

# A NATIONAL WATER RESOURCES MASTER PLAN FOR JAMAICA



**WRA**

**WATER RESOURCES AUTHORITY**

Jamaica's Water ... Every Drop Precious





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## **A National Water Resources Master Plan for Jamaica**

Water Resources Authority of Jamaica  
Hope Gardens, PO Box 91  
Kingston 7, Jamaica.



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# Glossary of Definitions

|                                            |                                                                                                                                                                                                                                                                  |
|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>7Q10</b>                                | The 7-Day Minimum Mean stream flow with a 10-year return period                                                                                                                                                                                                  |
| <b>ABSTRACTION</b>                         | Removal of water from any source, either permanently (consumptive) or temporarily (non-consumptive).                                                                                                                                                             |
| <b>ACTUAL<br/>EVAPOTRANSPIRATION</b>       | Quantity of water evaporated and transpired from the soil and the vegetative cover.                                                                                                                                                                              |
| <b>ALLOCATION</b>                          | Discharge assigned to abstractors via abstraction licenses                                                                                                                                                                                                       |
| <b>ALLUVIUM</b>                            | Clay, silt, sand, gravel, pebbles or other detrital material deposited by flowing water                                                                                                                                                                          |
| <b>AMBIENT WATER QUALITY<br/>STANDARDS</b> | The allowable amount of materials, as a concentration of pollutants, in water. The standard is set to protect against anticipated adverse effects on human health or welfare, wildlife, or the environment, with a margin of safety in the case of human health. |
| <b>AQUICLUDE</b>                           | Geological formation, or group of geological formations, with very low hydraulic conductivity.                                                                                                                                                                   |
| <b>AQUIFER</b>                             | Geological formation capable of storing, transmitting and yielding exploitable quantities of water.                                                                                                                                                              |
| <b>BASE FLOW</b>                           | Discharge which enters a stream channel mainly from groundwater during long periods when no precipitation occurs.                                                                                                                                                |
| <b>BASE FLOW INDEX</b>                     | Ratio of long-term baseflow to total streamflow                                                                                                                                                                                                                  |
| <b>BASIN (SYN. WATERSHED)</b>              | Area having a common outlet for its surface runoff                                                                                                                                                                                                               |
| <b>BOD</b>                                 | Biological Oxygen Demand                                                                                                                                                                                                                                         |
| <b>CROP COEFFICIENT</b>                    | Ratio of evapotranspiration observed for the crop studied over that observed for a well calibrated reference crop under the same conditions.                                                                                                                     |
| <b>DEMAND SIDE MANAGEMENT</b>              | A suite of policy measures, including pricing and education, to achieve water conservation                                                                                                                                                                       |
| <b>DISCHARGE</b>                           | Volume of water flowing through a river (or channel) cross-section per unit time.                                                                                                                                                                                |
| <b>EFFECTIVE RAINFALL</b>                  | 1. In Surface Hydrology, that part of the rainfall which contributes to runoff;                                                                                                                                                                                  |
| <b>EFFECTIVE RAINFALL</b>                  | 2. In Groundwater, that part of the rainfall which contributes to groundwater recharge;                                                                                                                                                                          |
| <b>EFFECTIVE RAINFALL</b>                  | 3. In agriculture, that part of the rainfall which remains in the soil and contributes to crop growth.                                                                                                                                                           |
| <b>EL NIÑO</b>                             | The abnormal warming of the eastern tropical Pacific Ocean caused by a southward-flowing ocean current off the coast of Peru, and that has global climatic effects                                                                                               |

**ENVIRONMENTAL FLOW**

Discharge of a stream that satisfies flow maintenance and ecological preservation within the stream.

**EVAPOTRANSPIRATION**

Combined process by which water is transferred to the atmosphere from the soil by evaporation, and from the vegetation by transpiration.

**GROUNDWATER**

Subsurface water occupying the saturated zone.

**GROUNDWATER BASIN**

Physiographic unit encompassing one major aquifer, or several connected or interrelated aquifers, whose waters are flowing to a common outlet.

**HYDRAULIC CONDUCTIVITY**

Property of a porous medium which, according to Darcy's Law, relates the specific discharge to the hydraulic gradient.

**INLIER**

An older rock formation isolated/surrounded by younger rock formation(s).



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**IRRIGATION EFFICIENCY**

The proportion of the amount of water delivered to crops in irrigation compared to the total amount of water released at the source

**KARST REGION**

A land area (mainly limestone or dolomite) having geological formations with large subterranean passages or fractures that enable underground movement of large quantities of water

**PAN COEFFICIENT**

Ratio of evaporation from a large body of water to that measured in an evaporation pan.

**POTENTIAL  
EVAPOTRANSPIRATION**

Maximum quantity of water capable of being evaporated in a given climate from a continuous stretch of vegetation covering the whole ground and well supplied with water; it thus includes evaporation from the soil and transpiration from the vegetation of a specified region in a given time interval, expressed as depth.

**PUBLIC WATER SUPPLY**

Water treated and delivered to people in residences, commercial establishments and offices.

**Q90, Q95**

The stream flow rate that is equalled or exceeded 90% or 95% of the time for the period of record

**RIVER**

Large stream which serves as the natural drainage for a basin.

**RUNOFF**

That part of the precipitation which flows on the ground surface (surface runoff) or within the soil (subsurface runoff or interflow)

**SAFE YIELD**

Maximum rate of water withdrawal that can be sustained by a groundwater basin without causing unacceptable effects such as decline in hydraulic head and/or land subsidence.

**SOURCE**

Origin of a river

**SPRING**

Place where water emerges naturally from the rock or soil and flows onto land or into a body of water.

**STREAM**

Flowing body of water in a natural surface channel.

Body of flowing groundwater in karst formation.

**SUBMARINE DISCHARGE**

Discharge of fresh and brackish groundwater from land into the sea. Governed by the Ghyben-Herzberg Principle.

**SURFACE WATER**

Water which flows over or is stored on the ground surface.

**TRANSMISSIVITY**

The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

**WATER DEMAND**

Quantity of water necessary to satisfy specific requirements over a given period

**WATERSHED MANAGEMENT  
UNIT**

A watershed/grouping of watersheds defined in relation to the 10 hydrologic basins of Jamaica as developed for the 1990 WRDMP.

**WETLAND**

Area of marsh, fen, peatland or water- whether natural or artificial, permanent or temporary- with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which does not exceed six metres at low tide.



# Foreword

The first completed National Water Resources Development Master Plan of Jamaica (WRDMP) was published in March, 1990 by the then-Underground Water Authority (UWA). Since that time, there have been many changes in Jamaica's water resources and environment, including (but not limited to):

- ◆ The promulgation of the Water Resources Act (1995) replacing the UWA with the Water Resources Authority (WRA) and providing directives regarding the management, allocation, conservation, monitoring and protection of Jamaica's water resources;
- ◆ Preparation and parliamentary approval of a National Water Policy (2004, updated 2019) and accompanying Strategies and Action Plans;
- ◆ Improvements in assessments and measurements of water resources data, hydrogeological data, and theoretical frameworks, including the use of technology, Geographical Information Systems (GIS), and isotope hydrology among others;
- ◆ Increasing awareness of the impacts of climate change on precipitation patterns and temperatures, and the subsequent impact on water resource fluxes and storage.
- ◆ Changes in demographic growth, distribution, industrial and agricultural land usages, and the subsequent changes in water demand for all sectors.

The WRA signed a contract on July 15, 2003 with McGill University Brace Centre for Water Resources Management of Montreal, Canada to prepare an updated WRDMP for Jamaica. The project was funded jointly by the Inter-American Development Bank (IADB) and the Government of Jamaica, and fieldwork for the update began on October 1, 2003. This update was completed but not finalized, and the last recorded updated WRDMP was April 2012. The WRA signed a contract with Mr. Michael White (Resource Consultant) and Mrs Beverline Brown-Smith (Demand Consultant) in January 2017 to complete the WRDMP update, and the current WRMP was updated and completed by Mr. Geoffrey Marshall between January 2019-August 2020, with updates and final review completed in August 2021.

This current WRMP is an assessment of Jamaica's water resources and demand as at 2016-2019, as mandated by section 16 of the Water Resources Act. It is an update of both the completed 1990 WRDMP and the draft 2005 WRDMP reflecting both the significant work done in the preparation of those reports and the various changes in available data and monitoring techniques, demography, economic activity, and impacts of climate change. The study team is listed below.

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The study team anticipates that the information presented herein will be an essential contribution towards Jamaica's Vision 2030 goal of making Jamaica the place of choice to live, work, raise families and do business.



**WRA**

WATER RESOURCES AUTHORITY

# Introduction

## BACKGROUND

The Government of Jamaica promulgated the Water Resources Act of 1995 into law on April 7, 1996, thereby establishing the Water Resources Authority (WRA) with a mandate for the “conservation, protection, allocation and otherwise management” of Jamaica’s water resources. The WRA currently operates under the portfolio of the Ministry of Economic Growth and Job Creation (MEGJC), and its major activities include:

- Hydrologic data collection, compilation, analysis, and forecasting,
- Water resources investigation, assessment, and planning,
- Water resources allocation,
- Flood plain mapping,
- Environmental monitoring and impact assessment.



This is a reflection of the importance of water to Jamaica’s socio-economic development and sustainable development of the natural environment. The WRA through the Water Resources Act provides the instrument to address several deficiencies, including:

- Need for a unified and cohesive legislative framework for proper administration, development and optimal use of water,
- Adequate water resources planning,
- Control and management of water quality in aquifers and streams,
- Recognition of the interactive process between ground and surface water.

### **Section 16 (1) of the Water Resources Act 1995 states:**

*“Subject to the provisions of this section, the Authority shall prepare and submit to the Minister for approval a draft National Water Resources Master Plan for Jamaica.”*

### **Section 16 (5) of the Water Resources Act 1995 states:**

*“The Authority shall ensure that the draft Master Plan-*

- a. Identifies objectives for the development, conservation and use of the water resources of Jamaica, taking into account all relevant considerations including the desirability of economic efficiency, the protection of the health, safety and welfare of persons, the protection or*

*encouragement of economic activity, and the protection of the environment and the enhancement of environmental values;*

- b. Identifies, describes and inventories in relation to Jamaica-*

- i. The occurrence, quantity, availability and quality of water;*
- ii. The current uses of water; and*
- iii. The activities which are dependent on, affected by, or related to water and its uses;*

- c. Identifies and describes in relation to Jamaica, the projected needs for water and recommends the projects, programmes and other steps which, in view of such needs, should be undertaken in respect of the development of water resources*



*and the control, abstraction and storage of water and the supply, distribution, drainage and disposal thereof;*

- d. Having regard to the current and projected needs for water identified pursuant to paragraph (c) and the projects, programmes and other steps recommended under that paragraph, indicates the objectives in relation to water quality whether in respect of Jamaica generally or in respect of regions thereof, and the programs designed to achieve those objectives;*
- e. Indicates and evaluates the ways in which all projects and programmes proposed in the draft Master Plan in respect of the current and projected use of water will achieve the objectives identified pursuant to paragraph (a).*

The Water Resources Act also requires that the WRA take cognizance of the plans of other Government Agencies in coordinating the drafting of the WRDMP.

The 1990 Water Resources Development Master Plan preceded the implementation of the Water Resources Act, and its stated purpose and objectives were as follows:

- ◆ A framework for the sustainable development and protection of Jamaica's water resources,
- ◆ A framework for the rational allocation of water resources,
- ◆ Strategies for meeting the current and future demands for water,
- ◆ Guidelines for the process of siting new housing, agricultural and industrial developments,
- ◆ Guidelines for environmental protection,

- ◆ Guidelines for integrating local, regional and national efforts in water resources projects.

The reasons for the preparation of the previously attempted draft 2005 Master Plan and this updated 2019 Master Plan are:

- ◆ To ensure that the items specified in Section 16(5) (water quality) of the Water Resources Act that were not considered in the 1990 WRMP are included;
- ◆ To meet the requirement of the Water Resources Act for an annual revision of the whole or any part of the Master Plan, given any significant changes. Over the 29 years since the first WRDMP and 14 years since the attempted draft WRDMP, the following factors have gained relevance::
  - + Improved estimates of water resources with the additional years of hydrological data.
  - + Water use has changed with the growth and decline of various sectors.
  - + Changes have taken place in the legislative and institutional framework of the water sector.
  - + Integrated watershed planning has been implemented at the level of the WMU and not the hydrological basins
  - + Impacts of Climate Change on projected water demands and availability needed to be considered; availability and demand need to be evaluated;
  - + Advances in technology allows for better analyses and publication of hydrological data.
- ◆ Environmental demands were not addressed in the previous Master Plan

## APPROACH

### DATA AND INFORMATION REVIEW

The data and information review included:

- ◆ Review of the 1990 WRDMP, Draft 2005 WRDMP, and all related Annexes, namely the Water Demand Inventory, Water Resources Inventory, Framework for Water Allocation and Hydrological Research Programme.
- ◆ Review of other relevant reports - listed in references.

Agencies which provided data and information include:

- ◆ Forestry Service,
- ◆ Meteorological Office,
- ◆ Climate Studies Group, Department of Physics, UWI Mona
- ◆ Ministry of Agriculture, Commerce, Industry and Fisheries
- ◆ Ministry of Economic Growth and Job Creation
- ◆ National Environmental and Planning Agency
- ◆ National Housing Trust
- ◆ National Irrigation Commission
- ◆ National Water Commission
- ◆ Statistical Institute of Jamaica
- ◆ Jamaica Tourist Board.

Information garnered from these agencies include:

- ◆ Rainfall data
- ◆ Maximum and Minimum Temperature Data
- ◆ Population statistics from 2016 and probable future trends,
- ◆ Industrial growth forecasts



- ◆ Statistics of irrigated areas in the present and future development plans,
- ◆ Numbers of hotel rooms and occupancy rates
- ◆ Quantities of water sold to cruise ships.

## CONSULTATIVE WORKSHOP

In the preparation of the draft 2005 WRDMP, a 1-day Stakeholders' Workshop was held by WRA and the then-Project Consultant on April 27, 2004. The workshop objectives were to provide sensitization of the draft Master Plan, and to garner feedback and suggestions from the various stakeholders regarding the update process and water resources in general. There were 48 participants, representing most Government ministries and interested agencies, parish councils, industry, private consultant experts, non-governmental organizations, and international agencies.

Important suggestions emanating from this workshop included:

- ◆ Standard water consumption rates to be established for urban and rural residential per capita use.
- ◆ Application of new technologies in the bauxite and sugar (rum) industries may result from sudden changes in water demand. Discussion needs to take place with these industries.
- ◆ Converting to sprinkler systems on some sugar estates has improved irrigation efficiencies to 70%. However, further investment is likely to be slow so gross surface irrigation efficiencies are likely to remain near 30% over the present planning horizon.

- ◆ Demand management options are needed in water-stressed WMU's such as Kingston. Options could include:

- + application of a cess to pay for construction of additional storage
- + application of efficiency standards for water providers (e.g. NWC, NIC) and water users (e.g. households, farmers)
- + incentives for changes in cropping patterns (e.g. seasonal production or the use of crops with lower irrigation water requirements), and
- + Public awareness campaigns to encourage water conservation.

- ◆ Introduction of a volumetric fee for water abstraction licences as a water demand management instrument and an income generator to augment research costs to be investigated. WRA had, in the past, advocated for a fee of \$0.17/1000 gallons (about \$0.50/m<sup>3</sup>).
- ◆ NWC plan to move to full-cost pricing was supported. However, NWC should first invest in measures to reduce non-revenue water and attain a level of efficiency of 70%. The net savings from these efforts should be used to reduce any proposed rate increases.
- ◆ Key criteria to establish priorities for allocation of water in water-stressed WMUs and basins are the rights approach (See section 19.2 of the Water Resources Act re "Right of access" and "Water required for sole domestic Use"), and environmental needs. For other needs, economic criteria can be used.
- ◆ High priority and sensitive water bodies and their catchment in each WMU should be identified in the WRDMP. These are to include drinking water sources, recreational waters and aquatic ecosystems.

- ◆ A watershed management and protection fee should be determined and included in future WRA tariffs. *[Note: while this was a recommendation from the Stakeholder's workshop, it would not fall within the mandate of the WRA.]*
- ◆ Water conservation practices should be incorporated in building codes and put financial incentives in place to reward the adoption of such measures.

Since that workshop, there have been certain actions that address some of the suggestions made, as presented below (not an exhaustive list):

- ◆ The classification of **urban** and **rural** areas for *per capita* demand has been replaced by **Utility Service Areas (USAs)** and **Non-Utility Service Areas (NUSAs)**, as per the 2019 National Water Sector Policy (NWSP). Access to water as defined by the NWSP is at least **50 litres of water per day** (11 gallons per day), and this *per capita* demand is used for NUSAs. In regions defined as USAs, the WRA utilizes the per capita figure of **227 litres per day** (50 imperial gallons per day) as used by the National Water Commission, reflecting the increased demand from piped supplies. These figures are utilized in the Demand Inventory.
- ◆ Changes in the macro-economic environment have significantly impacted both bauxite and sugar industries, leading to the closures and scaling-down of many of their operations and a subsequent significant decline in their water usage.
- ◆ The National Environment and Planning Agency (NEPA), along with multiple Parish Municipal Corporations have made it a standard practice to require developers/home-owners to install water storage

facilities (the colloquial 'black tanks') to provide short-term water storage to mitigate interruptions in public water supply service. Developers and home-owners are also consistently encouraged to implement **Rainwater Harvesting Techniques** to augment their existing water supply.

- ◆ Drought impacts on the Hermitage and Mona Reservoirs in 2015 and 2019, with the subsequent rationing of water supply and delivery, has led to an increase in public awareness and interest of water resources as it relates to water supply service delivery, and greater public demand for accountability and planning for drought impacts from water service providers.
- ◆ **Volume-Based Fees (VBF)** on licensed abstraction rates have been implemented in Jamaica effective April 8, 2019. The volumes of water are quantified per abstractions of 4.545 m<sup>3</sup>/annum (1,000 imperial gallons per year), and the fees are based on the specific purpose/use for which a license was granted, as follows:
  - + Domestic/Public Supply: JMD \$0.1150
  - + Industrial: JMD \$0.1725
  - + Agriculture (Irrigation): JMD \$0.1725
  - + Non-consumptive (recreation, hydropower): JMD \$0.0920
- ◆ The NWC plans to implement major projects to reduce non-revenue water (NRW) in its distribution network in the KSA, as well as rehabilitate groundwater sources in Kingston and construct a new water treatment facility on the Rio Cobre at Crescent.
- ◆ The Soapberry Wastewater Treatment Facility was constructed in 2008 to collect and treat all sewage from the Kingston Metropolitan Area and Portmore, and has been operating within capacity since that time with treated effluent being disposed in the Rio Cobre. There is potential for the treated effluent to be re-used for irrigation and other purposes.
- ◆ An Aquifer Vulnerability Area was demarcated on sections of the Rio Cobre Alluvium Aquifer in 2004 via Cabinet Decision, and the WRA continues to implement research and monitoring to provide more protection for sensitive groundwater and surface water quality areas. One such activity is the recent update and publishing of the Water Quality Atlas in 2019, which was last published and updated in 2001.
- ◆ The Hope-Yallahs Project, which seeks to protect and restore the severely degraded Hope and Yallahs Watersheds, includes plans for a **Payment-for-Ecosystems Scheme (PES)**. This would be a source of funds for further watershed protection, and would come from all beneficiaries of the watersheds' resources. The Nature Conservancy has also proposed a similar instrument called the **Water Fund** which would also be funded from beneficiaries of the watershed.



# Objectives for Development, Conservation and Use

## POLICY AND PLANNING

In November 2002, the UN Committee on Economic, Social and Cultural Rights declared that access to water is a human right. This right entitles all persons to sufficient, affordable, physically accessible, safe and acceptable water for personal and domestic use. In Jamaica this means that all residents have the right of access to safe water. However, it does not necessarily mean that the water must be provided for free to all. The WRDMP update must inform the overall Government framework for development of all sectors, including industry, agriculture, domestic supply and tourism. However, this sectorial development should not be at the expense of the environment by degrading watersheds or promoting unsuitable land use changes. Various global and local policy goals have been implemented to help guide the sustainable development of all sectors, including the water sector.

## GLOBAL SETTING

The WRDMP should conform to international agreements to which the GOJ is a signatory. These include the United Nations Sustainable Development Goals, and the United Nations Framework Convention on Climate Change Paris Agreement.

## UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

The United Nations Sustainable Development Goals are a call for all countries to promote prosperity while protecting the planet. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs, including education, health, social protection and job opportunities while tackling climate change and environmental protection.

| UN SUSTAINABLE DEVELOPMENT GOAL                                          | BENEFITS AND IMPACTS OF IMPROVED WATER RESOURCES MANAGEMENT AND ACCESS TO WATER SUPPLY AND SANITATION ON SDG                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| GOAL 1: End poverty in all its forms everywhere.                         | <ul style="list-style-type: none"> <li>Water is a factor of production in agriculture, industry and economic activities</li> <li>Investments in water infrastructure/services as a catalyst for local/regional development</li> <li>Reduced vulnerability to water-related hazards reduces risks in investments and production</li> <li>Reduced ecosystems degradation makes livelihood systems more secure</li> <li>Improved health increases productive capacities, reduces burden on those who care for the sick</li> </ul>                                                            |
| GOAL 2: Zero Hunger                                                      | <ul style="list-style-type: none"> <li>Water is a direct input to irrigation for expanded grain production</li> <li>Reliable water for subsistence agriculture, home gardens, livestock, tree crops</li> <li>Sustainable production of fish, tree crops and other foods gathered in common property resources (also affects poverty when such goods are sold for income)</li> <li>Reduced urban hunger due to cheaper food prices</li> <li>Healthy people are better able to absorb the nutrients in food than those suffering from water-related diseases, particularly worms</li> </ul> |
| GOAL 3: Ensure healthy lives and promote well-being for all at all ages. | <ul style="list-style-type: none"> <li>Water is a necessity for human consumption, hygiene, and healthy living.</li> <li>Proper management of natural water resources leads to a decline in the occurrence of water-borne and water-aided diseases.</li> </ul>                                                                                                                                                                                                                                                                                                                            |
| GOAL 4: Quality Education                                                | <ul style="list-style-type: none"> <li>Improved school attendance from improved health and reduced water-carrying burdens, especially for girls</li> <li>Having separate sanitation facilities for girls and boys in schools increases girls' school attendance</li> </ul>                                                                                                                                                                                                                                                                                                                |

| UN SUSTAINABLE DEVELOPMENT GOAL                                                                                         | BENEFITS AND IMPACTS OF IMPROVED WATER RESOURCES MANAGEMENT AND ACCESS TO WATER SUPPLY AND SANITATION ON SDG                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| GOAL 5: Achieve Gender Equality and empower all women and girls.                                                        | <ul style="list-style-type: none"> <li>Community-based organizations for water management improve social capital of women</li> <li>Reduced health, and care-giving burdens from improved water services give women time for productive endeavors, education, empowerment activities</li> <li>Water and sanitation facilities closer to home put women and girls at less risk for sexual harassment while gathering water and searching for privacy</li> <li>Higher rates of child survival are a precursor to the demographic transition toward lower fertility rates; having fewer children reduces women's reproductive responsibilities</li> </ul> |
| GOAL 6: Ensure Access to Water and Sanitation for all.                                                                  | <ul style="list-style-type: none"> <li>This SDG is the focus of all efforts to improve water resources management, monitoring, conservation and protection.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| GOAL 7: Ensure Access to affordable, reliable, sustainable and modern energy.                                           | <ul style="list-style-type: none"> <li>More efficient management of water will reduce the significant energy consumption required to produce and supply water to all users.</li> <li>Increased and sustainable usage of water for the generation of energy, both in consumptive usage (boiler cooling, etc.) and non-consumptive usage (hydro-electricity).</li> </ul>                                                                                                                                                                                                                                                                                |
| GOAL 8: Promote inclusive and sustainable economic growth, employment, and decent work for all.                         | <ul style="list-style-type: none"> <li>Improved management and allocation of water resources ensures a sustainable and equitably supply of water to all stakeholders requiring water for economic growth activities.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                       |
| GOAL 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation.                    | <ul style="list-style-type: none"> <li>Forecasting the impact of climate change on water resources (quantity, quality and risk of extreme events) guides the design of resilient infrastructure.</li> <li>Improved management and allocation of water resources provides a stable input for increased industrialization.</li> </ul>                                                                                                                                                                                                                                                                                                                   |
| GOAL 10: Reduce inequality within and among countries                                                                   | <ul style="list-style-type: none"> <li>Ensuring equitable access to water to all stakeholders will reduce the risk of conflicts between all water users.</li> <li>Better identification of regions which may be at risk of declining water resources, and implementation of strategies to mitigate and adapt to this decline in available water.</li> </ul>                                                                                                                                                                                                                                                                                           |
| GOAL 11: Make cities inclusive, safe, resilient and sustainable.                                                        | <ul style="list-style-type: none"> <li>Identification of safe, resilient and sustainable water supply sources for all cities.</li> <li>Providing sustainable strategies to inform efficient usage of available water.</li> <li>Ensuring protection of water quality and reducing contamination risks from urban activities.</li> </ul>                                                                                                                                                                                                                                                                                                                |
| GOAL 12: Ensure sustainable consumption and production patterns.                                                        | <ul style="list-style-type: none"> <li>Identification of reliable and sustainable water sources for industrial and agricultural production.</li> <li>Reducing the water footprint of all production activities across the economy.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                         |
| GOAL 13: Take urgent action to combat climate change and its impacts                                                    | <ul style="list-style-type: none"> <li>Measurement of water resources trends in quality and quantity over time in relation to climate change impacts from precipitation and evaporation changes.</li> <li>Protection of water resources infrastructure from climate change impacts.</li> <li>Implementation of effective adaptation and mitigation activities to protect water resources and water usage.</li> </ul>                                                                                                                                                                                                                                  |
| GOAL 14: Conserve and sustainably use the oceans, seas, and marine resources.                                           | <ul style="list-style-type: none"> <li>Implementation of "Ridge-to-Reef" concepts to mitigate the impact of deteriorating freshwater quality discharge into the marine environment (e.g. pollutant contamination, solid waste and plastics, etc).</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                          |
| GOAL 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss. | <ul style="list-style-type: none"> <li>Protection and sustainable use of water resources is integral to the management of forests, reduction of desertification, and reversal of land degradation.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| GOAL 16: Promote just, peaceful and inclusive societies.                                                                | <ul style="list-style-type: none"> <li>Equitable access to water resources and equitable compensation for water resource usage (via Volume-Based Fee) is a crucial role in societal balance.</li> <li>Allocation of water resources</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                        |
| GOAL 17: Revitalize the global partnership for sustainable development.                                                 | <ul style="list-style-type: none"> <li>Water as a universal human requirement provides a basis for unity and partnership on the best practices for management and implementation of sustainable development.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                               |



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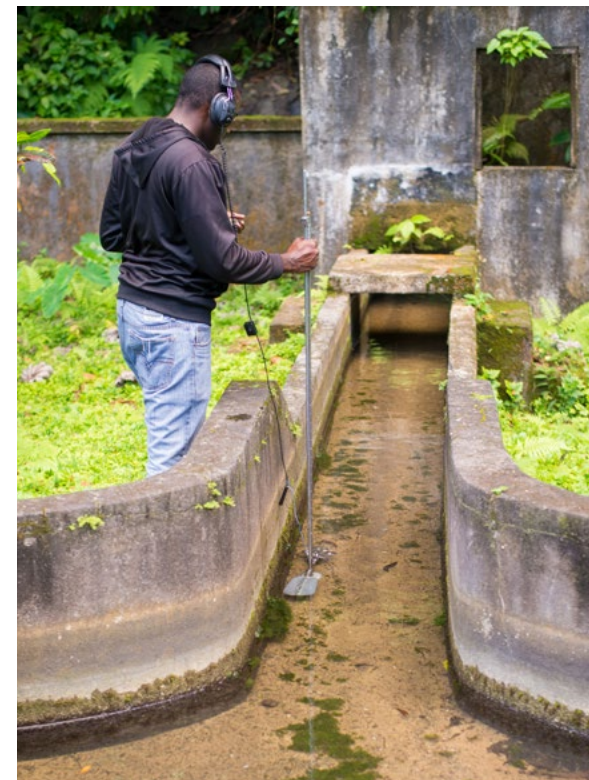
## UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE PARIS AGREEMENT.

The UNFCCC is a “Rio Convention”, one of three adopted at the “Rio Earth Summit” in 1992. Its sister Rio Conventions are the UN Convention on Biological Diversity and the Convention to Combat Desertification. The three are intrinsically linked. It is in this context that the Joint Liaison Group was set up to boost cooperation among the three Conventions, with the ultimate aim of developing synergies in their activities on issues of mutual concern. It now also incorporates the RAMSAR Convention on Wetlands. Preventing “dangerous” human interference with the climate system is the ultimate aim of the UNFCCC.

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change, which commits its Parties by setting internationally binding emission reduction targets. Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of “common but differentiated responsibilities.”

The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh, Morocco, in 2001, and are referred to as the “Marrakesh Accords.” Its first commitment period started in 2008 and ended in 2012.

The Paris Agreement builds upon the Convention and for the first time brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort. The Paris Agreement’s central aim is to strengthen the global response to the threat of climate change by keeping global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives. The Agreement



also provides for enhanced transparency of action and support through a more robust transparency framework.

## LOCAL SETTING

### VISION 2030

The overall development policy guideline for Jamaica is **Vision 2030 Jamaica- National Development Plan**. Vision 2030 Jamaica is the country’s first long-term strategic development plan, and covers the period 2009-2030. It embodies the plans and processes for the realization of a collective vision, encapsulated in the statement: **“Jamaica, the place of choice to live, work, raise families and do business.”**<sup>1</sup>

<sup>1</sup> <https://www.vision2030.gov.jm/>

There are Four National Goals for Vision 2030, and Fifteen National Outcomes linked to these goals. They are stated below:

**1. JAMAICANS ARE EMPOWERED TO ACHIEVE THEIR FULLEST POTENTIAL:**

- a. A Healthy and Stable Population
- b. World-Class Education and Training
- c. Effective Social Protection
- d. Authentic and Transformational Culture

**2. THE JAMAICAN SOCIETY IS SECURE, COHESIVE AND JUST:**

- a. Security and Safety
- b. Effective Governance

**3. JAMAICA'S ECONOMY IS PROSPEROUS:**

- a. A Stable Macroeconomy
- b. An Enabling Business Environment
- c. Strong Economic Infrastructure
- d. Energy Security and Efficiency
- e. A Technology-Enabled Society
- f. Internationally Competitive Industry Structures

**4. JAMAICA HAS A HEALTHY NATURAL ENVIRONMENT**

- a. Sustainable Management and Use of Environmental Natural Resources
- b. Hazard Risk Reduction and Adaptation to Climate Change
- c. Sustainable Urban and Rural Development

This WRDMP is directly linked to Vision 2030's Goal #4 Outcome #13, "*Sustainable Management and Use of Environmental Natural Resources.*"

## NATIONAL WATER SECTOR POLICY

The WRDMP operates under the framework of the 2019 National Water Sector Policy. The National Water Sector Policy (2019) projects the achievement of universal access to potable water by 2030, in keeping with the Government's Vision 2030 Jamaica - National Development Plan goals. The Sector Plan for Water is one of 31 sector plans that would form the foundation for the development of Jamaica 2030 - a plan designed to put Jamaica in a position to achieve developed country status by 2030. There are six (6) main principles guiding the Policy. These include:

- Sustainability and intergenerational equity;
- Efficiency;
- Integrated Water Resources Management (IWRM);
- Universal access;
- Responsiveness to gender and vulnerable groups; and
- Stakeholder participation.

Following these principles, the goal of the Policy is to ensure that Jamaica's water resources are effectively managed in order to provide for Jamaica's social, economic, and environmental well-being, now and in the future. It is a broad and comprehensive document that includes sections on urban water and sewerage, rural water and sanitation, urban drainage, and irrigation. It focuses on:

- Institutional responsibilities, and water allocation mechanisms.
- Ownership and private participation.
- Future water development and related capital expenditure to be driven by policy.

- Emphasis on water use efficiency and policies to encourage wise water use and conservation practices as mechanisms to reduce amount of water otherwise demanded.
- Shifting of national priorities from water resources development to restoration of existing resources and enhancement of water quality as means to reduce capital required.
- Systematic planning as a matter of policy, based on reliable information and a range of plausible alternatives to contain demand and reduce need for capital expenditure.
- Legislation to provide appropriate regulatory framework to protect consumers, investors and the environment in light of contemporary water problems.

**The stated objectives of the 2019 Water Sector Policy are as follows:**

1. To improve institutional arrangements for integrated water resources management.
2. To protect watershed areas, ecosystems, catchments and networks, and promote effective programmes for water conservation and protection.
3. To include research, adaptation and implementation of scientific and technological innovation to sustain ecosystems services of water.
4. To put in place the policy, programmes and physical structures for climate adaptation and energy efficiency in the water sector.
5. To allow for private sector participation in the water sector.
6. To facilitate and increase investments in the water sector.
7. To ensure economic efficiency by considering pricing and other economic incentives.

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8. To effectively manage water supply in Utility and Non-Utility Service Areas by ensuring equitable sharing of the water resources in the twenty-six (26) Watershed Management Units (WMUs).
9. To increase resilience to climatic shocks, such as drought.
10. To encourage rainwater harvesting, both as a primary source of access and as a drought management mechanism.
11. To ensure effective management of wastewater.
12. To provide sufficient water for achieving food security by improving irrigation services.
13. To ensure effective flood water control.

This Water Resources Development Master Plan will support the achievement of the stated objectives.

## EXISTING LEGISLATIVE FRAMEWORK

The management, protection, and controlled allocation and use of Jamaica's surface and underground water resources is the responsibility of the WRA – as mandated in the Water Resources Act (1995). The major activities of the WRA include hydrologic data collection, compilation, analysis, and forecasting, water resources investigation, assessment, and planning, water resources allocation, flood plain mapping, and environmental monitoring and impact assessment. There are other local policies and legislation to be considered in revising the WRDMP. These include:

- The National Water Commission (NWC) Act (1963). Section 4 (1) states the functions of NWC as follows:

- + Prepare and submit to the Minister from time to time proposals for establishment of an efficient, co-ordinated and economical water supply system capable of meeting the water needs of the country.
- + Prepare and submit for approval of the Minister details of schemes for development of water resources and the supply of water in particular areas, and to carry out such schemes when they are approved.
- + Keep under constant review the quality, reliability and availability of water supply services as a whole, and the rates charged for such services and advise the Minister on these and other matters relating to water supplies which may be referred to the Commission by the Minister.
- + Within the limits of its resources, provide and improve water supply services in the country.

- The National Irrigation Commission has implemented various Agro Parks, and has other irrigation projects planned and ongoing (e.g Black River Irrigation Project, Parnassus, Yallahs, Essex Valley, etc). The NIC would have performed an assessment of the current and potential state of the irrigated agricultural sector, the constraints and deficiencies facing the sector, and proposes policy, strategy and development plans to relieve the constraints and overcome deficiencies within the sector. The revised WRDMP will provide further context for irrigation development plans.
- The National Forest Management and Conservation Plan.

- + Part I provides background information on forest policy and law, a description of forest lands, and an overview of the forestry sector.
- + Part II presents the environmental and economic values of forests to society, together with the goals of the forestry sector, consistent with these values.
- + Part III provides recommendations for implementation, including strategies, activities, projects and budgets.
- + Linkages to the WRDMP include water production and soil conservation being recognised as some of the forest values to society. The forest protection strategy lists criteria for identifying Priority Areas for protection and Priority Watersheds.
- The National Watershed Policy. This policy's main objective is to promote the integrated protection, conservation and development of land and water resources in watersheds for their sustainable use and for the benefit of the country. It incorporates 12 guiding principles, including:
  - + Long term watershed management
  - + The design, planning and implementation of watershed management interventions,
  - + Special attention to people in watershed areas and their environment,
  - + Integral protection and production functions of land and water resources,
  - + Assessment of land use impacts and rehabilitation of damages,
  - + Compromise rather than confrontation and complimentary rather than contradictory in resolving conflicts of interest,
  - + Co-operation among agencies and the public to manage watersheds effectively,



- ◆ The Mining Act (1947). This Act defines the various categories of minerals and differentiates between minerals and construction materials, such as sand and limestone. Under the Act all minerals are vested in the State. The Quarries Control Act regulates the extraction of material such as sand, marl, gypsum and limestone for construction purpose.
- ◆ The draft 1997-1998 Corporate Plan for Ministry of Agriculture and Mining (MAM). This planning instrument includes the following national objectives for agricultural development in the country:
  - + Increase and sustain the contribution of agriculture to the general economic growth and development,
  - + Increase production and productivity,
  - + Make substantial contribution to meeting food and nutritional requirements of the population,
  - + Expand exports of agricultural commodities to increase foreign exchange earnings,
  - + Improve quality of rural life by increasing farm incomes and expanding rural infrastructure and services.
  - + Stem environmental degradation in general, and in the critical watershed areas in particular, and pursue development strategies aimed at achieving long-term conservation objectives and promoting the efficient use of natural resources.
- ◆ National Land Policy (1996). This is designed to establish the framework for efficient planning, management, development and use of land. A major issue related to the housing industry is development outside the formal regulatory and economic sectors.



It is estimated that 50-60% of new housing development occurs in this manner. This tends to occur on marginal lands such as wetlands, steep slopes and gully banks, which are unsuitable for housing or agriculture. Both formal and informal developments tend to occur on agricultural land as they tend to be flatter and hence require lower construction costs. Lands near existing cities and towns are particularly vulnerable. Some other issues are:

- + Over-intensive cultivation and misuse of steep slopes, frequently leading to accelerated soil erosion, land degradation, abandonment of farm lands, and siltation of water courses
- + The planting of crops with little regard to ecological and environmental conditions,
- + Inappropriate agricultural techniques and practices that can lead to water pollution, and the deforestation of many watersheds.
- + In recent years, public and private sector collaboration on housing development has increased.
- ◆ The National Integrated Watershed Management Council. Its focus is on issues critical to the health and survival of Jamaica's watersheds, to foster collaborative efforts in integrated watershed development and protection, and to recommend strategies and policy initiatives for long-term, sustainable integrated watershed management. Major findings and recommendations include:
  - + Need to integrate legislation among different national agencies, co-ordination of their activities,
  - + Raising of funds to assist in watershed management,

- + Preparation of a comprehensive national watershed policy document. A draft of this policy document was prepared recently.
- ◆ On environmental policy, the National Industrial Policy says that special attention to:
  - + Managed use of pesticides and fertilisers in agriculture, Forestry and watershed management,
  - + Construction of appropriate drainage systems and protected areas,
  - + Improvement of the standards for discharge of effluents.
- ◆ The Development Approval Process is implemented by NEPA to facilitate the optimal use of the nation's land resources in a manner to benefit the maximum number of persons presently and in future generations. Development is the responsibility of actors /agencies both at the local and national levels. Major actors include; the Town and Country Planning Authority, the local planning authorities mainly parish councils, the Minister with portfolio responsibility for planning and the National Environment and Planning Agency. Town Planning, Spatial Planning or Urban and Regional Planning is one of the major functional areas of the National Environment and Planning Agency's (NEPA) mandate. The WRA plays an extremely important role in the Development Approval Process by providing commentary on the developments' potential impacts on water quality from sewage disposal, providing information on available groundwater and surface water resources for the development's water demand, potential for water resource development for that development, and advising of potential flood risks and historical flooding that may impact

the development. The applications review process, plan preparation and enforcement are important aspects of this functional area of the agency's role. The National Spatial Plan, development plans, development orders and other planning documents such as the Investment Manual are critical tools to guide land use planning in Jamaica.

## WATER RESOURCES CONTRIBUTION TO JAMAICA'S ECONOMIC DEVELOPMENT

Jamaica's water resources are a crucial element of Jamaica's economic development. All sectors rely on water for their continued operation and development, from irrigation to industrial to commercial and tourism to the underlying municipal and domestic requirements. Without water, there can be no economic development for Jamaica. As of November 2019, there were 749 licensed abstraction sources with a total allocation of 2395.41 MCM/year. Figure 1 presents the sectoral distribution of the abstraction sources, while Figure 2 presents the sectoral distribution of abstraction volume. "Sources" refer to licensed abstraction sources; there may be additional abstractions that are unlicensed. The VBF classifications are:

- ◆ Domestic- for potable and municipal supply;
- ◆ Agricultural- for all consumptive agricultural and irrigation purposes;
- ◆ Industry- for all manufacturing and large-scale industrial usage
- ◆ Non-consumptive allocations- for all allocations which return the abstracted water to the natural environment or do not remove water from the environment. This includes hydro-electric and recreational allocations.

## No. of Sources

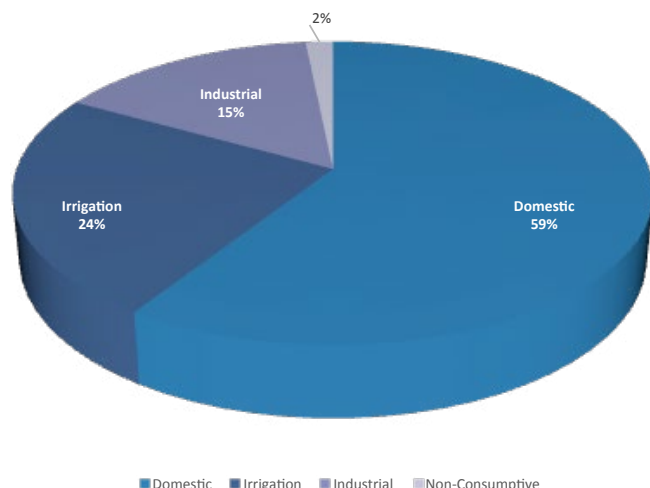


Figure 1: Distribution of Abstraction Sources by Sector

## Allocated Volume (MCM)

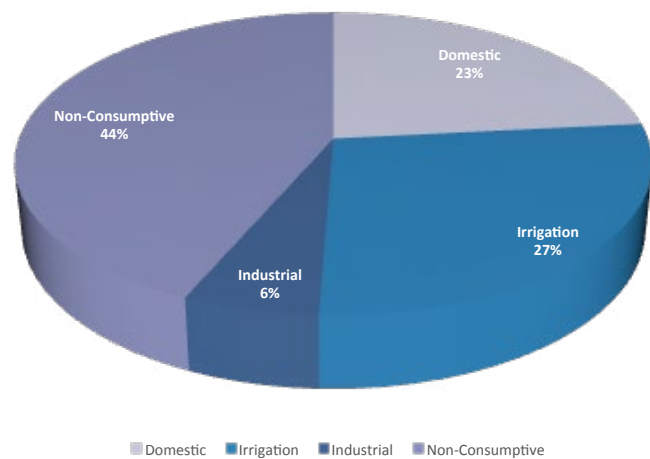


Figure 2: Distribution of Total Allocated Water by Sector

The figures reveal that while the Domestic sector has the most licensed sources by number (443), their combined allocation is only 23% of the total allocated volume of water. This reflects the localized nature of many domestic abstraction sources based on proximity to settlements, especially in NUSA areas. The non-consumptive allocation has the smallest number of sources (12), but the largest allocation of volume, reflecting the hydropower generation allocation of major rivers (e.g. Black River and Rio Bueno) and the significant flow volumes required for same. Much of this water remains available for consumptive allocation once it has flown through the turbines generating electricity. Irrigation allocation remains the largest consumptive allocation of the listed sectors.

Table 1 presents a comparison of the sectoral contributions towards Jamaica's Gross Domestic Product (GDP) with the allocated volumes of water for each sector. The comparison reveals a significant alignment with the industrial GDP contribution and industrial water allocations (when hydropower generation is included with industrial allocation) as well as with the domestic GDP and allocation. The comparison also reveals that while irrigation accounts for the most consumptive allocation (27%), it contributes only 7% of GDP.

**TABLE 1: IMPACT OF WATER ON JAMAICA'S GROSS DOMESTIC PRODUCT (SOURCE: STATIN AND WRA)**

|                                                    | DIRECT CONTRIBUTION TO GDP |     | EMPLOYMENT BY SECTOR (OCT 2019) |     | ANNUAL WATER ALLOCATION (FROM VBF FOR NOV 2019) |     |
|----------------------------------------------------|----------------------------|-----|---------------------------------|-----|-------------------------------------------------|-----|
|                                                    | (\$JMD MIL-LION)           | %   | PERSONS                         | %   | ALLOCATION (MCM/YEAR)*                          |     |
| Industrial                                         | 857,009.00                 | 42% | 549,200                         | 41% | 1,179.77                                        | 49% |
| Irrigation                                         | 133,626.00                 | 7%  | 190,500                         | 14% | 652.54                                          | 27% |
| Tourism                                            | 77,171.00                  | 4%  | 116,900                         | 9%  | 0.32                                            | 0%  |
| Domestic (Includes Commercial and Public Services) | 677,307.00                 | 33% | 488,500                         | 36% | 560.04                                          | 23% |
| Environmental                                      | *TBD                       |     |                                 |     |                                                 |     |
| <b>TOTAL</b>                                       | <b>2,025,075.00</b>        |     | <b>1,345,100</b>                |     | <b>**2,392.67</b>                               |     |

**Note:**

\* To be determined by the System of Economic Environmental Accounting compiled by STATIN.

\*\* Non-consumptive Hydropower allocation included in Industrial Usage for GDP purposes



## AGRICULTURE

Approximately 4440 km<sup>2</sup> of Jamaica's land area is classified as Agricultural land (approximately 41% of the total land area), of which 120,000 hectares is classified as Arable land (11 % of total land area). The agricultural sector underwent consecutive years of marginal declines between 2013 and 2015, due to hurricane Sandy and severe drought; however, in 2016 the sector grew by approximately 12.8%, driven by gains in Domestic Crops (17%); Poultry meat (11.5 %); Pork (38.9%); Eggs (16.2%); Coffee (28.8%); Banana (7.1%); Coconut (22.8%) and Cocoa (5.5%). In addition to better weather conditions, targeted interventions and expanding infrastructure within the sector, as well as increasing linkages with other sectors of the economy, were drivers of this resurgence within the agriculture sector. Sugar cane production has significantly declined by 26.1%. Domestic Agricultural Crops which include legumes, vegetables, fruits, condiments, cereals, plantains, potatoes, yams, other tubers and sorrel, recorded four quarters of growth (2.0 %, 13.9 %, 43.0 % and 19.2 % respectively). These contributed to an overall sub-sector growth of 17 % for the calendar year 2016. With the exception of sugar cane, most of the other traditional crops recorded growth for the calendar year. Better prices and renewed interest in coffee drove production up by 28.8%. The coconut subsector recovered from the drought of 2015 and with the production support activities by the Coconut Board, grew by 22.8 %. Banana production continues to grow reflecting a production increase of 7.1 %. Although affected by the Frosty Pod disease during the year, cocoa still managed to record an increase in production of 5.5%. Government policies are concentrated on measures to improve efficiency and competitiveness in the sector.<sup>2</sup>

## RAINFED-PLUS AGRICULTURE

Rainfed-plus agriculture includes irrigation, aquaculture and animal husbandry. There are about 25,200 hectares (6.3% of arable land area) on which water is added as a main input for production. The area that is supported without irrigation is 244,000 hectares.

## AQUACULTURE

Since the 1980's, aquaculture production has moved from being subsistence and small scale based, where 63 farmers produced approximately 32.6 tonnes per year utilizing 58 hectares of ponds, to a commercialized industry in 2006/7 where 189 farmers utilize approximately 1100 hectares to produce 8019 tonnes. However, since 2008 there has been a sharp decline in aquaculture production. Factors that contributed to this decline include high costs of energy, the absence of suitable feed inputs and limited research and development especially in the area of broodstock development. In 2013, production was estimated to be 785.5 tonnes, which is a decrease of approximately 86 percent compared to 2008. Most tilapia farms are located on the south-central plains where clay soils and an extensive system of irrigation canals installed by the sugar cane industry provide the water supply infrastructure (Hanley 2000). The total aquaculture area is estimated at 526 ha in 2001. Of this, some 90% is under tilapia farming. Of the total production of 5 000 t, 4 500 t is tilapia, approximately 150 t of Chinese carp and 150 t of *Colossoma macropomus*. It also includes 120 t of penaeid shrimp, 25 t of freshwater prawn (*Macrobrachium rosenbergii*) and a small quantity of mangrove oyster and ornamental fishes. Most of the ornamental fishes are for export to the United States. Of the other products,



<sup>2</sup> [https://tradingeconomics.com/jamaica/arable-land-percent-of-land-area-wb-data.html#:~:text=Arable%20land%20\(%25%20of%20land%20area\)%20in%20Jamaica%20was%20reported,compiled%20from%20officially%20recognized%20sources.](https://tradingeconomics.com/jamaica/arable-land-percent-of-land-area-wb-data.html#:~:text=Arable%20land%20(%25%20of%20land%20area)%20in%20Jamaica%20was%20reported,compiled%20from%20officially%20recognized%20sources.)

all except tilapia are almost exclusively for local markets. Major aquaculture enterprises are currently located in the Black River, Rio Cobre and Rio Minho Basins.

## IRRIGATION

About 1616,350 hectares (1313%) of the country's arable lands are currently irrigated. Figures 1 and 2 shows that, irrigation allocation is approximately 27% of total allocated water, and 48% of total allocated consumptive water. However, crops use only about 40% of the

irrigation water supplied. This rate is generally accepted as inefficient which suggests that there is considerable scope to improve irrigation efficiencies. The main irrigation water provider is the National Irrigation Commission (NIC) which manages all public irrigation schemes and the Black River Drainage and Irrigation Reclamation area in the Upper Morass. NIC operates over 210 km of open canals and pressurised pipelines, and 70 deep wells and pumping plants. Table 2 presents the NIC's customer base and irrigated land as presented in their 2016-2017 annual report.

**TABLE 2: NIC CUSTOMER BASE AND IRRIGATED LANDS**

| CUSTOMER STATUS | # OF CUSTOMERS | CUSTOMER % | IRRIGATED LAND AREA (HA) |
|-----------------|----------------|------------|--------------------------|
| Active          | 2,781          | 65.9%      | 8,915.91                 |
| Suspended       | 74             | 1.8%       | 279.88                   |
| Terminated      | 1,364          | 32.3%      | 7,153.91                 |
|                 | <b>4,219</b>   |            | <b>16,349.70</b>         |

Small agricultural users account for 98% of the NIC customer base, and 49% of the billed volume of water, while large agricultural users represent 0.05 % of customers and 33% of billed volume. Historically, large sugarcane and banana estates owned water supplies and managed their irrigation infrastructure. Examples include the Sugar Company of Jamaica, New Yarmouth Estates, Worthy Park, Seprod, and others. The decline in sugar and banana production has led to the discontinuation of irrigation from these sources, and some have been re-purposed to domestic usage or transferred to the NIC for usage.

A 1996 agricultural census by STATIN found that farmers attributed inadequate water supplies as their 4<sup>th</sup> largest problem with high farm input cost as the largest. It found that in 1995 the most popular methods of irrigation were overhead sprinkler (34%) and furrows (36%). The National Irrigation Development Master Plan reported that surface furrow irrigation comprised 80% of systems supplied by NIC and 70% of those supplied by private water sources, including aquaculture. Overhead sprinkler and drip irrigation systems exist in a combined 20% and 30% in NIC and privately supplied systems, respectively. The proportion of surface furrow irrigation systems is expected to decrease in favour of sprinkler and drip systems in the years to come.

## INDUSTRY

Industrial allocation of water is approximately 1,180 billion cubic metres of water per year, which is divided into 141.81 MCM of consumptive usage, and 1,038.18 MCM of non-consumptive usage for hydroelectric generation processes. The consumptive use is much less than that used for domestic or agricultural purposes; however, it is projected to increase based on the increased demand for construction materials, and a targeting emphasis on increased production of bauxite and alumina. Additionally, projected increases in food processing and beverage manufacture will lead to increased demand in the processing locations. This will be further covered in the Demand Inventory.

## TOURISM

The tourism sector plays an important role in the Jamaican economy accounting for 6.4% of gross domestic product (GDP) in 2021. In 2014, about 7.1% of the workforce was employed in the hotels and restaurants industry alone. This represented an increase from the previous year's rate of 6.8% (PIOJ 2015) and is reflective of the general trend in growth of the tourism sector. Jamaica has experienced a steady growth in the number of tourist arrivals over the last decade with total visitor arrivals increasing by 25% within five years, from 2.8 million in 2010 to 3.5



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million in 2014. Over this period, the sector's foreign exchange earnings grew by about 12% from US\$2 billion to US\$2.24 billion (PIOJ 2015). Due to its linkages with other sectors of the economy, the tourism sector has the potential to propel economic growth, especially in the agricultural, manufacturing, and entertainment sectors.<sup>3</sup>

In 2018, Jamaica counted over 23.6 thousand hotel rooms available, which showed a 4.7 percent growth in comparison to the number registered a year earlier. From 2010 to 2018, Montego Bay was the main spot for tourism accommodation availability. In that last year, Montego Bay registered 9,277 hotel rooms, equivalent to 39.3 percent of the total. Ocho Ríos, however, was the area with highest room occupancy in the Caribbean country in 2018, with 70 percent, ahead of Montego Bay.

The number of international tourist arrivals to Jamaica maintained an overall constant increase from 2009 to 2018. Foreign visitor arrivals reached the 4.3 million mark in that last year, surpassing the total population of the island by almost 1.4 million people. Overnight tourism accounted for 57.2 percent of the total inbound arrivals, while the influx of same-day visitors, only counting cruise passengers, represented the remaining 42.8 percent.

Jamaica registered a drop of 13.8 percent in the number of cruise ship calls in 2019 with respect to the previous year, when the country recorded the largest number of cruises served at its ports since 2013. However, this meant a decline of only 3.8 percent in the number of cruise passenger arrivals to the island, which between 2010 and 2017 surged by nearly 111 percent.<sup>4</sup>

The Tourism Product Development Company (TPDCO) inspects and monitors the standards of entities in the industry, and grants licenses on behalf of the Jamaica Tourist Board (JTB). A major international environmental initiative being adopted by the tourism sector is the Green Globe Certification program. This program aims to promote sound environmental practices in the sector, including water conservation, energy management, waste management, and control of hazardous substances. All of these components will have an impact on the water sector in terms of conserving water, encouraging recycling and reuse, and reducing the contamination of freshwater.

## RECREATION

The major recreational uses of water include tubing, rafting, swimming, kayaking and scenic observation. These primarily support the tourist industry and are concentrated along the north coast. There were 134 attractions registered with the Tourist Board as of February 2021. The contribution of this sub-sector to GDP is not quantified. Some of the major water-based attractions are listed in Table 3.

The recreational sites that require freshwater are located on rivers and require a defined minimum stream flow to remain viable and attractive. This flow is closely related to the environmental flow which is the water needed for sustainable maintenance of ecosystem services. Conservation of the environmental flow is therefore of great benefit to the Jamaican society in general and specifically to the high-earning tourist industry.



<sup>3</sup> <https://micaf.gov.jm/sites/default/files/pdfs/TourismDemandv3.pdf>

<sup>4</sup> <https://www.statista.com/statistics/375863/number-of-hotel-rooms-in-jamaica-by-resort/>

**TABLE 3: WATER-BASED ATTRACTIONS IN JAMAICA (NOT EXHAUSTIVE)**

| ACTIVITY               | ATTRACTION NAME                      | LOCATION               |               |     |
|------------------------|--------------------------------------|------------------------|---------------|-----|
|                        |                                      | RIVER CATCHMENT        | PARISH        | WMU |
| RAFTING AND TUBING     | White River                          | White River            | St. Ann       | 6   |
|                        | Great River                          | Great River            | St. James     | 3   |
|                        | Martha Brae                          | Martha Brae            | Trelawny      | 5   |
|                        | Cabarita                             | Cabarita               | Westmoreland  | 25  |
|                        | Rio Grande                           | Rio Grande             | Portland      | 13  |
| WATERFALLS             | Dunns River                          | Dunns River            | St. Ann       | 6   |
|                        | YS                                   | YS                     | St. Elizabeth | 23  |
|                        | The River Walk                       | Mayfield               | Westmoreland  | 25  |
|                        | Reich                                | Priestman's River      | Portland      | 14  |
|                        | Somerset                             | Somerset               | Portland      | 11  |
|                        | Konoko Falls (formerly Coyaba Falls) | Milford Stream         | St. Ann       | 6   |
|                        | Cane                                 | Cane                   | St. Andrew    | 18  |
|                        | Rozelle                              | White Horses           | St. Thomas    | 16  |
| TROPICAL GARDENS       | Shaw Park                            | Turtle River           | St. Ann       | 6   |
|                        | Cranbrook Flower Forest              | Laughlands Great River | St. Ann       | 6   |
|                        | Boon Hall Oasis                      | Wagwater River         | St. Andrew    | 9   |
| BOATING TOURS          | Black River Safari                   | Black River            | St. Elizabeth | 23  |
|                        | Glistening Waters                    | Martha Brae River      | Trelawny      | 5   |
| MINERAL BATHS AND SPAS | Salt River                           | Salt                   | Clarendon     | 20  |
|                        | Milk River                           | Milk                   | Clarendon     | 21  |
|                        | Bath                                 | Plantain Garden River  | St. Thomas    | 16  |
|                        | Rockfort                             | Hope River             | St. Andrew    | 18  |
|                        | Black River                          | Black River            | St. Elizabeth | 23  |
|                        | Windsor Spring (Fiyah Wata)          | St. Anns Great River   | St. Ann       | 6   |

## HOUSING DEVELOPMENT

Domestic/municipal water accounts for 23% of total water allocation and 41% of consumptive water allocation. This water demand is expected to increase because of the government's goal to provide adequate shelter for all by 2025. This will be guided by policies for Land and Settlement and a Programme for Resettlement. The Ministry of Economic Growth and Job Creation plans to continue housing developments through the National Housing Trust (NHT) and Housing Agency of Jamaica (HAJ) as well as facilitating developments from the Private Sector via the Development Approval Process. Major developments completed thus far are on former agricultural lands in St. Catherine, such as Jacaranda, Caribbean Estates, Sydenham, and many others.

## IMPACTS OF DEVELOPMENTS ON WATER QUALITY

The developments discussed above will not only impact the quantity but also the quality of the water resources. Some of these sector impacts are as follows:

- ◆ **Mining and Processing Sector.** Bauxite-alumina operations has the most severe impact. A caustic red mud suspension containing bauxite residue is produced at (4) plants across the island, after extraction of the alumina. This waste has seriously contaminated groundwater at some locations (e.g. Nain in St. Elizabeth, and Ewarton in St. Catherine) via the very high concentrations of sodium and hydroxide ions, and the presence of iron oxide and organic substances which yield an unpleasant odour on decomposition. There have been reports



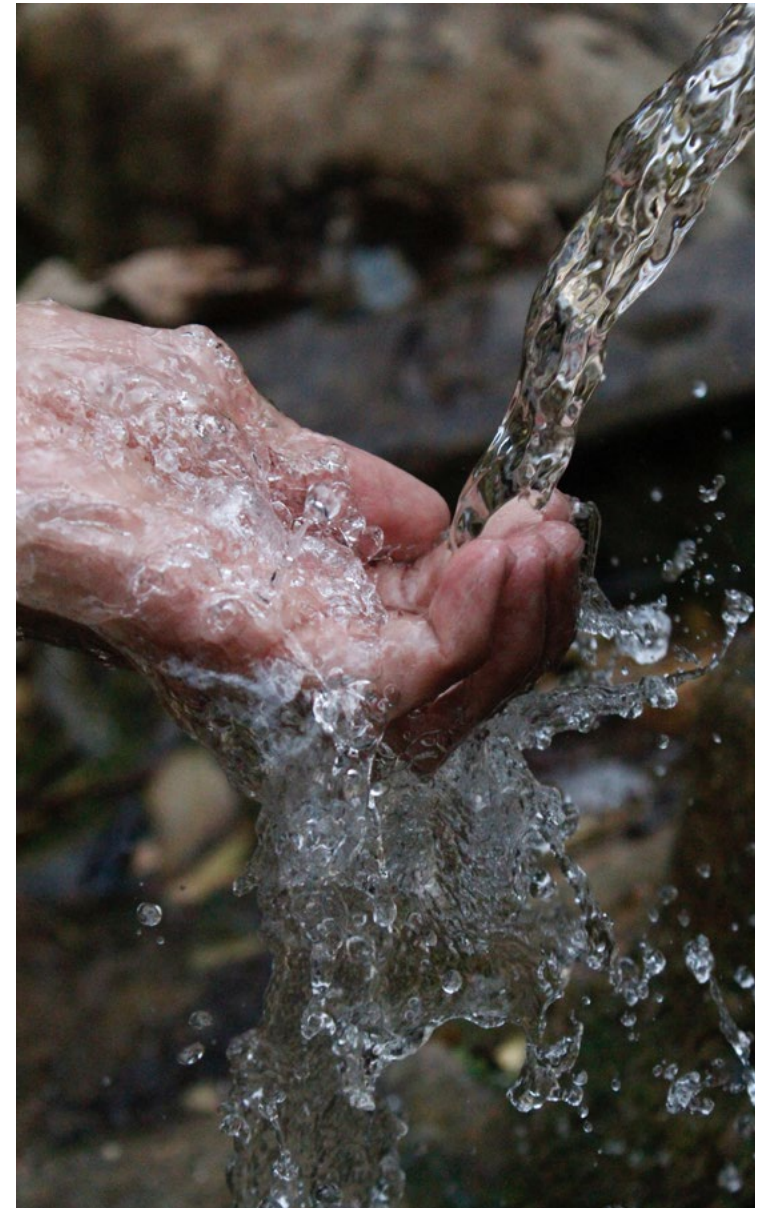
of the Ministry of Health closing a number of springs in the Upper Rio Cobre Sub-WMU which supplied drinking water to communities near bauxite processing waste disposal lagoons (Fernandez, 2002).

- ♦ Residential (Housing Sector). There are many parts of the country with inadequate waste disposal or septic systems. Therefore wastewater, containing large amounts of coliform and other pathogens, may end up in surface water and springs, and also in the deeper groundwater. The karstic geology can favour the easy percolation of such contaminants.
- ♦ Agricultural Sector. There is some movement of sediment, nutrients and pesticides with irrigation water, and this could contaminate both surface and ground waters. The same process can occur in the food and beverage processing sector. Distillery and sugar cane processing wastes have the potential to be major contaminants if not treated properly prior to disposal.
- ♦ Recreational Sector. The potential for contamination from unregulated recreational sites (e.g. on the White River, St. Ann/St. Mary) is a significant concern. Most of this contamination may come from improper sewage and solid waste disposal, as well as lack of treatment of the recreational water pre- and post-contact with recreational activity.

## PROJECTED GROWTH

According to the Government of Jamaica's Fiscal Policy Paper 2019-2020, economic growth of 2.5% is projected. Growth is projected for all industries and is expected to be driven by higher external and domestic demand and stronger linkages between industries. This will be supported by efficiency gains from investments in increased capacity, as well as the completion of major infrastructure projects. Agriculture, Forestry & Fishing is projected to grow by 8.0% due to increased output of all crop types following the completion of the ESSEX valley irrigation project in 2021, in addition to the impact of other climate smart technology used to strengthen resilience and increase output. Mining & Quarrying is projected to grow by 6.3% as continued growth in global demand for aluminium is expected to drive increased capacity utilization at all plants. Hotels & Restaurants is projected to grow by 5.0% as the industry is expected to benefit from product diversification, which is expected to lead to further increases in visitor arrivals.

This projected economic growth will lead to increased water demand and this will be reconciled with the availability of water to inform the plans and strategies to support the proposed economic growth. All factors of economic growth and development should take into consideration the amount of water that would be required for said development, and the efficient use and re-use of water should be incorporated into all development processes and projections from the beginning. This will be discussed further in chapter 7.



# Physical Setting

## GEOGRAPHIC SETTING

Jamaica is an archipelagic state located in the northwest Caribbean Sea, and is centred at latitude 18°15' N and longitude 77°20' W. The main island is elongated along a WNW - ESE alignment with a maximum length of 230 km, a maximum width of 80 km and an area of approximately 10,991 km<sup>2</sup>. Its physiography is dominated by a series of generally WNW - ESE trending mountain ranges that, in the east, averages over 1,000 m above sea level elevation and 2,257 m at the highest peak. The central mountain range acts as a divide from which the drainage system generally flow north and south. To the west, there are major alluvial lowlands often associated with coastal morass (swamps).

## HYDROLOGICAL SUBDIVISIONS: BASINS AND WATERSHED MANAGEMENT UNITS

Jamaica is divided into 10 Hydrologic basins. A basin is a geographical area drained by a particular surface water system, with boundaries demarcated such that there is generally no surface water flow from one basin to another. The 1990 WRDMP used these 10 basins as the basic hydrologic unit for resource and demand assessment. The 1990 WRDMP also stated that while the basin boundaries were mainly surface water divides, groundwater divides were used for basin division in certain cases, particular in karstic regions. This was the case in the western basins (Black River, Cabarita River, Great River, and Martha Brae Basins). Furthermore, the 1990 WRDMP also stated that for planning purposes, it was found convenient to subdivide the basins into sub-basins, defined as discrete hydrologic sub-units of a basin, the water resources of which could be assessed, developed and managed in a near-independent manner from the rest of the basin. According to the 1990 WRDMP, discharge can take place from one sub-basin to another within the same basin, via a surface channel or groundwater flow path. These 10 basins are

comprised of various watersheds. The standard definition of a watershed according to FEMA is "An area from which water drains to a single point in a natural basin...the area contributing flow to a given place or stream." In 1994, the Watershed Inventory and Prioritization Report prepared by Underground Water Authority under the UNDP funded Hydrologic Support Unit Project (HSUP) noted that there are over 100 watersheds in Jamaica based on the standard definition, and that most of these watersheds are seasonal, small in size, and relatively insignificant from a resource management perspective. Furthermore, the movement of surface water that sinks underground in karstic regions became uncertain, causing more difficulty in delineating those boundaries. As such, the HSUP recommended that some watersheds be grouped, and the final set of the grouped and other watersheds be renamed "Watershed Management Units" or WMUs. The total list of WMUs after grouping and analysis comprised of 26 WMUs, with some WMUs being equal to an entire basin (e.g. Black River, Rio Cobre, Rio



Bueno-White River/Dry Harbour Basin, Martha Brae). These 26 WMUs were the basis for the initial 2005 WRDMP update. The concept of sub-basins and inter-flow flow still applies to the WMUs, and these WMUs were further subdivided into sub-WMUs for consideration in the revision of the 2005 update. However, this subdivision requires more analysis of watershed boundaries and available water resources data to accurately estimate the resource availability at that scale. As such, the 26 WMU boundaries remain the basis for this WRMDP assessment. Future refinement of the watershed boundaries is planned for future updates of this master plan, including the use of artificial dye tracers and isotope hydrological tracing techniques to assess the origin and flow patterns of groundwater and underground rivers in karstic regions. This may result in an increase in the numbers of WMUs. Figure 3 presents the hydrologic basins and WMUs of Jamaica.



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## Hydrological Basins and Watershed Management Units (WMUs) of Jamaica

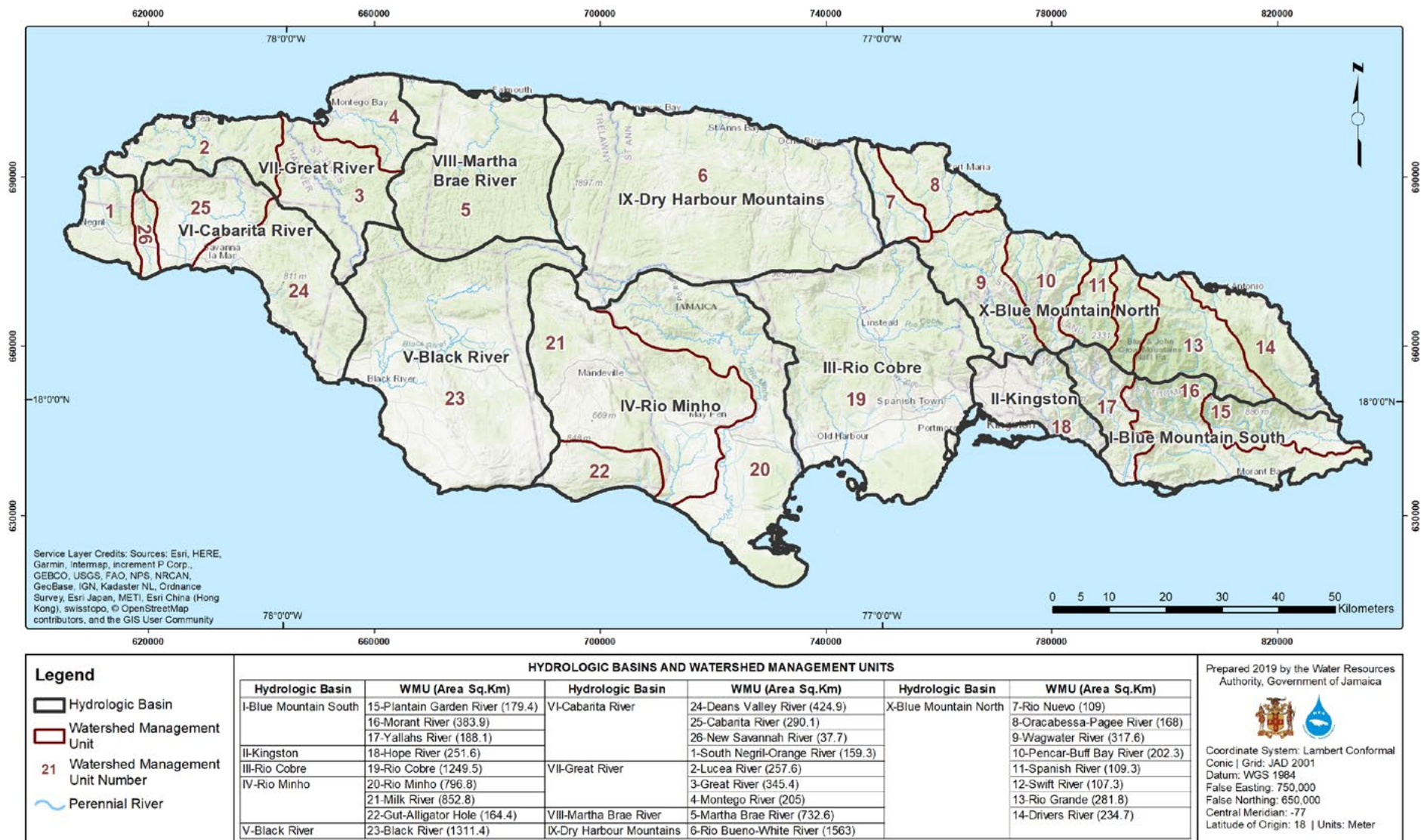


Figure 3: Hydrological Basins and Watershed Management Units (WMUs) of Jamaica

## GEOLOGY

Figure 4 presents the geology and geological structure of Jamaica.

### STRATIGRAPHY

The main elements of the stratigraphy, in chronologic sequence are:

- ◆ Tertiary (Upper Miocene) to Recent Sedimentary Deposits: They comprise:
  - + Alluvium. This occurs mainly in the southern lowlands, and may be greater than 300 metres in thickness in certain locations.
  - + Coastal Deposits. These are mainly reef and reefal deposits which outcrop mainly along the North Coast.
- ◆ Tertiary (Lower Miocene to Paleocene) Sedimentary Series
  - + White Limestone Group (Mid Eocene – Lower Miocene). This comprises deep and shallow water facies. Formations represented include the Montpelier and Bonnygate for the deep water facies and Newport, Walderston, Troy, Claremont and Somerset for the shallow water facies. White limestones comprise about 60% of surface exposures in Jamaica. The sequence thickens seaward southernly and northerly. Thickness is over 700 m in places (UWA: 1990).
  - + Yellow Limestone Group (Mid Eocene). They comprise limestone and non-limestone deposits. The limestone is represented by the Font Hill Formation and non-limestone by the Chapleton Formation.



- + Wagwater Group (Lower Eocene to Paleocene). They are heterogeneous clastics – the Wagwater and Richmond Formations. They include important limestone and intrusive members.
- ◆ Cretaceous Volcanoclastic Complex: These comprise mainly volcanoclastics – with some volcanics (mainly basaltic), some intrusives (mainly granodioritic) and important fossiliferous limestone members. They outcrop in inliers – mainly along the central rib of the country. The inliers are of major hydrologic importance and are the sources of many perennial springs.

### STRUCTURE

The structure is dominated by extensive faulting and fracturing as well as well-developed karst limestone features. In areas where the latter dominates, secondary permeability is usually well developed, especially in fault zones. Structurally, the country is divisible into (3) main blocks that are defined by major faults. They are:

- ◆ **Eastern (Blue Mountain) Block.** The central feature is the Blue Mountain Cretaceous Inlier that is fringed by younger sedimentary rocks. Its western extent is marked by the Wagwater Fault System, which runs from Yallahs River to Rio Nuevo. The topography is dominated by the Blue and John Crow Mountains.
- ◆ **Central Block.** The dominant features of this block are the well-developed karstic limestones along with several Cretaceous Inliers. Streams flow to the north and south from the central rib formed by inliers. It is bounded to the east by the Wagwater Fault, and to the west by a fault system running from the Great River and YS River catchments. Features of the karst include interior valleys with high flooding vulnerability, underground rivers, dry valleys with seasonal rivers, and collapse features that have been noted to occur during intense rain events. The direction of groundwater flow is difficult to determine by conventional mapping methods. Flow contributions to White River from the Moneague area have been implied by groundwater monitoring of



sodium contamination from the Rio Tinto/ Mount Rosser Red Mud Lake (Fernandez: 1973), and flow contributions to Rio Bueno from Cave River, Lowe River and Quashie River have been confirmed by dye tracing [Smith and Smart: 1976, WRA 2019]. Further investigations from dye tracing and isotope hydrology are under way. The Central Block can be further sub-divided as follows:

- + **North Central Coastal Block.** The dominant features of this block are limestones, along with the St. Anns Great River Inlier. The Montpelier Limestone forms a barrier to northern groundwater flow, and the block is characterised by numerous springs rising along the barrier contact. There is also significant submarine discharge along the coastline of this block, most notably around Discovery Bay [Gordon-Smith, et. Al, 2019]. The block is bounded by E-W Duanvale Fault System to its south.
- + **South Central Coastal Block.** This block is bounded by the E-W South Coast Fault to the south, and is dominated by alluvium. It forms a barrier to southern groundwater flow from the Central Block. The Cockpit Spring and Ferry Spring systems form the outflows at the block's distal ends.
- **Western Block.** The central feature is the Hanover Inlier which is exposed along the central rib of the block. It is bounded by a fault system that runs from Great River to YS River catchments. The topography is dominated by high elevation in the Dolphin Head Mountains. Fringing the Cretaceous rocks are sedimentary rocks of younger age.



## Geology of Jamaica

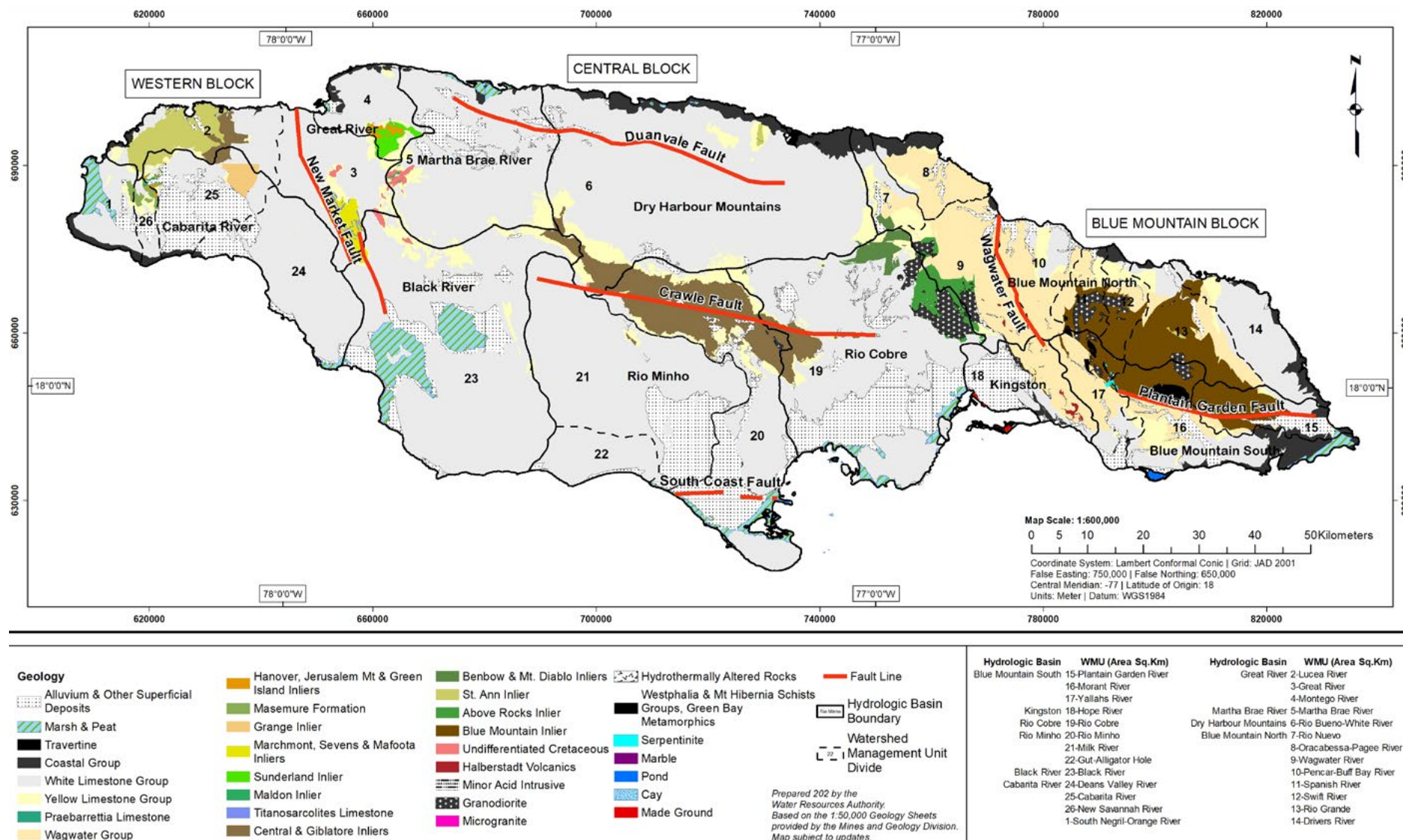


Figure 4: Geology of Jamaica



## HYDROSTRATIGRAPHY

Table 4 and Figure 5 present the general hydrostratigraphy of Jamaica based on classification of the underlying geology. The geological formations are classified as **aquifers** and **aquicludes** based on the impact of their intrinsic and structural properties on their ability or lack thereof to transmit and store water. **Wetlands** are classified separately from aquifers and aquicludes. Figures 6 through 15 displays the specific hydrostratigraphy for the 10 hydrologic basins of Jamaica.

### AQUIFERS

An aquifer is a geological formation capable of storing, transmitting and yielding exploitable quantities of water. This capability is due to the formation's **permeability**, which may be **primary** (due to the porosity and connectivity of pores) or **secondary** (due to the cracks, faults, joints and similar conduit features within the formation) in nature. Aquifers make up approximately 57% of Jamaica's land area. The major aquifer types in Jamaica are listed below:

- ◆ **Limestone aquifer**, comprised of the White Limestone Group, excluding the Montpelier Limestone. Limestone aquifers comprise approximately 50% of Jamaica's total land area. Normally, limestone has low primary permeability which would imply a poor aquifer. However, in Jamaica, limestones are often highly karstified, with extensive secondary permeability. Groundwater movement in such areas are characterised by high velocity, compartmentalised (conduit) flow. Water enters underground through channels connected to sinkholes and often extensive cave systems. When the limestone is in continuity with the sea, there may be significant intrusion of salt water with over-abstraction or reduction in available fresh water.
- ◆ **Alluvium aquifer**, comprised of Quaternary Alluvium formations with a sand/gravel nature. About 6% of Jamaica's total land area comprises alluvial aquifers. The historical assumption is that there is usually no hydraulic connection between the limestone and alluvial aquifers; however, recent isotope studies of the Liguanea Aquifer in Kingston seem to indicate that there is contribution of groundwater flow from the limestone aquifer to the alluvium aquifer in certain regions (NWC, IAEA 2018). Further study is required to verify the situation. The majority of alluvium aquifers are located in the plains area of the Rio Cobre and Rio Minho (south central) and Liguanea and Yallahs (south eastern) basins, with scattered deposits around major rivers (e.g. Rio Grande, Wag Water, etc). Alluvium aquifer thickness varies with location, from lenses less than 30 m thick in riverine locations to over 300 m thickness in the Liguanea Alluvium.
- ◆ **Coastal aquifers**, comprised of raised reefs of the Falmouth Formation and contributes approximately 0.35% of Jamaica's total land area. This aquifer occurs mainly on the north and north-western coast, and is expected to reflect a strong influence from the sea. It is most important in areas where there are no other aquifer sources.

*"Aquifers (limestone, alluvium and coastal) comprise approximately 57% of Jamaica's total land area."*

### AQUICLUDES

An aquiclude is a geologic units that is incapable of transmitting significant quantities of water under ordinary hydraulic gradients. Water resources in aquiclude regions are usually streams and springs maintained by precipitation stored within the overlying soil. However, in certain regions with significant faulting and secondary permeability, there may be possibilities of drilling a moderately productive well for groundwater abstraction (e.g. Limestone Aquiclude). Aquicludes make up approximately 41% of Jamaica's total area.

