Government of the Cooperative Republic of Guyana

Technology Action Plan for Adaptation

January 2018

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We are also grateful for the support provided by the Global Environment Facility, United Nations Environment Programme – Technical University of Denmark (UNEP-DTU) Partnership, and the TNA Regional Offices for the Latin American and Caribbean Region Fundación Bariloche and Libélula.

FOREWORD

The Government of the Cooperative Republic of Guyana is committed to the fight against global climate change. This commitment is demonstrated at the global level as exemplified in our Nationally Determined Contribution (NDC) under the Paris Agreement, and actions taken at the local level in the pursuit of a Green Economy.

Hon Lt. Col. (Ret'd) Joseph Harmon, MSM, MP
Minister of State

As expressed in our NDC, Guyana's overarching contribution goal is to achieve a Green Economy *via* a low emission economic-development pathway. We intend to continue the transition of our economy to realize improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. This includes the pursuit of a resilient, low-carbon, socially-inclusive economy that provides a better quality of life for all within the ecological limits of our planet, particularly as it pertains to our common global climate.

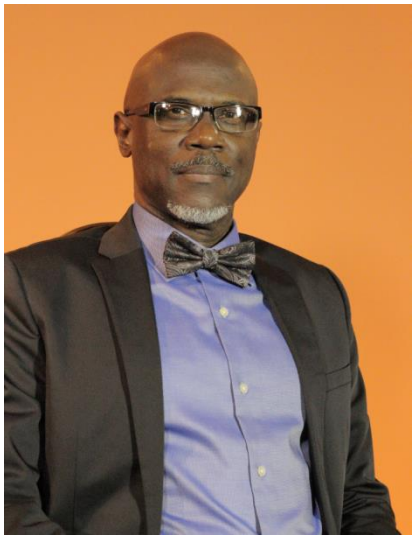
The Technology Needs Assessment (TNA) project has allowed Guyana to examine and prioritize our technology needs for key mitigations sectors (Forests -with a focus on Mining- and Energy) and key adaptation sectors (agriculture, coastal zone and low lying communities, and water), in accordance with commitments made in the NDC and within the framework of the Green State Development Strategy (GSDS).

The TNA process examined barriers to diffusion of the technologies and identified measures and actions to address the identified barriers in the technology action plans and project ideas presented in this report. The studies/analysis generated from the TNA project and resultant technology action plans provide valuable information in achieving our commitments towards emission reductions and to adaptation to climate change impacts.

As Minister responsible for climate change matters, it is my fervent hope that the technology action plans will form an integral part of our planning process for these key sectors and the project idea notes produced will help to initiate the request for funding in critical areas.

Joseph Harmon, MSM, MP
Minister of State
Ministry of the Presidency
Government of the Cooperative Republic of Guyana

STATEMENT FROM THE CHAIRMAN OF THE NATIONAL TNA COMMITTEE



Rear Admiral (Ret'd) Gary A R Best, MSS
Presidential Advisor on the Environment
June 2015 –January 2018

According to the Intergovernmental Panel on Climate Change (IPCC), 'adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change'. Adaptation and mitigation responses are underpinned by common enabling factors. These include effective institutions and governance, innovation and investments in environmentally sound technologies and infrastructure, sustainable livelihoods and behavioural and lifestyle choices. Effective adaptation and mitigation responses will depend on policies and measures across multiple scales: international, regional, national and sub-national. Policies across all scales supporting technology development, diffusion and transfer, as well as finance for responses to climate change, can complement and enhance the effectiveness of policies that directly promote adaptation and mitigation.' (IPCC 2014)

The Technology Needs Assessment (TNA) Project has allowed the Cooperative Republic of Guyana to prioritize adaptation and mitigation technologies suitable to local circumstances, taking into account Guyana's commitments under the Paris Agreement as expressed in the country's Nationally Determined Contributions.

The process of arriving at the Technology Action Plans for adaptation and mitigation and Project Idea Notes for the prioritized sectors has been an intense but rewarding one. This process included consultations with local experts and stakeholders who are in direct interface with the users of technologies, and other actors who hold responsibility for the diffusion of the technologies at various levels of government.

It is with great pleasure that I submit, on behalf of the Government of Guyana, the final Technology Action Plans and Project Idea Notes. As Chairman, I look forward to the development, enhancement and transfer of the identified technologies for integration into our national policies, strategies and plans.

Finally, I wish to thank the UNEP-DTU Partnership, the Global Environment Facility (GEF) and the members of the National TNA Committee for the execution of this project.

With every good wish,

Rear Admiral (rtd) Gary A R Best, MSS
Presidential Advisor on the Environment (June 2015-January 2018)
Chairman, National Technology Needs Assessment Committee

PREFACE

Guyana became a Non-Annex I party to the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 and has since made significant progress in the implementation of the Convention's principles to combat global climate change. In 2002, it prepared its Initial National Communication (INC), where the Greenhouse Gas (GHG) Inventory findings show Guyana as a net sink for the removal of greenhouse gases, due mainly to the country's large tract of tropical forests. The INC also highlighted the country's vulnerability to sea-level rises and extreme weather events. In 2012, the Second National Communication (SNC) was completed, which advanced on the findings of the INC and on the experiences of recent years, both nationally and globally, to provide more credible assessments and identify realistic solutions for climate change adaptation and mitigation.

To date, despite the many challenges (economic, technical, human resources etc.), Guyana is committed to addressing the issues associated with climate change. Over the years, it has built significant capacity in greenhouse gas inventories, mitigation and vulnerability assessments of key sectors, public awareness on climate change and assessing technology and capacity needs. Significant efforts have been made to define adaptation priorities and develop policies, strategies and actionable initiatives, including shore-zone protection and monitoring, crop diversification, water conservation and management, energy efficiency and renewable energy. Capacity has also strengthened in respect of early warnings, disaster management and weather forecasting. However, much more capacity is needed to build climate resilience in the key sectors of agriculture, water and coastal zones.

Recently, the Government of Guyana (GoG), recognizing the need for a long-term vision, has charted a path towards a climate-resilient economy through its 'green economy' plan, which builds on the previous Low Carbon Development Strategy (LCDS). The plan will promote the adoption of clean energy sources and the sustainable utilization of the country's natural resources (HE Granger, D. 2016), targeting low emissions across all sectors through vertical and horizontal policies and actions. Transitioning towards renewable sources of energy is a critical component of Guyana's thrust towards achieving 'green development'. Investments in solar, wind, hydro and biomass sources are cited as vital and must be augmented. Other targeted focal areas include coastal zone management, solid waste management, management of protected areas, protection of biodiversity, wildlife and the development of ecotourism. It is also planned to create several designated green towns across the country.

As Guyana takes this green development agenda further, technology transfer will be necessary to promote climate resilience. According to the Intergovernmental Panel on Climate Change (IPCC) (2000) in its special report on ' Methodological and Technological Issues in Technology Transfer', technology is defined as *'a piece of equipment, technique, practical knowledge or skills for performing a particular activity'.* The United Nations Development Programme (UNDP) handbook for conducting Technology Needs Assessments (TNA) for climate change defines the concept of technologies for adaptation very generically as *'All technologies that can be applied in the process of adapting to climatic variability and*

climate change' (UNDP,2010). A UNFCCC report on the development and transfer of technologies for adaptation to climate change proposes the following definition*: 'the application of technology to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change'* (UNFCCC 2010) (UNEP DTU, MCA Guideline, 2015).

TNA, as referenced by the UNDP and defined by the UNFCCC, is a '***set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of Parties other than developed country Parties, and other developed Parties not included in Annex II, particularly developing country Parties***'. It includes different stakeholders engaged through a consultative process to identify barriers to technology transfer and measures to address the barriers through sectoral analyses. This process allows for the use of soft and hard technologies, identification of regulatory options, the integration of national sustainable development priorities, the development of financial incentives and capacity-building.

Globally, the TNA is implemented in phases. Phase 1, or the first generation of TNAs, was completed during the period from 2001 to 2007, with support from the Global Environment Facility (GEF) and implemented by the UNDP and the United Nations Environment Programme (UNEP). The current project, Phase II, or the second generation of TNA, is being implemented with support from the GEF through its strategic program on technology transfer and with the collaboration of UNEP and the Technical University of Denmark (UNEP-DTU).

Guyana is among twenty-six (26) countries globally and one of seven countries in the Latin America and Caribbean Region participating in Phase II of the TNA. In September 2015, the GoG, through the Office of Climate Change (OCC), Ministry of the Presidency (MOTP), signed an agreement with UNEP-DTU to implement the TNA project in Guyana. The adaptation and mitigation technology assessments are completed by local consultants. The purpose of the TNA is to identify and analyze priority technology needs that will form a portfolio of Environmental Sound Technology (EST) projects and programmes and facilitate the transfer of, and access to, knowledge and experience during implementation. In addition to its integration into national development priorities, the TNA process provides an opportunity to find synergies with other processes and mechanisms under the UNFCCC, such as the Nationally Determined Contributions (NDC) and National Adaptation Plans (NAPs).

This Technology Action Plan (TAP) represents the final phase of the TNA process for Guyana. In the first phase, sectors and technologies were prioritized for further assessment. This was followed by a barrier analysis and the development of an enabling framework for the prioritized technologies. The final step is to prepare this TAP and Project Idea Notes which provide a framework for the implementation of actions to enable the transfer of prioritized technologies.

ABBREVIATIONS

AWS	Automatic Weather Station
BA	Barrier Analysis
BAEF	Barrier Analysis and Enabling Framework
CARDI	Caribbean Agriculture Research Development Institute
CDB	Caribbean Development Bank
CDC	Civil Defence Commission
CI	Conservation International
CIMH	Caribbean Institute of Meteorology and Hydrology
CPACC	Caribbean Planning for Adaptation to Climate Change
CRSAP	Climate Resilience Strategy and Action Plan
CTCN	Climate Technology Center and Network
DI	Drainage and Irrigation
EDF	European Development Fund
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EDWC	East Demerara Water Conservancy
EWS	Early Warning System
FAO	Food and Agriculture Organisation
GCF	Green Climate Fund
GDP	Gross Domestic Product
GDF	Guyana Defence Force
GEF	Global Environment Facility
GINA	Guyana Information Agency
GIS	Geographic Information Systems
GLDA	Guyana Livestock Development Authority
GLSC	Guyana Lands and Surveys Commission
GoG	Government of Guyana
GRDB	Guyana Rice Development Board
GSA	Guyana School of Agriculture
GuySuCo	Guyana Sugar Corporation
GWI	Guyana Water Incorporated
Ha	Hectares
IDB	Inter-American Development Bank
IMF	International Monetary Fund
INC	Initial National Communication
NDC	Nationally Determined Contributions
IRWR	Internal Renewable Water Resources
JCCCP	Japan-Caribbean Climate Change Project
MIPA	Ministry of Indigenous People Affairs
LCDS	Low Carbon Development Strategy
MMA/ADA	Mahaica, Mahaicony, Abary/Agriculture Development Authority
MoA	Ministry of Agriculture
MoC	Ministry of Communities
MPI	Ministry of Public Infrastructure
MOTP	Ministry of the Presidency
NAREI	National Agricultural Research and Extension Institute
NDIA	National Drainage and Irrigation Authority
NDS	National Development Strategy
NGO	Non-Governmental Organisation
NLUP	National Land Use Plan
NWC	National Water Council
NSA	National Strategy for Agriculture
OCC	Office of Climate Change
PRS	Poverty Reduction Strategy
SNC	Second National Communication
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TWG	Technology Working Group
UG	University of Guyana
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WUA	Water Users Association
WWF	World Wildlife Fund

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EXECUTIVE SUMMARY

This TAP is the third and final report in the TNA process. Several parts of the TAP are derived from the two previous reports: (1) 'Technology identification and prioritisation'; and (2) 'Barrier analysis and enabling framework (BA&EF)'. The TAP provides action plans for the prioritised adaptation technologies, including proposed project ideas that may be developed into detailed proposals for funding and implementation.

Guyana completed the first phase of the TNA process in July 2016, during which the critical sectors and technologies were prioritized for adaptation. Priority adaptation sectors were identified following a thorough review of national reports, strategies and plans addressing climate change in Guyana, namely, Guyana's Second National Communication (SNC) to the UNFCCC and the NDC. Following identification of the three (3) priority sectors, namely, ***agriculture, water,*** and ***coastal zone and low-lying communities,*** technologies were identified, screened and scored according to their technical potential, climate resilience and national development priority. In the final output, the following eight (8) technology options were prioritized for the BA&EF:

Agriculture Sector:

1. Freshwater harvesting: empoldering of water catchment areas
2. Agrometeorological system for forecasting and early warning

Water Sector:

1. Groundwater mapping and modeling
2. Surface water mapping and modeling
3. GIS mapping and modeling for water catchment protection

Coastal Zone and Low-lying Communities Sector

1. Mapping and modeling of coastal processes for the construction of seawalls and groynes
2. National early-warning system for floods and drought
3. Energy-efficient mobile pumps

The eight (8) prioritized technologies targeted Guyana's need to build capacity in research, forecasting, early warning systems, integrated water resource management and sea defense infrastructure to mitigate the impending hazards and improve planning at all levels. The BA&EF was prepared using a thorough participatory approach involving multi-stakeholders. Possible barriers were brainstormed and placed into two general categories: economic/financial and non-economic. These were further assessed based on their relative importance, ranked, and the critical barriers deconstructed into their root causes. The barriers prioritized for the respective sectors included high capital cost, limited sources of financing, a limited national budget, the lack of a coherent policy, overlapping institutional roles, weak technical capacity, a lack of research and a low level of awareness. The prioritized barriers were then assessed for linkages, and possible enabling measures were identified to create a framework to overcome the

barriers to each technology. The enabling framework outlined the key measures to overcome the critical as well as other barriers and facilitate the successful implementation of the technologies. The framework also included overlapping actions within the economic/financial and non-financial categories for all the sectors and across all technologies.

The actions and activities for the TAP were completed through a participatory, multi-stakeholder process, which engaged representatives from government institutions, the private sector and non-government organizations (NGOs) (See Annex 1 for list of participants). Technical Working Groups (TWG) were assembled for each sector to assess that sector's prioritized technologies. The actions and activities were developed from the measures identified in the BA&EF in order to overcome the critical and other barriers. A qualitative methodology was applied to rank and select the measures to be developed into actions. Each measure was assessed using a value score (1- Low; 2- Moderate and 3- High) for each of the four criteria below:

1. *Effectiveness*: the extent (how strong) to which a measure is expected to lead to the goal of technological implementation.
2. *Suitability for the country or sector*: how acceptable is the action within the country or sector? Some actions may be effective elsewhere but unsuitable to local context.
3. *Linkage with other measures*: positive/negative, or conflicts with other measures, policies in the sector or country, which could affect the measure's effectiveness and efficiency.
4. *Costs and benefits:* do the anticipated or known benefits outweigh the anticipated or known costs?

The scores were then summed up and ranked in descending order. The measure with the highest total was ranked No. 1. Where more than one measure had tied scores, the measures were further deliberated on and ranked based on the consensus of the TWG. For each technology, the top four to five measures were selected to become actions. Activities were then outlined for implementation with specific details, such as possible source of funding, responsible authority, timeframe, risks, success criteria, indicators for monitoring and estimated budget.

