a year-round warm, tropical climate with rainy seasons in the winter and in the summer. The area is kept temperate due to coastal winds from the Atlantic Ocean. The area of focus for this project was coastal lowlands, in between the Mahaica and Demerara rivers. Soil in this area is very fertile, and because of this there are large areas of land set aside for farming.

Goals & Objectives

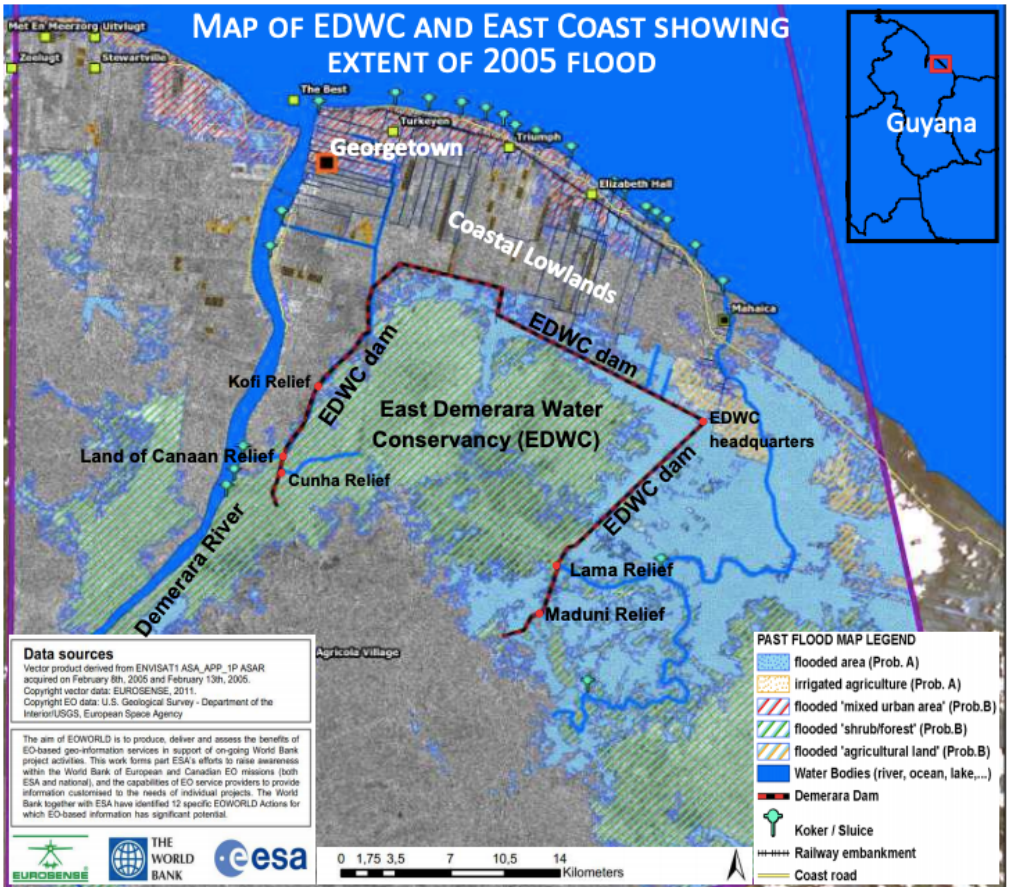


Figure 2 Map of East Demerara Water Conservancy (Bovolo 2013)

The goal of this project is to design a site plan for a research park near the East Demerara Water Conservancy (FIG2). The park will support the study of local natural resources, ecosystems, the impacts of climate change, and create educational opportunities to train the next generation of scientists and engineers in Guyana. The center aims to address four critical issues in Guyana:

First, STEM graduates in Guyana often leave to pursue careers in the Global North, particularly the United States, Canada, and the United Kingdom (The Committee for an American Guyana, 1999). Generations of this emigration have left Guyana with few leaders with skills to initiate the creation of lasting change (Steijn, R., Klostermann, J., & Westebring, F. 2016). Developing

this park could be an opportunity to retain these STEM professionals and increase the number of scientists and engineers who actively work in and around the community.

Second, flooding in urban and residential coastal areas have increased due to poor management of canals that are meant to move water away from these areas and inefficient flood water pump infrastructure that requires more frequent maintenance.(Steijn, R., Klostermann, J., & Westebring, F. 2016). In addition, while the seawall that protects the coast remains strong, storms are growing in frequency and intensity, therefore increasing the amount of water that gets over the seawall. (Caribbean Life, 2019)

The third critical issue that the center aims to address is the need to increase high quality STEM education for all types of learners. In Guyana, secondary education is based on British model, which is lecture heavy. Students rarely get out of the classroom, perform experiments, or engage in projects that would enhance their classroom learning. (NIHF 2020) While some students excel with lecture, research shows that many students learn STEM more effectively through hands-on, immersive project experiences, and particularly having those experiences outside.

The fourth and final critical issue that the center aims to address is lack of local 1) knowledge, such as expertise in hydrology, sustainable design, and appropriate research methodology; 2) data, such as ecosystem data - for example, how does sugarcane farming impact the local ecosystem?(Ministry of Finance, 2019); and 3) tools, such as indoor and outdoor laboratories, and potentially a lack of research equipment. (Ministry of Finance, 2019)

To achieve this project goal, I organized my research into the following objectives:

1. Develop an understanding approaches to land development in Guyana, primary and secondary learning objectives, and the associated role of scientists and engineers from inside and outside of Guyana
2. Investigate existing research parks around the world to understand how these spaces operate and determine which strategies, amenities, etc. from these spaces could fit or be adapted to best serve this space and community in Guyana.
3. Understand the existing conditions of the space, including soil composition, existing vegetation and road access, as well as its current uses by various stakeholders.
4. Develop a site plan to be evaluated by local community groups/organizations/stakeholders, including the University of Guyana, local government groups, and the community, and aid current and future scientific and engineering leadership.

Chapter 2: Background

Before these objectives are reached there is some context about Guyana that should be understood. This project is a great example for using new sustainable development methods as well as solving different STEM related issues in the country. These issues include educational resources for secondary and primary school students, professional opportunities for STEM graduates, floodwater preparedness and mitigation, and research opportunities for students at the University of Guyana. By solving these issues Guyana could have the opportunity to become more independent from the global north and develop solutions to improve communities in Guyana.

2.1 Sustainable development practice: Co-Design

International development and its methods have changed over time. Post-World War II development consisted mainly of top-down approaches like design by elimination, which attempted to create solutions by viewing developing nations as a blank slate. The global north would then develop these places in a model replicated after itself without considering the opinions and design considerations of culture and the people who exist in these communities. (Krueger & Telliel 2020) This approach to development creates unsustainable and unjust design outcomes for multiple reasons, including lack of user or community engagement, loss of local leadership, poor maintenance of infrastructure, and an increased dependence on the global north, resulting in the continuation of colonization, albeit in a new form (Krueger & Telliel 2020).

Some, more recent, development practices aim to include local cultures and the community in the design, planning, management and development of projects. One of these approaches is through the method of co-design. Co-design reevaluates the relationship between the design expert and the community and gives them equal say during design and development. This allows for experts to give effective recommendations, but the community would iterate and work with experts in identifying the problems and in generating solutions (Krueger & Telliel 2020). This method allows for design and developments to be influenced by culture and the community to produce a process and space that is more socially just, sustainable, and equitable.

Codesign requires a collaborative effort throughout the development process. This process usually begins with co-defining a problem or set of problems, then generating ideas on how to solve them. Then these ideas are evaluated and analyzed in their local communities to ensure that culture, and the local environment can shape the design (Murcott 2007). This codesign process is easily transferred to the Development Suitability Site Planning Process. This method of site planning selects the best possible use and development suited for a given site. This is different than the Site Selection process which selects from a list of potential sites one that suits best the given use and requirements of the project (Francisco, A. 2016). Remotely, the most effective way to get the information to develop an effective site would be to co-define and co-generate ideas in partnership with the local community. This is done through in-person

engagement and effective communication with the community stakeholders, a major part of the next steps in this development. Using these methods also creates models of alternatives to reduce unjust and unsustainable development practices like design by elimination.

2.2 Loss of Guyanese STEM graduates to the Global North

Guyana historically had a plantation economy that put its natural resources on a global scale. Since its independence in 1966 the emphasis on this plantation style economy has changed, and left Guyana with scarce opportunities. Guyana is a developing country that uses natural resource exports as its main profit sources on the global market. Even with these industries, there are still large populations that are unemployed, or underemployed, with college degrees. This group includes not only recent college graduates, but also those who have professional work experience with the government or with an academic institution.

As such, Guyana has struggled with college graduates emigrating to other countries, like the United States, the United Kingdom and the Netherlands because of a lack of opportunities in Guyana. Local opportunities are hard to find because of the history of influence and dependence on the global north (Steijn, R., Klostermann, J., & Westebring, F. 2016). Countries like the United States, the Netherlands, Japan, and many more often influence and lead new projects in Guyana. (Department of the environment 2019). This history of dependence leads to many skilled individuals who graduate with STEM degrees moving on to further their studies at institutions outside Guyana or finding a place in the workforce abroad. Few who leave Guyana for opportunities abroad actually stay abroad because of the lack of resources and support for starting a new life in another country. Many return to Guyana with professional degrees in engineering or science, but then they find they don't have the resources at home to do research or find job opportunities in their field (Interview Leanna Kalicharan 2/18/2021).

Many people with degrees in the STEM fields find employment in the Guyana public sector either through the government agencies, or in education at the secondary and collegiate level. Teaching at any level is usually a job opportunity given to those who are studying STEM at any level, from current students to PHD graduates. Other than these opportunities, there are very few resources that allow STEM graduates to use their technical degrees to the fullest potential (Interview, Wilbert Hope, 2/11/2021). There are opportunities where Guyana could use these graduates to their potential, especially in coastal development, research, floodwater management, data creation and more. These fields use chemists, engineers, biologists, ecologists and many more skillsets to solve problems that affect Guyanese communities (Steijn, R., Klostermann, J., & Westebring, F. 2016).

2.3 The Need for High Quality STEM Education

The Potential of Immersive STEM Education

Pre-College education in Guyana is modeled after the traditional British system of learning. This system was passed down from colonial times, before Guyanese independence in 1966.

Students start off in primary school from the ages of 5-11, where they learn basic writing and arithmetic as well as some social science. Higher primary school standardized test scores provide an opportunity for acceptance to a better secondary school. Some students choose the path of attending vocational school, while others use secondary school as a bridge to tertiary education (Scholaro). The Caribbean examination council or CXC is the administrative body that creates curriculum, educational goals, and materials for the Guyanese population. These educational goals include reading, writing, social science, science and math disciplines, as well as soft skill and ethical development (CXC 2021).

This research park space can help students build valuable experiences through activities to help expose students to ecology, hydrology, the environment, and other disciplines where they could learn to solve real world issues in the community. By exposing students to these areas, this park could help build the next generation of engineers, innovators, and scientists (Stohlmann, M., Moore, T. J., & Roehrig, G. H. 2012). Studies have shown that hands-on learning can allow for a deeper understanding of theory in a classroom by learning from real experiences, interactions with nature and more (interview Rhonda Benjamin 4/1/2021). Guyanese teachers are sometimes underprepared from a lack of materials and under experienced in the classroom from a lack of training and preparation. There is a need for programming to supplement and possibly introduce students to new learning environments. This research park aims to provide a space for project-based learning for students of all ages to aid teachers in programming and develop the next generation of change makers in Guyana. As the youth who use this park get older, they will be more knowledgeable on how to solve problems like those described in this chapter.

Tertiary education

During primary and secondary education in Guyana, students have the opportunity to learn about different disciplines that could require tertiary education. Tertiary education is also known as post-secondary education, which includes collegiate undergraduate and graduate studies. Different aspects of entrepreneurship and business, as well as professions in law, engineering, and medicine, are highly favored among secondary school graduates in Guyana (Interview Leanna Kalicharan 2/18/2021). Those who choose to follow the Science Technology Engineering or Math (STEM) field at the University of Guyana experience a curriculum with engaging labs, theoretical study, and evolving areas of study for research (Interview Leanna Kalicharan 2/18/2021). This park aims to provide a space for additional research for Guyanese students, especially focused on improving and developing infrastructure through the study of hydrology, flood resilience, and the natural environment.