- ◆ **Alluvium Aquiclude** covers about 6.5% of Jamaica's total area. These are comprised of alluvial deposits dominated by clays and other fine-grained material. These are prevalent in the alluvial plains of the Cabarita, Rio Minho and Rio Cobre Hydrologic Basins, and usually confine the underlying Limestone Aquifer.
- ◆ **Coastal Aquiclude** covers approximately 2.76 % of Jamaica's total area. It is comprised of the Coastal Limestone Group (excluding the Falmouth Formation), and forms a fringe on the north coast. This formation acts as a barrier that ponds water in the limestone aquifer.
- ◆ **Limestone Aquiclude** covers 6.25 % of Jamaica's total area. It is comprised of the Montpelier Formation, a member of the White Limestone Group. Karstification has not been as significant in this formation as in the other White Limestone members. It

occurs mainly as coastal belts in the northern part of the Island with minor exposures in the eastern and western parts. Faulting has served to generate zones of increased permeability in this formation, which may provide moderate yield of water to wells drilled in these zones.

- ◆ **Basal Aquiclude** covers approximately 25% of Jamaica's total area. It is comprised by the Cretaceous Volcanics, Volcaniclastics, and Yellow Limestone Group formations. Basal Aquiclude usually occurs in the inliers which are generally fringed by the White Limestone. Regions of basal aquiclude exposures are usually characterized by a dense network of streams.

## WETLANDS

Wetland deposits found in association with the Black River Morass (Black River Basin), Negril Morass (Cabarita River Basin) and other occurrences in the Rio Minho, Rio Cobre, Martha Brae and Blue Mountain South Basins are classified within this group. It covers approximately 2.4% of Jamaica's total area. Water resources in this region tend to be brackish and have a high organic content due to the wetland nature. These regions are ecologically sensitive, and are generally protected from any form of intense development or exploitation.





**TABLE 4: HYDROSTRATIGRAPHIC UNITS AND WATERSHED MANAGEMENT UNITS IN JAMAICA**

| BASIN                 | WMU                               | AQUIFER                  |                         |                           |                        | AQUICLUDE                |                       |                         |
|-----------------------|-----------------------------------|--------------------------|-------------------------|---------------------------|------------------------|--------------------------|-----------------------|-------------------------|
|                       |                                   | ALLUVIUM KM <sup>2</sup> | COASTAL KM <sup>2</sup> | LIMESTONE KM <sup>2</sup> | AQUIFER SUB-TOTAL AREA | ALLUVIUM KM <sup>2</sup> | BASAL KM <sup>2</sup> | COASTAL KM <sup>2</sup> |
| BLUE MOUNTAIN SOUTH   | Plantain Garden                   | 32.16                    |                         | 15.58                     | 47.74                  |                          | 110.30                | 14.77                   |
|                       | Morant River                      | 40.08                    |                         | 68.14                     | 108.22                 |                          | 182.62                | 43.95                   |
|                       | Yallahs River                     | 19.57                    |                         | 25.56                     | 45.12                  |                          | 138.41                | 1.46                    |
| KINGSTON              | Hope River                        | 100.59                   |                         | 43.41                     | 144.00                 | 0.05                     | 98.98                 | 5.65                    |
| RIO COBRE             | Rio Cobre                         | 124.12                   |                         | 703.78                    | 827.90                 | 176.54                   | 211.63                |                         |
| RIO MINHO             | Rio Minho                         | 65.02                    | 0.01                    | 260.73                    | 325.76                 | 115.09                   | 319.30                | 0.78                    |
|                       | Milk River                        | 56.27                    |                         | 678.29                    | 734.56                 | 106.28                   | 10.72                 |                         |
|                       | Gut River-Alligator Hole          | 3.03                     |                         | 155.39                    | 158.43                 | 5.93                     |                       |                         |
| BLACK RIVER           | Black River                       | 66.53                    |                         | 935.96                    | 1002.49                | 80.19                    | 93.32                 | 1.91                    |
| CABARITA RIVER        | Deans Valley River                | 20.77                    |                         | 355.06                    | 375.82                 | 40.10                    |                       | 4.72                    |
|                       | Cabarita River                    | 44.61                    | 0.01                    | 80.32                     | 124.94                 | 99.65                    | 49.70                 | 4.53                    |
|                       | New Savannah River                | 1.01                     |                         | 1.21                      | 2.22                   | 13.28                    | 16.60                 | 4.38                    |
|                       | South Negril-Orange River         | 3.81                     |                         | 89.74                     | 93.55                  | 9.05                     | 8.94                  | 20.67                   |
| GREAT RIVER           | Lucea River                       | 2.44                     | 0.58                    | 96.97                     | 99.98                  | 3.00                     | 134.80                | 10.54                   |
|                       | Great River                       |                          | 0.55                    | 210.24                    | 210.79                 |                          | 85.75                 |                         |
|                       | Montego River                     | 2.79                     | 0.73                    | 45.10                     | 48.62                  | 3.40                     | 53.19                 | 15.37                   |
| MARTHA BRAE           | Martha Brae                       | 27.59                    | 7.72                    | 407.63                    | 442.94                 | 46.79                    | 56.58                 | 4.17                    |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River             | 10.19                    | 28.25                   | 1079.07                   | 1117.51                | 12.97                    | 151.81                | 75.82                   |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                         | 1.50                     |                         | 10.22                     | 11.72                  | 0.32                     | 72.23                 | 14.35                   |
|                       | Oracabessa-Pagee                  | 9.68                     |                         | 3.02                      | 12.70                  | 0.85                     | 119.87                | 30.95                   |
|                       | Wagwater River                    | 15.73                    |                         | 7.97                      | 23.69                  |                          | 291.06                | 2.88                    |
|                       | Pencar River-Buff Bay             | 23.43                    |                         | 39.93                     | 63.36                  |                          | 137.89                | 0.50                    |
|                       | Spanish River                     | 3.01                     |                         | 18.56                     | 21.57                  |                          | 83.82                 | 3.04                    |
|                       | Swift River                       | 3.66                     |                         | 13.38                     | 17.03                  |                          | 80.64                 | 7.69                    |
|                       | Rio Grande                        | 8.42                     |                         | 36.23                     | 44.65                  |                          | 227.51                | 3.22                    |
|                       | Drivers River                     | 2.35                     |                         | 95.23                     | 97.57                  |                          | 21.06                 | 30.66                   |
| TOTAL AREA            | TOTAL UNIT AREA IN ISLAND (SQ KM) | 688.35                   | 37.83                   | 5476.71                   | 6202.89                | 713.48                   | 2756.74               | 302.01                  |
|                       | PERCENT OF ISLAND TOTAL AREA      | 6.30%                    | 0.35%                   | 50.14%                    | 56.79%                 | 6.53%                    | 25.24%                | 2.76%                   |



|  |                           |                          | WETLANDS          |              |                         | WMU TOTAL AREA |                                   | BASIN TOTAL AREA |                                             |
|--|---------------------------|--------------------------|-------------------|--------------|-------------------------|----------------|-----------------------------------|------------------|---------------------------------------------|
|  | LIMESTONE KM <sup>2</sup> | AQUICLUDE SUB-TOTAL AREA | SWAMP/ MARSH-LAND | WATER BODY   | WETLANDS SUB-TOTAL AREA | WMU TOTAL AREA | WMU AREA PERCENTAGE OF BASIN AREA | BASIN TOTAL AREA | BASIN PERCENT-AGE AREA OF TOTAL ISLAND AREA |
|  | 5.37                      | 130.45                   | 1.17              |              | 1.17                    | 179.35         | 23.9%                             | 751.37           | 6.88%                                       |
|  | 35.82                     | 262.39                   | 13.32             | 0.00         | 13.32                   | 383.93         | 51.1%                             |                  |                                             |
|  | 3.10                      | 142.97                   |                   |              | 0.00                    | 188.09         | 25.0%                             |                  |                                             |
|  | 1.77                      | 106.44                   | 1.10              | 0.10         | 1.20                    | 251.63         |                                   | 251.63           | 2.30%                                       |
|  |                           | 388.16                   | 32.97             | 0.48         | 33.45                   | 1249.51        |                                   | 1249.51          | 11.44%                                      |
|  |                           | 435.17                   | 35.90             | 0.00         | 35.90                   | 796.82         | 43.9%                             | 1814.02          | 16.61%                                      |
|  |                           | 117.00                   | 1.22              |              | 1.22                    | 852.78         | 47.0%                             |                  |                                             |
|  |                           | 5.93                     | 0.06              |              | 0.06                    | 164.42         | 9.1%                              |                  |                                             |
|  |                           | 175.42                   | 131.82            | 1.64         | 133.46                  | 1311.37        |                                   | 1311.37          | 12.01%                                      |
|  | 0.02                      | 44.84                    | 4.23              |              | 4.23                    | 424.90         | 46.6%                             | 911.93           | 8.35%                                       |
|  | 11.27                     | 165.15                   | 0.01              |              | 0.00                    | 290.09         | 31.8%                             |                  |                                             |
|  | 1.21                      | 35.46                    |                   |              | 0.00                    | 37.67          | 4.1%                              |                  |                                             |
|  |                           | 38.66                    | 27.06             |              | 27.06                   | 159.27         | 17.5%                             |                  |                                             |
|  | 9.23                      | 157.57                   |                   |              | 0.00                    | 257.55         | 31.9%                             | 807.95           | 7.40%                                       |
|  | 48.83                     | 134.58                   |                   |              | 0.00                    | 345.37         | 42.7%                             |                  |                                             |
|  | 81.45                     | 153.41                   | 3.00              |              | 3.00                    | 205.03         | 25.4%                             |                  |                                             |
|  | 170.61                    | 278.16                   | 11.48             |              | 11.48                   | 732.58         |                                   | 732.58           | 6.71%                                       |
|  | 204.34                    | 444.94                   | 0.54              |              | 0.54                    | 1562.99        |                                   | 1562.99          | 14.31%                                      |
|  | 10.38                     | 97.28                    |                   |              | 0.00                    | 109.00         | 7.1%                              | 1530.05          | 14.01%                                      |
|  | 3.66                      | 155.33                   |                   |              | 0.00                    | 168.03         | 11.0%                             |                  |                                             |
|  |                           | 293.94                   |                   |              | 0.00                    | 317.63         | 20.8%                             |                  |                                             |
|  | 0.51                      | 138.90                   |                   |              | 0.00                    | 202.26         | 13.2%                             |                  |                                             |
|  | 0.90                      | 87.76                    |                   |              | 0.00                    | 109.33         | 7.1%                              |                  |                                             |
|  | 1.89                      | 90.22                    |                   |              | 0.00                    | 107.25         | 7.0%                              |                  |                                             |
|  | 6.45                      | 237.18                   |                   |              | 0.00                    | 281.84         | 18.4%                             |                  |                                             |
|  | 85.42                     | 137.14                   |                   |              | 0.00                    | 234.71         | 15.3%                             |                  |                                             |
|  | <b>682.22</b>             | <b>4454.44</b>           | <b>263.86</b>     | <b>2.23</b>  | <b>266.09</b>           |                |                                   | <b>10923.42</b>  |                                             |
|  | <b>6.25%</b>              | <b>40.78%</b>            | <b>2.42%</b>      | <b>0.02%</b> | <b>2.44%</b>            |                |                                   | <b>100.00%</b>   |                                             |



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## Hydrostratigraphy of Jamaica

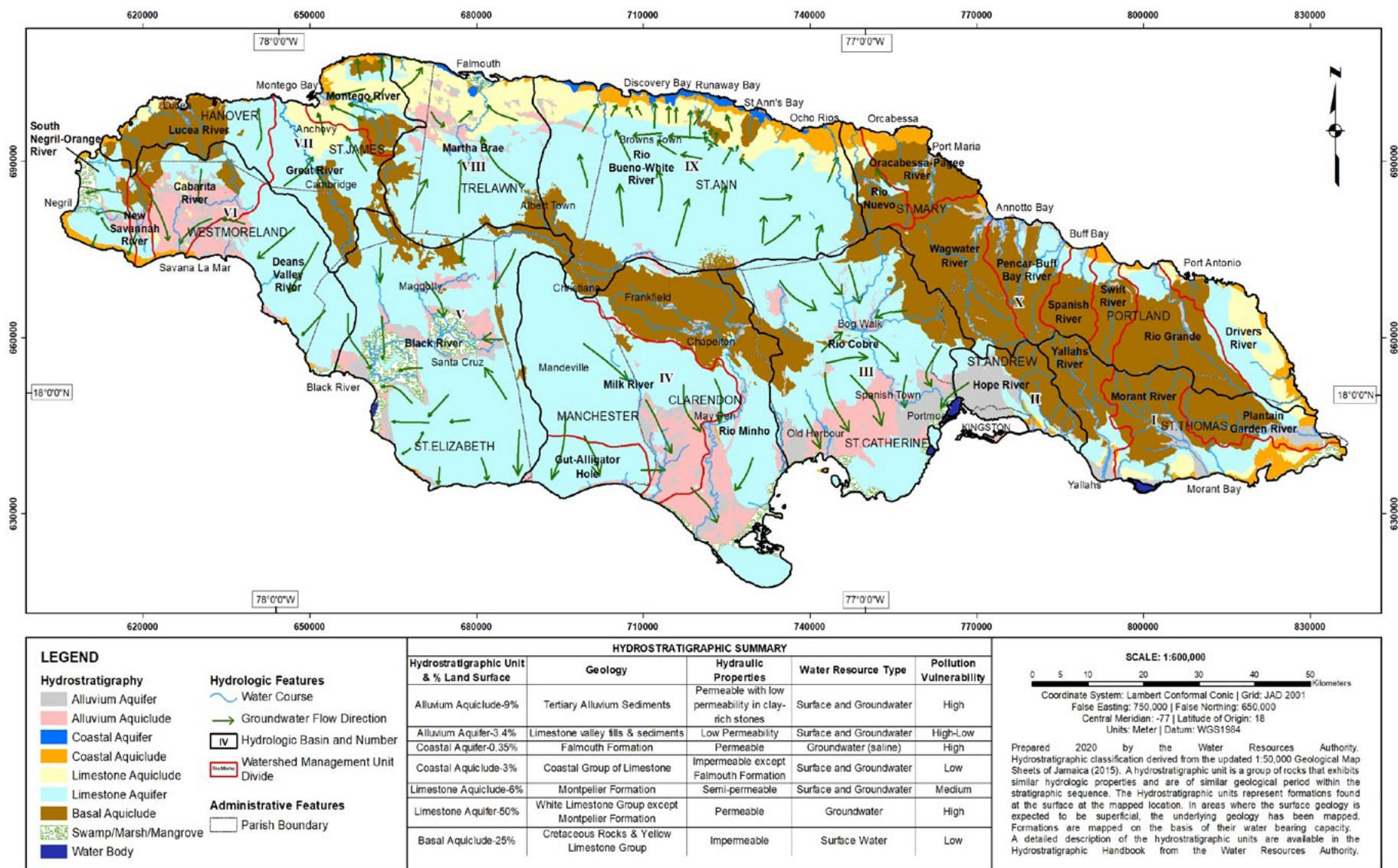


Figure 5: Hydrostratigraphy of Jamaica



## Hydrologic Features of the Blue Mountain South Basin and Component WMUs

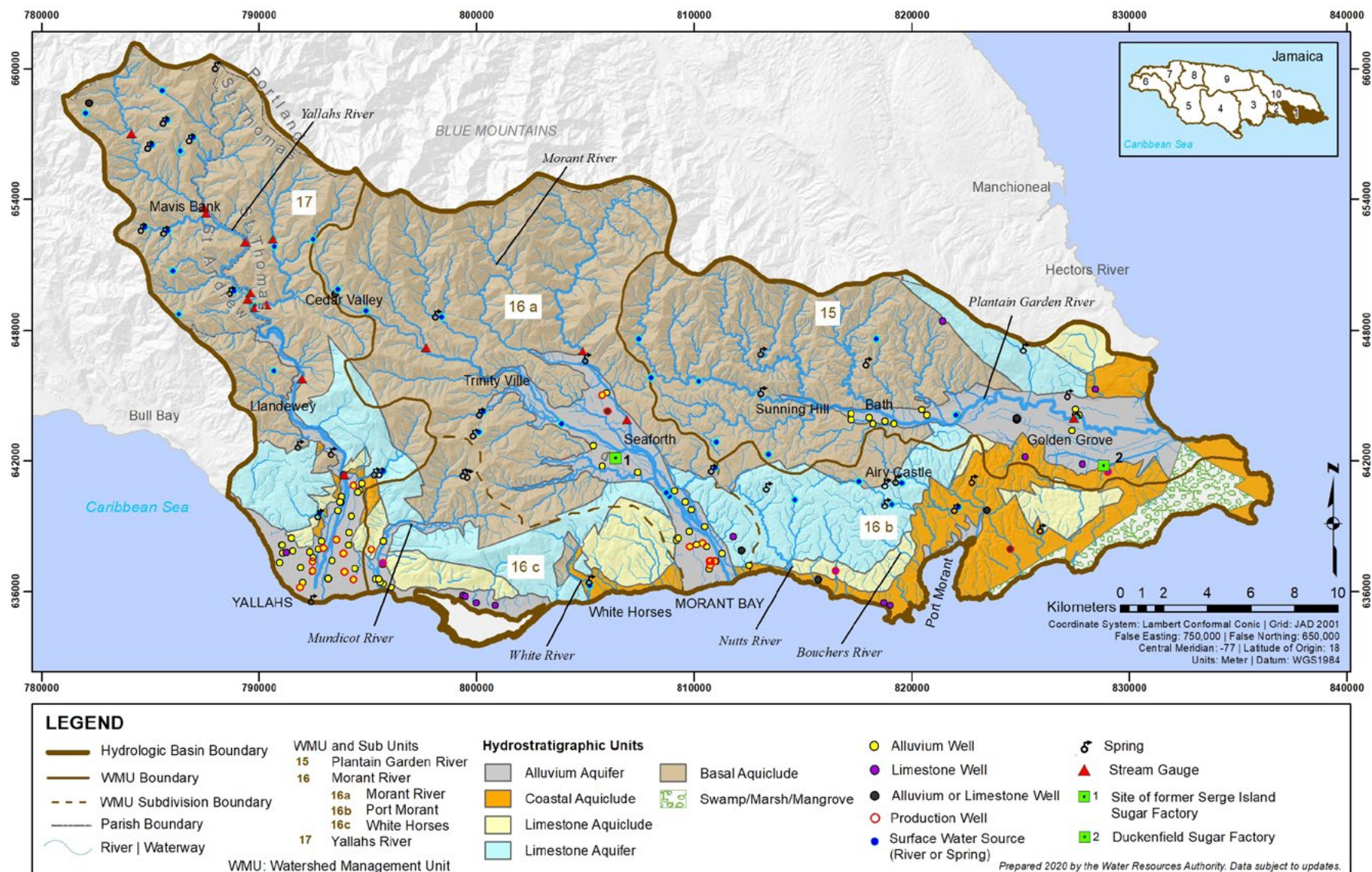


Figure 6: Hydrostratigraphy of the Blue Mountain South Basin



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## Hydrologic Features of the Kingston Basin and Component WMUs

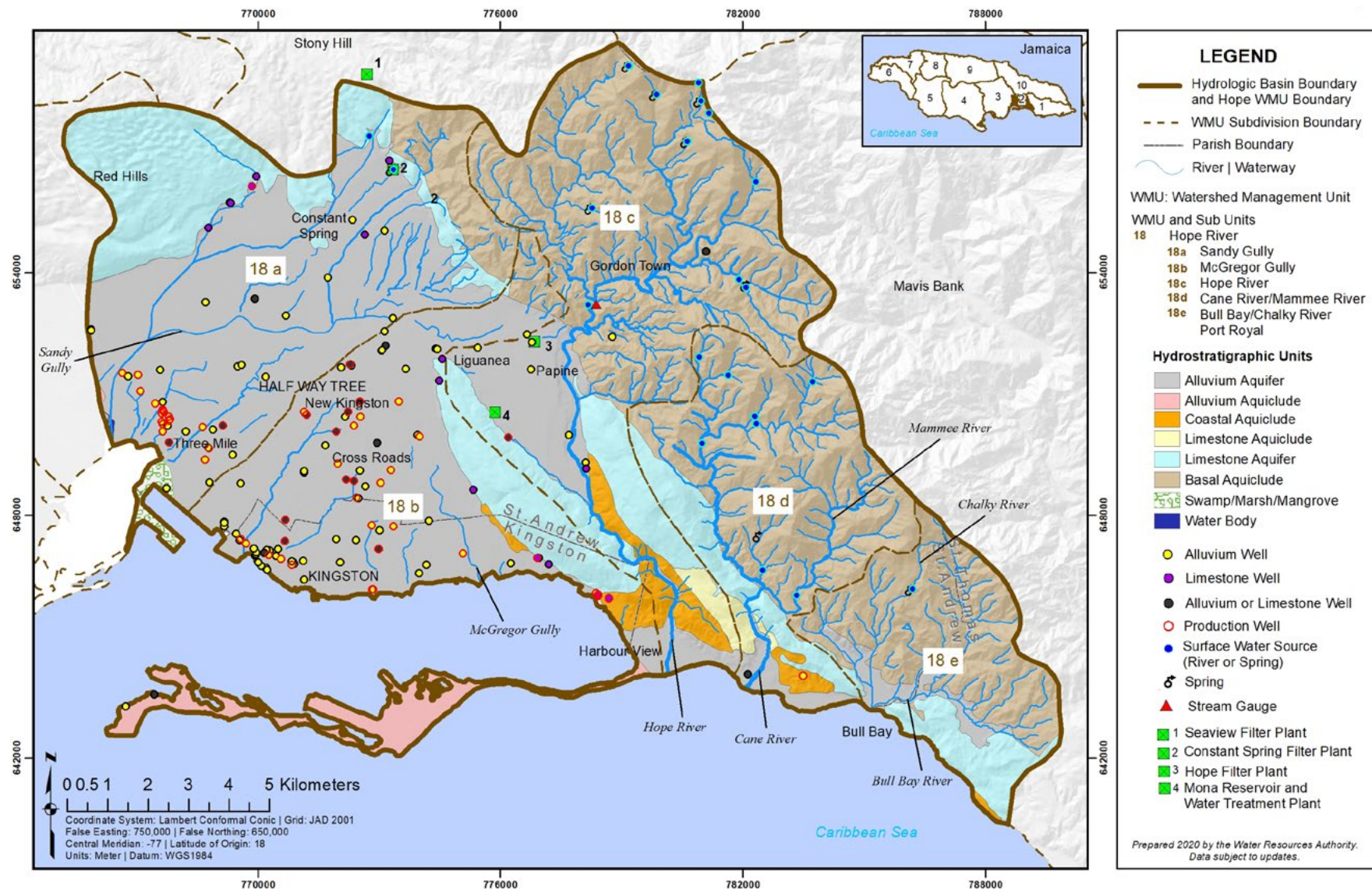


Figure 7: Hydrostratigraphy of the Kingston Basin

## Hydrologic Features of the Rio Cobre Basin and Component WMUs

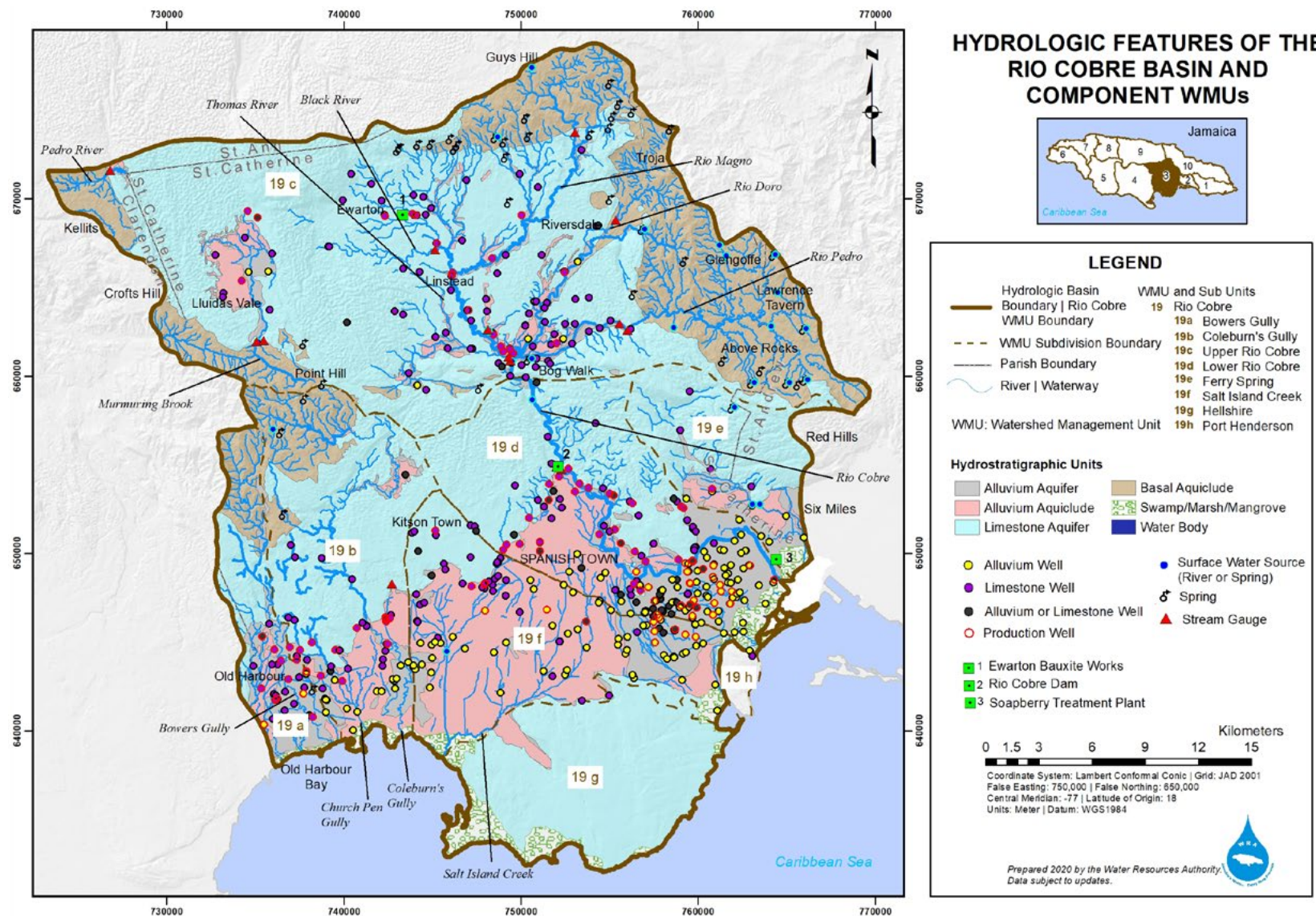


Figure 8: Hydrostratigraphy of the Rio Cobre Basin

## Hydrologic Features of the Rio Minho Basin and Component WMUs

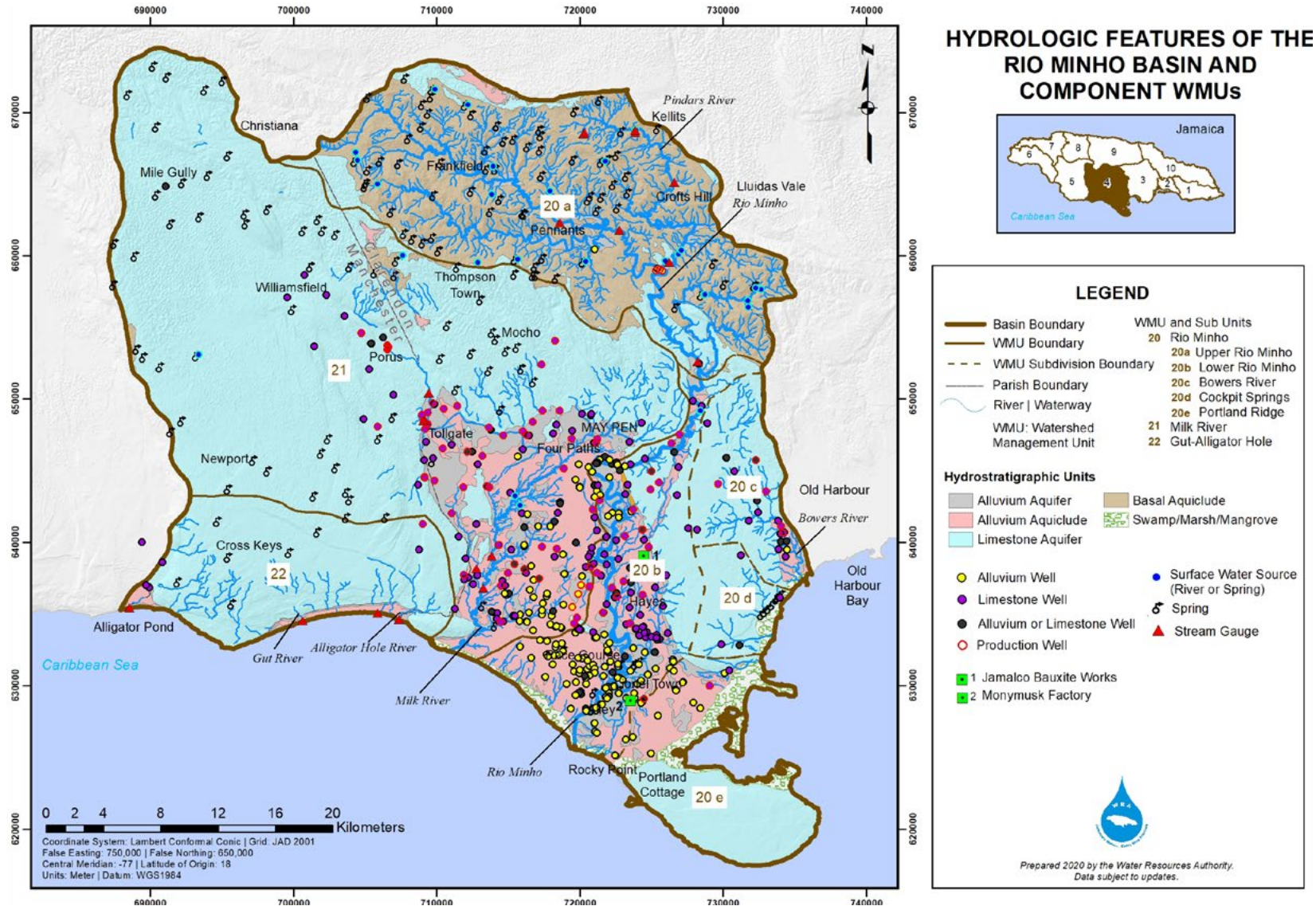


Figure 9: Hydrostratigraphy of the Rio Minho Basin

## Hydrologic Features of the Black River Basin and Component WMUs

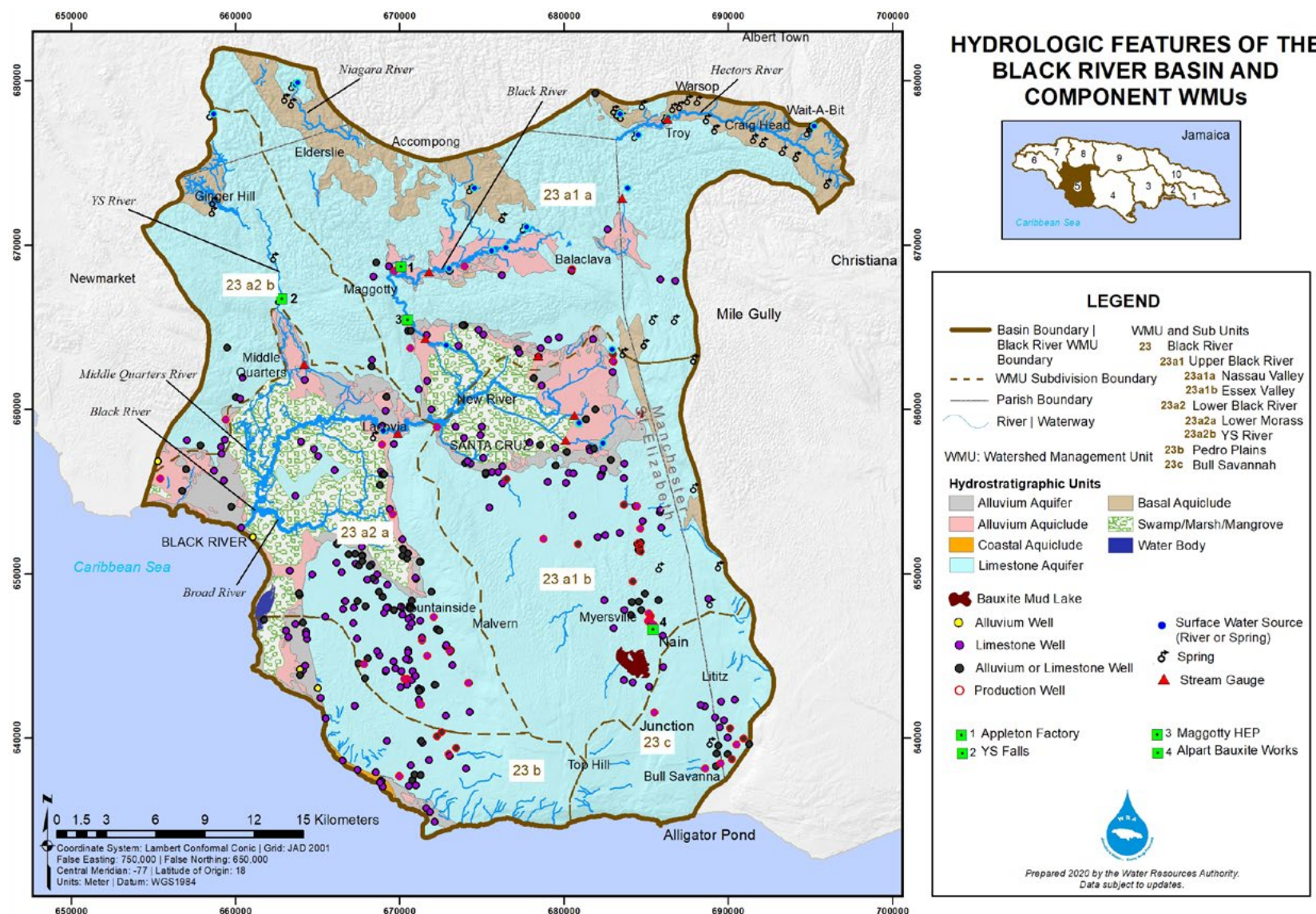


Figure 10: Hydrostratigraphy of the Black River Basin



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## Hydrologic Features of the Cabarita River Basin and Component WMUs

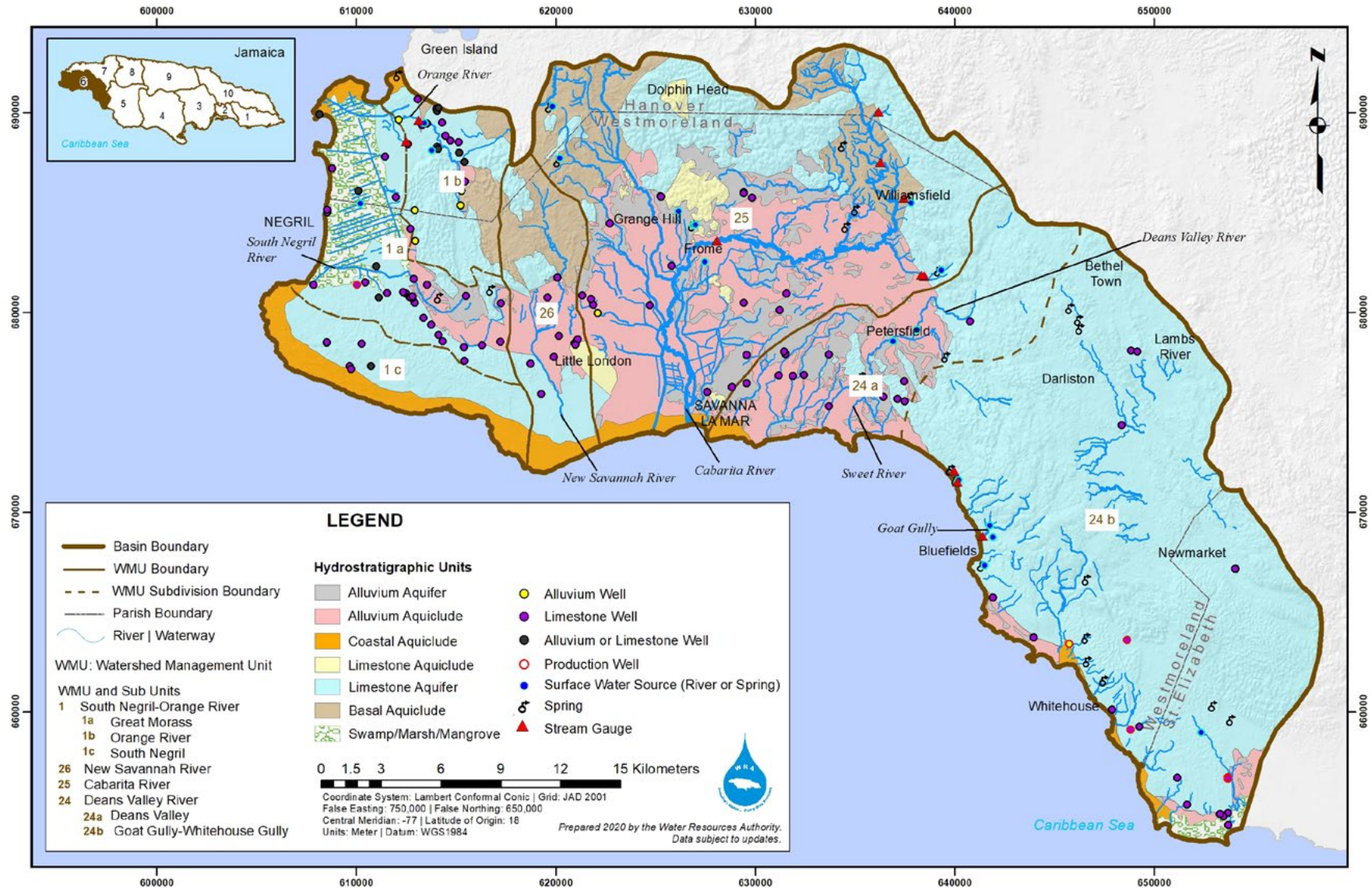


Figure 11: Hydrostratigraphy of the Cabarita River Basin



## Hydrologic Features of the Great River Basin and Component WMUs

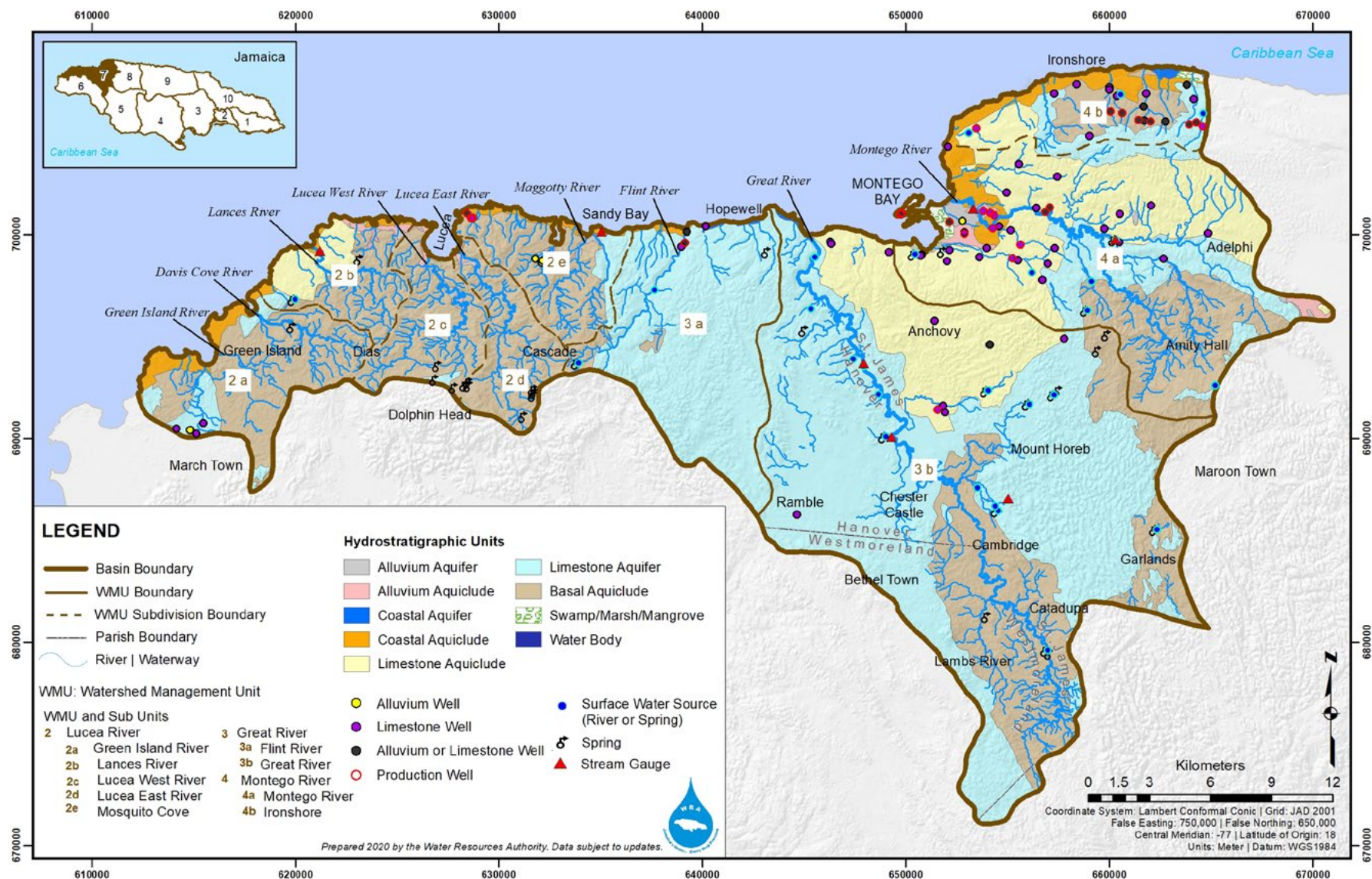


Figure 12: Hydrostratigraphy of the Great River Basin

## Hydrologic Features of the Martha Brae Basin and Component WMUs

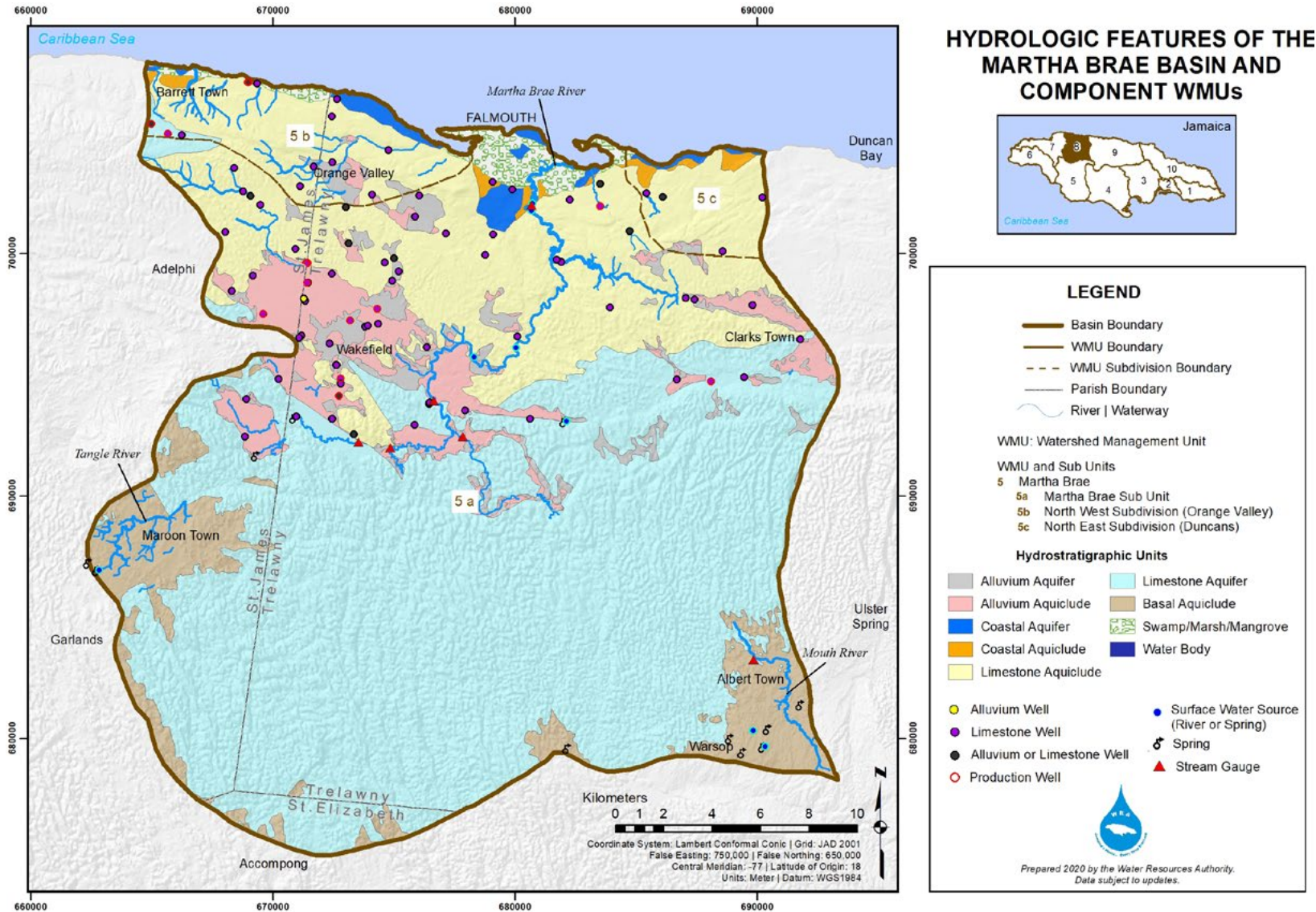


Figure 13: Hydrostratigraphy of the Martha Brae Basin



## Hydrologic Features of the Dry Harbour Mountains Basin and Component WMUs

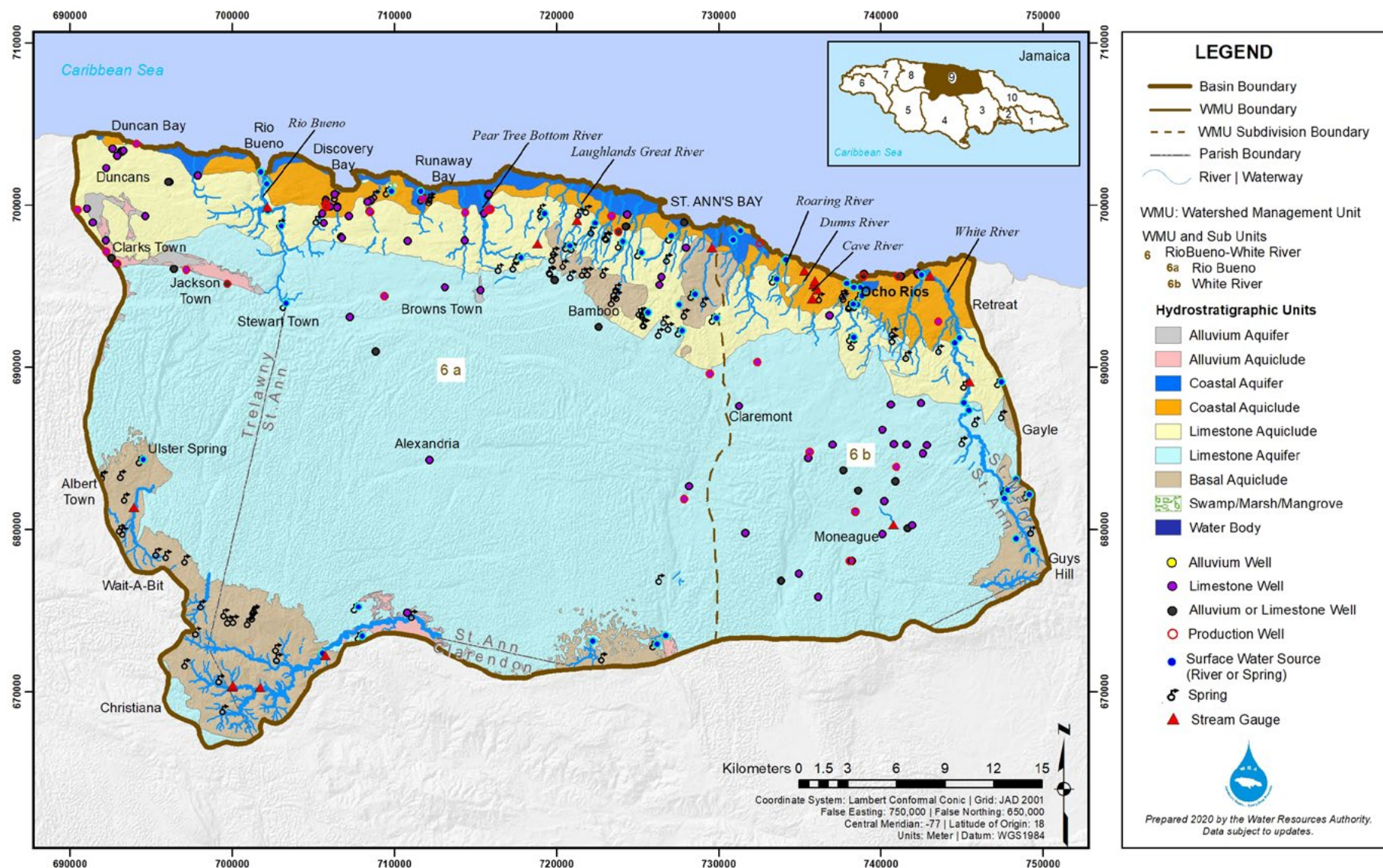


Figure 14: Hydrostratigraphy of the Dry Harbour Mountains Basin



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## Hydrologic Features of the Blue Mountain North Basin and Component WMUs

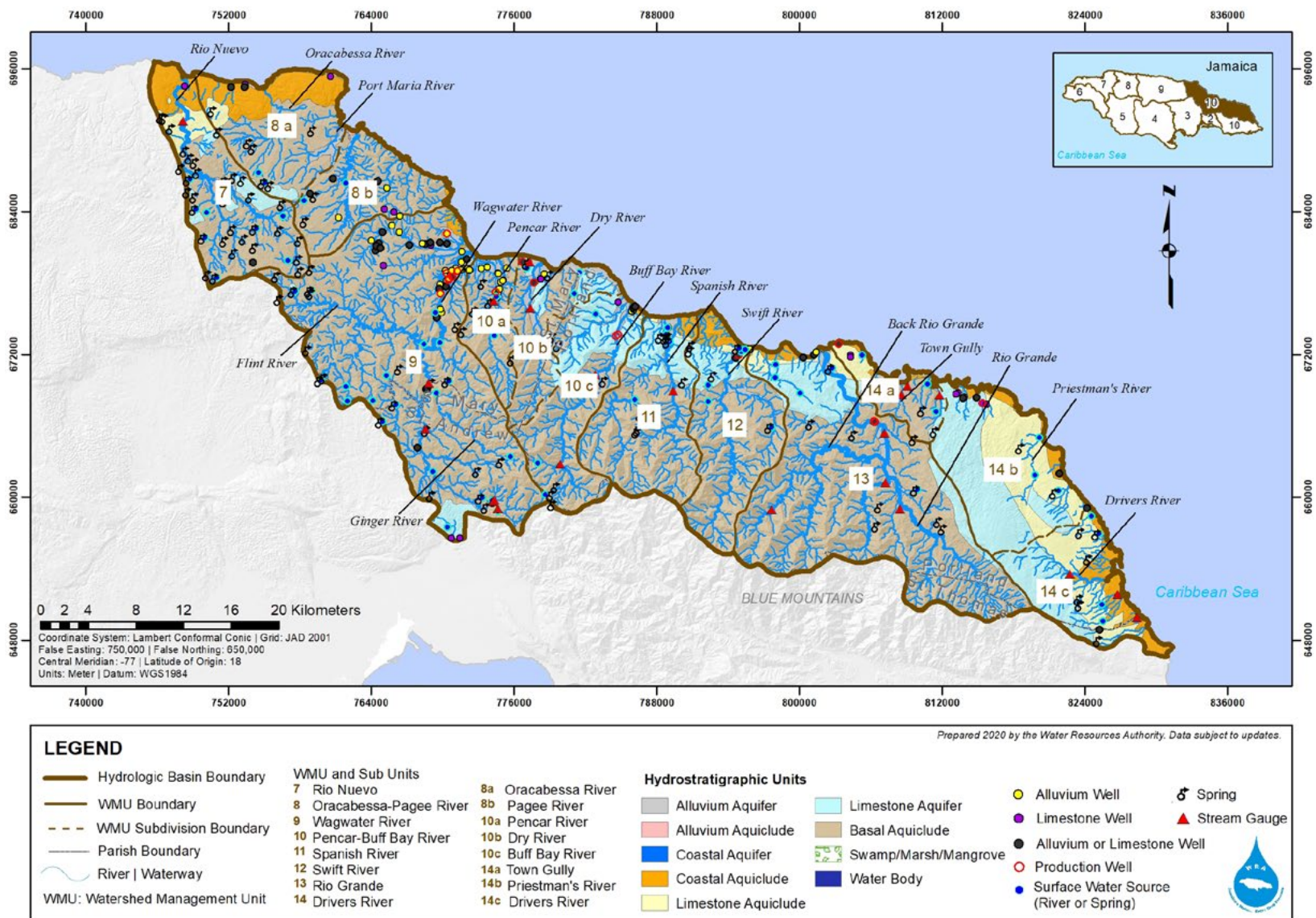


Figure 15: Hydrostratigraphy of the Blue Mountain North Basin.

## CLIMATE

### TEMPERATURE

Jamaica has a tropical maritime climate. Table 5 presents the mean daily temperatures over the period 1996-2015 for selected locations in Jamaica. The temperatures range from 26°C in February to 29.5°C in August, with cooler temperatures at interior higher elevations (Worthy Park) when compared to temperatures at sea level (both International Airports).

**TABLE 5: MEAN TEMPERATURES FOR JAMAICA, 1996-2015**

| LOCATION                    | JAN  | FEB  | MAR  | APR  | MAY  | JUN  | JUL  | AUG  | SEP  | OCT  | NOV  | DEC  | ANNUAL |
|-----------------------------|------|------|------|------|------|------|------|------|------|------|------|------|--------|
| NORMAN MANLEY INT'L AIRPORT | 25.6 | 26.9 | 27.1 | 27.8 | 28.5 | 29.2 | 29.5 | 29.5 | 29.3 | 28.8 | 28.2 | 27.4 | 28.3   |
| SANGSTER INT'L AIRPORT      | 25.9 | 26.0 | 26.5 | 27.4 | 28.0 | 28.7 | 29.0 | 29.1 | 28.8 | 28.2 | 27.5 | 26.5 | 27.6   |
| WORTHY PARK                 | 21.8 | 21.9 | 22.0 | 23.4 | 23.5 | 24.0 | 25.1 | 25.3 | 25.2 | 24.7 | 23.6 | 21.7 | 23.7   |

Data source: Meteorological Service of Jamaica

### RAINFALL

Table 6 presents the mean annual rainfall for Jamaica over varying periods as reported in the previous WRDMPs and the Meteorological Service of Jamaica.

**TABLE 6: MEAN ANNUAL RAINFALL FOR JAMAICA OVER VARYING PERIODS**

|                         | MEAN ANNUAL RAINFALL (MM) | PERCENTAGE CHANGE | PERIOD OF ANALYSIS |
|-------------------------|---------------------------|-------------------|--------------------|
| 1990 WRDMP              | 1,980                     |                   | 1931-1960          |
| 2005 WRDMP              | 1,924                     | -2.83%            | 1951-1980          |
| MET OFFICE 30-YEAR MEAN | 1,705                     | -11.38%           | 1971-2000          |
| 2019 WRDMP              | 1,684                     | -1.23%            | 1992-2018          |

The average annual rainfall in Jamaica appears to have declined by over 13% from 1931 to the present, based on the data analysis. Rainfall distribution patterns still remain consistent, with the north-eastern section of the island reporting the highest amount of rainfall and the southern sections generally reporting the least. Figure 16 presents a comparison chart of monthly mean rainfalls over the periods 1970-2000, and 1992-2018 as compiled from data submitted by the Meteorological Service of Jamaica, while Figure 17 presents the isohyetal map calculated from the 1992-2018 rainfall data. The rainfall patterns for both periods still reflect the expected bi-modal rainfall temporal distribution, with peak rainfall during the months of May and October. However, the rainfall during the dry period of December-April is lower for the 1992-2018 period when compared to the 1971-2000 period.

Given that rainfall is the sole inflow of water in the Jamaican water cycle, the apparent decrease in rainfall volumes over time will most likely have a significant impact on the available water resources (including stream flow and groundwater recharge) in the island.



## 1971-2000 Mean Precipitation vs 1992-2018 Mean Precipitation (mm)

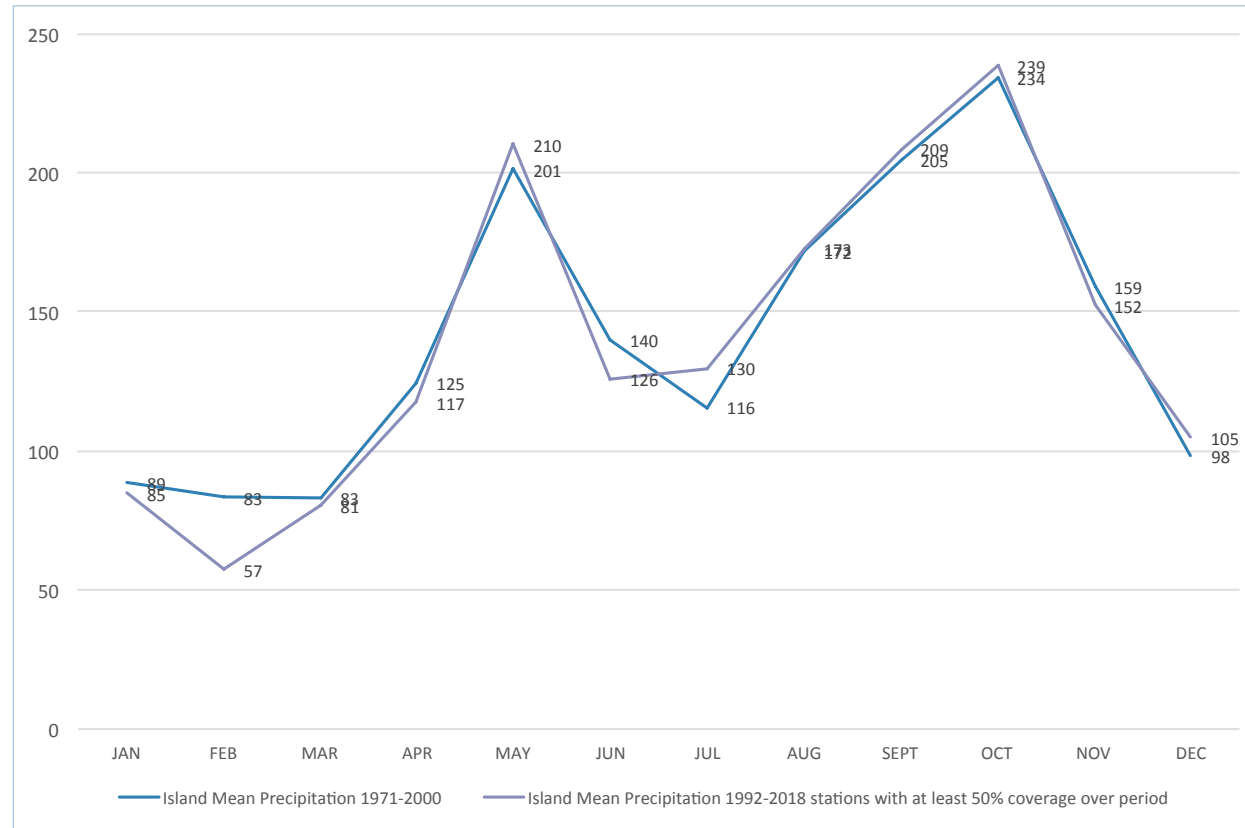


Figure 16: Comparison of 1971-2000 Monthly Mean Precipitation to 1992-2018 Monthly Mean Precipitation

## Rainfall Isohyets 1992-2018

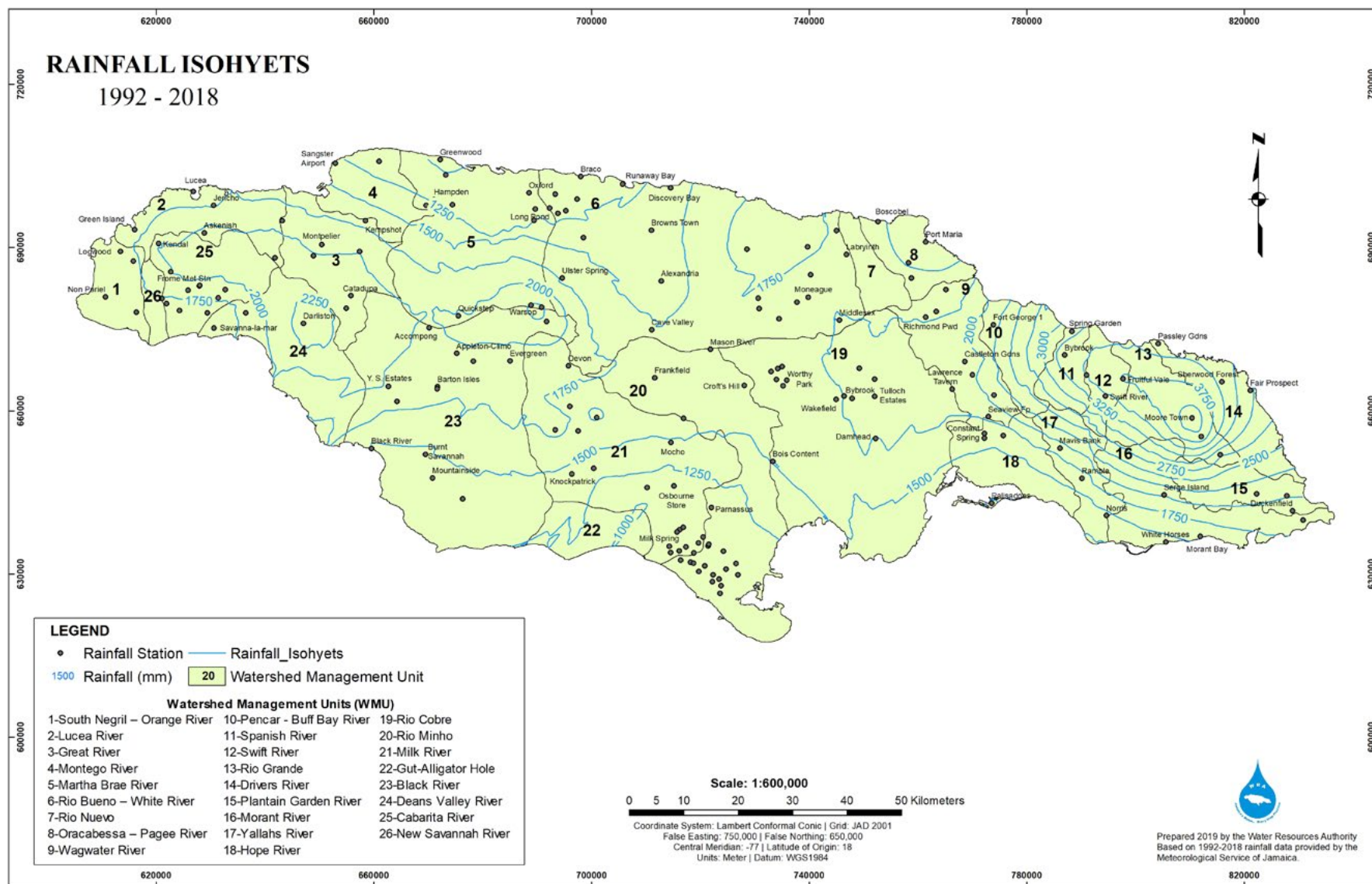


Figure 17: Isohyetal Map of Rainfall for Jamaica over the period 1992-2018



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## LAND USE

Changes in land usage will have an impact on water resources runoff, recharge, and storage. Increased urbanization will increase runoff and decrease groundwater recharge/storage, while declines in forest cover will lead to degraded watersheds and less water storage. Table 7 presents the most recent (2013) land use classification of Jamaica, as classified by the Forestry Department. Land use has been classified into 28 specific categories, which have been ranked and aggregated into four broad categories: Built-Up Land, Agricultural Land, Forests, and Other Non-Forests. The data shows that Forest and Agricultural lands remain the largest broad categories of land use in Jamaica at 46.3% and 39.74% respectively. Forests occupy the central ridge of the island, including the Blue and John Crow Mountains in the east, and the Cockpit Country to the north-west. Forests also occur on other western dry hilly upland regions with poor soils. Under the National Resources Conservation Act of 1991, many of these forested areas are designated as **Protected Areas** in order to protect their biodiversity.



**TABLE 7: LAND USE CLASSIFICATION IN JAMAICA**

| CATEGORY          | LAND USE CLASSIFICATION                                       | AREA (SQKM)     | PERCENT-AGE OF TO-TAL AREA | CATEGORY SUBTOTAL AREA | CATEGORY SUBTOTAL PERCENTAGE |
|-------------------|---------------------------------------------------------------|-----------------|----------------------------|------------------------|------------------------------|
| BUILT-UP LAND     | Buildings and other infrastructures                           | 1171.50         | 10.68%                     | 1212.91                | 11.06%                       |
|                   | Bauxite Extraction                                            | 33.93           | 0.31%                      |                        |                              |
|                   | Quarry                                                        | 7.48            | 0.07%                      |                        |                              |
| AGRICULTURAL LAND | Cultivation: Herbaceous crops, fallow, cultivated vegetables' | 1534.48         | 13.99%                     | 4359.66                | 39.74%                       |
|                   | Plantation: Tree crops, shrub crops, sugar cane, banana       | 701.68          | 6.40%                      |                        |                              |
|                   | Fields and Bamboo                                             | 373.08          | 3.40%                      |                        |                              |
|                   | Fields and Secondary Forest                                   | 1316.86         | 12.00%                     |                        |                              |
|                   | Fields: Bare Land                                             | 72.03           | 0.66%                      |                        |                              |
|                   | Fields: Pasture, Human disturbed, grassland                   | 66.26           | 0.60%                      |                        |                              |
|                   | Bamboo and Fields                                             | 295.27          | 2.69%                      |                        |                              |
| FOREST            | Bamboo                                                        | 46.67           | 0.43%                      | 5079.74                | 46.30%                       |
|                   | Bamboo and Secondary Forest                                   | 302.58          | 2.76%                      |                        |                              |
|                   | Secondary Forest and Bamboo                                   | 262.47          | 2.39%                      |                        |                              |
|                   | Disturbed broadleaf forest                                    | 1760.21         | 16.04%                     |                        |                              |
|                   | Hardwood Plantation: Eucalytus                                | 0.84            | 0.01%                      |                        |                              |
|                   | Hardwood Plantation: Mahoe                                    | 0.03            | 0.00%                      |                        |                              |
|                   | Hardwood Plantation: Mahogany                                 | 1.50            | 0.01%                      |                        |                              |
|                   | Hardwood Plantation: Mixed                                    | 0.77            | 0.01%                      |                        |                              |
|                   | Pine Plantations                                              | 80.13           | 0.73%                      |                        |                              |
|                   | Secondary Forest                                              | 1377.71         | 12.56%                     |                        |                              |
|                   | Closed broadleaf forest                                       | 846.46          | 7.72%                      |                        |                              |
|                   | Open dry forest - Short                                       | 24.68           | 0.22%                      |                        |                              |
|                   | Open dry forest - Tall (Woodland/Savanna)                     | 375.69          | 3.42%                      |                        |                              |
|                   |                                                               |                 |                            |                        |                              |
| OTHER NON-FOREST  | Bare Rock                                                     | 24.29           | 0.22%                      | 318.95                 | 2.91%                        |
|                   | Herbaceous Wetland                                            | 144.90          | 1.32%                      |                        |                              |
|                   | Mangrove Forest                                               | 96.31           | 0.88%                      |                        |                              |
|                   | Swamp Forest                                                  | 1.23            | 0.01%                      |                        |                              |
|                   | Water Body                                                    | 52.23           | 0.48%                      |                        |                              |
|                   | <b>TOTAL</b>                                                  | <b>10971.26</b> | <b>100.00%</b>             | <b>10971.26</b>        | <b>100.00%</b>               |

Source: Forestry Department

Table 8 presents the estimated changes in land use from 1998 to 2013 based on available land use data from the Forestry Department. The classifications were ranked to equate both years (20 classifications for 1998 vs 28 classifications for 2013), and the percentage of change was assessed. The classifications with the largest increases in 2013 when compared to 1998 were Bamboo/Secondary Forest and Built-Up Urban Areas, with increases of 292.1% and 125.13% respectively, while the greatest declines were in Cultivations, Bauxite/Quarries and Secondary Forests/Fields. This change could be due to the increased conversion of former agricultural lands into residential areas and the continued influence of population growth and housing demand. One area of concern is the continued decrease in Primary Forest Cover, which declined by 12.26% between 1998 and 2013.

Figure 18 presents the 2013 Land Cover classification, while Figure 19 presents the protected areas of Jamaica.

**TABLE 8: LAND USE CHANGE FOR JAMAICA BETWEEN 1998 AND 2013**

| LC RANK | LC CATEGORY                                       | 1998 AREA KM <sup>2</sup> | 2013 AREA KM <sup>2</sup> | 1998 PERCENT AREA | 2013 PERCENT AREA | PERCENT CHANGE IN RELATION TO LAND AREA | 2013 PERCENT CHANGE IN RELATION TO 1998 |
|---------|---------------------------------------------------|---------------------------|---------------------------|-------------------|-------------------|-----------------------------------------|-----------------------------------------|
| 1       | Water Body                                        | 59.11                     | 52.23                     | 0.54%             | 0.48%             | -0.06%                                  | -11.71%                                 |
| 2       | Wetlands/Bare Rock                                | 236.09                    | 266.73                    | 2.15%             | 2.43%             | 0.28%                                   | 12.90%                                  |
| 3       | Open Dry Forest/Closed Broadleaf Forest (Primary) | 1420.13                   | 1246.83                   | 12.95%            | 11.36%            | -1.59%                                  | -12.26%                                 |
| 4       | Secondary Forest/Pine Plantations                 | 1825.16                   | 3221.19                   | 16.65%            | 29.36%            | 12.71%                                  | 76.37%                                  |
| 5       | Bamboo and Secondary Forest                       | 155.90                    | 611.73                    | 1.42%             | 5.58%             | 4.15%                                   | 292.10%                                 |
| 6       | Secondary Forests and Fields                      | 1944.79                   | 295.27                    | 17.74%            | 2.69%             | -15.05%                                 | -84.83%                                 |
| 7       | Fields and Secondary Forests                      | 1172.21                   | 1828.23                   | 10.69%            | 16.66%            | 5.97%                                   | 55.86%                                  |
| 8       | Cultivations/Plantations                          | 3552.89                   | 2236.16                   | 32.41%            | 20.38%            | -12.02%                                 | -37.10%                                 |
| 9       | Bauxite and Quarries                              | 77.39                     | 41.41                     | 0.71%             | 0.38%             | -0.33%                                  | -46.53%                                 |
| 10      | Built-up Urban Areas                              | 520.00                    | 1171.50                   | 4.74%             | 10.68%            | 5.93%                                   | 125.13%                                 |
|         |                                                   | <b>10963.67</b>           | <b>10971.26</b>           | <b>1.00</b>       | <b>1.00</b>       |                                         |                                         |





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## 2013 Landcover Jamaica

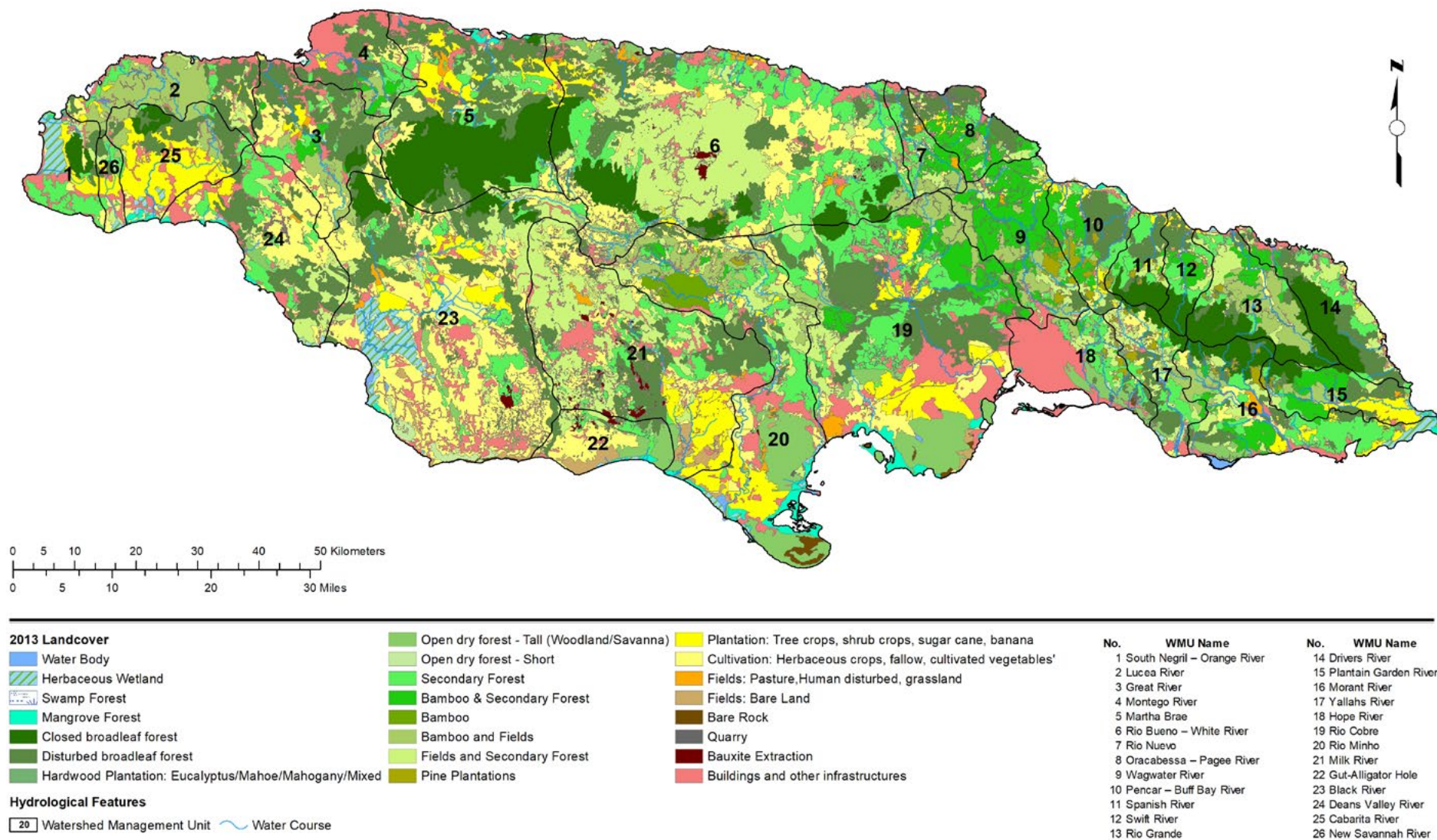


Figure 18: Land Use Classification 2013

## Protected Areas and Forest Estates

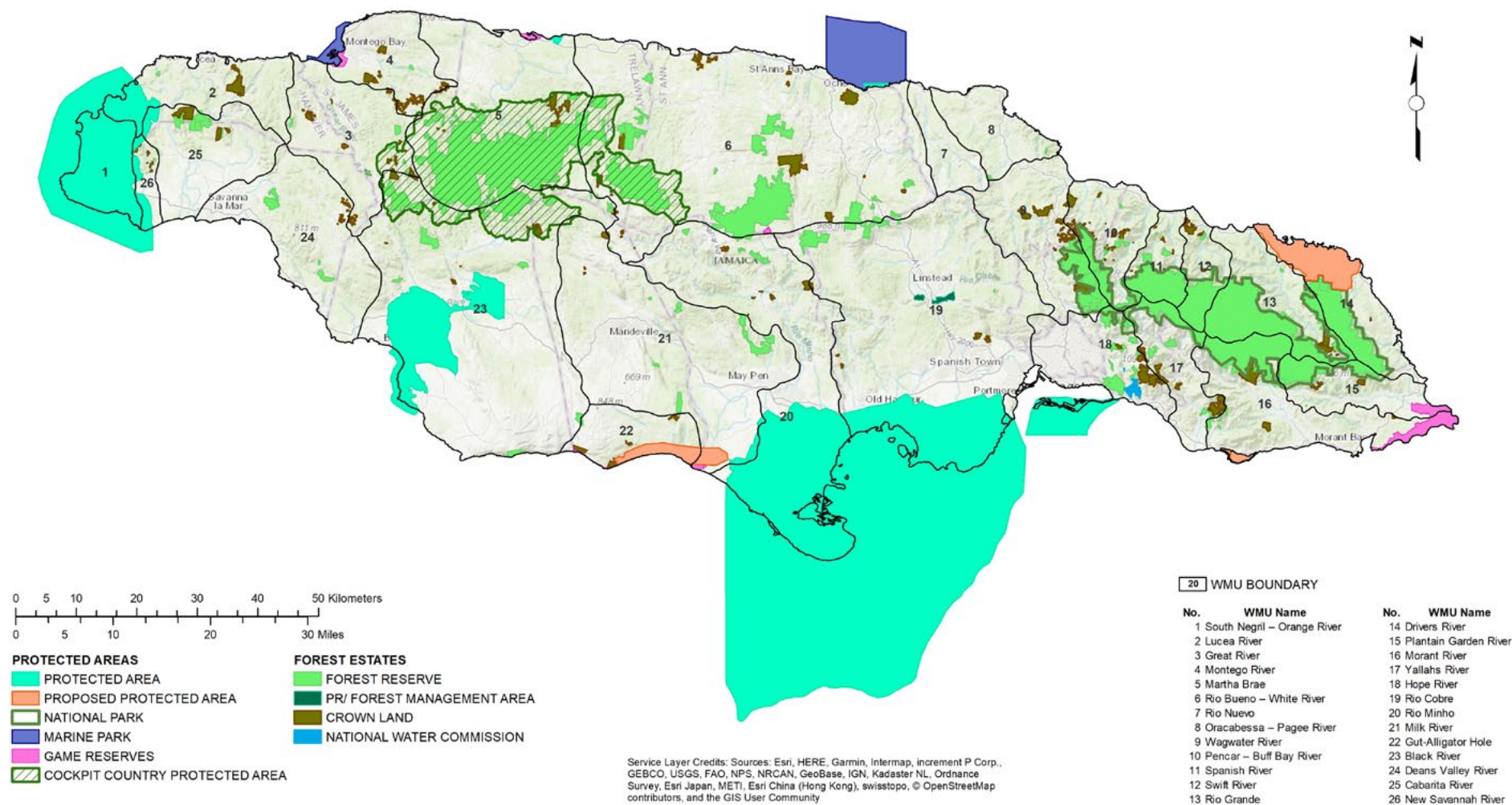


Figure 19: Protected Areas and Forest Reserves



## ENVIRONMENT

Jamaica has significant bio-diversity as featured in the ecosystems present, including forests, coral reefs, wetlands, rivers, wildlife habitats and coastal swamps. However, these ecosystems are threatened by:

- Anthropogenic developments (major construction of subdivisions, hotels, etc.). These developments usually involve the removal or severe alteration of the natural environment in a manner that is not environmentally sustainable, and which also disrupts aspects of the water cycle.
- Deforestation from increased development and unsustainable farming practices. This leads to increased runoff from rainfall, increased soil erosion, and decreased recharge/storage of water from rainfall.
- Insufficient environmental safeguards in bauxite mining and other industrial operations,
- Improper grazing practices by animals,
- Agricultural non-point source pollutants (fertilizers, pesticides, etc.).
- Improper disposal of industrial wastes and household garbage in rivers and other water bodies. Nutrient-rich wastewaters increase the chance of algal blooms in rivers and reservoirs, causing a depletion of dissolved oxygen and damage to aquatic fauna and flora.
- Contamination of aquifers by domestic sewage, industrial waste and other pollutants.

## WATER QUALITY STATUS

The WRA has water quality records for over 50 years and have made updates to the WQ Atlas in 2018. The standard parameters measured include: nitrates, sodium, dissolved salts, electrical conductivity, dissolved and total solids content. In addition, some parameters relevant to particular uses are also recorded. Use of water resources can be constrained by undesired quality. Table 9 lists the Ambient Guideline parameters, while Table 10 lists the WHO (2004) recommended allowable levels for drinking water as well as the limit of electrical conductivity recommended by NIC (1998) as suitable for irrigation water. Electrical conductivity provides an indirect measure of dissolved salts.