The actions identified focused primarily on creating the enabling environment for the transfer of the technologies, such as updating policy, national budgeting, capacity-building, research and education and awareness-raising. Based on the TNA guidelines, the actions may be developed or inform the development of Project Idea Notes (PIN). The PIN can be sector- or technology-specific and developed based on one or more actions which may facilitate the transfer of the technology. The following six (6) PINs were developed for Guyana, two (2) from each sector. Each PIN was conceptualized to reflect investment-phase technologies, incorporating the priority actions as key components in its implementation.

The project ideas proposed for Guyana are:

Agriculture Sector: *(1) Rainwater Harvesting for Sustainable Crop Production and Domestic Consumption; (2) Institutional Strengthening: establishing a National Agromet System to support climate-resilient agriculture.*

Water Sector: *(1) Integrated Water Resource Management: ground and surface water mapping and modeling; (2) Integrated Water Resource Management: capacity-building in GIS and finalization of IWRM Policy and Action Plan.*

Coastal Zone & Low-lying Communities: *(1) Development and Mainstreaming of Integrated Coastal Zone Management (ICZM) Policy and Action Plan; (2) Capacity strengthening of Early Warning System (EWS) and disaster management.*

This TAP report comprises three (3) chapters, which provide details on the process leading to the proposed PINs. Chapter 1 covers the agriculture sector, Chapter 2 the water sector and Chapter 3 the Coastal Zone sector. Each chapter provides a brief overview of the sector and discusses the general barriers and measures from the BA&EF process for each of the technologies. This was followed by the Action Plan for each technology, which includes a brief introduction to the technology, the ambition or reach intended or envisaged and the process of selecting the measures to be converted into action. Priority actions and activities for each technology have been summarized in Tables 2, 3, 6, 7, 8, 11, 12 and13. Each chapter concludes with a summary of the proposed project ideas for the sector and related technologies. Finally, based on the recommendation of the National TNA Committee, a list of possible project ideas for future consideration was compiled (Annex II). This list was informed by the list of technologies from the prioritization process and barriers and measures identified to enable technology transfer.

CHAPTER 1: TECHNOLOGY ACTION PLAN AND PROJECT IDEAS FOR THE AGRICULTURE SECTOR

1.1 Short Description of the Agriculture Sector

Agriculture accounts for approximately fifty percent (50%) of employment, twenty-five percent (25%) of the country's Gross Domestic Product (GDP) and one third of total exports. As a major revenue earner and a source of livelihood for approximately seventy percent (70%) of the population, agriculture has been regarded as the pillar of Guyana's economy. Most agricultural production is concentrated in regions two to six on the coastal plain, a low-lying fertile strip of land between five and seven kilometers wide, which lies at approximately 1.5 meters below sea level. This coastal strip is highly vulnerable to flooding, rises in sea level and storm surges.

An extensive system of natural and man-made sea defenses and a network of drainage and irrigation canals help to protect the coast from flooding. Surveys conducted indicate that the 'sea defenses comprise approximately 180 kilometers of man-made structures and 186 Kilometers of earthen embankments, mud-banks, mangroves, sand bars and other formations' (CDB, 2013). The system of drainage and irrigation canals feeds into the conservancies, which are designed primarily to provide irrigation water and secondarily other water needs. The conservancies are the 'backland' or upper stream catchment. The four major water conservancies are the Tapakuma Conservancy, Boerasirie, East Demerara Water Conservancy (EDWC) and Mahaica/Mahaicony/Abary (MMA). The major rivers include the Essequibo, Demerara and Berbice; smaller rivers are the Mahaica, Mahaicony, Abary and Canje. The rivers of eastern Guyana cut across the coastal zone, but they provide limited water access to the inland regions (GoG, 2012). There are also many large wetland areas, including ponds, swamps, seasonally flooded forests, lakes and mangrove forests. Based on climate assessments, inland regions are projected to experience more drought-like conditions. Droughts represent important economic losses for both the nation as a whole and those actually affected. The economic losses due to the 1997/98 and 2009/10 droughts were estimated at US$ 29M and US$14.7M respectively (GoG, 2015).

There are five principal sub-sectors, namely rice, sugar, fruit and vegetables, livestock and fisheries. The largest share of agriculture production is made up of crops representing twenty-five percent (25%) of agriculture GDP and five (5) percent of total GDP (MoA, 2013). Traditionally, agricultural production in Guyana has been dominated by two major export crops, sugar cane and rice, which occupy most of the irrigated land in the coastal regions – 2, 3, 4, 5 and 6. Many farmers are engaged in small-scale farming (less than five hectares) and practice an integrated type of system combining crop production with some livestock rearing (GoG, 2013). There is also a thriving wild marine fishing industry with recent expansions of aquaculture.

Institutionally, the agriculture sector is governed through various departments within the Ministry of Agriculture (MoA). The MoA's role is to ensure the formulation and implementation of policies and programmes which facilitate the development of agriculture and fisheries in Guyana. Its mission is addressed

through four key programme areas, namely, Administration, Crops and Livestock Support Services, Fisheries Department and Hydro-meteorological Services. Other sister or semi-autonomous agencies include the National Drainage and Irrigation Authority (NDIA), National Agriculture Research and Extension Institute (NAREI), Guyana Rice Development Board (GRDB) and Guyana Sugar Corporation (GuySuCo).

The Hydromet Service has the legal mandate for observing, archiving and understanding Guyana's weather and climate. It provides meteorological, hydrological and oceanographical services in support of Guyana's national needs and international obligations. GuySuCo also collects weather data for its crop cultivation. Table 1 below shows key legislation governing the agriculture sector, including provision for research, drainage and irrigation, and the development of rice and fisheries.

At the macro-economic level, Guyana is considered food-secure, since a significant portion of its agricultural produce is consumed in the domestic market. However, climate assessments have shown that agriculture in Guyana will be affected by the alternating conditions of excessive rainfall, flooding and drought (GoG, 2012). In recent years, the GoG has been promoting agricultural diversification as an adaptation measure and is investing more in inland agriculture, promoting crop varieties and new farming systems. In 2013, a National Strategy for Agriculture 2013- 2020 (NSA) was prepared to provide a detailed roadmap of the sector's needs and plans. The strategy is based on twenty-five (25) priority areas, which include water security and weather forecasting (GoG, 2013). A Disaster Risk Management Plan was also developed for the sector (MoA, 2013). In 2010, the Low Carbon Development Strategy (LCDS) sought to orient the sector within the context of a low-carbon economy to nurture investment in low-carbon sectors such as fruit, vegetables, aquaculture, and investment and development by the indigenous population in areas such as cattle-raising and value-added production (LCDS, 2010). Currently, the MoA is implementing initiatives in drought-prone regions, such as Region 9, to promote agricultural diversification and is scoping out locations for water-harvesting ponds (MoA, 2016). More initiatives are also being undertaken to expand the sector within the government's 'green economy' agenda. Some G$20.6B was budgeted for the agriculture sector in 2017 (MoA, 2017) to promote expansion and enhance the development of inland agriculture, diversification and drainage & irrigation (D&I) services.

TABLE 1: MAIN LEGISLATION IN THE AGRICULTURE SECTOR

Legislation	Authority	Mandate
National Agricultural Research and Extension Institute Act, Ch. 3173	Ministry of Agriculture: National Agricultural Research and Extension Institute	Research and extension services for other crops. To plan, develop and implement research designed to produce technologies and systems required to maintain national self-sufficiency and export capacities in agricultural commodities.
Guyana Rice Development Board Act, Ch. 7201	Guyana Rice Development Board	Research and development of the rice industry. This department promotes and supports the development of agriculture in Guyana through the provision of a range of technical and regulatory services to the sector.
Fisheries Act Ch. 1204	Ministry of Agriculture	Development of the fishery industry. The Fisheries unit is responsible for managing, regulating and promoting the sustainable development of the nation's fishery resources for the benefit of the participants in the sector and the national economy.
Mahaica Mahaicony Abary. Agriculture Development Authority (MMA/ADA) Act. Ch. 6901	Mahaica Mahaicony Abary/Agriculture Development Authority	Irrigation for agriculture in the MMA districts.
National Drainage and Irrigation Act 2004, Ch. 64:04	National Drainage and Irrigation Authority	Established in 2006, the act deals with all public matters pertaining to the management, improvement, extension and provision of drainage, irrigation and flood control infrastructure and services in declared areas of the country. Its primary water resources management strategy is locating, evaluating, conserving and distributing water resources for agricultural purposes. Works closely with local groups such as the Water Users Association.

1.2 General Barriers and Proposed Measures

The common barriers for the prioritized technologies, namely ***(A) Freshwater Harvesting: Empoldering of Water Collection Areas and (B) Agrometeorology for Forecasting and Early Warning***, are related to policy and regulation, financial availability, institutional, technical and human capacity, and public education and awareness-raising. In the BA&EF process, barriers were prioritized as 'critical/killer' barriers and deconstructed to identify root causes and measures. The critical barriers are those most likely to affect the transfer of the prioritized technologies. This section provides a summary of the general barriers and proposed measures for the two prioritized technologies in the agriculture sector:

A. Freshwater Harvesting. The top three critical *barriers* prioritized for this technology were:

1. High capital and maintenance costs
2. Unclear policy for freshwater harvesting
3. Low acceptance by local culture

There were also several financial and non-financial barriers, such as limited source of funding, a lack of incentives for private-sector participation, limited access to banking services in inland areas and high investment risk due to limited markets and protection mechanisms. Unclear policy, overlapping authority and conflicting uses in national planning were identified as the main policy and regulatory barriers.

Over the years, the lack of updated research on water resources has affected scientifically guided decision-making in the sector. Reliable and consistent water resources and ecosystem data (e.g. river/stream dynamics and biodiversity) are severely lacking. This situation presents challenges in determining the appropriate local intervention in both the immediate and long terms. The availability of local skills for the design and construction of large-scale impoundment structures and resources for the monitoring of water catchment areas are also key barriers to technology deployment and diffusion. Cultural acceptance and awareness of the long-term developmental benefits were also identified. However, as more communities are continuing to experience erratic weather patterns, including extensive droughts, the construction of holding areas for water harvesting is becoming more acceptable. Whereas the technology may be perceived as a large-scale investment to be pursued on a commercial scale and driven by private enterprise, its market success and sustainability also depend on the socio-economic context of the area or region in which it is located.

Macro-catchment water-harvesting requires significant financial resources, which can be huge barrier to the widespread and rapid diffusion of the technology. High capital and maintenance costs for the construction of dams, conveyance and storage systems can slow down or prevent its uptake. Freshwater harvesting in hinterland locations may utilize natural depressions to store water or create small lakes. This requires significant preparation of land and the design and construction of dams to contain and transport excess water, while ensuring minimal disruption to the natural functions of the ecosystem. The cost will be influenced by the remoteness of the location, the scale of the technology, studies to be completed and the construction and maintenance of freshwater harvesting systems. Inland areas often suffer from a lack of access to capital,

reliable transportation, increased material costs, a lack of local skills and technical support, limited market opportunities and slow bureaucratic processes, which will have varying levels of impact on the uptake of this technology. This type of technology is more likely to be undertaken by a large-scale investor or as a community-based system. Based on the critical barriers identified, the enabling and other *measures* proposed for freshwater harvesting technology included:

- Outline and clarify policy on freshwater resource use;
- Update existing regulations to reflect clear lines of authority among the various institutions;
- Build and strengthen institutional capacity to monitor water catchments and basins;
- Conduct research to identify areas suitable for freshwater empoldering;
- Provide low-cost options for the design and construction of dams, holding ponds and conveyance systems;
- Encourage and support partnerships and community collaboration for shared ownership and responsibility;
- Provide technical advice and support to interest persons, organizations, groups and communities; and
- Promote awareness of the likely impacts of climate change, such as drought and flood, and the importance of water management.

B. Agrometeorological System. The barriers identified emerged from financial, institutional capacity and cultural and behavioral concerns. The top three critical barriers prioritized were:

1. Inadequate budgetary allocation
2. Inadequate compensation for skills
3. Inadequate communication infrastructure

Other barriers included high investment and moderate maintenance costs, limited source of financing, ad-hoc inter-agency coordination, limited communication infrastructure, limited technical skills and research. Highly sophisticated agrometeorological systems can be costly to implement and sustain. A national-scale system will require a larger budget for new infrastructure and technical capacity. Given that institutions must share a limited pool of financial resources among other program activities, ultimately budget availability will determine the scale and sophistication of this technology. Additionally, poor compensation for skills has contributed to the difficulty in attracting and retaining the relevant expertise, leading to a decline in the delivery of agromet services in Guyana. Currently, the agromet sub-division is poorly staffed, with no qualified agrometeorologist and limited equipment.

Specific cultural and behavioral barriers identified were that farmers and other users may resist new techniques supported by this technology, and the lack of awareness of the range of benefits and its role in food security in the farming community. Since farmers are the primary beneficiaries of this technology, it is critical to have their acceptance or buy-in.

The proposed measures identified to overcome the barriers for this technology were:

- Increase annual budget for agrometeorological services from the Hydromet Service. Financial resources should be made available for adequate, well-maintained observation networks of high spatial density;
- Diversify sources of financing for technical support and capacity-building;
- Implement an operational policy to enable a more focused approach in agrometeorology;
- Provide a compensation package to attract and retain technical skills. Sufficient competent staff dedicated to agrometeorology are necessary to deliver the services needed by farmers and extension officers;
- Identify and secure support for training and research with local and regional institutions;
- Promote local and regional collaboration, as well as data-sharing among government agencies, NGOs and the private sector; and
- Promote awareness of technology needs and benefits among beneficiaries

1.3 Action Plan for Freshwater Harvesting: Empoldering of Water Collection Areas

1.3.1 Introduction

Water harvesting (WH) is often described as *'the collection and management of flood water or rainwater runoff to increase water availability for domestic and agricultural use, as well as ecosystem sustenance'* (Mekdaschi Studer *et al.* (2013), and it is an essential component of sustainable land and water management. Its basic application is to collect water in an area and transfer it to other areas where it is most needed to increase the availability and volume of water in that area.

The basic physical components of this type of water-harvesting system are (i) a catchment or collection area (ii) a run-off conveyance system (iii) a storage component and (iv) an application area. There are many water-harvesting technologies, depending on their application, but the most common are (i) flood-water harvesting (ii) macro-catchment water harvesting (iii) micro-catchment water harvesting and (iv) rooftop and courtyard water harvesting.

Freshwater harvesting is a mature technology in Guyana. Its application is concentrated in the coastal regions and has been undertaken on a macro scale by the government. For example, there are four large man-made conservancies which harvest and store rainwater run-off to provide a reliable supply of water to agricultural land and to act as a flood-control measure. Most of Guyana's water demand is for irrigation purposes, derived from water conservancies (Regions 2, 3, 4 and 5) and from the rivers through pumping. The EDWC is one of the major water conservancy systems in Guyana. Along with the East Demerara drainage and irrigation systems, it provides water storage and flood control for Guyana's most populated Region four, including the capital city, Georgetown. The EDWC was constructed in 1880 from several existing drainage systems. It is bounded on three sides by a dam embankment (67 kilometers in length) and has five main drainage relief canals. It covers an area of 571 square kilometers and stores approximately 250 million cubic meters of water at its maximum safe operating level (WB, 2013).