2.4 Flooding in Urban and Residential Coastal Areas

The effects of global climate change have very observable impacts on the environment and communities around the globe. Intense storms, loss of many sensitive habitats and sea level rise are only a few of the issues that impact Guyana specifically. Most of the inhabited area of Guyana lies below sea level (FIG3), and this becomes a great risk for the community's safety

during the rainy season. Flooding and storm surges threaten infrastructure as well as the health of families in the coastal lowlands (Steijn, R., Klostermann, J., & Westebring, F. 2016).

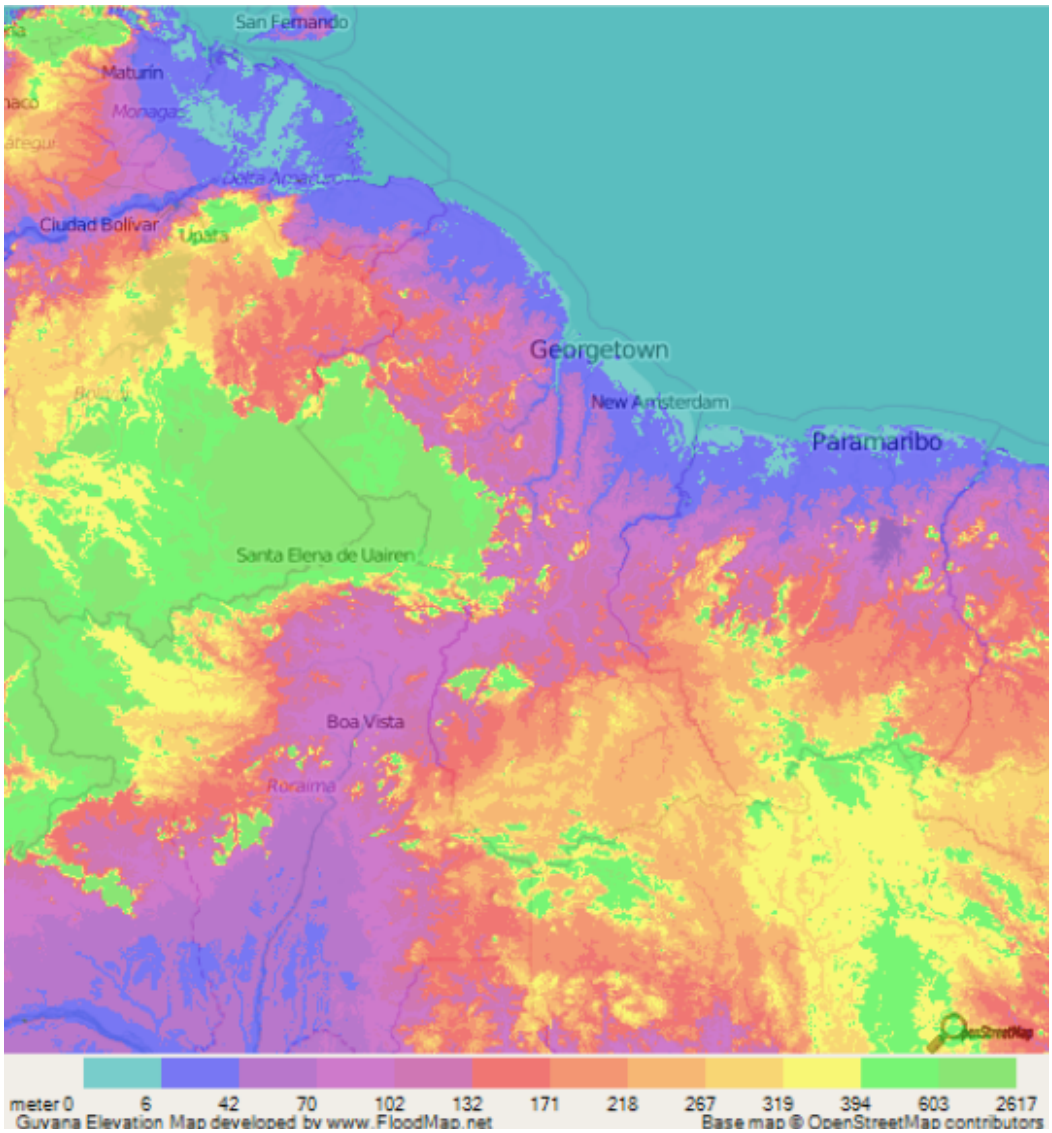


Figure 3 Map of Guyana coastline with elevation (Floodmap 2020)

The system of canals that crisscross through the residential and urban areas are crucial to making sure that floodwater is channeled towards areas that are more suitable for drainage, like agricultural lands (Bovolo, I. (2013). This drainage is often inadequate because of litter and trash that clog these drainage areas and a lack of maintenance and upkeep. These problems impact the safety of those who live on and near the coastline because of how dangerous the floodwaters can be when they are not controlled. Events like the 2005 100-year-flood event can put the lives of people on the coast at risk. Intense floods like this one wreak havoc by Destroying homes, roads, washing away crops and livestock, and more. (Steijn, R., Klostermann, J., & Westebring, F., 2016)

Much of the flood infrastructure was developed in the 17th and 18th centuries by Dutch efforts to reclaim the land using a series of levees and canals. The focus of this infrastructure was to increase agricultural efficiency of the already fertile land Mullenite, J. (2015). Since then this infrastructure added pumps and seawalls to make the coastal areas easier to develop. Over the years this infrastructure has had some updates but continues to require more maintenance as development on the coast continues (Bovolo, I. (2013). The administration struggles to develop ahead of crises like the 2005 flood because of reactive behavior of decision makers. This increases the risk of more catastrophic events in the future, as global warming increases. (Steijn, R., Klostermann, J., & Westebring, F., 2016)

This research park aims to increase flood resilience by providing a space for various types of research, like ecohydrology, groundwater and infiltration, and other smaller studies as well as implementing physical structures that aid in resilience, like improved earth dams and bioswales. Ecohydrology is a study that draws from both ecology and hydrology and examines how the local ecological systems interact with the hydrological cycle. This is a useful area of study for watershed locations because we can determine how water can affect the inland areas, agricultural features, and the watershed itself.

The location of this proposed park also could aid in developing flood resilience strategies because of its proximity to one of the main water storage systems in Guyana. The research park will be located on the bank of the EDWC, or the East Demerara-Mahaica Water Conservancy (FIG2). The EDWC has an area of almost 600 square kilometers and it services its most populous region, which includes the capital, Georgetown and its over 25 thousand inhabitants (Bovolo, I. (2013).

2.5 Lack of Local Knowledge, Expertise, and Resources in Hydrology and Sustainable Design

Developing Local Knowledge, Data, and Tools

Local improvements and development in infrastructure have been conducted, created or influenced by people outside of Guyana like the Conservancy adaptation project. These developments are usually led by organizations in foreign governments, or other large private entities like the US army Corps of Engineers (U.S Army Corps 1998). Upon the completion of the projects, these organizations often make recommendations for continuing improvements and additional developments (Steijn, R., Klostermann, J., & Westebring, F., 2016). One common recommendation to improve Guyana's development habits across multiple reports was to improve management and creation of data (Bovolo, I. 2013). Because of this lack of open source administrative data, the people don't have equal access to the knowledge that these outside organizations create through these projects b . To create lasting change, the people of Guyana should have the information needed to make sure that improvements are maintained (Steijn, R., Klostermann, J., & Westebring, F., 2016). This means making this data easily available for regular citizens and creating plans and graphics to make the data easily understandable.

Lastly the University of Guyana's research infrastructure was established by the Vice Chancellor in 2016 and is not as developed as other countries because of its infancy (University of Guyana 2019). Research, and the data from it, can be key to improving infrastructure, increasing social well-being, and creating change in countries. These changes and improvements can help transition Guyana out of poverty (Interview Wilbert Hope 2/11/2021). This Research park aims to provide a space to develop knowledge about Guyana, as well as share it with community members. The research conducted at this space will be used to create a database of information about Guyana for people to use and study for years to come.

How the park will help create change

This research park will provide potential research and employment opportunities for underemployed and unemployed people in Guyana. This space is meant to be used by professionals, students, and the community to understand more of the ecology, hydrology, and geology of the surrounding area. Those with advanced degrees in these topics would have a place to use their learned knowledge to aid development in Guyana through further research. With the development of this park there will also be some new employment opportunities, like technicians, teachers, community organizers, and administration staff that will make sure the park is run smoothly and effectively (nps.gov 2020). These job opportunities provide for all types of people and professionals, and not only those in STEM.

Chapter 3: Methods

Data collection was done remotely including interviews using mobile phones and Zoom, navigating scholarly databases, and utilizing geographic and mapping tools, such as Google earth and GIS . Different members of the Guyanese community were also recruited to help provide a glimpse as to what was happening on the site and in Guyana in general. The methods were used to find tangible data on the role of scientist from Guyana, research parks from around the world and their uses, and the proposed site area. This data, with added information from research and interviews was then used to create the final site plan and educational plan for the research park. Summaries from interviews are available in APPENDIX A.

3.1 Objective 1: Understand approaches to land development in Guyana, primary and secondary learning objectives and the associated role of scientists and engineers from inside and outside of Guyana

3.1.1 Data Collection for Objective 1

To collect data for this objective, I collected both primary and secondary data. For primary data collection, I focused on engaging in interviews with people who worked on the US Army Corps of Engineers Hydrology Assessment done in 1998, including engineers and ministries of government. From my outreach I was able to connect with Leanna Kalicharan, a graduate and now Professor at the University of Guyana, interviewed on February 18th 2021; Wilbert Hope, my grandfather and graduate of the university of Guyana, interviewed on February 11th 2021; Roopesh Sukhu, a professional engineer in Guyana, interviewed on March 9th 2021; and Rhonda Benjamin, a primary school principal, interviewed April 1st 2021. I aimed to collect data about the roles of local engineers who work professionally in Guyana and use this data in creating and implementing recommendations. I also aimed to collect data about the students' curriculum, and the research that is performed currently with the University. With this data I understood how the upcoming generation of students at the University of Guyana will interact with research in a collegiate environment and catered some amenities of the park to what students are studying.

For secondary data collection, I collected information from articles, book chapters, and government websites on hydrology of the area, past developments, new initiatives and developments in Guyana. From analyzing this data, I understood more of the context of development in Guyana, including where the government is focusing funding, the plans and results of past projects, and any issues that could arise during the physical development of the park. Understanding what the government focuses on could help determine additional amenities to add to the park that would allow for the development of the site to go smoothly.

3.1.2 Data Analysis for Objective 1

To analyze these interviews, I recorded and transcribed each interview using the voice memo and dictation feature that comes with Apple products. Once I read over these interviews, I annotated each of them to understand the main arguments and takeaways from each. Then, I categorized information found from the interviews into themes to answer each objective. This analysis is known as qualitative coding, and it is meant to categorize and organize qualitative data to find themes and patterns. To analyze the secondary information, I read various reports about developments in Guyana to understand who worked on what projects, the progress and results of each project, and to understand the overall development environment in Guyana. I wanted to know which parts of the government are working on these projects to understand how they will be able to aid in the development and utilization of the research park. Understanding the progress and results of these developments allowed me to develop a streamlined development plan for the park, that takes into consideration the obstacles that each of these other developments faced.

3.2 Objective 2: Investigate existing research parks around the world to understand how these spaces operate and develop the best usage for the land available.

3.2.1 Data Collection for Objective 2

To collect data for this objective, I used mostly secondary sources, drawing on databases including google, the WPI Library, and other online databases to find articles, journal publications, and administrative websites of different research parks. Some questions I asked through this research include:

- Why was this park/ research area built?
- What are some physical characteristics of the space the park was built on (soil, ecology topography & wildlife, urban/ rural/residential)?
- What programs do these spaces hold?
- What are the goals of this park?
- What are some examples of research that have been done in this space?
- How has the park impacted the surrounding area?... and more.