**TABLE 9: AMBIENT WATER QUALITY GUIDELINES**

| PARAMETER                 | MEASURED AS | STANDARD RANGE | UNIT            |
|---------------------------|-------------|----------------|-----------------|
| Calcium                   | (Ca)        | 40.0-101.0     | mg/L            |
| Chloride                  | (Cl-)       | 5.0- 20.0      | mg/L            |
| Magnesium                 | (Mg2+)      | 3.6- 27.0      | mg/L            |
| Nitrate                   | (NO3-)      | 0.1- 7.5       | mg/L            |
| Phosphate                 | (PO43-)     | 0.01 - 0.8     | mg/L            |
| Potassium                 | (K+)        | 0.74- 5.0      | mg/L            |
| Silica                    | (SiO2 )     | 5.0- 39.0      | mg/L            |
| Sodium                    | (Na+)       | 4.5- 12.0      | mg/L            |
| Sulfate                   | (SO42- )    | 3.0- 10.0      | mg/L            |
| Hardness                  | (CaCO3)     | 127.0-381.0    | mg/L (as CaCO3) |
| Biochemical Oxygen Demand | (O)         | 0.8- 1.7       | mg/L            |
| Total Dissolved Solids    |             | 120.0-300      | mg/L            |
| pH                        |             | 7.00- 8.40     |                 |
| Conductivity              |             | 150.0-600      | µS/cm           |

According to the MOH Drinking Water Regulation Guidelines of 2007, I-JAM is the national recommended water quality criteria for Jamaica. The list includes the accepted levels of contaminants currently recognized by Jamaica with respect to determining drinking water quality. For ease of analysis, the IJAM standards have been divided into two groups: Group 1 (high priority pollutants) and Group 2 (lower priority water quality indicators). Table 2 compares the IJAM criteria (Group 1) with other international drinking water standards that have been historically used as guidelines, and the NRCA freshwater standards.

*"Jamaica's biodiversity, ecosystem health and ambient water quality is threatened by human development actions and activities."*

**TABLE 10: I-JAM STANDARDS**

| PARAMETER                 | IJAM           | USEPA5 DRINKING WATER STANDARDS | WHO 3RD ED. <sup>6</sup> |
|---------------------------|----------------|---------------------------------|--------------------------|
| Arsenic                   | 0.05           | 0.05                            | 0.01                     |
| Barium                    | 1.0            | 2                               | 0.7                      |
| Cadmium                   | 0.01           | 0.005                           | 0.003                    |
| Chromium (Total)          | 0.05           | 0.10                            | 0.05                     |
| Copper                    | 1.0            | 1.0*                            | 2.0                      |
| Cyanide                   | 0.2            | 0.2                             | 0.07                     |
| Fluoride                  | 1.5            | 4.0                             | 1.5                      |
| Lead                      | 0.05           | 0.015                           | 0.01                     |
| Manganese                 | 0.05           | 0.05                            | 0.4                      |
| Maximum Total Coliforms** | 10 %           | 5 %                             | 5 %                      |
| Mercury                   | 0.002          | 0.002                           | 0.001                    |
| Nitrate (as N)            | 10.0           | 10                              | 11.3                     |
| Residual Chlorine         | Always present | -                               | 0.5                      |
| Selenium                  | 0.01           | 0.05                            | 0.01                     |

**All units are given in mg/l unless otherwise stated.**

\* USEPA National Secondary Drinking Water Regulations

\*\*For Maximum Total Coliforms, IJAM and USEPA refers to maximum percentage positive per month.

Table 11 includes IJAM parameters for which there are no WHO health based criteria or USEPA drinking water criteria. However, secondary USEPA standards (National Recommended Water Quality Criteria - Human Health) are available in most cases.

<sup>5</sup> USEPA - US Environmental Protection Agency Drinking Water Regulations. July 2002.

<sup>6</sup> WHO - World Health Organization Drinking Water Guidelines - 3rd Edition 2003.

<sup>7</sup> As of January 1, 2002, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month through out 12 month period.

**TABLE 11: I-JAM STANDARDS (GROUP 2)  
SECONDARY USEPA STANDARDS ONLY**

| PARAMETER              | IJAM    | USEPA              |
|------------------------|---------|--------------------|
| Calcium                | 200 **  | -                  |
| Chloride               | 250 **  | 250                |
| Color (Color Units)    | 15      | 15                 |
| Iron                   | 0.3     | 0.3                |
| Magnesium              | 1000 ** | -                  |
| Odor                   | 3       | 3                  |
| pH                     | 7 - 8.5 | 6.5 to 8.5         |
| Silver                 | 0.05    | 0.1                |
| Total Dissolved Solids | 500 **  | 500                |
| Turbidity              | 5NTU    | 1 NTU <sup>7</sup> |
| Zinc                   | 1.5     | 5                  |

All units are given in mg/l unless otherwise stated.

\*\* Recommended limits for distribution system, by IJAM

General observations are that:

1. IJAM is only more stringent than international guidelines in respect of copper and pH.
2. Only 10 of the 25 IJAM criteria are regarded as Priority Toxic Pollutants (USEPA) and also have WHO health-based criteria. Key WHO microbial standards and other USEPA priority pollutants or drinking water criteria are generally not covered by IJAM.
3. IJAM criteria allow higher concentrations than both WHO and USEPA in respect of: arsenic, cadmium, lead, and Total Coliforms.
4. Eleven of the 25 criteria established by IJAM do not have any health based criteria under the WHO Guidelines (Table 2).



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5. IJAM standards do not allow for monitoring of serious microbial threats in drinking water surveillance programmes.

### **SALINE/SEAWATER INTRUSION**

Seawater intrusion can occur whenever there is over-abstraction of groundwater (i.e. pumping groundwater beyond the reliable yield limit). This over-abstraction leads to pumping levels falling below sea-level, which then causes saline water to be drawn into the aquifer. Saline intrusion can also occur due to increased sea levels caused by Global Warming, where the increased sea levels cause encroachment of saline water into coastal aquifers. Saline intrusion is indicated by elevated concentrations of sodium and chloride, specifically when chloride concentrations exceed 250 mg/L. Aquifers which border the coast and have hydraulic continuity with the sea are especially vulnerable. These include Hope River, Rio Cobre, Rio Minho and Black River WMU's in the south and Montego River and Martha Brae River WMUs in the north. Contamination can extend further inland if there is significant connectivity via faults to the coastline, as seen in the Bull Savanna sub-WMU in Southern Manchester/St. Elizabeth. Elevated salinity can also occur if connate saline groundwater is encountered in drilling.

### **SEWAGE**

Sewage contamination is generally indicated by elevated concentrations of nitrate (>45 mg/L). Areas such as Kingston and Montego Bay, where high population densities coincide with intensive use of absorption pits for sewage disposal, are particularly vulnerable to sewage contamination. This is corroborated by historical data indicating the prevalence of elevated nitrate levels in the Liguanea Aquifer underling





the Kingston Metropolitan Area, along with the northern areas of the Montego River WMU. The Soapberry Treatment plant, constructed in 2008, has been treating the sewage for the KMA and Portmore with treated effluent being discharged into the Rio Cobre close to Hunts Bay.

Since 2000, systematic efforts have been made to restrict the use of absorption pits in areas considered vulnerable to pollution from inappropriate onsite sewage treatment systems. The WRA contribution to the Development Approval Process includes recommending appropriate levels of sewage treatment for subdivisions and other development applications based on the assessed potential impact on freshwater resources by the proposed application. As such, all new developments are required to implement appropriate sewage treatment systems to reduce the risk of water contamination. The WRA completed a study of selected wells in the lower Rio Cobre Alluvium Aquifer Protection Zone to establish a baseline of water quality and potential impacts. The study indicated that while the impact of sewage may be lower than previously feared, there is

a significant impact of saline intrusion. This report is available from the WRA upon request. Further monitoring, research and technological development are needed to discover ways to possibly remediate and reverse the existing contamination.

### CAUSTIC EFFLUENT

Caustic Effluent is indicated by elevated sodium and pH levels. Historical Water quality data indicate leakage of caustic effluent from alumina refinery activities and red mud storage facilities sited in natural unlined limestone depressions in the following areas:

- ◆ WINDALCO in Kirkvine, Manchester (Rio Minho Basin)
- ◆ ALPART in Nain, St. Elizabeth (Black River Basin)
- ◆ WINDALCO in Mount Rosser, St. Catherine/St. Ann (Rio Cobre and Dry Harbour Basins)

Seepage at the base and sides of these ponds into the cracks and fissures of white limestone rocks has contaminated the groundwater in

these areas. The Mount Rosser Mud Lake was decommissioned in 1991 and replaced by a sealed containment system that reduced the risk of direct seepage into the groundwater. This newer system incorporated strategies to reuse the caustic effluent within the alumina production process, and rehabilitation efforts are currently under way at the decommissioned mud lake. However, there are challenges in controlling effluent levels to avoid overtopping of the lake. During heavy and prolonged rainfall events, the Rio Cobre is contaminated by overflows from the mud lake drying beds and the Effluent Holding Pond (EHP). This has impacts on the ecological health of the Rio Cobre, and the downstream usages of irrigation and domestic water supplies from the river diversion at Damhead.

The other (2) red mud storage ponds are still in use. There have been design and operational modifications over the years to reduce the extent of seepage from the ponds, and consequently the contamination of water resources. However, as indicated in Figure 20, sections of the limestone aquifers in Black River, Rio Cobre and Rio Bueno-White River WMUs have been contaminated.

### ORGANIC EFFLUENT FROM RUM AND SUGAR FACTORIES

Historically, there were 8 operational sugar factories and 6 rum distilleries in the country. They generated high strength organic wastewater that is discharged directly or indirectly to the environment. Figure 20 shows the location and contamination extent of those that were known to contaminate water resources. Surface waters were contaminated in Black, North Elim, Cabarita rivers and limestone aquifer Martha Brae and Rio Cobre WMUs. The vast majority of these factories are no longer in operation, with only Worthy Park and Frome remaining as sugar producing factories. Most of the dunder contamination appears to have been mitigated with the cessation/closure of activities at the sugar factories, though the rum distilleries continue to operate.



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## Water Pollution Sources

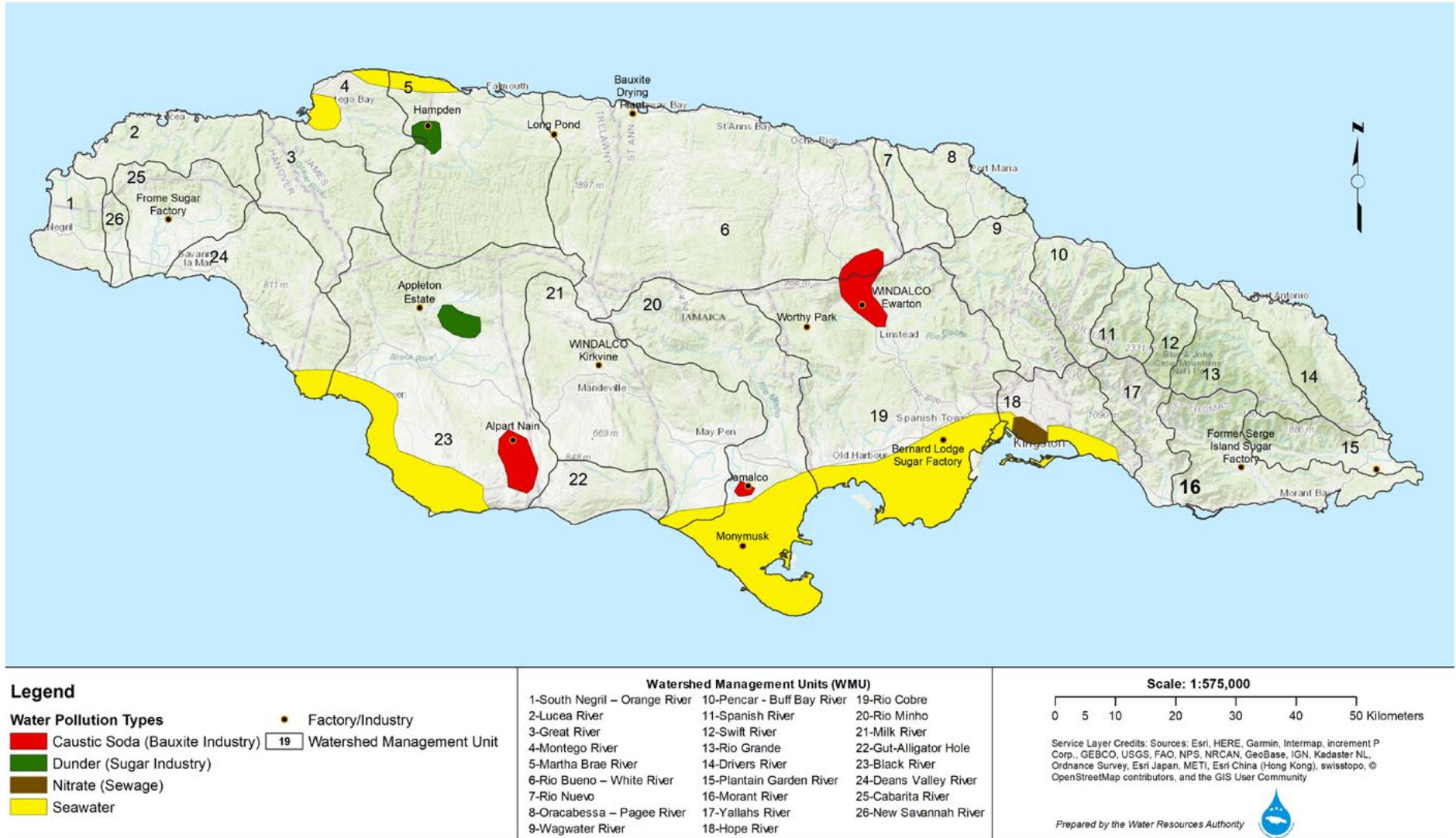


Figure 20: Historical Water Pollution (Groundwater)

# Water Resources Assessment

## WATER RESOURCES INVENTORY

Figure 21 indicates the basic components of the water budget for Jamaica. The components include:

- ◆ Precipitation or Total Rainfall (P)
- ◆ Evapotranspiration, i.e. Evaporation + Transpiration (ET)
- ◆ Surface Runoff ( $R_o$ )
- ◆ Aquifer Recharge or Groundwater Recharge ( $GW_r$ )
- ◆ Groundwater Discharge ( $GW_d$ ) which includes:
  - + Well Abstraction ( $GW_w$ )
  - + Submarine Discharge ( $GW_{GH}$ )
  - + Springflow ( $GW_s$ )
  - + Baseflow ( $GW_b$ ).
- ◆ Change in Storage ( $\delta S$ )
- ◆ Inter-WMU Transfer of groundwater ( $GW_{IT}$ )
- ◆ Streamflow ( $R_o + GW_s + GW_b$ )

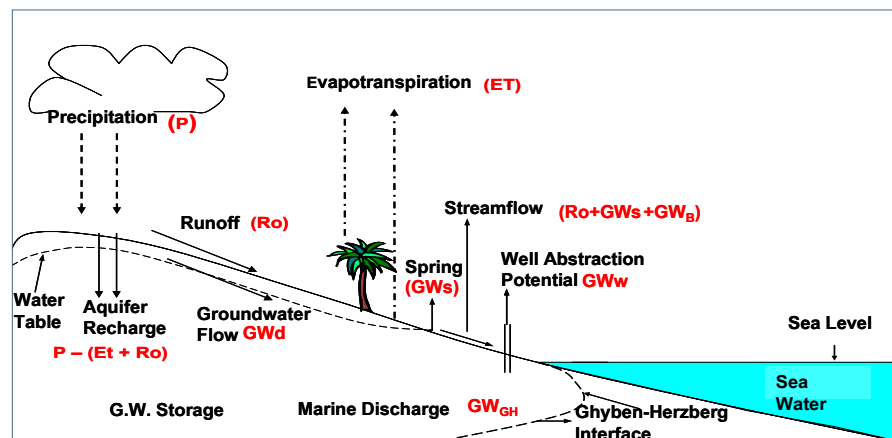


Figure 21: Components of the Hydrological Cycle

The estimate of groundwater resources is based on the Continuity Principle:

$$GW_r = GW_d + \delta S \quad (1)$$

Where:

$$GW_r = P - (ET + R_o) \quad (2)$$

And:

$$GW_d = GW_s + GW_b + GW_w + GW_{GH} + GW_{IT} \quad (3)$$

Substituting equations (2) and (3) into equation (1) gives:

$$P - (ET + R_o) = GW_d = GW_s + GW_b + GW_w + GW_{GH} + GW_{IT} + \delta S \quad (4)$$

Transposing equation (4) for abstraction of groundwater gives:

$$GW_w = P - ET - (R_o + GW_s + GW_b) - GW_{GH} - GW_{IT} - \delta S \quad (5)$$

## GROUNDWATER SAFE YIELD DETERMINATION

“Safe abstraction” or “Safe Yield” is defined from equation (5), assuming that there is no change in groundwater storage ( $\delta S$ ) in the long term. Thus:

$$\text{Groundwater Safe Yield} = P - ET - (R_o + GW_s + GW_b) - GW_{GH} - GW_{IT} \quad (6)$$

Equation (6) is a large-scale simplification of very complex processes on the smaller scale, with various assumptions. Some key assumptions in equation (6) are as follows:

- ◆ All “Effective rain” ( $P - ET$ ) is used for either aquifer recharge or surface runoff.
- ◆ Impacts of water storage and movement within soil, the Vadose zone, rainwater collection and other processes not mentioned are assumed to be negligible.
- ◆ Streamflow ( $R_o + GW_s + GW_b$ ) is defined by gauged river flows; ungauged perennial streamflow would need to be accounted for in future updates.

The components of equation (6) are quantified in the following sections.



## PRECIPITATION

Mean annual rainfall for the WMUs was derived from data over the period 1992-2018, based on isohyet interpolation of measured annual rainfall from all stations with >50% data measurement over the period (total of 178 stations). Table 12 presents the average annual rainfall for the basins over the period of record for the 26 WMUs. Analysis of the rainfall data indicates that:

- The island wide average annual rainfall of 1,684 mm/year calculated from the 178 rainfall stations for the period is slightly less than the calculated island wide mean value of 1,786.54 derived from the WMU area and estimated volume of rainfall per WMU. This discrepancy would be due to the spatial variation inherent in the interpolated rainfall values used to derive the estimated volume of rainfall in each WMU.
- There is high spatial variation in the distribution of mean annual rainfall over the island, with the highest mean rainfall occurring in the Rio Grande WMU (3,571.74 mm/year) and the lowest mean rainfall occurring in the Gut River-Alligator Hole WMU (1,152.81 mm/year).

**TABLE 12: MEAN PRECIPITATION AND TOTAL PRECIPITATION PER WMU**

| BASIN                 | WMU                       | MEAN ANNUAL PRECIPITATION | AREA OF WMU     | MEAN ANNUAL PRECIPITATION VOLUME |
|-----------------------|---------------------------|---------------------------|-----------------|----------------------------------|
|                       |                           | MM/YEAR                   | KM <sup>2</sup> | MCM                              |
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 2,265.22                  | 179.35          | 406.27                           |
|                       | Morant River              | 2,007.14                  | 383.93          | 770.61                           |
|                       | Yallahs River             | 1,883.03                  | 188.09          | 354.18                           |
| KINGSTON              | Hope River                | 1,533.64                  | 251.63          | 385.91                           |
| RIO COBRE             | Rio Cobre                 | 1,644.78                  | 1,249.51        | 2,055.17                         |
| RIO MINHO             | Rio Minho                 | 1,407.48                  | 796.82          | 1,121.52                         |
|                       | Milk River                | 1,451.15                  | 852.78          | 1,237.51                         |
|                       | Gut River-Alligator Hole  | 1,152.81                  | 164.42          | 189.54                           |
| BLACK RIVER           | Black River               | 1,700.84                  | 1,311.37        | 2,230.43                         |
| CABARITA RIVER        | Deans Valley River        | 2,011.55                  | 424.90          | 854.71                           |
|                       | Cabarita River            | 1,936.06                  | 290.09          | 561.63                           |
|                       | New Savannah River        | 1,696.34                  | 37.67           | 63.91                            |
|                       | South Negril-Orange River | 1,666.76                  | 159.27          | 265.46                           |
| GREAT RIVER           | Lucea River               | 1,839.84                  | 257.55          | 473.86                           |
|                       | Great River               | 1,981.65                  | 345.37          | 684.40                           |
|                       | Montego River             | 1,417.06                  | 205.03          | 290.54                           |
| MARTHA BRAE           | Martha Brae               | 1,536.15                  | 732.58          | 1,125.35                         |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River     | 1,570.36                  | 1,562.99        | 2,454.45                         |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 1,640.63                  | 109.00          | 178.82                           |
|                       | Oracabessa-Pagee          | 1,499.72                  | 168.03          | 252.01                           |
|                       | Wagwater River            | 1,876.57                  | 317.63          | 596.06                           |
|                       | Pencar-Buff Bay River     | 2,555.77                  | 202.26          | 516.93                           |
|                       | Spanish River             | 3,130.13                  | 109.33          | 342.22                           |
|                       | Swift River               | 3,422.49                  | 107.25          | 367.08                           |
|                       | Rio Grande                | 3,571.74                  | 281.84          | 1,006.64                         |
|                       | Drivers River             | 3,109.78                  | 234.71          | 729.90                           |
| TOTAL                 |                           | 1,786.54                  | 10,923.42       | 19,515.11                        |



## EVAPOTRANSPIRATION

Evapotranspiration was estimated from recorded maximum and minimum daily temperatures from Meteorological Service of Jamaica AWS stations over the period 2017-2018, (available data at time of writing). These daily temperatures were inputted into the ETo Calculator Software provided by the Food and Agriculture Organization (FAO) of the United Nations along with climatic classifications based on the location (latitude, longitude), coastal proximity, elevation and wind-speed assumptions for each AWS station. The program estimated Potential Evapotranspiration for each site based on the available data utilizing the Penman-Monteith Equation, the standard for reference evapotranspiration as shown below:

$$ET_o = \frac{0.408 \Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where

$ET_o$  = reference evapotranspiration [ $\text{mm day}^{-1}$ ],  
 $R_n$  = net radiation at the crop surface [ $\text{MJ m}^{-2} \text{day}^{-1}$ ],  
 $G$  = soil heat flux density [ $\text{MJ m}^{-2} \text{day}^{-1}$ ],  
 $T$  = mean daily air temperature at 2 m height [ $^{\circ}\text{C}$ ],  
 $u_2$  = wind speed at 2 m height [ $\text{m s}^{-1}$ ],  
 $e_s$  = saturation vapour pressure [ $\text{kPa}$ ],  
 $e_a$  = actual vapour pressure [ $\text{kPa}$ ],  
 $e_s - e_a$  = saturation vapour pressure deficit [ $\text{kPa}$ ],  
 $\Delta$  = slope vapour pressure curve [ $\text{kPa } ^{\circ}\text{C}^{-1}$ ],  
 $\gamma$  = psychrometric constant [ $\text{kPa } ^{\circ}\text{C}^{-1}$ ].

The software interpolated potential ET from the calculated available potential ET wherever gaps were present. Table 13 presents the estimated Potential ET from the 77 available weather stations. A Pan-coefficient of 0.8 and a crop co-efficient of 0.65<sup>8</sup> was applied to estimate the actual evapotranspiration from the potential evapotranspiration for each WMU. Further research and more data is needed to specify the co-efficient values for each watershed, and to increase the accuracy of the estimated evapotranspiration. Projected impacts of climate change on temperature and evapotranspiration are presented in chapter 6. The estimated potential ET from the available 77 stations was interpolated across the island using

the Kriegering method via GIS software, and assessed in a similar fashion to the rainfall across each WMU for an estimated total ET islandwide. Figure 22 presents the distribution of estimated Potential Evapotranspiration.

## EFFECTIVE RAINFALL

The effective rainfall was calculated as the difference between the total mean precipitation and the total estimated actual evapotranspiration. This would be the volume of water expected to be available for surface runoff and groundwater recharge, and by extension would be the volume of water available for all uses (anthropogenic and environmental). Table 14 provides the islandwide data for precipitation, actual evapotranspiration, and effective rainfall for the 26 WMUs, and figure 23 presents a map of effective rainfall for Jamaica, while figure 24 presents normalized effective rainfall for Jamaica.

**TABLE 13: ESTIMATED MEAN POTENTIAL EVAPOTRANSPIRATION FROM MET OFFICE AWS OVER 2017-2018**

| STATION NAME        | PARISH    | LOCATION | CLIMATE | WIND     | AVERAGE POTENTIAL ET 2017-2018 (MM) |
|---------------------|-----------|----------|---------|----------|-------------------------------------|
| KEMPS HILL HS       | Clarendon | Coastal  | Humid   | Moderate | 1706.7                              |
| MASON RIVER 2       | Clarendon | Interior | Humid   | Moderate | 1408                                |
| MASON RIVER_10      | Clarendon | Interior | Humid   | Moderate | 1347.45                             |
| MAY PEN             | Clarendon | Interior | Arid    | Moderate | 1519.3                              |
| MITCHELL TOWN       | Clarendon | Coastal  | Arid    | Moderate | 1641.75                             |
| MONYMUSK            | Clarendon | Coastal  | Arid    | Moderate | 1986                                |
| N.YARMOUTH (OFFICE) | Clarendon | Interior | Humid   | Moderate | 1655.3                              |
| ROCKY PT. COM CEN.  | Clarendon | Coastal  | Arid    | High     | 1932.3                              |
| SALT RIVER          | Clarendon | Coastal  | Arid    | High     | 1623.7                              |
| VERNAMFIELD         | Clarendon | Coastal  | Arid    | Moderate | 1773                                |
| GREEN ISLAND HS     | Hanover   | Coastal  | Humid   | Moderate | 1711.1                              |

<sup>8</sup> "Water requirements and crop coefficients of tropical forest seedlings in different shading conditions" Montiero et al, "Revista Brasileira de Engenharia Agrícola e Ambiental v.20, n.8, p.709-715, 2016 Campina Grande, PB, UAEA/UFCEG – <http://www.agriambi.com.br>



| STATION NAME           | PARISH     | LOCATION | CLIMATE | WIND     | AVERAGE POTENTIAL ET 2017-2018 (MM) |
|------------------------|------------|----------|---------|----------|-------------------------------------|
| MOUNT PETO PRIM.       | Hanover    | Interior | Humid   | Moderate | 1550                                |
| RHODES HALL HS         | Hanover    | Coastal  | Humid   | High     | 1767.5                              |
| SHETTLEWOOD            | Hanover    | Interior | Humid   | Moderate | 1622.8                              |
| JACKS HILL (IVOR)      | Kingston   | Interior | Humid   | Moderate | 1247.9                              |
| MICO UC                | Kingston   | Coastal  | Humid   | Moderate | 1659.7                              |
| SHORTWOOD              | Kingston   | Interior | Humid   | Moderate | 1558.7                              |
| WOODFORD               | Kingston   | Interior | Humid   | Moderate | 1466.15                             |
| CROSS KEYS HS          | Manchester | Interior | Arid    | Moderate | 1358.3                              |
| GROVE PLACE            | Manchester | Interior | Humid   | Moderate | 1501.45                             |
| MARSHALL'S PEN SUTTON  | Manchester | Interior | Humid   | Moderate | 1432.3                              |
| NEW FOREST             | Manchester | Coastal  | Arid    | High     | 2208.9                              |
| ECCLESDOWN             | Portland   | Interior | Humid   | Moderate | 1218.2                              |
| FAIR PROSPECT          | Portland   | Coastal  | Humid   | High     | 1682.2                              |
| FAIR PROSPECT          | Portland   | Coastal  | Humid   | High     | 1497                                |
| HAPPY GROVE            | Portland   | Coastal  | Humid   | High     | 1344.15                             |
| PASSLEY GDN            | Portland   | Coastal  | Humid   | High     | 1398.9                              |
| BAMBOO (CHIPPENHAM PK) | St. Ann    | Interior | Humid   | Moderate | 1189.9                              |
| BENGAL FARM            | St. Ann    | Coastal  | Humid   | High     | 1616.7                              |
| COLE GATE              | St. Ann    | Coastal  | Humid   | Moderate | 1459                                |
| DUNNS RIVER            | St. Ann    | Coastal  | Humid   | High     | 1486.2                              |
| LLANDOVERY             | St. Ann    | Coastal  | Humid   | High     | 1404.6                              |
| MIDDLESEX              | St. Ann    | Interior | Humid   | Moderate | 1224.65                             |
| MINARDS EST.           | St. Ann    | Interior | Humid   | Moderate | 1356.7                              |
| MONEAGUE (UNITY VAL.)  | St. Ann    | Interior | Humid   | Moderate | 1296.7                              |
| WALKERSWOOD            | St. Ann    | Interior | Humid   | Moderate | 1395.6                              |

| STATION NAME            | PARISH        | LOCATION | CLIMATE | WIND     | AVERAGE POTENTIAL ET 2017-2018 (MM) |
|-------------------------|---------------|----------|---------|----------|-------------------------------------|
| WATT TOWN               | St. Ann       | Interior | Humid   | Moderate | 1573.4                              |
| BODLES                  | St. Catherine | Coastal  | Arid    | Moderate | 1807.6                              |
| GREATER PORT-MORE PRIM. | St. Catherine | Coastal  | Arid    | Moderate | 1539.8                              |
| HILL RUN FISH FARM      | St. Catherine | Coastal  | Humid   | Moderate | 1775.9                              |
| TULLOCH EST.            | St. Catherine | Interior | Humid   | Moderate | 1599                                |
| TWICKENHAM              | St. Catherine | Interior | Humid   | Moderate | 1517.8                              |
| WORTHY PARK             | St. Catherine | Interior | Humid   | Moderate | 1481.2                              |
| APPLETON                | St. Elizabeth | Interior | Humid   | Moderate | 1653.95                             |
| BARTON ISLES (CIB)      | St. Elizabeth | Interior | Humid   | Moderate | 1690.15                             |
| BETHLEHEM TC.           | St. Elizabeth | Interior | Arid    | High     | 1596.55                             |
| COMMA PEN               | St. Elizabeth | Coastal  | Arid    | High     | 2181                                |
| CRAWFORD                | St. Elizabeth | Coastal  | Arid    | High     | 2341.8                              |
| FLAGAMAN                | St. Elizabeth | Coastal  | Arid    | High     | 2178.15                             |
| HOLLAND BAMBOO          | St. Elizabeth | Interior | Humid   | Moderate | 1680.3                              |
| MAYFIELD AA             | St. Elizabeth | Interior | Arid    | High     | 1402.3                              |
| NEWCORBE VAL PRIM.      | St. Elizabeth | Coastal  | Arid    | Moderate | 1871.8                              |
| PONDSIDE PRIM.          | St. Elizabeth | Coastal  | Humid   | Moderate | 1891                                |
| SANTA CRUZ              | St. Elizabeth | Interior | Humid   | Moderate | 1659                                |
| MONTPELIER              | St. James     | Interior | Humid   | Moderate | 1562.15                             |
| ROEHAMPTON              | St. James     | Interior | Humid   | Moderate | 1434.1                              |
| FT GEORGE BOT. GDNS     | St. Mary      | Coastal  | Humid   | Moderate | 1699.7                              |
| ORANGE RIVER            | St. Mary      | Interior | Humid   | Moderate | 1384.35                             |
| DUCKENFIELD             | St. Thomas    | Coastal  | Humid   | Moderate | 1315.6                              |
| EAST ALBION             | St. Thomas    | Coastal  | Arid    | High     | 1934.6                              |
| JOHNS TOWN              | St. Thomas    | Coastal  | Humid   | Moderate | 1365.9                              |

| STATION NAME         | PARISH       | LOCATION | CLIMATE | WIND     | AVERAGE POTENTIAL ET 2017-2018 (MM) |
|----------------------|--------------|----------|---------|----------|-------------------------------------|
| NUTTS RIVER          | St. Thomas   | Coastal  | Humid   | Moderate | 1387                                |
| PLANTAIN GARDEN      | St. Thomas   | Coastal  | Humid   | Moderate | 1514.2                              |
| SERGE ISLAND         | St. Thomas   | Interior | Humid   | Moderate | 1535.1                              |
| YALLAHS              | St. Thomas   | Coastal  | Arid    | High     | 1427.65                             |
| BRACO ESTATE         | Trelawny     | Coastal  | Humid   | High     | 1690                                |
| HAMPDEN EST.         | Trelawny     | Coastal  | Humid   | Moderate | 1775.5                              |
| HOLLAND HS           | Trelawny     | Coastal  | Humid   | High     | 1673.2                              |
| LOWE RIVER           | Trelawny     | Interior | Humid   | Moderate | 1223.1                              |
| ORANGE VALLEY        | Trelawny     | Coastal  | Humid   | Moderate | 1576.2                              |
| PANTREPANT FARM      | Trelawny     | Interior | Humid   | Moderate | 1626.6                              |
| BURNT GROUND         | Westmoreland | Interior | Humid   | Moderate | 1607.2                              |
| FROME ESTATE         | Westmoreland | Interior | Humid   | Moderate | 1594.1                              |
| NEW HOPE PRIM        | Westmoreland | Coastal  | Humid   | High     | 1654.4                              |
| PINNOCK SHAFSTON     | Westmoreland | Interior | Humid   | Moderate | 1048.7                              |
| ROYAL PALM (NE-GRIL) | Westmoreland | Coastal  | Humid   | High     | 2160.35                             |





**TABLE 14: MEAN ANNUAL PRECIPITATION, ACTUAL EVAPORATION AND EFFECTIVE RAINFALL FOR WMUS (1992-2018)**

| BASIN                 | WMU                       | PRECIPITATION AND EVAPOTRANSPIRATION |                                        |                          |                      |                           |                      |
|-----------------------|---------------------------|--------------------------------------|----------------------------------------|--------------------------|----------------------|---------------------------|----------------------|
|                       |                           | MEAN ANNUAL PRECIPITATION            | MEAN ANNUAL ACTUAL EVAPO-TRANSPIRATION | TOTAL EFFECTIVE RAINFALL | BASIN PRECIPITA-TION | BASIN EVAPO-TRANSPIRATION | BASIN EFFECTIVE RAIN |
|                       |                           | MCM                                  | MCM                                    | MCM                      | MCM                  | MCM                       | MCM                  |
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 406.27                               | 134.19                                 | 272.08                   | 1,531.06             | 580.33                    | 950.73               |
|                       | Morant River              | 770.61                               | 296.45                                 | 474.16                   |                      |                           |                      |
|                       | Yallahs River             | 354.18                               | 149.68                                 | 204.49                   |                      |                           |                      |
| KINGSTON              | Hope River                | 385.91                               | 201.70                                 | 184.22                   | 385.91               | 201.70                    | 184.22               |
| RIO COBRE             | Rio Cobre                 | 2,055.17                             | 1,001.24                               | 1,053.93                 | 2,055.17             | 1,001.24                  | 1,053.93             |
| RIO MINHO             | Rio Minho                 | 1,121.52                             | 656.09                                 | 465.43                   | 2,548.57             | 1,517.40                  | 1,031.18             |
|                       | Milk River                | 1,237.51                             | 712.91                                 | 524.60                   |                      |                           |                      |
|                       | Gut River-Alligator Hole  | 189.54                               | 148.40                                 | 41.14                    |                      |                           |                      |
| BLACK RIVER           | Black River               | 2,230.43                             | 1,164.79                               | 1,065.64                 | 2,230.43             | 1,164.79                  | 1,065.64             |
| CABARITA RIVER        | Deans Valley River        | 854.71                               | 356.72                                 | 497.99                   | 1,745.71             | 790.72                    | 954.98               |
|                       | Cabarita River            | 561.63                               | 251.23                                 | 310.39                   |                      |                           |                      |
|                       | New Savannah River        | 63.91                                | 34.26                                  | 29.64                    |                      |                           |                      |
|                       | South Negril-Orange River | 265.46                               | 148.50                                 | 116.96                   |                      |                           |                      |
| GREAT RIVER           | Lucea River               | 473.86                               | 223.89                                 | 249.97                   | 1,448.80             | 677.36                    | 771.44               |
|                       | Great River               | 684.40                               | 282.16                                 | 402.25                   |                      |                           |                      |
|                       | Montego River             | 290.54                               | 171.31                                 | 119.22                   |                      |                           |                      |
| MARTHA BRAE           | Martha Brae               | 1,125.35                             | 609.84                                 | 515.51                   | 1,125.35             | 609.84                    | 515.51               |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River     | 2,454.45                             | 1,160.29                               | 1,294.16                 | 2,454.45             | 1,160.29                  | 1,294.16             |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 178.82                               | 80.65                                  | 98.17                    | 3,989.65             | 1,172.36                  | 2,817.28             |
|                       | Oracabessa-Pagee          | 252.01                               | 126.21                                 | 125.80                   |                      |                           |                      |
|                       | Wagwater River            | 596.06                               | 244.64                                 | 351.42                   |                      |                           |                      |
|                       | Pencar-Buff Bay River     | 516.93                               | 158.14                                 | 358.79                   |                      |                           |                      |
|                       | Spanish River             | 342.22                               | 85.89                                  | 256.32                   |                      |                           |                      |
|                       | Swift River               | 367.08                               | 83.95                                  | 283.13                   |                      |                           |                      |
|                       | Rio Grande                | 1,006.64                             | 216.19                                 | 790.45                   |                      |                           |                      |
|                       | Drivers River             | 729.90                               | 176.69                                 | 553.21                   |                      |                           |                      |
| TOTAL                 |                           | 19,515.11                            | 8,876.04                               | 10,639.07                | 19,515.11            | 8,876.04                  | 10,639.07            |

## Potential Evapotranspiration (ET) Contours for the Period 2017-2018

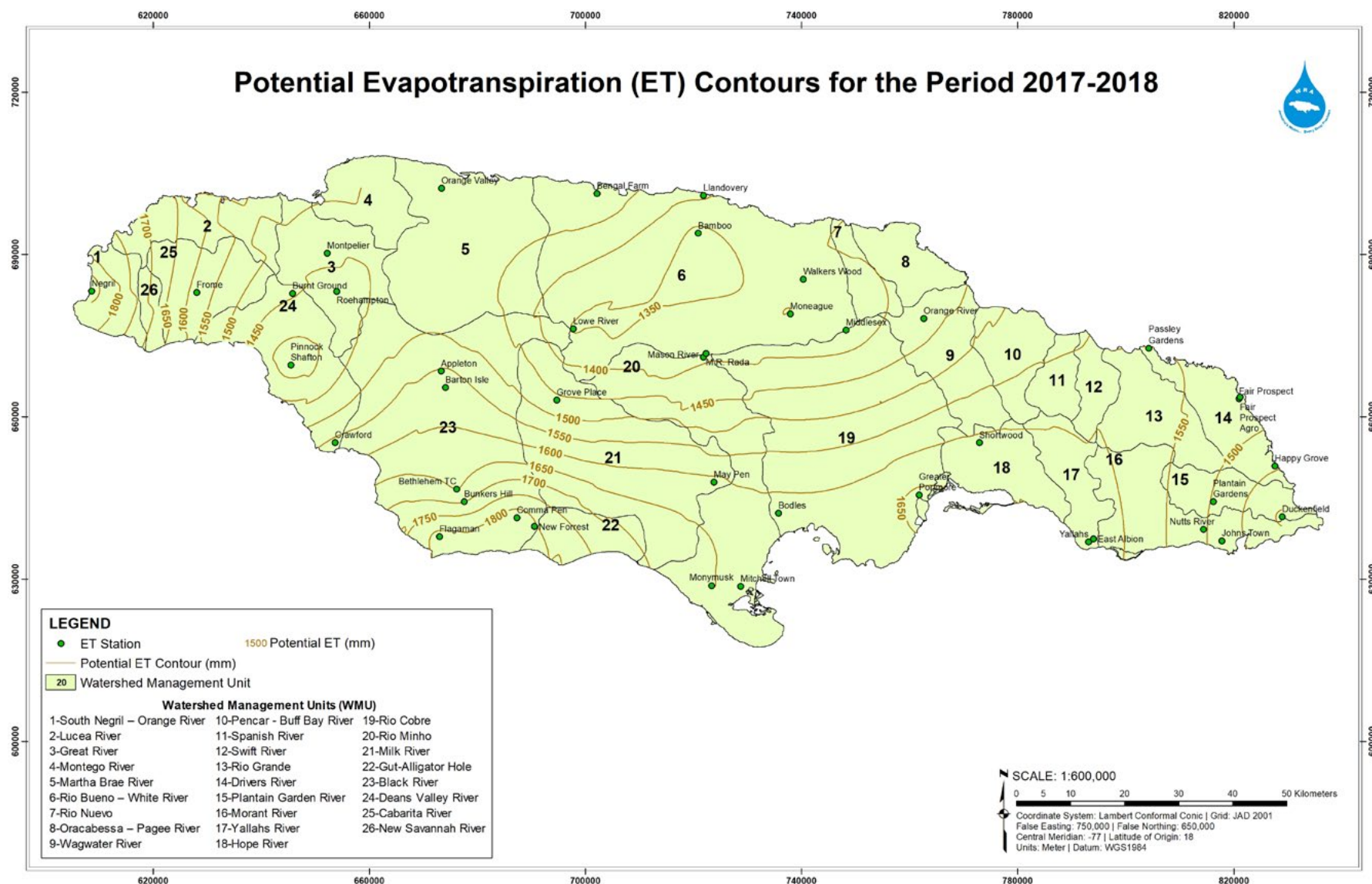


Figure 22: Estimated Actual Evapotranspiration for the Period 2017-2018



WRA

WATER RESOURCES AUTHORITY

## Effective Rainfall per WMU

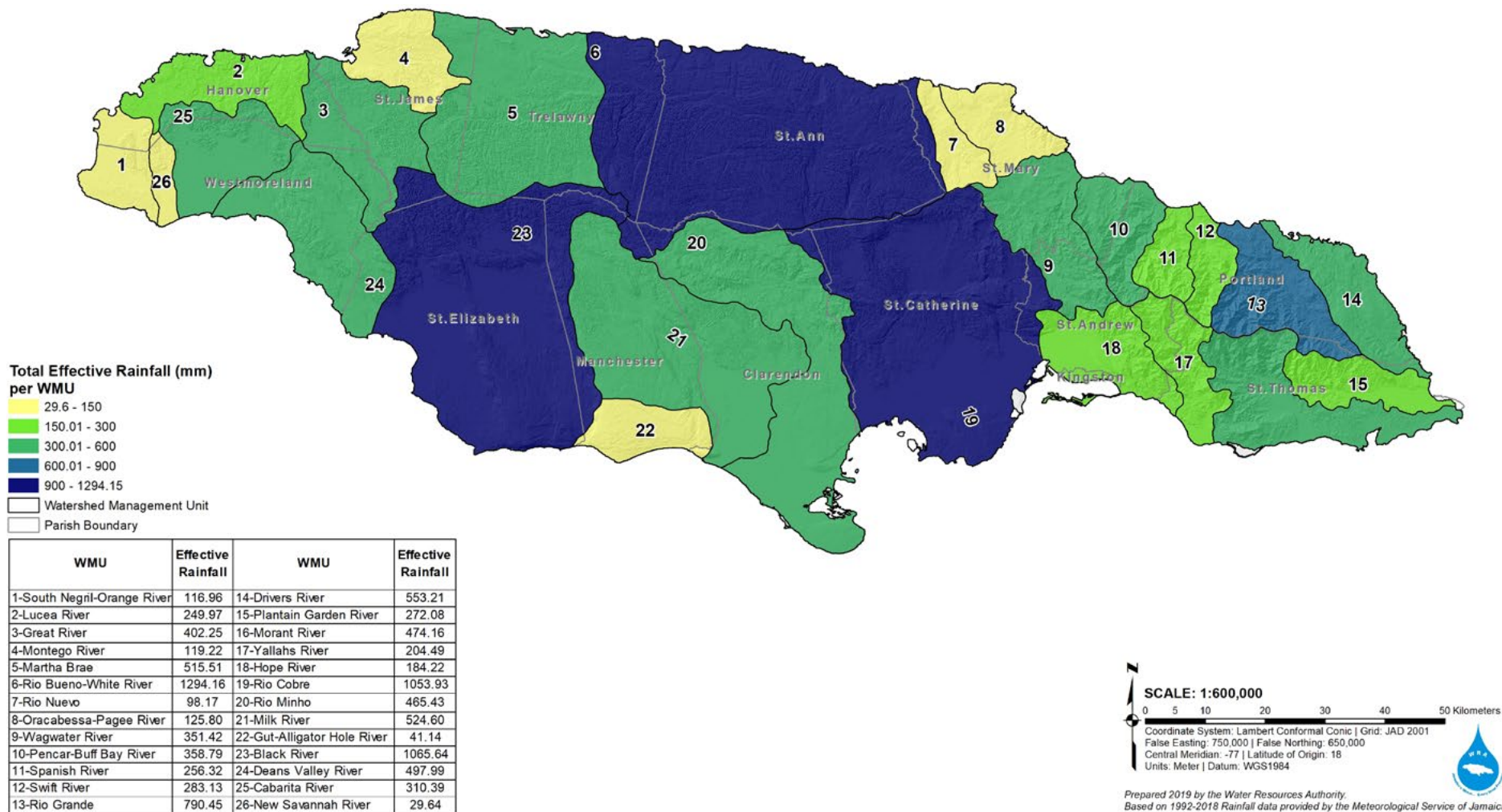


Figure 23: Total Mean Effective Rainfall per WMU



## Normalised Effective Rainfall per WMU

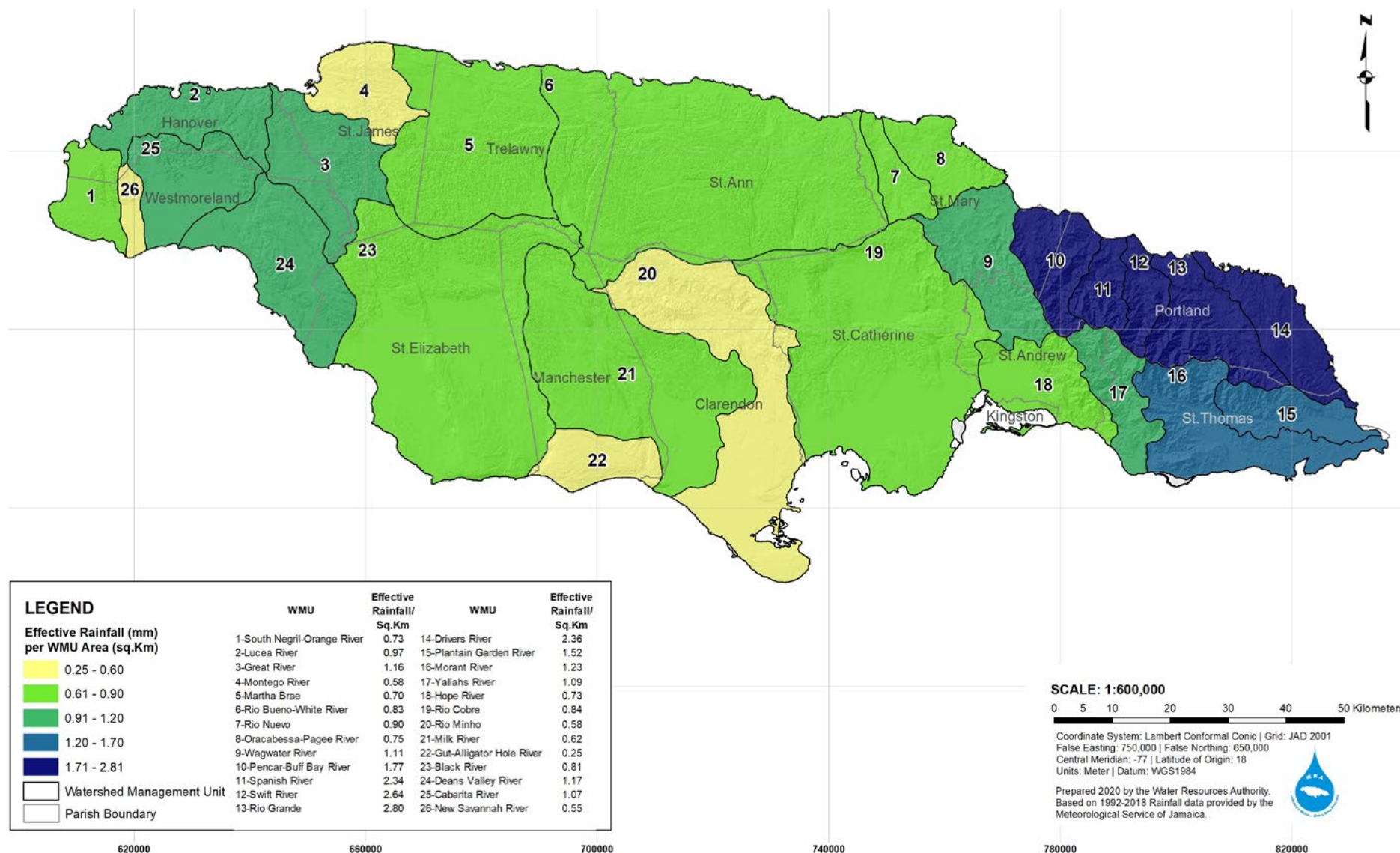


Figure 24: Total Mean Effective Rainfall per Square KM for WMU



## STREAMFLOW

Streamflow data was collected from 127 current stream gauge stations (including continuous flow and spot flow measurement stations) and 52 discontinued stream gauge stations (historical data) to give an estimate of mean river discharge from the various WMUs. Mean Annual Flow data from Gauge Stations near the WMU outlet(s) were used to represent the streamflow component of Equation 4. Baseflow Index (BFI) values were calculated and applied where available to estimate the baseflow contributions of the MAFs, and the difference between Baseflow and MAF was estimated as the Surface Runoff. Table 15 presents the Mean Annual Flows from available streamflow stations within each WMU. Figure 25 presents a linear regression between estimated Effective Rain and Mean Annual Flow for all 10 hydrologic basins. The MAFs do not include ungauged streams which may flow into the major streams down-gradient of the established stations (e.g. Negro River which flows into the Morant River below the gauge station), so this estimate may be an under-estimation of available runoff. Possible methods for future estimation of ungauged runoff would include modelling, correlation of runoff and drainage areas, and establishment of gauges on currently ungauged streams. These can be considered for future updates of the WRMDP.

**TABLE 15: ESTIMATED MEAN ANNUAL FLOW FROM WMUS**

| BASIN                 | WMU                       | BASE FLOW<br>(MCM/YEAR) | RUNOFF<br>(MCM/YEAR) | TOTAL MAF<br>(MCM/YEAR) |
|-----------------------|---------------------------|-------------------------|----------------------|-------------------------|
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 64.17                   | 117.61               | 181.77                  |
|                       | Morant River              | 43.88                   | 45.13                | 89.01                   |
|                       | Yallahs River             | 87.99                   | 55.97                | 143.96                  |
| KINGSTON              | Hope River                | 13.59                   | 8.80                 | 22.39                   |
| RIO COBRE             | Rio Cobre                 | 222.34                  | 127.39               | 349.73                  |
| RIO MINHO             | Rio Minho                 | 41.90                   | 105.12               | 147.02                  |
|                       | Milk River                | 20.50                   | 28.66                | 49.16                   |
|                       | Gut River-Alligator Hole  | 243.74                  | 27.08                | 270.82                  |
| BLACK RIVER           | Black River               | 616.27                  | 160.15               | 776.42                  |
| CABARITA RIVER        | Deans Valley River        | 8.56                    | 74.94                | 83.51                   |
|                       | Cabarita River            | 157.91                  | 79.55                | 237.47                  |
|                       | New Savannah River        | 3.37                    | 18.23                | 21.60                   |
|                       | South Negril-Orange River | 13.17                   | 14.42                | 27.59                   |
| GREAT RIVER           | Lucea River               | 5.96                    | 13.93                | 19.89                   |
|                       | Great River               | 220.29                  | 142.63               | 362.91                  |
|                       | Montego River             | 23.89                   | 38.33                | 62.22                   |
| MARTHA BRAE           | Martha Brae               | 336.11                  | 92.60                | 428.71                  |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River     | 613.21                  | 101.02               | 714.23                  |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 38.61                   | 31.08                | 69.69                   |
|                       | Oracabessa-Pagee          | 41.26                   | 48.44                | 89.70                   |
|                       | Wagwater River            | 70.06                   | 83.24                | 153.30                  |
|                       | Pencar-Buff Bay River     | 106.42                  | 214.41               | 320.83                  |
|                       | Spanish River             | 57.78                   | 68.92                | 126.70                  |
|                       | Swift River               | 77.33                   | 142.35               | 219.68                  |
|                       | Rio Grande                | 255.05                  | 506.29               | 761.34                  |
|                       | Drivers River             | 3.32                    | 6.30                 | 9.62                    |
| TOTAL                 | 3386.69                   | 2352.59                 | 5739.29              |                         |

## Hydrological Basins and Watershed Management Units (WMUs) of Jamaica

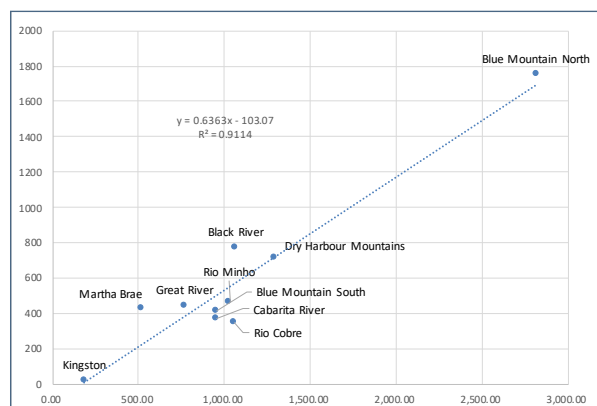


Figure 25: Effective Rain vs Mean Annual Flow (basins)

### SUBMARINE DISCHARGE

The assessment of Jamaica's water resources carried out in 1990 (Underground Water Authority, 1990) used the Ghyben-Herzberg equation (Badon-Ghyben, 1889; Herzberg, 1901; Freeze and Cherry, 1979) to calculate the minimum required submarine discharge to prevent saltwater intrusion in Jamaica's ten hydrologic basins. This equation is:

$$GW_{GH} = \frac{T * h * w * a}{2 * L}$$

where:

$GW_{GH}$  = the required freshwater discharge ( $m^3/day$ )

T = aquifer transmissivity ( $m^2/day$ )

h = thickness of the aquifer (m)

w = width of the aquifer, or coastline length, through which discharge takes place (m)

a = Ghyben-Herzberg ratio = 0.025

L = distance inland to the toe of the sea water wedge (m).

Table 16 gives the hydro-geological parameters that were estimated for the 1990 and 2005 WRDMP update, as well as the required submarine discharge rates for WMU's with the estimated parameters. Further research is needed to more accurately determine the parameters and submarine discharge.

**TABLE 16 HYDRO-GEOLOGICAL PARAMETERS OF THE REQUIRED SUBMARINE DISCHARGE RATE FOR EACH WMU**

| BASIN | WMU | M/DAY                          | K<br>M | H<br>M <sup>2</sup> /DAY | T<br>M | W<br>M | L<br>M | QS<br>106M <sup>3</sup> /<br>YEAR M <sup>3</sup> /<br>YEAR |
|-------|-----|--------------------------------|--------|--------------------------|--------|--------|--------|------------------------------------------------------------|
| I     | 15  | Plantain Garden River Alluvium | 25     | 60                       | 1,490  | 3,000  | 1,000  | 1.2                                                        |
|       | 16  | Morant Alluvium                | 50     | 30                       | 1,490  | 2,750  | 250    | 2.2                                                        |
|       | 17  | Yallahs Alluvium               | 50     | 30                       | 1,490  | 3,350  | 500    | 1.4                                                        |
| II    | 18  | Hope River                     | 18     | 60                       | 1,080  | 10500  | 150    | 20.7                                                       |
| III   | 19  | Rio Cobre Limestone            | 99     | 30                       | 2,980  | 27,000 | 150    | 73.4                                                       |
| IV    | 20  | Rio Minho                      | 167    | 90                       | 15,000 | 18,000 | 750    | 147.8                                                      |
|       | 21  | Milk River                     | 167    | 90                       | 15,000 | 6,700  | 750    | 55                                                         |
|       | 22  | Gut River - Alligator Hole     | 167    | 90                       | 15,000 | 19000  | 750    | 156                                                        |
| V     | 23  | Black River                    | 250    | 50                       | 12,500 | 54,000 | 1000   | 154                                                        |
| VI    | 24  | Dean's Valley River            | 67     | 45                       | 3,000  | 9,000  | 500    | 11.1                                                       |
|       | 25  | Cabarita River                 | 67     | 45                       | 3,000  | 5,500  | 500    | 6.8                                                        |
|       | 26  | New Savannah River             | 67     | 45                       | 3,000  | 6,500  | 500    | 8                                                          |
|       | 1   | South Negril - Orange River    | 67     | 45                       | 3,000  | 13,000 | 500    | 16                                                         |
| VII   | 2   | Lucea River                    | 66     | 45                       | 2,980  | 8,000  | 750    | 6.5                                                        |
|       | 3   | Great River Limestone          | 66     | 45                       | 2,980  | 6,000  | 150    | 24.5                                                       |
|       | 4   | Montego River Limestone        | 66     | 45                       | 2,980  | 9,000  | 300    | 18.4                                                       |
| VIII  | 5   | Martha Brae River              | 22     | 45                       | 1,000  | 22,000 | 300    | 15.1                                                       |

|       |     |                         | K  | H                   | T     | W      | L    | QS                                           |
|-------|-----|-------------------------|----|---------------------|-------|--------|------|----------------------------------------------|
| BASIN | WMU | M/DAY                   | M  | M <sup>2</sup> /DAY | M     | M      | M    | 106M <sup>3</sup> /YEAR M <sup>3</sup> /YEAR |
| IX    | 6   | Rio Bueno - White River | 24 | 250                 | 6,000 | 50,000 | 1000 | 142.6 (2005)                                 |
| X     | 7   | Rio Nuevo               | -  | 0                   | -     | 4,500  | -    | 0                                            |
|       | 8   | Oracabessa REiver       | -  | 0                   | -     | -      | -    | 0                                            |
|       | 9   | Wagwater River          | -  | 0                   | -     | -      | -    | 0                                            |
|       | 10  | Pencar - Buff Bay River | -  | 0                   | -     | -      | -    | 0                                            |
|       | 11  | Spanish River           | -  | 0                   | -     | 2,000  | -    | 0                                            |
|       | 12  | Swift River             | -  | 0                   | -     | 3,000  | -    | 0                                            |
|       | 13  | Rio Grande              | -  | 0                   | -     | 5,000  | -    | 0                                            |
|       | 14  | Drivers River           | -  | 0                   | -     | 25,000 | -    | 0                                            |
| TOTAL |     |                         |    |                     |       |        |      | 1,060.30                                     |

## INTER-WMU FLOW

Watershed Management Units in Jamaica are established by ground surface elevations, and their boundaries are usually the divides between surface water flow to one river system in one direction, and to another in an opposite direction. However, the groundwater elevation in an aquifer may not necessarily reflect the surface contours. A schematic view of such a situation is given in Figure 25 where the divide is the highest surface elevation between two adjacent WMUs. However, there is a groundwater potential (energy per unit weight) gradient across the WMU boundary that causes sub-surface flow across the WMUs, referred to as Inter-WMU Flow. It is possible that there are inter-WMU flows across many watershed boundaries in Jamaica. Preliminary observations based on well water levels and estimated aquifer properties indicated that these are generally small. However, there are instances where the inter-WMU transfer may be considerable, as implied by streamflows of significant volume which differ from the observed mean annual rainfall input and WMU area. A possible example of this is the Gut River WMU, which has a combined Mean Annual Discharge of 270.82 MCM/year from its three rivers (Gut River, Swift River, Alligator Hole) but has a total precipitation input over the WMU area of 189.54 MCM/year **before** accounting for ET. Other potential areas that may have significant inter-WMU transfer are the Black River/Rio Minho Basin boundaries in the Bull Savannah region, and the Lucea and Great River WMUs in north-western Jamaica. Further research is needed to accurately describe and quantify this phenomenon.

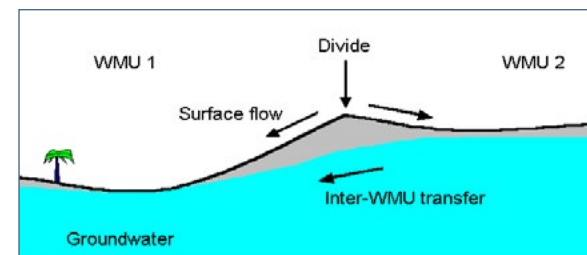


Figure 26: Mechanism for Inter-WMU Transfer

## SURFACE WATER SAFE YIELD DETERMINATION

Total surface water resources are estimated as the long-term mean annual flows. The 1990 WRDMP used  $Q_{90}$  and the minimum mean daily flow to define reliable surface water yield. The  $Q_{90}$  as an index of reliability is usually sufficient for agricultural supply but the higher reliability of the  $Q_{95}$  is used for domestic and industrial supplies. This study has adopted the same definition. The reliable surface water yield for gauged rivers was determined from stream flow records (Table 4.4). For ungauged rivers in the draft 2005 master plan, these were derived based on regression analysis as shown in figure 23.

## Q95, Q90 7-DAY 10-YEAR MINIMUM FLOW AND ENVIRONMENTAL FLOW.

Table 17 presents the summarized  $Q_{95}$ ,  $Q_{90}$ , 7Day10Year and Environmental flows from historical (current and discontinued) stations within each WMU. Flows from ungauged streams are not quantified at this time; further research is needed to provide accurate estimates of flow reliability and annual flow from these sources. This indicates that the reliable surface water safe

yield may potentially increase with further validation of ungauged flows. The 7-Day Minimum Flow over 10 year return period refers to the lowest 7-day average flow that occurs on average once in 10 years over a long period, or has a 10% chance of occurring in any given year. Environmental flow refers to the lowest stream discharge that satisfies flow maintenance and ecological preservation. For the WRDMP, Environmental Flow was defined as 60% of the 7-Day -10 Year Minimum Flow (where available).

**TABLE 17: Q95, Q90, 7D10 AND ENVIRONMENTAL FLOWS FOR WMUS.**

| BASIN                    | WMU                       | Q95<br>(MCM/<br>YEAR) | Q90<br>(MCM/<br>YEAR) | 7D10<br>(MCM/<br>YEAR) | ENVI-<br>RON-<br>MENTAL<br>FLOW<br>(MCM/<br>YEAR) |
|--------------------------|---------------------------|-----------------------|-----------------------|------------------------|---------------------------------------------------|
| BLUE MOUNTAIN<br>SOUTH   | Plantain Garden River     | 10.41                 | 17.00                 | 4.45                   | 2.67                                              |
|                          | Morant River              | 28.16                 | 35.07                 | 14.29                  | 8.57                                              |
|                          | Yallahs River             | 55.94                 | 66.64                 | 21.82                  | 13.09                                             |
| KINGSTON                 | Hope River                | 4.79                  | 5.71                  | 3.03                   | 1.82                                              |
| RIO COBRE                | Rio Cobre                 | 93.54                 | 122.27                | 57.36                  | 34.42                                             |
| RIO MINHO                | Rio Minho                 | 66.41                 | 86.00                 | 7.85                   | 4.71                                              |
|                          | Milk River                | 18.98                 | 23.97                 | 0.76                   | 0.45                                              |
|                          | Gut River-Alligator Hole  | 42.32                 | 93.83                 | 4.19                   | 2.52                                              |
| BLACK RIVER              | Black River               | 484.61                | 587.48                | 330.97                 | 198.58                                            |
| CABARITA RIVER           | Deans Valley River        | 5.96                  | 8.61                  | 2.96                   | 1.78                                              |
|                          | Cabarita River            | 85.34                 | 107.92                | 52.41                  | 31.45                                             |
|                          | New Savannah River        | 0.22                  | 0.38                  | 0.00                   | 0.00                                              |
|                          | South Negril-Orange River | 1.23                  | 2.65                  | 0.57                   | 0.34                                              |
| SGREAT RIVER             | Lucea River               | 1.61                  | 2.14                  | 0.73                   | 0.44                                              |
|                          | Great River               | 61.15                 | 75.28                 | 31.16                  | 18.69                                             |
|                          | Montego River             | 9.21                  | 11.89                 | 4.54                   | 2.72                                              |
| MARTHA BRAE              | Martha Brae               | 166.16                | 232.26                | 93.00                  | 55.80                                             |
| DRY HARBOUR<br>MOUNTAINS | Rio Bueno-White River     | 378.09                | 434.38                | 314.98                 | 188.99                                            |

The Rio Minho, Rio Cobre and Black River basins account for 44%, 21% and 14% of current groundwater allocations respectively, which indicates the necessity for precise and accurate monitoring of groundwater from these basins to ensure sustainable abstraction and protection of the existing water resources therein.

| BASIN                  | WMU                   | Q95<br>(MCM/<br>YEAR) | Q90<br>(MCM/<br>YEAR) | 7D10<br>(MCM/<br>YEAR) | ENVI-<br>RON-<br>MENTAL<br>FLOW<br>(MCM/<br>YEAR) |
|------------------------|-----------------------|-----------------------|-----------------------|------------------------|---------------------------------------------------|
| BLUE MOUNTAIN<br>NORTH | Rio Nuevo             | 14.03                 | 17.03                 | 12.49                  | 7.49                                              |
|                        | Oracabessa-Pagee      | 19.74                 | 24.38                 | 13.62                  | 8.17                                              |
|                        | Wagwater River        | 42.57                 | 57.36                 | 15.02                  | 9.01                                              |
|                        | Pencar-Buff Bay River | 53.67                 | 63.89                 | 24.00                  | 14.40                                             |
|                        | Spanish River         | 53.49                 | 70.64                 | 25.83                  | 15.50                                             |
|                        | Swift River           | 59.48                 | 74.74                 | 27.66                  | 16.59                                             |
|                        | Rio Grande            | 169.76                | 216.05                | 88.33                  | 53.00                                             |
|                        | Drivers River         | 0.32                  | 1.14                  | 0.00                   | 0.00                                              |
| TOTAL                  | 1927.19               | 2438.69               | 1152.01               | 691.21                 |                                                   |

## GROUNDWATER INVENTORY

Table 18 presents a summary of the known wells/boreholes in Jamaica with the available reported abstraction data and licensed abstraction rates over the period of record as at November 2019. The data indicates that the reported abstraction is generally less than the allocated abstraction; however, this may not reflect the actual abstractions in the basin, due to the non-reporting of some abstractors. Additionally, the observed mean abstraction data for the Milk River WMU and Black River WMU may not reflect the actual abstraction, as the figures appear to have been reported as an over-estimation or inaccurate unit conversions in the historical records. The median reported abstraction may be a more realistic estimation of the reported abstraction over the various periods of record at this time, and is included in Table 18 instead of the mean abstraction.

50.03% of the wells on record are drilled into the various Limestone Aquifers /Aquicludes, while 30.29% are drilled into the various Alluvium Aquifers/Aquicludes. The remaining 19.23% of wells are drilled into one of the two aquifer types (alluvium/limestone) but the exact lithology is not on record to confirm the well aquifer provenance. Some of these wells tap both alluvium and limestone sources, while a few may be drilled into peats (wetlands).



**TABLE 18: AVAILABLE WELL INFORMATION AND REPORTED ABSTRACTION FOR JAMAICA**

| BASIN                 | WMU                       | WELLS           |                |                     |                 |             |                   |  |
|-----------------------|---------------------------|-----------------|----------------|---------------------|-----------------|-------------|-------------------|--|
|                       |                           | LIMESTONE WELLS | ALLUVIUM WELLS | UNKNOWN/OTHER WELLS | WMU TOTAL WELLS | % OF TOTAL  | BASIN TOTAL WELLS |  |
| BLUE MOUNTAIN SOUTH   | Plantain Garden           | 5               | 11             | 7                   | 23              | 1%          | 112               |  |
|                       | Morant River              | 9               | 31             | 8                   | 48              | 2%          |                   |  |
|                       | Yallahs River             | 2               | 32             | 7                   | 41              | 2%          |                   |  |
| KINGSTON              | Hope River                | 17              | 115            | 27                  | 159             | 7%          | 159               |  |
| RIO COBRE             | Rio Cobre                 | 281             | 229            | 54                  | 564             | 25%         | 564               |  |
| RIO MINHO             | Rio Minho                 | 103             | 133            | 34                  | 270             | 12%         | 466               |  |
|                       | Milk River                | 114             | 45             | 31                  | 190             | 9%          |                   |  |
|                       | Gut River-Alligator Hole  | 4               | 0              | 2                   | 6               | 0%          |                   |  |
| BLACK RIVER           | Black River               | 231             | 4              | 111                 | 346             | 16%         | 346               |  |
| CABARITA RIVER        | Deans Valley River        | 32              | 1              | 0                   | 33              | 1%          | 125               |  |
|                       | Cabarita River            | 19              | 1              | 0                   | 20              | 1%          |                   |  |
|                       | New Savannah River        | 9               | 0              | 0                   | 9               | 0%          |                   |  |
|                       | South Negril-Orange River | 46              | 5              | 12                  | 63              | 3%          |                   |  |
| GREAT RIVER           | Lucea River               | 6               | 4              | 6                   | 16              | 1%          | 88                |  |
|                       | Great River               | 9               | 0              | 1                   | 10              | 0%          |                   |  |
|                       | Montego River             | 43              | 1              | 18                  | 62              | 3%          |                   |  |
| MARTHA BRAE           | Martha Brae               | 79              | 0              | 22                  | 101             | 5%          | 101               |  |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River     | 88              | 0              | 27                  | 115             | 5%          | 115               |  |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 1               | 0              | 1                   | 2               | 0%          | 139               |  |
|                       | Oracabessa-Pagee          | 4               | 2              | 5                   | 11              | 0%          |                   |  |
|                       | Wagwater River            | 4               | 29             | 24                  | 57              | 3%          |                   |  |
|                       | Pencar River-Buff Bay     | 3               | 21             | 13                  | 37              | 2%          |                   |  |
|                       | Spanish River             | 0               | 0              | 1                   | 1               | 0%          |                   |  |
|                       | Swift River               | 0               | 2              | 3                   | 5               | 0%          |                   |  |
|                       | Rio Grande                | 0               | 5              | 7                   | 12              | 1%          |                   |  |
|                       | Drivers River             | 7               | 0              | 7                   | 14              | 1%          |                   |  |
| <b>TOTAL</b>          | <b>1116</b>               | <b>671</b>      | <b>428</b>     | <b>2215</b>         | <b>100%</b>     | <b>2215</b> | <b>100%</b>       |  |



| % OF TOTAL | ALLOCATIONS                               |            |                                              |            | REPORTED ABSTRACTION                                               |                                                    |
|------------|-------------------------------------------|------------|----------------------------------------------|------------|--------------------------------------------------------------------|----------------------------------------------------|
|            | WMU TOTAL LICENSED ALLOCATIONS (MCM/YEAR) | % OF TOTAL | BASIN TOTAL ALLOCATED ABSTRACTION (MCM/YEAR) | % OF TOTAL | REPORTED TOTAL MEDIAN ABSTRACTION OVER PERIOD OF RECORD (MCM/YEAR) | BASIN TOTAL MEDIAN REPORTED ABSTRACTION (MCM/YEAR) |
| 5%         | 0.29                                      | 0%         | 23.22                                        | 4%         | 0.00                                                               | 0.00                                               |
|            | 14.26                                     | 2%         |                                              |            | 0.00                                                               |                                                    |
|            | 8.67                                      | 1%         |                                              |            | 0.00                                                               |                                                    |
| 7%         | 24.91                                     | 4%         | 24.91                                        | 4%         | 0.00                                                               | 0.00                                               |
| 25%        | 136.10                                    | 21%        | 136.10                                       | 21%        | 136.01                                                             | 136.01                                             |
| 21%        | 99.34                                     | 15%        | 282.76                                       | 44%        | 102.69                                                             | 213.41                                             |
|            | 181.76                                    | 28%        |                                              |            | 109.34                                                             |                                                    |
|            | 1.66                                      | 0%         |                                              |            | 1.38                                                               |                                                    |
| 16%        | 88.11                                     | 14%        | 88.11                                        | 14%        | 38.59                                                              | 38.59                                              |
| 6%         | 2.25                                      | 0%         | 3.06                                         | 0%         | 0.09                                                               | 0.13                                               |
|            | 0.00                                      | 0%         |                                              |            | 0.00                                                               |                                                    |
|            | 0.00                                      | 0%         |                                              |            | 0.00                                                               |                                                    |
|            | 0.81                                      | 0%         |                                              |            | 0.03                                                               |                                                    |
| 4%         | 2.24                                      | 0%         | 18.40                                        | 3%         | 0.82                                                               | 7.46                                               |
|            | 0.24                                      | 0%         |                                              |            | 0.00                                                               |                                                    |
|            | 15.92                                     | 2%         |                                              |            | 6.64                                                               |                                                    |
| 5%         | 15.92                                     | 2%         | 15.92                                        | 2%         | 13.11                                                              | 13.11                                              |
| 5%         | 21.88                                     | 3%         | 21.88                                        | 3%         | 10.10                                                              | 10.10                                              |
| 6%         | 0.00                                      | 0%         | 28.06                                        | 4%         | 0.00                                                               | 0.36                                               |
|            | 0.00                                      | 0%         |                                              |            | 0.00                                                               |                                                    |
|            | 10.57                                     | 2%         |                                              |            | 0.16                                                               |                                                    |
|            | 16.10                                     | 3%         |                                              |            | 0.09                                                               |                                                    |
|            | 0.00                                      | 0%         |                                              |            | 0.00                                                               |                                                    |
|            | 0.00                                      | 0%         |                                              |            | 0.00                                                               |                                                    |
|            | 0.00                                      | 0%         |                                              |            | 0.10                                                               |                                                    |
|            | 1.39                                      | 0%         |                                              |            | 0.01                                                               |                                                    |
| 642.42     | 100%                                      | 642.42     | 100%                                         | 419.16     | 419.16                                                             |                                                    |



## WATER RESOURCES ASSESSMENT

Table 19 is a summary of the water budget for each WMU in Jamaica, as well as the annual safe groundwater and the reliable surface water yields based on the methodology described in section 4. Some uncertainty remains in the estimation of inter-basin flow, as there is strong evidence of this occurrence in the Gut River WMU in particular. The observed negative GW safe yield in this WMU is due to the relatively high stream discharge when compared to the observed rainfall in that region. This is further complicated by the fact that the streamflow stations in this WMU are spot measurements. It is most likely that the sustained streamflow in this WMU is due to some form of groundwater discharge from aquifer storage outside the WMU, but further research and investigation is required to better understand this phenomenon.

Additionally, a significant portion of the runoff in ungauged streams is reflected in the estimated GW yield. The TOR for the current WRDMP focused on the 26 WMUs, which had stream gauge stations on the majority of constituent watersheds, but not on all rivers. Future revisions of this master plan will focus on the smaller sub-WMUs with both gauged and ungauged streams for a more discrete examination of the water budget as well as statistical analysis to better estimate the flows in ungauged basins. Suggestions for new flow measurement stations are presented in Chapter 9 of this document.



**TABLE 19: WMU WATER BUDGET (MCM/YEAR)**

| BASIN               | WMU                      | MEAN ANNUAL PRECIPITATION | MEAN ANNUAL ACTUAL EVAPO-TRANSPIRATION | EFFECTIVE RAIN | BASE FLOW     | RUNOFF        | GH FLOW       | GW SAFE YIELD* | Q95 (DOMESTIC) SAFE YIELD | Q90 SAFE YIELD | ENVIRONMENTAL FLOW | INTER-BASIN FLOW | TOTAL DOMESTIC SAFE YIELD | TOTAL SAFE YIELD |
|---------------------|--------------------------|---------------------------|----------------------------------------|----------------|---------------|---------------|---------------|----------------|---------------------------|----------------|--------------------|------------------|---------------------------|------------------|
| BLUE MOUNTAIN SOUTH | Plantain Garden River    | 406.27                    | 134.19                                 | 272.08         | 64.17         | 117.61        | 1.20          | 89.11          | 10.41                     | 17.00          | 2.67               |                  | 96.85                     | 103.44           |
|                     | Morant River             | 770.61                    | 296.45                                 | 474.16         | 43.88         | 45.13         | 2.20          | 382.95         | 28.16                     | 35.07          | 8.57               |                  | 402.54                    | 409.45           |
|                     | Yallahs River            | 354.18                    | 149.68                                 | 204.49         | 87.99         | 55.97         | 1.40          | 59.13          | 55.94                     | 66.64          | 13.09              |                  | 101.98                    | 112.67           |
|                     | <b>BASIN TOTAL</b>       | <b>1531.06</b>            | <b>580.33</b>                          | <b>950.73</b>  | <b>196.04</b> | <b>218.70</b> | <b>4.80</b>   | <b>531.19</b>  | <b>94.51</b>              | <b>118.70</b>  | <b>24.33</b>       | <b>0.00</b>      | <b>601.37</b>             | <b>625.56</b>    |
| KINGSTON            | HOPE RIVER               | 385.91                    | 201.70                                 | 184.22         | 13.59         | 8.80          | 20.70         | 141.12         | 4.79                      | 5.71           | 1.82               |                  | 144.10                    | 145.01           |
| RIO COBRE           | RIO COBRE                | 2055.17                   | 1001.24                                | 1053.93        | 222.34        | 127.39        | 73.40         | 630.80         | 93.54                     | 122.27         | 34.42              |                  | 689.92                    | 718.65           |
| RIO MINHO           | Rio Minho                | 1121.52                   | 656.09                                 | 465.43         | 41.90         | 105.12        | 90.50         | 227.91         | 66.41                     | 86.00          | 4.71               |                  | 289.61                    | 309.20           |
|                     | Milk River               | 1237.51                   | 712.91                                 | 524.60         | 20.50         | 28.66         | 156.00        | 319.44         | 18.98                     | 23.97          | 0.45               |                  | 337.97                    | 342.95           |
|                     | Gut River-Alligator Hole | 189.54                    | 148.40                                 | 41.14          | 243.74        | 27.08         | 41.30         | -270.98        | 42.32                     | 93.83          | 2.52               |                  | -231.17                   | -179.66          |
|                     | <b>Basin Total</b>       | <b>2548.57</b>            | <b>1517.40</b>                         | <b>1031.18</b> | <b>306.14</b> | <b>160.86</b> | <b>287.80</b> | <b>276.37</b>  | <b>127.72</b>             | <b>203.80</b>  | <b>7.68</b>        | <b>0.00</b>      | <b>396.41</b>             | <b>472.49</b>    |

| BASIN                 | WMU                       | MEAN ANNUAL PRECIPITATION | MEAN ANNUAL ACTUAL EVAPO-TRANSPIRATION | EFFECTIVE RAIN | BASE FLOW      | RUNOFF         | GH FLOW        | GW SAFE YIELD* | Q95 (DOMESTIC) SAFE YIELD | Q90 SAFE YIELD | ENVIRONMENTAL FLOW | INTER-BASIN FLOW | TOTAL DOMESTIC SAFE YIELD | TOTAL SAFE YIELD |
|-----------------------|---------------------------|---------------------------|----------------------------------------|----------------|----------------|----------------|----------------|----------------|---------------------------|----------------|--------------------|------------------|---------------------------|------------------|
| BLACK RIVER           | Black River               | 2230.43                   | 1164.79                                | 1065.64        | 616.27         | 160.15         | 154.00         | 135.22         | 484.61                    | 587.48         | 198.58             |                  | 421.26                    | 524.13           |
| CABARITA RIVER        | Deans Valley River        | 854.71                    | 356.72                                 | 497.99         | 8.56           | 74.94          | 11.10          | 403.38         | 5.96                      | 8.61           | 1.78               |                  | 407.56                    | 410.21           |
|                       | Cabarita River            | 561.63                    | 251.23                                 | 310.39         | 157.91         | 79.55          | 6.80           | 66.13          | 85.34                     | 107.92         | 31.45              |                  | 120.02                    | 142.60           |
|                       | New Savannah River        | 63.91                     | 34.26                                  | 29.64          | 3.37           | 18.23          | 8.00           | 0.04           | 0.22                      | 0.38           | 0.00               |                  | 0.26                      | 0.42             |
|                       | South Negril-Orange River | 265.46                    | 148.50                                 | 116.96         | 13.17          | 14.42          | 16.00          | 73.36          | 1.23                      | 2.65           | 0.34               |                  | 74.25                     | 75.67            |
|                       | Basin Total               | 1745.71                   | 790.72                                 | 954.98         | 183.02         | 187.15         | 41.90          | 542.92         | 92.75                     | 119.55         | 33.57              | 0.00             | 602.10                    | 628.90           |
| GREAT RIVER           | Lucea River               | 473.86                    | 223.89                                 | 249.97         | 5.96           | 13.93          | 6.50           | 223.58         | 1.61                      | 2.14           | 0.44               |                  | 224.75                    | 225.29           |
|                       | Great River               | 684.40                    | 282.16                                 | 402.25         | 220.29         | 142.63         | 9.50           | 29.83          | 61.15                     | 75.28          | 18.69              |                  | 72.28                     | 86.41            |
|                       | Montego River             | 290.54                    | 171.31                                 | 119.22         | 23.89          | 38.33          | 18.40          | 38.60          | 9.21                      | 11.89          | 2.72               |                  | 45.08                     | 47.77            |
|                       | Basin Total               | 1448.80                   | 677.36                                 | 771.44         | 250.14         | 194.88         | 34.40          | 292.01         | 71.96                     | 89.31          | 21.85              | 0.00             | 342.12                    | 359.47           |
| MARTHA BRAE           | Martha Brae               | 1125.35                   | 609.84                                 | 515.51         | 336.11         | 92.60          | 15.10          | 71.69          | 166.16                    | 232.26         | 55.80              |                  | 182.06                    | 248.16           |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River     | 2454.45                   | 1160.29                                | 1294.16        | 613.21         | 101.02         | 142.60         | 437.33         | 378.09                    | 434.38         | 188.99             |                  | 626.43                    | 682.72           |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 178.82                    | 80.65                                  | 98.17          | 38.61          | 31.08          | 0.00           | 28.48          | 14.03                     | 17.03          | 7.49               |                  | 35.02                     | 38.01            |
|                       | Oracabessa-Pagee          | 252.01                    | 126.21                                 | 125.80         | 41.26          | 48.44          | 0.00           | 36.10          | 19.74                     | 24.38          | 8.17               |                  | 47.67                     | 52.31            |
|                       | Wagwater River            | 596.06                    | 244.64                                 | 351.42         | 70.06          | 83.24          | 0.00           | 198.12         | 42.57                     | 57.36          | 9.01               |                  | 231.68                    | 246.47           |
|                       | Pencar-Buff Bay River     | 516.93                    | 158.14                                 | 358.79         | 106.42         | 214.41         | 0.00           | 37.96          | 53.67                     | 63.89          | 14.40              |                  | 77.23                     | 87.45            |
|                       | Spanish River             | 342.22                    | 85.89                                  | 256.32         | 57.78          | 68.92          | 0.00           | 129.62         | 53.49                     | 70.64          | 15.50              |                  | 167.61                    | 184.77           |
|                       | Swift River               | 367.08                    | 83.95                                  | 283.13         | 77.33          | 142.35         | 0.00           | 63.45          | 59.48                     | 74.74          | 16.59              |                  | 106.33                    | 121.59           |
|                       | Rio Grande                | 1006.64                   | 216.19                                 | 790.45         | 255.05         | 506.29         | 0.00           | 29.11          | 169.76                    | 216.05         | 53.00              |                  | 145.87                    | 192.16           |
|                       | Drivers River             | 729.90                    | 176.69                                 | 553.21         | 3.32           | 6.30           | 0.00           | 543.59         | 0.32                      | 1.14           | 0.00               |                  | 543.90                    | 544.72           |
|                       | <b>BASIN TOTAL</b>        | <b>3989.65</b>            | <b>1172.36</b>                         | <b>2817.28</b> | <b>649.83</b>  | <b>1101.03</b> | <b>0.00</b>    | <b>1066.42</b> | <b>413.06</b>             | <b>525.23</b>  | <b>124.17</b>      | <b>0.00</b>      | <b>1355.32</b>            | <b>1467.49</b>   |
| <b>GRAND TOTAL</b>    | <b>19515.11</b>           | <b>8876.04</b>            | <b>10639.07</b>                        | <b>3386.69</b> | <b>2352.59</b> | <b>774.70</b>  | <b>4125.08</b> | <b>1927.19</b> | <b>2438.69</b>            | <b>691.21</b>  | <b>0.00</b>        | <b>5361.06</b>   | <b>5872.56</b>            |                  |

## ESTIMATED WATER BALANCE

The average rainfall over the island is 19,515 million cubic metres per year (MCM/y) and is distributed into its hydrologic components as shown below in figure 27. The groundwater component includes the base flow contribution to streamflow.