1.3.2 Ambition for the TAP

Empoldering for water harvesting ensures that water is stored and available locally, especially in the outlying or inland regions, thus preventing food insecurity and population displacements because of drought. Deploying the technology in the agriculture sector contributes to climate change adaptation by providing a source of water for crops, livestock and inland fisheries in dry conditions. The collection area also allows water to be stored during periods of extremely high rainfall and reduces the impact of flooding on communities. The target for the technology is that it should provide an adequate water supply for agriculture and domestic use by communities, particularly in drought-prone areas. Recently, several hinterland regions (1 & 9) have experienced prolonged drought-like conditions, and the MoA has begun assessments to identify sites for water empoldering, in addition to the government's plans to establish more wells to access groundwater and provide water storage tanks and pumps to communities (MoA, 2017). It is intended that water-harvesting will form part of a broader 'sustainable water supply

management' project or program, and therefore this technology will be applied on the medium to large scale.

1.3.3 Action and Activities for the TAP

Generally, the priority actions for freshwater empoldering related to technical assessments and capacity, the need for clarity on policy and education and awareness raising. The increasing risks to water resources, agriculture and livelihoods from prolonged dry weather have highlighted the need for water harvesting in large quantities to sustain communities during excessively dry periods. For example, North and South Rupununi villages usually suffer from an inadequate water supply for crops, livestock and living purposes during the extremely dry season. In the past, this has resulted in the loss of crops and livestock (MoA, 2017). Several studies have been completed in specific areas and solutions have been identified, such as the harvesting of water from springs and creeks. A total of G$30M was approved in the 2017 national budget to develop water-harvesting facilities in Region 9 (MoA, 2017). As the need and viability of freshwater harvesting gain momentum in Guyana, so does the urgency for research to provide data and guide decision-making. Stakeholders felt that this was critical to the effectiveness and sustainability of the technology.

A qualitative methodology was applied to rank and prioritize the measures. Each measure was assessed using a value score (1 Low, 2 Moderate and 3 High) for each of the four criteria: (1) effectiveness; (2) suitability for the country or sector; (3) linkage with other measures; and (4) costs and benefits. The top four (4) measures were selected to be turned into actions intended to create the enabling environment for the transfer of the technology. The four measures identified for development into actions are:

1. Conduct research to provide updated data and baseline on the status of water resources to identify suitable areas for empoldering more efficiently
2. Showcase successful technology applications to stimulate interest and promote awareness
3. Promote awareness of the likely impacts of climate change, such as droughts and flooding and the need for water management
4. Update existing regulations to reflect clear lines of authority among the various institutions.

Table 2 below shows the actions and proposed activities with details of implementation for freshwater harvesting technology. The time frame assigned for each activity was based on three periods: Short term: 1 – 3 years; Medium term: 3-5 years; and Long term: 5-10 years. Budget estimates included consideration of known costs for expertise and equipment. For activities where costs are unknown, the best judgement was used based on examples from other countries. The budget for some activities may have been either under-or over-estimated. However, this can be adjusted for greater precision in the detailed proposal.

TABLE 2: ACTIONS & ACTIVITIES FOR FRESHWATER HARVESTING – EMPOLDERING OF WATER COLLECTION AREAS

Actions	Activities to be implemented	Sources of funding	Responsible Institution & focal point	Time frame	Risks	Success criteria	Indicators for Monitoring of implementation	Budget per Activity
Action 1: Conduct research to provide updated data/baseline on the status of water resources to identify suitable areas for empoldering more efficiently	Activity 1.1 - Aerial surveys using drones	GoG, Bilateral, WB, UN NGOs, Private Sector	MoA	Short term	High capital cost	Updated data available on water resources	1. Technical proposal for survey 2. Expertise sourced 3. Surveys completed 4. Maps and report available.	US$150,000
	Activity 1.2 - Analysis of historical data	GoG, Bilateral, WB, NGOs, Private Sector	Hydromet/Guyana Water Incorporated (GWI)	Short term	Availability and accessibility of data	Report on historical trends in water resources	1. Technical proposal prepared 2. Expertise sourced 3. Report of analysis completed	US$ 75,000
	Activity 1.3 – Conduct Soil surveys	GoG, Bilateral, WB, NGOs, Private Sector	NAREI	Short term	1. Limited skills and labour 2. High capital cost	Soil profile for possible areas	1. Technical proposal prepared 2. Expertise sourced 3. Maps and Report of survey completed	US$ 250,000
	Activity 1.4 - Collaborate through EIAs	Developer/Private Sector, NGO	Environmental Protection Agency (EPA)	Short term	1. Additional cost to developer 2. Lack of capacity/skills	Data supplemented through EIA reports	EIA studies required to provide detailed assessment of water resources.	US$1,000
Action 2: Showcase successful technology application to stimulate interest and promote awareness	Activity 2.1 - Establish model pilot areas	GCF, GoG, WB, NGOs, Private Sector	MoA	Short term	Low interest and stakeholder buy-in	2-3 Pilot areas established	1. Pilot sites identified 2. Design approved 3. Construction of dams completed	US$300,000
	Activity 2.2 - Create farming clusters	GCF, GoG, Caribbean Agriculture Research and Development Institute (CARDI)UNDP, WB	Agriculture extension services (NAREI, Guyana Livestock Development Authority (GLDA), GRDB)	Short term	Low interest and stakeholder buy-in	Farming clusters established in priority Regions e.g. 1, 9 &10.	1.Suitable farming sites identified 2. Community consultations 3.Farming clusters operational	US$10,000
	Activity 2.3 - Media events	GCF, GoG, CARDI, UNDP, WB	Guyana Information News Agency (GINA)	Short term	1. Logistics 2. Competing priorities	1. Country wide dissemination of information on technology 2. Increased awareness and interest in	1. TV coverage of consultations and pilot areas 2. Newspaper articles, including farmers bulletin	US$15,000

						water harvesting		
	Activity 2.4 – Develop ground capacity to manage model farms	GCF, GoG, CARDI, UNDP, WB	Agriculture extension services (NAREI, GLDA, GRDB), NDIA	Short term	1. Low interest within community 2. Lack of relevant skills	Management of farms by skilled personnel	1. 3 persons identified for training 2. Training completed 3. Personnel assigned to model farms	US$20,000
Action 3: Promote awareness of the likely impacts of climate change, such as droughts and floods, and the need for water management	Activity 3.1 - Develop IEC (information, education, communications plan)	GCF, GoG, UNDP, UNEP, WB, Bilateral cooperation, World Wildlife Fund(WWF), Conservation International (CI), Private Sector	Hydromet/Office of Climate Change (OCC)	Short term	Logistics and finance	Integrated public awareness plan developed.	1. Stakeholder discussions 2. Public awareness/communication strategy prepared	US$ 10,000
	Activity 3.2 – Establish Public Relations Committee	GoG	OCC	Short term	1. Limited personnel 2. Overlap with existing bodies	Functional Public Relations Committee	1. Terms of Reference 2. PRC meetings	US$1,000
	Activity 3.3 – Promote monitoring and enforcement of water conservation schemes	GoG, GCF	OCC & MoA	Short term	1. Overlapping authority 2. Low interest and cooperation among users	Increased collaboration with water management authorities and users	1. Monitoring plan prepared 2. Increased compliance 3. Improved water availability	US$1,500
Action 4: Update existing regulations to reflect clear lines of authority among the various institutions	Activity 4.1 - Review current legislation	GoG, UN, WB, NGO.	MOA/OCC	Medium term	1. Cost 2. Competing national priorities	Updated legislation for water management	1. Report of review 2. Legislation passed	US$ 30,000
	Activity 4.2 - Draft water management policy	GoG, UN, WB, NGO.	MOA/OCC	Short term	1. Cost 2. Competing national priorities	National Water Management Policy completed.	1. Draft policy completed 2. National consultations held 3. Policy approved	US$ 40,000

1.4 Action Plan for Agrometeorological System for Forecasting and Early Warning

1.4.1 Introduction

Agrometeorological forecasting and early warning systems (EWS) are a mature technology worldwide, countries having developed advanced remote-sensing and forecasting technologies. In France, for example, an EWS is used alongside plant protection and extension services to deliver information to farmers. In India, the Indian Meteorological Department (IMD) has developed integrated systems utilizing satellite technology to produce crop-specific weather-based agronomic advisories, and operational agrometeorological schemes are being implemented country-wide. According to the IMD, agromet services are available in 550 districts. Farmers receive advisories before various stages of farming, and about 2.5 million farmers are using this information through mobiles (GoI, 2017).

The application of such systems can range from advanced, modern systems that include numerical models and data analysis to less complex systems using basic climate data. The application depends largely on needs and resources, including human skills. Presently, the Caribbean Climate Outlook Program provides seasonal forecasting using a regional model. Also, the Caribbean Institute for Meteorology and Hydrology (CIMH) provides training and studies in forecasting and modeling for the region. The modernization of agrometeorology has introduced new tools, which include data acquisition techniques (ground observation, aircraft and satellite), data transmission techniques (including the Internet) and data analysis (models and other software). There are many sources of data and techniques of analysis, including crop models and Geographic Information Systems (GIS). In addition, the transmission of crop and weather data from rural areas to national agromet services is now easier than in the past due to telecommunications and improved transport systems. Nevertheless, modern agromet systems are costly and require constant maintenance.

An agromet system for Guyana should build on the capacity that already exists in respect of historical data, automatic weather stations (AWS) and EWS. As hinterland agriculture is being advanced, stations will need to be installed in outlying areas (e.g. Ebini and Manari) and/or the use of existing ones maximized. Generally, capital costs will include preparation of sites, AWS and computers, mapping and modelling software, licensed fees and staff training in applied meteorology and the forecasting of outputs.

This technology will be implemented by the agromet unit of the Hydro-meteorological Service. Collaborative institutions include the GRDB Research Station, GuySuCo, NAREI, the Guyana School of Agriculture (GSA) and the University of Guyana (UG). Regional institutions include CARDI, the Caribbean Institute for Meteorology and Hydrology (CIMH) and the Caribbean Community Climate Change Center (CCCCC).

1.4.2 Ambition for the TAP

This technology will be of tremendous benefit to all stakeholders and the country, since it will provide advance information on weather conditions and projections. When early warnings are properly provided

to farmers and local communities, they are enabled to manage their farms and water resources in a manner whereby they can adapt to climate change and reduce their vulnerability.

The target for this technology is to provide agromet services, such as weather information and planting advisories. Improved weather and climate early-warning systems have become necessary to assist farmers in the context of climate change. This system will be integrated with the national EWS to provide early warning advisories to the farming community. The effective use of weather and climate information can help to make better informed policy, institutional and community decisions that reduce related risks and enhance opportunities, improve the efficient use of limited resources, and increase crop, livestock and fisheries production. The proposed scope of this technology is to introduce on a large and/or national scale. It will include the development of an agromet system and the communication infrastructure (phone/radio/TV/print) to deliver agromet services to farming communities across the country. The large-scale application of this technology will strengthen the quality of extension services and support research in the agriculture sector.

1.4.3 Actions and Activities for the TAP

The measures selected to become actions for agrometeorological systems are aimed at institutional strengthening to provide much-needed services to farmers and support the agriculture sector. Stakeholders have emphasised the weakness of this capacity in Guyana and the disadvantages presented in the areas of crop planning, protection and research.

Using the same methodology as that discussed in Section 1.2.3, measures were ranked and the top four (4) selected to become actions. The four measures identified to be turned into actions are:

1. Identify and secure support for ongoing training and research
2. Promote research with local academic institutions
3. Strengthen inter-agency collaboration (Hydromet Service, NAREI, GSA, UG, OCC, etc.)
4. Promote local and regional collaboration and data-sharing among government agencies, NGOs and the private sector, for example, CIMH, CARDI, NAREI, GRDB, GuySuCo, etc.

Table 3 below shows the actions and proposed activities with details of their implementation for the deployment of an agromet system in Guyana. The timeframe assigned to each activity was based on three periods: Short term: 1 – 3 years; Medium term: 3-5 years; and Long term: 5-10 years. The estimated budget included consideration of known costs for expertise and equipment. For activities where the costs are unknown, the best judgement was used based on examples from other countries. The budgets for some activities may be under- or over-estimates. However, this can be adjusted in the detailed proposal.

TABLE 3: ACTIONS AND ACTIVITIES FOR AGROMETEOROLOGICAL SYSTEMS FOR FORECASTING AND EARLY WARNING

Actions	Activities to be implemented	Sources of funding	Responsible Institution and focal point	Time frame	Risks	Success criteria	Indicators for monitoring of implementation	Estimated budget per activity
Action 1 - Identify and secure support for ongoing training and research	Activity 1.1 - Conduct Needs Analysis	GoG, Global Environment Fund (GEF), CDB, Bilateral	Hydromet	Short term	Available finance	Report on national status of Agromet technology	1. Draft needs analysis report 2. Approved final report	US$ 25,000
	Activity 1.2 - Prepare training programme	GoG, GEF, CDB, Bilateral	Hydromet	Short term	Available skill/expertise	Training programme initiated	Approved training programme	US$ 10,000
	Activity 1.3 - Secure personnel /institutions for training	GoG, GEF, CDB, Bilateral	Hydromet	Short to medium term	1. Cost 2. Available skills/expertise	Trained staff in agromet technology	3-5 persons trained	US$ 75,000
Action 2 - Promote research with local academic institutions	Activity 2.1 - Establish MOU with Hydromet & local academic institutions	GoG	Hydromet	Medium term	Conflicting interest	MOUs signed	Signed MOUs with UG, GSA, IAST & CARDI	US$500
	Activity 2.2 - Strengthen capacity of academic institutions	GCF, GoG, GEF, CDB, Bilateral	MOE/UG	Medium to long term	Available finance	Capacity developed	1. Equipment and skills available 2. Research proposals developed 3. Research conducted	US$250,000
	Activity 2.3 - Review curriculum to reflect current needs/trends	GoG, GEF, CDB, Bilateral	MOE/UG	Long term	1. Available Finance 2. Low priority	Updated curriculum	1. Review completed 2. Approved report 3. Curriculum updated	US$ 30,000
Action 3 - Strengthen inter-agency collaboration (Hydromet Service, NAREI, Guyana School of Agriculture (GSA), UG, OCC, etc.)	Activity 3.1 - Establish MOU with all institutions and Hydromet	GoG	Hydromet and all institutions	Medium term	Conflicting interest	Increased collaboration	Signed MOUs	US$500
	Activity 3.2 - Annual review conference for presentation of research findings	GoG, GEF, CDB, Bilateral	NAREI	Long term	Finance	Strengthened scientific basis for decision making	1. Research completed 2. Conference report	US$ 25,000
	Activity 3.3 - Harmonise research agenda	GoG	NAREI/UG	Medium to long term	Conflicting interest	Approved research agenda		US$1,000

	Activity 3.4 Promote incentives (Grants, Merit Awards) for research	GoG	NAREI/UG	Medium to long term	1. Available Finance 2. Low priority	Increased research and interest	1. Research grants and merit awards system established 2. 2- 3 Grants / Merit Awards issued	US$1M
Action 4 - Promote local and regional collaboration, and data-sharing among government agencies, NGOs and the private sector, for example, Caribbean Institute for Hydrology and Meteorology(CIMH), Caribbean Agriculture Research Development Institute (CARDI), MoA, NAREI, GWI, EPA, GRDB, GuySuCo, UNFAO and IICA	Activity 4.1 - Establish a national clearing house mechanism	GCF, GoG, GEF, CDB, Bilateral	University of Guyana	Medium to long term	1. Physical infrastructure 2. Available finance 3. Low priority	National Clearing House operational	1. Feasibility studies 2. Proposal approved for NCH 3. Funding rececived 4. NCH operational	US$ 1M
	Activity 4.2 - Coordinate data management committee	GoG	University of Guyana	Short to medium term	Available finance	Data Management Committee established	1. TOR for DMC 2. Membership approved 3. Meetings held	US$1,000
	Activity 4.3 Develop mandatory requirements for data sharing and management	GoG	University of Guyana	Medium to long term	Available finance	Approved guidelines	1. Meetings/consultations 2. Draft guidelines 3. Approved guidelines	US$ 5,000

1.5 Project Ideas for the Agriculture Sector

The project ideas for the agriculture sector are technology-specific. Selection of the actions was guided by the ranking method used in selecting the measures. In the identification of project ideas, one or more actions may constitute a project. In addition, an action may become an activity within a project, and it may not be possible to address all the actions as a project idea. For example, in Table 4, Action 5, aerial survey, is now recommended for inclusion as an activity to identify sites for rainwater harvesting. Initially, aerial survey was an action identified to address barriers and measures regarding the lack of data for possible sites. Also, the proposed project idea for the establishment of a national agromet system will include actions for institutional collaboration in training, research and data-sharing. Table 4 provides a summary of the prioritized technology, the proposed actions emanating from the TAP process and the proposed project idea, which can be developed into detailed proposals for funding and implementation.