This data helped me define a list of criteria for the design and use of the research park.

3.2.2 Data Analysis for Objective 2

To analyze this data, I created a chart that lists characteristics from each of the research parks from my research (SEE APPENDIX B). This chart was used to compare the goals and steps for development of the park we are developing to different characteristics that affect development and operations of other parks. Some characteristics addressed and compared were the size of the park, time of development, overall focus of the park, if they conduct academic research,

their location, climate of the area, and many more that specifically relate to the park that we aim to design. I also created a list of all the possible amenities to be added to this research park (See Chapter 5). These amenities were categorized and described. This list was influenced by the parks that were researched, but also from the interviews. Some of these amenities were used in the final site design (See Chapter 5).

3.3 Understand the conditions of the site, including soil composition, existing vegetation and road access, as well as its current uses by various stakeholders.

3.3.1 Data Collection for Objective 3

For this objective, both primary and secondary sources were utilized. For primary sources, I interviewed different contacts in the area with questions about the space, development in the area, who owns the land, and more. These contacts were former engineering professionals and members of the community listed earlier in section 3.1. I also used the Geographical Information Systems or GIS, to map out the characteristics of the area. GIS data was obtained from an online database that listed different social, topographical, administrative and environmental data (Guynode 2019). The GIS data found provided even more details about the land, like soil structure, watershed data and more. GIS also allows for the creation of maps that compare contrast and display different characteristics of the land. Using this data, we created maps that allow for the best placement of the different amenities throughout the research park area. Secondary sources included using databases such as Google, the WPI Library, and other online databases to find articles, journal publications, and administrative websites of different research parks.

3.3.2 Data Analysis for Objective 3

To analyze this data, I used the same qualitative coding technique mentioned earlier in Section 3.1.2. Using the results from these interviews created some technical solutions to achieve the goals of the research park. This information gives better insights to questions specifically about the current conditions of the site and about the social climate in the area. In addition, the GIS data informed the initial design. These maps visualized and analyzed data in the proposed research park space, and they show an overall image of the area, as well as hydrological influences in the area. This data was used in with the research park chart analysis to determine what amenities could possibly be developed in the park.

3.4 Develop a site plan to aid current and future scientific and engineering leadership.

3.4.1 Data Collection for Objective 4

All the technical and social considerations generated from the data gathered from the previous three objectives were used to develop the site plan. To do this, the goals of the research park were initially listed out and assessed. These goals were compared to those of other parks then used to find an initial set of transferrable amenities. Next the amenities were categorized into research, educational, or recreational focuses.

3.4.2 Data Analysis for Objective 4

The data collected through interviews and other analyses provided enough information to understand the natural and cultural factors to developing the park. With this information, a site checklist was created (See APPENDIX C). This checklist was meant to organize and compare what information would be needed to create a site plan. Some categories of the checklist included land use, accessibility, topography, water bodies near the location, among others. With organized site information, informative maps, effective amenities, and a community centered plan for initial use of the park, a well-designed site plan that will aid Guyana for future development and academic research was created.

Chapter 4: Results

The data collection and analyses resulted in a detailed comparison of different research parks from around the world. Each of the parks provided different insights into developing the Guyana research park. Semi-structured interviews of different community members were also used to create data that impacts different aspects of the site plan. These aspects are designated through the themes the interview material was classified into.

4.1 Interviews

To create a research park space that can serve multiple uses effectively, I believe codesign should be the main influence in the development process. To ensure that insights from each of the different users of the space could impact the development process, interviews were used to address different themes that could influence development. Four participants were interviewed, and each had different roles in the community: a primary school principal, a college professor, a professional engineer, and a business owner/retiree.

Themes

- Research

From the interviews, I learned about a historical program that was a part of the undergraduate system, how research works within Guyanese schools, and areas of study that could be explored. Research at the University of Guyana is quite flexible. To begin research, students need a supervisor, from either inside or outside of the school, and a research topic. Projects don't have to be specific to a major field of study: for example, biology majors could work on a project in ecology or applied biology. Some projects are formed from international groups, like the Dutch government or the US army Corps, are required to involve students as well.(Interview Leanna Kalicharan 2/18/2021) Students can often work on research in collaboration with different departments of the government, like the department of agriculture. Historically, students in school right after Guyana gained independence from Britain had received the opportunity to study abroad from other British commonwealth colleges, like the University of New South Wales in Australia (Interview Wilbert Hope 2/11/2021). This theme gave an understanding to how research was done in the past and currently at the University of Guyana.

Figure 4 Dr. Wilbert Hope (Back row right) During his Study Abroad Experience at the University of New South Wales in Australia (Wilbert Hope)

- Education

From these interviews, I learned about different learning opportunities for students of all ages, but also where the education system fails to provide for its students. Guyana has a fairly complex education system that uses the CXC (Caribbean examination council) testing and curriculum goals. "The CXC program is very good in terms of the number and variety of subjects it introduces to students. Students in rural primary and secondary schools could face material deficiencies, like a lack of pencils and notebooks, or could be left without teachers for specific subjects like physics and chemistry"(Interview Wilbert Hope 2/11/2021). There are opportunities for outdoor learning worked into many school's curriculum, but teachers might not have all the resources necessary. (Interview Rhonda Benjamin 4/1/2021) Students who do well in their secondary proficiency exams are more likely to gain admission to the University of Guyana's science and engineering programs. Once attending, students have access to a great education. Some students who are interested in medicine complete a two-year Associates Degree in Biology before starting medical studies. Students have an opportunity to take effective lab courses, but often face setbacks due to facilities and resources that the University struggles to offer, like laboratory materials and equipment. (Interview Leanna Kalicharan 2/18/2021) This theme aids the final deliverables in serving as effective plans for achieving curriculum requirements and appealing to both collegiate and precollege students' educational needs.

- Engineering in Guyana

Data was also gathered on the culture around STEM (Science, Technology, engineering, and math) in Guyana. Some who graduate with STEM degrees find professional jobs in their field,

but others are forced to work outside of their major (Interview Leanna Kalicharan 2/18/2021). Engineers and scientists work in the community through programs that introduce primary and secondary school students to different careers. Many who perform field work in communities also make it a point to interact with those near the project site (Interview Roopesh Sukhu 3/9/2021). This theme gave an understanding of the life of an engineer in Guyana, and the social aspect of how projects are done. Final deliverables took into account these social aspects of engineering in Guyana.

- Site Information

Results from interviews also gave insight to characteristics of the site as well as the area around it. I learned that the entire coastal lowlands area was formerly used for sugarcane planting, and the land was owned by the large- scale sugar plantations. These plantations eventually sold/ gave the land to the government of Guyana or NDC (National Democratic Councils) were created. The East Demerara Watershed is also quite important for flooding mitigation and was used to irrigate the sugar cane crops. The soil in the site area near the watershed is also pegasi, or peat, which can sometimes be difficult to develop on (Interview Wilbert Hope 2/11/2021). This theme aided in the development of a site plan that understands the past uses and existing conditions, a key part of the Development Suitability Site Planning Process.

- Misc. themes

Other Miscellaneous themes I found were centered around policy and possible opportunities for the space. The policy around dividing and reallocating village land centers around NDC. NDC's are the village's administrative body, but they often focus on current events in villages more than creating plans for the future of the village (Interview Wilbert Hope 2/11/2021). As far as infrastructure goes, Guyana needs a push for development of more roads and bridges as well as opportunities to improve coastal engineering(Interview Roopesh Sukhu 3/9/2021). This theme helped develop deliverables that take into account village policy and future development goals.

4.2 Research parks

To create a space that can function as an effective research park, we must understand how similar spaces work around the world. To collect this information, I researched five different parks that aim to achieve similar goals of my proposed development. The parks I researched were the Houston Arboretum, Tampines Eco green, Jurong Lake Gardens, Iguaçu National Park, and Kruger national park. Each of these parks aim to educate the public about their natural environment in different ways. To assist in designing an effective site, the size, location development time, focus of the park, and academic programs (if any) were compared. Many of these parks have had ecological and natural science research that study flora and fauna of these spaces. These parks allow for researchers to have a designated environment to research, and added resources like equipment, guides, and more.

Figure 5 Entrance to the Houston Arboretum (Houston Arboretum & Nature Center Houston. 2020)

Houston Arboretum

The Houston arboretum is a 155-acre nature sanctuary that serves as a multi-use space for natural environment education, events, and recreation. This space was originally a part of a World War I training camp that, with the help of ecologist and educator Robert A. Vines, became a nature sanctuary in 1951. The Arboretum is home to many native species of plants and animals that have been threatened by urbanization and development in the city. This park has many different amenities and programs that help educate and introduce people who live in the city to plants and animals that they would traditionally see instead of concrete and cars. Some of these amenities include walking trails through four different habitats, scenic views for birdwatching, a wildlife garden, and a nature center which holds “the Discovery room,” an interactive space to learn about the arboretum's various habitats. Educational programs include field trips, various camps and guided hikes, art & photography excursions, food & wine classes, after dark events, and many more (Houston Arboretum & Nature Center Houston. 2020). Each of these programs emphasize the importance of learning about the natural environment, and how to be better stewards for these spaces. The Houston Arboretum was analyzed because of the park’s utilization of its space as well as its educational activities that cater to teaching people of all ages.

Figure 6 Entrance for Tampines Eco Green

Tampines Eco Green

Tampines Eco Green park is a 36-hectare nature reserve located in Singapore. Tampines is a part of a national network of parks and nature reserves that are located throughout Singapore to encourage nature recreation and conservation. Singapore is known as one of the most sustainable cities in Asia because of its infrastructure, and emphasis on creating an effective and environmentally friendly built environment. (Arcadis 2018) Tampines Eco Green Park serves as a sanctuary for local flora and fauna. This park has miles of walking trails that are only accessible by foot, as well as areas for birdwatching and nature appreciation. This area is often used by nearby schools for nature education. The University of Singapore has conducted various biological and environmental research at the park including an analysis of thermal performance of tropical urban parks in Singapore and the study of flower-visiting bees and wasps in Singapore parks. This research created data about the species of insects that were visiting Tampines Eco Green and analyzed the effectiveness of the park in fighting against the urban heat island effect (Hwang, Y. H., Lum, Q. J., & Chan, Y. K., 2015). This research allows the park to create new solutions to improve its operations and biodiversity. Tampines Eco Green was analyzed and compared because of the ease of access to the park, but also because of the effective research topics that help to improve the usage of the park.

Figure 7 Aerial view of Jurong Lake Gardens (National Parks Board 2021)

Jurong Lake Gardens

The Jurong Lake gardens are a 173-acre nature park that serves as Singapore's national garden. This space specifically is used to connect families and the community with nature. Different amenities throughout this space are under development and will be developed as time goes on. This park has many natural, recreational, and educational amenities like a sports and boating facility, boardwalks, birdwatching streams and Islands for exploration and many more. Like its name states, this park surrounds the Jurong lake. Programs include guided walking and biodiversity tours, boating excursions, public bicycles and more (National Parks Board 2021). This park may seem advanced for a comparison on natural research parks, but Jurong Lake Gardens are compared because of its government involvement and promotion of the park. The Singapore government places a large emphasis on creating experiences in the natural environment, and this park and its evolving amenities exemplify the government's directives. In addition to the government focuses, the Jurong Lake Gardens has been involved in a few societal research projects around tourism and usage of the space as well as research on the Jurong lake habitat.(Pham et al 2011) & (Juang, W. & Carrasco, L.R. 2020)

Figure 8 Aerial view of a section of Iguaçu National Park

Iguaçu National Park

Iguacu national park is a 90-acre national park located right on the border of Brazil & Argentina. These lands, along with other protected areas in the region are major remnants of the interior Atlantic Forest “a region of tropical and subtropical moist forest, tropical dry forest, tropical savannas, and mangrove forests that extends along the Atlantic Ocean” (Atlantic Forest 2016). This area is extremely biodiverse and is home to many rare and endangered species of flora and fauna. For example, this area has about 90 percent of amphibians that are not found anywhere else in the world. Because of this biodiversity this area is home to various ecological and species-based research. Similar to the East Demerara Water Conservancy, a protected area in Guyana, this park is located in a conservation area designated by the United Nations Educational, Scientific, and Cultural Organization or UNESCO (Atlantic Forest 2016). Iguaçu National Park was analyzed and compared because of the similarity in remoteness to the projected site area in Guyana, and because of the similar conservation of both areas of land.