**WRA**

WATER RESOURCES AUTHORITY

## Hydrological Basins and Watershed Management Units (WMUs) of Jamaica

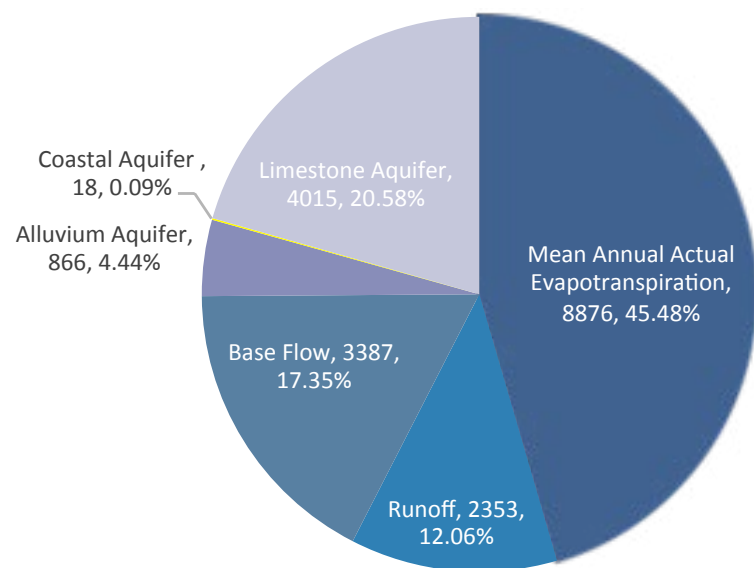


Figure 27: Water Balance Summary (MCM)

## EXPLOITABLE WATER RESOURCES

The exploitable potential yield is 5872 MCM/year, with a domestic exploitable potential yield of 5361 MCM/year. This does not include potential re-use of water, but it does include the estimated groundwater safe yield, plus all available Q90 and Q95 (for domestic potential yield) flows on record minus the estimated environmental flows. This figure may increase as more streamflows are gauged and their reliable flows established over time. It may also increase if methods to re-use wastewater are implemented, allowing wastewater to be viewed as a resource to be utilized instead of as a waste to be disposed. The calculated total demand is 841.6 MCM/year, and the total consumptive licensed allocation as of November 2019 was 1354.49 MCM/year. This would leave approximately 4464.33 MCM/year available for allocation. However, this volume would not be equally distributed across the island. Figure 28 presents the comparative exploitable potential.

## Hydrological Basins and Watershed Management Units (WMUs) of Jamaica

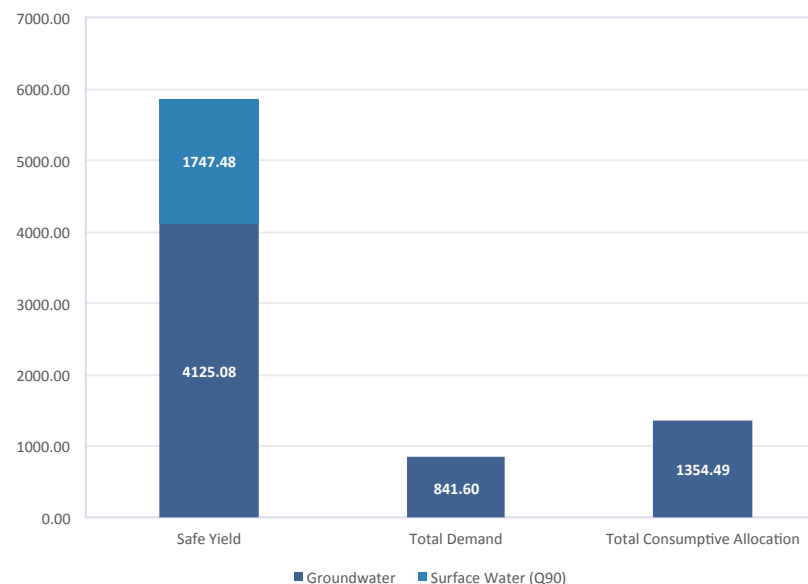


Figure 28: Exploitable Potential

## NATIONAL WATER RESOURCES SUMMARY

The Water Balance for Jamaica is summarised as follows in table 20:

**TABLE 20: WATER RESOURCE SUMMARY**

|                    | 1990    | 2010   | 2020   |        |
|--------------------|---------|--------|--------|--------|
| EVAPOTRANSPIRATION | 11,945  | 10,548 | 8,876  | (-12%) |
| SURFACE WATER      | *5,576  | 9,051  | 2,353  | (62%)  |
| GROUNDWATER        | **3,691 | 1,669  | 8,286  | (-55%) |
| RAINFALL           | 21,212  | 21,268 | 19,515 |        |

\*\* Surface water runoff only,  
\*\*GW discharge includes baseflow

The possible explanations for the variations in the various estimates are as follows

- ◆ Differences in evaluation of evapotranspiration (especially the usage of the Penman-Monteith method in the current report) between the three Master Plans may have led to a greater variance in the estimated values. Slight differences in the various parameters values for the 2020 Master Plan (e.g. pan co-efficient and crop co-efficient) would lead to a significant difference in the estimated values for actual ET, Effective Rainfall and all subsequent calculations. More data and more research into ET determination will lead to more accurate results for future Master Plans.
- ◆ The difference of 194 MCM/year between the Total Precipitation and the summarized Precipitation in Table 13 is most likely the rainfall contributions to Wetlands and Water Body areas, as these hydrostratigraphic units were not included in the water balance calculations.
- ◆ For the 2005 MP, the surface water discharge (the MAF) is separated into surface runoff estimated at 5,322 MCM/year ( 58%) and Baseflow 3,729 MCM/year (42%). For the 1990 and 2020 WRDMP, the base flow was treated as groundwater discharge. Spring Flows contributions were assumed to be a part of the Base Flow.
- ◆ The estimated GW safe yield includes a component of ungauged streamflow. Future updates will include statistical measures to more accurately identify and estimate ungauged streamflow.

## BASIN AND WMU SUMMARY

Details of the water resources status in each WMU are shown in table 21. Previous basin estimates of the resources status from the 1990 and 2005 Master Plan are shown in table 22, and figure 29 presents a map of water resources safe yield per WMU. The data shows that the WMUs with the three highest safe yields (before current abstractions and allocations) are the Rio Cobre, Rio Bueno-White River, and Black River WMUs (in that order). The WMUs with the lowest safe yields are (in descending order) the Rio Nuevo, New Savannah, and Gut River-Alligator Hole WMUs.





**TABLE 21: DETAILED WATER BALANCE SUMMARY FOR WMUS AND BASINS (2016)**

| BASIN                                 |                                        |       | BLUE MOUNTAIN SOUTH   |              |               | KINGSTON   | RIO COBRE | RIO MINHO |            |                          | BLACK RIVER | CABARITA RIVER     |                |                    |
|---------------------------------------|----------------------------------------|-------|-----------------------|--------------|---------------|------------|-----------|-----------|------------|--------------------------|-------------|--------------------|----------------|--------------------|
| WMU                                   |                                        |       | PLANTAIN GARDEN RIVER | MORANT RIVER | YALLAHS RIVER | HOPE RIVER | RIO COBRE | RIO MINHO | MILK RIVER | GUT RIVER-ALLIGATOR HOLE | BLACK RIVER | DEANS VALLEY RIVER | CABARITA RIVER | NEW SAVANNAH RIVER |
| PRECIPITATION AND EVAPO-TRANSPIRATION | Mean Annual Precipitation              | MCM   | 406.27                | 770.61       | 354.18        | 385.91     | 2,055.17  | 1,121.52  | 1,237.51   | 189.54                   | 2,230.43    | 854.71             | 561.63         | 63.9               |
|                                       | Mean Annual Actual Evapo-transpiration | MCM   | 134.19                | 296.45       | 149.68        | 201.70     | 1,001.24  | 656.09    | 712.91     | 148.40                   | 1,164.79    | 356.72             | 251.23         | 34.2               |
|                                       | Effective Rain                         | MCM   | 272.08                | 474.16       | 204.49        | 184.22     | 1,053.93  | 465.43    | 524.60     | 41.14                    | 1,065.64    | 497.99             | 310.39         | 29.6               |
|                                       | BASIN PRECIPITATION                    | MCM   | 1,531.06              |              |               | 385.91     | 2,055.17  | 2,548.57  |            |                          | 2,230.43    | 1,745.71           |                |                    |
|                                       | BASIN EVAPOTRANSPIRATION               | MCM   | 580.33                |              |               | 201.70     | 1,001.24  | 1,517.40  |            |                          | 1,164.79    | 790.72             |                |                    |
|                                       | BASIN EFFECTIVE RAIN                   | MCM   | 950.73                |              |               | 184.22     | 1,053.93  | 1,031.18  |            |                          | 1,065.64    | 954.98             |                |                    |
| MEAN ANNUAL FLOW                      | Base Flow                              | MCM   | 64.17                 | 43.88        | 87.99         | 13.59      | 222.34    | 41.90     | 20.50      | 243.74                   | 616.27      | 8.56               | 157.91         | 3.3                |
|                                       | Runoff                                 | MCM   | 117.61                | 45.13        | 55.97         | 8.80       | 127.39    | 105.12    | 28.66      | 27.08                    | 160.15      | 74.94              | 79.55          | 18.2               |
|                                       | TOTAL                                  | MCM   | 181.77                | 89.01        | 143.96        | 22.39      | 349.73    | 147.02    | 49.16      | 270.82                   | 776.42      | 83.51              | 237.47         | 21.6               |
|                                       | BASIN BASE FLOW                        | MCM   | 196.04                |              |               | 13.59      | 222.34    | 306.14    |            |                          | 616.27      | 183.02             |                |                    |
|                                       | BASIN RUNOFF                           | MCM   | 218.70                |              |               | 8.80       | 127.39    | 160.86    |            |                          | 160.15      | 187.15             |                |                    |
|                                       | BASIN TOTAL                            | MCM   | 414.74                |              |               | 22.39      | 349.73    | 467.01    |            |                          | 776.42      | 370.17             |                |                    |
| TOTAL GROUND-WATER                    | GH Flow                                | AL    | 0.81                  | 0.81         | 0.61          | 14.46      | 11.00     | 18.06     | 11.95      | 0.79                     | 10.22       | 0.61               | 2.43           | 3.6                |
|                                       |                                        | CS    | 0.00                  | 0.00         | 0.00          | 0.00       | 0.00      | 0.00      | 0.00       | 0.00                     | 0.00        | 0.00               | 0.00           | 0.00               |
|                                       |                                        | LS    | 0.39                  | 1.39         | 0.79          | 6.24       | 62.40     | 72.44     | 144.05     | 40.51                    | 143.78      | 10.49              | 4.37           | 4.30               |
|                                       |                                        | Total | 1.20                  | 2.20         | 1.40          | 20.70      | 73.40     | 90.50     | 156.00     | 41.30                    | 154.00      | 11.10              | 6.80           | 8.00               |
|                                       | BASIN TOTAL GH FLOW                    | MCM   | 4.80                  |              |               | 20.70      | 73.40     | 287.80    |            |                          | 154.00      | 41.90              |                |                    |
|                                       | GW Safe Yield*                         | AL    | 60.03                 | 141.83       | 25.64         | 98.58      | 94.57     | 45.49     | 24.47      | -5.19                    | 8.97        | 22.29              | 23.61          | 0.02               |
|                                       |                                        | CS    | 0.00                  | 0.00         | 0.00          | 0.00       | 0.00      | 0.00      | 0.00       | 0.00                     | 0.00        | 0.00               | 0.00           | 0.00               |
|                                       |                                        | LS    | 29.08                 | 241.12       | 33.49         | 42.54      | 536.23    | 182.42    | 294.97     | -265.79                  | 126.25      | 381.09             | 42.51          | 0.02               |
|                                       |                                        | Total | 89.11                 | 382.95       | 59.13         | 141.12     | 630.80    | 227.91    | 319.44     | -270.98                  | 135.22      | 403.38             | 66.13          | 0.04               |
|                                       | BASIN GW SAFE YIELD                    | MCM   | 531.19                |              |               | 141.12     | 630.80    | 276.37    |            |                          | 135.22      | 542.92             |                |                    |

| W<br>NAH<br>ER | SOUTH NE-<br>GRIL-OR-<br>ANGE<br>RIVER | GREAT RIVER    |                |                  | MARTHA<br>BRAE | DRY<br>HARBOUR<br>MOUN-<br>TAINS | BLUE MOUNTAIN NORTH |                       |                     |                               |                  |                |               |                  | TOTAL     |
|----------------|----------------------------------------|----------------|----------------|------------------|----------------|----------------------------------|---------------------|-----------------------|---------------------|-------------------------------|------------------|----------------|---------------|------------------|-----------|
|                |                                        | LUCEA<br>RIVER | GREAT<br>RIVER | MONTEGO<br>RIVER | MARTHA<br>BRAE | RIO BUE-<br>NO-WHITE<br>RIVER    | RIO NUEVO           | ORACABES-<br>SA-PAGEE | WAGWA-<br>TER RIVER | PEN-<br>CAR-BUFF<br>BAY RIVER | SPANISH<br>RIVER | SWIFT<br>RIVER | RIO<br>GRANDE | DRIVERS<br>RIVER |           |
| 1              | 265.46                                 | 473.86         | 684.40         | 290.54           | 1,125.35       | 2,454.45                         | 178.82              | 252.01                | 596.06              | 516.93                        | 342.22           | 367.08         | 1,006.64      | 729.90           | 19,515.11 |
| 6              | 148.50                                 | 223.89         | 282.16         | 171.31           | 609.84         | 1,160.29                         | 80.65               | 126.21                | 244.64              | 158.14                        | 85.89            | 83.95          | 216.19        | 176.69           | 8,876.04  |
| 4              | 116.96                                 | 249.97         | 402.25         | 119.22           | 515.51         | 1,294.16                         | 98.17               | 125.80                | 351.42              | 358.79                        | 256.32           | 283.13         | 790.45        | 553.21           | 10,639.07 |
|                |                                        | 1,448.80       |                |                  | 1,125.35       | 2,454.45                         | 3,989.65            |                       |                     |                               |                  |                |               |                  | 19,515.11 |
|                |                                        | 677.36         |                |                  | 609.84         | 1,160.29                         | 1,172.36            |                       |                     |                               |                  |                |               |                  | 8,876.04  |
|                |                                        | 771.44         |                |                  | 515.51         | 1,294.16                         | 2,817.28            |                       |                     |                               |                  |                |               |                  | 10,639.07 |
| 7              | 13.17                                  | 5.96           | 220.29         | 23.89            | 336.11         | 613.21                           | 38.61               | 41.26                 | 70.06               | 106.42                        | 57.78            | 77.33          | 255.05        | 3.32             | 3,386.69  |
| 3              | 14.42                                  | 13.93          | 142.63         | 38.33            | 92.60          | 101.02                           | 31.08               | 48.44                 | 83.24               | 214.41                        | 68.92            | 142.35         | 506.29        | 6.30             | 2,352.59  |
| 0              | 27.59                                  | 19.89          | 362.91         | 62.22            | 428.71         | 714.23                           | 69.69               | 89.70                 | 153.30              | 320.83                        | 126.70           | 219.68         | 761.34        | 9.62             | 5,739.29  |
|                |                                        | 250.14         |                |                  | 336.11         | 613.21                           | 649.83              |                       |                     |                               |                  |                |               |                  | 3,386.69  |
|                |                                        | 194.88         |                |                  | 92.60          | 101.02                           | 1,101.03            |                       |                     |                               |                  |                |               |                  | 2,352.59  |
|                |                                        | 445.02         |                |                  | 428.71         | 714.23                           | 1,750.86            |                       |                     |                               |                  |                |               |                  | 5,739.29  |
| 4              | 0.65                                   | 0.16           | 0.00           | 1.06             | 0.94           | 1.30                             | 0.00                | 0.00                  | 0.00                | 0.00                          | 0.00             | 0.00           | 0.00          | 0.00             | 79.51     |
| 0              | 0.00                                   | 0.04           | 0.02           | 0.28             | 0.26           | 3.60                             | 0.00                | 0.00                  | 0.00                | 0.00                          | 0.00             | 0.00           | 0.00          | 0.00             | 4.21      |
| 6              | 15.35                                  | 6.30           | 9.48           | 17.07            | 13.90          | 137.70                           | 0.00                | 0.00                  | 0.00                | 0.00                          | 0.00             | 0.00           | 0.00          | 0.00             | 690.98    |
| 0              | 16.00                                  | 6.50           | 9.50           | 18.40            | 15.10          | 142.60                           | 0.00                | 0.00                  | 0.00                | 0.00                          | 0.00             | 0.00           | 0.00          | 0.00             | 774.70    |
|                |                                        | 34.40          |                |                  | 15.10          | 142.60                           | 0.00                |                       |                     |                               |                  |                |               |                  | 774.70    |
| 2              | 2.99                                   | 5.45           | 0.00           | 2.21             | 4.47           | 3.99                             | 3.64                | 27.52                 | 131.51              | 14.04                         | 18.07            | 13.62          | 5.49          | 13.08            | 786.40    |
| 0              | 0.00                                   | 1.29           | 0.08           | 0.58             | 1.25           | 11.05                            | 0.00                | 0.00                  | 0.00                | 0.00                          | 0.00             | 0.00           | 0.00          | 0.00             | 14.25     |
| 2              | 70.37                                  | 216.85         | 29.75          | 35.81            | 65.98          | 422.29                           | 24.83               | 8.58                  | 66.61               | 23.92                         | 111.55           | 49.83          | 23.62         | 530.51           | 3,324.43  |
| 4              | 73.36                                  | 223.58         | 29.83          | 38.60            | 71.69          | 437.33                           | 28.48               | 36.10                 | 198.12              | 37.96                         | 129.62           | 63.45          | 29.11         | 543.59           | 4,125.08  |
|                |                                        | 292.01         |                |                  | 71.69          | 437.33                           | 1,066.42            |                       |                     |                               |                  |                |               |                  | 4,125.08  |



| BASIN                     |                                   |     | BLUE MOUNTAIN SOUTH   |              |               | KINGSTON   | RIO COBRE | RIO MINHO |            |                          | BLACK RIVER | CABARITA RIVER     |                |                    |
|---------------------------|-----------------------------------|-----|-----------------------|--------------|---------------|------------|-----------|-----------|------------|--------------------------|-------------|--------------------|----------------|--------------------|
| WMU                       |                                   |     | PLANTAIN GARDEN RIVER | MORANT RIVER | YALLAHS RIVER | HOPE RIVER | RIO COBRE | RIO MINHO | MILK RIVER | GUT RIVER-ALLIGATOR HOLE | BLACK RIVER | DEANS VALLEY RIVER | CABARITA RIVER | NEW SAVANNAH RIVER |
| SURFACE WATER SAFE YIELDS | Total Q90                         | MCM | 17.00                 | 35.07        | 66.64         | 5.71       | 122.27    | 86.00     | 23.97      | 93.83                    | 587.48      | 8.61               | 107.92         | 0.38               |
|                           | Total Q95                         | MCM | 10.41                 | 28.16        | 55.94         | 4.79       | 93.54     | 66.41     | 18.98      | 42.32                    | 484.61      | 5.96               | 85.34          | 0.22               |
|                           | Total 7-Day Minimum Flow          | MCM | 4.45                  | 14.29        | 21.82         | 3.03       | 57.36     | 7.85      | 0.76       | 4.19                     | 330.97      | 2.96               | 52.41          | 0.00               |
|                           | Total Environmental Demand        | MCM | 2.67                  | 8.57         | 13.09         | 1.82       | 34.42     | 4.71      | 0.45       | 2.52                     | 198.58      | 1.78               | 31.45          | 0.00               |
|                           | Surface Water Safe Yield          | MCM | 14.33                 | 26.50        | 53.54         | 3.89       | 87.85     | 81.29     | 23.51      | 91.32                    | 388.90      | 6.83               | 76.47          | 0.38               |
|                           | Surface Water Domestic Safe Yield | MCM | 7.74                  | 19.59        | 42.85         | 2.98       | 59.12     | 61.70     | 18.53      | 39.80                    | 286.03      | 4.18               | 53.89          | 0.22               |
|                           | BASIN SURFACE SAFE YIELD          | MCM | 94.37                 |              |               | 3.89       | 87.85     | 196.12    |            |                          | 388.90      | 85.99              |                |                    |
|                           | BASIN SURFACE DOMESTIC SAFE YIELD | MCM | 70.18                 |              |               | 2.98       | 59.12     | 120.04    |            |                          | 286.03      | 59.18              |                |                    |
|                           | BASIN ENVIRONMENTAL DEMAND        | MCM | 24.33                 |              |               | 1.82       | 34.42     | 4.71      |            |                          | 198.58      | 33.57              |                |                    |
| WMU TOTALS                | Total Safe Yield                  | MCM | 103.44                | 409.45       | 112.67        | 145.01     | 718.65    | 309.20    | 342.95     | -179.66                  | 524.13      | 410.21             | 142.60         | 0.42               |
|                           | Total Domestic Safe Yield         | MCM | 96.85                 | 402.54       | 101.98        | 144.10     | 689.92    | 289.61    | 337.97     | -231.17                  | 421.26      | 407.56             | 120.02         | 0.22               |
| BASIN TOTALS              | BASIN TOTAL SAFE YIELD            | MCM | 625.56                |              |               | 145.01     | 718.65    | 472.49    |            |                          | 524.13      | 628.90             |                |                    |
|                           | BASIN TOTAL DOMESTIC SAFE YIELD   | MCM | 601.37                |              |               | 144.10     | 689.92    | 396.41    |            |                          | 421.26      | 602.10             |                |                    |

| W<br>NAH<br>ER | SOUTH NE-<br>GRIL-OR-<br>ANGE<br>RIVER | GREAT RIVER    |                |                  | MARTHA<br>BRAE | DRY<br>HARBOUR<br>MOUN-<br>TAINS | BLUE MOUNTAIN NORTH |                       |                     |                               |                  |                |               |                  | TOTAL    |
|----------------|----------------------------------------|----------------|----------------|------------------|----------------|----------------------------------|---------------------|-----------------------|---------------------|-------------------------------|------------------|----------------|---------------|------------------|----------|
|                |                                        | LUCEA<br>RIVER | GREAT<br>RIVER | MONTEGO<br>RIVER | MARTHA<br>BRAE | RIO BUE-<br>NO-WHITE<br>RIVER    | RIO NUEVO           | ORACABES-<br>SA-PAGEE | WAGWA-<br>TER RIVER | PEN-<br>CAR-BUFF<br>BAY RIVER | SPANISH<br>RIVER | SWIFT<br>RIVER | RIO<br>GRANDE | DRIVERS<br>RIVER |          |
| 3              | 2.65                                   | 2.14           | 75.28          | 11.89            | 232.26         | 434.38                           | 17.03               | 24.38                 | 57.36               | 63.89                         | 70.64            | 74.74          | 216.05        | 1.14             | 2,438.69 |
| 2              | 1.23                                   | 1.61           | 61.15          | 9.21             | 166.16         | 378.09                           | 14.03               | 19.74                 | 42.57               | 53.67                         | 53.49            | 59.48          | 169.76        | 0.32             | 1,927.19 |
| 0              | 0.57                                   | 0.73           | 31.16          | 4.54             | 93.00          | 314.98                           | 12.49               | 13.62                 | 15.02               | 24.00                         | 25.83            | 27.66          | 88.33         | 0.00             | 1,152.01 |
| 0              | 0.34                                   | 0.44           | 18.69          | 2.72             | 55.80          | 188.99                           | 7.49                | 8.17                  | 9.01                | 14.40                         | 15.50            | 16.59          | 53.00         | 0.00             | 691.21   |
| 3              | 2.31                                   | 1.71           | 56.58          | 9.16             | 176.46         | 245.39                           | 9.54                | 16.21                 | 48.35               | 49.49                         | 55.15            | 58.15          | 163.05        | 1.14             | 1,747.48 |
| 2              | 0.89                                   | 1.17           | 42.45          | 6.48             | 110.36         | 189.10                           | 6.54                | 11.57                 | 33.56               | 39.27                         | 37.99            | 42.88          | 116.76        | 0.32             | 1,235.98 |
|                |                                        | 67.46          |                |                  | 176.46         | 245.39                           | 401.07              |                       |                     |                               |                  |                |               |                  | 1,747.48 |
|                |                                        | 50.11          |                |                  | 110.36         | 189.10                           | 288.89              |                       |                     |                               |                  |                |               |                  | 1,235.98 |
|                |                                        | 21.85          |                |                  | 55.80          | 188.99                           | 124.17              |                       |                     |                               |                  |                |               |                  | 688.24   |
| 2              | 75.67                                  | 225.29         | 86.41          | 47.77            | 248.16         | 682.72                           | 38.01               | 52.31                 | 246.47              | 87.45                         | 184.77           | 121.59         | 192.16        | 544.72           | 5,872.56 |
| 6              | 74.25                                  | 224.75         | 72.28          | 45.08            | 182.06         | 626.43                           | 35.02               | 47.67                 | 231.68              | 77.23                         | 167.61           | 106.33         | 145.87        | 543.90           | 5,361.06 |
|                |                                        | 359.47         |                |                  | 248.16         | 682.72                           | 1,467.49            |                       |                     |                               |                  |                |               |                  | 5,872.56 |
|                |                                        | 342.12         |                |                  | 182.06         | 626.43                           | 1,355.32            |                       |                     |                               |                  |                |               |                  | 5,361.06 |



TABLE 22: PREVIOUS ESTIMATES OF WATER RESOURCES FROM PRIOR MASTER PLANS

| Hydrologic Parameters             |                        | 1990 WRDMP Hydrologic Sub-divisions (Basins) |                |       |          |        |         |       |        |         |       |        | 2007 WRDMP Hydrologic Sub-Divisions (Basins and Component Watersheds) |        |      |       |           |           |           |       |       |       |           |           |       |       |      |       |           |       |       |      |      |  |  |
|-----------------------------------|------------------------|----------------------------------------------|----------------|-------|----------|--------|---------|-------|--------|---------|-------|--------|-----------------------------------------------------------------------|--------|------|-------|-----------|-----------|-----------|-------|-------|-------|-----------|-----------|-------|-------|------|-------|-----------|-------|-------|------|------|--|--|
|                                   |                        | # 1                                          | # 2            | # 3   | # 4      | # 5    | # 6     | # 7   | # 8    | # 9     | # 10  | Total  | Basin # 1                                                             |        |      |       | Basin # 2 | Basin # 3 | Basin # 4 |       |       |       | Basin # 5 | Basin # 6 |       |       |      |       | Basin # 7 |       |       |      |      |  |  |
|                                   |                        | Blue                                         | King-          | Rio   | R. Minho | Black  | Caba-   | Great | Martha | Dry     | Blue  |        | WMU #                                                                 |        |      | Total | WMU #     | WMU #     | WMU #     |       |       | Total | WMU #     | WMU #     |       |       |      | Total | WMU #     |       |       |      |      |  |  |
|                                   |                        | Mtn.                                         | ston           | Cobre | to       | R.     | rita R. | R.    | Brae   | Harbour | Mtn.  |        | 15                                                                    | 16     | 17   | al    | 18        | 19        | 20        | 21    | 22    | al    | 23        | 24        | 25    | 26    | 1    | al    | 2         | 3     | 4     |      |      |  |  |
| Potential Exploitable Yield (Mcm) | SFReliable Yield (Q90) | 113.2                                        | 4.3            | 210.3 | 31.5     | 48.9   | 0.0     | 65.1  | 19.7   | 27.6    | 16.5  | 537.1  | 15.8                                                                  | 97.2   | 13.2 | 126.1 | 15.8      | 175.8     | 59.7      | 0.0   | 0.0   | 59.7  | 147.6     | 102.5     | 74.5  | 9.7   | 27.7 | 214.3 | 32.6      | 101.5 | 9.8   |      |      |  |  |
|                                   | Groundwater            | Safe yield                                   | 17.5           | 5.0   | 10.9     | 51.0   | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 7.4    | 91.8                                                                  | 14.3   | 16.5 | 4.1   | 35.0      | 2.5       | 2.0       | 47.1  | 9.7   | 0.0   | 56.8      | 42.3      | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   |      |      |  |  |
|                                   |                        | Intra-Unit Flow                              | 17.7           | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 23.9   | 41.6                                                                  | 0.0    | 7.4  | 10.3  | 17.7      | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   |      |      |  |  |
|                                   |                        | Subtotal                                     | 35.2           | 5.0   | 10.9     | 51.0   | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 31.3   | 133.4                                                                 | 14.3   | 23.9 | 14.4  | 52.7      | 2.5       | 2.0       | 47.1  | 9.7   | 0.0   | 56.8      | 42.3      | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        | Safe yield                                   | 98.6           | 10.2  | 180.4    | 361.0  | 138.3   | 451.0 | 316.1  | 150.6   | 691.1 | 0.0    | 2397.3                                                                | 7.2    | 10.0 | 8.7   | 25.8      | 5.9       | 175.5     | 124.7 | 531.0 | 2.1   | 657.8     | 189.5     | 24.2  | 27.2  | 4.5  | 9.2   | 65.2      | 15.3  | 31.0  | 10.5 |      |  |  |
|                                   | Intra-UnitFlow         | 0.0                                          | 2.5            | 16.7  | 20.0     | 525.3  | 39.0    | 0.0   | 0.0    | 0.0     | 10.0  | 613.5  | 0.0                                                                   | 0.0    | 0.0  | 0.0   | 2.9       | 16.7      | 20.0      | 0.0   | 0.0   | 20.0  | 0.0       | 219.7     | 0.0   | 0.0   | 0.0  | 219.7 | 0.0       | 0.0   | 0.0   |      |      |  |  |
|                                   | Subtotal               | 98.6                                         | 12.7           | 197.1 | 381.0    | 663.6  | 490.0   | 316.1 | 150.6  | 691.1   | 10.0  | 3010.8 | 7.2                                                                   | 10.0   | 8.7  | 25.8  | 8.8       | 192.2     | 144.7     | 531.0 | 2.1   | 677.8 | 189.5     | 243.9     | 27.2  | 4.5   | 9.2  | 284.9 | 15.3      | 31.0  | 10.5  |      |      |  |  |
|                                   | Total                  | 133.8                                        | 17.7           | 208.0 | 432.0    | 663.6  | 490.0   | 316.1 | 150.6  | 691.1   | 41.3  | 3144.2 | 21.4                                                                  | 33.9   | 23.1 | 78.5  | 11.3      | 194.1     | 191.8     | 540.7 | 2.1   | 734.6 | 231.8     | 243.9     | 27.2  | 4.5   | 9.2  | 284.9 | 15.3      | 31.0  | 10.5  |      |      |  |  |
|                                   | Reuse                  | Irrigation returns Mcm                       | 0.0            | 2.5   | 0.0      | 39.0   | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 41.5                                                                  | 0.0    | 0.0  | 0.0   | 0.0       | 2.9       | 39.0      | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        | Sewage Return Mcm                            | 0.0            | 24.6  | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 24.6                                                                  | 0.0    | 0.0  | 0.0   | 0.0       | 24.6      | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        | Subtotal                                     | 0.0            | 27.1  | 0.0      | 39.0   | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 66.1                                                                  | 0.0    | 0.0  | 0.0   | 0.0       | 27.5      | 39.0      | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   | Grand Total            | 247.0                                        | 49.1           | 418.3 | 502.5    | 712.5  | 490.0   | 381.2 | 170.3  | 718.7   | 57.9  | 3747.4 | 37.2                                                                  | 131.1  | 36.3 | 204.6 | 54.6      | 409.0     | 251.6     | 540.7 | 2.1   | 794.3 | 379.4     | 346.4     | 101.7 | 14.2  | 36.9 | 499.2 | 47.9      | 132.5 | 20.3  |      |      |  |  |
| Allocated                         | SW                     | Use in Subunit                               | 9.6            | 11.2  | 18.6     | 0.0    | 0.0     | 0.0   | 4.1    | 1.4     | 1.2   | 46.2   | 1.5                                                                   | 0.1    | 1.0  | 2.6   | 31.1      | 124.9     | 40.9      | 0.9   | 0.0   | 41.8  | 0.0       | 1.2       | 11.9  | 0.0   | 11.9 | 25.0  | 0.1       | 38.1  | 25.3  |      |      |  |  |
|                                   |                        | Export                                       | 26.7           | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.2    | 0.0     | 1.8   | 0.2    | 28.7                                                                  | 0.0    | 0.0  | 17.9  | 17.9      | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   |      |      |  |  |
|                                   |                        | Sub-Total                                    | 36.3           | 11.2  | 18.6     | 0.0    | 0.0     | 0.0   | 4.3    | 1.4     | 3.0   | 0.2    | 74.9                                                                  | 1.5    | 0.1  | 19.0  | 20.6      | 31.1      | 124.9     | 40.9  | 0.9   | 0.0   | 41.8      | 0.0       | 1.2   | 11.9  | 0.0  | 11.9  | 25.0      | 0.1   | 38.1  | 25.3 |      |  |  |
|                                   | GW                     | Alluvium                                     | 6.9            | 8.8   | 46.4     | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 62.1                                                                  | 0.0    | 1.7  | 10.4  | 12.1      | 16.5      | 57.4      | 30.6  | 19.0  | 0.0   | 49.5      | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        | LS                                           | Use in Subunit | 2.0   | 12.7     | 260.7  | 0.0     | 0.0   | 25.0   | 12.8    | 12.3  | 32.8   | 0.0                                                                   | 358.3  | 0.0  | 0.0   | 0.0       | 0.0       | 9.2       | 126.8 | 130.2 | 191.2 | 0.0       | 321.4     | 97.9  | 6.5   | 0.1  | 2.5   | 1.2       | 10.4  | 0.0   | 0.0  | 0.0  |  |  |
|                                   |                        |                                              | Export         | 0.0   | 0.0      | 0.0    | 0.0     | 8.3   | 0.0    | 0.0     | 10.3  | 0.0    | 0.0                                                                   | 18.6   | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 19.2  | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 3.9   | 10.9 |      |  |  |
|                                   | Sub-Total              | 8.9                                          | 21.5           | 307.1 | 0.0      | 8.3    | 25.0    | 12.8  | 22.6   | 32.8    | 0.0   | 439.0  | 0.0                                                                   | 1.7    | 10.5 | 12.2  | 25.7      | 203.4     | 160.8     | 210.1 | 0.0   | 370.9 | 97.9      | 6.5       | 0.1   | 2.5   | 1.2  | 10.4  | 0.0       | 3.9   | 10.9  |      |      |  |  |
|                                   | Grand Total            | 45.2                                         | 32.7           | 325.7 | 0.0      | 8.3    | 25.0    | 17.1  | 24.0   | 35.8    | 0.2   | 513.9  | 1.5                                                                   | 1.8    | 29.4 | 32.8  | 56.8      | 328.3     | 201.7     | 211.1 | 0.0   | 412.7 | 97.9      | 7.7       | 12.1  | 2.5   | 13.2 | 35.4  | 0.1       | 42.0  | 36.2  |      |      |  |  |
| Available Water (Mcm)             | Local                  | SF                                           | 76.9           | -6.9  | 191.7    | 31.5   | 48.9    | 0.0   | 61.0   | 18.3    | 26.4  | 470.1  | 14.3                                                                  | 97.0   | -5.8 | 105.6 | -15.4     | 50.9      | 18.8      | -9.2  | 0.0   | 9.7   | 142.9     | 101.4     | 62.5  | 9.7   | 15.7 | 189.3 | 32.5      | 63.4  | -15.5 |      |      |  |  |
|                                   |                        | GW                                           | AI             | 28.3  | -3.8     | -35.5  | 51.0    | 0.0   | 0.0    | 0.0     | 0.0   | 8.3    | 48.3                                                                  | 14.3   | 22.3 | 4.0   | 40.5      | -14.0     | -55.4     | 16.5  | -9.3  | 0.0   | 7.3       | 42.3      | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        |                                              | LS             | -8.9  | -11.3    | -110.0 | 381.0   | 663.6 | 476.0  | 303.3   | 128.0 | 658.3  | 30.6                                                                  | 2510.5 | 7.1  | 8.3   | -1.8      | 13.6      | -19.8     | -11.3 | -16.0 | 320.9 | 2.1       | 306.9     | 91.6  | 237.4 | 27.1 | 2.0   | 8.0       | 274.5 | 15.3  | 27.0 | -0.4 |  |  |
|                                   |                        | Sub-Total                                    | 19.4           | -15.1 | -145.5   | 432.0  | 663.6   | 476.0 | 303.3  | 128.0   | 658.3 | 38.9   | 2558.8                                                                | 21.4   | 30.6 | 2.2   | 54.1      | -33.8     | -66.7     | 0.5   | 311.6 | 2.1   | 314.2     | 133.9     | 237.4 | 27.1  | 2.0  | 8.0   | 274.5     | 15.3  | 27.0  | -0.4 |      |  |  |
|                                   | Total                  | 96.3                                         | -22.0          | 46.2  | 463.5    | 712.5  | 476.0   | 364.3 | 146.3  | 684.7   | 61.1  | 3029.0 | 35.7                                                                  | 127.6  | -3.5 | 159.7 | -49.1     | -15.7     | 19.3      | 302.4 | 2.1   | 323.8 | 276.9     | 338.7     | 89.6  | 11.7  | 23.7 | 463.7 | 47.8      | 90.5  | -15.9 |      |      |  |  |
|                                   | Import                 | SW                                           | 0.0            | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 0.0                                                                   | 0.0    | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        | GW                                           | AI             | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 0.0                                                                   | 0.0    | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        |                                              | LS             | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 0.0                                                                   | 0.0    | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        | Sub-Total                                    | 0.0            | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 0.0                                                                   | 0.0    | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   | Total                  | 0.0                                          | 0.0            | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 0.0                                                                   | 0.0    | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   | Storage                | Yield: Microdams                             | 0.0            | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 0.0                                                                   | 0.0    | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        | Yield: Large                                 | 23.1           | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 23.1                                                                  | 0.0    | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   |                        | Run-of-River                                 | 0.0            | 0.0   | 0.0      | 0.0    | 0.0     | 0.0   | 0.0    | 0.0     | 0.0   | 0.0    | 127.6                                                                 | 0.0    | 0.0  | 0.0   | 0.0       | 0.0       | 0.0       | 0.0   | 0.0   | 0.0   | 0.0       | 0.0       | 0.0   | 0.0   | 0.0  | 0.0   | 0.0       | 0.0   | 0.0   | 0.0  |      |  |  |
|                                   | Grand Total            | 119.4                                        | -22.0          | 46.2  | 463.5    | 712.5  | 476.0   | 364.3 | 146.3  | 684.7   | 188.7 | 3179.6 | 35.7                                                                  | 127.6  | 46.3 | 209.5 | -49.1     | -15.7     | 19.3      | 302.4 | 2.1   | 323.8 | 276.9     | 338.7     | 89.6  | 11.7  | 23.7 | 463.7 | 47.8      | 90.5  | -15.9 |      |      |  |  |
| Demand                            | Residential            | 4.6                                          | 85.4           | 0.0   | 17.7     | 6.8    | 6.2     | 11.9  | 2.9    | 8.7     | 10.0  | 154.2  | 1.0                                                                   | 4.3    | 2.2  | 7.5   | 61.4      | 57.0      | 12.1      | 14.4  | 9.8   | 36.3  | 12.7      | 3.2       | 2.7   | 0.5   | 1.4  | 7.9   | 3.1       | 2.4   | 12.9  |      |      |  |  |
|                                   | Commercial/Export      | 26.5                                         | 0.0            | 0.0   | 8.3      | 8.3    | 1.2     | 0.2   | 10.3   | 1.8     | 28.1  | 84.7   | 0.2                                                                   | 1.1    | 0.4  | 1.8   | 15.4      | 14.2      | 3.0       | 2.1   | 2.5   | 7.5   | 3.2       | 0.8       | 0.7   | 0.1   | 0.4  | 2.0   | 0.8       | 0.6   | 3.2   |      |      |  |  |
|                                   | Tourism                | 0.0                                          | 0.8            | 0.5   | 0.1      | 0.0    | 0.8     | 2.7   | 0.5    | 1.7     | 0.3   | 7.4    | 0.0                                                                   | 0.0    | 0.0  | 0.0   | 0.3       | 0.0       | 0.0       | 0.0   | 0.0   | 0.1   | 0.9       | 0.0       | 0.0   | 0.0   | 1.1  | 1.1   | 0.1       | 0.0   | 0.8   |      |      |  |  |
|                                   | Agricultural           | 30.2                                         | 2.0            | 197.3 | 298.0    | 237.0  | 24.0    | 2.2   | 10.8   | 14.5    | 21.7  | 837.7  | 0.0                                                                   | 8.3    | 0.3  | 8.6   | 0.0       | 189.9     | 251.7     | 0.0   | 7.4   | 259.1 | 49.7      | 0.0       | 2.7   | 0.0   | 0.0  | 2.7   |           |       |       |      |      |  |  |



| MUs)  |           |           |            |      |       |      |      |      |       |       |       |        |       |
|-------|-----------|-----------|------------|------|-------|------|------|------|-------|-------|-------|--------|-------|
|       | Basin # 8 | Basin # 9 | Basin # 10 |      |       |      |      |      |       |       |       |        | Grand |
| Tot-  | WMU #     | WMU #     | WMU #      |      |       |      |      |      |       |       |       |        | Total |
| al    | 5         | 6         | 7          | 8    | 9     | 10   | 11   | 12   | 13    | 14    | Tot-  |        |       |
| 143.9 | 188.8     | 386.7     | 15.4       | 19.5 | 49.4  | 61.5 | 41.9 | 38.2 | 133.9 | 126.7 | 486.5 | 1945.3 |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 138.5  |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 17.7   |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 156.2  |       |
| 56.7  | 54.7      | 70.3      | 6.8        | 10.7 | 26.3  | 19.2 | 17.6 | 19.3 | 63.2  | 37.7  | 200.9 | 1502.3 |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 259.3  |       |
| 56.7  | 54.7      | 70.3      | 6.8        | 10.7 | 26.3  | 19.2 | 17.6 | 19.3 | 63.2  | 37.7  | 200.9 | 1761.6 |       |
| 56.7  | 54.7      | 70.3      | 6.8        | 10.7 | 26.3  | 19.2 | 17.6 | 19.3 | 63.2  | 37.7  | 200.9 | 1917.8 |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 41.9   |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 24.6   |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 66.5   |       |
| 200.6 | 243.5     | 457.1     | 22.2       | 30.3 | 75.7  | 80.8 | 59.5 | 57.5 | 197.1 | 164.4 | 687.4 | 3929.7 |       |
| 63.5  | 9.9       | 36.1      | 1.1        | 1.2  | 32.5  | 10.2 | 0.0  | 0.9  | 0.2   | 1.9   | 48.0  | 383.0  |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 17.9   |       |
| 63.5  | 9.9       | 36.1      | 1.1        | 1.2  | 32.5  | 10.2 | 0.0  | 0.9  | 0.2   | 1.9   | 48.0  | 400.9  |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 10.5  | 6.3  | 0.0  | 0.0  | 0.0   | 0.0   | 16.8  | 152.4  |       |
| 0.0   | 18.6      | 26.8      | 0.0        | 0.0  | 0.0   | 4.9  | 0.0  | 0.0  | 0.0   | 0.0   | 4.9   | 616.0  |       |
| 14.8  | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 34.0   |       |
| 14.8  | 18.6      | 26.8      | 0.0        | 0.0  | 10.5  | 11.2 | 0.0  | 0.0  | 0.0   | 0.0   | 21.7  | 802.4  |       |
| 78.3  | 28.6      | 62.9      | 1.1        | 1.2  | 43.0  | 21.4 | 0.0  | 0.9  | 0.2   | 1.9   | 69.7  | 1203.3 |       |
| 80.4  | 178.9     | 350.6     | 14.3       | 18.3 | 16.8  | 51.4 | 41.9 | 37.3 | 133.7 | 124.8 | 438.5 | 1531.5 |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | -10.5 | -6.3 | 0.0  | 0.0  | 0.0   | 0.0   | -16.8 | 3.8    |       |
| 41.9  | 36.1      | 43.6      | 6.8        | 10.7 | 15.8  | 8.0  | 17.6 | 19.3 | 63.2  | 37.7  | 179.2 | 956.3  |       |
| 41.9  | 36.1      | 43.6      | 6.8        | 10.7 | 5.3   | 1.7  | 17.6 | 19.3 | 63.2  | 37.7  | 162.3 | 960.2  |       |
| 122.3 | 215.0     | 394.2     | 21.1       | 29.1 | 22.1  | 53.1 | 59.5 | 56.6 | 196.9 | 162.4 | 600.9 | 2491.7 |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 0.0    |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 0.0    |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 0.0    |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 0.0    |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 0.0    |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 0.0    |       |
| 0.0   | 0.0       | 0.0       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 0.0    |       |
| 122.3 | 215.0     | 394.2     | 21.1       | 29.1 | 22.1  | 53.1 | 59.5 | 56.6 | 196.9 | 162.4 | 600.9 | 2541.5 |       |
| 18.4  | 3.7       | 16.5      | 1.1        | 3.1  | 4.6   | 1.9  | 0.3  | 0.4  | 2.2   | 1.6   | 15.3  | 236.7  |       |
| 4.6   | 0.9       | 4.1       | 0.3        | 0.8  | 1.2   | 0.5  | 0.1  | 0.1  | 0.6   | 0.4   | 3.8   | 57.4   |       |
| 0.9   | 0.4       | 1.1       | 0.0        | 0.1  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.1   | 0.2   | 5.0    |       |
| 3.0   | 3.8       | 3.2       | 0.0        | 0.0  | 2.3   | 0.6  | 0.0  | 0.0  | 0.0   | 0.0   | 2.9   | 522.9  |       |
| 3.1   | 0.0       | 7.1       | 0.0        | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.0   | 91.0   |       |
| 38.5  | 100.1     | 190.9     | 3.8        | 5.7  | 13.5  | 11.8 | 9.8  | 10.0 | 34.4  | 20.6  | 109.5 | 902.6  |       |
| 68.5  | 109.0     | 222.9     | 5.2        | 9.7  | 21.6  | 14.7 | 10.2 | 10.5 | 37.2  | 22.7  | 131.8 | 1812.8 |       |



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## Water Resources Safe Yield per Watershed Management Units (WMU)

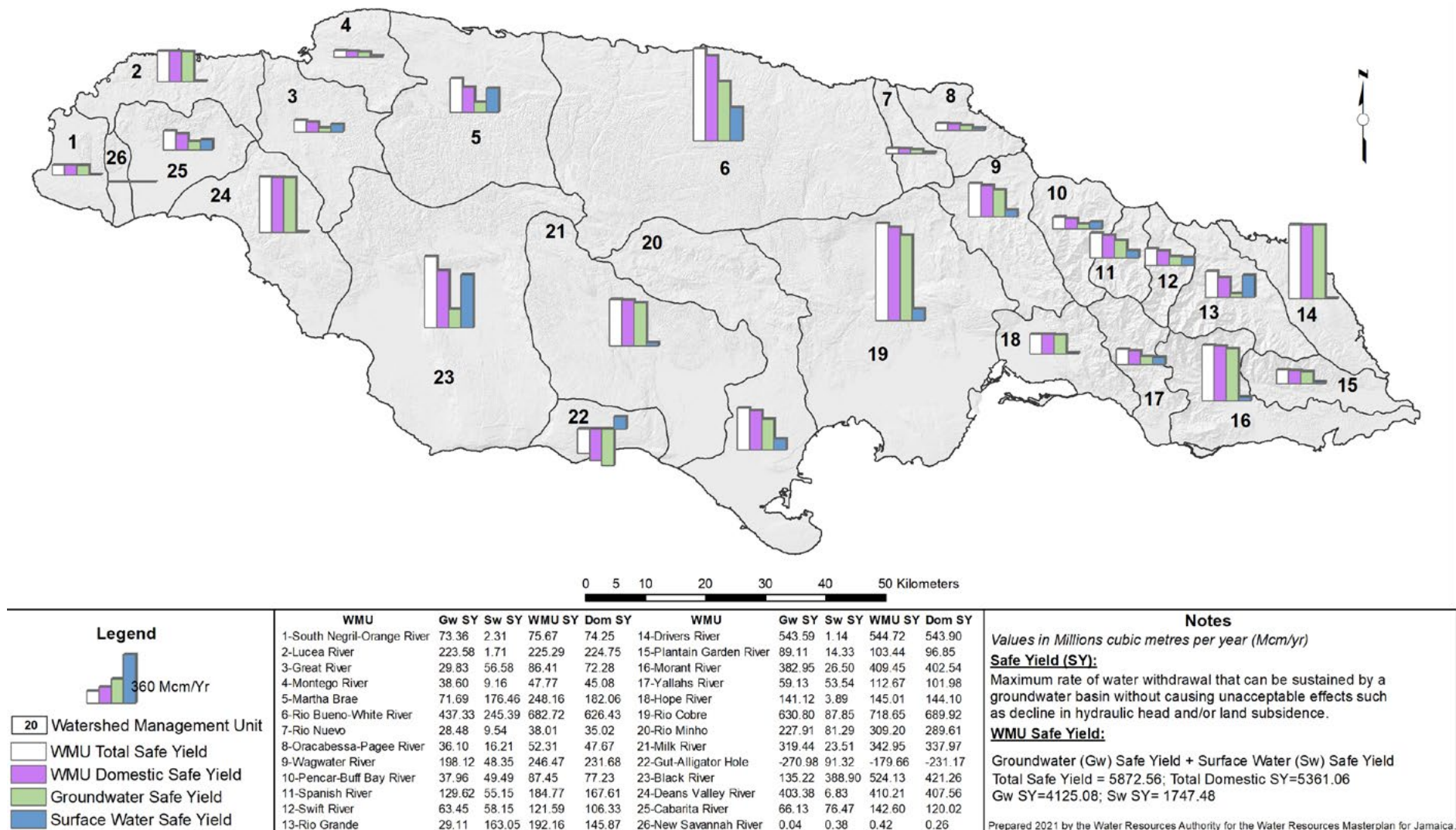


Figure 29: Water Resources Safe Yield per WMU

## EXPLOITABLE WATER RESOURCES

Table 23 presents the exploitable surface water or reliable yield for the country, defined as the daily mean flow that is exceeded 90 % of the time. While this level of reliability is sufficient for irrigation, domestic water supplies usually need a higher level of reliability (95%). The exploitable ground water or safe yield is defined as the quantity of groundwater which can be withdrawn over a long period without compromising the aquifer as a source of water or causing contamination by intrusion of seawater into the aquifer.

**TABLE 23: SAFE YIELD SUMMARY (MCM/YEAR)**

|                                                      | 1990         | 2010          | 2020         |       |
|------------------------------------------------------|--------------|---------------|--------------|-------|
| Exploitable Surface water discharge (reliable yield) | 666          | 1,924.1       | 1,747        | (21%) |
| Exploitable Groundwater discharge (safe yield)       | 3,419        | 1,597.4       | 4,125        | (96%) |
| <b>TOTAL EXPLOITABLE RESOURCES</b>                   | <b>4,085</b> | <b>3521.5</b> | <b>5,872</b> |       |

## VARIATIONS FROM THE AVERAGE ESTIMATED CONDITIONS

The available water resources calculated in the sections above are based on annual averages and sometimes on estimated parameters. The average rainfall in Jamaica has been measured over a 50 year period (30 year mean of 1951-1980) as 1,924 mm per year, and appears to have decreased in recent times as per Chapter 5 of this Master Plan. However, monthly rainfall may vary widely. The rainfall in May and June and September to November is usually higher and, during the latter period, can be up to two and a half times the annual monthly average. The December-April period is drier and is usually about 25% of the monthly average.

During the dry months, when both surface and ground water resources are lower, the irrigation demand increases. In addition, annual rainfall can vary widely. The Meteorological Service of Jamaica (2005) reports an annual maximum rainfall of 2,593 mm in 1963, and a minimum of 1,324 mm in 1976 – a difference of about  $\pm 30\%$ .

## PROJECTED IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES

Global climate change effects are likely to include seasonal changes in rainfall intensities, more extreme events (floods and droughts) and enhancement of the El Niño effect. The World Bank's Intergovernmental Panel on Climate Change (Watson, 2001) projects that by 2050:

- December to February temperatures could rise by 1.4-2°C and June to August temperatures by 1.5-1.9°C.
- December to February precipitation could change from a decrease of 1.5% to an increase of 13.1% and that for June to August from a decrease of 18.4% to an increase of 17.1%. Based on median values, the models indicate 5.9% less rain in the rain season and 5.9% more in the dry season.
- The higher rainfall intensities during the rainy season will increase surface runoff and decrease groundwater recharge. The higher rainfall could elevate soil erosion and increase siltation of reservoirs. On the positive side, it could lessen the severity of drought.
- Sea level could rise by 30 to 50 cm. This will have an enormous impact on coastal communities and infrastructure. Adverse effects could include beach erosion which would affect the tourism industry as well as fisheries, wetlands and coral reefs. Positive effects could include marginal reduction of crop losses or failure due to drought - given predictions of a small increase in precipitation during the dry season.
- In Jamaica, the coast from Treasure Beach in St. Elizabeth to Savanna-la-Mar in Westmoreland could be affected by severe sea wave conditions. Prediction for the next 50 years are that Savanna-la-Mar will have high vulnerability to storm surge effects.
- Lower dry season water availability could affect households, agriculture, tourism and industry through:
- Lowering of reservoir water levels, reducing water supplies for irrigation, and lowering of soil moisture thereby increasing demand for irrigation water.
- Impairment of water quality – especially by saline water intrusion along the coast. This could result because of over-pumping of wells and reduced submarine discharge.
- Increase incidence of water borne diseases.
- Higher treatment costs for domestic water supplies.

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- Decreased agricultural productivity since irrigation water supplies could become more brackish. This could impact adversely on crop growth and increase salinization of soils.

The IPCC predicts that climate in the Caribbean will become more “El Niño - like”. Based on the El Niño events in Jamaica in 1997-8, there could be:

- Reduction in stream flows.
- Shortages in domestic water supply resulting in water lock-offs and extra cost to truck water to water scarce areas.
- Losses of agricultural commodities.
- Adverse effect on public health.

The Climate Studies group at the UWI Mona have predicted the following changes in temperature and precipitation for Jamaica over the stated period as depicted in Table 24 (Climate Studies Group, 2017).

**TABLE 24: PREDICTED SHIFTS IN TEMPERATURE AND RAINFALL DUE TO CLIMATE CHANGE BETWEEN THE YEARS 2020-2080**

| YEAR | TEMPERATURE INCREASE (OC) | RAINFALL DECREASE (%) |
|------|---------------------------|-----------------------|
| 2020 | 0.5                       | -2.23                 |
| 2025 | 1                         | -4.53                 |
| 2030 | 1.5                       | -6.85                 |
| 2050 | 2.5                       | -16.1                 |
| 2080 | 3.5                       | -30                   |

These predicted impacts were applied to the baseline values for precipitation and temperatures (for calculation of evapotranspiration). Table 25 presents a summarized account of the estimated shifts in rainfall and evapotranspiration for the given periods, while Tables 26 through 30 present a detailed breakdown for each WMU of the predicted changes in water resources due to the stated shifts in temperature and rainfall. The data indicates a significant decline in total precipitation and a steady increase in actual evapotranspiration, which would lead to an overall deficit in available water resources by 2080. Submarine Discharge, baseflow and runoff for all WMUs were assumed at 2016 levels for purposes of assessment, but these would also likely change over the period due to climate change impacts. Future updates of the Master Plan will include developing methods to assess the potential impacts of climate change on the baseflow, runoff and submarine discharge.

**TABLE 25: TOTAL PREDICTED ANNUAL RAINFALL AND ACTUAL EVAPOTRANSPIRATION FOR STATED YEARS**

|                                             | 2020     | 2025     | 2030     | 2050     | 2080     |
|---------------------------------------------|----------|----------|----------|----------|----------|
| MEAN ANNUAL PRECIPITATION (MCM)             | 19079.92 | 18631.07 | 18178.32 | 16373.17 | 13660.57 |
| MEAN ANNUAL ACTUAL EVAPOTRANSPIRATION (MCM) | 9071.70  | 9191.42  | 9511.43  | 9534.99  | 9740.00  |





TABLE 26: ESTIMATED WATER BALANCE FOR 2020

| BASIN                 | WMU                       | MEAN ANNUAL PRECIPITATION | MEAN ANNUAL ACTUAL EVAPO-TRANSPIRATION | EFFECTIVE RAIN | BASE FLOW     | RUNOFF         | GH FLOW       | GW SAFE YIELD* | Q95 (DOMESTIC) SAFE YIELD | Q90 SAFE YIELD | ENVIRONMENTAL FLOW | INTER-BASIN FLOW | TOTAL DOMESTIC SAFE YIELD | TOTAL SAFE YIELD |
|-----------------------|---------------------------|---------------------------|----------------------------------------|----------------|---------------|----------------|---------------|----------------|---------------------------|----------------|--------------------|------------------|---------------------------|------------------|
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 397.21                    | 142.26                                 | 254.95         | 64.17         | 117.61         | 1.20          | 71.98          | 10.41                     | 17.00          | 2.67               |                  | 79.72                     | 86.31            |
|                       | Morant River              | 753.42                    | 316.54                                 | 436.88         | 43.88         | 45.13          | 2.20          | 345.68         | 28.16                     | 35.07          | 8.57               |                  | 365.27                    | 372.18           |
|                       | Yallahs River             | 346.28                    | 155.07                                 | 191.21         | 87.99         | 55.97          | 1.40          | 45.84          | 55.94                     | 66.64          | 13.09              |                  | 88.70                     | 99.39            |
|                       | <b>BASIN TOTAL</b>        | <b>1496.92</b>            | <b>613.87</b>                          | <b>883.04</b>  | <b>196.04</b> | <b>218.70</b>  | <b>4.80</b>   | <b>463.50</b>  | <b>94.51</b>              | <b>118.70</b>  | <b>24.33</b>       | <b>0.00</b>      | <b>533.68</b>             | <b>557.87</b>    |
| KINGSTON              | HOPE RIVER                | 377.31                    | 210.26                                 | 167.05         | 13.59         | 8.80           | 20.70         | 123.96         | 4.79                      | 5.71           | 1.82               |                  | 126.93                    | 127.85           |
| RIO COBRE             | RIO COBRE                 | 2009.34                   | 1021.13                                | 988.21         | 222.34        | 127.39         | 73.40         | 565.07         | 93.54                     | 122.27         | 34.42              |                  | 624.19                    | 652.92           |
| RIO MINHO             | Rio Minho                 | 1096.51                   | 667.14                                 | 429.37         | 41.90         | 105.12         | 90.50         | 191.84         | 66.41                     | 86.00          | 4.71               |                  | 253.55                    | 273.13           |
|                       | Milk River                | 1209.92                   | 723.54                                 | 486.38         | 20.50         | 28.66          | 156.00        | 281.22         | 18.98                     | 23.97          | 0.45               |                  | 299.75                    | 304.73           |
|                       | Gut River-Alligator Hole  | 185.32                    | 148.87                                 | 36.45          | 243.74        | 27.08          | 41.30         | -275.67        | 42.32                     | 93.83          | 2.52               |                  | -235.87                   | -184.36          |
|                       | <b>BASIN TOTAL</b>        | <b>2491.74</b>            | <b>1539.55</b>                         | <b>952.19</b>  | <b>306.14</b> | <b>160.86</b>  | <b>287.80</b> | <b>197.39</b>  | <b>127.72</b>             | <b>203.80</b>  | <b>7.68</b>        | <b>0.00</b>      | <b>317.42</b>             | <b>393.50</b>    |
| BLACK RIVER           | BLACK RIVER               | 2180.69                   | 1179.21                                | 1001.48        | 616.27        | 160.15         | 154.00        | 71.07          | 484.61                    | 587.48         | 198.58             |                  | 357.10                    | 459.97           |
| CABARITA RIVER        | Deans Valley River        | 835.65                    | 363.74                                 | 471.91         | 8.56          | 74.94          | 11.10         | 377.31         | 5.96                      | 8.61           | 1.78               |                  | 381.49                    | 384.14           |
|                       | Cabarita River            | 549.10                    | 256.22                                 | 292.88         | 157.91        | 79.55          | 6.80          | 48.62          | 85.34                     | 107.92         | 31.45              |                  | 102.51                    | 125.09           |
|                       | New Savannah River        | 62.48                     | 34.89                                  | 27.60          | 3.37          | 18.23          | 8.00          | -2.00          | 0.22                      | 0.38           | 0.00               |                  | -1.78                     | -1.62            |
|                       | South Negril-Orange River | 259.54                    | 151.09                                 | 108.45         | 13.17         | 14.42          | 16.00         | 64.85          | 1.23                      | 2.65           | 0.34               |                  | 65.74                     | 67.16            |
|                       | <b>BASIN TOTAL</b>        | <b>1706.78</b>            | <b>805.94</b>                          | <b>900.84</b>  | <b>183.02</b> | <b>187.15</b>  | <b>41.90</b>  | <b>488.77</b>  | <b>92.75</b>              | <b>119.55</b>  | <b>33.57</b>       | <b>0.00</b>      | <b>547.95</b>             | <b>574.76</b>    |
| GREAT RIVER           | Lucea River               | 463.29                    | 227.89                                 | 235.40         | 5.96          | 13.93          | 6.50          | 209.01         | 1.61                      | 2.14           | 0.44               |                  | 210.18                    | 210.72           |
|                       | Great River               | 669.14                    | 286.71                                 | 382.43         | 220.29        | 142.63         | 9.50          | 10.02          | 61.15                     | 75.28          | 18.69              |                  | 52.47                     | 66.60            |
|                       | Montego River             | 284.06                    | 174.08                                 | 109.98         | 23.89         | 38.33          | 18.40         | 29.36          | 9.21                      | 11.89          | 2.72               |                  | 35.84                     | 38.52            |
|                       | <b>BASIN TOTAL</b>        | <b>1416.49</b>            | <b>688.68</b>                          | <b>727.81</b>  | <b>250.14</b> | <b>194.88</b>  | <b>34.40</b>  | <b>248.38</b>  | <b>71.96</b>              | <b>89.31</b>   | <b>21.85</b>       | <b>0.00</b>      | <b>298.49</b>             | <b>315.84</b>    |
| MARTHA BRAE           | MARTHA BRAE               | 1100.25                   | 621.48                                 | 478.77         | 336.11        | 92.60          | 15.10         | 34.96          | 166.16                    | 232.26         | 55.80              |                  | 145.32                    | 211.42           |
| DRY HARBOUR MOUNTAINS | RIO BUENO-WHITE RIVER     | 2399.72                   | 1179.31                                | 1220.41        | 613.21        | 101.02         | 142.60        | 363.59         | 378.09                    | 434.38         | 188.99             |                  | 552.68                    | 608.97           |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 174.84                    | 82.09                                  | 92.75          | 38.61         | 31.08          | 0.00          | 23.05          | 14.03                     | 17.03          | 7.49               |                  | 29.59                     | 32.59            |
|                       | Oracabessa-Pagee          | 246.39                    | 128.57                                 | 117.82         | 41.26         | 48.44          | 0.00          | 28.12          | 19.74                     | 24.38          | 8.17               |                  | 39.69                     | 44.33            |
|                       | Wagwater River            | 582.77                    | 250.91                                 | 331.85         | 70.06         | 83.24          | 0.00          | 178.56         | 42.57                     | 57.36          | 9.01               |                  | 212.12                    | 226.91           |
|                       | Pencar-Buff Bay River     | 505.40                    | 164.10                                 | 341.30         | 106.42        | 214.41         | 0.00          | 20.47          | 53.67                     | 63.89          | 14.40              |                  | 59.75                     | 69.96            |
|                       | Spanish River             | 334.58                    | 89.65                                  | 244.94         | 57.78         | 68.92          | 0.00          | 0.43           | 53.49                     | 70.64          | 15.50              |                  | 38.42                     | 55.57            |
|                       | Swift River               | 358.89                    | 87.56                                  | 271.33         | 77.33         | 142.35         | 0.00          | 51.65          | 59.48                     | 74.74          | 16.59              |                  | 94.54                     | 109.80           |
|                       | Rio Grande                | 984.20                    | 226.62                                 | 757.58         | 255.05        | 506.29         | 0.00          | -3.76          | 169.76                    | 216.05         | 53.00              |                  | 113.00                    | 159.29           |
|                       | Drivers River             | 713.62                    | 182.78                                 | 530.84         | 3.32          | 6.30           | 0.00          | 521.22         | 0.32                      | 1.14           | 0.00               |                  | 521.53                    | 522.35           |
|                       | <b>BASIN TOTAL</b>        | <b>3900.68</b>            | <b>1212.27</b>                         | <b>2688.41</b> | <b>649.83</b> | <b>1101.03</b> | <b>0.00</b>   | <b>819.74</b>  | <b>413.06</b>             | <b>525.23</b>  | <b>124.17</b>      | <b>0.00</b>      | <b>1108.63</b>            | <b>1220.80</b>   |
| GRAND TOTAL           | 19079.92                  | 9071.70                   | 10008.22                               | 3386.69        | 2352.59       | 774.70         | 3376.42       | 1927.19        | 2438.69                   | 691.21         | 0.00               | 4612.40          | 5123.90                   |                  |



TABLE 27: ESTIMATED WATER BALANCE FOR 2025

| BASIN                 | WMU                       | MEAN ANNUAL PRECIPITATION | MEAN ANNUAL ACTUAL EVAPO-TRANSPIRATION | EFFECTIVE RAIN | BASE FLOW     | RUNOFF         | GH FLOW       | GW SAFE YIELD* | Q95 (DOMESTIC) SAFE YIELD | Q90 SAFE YIELD | ENVIRONMENTAL FLOW | INTER-BASIN FLOW | TOTAL DOMESTIC SAFE YIELD | TOTAL SAFE YIELD |
|-----------------------|---------------------------|---------------------------|----------------------------------------|----------------|---------------|----------------|---------------|----------------|---------------------------|----------------|--------------------|------------------|---------------------------|------------------|
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 387.87                    | 142.80                                 | 245.06         | 64.17         | 117.61         | 1.20          | 62.09          | 10.41                     | 17.00          | 2.67               |                  | 69.83                     | 76.42            |
|                       | Morant River              | 735.70                    | 316.51                                 | 419.19         | 43.88         | 45.13          | 2.20          | 327.98         | 28.16                     | 35.07          | 8.57               |                  | 347.57                    | 354.48           |
|                       | Yallahs River             | 338.13                    | 160.38                                 | 177.76         | 87.99         | 55.97          | 1.40          | 32.40          | 55.94                     | 66.64          | 13.09              |                  | 75.25                     | 85.94            |
|                       | <b>BASIN TOTAL</b>        | <b>1461.70</b>            | <b>619.69</b>                          | <b>842.01</b>  | <b>196.04</b> | <b>218.70</b>  | <b>4.80</b>   | <b>422.47</b>  | <b>94.51</b>              | <b>118.70</b>  | <b>24.33</b>       | <b>0.00</b>      | <b>492.65</b>             | <b>516.84</b>    |
| KINGSTON              | HOPE RIVER                | 368.43                    | 213.24                                 | 155.20         | 13.59         | 8.80           | 20.70         | 112.10         | 4.79                      | 5.71           | 1.82               |                  | 115.08                    | 115.99           |
| RIO COBRE             | RIO COBRE                 | 1962.07                   | 1033.42                                | 928.65         | 222.34        | 127.39         | 73.40         | 505.51         | 93.54                     | 122.27         | 34.42              |                  | 564.63                    | 593.36           |
| RIO MINHO             | Rio Minho                 | 1070.71                   | 676.31                                 | 394.40         | 41.90         | 105.12         | 90.50         | 156.88         | 66.41                     | 86.00          | 4.71               |                  | 218.58                    | 238.17           |
|                       | Milk River                | 1181.45                   | 735.91                                 | 445.54         | 20.50         | 28.66          | 156.00        | 240.38         | 18.98                     | 23.97          | 0.45               |                  | 258.91                    | 263.89           |
|                       | Gut River-Alligator Hole  | 180.96                    | 151.09                                 | 29.87          | 243.74        | 27.08          | 41.30         | -282.25        | 42.32                     | 93.83          | 2.52               |                  | -242.45                   | -190.93          |
|                       | <b>BASIN TOTAL</b>        | <b>2433.12</b>            | <b>1563.31</b>                         | <b>869.81</b>  | <b>306.14</b> | <b>160.86</b>  | <b>287.80</b> | <b>115.01</b>  | <b>127.72</b>             | <b>203.80</b>  | <b>7.68</b>        | <b>0.00</b>      | <b>235.04</b>             | <b>311.12</b>    |
| BLACK RIVER           | BLACK RIVER               | 2129.39                   | 1195.47                                | 933.93         | 616.27        | 160.15         | 154.00        | 3.51           | 484.61                    | 587.48         | 198.58             |                  | 289.54                    | 392.41           |
| CABARITA RIVER        | Deans Valley River        | 815.99                    | 370.02                                 | 445.98         | 8.56          | 74.94          | 11.10         | 351.37         | 5.96                      | 8.61           | 1.78               |                  | 355.55                    | 358.20           |
|                       | Cabarita River            | 536.18                    | 260.17                                 | 276.01         | 157.91        | 79.55          | 6.80          | 31.74          | 85.34                     | 107.92         | 31.45              |                  | 85.63                     | 108.21           |
|                       | New Savannah River        | 61.01                     | 35.24                                  | 25.78          | 3.37          | 18.23          | 8.00          | -3.82          | 0.22                      | 0.38           | 0.00               |                  | -3.60                     | -3.44            |
|                       | South Negril-Orange River | 253.44                    | 152.05                                 | 101.39         | 13.17         | 14.42          | 16.00         | 57.80          | 1.23                      | 2.65           | 0.34               |                  | 58.68                     | 60.10            |
|                       | <b>BASIN TOTAL</b>        | <b>1666.63</b>            | <b>817.47</b>                          | <b>849.15</b>  | <b>183.02</b> | <b>187.15</b>  | <b>41.90</b>  | <b>437.08</b>  | <b>92.75</b>              | <b>119.55</b>  | <b>33.57</b>       | <b>0.00</b>      | <b>496.26</b>             | <b>523.07</b>    |
| GREAT RIVER           | Lucea River               | 452.39                    | 230.80                                 | 221.59         | 5.96          | 13.93          | 6.50          | 195.20         | 1.61                      | 2.14           | 0.44               |                  | 196.38                    | 196.91           |
|                       | Great River               | 653.40                    | 290.66                                 | 362.74         | 220.29        | 142.63         | 9.50          | -9.68          | 61.15                     | 75.28          | 18.69              |                  | 32.78                     | 46.91            |
|                       | Montego River             | 277.38                    | 176.01                                 | 101.37         | 23.89         | 38.33          | 18.40         | 20.75          | 9.21                      | 11.89          | 2.72               |                  | 27.23                     | 29.91            |
|                       | <b>BASIN TOTAL</b>        | <b>1383.17</b>            | <b>697.46</b>                          | <b>685.70</b>  | <b>250.14</b> | <b>194.88</b>  | <b>34.40</b>  | <b>206.28</b>  | <b>71.96</b>              | <b>89.31</b>   | <b>21.85</b>       | <b>0.00</b>      | <b>256.39</b>             | <b>273.73</b>    |
| MARTHA BRAE           | MARTHA BRAE               | 1074.37                   | 629.17                                 | 445.20         | 336.11        | 92.60          | 15.10         | 1.39           | 166.16                    | 232.26         | 55.80              |                  | 111.75                    | 177.85           |
| DRY HARBOUR MOUNTAINS | RIO BUENO-WHITE RIVER     | 2343.27                   | 1195.59                                | 1147.67        | 613.21        | 101.02         | 142.60        | 290.85         | 378.09                    | 434.38         | 188.99             |                  | 479.94                    | 536.24           |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 170.72                    | 83.38                                  | 87.35          | 38.61         | 31.08          | 0.00          | 17.65          | 14.03                     | 17.03          | 7.49               |                  | 24.19                     | 27.19            |
|                       | Oracabessa-Pagee          | 240.59                    | 130.15                                 | 110.44         | 41.26         | 48.44          | 0.00          | 20.74          | 19.74                     | 24.38          | 8.17               |                  | 32.31                     | 36.95            |
|                       | Wagwater River            | 569.06                    | 253.93                                 | 315.12         | 70.06         | 83.24          | 0.00          | 161.83         | 42.57                     | 57.36          | 9.01               |                  | 195.39                    | 210.18           |
|                       | Pencar-Buff Bay River     | 493.51                    | 165.86                                 | 327.65         | 106.42        | 214.41         | 0.00          | 6.82           | 53.67                     | 63.89          | 14.40              |                  | 46.09                     | 56.31            |
|                       | Spanish River             | 326.71                    | 90.81                                  | 235.90         | 57.78         | 68.92          | 0.00          | 109.20         | 53.49                     | 70.64          | 15.50              |                  | 147.19                    | 164.35           |
|                       | Swift River               | 350.45                    | 88.67                                  | 261.78         | 77.33         | 142.35         | 0.00          | 42.10          | 59.48                     | 74.74          | 16.59              |                  | 84.98                     | 100.25           |
|                       | Rio Grande                | 961.04                    | 228.96                                 | 732.08         | 255.05        | 506.29         | 0.00          | -29.26         | 169.76                    | 216.05         | 53.00              |                  | 87.50                     | 133.79           |
|                       | Drivers River             | 696.83                    | 184.83                                 | 512.00         | 3.32          | 6.30           | 0.00          | 502.38         | 0.32                      | 1.14           | 0.00               |                  | 502.70                    | 503.52           |
|                       | <b>BASIN TOTAL</b>        | <b>3808.92</b>            | <b>1226.59</b>                         | <b>2582.33</b> | <b>649.83</b> | <b>1101.03</b> | <b>0.00</b>   | <b>831.47</b>  | <b>413.06</b>             | <b>525.23</b>  | <b>124.17</b>      | <b>0.00</b>      | <b>1120.36</b>            | <b>1232.53</b>   |
| GRAND TOTAL           | 18631.07                  | 9191.42                   | 9439.65                                | 3386.69        | 2352.59       | 774.70         | 2925.66       | 1927.19        | 2438.69                   | 691.21         | 0.00               | 4161.64          | 4673.15                   |                  |

**TABLE 28: ESTIMATED WATER BALANCE FOR 2030**

| BASIN                 | WMU                       | MEAN ANNUAL PRECIPITATION | MEAN ANNUAL ACTUAL EVAPO-TRANSPIRATION | EFFECTIVE RAIN | BASE FLOW     | RUNOFF         | GH FLOW       | GW SAFE YIELD* | Q95 (DOMESTIC) SAFE YIELD | Q90 SAFE YIELD | ENVIRONMENTAL FLOW | INTER-BASIN FLOW | TOTAL DOMESTIC SAFE YIELD | TOTAL SAFE YIELD |
|-----------------------|---------------------------|---------------------------|----------------------------------------|----------------|---------------|----------------|---------------|----------------|---------------------------|----------------|--------------------|------------------|---------------------------|------------------|
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 378.44                    | 150.28                                 | 228.16         | 64.17         | 117.61         | 1.20          | 45.19          | 10.41                     | 17.00          | 2.67               |                  | 52.93                     | 59.52            |
|                       | Morant River              | 717.82                    | 333.34                                 | 384.48         | 43.88         | 45.13          | 2.20          | 293.27         | 28.16                     | 35.07          | 8.57               |                  | 312.86                    | 319.77           |
|                       | Yallahs River             | 329.92                    | 167.23                                 | 162.69         | 87.99         | 55.97          | 1.40          | 17.33          | 55.94                     | 66.64          | 13.09              |                  | 60.18                     | 70.87            |
|                       | <b>BASIN TOTAL</b>        | <b>1426.18</b>            | <b>650.85</b>                          | <b>775.33</b>  | <b>196.04</b> | <b>218.70</b>  | <b>4.80</b>   | <b>355.79</b>  | <b>94.51</b>              | <b>118.70</b>  | <b>24.33</b>       | <b>0.00</b>      | <b>425.97</b>             | <b>450.16</b>    |
| KINGSTON              | HOPE RIVER                | 359.48                    | 220.26                                 | 139.22         | 13.59         | 8.80           | 20.70         | 96.12          | 4.79                      | 5.71           | 1.82               |                  | 99.10                     | 100.01           |
| RIO COBRE             | RIO COBRE                 | 1914.39                   | 1067.70                                | 846.70         | 222.34        | 127.39         | 73.40         | 423.56         | 93.54                     | 122.27         | 34.42              |                  | 482.68                    | 511.41           |
| RIO MINHO             | Rio Minho                 | 1044.69                   | 697.19                                 | 347.50         | 41.90         | 105.12         | 90.50         | 109.98         | 66.41                     | 86.00          | 4.71               |                  | 171.68                    | 191.27           |
|                       | Milk River                | 1152.74                   | 756.53                                 | 396.22         | 20.50         | 28.66          | 156.00        | 191.05         | 18.98                     | 23.97          | 0.45               |                  | 209.59                    | 214.57           |
|                       | Gut River-Alligator Hole  | 176.56                    | 155.63                                 | 20.93          | 243.74        | 27.08          | 41.30         | -291.19        | 42.32                     | 93.83          | 2.52               |                  | -251.39                   | -199.88          |
|                       | <b>BASIN TOTAL</b>        | <b>2374.00</b>            | <b>1609.35</b>                         | <b>764.65</b>  | <b>306.14</b> | <b>160.86</b>  | <b>287.80</b> | <b>9.84</b>    | <b>127.72</b>             | <b>203.80</b>  | <b>7.68</b>        | <b>0.00</b>      | <b>129.88</b>             | <b>205.96</b>    |
| BLACK RIVER           | BLACK RIVER               | 2077.65                   | 1232.74                                | 844.91         | 616.27        | 160.15         | 154.00        | -85.51         | 484.61                    | 587.48         | 198.58             |                  | 200.52                    | 303.39           |
| CABARITA RIVER        | Deans Valley River        | 796.16                    | 381.13                                 | 415.03         | 8.56          | 74.94          | 11.10         | 320.43         | 5.96                      | 8.61           | 1.78               |                  | 324.61                    | 327.26           |
|                       | Cabarita River            | 523.15                    | 268.23                                 | 254.92         | 157.91        | 79.55          | 6.80          | 10.66          | 85.34                     | 107.92         | 31.45              |                  | 64.54                     | 87.12            |
|                       | New Savannah River        | 59.53                     | 36.52                                  | 23.02          | 3.37          | 18.23          | 8.00          | -6.58          | 0.22                      | 0.38           | 0.00               |                  | -6.36                     | -6.20            |
|                       | South Negril-Orange River | 247.28                    | 158.09                                 | 89.19          | 13.17         | 14.42          | 16.00         | 45.59          | 1.23                      | 2.65           | 0.34               |                  | 46.48                     | 47.90            |
|                       | <b>BASIN TOTAL</b>        | <b>1626.13</b>            | <b>843.97</b>                          | <b>782.16</b>  | <b>183.02</b> | <b>187.15</b>  | <b>41.90</b>  | <b>370.09</b>  | <b>92.75</b>              | <b>119.55</b>  | <b>33.57</b>       | <b>0.00</b>      | <b>429.27</b>             | <b>456.08</b>    |
| GREAT RIVER           | Lucea River               | 441.40                    | 238.31                                 | 203.09         | 5.96          | 13.93          | 6.50          | 176.70         | 1.61                      | 2.14           | 0.44               |                  | 177.87                    | 178.41           |
|                       | Great River               | 637.52                    | 299.84                                 | 337.68         | 220.29        | 142.63         | 9.50          | -34.74         | 61.15                     | 75.28          | 18.69              |                  | 7.72                      | 21.85            |
|                       | Montego River             | 270.64                    | 182.09                                 | 88.55          | 23.89         | 38.33          | 18.40         | 7.93           | 9.21                      | 11.89          | 2.72               |                  | 14.41                     | 17.09            |
|                       | <b>BASIN TOTAL</b>        | <b>1349.56</b>            | <b>720.24</b>                          | <b>629.31</b>  | <b>250.14</b> | <b>194.88</b>  | <b>34.40</b>  | <b>149.89</b>  | <b>71.96</b>              | <b>89.31</b>   | <b>21.85</b>       | <b>0.00</b>      | <b>200.00</b>             | <b>217.34</b>    |
| MARTHA BRAE           | MARTHA BRAE               | 1048.26                   | 651.13                                 | 397.13         | 336.11        | 92.60          | 15.10         | -46.68         | 166.16                    | 232.26         | 55.80              |                  | 63.68                     | 129.78           |
| DRY HARBOUR MOUNTAINS | RIO BUE-NO-WHITE RIVER    | 2286.32                   | 1239.82                                | 1046.51        | 613.21        | 101.02         | 142.60        | 189.68         | 378.09                    | 434.38         | 188.99             |                  | 378.77                    | 435.07           |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 166.57                    | 86.25                                  | 80.32          | 38.61         | 31.08          | 0.00          | 10.63          | 14.03                     | 17.03          | 7.49               |                  | 17.17                     | 20.16            |
|                       | Oracabessa-Pagee          | 234.74                    | 134.97                                 | 99.78          | 41.26         | 48.44          | 0.00          | 10.08          | 19.74                     | 24.38          | 8.17               |                  | 21.65                     | 26.28            |
|                       | Wagwater River            | 555.23                    | 262.73                                 | 292.50         | 70.06         | 83.24          | 0.00          | 139.20         | 42.57                     | 57.36          | 9.01               |                  | 172.77                    | 187.55           |
|                       | Pencar-Buff Bay River     | 481.52                    | 172.09                                 | 309.43         | 106.42        | 214.41         | 0.00          | -11.40         | 53.67                     | 63.89          | 14.40              |                  | 27.88                     | 38.09            |
|                       | Spanish River             | 318.77                    | 94.22                                  | 224.55         | 57.78         | 68.92          | 0.00          | 97.85          | 53.49                     | 70.64          | 15.50              |                  | 135.84                    | 153.00           |
|                       | Swift River               | 341.93                    | 92.18                                  | 249.75         | 77.33         | 142.35         | 0.00          | 30.07          | 59.48                     | 74.74          | 16.59              |                  | 72.95                     | 88.22            |
|                       | Rio Grande                | 937.69                    | 239.28                                 | 698.41         | 255.05        | 506.29         | 0.00          | -62.93         | 169.76                    | 216.05         | 53.00              |                  | 53.82                     | 100.12           |
|                       | Drivers River             | 679.90                    | 193.65                                 | 486.25         | 3.32          | 6.30           | 0.00          | 476.63         | 0.32                      | 1.14           | 0.00               |                  | 476.94                    | 477.76           |
|                       | <b>BASIN TOTAL</b>        | <b>3716.36</b>            | <b>1275.37</b>                         | <b>2440.99</b> | <b>649.83</b> | <b>1101.03</b> | <b>0.00</b>   | <b>690.13</b>  | <b>413.06</b>             | <b>525.23</b>  | <b>124.17</b>      | <b>0.00</b>      | <b>979.02</b>             | <b>1091.19</b>   |
| GRAND TOTAL           | 18178.32                  | 9511.43                   | 8666.89                                | 3386.69        | 2352.59       | 774.70         | 2152.90       | 1927.19        | 2438.69                   | 691.21         | 0.00               | 3388.89          | 3900.39                   |                  |