TABLE 4: SUMMARY OF PROPOSED ACTIONS AND PROJECT IDEA FOR THE PRIORITIZED TECHNOLOGIES IN THE AGRICULTURE SECTOR

Technology	Proposed Actions	Proposed Project Idea
Freshwater Harvesting: Empoldering of Water Collection Areas	1. Conduct research to provide updated data and baseline on the status of water resources to identify suitable areas for impoundment more efficiently 2. Showcase successful technology application to stimulate interest and promote awareness 3. Promote awareness of the likely impacts of climate change, such as droughts and floods and the need for water management 4. Update existing regulations to reflect clear lines of authority among the various institutions. 5. Aerial survey to identify suitable sites	**Rainwater Harvesting for Sustainable Crop Production and Domestic Consumption**
Agrometeorological Systems for Forecasting and Early Warning	1. Identify and secure support for ongoing training and research 2. Promote research with local academic institutions 3. Establish a task force to strengthen inter-agency collaboration 4. Promote local and regional collaboration and data-sharing among government agencies. MoUs between key agencies, for example, NAREI – data on soil, crops, pests, farms; GuySuCo – weather, soil and crops; GRDB – rice cultivation, pests, farms etc.	**Institutional Strengthening: Establishment of a National Agrometeorological System (NAS)**

CHAPTER 2: TECHNOLOGY ACTION PLAN AND PROJECT IDEAS FOR THE WATER SECTOR

2.1 Short Description of the Water Sector

With its extensive network of rivers and streams that have many rapids and waterfalls, Guyana is considered to have an abundance of water. According to the Food and Agriculture Organisation (FAO), renewable internal freshwater resources per capita in Guyana were 315,695 m^3 as of 2014 (WB, 2017). It has the distinction of being the country with the second highest renewable freshwater resource per capita in the world (Iceland is first, with 519,264 m^3). This has contributed to the country's water security, despite challenges in accessing potable water.

Climatically, Guyana's weather regime ensures that rain falls throughout the year, with seasonal variations along the coast and in inland areas. Annual average rainfall is 1500 to 3000 mm, with the higher amounts experienced in the southern highlands and forested regions and the lower levels in the southeast and interior (GoG, 2012). There are two rainy seasons along the coast that extend from May to July and December to February, as well as two dry seasons from March to April and from September to November (GoG, 2012).

In the highly populated coastal area, residents depend completely on groundwater to meet their domestic needs, except for Georgetown, which uses about ten (10) percent of surface water from the EDWC (FAO, 2017). Fresh groundwater is the most reliable and important source of water for public use and is abundant along the coastal lowlands and the foothills immediately south, where most of the population resides. Large quantities are available from the coastal aquifer system. This system occupies a subsurface area of about 20,000 square kilometers, extending about 250 kilometers along the Atlantic coast and 40 to 150 kilometers inland (FAO, 2015).

Because of the abundant surface water resources, sparse population and lack of suitable aquifer-forming rock types, the interior locations have only a limited number of wells. The intermediate savannahs and hinterland use a mixture of surface and groundwater. Many businesses that use large quantities of water have their own wells to meet their needs. Surface water, which is extracted from shallow reservoirs, streams or canals, is primarily used for agricultural and industrial purposes. Nationwide, water supply facilities included about 178 groundwater wells and eight surface water sources in 2000 (FAO, 2017).

The demand for water is increasing for various uses, such as irrigated agriculture, the domestic sector, industry and commerce, thereby challenging the availability of this resource. Guyana also faces increasing risks associated with drought and changes in seasonal temperatures. According to climate projections using two downscaled climate scenarios, Guyana will experience increases in temperature, increased rainfall in the rainy season and less precipitation in months when there are already water deficits. Severe water deficits will lead to droughts, particularly in the south of the country, as experienced in 1997-1998 during the warm El Niño phase (GoG, 2012). Dryer conditions will have an impact on groundwater recharge and water quality. Already, saline intrusion is a problem in some aquifers.

Given the growing demand on surface water to satisfy agricultural and industrial needs, the monitoring and management of water resources is becoming an increasingly important issue. The situation is aggravated by the lack of scientific assessments, the outdated water resource management approach and inadequate institutional arrangements (Bynoe, P., 2011). To date, there is no policy for water resource management in Guyana. In 2013, with support from the Global Water Partnership – Caribbean, a National Integrated Water Resource Management Policy and Plan (IWRMPP) was prepared. However, this has not been approved by the government and as such it is not an official document. Stakeholders recommended that the policy and plan be updated and implemented, as this will help to clarify the various roles of the institutions and provide a road map for governance of the sector. The system for water management remains fragmented among several key agencies, namely the Ministry of Communities (MoC), the Hydromet Service, GWI, NDIA, MMA/ADA and the EPA. The current legislative framework for water resource management is shown in Table 5. Other secondary water management stakeholders include GuySuCo, GRDB and the Water Users Associations (WUA).

TABLE 5: MAIN LEGISLATION IN THE WATER SECTOR

Legislation	Responsible Institution	Mandate
Guyana Water and Sewerage Act (2002)	GWI, MoC, MoA, Hydromet Service.	The main legislation which governs the use and regulation of all of Guyana's water resources. Provides for the establishment of the National Water Council (NWC), National Water Policy, establishment of GWI, public supply of water, conservation of water resources, use of groundwater and management of waste water. It outlines the role of the Hydromet Service, which has oversight over the user of ground water and surface water. The department is the licensing agency for water extraction.
National Drainage and Irrigation Act (2004)	MoA - NDIA	Establishing the NDIA in 2006, the act deals with all public matters pertaining to water management, improvement, extension and provision of drainage, irrigation and flood control infrastructure and services in declared areas of the country. Its primary water resources management strategy is locating, evaluating, conserving and distributing water resources for agricultural purposes. Works closely with local groups such as the Water Users Association.
East Demerara Water Conservancy Act (1935)	MoA	This Act (revised in 1998) provides for the supply of water in East Demerara, the management of the conservancy and purposes connected to it.
Environment Protection Act (1996)	EPA	Oversees the effective management, conservation and protection of the country's natural resources and the environment. Mandates the Agency to take the necessary measures for the prevention and control of pollution and assessment of the impact of development on the environment and use of resources. Specific regulations under the Act which address water resources are: Water Quality and Hazardous Waste Regulations.
Mining Amendment Act (2005)	Guyana Geology and Mines Commission (GGMC)	Regulate safe environmental practices within the mining sector to prevent the contamination of rivers, creeks and waterways. The law encompasses mercury use, mine reclamation, mine effluents, mine waster, tailings management etc.
Amerindian Act (2006)	Ministry of Indigenous Affairs (MoIA)	Maintain and regulate water supplies in indigenous communities.

2.2 General Barriers and Proposed Measures

The common barriers to the water sector relate to policy and regulation, financial availability, institutional, technical and human capacity, and public education/awareness. The general barriers identified for the technologies: (i) groundwater mapping and modeling; (ii) surface water mapping and modeling; and (iii) GIS mapping and modeling of water catchment areas, are discussed below.

Groundwater Mapping and Modeling. The main critical barriers for this technology were (i) lack of baseline or scientific data for decision-making; and (ii) low levels of awareness and interest in the long-term benefits of groundwater security. Other barriers included high capital and maintenance costs, lack of or limited national budget to develop capacity, and limited access to funding sources. The non-financial barriers related mainly to technical and institutional capacity. Specifically, the lack of political buy-in, unclear policy, ad-hoc planning, weak institutional capacity, such as a lack of or limited technical skills and a lack of updated data on the status of water resource were identified as barriers that can have a significant impact on the adoption of this technology. Overall, despite having a limited budget, the Hydromet Service, which has the mandate for groundwater resources, has the potential to generate significant revenues through its licensing system and fees for the provision of data. However, these sources of revenue have not been fully harnessed. The enabling and other measures proposed to overcome the critical barriers for groundwater mapping are aimed at prioritizing groundwater management in national planning and strengthening institutional and technical capacities. These include:

- Prioritize groundwater management nationally and implement it as part of long-term planning;
- Promote policy and allocate adequate national budget for groundwater research and assessments;
- Designate institution with clear role and responsibility;
- Strengthen the institutional capacity and skills needed to provide data and share information;
- Provide opportunities for technical training and capacity-building;
- Provide attractive compensation package to retain technical skills;
- Strengthen communication systems with water-users and decision-makers; and
- Promote education and raise awareness among all stakeholders, including decision-makers and manufacturers.

Surface Water Mapping and Modeling. The critical barriers for this technology were mainly non-financial: (i) limited understanding of the immediate and long-term benefits among water users; and (ii) the overlapping roles of multiple institutions. The lack of or limited institutional and technical capacity are similar to that in groundwater mapping and modeling, e.g. their low national priority, may be perceived as resource-intensive, lack of or limited technical skills and incentive to develop relevant skills, and the need for ongoing training. Financial barriers identified included high initial capital and maintenance costs, limited budget allocations and source of funding, and inadequate compensation for technical skills. The proposed measures identified to overcome the barriers to this technology focused on strengthening the policy framework and institutional arrangements for surface-water mapping and modeling. These included the need to:

- Provide an overarching and clearly defined policy and objectives for Surface Water Management (SWM);
- Develop a holistic surface-water management plan to address multiple benefits, uses and scope, including domestic, ecosystem services, transport, recreation and agriculture;
- Activate or resuscitate the National Water Council;
- Promote awareness among policy-makers and users on the importance of scientific data for SWM;
- Allocate adequate national budget for SWM;
- Provide opportunities for technical training and capacity-building;
- Provide attractive compensation package to retain technical skills; and
- Promote collaboration and research.

GIS Mapping for Water Catchment Protection. GIS technology is fairly well developed in Guyana. Several key institutions, such as UG, EPA, the Guyana Forestry Commission (GFC), GL&SC and the Ministry of Natural Resources and Environment (MNRE), have GIS capability. However, there is a need to increase awareness among policy-makers and users of the numerous applications of GIS, especially in freshwater management and water catchment protection. A low level of awareness was identified as a critical barrier to the more rapid diffusion of GIS technology in water resource management and decision-making. Other critical barriers included the high capital cost and limited financing. In addition, there is no national policy or plan for GIS applications. GIS mapping of water resources will require multiple agency coordination, due to the shared management of water in Guyana and the data available. This can affect the commitment to and interest in undertaking responsibility. Other barriers identified include limited or unreliable baseline data, the limited availability of technical skills, the perceived complexity of the technology and the time-consuming nature of these activities. The following key measures were proposed to overcome the barriers identified:

- Promote a holistic approach to water management and define the institutional mandate;
- Promote awareness among decision-makers and users of water as a high-value resource, including the importance of water catchment and watershed management;
- Establish coordinating and technical bodies to promote a national policy for water catchment protection;
- Strengthen collaboration and data-sharing systems among institutions;
- Provide adequate funding and support for research to guide decision-making and build capacity; and
- Strengthen data-sharing systems, particularly for digital spatial data.

2.3 Action Plan for Technology: Groundwater Mapping and Modeling

2.3.1 Introduction

Hydrologic data for Guyana are lacking, particularly since the late 1960s, after which data collection decreased dramatically. The Hydromet Service is tasked with the legislative mandate for managing Guyana's groundwater resources. However, over decades, there has been a decline in its capacity to conduct scientific assessments and collect data on the country's groundwater resources. The most recent water resource assessment was completed in 2009 by the United Stated Army Corps of Engineers (WRA, 2009). This assessment highlighted the need to improve understanding of how Guyana's ground-water hydrogeology works and the risks posed by increased extraction, land-use change, hydropower generation and climate change through the monitoring and determination of the long-term viability of groundwater resources (WRA, 2009). Overall, there is a need to generate and update data on well inventories and characteristics, such as pumping rates and piezometric heads.

A model is the primary quantitative tool available in a groundwater investigation. The mapping and modeling of water resources is highly technical and resource-intensive. Groundwater models include physical (laboratory) models and mathematical models, including process-based numerical models (USGS,2016). The models used will depend on the degree of sophistication required. Hydrological and geochemical simulation models are widely used to predict the responses of hydrological systems to changing stresses, such as increases in precipitation, land use change or ground-water pumping rates, as well as to predict the fate and movement of solutes and contaminants in water (USGS, 2016). However, to drive a hydrological model, reliable information on climatological variables and their distribution in space and time are required, as well as the technical skills to run and interpret the models. The successful implementation of this technology will require specialized training to build the necessary skills in the use of hydrological models.

2.3.2 Ambition for the TAP

Groundwater mapping and modeling form part of a wider national thrust towards integrated water-resource management. With changing patterns in development and climate, it is imperative that previous assessments of the country's groundwater resources be updated. This technology will be applied nationally scale and will aim to improve understanding of the country's groundwater systems (charging and recharging of aquifers, changing water stress, movement of contaminants etc.). It will focus on institutional strengthening of the groundwater subdivision of the Hydromet Service and build awareness of groundwater resource management. Currently, the coastal population is highly dependent on groundwater sources. As this zone is where approximately 90 percent of the population lives, this technology will have a direct impact on the lives of more than 600,000 people.

2.3.3 Actions and Activities for the TAP

The measures selected to become actions for groundwater mapping and modeling followed intense discussions among stakeholders. Generally, there is a consensus that groundwater management needs to be given more prominence at the political level and be allocated sufficient financial resources to develop institutional, technical and human capacity. It was recognized that, to develop groundwater mapping and modeling capacity, actions need to address issues of national recognition and the framework for water governance. As a result, the following measures were selected to become actions for this technology:

1. Recognize groundwater management as a high national priority
2. Implement Integrated Water Resource Management (IWRM) as part of long-term national planning
3. Allocate an adequate national budget for groundwater management, including attractive salary and compensation packages for technical skills and research
4. Identify and secure other sources of financial support, for example, external funding agencies (IDB, WB etc.).
5. Provide an adequate budget to relevant national institutions for scientific assessments.