Figure 9 Watering Hole at Krueger National Park (tripadvidsor 2019)

Kruger National Park

Kruger National Park is the largest National Park in South Africa with an area of approximately 7500 square miles. This national park and game reserve are home to many different flora and fauna including big cats, elephants and many species of birds. Because of its biodiversity there has also been academic research in the park surrounding climate change and species research. Kruger national park has a set of base locations or lodges where visitors can perform research, and take part in recreational activities like safari rides, trail hikes, bird watching and hunting. Some past research topics for the space emphasize management and learning styles that aid in operation of the entire park. Kruger National Park was compared and analyzed because of the different lodges and the scalability of programs. In the near future a similar lodge-like organizational style could be helpful in developing new areas of the coastal lowlands in Guyana, like near the sea wall.

4.2.1 Analysis

Each of these research parks have specific methods of development, education and research that allows them to be successful in their specific location. I aim to focus on these aspects of each park and reimagine the implementation for the Guyanese community. These specific strategies act as only a guideline for the future development. Development and implementation of final amenities, research topics, and educational activities will be fully developed in collaboration with different stakeholders in the Guyanese community. This codesign process is necessary to make sure that the community fully understands what is being developed and to help break the cycle of dependence on the global north.

Modular Amenities

Modular amenities are additions and installations that can be used during the development process. During each stage of development, the amenity is focused on a different type of user. Each of these parks took considerable time to develop into the spaces they are now, and over time these parks have grown to further fulfill their goals. From my research I believe this growth to be through Modular Amenities. Initially the biggest resources these parks have is space, and some sort of natural amenity i.e. diverse wildlife or natural features. Modular Amenities allow for the usage/ resources of these spaces, while also adding new infrastructure for the park to use to achieve its goals. A great example of a modular amenity would be building the laboratory space. The first stage would involve Civil Engineering faculty and students from the University of Guyana (Interview Leanna Kalicharan 2/18/2021). During the construction stage, visitors to the park could learn about different aspects of construction and what is being built, and then once the lab is finished it will be a space for different types of natural science research. This method of creating amenities for this park will allow for an educational experience to all of those that will use the park. Creating other amenities that can be developed in modules will be important to keeping the community engaged in the development process of the park.

Coastal research

Even though receding coastlines and flooding is a danger for the future of Guyana, these issues are experienced by communities all over the Caribbean. By linking the development of this park with the University of Guyana the research park could use student projects to further research and develop coastline resilience solutions. This specific niche of research would improve the quality of life of those who live in the coastal lowlands, but also provide the park with a unique characteristic that could allow for international interest (Interview Roopesh Sukhu 3/9/2021). Solutions from this research would aid in creating new infrastructure for Guyana and the rest of the Caribbean.

Educational opportunities

In addition to the collegiate assistance this park will also aim to assist in educating about the natural environment. Research has led us to understand that the best way to educate groups is through exposure and employment opportunities, which incentivize participant's time. In addition to the educational plan that was developed for students in the community, this park can provide employment opportunities that aid in the development of the park, as well as educate employees about land development, coastal resilience, flood mitigation and more.

4.3 Existing Conditions

To create the best recommendation for the site, all the data collected from interviews, administrative reports, existing parks, and past projects were used. Figures 10, 11, and 12 detail some of the data and information about the site and the area around it.

Coastline of Guyana

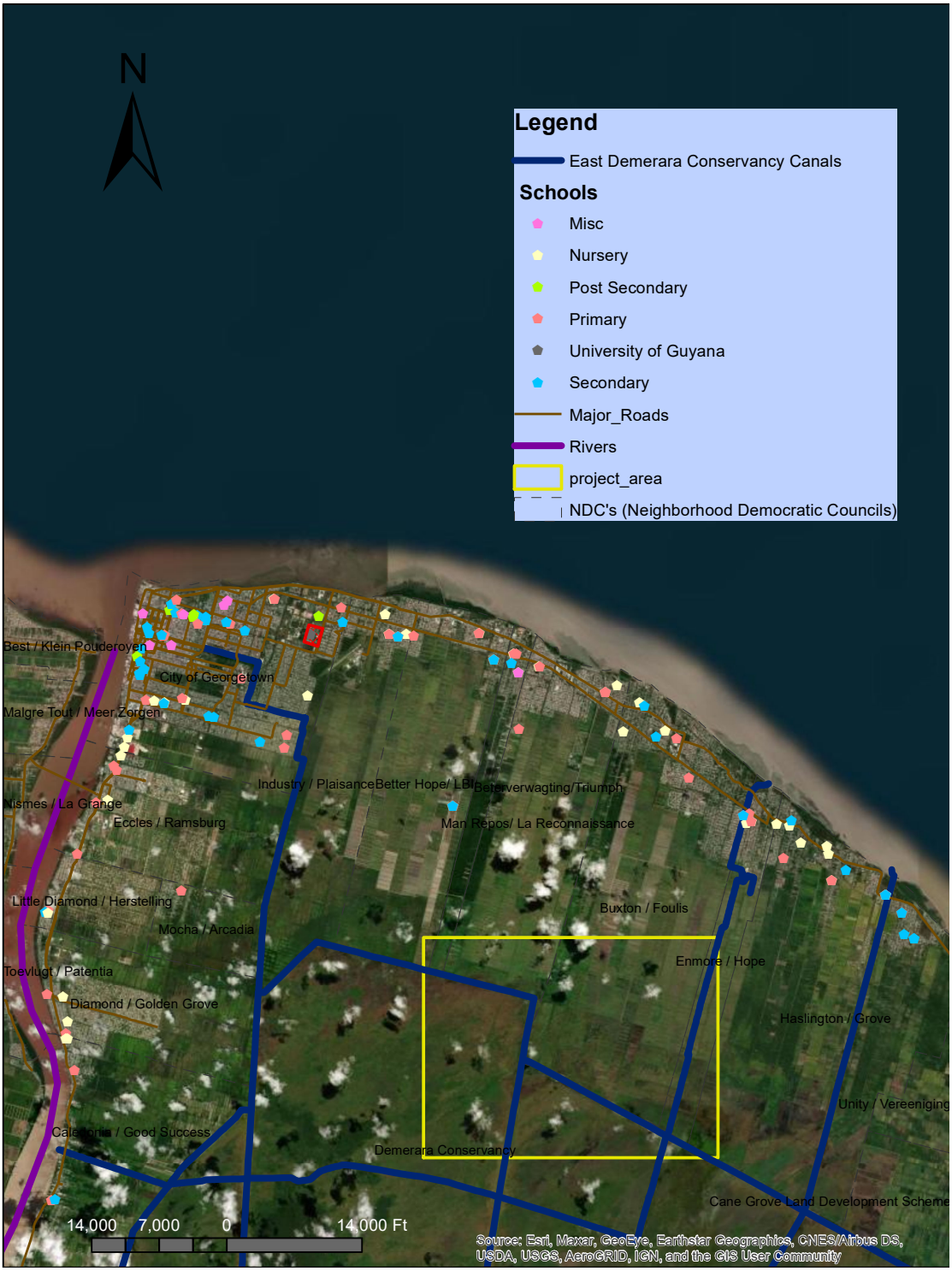


Figure 10 Coastline of Guyana map created from GIS data. Colored shapes represent schools in the area that could use the park for supplemental learning

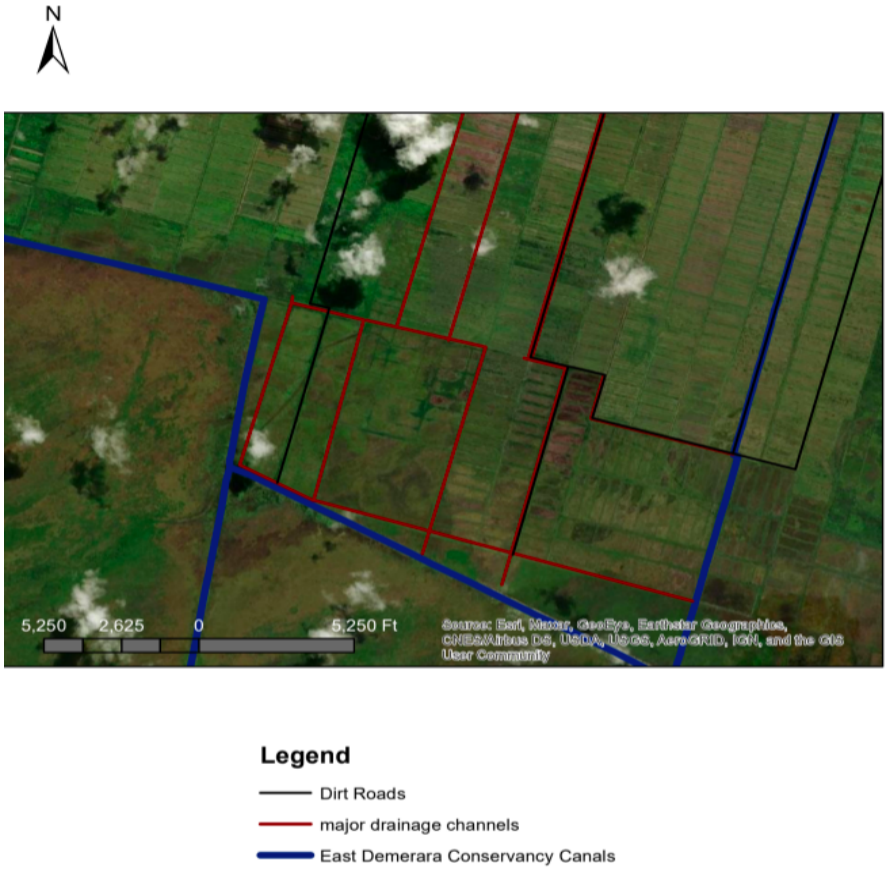


Figure 11 Major paths and Drainage map the black lines indicate areas where the land seems most appropriate for roads to be built, and the red lines indicate where the largest drainage channels are.