**TABLE 29: ESTIMATED WATER BALANCE FOR 2050**

| BASIN                 | WMU                       | MEAN ANNUAL PRECIPITATION | MEAN ANNUAL ACTUAL EVAPO-TRANSPIRATION | EFFECTIVE RAIN | BASE FLOW     | RUNOFF         | GH FLOW       | GW SAFE YIELD* | Q95 (DOMESTIC) SAFE YIELD | Q90 SAFE YIELD | ENVIRONMENTAL FLOW | INTER-BASIN FLOW | TOTAL DOMESTIC SAFE YIELD | TOTAL SAFE YIELD |
|-----------------------|---------------------------|---------------------------|----------------------------------------|----------------|---------------|----------------|---------------|----------------|---------------------------|----------------|--------------------|------------------|---------------------------|------------------|
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 340.86                    | 149.66                                 | 191.20         | 64.17         | 117.61         | 1.20          | 8.23           | 10.41                     | 17.00          | 2.67               |                  | 15.97                     | 22.56            |
|                       | Morant River              | 646.54                    | 332.85                                 | 313.69         | 43.88         | 45.13          | 2.20          | 222.48         | 28.16                     | 35.07          | 8.57               |                  | 242.07                    | 248.98           |
|                       | Yallahs River             | 297.16                    | 167.39                                 | 129.77         | 87.99         | 55.97          | 1.40          | -15.59         | 55.94                     | 66.64          | 13.09              |                  | 27.26                     | 37.95            |
|                       | <b>BASIN TOTAL</b>        | <b>1284.56</b>            | <b>649.90</b>                          | <b>634.66</b>  | <b>196.04</b> | <b>218.70</b>  | <b>4.80</b>   | <b>215.12</b>  | <b>94.51</b>              | <b>118.70</b>  | <b>24.33</b>       | <b>0.00</b>      | <b>285.30</b>             | <b>309.48</b>    |
| KINGSTON              | HOPE RIVER                | 323.78                    | 220.80                                 | 102.99         | 13.59         | 8.80           | 20.70         | 59.89          | 4.79                      | 5.71           | 1.82               |                  | 62.87                     | 63.78            |
| RIO COBRE             | RIO COBRE                 | 1724.29                   | 1071.97                                | 652.32         | 222.34        | 127.39         | 73.40         | 229.19         | 93.54                     | 122.27         | 34.42              |                  | 288.31                    | 317.04           |
| RIO MINHO             | Rio Minho                 | 940.95                    | 700.37                                 | 240.58         | 41.90         | 105.12         | 90.50         | 3.06           | 66.41                     | 86.00          | 4.71               |                  | 64.76                     | 84.35            |
|                       | Milk River                | 1038.27                   | 759.29                                 | 278.98         | 20.50         | 28.66          | 156.00        | 73.82          | 18.98                     | 23.97          | 0.45               |                  | 92.35                     | 97.33            |
|                       | Gut River-Alligator Hole  | 159.03                    | 156.39                                 | 2.63           | 243.74        | 27.08          | 41.30         | -309.49        | 42.32                     | 93.83          | 2.52               |                  | -269.68                   | -218.17          |
|                       | <b>BASIN TOTAL</b>        | <b>2138.25</b>            | <b>1616.06</b>                         | <b>522.20</b>  | <b>306.14</b> | <b>160.86</b>  | <b>287.80</b> | <b>-232.61</b> | <b>127.72</b>             | <b>203.80</b>  | <b>7.68</b>        | <b>0.00</b>      | <b>-112.57</b>            | <b>-36.49</b>    |
| BLACK RIVER           | BLACK RIVER               | 1871.33                   | 1238.13                                | 633.20         | 616.27        | 160.15         | 154.00        | -297.22        | 484.61                    | 587.48         | 198.58             |                  | -11.19                    | 91.68            |
| CABARITA RIVER        | Deans Valley River        | 717.10                    | 382.02                                 | 335.09         | 8.56          | 74.94          | 11.10         | 240.48         | 5.96                      | 8.61           | 1.78               |                  | 244.66                    | 247.31           |
|                       | Cabarita River            | 471.20                    | 269.32                                 | 201.89         | 157.91        | 79.55          | 6.80          | -42.38         | 85.34                     | 107.92         | 31.45              |                  | 11.51                     | 34.09            |
|                       | New Savannah River        | 53.62                     | 36.72                                  | 16.90          | 3.37          | 18.23          | 8.00          | -12.70         | 0.22                      | 0.38           | 0.00               |                  | -12.48                    | -12.32           |
|                       | South Negril-Orange River | 222.72                    | 159.15                                 | 63.57          | 13.17         | 14.42          | 16.00         | 19.97          | 1.23                      | 2.65           | 0.34               |                  | 20.86                     | 22.28            |
|                       | <b>BASIN TOTAL</b>        | <b>1464.65</b>            | <b>847.21</b>                          | <b>617.44</b>  | <b>183.02</b> | <b>187.15</b>  | <b>41.90</b>  | <b>205.37</b>  | <b>92.75</b>              | <b>119.55</b>  | <b>33.57</b>       | <b>0.00</b>      | <b>264.55</b>             | <b>291.36</b>    |
| GREAT RIVER           | Lucea River               | 397.57                    | 239.62                                 | 157.94         | 5.96          | 13.93          | 6.50          | 131.55         | 1.61                      | 2.14           | 0.44               |                  | 132.73                    | 133.26           |
|                       | Great River               | 574.22                    | 300.87                                 | 273.34         | 220.29        | 142.63         | 9.50          | -99.07         | 61.15                     | 75.28          | 18.69              |                  | -56.62                    | -42.49           |
|                       | Montego River             | 243.76                    | 182.87                                 | 60.89          | 23.89         | 38.33          | 18.40         | -19.73         | 9.21                      | 11.89          | 2.72               |                  | -13.25                    | -10.57           |
|                       | <b>BASIN TOTAL</b>        | <b>1215.54</b>            | <b>723.36</b>                          | <b>492.18</b>  | <b>250.14</b> | <b>194.88</b>  | <b>34.40</b>  | <b>12.75</b>   | <b>71.96</b>              | <b>89.31</b>   | <b>21.85</b>       | <b>0.00</b>      | <b>62.86</b>              | <b>80.21</b>     |
| MARTHA BRAE           | MARTHA BRAE               | 944.17                    | 653.20                                 | 290.97         | 336.11        | 92.60          | 15.10         | -152.85        | 166.16                    | 232.26         | 55.80              |                  | -42.48                    | 23.62            |
| DRY HARBOUR MOUNTAINS | RIO BUE-NO-WHITE RIVER    | 2059.29                   | 1239.27                                | 820.01         | 613.21        | 101.02         | 142.60        | -36.81         | 378.09                    | 434.38         | 188.99             |                  | 152.28                    | 208.58           |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 150.03                    | 86.25                                  | 63.78          | 38.61         | 31.08          | 0.00          | -5.91          | 14.03                     | 17.03          | 7.49               |                  | 0.63                      | 3.62             |
|                       | Oracabessa-Pagee          | 211.43                    | 135.13                                 | 76.30          | 41.26         | 48.44          | 0.00          | -13.40         | 19.74                     | 24.38          | 8.17               |                  | -1.83                     | 2.81             |
|                       | Wagwater River            | 500.09                    | 263.54                                 | 236.55         | 70.06         | 83.24          | 0.00          | 83.25          | 42.57                     | 57.36          | 9.01               |                  | 116.82                    | 131.61           |
|                       | Pencar-Buff Bay River     | 433.70                    | 172.50                                 | 261.20         | 106.42        | 214.41         | 0.00          | -59.63         | 53.67                     | 63.89          | 14.40              |                  | -20.35                    | -10.14           |
|                       | Spanish River             | 287.12                    | 94.26                                  | 192.86         | 57.78         | 68.92          | 0.00          | 66.16          | 53.49                     | 70.64          | 15.50              |                  | 104.15                    | 121.31           |
|                       | Swift River               | 307.98                    | 92.47                                  | 215.51         | 77.33         | 142.35         | 0.00          | -4.17          | 59.48                     | 74.74          | 16.59              |                  | 38.71                     | 53.97            |
|                       | Rio Grande                | 844.57                    | 238.47                                 | 606.11         | 255.05        | 506.29         | 0.00          | -155.23        | 169.76                    | 216.05         | 53.00              |                  | -38.47                    | 7.82             |
|                       | Drivers River             | 612.38                    | 192.48                                 | 419.91         | 3.32          | 6.30           | 0.00          | 410.29         | 0.32                      | 1.14           | 0.00               |                  | 410.60                    | 411.42           |
|                       | <b>BASIN TOTAL</b>        | <b>3347.31</b>            | <b>1275.10</b>                         | <b>2072.22</b> | <b>649.83</b> | <b>1101.03</b> | <b>0.00</b>   | <b>321.36</b>  | <b>413.06</b>             | <b>525.23</b>  | <b>124.17</b>      | <b>0.00</b>      | <b>610.25</b>             | <b>722.42</b>    |
| GRAND TOTAL           | 16373.17                  | 9534.99                   | 6838.18                                | 3386.69        | 2352.59       | 774.70         | 324.19        | 1927.19        | 2438.69                   | 691.21         | 0.00               | 1560.18          | 2071.68                   |                  |

**TABLE 30: ESTIMATED WATER BALANCE FOR 2080**

| BASIN                 | WMU                       | MEAN ANNUAL PRECIPITATION | MEAN ANNUAL ACTUAL EVAPOTRANSPIRATION | EFFECTIVE RAIN | BASE FLOW     | RUNOFF         | GH FLOW       | GW SAFE YIELD* | Q95 (DOMESTIC) SAFE YIELD | Q90 SAFE YIELD | ENVIRONMENTAL FLOW | INTER-BASIN FLOW | TOTAL DOMESTIC SAFE YIELD | TOTAL SAFE YIELD |
|-----------------------|---------------------------|---------------------------|---------------------------------------|----------------|---------------|----------------|---------------|----------------|---------------------------|----------------|--------------------|------------------|---------------------------|------------------|
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 284.39                    | 153.05                                | 131.34         | 64.17         | 117.61         | 1.20          | -51.63         | 10.41                     | 17.00          | 2.67               |                  | -43.89                    | -37.30           |
|                       | Morant River              | 539.42                    | 340.43                                | 199.00         | 43.88         | 45.13          | 2.20          | 107.79         | 28.16                     | 35.07          | 8.57               |                  | 127.38                    | 134.29           |
|                       | Yallahs River             | 247.92                    | 170.91                                | 77.02          | 87.99         | 55.97          | 1.40          | -68.35         | 55.94                     | 66.64          | 13.09              |                  | -25.50                    | -14.80           |
|                       | <b>BASIN TOTAL</b>        | <b>1071.74</b>            | <b>664.38</b>                         | <b>407.36</b>  | <b>196.04</b> | <b>218.70</b>  | <b>4.80</b>   | <b>-12.18</b>  | <b>94.51</b>              | <b>118.70</b>  | <b>24.33</b>       | <b>0.00</b>      | <b>58.00</b>              | <b>82.19</b>     |
| KINGSTON              | HOPE RIVER                | 270.14                    | 224.99                                | 45.15          | 13.59         | 8.80           | 20.70         | 2.06           | 4.79                      | 5.71           | 1.82               |                  | 5.03                      | 5.95             |
| RIO COBRE             | RIO COBRE                 | 1438.62                   | 1093.97                               | 344.65         | 222.34        | 127.39         | 73.40         | -78.48         | 93.54                     | 122.27         | 34.42              |                  | -19.37                    | 9.36             |
| RIO MINHO             | Rio Minho                 | 785.06                    | 716.54                                | 68.52          | 41.90         | 105.12         | 90.50         | -169.00        | 66.41                     | 86.00          | 4.71               |                  | -107.29                   | -87.71           |
|                       | Milk River                | 866.26                    | 776.07                                | 90.19          | 20.50         | 28.66          | 156.00        | -114.97        | 18.98                     | 23.97          | 0.45               |                  | -96.44                    | -91.46           |
|                       | Gut River-Alligator Hole  | 132.68                    | 160.13                                | -27.45         | 243.74        | 27.08          | 41.30         | -339.57        | 42.32                     | 93.83          | 2.52               |                  | -299.77                   | -248.25          |
|                       | <b>BASIN TOTAL</b>        | <b>1784.00</b>            | <b>1652.74</b>                        | <b>131.27</b>  | <b>306.14</b> | <b>160.86</b>  | <b>287.80</b> | <b>-623.54</b> | <b>127.72</b>             | <b>203.80</b>  | <b>7.68</b>        | <b>0.00</b>      | <b>-503.50</b>            | <b>-427.42</b>   |
| BLACK RIVER           | BLACK RIVER               | 1561.30                   | 1265.01                               | 296.29         | 616.27        | 160.15         | 154.00        | -634.12        | 484.61                    | 587.48         | 198.58             |                  | -348.09                   | -245.22          |
| CABARITA RIVER        | Deans Valley River        | 598.30                    | 389.84                                | 208.46         | 8.56          | 74.94          | 11.10         | 113.85         | 5.96                      | 8.61           | 1.78               |                  | 118.04                    | 120.69           |
|                       | Cabarita River            | 393.14                    | 274.99                                | 118.15         | 157.91        | 79.55          | 6.80          | -126.12        | 85.34                     | 107.92         | 31.45              |                  | -72.23                    | -49.65           |
|                       | New Savannah River        | 44.74                     | 37.55                                 | 7.19           | 3.37          | 18.23          | 8.00          | -22.41         | 0.22                      | 0.38           | 0.00               |                  | -22.19                    | -22.03           |
|                       | South Negril-Orange River | 185.82                    | 162.90                                | 22.93          | 13.17         | 14.42          | 16.00         | -20.67         | 1.23                      | 2.65           | 0.34               |                  | -19.78                    | -18.36           |
|                       | <b>BASIN TOTAL</b>        | <b>1221.99</b>            | <b>865.27</b>                         | <b>356.72</b>  | <b>183.02</b> | <b>187.15</b>  | <b>41.90</b>  | <b>-55.35</b>  | <b>92.75</b>              | <b>119.55</b>  | <b>33.57</b>       | <b>0.00</b>      | <b>3.83</b>               | <b>30.64</b>     |
| GREAT RIVER           | Lucea River               | 331.70                    | 244.91                                | 86.79          | 5.96          | 13.93          | 6.50          | 60.40          | 1.61                      | 2.14           | 0.44               |                  | 61.57                     | 62.11            |
|                       | Great River               | 479.08                    | 307.28                                | 171.80         | 220.29        | 142.63         | 9.50          | -200.61        | 61.15                     | 75.28          | 18.69              |                  | -158.16                   | -144.03          |
|                       | Montego River             | 203.38                    | 186.92                                | 16.45          | 23.89         | 38.33          | 18.40         | -64.17         | 9.21                      | 11.89          | 2.72               |                  | -57.69                    | -55.01           |
|                       | <b>BASIN TOTAL</b>        | <b>1014.16</b>            | <b>739.11</b>                         | <b>275.04</b>  | <b>250.14</b> | <b>194.88</b>  | <b>34.40</b>  | <b>-204.38</b> | <b>71.96</b>              | <b>89.31</b>   | <b>21.85</b>       | <b>0.00</b>      | <b>-154.27</b>            | <b>-136.93</b>   |
| MARTHA BRAE           | MARTHA BRAE               | 787.74                    | 667.28                                | 120.47         | 336.11        | 92.60          | 15.10         | -323.35        | 166.16                    | 232.26         | 55.80              |                  | -212.98                   | -146.88          |
| DRY HARBOUR MOUNTAINS | RIO BUENO-WHITE RIVER     | 1718.12                   | 1265.66                               | 452.46         | 613.21        | 101.02         | 142.60        | -404.37        | 378.09                    | 434.38         | 188.99             |                  | -215.27                   | -158.98          |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 125.18                    | 88.05                                 | 37.13          | 38.61         | 31.08          | 0.00          | -32.57         | 14.03                     | 17.03          | 7.49               |                  | -26.03                    | -23.03           |
|                       | Oracabessa-Pagee          | 176.40                    | 138.01                                | 38.39          | 41.26         | 48.44          | 0.00          | -51.31         | 19.74                     | 24.38          | 8.17               |                  | -39.74                    | -35.10           |
|                       | Wagwater River            | 417.24                    | 268.95                                | 148.29         | 70.06         | 83.24          | 0.00          | -5.01          | 42.57                     | 57.36          | 9.01               |                  | 28.56                     | 43.35            |
|                       | Pencar-Buff Bay River     | 361.85                    | 176.13                                | 185.71         | 106.42        | 214.41         | 0.00          | -135.11        | 53.67                     | 63.89          | 14.40              |                  | -95.84                    | -85.63           |
|                       | Spanish River             | 239.55                    | 96.19                                 | 143.36         | 57.78         | 68.92          | 0.00          | 16.66          | 53.49                     | 70.64          | 15.50              |                  | 54.65                     | 71.81            |
|                       | Swift River               | 256.95                    | 94.03                                 | 162.92         | 77.33         | 142.35         | 0.00          | -56.76         | 59.48                     | 74.74          | 16.59              |                  | -13.87                    | 1.39             |
|                       | Rio Grande                | 704.65                    | 243.63                                | 461.02         | 255.05        | 506.29         | 0.00          | -300.32        | 169.76                    | 216.05         | 53.00              |                  | -183.56                   | -137.27          |
|                       | Drivers River             | 510.93                    | 196.59                                | 314.34         | 3.32          | 6.30           | 0.00          | 304.72         | 0.32                      | 1.14           | 0.00               |                  | 305.03                    | 305.85           |
|                       | <b>BASIN TOTAL</b>        | <b>2792.75</b>            | <b>1301.59</b>                        | <b>1491.17</b> | <b>649.83</b> | <b>1101.03</b> | <b>0.00</b>   | <b>-259.69</b> | <b>413.06</b>             | <b>525.23</b>  | <b>124.17</b>      | <b>0.00</b>      | <b>29.20</b>              | <b>141.37</b>    |
| GRAND TOTAL           | 13660.57                  | 9740.00                   | 3920.57                               | 3386.69        | 2352.59       | 774.70         | -2593.41      | 1927.19        | 2438.69                   | 691.21         | 0.00               | -1357.43         | -845.93                   |                  |



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## Effective Rainfall Change per WMU 2019-2080

### EFFECTIVE RAINFALL CHANGE PER WMU

**2019-2080**

(WITH PERCENT CHANGE)

#### Legend

| Effective Rainfall<br>Mm3/Sq.Km | Min/Max Rainfall Mm3/<br>Sq. Km by Year |
|---------------------------------|-----------------------------------------|
| -0.17 - 0.00                    | Year 2019: 0.25 - 2.80                  |
| 0.01 - 0.25                     | Year 2020: 0.22 - 2.69                  |
| 0.26 - 0.60                     | Year 2025: 0.18 - 2.60                  |
| 0.61 - 0.90                     | Year 2030: 0.13 - 2.48                  |
| 0.91 - 1.20                     | Year 2050: 0.02 - 2.15                  |
| 1.21 - 1.64                     | Year 2080: -0.17 - 2.80                 |

20 Watershed Management Unit (WMU)  
& WMU Number

| WMU                         | % Effective Rainfall Change |      |      |      |      |
|-----------------------------|-----------------------------|------|------|------|------|
|                             | 2020                        | 2025 | 2030 | 2050 | 2080 |
| 1-South Negril-Orange River | -7                          | -13  | -24  | -46  | -80  |
| 2-Lucea River               | -6                          | -11  | -19  | -37  | -65  |
| 3-Great River               | -5                          | -10  | -16  | -32  | -57  |
| 4-Montego River             | -8                          | -15  | -26  | -49  | -86  |
| 5-Martha Brae               | -7                          | -14  | -23  | -44  | -77  |
| 6-Rio Bueno-White River     | -6                          | -11  | -19  | -37  | -65  |
| 7-Rio Nuevo                 | -6                          | -11  | -18  | -35  | -62  |
| 8-Oracabessa-Pagee          | -6                          | -12  | -21  | -39  | -69  |
| 9-Wagwater River            | -6                          | -10  | -17  | -33  | -58  |
| 10-Pencar-Buff Bay River    | -5                          | -9   | -14  | -27  | -48  |
| 11-Spanish River            | -4                          | -8   | -12  | -25  | -44  |
| 12-Swift River              | -4                          | -8   | -12  | -24  | -42  |
| 13-Rio Grande               | -4                          | -7   | -12  | -23  | -42  |
| 14-Drivers River            | -4                          | -7   | -12  | -24  | -43  |
| 15-Plantain Garden River    | -6                          | -10  | -16  | -30  | -52  |
| 16-Morant River             | -8                          | -12  | -19  | -34  | -58  |
| 17-Yallahs River            | -6                          | -13  | -20  | -37  | -62  |
| 18-Hope River               | -9                          | -16  | -24  | -44  | -75  |
| 19-Rio Cobre                | -6                          | -12  | -20  | -38  | -67  |
| 20-Rio Minho                | -8                          | -15  | -25  | -48  | -85  |
| 21-Milk River               | -7                          | -15  | -24  | -47  | -83  |
| 22-Gut River-Alligator Hole | -11                         | -27  | -49  | -94  | -167 |
| 23-Black River              | -6                          | -12  | -21  | -41  | -72  |
| 24-Deans Valley River       | -5                          | -10  | -17  | -33  | -58  |
| 25-Cabrita River            | -6                          | -11  | -18  | -35  | -62  |
| 26-New Savannah River       | -7                          | -13  | -22  | -43  | -76  |



Based on the Water Resources Masterplan 2020.

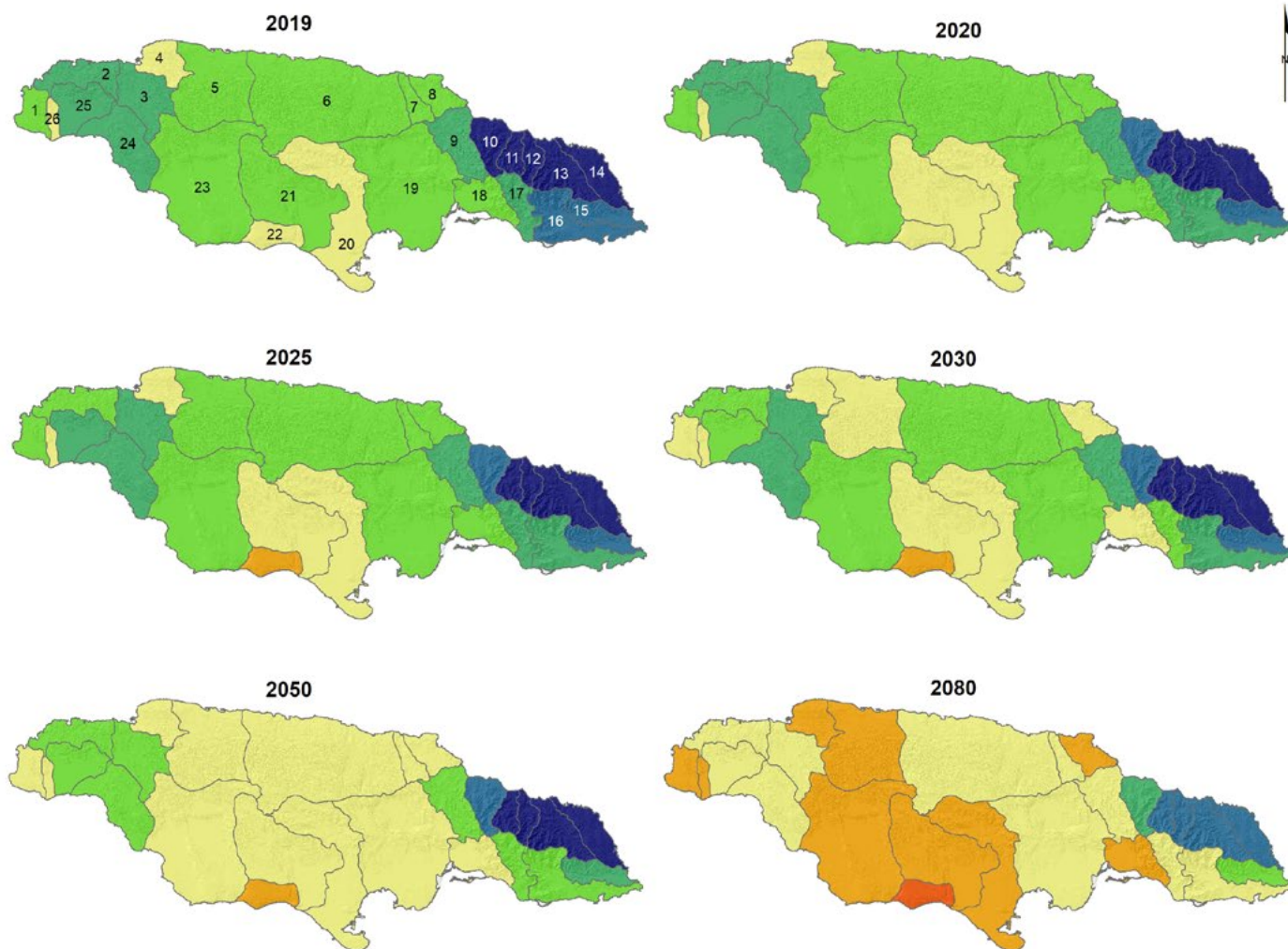


Figure 30: Effective Rainfall Change 2019-2080

## Water Surplus/Deficit per Watershed Management Unit (WMU) 2019-2080

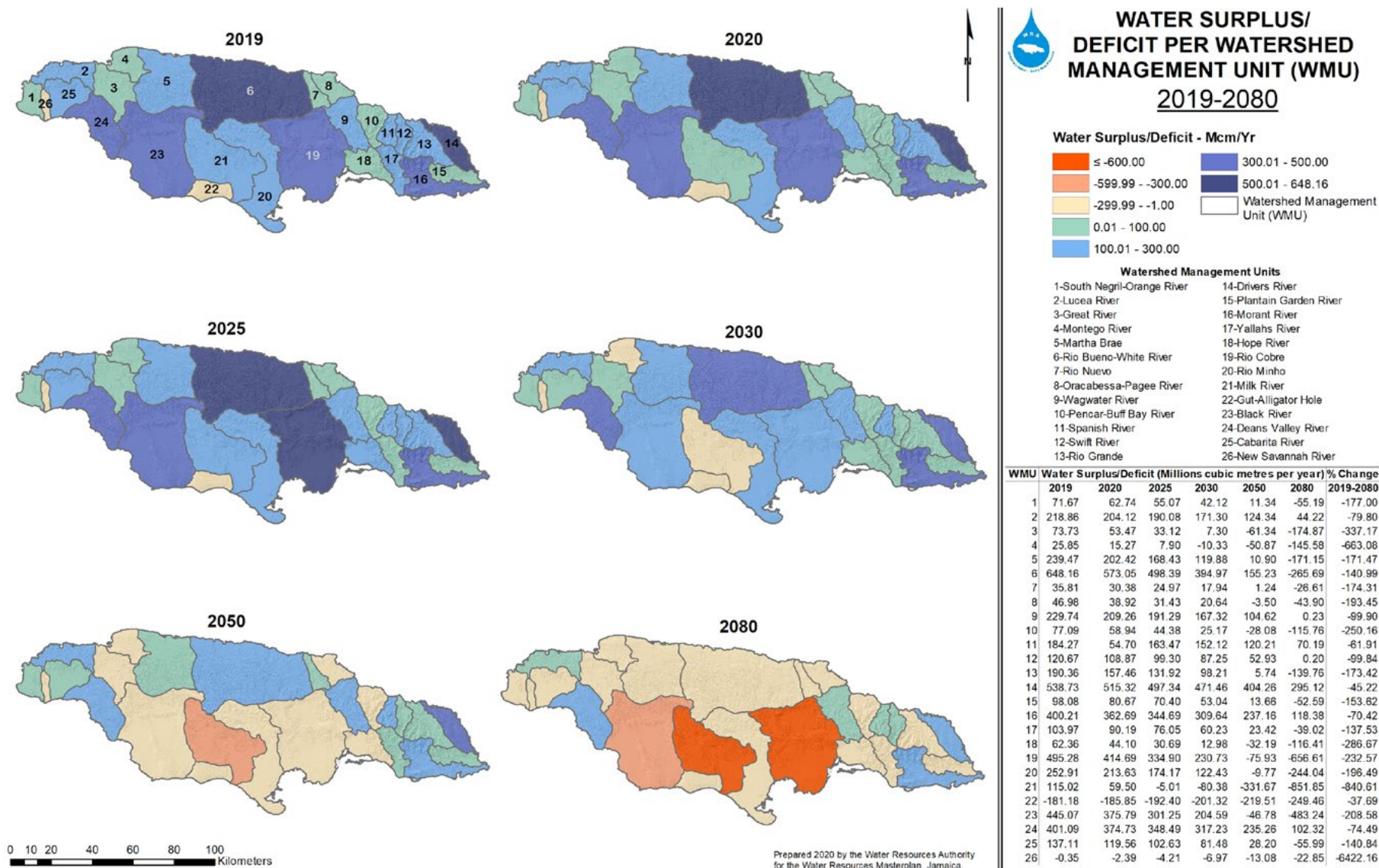


Figure 31: Water Surplus and Deficit 2019-2080

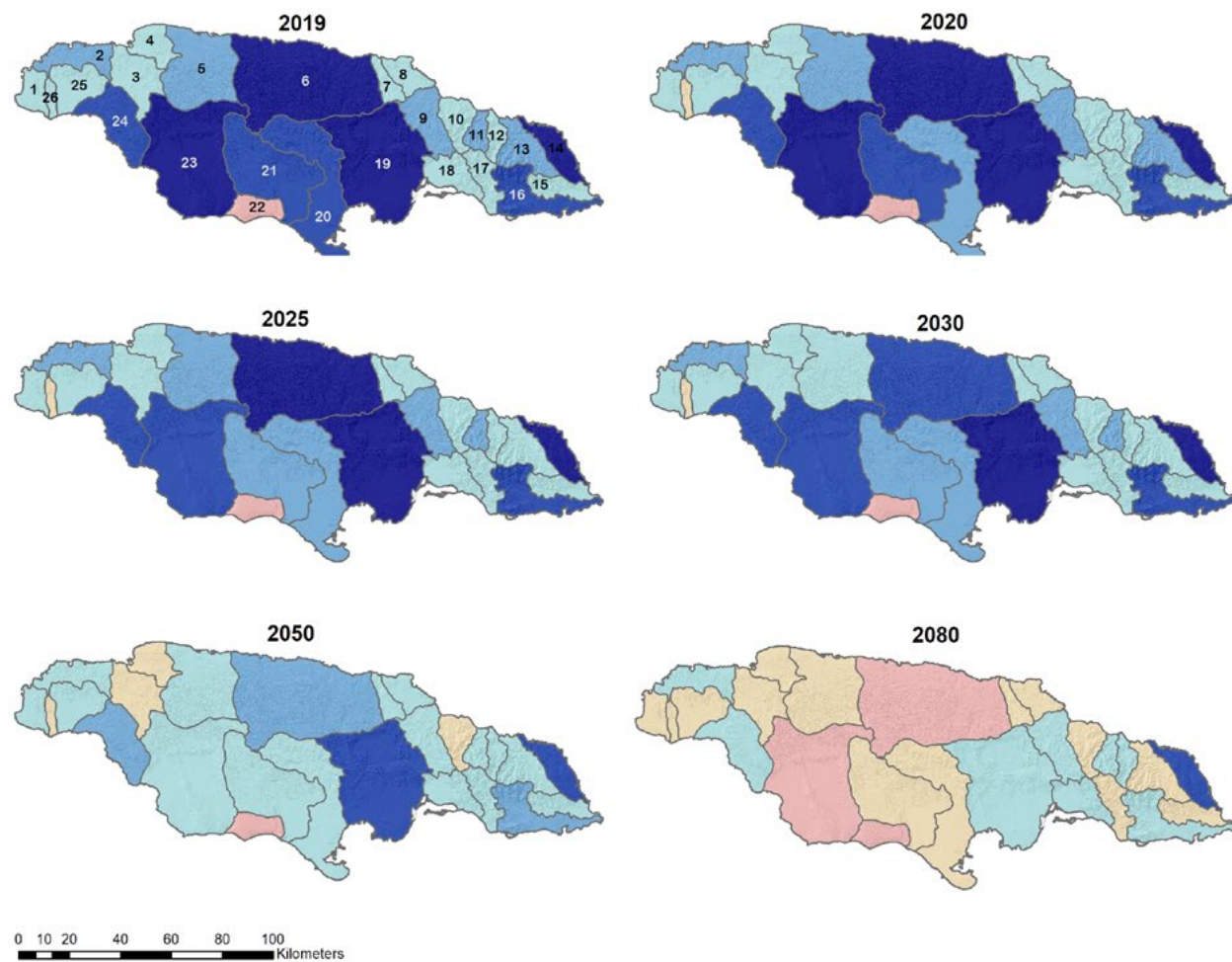


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## Safe Yield per Watershed Management Unit (WMU) 2019-2080

### WATER RESOURCES SAFE YIELD PER WATERSHED MANAGEMENT UNIT (WMU) 2019-2080



#### Safe Yield

(Millions cubic metres per year)



20 Watershed Management Unit (WMU)

#### Watershed Management Units

- |                             |                          |
|-----------------------------|--------------------------|
| 1-South Negril-Orange River | 14-Drivers River         |
| 2-Lucea River               | 15-Plantain Garden River |
| 3-Great River               | 16-Morant River          |
| 4-Montego River             | 17-Yallahs River         |
| 5-Martha Brae               | 18-Hope River            |
| 6-Rio Bueno-White River     | 19-Rio Cobre             |
| 7-Rio Nuevo                 | 20-Rio Minho             |
| 8-Oracabessa-Pagee River    | 21-Milk River            |
| 9-Wagwater River            | 22-Gut-Alligator Hole    |
| 10-Pencar-Buff Bay River    | 23-Black River           |
| 11-Spanish River            | 24-Deans Valley River    |
| 12-Swift River              | 25-Cabarita River        |
| 13-Rio Grande               | 26-New Savannah River    |

| WMU | Safe Yield (Millions cubic metres per year) |         |         |         |         |         | % Change 2019-2080 |
|-----|---------------------------------------------|---------|---------|---------|---------|---------|--------------------|
|     | 2019                                        | 2020    | 2025    | 2030    | 2050    | 2080    |                    |
| 1   | 75.67                                       | 67.16   | 60.10   | 47.90   | 22.28   | -18.36  | -124.26            |
| 2   | 225.29                                      | 210.72  | 196.91  | 178.41  | 133.26  | 62.11   | -72.43             |
| 3   | 86.41                                       | 66.60   | 46.91   | 21.85   | -42.49  | -144.03 | -266.68            |
| 4   | 47.77                                       | 38.52   | 29.91   | 17.09   | -10.57  | -55.01  | -215.15            |
| 5   | 248.16                                      | 211.42  | 177.85  | 129.78  | 23.62   | -146.88 | -159.19            |
| 6   | 682.72                                      | 608.97  | 536.24  | 435.07  | 208.58  | -158.98 | -123.29            |
| 7   | 38.01                                       | 32.59   | 27.19   | 20.16   | 3.62    | -23.03  | -160.59            |
| 8   | 52.31                                       | 44.33   | 36.95   | 26.28   | 2.81    | -35.10  | -167.11            |
| 9   | 246.47                                      | 226.91  | 210.18  | 187.55  | 131.61  | 43.35   | -82.41             |
| 10  | 87.45                                       | 69.96   | 56.31   | 38.09   | -10.14  | -85.63  | -197.92            |
| 11  | 184.77                                      | 55.57   | 164.35  | 153.00  | 121.31  | 71.81   | -61.14             |
| 12  | 121.59                                      | 109.80  | 100.25  | 88.22   | 53.97   | 1.39    | -98.86             |
| 13  | 192.16                                      | 159.29  | 133.79  | 100.12  | 7.82    | -137.27 | -171.43            |
| 14  | 544.72                                      | 522.35  | 503.52  | 477.76  | 411.42  | 305.85  | -43.85             |
| 15  | 103.44                                      | 86.31   | 76.42   | 59.52   | 22.56   | -37.30  | -136.06            |
| 16  | 409.45                                      | 372.18  | 354.48  | 319.77  | 248.98  | 134.29  | -67.20             |
| 17  | 112.67                                      | 99.39   | 85.94   | 70.87   | 37.95   | -14.80  | -113.14            |
| 18  | 145.01                                      | 127.85  | 115.99  | 100.01  | 63.78   | 5.95    | -95.90             |
| 19  | 718.65                                      | 652.92  | 593.36  | 511.41  | 317.04  | 9.36    | -98.70             |
| 20  | 309.20                                      | 273.13  | 238.17  | 191.27  | 84.35   | -87.71  | -128.37            |
| 21  | 342.95                                      | 304.73  | 263.89  | 214.57  | 97.33   | -91.46  | -126.67            |
| 22  | -179.66                                     | -184.36 | -190.93 | -199.88 | -218.17 | -248.25 | 38.18              |
| 23  | 524.13                                      | 459.97  | 392.41  | 303.39  | 91.68   | -245.22 | -146.79            |
| 24  | 410.21                                      | 384.14  | 358.20  | 327.26  | 247.31  | 120.69  | -70.58             |
| 25  | 142.60                                      | 125.09  | 108.21  | 87.12   | 34.09   | -49.65  | -134.82            |
| 26  | 0.42                                        | -1.62   | -3.44   | -6.20   | -12.32  | -22.03  | -5293.97           |

Figure 32: Safe Yield per WMU 2019-2080



# Water Demand Assessment

One of the main pillars of the GoJ Water Sector Policy (2019) is providing access to potable water supply to all households by 2020. In this regard Vision 2030 Jamaica Development Plan (Planning Institute of Jamaica 2012) and other GoJ policy documents have stated a clear commitment to an Integrated Water Resources Management (IWRM) approach to the management of the islands water resources. The existing institutional framework for water resources include the coordination of the National Environment and Planning Agency (NEPA) and the Water Resources Authority (WRA), whose specific technical mandate include the “determination of water availability to satisfy domestic and agricultural water demands and determination of the ecological water demand associated with surface streams, inland and coastal wetlands.” The collaboration between both GoJ agencies will continue under the IWRM during which research and development will be encouraged in order to achieve continuous improvement in technologies and operational efficiencies in water, sanitation and wastewater systems; and to increase resilience to climate change.

**Nationally, the provision of domestic water supply to the public is shared between the following institutions: -**

- ◆ National Water Commission - Island wide (urban and rural) by statute (National Water Commission Act, 1980)
- ◆ Parish Councils - Specific Supply areas by Licence
- ◆ GOJ Enterprises - Specific supply areas by License
- ◆ Private Enterprises - Specific supply areas by License
- ◆ ODPEM - island wide under conditions of disaster<sup>9</sup>

## WATER USE AND CONSUMPTION

Reig (2013) defines water use as the total amount of water withdrawn from its source to be used. This results in measures of water usage that help in the evaluation of the level of demand from users in various sectors, such as, municipal, industrial and agricultural. This definition does not account for re-use, recycling, or non-consumption of the abstracted water. For example, if a manufacturing plant requires 450 m<sup>3</sup> of freshwater daily for its operations and returns 95% of that water to the environment, the plant's water use is still 450 m<sup>3</sup>. Water consumption, according to Reig (2013) refers to the portion of water use that is not returned to the environment after being withdrawn. For example, consumption occurs when water is incorporated into a product or crop and is no longer available for reuse.

<sup>9</sup> Water Task Force. 2009. National Development Plan Jamaica 2030 – Water Sector Plan 2009-2030

*"Jamaica's Water Sector Policy is committed to providing access to potable water supply for all residents of Jamaica."*

According to the National Water Sector Policy there are differences in environmental and infrastructural conditions in rural and urban areas that create different obstacles to the way water supply can be provided to the population. In order to overcome these obstacles to universal access to safe water supply, different technical solutions and institutional arrangements it will become necessary. Utility Service Areas (USAs) are defined as urban areas and other densely populated settlements where piped supply from a water utility is considered the least-cost way to deliver water service. On the other hand, Non-Utility Service Areas (NUSAs) are other areas of the country where piped water service is uneconomical, and requires a variety of alternative techniques to provide access to a safe and convenient water supply. One of the objectives of the Water Sector policy is to effectively manage water supply in Utility Service Areas and Non-Utility Service Areas by ensuring equitable distribution of water supply across the ten hydrological basins. Utilities are defined as companies which serve numerous households, operate electro-mechanical systems such as pumps, and have computerized billing and accounting systems. However, small piped systems that operate by gravity flow are not considered to be utilities.

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## COMPONENTS OF WATER SUPPLY

### RURAL WATER SUPPLY

The Rural Water Supply Ltd. (RWSL) is one of the partners in satisfying the demand for fresh water in non-utility service areas. (NUSA). They provide technical assistance to households and communities in rural areas to build and maintain water supply and sanitation infrastructure in non-utility service areas. Water may be self-supplied and used in suburban or farm areas for domestic and livestock needs, and include domestic use, drinking water for livestock, and other uses such as dairy sanitation, cleaning, and waste disposal.

### MINOR WATER SUPPLY

Minor Water Supplies, Water Shops and Community Catchment Tanks within non-utility services areas are the responsibilities of the Ministry of Local Government and Community Development. The structures used include rainwater catchment tanks, wayside tanks, entombed springs and gravity-fed systems attached to community standpipes. In addition there are approximately thirteen (13) private licensees who supply fresh water to specially defined communities or the NWC. They include Dynamic Environmental Management Limited, Richmond Environmental Service Limited, Can Cara Development Limited and Four Rivers Development Company Limited (please see Appendix 1),

The GoJ in its National *Sanitation Policy* in 2005 recognized the need for the upgrading of the catchment of distribution systems where water may be distributed through stand pipes from which community members must fetch the water for domestic use. Attempts are sometimes made to restrict access to entombed springs where there are issues with poor water quality.

### PUBLIC SUPPLY

This refers to water supplied from a public supplier and used for such purposes as firefighting, street washing, flushing of water lines, and maintaining municipal parks and supplements domestic supply at the Parish Council level. This demand component has been included in Municipal demand.

### NON-REVENUE WATER

Non-Revenue Water is water that is collected, treated and supplied, but is either lost via leakages or stolen via illegal connections and therefore earns no revenue for the NWC or the Government. The Jamaica Water Sector Policy (GoJ 2004) speaks to proposed steps to reduce non-revenue, including a Network Audit and the replacement of leaky mains and, various measures aimed at reducing and controlling non-revenue water (NRW). In Kingston and St. Andrew (KSA), for example, these measures were expected to reduce NRW from 60<sup>10</sup>% to 25% <sup>11</sup>.

### GENERAL METHODOLOGY USES

Water demand projections for all major water users throughout the island were developed for the base year, with 2016 as the starting point of the forecast and then for the intervals - 2020, 2025, 2030, 2050 and 2080. Water users are grouped into four major categories as follows:

- 💧 Municipal – domestic, commercial, institutional
- 💧 Tourism – hotels, recreation/scenic usage, health and wellness (mineral spas), cruise ships
- 💧 Agricultural – crop irrigation, livestock, aquaculture
- 💧 Industrial – consumptive, non-consumptive
- 💧 Environmental

<sup>10</sup> <http://jis.gov.jm/reduction-non-revenue-water-boost-drought-resilience/> Retrieved July 09, 2017

<sup>11</sup> Ministry of Water, Land, Environment & Climate Change . 2016.



The basic methodology is to estimate water demand separately for each water use category or sector. The methodology selected to determine demand is determined by data availability. A countable unit is applied and used to project water demands up or down over the forecast horizon. These units include number of persons, number of hectares and number of rooms. The rate of water use is the quantity of water used according to the countable unit, such as litres per person. The per-unit water use rate was developed within a defined demographic unit such as hydrologic basin, Watershed Management Unit (WMU) or parish based on historical and current water use data, and findings from a literature review.

Water demand is calculated from the projected values within the defined demographic unit in order to determine if it remains constant into the future, decrease over time due to increases in water use efficiency, or increase over time due to more intensive water use. While actual trends in future water use cannot be predicted with absolute certainty, reasonable assumptions can be made that provide the foundation for estimating trends in the future and scenarios can be developed that consider demands under potential alternative conditions. The inventory of water resources and demand occur within the existing and projected water demands for the geographically delineated twenty-six (26) WMUs that fall within the ten (10) Hydrologic basins on the island. Essentially, not all variables that may impact demand are taken into account, such as, new legislations, conservation programmes, and demographic changes. Climate change scenarios that offer insight into the potential impact of climate change on demand are addressed in Section 7.5.

## MUNICIPAL DEMAND

Municipal water demand refers to the annual quantity of water withdrawn primarily for the direct use by the population. It can include water from primary renewable and secondary freshwater resources, as well as water from over-abstraction of renewable groundwater or withdrawal from fossil groundwater, direct use of agricultural drainage water, direct use of (treated) wastewater, and desalinated water. It is usually computed as the total water withdrawn by the public distribution network. It can include that part of the industries and urban agriculture, which is connected to the municipal network. The ratio between the net consumption and the water withdrawn can vary from 5 to 15% in urban areas and from 10 to 50% in rural areas. Municipal water is calculated in terms of km<sup>3</sup>/year or 10<sup>9</sup> m<sup>3</sup>/year. Residential domestic demand includes the demand for both Utility Service and Non-Utility Service areas. The calculated municipal demands do not take into account new legislation, conservation programmes, demographic changes, or climate change scenarios.

## PROJECTED POPULATION GROWTH AND WATER DEMAND

It is estimated that in 2016 slightly less than 90% of the island's population of approximately 2,736,766 was served by a public utility source, as shown in Table 31. This population total is also set to increase by almost one third by 2080 based on current population growth trend in spite of the negative population growth projected for the Great River (-20,404) Plantain Garden (-7197), Gut River (-3,406), Drivers River (-2568), Rio Nuevo (-1424), New Savannah (-650), and WMUs as shown in Table 32. The WMUs with the greatest total projected population include Rio Cobre (295,145), Milk River (84,305) and South Negril-Orange River (43,499).

**TABLE 31: ADJUSTED 2011 POPULATION AND SUMMARY OF THE POPULATION PROJECTION OVER THE PERIODS 2016, 2025, 2030, 2050 AND 2080 FOR UTILITY AND NON-UTILITY SERVICE AREAS**

| YEAR              | UTILITY SERVICE AREAS | NON-UTILITY SERVICE AREAS |
|-------------------|-----------------------|---------------------------|
| 2011              | 2,690,505             | -                         |
| 2016              | 2,443,298             | 293,468                   |
| 2020              | 2,477,295             | 297,155                   |
| 2025              | 2,521,262             | 301,916                   |
| 2030              | 2,566,915             | 306,847                   |
| 2050              | 2,767,681             | 328,347                   |
| 2080              | 3,131,740             | 366,381                   |
| POPULATION CHANGE | 688,442               | 72,861                    |



**TABLE 32: PROJECTED POPULATION CHANGE IN JAMAICA 2016-2080 BY WMU**

| BASIN            | NO | WMU NAME        | PARISH        | POP GROWTH RATE P.A. | USA     | NUSA   | SUB-TOTAL | 2020   | 2025   | 2030   | 2050   | 2080   | POP. CHANGE | WMU TOTAL POPULATION CHANGE | POPULATION % CHANGE 2016-2080 |
|------------------|----|-----------------|---------------|----------------------|---------|--------|-----------|--------|--------|--------|--------|--------|-------------|-----------------------------|-------------------------------|
| I-BLUE MOUNTAINS | 15 | Plantain Garden | St. Thomas    | -1.28                | 9,085   | 3,728  | 12,813    | 12169  | 11410  | 10698  | 8268   | 5618   | -7,195      | -7197                       | -56.15%                       |
|                  |    |                 | Portland      | -1.28                | 0       | 3      | 3         | 3      | 3      | 3      | 2      | 1      | -2          |                             |                               |
|                  | 16 | Morant River    | St. Thomas    | 0.28                 | 58,829  | 4,341  | 63,170    | 63880  | 64780  | 65692  | 69470  | 75549  | 12,379      | 12382                       | 19.60%                        |
|                  |    |                 | Portland      | 0.28                 | 0       | 17     | 17        | 17     | 17     | 18     | 19     | 20     | 3           |                             |                               |
|                  | 17 | Yallahs River   | St. Thomas    | 0.08                 | 13,847  | 397    | 14,244    | 14290  | 14347  | 14404  | 14637  | 14992  | 748         | 1175                        | 5.25%                         |
|                  |    |                 | St. Andrew    | 0.08                 | 8,053   | 71     | 8,124     | 8150   | 8183   | 8215   | 8348   | 8551   | 427         |                             |                               |
|                  |    |                 | Portland      | 0.08                 | 0       | 14     | 14        | 14     | 14     | 14     | 14     | 15     | 1           |                             |                               |
| II-KINGSTON      | 18 | Hope River      | St. Andrew    | 0.09                 | 492,552 | 7,002  | 499,554   | 501355 | 503615 | 505885 | 515070 | 529159 | 29,605      | 35105                       | 5.93%                         |
|                  |    |                 | Kingston      | 0.09                 | 87,687  | 1,438  | 89,125    | 89446  | 89850  | 90255  | 91893  | 94407  | 5,282       |                             |                               |
|                  |    |                 | St. Thomas    | 0.09                 | 2,246   | 1,432  | 3,678     | 3691   | 3708   | 3725   | 3792   | 3896   | 218         |                             |                               |
| III-RIO COBRE    | 19 | Rio Cobre       | St. Catherine | 0.66                 | 476,499 | 51,542 | 528,041   | 542120 | 560248 | 578981 | 660394 | 804472 | 276,431     | 295140                      | 52.35%                        |
|                  |    |                 | St. Andrew    | 0.66                 | 20,503  | 8,863  | 29,366    | 30149  | 31157  | 32199  | 36727  | 44739  | 15,373      |                             |                               |
|                  |    |                 | Clarendon     | 0.66                 | 2,214   | 2,655  | 4,869     | 4999   | 5166   | 5339   | 6089   | 7418   | 2,549       |                             |                               |
|                  |    |                 | St. Ann       | 0.66                 | 598     | 385    | 983       | 1009   | 1043   | 1078   | 1229   | 1498   | 515         |                             |                               |
|                  |    |                 | St. Mary      | 0.66                 | 360     | 161    | 521       | 535    | 553    | 571    | 652    | 794    | 273         |                             |                               |
| IV-RIO MINHO     | 20 | Rio Minho       | Clarendon     | 0.09                 | 134,135 | 25,191 | 159,326   | 159900 | 160621 | 161345 | 164274 | 168768 | 9,442       | 9589                        | 5.93%                         |
|                  |    |                 | St. Catherine | 0.09                 | 836     | 1,637  | 2,473     | 2482   | 2493   | 2504   | 2550   | 2620   | 147         |                             |                               |
|                  | 21 | Milk River      | Clarendon     | 0.51                 | 68,984  | 8,289  | 77,273    | 78861  | 80893  | 82977  | 91864  | 107009 | 29,736      | 84305                       | 38.48%                        |
|                  |    |                 | Manchester    | 0.51                 | 111,980 | 29,823 | 141,803   | 144718 | 148446 | 152270 | 168578 | 196372 | 54,569      |                             |                               |
|                  | 22 | Gut River       | Manchester    | -0.36                | 10,864  | 5,498  | 16,362    | 16128  | 15839  | 15556  | 14474  | 12990  | -3,372      | -3406                       | -20.61%                       |
|                  |    |                 | Clarendon     | -0.36                | 109     | 0      | 109       | 107    | 106    | 104    | 96     | 87     | -22         |                             |                               |
|                  |    |                 | St. Elizabeth | -0.36                | 0       | 52     | 52        | 51     | 50     | 49     | 46     | 41     | -11         |                             |                               |

| BASIN              | NO | WMU NAME                  | PARISH        | POP GROWTH RATE P.A. | USA     | NUSA   | SUB-TOTAL | 2020   | 2025   | 2030   | 2050   | 2080   | POP. CHANGE | WMU TOTAL POPULATION CHANGE | POPULATION % CHANGE 2016-2080 |
|--------------------|----|---------------------------|---------------|----------------------|---------|--------|-----------|--------|--------|--------|--------|--------|-------------|-----------------------------|-------------------------------|
| V-BLACK RIVER      | 23 | Black River               | St. Elizabeth | 0.15                 | 121,717 | 19,602 | 141,319   | 142169 | 143238 | 144316 | 148708 | 155547 | 14,228      | 11813                       | 6.90%                         |
|                    |    |                           | Westmoreland  | 0.15                 | 0       | 0      | 0         | 0      | 0      | 0      | 0      | 0      | 0           |                             |                               |
|                    |    |                           | Manchester    | 0.15                 | 18,914  | 4,384  | 23,298    | 23438  | 23614  | 23792  | 24516  | 25644  | 2,346       |                             |                               |
|                    |    |                           | Trelawny      | 0.15                 | 3,518   | 1,403  | 4,921     | 0      | 0      | 0      | 0      | 0      | -4,921      |                             |                               |
|                    |    |                           | St. James     | 0.15                 | 1,044   | 546    | 1,590     | 1600   | 1612   | 1624   | 1673   | 1750   | 160         |                             |                               |
| VI-CABARITA RIVER  | 24 | Deans Valley River        | Westmoreland  | 0.18                 | 52,447  | 17,797 | 70,244    | 70751  | 71390  | 72035  | 74673  | 78812  | 8,568       | 8576                        | 12.20%                        |
|                    |    |                           | Hanover       | 0.18                 | 61      | 0      | 61        | 61     | 62     | 63     | 65     | 68     | 7           |                             |                               |
|                    | 25 | Cabarita River            | Westmoreland  | 0.20                 | 40,554  | 1,236  | 41,790    | 42125  | 42548  | 42975  | 44728  | 47490  | 5,700       | 6317                        | 13.64%                        |
|                    |    |                           | Hanover       | 0.20                 | 2,898   | 1,621  | 4,519     | 4555   | 4601   | 4647   | 4837   | 5135   | 616         |                             |                               |
|                    | 26 | New Savannah              | Westmoreland  | -0.16                | 6,065   | 512    | 6,577     | 6535   | 6483   | 6431   | 6228   | 5936   | -641        | -650                        | -9.74%                        |
|                    |    |                           | Hanover       | -0.16                | 0       | 100    | 100       | 99     | 99     | 98     | 95     | 90     | -10         |                             |                               |
|                    | 1  | South Negril-Orange River | Westmoreland  | 1.57                 | 17,263  | 912    | 18,175    | 19344  | 20910  | 22604  | 30867  | 49256  | 31,081      | 43499                       | 171.01%                       |
|                    |    |                           | Hanover       | 1.57                 | 7,261   | 0      | 7,261     | 7728   | 8354   | 9031   | 12332  | 19678  | 12,417      |                             |                               |
| VII-GREAT RIVER    | 2  | Lucea River               | Hanover       | 0.35                 | 48,487  | 2,522  | 51,009    | 51727  | 52638  | 53566  | 57443  | 63791  | 12,782      | 12782                       | 40.00%                        |
|                    | 3  | Great River               | St. James     | -0.99                | 24,404  | 1,787  | 26,191    | 25169  | 23948  | 22786  | 18674  | 13855  | -12,336     | -20403                      | -47.10%                       |
|                    |    |                           | Hanover       | -0.99                | 7,244   | 283    | 7,527     | 7233   | 6882   | 6548   | 5367   | 3982   | -3,545      |                             |                               |
|                    |    |                           | Westmoreland  | -0.99                | 6,442   | 2,777  | 9,219     | 8859   | 8429   | 8020   | 6573   | 4877   | -4,342      |                             |                               |
|                    |    |                           | St. Elizabeth | -0.99                | 7       | 376    | 383       | 368    | 350    | 333    | 273    | 203    | -180        |                             |                               |
|                    | 4  | Montego River             | St. James     | 1.11                 | 137,278 | 1,892  | 139,170   | 145453 | 153707 | 162429 | 202556 | 282078 | 142,908     | 142910                      | 102.69%                       |
|                    |    |                           | Trelawny      | 1.11                 | 0       | 2      | 2         | 2      | 2      | 2      | 3      | 4      | 2           |                             |                               |
| VIII-MARTHA BRAE R | 5  | Martha Brae               | Trelawny      | 0.59                 | 39,518  | 5,441  | 44,959    | 46029  | 47403  | 48818  | 54914  | 65513  | 20,554      | 31444                       | 45.72%                        |
|                    |    |                           | St. James     | 0.59                 | 23,058  | 763    | 23,821    | 24388  | 25116  | 25866  | 29095  | 34711  | 10,890      |                             |                               |



| BASIN              | NO | WMU NAME              | PARISH        | POP GROWTH RATE P.A. | USA       | NUSA    | SUB-TOTAL | 2020      | 2025      | 2030      | 2050      | 2080      | POP. CHANGE | WMU TOTAL POPULATION CHANGE | POPULATION % CHANGE 2016-2080 |
|--------------------|----|-----------------------|---------------|----------------------|-----------|---------|-----------|-----------|-----------|-----------|-----------|-----------|-------------|-----------------------------|-------------------------------|
| IX-DRY HARBOUR MT  | 6  | Rio Bueno-White River | St. Ann       | 0.23                 | 126,417   | 47,428  | 173,845   | 175450    | 177477    | 179527    | 187968    | 201380    | 27,535      | 36446                       | 15.84%                        |
|                    |    |                       | Trelawny      | 0.23                 | 23,009    | 3,946   | 26,955    | 27204     | 27518     | 27836     | 29145     | 31224     | 4,269       |                             |                               |
|                    |    |                       | St.mary       | 0.23                 | 5,819     | 4       | 5,823     | 5877      | 5945      | 6013      | 6296      | 6745      | 922         |                             |                               |
|                    |    |                       | Clarendon     | 0.23                 | 6,387     | 2,038   | 8,425     | 8503      | 8601      | 8700      | 9109      | 9759      | 1,334       |                             |                               |
|                    |    |                       | Manchester    | 0.23                 | 14,158    | 3       | 14,161    | 14292     | 14457     | 14624     | 15311     | 16404     | 2,243       |                             |                               |
|                    |    |                       | St. Catherine | 0.23                 | 688       | 206     | 894       | 902       | 913       | 923       | 967       | 1036      | 142         |                             |                               |
| X-BLUE MOUNTAINS N | 7  | Rio Nuevo             | St. Mary      | -0.12                | 16,803    | 2,448   | 19,251    | 19159     | 19044     | 18930     | 18481     | 17827     | -1,424      | -1423.95                    | -7.40%                        |
|                    | 8  | Ora-cabessa-Pagee     | St. Mary      | 0.30                 | 41,405    | 3,805   | 45,210    | 45755     | 46445     | 47146     | 50057     | 54764     | 9,554       | 9553.88                     | 21.13%                        |
|                    | 9  | Wagwater River        | St. Mary      | 0.56                 | 30,293    | 2,354   | 32,647    | 33384     | 34330     | 35302     | 39473     | 46672     | 14,025      | 31760.48                    | 42.96%                        |
|                    |    |                       | St. Andrew    | 0.56                 | 28,902    | 12,205  | 41,107    | 42036     | 43226     | 44450     | 49702     | 58767     | 17,660      |                             |                               |
|                    |    |                       | St. Catherine | 0.56                 | 88        | 77      | 165       | 169       | 174       | 178       | 200       | 236       | 71          |                             |                               |
|                    |    |                       | Portland      | 0.56                 | 0         | 10      | 10        | 10        | 11        | 11        | 12        | 14        | 4           |                             |                               |
|                    | 10 | Pen-car-Buff Bay R    | Portland      | 0.62                 | 14,672    | 0       | 14,672    | 15039     | 15511     | 15998     | 18103     | 21791     | 7,119       | 12919.95                    | 48.52%                        |
|                    |    |                       | St. Mary      | 0.62                 | 11,783    | 0       | 11,783    | 12078     | 12457     | 12848     | 14539     | 17501     | 5,718       |                             |                               |
|                    |    |                       | St. Andrew    | 0.62                 | 64        | 107     | 171       | 175       | 181       | 186       | 211       | 254       | 83          |                             |                               |
|                    | 11 | Spanish River         | Portland      | 0.15                 | 3,643     | 604     | 4,247     | 4273      | 4305      | 4337      | 4469      | 4675      | 428         | 428.59                      | 10.07%                        |
|                    |    |                       | St. Andrew    | 0.15                 | 0         | 10      | 10        | 10        | 10        | 10        | 11        | 11        | 1           |                             |                               |
|                    | 12 | Swift River           | Portland      | 0.32                 | 7,252     | 34      | 7,286     | 7380      | 7499      | 7619      | 8122      | 8939      | 1,653       | 1653.04                     | 22.69%                        |
|                    | 13 | Rio Grande            | Portland      | 0.36                 | 14,388    | 171     | 14,559    | 14770     | 15038     | 15310     | 16451     | 18324     | 3,765       | 3788.24                     | 25.86%                        |
|                    |    |                       | St. Thomas    | 0.36                 | 0         | 91      | 91        | 92        | 94        | 96        | 103       | 115       | 24          |                             |                               |
|                    | 14 | Drivers River         | Portland      | -0.10                | 39,770    | 1,188   | 40,958    | 40794     | 40591     | 40388     | 39588     | 38418     | -2,540      | -2567.71                    | -6.20%                        |
|                    |    |                       | St. Thomas    | -0.10                | 196       | 244     | 440       | 438       | 436       | 434       | 425       | 413       | -27         |                             |                               |
| TOTALS             |    |                       |               |                      | 2,443,298 | 293,468 | 2,736,766 | 2,769,500 | 2,818,190 | 2,868,737 | 3,090,849 | 3,492,705 | 755,939     | 755,939                     |                               |

## DEMAND ASSESSMENT METHODOLOGY

### DOMESTIC, COMMERCIAL AND INSTITUTIONAL

Per capita water use estimates used for evaluating water demands include residential, commercial and institutional components within defined geographic units. Population data from the 2001 and 2011 National Census was classified by Enumeration Districts (EDs) which are the smallest spatially independent population units which share common boundaries with contiguous EDs. Utility Service Areas were demarcated as all Electoral Divisions within 100 metres of a National Water Commission (NWC) Pipeline, while Non-Utility Service Areas were the EDs not meeting that criterion as shown in Table 32. Therefore, combining per capita consumption (PCC) estimates with the population growth rate within these geographic units over the planning horizon implicitly account for future growth in the sectors. In this context the PCC of 227 litres per person per day (50 imperial gallons) as used by the NWC was adopted for utility service areas. Commercial demand is defined as the water demand for commercial activities (shopping, businesses, etc), while institutional demand is defined as the water demand for public institutions such as schools, hospitals, government services, etc. The commercial and institutional rates were both estimated as 25% of residential PCC rate. For non-utility service areas, the defined access to water PCC of 50 litres per person per day (as per the National Water Sector Policy) was used. The relevant formulae are shown below.

Population growth assumes a geometric series expressed as:

$$P_t = P_0(1 + r)^t$$

where

$P_0$  = base year population  
 $P_t$  = population t years later  
 $r$  = rate of population growth

**Residential Demand** = [Population\*227 litres/day\*WMU growth rate]

**Commercial Demand** = [0.25\*[Residential demand\*WMU growth rate]

**Institutional Demand** = [0.25\*[Residential demand\*WMU growth rate]

### TOURISM DEMAND

Tourism demand includes the use of water in rooms, kitchen, laundry, grounds, public washrooms, and swimming pools. This component not only includes stop-over visits but also cruise ships that dock at the three main ports of Ocho Rios (St. Ann), Falmouth (Trelawny) and Montego Bay (St. James). Other ports of less significance are Port Antonio (Portland) and Kingston. The contribution of cruise ships to total demand not only includes their length of stay in the ports when they may take on fresh-water to fill their tanks to meet the demand of their passengers but also on the island for those passengers who disembark and visit restaurants, golf courses and other facilities.

The tourism sector is a significant contributor to the island's GDP. In 2016 alone the sector contributed approximately one third of the island's total GDP. Tourism continues to grow and is, therefore, increasingly adding to local and seasonal pressures on water supply systems. In 2016 the arrivals of both cruise ship passengers and tourist accommodation grew by over 5 % (5.5 and 5.1% respectively) as shown in Table 33.

**TABLE 33: SHOWING VISITOR ARRIVALS AND GROWTH RATE FOR 2015/2016**

| ARRIVALS                      | 2015      | 2016      | % CHANGE 2015/2016 |
|-------------------------------|-----------|-----------|--------------------|
| CRUISE SHIP PASSENGERS        | 1,568,702 | 1,655,565 | 5.5                |
| TOURIST ACCOMMODATION (ROOMS) | (28,408)  | 29,866    | 5.1                |

Source: The Jamaica Tourist Board

The number and rooms and occupancy rates for the tourism sector and the number of cruise ship arrivals were obtained from the Tourism Product Development Company (TPDCO) and the Jamaica Tourist Board (JTB). Recent surveys of hotels in Jamaica have estimated a daily consumption rate of 849 litres per day (Becken 2014). Current and future water demand in hotels was estimated as follows:

**Tourism Water demand** = [No. rooms]\*[Annual occupancy rate]\*[849 litres/day/room]  
 \*[Annual growth rate]

**WRA**

WATER RESOURCES AUTHORITY

*"Water Demands include Domestic, Commercial, Institutional, Industrial, Tourism, Agricultural/Irrigation, and Non-Consumptive (e.g. Hydro-electric, Recreational)"*

Cruise shipping demand assumes that passengers stay an average 7.5 hours per visit when approximately 75 % of these visitors disembark from the vessels. Using the PCC demand of 182 litres per person per day and converting same to 7.583 litres per person per hour, the PCC demand for cruise ship passengers is therefore estimated at 7.5 hours \* 7.583 litres per person per hour which equals 5656.875 litres per passenger per day, which would grow at a rate of 5.5 % per annum. In addition, the estimated demand for cruise ship water re-supply is set at 350 litres per person per day.

**Cruise Shipping Demand = [No. daily of arrivals]\*[350 m<sup>3</sup>/day] for base year**

**CSD Projections = [No. of daily arrivals]\*[350 m<sup>3</sup>/day] \*[Annual growth rate]**

## INDUSTRIAL DEMAND

### COMPONENTS OF INDUSTRIAL DEMAND

In the local context, the components of industrial demand include withdrawals that are self-supplied for industrial activities and mining. Industries that are supplied by the public water supply system are included under municipal in order to avoid double counting.

### METHODOLOGY

Daily demand from abstraction licences for industries on record at the WRA account for industrial demand. Industries include mining,

food and beverage and manufacturing. A growth rate of 2 % (PIOJ 2015) was applied to the demand forecast for the sector. This was supported by a high correlation found between GDP and the mining and quarrying sectors (2010 to 2016) indicating a strong relationship between both sectors. A country's GDP is the monetary value of all the finished goods and services produced within its borders in a specific time period which is calculated on a quarterly basis. It serves as an indicator of the economic health of a country, as well as a gauge of a country's standard of living. Industrial demand was therefore estimated as:

**Industrial Demand Forecast = [Industrial Allocations in m<sup>3</sup>/day\*365]\*[Annual GDP]**

## AGRICULTURAL AND IRRIGATION DEMAND

### COMPONENTS OF AGRICULTURAL AND IRRIGATION DEMAND

#### LIVESTOCK

**Livestock** - Livestock require water for animal nutrition, animal cooling, sanitation, and waste removal. Water demand for livestock refers to water used in the production of various types of livestock including cattle (beef and dairy), pigs, poultry, horses, and goats. Forecast for this subgroup is included in the general estimates for agriculture. Increases in livestock production occur as a result of expansion in livestock numbers, for example, particularly ruminants. The daily water requirements and intake by livestock varies considerably according to class of stock, production status, age and condition of the animal, dry matter intake, quality and nature of feed, climatic conditions, and the quality of the water.

#### FISHERIES AND AQUACULTURE

Aquaculture farms may be considered as (a) small-scale (b) medium-scale and (c) A large commercial operations. Approximately 75 % of the farms in 2001 were small scale of 1-4 ha and operated by about 300 farmers. The largest producer is Aquaculture Jamaica Limited comprising some 42 ha in surface area in western and central parts of the island. The main areas in aquaculture are St. Catherine (Hartlands) and St. Elizabeth.

The principal fish species now cultured in Jamaica is the tilapia (red hybrid) with tilapia culture becoming more widespread since

the 1980's (Aiken 2002). By 2013 Tilapia accounted for approximately 98% total fish production<sup>12</sup>. Total Production in 2016 stood at approximately 1000 tons.

## IRRIGATED AGRICULTURE

Crop production growth comes mostly from yield increases rather than from area expansion. Among the steps to ensure food and nutrition security is improvement in access to water and water storage systems and facilities for the purpose of irrigation<sup>13</sup>. The most recent census of agriculture for Jamaica conducted in 2007 identified approximately 319,000 ha of land in farms. This represents 29 % of the total land area of approximately 1.099 million ha<sup>14</sup>. Of the area of land in farms approximately 205,000 hectares is suitable for irrigation as shown in Figure 33 According to NIC (1998) areas suitable for irrigation have been classified into three land categories:

1. Lands which may be irrigated with all common irrigation techniques;
2. Lands suited only to sprinkler and localized irrigation techniques;
3. Lands with generally steep slopes (>10%) and thin soils, which are productive with careful management of the limitations and responsive to manual irrigation (including hillside farmers)



However, in 2010, the area equipped for irrigation was estimated at 30 682 ha. Surface irrigation accounted for 23 012 or 75%, sprinkler irrigation for 5 216 ha or 17% and drip irrigation for 2 454 ha or 8%<sup>15</sup>. Public irrigation systems managed by the NIC cover approximately 50% of the total area equipped for irrigation, commercial estates and private individual systems the other 50%. The Rural Agricultural Development Authority (RADA) also assists small land holders with small-scale irrigation schemes. The volume of water per annum required at the source, be it groundwater or surface water, for each crop was estimated by the Rural Agricultural Development Agency (RADA) as shown in Appendix 2. According to the Food and Agriculture Organization (FAO), effective rainfall is that portion of total monthly rainfall that is useful directly and/or indirectly for crop production, and not lost by surface run-off and unnecessary deep percolation crop, and that is not useful for next season's crop. CropWat, a computer program developed by the FAO, is an effective tool in estimating irrigation requirements based on climate, crop and soil data.

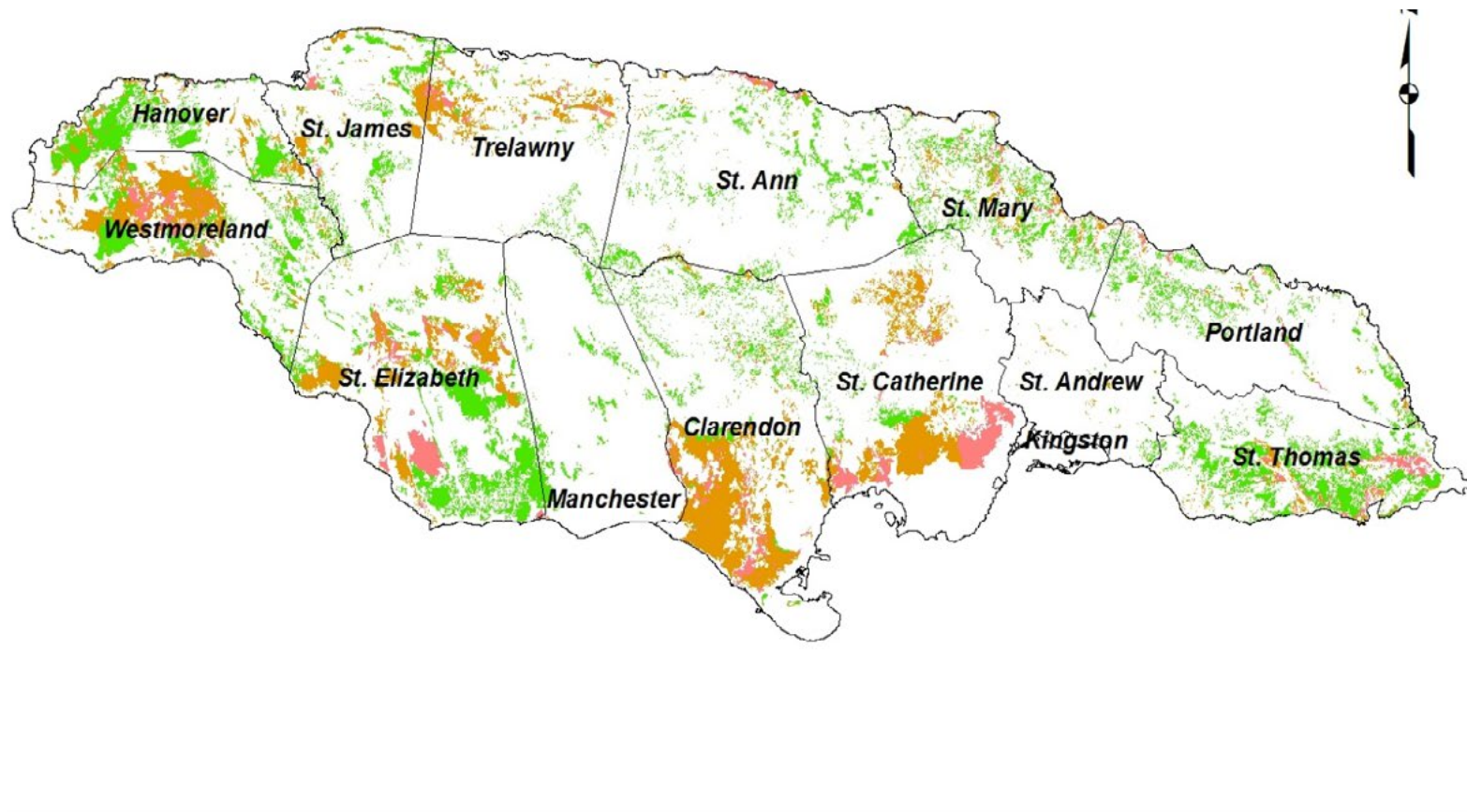
<sup>12</sup> FAO. National Aquaculture Overview, Jamaica. [http://www.fao.org/fishery/countrysector/naso\\_jamaica/en](http://www.fao.org/fishery/countrysector/naso_jamaica/en) Retrieved August 3, 2017.

<sup>13</sup> [http://www.fao.org/nr/water/aquastat/countries\\_regions/JAM/](http://www.fao.org/nr/water/aquastat/countries_regions/JAM/) Retrieved Jul 10, 2017

<sup>14</sup> NEPA. 2011. State of the Environment Report.

<sup>15</sup> Ibid

## Suitability of Lands for Irrigation



### Legend

-  PARISH BOUNDARY
-  CATEGORY I - MOST SUITABLE ( 25,043.41 Ha)
-  CATEGORY II - MORE SUITABLE ( 74,717.53 Ha)
-  CATEGORY III - SUITABLE ( 105,123.93 Ha)

SCALE 1:900,000



SOURCE: NIDP

Figure 33: Suitability of Land for Irrigation Usage

## METHODOLOGY

The overall freshwater demand for the agriculture was derived from the daily demand (m<sup>3</sup>/day) based on active licenses at the WRA. However, irrigation crop demand was disaggregated based on data of total hectares in production. The forecast for the sector over the planning horizon was also based on a GDP of 2 % rate of growth although a low correlation was found between both sets of variables over the period 2010 to 2016. This was likely due to a significantly higher rate of growth of the agriculture sector over GDP. Projections are based upon the water use estimates for the base year and held constant into the future.

## LIVESTOCK

Data on daily water requirements for each livestock group is unavailable and was therefore included in the global agricultural demand estimates. Livestock water demand includes water used in the production of various types of livestock including cattle (beef and dairy), hogs, poultry, horses and goats. However, a literature review was conducted to verify the FAO livestock water requirements and these are shown in Table 34 below. Of the three categories, the greatest demand for fresh water would be the genetically upgraded cows (70 litres/day). Estimated daily demand in 2016, based on Table 34, was approximately 10,000 m<sup>3</sup>.

**TABLE 34: ESTIMATED WATER REQUIREMENTS FOR LIVESTOCK PER DAY (2016)**

| TYPE                                                            | POPULATION | DAILY NEED IN LITRES PER ANIMAL | TOTAL DAILY NEED IN LITRES |
|-----------------------------------------------------------------|------------|---------------------------------|----------------------------|
| GENETICALLY UPGRADED DAIRY COWS ETC.                            | 31,000     | 70                              | 2,170,000                  |
| GENETICALLY UPGRADED BEEF COWS ETC.                             | 125,000    | 50                              | 6,250,000                  |
| LOCAL CATTLE (SPECIFIC DATA UNAVAILABLE BUT ARE INCLUDED ABOVE) |            | 20                              |                            |
| SHEEP                                                           | 14,000     | 5                               | 70,000                     |
| GOATS                                                           | 498,000    | 3                               | 1,494,000                  |
| <b>TOTAL LIVESTOCK WATER DEMAND (LITRES)</b>                    |            |                                 | <b>9,984,000</b>           |

Source: <http://www.fao.org/docrep/015/i2433e/i2433e11.pdf> Retrieved September 14, 2017

## FISHERIES AND AQUACULTURE

According to MICAFA, demand for water in the aquaculture sector is based on the volume of water per hectare per crop. For example, a pond of ½ hectare (1.2 acres) requires 7.2 m<sup>3</sup> per crop where there may be two (2) crops annually<sup>16</sup>. The primary sources of water are wells and rivers. Water demand in the sector is calculated as:

**Total demand = [Area under production\* volume per crop]**

## IRRIGATED AGRICULTURE

Baseline data for forecasting crop water demand in agriculture were derived as follows:

- The total daily demand by WMU based on current licences on record for baseline year at the WRA.
- Estimates of the percentage of each crop under irrigation<sup>17</sup>.
- Crop water requirement from Rural Area Development Agency RADA.

<sup>16</sup> [http://www.moa.gov.jm/Fisheries/start\\_fish\\_farm.php](http://www.moa.gov.jm/Fisheries/start_fish_farm.php)

<sup>17</sup> ECLAC, An Assessment of the Economic Impact of Climate Change Impact on the Agriculture Sector in Jamaica, 2011

*"Irrigation Demand is approximately 53% of the total demand..."*



- Total area under crop production by parish derived from the Ministry of Commerce Agriculture and Fisheries (MICAFA), the Banana Board and the Sugar Industry Research Council (SIRC) are shown in Appendix 5.
- Calculate the effects of climate change on crop water needs based on precipitation and temperature data (Climate Studies Group, UWI, Mona)
- Crop water requirement for a range of crops was obtained from RADA (see Appendix 2).