Table 8 below summarizes the main activities and details for implementation of the actions, including potential source of funding, responsible authority, the estimated timeframe for each activity, possible risks which may cause delays or stop the activity, the criteria for the success of the activity, indicators for monitoring and estimated budget. The timeframe was based on three durations: Short term: 1-3 years; Medium term: 3-5 years; and Long term: 5-10 years.

TABLE 6: ACTION AND ACTIVITIES FOR GROUNDWATER MAPPING AND MODELING

Actions	Activities to be implemented	Sources of funding	Responsible institution and focal point	Timeframe	Risks	Success criteria	Indicators for monitoring of implementation	Budget per activity
Action 1 - Integrate IWRM in long-term national planning	Activity 1.1: Promote resuscitation of National Water Council (NWC)	GoG	Ministry of Housing & Water /GWI/MoA	Short term	1. Low national priority 2. Limited institutional resources	Functional National Water Council	1. Confirmation of members 2. Minutes of meetings	US$2,000
	Activity 1.2: Review and finalize Integrated Water Resource Management (IWRM) policy/plan	GoG, IDB, CIMH, Bilateral	Ministry of Housing and Water /GWI/MoA	Short term	1. Low national priority 2. Availability of finance	IWRM Policy/Plan Approved	Draft & final IWRM Policy/Plan	US$20,000
	Activity 1.3: Promote IWRM management through working groups and consultations	GoG, IDB, CIMH, Bilateral	Ministry of Housing and Water /GWI/MoA	Short term	1. Low national priority 2. Availability of finance 3. Poor participation	Integration of IWRM in planning	1. Amount of consultations completed 2. Working group meetings	US$ 10,000
Action 2 - Promote groundwater management as a high national priority	Activity 2.1 Dissemination of technical briefs/status on groundwater resources	GoG	MoA - Hydromet Service	Short term	1. Limited technical skills 2. Low national interest	Increased awareness among decision makers	1. Number of briefs prepared 2. Distribution list	US$1,000
	Activity 2.2: Strengthen synergy with Water Users Associations and other groups	GoG	MoA - Hydromet Service	Short term	1. Lack of coordination among groups 2. Limited capacity	Improved stakeholder participation	1. List of WUA and other groups 2. Meetings held 3. Activities collaborated on	US$2,000
	Activity 2.3 Establish Technical Group for Groundwater Resources	GoG	MoA - Hydromet Service	Short term	Limited capacity	Strengthened focus on GW	1. Proposal for TG 2. Membership confirmed 3. Record of meetings	US$2500
	Activity 2.4 Modernize groundwater decision-making process	GoG, IDB, CIMH, Bilateral	MoA - Hydromet Service	Medium / Long term	1. Availability of finance 2. Limited capacity	Improved service and management	1. Licensing data stored and processed electronically 2. Integrated with technical data on GW resources 3. Mapping and modeling services provided	US$ 150,000

Actions	Activities to be implemented	Sources of funding	Responsible institution and focal point	Timeframe	Risks	Success criteria	Indicators for monitoring of implementation	Budget per activity
Action 3 - Increase national budget for groundwater management, including attractive salary and compensation package for technical skills and research	Activity 3.1: Establish a competitive salary scale using a regional benchmark	GoG	MoA - Hydromet Service/ Public Service Commission	Medium / Long term	1. Availability of finance 2. Low priority	Revised salary scale	1. Review of current scale 2. Approved new scale	US$24,000
	Activity 3.2: Revise HR policy to include non-salary benefits, such as, training and allowances	GoG	MoA - Hydromet Service/Public Service Commission	Medium /long term	1. Availability of finance 2. Low priority	Revised HR Policy	1. Revised HR policy 2. Increased training opportunities and benefits	US$3,000
	Activity 3.3 Identify skills needed and research priorities	GoG	MoA - Hydromet Service	Short/ medium term	1. Low priority	Capacity needs and research identified	1. List of skills 2. Research concept notes	US$2,000
Action 4 - Identify and secure other sources of financial support, for example, external funding agencies (IDB, WB etc.).	Activity 4.1: Research funding opportunities e.g. CIMH, WMO, IGRAC, UNESCO, GWP, CCCCC, UNFCCC	GoG	MoA - Hydromet Service	Short/ medium term	Limited capacity	Funding identified	List of funding sources	US$2,000
	Activity 4.2: Prepare proposals based on funding opportunities available	GoG	MoA - Hydromet Service	Short/medium term	Limited capacity	Funding approved	1. Draft & final proposals 2. Approved proposal	US$1,500
Action 5 - Provide adequate budget to relevant national institutions for scientific assessments	Activity 5.1: Identify the specific activities required	GoG	MoA - Hydromet Service	Medium/long term	1. Availability of finance 2. Limited capacity	Detailed activities	Approved activities	US$1,000
	Activity 5.2: Develop programme of implementation with costing for the identified activity	GoG	MoA - Hydromet Service	Medium/long term	1. Availability of finance 2. Limited capacity	Implementation plan	Approved Implementation Plan and proposed budget	US$2,000
	Activity 5.3: Incorporate financial requirements into annual budgets	GoG	MoA - Hydromet Service	Medium/long term	1. Availability of finance 2. Limited capacity	Included in national budget	Annual budget to institutions for scientific assessments	US$2,000

2.4 Action Plan for Technology: Surface Water Mapping and Modeling

2.4.1 Introduction

Guyana has an extensive network of rivers and streams that have many rapids and waterfalls. Surface water, which is extracted from shallow reservoirs, streams or drainage canals, is primarily used for agricultural and industrial purposes. Numerous rivers flow into the Atlantic Ocean, generally in a northward direction. There are fourteen major river basins: the Waini, Pomeroon, Essequibo, Potaro (tributary of the Essequibo), Mazaruni, Cuyuni, Supenaam, Demerara, Berbice, Canje (tributary of the Berbice), Boerasirie, Mahaica, Mahaicony and Abary. The Essequibo, the country's largest river, runs from the Brazilian border in the south and the Venezuelan border to the west into a wide delta west of Georgetown.

Hydrological data collection has decreased significantly over recent decades in Guyana. Measuring equipment, such as, stream gauges need to be repaired or replaced, and efforts are being made to install modern telemetric gauges throughout the country (WRA, 2009). Hydrographic surveys are carried out by the Geodetic Section of the GL&SC to determine the topography and bathometry of conservancy beds, river beds and ocean beds. This service has been halted due to the need to improve the current hydrographic stock of equipment.

The Hydromet Service is the regulatory authority for the management of surface water in Guyana. The surface water section of this institution is tasked with the collection, processing and analyzing of surface water data (water level, discharge, water quality and sediment transport); the expansion and maintenance of the surface water station network, the publication of an annual hydrological bulletin, the updating and maintenance of the hydrological database and research on hydrological phenomena (MoA, 2015). In terms of capacity, there are currently sixty-one (61) surface water-level monitoring stations, of which sixteen (16) monitor water levels continuously with water-level recorders, 10 are operated manually and 30 use frog loggers (automatic stations) to transmit water-level data from the EDWC (MoA, 2015).

Mapping of water is a prerequisite for establishing water availability, accessibility, fair use and management. Effective data regarding surface-water availability demands the application of geospatial techniques such as remote sensing, image-processing techniques and GIS. It involves a range of data sets, sophisticated equipment and skills, such as digital terrain model, soil characteristics, stream flow, field staff and water engineers, software etc. Despite the lack of adequately qualified personnel, the Hydromet Service continues to collect surface water data from a few areas. However, these data are not being used to make scientific assessments to guide national water management. At the basic level, mapping and modeling requires skilled personnel, computers and field equipment, and software programs to run the models. Digitizing and mapping services exist locally and can be procured. Operation and maintenance of this technology may include ongoing training, data collection, the repair and maintenance of equipment, software subscriptions and procuring technical services. The initial investment and maintenance costs will be high given the needs for equipment, software licenses, the updating of data, and obtaining expert and consultancy services for training purposes.

2.4.2 Ambition for the TAP

Surface water mapping and modeling will be applied nationally to strengthen policy and the institutional capacity for collaboration and research to provide an updated status for Guyana's surface water. Successful implementation of this technology will strengthen the Hydromet Service's capacity and support the completion of a national integrated water-resource management policy and plan. Due to the increased vulnerability risks posed by climate change, increased economic activities and changing demographics, it is important to assess and reduce water-related risks and vulnerabilities in sectors such as agriculture, energy, health, environment and urban water utilities as part of overall development planning.

2.4.3 Action and Activities for the TAP

The measures selected to become actions for surface water mapping and modeling target the need for financial resources, policy direction, technical skills and awareness of the importance of surface water management. There is a consensus that strong political support and adequate financial resources are necessary to develop the institutional, technical and human capacity for successful surface water management. Based on the BA, the following measures were selected to become actions for this technology:

1. Allocate an adequate budget for surface water management
2. Provide an attractive compensation package (including salary) to retain technical skills.
3. Activate and resuscitate the National Water Council (NWC) and provide it with strong political support
4. Identify opportunities and provide support for technical training and capacity-building
5. Promote or create education and raise awareness to foster and enhance knowledge and understanding of all stakeholders, especially the private sector

Table 7 below summarizes the actions, main activities and details for implementation. As shown, most of the actions or activities will be led by the Hydromet Service and implemented in the short to medium terms. The general risks to implementation include the availability of finance, shifting national priorities and limited institutional skills.

TABLE 7: ACTIONS AND ACTIVITIES FOR SURFACE WATER MAPPING AND MODELING

Actions	Activities to be implemented	Sources of funding	Responsible institution and focal point	Timeframe	Risks	Success criteria	Indicators for monitoring of implementation	Budget per activity
Action 1 - Allocate adequate national budget for surface water management	Activity 1.1: Conduct capacity needs assessment	GoG, GEF, WB, Bilateral, WWF, CIMH, CCCCC	MoA- Hydromet Service	Short term	1. Availability of finance 2. Overriding priorities	Report on capacity needs completed	1. Stakeholder consultation 2. Report approved	US$25,000
	Activity 1.2: Develop a proposal to secure funding based on needs assessment	GoG, GEF, WB, Bilateral, WWF, CIMH, CCCCC	MoA- Hydromet Service	Medium/long term	1. Overriding priorities 2. Limited institutional skills	Funding approved	1. Proposal approved and submitted to funding agencies 2. Funding received	US$5,000
	Activity 1.3: Integrate proposals into work plans and budget	GoG	MoA- Hydromet Service	Medium/long term	Considered of low importance by institution	Proposal activity included in work plan	Work plan updated	US$1,000
Action 2 - Provide attractive compensation package (including salary) to retain technical skills.	Activity 2.1: Establish a competitive salary scale using a regional benchmark	GoG	MoA - Hydromet Service/ Public Service Commission	Medium/ long term	1. Availability of finance 2. Low priority	Revised salary scale	1. Review of current scale 2. Approved new scale	US$1,000
	Activity 2.2: Revise HR policy to include non-salary benefits, such as training and allowances	GoG	MoA - Hydromet Service/Public Service Commission	Medium / long term	1. Availability of finance 2. Low priority	Revised HR Policy	1. Revised HR policy 2. Increased training opportunities and benefits	US$2,000
Action 3 - Promote resuscitation of National Water Council	Activity 3.1: Prepare Action Plan to resuscitate NWC	GoG	Ministry of Housing and Water/MoA	Short term	1. Low national interest 2. Limited capacity	Action Plan	1. Consultations 2. Proposed Action Plan	US$2000
	Activity 3.2 Promote IWRM/Research Seminars	GoG,CIMH, IDB, WWF, GEF, CCCCC	GoG,CIMH, IDB, WWF, GEF, CCCCC	Short term	1. Availability of finance 2. Overriding national priorities	Recognition of the importance of NWC	Number of seminars completed	US$ 30,000
Action 4 - Identify opportunities and provide support for technical training and capacity-building	Activity 4.1: Conduct capacity needs assessment	GoG, GEF, WB, Bilateral, WWF, CIMH, CCCCC	MoA- Hydromet Service	Short /Medium term	1. Availability of finance 2. Overriding priorities	Report on capacity needs completed	1. Stakeholder consultation 2. Report approved	US$15,000
	Activity 4.2: Develop a proposal to secure funding based on needs assessment	GoG, GEF, WB, Bilateral, WWF, CIMH, CCCCC	MoA- Hydromet Service	Short/medium term	1. Overriding priorities 2. Limited institutional skills	Funding approved	1. Proposal approved and submitted to funding agencies 2. Funding received	US$5,000

	Activity 4.3: Integrate training and capacity-building into work plans	GoG	MoA- Hydromet Service	Medium to long term	low importance by institution	Proposal activity included in work plan	Work plan updated	US$1,000
Action 5 - Promote or create education/raise awareness to foster and enhance knowledge/ understanding of all stakeholders, especially private sector	Activity 5.1: Rapid assessment of the level of awareness and knowledge	GoG, GEF, WB, Bilateral	MoA/UG/EPA	Short to medium term	1. Low priority 2. Availability of finance	Report on the status of awareness of GIS technology	Draft and final reports	US$15,000
	Activity 5.2: Identify gaps	GoG, GEF, WB, Bilateral	MoA/UG/EPA	Short to medium term	1. Low priority 2. Availability of finance	Gaps in GIS Technology application identified & documented	Draft and final reports	US$5,000
	Activity 5.3: Design a comprehensive and sustainable public awareness and education programme	GoG, GEF, WB, Bilateral	MoA/UG/EPA	Short to medium term	1. Low priority 2. Availability of finance	Public Awareness Programme rolled out	1. Draft and final PA&E programme 2. PA&E Programme activities rolled out	US$5,000

2.5 Action Plan for Technology: GIS Mapping and Modeling of Water Catchment Areas

2.5.1 Introduction

Water catchment and watershed protection are recognized as important for the sustainable management and utilization of land and water resources. The Guyana Lands and Surveys Commission (GL&SC) is mandated to develop and implement a national Land Use Plan (LUP). The mapping of water catchments will aid in the implementation of the LUP by adopting an integrated approach to water and land uses within the catchment areas. GIS uses spatial and temporal data in an integrative planning tool for watershed management. It is a system designed to capture, store, manipulate, analyze, manage and present geographically referenced data, and can be used for scientific investigations, resource management and planning. For example, in water catchment monitoring, this technology may be used to find wetlands which need protection from pollution or other activities which may result in harmful impacts.

GIS improves the calculations for watershed characteristics, flow statistics, debris flow probability etc. Technologies like remote sensing and GIS help by providing a quicker and more cost-effective analysis for various applications with accuracy for planning, including predicting the impacts of land-use change on freshwater quality and quantity. It also provides a better perspective for understanding the problems and thus helps to find better solutions in national planning. When used in hydrological models, remote-sensed data can be converted to the type of information useful to water resource systems operators. With such information on water catchment, areas can be demarcated, micro-catchment areas identified, buffer zones established and water safety plans developed (FAO, 2011). This technology includes engineering hardware and software components, such as computers (desktop and field notebooks), servers, data collection, GIS tools, numerical models, training and capacity-building.