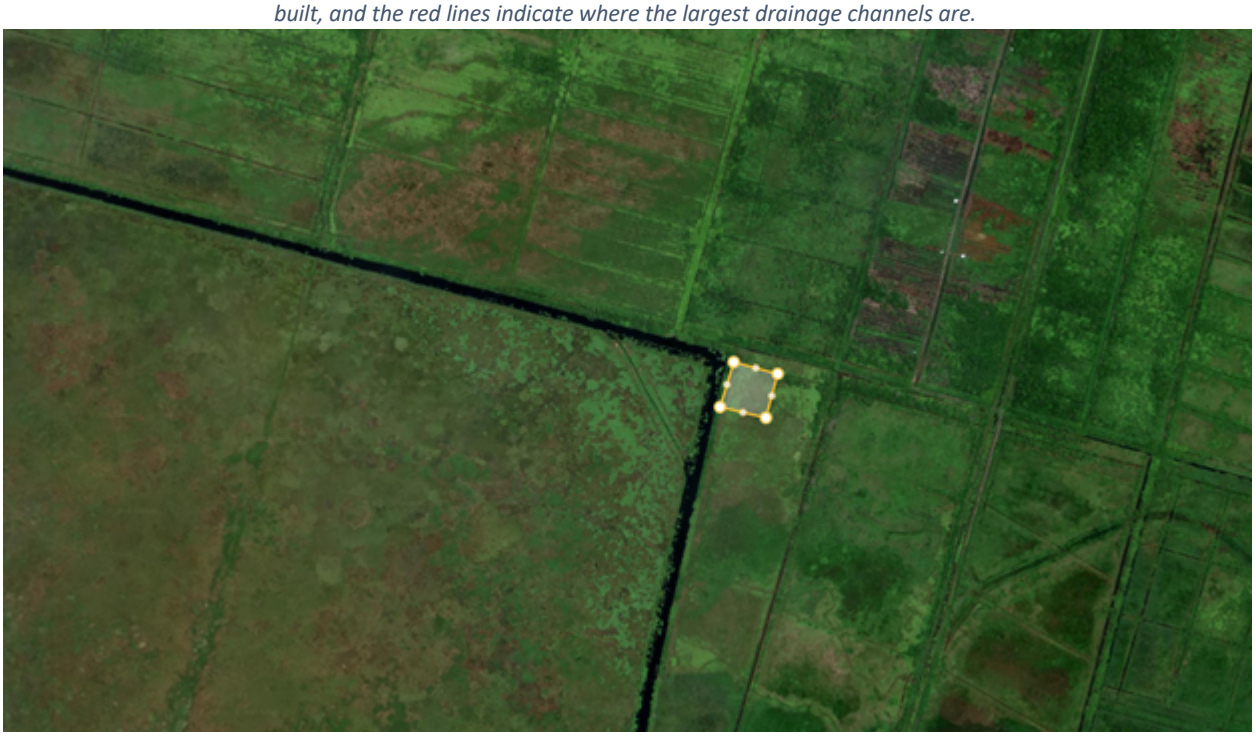


Figure 12 Zoomed in site area. proposed development highlighted in yellow

The Eastern Demerara Watershed is connected to the populated areas of Guyana through canals meant to irrigate farmland and manmade trails that farmers create to access their plots of land. The distance from the main road in the village of Buxton to the site (*Figure 10*) is approximately 9 kilometers. The main setback of this is that there is not a singular accessway to this specific area of the watershed where the site will be located. Further away from the populated areas, canals serve a dual purpose; irrigating farmlands and providing floodwater mitigation. Figure 11 details the widest areas both for possible roads and larger drainage canals. Many of these plots are left untouched and wild and, as the areas become more remote, the upkeep and management of these canals becomes less frequent. Soil in the area is mostly peat, a dense organic material, with sandbanks scattered throughout the coastal lowlands farm area. Lastly Figure 12 shows the main area of development, which covers an area of about 12000 sq meters.

4.3.1 Hydrologic Calculations

Because the East Demerara Water Conservancy is a protected area, precautions must be made to make sure that the park will not negatively impact the flow of water on the site. To do so I used the rational method to find the flow rate of flood waters on the site area.

$$Qp = ciA$$

Q_p = peak flow rate at the outlet of watershed area

c = runoff coefficient

i = rainfall intensity (in/hr)

A = Area of contributing watershed (acres)

(Bedient et al 2019)

The runoff coefficient (c) of peat is variable depending on time because of the compressive nature of the highly organic soil. After peat has been saturated it becomes compressed at a slower rate as time goes on. In Malaysia, over a 12-year period the runoff coefficient decreased from 1.2 to .2 (Katimon A et al 2013). Because of this variance, and my inability to go to the site I used an approximation to find the runoff coefficient. The coefficient I used is .5 because of the medium value of the coefficients from the study.

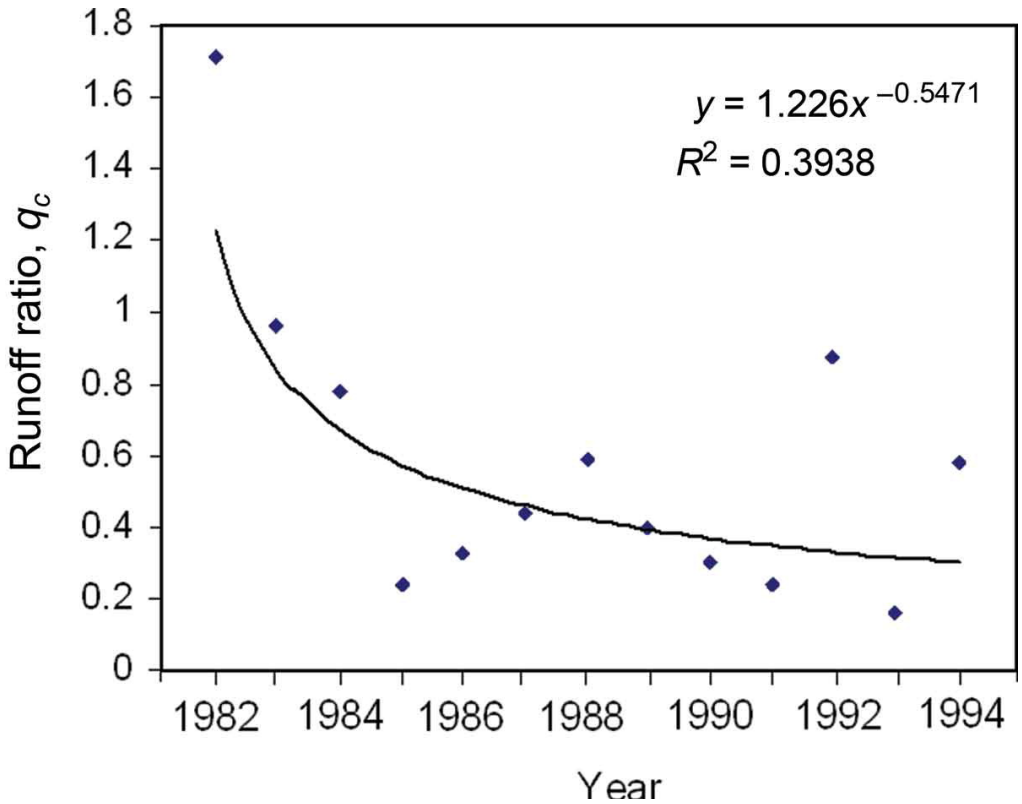


Figure 13 runoff ratio variations over time of peat soil (Katimon A et al 2013)

I found intensity of rainfall (i) using 5-year data because drainage facilities in Georgetown are designed for 5 and 10-year return periods. Rainfall intensity in this area is high for a short duration of time, so to prevent over-planning of facilities the protection level is set to 5 years (Japan International 2017). From a frequency analysis done by the NDIA (National Drainage and Irrigation Authority) and JICA(Japan International Cooperation Agency) Survey team, an intensity of 132.4 mm/day was found. To utilize in the equation above this value must be converted into in/hr. As such, the final value for intensity is .2174 in/hr.

The area of the site area was found using ARC GIS measurement tool. This area is only proposed theoretically, and physical development will use a specific area depending on approval of lands from the government. The value determined from GIS for area was 4.2 acres

The peak flow rate ($Q_{p)}$ using the runoff coefficient, intensity, and area above is .457 *cfs*. This value will be compared to a flow analysis of the site plan to determine hydrological impact of proposed development on the site. Since 24-hour rainfall data was used we will assume a 24 hour duration for calculating the associated volume. Using this value, the associated volume is 39,484 cubic feet.

4.4 Amenities List & Site Plan

The amenities list and site plan below were created in tandem from results of the research described in chapter 3. The amenities proposed are not all a part of the initial set of recommendations, but the recommended site plan has amenities to start initial research and create a usable park space. With community input more amenities can be suggested to achieve the goal of the park, to design a site plan for a research park that supports the study of local natural resources, ecosystems, the impacts of climate change, and creates educational opportunities to train the next generation of scientists and engineers in Guyana.

4.4.1 Amenities List

This list is meant to serve as a guideline for recommended installations that will aid in the development of the research park and surrounding areas. This list was created from research for the GRP including research park analyses, interviews, and findings from various reports on hydrology, sustainability, and infrastructure in Guyana. This list is filled with multiple and diverse options to make sure the research park can accomplish its objectives. Upon initial development all amenities will not be made, but over time developments can be added depending on the resources available.

The priority schedule shown below is meant to serve as a guide for developing the park to be used as soon as possible. Because the community, students and other stakeholders should be involved in the development process these steps will need to be laid out in a physical development plan that will be created later on in the development timeline. This plan will be codesigned with these stakeholders to ensure that the community completely understands what this research park will bring to the surrounding area.

Priority Schedule

1. Necessities
    a. Energy
    b. Water
    c. Food
    d. Safety
    e. Living quarters
2. Open space amenities
3. Research and testing

Necessities

Name	Rainwater catchment system
 *Figure 14 Example of rainwater catchment system (Smith G.M)*	A Rainwater catchments system, like pictured here, is the primary way most Guyanese buildings store water. These systems are instrumental for the operation of a space. This system will allow the park area to have water for various activities
Materials & Cost	pump, catchment barrel, and plumbing of the space. Costs depend on the size of each material
Alternatives	Well, surface water purification

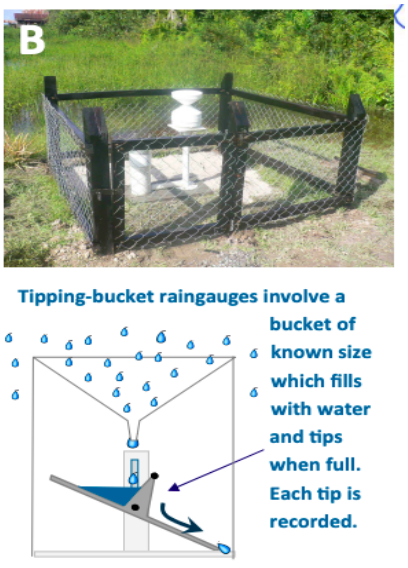
Name	Laboratory space
 *Figure 15 Example of Guyanese Architecture (Daily life 2018)*	On this site I hope to develop a 150- 200 sq meter space for laboratory equipment, experimentation, storage, and more. Like other developments in Guyana this building will be built on stilts to ensure that the structure is not damaged by floodwaters. To make sure that all the furniture and appliances are safe from theft, I recommend for them to be attached to the walls or floor. This space provides a location for potential overnight stays with adequate lighting, and First aid equipment
Materials & Cost	Wood, concrete, electrical equipment, laboratory tables, fire extinguisher & other safety materials
Alternatives	Gondola, or other type of covered structure

Name	Residential space
	This space will be shared with the laboratory area but sectioned off from the lab space. This space provides a location for potential overnight stays with adequate lighting, and First aid equipment
Materials & Cost	Wood, concrete, electrical equipment, cots with mosquito nets(in separate room), fire extinguisher & other safety materials
Alternatives	Cabin or other space specifically for beds/ cots

Name	Energy
 *Figure 16 Solar panels on government building. (G.E.A 2018)*  *Figure 17 (Honda Generators)*	To provide energy for the site when needed there are two main options this far from the power grid. 1. Photovoltaic/ Solar Panels 2. Gasoline Generator In the Guyanese community most homes have backup generators that kick in whenever the power grid is down. Those who are privileged enough use photovoltaic solar panels to supplement their energy use. Both of these methods are effective in powering the small appliances that would be located on the site. As the park grows and develops in the future there will have to be further research on developing a completely sustainable power source.
Cost	$500(Gen)-$1500(Photo)
Alternatives	None* *Wind and Hydropower options are available, but not directly feasible because of 2 reasons; 1lack of infrastructure around those energy sources and 2 Guyanese government focus on small scale solar opportunities (GEA 2018)

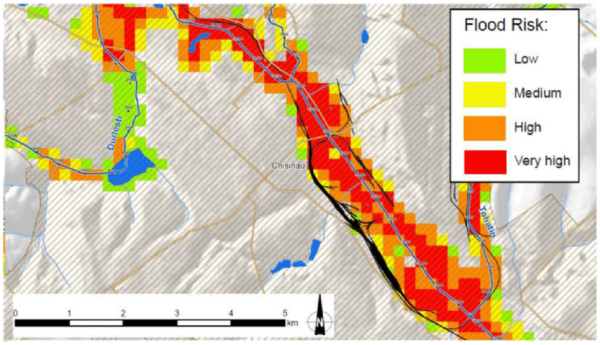
Name	Accessibility
 *Figure 18 example road that could be built near the site*	Creating accessibility for this site might be the most difficult challenge because the villages don't have a direct way to access the water conservancy area. From my research I created a map that details the larger areas where roads could be built. These roads would be simple cleared paths, with small stones and pebbles to create the road surface. For future development researching ways to develop more sustainable roads could be used
Cost	25 USD/ton (stabroeknews, 2016)
Alternatives	Paved road- more expensive Paved stones or other permeable surfaces- more expensive