## DEMAND FORECASTS

The demand for water is a function of the location of the main demand activities and population centres. The area of greatest demand is to the south of the island, where rainfall is lowest but where there are major population centres and extensive irrigated agricultural activities on the plains. Large water-intensive industries and activities, such as brewers, bauxite mining/alumina processing, agricultural and agricultural processing are located in the south. Many water intensive activities occur in the main population centres such as the Kingston Metropolitan Region (KMR), with related dependencies, labour and economic activities. Unlike the South, the rugged terrain of the central areas does not support intensive economic activities, hence there is less demand for water resources. On the other hand, the northern section of the island has the tourism sector as the main economic activity with a significant demand for potable water.

The National Water Commission (NWC) plans to provide coverage into utility service areas, as well as, improve existing service island wide. It continues with projects, such as;

- Nonpareil Water Supply System in Westmoreland which will serve the communities of Nonpareil, Sheffield, Orange Hill, Little London, Mount Airy, Good Hope and Whitehall
- Clydesdale to Content Gp Water Supply Project in St. Andrew, and
- RoseWell Water Supply Project in Clarendon

Potential outcomes for environmental demand are also included in Table 35.

**TABLE 35: DEMAND FORECASTS**

| Component                             | Demand/Forecast |               |            |              |        |              | Comments                                                                                                                |
|---------------------------------------|-----------------|---------------|------------|--------------|--------|--------------|-------------------------------------------------------------------------------------------------------------------------|
|                                       | L/day/Unit      | Growth Rate % | M³/day     | Growth Rate% | M³/ha  | Growth Rate% |                                                                                                                         |
| Municipal                             |                 |               |            |              |        |              |                                                                                                                         |
| Per capita (residential)              | 227             | By WMU        | 569,302    |              |        |              | Based on projected population growth by WMU                                                                             |
| Commercial demand                     | 56.75           | By WMU        | 142,325.51 |              |        |              | 25%/ of Residential demand                                                                                              |
| Institutional demand                  | 56.75           | By WMU        | 142,325.51 |              |        |              | 25%/ of Residential demand                                                                                              |
| Tourism                               |                 |               |            |              |        |              |                                                                                                                         |
| Hotels (stop-over visitors)           | 849 per room    | 5.5           | 1,531,745  | 5.5          |        |              | This demand incorporates all types of accommodation in the sector.                                                      |
| Cruise Shipping                       | 350             | 5.5           | 46,626     | 5.5          |        |              |                                                                                                                         |
| Cruise ship passenger s (disembarked) | 48.5            | 5.5           | 165        | 5.5          |        |              | It was assumed that passengers remained approximately 7.5 hours on land                                                 |
| Industry                              |                 |               |            |              |        |              |                                                                                                                         |
| Industry(total)                       |                 |               | 2,728,200  | 2            |        |              | WRA licenses                                                                                                            |
| Agriculture                           |                 |               |            |              |        |              |                                                                                                                         |
| Irrigation (crops)                    |                 |               |            |              | 32,720 | 4.7          | MICAF/RADA data                                                                                                         |
| Irrigation (licenses)                 |                 |               | 1,238,468  | 2            |        |              | WRA licenses                                                                                                            |
| Livestock                             |                 |               | 10,000     |              |        |              | RADA data                                                                                                               |
| Environment                           |                 |               |            |              |        |              |                                                                                                                         |
| Environment                           | n/a             |               |            |              |        |              | Recommendations made based on literature review is to establish Abstraction Sensitivity Bands - high, moderate and low. |
| Demand - All Components               | 739 L/day       | -             | 6,409,157  | -            | 32,720 | -            | -                                                                                                                       |

## MUNICIPAL

Among the components of the municipal demand (residential, commercial and institutional) the greatest contributor is residential demand which was 569,302 m<sup>3</sup> /day or 207.8 MCM/year in 2016 as seen in Table 36. When combined with the additional components of commercial and institutional demand which are each estimated as 25% of residential demand, total municipal demand in 2016 was 853,953 m<sup>3</sup> /day or 311.7 MCM/year. Table 37 presents the forecasted total municipal demand for the periods 2020, 2025, 2030, 2050 and 2080 based on projected population growth trends per WMU as previously described in table 36. Adjustments for non-revenue water and peak demands were not included for this projection; any such adjustments would increase the demand figures above.

**TABLE 36 MUNICIPAL WATER DEMAND FOR 2016 (CUBIC METRES PER DAY)**

| BASIN                  | NO | WMU NAME                  | TOTAL WMU RESIDENTIAL DEMAND (M3/DAY) | TOTAL WMU COMMERCIAL DEMAND (M3/DAY) | TOTAL WMU INSTITUTIONAL DEMAND (M3/DAY) | TOTAL WMU MUNICIPAL DEMAND 2016 | TOTAL BASIN MUNICIPAL DEMAND 2016 |
|------------------------|----|---------------------------|---------------------------------------|--------------------------------------|-----------------------------------------|---------------------------------|-----------------------------------|
| I-BLUE MOUNTAINS SOUTH | 15 | Plantain Garden           | 2,248.85                              | 562.21                               | 562.21                                  | 3,373.27                        | 31,224.49                         |
|                        | 16 | Morant River              | 13,572.08                             | 3,393.02                             | 3,393.02                                | 20,358.12                       |                                   |
|                        | 17 | Yallahs River             | 4,995.40                              | 1,248.85                             | 1,248.85                                | 7,493.10                        |                                   |
| II-KINGSTON            | 18 | Hope River                | 132,717.70                            | 33,179.42                            | 33,179.42                               | 199,076.54                      | 199,076.54                        |
| III-RIO COBRE          | 19 | Rio Cobre                 | 116,719.80                            | 29,179.95                            | 29,179.95                               | 175,079.70                      | 175,079.70                        |
| IV-RIO MINHO           | 20 | Rio Minho                 | 31,979.82                             | 7,994.95                             | 7,994.95                                | 47,969.73                       | 116,598.92                        |
|                        | 21 | Milk River                | 42,984.43                             | 10,746.11                            | 10,746.11                               | 64,476.64                       |                                   |
|                        | 22 | Gut River                 | 2,768.37                              | 692.09                               | 692.09                                  | 4,152.56                        |                                   |
| V-BLACK RIVER          | 23 | Black River               | 34,255.56                             | 8,563.89                             | 8,563.89                                | 51,383.34                       | 51,383.34                         |
| VI-CABARITA RIVER      | 24 | Deans Valley River        | 12,809.17                             | 3,202.29                             | 3,202.29                                | 19,213.75                       | 44,753.28                         |
|                        | 25 | Cabarita River            | 10,006.45                             | 2,501.61                             | 2,501.61                                | 15,009.68                       |                                   |
|                        | 26 | New Savannah              | 1,407.36                              | 351.84                               | 351.84                                  | 2,111.03                        |                                   |
| VII-GREAT RIVER        | 1  | South Negril-Orange River | 5,612.55                              | 1,403.14                             | 1,403.14                                | 8,418.82                        | 76,947.94                         |
|                        | 2  | Lucea River               | 11,132.65                             | 2,783.16                             | 2,783.16                                | 16,698.97                       |                                   |
|                        | 3  | Great River               | 8,909.17                              | 2,227.29                             | 2,227.29                                | 13,363.75                       |                                   |
|                        | 4  | Montego River             | 31,256.81                             | 7,814.20                             | 7,814.20                                | 46,885.21                       |                                   |
| VIII-MARTHA BRAE R     | 5  | Martha Brae               | 14,514.95                             | 3,628.74                             | 3,628.74                                | 21,772.43                       | 21,772.43                         |
| IX-DRY HARBOUR MT      | 6  | Rio Bueno-White River     | 42,741.76                             | 10,685.44                            | 10,685.44                               | 64,112.63                       | 64,112.63                         |
| XX-BLUE MOUNTAINS N    | 7  | Rio Nuevo                 | 3,936.68                              | 984.17                               | 984.17                                  | 5,905.02                        | 73,003.79                         |
|                        | 8  | Oracabessa-Pagee          | 9,589.19                              | 2,397.30                             | 2,397.30                                | 14,383.78                       |                                   |
|                        | 9  | Wagwater River            | 14,189.54                             | 3,547.39                             | 3,547.39                                | 21,284.31                       |                                   |
|                        | 10 | Pencar-Buff Bay R         | 6,025.16                              | 1,506.29                             | 1,506.29                                | 9,037.74                        |                                   |
|                        | 11 | Spanish River             | 857.66                                | 214.42                               | 214.42                                  | 1,286.49                        |                                   |
|                        | 12 | Swift River               | 1,647.90                              | 411.98                               | 411.98                                  | 2,471.86                        |                                   |
|                        | 13 | Rio Grande                | 3,279.18                              | 819.79                               | 819.79                                  | 4,918.76                        |                                   |
|                        | 14 | Drivers River             | 9,143.88                              | 2,285.97                             | 2,285.97                                | 13,715.82                       |                                   |
| TOTAL                  |    |                           | 569,302.05                            | 142,325.51                           | 142,325.51                              | 853,953.07                      | 853,953.07                        |



**TABLE 37: FORECASTED TOTAL MUNICIPAL DEMAND FOR 2016-2080 (MCM)**

| BASIN                 | WMU                       | 2016   |       |       |            |             | 2020   |       |       |            |             |        |       |
|-----------------------|---------------------------|--------|-------|-------|------------|-------------|--------|-------|-------|------------|-------------|--------|-------|
|                       |                           | DOM.   | COM.  | INST  | WMU TO-TAL | BASIN TOTAL | DOM.   | COM.  | INST  | WMU TO-TAL | BASIN TOTAL | DOM.   | COM.  |
| BLUE MOUNTAIN SOUTH   | Plantain Garden           | 0.82   | 0.21  | 0.21  | 1.23       | 11.40       | 0.78   | 0.19  | 0.19  | 1.17       | 11.43       | 0.73   | 0.18  |
|                       | Morant River              | 4.95   | 1.24  | 1.24  | 7.43       |             | 5.01   | 1.25  | 1.25  | 7.51       |             | 5.08   | 1.27  |
|                       | Yallahs River             | 1.82   | 0.46  | 0.46  | 2.73       |             | 1.83   | 0.46  | 0.46  | 2.74       |             | 1.84   | 0.46  |
| KINGSTON              | Hope River                | 48.44  | 12.11 | 12.11 | 72.66      | 72.66       | 48.62  | 12.15 | 12.15 | 72.92      | 72.92       | 48.84  | 12.21 |
| RIO COBRE             | Rio Cobre                 | 42.60  | 10.65 | 10.65 | 63.90      | 63.90       | 43.74  | 10.93 | 10.93 | 65.61      | 65.61       | 45.20  | 11.30 |
| RIO MINHO             | Rio Minho                 | 11.67  | 2.92  | 2.92  | 17.51      | 42.56       | 11.71  | 2.93  | 2.93  | 17.57      | 43.08       | 11.77  | 2.94  |
|                       | Milk River                | 15.69  | 3.92  | 3.92  | 23.53      |             | 16.01  | 4.00  | 4.00  | 24.02      |             | 16.42  | 4.11  |
|                       | Gut River                 | 1.01   | 0.25  | 0.25  | 1.52       |             | 1.00   | 0.25  | 0.25  | 1.49       |             | 0.98   | 0.24  |
| BLACK RIVER           | Black River               | 12.50  | 3.13  | 3.13  | 18.75      | 18.75       | 12.58  | 3.14  | 3.14  | 18.87      | 18.87       | 12.67  | 3.17  |
| CABARITA RIVER        | Deans Valley River        | 4.68   | 1.17  | 1.17  | 7.01       | 16.33       | 4.71   | 1.18  | 1.18  | 7.06       | 16.62       | 4.75   | 1.19  |
|                       | Cabarita River            | 3.65   | 0.91  | 0.91  | 5.48       |             | 3.68   | 0.92  | 0.92  | 5.52       |             | 3.72   | 0.93  |
|                       | New Savannah              | 0.51   | 0.13  | 0.13  | 0.77       |             | 0.51   | 0.13  | 0.13  | 0.77       |             | 0.51   | 0.13  |
|                       | South Negril-Orange River | 2.05   | 0.51  | 0.51  | 3.07       |             | 2.18   | 0.55  | 0.55  | 3.27       |             | 2.36   | 0.59  |
| GREAT RIVER           | Lucea River               | 4.06   | 1.02  | 1.02  | 6.10       | 28.09       | 4.12   | 1.03  | 1.03  | 6.18       | 28.75       | 4.19   | 1.05  |
|                       | Great River               | 3.25   | 0.81  | 0.81  | 4.88       |             | 3.12   | 0.78  | 0.78  | 4.69       |             | 2.97   | 0.74  |
|                       | Montego River             | 11.41  | 2.85  | 2.85  | 17.11      |             | 11.92  | 2.98  | 2.98  | 17.89      |             | 12.60  | 3.15  |
| MARTHA BRAE           | Martha Brae               | 5.30   | 1.32  | 1.32  | 7.95       | 7.95        | 5.42   | 1.36  | 1.36  | 8.14       | 8.14        | 5.59   | 1.40  |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River     | 15.60  | 3.90  | 3.90  | 23.40      | 23.40       | 15.74  | 3.94  | 3.94  | 23.62      | 23.62       | 15.93  | 3.98  |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 1.44   | 0.36  | 0.36  | 2.16       | 26.65       | 1.43   | 0.36  | 0.36  | 2.15       | 26.98       | 1.42   | 0.36  |
|                       | Oracabessa-Pagee          | 3.50   | 0.88  | 0.88  | 5.25       |             | 3.54   | 0.89  | 0.89  | 5.31       |             | 3.60   | 0.90  |
|                       | Wagwater River            | 5.18   | 1.29  | 1.29  | 7.77       |             | 5.30   | 1.32  | 1.32  | 7.94       |             | 5.45   | 1.36  |
|                       | Pencar-Buff Bay R         | 2.20   | 0.55  | 0.55  | 3.30       |             | 2.25   | 0.56  | 0.56  | 3.38       |             | 2.32   | 0.58  |
|                       | Spanish River             | 0.31   | 0.08  | 0.08  | 0.47       |             | 0.31   | 0.08  | 0.08  | 0.47       |             | 0.32   | 0.08  |
|                       | Swift River               | 0.60   | 0.15  | 0.15  | 0.90       |             | 0.61   | 0.15  | 0.15  | 0.91       |             | 0.62   | 0.15  |
|                       | Rio Grande                | 1.20   | 0.30  | 0.30  | 1.80       |             | 1.21   | 0.30  | 0.30  | 1.82       |             | 1.24   | 0.31  |
|                       | Drivers River             | 3.34   | 0.83  | 0.83  | 5.01       |             | 3.32   | 0.83  | 0.83  | 4.99       |             | 3.31   | 0.83  |
| TOTAL                 |                           | 207.80 | 51.95 | 51.95 | 311.69     | 311.69      | 210.68 | 52.67 | 52.67 | 316.02     | 316.02      | 214.41 | 53.60 |



| 2025 |       |           |             | 2030   |       |       |           |             | 2050   |       |       |           |             | 2080   |       |       |           |             |
|------|-------|-----------|-------------|--------|-------|-------|-----------|-------------|--------|-------|-------|-----------|-------------|--------|-------|-------|-----------|-------------|
|      | INST  | WMU TOTAL | BASIN TOTAL | DOM.   | COM.  | INST  | WMU TOTAL | BASIN TOTAL | DOM.   | COM.  | INST  | WMU TOTAL | BASIN TOTAL | DOM.   | COM.  | INST  | WMU TOTAL | BASIN TOTAL |
|      | 0.18  | 1.10      | 11.47       | 0.69   | 0.17  | 0.17  | 1.03      | 11.52       | 0.53   | 0.14  | 0.14  | 0.81      | 11.75       | 0.36   | 0.12  | 0.12  | 0.59      | 12.18       |
|      | 1.27  | 7.62      |             | 5.15   | 1.29  | 1.29  | 7.73      |             | 5.45   | 1.34  | 1.34  | 8.13      |             | 5.92   | 1.40  | 1.40  | 8.73      |             |
|      | 0.46  | 2.75      |             | 1.84   | 0.46  | 0.46  | 2.77      |             | 1.87   | 0.47  | 0.47  | 2.81      |             | 1.92   | 0.47  | 0.47  | 2.86      |             |
|      | 12.21 | 73.25     | 73.25       | 49.06  | 12.26 | 12.26 | 73.58     | 73.58       | 49.95  | 12.43 | 12.43 | 74.81     | 74.81       | 51.31  | 12.60 | 12.60 | 76.51     | 76.51       |
|      | 11.30 | 67.80     | 67.80       | 46.71  | 11.68 | 11.68 | 70.07     | 70.07       | 53.28  | 12.89 | 12.89 | 79.06     | 79.06       | 64.91  | 14.23 | 14.23 | 93.36     | 93.36       |
|      | 2.94  | 17.65     | 43.76       | 11.82  | 2.96  | 2.96  | 17.73     | 44.44       | 12.04  | 3.00  | 3.00  | 18.03     | 47.12       | 12.36  | 3.04  | 3.04  | 18.44     | 51.21       |
|      | 4.11  | 24.64     |             | 16.85  | 4.21  | 4.21  | 25.27     |             | 18.65  | 4.55  | 4.55  | 27.74     |             | 21.73  | 4.91  | 4.91  | 31.54     |             |
|      | 0.24  | 1.47      |             | 0.96   | 0.24  | 0.24  | 1.44      |             | 0.89   | 0.23  | 0.23  | 1.35      |             | 0.80   | 0.22  | 0.22  | 1.23      |             |
|      | 3.17  | 19.01     | 19.01       | 12.77  | 3.19  | 3.19  | 19.15     | 19.15       | 13.16  | 3.26  | 3.26  | 19.69     | 19.69       | 13.76  | 3.34  | 3.34  | 20.44     | 20.44       |
|      | 1.19  | 7.13      | 17.00       | 4.79   | 1.20  | 1.20  | 7.19      | 17.40       | 4.97   | 1.23  | 1.23  | 7.43      | 19.10       | 5.25   | 1.27  | 1.27  | 7.78      | 22.21       |
|      | 0.93  | 5.58      |             | 3.76   | 0.94  | 0.94  | 5.63      |             | 3.91   | 0.97  | 0.97  | 5.84      |             | 4.15   | 1.00  | 1.00  | 6.14      |             |
|      | 0.13  | 0.76      |             | 0.50   | 0.13  | 0.13  | 0.75      |             | 0.49   | 0.12  | 0.12  | 0.73      |             | 0.46   | 0.12  | 0.12  | 0.70      |             |
|      | 0.59  | 3.54      | 29.65       | 2.55   | 0.64  | 0.64  | 3.82      | 30.62       | 3.48   | 0.80  | 0.80  | 5.09      | 34.82       | 5.55   | 1.02  | 1.02  | 7.58      | 42.62       |
|      | 1.05  | 6.29      |             | 4.27   | 1.07  | 1.07  | 6.40      |             | 4.58   | 1.12  | 1.12  | 6.82      |             | 5.08   | 1.18  | 1.18  | 7.45      |             |
|      | 0.74  | 4.46      |             | 2.83   | 0.71  | 0.71  | 4.24      |             | 2.32   | 0.61  | 0.61  | 3.54      |             | 1.72   | 0.52  | 0.52  | 2.77      |             |
|      | 3.15  | 18.90     | 8.38        | 13.32  | 3.33  | 3.33  | 19.97     | 8.63        | 16.60  | 3.93  | 3.93  | 24.46     | 9.61        | 23.12  | 4.64  | 4.64  | 32.40     | 11.15       |
|      | 1.40  | 8.38      |             | 5.75   | 1.44  | 1.44  | 8.63      |             | 6.47   | 1.57  | 1.57  | 9.61      |             | 7.72   | 1.72  | 1.72  | 11.15     |             |
|      | 3.98  | 23.89     |             | 16.11  | 4.03  | 4.03  | 24.17     |             | 16.87  | 4.17  | 4.17  | 25.21     |             | 18.07  | 4.32  | 4.32  | 26.70     |             |
|      | 0.36  | 2.13      | 27.40       | 1.41   | 0.35  | 0.35  | 2.12      | 27.84       | 1.38   | 0.35  | 0.35  | 2.07      | 29.55       | 1.33   | 0.34  | 0.34  | 2.01      | 32.20       |
|      | 0.90  | 5.39      |             | 3.65   | 0.91  | 0.91  | 5.47      |             | 3.88   | 0.95  | 0.95  | 5.78      |             | 4.24   | 1.00  | 1.00  | 6.24      |             |
|      | 1.36  | 8.17      |             | 5.60   | 1.40  | 1.40  | 8.40      |             | 6.26   | 1.52  | 1.52  | 9.31      |             | 7.40   | 1.66  | 1.66  | 10.72     |             |
|      | 0.58  | 3.49      |             | 2.40   | 0.60  | 0.60  | 3.60      |             | 2.71   | 0.66  | 0.66  | 4.03      |             | 3.27   | 0.72  | 0.72  | 4.71      |             |
|      | 0.08  | 0.48      |             | 0.32   | 0.08  | 0.08  | 0.48      |             | 0.33   | 0.08  | 0.08  | 0.49      |             | 0.34   | 0.08  | 0.08  | 0.51      |             |
|      | 0.15  | 0.93      |             | 0.63   | 0.16  | 0.16  | 0.94      |             | 0.67   | 0.16  | 0.16  | 1.00      |             | 0.74   | 0.17  | 0.17  | 1.08      |             |
|      | 0.31  | 1.85      |             | 1.26   | 0.31  | 0.31  | 1.89      |             | 1.35   | 0.33  | 0.33  | 2.02      |             | 1.51   | 0.35  | 0.35  | 2.21      |             |
|      | 0.83  | 4.96      |             | 3.29   | 0.82  | 0.82  | 4.94      |             | 3.23   | 0.81  | 0.81  | 4.85      |             | 3.13   | 0.80  | 0.80  | 4.73      |             |
|      | 53.60 | 321.61    | 321.61      | 218.28 | 54.57 | 54.57 | 327.42    | 327.42      | 235.31 | 57.70 | 57.70 | 350.71    | 350.71      | 266.17 | 61.21 | 61.21 | 388.58    | 388.58      |



## TOURISM

Table 38 presents the Tourism demand based on the reported hotel rooms for 2016. The largest demands are reflected in the Great River, Dry Harbour and Cabarita Basins (reflecting the major hotel operations in Montego Bay, Negril and St. Ann).

**TABLE 38: TOURISM DEMAND BASED ON REPORTED ROOMS PER WMU, 2016**

| BASIN                  | NO | WMU NAME                  | TOTAL HOTEL ROOMS | TOTAL HOTEL ROOM WATER DEMAND (M3/DAY) | TOTAL BASIN HOTEL DEMAND (M3/DAY) | TOTAL HOTEL ROOM DEMAND (MCM) | TOTAL BASIN HOTEL ROOM DEMAND (MCM) |
|------------------------|----|---------------------------|-------------------|----------------------------------------|-----------------------------------|-------------------------------|-------------------------------------|
| I-BLUE MOUNTAINS SOUTH | 15 | Plantain Garden           | 18                | 10.09                                  | 85.17                             | 0.0037                        | 0.03                                |
|                        | 16 | Morant River              | 106               | 59.40                                  |                                   | 0.0217                        |                                     |
|                        | 17 | Yallahs River             | 28                | 15.69                                  |                                   | 0.0057                        |                                     |
| II-KINGSTON            | 18 | Hope River                | 1809              | 1,013.66                               | 1,013.66                          | 0.3700                        | 0.37                                |
| III-RIO COBRE          | 19 | Rio Cobre                 | 392               | 219.65                                 | 219.65                            | 0.0802                        | 0.08                                |
| IV-RIO MINHO           | 20 | Rio Minho                 | 30                | 16.81                                  | 220.77                            | 0.0061                        | 0.08                                |
|                        | 21 | Milk River                | 364               | 203.96                                 |                                   | 0.0744                        |                                     |
|                        | 22 | Gut River                 | 0                 | 0.00                                   |                                   | 0.0000                        |                                     |
| V-BLACK RIVER          | 23 | Black River               | 560               | 313.79                                 | 313.79                            | 0.1145                        | 0.11                                |
| VI-CABARITA RIVER      | 24 | Deans Valley River        | 538               | 301.46                                 | 2,860.54                          | 0.1100                        | 1.04                                |
|                        | 25 | Cabarita River            | 18                | 10.09                                  |                                   | 0.0037                        |                                     |
|                        | 26 | New Savannah              | 20                | 11.21                                  |                                   | 0.0041                        |                                     |
| VII-GREAT RIVER        | 1  | South Negril-Orange River | 4529              | 2,537.78                               | 4,886.73                          | 0.9263                        | 1.78                                |
|                        | 2  | Lucea River               | 1632              | 914.47                                 |                                   | 0.3338                        |                                     |
|                        | 3  | Great River               | 100               | 56.03                                  |                                   | 0.0205                        |                                     |
| VIII-MARTHA BRAE R     | 4  | Montego River             | 6989              | 3,916.22                               | 1,011.97                          | 1.4294                        | 0.37                                |
|                        | 5  | Martha Brae               | 1806              | 1,011.97                               |                                   | 0.3694                        |                                     |
| IX-DRY HARBOUR MT      | 6  | Rio Bueno-White River     | 7197              | 4,032.77                               | 4,032.77                          | 1.4720                        | 1.47                                |
| XX-BLUE MOUNTAINS N    | 7  | Rio Nuevo                 | 251               | 140.65                                 | 672.41                            | 0.0513                        | 0.25                                |
|                        | 8  | Oracabessa-Pagee          | 388               | 217.41                                 |                                   | 0.0794                        |                                     |
|                        | 9  | Wagwater River            | 30                | 16.81                                  |                                   | 0.0061                        |                                     |
|                        | 10 | Pencar-Buff Bay R         | 29                | 16.25                                  |                                   | 0.0059                        |                                     |
|                        | 11 | Spanish River             | 0                 | 0.00                                   |                                   | 0.0000                        |                                     |
|                        | 12 | Swift River               | 4                 | 2.24                                   |                                   | 0.0008                        |                                     |
|                        | 13 | Rio Grande                | 38                | 21.29                                  |                                   | 0.0078                        |                                     |
|                        | 14 | Drivers River             | 460               | 257.76                                 |                                   | 0.0941                        |                                     |
| TOTAL                  |    |                           | 27336             | 15,317.45                              | 15,317.45                         | 5.5909                        | 5.59                                |

*"Tourism Demand is often supplied from Municipal Sources. However, some hotels will utilize their own wells or river abstraction, or use desalination."*

Of the three main components of tourism demand, the highest consumer of fresh water are hotels (approximately 6 MCM/year or 88.9%). Growth at a rate of 5.5 % total demand could increase to 13 MCM/year by 2030 and 191 MCM/year by 2080 as shown in Table 39.

**TABLE 39 SUMMARY OF TOURISM DEMAND - 2016, 2020, 2025, 2030, 2050 AND 2080-MCM/YEAR**

| AREA                                       | 2016       | % OF TOTAL DEMAND | 2020       | 2025        | 2030        | 2050        | 2080         |
|--------------------------------------------|------------|-------------------|------------|-------------|-------------|-------------|--------------|
| Tourism demand -hotels                     | 5.6        | 88.9              | 6.9        | 9.1         | 11.8        | 34.5        | 172.0        |
| Cruise ships                               | 0.6        | 9.5               | 0.7        | 0.9         | 1.2         | 3.6         | 17.8         |
| Cruise ships disembarked passengers        | 0.1        | 1.6               | 0.1        | 0.1         | 0.1         | 0.3         | 1.3          |
| other (golf etc. included with irrigation) | -          | -                 | -          | -           | -           | -           | -            |
| <b>TOTAL</b>                               | <b>6.3</b> | <b>100</b>        | <b>7.7</b> | <b>10.1</b> | <b>13.2</b> | <b>38.4</b> | <b>191.2</b> |

Cruise ship demand was estimated at 4,536 m<sup>3</sup> per day, as shown in Table 40 (assuming water was supplied at the major ports of Ocho Rios, Montego Bay and Falmouth). Table 41 shows estimates for fresh water demand for cruise ship passengers who disembark at the ports of call. The 2016 contribution of disembarking passengers to annual tourism fresh water demand was estimated at 60,218 m<sup>3</sup>, increasing to 127,418 m<sup>3</sup> by 2030. Cruise ships could add approximately 19 MCM/year to total demand by 2080 with the Falmouth pier as the port with the highest demand (7.62 MCM/year). Cruise ship demand is usually met from the Municipal demand.



**TABLE 40 DAILY CRUISE SHIP DEMAND FOR FRESH WATER- 2020, 2025, 2030, 2050 AND 2080 -MCM/YEAR**

| BASIN               | PORT        | CRUISE SHIP PASSENGERS/DAY - 2016 | 2016        | 2020        | 2025        | 2030        | 2050        | 2080         |
|---------------------|-------------|-----------------------------------|-------------|-------------|-------------|-------------|-------------|--------------|
| IX DRY HARBOUR MTN. | Ocho Rios   | 1,347                             | 0.17        | 0.21        | 0.28        | 0.36        | 1.06        | 5.30         |
| IX GREAT RIVER      | Montego Bay | 1,243                             | 0.16        | 0.20        | 0.26        | 0.34        | 0.98        | 4.89         |
| VII MARTHA BRAE     | Falmouth    | 1,939                             | 0.25        | 0.31        | 0.40        | 0.52        | 1.53        | 7.62         |
|                     | Other       | 7                                 | 0.00        | 0.00        | 0.00        | 0.00        | 0.01        | 0.03         |
| <b>TOTALS</b>       |             | <b>4,536</b>                      | <b>0.58</b> | <b>0.72</b> | <b>0.94</b> | <b>1.23</b> | <b>3.58</b> | <b>17.83</b> |

**TABLE 41: DAILY CRUISE SHIPPING CONTRIBUTION TO MUNICIPAL DEMAND FOR FRESH WATER FROM DISEMBARKED PASSENGERS- 2020, 2025, 2030, 2050 AND 2080 - M3/DAY**

| BASIN               | PORTS       | CRUISE SHIP PASSENGERS/ M3/ DAY - 2016 | WATER DEMAND FOR DISEM-BARKED PASSENGERS - 2016 | 2020          | 2025          | 2030           | 2050           | 2080             |
|---------------------|-------------|----------------------------------------|-------------------------------------------------|---------------|---------------|----------------|----------------|------------------|
| IX DRY HARBOUR MTN. | Ocho Rios   | 1347                                   | 17,879                                          | 22,148        | 28,947        | 37,833         | 110,386        | 550,160          |
| IX GREAT RIVER      | Montego Bay | 1243                                   | 16,503                                          | 20,445        | 26,720        | 34,922         | 101,894        | 507,837          |
| VII MARTHA BRAE     | Falmouth    | 1939                                   | 25,744                                          | 31,892        | 41,682        | 54,476         | 158,949        | 792,193          |
|                     | Other       | 7                                      | 94                                              | 115           | 150           | 197            | 574            | 2,860            |
| <b>TOTALS</b>       |             | <b>4,536</b>                           | <b>60,218</b>                                   | <b>74,600</b> | <b>97,499</b> | <b>127,428</b> | <b>371,803</b> | <b>1,853,050</b> |

## INDUSTRIAL

The greatest demand for water in 2016 was in the industrial sector at 2.73 million m<sup>3</sup>/day or 996 MCM/year (including non-consumptive water). Actual consumptive industrial demand was estimated at 198,540 m<sup>3</sup>/day or 73 10<sup>6</sup> m<sup>3</sup>/ year in 2016, with a forecast of 95.6 10<sup>6</sup> m<sup>3</sup> in 2030 and 257.4 10<sup>6</sup> m<sup>3</sup> in 2080, representing 11.1 % of total demand.

## AGRICULTURE

When compared with the overall irrigation demand (WRA), crop demand (MICA/RADA) was 277 MCM per year or 62 % of the total, as shown, in Figure 34.

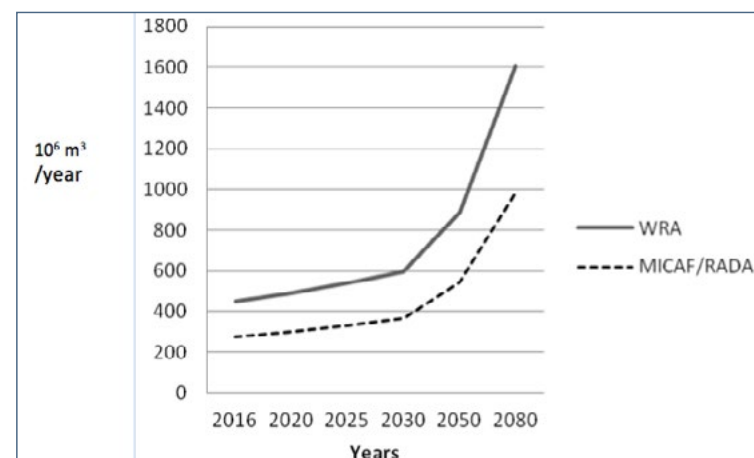


Figure 34: Irrigation Demand – 2016 and Forecast Values

Note: WRA data calculates daily values x 365 days. MICA/RADA values are based on estimates actual crop water requirement per ha

A complete data set by actual data Water Management Unit is presently unavailable; however, Figure 35 shows the distribution of livestock (cattle and small ruminants) by parish. The parishes with the largest counts are Clarendon (112,920) and St. Elizabeth (112,300). The least count was recorded in the parishes of St. Andrew (13,260) and Portland (20,910).

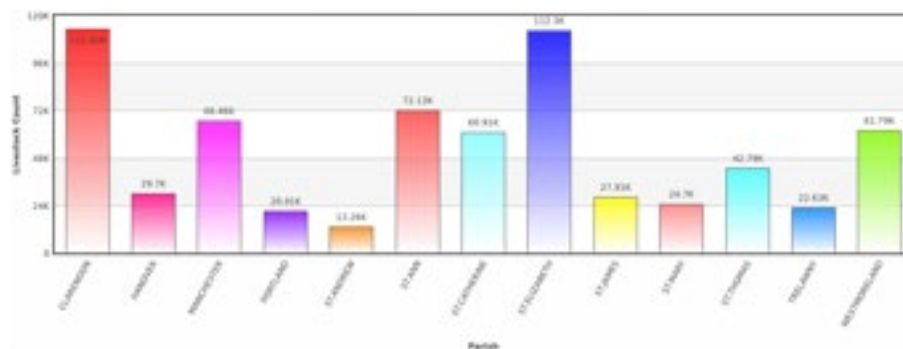


Figure 35: Livestock count by parish, 2016

## FISHERIES AND AQUACULTURE

Based on the data in Table 42 that was provided by RADA, the greatest concentration of fish farms is in the parish of St. Catherine where it is estimated that demand for fresh water in 2016 was 6.72 106 m<sup>3</sup> /per crop or almost 46 % of demand. Clarendon (33%) and St. Elizabeth (12.9) were the other parishes with significant aquaculture operations. Manchester had made the least number of fish farms (1).

TABLE 42: DISTRIBUTION OF FISH FARMS BY PARISH AS AT DECEMBER 2016

| PARISH        | NUMBER OF FARMS PER PARISH | TOTAL POND ACREAGE PER PARISH | DEMAND (106 M <sup>3</sup> /PER CROP) | %     | WRA DATA M <sup>3</sup> |
|---------------|----------------------------|-------------------------------|---------------------------------------|-------|-------------------------|
| ST. CATHERINE | 123                        | 1,120.3                       | 6.72                                  | 45.7  | 6,105                   |
| CLARENDON     | 30                         | 811.79                        | 4.9                                   | 33.3  |                         |
| ST ANDREW     | 5                          | 2.1                           | 0.01                                  | 0.07  |                         |
| ST. THOMAS    | 6                          | 3,569                         | 0.02                                  | 0.14  | 275                     |
| HANOVER       | 3                          | 12                            | 0.07                                  | 0.48  |                         |
| TRELAWNY      | 2                          | 46                            | 0.28                                  | 1.90  |                         |
| ST. ANN       | 4                          | 6,757                         | 0.04                                  | 0.27  |                         |
| PORTLAND      | 7                          | 34.37                         | 0.21                                  | 1.43  |                         |
| ST MARY       | 6                          | 27.3                          | 0.16                                  | 1.09  |                         |
| MANCHESTER    | 1                          | 0.25                          | 0.002                                 | 0.01  |                         |
| WESTMORELAND  | 6                          | 61.04                         | 0.37                                  | 2.51  |                         |
| ST. JAMES     | 5                          | 6.32                          | .04                                   | 0.27  |                         |
| ST. ELIZABETH | 8                          | 322.25                        | 1.9                                   | 12.91 | 243,200                 |
| TOTAL         | 206                        | 2,454.046                     | 14.7                                  | 100   | 249,580                 |

## ENVIRONMENTAL DEMAND

Under the Brisbane Declaration, 2007, environmental demand is defined as the science and practice of determining and implementing the environmental water requirements (EWR) for aquatic ecosystems – “the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems”<sup>18</sup> This demand component is also referred to as eco-environmental demand as the ecosystem is the resource which provides the services that sustain society. In order to ensure this provision, it is essential that the various components of the ecosystem are all managed in a way so that the service provision can continue. These components all form part of the environmental water requirements (EWR) of the river basin.

<sup>18</sup> Brisbane Declaration. (2007). The Brisbane Declaration: Environmental flows are essential for freshwater ecosystem health and human well-being. In *Declaration of the 10th International River Symposium and International Environmental Flows Conference* (pp. 1-7). Retrieved from <https://www.conservationgateway.org/Documents/Brisbane-Declaration-English.pdf> October 4, 2017

The ecosystem approach to management of water resources requires that each of these components should be considered in an integrated way through IWRM. Management of quantity may be achieved through not only the management of the catchment but also the off-takes of water for irrigation and domestic use. It may also mean management of activities in the catchment that would reduce the amount of water in the river e.g. hydro electrical operations. In the case of Jamaica, for example, impacts related to the hydroelectric plants within the Black River, Dry Harbour Mountain and Blue Mountain South hydrological basins would be considered.

An EWR assessment is naturally a complex process that is beyond the scope of this master plan at the moment. However, in the absence of specific data the precautionary principle should apply so that decisions are based on good science and that where the risk to the environment is significant, a lack of scientific certainty is not used as an excuse for postponing measures to protect the environment. However, within the

components of the ecosystem it is important that the following aspects are understood if the EWR is to be managed:

- The state of each component (i.e. its reference condition)
- An understanding of the importance and sensitivity of each component within the context of the overall ecosystem
- The current ecological state (PES) of each component
- The trajectory of change that each component is undergoing
- Determine the role that each component plays in the functioning of the aquatic ecosystem

There is, however, still no tangible rule of thumb that can be used to determine the natural flow regime and ensure the health of the ecosystem of a river. Methods that use both biological and hydrological data can be distinguished from those that use only hydrological data as a substitute for data on biological needs

Given the paucity of field data to derive statistically significant relationships between the level of hydrological change and the degree of ecological impact general inferences have been drawn based on findings from a literature review for methodologies used in EWR. For example, standards may vary under different conditions based on levels of sensitivity, for example, levels of sensitivity may range from naturally low (Q95) to naturally higher (Q30) as shown in Table 43.

*"Environmental Demand is an important aspect that will be further defined in future Master Plans."*

**TABLE 43: PERCENTAGE ALLOWABLE ABSTRACTION FROM NATURAL FLOWS AT DIFFERENT SENSITIVITY BANDS<sup>19</sup>**

|                              | HIGH FLOW >>>>>>>>>>>> | LOW FLOW |     |     |
|------------------------------|------------------------|----------|-----|-----|
| ABSTRACTION SENSITIVITY BAND | Q30                    | Q50      | Q70 | Q95 |
| High sensitivity             | 24%                    | 20%      | 15% | 10% |
| Moderate Sensitivity         | 26%                    | 24%      | 20% | 15% |
| Low sensitivity              | 30%                    | 26%      | 24% | 20% |

In the case of Jamaica sensitivity levels may vary by season (warm and hot seasons), type or recreational activities (for example, rafting on the Rio Grande River) and ecosystem type, for example wetlands (spawning and nursery areas). In some jurisdictions such as Australia water resource planning can require the 'quarantine' of environmental water and ensure a proportion of the mean annual flow is reserved solely for environmental benefit. For the Jamaican context, environmental flow is estimated as 60% of the 7-Day Minimum Flow over a 10-year return period for a given flow regiment.

<sup>19</sup> Environment Agency. Environmental Flow Indicator , April 2013

## CONCENTRATIONS OF WATER RESOURCES DEMANDS

Table 44 presents the forecast municipal and tourism demand forecast to 2080. Municipal demand is likely to be greatest in the Rio Cobre and Hope River WMUs and with 49 MCM/year (24.5 %) and 36 MCM/year (18%) respectively over the planning horizon as shown in Table 45. The WMUs which are likely to experience the least growth over the planning period are located with Blue Mountain North and South hydrologic basins, for example in Plantain Garden and Spanish River demand could each grow by approximately 0.3%. In the case of demand for fresh water for local hotels the dominant locations are likely to be Rio Bueno-White River (45 MCM/year or 26 %) and Montego River 44 MCM/year or 26%). Cruise shipping demand add an additional 5 MCM/year each to the WMUs.

**TABLE 44: 2016 MUNICIPAL AND TOURISM DEMAND FORECAST TO 2080 - MCM/YEAR**

| WMU#         | WMU NAME                  | PAR | RES.         | 2080         | % CHANGE   | TOURISM    | 2080         | % CHANGE   |
|--------------|---------------------------|-----|--------------|--------------|------------|------------|--------------|------------|
| 15           | PLANTAIN GARDEN           | ST  | 0.7          | 0.3          | 0.2%       | 0.00       | 0.1          | 0.1%       |
| 16           | MORANT RIVER              | ST  | 3.6          | 4.3          | 2.2%       | 0.02       | 0.7          | 0.4%       |
| 17           | YALLAHS RIVER             | ST  | 1.3          | 1.3          | 0.7%       | 0.00       | 0.2          | 0.1%       |
| 18           | HOPE RIVER                | KSA | 33.7         | 35.7         | 17.9%      | 0.01       | 11.4         | 6.6%       |
| 19           | RIO COBRE                 | SC  | 32.1         | 48.9         | 24.5%      | 0.00       | 2.5          | 1.4%       |
| 20           | RIO MINHO                 | CL  | 9.2          | 9.8          | 4.9%       | 0.00       | 0.2          | 0.1%       |
| 21           | MILK RIVER                | CL  | 12.5         | 17.3         | 8.7%       | 0.06       | 2.3          | 1.3%       |
| 22           | GUT RIVER                 | MA  | 0.9          | 0.7          | 0.4%       | 0.00       | 0            | 0.0%       |
| 23           | BLACK RIVER               | SE  | 9.7          | 10.7         | 5.4%       | 0.00       | 3.5          | 2.0%       |
| 24           | DEANS VALLEY RIVER        | WE  | 4.0          | 4.5          | 2.3%       | 0.11       | 3.4          | 2.0%       |
| 25           | CABARITA RIVER            | WE  | 2.6          | 3.09         | 1.5%       | 0.0        | 0.1          | 0.1%       |
| 26           | NEW SAVANNAH              | WE  | 0.4          | 0.4          | 0.2%       | 0.0        | 0.1          | 0.1%       |
| 1            | SOUTH NEGRIL-ORANGE RIVER | HA  | 1.5          | 3.9          | 2.0%       | 0.4        | 28.5         | 16.6%      |
| 2            | LUCEA RIVER               | HA  | 2.9          | 3.6          | 1.8%       | 0.3        | 10.3         | 6.0%       |
| 3            | GREAT RIVER               | SJ  | 2.5          | 1.3          | 0.7%       | 0.0        | 0.6          | 0.4%       |
| 4            | MONTEGO RIVER             | SJ  | 7.9          | 16.1         | 8.1%       | 17         | 43.99        | 25.6%      |
| 5            | MARTHA BRAE               | TR  | 3.9          | 5.8          | 2.9%       | 0.2        | 11.4         | 6.6%       |
| 6            | RIO BUENO-WHITE RIVER     | SA  | 13.1         | 15.2         | 7.6%       | 0.0        | 45.3         | 26.3%      |
| 7            | RIO NUEVO                 | SM  | 1.1          | 1.0          | 0.5%       | 0.1        | 1.6          | 0.9%       |
| 8            | ORACABESSA-PAGEE          | SM  | 2.6          | 3.1          | 1.6%       | 0.1        | 2.4          | 1.4%       |
| 9            | WAGWATER RIVER            | SM  | 4.2          | 6.0          | 3.0%       | 0.0        | 0.2          | 0.1%       |
| 10           | PENCAR-BUFF BAY R         | PO  | 1.5          | 2.3          | 1.1%       | 0.0        | 0.2          | 0.1%       |
| 11           | SPANISH RIVER             | PO  | 0.2          | 0.3          | 0.1%       | 0.0        | 0.0          | 0.0%       |
| 12           | SWIFT RIVER               | PO  | 0.4          | 0.5          | 0.3%       | 0.0        | 0.0          | 0.0%       |
| 13           | RIO GRANDE                | PO  | 0.8          | 1.1          | 0.5%       | 0.00       | 0.2          | 0.1%       |
| 14           | DRIVERS RIVER             | PO  | 2.4          | 2.2          | 1.1%       | 0.0        | 2.9          | 1.7%       |
| <b>TOTAL</b> |                           |     | <b>155.8</b> | <b>199.2</b> | <b>100</b> | <b>5.6</b> | <b>172.0</b> | <b>100</b> |



Tables 45 and 46 present the projected irrigation and industrial demands up to 2080. The Milk River WMU was the highest contributor to irrigation agriculture demand (528,280 m<sup>3</sup>/day) in 2016. By the end of the planning horizon in 2080, the demand in the WMU would potentially increase to 684 MCM/year with 47.2% of total demand followed by Rio Cobre (501 MCM/year) or 31 % of the projected demand. Locations of moderate demand were Black River (9%) and Rio Minho (8%). During the baseline year, 2016, the highest demand for fresh water for industrial use was in Black River (62,785 m<sup>3</sup>/day or 31.62%), followed by the Rio Cobre (49,940 or 25 %). By 2080, demand in these WMUs is likely to contribute 32% and 25% respectively to total demand. The data for industrial use shown in Table 46 omit water required for generating electricity.

**TABLE 45: IRRIGATION DEMAND FORECAST -2020, 2025, 2030, 2050 AND 2080 FOR LICENSED WRA WELLS - MCM/YEAR**

| WMU # | WMU NAME           | PAR | TOTAL/ M3/<br>DAY   | 2016          | 2020          | 2025          | 2030          | 2050          | 2080           | % INCREASE    |
|-------|--------------------|-----|---------------------|---------------|---------------|---------------|---------------|---------------|----------------|---------------|
| 15    | Plantain Garden R  | ST  | 11,290.00           | 4.12          | 4.46          | 4.92          | 5.44          | 8.08          | 14.64          | 0.9%          |
| 16    | Morant River       | ST  | 4,910.00            | 1.79          | 1.94          | 2.14          | 2.36          | 3.51          | 6.36           | 0.4%          |
| 17    | Yallahs River      | ST  | 16,306.00           | 5.95          | 6.44          | 7.11          | 7.85          | 11.67         | 21.14          | 1.3%          |
| 18    | Hope River         | KSA | 4,707.00            | 1.72          | 1.86          | 2.05          | 2.27          | 3.37          | 6.10           | 0.4%          |
| 19    | Rio Cobre          | SC  | 386,799.10          | 141.18        | 152.82        | 168.73        | 186.29        | 276.81        | 501.41         | 31.2%         |
| 20    | Rio Minho          | CL  | 104,839.00          | 38.27         | 41.42         | 45.73         | 50.49         | 75.03         | 135.90         | 8.5%          |
| 21    | Milk River         | CL  | 528,279.74          | 192.82        | 208.72        | 230.44        | 254.42        | 378.06        | 684.81         | 42.7%         |
| 23    | Black River        | SE  | 102,172.00          | 37.29         | 40.37         | 44.57         | 49.21         | 73.12         | 132.45         | 8.2%          |
| 24    | Deans Valley River | WE  | 9.10                | 0.00          | 0.00          | 0.00          | 0.00          | 0.01          | 0.01           | 0.0%          |
| 3     | Great River        | SJ  | 21,306.32           | 7.78          | 8.42          | 9.29          | 10.26         | 15.25         | 27.62          | 1.7%          |
| 4     | Montego River      | SJ  | 1,018.00            | 0.37          | 0.40          | 0.44          | 0.49          | 0.73          | 1.32           | 0.1%          |
| 5     | Martha Brae River  | TR  | 1,015.00            | 0.37          | 0.40          | 0.44          | 0.49          | 0.73          | 1.32           | 0.1%          |
| 6     | Rio Bueno-White R  | SA  | 9,565.50            | 3.49          | 3.78          | 4.17          | 4.61          | 6.85          | 12.40          | 0.8%          |
| 9     | Wagwater River     | SM  | 24,456.00           | 8.93          | 9.66          | 10.67         | 11.78         | 17.50         | 31.70          | 2.0%          |
| 10    | Pencar-Buff Bay R  | PO  | 19,322.00           | 7.05          | 7.63          | 8.43          | 9.31          | 13.83         | 25.05          | 1.6%          |
| 12    | Swift River        | PO  | 46.87               | 0.02          | 0.02          | 0.02          | 0.02          | 0.03          | 0.06           | 0.0%          |
| 14    | Drivers River      | PO  | 2,426.00            | 0.89          | 0.96          | 1.06          | 1.17          | 1.74          | 3.14           | 0.2%          |
|       |                    |     | <b>1,238,467.63</b> | <b>452.04</b> | <b>489.30</b> | <b>540.23</b> | <b>596.46</b> | <b>886.31</b> | <b>1605.42</b> | <b>100.00</b> |

**TABLE 46: INDUSTRIAL DEMAND FORECAST (CONSUMPTIVE) - 2020, 2025, 2030, 2050 AND 2080 -MCM/YEAR**

| BASIN              | NO | WMU NAME           | PAR | TOTAL/<br>M3/DAY | 2016        | 2020        | 2025        | 2030        | 2050         | 2080         | % IN-<br>CREASE |
|--------------------|----|--------------------|-----|------------------|-------------|-------------|-------------|-------------|--------------|--------------|-----------------|
| I-BLUE MOUNTAINS S | 15 | Plantain Garden R  | ST  | 0                | 0           | 0           | 0           | 0           | 0            | 0            | 0.00%           |
|                    | 17 | Yallahs River      | ST  | 15               | 0.01        | 0.01        | 0.01        | 0.01        | 0.01         | 0.02         | 0.01%           |
| II-KINGSTON        | 18 | Hope River         | KSA | 21,552           | 7.9         | 8.5         | 9.4         | 10.4        | 15.4         | 27.9         | 10.9%           |
| III-RIO COBRE      | 19 | Rio Cobre          | SC  | 49,940           | 18.2        | 19.7        | 21.8        | 24.15       | 35.74        | 64.74        | 25.2%           |
| IV-RIO MINHO       | 20 | Rio Minho          | CL  | 1,323            | 0.5         | 0.5         | 0.6         | 0.6         | 1.0          | 1.7          | 0.7%            |
|                    | 21 | Milk River         | CL  | 31,380           | 11.5        | 12.4        | 13.7        | 15.1        | 22.5         | 40.7         | 15.8%           |
| V-BLACK RIVER      | 23 | Black River        | SE  | 62,785           | 22.9        | 24.8        | 27.4        | 30.2        | 44.9         | 81.4         | 31.6%           |
| VI-CABARITA RIVER  | 24 | Deans Valley River | WE  | 5,483            | 2.0         | 2.2         | 2.4         | 2.6         | 3.9          | 7.1          | 2.8%            |
|                    | 3  | Great River        | SJ  | 10               | 0.00        | 0.00        | 0.00        | 0.00        | 0.01         | 0.01         | 0.01%           |
|                    | 4  | Montego River      | SJ  | 8,160            | 3.0         | 3.2         | 3.6         | 3.93        | 5.84         | 10.58        | 4.1%            |
| VIII-MARTHA BRAE R | 5  | Martha Brae River  | TR  | -                | 0           | 0           | 00          | 0           | 0            | 0            | 0.0%            |
| IX-DRY HARBOUR MT  | 6  | Rio Bueno-White R  | SA  | 16,925           | 6.2         | 6.7         | 7.4         | 8.2         | 12.1         | 21.9         | 8.5%            |
| X-BLUE MOUNTAINS N | 7  | Rio Nuevo          | SM  | -                | 0           | 0           | 0           | 0           | 0            | 0            | 0.0%            |
|                    | 9  | Wagwater River     | SM  | 90               | 0.03        | 0.04        | 0.04        | 0.04        | 0.06         | 0.12         | 0.1%            |
|                    | 11 | Spanish River      | PO  | 877              | 0.3         | 0.4         | 0.4         | 0.4         | 0.6          | 1.1          | 0.4%            |
| <b>TOTALS</b>      |    |                    |     | <b>198,540</b>   | <b>72.5</b> | <b>78.4</b> | <b>86.6</b> | <b>95.6</b> | <b>142.1</b> | <b>257.4</b> | <b>100.00%</b>  |

As stated above, the demand for water varies throughout the island. In addition to the demand forecast for the WRA defined Basins over the planning horizon, there are the potential population growth centres which would signal greater demand for potable water. An assessment of the location of communities that have grown into Sub-Regional Centres since the publication of the National Physical Plan 1978 - 1998 (Appendix 4) concluded that among the communities likely to be impacted are Portmore and Guys Hill (Rio Cobre), and Chapleton and Kellits (Rio Minho).

When the baseline year data is compared with the demand forecasts in the *Draft Water Resources Master Plan* of 2005 all sectors were below demand forecasts for 2015 as shown in Table 47. In the case of municipal water demand tourism was assigned a separate category, therefore, municipal demand is represented as 240 MCM/year (2016) and 340 MCM/year (2015). The significant difference in the 2016 and the projected 2015 figures is which is likely due to the decision to exclude the non-consumptive use (electricity generation). Overall municipal demand is expected to reduce from 31% to 12% of total fresh water demand by 2080, coinciding with the current trend of a declining population growth rate.

**TABLE 47: SUMMARY OF FRESH WATER DEMAND FORECASTS - 2020, 2025, 2030, 2050 AND 2080 - MCM/YEAR AND PERCENTAGE OF ANNUAL TOTAL**

| YEAR | MUNICIPAL | %  | TOURISM | % | INDUSTRIAL | %  | IRRIGATION | %  | TOTALS |
|------|-----------|----|---------|---|------------|----|------------|----|--------|
| 2016 | 240/340*  | 31 | 6       | 1 | 73/297*    | 10 | 452/639*   | 59 | 771    |
| 2020 | 238/326*  | 29 | 8       | 1 | 78/342*    | 10 | 489/714*   | 60 | 813    |
| 2025 | 241/393*  | 27 | 10      | 1 | 87/393*    | 10 | 540/809*   | 62 | 878    |
| 2030 | 246       | 26 | 13      | 1 | 96         | 10 | 596        | 7  | 951    |
| 2050 | 262       | 20 | 38      | 3 | 142        | 11 | 886        | 67 | 1,328  |
| 2080 | 291       | 12 | 191     | 8 | 257        | 11 | 1,605      | 68 | 2,344  |

**Note:**

1. \*Water demand projections for 2015 based on the *Draft Water Resources Master Plan* (WRA, 2005) MCM/yr.
2. Data excludes cruise ship demand
3. Data excludes specific demand requirements for the agricultural components of livestock and aquaculture
4. Industrial water data excludes non-consumptive use

Tourism demand increased from 4 to 6 MCM/year (50%) which can be attributed to the growth in the number of rooms, a higher growth rate in visitor arrivals (5.5%) and a higher estimated consumption rate per room in the industry as shown in Figure 5.4. Therefore, at the end of the planning horizon, fresh water demand for irrigation (68%), in line with international trends, is expected to significantly exceed municipal (12%), tourism (8%) and industrial (11%) demand.

Figures 38 through 43 presents a graphical representation of the various water demands islandwide.



## Water Demand per Watershed Management Unit (WMU)

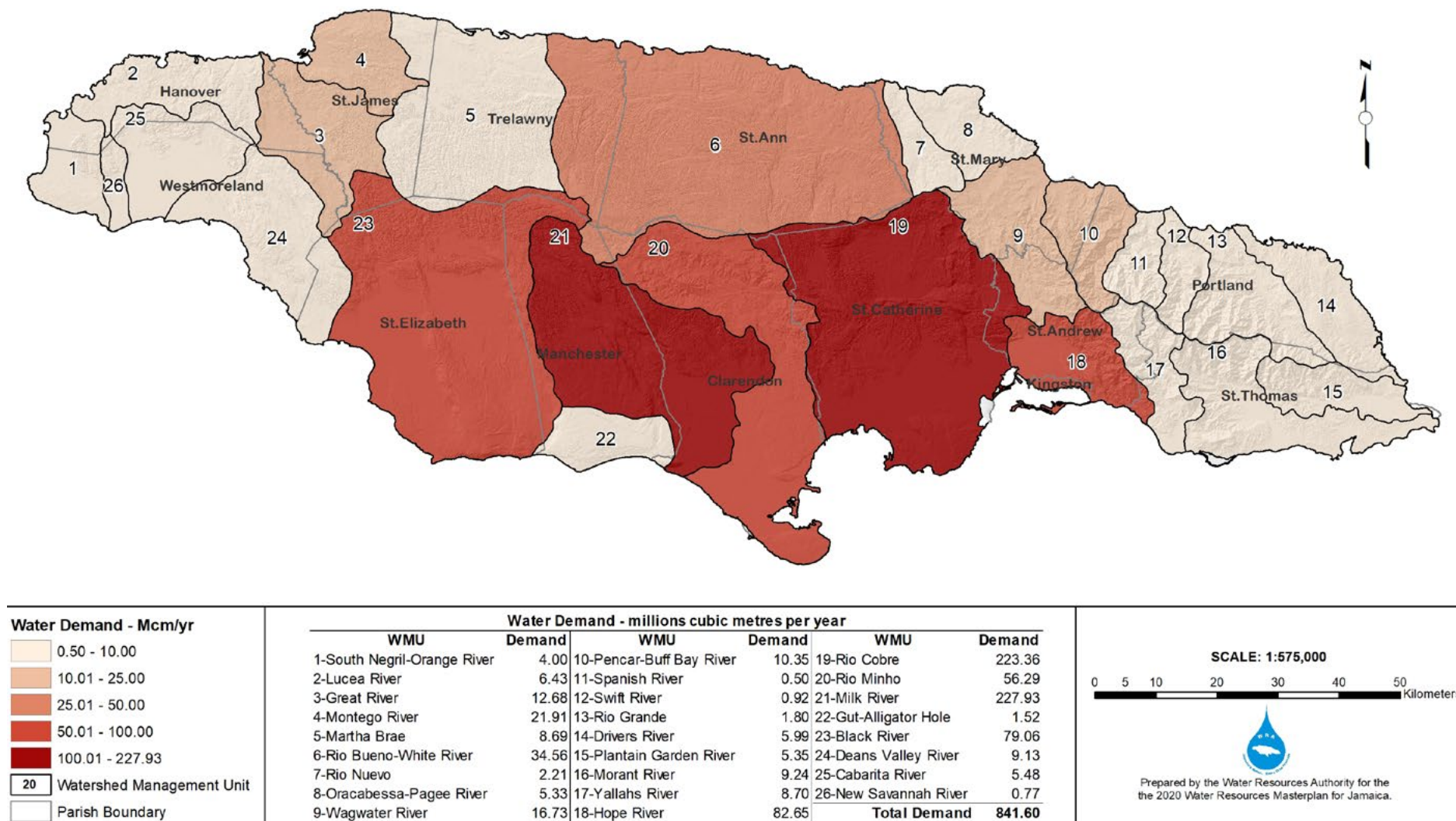


Figure 36: Water Demand per WMU



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## Water Demand by Sector and WMU

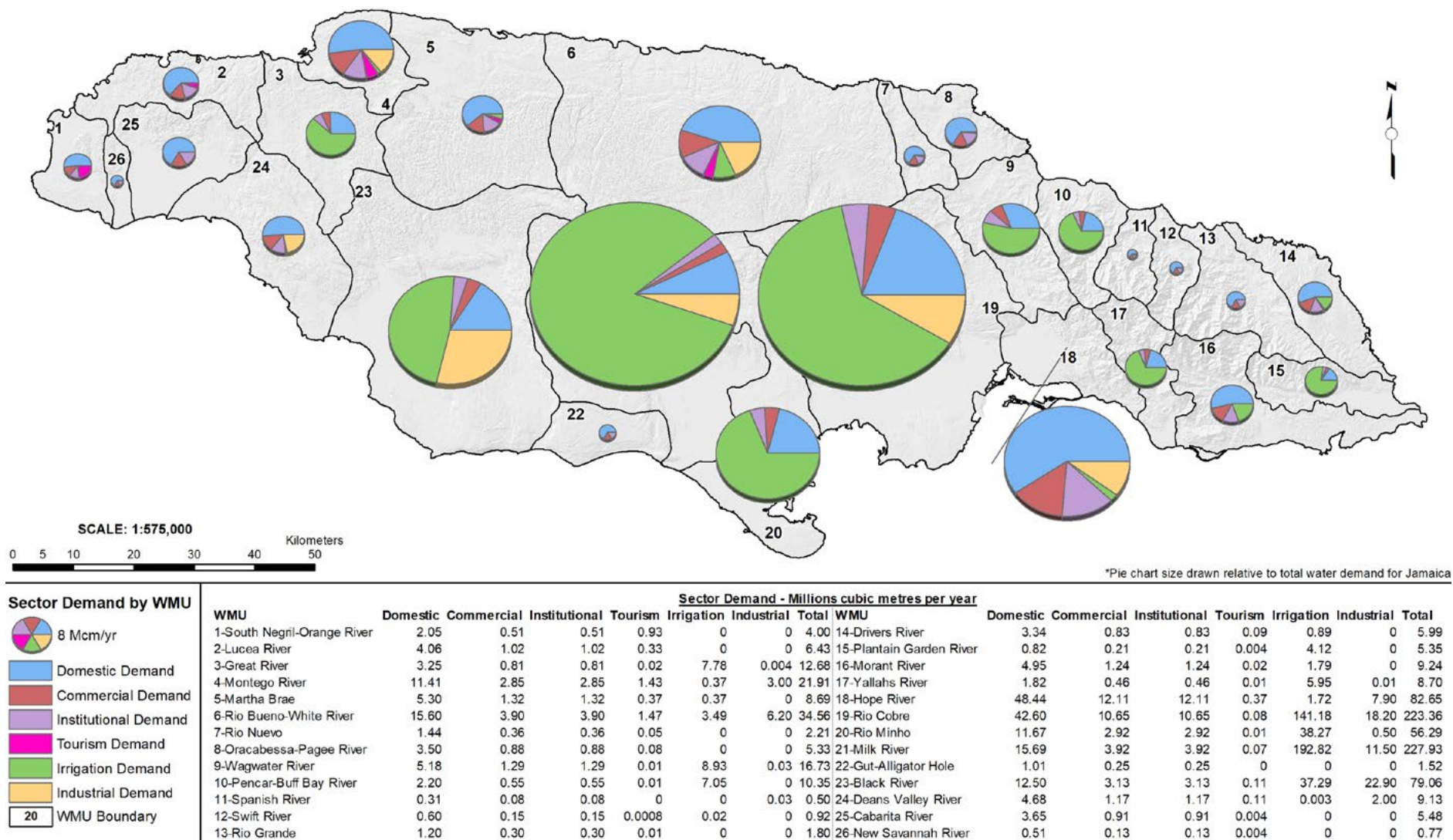


Figure 37: Water Demand by Sector and WMU



## Domestic Water Demand per Watershed Management Unit (WMU)

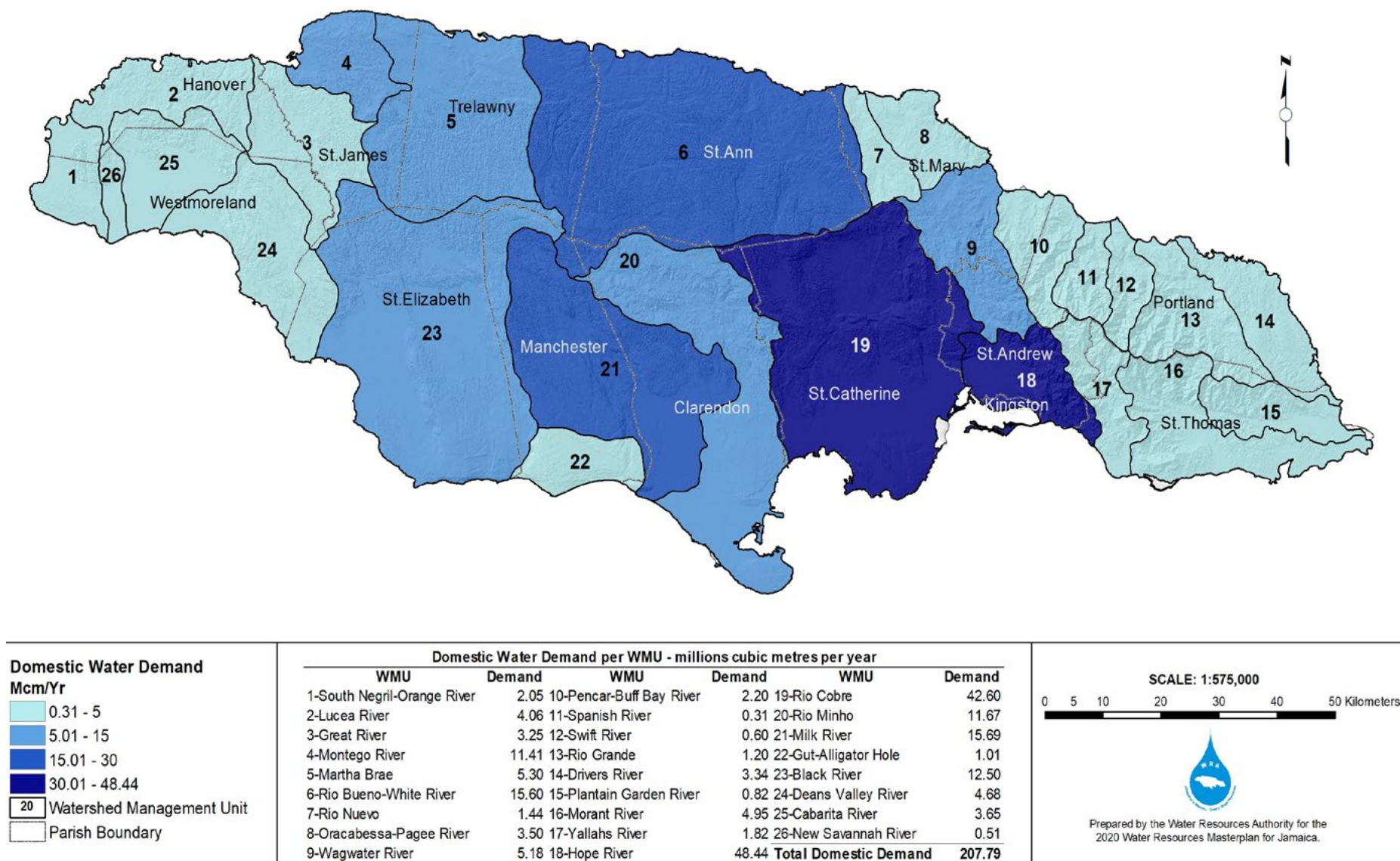


Figure 38: Domestic Water Demand by WMU



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## Commercial Water Demand per Watershed Management Unit (WMU)

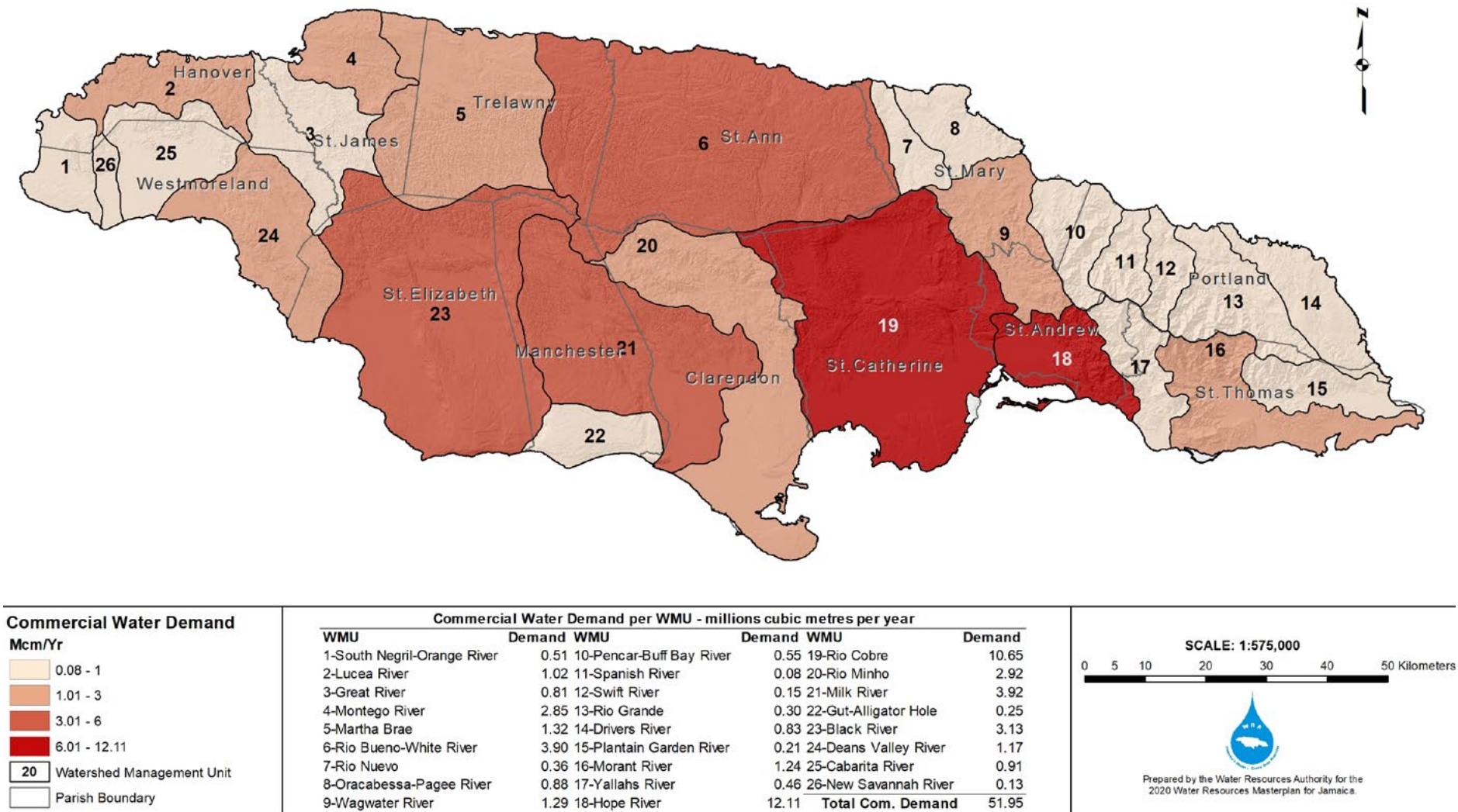
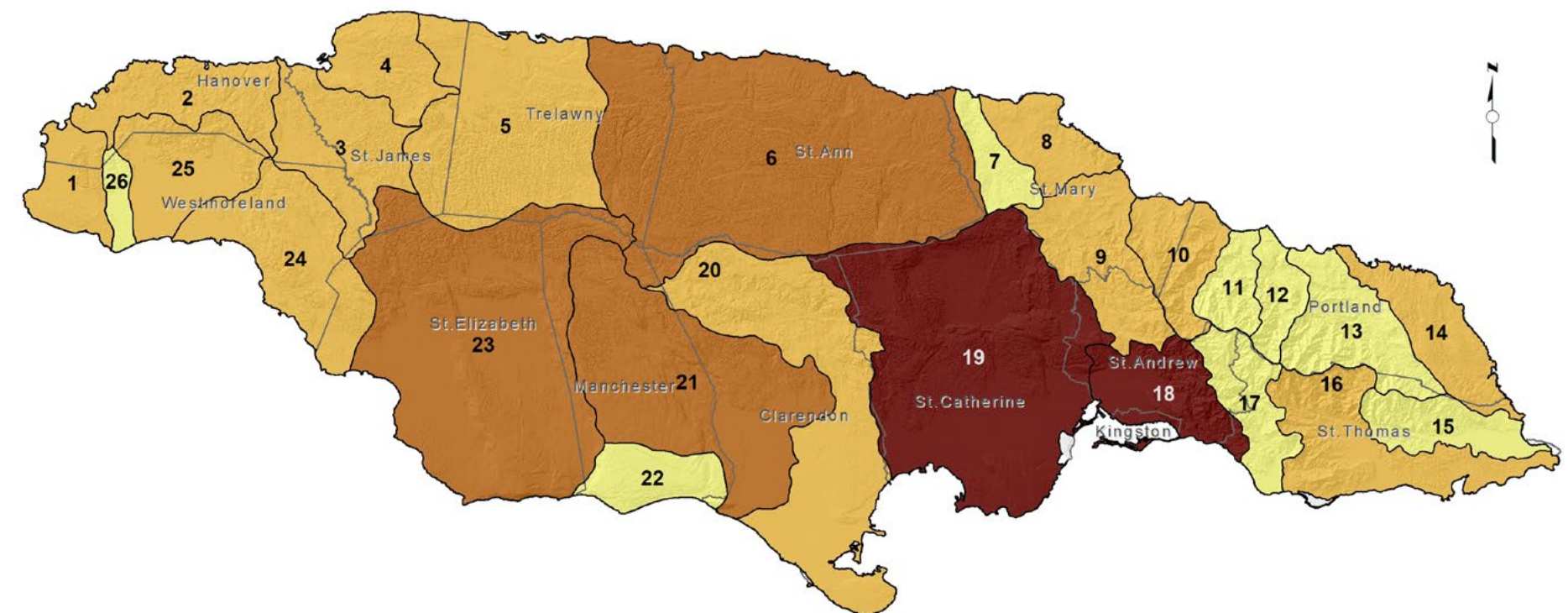


Figure 39: Commercial Water Demand by WMU



## Institutional Water Demand per Watershed Management Unit (WMU)



| Institutional Water Demand - Mcm/Yr | Institutional Water Demand per WMU - millions cubic metres per year |        |                          |        |                           |              |
|-------------------------------------|---------------------------------------------------------------------|--------|--------------------------|--------|---------------------------|--------------|
|                                     | WMU                                                                 | Demand | WMU                      | Demand | WMU                       | Demand       |
| 0.08 - 0.50                         | 1-South Negril-Orange River                                         | 0.51   | 10-Pencar-Buff Bay River | 0.55   | 19-Rio Cobre              | 10.65        |
| 0.5 - 3                             | 2-Lucea River                                                       | 1.02   | 11-Spanish River         | 0.08   | 20-Rio Minho              | 2.92         |
| 3.01 - 6                            | 3-Great River                                                       | 0.81   | 12-Swift River           | 0.15   | 21-Milk River             | 3.92         |
| 6.01 - 12.11                        | 4-Montego River                                                     | 2.85   | 13-Rio Grande            | 0.30   | 22-Gut-Alligator Hole     | 0.25         |
| 20 Watershed Management Unit        | 5-Martha Brae                                                       | 1.32   | 14-Drivers River         | 0.83   | 23-Black River            | 3.13         |
| Parish Boundary                     | 6-Rio Bueno-White River                                             | 3.90   | 15-Plantain Garden River | 0.21   | 24-Deans Valley River     | 1.17         |
|                                     | 7-Rio Nuevo                                                         | 0.36   | 16-Morant River          | 1.24   | 25-Cabarita River         | 0.91         |
|                                     | 8-Oracabessa-Pagee River                                            | 0.88   | 17-Yallahs River         | 0.46   | 26-New Savannah River     | 0.13         |
|                                     | 9-Wagwater River                                                    | 1.29   | 18-Hope River            | 12.11  | <b>Total Inst. Demand</b> | <b>51.95</b> |

SCALE: 1:575,000  
0 5 10 20 30 40 50 Kilometers



Prepared by the Water Resources Authority for the  
2020 Water Resources Masterplan for Jamaica.