2.5.2 Ambition for the TAP

This technology will be of national scope and will be applied on a large scale. The aim is to provide data to inform policy and strengthen institutional planning in an integrated manner. As Guyana takes measures to improve water management, this technology will also be part of a broader sustainable water supply plan. The primary beneficiaries will be the decision-makers, such as water resource managers, natural resource managers, land use planners and researchers. Other users include households, farmers, fisheries, miners and manufacturers.

2.5.3 Actions and Activities

The measures selected to become actions for the GIS mapping of water catchment areas focus on the need to provide adequate financing for research, promote awareness and strengthen frameworks for IWRM, including mechanisms for data-sharing. These actions and activities are reflective of the GIS capacity, which already exists, although there is a need to enhance its visibility and application. The following four actions were selected for possible implementation of this technology:

1. Provide adequate funding for GIS-based research and to create and strengthen information systems to guide decision-making.
2. Promote education and raise awareness of the usefulness of GIS as a tool for stakeholders of water resources.
3. Develop and establish a framework for data-sharing.
4. Support the IWRM approach to water management to define the institutional mandate

Table 8 below summarizes the main activities and details for implementation. All activities will be implemented over the short to medium term and will be led by the GL&SC. The potential risks include the availability of finance, overlapping or unclear institutional roles, limited skills, low priority due to competing priorities, and low interest where the activity may not be considered important.

TABLE 8: ACTIONS AND ACTIVITIES FOR GIS MAPPING OF WATER CATCHMENT AREAS

Actions	Activities to be implemented	Sources of funding	Responsible institution and focal point	Timeframe	Risks	Success criteria	Indicators for monitoring of implementation	Budget per activity
Action 1 - Provide adequate funding for GIS-based research and to create/strengthen information systems to guide decision-making	Activity 1.1: Conduct capacity needs assessment	GoG, GEF, WB, Bilateral	Guyana Lands & Surveys Commission	Short to medium term	1. Availability of finance 2. Competing priorities	Report on capacity needs completed	1. Stakeholder consultation 2. Report approved	US$15,000
	Activity 1.2: Develop proposal & secure funding based on needs assessment	GoG, GEF, WB, Bilateral	Guyana Lands & Surveys Commission	Short to medium term	1. Competing priorities 2. Limited institutional skills	Funding approved	1. Proposal approved & submitted to funding agencies 2. Funding received	US$5,000
	Activity 1.3: Integrate proposals into work plans	GoG	Guyana Lands & Surveys Commission	Medium to long term	Low importance by institution	Proposal activity included in work plan	Work plan updated	US$1,000
Action 2 - Create/ promote awareness of the usefulness of GIS as a tool for stakeholders of water resources, including decision-makers	Activity 2.1: Rapid assessment of the level of awareness and knowledge of the use of GIS as a tool.	GoG, GEF, WB, Bilateral	Guyana Lands & Surveys Commission / UG	Short to medium term	1. Low interest 2. Availability of finance	Report on the status of awareness of GIS technology	Draft and final reports	US$15,000
	Activity 2.2: Conduct a gap analysis	GoG, GEF, WB, Bilateral	Guyana Lands & Surveys Commission / UG	Short to medium term	1. Low interest 2. Availability of finance	Gaps in GIS Technology application identified & documented	Draft and final reports	US$5,000
	Activity 2.3: Design a comprehensive and sustainable public awareness and education programme	GoG, GEF, WB, Bilateral	Guyana Lands & Surveys Commission / UG	Short to medium term	1. Low interest /priority 2. Availability of finance	Public Awareness Programme rolled out	1. Draft and final PA&E programme 2. PA&E Programme activities rolled out	US$5,000
Action 3 - Develop and establish a framework for data-sharing among institutions	Activity 3.1: Conduct a stakeholder engagement meeting	GoG, GEF, WB, Bilateral	Guyana Lands & Surveys Commission	Medium to long term	Low interest/priority	Stakeholder input included in framework	1.Key Stakeholders consulted 2. Meeting reports	US$10,000
	Activity 3.2: Develop an action plan or MoU for data-sharing	GoG	Guyana Lands & Surveys Commission	Medium to long term	1.Overalpping/unclear roles 2. Low priority	MoU signed with Agencies/Action Plan completed	Signed MoUs / Draft & final Action Plan	US$1,000
	Activity 3.3: Establish a Data/Information Management Committee	GoG	Guyana Lands & Surveys Commission	Medium to long term	1. Limited human capacity 2. Low interest	Inter-Agency Committee convened	1. List of Members 2. ToR of Committee	US$2000
	Activity 3.4: Develop monitoring protocols	GoG	Guyana Lands & Surveys Commission	Medium to long term	1. Limited human capacity 2. Low interest	Monitoring protocols established	Draft & final guidelines	US$2,000

Actions	Activities to be implemented	Sources of funding	Responsible institution and focal point	Timeframe	Risks	Success criteria	Indicators for Monitoring of implementation	Budget per activity
Action 4 - Support Integrated Water Resource Management (IWRM) approach to define institutional mandate through consultations and research	Activity 4.1: Consultations with primary and secondary water management agencies	GoG	Ministry of Communities/Guyana Lands & Surveys Commission	Short to medium term	1. Low participation 2. Unclear roles	Institutional mandate clarified	1. List of stakeholders 2. Consultation reports 3. Recommendations implemented	US$10,000
	Activity 4.2 Collaborate on research to support water catchment protection (MoA, GWI, EPA, GL&SC, EPA, MNR, UG)	GoG, GEF, WB, Bilateral	Guyana Lands & Surveys Commission/University of Guyana	Short to medium term	1. Availability of finance 2. Limited human capacity	Scientific data available to support decision-making	1. Research proposals 2. Funding for research received 3. Research completed	US$5,000
	Activity 4.3 Incorporate IWRM approach into institutional work programme	GoG	Ministry of Communiities/Guyana Lands & Surveys Commission	Short to medium term	1. Unclear roles 2. May need additional resources	Holistic approach to water management strengthened	Updated work plan	US$1,000

2.6 Project Ideas for the Water Sector

Two project ideas are proposed for the water sector. The first idea is to incorporate the technologies for ground and surface water mapping and modeling into a single project. This was recommended based on the similarity of the intended impact, barriers and proposed actions. The second idea relates to the actions to establish a national policy for water management and the use of technology in its implementation. The following project ideas have been developed into PIN for the water sector, which may inform detailed proposals for funding:

1. Integrated Water Resource Management: mapping and modeling of ground and surface water
2. Integrated Water Resource Management: capacity-building in GIS and finalization of IWRM Policy and Action Plan

TABLE 9: SUMMARY OF PROPOSED ACTIONS AND PROJECT IDEAS FOR THE PRIORITIZED TECHNOLOGIES IN THE WATER SECTOR

Technology	Proposed Actions	Proposed Project Ideas
Mapping and Modeling of Groundwater	1. Recognise groundwater management as a high national priority 2. Implement IWRM in long-term national planning 3. Allocate adequate national budget for groundwater management, including attractive salary and compensation packages for technical skills and research 4. Identify and secure other sources of financial support, for example, international funding agencies 5. Provide adequate budget to relevant national institutions for scientific assessments	
Mapping and Modeling of Surface Water	1. Allocate adequate national budget for surface water management 2. Provide attractive compensation packages (including salary) to retain technical skills. 3. Activate and resuscitate the National Water Council (NWC) and provide it with strong political support 4. Identify opportunities and provide support for technical training and capacity-building 5. Promote or create education and raise awareness to foster and enhance knowledge and understanding of all stakeholders, especially the private sector	**Integrated Water Resource Management: ground and surface water mapping and modeling**
GIS Mapping for Water Catchment Protection	1. Provide adequate funding for GIS based research and creating and strengthening information systems to guide decision making. 2. Create and promote awareness and education on the usefulness of GIS as a tool for stakeholders of water resources, especially decision-makers 3. Develop and establish a framework for data sharing 4. Support the IWRM approach to water management to define institutional mandate through consultations and research	**Integrated Water Resource Management: capacity-building in GIS and development of Integrated Water Resource Management Policy and Action Plan**

CHAPTER 3: TECHNOLOGY ACTION PLAN AND PROJECT IDEAS FOR COASTAL ZONE AND LOW-LYING COMMUNITIES

3.1 Short Description of the Coastal Zone and Low-lying Communities Sector

About ninety (90) percent of Guyana's population of approximately 746,955 reside on the coastal plain (Bureau of Statistics, 2012), which is particularly vulnerable at high tides. Much of it lies at elevations of between 0.5 meters and 0.7 meters below mean sea level, but is threatened by tides which rise to 1.6 meters above mean sea level. Hence the need to maintain sea defense systems, both man-made (sea wall) and natural (mangrove forests), for the continued occupation of the coastal areas. The country's towns, major settlements and most commercial, industrial and other economic activity occur within the coastal zone. Several major rivers also run through the coastal zone, including the three main rivers, Demerara, Berbice and Essequibo. It is estimated that 49% of the sources of the country's gross domestic product (GDP) are in areas at risk of significant flooding (CDB, 2013).

High tides accompanied by high winds can cause storm surges that overtop the walls and cause flooding. In assessing the vulnerability of the coastal areas, it is necessary to incorporate sea level rises and coastal topography into the design of sea defenses. Inland areas and low-lying communities are also at high risk from floods. Frequently occurring excessive rainfall and flash floods have resulted in severe losses in many regions. The main causes of flooding in Guyana are heavy rainfall, rivers overtopping their banks, and breaches in sea defenses. Flooding is also often exacerbated by the blockage of drains with garbage.

The successful implementation of policies and plans will require significant resources to transcend the country's continued challenges in respect of its financing and technical capacities, institutional arrangements and appreciation or awareness of climate-related risks and solutions. At the political level, the GoG has committed itself to introducing adaptation measures, which include upgrading infrastructure and assets to protect against flooding and the establishment of early warning systems. These actions have been recommended in previous assessments, policies and action plans and strategies for the sector.

TABLE 10: MAIN LEGISLATION/PLAN/STRATEGY FOR COASTAL ZONE MANAGEMENT

National Policy/Legislation/Plan/Strategy	Authority	Mandate
Initial/Second National Communication to the UNFCCC (1998/2012)	Office of Climate Change	Guyana's national report as a party to the UNFCCC. Establish baseline information on GHG emissions and mitigation assessment vulnerability and adaptation, education/awareness/capacity-building on climate change, research and systematic observations.
Integrated Coastal Zone Management Plan, 2001	Environment Protection Agency	Provide guidance to stakeholders involved in ICZM towards a more coordinated approach to coastal zone management. Key objectives include institutional strengthening of key agencies, compilation of data, research and training, and public awareness.
National Development Strategy, 1998/2002	Ministry of the Presidency	Provides an overarching framework for Guyana's long-term (25 years) development. Includes provisions for coastal zone protection and improvements to sea defence infrastructure.
Low Carbon Development Strategy, 2010	Ministry of the Presidency	Sets out the country's strategy to forge a new low-carbon economy as part of future planning. It identifies the national developmental for the period 2012-2015, which includes strengthening coastal protection infrastructure.
National Land Use Plan, 2013	Guyana Lands and Surveys Commission	A strategic framework to guide land development. Incorporates the need to develop land away from the coastal zone.
National Disaster Risk Management Plan and Implementation Strategy, 2013.	Civil Defence Commission	Details the key activities that will contribute to the National Integrated Disaster Risk Management Plan. These activities directly address all of the gaps, challenges and priorities that Guyana faces in disaster risk management.
Multi-Hazard Disaster Preparedness and Response Plan, 2013	Civil Defence Commission	Detailed arrangements for coping with the effects of natural and/or man-made disasters occurring in Guyana. Seeks to assign responsibilities and provide coordination of emergency activities connected with major disasters, in general and specific ways. Classifies different types of hazards, levels of vulnerability and its causes, as well as the structure, functions and coordination methodology of the National Disaster Management Structure (CDC, RDCs, City Council, NDCs etc.).
Disaster Risk Management Plan for the Agriculture Sector, 2013 – 2018.	Ministry of Agriculture	A multi-hazard holistic framework for the effective mainstreaming of disaster risk reduction (DRR) into the agriculture sub-sector. The Plan elaborates a comprehensive approach to building resilience in the agriculture sector, while simultaneously improving risk assessment, preparedness and responses within a well-coordinated institutional framework.
National Early Warning System Framework, 2013	Civil Defence Commission	Details the many aspects, elements, challenges and key strategies of early warning for Guyana. Outlines various approaches to EWS, national capacities and future perspectives. Makes key recommendations for more robust early warning in Guyana.

Sea and River Defence Sector Policy, 2015	Ministry of Public Infrastructure	Provides for an integrated approach to delivering sustainable sea and river defense policies within Guyana's coastal zone. Include aspects for efficient and effective planning, management and monitoring regarding the utilization, development and protection of the coastal zone and its resources, including flood protection, erosion control and disaster risk management.
Climate Resilience Strategy & Action Plan, 2015.	Office of Climate Change	Provides a framework for adaptation and resilience-building in Guyana.
Sea Defence Act (64:01/62:02)	Ministry of Public Infrastructure	To secure the maintenance of the sea, river and outer dams of estates and to improve provision for the maintenance and construction of sea defenses.
Nationally Determined Contributions, 2016	Ministry of the Presidency	Guyana is committed to undertaking efforts to strengthen adaptation, including the rehabilitation and upgrading of sea defenses and development/implementation of EWS.

3.2 General Barriers and Proposed Measures

This section provides a summary of the prioritized barriers and measures for the prioritized technologies in the coastal zone and low-lying communities sector. The prioritized technologies are: (i) the mapping and modeling of coastal processes, (ii) early warning systems and (iii) energy-efficient mobile pumps.

Mapping and Modeling of Coastal Processes. The critical barriers prioritized for this technology were (i) insufficient or limited allocation in the national budget and (ii) limited or weak institutional capacity. Other key financial barriers included high capital and maintenance costs, limited access to financing and poor compensation for specialized skills. Non-financial barriers included challenges in policy and planning, institutional capacity, technical capacity, and education and awareness-raising.

There is no comprehensive policy for coastal zone management in Guyana. Overlapping legislation has led to different aspects of coastal zone management being shared among institutions such as the MoPI, EPA, GFC, NAREI and GL&SC. Unclear institutional roles and weak inter-agency coordination also hamper the implementation of solutions. This technology requires a very high level of technical capacity, which is severely lacking and will impact on effective implementation. Specifically, there is limited support in respect of the ready supply of construction materials and equipment, the lack of technical studies and consistent long-term data and the need for ongoing training to ensure availability of skills. The possible measures seek to address the barriers of high importance regarding policy, capacity and awareness:

- Implement a policy for coastal zone management and strengthen inter-agency coordination and ollaboration;
- Widen focus on programmes and interventions in coastal sea defense;
- Provide support for research and capacity-building within local institutions in coastal engineering;
- Implement strategic planning by agency through increased awareness and dedicated human resources;
- Provide financing from the national budget and diversify financial sources;
- Promote intra-agency coordination, collaborative meetings and training on budget preparation; and
- Review overlapping policies, institutional roles and salaries and benefits to attract and retain skilled and experienced staff within the public sector.