Name	Aerial Imaging Drones
 *Figure 19 example drone for generating maps (Yuneec official website)*	Drones are the next step in technology to continue to monitor and map topography, visible infrastructure, and surface hydrological features. Researchers in the Conservancy adaptation project used multiple aerial imaging studies to create data about the conservancy lands. For this research park's future studies drones can be extremely helpful and can introduce younger members of the park to a new trade/ skill. 3D data derived from digital aerial photogrammetry using drones like pictured here can be used to create and update maps.
Cost	1,000-10,000 USD
Alternatives	Manual Lidar camera in a plane

Name	Rain & Soil Station
 *Figure 20 Raingauges for Monitoring Station (Bovolo 2013)*	To discover and establish data about the stormwater, rainfall, and the soil of the site these rain and soil measurement/sample stations would be spread around the site. These Stations would provide an area to understand recent rainfall data, and a place to take soil samples for a variety of different tests 1. Moisture content **test**. 2. Atterberg limits **tests**. 3. Specific gravity of **soil**. 4. Dry density of **soil**. 5. Compaction **test** (Proctor's **test**). Data created from these tests as well as from rainwater measurements can be archived and used in future research.
Cost	unknown
Alternatives	There are other stations like this in Guyana that monitor rainfall, but none in this area

Hydrology

Name	Bioswale
 *Figure 21 Bioswale Example (landscapeforlife.org 2021)*	A bioswale is a trench that receives rainwater runoff and has vegetation (such as grasses, flowering herbs, and shrubs) and organic matter (such as mulch) to slow water infiltration and filter out pollutants. (Merriam-Webster. n.d.) Future research at the park can study the effectiveness of Bioswales and study the types of plants that best absorb water. Research from this amenity could be key to building natural flood resilience infrastructure throughout the coastal lowlands.
Cost	Base mulch or stones, local plants, Costs are Variable
Alternatives	Coastal resilience techniques- living shorelines

Name	Flood risk mapping
 *Figure 22 Example of flood risk map (Ramsbottom 2008)*	Flood risk mapping- creating infrastructure to visualize flood risks in the area. To analyze flood risk you must consider hydrologic, geomorphic, hydraulic and land use conditions. Once these factors are understood the entire coastal lowlands area could use Flood Zone Demarcation to visualize flood risk. This amenity would be another result of targeted research and study from the park. Using physical and visual aids this could teach users of the space about flood risk
Cost	Varies
Alternatives	none

Open environment amenities

Name	Recreational Space
 *Figure 23 Fisherman on the bank of the East Demerara Water Conservancy (Dhanraj Stabroek 2018)*	Having a large recreational space could be a great way to use this space as a community gathering location. Once the community is together in this area information about research that could affect them could easily be passed back and forth. Activities that could be done in this space include cricket, soccer and track races.
Cost	Varies, (soccer goals cricket equipment)
Alternatives	none

4.4.2 Site Plan

Below is the proposed site plan for the Guyana Research Park. This plan includes 9 amenities that aim to achieve the goal of the park, to support the study of local natural resources, ecosystems, the impacts of climate change, and create educational opportunities for the local community. Rain & Soil monitoring stations are strategically placed near the proposed road, the center of the site and the far end of the bioswale to monitor how soil changes over time in these areas, and if the developments near these monitoring sites drastically changes the properties of the soil. The earth dam is meant to be an improvement to the existing dam at the edge of the conservancy. This amenity will require an assessment of the current dam, and deliberation on how to make it replicable for the entire conservancy area. The energy station, laboratory space, and rainwater catchment system are all connected because they are necessary for creating the laboratory space safe. These amenities provide the laboratory area with running water and energy for possible appliances. The recreational area to the south of the site is meant to be an open grassy area for a variety of uses. Bioswale amenity is a space to study infiltration, native flora and fauna, and overall flood mitigation. Lastly the educational area will host the educational activity amenities listed in the example activities (Appendix D)

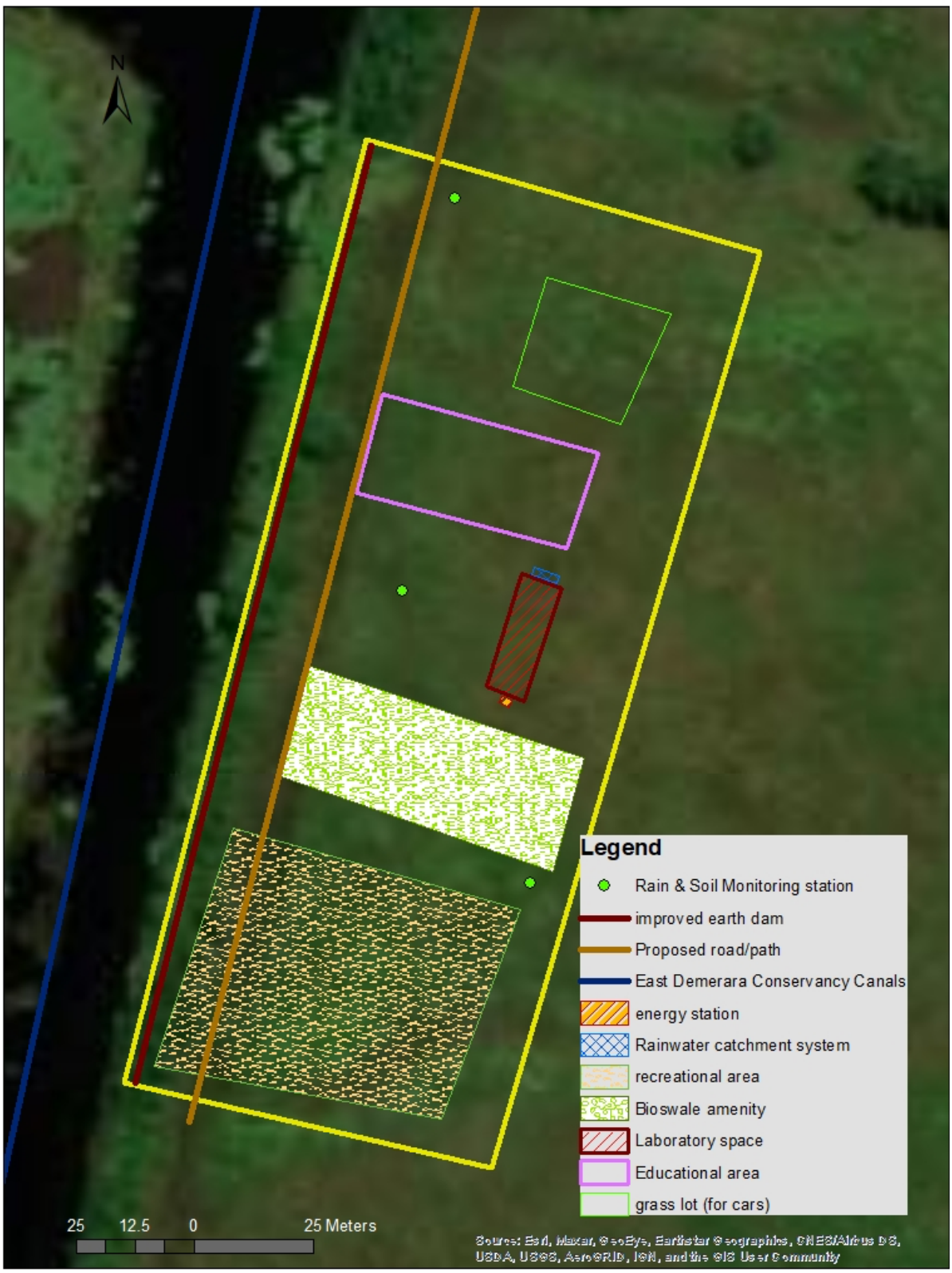


Figure 24 Recommended site plan created with GIS

4.4.3 Hydrologic Impact of the Proposed Site Plan

To determine how the recommendations provided would impact the site, a flow analysis was performed using a weighted runoff coefficient. To do this I used the areas of the proposed path and the laboratory space since those areas will change in material. The proposed path would be a dirt path which is different from the untilled farmland. This path had about 6% of the land area, and the coefficient for this path area is .48 because the path would be more compressed than the untilled land around it. The area of the laboratory space is approximately 1.3% of the total area, and because of the roof an assumed coefficient of .95 will be used. Intensity and area values, .2174 in/hr. and 4.2 acres respectively, are the same as the existing condition measurements.

To create the weighted runoff coefficient the percentage of the areas will be calculated and multiplied by the ratio of that area

$$c = (.06 * .48) + (.013 * .95) + (.927 * .5)$$
$$c = (.0288) + (.0124) + (.464)$$
$$c = (.505)$$

Using this runoff coefficient, we found a flow rate for the site of .461 cubic feet per second. Compared to the existing conditions this value is .046 more cubic feet per second. The associated volume with this value is 39,855 cubic feet. The difference in volume between the proposed and existing development is approximately 370 cubic feet. To account for this difference the bioswale on the site is designed to provide additional infiltration. The bioswale should be designed to account for the 370 cubic foot increase the site would theoretically have on the surrounding area.

4.5 Education Plan

This educational plan is made to list and describe the activities that students of all ages can participate in with help from the Guyana Research Park (GRP). Activities stated below encompass objectives that can be learned throughout all aspects of the development process of the park. This plan and its activities are recommendations made with data from interviews and reports. To develop these activities, I worked with educational experts from WPI's K-12 STEM education program as well as receive input from present and past Guyanese educators. I will also use my research from other Parks that have educational components to influence the types of activities that could be done once the park space is developed. To fully develop this educational plan, local teachers, and administrators will be needed to codesign a concrete process for using the GRP as a learning space. This educational plan will help increase the different ways that Guyanese students can be exposed to STEM. The park's activities will supplement Caribbean Examination Council (CXC) curriculum standards of different subjects. For example, Biology, Agricultural studies Activities that students can participate in to develop existing skills, learn about hydrology, the environment, etc., and find new avenues for future employment.

The CXC curriculum guides students to learn in nontraditional ways. One way they do this is testing for literacies rather than only theory “The CPEA™ will therefore focus on the assessment of literacies and not individual subjects as is the case with traditional end-of primary examinations.” (CXC) These Literacies are learning objectives that develop soft skills to help students communicate and apply the learned theory.

Secondary/community Education theory (from CPEA standards)

1. Biology
    a. Cell and Molecular Biology
    b. Genetics, Variation and Natural Selection
    c. Reproductive Biology
    d. Bioenergetics
    e. Biosystems Maintenance
    f. Applications of Biology
2. Agriculture
    a. The Science and Business of Agriculture
    b. Horticulture and Management
    c. Postharvest Technology and Innovation
    d. Agriculture and the Environment
    e. Animal Production and Management
    f. Livestock Products and Innovation
3. Chemistry
    a. Fundamentals in Chemistry
    b. Kinetics and Equilibria
    c. Chemistry of the Elements
    d. The Chemistry of Carbon Compounds
    e. Analytical Methods and Separation Techniques
    f. Industry and the Environment
4. Hydrology
    a. Flows
    b. Infiltration
    c. Ecology & Hydrology
    d. Flood Mitigation

Literacies & soft skills

1. WORKING LIKE A SCIENTIST- Scientific method and experimentation
2. INVESTIGATING MATTER- How to work with different materials and their properties
3. UNDERSTANDING LIFE- Understanding how life is made and maintained
4. FOCUSING ON ME- Understanding mental and physical health
5. EXPLORING ENERGY- Understanding energy options and efficiency
6. NUMBER AND NUMBER SENSE- Understanding numbers and their importance
7. CONSCIOUS CONSUMER- Being smart with money
8. SPACES IN THE ENVIRONMENT-Understanding habitats around us

9. MEASURING AROUND US- Making accurate real world measurements
10. DATA HANDLING- How to organize and analyze data

Activities for various Literacies

Mathematics	Science (how things are made)	Civic	Language
Tables Charts and graphs Calculations Shapes	(focus on the scientific process) Classify materials according to type and property Criteria for selecting materials for different things Making costumes, instruments etc.	Research origin of festival/celebration Customs Practices	Speeches Interviews Developing listening, speaking, writing & reading skills

Figure 25 Activities for various literacies from CXC administrative standards

The research park would serve as a space to develop these literacies using hands on and outdoor educational activities. This supplemental space could aid in achieving curriculum goals and objectives, as well as give Guyanese students a new perspective on learning.