Figure 40: Institutional Water Demand by WMU



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## Industrial Water Demand per Watershed Management Unit (WMU)

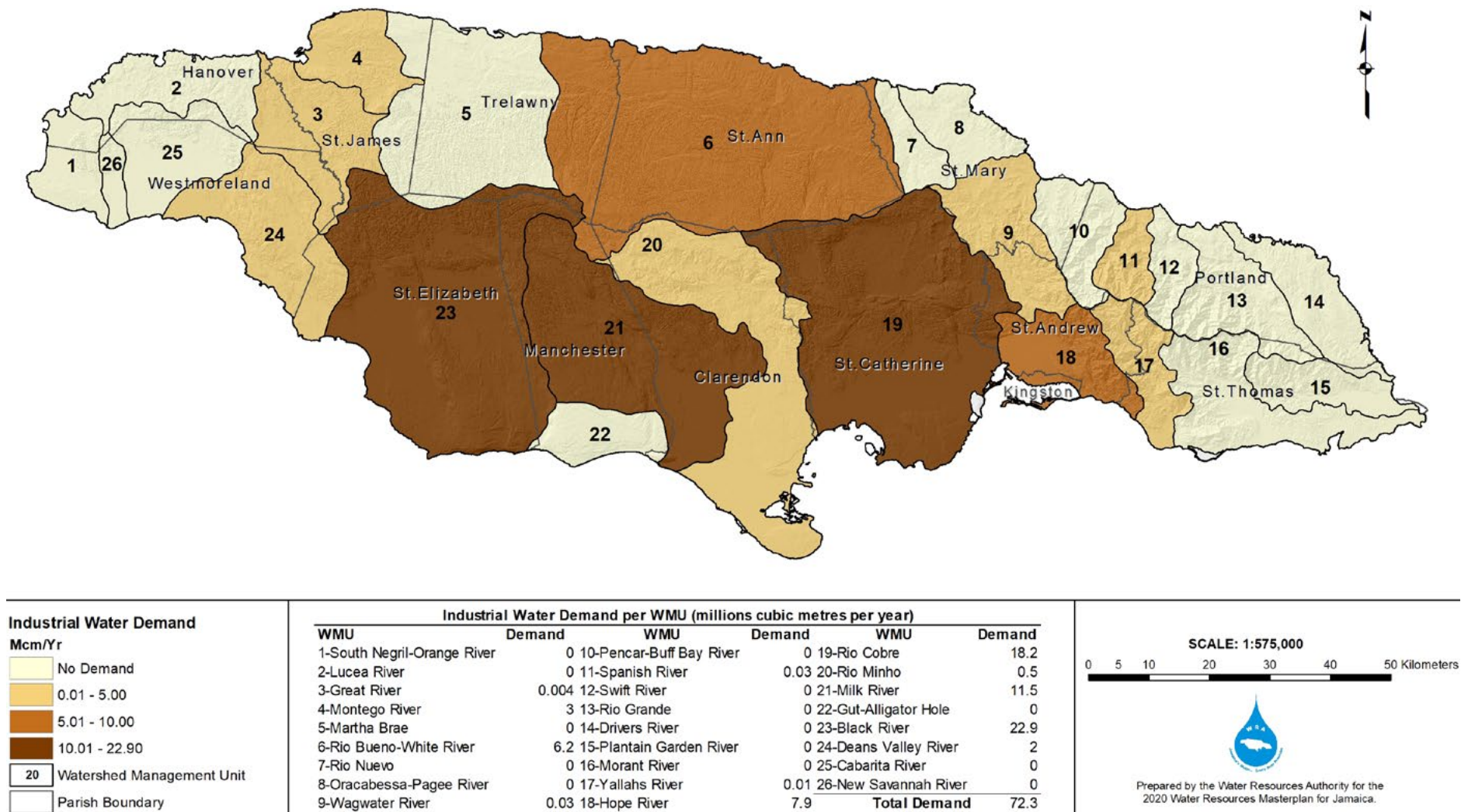


Figure 41: Industrial Water Demand by WMU

## Irrigation Water Demand per Watershed Management Unit (WMU)

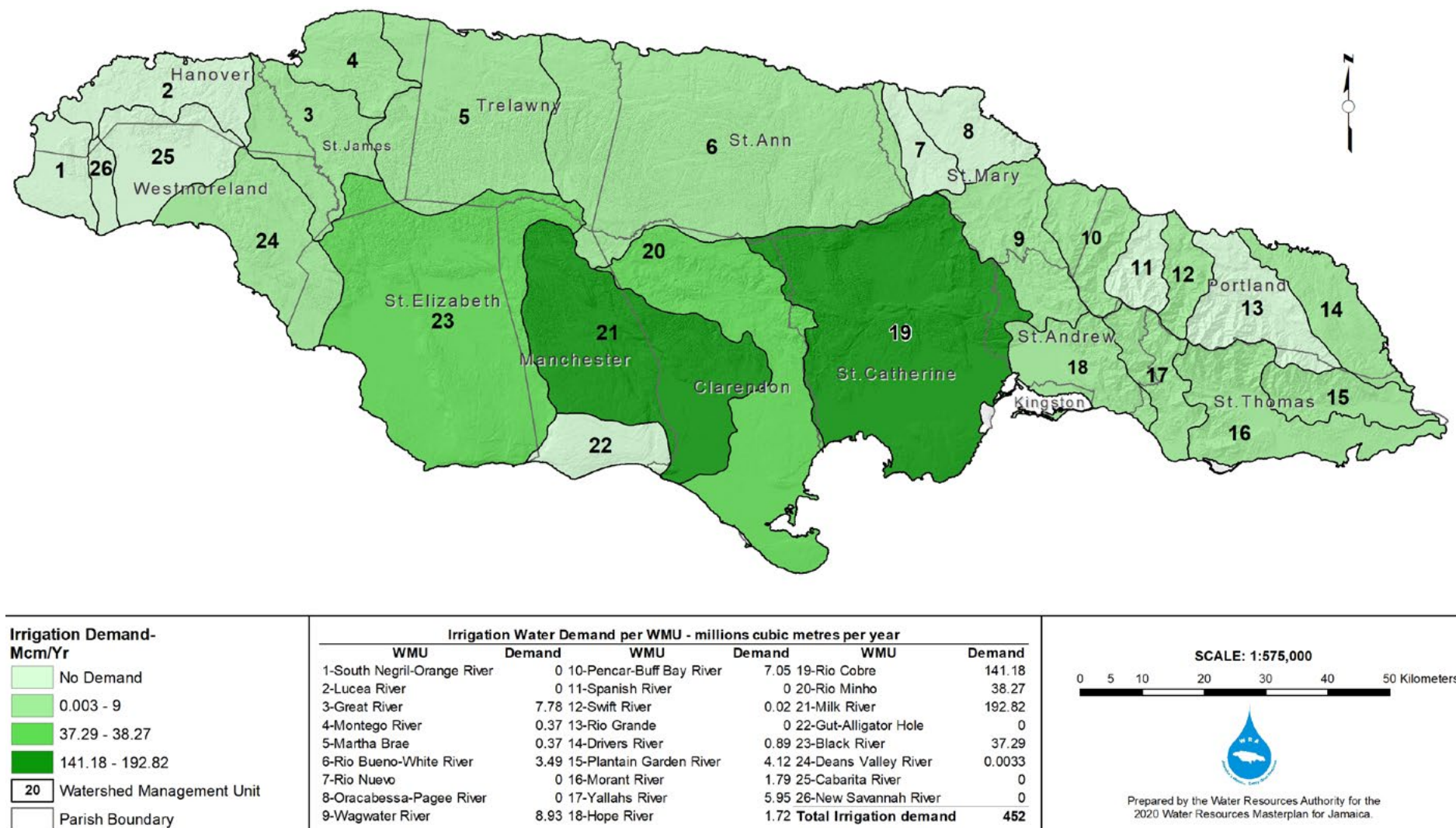


Figure 42: Irrigation Water Demand by WMU



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## Tourism Water Demand per Watershed Management Unit (WMU) w. Hotel Locations

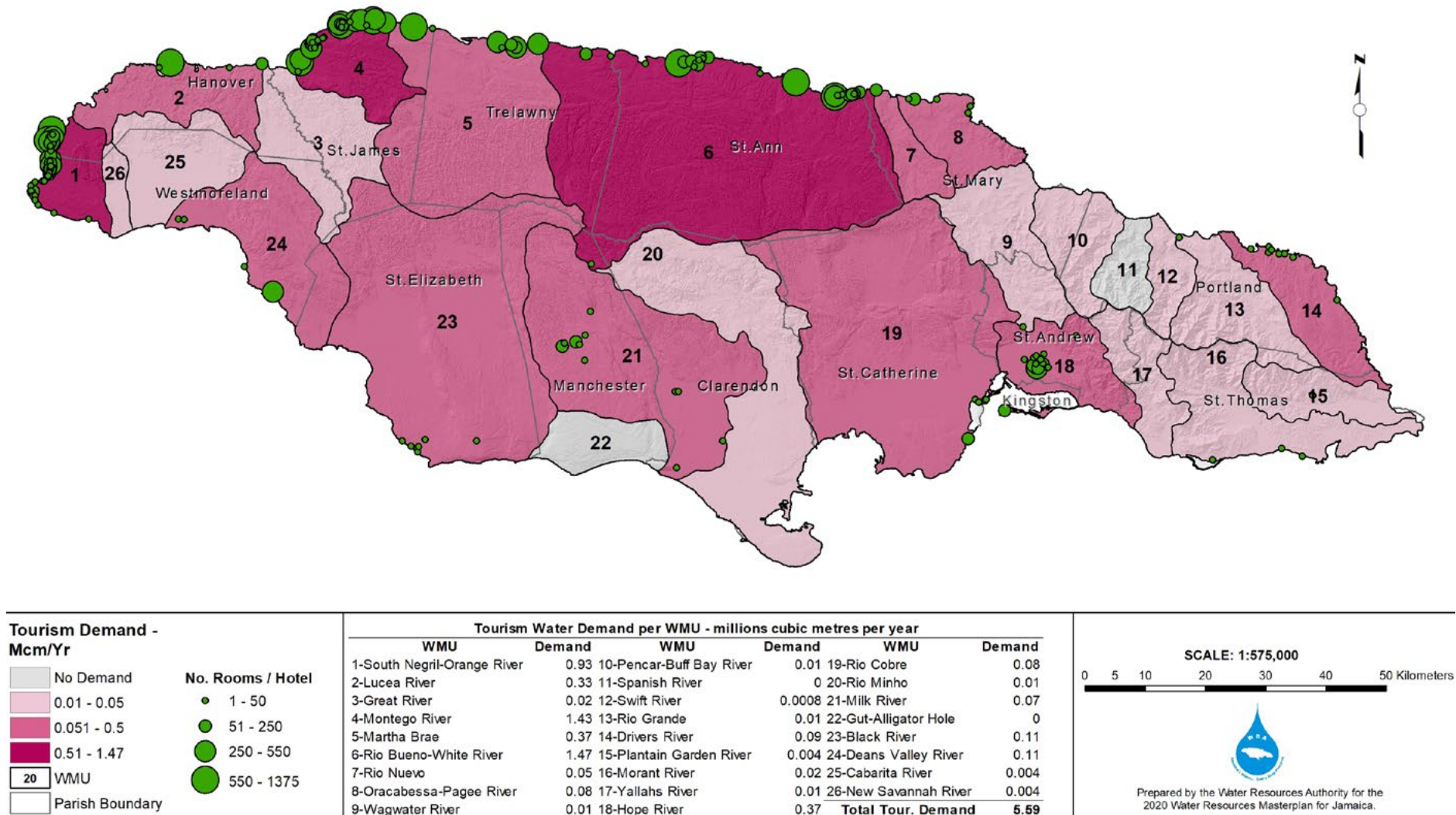


Figure 43: Tourism Water Demand by WMU

## IMPACTS OF CLIMATE CHANGE ON DEMAND

There has been growing concern that if the earth mean temperature increases due to the increasing greenhouse effect of CO<sub>2</sub> and other trace gases in the atmosphere, the patterns of rainfall will shift and greatly affect agricultural productivity and availability of fresh water. The GoJ has acknowledged the urgency of Climate Change as outlined in the Draft Water Policy which suggests that Climate change should not be a standalone issue that is dealt with at the end but should be mainstreamed throughout the discussion/objectives of IWRM.

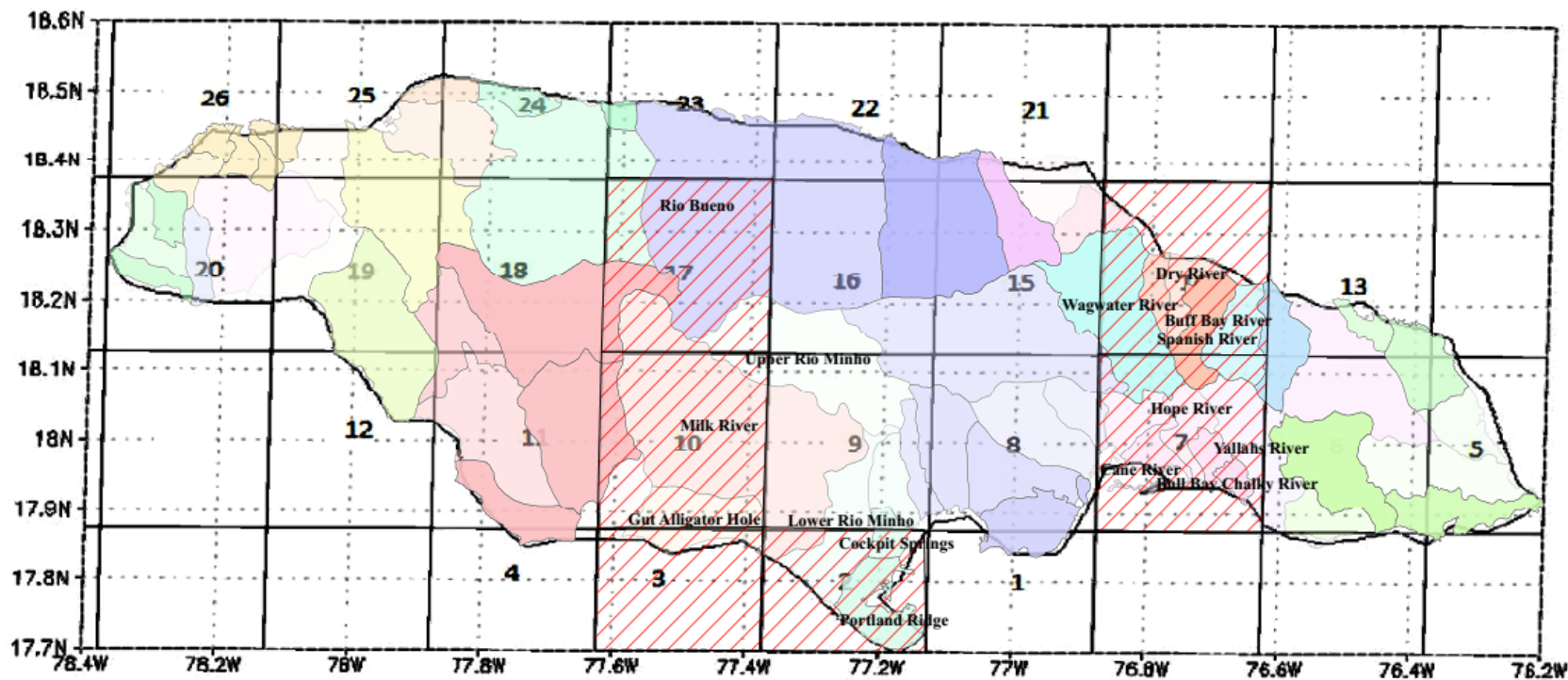
One way to study what might happen is to look at the relationship between precipitation and temperature. According to Waite (2012) the PRECIS model assumes in 2050 a reduction of 25% in average rainfall and a 40% decline by 2080. More recent data on future rainfall and temperature were provided by the Climate Studies Group (CSG) at the University of the West Indies, Mona as previously discussed in section 7.5. The variables were the absolute change in recorded temperature (°C) and the percentage change in rainfall using the Providing Regional Climates for Impact Studies (PRECIS) and regional climate model (RCM).

Models have shown some robust correlations between temperature and precipitation in many regions in the world providing evidence that processes controlling the hydrological cycle and temperature are closely related. However the findings in the case of Jamaica were less conclusive as of the 26 grids, only grid 15 shows correlation between mean temperature and precipitation within the 30's, 50's and 80's time slices. Additionally, only grids 2, 3, 7, 10, 14 and 17 in a linear regression model shows that temperature is likely to play a significant role in determining precipitation (Figure 40). These grids coincide with the Rio Minho, Rio Cobre and the Blue Mountain North basins where higher temperatures would likely result in lower rainfall events, which could, in turn, result in an increased demand for fresh water.

In the case of municipal demand, for example, an increase in household water demand for activities such as, garden watering and industrial water demand, due to climate change, is likely to be negligible for example, less than 5% by the 2050s for selected models (Bates et al. 2008). In addition, different climate models project different worldwide changes in net irrigation requirements, with estimated increases ranging from 1–3% by the 2020s and 2–7% by the 2070s (Bates et al. 2008). However, currently the feedback from adaptation measures to climate change such as the longer growing season of crops and more regulations on river flow and an increase in reservoir storage are not fully considered in current future predictions.



## Projected Impacts of Climate Change from Climate Change Group



### Legend

- 3 PRECIS Grid (Jamaica Climate Change Group)       Potential Climate Change Impact Areas

### Watershed Management Unit (WMU)

- |                               |                  |
|-------------------------------|------------------|
| 23 Black River                | 20 Rio Minho     |
| 22 Gut - Alligator Hole River | 11 Spanish River |
| 21 Milk River                 | 9 Wagwater River |

0 5 10 20 30 40  
Kilometers

Figure 44: Projected Impacts of Climate Change from Climate Change Group

## POTENTIAL EFFECTS OF CLIMATE CHANGE ON CROP WATER REQUIREMENT

The irrigation water demand was also estimated based on potential climate change impacts using the Hargreaves equation for the reference crop evapotranspiration ( $E_{rc}$ ) and a crop coefficient ( $K_c$ ) to estimate the crop water requirement ( $E_c$ ). The Hargreaves equation was used because only changes in temperature and rainfall data were available from the climate models. The Hargreaves equation is as follows:

$$E_{rc} = 0.0022 * R_A * \delta_T^{0.5} * (T + 17.8)$$

Where:

$R_A$  = mean extra-terrestrial radiation (mm/day) which is a function of latitude. A constant radiation at latitude °18 North = 2.45 mm/day was used.

$\delta_T$  = temperature difference = mean monthly maximum temperature – mean monthly minimum temperature for the month of interest (°C)

T = Mean air temperature (°C)

The Crop Water Requirement was determined by the equation:

$$E_c = K_c * E_{rc}$$

## CROP DATA

Crop data was obtained from a number of sources including the Rural Agricultural Development Authority (RADA), Sugar Industry Research Institute (SIRI), United State Department of Agriculture (USDA) Foreign Agricultural Service, Sugar Industry Authority (SIA), Sugar Company of Jamaica Holdings (SCJH) Limited, and the Banana Board.

The crop data obtained was compiled by communities and by parish so that a direct application of the data to the WMUs and the hydrologic basins was not possible. To estimate the crop water requirement and the irrigation water demand by WMU and hydrologic basins, the information was first estimated by parish. The “area weighted average” methodology was then used to estimate the quantities for each WMU and hydrologic basin.

For simplicity, the crop data was grouped into the following categories:

- Sugarcane
- Banana/Plantain
- Vegetables, Legumes, Condiments, and Cereals
- Tubers (yam, potato, cassava etc.)
- Fruit Trees
- Rice

## SUGARCANE

The sugarcane acreage was obtained from the USDA Foreign Agricultural Service GAIN Reports (Annual) for the period 2014 to 2017 and the SCJH. This average acreage was used for the present, medium and long-term projections as it presents a more conservative outlook because sugarcane production is showing a declining trend as shown in Table 48 below.

TABLE 48: SUGAR CANE PRODUCTION 2014-2017

|                             | SUGARCANE PRODUCTION - ACREAGE (HA) |           |           |           |         |
|-----------------------------|-------------------------------------|-----------|-----------|-----------|---------|
| ANNUAL REPORT               | 2014                                | 2015      | 2016      | 2017      | AVERAGE |
| CROP YEAR                   | 2012/2013                           | 2013/2014 | 2014/2015 | 2015/2016 |         |
| FACTORY / PARISH            |                                     |           |           |           |         |
| Frome / Westmoreland        | 8,830                               | 8,008     | 6,836     | 6,460     | 7,534   |
| Monymusk / Clarendon        | 6,940                               | 7,298     | 5,858     | 4,752     | 6,212   |
| Appleton / St. Elizabeth    | 5,184                               | 5,268     | 5,278     | 1,205     | 4,234   |
| Worthy Park / St. Catherine | 3,568                               | 3,503     | 3,742     | 4,105     | 3,730   |
| Everglades / Trelawny       | 1,671                               | 2,367     | 2,792     | 2,312     | 2,286   |
| Golden Grove / St. Thomas   | 3,004                               | 3,261     | 3,030     | 2,330     | 2,906   |
| TOTAL                       | 29,197                              | 29,705    | 27,536    | 21,164    | 26,901  |

## BANANA/PLANTAIN

The acreage for banana and plantain was obtained from The Banana Board's Annual Reports for the period 2010 to 2013. This average acreage was used for the present, medium and long-term projections as no definite trend could be determined as shown in the table below.



## IRRIGATION EFFICIENCIES

Irrigation efficiencies were not included in the irrigation water requirements. Additional information is required on the irrigation methods (surface, sprinkler, drip) used across the country as these methods operate at significantly different efficiencies. The National Irrigation Development Plan (NIDP) has efficiencies for these methods as follows:

|                  | ON-FARM | CONVEYANCE | TOTAL |
|------------------|---------|------------|-------|
| <b>SURFACE</b>   | .4      | .8         | .32   |
| <b>SPRINKLER</b> | .5      | .9         | .45   |
| <b>DRIP</b>      | .9      | .9         | .81   |

### Sources

Hales, "A Model to determine Optimal Water Management Procedures for Multi-Variable Systems", 1994

Melamed, "Improvement of Irrigation at Innswood Estate", 1989.

Gan, "On-Farm Water management in the Rio Cobre Irrigation Works" 1989.

JICA, "Feasibility Report on modernization and Expansion of Rio Cobre Irrigation Scheme", 1987.

Alder, "The Reservoir Solution for Improving Water Balance in ST. Catherine, Plains", 1988.

These efficiencies should be applied when calculating the irrigation water demand for specific areas.

## IRRIGATION REQUIREMENTS

The year 2016 was used as the based year for estimating the irrigation requirements and therefore represents the present irrigation demands. The climate change data, which are given as incremental changes in rainfall and temperature, were then used to estimate the short, medium and long-term irrigation requirements. The estimated irrigation requirements by Basins and WMUs are presented in the Table 16 below.

*"Increased usage of hydroponics and reuse of treated wastewater will reduce the need for new irrigation abstraction."*

The present irrigation requirements are estimated at approximately 110 MCM/year. It is estimate that by the 2030s, 2050s and 2080s the irrigation requirements will increase by approximately 50 MCM/year, 66MCM/year, and 141 MCM/year respectively. These represent increases of 46%, 61% and 129% in irrigation water requirement. These increases are due to the projected higher temperatures and reduced rainfall as predicted by the climate change models.

**TABLE 49: IRRIGATION WATER REQUIREMENT BY WMU**

| HYDROBASIN |                     | WATERSHED MANAGEMENT UNIT |                       | IRRIGATION REQUIREMENT (M3/YEAR) |            |            |            |            |            |            |            |
|------------|---------------------|---------------------------|-----------------------|----------------------------------|------------|------------|------------|------------|------------|------------|------------|
|            |                     |                           |                       | BY WMU                           |            |            |            | BY BASIN   |            |            |            |
|            |                     |                           |                       | 2016                             | 2030S      | 2050S      | 2080S      | 2016       | 2030S      | 2050S      | 2080S      |
| I          | BLUE MOUNTAIN SOUTH | 15                        | Plantain Garden River | 890,782                          | 1,586,639  | 2,050,941  | 3,349,370  | 3,482,653  | 6,216,995  | 8,044,153  | 13,171,459 |
|            |                     | 16                        | Morant River          | 1,906,990                        | 3,396,569  | 4,390,453  | 7,169,611  |            |            |            |            |
|            |                     | 17                        | Yallahs River         | 684,881                          | 1,233,787  | 1,602,758  | 2,652,478  |            |            |            |            |
| II         | KINGSTON            | 18                        | Hope River            | 289,255                          | 567,980    | 764,357    | 1,379,771  | 289,255    | 567,980    | 764,357    | 1,379,771  |
| III        | RIO COBRE           | 19                        | Rio Cobre             | 17,698,705                       | 25,409,122 | 28,671,496 | 39,890,178 | 17,698,705 | 25,409,122 | 28,671,496 | 39,890,178 |

| HYDROBASIN                                                  |                       | WATERSHED MANAGEMENT UNIT |                             | IRRIGATION REQUIREMENT (M3/YEAR) |             |             |             |             |                  |                  |                    |
|-------------------------------------------------------------|-----------------------|---------------------------|-----------------------------|----------------------------------|-------------|-------------|-------------|-------------|------------------|------------------|--------------------|
|                                                             |                       |                           |                             | BY WMU                           |             |             |             | BY BASIN    |                  |                  |                    |
|                                                             |                       |                           |                             | 2016                             | 2030S       | 2050S       | 2080S       | 2016        | 2030S            | 2050S            | 2080S              |
| IV                                                          | RIO MINHO             | 20                        | Rio Minho                   | 19,125,645                       | 26,409,143  | 29,305,313  | 47,576,320  | 33,878,568  | 47,850,852       | 53,798,666       | 83,153,741         |
|                                                             |                       | 21                        | Milk River                  | 13,172,792                       | 18,998,443  | 21,610,592  | 31,931,144  |             |                  |                  |                    |
|                                                             |                       | 22                        | Gut - Alligator Hole        | 1,580,131                        | 2,443,266   | 2,882,760   | 3,646,277   |             |                  |                  |                    |
| VI                                                          | BLACK RIVER           | 23                        | Black River                 | 16,076,751                       | 23,128,704  | 26,820,464  | 34,770,017  | 16,076,751  | 23,128,704       | 26,820,464       | 34,770,017         |
| VI                                                          | CABARITA RIVER        | 1                         | South Negril - Orange River | 1,970,991                        | 2,779,900   | 2,530,220   | 3,102,851   | 14,521,432  | 20,364,526       | 18,789,176       | 23,145,949         |
|                                                             |                       | 24                        | Deans Valley River          | 7,313,978                        | 10,242,244  | 9,620,552   | 11,912,047  |             |                  |                  |                    |
|                                                             |                       | 25                        | Cabarita River              | 4,300,438                        | 6,034,023   | 5,459,744   | 6,688,305   |             |                  |                  |                    |
|                                                             |                       | 26                        | New Savannah River          | 936,025                          | 1,308,359   | 1,178,660   | 1,442,745   |             |                  |                  |                    |
| VII                                                         | GREAT RIVER           | 2                         | Lucea River                 | 12,132                           | 156,737     | 286,643     | 383,006     | 1,696,021   | 2,809,311        | 2,789,569        | 3,847,067          |
|                                                             |                       | 3                         | Great River                 | 1,431,049                        | 2,169,115   | 2,040,799   | 2,701,174   |             |                  |                  |                    |
|                                                             |                       | 4                         | Montego River               | 252,840                          | 483,459     | 462,127     | 762,888     |             |                  |                  |                    |
| VIII                                                        | MARTHA BRAE           | 5                         | Martha Brae                 | 10,046,319                       | 14,896,137  | 15,796,350  | 20,446,386  | 10,046,319  | 14,896,137       | 15,796,350       | 20,446,386         |
| IX                                                          | DRY HARBOUR MOUNTAINS | 6                         | Rio Bueno - White River     | 9,835,323                        | 14,639,727  | 15,559,126  | 21,283,463  | 9,835,323   | 14,639,727       | 15,559,126       | 21,283,463         |
| X                                                           | BLUE MOUNTAIN NORTH   | 7                         | Rio Nuevo                   | 243,296                          | 374,523     | 580,963     | 1,085,715   | 1,715,672   | 3,073,300        | 4,656,391        | 9,415,674          |
|                                                             |                       | 8                         | Oracabessa - Pagee River    | 372,976                          | 574,418     | 892,614     | 1,670,181   |             |                  |                  |                    |
|                                                             |                       | 9                         | Wagwater River              | 585,287                          | 946,668     | 1,418,606   | 2,630,947   |             |                  |                  |                    |
|                                                             |                       | 10                        | Pencar - Buff Bay River     | 216,690                          | 382,267     | 595,305     | 1,227,599   |             |                  |                  |                    |
|                                                             |                       | 11                        | Spanish River               | 19,667                           | 76,586      | 121,010     | 337,154     |             |                  |                  |                    |
|                                                             |                       | 12                        | Swift River                 | 19,552                           | 75,612      | 119,342     | 331,897     |             |                  |                  |                    |
|                                                             |                       | 13                        | Rio Grande                  | 159,832                          | 383,207     | 547,526     | 1,225,080   |             |                  |                  |                    |
|                                                             |                       | 14                        | Drivers River               | 98,371                           | 260,019     | 381,026     | 907,102     |             |                  |                  |                    |
| TOTAL                                                       |                       |                           |                             | 109,240,700                      | 158,956,653 | 175,689,747 | 250,503,706 | 109,240,700 | 158,956,653      | 175,689,747      | 250,503,706        |
| INCREASE IRRIGATION WATER REQUIREMENT DUE TO CLIMATE CHANGE |                       |                           |                             |                                  |             |             |             | -           | 49,715,953 (46%) | 66,449,047 (61%) | 141,263,005 (129%) |



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## CLIMATE CHANGE ADAPTATION METHODS

Small island developing states (SIDS) such as Jamaica are increasingly vulnerable to disruptions in water resources availability (e.g. droughts, flooding, and precipitation variability) due to the impacts of global climate change. One adaptation strategy being encouraged by the Government of Jamaica is rain water harvesting (RWH). Within the National Policy on Poverty (GOJ 2016) the Rain Water Harvesting and Catchment Tank Rehabilitation Program was listed intervention for the 2015/2016 budget year. Over the past three years some 112 catchment tanks in several parishes were refurbished at a cost of more than J\$100 million<sup>20</sup>.

Rainwater harvesting systems catch rainwater and feed water into a storage tank which supplies individual households or communities. Typically, household systems are supplied from a house's roof, into storage tank that and may include a system of pipes to deliver water to the household. This alternative technique is scalable and can be improved as the need arises.

There are also community systems that collect rainwater from a large concrete or metal catchment area (aka *barbecues*) and transfer it to a large storage tank through pipes. Rainwater harvesting is a reliable and safe form of water supply, used by 15% of households as their main source of water supply, including 31% of rural households. There are 353 community rainwater harvesting tanks that serve rural communities across the island.



<sup>20</sup> <http://jis.gov.jm/prime-ministers-speech-at-nwcs-non-revenue-water-contract-signing/> Retrieved July 1, 2017

# Water Resources Management

## WATER RESOURCES AND DEMAND ASSESSMENT

Table 50 presents the 2016 summary of WMU safe yield, consumptive allocation and estimated demand, while Table 51 presents the 2016 summary of water availability for various usages. These figures should be viewed through the implications of section 4.6 which indicates a strong possibility of declining water resources availability due to the impacts of climate change, along with the increased demand due to population increase and economic development. Tables 52 through 55 present the estimated balances for projected water availability based on previously stated climate change impacts on water availability and water demand. The data predicts that there will be a consistent decrease in water resources availability for the island if the projected climate change impacts come to pass. This illustrates the necessity of increasing the resilience of water resources and water usage, including the efficiency of water use and the consideration of alternate water sources, including the re-use of wastewater. These options will be discussed later in this chapter. Figures 45 through 51 present a spatial representation of the data in the aforementioned tables.

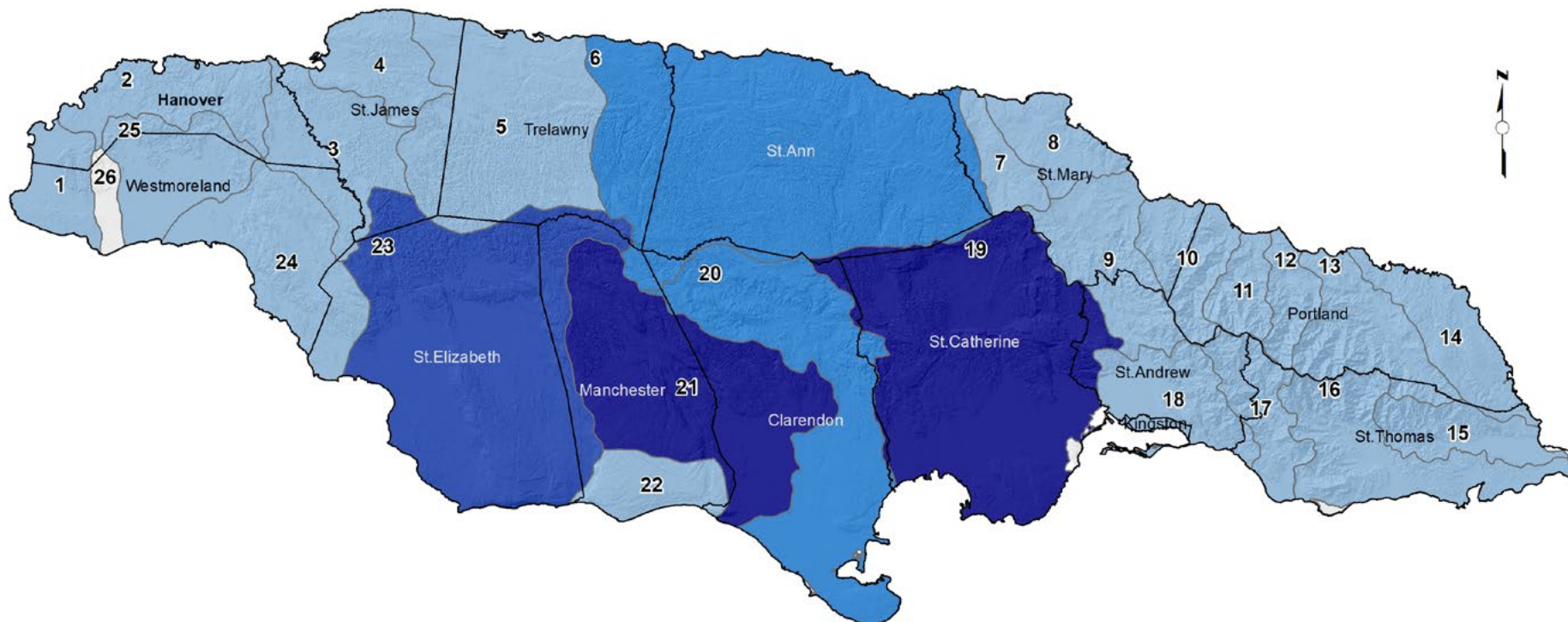




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## Total Consumptive Allocation per Watershed Management Unit (WMU)



### Total Consumptive Allocation\* per WMU - Mcm/yr

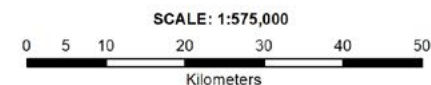
|                 |
|-----------------|
| No Allocation   |
| 0.01 - 50.00    |
| 50.01 - 100.10  |
| 100.11 - 200.00 |
| 200.01 - 438.24 |

|                 |
|-----------------|
| Parish Boundary |
| WMU Boundary    |

\*Nonconsumptive Allocations (hydropower) not included.

### Total Consumptive Allocation per WMU (Millions Cubic Metres/Year)

| WMU                         | Allocated | WMU                      | Allocated | WMU                    | Allocated      |
|-----------------------------|-----------|--------------------------|-----------|------------------------|----------------|
| 1-South Negril-Orange River | 11.55     | 10-Pencar-Buff Bay River | 21.60     | 19-Rio Cobre           | 438.24         |
| 2-Lucea River               | 1.97      | 11-Spanish River         | 2.45      | 20-Rio Minho           | 74.41          |
| 3-Great River               | 37.33     | 12-Swift River           | 0.35      | 21-Milk River          | 205.46         |
| 4-Montego River             | 22.87     | 13-Rio Grande            | 8.61      | 22-Gut-Alligator Hole  | 1.66           |
| 5-Martha Brae               | 47.27     | 14-Drivers River         | 3.53      | 23-Black River         | 186.37         |
| 6-Rio Bueno-White River     | 100.10    | 15-Plantain Garden River | 8.87      | 24-Deans Valley River  | 8.84           |
| 7-Rio Nuevo                 | 1.66      | 16-Morant River          | 17.54     | 25-Cabarita River      | 40.39          |
| 8-Oracabessa-Pagee River    | 2.21      | 17-Yallahs River         | 31.83     | 26-New Savannah River  | 0.00           |
| 9-Wagwater River            | 46.06     | 18-Hope River            | 33.34     | <b>Total Allocated</b> | <b>1354.49</b> |



Prepared 2020 by the Water Resources Authority for the Water Resources Masterplan.



## General Water Surplus/Deficit per Watershed Management Unit (WMU)

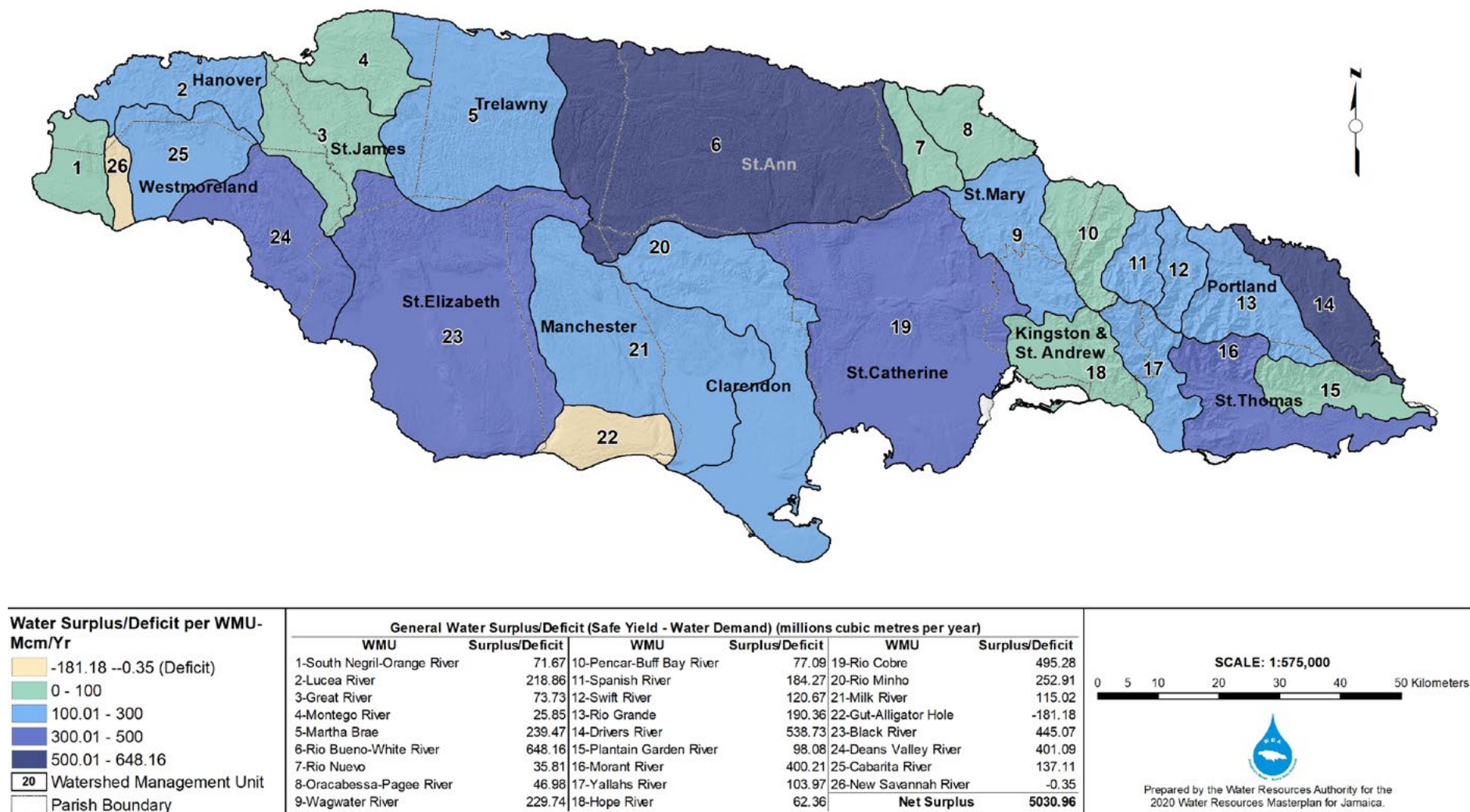


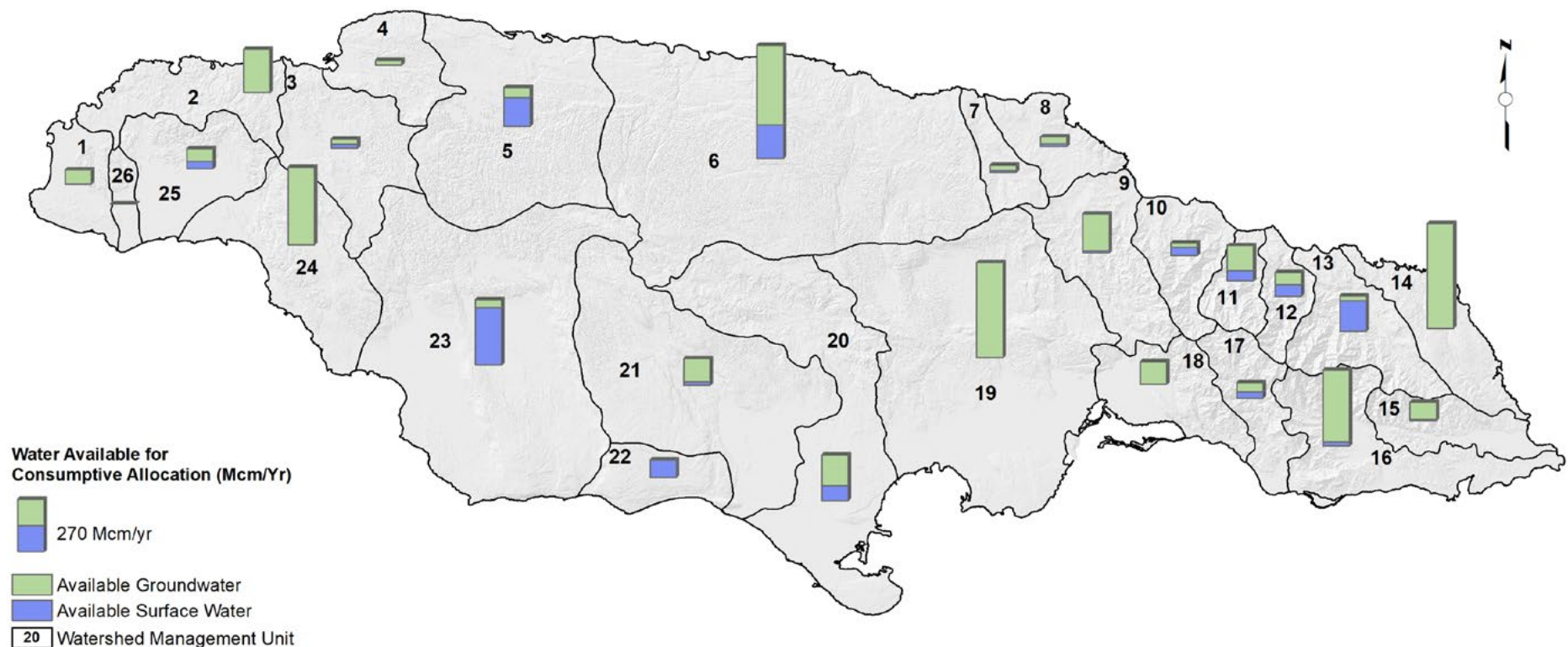
Figure 46: General Water Surplus/Deficit by WMU



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## Water Available for Consumptive Allocation per WMU by Source



| Water Available for Consumptive Allocation (Safe Yield - Consumptive Allocated Water) (Millions cubic metres per year) |             |               |                          |             |               |                        |                |                |
|------------------------------------------------------------------------------------------------------------------------|-------------|---------------|--------------------------|-------------|---------------|------------------------|----------------|----------------|
| WMU                                                                                                                    | Groundwater | Surface Water | WMU                      | Groundwater | Surface Water | WMU                    | Groundwater    | Surface Water  |
| 1-South Negril-Orange River                                                                                            | 72.89       | -8.76         | 10-Pencar-Buff Bay River | 23.33       | 42.51         | 19-Rio Cobre           | 489.29         | -208.88        |
| 2-Lucea River                                                                                                          | 222.74      | 0.58          | 11-Spanish River         | 129.62      | 52.69         | 20-Rio Minho           | 157.46         | 77.32          |
| 3-Great River                                                                                                          | 29.59       | 19.49         | 12-Swift River           | 63.43       | 57.82         | 21-Milk River          | 118.35         | 19.14          |
| 4-Montego River                                                                                                        | 21.08       | 3.83          | 13-Rio Grande            | 24.82       | 158.73        | 22-Gut-Alligator Hole  | -272.63        | 91.32          |
| 5-Martha Brae                                                                                                          | 53.21       | 147.67        | 14-Drivers River         | 542.34      | -1.16         | 23-Black River         | 42.32          | 295.44         |
| 6-Rio Bueno-White River                                                                                                | 409.70      | 172.93        | 15-Plantain Garden River | 88.82       | 5.75          | 24-Deans Valley River  | 401.09         | 0.29           |
| 7-Rio Nuevo                                                                                                            | 28.48       | 7.88          | 16-Morant River          | 370.05      | 21.86         | 25-Cabarita River      | 66.13          | 36.08          |
| 8-Oracabessa-Pagee River                                                                                               | 36.10       | 13.99         | 17-Yallahs River         | 49.41       | 31.44         | 26-New Savannah River  | 0.04           | 0.38           |
| 9-Wagwater River                                                                                                       | 188.35      | 12.07         | 18-Hope River            | 115.40      | -3.72         | <b>Total Available</b> | <b>3471.39</b> | <b>1046.68</b> |

SCALE: 1:575,000

0 5 10 20 30 40 50

Kilometers



Prepared by the Water Resources Authority for the 2020 Water Resources Masterplan for Jamaica.

Figure 47: Water Available for Consumptive Allocation per WMU by Source

## Projected Surplus/Deficit per Watershed Management Unit (WMU) 2019-2080

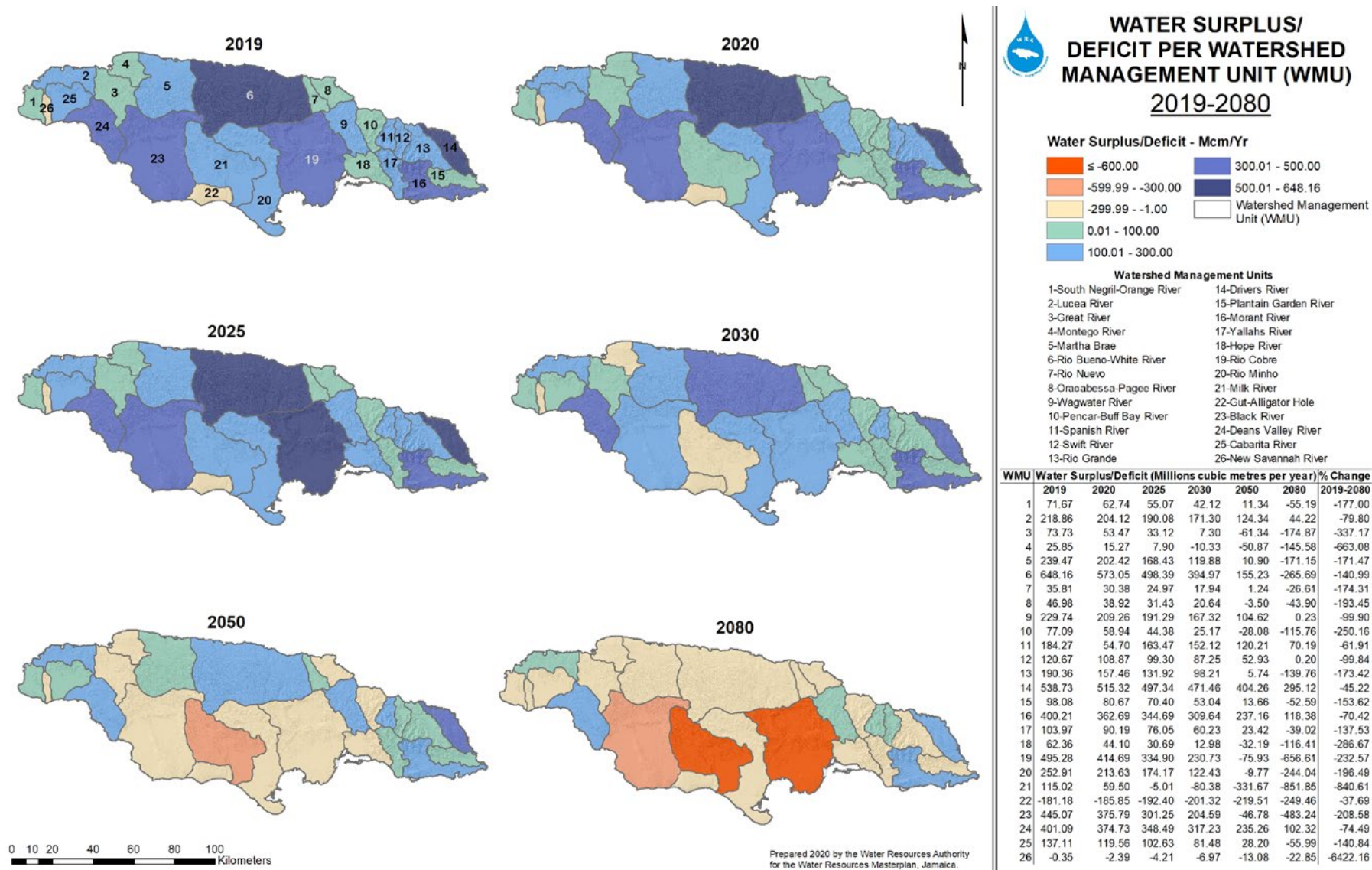


Figure 48: Projected Surplus-Deficit



WRA

WATER RESOURCES AUTHORITY

## Water Availability for Consumptive Allocation per Watershed Management Unit (WMU) 2020-2080

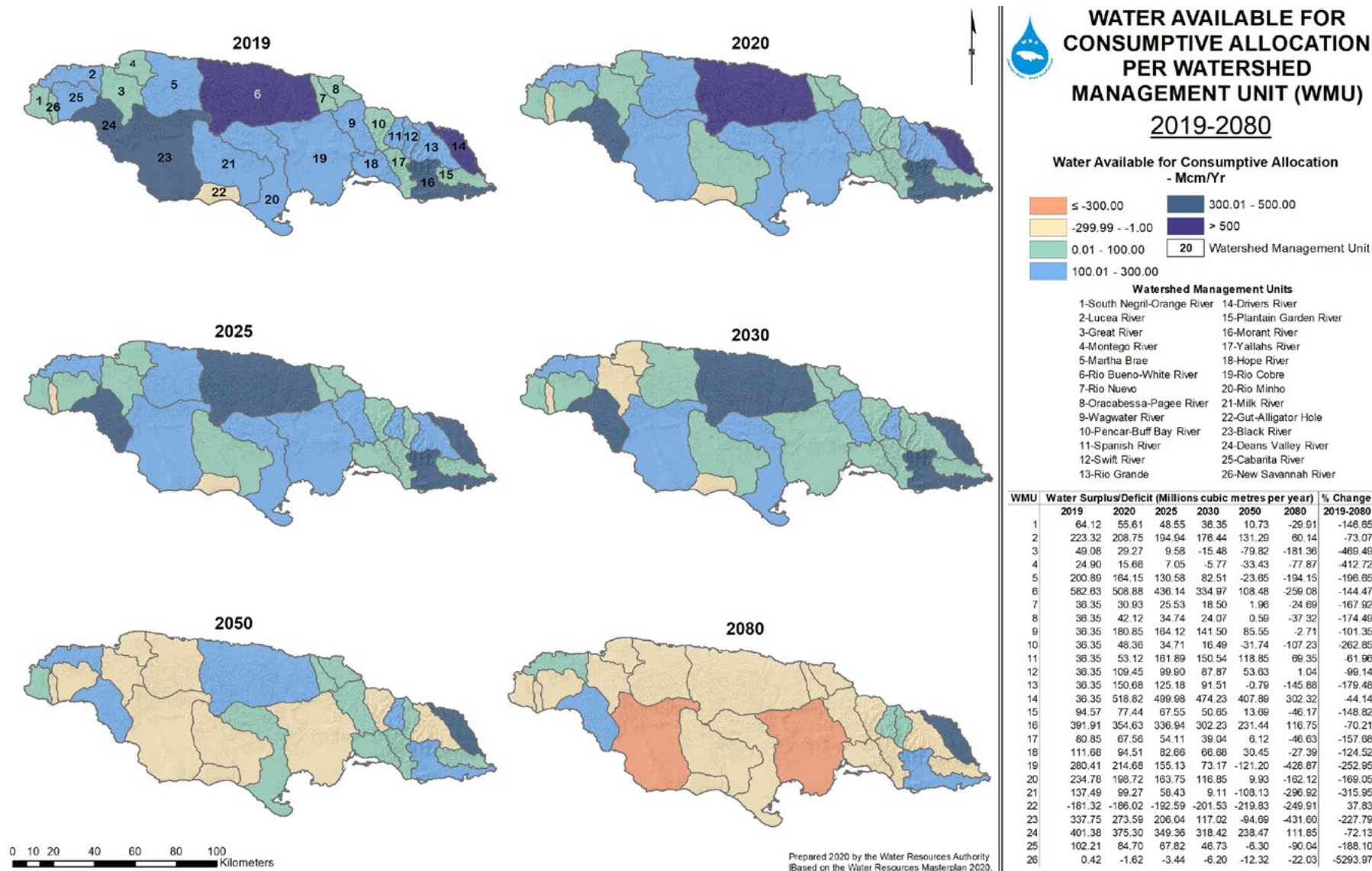
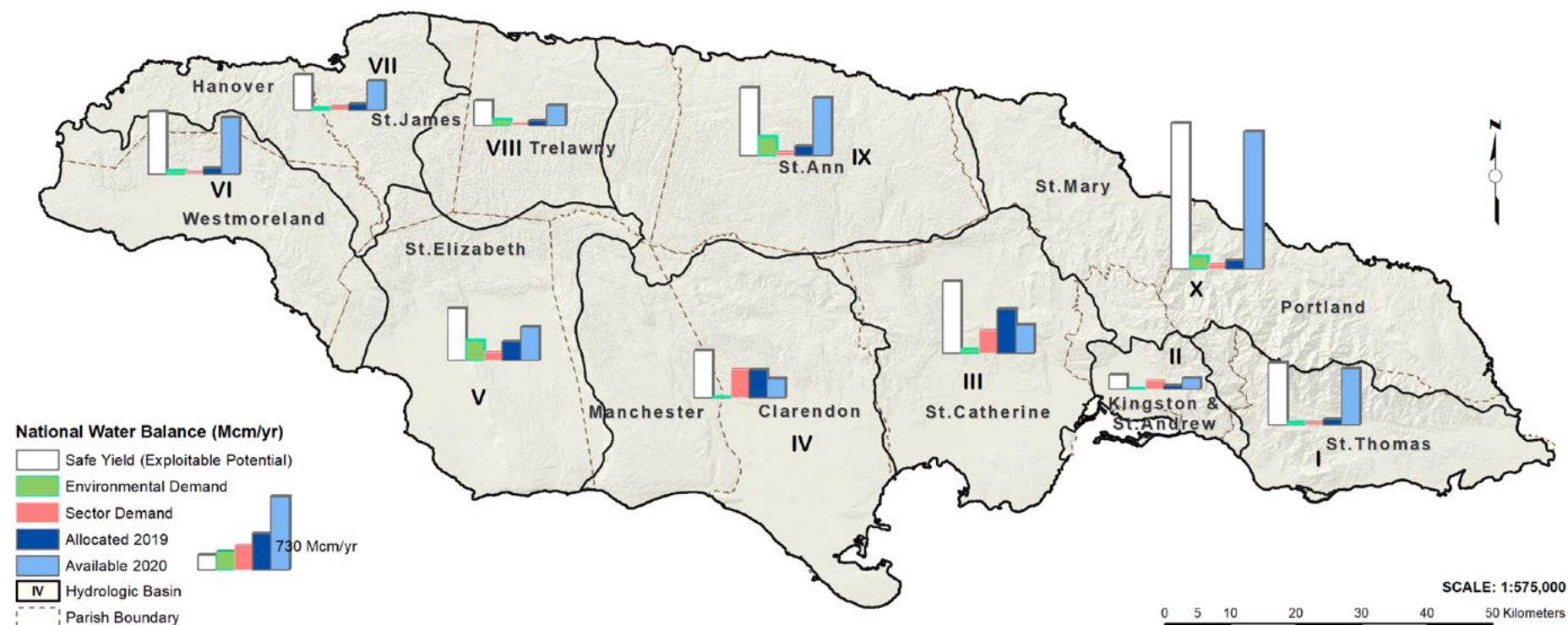


Figure 49: Projected Water Allocation Availability 2020-2080

## National Water Balance



| National Water Balance (Millions cubic metres per year) |                |                      |               |                |                |
|---------------------------------------------------------|----------------|----------------------|---------------|----------------|----------------|
| Hydrologic Basin                                        | Safe Yield     | Environmental Demand | Sector Demand | Available      | Allocated 2019 |
| I-Blue Mountain South                                   | 625.56         | 24.33                | 23.30         | 567.33         | 58.23          |
| II-Kingston                                             | 145.01         | 1.82                 | 82.65         | 111.68         | 33.34          |
| III-Rio Cobre                                           | 718.65         | 34.42                | 223.36        | 280.41         | 438.24         |
| IV-Rio Minho                                            | 472.49         | 7.68                 | 285.73        | 190.96         | 281.53         |
| V-Black River                                           | 524.13         | 198.58               | 79.06         | 337.75         | 186.37         |
| VI-Cabarita River                                       | 628.90         | 33.57                | 19.38         | 568.13         | 60.78          |
| VII-Great River                                         | 359.47         | 21.85                | 41.02         | 297.30         | 62.16          |
| VIII-Martha Brae River                                  | 248.16         | 55.80                | 8.69          | 200.89         | 47.27          |
| IX-Dry Harbour Mountains                                | 682.72         | 188.99               | 34.56         | 582.63         | 100.10         |
| X-Blue Mountain North                                   | 1467.49        | 124.17               | 43.84         | 1381.01        | 86.48          |
| <b>Total</b>                                            | <b>5872.56</b> | <b>691.21</b>        | <b>841.60</b> | <b>4518.08</b> | <b>1354.49</b> |

### NOTES:

**Hydrologic Basin:** The spatial unit of management where no surface water naturally flows from one basin to the next. May include more than 1 WMU grouped for management purposes.

**Safe Yield:** Total exploitable potential of water resources.

**Environmental Demand:** Water needed for environmental purposes (i.e. to maintain aquatic systems).

**Sector Demand:** Water demand for all sectors in 2019.

**Allocated 2019:** Water allocated by the WRA to all users as of November 2019.

**Available:** Water that remains available for new allocations (potential for development) as of 2020.

### The map shows that:

- (1) For all basins except Rio Cobre (III) and Rio Minho (IV) the potential for development exceeds the total 2019 demand.
- (2) The potential for development in the Kingston (II) basin only barely exceeds the 2019 demand.
- (3) For all basins except Kingston (II) and Cabarita (VI), the water allocated exceeds the total 2019 demand, excluding the environment water.
- (4) Higher safe yield and lower demand are mostly located along the northern basins whereas the reverse is true for the south coast basins.
- (5) The existing assessment of the islands water resources are depicted in a positive light.
- (6) However, while there is still water generally available to be allocated across the island at this time, new allocations in the Rio Cobre (III), Rio Minho (IV) & Kingston (II) basins will need to be revised & potentially limited (or, in the case of the Rio Cobre basin, continue to be limited).
- (7) Projected impacts of climate change on water resources from present to 2080 will further diminish potential for development across all basins.
- (8) Efficient water use is therefore essential & can be done through reducing water losses or Non-Revenue Water (NRW) by water providers, more efficient use/conservation of water by all end-users (domestic, industrial, agricultural, tourist) & the re-use of treated wastewater effluent for irrigation & domestic purposes (as currently practiced in Singapore, Israel & other localities). These would reduce the pressure on water resources from new allocation demands, & potentially increase the amount of water available for new allocations.

Figure 50: National Water Balance (2016-2019)

## National Water Balance 2019-2080

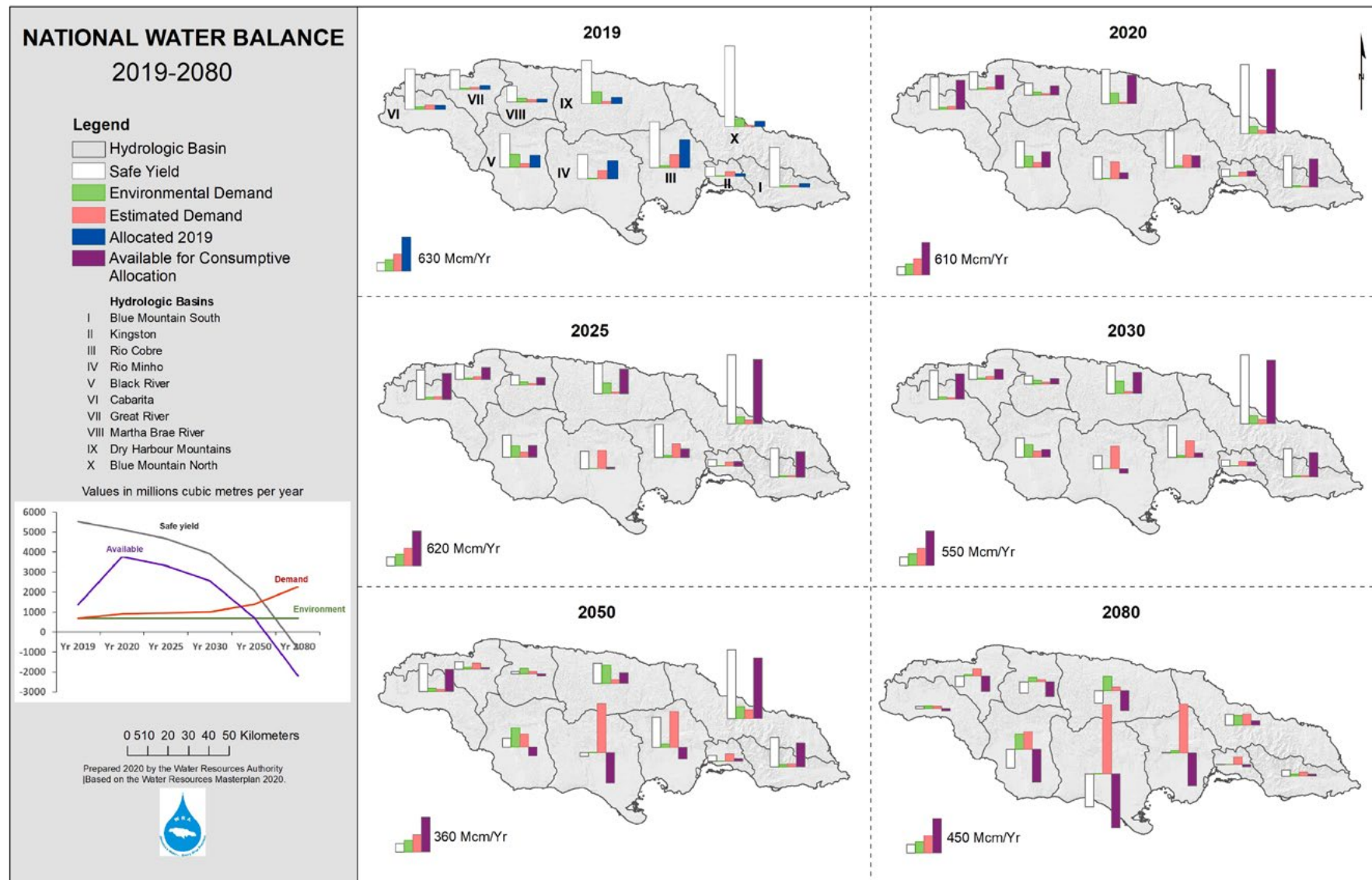


Figure 51: Water Balance per WMU 2019-2080





TABLE 50: WATER RESOURCES AND DEMAND SUMMARY OF SAFE YIELD, CONSUMPTIVE ALLOCATION, AND DEMAND FOR 2016.

| BASIN                                                                                                   |                      | BLUE MOUNTAIN SOUTH   |              |               | KINGS-TON  | RIO COBRE | RIO MINHO |            |                          | BLACK RIVER | CABARITA RIVER     |                |                    |
|---------------------------------------------------------------------------------------------------------|----------------------|-----------------------|--------------|---------------|------------|-----------|-----------|------------|--------------------------|-------------|--------------------|----------------|--------------------|
| WMU                                                                                                     |                      | PLANTAIN GARDEN RIVER | MORANT RIVER | YALLAHS RIVER | HOPE RIVER | RIO COBRE | RIO MINHO | MILK RIVER | GUT RIVER-ALLIGATOR HOLE | BLACK RIVER | DEANS VALLEY RIVER | CABARITA RIVER | NEW SAVANNAH RIVER |
| SAFE YIELD                                                                                              | GW                   | 89.11                 | 382.95       | 59.13         | 141.12     | 630.80    | 227.91    | 319.44     | -270.98                  | 135.22      | 403.38             | 66.13          | 0.04               |
|                                                                                                         | SW                   | 14.33                 | 26.50        | 53.54         | 3.89       | 87.85     | 81.29     | 23.51      | 91.32                    | 388.90      | 6.83               | 76.47          | 0.38               |
|                                                                                                         | DOMESTIC SW          | 7.74                  | 19.59        | 42.85         | 2.98       | 59.12     | 61.70     | 18.53      | 39.80                    | 286.03      | 4.18               | 53.89          | 0.22               |
|                                                                                                         | WMU TOTAL            | 103.44                | 409.45       | 112.67        | 145.01     | 718.65    | 309.20    | 342.95     | -179.66                  | 524.13      | 410.21             | 142.60         | 0.42               |
|                                                                                                         | WMU DOMESTIC TOTAL   | 96.85                 | 402.54       | 101.98        | 144.10     | 689.92    | 289.61    | 337.97     | -231.17                  | 421.26      | 407.56             | 120.02         | 0.26               |
|                                                                                                         | BASIN TOTAL          | 625.56                |              | 145.01        | 718.65     | 472.49    |           |            | 524.13                   | 628.90      |                    |                |                    |
|                                                                                                         | BASIN DOMESTIC TOTAL | 601.37                |              | 144.10        | 689.92     | 396.41    |           |            | 421.26                   | 602.10      |                    |                |                    |
| TOTAL CONSUMPTIVE ALLOCATION                                                                            | GW                   | 0.29                  | 12.90        | 9.72          | 25.73      | 141.51    | 70.45     | 201.09     | 1.66                     | 92.91       | 2.29               | 0.00           | 0.00               |
|                                                                                                         | SW                   | 8.58                  | 4.64         | 22.10         | 7.61       | 296.73    | 3.96      | 4.37       | 0.00                     | 93.47       | 6.54               | 40.39          | 0.00               |
|                                                                                                         | WMU TOTAL            | 8.87                  | 17.54        | 31.83         | 33.34      | 438.24    | 74.41     | 205.46     | 1.66                     | 186.37      | 8.84               | 40.39          | 0.00               |
|                                                                                                         | BASIN TOTAL          | 58.23                 |              | 33.34         | 438.24     | 281.53    |           |            | 186.37                   | 60.78       |                    |                |                    |
| DEMAND                                                                                                  | DOMESTIC             | 0.82                  | 4.95         | 1.82          | 48.44      | 42.60     | 11.67     | 15.69      | 1.01                     | 12.50       | 4.68               | 3.65           | 0.51               |
|                                                                                                         | COMMERCIAL           | 0.21                  | 1.24         | 0.46          | 12.11      | 10.65     | 2.92      | 3.92       | 0.25                     | 3.13        | 1.17               | 0.91           | 0.13               |
|                                                                                                         | INSTITUTIONAL        | 0.21                  | 1.24         | 0.46          | 12.11      | 10.65     | 2.92      | 3.92       | 0.25                     | 3.13        | 1.17               | 0.91           | 0.13               |
|                                                                                                         | TOURISM              | 0.00                  | 0.02         | 0.01          | 0.37       | 0.08      | 0.01      | 0.07       | 0.00                     | 0.11        | 0.11               | 0.00           | 0.00               |
|                                                                                                         | IRRIGATION           | 4.12                  | 1.79         | 5.95          | 1.72       | 141.18    | 38.27     | 192.82     | 0.00                     | 37.29       | 0.00               | 0.00           | 0.00               |
|                                                                                                         | INDUSTRIAL           | 0.00                  | 0.00         | 0.01          | 7.90       | 18.20     | 0.50      | 11.50      | 0.00                     | 22.90       | 2.00               | 0.00           | 0.00               |
|                                                                                                         | WMU TOTAL            | 5.35                  | 9.24         | 8.70          | 82.65      | 223.36    | 56.29     | 227.93     | 1.52                     | 79.06       | 9.13               | 5.48           | 0.77               |
|                                                                                                         | BASIN TOTAL          | 23.30                 |              | 82.65         | 223.36     | 285.73    |           |            | 79.06                    | 19.38       |                    |                |                    |
| Water Available for Consumptive Allocation (Safe Yield - Consumptive Allocated Water)                   | GW                   | 88.82                 | 370.05       | 49.41         | 115.40     | 489.29    | 157.46    | 118.35     | -272.63                  | 42.32       | 401.09             | 66.13          | 0.04               |
|                                                                                                         | SW                   | 5.75                  | 21.86        | 31.44         | -3.72      | -208.88   | 77.32     | 19.14      | 91.32                    | 295.44      | 0.29               | 36.08          | 0.38               |
|                                                                                                         | WMU TOTAL            | 94.57                 | 391.91       | 80.85         | 111.68     | 280.41    | 234.78    | 137.49     | -181.32                  | 337.75      | 401.38             | 102.21         | 0.42               |
|                                                                                                         | BASIN TOTAL          | 567.33                |              | 111.68        | 280.41     | 190.96    |           |            | 337.75                   | 568.13      |                    |                |                    |
| General Water Surplus/ Deficit (Safe Yield - Water Demand)                                              | WMU TOTAL            | 98.08                 | 400.21       | 103.97        | 62.36      | 495.28    | 252.91    | 115.02     | -181.18                  | 445.07      | 401.09             | 137.11         | -0.35              |
|                                                                                                         | BASIN TOTAL          | 602.26                |              | 62.36         | 495.28     | 186.76    |           |            | 445.07                   | 609.52      |                    |                |                    |
| Domestic Water Availability (Domestic Safe Yield - Domestic Demand)                                     | WMU TOTAL            | 96.03                 | 397.59       | 100.16        | 95.66      | 647.31    | 277.94    | 322.28     | -232.18                  | 408.75      | 402.89             | 116.36         | -0.25              |
|                                                                                                         | BASIN TOTAL          | 593.77                |              | 95.66         | 647.31     | 368.03    |           |            | 408.75                   | 591.21      |                    |                |                    |
| Municipal Water Availability - Domestic Safe Yield - (Domestic+Institutional+Commercial+Tourism Demand) | WMU TOTAL            | 95.61                 | 395.09       | 99.24         | 71.06      | 625.93    | 272.10    | 314.36     | -232.69                  | 402.39      | 400.44             | 114.53         | -0.51              |
|                                                                                                         | BASIN TOTAL          | 589.94                |              | 71.06         | 625.93     | 353.77    |           |            | 402.39                   | 584.72      |                    |                |                    |



|  |                           | GREAT RIVER   |              |               | MARTHA BRAE   | DRY HARBOUR MOUNTAINS  | BLUE MOUNTAIN NORTH |                    |                |                        |               |               |               |               | TOTAL          |
|--|---------------------------|---------------|--------------|---------------|---------------|------------------------|---------------------|--------------------|----------------|------------------------|---------------|---------------|---------------|---------------|----------------|
|  | SOUTH NEGRIL-ORANGE RIVER | LUCEA RIVER   | GREAT RIVER  | MONTEGO RIVER | MARTHA BRAE   | RIO BUE-NO-WHITE RIVER | RIO NUEVO           | ORA-CABES-SA-PAGEE | WAGWATER RIVER | PEN-CAR-BUFF BAY RIVER | SPANISH RIVER | SWIFT RIVER   | RIO GRANDE    | DRIVERS RIVER |                |
|  | 73.36                     | 223.58        | 29.83        | 38.60         | 71.69         | 437.33                 | 28.48               | 36.10              | 198.12         | 37.96                  | 129.62        | 63.45         | 29.11         | 543.59        | 4125.08        |
|  | 2.31                      | 1.71          | 56.58        | 9.16          | 176.46        | 245.39                 | 9.54                | 16.21              | 48.35          | 49.49                  | 55.15         | 58.15         | 163.05        | 1.14          | 1747.48        |
|  | 0.89                      | 1.17          | 42.45        | 6.48          | 110.36        | 189.10                 | 6.54                | 11.57              | 33.56          | 39.27                  | 37.99         | 42.88         | 116.76        | 0.32          | 1235.98        |
|  | <b>75.67</b>              | <b>225.29</b> | <b>86.41</b> | <b>47.77</b>  | <b>248.16</b> | <b>682.72</b>          | <b>38.01</b>        | <b>52.31</b>       | <b>246.47</b>  | <b>87.45</b>           | <b>184.77</b> | <b>121.59</b> | <b>192.16</b> | <b>544.72</b> | <b>5872.56</b> |
|  | <b>74.25</b>              | <b>224.75</b> | <b>72.28</b> | <b>45.08</b>  | <b>182.06</b> | <b>626.43</b>          | <b>35.02</b>        | <b>47.67</b>       | <b>231.68</b>  | <b>77.23</b>           | <b>167.61</b> | <b>106.33</b> | <b>145.87</b> | <b>543.90</b> | <b>5361.06</b> |
|  | <b>359.47</b>             |               |              | <b>248.16</b> | <b>682.72</b> | <b>1467.49</b>         |                     |                    |                |                        |               |               |               |               | <b>5872.56</b> |
|  | <b>342.12</b>             |               |              | <b>182.06</b> | <b>626.43</b> | <b>1355.32</b>         |                     |                    |                |                        |               |               |               |               | <b>5361.06</b> |
|  | 0.48                      | 0.84          | 0.24         | 17.53         | 18.48         | 27.63                  | 0.00                | 0.00               | 9.77           | 14.62                  | 0.00          | 0.02          | 4.28          | 1.24          | 653.69         |
|  | 11.07                     | 1.13          | 37.09        | 5.34          | 28.79         | 72.46                  | 1.66                | 2.21               | 36.28          | 6.98                   | 2.45          | 0.33          | 4.33          | 2.29          | 700.80         |
|  | 11.55                     | 1.97          | 37.33        | 22.87         | 47.27         | 100.10                 | 1.66                | 2.21               | 46.06          | 21.60                  | 2.45          | 0.35          | 8.61          | 3.53          | 1354.49        |
|  | <b>62.16</b>              |               |              | <b>47.27</b>  | <b>100.10</b> | <b>86.48</b>           |                     |                    |                |                        |               |               |               |               | <b>1354.49</b> |
|  | 2.05                      | 4.06          | 3.25         | 11.41         | 5.30          | 15.60                  | 1.44                | 3.50               | 5.18           | 2.20                   | 0.31          | 0.60          | 1.20          | 3.34          | 207.79         |
|  | 0.51                      | 1.02          | 0.81         | 2.85          | 1.32          | 3.90                   | 0.36                | 0.88               | 1.29           | 0.55                   | 0.08          | 0.15          | 0.30          | 0.83          | 51.95          |
|  | 0.51                      | 1.02          | 0.81         | 2.85          | 1.32          | 3.90                   | 0.36                | 0.88               | 1.29           | 0.55                   | 0.08          | 0.15          | 0.30          | 0.83          | 51.95          |
|  | 0.93                      | 0.33          | 0.02         | 1.43          | 0.37          | 1.47                   | 0.05                | 0.08               | 0.01           | 0.01                   | 0.00          | 0.00          | 0.01          | 0.09          | 5.59           |
|  | 0.00                      | 0.00          | 7.78         | 0.37          | 0.37          | 3.49                   | 0.00                | 0.00               | 8.93           | 7.05                   | 0.00          | 0.02          | 0.00          | 0.89          | 452.04         |
|  | 0.00                      | 0.00          | 0.00         | 3.00          | 0.00          | 6.20                   | 0.00                | 0.00               | 0.03           | 0.00                   | 0.03          | 0.00          | 0.00          | 0.00          | 72.27          |
|  | 4.00                      | 6.43          | 12.68        | 21.91         | 8.69          | 34.56                  | 2.21                | 5.33               | 16.73          | 10.35                  | 0.50          | 0.92          | 1.80          | 5.99          | 841.60         |
|  | <b>41.02</b>              |               |              | <b>8.69</b>   | <b>34.56</b>  | <b>43.84</b>           |                     |                    |                |                        |               |               |               |               | <b>841.60</b>  |
|  | 72.89                     | 222.74        | 29.59        | 21.08         | 53.21         | 409.70                 | 28.48               | 36.10              | 188.35         | 23.33                  | 129.62        | 63.43         | 24.82         | 542.34        | 3471.39        |
|  | -8.76                     | 0.58          | 19.49        | 3.83          | 147.67        | 172.93                 | 7.88                | 13.99              | 12.07          | 42.51                  | 52.69         | 57.82         | 158.73        | -1.16         | 1046.68        |
|  | 64.12                     | 223.32        | 49.08        | 24.90         | 200.89        | 582.63                 | 36.35               | 50.10              | 200.42         | 65.85                  | 182.32        | 121.25        | 183.55        | 541.19        | 4518.08        |
|  | <b>297.30</b>             |               |              | <b>200.89</b> | <b>582.63</b> | <b>1,381.01</b>        |                     |                    |                |                        |               |               |               |               | <b>4518.08</b> |
|  | 71.67                     | 218.86        | 73.73        | 25.85         | 239.47        | 648.16                 | 35.81               | 46.98              | 229.74         | 77.09                  | 184.27        | 120.67        | 190.36        | 538.73        | 5030.96        |
|  | <b>318.44</b>             |               |              | <b>239.47</b> | <b>648.16</b> | <b>1,423.65</b>        |                     |                    |                |                        |               |               |               |               | <b>5030.96</b> |
|  | 72.20                     | 220.69        | 69.03        | 33.68         | 176.76        | 610.83                 | 33.58               | 44.17              | 226.50         | 75.03                  | 167.30        | 105.73        | 144.67        | 540.57        | 5153.27        |
|  | <b>323.40</b>             |               |              | <b>176.76</b> | <b>610.83</b> | <b>1,337.55</b>        |                     |                    |                |                        |               |               |               |               | <b>5153.27</b> |
|  | 70.25                     | 218.32        | 67.39        | 26.54         | 173.74        | 601.56                 | 32.81               | 42.34              | 223.91         | 73.93                  | 167.14        | 105.43        | 144.06        | 538.80        | 5043.78        |
|  | <b>312.25</b>             |               |              | <b>173.74</b> | <b>601.56</b> | <b>1,328.42</b>        |                     |                    |                |                        |               |               |               |               | <b>5043.78</b> |