Early warning systems for disaster preparedness. This EWS is a multi-hazard response emergency mechanism. The prioritized barriers likely to affect the uptake of EWS focused on the access and availability of finance and limited training and public education. The critical barrier was the heavy reliance on financial resources from the government to implement and sustain EWS. High capital and maintenance costs for the installation of communications infrastructure, regular training and testing, operation and sustainability, and limited revenue streams or sources of funding were also identified as key financial barriers.

Non-financial barriers included policy, institutional and technical capacity, research and education/awareness. There is a general observation that the legislative framework for EWS is unclear and that comprehensive strategies are needed to address issues of flooding and drought. At the institutional

level, there is no designated institution to oversee and manage a national EWS, and coordination among institutions can be problematic. Another barrier to an efficient EWS is the limited technical capacity that exists at various levels. Specifically, there is a lack of adequately trained personnel in emergency response, climatology, forecasting, and data management and planning. Institutions continue to experience high attrition rates for skills due to the unattractive salaries and incentives. Although much work has been done to prepare the foundations for EWS in Guyana, there is still a lack of data and research at local levels, such as downscaled regional forecasting and historical information on disasters and their impacts. In terms of the level of awareness of EWS as a barrier, there is the perception that this is a complex and resource-intensive technology, which can limit the extent to which it is applied. In Guyana, EWS is also seen as a government responsibility, and there is only limited understanding of disasters and response measures among the vulnerable stakeholder groups. The following possible measures were identified:

- Revise/update legislation/regulations to improve coherence and clarify institutional roles and responsibilities;
- Conduct adequate assessments and costing of needs, including human capacity;
- Provide tools and training to strengthen the capacity to complete assessments;
- Promote research to generate data and develop a strong understanding of disaster events in Guyana;
- Allocate sufficient funds in the national budget to implement the EWS framework and policy;
- Diversify revenue streams through access to information on financial options;
- Develop a framework strategy for private partnerships and collaboration;
- Provide an adequate budget for public education activities;
- Develop and implement training plan; and
- Provide attractive incentives to develop local skills.

Energy-efficient mobile pumps. The primary barrier to this technology is cost. High capital and maintenance costs and weak inter-agency coordination were the main prioritized barriers. Other financial barriers included reliance on the national budget and limited marketing opportunities to stimulate private-sector interest. Non-financial barriers were: a single institutional authority, an ad hoc approach to the use of pumps, low interest due to seasonal use, and alternative flood- or drought-control measures, which can deter interest.

The following measures were proposed to overcome the barriers to energy-efficient pumps:

- Increase the national budget allocation for transition to a new technology;
- Include in procurement policy for ‘energy-efficient’ equipment;
- Provide clarity on roles and responsibilities among agencies for the deployment and use of pumps;
- Develop local skills through specialised training to upgrade/maintain equipment;
- Stimulate interest in local market to supply spares and services;
- Establish information-sharing protocol to improve the sharing of resources and information and strengthen efficient response actions;

- Increase awareness of the benefits, mainly financial, of energy-efficient equipment.

3.3 Action Plan for Mapping and Modeling of Coastal Processes

3.3.1 Introduction

Guyana's 430 km-long coastline is protected from coastal flooding by a system of natural and man-made sea defenses, as well as an extensive network of drainage and irrigation canals, many of which were constructed 150 years ago (CDB,2013). Despite the significant investments in rehabilitating sections of Guyana's sea defenses, the 2014 survey of them, which covered 91.2% of their total length, shows that 2.28 km (1%) are in critical condition, 20.53km (9%) are poor and 80.22 km (34.4%) are in fair condition (Budget Speech, 2016). Assessments have shown that Guyana will have to find ways to mitigate rising sea levels. The estimated cost of building one meter of sea defense using rip-rap or concrete is US$3,500. The GoG has placed a US$1B price tag on fixing the country's sea defenses (LCDS, 2010). In 2016, the budget allocation for sea and river defense works amounted to US$672M.

Guyana's sea defense structures are maintained mainly through repairs and the construction of sea walls and groynes. However, the scientific capacity to study and monitor coastal hydrodynamic and oceanographic processes to inform the design and construction of these physical infrastructure better is lacking. On the coast, natural ecosystems also play an important role in coastal protection and sea defense. For example, mangrove forests are found on large sections of the Atlantic Coast from the Corentyne River to the Waini River, which stabilize the shoreline by controlling erosion from the waves. Mangroves are the first line of defence against wave actions and storms. They help to protect the sea wall or embankment and reduce the damage to sea defence systems. Mangrove forests are also found at the interface between the terrestrial and marine eco-systems, in estuarine wetlands and in tidal reaches of riverain areas (EPA, 2000).

Improved designs of sea defense infrastructure should incorporate parameters such as the impact of shore currents, subsoil conditions, tides and wave climate. Nearshore hydrodynamics is important in the 'stability of built infrastructure, of its long-term functionality or of the possibility for its destruction because of coastal erosion. Modeling is a useful tool to assess coastal currents, sediment transportation and the risk for erosion. For example, the movement of sandbanks can locally lead to the regression of mangroves and exacerbate the impact of wave action on the seawall' (Staljanssens, M., et al., 2008). Modeling simulates life situations through physical or computer models and explores the different ways in which a situation can develop, based on differing influences. A model can be developed of how the sea responds to tides and the weather to assess how coastal erosion may develop. In the analysis of coastal hydrodynamic processes, modeling (physical, numerical and composite) is often employed to simulate the main phenomena in the coastal region. This technology involves the extensive use of data, such as hydrology, flood defense conditions and information on ground surfaces.

3.3.2 Ambition for the TAP

As a low-lying coastal state, Guyana is highly vulnerable to rising sea levels, storm surges and flash floods. The construction and maintenance of coastal sea defenses is an ongoing planning activity of the

government. However, with the introduction of new risks and the development of new tools, there is a growing need to strengthen sea and river defense infrastructure. This technology aims to build institutional capacity in coastal engineering, which includes implementing strategic planning, training and research capacity. This will be applied on a national scale, targeting the country's coastline.

3.3.3 Actions and Activities for TAP

The measures selected for the mapping and modeling of coastal dynamics focused on access to finance, policy, research and capacity-building and raising awareness among decision-makers. The five actions listed below were selected based on an assessment of the measures needed for the successful implementation of this technology. The five actions can be further developed into a project or several projects:

1. Secure financing from the national budget and diversify financial sources;
2. Develop a policy for coastal zone management;
3. Provide support for research and capacity-building within local institutions in coastal engineering;
4. Strengthen interagency coordination and collaboration for the coastal zone; and
5. Raise awareness of coastal zone management among policy-makers, the national budget office and stakeholders.

Table 11 below summarizes the main activities and details for implementation of the actions. Implementation of the activities will be shared between two main institutions, the MoPI and EPA. Many of the activities will be implemented over the short to medium term. Actions for policy development and research capacity may be implemented over the medium to long term. General risks include the high cost, competing development priorities, economic downturns, changing global priorities, and limited institutional capacity, such as skills and competing workload priorities.

TABLE 11: SUMMARY OF ACTIONS AND ACTIVITIES FOR MAPPING AND MODELING OF COASTAL PROCESSES

Actions	Activities to be implemented	Sources of funding	Responsible institution and focal point	Timeframe	Risks	Success criteria	Indicators for monitoring of implementation	Budget per activity
Action 1: **Secure financing from national budget and diversify financing sources**	Activity 1.1 Focal Point identify potential/available financing	GoG, UN	Ministry of PI	Short term	Competing development priorities; diversion of funds due to national emergencies; economic downturn and changing global priorities; changes of Ggovernment.	Interested/potential financers identified and contacted.	1. List of confirmed financers 2. Established communication with financing institutions.	Not applicable. This will be a part of the Focal Point program activity.
	Activity 1.2 Prepare detailed proposals and secure approval for submission	GoG, UN	Ministry of PI	Short/ medium term	1. Limited institutional capacity in terms of staff available, skills and time among competing workload priorities 2. Delays in the approval process may result in loss of timely budgetary request submission.	1. Timely completion and approval of proposal 2. Budget line for technology program activities in national budget	1. Proposal formally submitted to the financing agency. 2. Formal approval of proposal received from financing agency 3. National budget approved for technology program activities	US$30,000 (consultant cost)
Action 2: **Develop Policy for Coastal Zone Management**	Activity 2.1 Review of existing framework for coastal zone management	GoG, UN, CDB, European Union (EU)	EPA /MoPI/NAREI	Short/medium term	1. Low level of interest at decision-making level 2. Lack of funding	Report received/approved by the EPA	1. Approved TOR 2. Signed contract of consultancy 3. Draft and final reports	US$ 15,000 (Local consultancy fee)
	Activity 2.2 Draft policy for coastal zone management	GoG, UN, CDB, EU	EPA /MoPI/NAREI	Medium/ long term	1. Limited funding 2. Not viewed as a priority 3. Change of government can cause a shift in momentum and priorities	Policy approved for coastal zone management	1. Approval of funding 2. Contract for procurement of expertise 3. Stakeholder consultation reports 4. Draft and final policy	US$35,000

	Activity 2.3 Implement program for sea defence infrastructure	GCF, GoG, , UN, CDB, EU	MOPI, NDIA	Medium/long term	1. Limited funding 2. Change of government; lack of inter-agency consensus; not a political priority	1. Program rolled out for the application of models to the design and construction of sea defence. 2. Improved design /strengthened infrastructure	1. Approved program budget 2. Financial and technical progress reports of program implementation 3. Less incidence of breakage/collapse of sea defence infrastructure	US$ 5M
Action 3: **Provide support for research and capacity-building within local institutions in coastal engineering**	Activity 3.1 Sensitisation (workshops/seminars) of key stakeholders on research needs	GCF, GoG,, private sector, CDB, EU,	MOPI, University of Guyana	Short /medium term	1. Low level of interest 2. Not a priority due to other competing interests	High level of stakeholder awareness on research CZM and research needs	1. Number of workshops/seminars completed 2. Increased interest in research	US$ 10,000
	Activity 3.2 Engage private sector in partnerships for research and capacity-building	GCF, GoG, private sector, CDB, EU, bilateral collaboration	MOPI, NDIA, MOF	Medium /long term	1. Lack of interest 2. Unclear role and benefits 3. Low level of trust between parties	Research and training initiated with the private sector	1. Signed agreement/s 2. Approved research proposals	US$ 10,000
	Activity 3.3 Enhance research skills in coastal engineering through workshops/scholarships	GCF, GoG,, private sector, CDB, EU, bilateral collaboration, scholarships	MOPI & UG	Medium/long term	1. Low interest in the discipline 2. Limited funding 3. Loss of skills due to poor compensation policies	1. Increased research capacity at institutions 2. Local expertise in coastal engineering available	1. Workshop reports 2. Three scholarships granted	US$ 1M
	Activity 3.4 Develop collaborative research program with focus on coastal engineering with institutions such as, MoPI, UG and international universities.	GoG, private sector, foreign academic & research institutions	MOPI & UG	Medium/ long term	1. Resource intensive 2. Limited financial and human capacity 3. Overriding and competing priorities 4. Poor compensation for technical expertise	Collaborative agreements established with national/external institutions for research and training	1. Signed agreement/s 2. Research program implemented	US$ 2.5
Action 4: **Strengthen interagency coordination for coastal zone**	Activity 4.1 Establish MOUs/Committee with key agencies, for example, EPA, MoPI, UG, MoC and MoA.	GoG	EPA	Short/ medium term	1. Low level of interest 2. Persistent turf issues 3. Unclear roles and responsibilities	1. MOUs signed with several agencies 2. A national CZM committee established	Signed MOUs	US$2,000

	Activity 4.2 Conduct regular meetings/workshops to provide updates and strategies for CZM	GoG	EPA	Short /medium term	1. Competing workload priorities 2. Ineffective participation by agencies as a result of weak staff commitment and continuity	Bi-annual meetings/workshops sustained	1. Meetings/ workshop reports	US$2,500
Action 5: **Raise awareness for coastal zone management to policy makers, national budget office and stakeholders**	Activity 5.1 Conduct sensitisation workshops/seminars at decision- making level	GoG	EPA	Short/medium term	1. Limited resources 2. Perceived low level of importance	Improved understanding of CZM among decision makers	1. Workshop reports 2. Increased inclusion of CZM issues in agencies work plans/programs	US$15,000
	Activity 5.2 Provide regular briefs to policy makers	GoG	EPA	Short /medium term	1. Delays due to availability of policy makers 2. Low level of importance among policy makers 3. Override by competing development priorities	Level of interest and importance of CZM improved	1. Briefing notes and presentations 2. Meetings notes	US$1,000
	Activity 5.3 Promote national PR programs on CZM programs/projects/success stories	GCF, GoG, UN, NGO.	EPA, MPOI, NDIA	Short /medium term	1. Limited finance 2. Overlapping roles of agencies	Increased awareness at the national level	1. Number of aired PR programs	US$10,000
	Activity 5.4 Conduct community outreach exercises	GCF, GoG, UN, NGO.	EPA	Short /medium term	1. Lack of resources at community level 2. Overriding community priorities 3. Low level of interest/participation	Increased awareness and involvement of communities in CZM initiatives.	1. Number of communities reached 2. Sustained collaboration with communities	US$30,000

3.4 Action Plan for Early Warning Systems for Flood and Drought

3.4.1 Introduction

Flood and drought are events of national significance. Overall, known hazards in Guyana have a greater impact on people's livelihoods than are a threat to their lives, with very few people having been killed by natural hazards in recent years. The 2005 flood and the 1997-8 drought were both considered to be extreme examples in terms of the severity of their impact, and this prompted recommendations for the establishment of a national EWS. While flooding has major impact on both the national economy and quality of life for more than half the population, droughts impact more on the quality of life, particularly for agricultural communities and in terms of damage to the environment, much of it through fire (GL&SC, 2009). There is less quantitative data on drought impacts, which are considered a secondary threat. However, droughts are likely to have major long-term impacts on the natural environment. Both floods and droughts have deleterious effects in Guyana, with major impacts, both being top priorities for an appropriate EWS.

An effective EWS need to have the capacity to detect, monitor and forecast hazards, analyze risks, and acquire mechanisms for the dissemination of information and emergency plans to activate response actions (WMO, 2016). These four components need to be coordinated across many agencies both nationally and locally for the system to work. Failure in one component or a lack of coordination across components could lead the whole system to fail. The issuance of warnings is a national responsibility, meaning that the roles and responsibilities of various public- and private-sector stakeholders in implementing EWS should be clarified and reflected in the national to local regulatory frameworks, planning, budgetary, coordination and operational mechanisms (GL&SC, 2009).

Currently, the Civil Defense Commission (CDC) oversees disaster responses and collaborates or is coordinated with other institutions, such as the private sector and non-governmental organizations. Essentially, Guyana already has several components promoting the establishment of an EWS. Although there is no legal framework, the four components of an EWS are reflected in the work of institutions such as the GL&SC & EPA, which provides data on knowledge about risks, the Hydromet Service, with functions for monitoring and warning, and the Guyana Information Agency (GINA), as well as NGOs which communicate and disseminate warnings, and the response and preparedness capabilities provided by the CDC, Guyana Defense Force (GDF), Red Cross, NDIA, etc. (GL&SC, 2009).