Collegiate- The research park aims to aid The University of Guyana and its students in developing solutions for through projects, research, and laboratory experience

1. capstone design
    a. engineering students completing their design capstone could use this space as a medium to complete the requirement. Possible future topics include
        i. Design research/lab spaces
        ii. Accessibility assessment
        iii. Sustainable & local material sourcing and usage
        iv. Building and development scheduling, permitting
        v. Developing clean and consistent energy sources
        vi. Future uses and planning
2. Capstone other
3. Natural science laboratory
4. Hydrology & geology study
5. Coastal research

a. A need for understanding the effects of climate change on the coast can lead to Guyanese research similar to those linked below. With the help of Guyanese students, understanding the effects of climate change on the coastal lowlands could be focused on finding local solutions.
b. Examples:
    i. **Flat Wetland Flood Defenses** D. Reed, B. van Wesenbeeck, P. M.J. Herman, E. Meselhe, Tidal flat-wetland systems as flood defenses: Understanding biogeomorphic controls,Estuarine, Coastal and Shelf Science, Volume 213,2018, Pages 269-282, ISSN 0272-7714,https://doi.org/10.1016/j.ecss.2018.08.017.
    ii. **Living Shoreline** CT DEEP. (n.d.). *Story Map Journal*. ctdeep.maps.arcgis.com. https://ctdeep.maps.arcgis.com/apps/MapJournal/index.html?appid=4f6604af81934bcb9126cb31597d0f5f.

Sample activities can be found in APPENDIX D

Chapter 6: Next Steps & Conclusion

Next steps for this project are to have the plans reviewed by different engineers, educators and community members in Guyana to assess the possibility of developing this into a tangible research space. Engineers in Guyana would have the knowledge on the best process for developing spaces. Using their expertise, we would be able to develop a more specific site plan, and hydraulic analysis. Because of the nature of this project, geotechnical, civil, hydro/water management engineers would be most effective, but all engineering disciplines would be helpful during this stage. Professional engineers would also understand the policy and best methods for acquiring permits for new development.

The next steps in the development process also aim to include students from the University of Guyana. These students will use the different aspects of this park, accessibility, construction, energy and more to achieve final year design objectives as a part of their curriculum, but also develop the park into a space they can use for further research and community education.

The last part of the stakeholder evaluation involves the Guyanese community, specifically entrepreneurs, government workers, undereducated persons, and those looking for new opportunities. If these members of the community are involved in the development of this park it would give them a say in the development process, which would keep them engaged when the park is developed. Community involvement would also help educate them about technical aspects of the park that could improve their lives, like new employment opportunities, floodwater management strategies and much more.

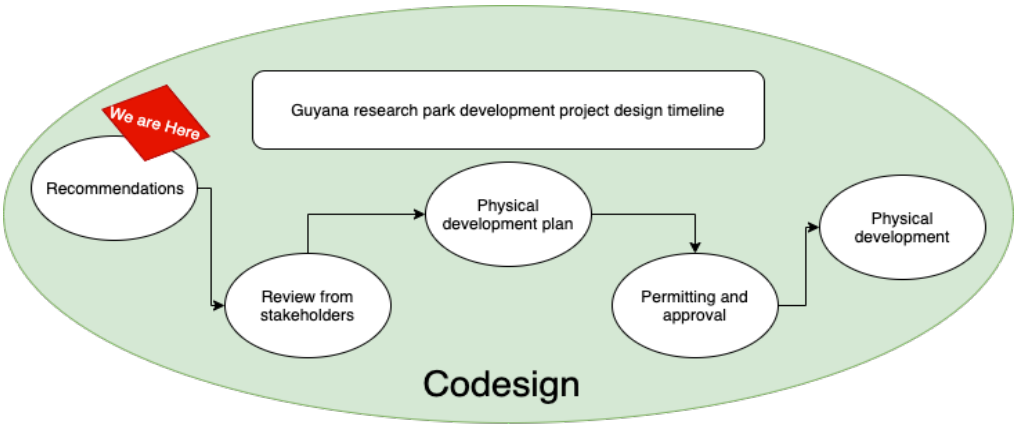


Figure 26 Proposed Project timeline

Throughout this entire development process, codesign is crucial to breaking the cycle of dependence on the global north. New development methods like codesign aim to relieve developing countries like Guyana from these top down, western development methods. These methods are the remnants of colonialism in the global south(Krueger & Telliel 2020). By empowering the community and introducing strategies for creating solutions to specific problems, Guyana could face its issues with a new mindset on how to use the tools and talents of the Guyanese people.

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Appendix

Appendix A: Summary from Interviews

*Disclaimer-Most of the interviewees spoke in Pidgeon English, which was difficult for the dictation software to pick up. In an effort to keep the summaries as unedited as possible grammatical mistakes by the software are left in the summaries for context. Leanna Kalicharan, a graduate and now Professor at the University of Guyana, was interviewed on February 18th 2021; Wilbert Hope, my grandfather and graduate of the university of Guyana, was interviewed on February 11th 2021; Roopesh Sukhu, a professional engineer in Guyana, interviewed on March 9th 2021; and Rhonda Benjamin, a primary school principal, interviewed April 1st 2021.
Education

- students come to UG because they want to get a degree out of high school and they have opportunities for college studies is the primary reason for students to come to UG. They're here because they want to do a degree or they have something that requires a degree
- they have consolidated all the courses that have lab appointments until one for that lab course which is one credit only you have three different types of life that you have to do for each section every week
- practical exercises following that there are brief tests and quizzes that they will have to take in the course also has assignments that they have to get done it's three components of different courses that they have to do so for three weeks they may do biology microorganisms in the next week they will do biology of animals
- an English course that I can't recall the name of this course require students to think about an actual project that can be possibly done on campus to enhance learning experiences for our campus students so that's what idea could possibly or may possibly have been done before a capstone final project
- there's no pre-like premed or pre-law we don't have a premade to begin with that's why students have to do either they come from Cape or a levels with the requirements there or they have a 3.0 GPA from any science program in UG
- associates degree and a bachelors degree so you can do the associate program where you spent two years doing various applied courses in biology as you were completed that two years you can transition into medicine or whichever program you would like to inclusive of the degree so move over to legally you have to have the requirements and then you will put register for the degree program
- University of Guyana as well they also have and open D work schools from all three counties can go in there is a facility for persons to get engaged in career development
- I was about 14 or 15 I start a chemistry and physics in form 4 because the primary school I went to a Guyana an East Demerara Water Conservancy in the village called Buxton we never had a chemistry teacher.
- , I was given a scholarship to study chemistry and continue in a laboratory to work so I went to university of Guyana and I did a degree in chemistry and then later on continue my training to get a PhD in the university of New South Wales in Australia

- chemistry teacher in high school was also attending university of Guyana and he would open a textbook and read from it my ...he was learning chemistry the same time he was teaching us it in high school so basically that's the level of teaching we had and maybe the same thing for our physics teacher. These are all young high school graduates that were learning the subjects as they teach that's the best we could've done
- CXC the Caribbean examination council and they focus on secondary education to be a high school graduate you have to pass about at least five subjects out of the Cxc curriculum and they have a variety of science they have general science chemistry physics agriculture science the program the CXC program is very good in terms of the number and variety of subjects and science so they prepare students to acquire the basic knowledge of understanding of science
- A lot of the schools especially when you're in a rural area it's difficult to even have the teachers to teach the science programs and secondary schools
- Schools do outside learning in their yards when possible
- Curriculum includes field trips, but due to lack of resources they are hard to organize
- prior to 2016 it was the full four years it's an undergrad degree there's no pre-like premed or pre-law we don't have a premade to begin with that's why students have to do either they come from Cape or a levels with the requirements there or they have a 3.0 GPA from any science program in UG With the revised biology program they introduced associates degree and a bachelor's degree so you can do the associate program where you spent two years doing various applied courses in biology as you were completed that two years you can transition into medicine or whichever program you would like to inclusive of the degree so move over to legally you have to have the requirements and then you will put register for the degree program that you do the additional two years and then you're eligible to have the degree in biology otherwise students will do the CxC exam get registered to the biology program do the two years in a new program and then transitioning to medicine provider they have the required GPA so I think medicine requires at least 3.0 and above to get into medicine

Research

- infrastructure facilities and even teachers so you might have a bachelor's degree program you might do very well in academic practical research work is something that they might now be focusing on but it's a lot of effort I didn't undergraduate research thesis what I did my bachelors and I was because I had connect with Ministry of agriculture I did nitrogen looking at different treatments of rice plants in the nitrogen fertilizer and then analyzing the plant itself at very stages for nitrogen content, but how many of us had that opportunity to do research and how well we are prepared that's a big problem in Guyana a poor country the Facilities are limited especially inside I was lucky I had exposure in the laboratory already so I was able to do some work nitrogen analysis on plant issues and come up with a 25 page report and statistical analysis that I think could give us some kind of practice some kind of capstone experience
- Australia is a more development commonwealth country and would often provide experiences to less developed the Commonwealth countries of course Guyana Canada Australia are all former British Commonwealth So the Australian government your

house program we being less developed the office scientist from Guyana to further develop I was a young scientist doing work in Guyana on ethnobotanical studies when you try to relate folk medicine to the actual Phyto chemistry chemicals are active ingredients in actual plant that might be good for pharmaceuticals

- UG in biology degree requires you to conduct research through a captain research project and I said to be requirement without that you can't graduate or have a degree in terms of flexibility of how they can choose projects it's quite flexible students are given opportunity to develop ideas on their own and from there they consult with potential supervisors in a department some our external supervisors can be consulted some of my other faculty or out of the University and they develop a project. In some cases, academics in or extra love department may have ideas and students if they're interested can work with him and consult with cell it's quite flexible and it's also not rigid in a sense that it must be biology focus it can be applied
- t will take some efforts to study those areas on a continuous basis to relate with the area know what's going on so that in time we can come with a proper ideas to use the lens close to the Conservancy the Conservancy was built in mud the Conservancy is a mud dam. New hope Darfour The Conservancy was built more than 100 years ago and it's only a Mad dam at some point in time we have to figure how the whole area is going to develop
- coming into the country to do research projects by law they are mandated to have a student from the University of Guyana accompany them on their research in that sense it's very competitive and selective there are a lot of bias test involved but on those grounds and have opportunities and their opportunities for students to get on board with research and that's how they get to conduct research the lead researcher from these various centers across the country

STEM Culture

- Guyana is a poor country and science is expensive always a problem
- I grew up just after independence and the whole thing was to train local people to pick up a lot of positions including science. A lot of the scientists were people from other countries people from Europe to from India my professor was a guy name ram Ralph from India he was an expert in rice I think at that time because the country was going rice and developing a bunch of different breeds and varieties of rice and the focus then was supporting agriculture industry, and so on so research agriculture research scientists were all foreigners they came from India and other parts of the world and around that time the government was trying to train local scientists in fact a lot of us got scholarships to study in England and Canada in various areas that involve science water before she in Canada for agriculture in the UK in my case I went to Australia and I did chemistry analytical chemistry so that was a thrust to try and train as many people as possible to pick up a lot of the positions available of course later on the economy couldn't support a lot of the research activities so that's why you have so many of us in this part of the world.... Oh yes England Canada Australia India to the government had a focus to train a lot of local people for the size of positions Weather by the bauxite industry agriculture industry and the sugar industry the whole thrust was to train the local people for key scientific positions that were headed by foreigner