3.4.2 Ambition for the TAP

This technology will be applied on a national scale. The aim is to identify the resources needed for an EWS and to strengthen the country’s legislative framework and human capacity. Currently, emergency response action is activated by the CDC, which is based in the capital city. As more inland locations continue to experience extreme weather events, there is a need for EWS to strengthen its communication systems. This technology will scale up the monitoring and communication capacities across the country, linking together different types of hazard. It is intended to establish decentralized community warning systems and is expected to benefit coastal as well as inland communities. Currently, coastal communities are better

placed to receive early warnings, which can be more challenging for hinterland communities. The operationalization of the EWS will ensure that warning communications, including the use of multiple communication media, reaches the entire population.

3.4.3 Action and Activities for the TAP

The measures selected for an EWS focused on the determination of needs, access to finance, appropriate legislation and institutional collaboration. The five actions listed below were selected based on an assessment of the measures needed for the successful implementation of this technology. Overall, there is consensus that, to develop Guyana's EWS, an assessment is needed of the status of the existing framework and resources. The following five actions were derived from the measures assessed and may be developed into projects to be implemented:

1. Conduct adequate assessment and costing of needs
2. Provide funds in the national budget and diversify financial sources
3. Revise and update legislation and regulations to develop a coherent framework for EWS
4. Promote attractive incentives to develop local skills
5. Make data-sharing efficient across institutions.

Table 12 summarizes the main activities and details for implementation of the actions. Most of the activities may be implemented in the short to medium term. The CDC is expected to be the lead implementing agency. General risks include low priority, limited finance, unclear institutional role, weak collaboration, actions viewed as resource-intensive and the lack of available expertise and human resources.

TABLE 12: SUMMARY OF ACTIONS AND ACTIVITIES FOR NATIONAL EARLY WARNING SYSTEMS

Actions	Activities to be implemented	Sources of funding	Responsible institution and focal point	Time frame	Risks	Success criteria	Indicators for Monitoring of implementation	Budget per activity
Action 1: Conduct adequate assessment and costing of needs	Activity 1.1 National consultations on EWS	GCF, GoG, CDB, CDEMA, CTCN	CDC/ Hydromet	Short /medium term	1. Not a priority 2. Lack of clear institutional role 3. limited access to funding	Consultations completed	Participant lists and consultation report	US$ 15,000
	Activity 1.2 Evaluate status of EWS resources	GCF, GoG, CDB, CDEMA, CTCN	CDC/ Hydromet	Short /medium term	1. Not a priority 2. limited access to funding	Updated information on the status of resources	Evaluation report	US$ 10,000
	Activity 1.3 Complete cost/benefit analysis	GCF, GoG, CDB, CDEMA, CTCN	CDC/ Hydromet	Short /medium term	1. Lack of funding and expertise 2. Low level of interest	CBA Approved	CBA report available	US$ 5,000
Action 2: Provide funds in national budget and diversify financial sources	Activity 2.1 Prepare budget projection	GoG	CDC/ Hydromet	Short/medium term	1. Overlapping institutional mandate 2. Limited capacity	Budget completed	Projected budget available	US$1,000
	Activity 2.2 Secure national budget allocation for EWS	GoG	CDC/ Hydromet	Short /medium term	1. Overlapping institutional mandate 2. Competing institutional priorities 3. Proven capacity to spend	National budget allocation approved	1. Work plan with committed budget 2. Expenditure reports 3. Implementation of EWS programs/activities	US$1,000
	Activity 2.3 Establish financial support arrangements with external donors	GCF, GoG, CDB, CDEMA, CTCN	CDC/ Hydromet	Short/medium term	1. Overlapping institutional mandate 2. Competition for small pool of resources	Donor support received.	Signed agreements with donors	US$2,000
Action 3 - Revise/update legislation/regulations to develop a coherent framework for EWS	Activity 3.1 Review of existing legislation and regulations	GoG, GCF	CDC	Short/ medium term	1. Considered a low priority 2. Limited financial support 3. Lack of political support	Analysis of Legal status of EWS completed.	Report of review	US$ 10,000

	Activity 3.2 Integrate EWS framework	GoG, GCF	CDC	Short /medium term	1. Lack of financial support 2. Weak political support	Approved EWS Framework	Draft and final reports	US$20,000
Action 4 - Promote attractive incentives to develop local skills	Activity 4.1 Revise existing HR policy	GoG	Public Service Ministry	Short /medium term	Low level of importance by decision makers	Revised policy approved and implemented	1. HR policy document 2. Relevant positions filled	US$3,000
	Activity 4.2 Provide training and opportunities for employment	GCF, GoG, CDB, CDEMA, CTCN	CDC / Hydromet	Short/medium term	1. Low priority at decision making level 2. Low level of stakeholder interest 3. Lack of financial support	Training and recruitment program implemented	1. Number/type of training completed 2. Persons hired	US$5,000
Action 5 - Efficient data information sharing among institutions	Activity 5.1 Develop/review/ update information sharing guidelines	GOG	CDC / Hydromet	Short / medium term	1. Weak collaboration 2. Limited capacity to implement	Improved information sharing	1. Approved guidelines 2. Analytics of data shared	US$1,000
	Activity 5.2 Establish MOU with institutions (MoA, EPA, GL&SC, OCC,MoC).	GoG	CDC / Hydromet	Short /medium term		MOUs signed	1. Signed MoUs 2.Record of data sharing	US$2,000
	Activity 5.3 Promote electronic archiving/access of data/information	GCF, GoG, CDB, CDEMA, CTCN	CDC / Hydromet	Medium/long term	1. Resource intensive 2. Lack of available expertise and staffing	Database and information sharing network system completed	1. Hardware and software acquired 2. System designed and approved 3. Efficient access to data	US$ 150,000
	Activity 5.4 Establish data management unit	GCF, GoG, CDB, CDEMA, CTCN	CDC / Hydromet	Medium/long term	1. Resource intensive 2. Lack of available expertise and staffing	Data management unit completed		US$ 300,000

3.5 Action Plan for Technology: Energy-efficient Mobile Pumps

3.5 1 Introduction

During the biannual seasonal heavy rains, water inundating residential areas along the coast during the high tides can only be drained using pumps. Heavy rains, together with persistent high tides, impede the appropriate drainage of the flooded areas, causing drainage waters to overflow. At high tide, the drainage of surplus water into the sea through the sluices is impossible. The system suffers from the impact of sea level rises because an adequate discharge window is no longer available. As the sea level continues to rise and the discharge window continues to shrink, the ability to manage water levels becomes seriously compromised (CDB, 2015).

Mobile pumps are easily towed and able to pump very large volumes of water within minutes of reaching a location. With minimal training, they can be operated by one person. The portability of the mobile pumps permits easy movement to various locations where large volumes of water need to be pumped. Everything needed for pumping is mounted on a trailer. Typically, the pumps comprise a diesel engine, water pump, fuel tank, hydraulic oil reservoir, discharge pipe, discharge hose and a safety shutdown system. According to the NDIA, there are currently 33 mobile pumps throughout the country, with a discharge capacity of between 20 and 120 cubic metres a second (MoA, 2016). However, the high fuel costs to operate the pumps is a challenge to their effective use. Hence the recommendation for the acquisition of energy-efficient pumps to reduce operating and maintenance costs.

3.5.2 Ambition for the TAP

Energy-efficient mobile pumps may not be feasible or practical as high-capacity pumps. The massive volumes of water and the affected locations may limit the application of this technology on a wide scale.

3.5.3 Action and Activities for the TAP

The measures selected for energy-efficient mobile pumps focused on access to finance, a procurement policy for clean technology, market conditions and skills training. Generally, it is felt that this technology can be implemented with adequate finance and that there are no significant non-financial barriers. The following actions were identified:

1. Increase the national budget and pursue other financial donors
2. Include in procurement policy
3. Promote private-sector involvement and market opportunities
4. Local training and capacity-building.

Table 13 summarizes the main activities and details for implementation of the actions. The lead agency will be the NDIA, and most of the activities are targeted ro the medium to long term. The general risks include not being considered practical, only seasonal interest and low priority.

TABLE 13: SUMMARY OF ACTIONS AND ACTIVITIES FOR ENERGY EFFICIENT MOBILE PUMPS

Actions	Activities to be implemented	Sources of funding	Responsible institution and focal point	Timeframe	Risks	Success criteria	Indicators for monitoring of implementation	Budget per activity
Action 1 - Increase national budget and pursue other financial donors	Activity 1.1 Prepare and submit budget proposals	GoG and bilateral donors	NDIA	Medium/long term	1. Driven by national emergencies 2. Reliance on external support	Committed budget line and bilateral agreement signed for the supply of equipment	1. Committed budget line 2. Equipment received	US$1,000
Action 2 - Include in procurement policy	Activity 2.1 Update procurement guidelines	GoG	NDIA	Medium/long term	Not seen as important or practical	Updated guidelines	Energy /mechanical requirements included in guidelines	US$2,000
Action 3 - Promote private sector involvement and market opportunities	Activity 3.1 Promote public/private partnerships for supply and maintenance	GoG	NDIA	Medium/long term	Lack of interest by the private sector	Private sector included	1. Consultations with Private Sector Commission and businesses 2. Partnership agreements	US$2,000
	Activity 3.2 Provide financial incentives, such as, tax breaks, low interest loans	GoG	NDIA/GoG	Short/ medium term	1. Competing enterprises 2. Not considered a priority	Financial incentives available	1. Financial incentives approved	US$5,000
Action 4 - Local training and capacity-building	Activity 4.1 Identify and access mechanical skills building opportunities	GoG	NDIA	Short /medium term	1. Low level of importance for specialised skills 2. Poor compensation for skills	Mechanical expertise available	1. Skills training plan developed 2. Persons trained	US$ 15,000

3.6 Project Ideas for the Coastal Zone and Low-Lying Communities Sector

The ICZM Action Plan 2000 identified, among other factors, sea level and floods as social, economic and ecological stresses that impact on the coastal zone. The Plan basically addressed issues related to policy development, analysis and planning, inter-agency coordination, public education and awareness-building, environmental control and compliance, monitoring and measurement, and information management, all of which are necessary to reduce the risks posed by climate change. One of the constraints in the implementation of the ICZM is limited institutional capacity in terms of the human, technical and physical capital to implement the specific actions to address issues affecting the coastal zone.

The project ideas for the Coastal Zone and Low-lying Communities sector highlights the key actions which can enable the successful implementation of technologies for the mapping and modeling of coastal processes and EWS. The following project ideas have been proposed for the sector:

1. Development and mainstreaming of ICZM Policy & Action Plan
2. Capacity strengthening of EWS and disaster management

TABLE 14: SUMMARY OF PROPOSED ACTIONS AND PROJECT IDEAS FOR THE COASTAL ZONE SECTOR

TECHNOLOGY	PROPOSED ACTIONS	PROPOSED PROJECT IDEA
Mapping and Modeling of Coastal Processes	1. Secure financing from national budget and diversify financial sources; 2. Develop Policy for Coastal Zone Management; 3. Provide support for research and capacity-building within local institutions in coastal engineering; 4. Establish a national task force to strengthen interagency coordination for the coastal zone; and 5. Raise awareness of coastal zone management for policy-makers, the national budget office and stakeholders	**Development and Mainstreaming of ICZM Policy & Action Plan**
Early Warning Systems for Flood and Drought	1. Conduct adequate assessment and costing of needs 2. Provide funds in national budget and diversify financial sources 3. Revise and update legislation and regulations to develop a coherent framework for EWS 4. Promote attractive incentives to develop local skills 5. Ensufe efficient data-sharing among institutions	**Capacity strengthening of EWS and disaster management**
Energy-efficient Mobile Pumps	1. Increase national budget and pursue other financial donors 2. Include in procurement policy 3. Promote private-sector involvement and market opportunity 4. Local training and capacity-building	**No Project Idea was developed for this technology.**

For the mapping and modeling of coastal processes, it is recommended that a broad-based scientific assessment be conducted to inform the development of sea defence infrastructure. However, this needs to be part of a national policy to ensure the sustainability of the technology.

As mentioned earlier, the foundations for an EWS already exist in Guyana. However, there is a need to assess the resources available and identify what is required in developing an operational multi-hazard EWS.

Through this project, the institutional capacity of the responsible authorities, namely CDC, EPA and Hydromet, will be strengthened.

No project idea was developed for energy-efficient mobile pumps since implementation of the technology is based on institutional decisions in procurement policy and the practicality of its application. Energy-efficient mobile pumps may not be feasible or practical for large-scale pumping.

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ANNEX I: LIST OF TNA COMMITTEE MEMBERS

Organisation	Members, Replacement and Alternates
Ministry of the Presidency	Rear Admiral (rtd) Gary A R Best – Chairman
Ministry of the Presidency Office of Climate Change	Ms. Janelle Christian – Deputy Chair Janelle.Christian.occ@motp.gov.gy Tel: 223 5231
Ministry of Agriculture	Dr. Garvin Cummings Chief Hydrometeorological Officer (ag.) Hydrometeorological Service garvin.cummings@gmail.com Tel: 225 9303
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Guyana Energy Agency	Dr. Mahender Sharma Chief Executive Officer mahender.sharma@hotmail.com Ms. Shevon Wood (alternate) Economist shevon.wood@yahoo.com; Tel: 226 0394 Ext 211/ 618 8420
Environmental Protection Agency	Mrs. Angela Franklin Senior Environmental Officer, Water Quality Unit Mr. Frank Grogan (replacement for Angela Franklin) Environmental Officer II, Water Quality Unit Ms. Malicia Hall (replacement for Frank Grogan) Environmental Officer malicia.epa@gmail.com; Tel: 225 5467
Guyana Geology and Mines Commission	Ms. Dianne McDonald Deputy Commissioner mmmdggmc@yahoo.com; Tel: 623 1207 Mr. Lloyd Bandoo (representative) Senior Mineral Processing Engineer Lloyd_bandoo@ggmc.gov.gy; Tel: 610 2832
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ANNEX III: LIST OF POSSIBLE PROJECT IDEAS FOR FUTURE CONSIDERATION

The list of projects below was informed by the long-list of projects from the technology prioritization process, the enabling measures from the barrier analysis and the actions identified in the TAP process. The following PIs may be expanded or modified to include other needs during project development.

AGRICULTURE SECTOR

1. Scaling up climate resilience in agriculture through varietal development of saline-tolerant and flood-resistant crops
2. Enhancing adaptation and mitigation benefits: composting of agricultural waste and promotion of organic farming

WATER SECTOR

1. Water reclamation and reuse: domestic and industrial water treatment
2. Infiltration basins to increase groundwater recharge
3. Development of Community Water Safety Plans
4. Infrastructure to protect wells from contamination and barriers to salt-water intrusion in vulnerable areas

COASTAL ZONE AND LOW-LYING COMMUNITIES SECTOR

1. Research and monitoring of coastal hydrodynamic processes to guide scientific decision-making in coastal sea defence infrastructure
2. Infrastructure to flood-proof the coastal zone and low-lying communities; construction of storm-surge barriers, closure dams and storm-water drains.
3. GIS for operationalization of Land Use Plan
4. Energy-efficient mobile pumps for flood control and irrigation
5. Establish national data-management unit for EWS