- Guyana and kept on doing that I've only done a few things in the water industry so far; I work mostly for private companies, but I also used to liaise for GGMC Guyana geology and mines from time to time and do some part time work for them
- I was a child probably about seven or eight we had an infrastructure project within the community where they removed or transferred the mud drain into concrete drains and I interacted with the guys there who were digging and they were talking about the improvements that we were going to see and I did see that because we stop getting floods from seeing what they do and then explaining things to me as a child in a push the water let it drain that way I had interactions with proper engineers and proper construction sites so that gave me an idea of what they did
- leaving Guyana is not just a choice you're a persons who have opportunities and the relatives are there and maybe UG is just a stepping stone and soon they will make me too well soon of us some of us are stuck in the country and must return home after going on scholarship and less work from there
- I got a scholarship from the university of West Indies I had to come back like him he had to come back but if there's an opportunity for both of us we would leave but we have a live so far because we don't have relatives over there for anyone close that we can rely on so if we go will be completely independent and that takes time again to the point if facility like that would keep some young professionals over here and it's not if they do not have opportunities out of the country
-

Site

- The watershed area is at the back of a historic village Buxton not only Buxton but a village called Victoria
- before you get to the watershed area you have part of the village that was a sign performing so you have to park pass through farmland so the village had basically if you divide the land into two sections the township for the village where people live in the farmland and behind the farmland if you move from the ocean in land south you have to walk at least 2 km of the Township that's where people live and then if you go for the south do you have another 10 km 6-8 will be farmland that might be long as individuals that own House plots these housing areas were assign farming portions
- we move south and west More land's for agriculture at some point you got to figure out how we're going to use the land close to the Conservancy so another point is we don't have access roads at all weather road from the front from Atlantic to the Conservancy so all that area now is not properly used to live it's almost a banded remember we're not our economy is not relying on subsistence farming
- Remember the whole area was used for planting sugarcane and it would use the water in the Conservancy To flood the fuse for the cane and so on as a way to pack a crap
- the whole Conservancy area is so important to regulate flooding know if there's too much rain the water can over top the dam at the Conservancy and for the villages which happened in 2005. This was a trigger for Guyana to request help to have a look at Georgetown (flood issues) and now I have to look beyond.
- I think it's controlled by the drainage and irrigation authority although the village my own the land that is formed but that's only in the villages only some of the villages like

Victoria and Buxton have ownership in terms of ownership of certain lands Village ownership estate ownership and then there's state ownership the watershed might be state owned and controlled by the drainage authority they have some control in relation to agriculture and relation to flooding you have a drainage control people

- we don't have access roads at all weather road from the front from Atlantic to the Conservancy so all that area now is not properly used to live it's almost a banded remember we're not our economy is not relying on subsistence farming A lot of the lounge and that you lost property because we don't have proper access roads the whole idea of developing this area near a Conservancy is one have to be cognizant of the role that the Conservancy plays in irrigation drainage and so on
- The Conservancy area is like a catchment area that holds and guides of water rather than allowing it to pass through without control. If in heavy rainy season the rain water is coming down from the region down to the coast they have to make sure that the water is guided into a Cashman area and East Demerara water service we can do that the Conservancy damn well guide water to bigger canals that will direct the water out to the ocean so when is low tide the water will escape now when you get high tide and heavy rain you have some problems and right now the damn with work but you can draw models and they are existing models to show what it will take to over top of the dam

Misc.

- Number one to get all the permission and all of that and to get agreement because you have a lot of discriminate and you have to have an eye just a park you have to get some version that will appeal to the interest of whoever's in government the drainage people and maybe you have to figure out if it's going to be only on state land if it is only on state land once you have government Google it is OK if you have state man at a state land and all of that
- village council for the neighborhood Democratic Council which is the administrators body for the villages for instance Buxton would involve Buxton file neighborhood district which is a committee of 18 people with diverse political sides. And I don't know of any long-term plans these villages don't come up with five year or attend your plans you have to incorporate this idea in the five-year/tenure projection you have to get people to see how we can benefit the area see how we can provide access to the park but if their land because if they have a good road it might be able to bring and things that help develop some kind of tourism around village history the whole idea is to find somewhere the village can also benefit from it
- infrastructure upgrade every aspect of the country with oil and gas now there's a big push for coleslaw engineering and wharfs but at the same time there's a massive need for bridges because you need to link across three major rivers that we have and as well we need a proper bridges and roads system to go onto the drill and open up the country and spread to our people out because the coast line is below sea level so we have to start migrating people infrastructure development is sea coastal stuff and roads and bridges
- for the final cut capstone project we do use government labs like the ISP lab and the Ministry of agriculture labs we do go out to other agencies and do experiments and so if

we have a more high-tech and consolidated laboratory we could have multiple experience and different types of experience for various applied sciences that would be ideal and ideal world conditions for students to get hands-on experience and learning

Appendix B: Park comparison Chart

Characteristics	Location	Size	time of development	overall focus of the park	academic programs	climate of the area
Houston Arboretum	Houston TX USA	155 acres	16 yrs. (1951-1967)	Urban nature sanctuary/natural environment education	Yes	Humid subtropical
Tampines Eco green	Singapore	36.5 hectare	21	recreation, urban nature sanctuary	Yes	Tropical
Jurong Lake Gardens	Singapore	173 acres	approx. 10 yrs.	nature education, tourism, events	Yes	Tropical
Iguaçu National Park	Brazil/ Argentina	656 sq mi	unknown	Conservation, tourism	yes	subtropical
Kruger national park	South Africa	7,523 sq mi	unknown	Tourism, safari's, wildlife conservation, hunting	yes	Subtropical

Appendix C: Site Design Checklist

This Site plan checklist is a tool to organize site data to initiate the process of creating an effective site plan. Some characteristics include soil conditions, drainage, slope, elevation, power, fuel, and communications, employment, density of development costs, utility costs, design of exteriors and more. The data for this checklist was sourced from research pertaining to the GRP including government websites, interviews, and various reports on the surrounding area.

Site area

Characteristics	Remarks
Topography hydrology	Level of land, Intense slopes, water bodies Determines suitability of the site for development
accessibility	Distance from users (community, University of Guyana) Distance from major roads, and nearby road configurations
natural resources	Vegetation
safety	None existing
Structures	None existing

Checklist	Sourced from
topography	Guynode. (2019). Google earth, (Interview Wilbert Hope 2/11/2021)
hydrology Water bodies & streams Susceptibility to flood	U. (1998, December), JAPAN INTERNATIONAL COOPERATION AGENCY, & CTI ENGINEERING INTERNATIONAL CO., LTD. (2017), Bovolo, I. (2013), Mullenite, J. (2015), W. Abtew, P., Aceituno, P., SA. Bischoff, N., F. Chiew, P., F. Chiew, P., D. Cluis, C., . . . PJ. Ward, W. (1970, January 01).
accessibility	(Jemmott, S. (2017, January 24) Interview Wilbert Hope 2/11/2021
natural resources	(Interview Wilbert Hope 2/11/2021) (Interview Leanna Kalicharan 2/18/2021)

land use	reports Interviews, Humphrey, D. (2018) Guynode. (2019). (Interview Leanna Kalicharan 2/18/2021)
Architectural features Homes Open/park Spaces	Smith, G. M. (n.d.). Interview Wilbert Hope 2/11/2021
Transport Public transport Roads	Interviews (Interview Roopesh Sukhu 3/9/2021) (Interview Wilbert Hope 2/11/2021)
Safety streetlights	(Interview Wilbert Hope 2/11/2021)
Economic & Natural resources	Ministry of Finance. (2019, July) , U. (1998, December), (Interview Roopesh Sukhu 3/9/2021) (Interview Leanna Kalicharan 2/18/2021)
Utilities Energy Sewage/septic	G. E. A.(2018), NREL (Ed.). (2020, August) (Interview Wilbert Hope 2/11/2021)

Appendix D: Example Educational Activities

*materials are to be locally sourced when available
*activities are initial recommendations
*Before implementation direct input from Guyanese teachers is needed

Composting

Composting, the natural process in which organic waste decomposes into rich fertilizer, offers a sustainable solution for reducing waste and pollution, protecting and maintaining clean air, water, and soil, as well as finding methods to combat the effects of natural or human activities and can be easily performed in local communities and schools.

Objectives

The Purpose of this activity is to Identify and differentiate between living and non-living things. Students will develop an understanding on how soil is formed, and that living and non-living things are used as the basis of soil (such as rocks, dead plants and animals, as well as waste from animals, such as castings). Explain how compost is found in nature and is also a sustainable practice used to reduce food waste.
Materials List

- compost bin(s)
- soil, leaves, and other organic materials found outside for compost; (if the school environment has limited access to organic materials, teachers can purchase various items at a home improvement store and students can choose which to include as their design challenge (for instance: dirt, topsoil, sand, mulch, rocks, leaves, and peat moss)
- cardboard, newspaper, paper, hay, or pine needles to use as bedding for compost bins (see *Troubleshooting Tips*)
- reusable or compostable cups; used to scoop organic materials from outside
- magnifying glasses
- a lab notebook and pencil
- various colored pencils, crayons, and markers
- Materials List Sheet

Outline

- Group arrives at the park with materials or finds organic materials on site
- Before adding to the compost students will qualitatively analyze existing compost and record findings
- Students will analyze the organic materials collected and record findings
- The group will then have a discussion about the benefits of composting, importance of good waste Management and importance of soil health

Water Works- trench flow Exercise

The purpose of the trench flow activity is to demonstrate water flows and the importance of the trenches for flood management. During this activity groups will make guesses as to where

the “water” will flow, and why. After each turn a different passage will be blocked off to demonstrate a blockage in the trenches. After only 2 or 3 drops of water makes to the bottom of the Trench the group will discuss what was learned through the activity

Materials

1. Large plinko style board made from locally sourced, or reusable material.
2. Stones or bottlecaps, or other locally sourced materials
3. Notebook for notes and discussion

Outline

- Each student selects 5 drops of “water”
- Students place their drops in the best position to make it to the end of the trench
- After each trial, an instructor/ moderator introduces debris into the system
- Students must still find the best way to get their drops to the end of the trench
- Repeat until blockages make it impossible for 80% or more of drops to pass
- Debrief and discuss the importance of flows for safety and help provide a deeper understanding of the trench system.

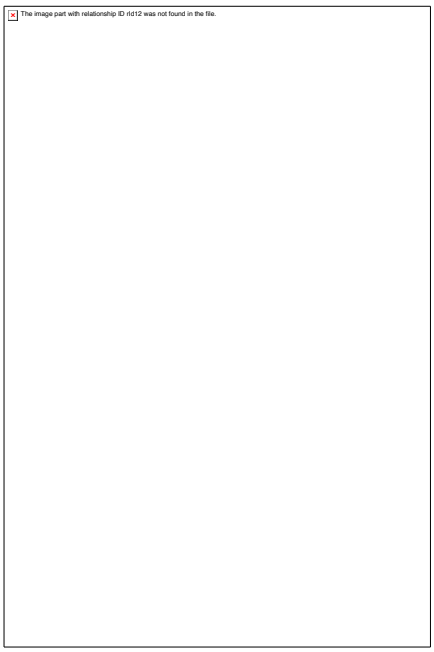

Figure 27 Example of Trench Flow Board (Pinterest 2019)

Ecology/ habitat- classification

The purpose of the activity is to find and organize what types of flora and fauna are on the site for development. Students will have the opportunity to examine the natural environment and discover different species in the project area. For older students this activity could also include listing and describing different types of plants that do well

Materials

-Notebook
-Outdoors
-disposable or digital camera

Outline

-Students will aim to find 5 unique species of plants and animals in the area
*Different grasses, shrubs trees insects rodents reptiles amphibians and more
-Students will aim to draw or take a picture of these different organisms and present them to the group