**TABLE 51: 2020 WATER RESOURCES AND DEMAND SUMMARY OF SAFE YIELD, CONSUMPTIVE ALLOCATION, AND DEMAND**

| BASIN                                                                                                              |                         | BLUE MOUNTAIN SOUTH         |                 |                  | KINGS-<br>TON | RIO<br>COBRE | RIO MINHO    |               |                                       | BLACK<br>RIVER | CABARITA RIVER           |                   |                            |  |
|--------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------|-----------------|------------------|---------------|--------------|--------------|---------------|---------------------------------------|----------------|--------------------------|-------------------|----------------------------|--|
| WMU                                                                                                                |                         | PLANTAIN<br>GARDEN<br>RIVER | MORANT<br>RIVER | YALLAHS<br>RIVER | HOPE<br>RIVER | RIO<br>COBRE | RIO<br>MINHO | MILK<br>RIVER | GUT RIV-<br>ER-ALLI-<br>GATOR<br>HOLE | BLACK<br>RIVER | DEANS<br>VALLEY<br>RIVER | CABARITA<br>RIVER | NEW SA-<br>VANNAH<br>RIVER |  |
| SAFE YIELD                                                                                                         | GW                      | 71.98                       | 345.68          | 45.84            | 123.96        | 565.07       | 191.84       | 281.22        | -275.67                               | 71.07          | 377.31                   | 48.62             | -2.00                      |  |
|                                                                                                                    | SW                      | 14.33                       | 26.50           | 53.54            | 3.89          | 87.85        | 81.29        | 23.51         | 91.32                                 | 388.90         | 6.83                     | 76.47             | 0.38                       |  |
|                                                                                                                    | DOMESTIC SW             | 7.74                        | 19.59           | 42.85            | 2.98          | 59.12        | 61.70        | 18.53         | 39.80                                 | 286.03         | 4.18                     | 53.89             | 0.22                       |  |
|                                                                                                                    | WMU TOTAL               | 86.31                       | 372.18          | 99.39            | 127.85        | 652.92       | 273.13       | 304.73        | -184.36                               | 459.97         | 384.14                   | 125.09            | -1.62                      |  |
|                                                                                                                    | WMU DOMESTIC<br>TOTAL   | 79.72                       | 365.27          | 88.70            | 126.93        | 624.19       | 253.55       | 299.75        | -235.87                               | 357.10         | 381.49                   | 102.51            | -1.78                      |  |
|                                                                                                                    | BASIN TOTAL             | 557.87                      |                 |                  | 127.85        | 652.92       | 393.50       |               |                                       | 459.97         | 574.76                   |                   |                            |  |
|                                                                                                                    | BASIN DOMESTIC<br>TOTAL | 533.68                      |                 |                  | 126.93        | 624.19       | 317.42       |               |                                       | 357.10         | 547.95                   |                   |                            |  |
| TOTAL CONSUMPTIVE AL-<br>LOCATION                                                                                  | GW                      | 0.29                        | 12.90           | 9.72             | 25.73         | 141.51       | 70.45        | 201.09        | 1.66                                  | 92.91          | 2.29                     | 0.00              | 0.00                       |  |
|                                                                                                                    | SW                      | 8.58                        | 4.64            | 22.10            | 7.61          | 296.73       | 3.96         | 4.37          | 0.00                                  | 93.47          | 6.54                     | 40.39             | 0.00                       |  |
|                                                                                                                    | WMU TOTAL               | 8.87                        | 17.54           | 31.83            | 33.34         | 438.24       | 74.41        | 205.46        | 1.66                                  | 186.37         | 8.84                     | 40.39             | 0.00                       |  |
|                                                                                                                    | BASIN TOTAL             | 58.23                       |                 |                  | 33.34         | 438.24       | 281.53       |               |                                       | 186.37         | 60.78                    |                   |                            |  |
| DEMAND                                                                                                             | DOMESTIC                | 0.78                        | 5.01            | 1.83             | 48.62         | 43.74        | 11.71        | 16.01         | 1.00                                  | 12.58          | 4.71                     | 3.68              | 0.51                       |  |
|                                                                                                                    | COMMERCIAL              | 0.19                        | 1.25            | 0.46             | 12.15         | 10.93        | 2.93         | 4.00          | 0.25                                  | 3.14           | 1.18                     | 0.92              | 0.13                       |  |
|                                                                                                                    | INSTITUTIONAL           | 0.19                        | 1.25            | 0.46             | 12.15         | 10.93        | 2.93         | 4.00          | 0.25                                  | 3.14           | 1.18                     | 0.92              | 0.13                       |  |
|                                                                                                                    | TOURISM                 | 0.00                        | 0.03            | 0.01             | 0.46          | 0.10         | 0.01         | 0.09          | 0.00                                  | 0.14           | 0.14                     | 0.00              | 0.01                       |  |
|                                                                                                                    | IRRIGATION              | 4.46                        | 1.94            | 6.44             | 1.86          | 152.82       | 41.42        | 208.72        | 0.00                                  | 40.37          | 0.00                     | 0.00              | 0.00                       |  |
|                                                                                                                    | INDUSTRIAL              | 0.00                        | 0.00            | 0.01             | 8.50          | 19.70        | 0.50         | 12.40         | 0.00                                  | 24.80          | 2.20                     | 0.00              | 0.00                       |  |
|                                                                                                                    | WMU TOTAL               | 5.63                        | 9.48            | 9.20             | 83.74         | 238.23       | 59.50        | 245.23        | 1.49                                  | 84.18          | 9.40                     | 5.53              | 0.77                       |  |
|                                                                                                                    | BASIN TOTAL             | 24.32                       |                 |                  | 83.74         | 238.23       | 306.22       |               |                                       | 84.18          | 20.12                    |                   |                            |  |
| Water Available for Con-<br>sumptive Allocation (Safe<br>Yield - Consumptive Allocat-<br>ed Water)                 | GW                      | 71.69                       | 332.78          | 36.12            | 98.23         | 423.56       | 121.39       | 80.13         | -277.33                               | -21.84         | 375.01                   | 48.62             | -2.00                      |  |
|                                                                                                                    | SW                      | 5.75                        | 21.86           | 31.44            | -3.72         | -208.88      | 77.32        | 19.14         | 91.32                                 | 295.44         | 0.29                     | 36.08             | 0.38                       |  |
|                                                                                                                    | WMU TOTAL               | 77.44                       | 354.63          | 67.56            | 94.51         | 214.68       | 198.72       | 99.27         | -186.02                               | 273.59         | 375.30                   | 84.70             | -1.62                      |  |
|                                                                                                                    | BASIN TOTAL             | 499.63                      |                 |                  | 94.51         | 214.68       | 111.97       |               |                                       | 273.59         | 513.99                   |                   |                            |  |
| General Water Surplus/<br>Deficit (Safe Yield - Water<br>Demand)                                                   | WMU TOTAL               | 80.67                       | 362.69          | 90.19            | 44.10         | 414.69       | 213.63       | 59.50         | -185.85                               | 375.79         | 374.73                   | 119.56            | -2.39                      |  |
|                                                                                                                    | BASIN TOTAL             | 533.55                      |                 |                  | 44.10         | 414.69       | 87.28        |               |                                       | 375.79         | 554.64                   |                   |                            |  |
| Domestic Water Availability<br>(Domestic Safe Yield - Do-<br>mestic Demand)                                        | WMU TOTAL               | 78.94                       | 360.26          | 86.87            | 78.32         | 580.45       | 241.83       | 283.74        | -236.87                               | 344.52         | 376.78                   | 98.83             | -2.29                      |  |
|                                                                                                                    | BASIN TOTAL             | 526.06                      |                 |                  | 78.32         | 580.45       | 288.70       |               |                                       | 344.52         | 536.87                   |                   |                            |  |
| Municipal Water Availability<br>Domestic Safe Yield - (Do-<br>mestic+Institutional+Com-<br>mercial+Tourism Demand) | WMU TOTAL               | 78.54                       | 357.73          | 85.94            | 53.55         | 558.48       | 235.97       | 275.64        | -237.37                               | 338.09         | 374.29                   | 96.98             | -2.55                      |  |
|                                                                                                                    | BASIN TOTAL             | 522.21                      |                 |                  | 53.55         | 558.48       | 274.24       |               |                                       | 338.09         | 530.04                   |                   |                            |  |



|                            | GREAT RIVER   |              |               | MARTHA BRAE   | DRY HARBOUR MOUNTAINS  | BLUE MOUNTAIN NORTH |                    |                 |                        |               |               |               |               | TOTAL          |
|----------------------------|---------------|--------------|---------------|---------------|------------------------|---------------------|--------------------|-----------------|------------------------|---------------|---------------|---------------|---------------|----------------|
| SOUTH NE-GRIL-ORANGE RIVER | LUCEA RIVER   | GREAT RIVER  | MONTEGO RIVER | MARTHA BRAE   | RIO BUE-NO-WHITE RIVER | RIO NUEVO           | ORA-CABES-SA-PAGEE | WAG-WATER RIVER | PEN-CAR-BUFF BAY RIVER | SPANISH RIVER | SWIFT RIVER   | RIO GRANDE    | DRIVERS RIVER |                |
| 64.85                      | 209.01        | 10.02        | 29.36         | 34.96         | 363.59                 | 23.05               | 28.12              | 178.56          | 20.47                  | 0.43          | 51.65         | -3.76         | 521.22        | 3376.42        |
| 2.31                       | 1.71          | 56.58        | 9.16          | 176.46        | 245.39                 | 9.54                | 16.21              | 48.35           | 49.49                  | 55.15         | 58.15         | 163.05        | 1.14          | 1747.48        |
| 0.89                       | 1.17          | 42.45        | 6.48          | 110.36        | 189.10                 | 6.54                | 11.57              | 33.56           | 39.27                  | 37.99         | 42.88         | 116.76        | 0.32          | 1235.98        |
| <b>67.16</b>               | <b>210.72</b> | <b>66.60</b> | <b>38.52</b>  | <b>211.42</b> | <b>608.97</b>          | <b>32.59</b>        | <b>44.33</b>       | <b>226.91</b>   | <b>69.96</b>           | <b>55.57</b>  | <b>109.80</b> | <b>159.29</b> | <b>522.35</b> | <b>5123.90</b> |
| <b>65.74</b>               | <b>210.18</b> | <b>52.47</b> | <b>35.84</b>  | <b>145.32</b> | <b>552.68</b>          | <b>29.59</b>        | <b>39.69</b>       | <b>212.12</b>   | <b>59.75</b>           | <b>38.42</b>  | <b>94.54</b>  | <b>113.00</b> | <b>521.53</b> | <b>4612.40</b> |
|                            | <b>315.84</b> |              |               | <b>211.42</b> | <b>608.97</b>          | <b>1220.80</b>      |                    |                 |                        |               |               |               |               | <b>5123.90</b> |
|                            | <b>298.49</b> |              |               | <b>145.32</b> | <b>552.68</b>          | <b>1108.63</b>      |                    |                 |                        |               |               |               |               | <b>4612.40</b> |
| 0.48                       | 0.84          | 0.24         | 17.53         | 18.48         | 27.63                  | 0.00                | 0.00               | 9.77            | 14.62                  | 0.00          | 0.02          | 4.28          | 1.24          | 653.69         |
| 11.07                      | 1.13          | 37.09        | 5.34          | 28.79         | 72.46                  | 1.66                | 2.21               | 36.28           | 6.98                   | 2.45          | 0.33          | 4.33          | 2.29          | 700.80         |
| 11.55                      | 1.97          | 37.33        | 22.87         | 47.27         | 100.10                 | 1.66                | 2.21               | 46.06           | 21.60                  | 2.45          | 0.35          | 8.61          | 3.53          | 1354.49        |
|                            | <b>62.16</b>  |              |               | <b>47.27</b>  | <b>100.10</b>          | <b>86.48</b>        |                    |                 |                        |               |               |               |               | <b>1354.49</b> |
| 2.18                       | 4.12          | 3.12         | 11.92         | 5.42          | 15.74                  | 1.43                | 3.54               | 5.30            | 2.25                   | 0.31          | 0.61          | 1.21          | 3.32          | 210.68         |
| 0.55                       | 1.03          | 0.78         | 2.98          | 1.36          | 3.94                   | 0.36                | 0.89               | 1.32            | 0.56                   | 0.08          | 0.15          | 0.30          | 0.83          | 52.67          |
| 0.55                       | 1.03          | 0.78         | 2.98          | 1.36          | 3.94                   | 0.36                | 0.89               | 1.32            | 0.56                   | 0.08          | 0.15          | 0.30          | 0.83          | 52.67          |
| 1.15                       | 0.41          | 0.03         | 1.77          | 0.46          | 1.82                   | 0.06                | 0.10               | 0.01            | 0.01                   | 0.00          | 0.00          | 0.01          | 0.12          | 6.93           |
| 0.00                       | 0.00          | 8.42         | 0.40          | 0.40          | 3.78                   | 0.00                | 0.00               | 9.66            | 7.63                   | 0.00          | 0.02          | 0.00          | 0.96          | 489.30         |
| 0.00                       | 0.00          | 0.00         | 3.20          | 0.00          | 6.70                   | 0.00                | 0.00               | 0.04            | 0.00                   | 0.40          | 0.00          | 0.00          | 0.96          | 79.41          |
| 4.42                       | 6.59          | 13.13        | 23.26         | 8.99          | 35.92                  | 2.21                | 5.41               | 17.65           | 11.02                  | 0.87          | 0.93          | 1.83          | 7.02          | 891.66         |
|                            | <b>42.98</b>  |              |               | <b>8.99</b>   | <b>35.92</b>           | <b>46.95</b>        |                    |                 |                        |               |               |               |               | <b>891.66</b>  |
| 64.38                      | 208.16        | 9.78         | 11.83         | 16.48         | 335.95                 | 23.05               | 28.12              | 168.78          | 5.85                   | 0.43          | 51.64         | -8.05         | 519.97        | 2722.73        |
| -8.76                      | 0.58          | 19.49        | 3.83          | 147.67        | 172.93                 | 7.88                | 13.99              | 12.07           | 42.51                  | 52.69         | 57.82         | 158.73        | -1.16         | 1046.68        |
| 55.61                      | 208.75        | 29.27        | 15.66         | 164.15        | 508.88                 | 30.93               | 42.12              | 180.85          | 48.36                  | 53.12         | 109.45        | 150.68        | 518.82        | 3769.42        |
|                            | <b>253.68</b> |              |               | <b>164.15</b> | <b>508.88</b>          | <b>1,134.33</b>     |                    |                 |                        |               |               |               |               | <b>3769.42</b> |
| 62.74                      | 204.12        | 53.47        | 15.27         | 202.42        | 573.05                 | 30.38               | 38.92              | 209.26          | 58.94                  | 54.70         | 108.87        | 157.46        | 515.33        | 4232.25        |
|                            | <b>272.86</b> |              |               | <b>202.42</b> | <b>573.05</b>          | <b>1,173.85</b>     |                    |                 |                        |               |               |               |               | <b>4232.25</b> |
| 63.56                      | 206.06        | 49.35        | 23.92         | 139.90        | 536.94                 | 28.16               | 36.15              | 206.82          | 57.49                  | 38.10         | 93.93         | 111.78        | 518.21        | 4401.72        |
|                            | <b>279.32</b> |              |               | <b>139.90</b> | <b>536.94</b>          | <b>1,090.65</b>     |                    |                 |                        |               |               |               |               | <b>4401.72</b> |
| 61.32                      | 203.59        | 47.76        | 16.19         | 136.73        | 527.24                 | 27.38               | 34.28              | 204.17          | 56.36                  | 37.94         | 93.62         | 111.17        | 516.43        | 4289.46        |
|                            | <b>267.53</b> |              |               | <b>136.73</b> | <b>527.24</b>          | <b>1,081.35</b>     |                    |                 |                        |               |               |               |               | <b>4289.46</b> |



TABLE 52: 2025 WATER RESOURCES AND DEMAND SUMMARY OF SAFE YIELD, CONSUMPTIVE ALLOCATION, AND DEMAND

| BASIN                                                                                                   |                      | BLUE MOUNTAIN SOUTH   |              |               | KINGS-TON  | RIO COBRE | RIO MINHO |            |                          | BLACK RIVER | CABARITA RIVER     |                |                    |                           |  |
|---------------------------------------------------------------------------------------------------------|----------------------|-----------------------|--------------|---------------|------------|-----------|-----------|------------|--------------------------|-------------|--------------------|----------------|--------------------|---------------------------|--|
| WMU                                                                                                     |                      | PLANTAIN GARDEN RIVER | MORANT RIVER | YALLAHS RIVER | HOPE RIVER | RIO COBRE | RIO MINHO | MILK RIVER | GUT RIVER-ALLIGATOR HOLE | BLACK RIVER | DEANS VALLEY RIVER | CABARITA RIVER | NEW SAVANNAH RIVER | SOUTH NEGRIL-ORANGE RIVER |  |
| SAFE YIELD                                                                                              | GW                   | 62.09                 | 327.98       | 32.40         | 112.10     | 505.51    | 156.88    | 240.38     | -282.25                  | 3.51        | 351.37             | 31.74          | -3.82              | 57.80                     |  |
|                                                                                                         | SW                   | 14.33                 | 26.50        | 53.54         | 3.89       | 87.85     | 81.29     | 23.51      | 91.32                    | 388.90      | 6.83               | 76.47          | 0.38               | 2.31                      |  |
|                                                                                                         | DOMESTIC SW          | 7.74                  | 19.59        | 42.85         | 2.98       | 59.12     | 61.70     | 18.53      | 39.80                    | 286.03      | 4.18               | 53.89          | 0.22               | 0.89                      |  |
|                                                                                                         | WMU TOTAL            | 76.42                 | 354.48       | 85.94         | 115.99     | 593.36    | 238.17    | 263.89     | -190.93                  | 392.41      | 358.20             | 108.21         | -3.44              | 60.10                     |  |
|                                                                                                         | WMU DOMESTIC TOTAL   | 69.83                 | 347.57       | 75.25         | 115.08     | 564.63    | 218.58    | 258.91     | -242.45                  | 289.54      | 355.55             | 85.63          | -3.60              | 58.68                     |  |
|                                                                                                         | BASIN TOTAL          | 516.84                |              |               | 115.99     | 593.36    | 311.12    |            |                          | 392.41      | 523.07             |                |                    |                           |  |
|                                                                                                         | BASIN DOMESTIC TOTAL | 492.65                |              |               | 115.08     | 564.63    | 235.04    |            |                          | 289.54      | 496.26             |                |                    |                           |  |
| TOTAL CONSUMPTIVE ALLOCATION                                                                            | GW                   | 0.29                  | 12.90        | 9.72          | 25.73      | 141.51    | 70.45     | 201.09     | 1.66                     | 92.91       | 2.29               | 0.00           | 0.00               | 0.48                      |  |
|                                                                                                         | SW                   | 8.58                  | 4.64         | 22.10         | 7.61       | 296.73    | 3.96      | 4.37       | 0.00                     | 93.47       | 6.54               | 40.39          | 0.00               | 11.07                     |  |
|                                                                                                         | WMU TOTAL            | 8.87                  | 17.54        | 31.83         | 33.34      | 438.24    | 74.41     | 205.46     | 1.66                     | 186.37      | 8.84               | 40.39          | 0.00               | 11.55                     |  |
|                                                                                                         | BASIN TOTAL          | 58.23                 |              |               | 33.34      | 438.24    | 281.53    |            |                          | 186.37      | 60.78              |                |                    |                           |  |
| DEMAND                                                                                                  | DOMESTIC             | 0.73                  | 5.08         | 1.84          | 48.84      | 45.20     | 11.77     | 16.42      | 0.98                     | 12.67       | 4.75               | 3.72           | 0.51               | 2.36                      |  |
|                                                                                                         | COMMERCIAL           | 0.18                  | 1.27         | 0.46          | 12.21      | 11.30     | 2.94      | 4.11       | 0.24                     | 3.17        | 1.19               | 0.93           | 0.13               | 0.59                      |  |
|                                                                                                         | INSTITUTIONAL        | 0.18                  | 1.27         | 0.46          | 12.21      | 11.30     | 2.94      | 4.11       | 0.24                     | 3.17        | 1.19               | 0.93           | 0.13               | 0.59                      |  |
|                                                                                                         | TOURISM              | 0.01                  | 0.04         | 0.01          | 0.60       | 0.13      | 0.01      | 0.12       | 0.00                     | 0.19        | 0.18               | 0.01           | 0.01               | 1.50                      |  |
|                                                                                                         | IRRIGATION           | 4.92                  | 2.14         | 7.11          | 2.05       | 168.73    | 45.73     | 230.44     | 0.00                     | 44.57       | 0.00               | 0.00           | 0.00               | 0.00                      |  |
|                                                                                                         | INDUSTRIAL           | 0.00                  | 0.00         | 0.01          | 9.40       | 21.80     | 0.60      | 13.70      | 0.00                     | 27.40       | 2.40               | 0.00           | 0.00               | 0.00                      |  |
|                                                                                                         | WMU TOTAL            | 6.02                  | 9.80         | 9.88          | 85.30      | 258.46    | 63.99     | 268.90     | 1.47                     | 91.17       | 9.71               | 5.58           | 0.77               | 5.04                      |  |
|                                                                                                         | BASIN TOTAL          | 25.70                 |              |               | 85.30      | 258.46    | 334.36    |            |                          | 91.17       | 21.09              |                |                    |                           |  |
| Water Available for Consumptive Allocation (Safe Yield - Consumptive Allocated Water)                   | GW                   | 61.80                 | 315.08       | 22.67         | 86.38      | 364.01    | 86.43     | 39.29      | -283.91                  | -89.40      | 349.08             | 31.74          | -3.82              | 57.32                     |  |
|                                                                                                         | SW                   | 5.75                  | 21.86        | 31.44         | -3.72      | -208.88   | 77.32     | 19.14      | 91.32                    | 295.44      | 0.29               | 36.08          | 0.38               | -8.76                     |  |
|                                                                                                         | WMU TOTAL            | 67.55                 | 336.94       | 54.11         | 82.66      | 155.13    | 163.75    | 58.43      | -192.59                  | 206.04      | 349.36             | 67.82          | -3.44              | 48.55                     |  |
|                                                                                                         | BASIN TOTAL          | 458.60                |              |               | 82.66      | 155.13    | 29.59     |            |                          | 206.04      | 462.30             |                |                    |                           |  |
| General Water Surplus/Deficit (Safe Yield - Water Demand)                                               | WMU TOTAL            | 70.40                 | 344.69       | 76.05         | 30.69      | 334.90    | 174.17    | -5.01      | -192.40                  | 301.25      | 348.49             | 102.63         | -4.21              | 55.07                     |  |
|                                                                                                         | BASIN TOTAL          | 491.14                |              |               | 30.69      | 334.90    | -23.23    |            |                          | 301.25      | 501.98             |                |                    |                           |  |
| Domestic Water Availability (Domestic Safe Yield - Domestic Demand)                                     | WMU TOTAL            | 69.10                 | 342.49       | 73.41         | 66.24      | 519.43    | 206.81    | 242.48     | -243.43                  | 276.87      | 350.80             | 81.91          | -4.11              | 56.33                     |  |
|                                                                                                         | BASIN TOTAL          | 485.00                |              |               | 66.24      | 519.43    | 205.87    |            |                          | 276.87      | 484.93             |                |                    |                           |  |
| Municipal Water Availability (Domestic Safe Yield - (Domestic+Institutional+Commercial+Tourism Demand)) | WMU TOTAL            | 68.73                 | 339.92       | 72.48         | 41.22      | 496.70    | 200.92    | 234.15     | -243.92                  | 270.35      | 348.25             | 80.05          | -4.37              | 53.65                     |  |
|                                                                                                         | BASIN TOTAL          | 481.13                |              |               | 41.22      | 496.70    | 191.16    |            |                          | 270.35      | 477.57             |                |                    |                           |  |



| GREAT RIVER |             |               | MARTHA BRAE | DRY HARBOUR MOUNTAINS  | BLUE MOUNTAIN NORTH |                    |                  |                        |               |             |            |               | TOTAL   |
|-------------|-------------|---------------|-------------|------------------------|---------------------|--------------------|------------------|------------------------|---------------|-------------|------------|---------------|---------|
| LUCEA RIVER | GREAT RIVER | MORTEGO RIVER | MARTHA BRAE | RIO BUE-NO-WHITE RIVER | RIO NUEVO           | ORA-CABES-SA-PAGEE | WAG-WA-TER RIVER | PEN-CAR-BUFF BAY RIVER | SPANISH RIVER | SWIFT RIVER | RIO GRANDE | DRIVERS RIVER |         |
| 195.20      | -9.68       | 20.75         | 1.39        | 290.85                 | 17.65               | 20.74              | 161.83           | 6.82                   | 109.20        | 42.10       | -29.26     | 502.38        | 2925.66 |
| 1.71        | 56.58       | 9.16          | 176.46      | 245.39                 | 9.54                | 16.21              | 48.35            | 49.49                  | 55.15         | 58.15       | 163.05     | 1.14          | 1747.48 |
| 1.17        | 42.45       | 6.48          | 110.36      | 189.10                 | 6.54                | 11.57              | 33.56            | 39.27                  | 37.99         | 42.88       | 116.76     | 0.32          | 1235.98 |
| 196.91      | 46.91       | 29.91         | 177.85      | 536.24                 | 27.19               | 36.95              | 210.18           | 56.31                  | 164.35        | 100.25      | 133.79     | 503.52        | 4673.15 |
| 196.38      | 32.78       | 27.23         | 111.75      | 479.94                 | 24.19               | 32.31              | 195.39           | 46.09                  | 147.19        | 84.98       | 87.50      | 502.70        | 4161.64 |
| 273.73      |             |               | 177.85      | 536.24                 | 1232.53             |                    |                  |                        |               |             |            |               | 4673.15 |
| 256.39      |             |               | 111.75      | 479.94                 | 1120.36             |                    |                  |                        |               |             |            |               | 4161.64 |
| 0.84        | 0.24        | 17.53         | 18.48       | 27.63                  | 0.00                | 0.00               | 9.77             | 14.62                  | 0.00          | 0.02        | 4.28       | 1.24          | 653.69  |
| 1.13        | 37.09       | 5.34          | 28.79       | 72.46                  | 1.66                | 2.21               | 36.28            | 6.98                   | 2.45          | 0.33        | 4.33       | 2.29          | 700.80  |
| 1.97        | 37.33       | 22.87         | 47.27       | 100.10                 | 1.66                | 2.21               | 46.06            | 21.60                  | 2.45          | 0.35        | 8.61       | 3.53          | 1354.49 |
| 62.16       |             |               | 47.27       | 100.10                 | 86.48               |                    |                  |                        |               |             |            |               | 1354.49 |
| 4.19        | 2.97        | 12.60         | 5.59        | 15.93                  | 1.42                | 3.60               | 5.45             | 2.32                   | 0.32          | 0.62        | 1.24       | 3.31          | 214.41  |
| 1.05        | 0.74        | 3.15          | 1.40        | 3.98                   | 0.36                | 0.90               | 1.36             | 0.58                   | 0.08          | 0.15        | 0.31       | 0.83          | 53.60   |
| 1.05        | 0.74        | 3.15          | 1.40        | 3.98                   | 0.36                | 0.90               | 1.36             | 0.58                   | 0.08          | 0.15        | 0.31       | 0.83          | 53.60   |
| 0.54        | 0.03        | 2.31          | 0.60        | 2.38                   | 0.08                | 0.13               | 0.01             | 0.01                   | 0.00          | 0.00        | 0.01       | 0.15          | 9.05    |
| 0.00        | 9.29        | 0.44          | 0.44        | 4.17                   | 0.00                | 0.00               | 10.67            | 8.43                   | 0.00          | 0.02        | 0.00       | 1.06          | 540.21  |
| 0.00        | 0.00        | 0.36          | 0.00        | 7.40                   | 0.00                | 0.00               | 0.04             | 0.00                   | 0.40          | 0.00        | 0.00       | 0.00          | 83.51   |
| 6.83        | 13.78       | 22.01         | 9.42        | 37.84                  | 2.22                | 5.52               | 18.89            | 11.93                  | 0.88          | 0.95        | 1.87       | 6.17          | 954.39  |
| 42.63       |             |               | 9.42        | 37.84                  | 48.42               |                    |                  |                        |               |             |            |               | 954.39  |
| 194.36      | -9.92       | 3.22          | -17.09      | 263.21                 | 17.65               | 20.74              | 152.05           | -7.80                  | 109.20        | 42.08       | -33.55     | 501.14        | 2271.97 |
| 0.58        | 19.49       | 3.83          | 147.67      | 172.93                 | 7.88                | 13.99              | 12.07            | 42.51                  | 52.69         | 57.82       | 158.73     | -1.16         | 1046.68 |
| 194.94      | 9.58        | 7.05          | 130.58      | 436.14                 | 25.53               | 34.74              | 164.12           | 34.71                  | 161.89        | 99.90       | 125.18     | 499.98        | 3318.66 |
| 211.57      |             |               | 130.58      | 436.14                 | 1,146.05            |                    |                  |                        |               |             |            |               | 3318.66 |
| 190.08      | 33.12       | 7.90          | 168.43      | 498.39                 | 24.97               | 31.43              | 191.29           | 44.38                  | 163.47        | 99.30       | 131.92     | 497.34        | 3718.76 |
| 231.10      |             |               | 168.43      | 498.39                 | 1,184.11            |                    |                  |                        |               |             |            |               | 3718.76 |
| 192.18      | 29.80       | 14.63         | 106.16      | 464.02                 | 22.77               | 28.72              | 189.95           | 43.77                  | 146.87        | 84.36       | 86.26      | 499.39        | 3947.24 |
| 236.62      |             |               | 106.16      | 464.02                 | 1,102.09            |                    |                  |                        |               |             |            |               | 3947.24 |
| 189.55      | 28.28       | 6.02          | 102.77      | 453.67                 | 21.98               | 26.79              | 187.21           | 42.60                  | 146.71        | 84.05       | 85.63      | 497.58        | 3830.98 |
| 223.85      |             |               | 102.77      | 453.67                 | 1,092.56            |                    |                  |                        |               |             |            |               | 3830.98 |



TABLE 53: 2030 WATER RESOURCES AND DEMAND SUMMARY OF SAFE YIELD, CONSUMPTIVE ALLOCATION, AND DEMAND

| BASIN                                                                                                   |                      | BLUE MOUNTAIN SOUTH   |              |               | KINGS-TON  | RIO COBRE | RIO MINHO |            |                          | BLACK RIVER | CABARITA RIVER     |                |                    |                            |
|---------------------------------------------------------------------------------------------------------|----------------------|-----------------------|--------------|---------------|------------|-----------|-----------|------------|--------------------------|-------------|--------------------|----------------|--------------------|----------------------------|
| WMU                                                                                                     |                      | PLANTAIN GARDEN RIVER | MORANT RIVER | YALLAHS RIVER | HOPE RIVER | RIO COBRE | RIO MINHO | MILK RIVER | GUT RIVER-ALLIGATOR HOLE | BLACK RIVER | DEANS VALLEY RIVER | CABARITA RIVER | NEW SAVANNAH RIVER | SOUTH NE-GRIL-ORANGE RIVER |
| SAFE YIELD                                                                                              | GW                   | 45.19                 | 293.27       | 17.33         | 96.12      | 423.56    | 109.98    | 191.05     | -291.19                  | -85.51      | 320.43             | 10.66          | -6.58              | 45.59                      |
|                                                                                                         | SW                   | 14.33                 | 26.50        | 53.54         | 3.89       | 87.85     | 81.29     | 23.51      | 91.32                    | 388.90      | 6.83               | 76.47          | 0.38               | 2.31                       |
|                                                                                                         | DOMESTIC SW          | 7.74                  | 19.59        | 42.85         | 2.98       | 59.12     | 61.70     | 18.53      | 39.80                    | 286.03      | 4.18               | 53.89          | 0.22               | 0.89                       |
|                                                                                                         | WMU TOTAL            | 59.52                 | 319.77       | 70.87         | 100.01     | 511.41    | 191.27    | 214.57     | -199.88                  | 303.39      | 327.26             | 87.12          | -6.20              | 47.90                      |
|                                                                                                         | WMU DOMESTIC TOTAL   | 52.93                 | 312.86       | 60.18         | 99.10      | 482.68    | 171.68    | 209.59     | -251.39                  | 200.52      | 324.61             | 64.54          | -6.36              | 46.48                      |
|                                                                                                         | BASIN TOTAL          | 450.16                |              |               | 100.01     | 511.41    | 205.96    |            |                          | 303.39      | 456.08             |                |                    |                            |
|                                                                                                         | BASIN DOMESTIC TOTAL | 425.97                |              |               | 99.10      | 482.68    | 129.88    |            |                          | 200.52      | 429.27             |                |                    |                            |
| TOTAL CONSUMPTIVE ALLOCATION                                                                            | GW                   | 0.29                  | 12.90        | 9.72          | 25.73      | 141.51    | 70.45     | 201.09     | 1.66                     | 92.91       | 2.29               | 0.00           | 0.00               | 0.48                       |
|                                                                                                         | SW                   | 8.58                  | 4.64         | 22.10         | 7.61       | 296.73    | 3.96      | 4.37       | 0.00                     | 93.47       | 6.54               | 40.39          | 0.00               | 11.07                      |
|                                                                                                         | WMU TOTAL            | 8.87                  | 17.54        | 31.83         | 33.34      | 438.24    | 74.41     | 205.46     | 1.66                     | 186.37      | 8.84               | 40.39          | 0.00               | 11.55                      |
|                                                                                                         | BASIN TOTAL          | 58.23                 |              |               | 33.34      | 438.24    | 281.53    |            |                          | 186.37      | 60.78              |                |                    |                            |
| DEMAND                                                                                                  | DOMESTIC             | 0.69                  | 5.15         | 1.84          | 49.06      | 46.71     | 11.82     | 16.85      | 0.96                     | 12.77       | 4.79               | 3.76           | 0.50               | 2.55                       |
|                                                                                                         | COMMERCIAL           | 0.17                  | 1.29         | 0.46          | 12.26      | 11.68     | 2.96      | 4.21       | 0.24                     | 3.19        | 1.20               | 0.94           | 0.13               | 0.64                       |
|                                                                                                         | INSTITUTIONAL        | 0.17                  | 1.29         | 0.46          | 12.26      | 11.68     | 2.96      | 4.21       | 0.24                     | 3.19        | 1.20               | 0.94           | 0.13               | 0.64                       |
|                                                                                                         | TOURISM              | 0.01                  | 0.05         | 0.01          | 0.78       | 0.17      | 0.01      | 0.16       | 0.00                     | 0.24        | 0.23               | 0.01           | 0.01               | 1.96                       |
|                                                                                                         | IRRIGATION           | 5.44                  | 2.36         | 7.85          | 2.27       | 186.29    | 50.49     | 254.42     | 0.00                     | 49.21       | 0.00               | 0.00           | 0.00               | 0.00                       |
|                                                                                                         | INDUSTRIAL           | 0.00                  | 0.00         | 0.01          | 10.40      | 24.15     | 0.60      | 15.10      | 0.00                     | 30.20       | 2.60               | 0.00           | 0.00               | 0.00                       |
|                                                                                                         | WMU TOTAL            | 6.48                  | 10.13        | 10.64         | 87.04      | 280.68    | 68.83     | 294.95     | 1.44                     | 98.80       | 10.02              | 5.64           | 0.76               | 5.78                       |
|                                                                                                         | BASIN TOTAL          | 27.25                 |              |               | 87.04      | 280.68    | 365.22    |            |                          | 98.80       | 22.21              |                |                    |                            |
| Water Available for Consumptive Allocation (Safe Yield - Consumptive Allocated Water)                   | GW                   | 44.90                 | 280.37       | 7.60          | 70.40      | 282.05    | 39.53     | -10.03     | -292.85                  | -178.42     | 318.13             | 10.66          | -6.58              | 45.12                      |
|                                                                                                         | SW                   | 5.75                  | 21.86        | 31.44         | -3.72      | -208.88   | 77.32     | 19.14      | 91.32                    | 295.44      | 0.29               | 36.08          | 0.38               | -8.76                      |
|                                                                                                         | WMU TOTAL            | 50.65                 | 302.23       | 39.04         | 66.68      | 73.17     | 116.85    | 9.11       | -201.53                  | 117.02      | 318.42             | 46.73          | -6.20              | 36.35                      |
|                                                                                                         | BASIN TOTAL          | 391.92                |              |               | 66.68      | 73.17     | -75.57    |            |                          | 117.02      | 395.30             |                |                    |                            |
| General Water Surplus/ Deficit (Safe Yield - Water Demand)                                              | WMU TOTAL            | 53.04                 | 309.64       | 60.23         | 12.98      | 230.73    | 122.43    | -80.38     | -201.32                  | 204.59      | 317.23             | 81.48          | -6.97              | 42.12                      |
|                                                                                                         | BASIN TOTAL          | 422.91                |              |               | 12.98      | 230.73    | -159.27   |            |                          | 204.59      | 433.87             |                |                    |                            |
| Domestic Water Availability (Domestic Safe Yield - Domestic Demand)                                     | WMU TOTAL            | 52.24                 | 307.71       | 58.34         | 50.04      | 435.97    | 159.86    | 192.74     | -252.35                  | 187.75      | 319.81             | 60.79          | -6.87              | 43.94                      |
|                                                                                                         | BASIN TOTAL          | 418.29                |              |               | 50.04      | 435.97    | 100.25    |            |                          | 187.75      | 417.67             |                |                    |                            |
| Municipal Water Availability (Domestic Safe Yield - (Domestic+Institutional+Commercial+Tourism Demand)) | WMU TOTAL            | 51.89                 | 305.09       | 57.40         | 24.73      | 412.44    | 153.94    | 184.16     | -252.83                  | 181.13      | 317.18             | 58.90          | -7.13              | 40.70                      |
|                                                                                                         | BASIN TOTAL          | 414.38                |              |               | 24.73      | 412.44    | 85.26     |            |                          | 181.13      | 409.66             |                |                    |                            |



|  | GREAT RIVER   |              |               | MARTHA BRAE   | DRY HARBOUR MOUNTAINS  | BLUE MOUNTAIN NORTH |                    |                  |                        |               |              |               |               | TOTAL          |
|--|---------------|--------------|---------------|---------------|------------------------|---------------------|--------------------|------------------|------------------------|---------------|--------------|---------------|---------------|----------------|
|  | LUCEA RIVER   | GREAT RIVER  | MONTEGO RIVER | MARTHA BRAE   | RIO BUE-NO-WHITE RIVER | RIO NUEVO           | ORA-CABES-SA-PAGEE | WAG-WA-TER RIVER | PEN-CAR-BUFF BAY RIVER | SPANISH RIVER | SWIFT RIVER  | RIO GRANDE    | DRIVERS RIVER |                |
|  | 176.70        | -34.74       | 7.93          | -46.68        | 189.68                 | 10.63               | 10.08              | 139.20           | -11.40                 | 97.85         | 30.07        | -62.93        | 476.63        | 2152.90        |
|  | 1.71          | 56.58        | 9.16          | 176.46        | 245.39                 | 9.54                | 16.21              | 48.35            | 49.49                  | 55.15         | 58.15        | 163.05        | 1.14          | 1747.48        |
|  | 1.17          | 42.45        | 6.48          | 110.36        | 189.10                 | 6.54                | 11.57              | 33.56            | 39.27                  | 37.99         | 42.88        | 116.76        | 0.32          | 1235.98        |
|  | <b>178.41</b> | <b>21.85</b> | <b>17.09</b>  | <b>129.78</b> | <b>435.07</b>          | <b>20.16</b>        | <b>26.28</b>       | <b>187.55</b>    | <b>38.09</b>           | <b>153.00</b> | <b>88.22</b> | <b>100.12</b> | <b>477.76</b> | <b>3900.39</b> |
|  | <b>177.87</b> | <b>7.72</b>  | <b>14.41</b>  | <b>63.68</b>  | <b>378.77</b>          | <b>17.17</b>        | <b>21.65</b>       | <b>172.77</b>    | <b>27.88</b>           | <b>135.84</b> | <b>72.95</b> | <b>53.82</b>  | <b>476.94</b> | <b>3388.89</b> |
|  | <b>217.34</b> |              |               | <b>129.78</b> | <b>435.07</b>          | <b>1091.19</b>      |                    |                  |                        |               |              |               |               | <b>3900.39</b> |
|  | <b>200.00</b> |              |               | <b>63.68</b>  | <b>378.77</b>          | <b>979.02</b>       |                    |                  |                        |               |              |               |               | <b>3388.89</b> |
|  | 0.84          | 0.24         | 17.53         | 18.48         | 27.63                  | 0.00                | 0.00               | 9.77             | 14.62                  | 0.00          | 0.02         | 4.28          | 1.24          | 653.69         |
|  | 1.13          | 37.09        | 5.34          | 28.79         | 72.46                  | 1.66                | 2.21               | 36.28            | 6.98                   | 2.45          | 0.33         | 4.33          | 2.29          | 700.80         |
|  | 1.97          | 37.33        | 22.87         | 47.27         | 100.10                 | 1.66                | 2.21               | 46.06            | 21.60                  | 2.45          | 0.35         | 8.61          | 3.53          | 1354.49        |
|  | <b>62.16</b>  |              |               | <b>47.27</b>  | <b>100.10</b>          | <b>86.48</b>        |                    |                  |                        |               |              |               |               | <b>1354.49</b> |
|  | 4.27          | 2.83         | 13.32         | 5.75          | 16.11                  | 1.41                | 3.65               | 5.60             | 2.40                   | 0.32          | 0.63         | 1.26          | 3.29          | 218.28         |
|  | 1.07          | 0.71         | 3.33          | 1.44          | 4.03                   | 0.35                | 0.91               | 1.40             | 0.60                   | 0.08          | 0.16         | 0.31          | 0.82          | 54.57          |
|  | 1.07          | 0.71         | 3.33          | 1.44          | 4.03                   | 0.35                | 0.91               | 1.40             | 0.60                   | 0.08          | 0.16         | 0.31          | 0.82          | 54.57          |
|  | 0.71          | 0.04         | 3.02          | 0.78          | 3.11                   | 0.11                | 0.17               | 0.01             | 0.01                   | 0.00          | 0.00         | 0.02          | 0.20          | 11.83          |
|  | 0.00          | 10.26        | 0.49          | 0.49          | 4.61                   | 0.00                | 0.00               | 11.78            | 9.31                   | 0.00          | 0.02         | 0.00          | 1.17          | 596.46         |
|  | 0.00          | 0.00         | 3.93          | 0.00          | 8.20                   | 0.00                | 0.00               | 0.04             | 0.00                   | 0.40          | 0.00         | 0.00          | 0.00          | 95.63          |
|  | 7.11          | 14.55        | 27.42         | 9.90          | 40.09                  | 2.23                | 5.64               | 20.23            | 12.92                  | 0.88          | 0.97         | 1.90          | 6.31          | 1031.34        |
|  | <b>49.07</b>  |              |               | <b>9.90</b>   | <b>40.09</b>           | <b>51.08</b>        |                    |                  |                        |               |              |               |               | <b>1031.34</b> |
|  | 175.85        | -34.97       | -9.60         | -65.16        | 162.05                 | 10.63               | 10.08              | 129.43           | -26.02                 | 97.85         | 30.05        | -67.22        | 475.39        | 1499.22        |
|  | 0.58          | 19.49        | 3.83          | 147.67        | 172.93                 | 7.88                | 13.99              | 12.07            | 42.51                  | 52.69         | 57.82        | 158.73        | -1.16         | 1046.68        |
|  | 176.44        | -15.48       | -5.77         | 82.51         | 334.97                 | 18.50               | 24.07              | 141.50           | 16.49                  | 150.54        | 87.87        | 91.51         | 474.23        | 2545.90        |
|  | <b>155.18</b> |              |               | <b>82.51</b>  | <b>334.97</b>          | <b>1,004.71</b>     |                    |                  |                        |               |              |               |               | <b>2545.90</b> |
|  | 171.30        | 7.30         | -10.33        | 119.88        | 394.97                 | 17.94               | 20.64              | 167.32           | 25.17                  | 152.12        | 87.25        | 98.21         | 471.46        | 2869.05        |
|  | <b>168.27</b> |              |               | <b>119.88</b> | <b>394.97</b>          | <b>1,040.11</b>     |                    |                  |                        |               |              |               |               | <b>2869.05</b> |
|  | 173.60        | 4.89         | 1.10          | 57.93         | 362.66                 | 15.76               | 18.00              | 167.17           | 25.48                  | 135.52        | 72.33        | 52.57         | 473.65        | 3170.61        |
|  | <b>179.59</b> |              |               | <b>57.93</b>  | <b>362.66</b>          | <b>960.46</b>       |                    |                  |                        |               |              |               |               | <b>3170.61</b> |
|  | 170.76        | 3.43         | -8.59         | 54.27         | 351.49                 | 14.94               | 16.00              | 164.35           | 24.27                  | 135.36        | 72.01        | 51.92         | 471.81        | 3049.63        |
|  | <b>165.61</b> |              |               | <b>54.27</b>  | <b>351.49</b>          | <b>950.66</b>       |                    |                  |                        |               |              |               |               | <b>3049.63</b> |



TABLE 54: 2050 WATER RESOURCES AND DEMAND SUMMARY OF SAFE YIELD, CONSUMPTIVE ALLOCATION, AND DEMAND

| BASIN                                                                                                 |                      | BLUE MOUNTAIN SOUTH   |              |               | KINGS-TON  | RIO COBRE | RIO MINHO |            |                          | BLACK RIVER | CABARITA RIVER     |                |                    |                           |
|-------------------------------------------------------------------------------------------------------|----------------------|-----------------------|--------------|---------------|------------|-----------|-----------|------------|--------------------------|-------------|--------------------|----------------|--------------------|---------------------------|
| WMU                                                                                                   |                      | PLANTAIN GARDEN RIVER | MORANT RIVER | YALLAHS RIVER | HOPE RIVER | RIO COBRE | RIO MINHO | MILK RIVER | GUT RIVER-ALLIGATOR HOLE | BLACK RIVER | DEANS VALLEY RIVER | CABARITA RIVER | NEW SAVANNAH RIVER | SOUTH NEGRIL-ORANGE RIVER |
| SAFE YIELD                                                                                            | GW                   | 8.23                  | 222.48       | -15.59        | 59.89      | 229.19    | 3.06      | 73.82      | -309.49                  | -297.22     | 240.48             | -42.38         | -12.70             | 19.97                     |
|                                                                                                       | SW                   | 14.33                 | 26.50        | 53.54         | 3.89       | 87.85     | 81.29     | 23.51      | 91.32                    | 388.90      | 6.83               | 76.47          | 0.38               | 2.31                      |
|                                                                                                       | DOMESTIC SW          | 7.74                  | 19.59        | 42.85         | 2.98       | 59.12     | 61.70     | 18.53      | 39.80                    | 286.03      | 4.18               | 53.89          | 0.22               | 0.89                      |
|                                                                                                       | WMU TOTAL            | 22.56                 | 248.98       | 37.95         | 63.78      | 317.04    | 84.35     | 97.33      | -218.17                  | 91.68       | 247.31             | 34.09          | -12.32             | 22.28                     |
|                                                                                                       | WMU DOMESTIC TOTAL   | 15.97                 | 242.07       | 27.26         | 62.87      | 288.31    | 64.76     | 92.35      | -269.68                  | -11.19      | 244.66             | 11.51          | -12.48             | 20.86                     |
|                                                                                                       | BASIN TOTAL          | 309.48                |              |               | 63.78      | 317.04    | -36.49    |            |                          | 91.68       | 291.36             |                |                    |                           |
|                                                                                                       | BASIN DOMESTIC TOTAL | 285.30                |              |               | 62.87      | 288.31    | -112.57   |            |                          | -11.19      | 264.55             |                |                    |                           |
| TOTAL CONSUMPTIVE ALLOCATION                                                                          | GW                   | 0.29                  | 12.90        | 9.72          | 25.73      | 141.51    | 70.45     | 201.09     | 1.66                     | 92.91       | 2.29               | 0.00           | 0.00               | 0.48                      |
|                                                                                                       | SW                   | 8.58                  | 4.64         | 22.10         | 7.61       | 296.73    | 3.96      | 4.37       | 0.00                     | 93.47       | 6.54               | 40.39          | 0.00               | 11.07                     |
|                                                                                                       | WMU TOTAL            | 8.87                  | 17.54        | 31.83         | 33.34      | 438.24    | 74.41     | 205.46     | 1.66                     | 186.37      | 8.84               | 40.39          | 0.00               | 11.55                     |
|                                                                                                       | BASIN TOTAL          | 58.23                 |              |               | 33.34      | 438.24    | 281.53    |            |                          | 186.37      | 60.78              |                |                    |                           |
| DEMAND                                                                                                | DOMESTIC             | 0.53                  | 5.45         | 1.87          | 49.95      | 53.28     | 12.04     | 18.65      | 0.89                     | 13.16       | 4.97               | 3.91           | 0.49               | 3.48                      |
|                                                                                                       | COMMERCIAL           | 0.13                  | 1.36         | 0.47          | 12.49      | 13.32     | 3.01      | 4.66       | 0.22                     | 3.29        | 1.24               | 0.98           | 0.12               | 0.87                      |
|                                                                                                       | INSTITUTIONAL        | 0.13                  | 1.36         | 0.47          | 12.49      | 13.32     | 3.01      | 4.66       | 0.22                     | 3.29        | 1.24               | 0.98           | 0.12               | 0.87                      |
|                                                                                                       | TOURISM              | 0.02                  | 0.13         | 0.04          | 2.28       | 0.50      | 0.04      | 0.46       | 0.00                     | 0.71        | 0.68               | 0.02           | 0.03               | 5.72                      |
|                                                                                                       | IRRIGATION           | 8.08                  | 3.51         | 11.67         | 3.37       | 276.81    | 75.03     | 378.06     | 0.00                     | 73.12       | 0.01               | 0.00           | 0.00               | 0.00                      |
|                                                                                                       | INDUSTRIAL           | 0.00                  | 0.00         | 0.01          | 15.40      | 35.74     | 1.00      | 22.50      | 0.00                     | 44.90       | 3.90               | 0.00           | 0.00               | 0.00                      |
|                                                                                                       | WMU TOTAL            | 8.90                  | 11.82        | 14.53         | 95.97      | 392.97    | 94.12     | 429.00     | 1.34                     | 138.46      | 12.04              | 5.89           | 0.75               | 10.94                     |
|                                                                                                       | BASIN TOTAL          | 35.24                 |              |               | 95.97      | 392.97    | 524.46    |            |                          | 138.46      | 29.62              |                |                    |                           |
| Water Available for Consumptive Allocation (Safe Yield - Consumptive Allocated Water)                 | GW                   | 7.94                  | 209.58       | -25.32        | 34.17      | 87.68     | -67.39    | -127.27    | -311.14                  | -390.13     | 238.18             | -42.38         | -12.70             | 19.50                     |
|                                                                                                       | SW                   | 5.75                  | 21.86        | 31.44         | -3.72      | -208.88   | 77.32     | 19.14      | 91.32                    | 295.44      | 0.29               | 36.08          | 0.38               | -8.76                     |
|                                                                                                       | WMU TOTAL            | 13.69                 | 231.44       | 6.12          | 30.45      | -121.20   | 9.93      | -108.13    | -219.83                  | -94.69      | 238.47             | -6.30          | -12.32             | 10.73                     |
|                                                                                                       | BASIN TOTAL          | 251.25                |              |               | 30.45      | -121.20   | -318.02   |            |                          | -94.69      | 230.58             |                |                    |                           |
| General Water Surplus/Deficit (Safe Yield - Water Demand)                                             | WMU TOTAL            | 13.66                 | 237.16       | 23.42         | -32.19     | -75.93    | -9.77     | -331.67    | -219.51                  | -46.78      | 235.26             | 28.20          | -13.08             | 11.34                     |
|                                                                                                       | BASIN TOTAL          | 274.25                |              |               | -32.19     | -75.93    | -560.95   |            |                          | -46.78      | 261.73             |                |                    |                           |
| Domestic Water Availability (Domestic Safe Yield - Domestic Demand)                                   | WMU TOTAL            | 15.44                 | 236.62       | 25.38         | 12.92      | 235.03    | 52.73     | 73.70      | -270.58                  | -24.34      | 239.69             | 7.60           | -12.97             | 17.38                     |
|                                                                                                       | BASIN TOTAL          | 277.44                |              |               | 12.92      | 235.03    | -144.15   |            |                          | -24.34      | 251.71             |                |                    |                           |
| Municipal Water Availability Domestic Safe Yield - (Domestic+Institutional+Commercial+Tourism Demand) | WMU TOTAL            | 15.15                 | 233.77       | 24.41         | -14.34     | 207.89    | 46.67     | 63.91      | -271.02                  | -31.63      | 236.53             | 5.62           | -13.24             | 9.92                      |
|                                                                                                       | BASIN TOTAL          | 273.33                |              |               | -14.34     | 207.89    | -160.44   |            |                          | -31.63      | 238.84             |                |                    |                           |



|  | GREAT RIVER   |               |               | MARTHA BRAE   | DRY HARBOUR MOUNTAINS  | BLUE MOUNTAIN NORTH |                   |                 |                        |               |              |               |               | TOTAL          |
|--|---------------|---------------|---------------|---------------|------------------------|---------------------|-------------------|-----------------|------------------------|---------------|--------------|---------------|---------------|----------------|
|  | LUCEA RIVER   | GREAT RIVER   | MONTEGO RIVER | MARTHA BRAE   | RIO BUE-NO-WHITE RIVER | RIO NUEVO           | ORACABES-SA-PAGEE | WAG-WATER RIVER | PEN-CAR-BUFF BAY RIVER | SPANISH RIVER | SWIFT RIVER  | RIO GRANDE    | DRIVERS RIVER |                |
|  | 131.55        | -99.07        | -19.73        | -152.85       | -36.81                 | -5.91               | -13.40            | 83.25           | -59.63                 | 66.16         | -4.17        | -155.23       | 410.29        | 324.19         |
|  | 1.71          | 56.58         | 9.16          | 176.46        | 245.39                 | 9.54                | 16.21             | 48.35           | 49.49                  | 55.15         | 58.15        | 163.05        | 1.14          | 1747.48        |
|  | 1.17          | 42.45         | 6.48          | 110.36        | 189.10                 | 6.54                | 11.57             | 33.56           | 39.27                  | 37.99         | 42.88        | 116.76        | 0.32          | 1235.98        |
|  | <b>133.26</b> | <b>-42.49</b> | <b>-10.57</b> | <b>23.62</b>  | <b>208.58</b>          | <b>3.62</b>         | <b>2.81</b>       | <b>131.61</b>   | <b>-10.14</b>          | <b>121.31</b> | <b>53.97</b> | <b>7.82</b>   | <b>411.42</b> | <b>2071.68</b> |
|  | <b>132.73</b> | <b>-56.62</b> | <b>-13.25</b> | <b>-42.48</b> | <b>152.28</b>          | <b>0.63</b>         | <b>-1.83</b>      | <b>116.82</b>   | <b>-20.35</b>          | <b>104.15</b> | <b>38.71</b> | <b>-38.47</b> | <b>410.60</b> | <b>1560.18</b> |
|  | <b>80.21</b>  |               |               | <b>23.62</b>  | <b>208.58</b>          | <b>722.42</b>       |                   |                 |                        |               |              |               |               | <b>2071.68</b> |
|  | <b>62.86</b>  |               |               | <b>-42.48</b> | <b>152.28</b>          | <b>610.25</b>       |                   |                 |                        |               |              |               |               | <b>1560.18</b> |
|  | 0.84          | 0.24          | 17.53         | 18.48         | 27.63                  | 0.00                | 0.00              | 9.77            | 14.62                  | 0.00          | 0.02         | 4.28          | 1.24          | 653.69         |
|  | 1.13          | 37.09         | 5.34          | 28.79         | 72.46                  | 1.66                | 2.21              | 36.28           | 6.98                   | 2.45          | 0.33         | 4.33          | 2.29          | 700.80         |
|  | 1.97          | 37.33         | 22.87         | 47.27         | 100.10                 | 1.66                | 2.21              | 46.06           | 21.60                  | 2.45          | 0.35         | 8.61          | 3.53          | 1354.49        |
|  | <b>62.16</b>  |               |               | <b>47.27</b>  | <b>100.10</b>          | <b>86.48</b>        |                   |                 |                        |               |              |               |               | <b>1354.49</b> |
|  | 4.58          | 2.32          | 16.60         | 6.47          | 16.87                  | 1.38                | 3.88              | 6.26            | 2.71                   | 0.33          | 0.67         | 1.35          | 3.23          | 235.31         |
|  | 1.14          | 0.58          | 4.15          | 1.62          | 4.22                   | 0.34                | 0.97              | 1.57            | 0.68                   | 0.08          | 0.17         | 0.34          | 0.81          | 58.83          |
|  | 1.14          | 0.58          | 4.15          | 1.62          | 4.22                   | 0.34                | 0.97              | 1.57            | 0.68                   | 0.08          | 0.17         | 0.34          | 0.81          | 58.83          |
|  | 2.06          | 0.13          | 8.83          | 2.28          | 9.09                   | 0.32                | 0.49              | 0.04            | 0.04                   | 0.00          | 0.01         | 0.05          | 0.58          | 34.52          |
|  | 0.00          | 15.25         | 0.73          | 0.73          | 6.85                   | 0.00                | 0.00              | 17.50           | 13.83                  | 0.00          | 0.03         | 0.00          | 1.74          | 886.32         |
|  | 0.00          | 0.00          | 5.84          | 0.00          | 12.10                  | 0.00                | 0.00              | 0.06            | 0.00                   | 0.60          | 0.00         | 0.00          | 0.00          | 142.05         |
|  | 8.92          | 18.85         | 40.30         | 12.72         | 53.34                  | 2.39                | 6.30              | 26.99           | 17.94                  | 1.09          | 1.04         | 2.08          | 7.16          | 1415.85        |
|  | <b>68.08</b>  |               |               | <b>12.72</b>  | <b>53.34</b>           | <b>64.99</b>        |                   |                 |                        |               |              |               |               | <b>1415.85</b> |
|  | 130.71        | -99.31        | -37.26        | -171.32       | -64.45                 | -5.91               | -13.40            | 73.48           | -74.25                 | 66.16         | -4.19        | -159.52       | 409.04        | -329.50        |
|  | 0.58          | 19.49         | 3.83          | 147.67        | 172.93                 | 7.88                | 13.99             | 12.07           | 42.51                  | 52.69         | 57.82        | 158.73        | -1.16         | 1046.68        |
|  | 131.29        | -79.82        | -33.43        | -23.65        | 108.48                 | 1.96                | 0.59              | 85.55           | -31.74                 | 118.85        | 53.63        | -0.79         | 407.89        | 717.19         |
|  | <b>18.04</b>  |               |               | <b>-23.65</b> | <b>108.48</b>          | <b>635.95</b>       |                   |                 |                        |               |              |               |               | <b>717.19</b>  |
|  | 124.34        | -61.34        | -50.87        | 10.90         | 155.23                 | 1.24                | -3.50             | 104.62          | -28.08                 | 120.21        | 52.93        | 5.74          | 404.26        | 655.82         |
|  | <b>12.13</b>  |               |               | <b>10.90</b>  | <b>155.23</b>          | <b>657.44</b>       |                   |                 |                        |               |              |               |               | <b>655.82</b>  |
|  | 128.15        | -58.94        | -29.85        | -48.95        | 135.42                 | -0.75               | -5.71             | 110.56          | -23.07                 | 103.82        | 38.04        | -39.83        | 407.38        | 1324.87        |
|  | <b>39.36</b>  |               |               | <b>-48.95</b> | <b>135.42</b>          | <b>590.44</b>       |                   |                 |                        |               |              |               |               | <b>1324.87</b> |
|  | 123.80        | -60.22        | -46.98        | -54.47        | 117.89                 | -1.76               | -8.14             | 107.39          | -24.46                 | 103.65        | 37.70        | -40.55        | 405.18        | 1172.69        |
|  | <b>16.60</b>  |               |               | <b>-54.47</b> | <b>117.89</b>          | <b>579.02</b>       |                   |                 |                        |               |              |               |               | <b>1172.69</b> |



**TABLE 55: 2080 WATER RESOURCES AND DEMAND SUMMARY OF SAFE YIELD, CONSUMPTIVE ALLOCATION, AND DEMAND**

| BASIN                                                                                                                   |                           | BLUE MOUNTAIN SOUTH         |                 |                  | KINGS-<br>TON | RIO<br>COBRE | RIO MINHO    |               |                                    | BLACK<br>RIVER | CABARITA RIVER           |                        |                          |                                   |
|-------------------------------------------------------------------------------------------------------------------------|---------------------------|-----------------------------|-----------------|------------------|---------------|--------------|--------------|---------------|------------------------------------|----------------|--------------------------|------------------------|--------------------------|-----------------------------------|
| WMU                                                                                                                     |                           | PLANTAIN<br>GARDEN<br>RIVER | MORANT<br>RIVER | YALLAHS<br>RIVER | HOPE<br>RIVER | RIO<br>COBRE | RIO<br>MINHO | MILK<br>RIVER | GUT RIV-<br>ER-ALLIGA-<br>TOR HOLE | BLACK<br>RIVER | DEANS<br>VALLEY<br>RIVER | CABAR-<br>ITA<br>RIVER | NEW<br>SAVANNAH<br>RIVER | SOUTH NE-<br>GRIL-ORANGE<br>RIVER |
| SAFE YIELD                                                                                                              | GW                        | -51.63                      | 107.79          | -68.35           | 2.06          | -78.48       | -169.00      | -114.97       | -339.57                            | -634.12        | 113.85                   | -126.12                | -22.41                   | -20.67                            |
|                                                                                                                         | SW                        | 14.33                       | 26.50           | 53.54            | 3.89          | 87.85        | 81.29        | 23.51         | 91.32                              | 388.90         | 6.83                     | 76.47                  | 0.38                     | 2.31                              |
|                                                                                                                         | DOMESTIC SW               | 7.74                        | 19.59           | 42.85            | 2.98          | 59.12        | 61.70        | 18.53         | 39.80                              | 286.03         | 4.18                     | 53.89                  | 0.22                     | 0.89                              |
|                                                                                                                         | WMU TOTAL                 | -37.30                      | 134.29          | -14.80           | 5.95          | 9.36         | -87.71       | -91.46        | -248.25                            | -245.22        | 120.69                   | -49.65                 | -22.03                   | -18.36                            |
|                                                                                                                         | WMU DOMESTIC<br>TOTAL     | -43.89                      | 127.38          | -25.50           | 5.03          | -19.37       | -107.29      | -96.44        | -299.77                            | -348.09        | 118.04                   | -72.23                 | -22.19                   | -19.78                            |
|                                                                                                                         | BASIN TOTAL               | 82.19                       |                 |                  | 5.95          | 9.36         | -427.42      |               |                                    | -245.22        | 30.64                    |                        |                          |                                   |
|                                                                                                                         | BASIN DOMES-<br>TIC TOTAL | 58.00                       |                 |                  | 5.03          | -19.37       | -503.50      |               |                                    | -348.09        | 3.83                     |                        |                          |                                   |
| TOTAL CONSUMPTIVE<br>ALLOCATION                                                                                         | GW                        | 0.29                        | 12.90           | 9.72             | 25.73         | 141.51       | 70.45        | 201.09        | 1.66                               | 92.91          | 2.29                     | 0.00                   | 0.00                     | 0.48                              |
|                                                                                                                         | SW                        | 8.58                        | 4.64            | 22.10            | 7.61          | 296.73       | 3.96         | 4.37          | 0.00                               | 93.47          | 6.54                     | 40.39                  | 0.00                     | 11.07                             |
|                                                                                                                         | WMU TOTAL                 | 8.87                        | 17.54           | 31.83            | 33.34         | 438.24       | 74.41        | 205.46        | 1.66                               | 186.37         | 8.84                     | 40.39                  | 0.00                     | 11.55                             |
|                                                                                                                         | BASIN TOTAL               | 58.23                       |                 |                  | 33.34         | 438.24       | 281.53       |               |                                    | 186.37         | 60.78                    |                        |                          |                                   |
| DEMAND                                                                                                                  | DOMESTIC                  | 0.36                        | 5.92            | 1.92             | 51.31         | 64.91        | 12.36        | 21.73         | 0.80                               | 13.76          | 5.25                     | 4.15                   | 0.46                     | 5.55                              |
|                                                                                                                         | COMMERCIAL                | 0.09                        | 1.48            | 0.48             | 12.83         | 16.23        | 3.09         | 5.43          | 0.20                               | 3.44           | 1.31                     | 1.04                   | 0.12                     | 1.39                              |
|                                                                                                                         | INSTITUTIONAL             | 0.09                        | 1.48            | 0.48             | 12.83         | 16.23        | 3.09         | 5.43          | 0.20                               | 3.44           | 1.31                     | 1.04                   | 0.12                     | 1.39                              |
|                                                                                                                         | TOURISM                   | 0.11                        | 0.67            | 0.18             | 11.39         | 2.47         | 0.19         | 2.29          | 0.00                               | 3.52           | 3.39                     | 0.11                   | 0.13                     | 28.50                             |
|                                                                                                                         | IRRIGATION                | 14.64                       | 6.36            | 21.14            | 6.10          | 501.41       | 135.90       | 684.81        | 0.00                               | 132.45         | 0.01                     | 0.00                   | 0.00                     | 0.00                              |
|                                                                                                                         | INDUSTRIAL                | 0.00                        | 0.00            | 0.02             | 27.90         | 64.74        | 1.70         | 40.70         | 0.00                               | 81.40          | 7.10                     | 0.00                   | 0.00                     | 0.00                              |
|                                                                                                                         | WMU TOTAL                 | 15.29                       | 15.91           | 24.21            | 122.35        | 665.98       | 156.34       | 760.39        | 1.20                               | 238.02         | 18.36                    | 6.34                   | 0.82                     | 36.83                             |
|                                                                                                                         | BASIN TOTAL               | 55.42                       |                 |                  | 122.35        | 665.98       | 917.93       |               |                                    | 238.02         | 62.36                    |                        |                          |                                   |
| Water Available for<br>Consumptive Allocation<br>(Safe Yield - Consumptive<br>Allocated Water)                          | GW                        | -51.92                      | 94.89           | -78.07           | -23.67        | -219.99      | -239.45      | -316.06       | -341.23                            | -727.03        | 111.56                   | -126.12                | -22.41                   | -21.14                            |
|                                                                                                                         | SW                        | 5.75                        | 21.86           | 31.44            | -3.72         | -208.88      | 77.32        | 19.14         | 91.32                              | 295.44         | 0.29                     | 36.08                  | 0.38                     | -8.76                             |
|                                                                                                                         | WMU TOTAL                 | -46.17                      | 116.75          | -46.63           | -27.39        | -428.87      | -162.12      | -296.92       | -249.91                            | -431.60        | 111.85                   | -90.04                 | -22.03                   | -29.91                            |
|                                                                                                                         | BASIN TOTAL               | 23.95                       |                 |                  | -27.39        | -428.87      | -708.95      |               |                                    | -431.60        | -30.13                   |                        |                          |                                   |
| General Water Surplus/<br>Deficit (Safe Yield - Water<br>Demand)                                                        | WMU TOTAL                 | -52.59                      | 118.38          | -39.02           | -116.41       | -656.61      | -244.04      | -851.85       | -249.46                            | -483.24        | 102.32                   | -55.99                 | -22.85                   | -55.19                            |
|                                                                                                                         | BASIN TOTAL               | 26.76                       |                 |                  | -116.41       | -656.61      | -1,345.35    |               |                                    | -483.24        | -31.72                   |                        |                          |                                   |
| Domestic Water Availabi-<br>lity (Domestic Safe Yield<br>- Domestic Demand)                                             | WMU TOTAL                 | -44.25                      | 121.46          | -27.41           | -46.28        | -84.27       | -119.66      | -118.17       | -300.57                            | -361.85        | 112.79                   | -76.38                 | -22.66                   | -25.33                            |
|                                                                                                                         | BASIN TOTAL               | 49.79                       |                 |                  | -46.28        | -84.27       | -538.40      |               |                                    | -361.85        | -11.58                   |                        |                          |                                   |
| Municipal Water Avail-<br>ability Domestic Safe<br>Yield - (Domestic+Institu-<br>tional+Commercial+Tour-<br>ism Demand) | WMU TOTAL                 | -44.54                      | 117.83          | -28.55           | -83.32        | -119.19      | -126.03      | -131.33       | -300.97                            | -372.26        | 106.78                   | -78.57                 | -23.01                   | -56.61                            |
|                                                                                                                         | BASIN TOTAL               | 44.74                       |                 |                  | -83.32        | -119.19      | -558.32      |               |                                    | -372.26        | -51.41                   |                        |                          |                                   |



|  | GREAT RIVER    |                |               | MARTHA BRAE    | DRY HARBOUR MOUNTAINS  | BLUE MOUNTAIN NORTH |                    |                  |                        |               |               |                |               | TOTAL           |
|--|----------------|----------------|---------------|----------------|------------------------|---------------------|--------------------|------------------|------------------------|---------------|---------------|----------------|---------------|-----------------|
|  | LUCEA RIVER    | GREAT RIVER    | MORTEGO RIVER | MARTHA BRAE    | RIO BUE-NO-WHITE RIVER | RIO NUEVO           | ORA-CABES-SA-PAGEE | WAG-WA-TER RIVER | PEN-CAR-BUFF BAY RIVER | SPANISH RIVER | SWIFT RIVER   | RIO GRANDE     | DRIVERS RIVER |                 |
|  | 60.40          | -200.61        | -64.17        | -323.35        | -404.37                | -32.57              | -51.31             | -5.01            | -135.11                | 16.66         | -56.76        | -300.32        | 304.72        | -2593.41        |
|  | 1.71           | 56.58          | 9.16          | 176.46         | 245.39                 | 9.54                | 16.21              | 48.35            | 49.49                  | 55.15         | 58.15         | 163.05         | 1.14          | 1747.48         |
|  | 1.17           | 42.45          | 6.48          | 110.36         | 189.10                 | 6.54                | 11.57              | 33.56            | 39.27                  | 37.99         | 42.88         | 116.76         | 0.32          | 1235.98         |
|  | <b>62.11</b>   | <b>-144.03</b> | <b>-55.01</b> | <b>-146.88</b> | <b>-158.98</b>         | <b>-23.03</b>       | <b>-35.10</b>      | <b>43.35</b>     | <b>-85.63</b>          | <b>71.81</b>  | <b>1.39</b>   | <b>-137.27</b> | <b>305.85</b> | <b>-845.93</b>  |
|  | <b>61.57</b>   | <b>-158.16</b> | <b>-57.69</b> | <b>-212.98</b> | <b>-215.27</b>         | <b>-26.03</b>       | <b>-39.74</b>      | <b>28.56</b>     | <b>-95.84</b>          | <b>54.65</b>  | <b>-13.87</b> | <b>-183.56</b> | <b>305.03</b> | <b>-1357.43</b> |
|  | <b>-136.93</b> |                |               | <b>-146.88</b> | <b>-158.98</b>         | <b>141.37</b>       |                    |                  |                        |               |               |                |               | <b>-845.93</b>  |
|  | <b>-154.27</b> |                |               | <b>-212.98</b> | <b>-215.27</b>         | <b>29.20</b>        |                    |                  |                        |               |               |                |               | <b>-1357.43</b> |
|  | 0.84           | 0.24           | 17.53         | 18.48          | 27.63                  | 0.00                | 0.00               | 9.77             | 14.62                  | 0.00          | 0.02          | 4.28           | 1.24          | 653.69          |
|  | 1.13           | 37.09          | 5.34          | 28.79          | 72.46                  | 1.66                | 2.21               | 36.28            | 6.98                   | 2.45          | 0.33          | 4.33           | 2.29          | 700.80          |
|  | 1.97           | 37.33          | 22.87         | 47.27          | 100.10                 | 1.66                | 2.21               | 46.06            | 21.60                  | 2.45          | 0.35          | 8.61           | 3.53          | 1354.49         |
|  | <b>62.16</b>   |                |               | <b>47.27</b>   | <b>100.10</b>          | <b>86.48</b>        |                    |                  |                        |               |               |                |               | <b>1354.49</b>  |
|  | 5.08           | 1.72           | 23.12         | 7.72           | 18.07                  | 1.33                | 4.24               | 7.40             | 3.27                   | 0.34          | 0.74          | 1.51           | 3.13          | 266.17          |
|  | 1.27           | 0.43           | 5.78          | 1.93           | 4.52                   | 0.33                | 1.06               | 1.85             | 0.82                   | 0.09          | 0.18          | 0.38           | 0.78          | 66.54           |
|  | 1.27           | 0.43           | 5.78          | 1.93           | 4.52                   | 0.33                | 1.06               | 1.85             | 0.82                   | 0.09          | 0.18          | 0.38           | 0.78          | 66.54           |
|  | 10.27          | 0.63           | 43.99         | 11.37          | 45.30                  | 1.58                | 2.44               | 0.19             | 0.18                   | 0.00          | 0.03          | 0.24           | 2.90          | 172.04          |
|  | 0.00           | 27.62          | 1.32          | 1.32           | 12.40                  | 0.00                | 0.00               | 31.70            | 25.05                  | 0.00          | 0.06          | 0.00           | 3.14          | 1605.43         |
|  | 0.00           | 0.01           | 10.58         | 0.00           | 21.90                  | 0.00                | 0.00               | 0.12             | 0.00                   | 1.10          | 0.00          | 0.00           | 0.00          | 257.27          |
|  | 17.89          | 30.84          | 90.57         | 24.27          | 106.70                 | 3.58                | 8.80               | 43.12            | 30.13                  | 1.62          | 1.19          | 2.50           | 10.73         | 2433.99         |
|  | <b>139.31</b>  |                |               | <b>24.27</b>   | <b>106.70</b>          | <b>101.66</b>       |                    |                  |                        |               |               |                |               | <b>2433.99</b>  |
|  | 59.56          | -200.85        | -81.70        | -341.82        | -432.00                | -32.57              | -51.31             | -14.78           | -149.74                | 16.66         | -56.77        | -304.60        | 303.47        | -3247.10        |
|  | 0.58           | 19.49          | 3.83          | 147.67         | 172.93                 | 7.88                | 13.99              | 12.07            | 42.51                  | 52.69         | 57.82         | 158.73         | -1.16         | 1046.68         |
|  | 60.14          | -181.36        | -77.87        | -194.15        | -259.08                | -24.69              | -37.32             | -2.71            | -107.23                | 69.35         | 1.04          | -145.88        | 302.32        | -2200.42        |
|  | <b>-199.09</b> |                |               | <b>-194.15</b> | <b>-259.08</b>         | <b>54.89</b>        |                    |                  |                        |               |               |                |               | <b>-2200.42</b> |
|  | 44.22          | -174.87        | -145.58       | -171.15        | -265.69                | -26.61              | -43.90             | 0.23             | -115.76                | 70.19         | 0.20          | -139.76        | 295.12        | -3279.92        |
|  | <b>-276.23</b> |                |               | <b>-171.15</b> | <b>-265.69</b>         | <b>39.71</b>        |                    |                  |                        |               |               |                |               | <b>-3279.92</b> |
|  | 56.49          | -159.88        | -80.81        | -220.70        | -233.35                | -27.36              | -43.98             | 21.15            | -99.11                 | 54.31         | -14.61        | -185.07        | 301.90        | -1623.60        |
|  | <b>-184.20</b> |                |               | <b>-220.70</b> | <b>-233.35</b>         | <b>7.24</b>         |                    |                  |                        |               |               |                |               | <b>-1623.60</b> |
|  | 43.68          | -161.37        | -136.36       | -235.93        | -287.68                | -29.60              | -48.54             | 17.26            | -100.92                | 54.13         | -15.00        | -186.06        | 297.44        | -1928.72        |
|  | <b>-254.05</b> |                |               | <b>-235.93</b> | <b>-287.68</b>         | <b>-11.30</b>       |                    |                  |                        |               |               |                |               | <b>-1928.72</b> |



## WATER RESOURCES MANAGEMENT FRAMEWORK

Since the publication of the 1990 WRDMP, there have been significant developments nationally and globally that provide guidance for integrated water resources management (IWRM). As previously stated in Chapter 4, the major developments that set the framework for water resources management IWRM include the National Water Sector Policy, the Water Resources Act and Vision 2030, under the over-arching remit of the Sustainable Development Goals. Specific principles which delineate the Water Resources Management Framework are presented in this section from their various sources.

### PROVISIONS IN THE WATER RESOURCES ACT

The Water Resources Act provides the legislative framework for the Water Resources Authority to implement water management IWRM activities. The activities established by the Water Resources Act are as follows:

- ◆ Overall management responsibility, as per Part II, Section 4 (1): *"It shall be the duty of the Authority to regulate, allocate, conserve and otherwise manage the water resources of Jamaica."*
  - ◆ Establishment of the Water Resources Advisory Committee, as per Part II Section 14 (1): *"There is hereby established a body to be known as the Water Resources Advisory Committee."* The committee is to be comprised of the following *ex officio* and appointed members:
    - + The Director-General of the Planning Institute of Jamaica;
    - + The CEO of the Natural Resources Conservation Authority;
    - + The CEO of the National Water Commission;
    - + The CEO of the National Irrigation Commission;
    - + The CEO of the Water Resources Authority;
    - + The Government Town Planner;
- + Not more than five (5) appointed members, including representatives from agricultural interests, consumer interests, private sector interests, and bauxite mining interests.
- ◆ Establishment of the National Water Resources Master Plan, as per Part II, Section 16 (1): *"...the Authority shall prepare and submit to the Minister for approval a draft National Water Resources Master Plan for Jamaica."*
- ◆ Regulation of the Abstraction and Use of Water via Abstraction Licenses, as per:
  - + Part III, Section 17 (1): *"...the abstraction and use of water in Jamaica and the construction of any works for such abstraction and use shall be governed by the provisions of this Act..."*
  - + Part III, Section 19 (1) *"...no person shall abstract and use water, or construct... any works for the abstraction...of water except under and in accordance with a license for the purpose granted to him by the Authority under this Act."*
- ◆ Declaration of an emergency area due to insufficiency of water as per Part III Section 30 (1): *"...the Minister...may by order declare an area to be an emergency area if he is satisfied that...the supply of water...is likely to become insufficient as respects its quantity or unsuitably as respect its quality (or both) to satisfy the requirements of all licenses granted under this Act to abstract and use water."*
- ◆ Impose restrictions on abstractors in a declared emergency area as per Part III Section 31 (1): *"The Authority may, in an area declared to be an emergency area...impose such restrictions as it thinks necessary in the circumstances..."*
- ◆ Reserve water for public purposes as per Part III Section 32 (1): *"On the recommendation of the Authority the Minister...may by order... reserve the whole or part of a source of supply...for a public purpose and may indicate in such order the person or authority entitled to use the reserved water."*
- ◆ Control and protect underground water and well drilling as per:
  - + Part IV Section 34 (1) *"...no person shall sink, construct, enlarge or otherwise alter a well for...any...purpose unless...he has obtained the Authority's consent to do so."*
  - + Part IV Section 35 (1) *"No person shall practice as a well driller except under and in accordance with a license granted by the Authority..."*

- ◆ Determine the safe yield of aquifers, impose restrictions on artesian wells to prevent waste or contamination of water or loss of artesian pressure, and carry out programs for the recharge of aquifers as per Part IV Section 38 (a),(b) and (c).
- ◆ Declaration of a Water Quality Control Area as per Part V Section 39: *"If the Minister...is satisfied that a plan...for the protection of the quality of water resources in any area is necessary...he may make an order defining the area in question, and declaring the area to be a Water Quality Control Area."*
- ◆ Enforce various regulatory controls for any breaches of the Water Resources Act as per Part VI Section 41 (1): *"...the Authority may serve...an enforcement notice"*.

## INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)

Integrated Water Resources Management (IWRM) is a central component of the National Water Sector Policy (2019). The stated goal of IWRM as presented in the Water Sector Policy is:

*"...to promote the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."*

The IWRM framework is organized under three fundamental elements:

- ◆ Enabling environments, which refer to the policies, legislative framework, financing and incentive structures in place to facilitate the IWRM process,
- ◆ Institutional Roles, which involve creating an organizational framework and building the capacity of the organization,
- ◆ Various management instruments, including data sharing, demand management, social change instruments, and many others.

The existing institutional framework for water resources management largely supports the IWRM goal in that the land and water management agencies fall under a single Ministry, which is the Ministry with portfolio responsibility for Water. From the mid 1990's, a new approach to watershed management in Jamaica emerged. In 1996, the Chairperson of the Natural Resources Conservation Authority (NRCA) and the Senior Advisor to the Prime Minister on Land Policy and Physical Development, convened an *ad-hoc* Watershed Management Committee, which comprised a senior level multi-disciplinary team of persons from the Public and Private Sectors and NGOs.





The Committee concluded that because of the widespread incidence of poverty, environmental restoration could be achieved primarily through the sustainable development of watershed communities, and that the pattern of unrelated watershed projects needed to be replaced by an integrated national approach and programme.

In 2000, Cabinet approved the institutional framework for the National Integrated Water Management Programme (NIWMP), including the appointment of the National Integrated Watershed Management Council (NIWMC), in an effort to overcome the constraints to watershed management strategies islandwide. The NIWMC was a multi-disciplinary, multi-sectorial entity, comprising public and private sector, NGOs and educational institutions that served as a central point of reference for overall planning, co-ordination, implementation and monitoring of watershed projects, programmes and activities; and was the key link between lending agencies that were active in watershed management in Jamaica. The NIWMC reported to Cabinet through the Minister with responsibility for the Environment, who appointed sub-committees to facilitate its work. This entity replaced the former multi-sectorial National Watershed Task Force.

Currently, the major shortcomings to establishing an IWRM approach are:

- ◆ The inactivity of an apex body responsible for policy coordination across the sectors to ensure the IWRM goals are met; and
- ◆ The non-establishment of the Water Resources Advisory Committee (WRAC) as described in the previous section. The Water Resources Act dictates the membership of the WRAC, and it was proposed to amend the Act to include the:

- + Chief Medical Officer, Ministry of Health;
- + Chief Executive Officer, National Works Agency (NWA); and
- + A representative from an Environmental NGO.

It was recommended that an amendment be made to the Water Resources Act to allow the Minister with portfolio responsibility for Water to appoint the WRAC Secretary, who would be the National IWRM Coordinator. The amendment would address the current situation where the WRA does not have the authority to interact at a ministerial level, which could lead to difficulties in implementing the IWRM.

Currently, GOJ agencies already receive and act upon the recommendations of a variety of stakeholders, including businesses and civil society groups, with regards to water resources management. However, many citizens lack opportunities to participate in decision-making on water resources management. In addition, many citizens are unaware of the importance of water resources management. This is particularly true for vulnerable groups, such as women.

Obstacles to scaling up successful models for citizen participation in IWRM include lack of information on the importance of land and water resources management, or the technical knowledge to make decisions. Further, parties with a vested interest in land and water management, such as farmers or manufacturers, may attempt to dominate IWRM because they have a greater incentive to participate, than private citizens.

The GOJ's policy is to adopt an IWRM approach to managing land, watersheds and water resources. This will include institutional co-

ordination and stakeholder participation through IWRM Committees. The Ministry with portfolio responsibility for Land and Water will lead the establishment of the IWRM Committees». A technical committee will be established to give strategic direction to the IWRM approach and ensure coordination of sector policies.

Activation of the Water Resources Advisory Committee (WRAC), as required under the Water Resources Act (1995), will be necessary. This committee will advise the Minister on the Water Resources Strategy and Action Plan, in addition to other statutory responsibilities assigned by the Water Resources Act.

Efforts shall be made to synchronize policies and legislation to provide an enabling environment to effectively implement the IWRM approach. A National IWRM Coordinator will be appointed to:

- ◆ Coordinate the implementation of the IWRM Framework, water sector strategies and plans;
- ◆ Function as the administrative link between WRAC and the Minister with portfolio responsibility for Water; and
- ◆ Promote stakeholder participation in land and water resources management.

The GOJ shall establish the Integrated Water Resources Management Council (IWRMC) by expanding its role to replace the National Integrated Watershed Management Council. The IWRMC shall be a multi-disciplinary and multi-sectorial body led by the Ministry with portfolio responsibility for Land and Water and reporting to the Cabinet. It shall involve key stakeholders in the land and water sectors.

## INTER-AGENCY COLLABORATION

Table 56 lists the main agencies, and their existing roles, in management of the water resources of the country. WRA is responsible for the management, protection, and controlled allocation and use of the water resources. However, many other Government agencies exercise some form of control and legislation on aspects related to water resources management in the country. Table 58 presents the proposed implementation roles for IWRM.

**TABLE 56: IWRM IMPLEMENTATION ROLES (EXISTING)**

| AGENCY                                                                                                        | RESPONSIBILITY                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>OVERALL IMPLEMENTATION</b>                                                                                 |                                                                                                                                                                                                                                                        |
| Ministry with portfolio responsibility for Water                                                              | Implement the Policy nationwide by coordinating Agencies' efforts. The Ministry with portfolio responsibility for Water will also monitor and evaluate implementation efforts.                                                                         |
| <b>OTHER MINISTRIES, DEPARTMENTS AND AGENCIES (MDAS) WITH POLICY MAKING AND COORDINATING RESPONSIBILITIES</b> |                                                                                                                                                                                                                                                        |
| Ministry with portfolio responsibility for Agriculture                                                        | Coordinate implementation of irrigation services                                                                                                                                                                                                       |
| Climate Change Division                                                                                       | Monitor and coordinate national climate change adaptation efforts, including in the water sector                                                                                                                                                       |
| Ministry of Local Government                                                                                  | Manage minor water supplies, water shops and community catchment tanks                                                                                                                                                                                 |
| Ministry of Finance and the Public Service                                                                    | Ensure efficient allocation and facilitate mobilization of financial resources                                                                                                                                                                         |
| Cabinet Office                                                                                                | Provide policy directives on major national and sectoral policies                                                                                                                                                                                      |
| Forestry Department                                                                                           | Protect the forests and forest watersheds on crown lands managed by the Agency                                                                                                                                                                         |
| Office of Disaster Preparedness & Emergency Management (ODPEM)                                                | Provide disaster management, to include drought and major meteorological events                                                                                                                                                                        |
| <b>SERVICE PROVIDERS</b>                                                                                      |                                                                                                                                                                                                                                                        |
| National Water Commission (NWC)                                                                               | Provide piped water supply in all areas where it is economical to do so, and provide piped sewerage services in all major towns                                                                                                                        |
| Rural Water Supply Ltd. (RWSL)                                                                                | Provide technical assistance to households and communities in rural areas and to build and maintain water supply and sanitation infrastructure                                                                                                         |
| National Irrigation Commission (NIC)                                                                          | Provide irrigation services                                                                                                                                                                                                                            |
| National Works Agency (NWA)                                                                                   | Provide flood water control services around roads, settlements and agricultural lands                                                                                                                                                                  |
| Municipal Corporations and Local Authorities                                                                  | Provide water supply to the public, by operating and maintaining local systems                                                                                                                                                                         |
| National Solid Waste Management Authority (NSWMA)                                                             | Manage solid waste islandwide                                                                                                                                                                                                                          |
| Private Providers                                                                                             | Provide water supply, sanitation, and irrigation services                                                                                                                                                                                              |
| <b>REGULATORS</b>                                                                                             |                                                                                                                                                                                                                                                        |
| Water Resources Authority (WRA)                                                                               | Regulate abstraction of groundwater, use of surface water, and coordinate integrated water resources management. The WRA along with the NRCA/NEPA will also lead the establishment of IWRM Committees in each hydrological basin, along with the NEPA. |
| National Environment and Planning Agency (NEPA)                                                               | Responsibility for conservation, protection and proper use of land, water and other resources, and sets standards for treating and discharging effluent, along with the Ministry of Health.                                                            |
| Ministry of Health (MOH)                                                                                      | Set and monitor standards for potable water supply,                                                                                                                                                                                                    |
| Office of Utilities Regulation (OUR)                                                                          | Set tariffs and regulate service standards for providers of piped water supply and sewerage systems, as well as, recommend licensees, providing policy advice and dispute resolution                                                                   |



TABLE 57: IWRM IMPLEMENTATION ROLES (PROPOSED)

| AGENCY/DIVISION                                                                            | RESPONSIBILITY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The Ministry with portfolio responsibility for Water, Land, Environment and Climate Change | Oversee the implementation and operation of the IWRM process.                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| WRA                                                                                        | Contribute to the:<br>(1) <b>Enabling Environment</b> by<br>(i) Recommending policy/policy change considerations.<br>(ii) Developing and periodically updating the " <i>Water Resources Development Master Plan.</i> "<br>(2) <b>Institutional Support</b> by:<br>Presenting/informing/disseminating data and information to stakeholder groups for informing decisions at local levels.<br>(3) <b>Management Instruments</b> : through its water allocation system being guided by economic, equity and environmental considerations. |
| NEPA                                                                                       | Coordinate and implement Integrated watershed management; regulate development; pollution control and wastewater management; ecosystem protection and conservation; public education; policy formulation and legislative review related to resource management.                                                                                                                                                                                                                                                                        |
| Environment and Risk Management Division                                                   | Develop national environmental policies and programmes, including those related to watersheds management, as the well the promulgation of legislation related to the environment, including regulations governing the management of wastewater and sludge.                                                                                                                                                                                                                                                                             |
| Climate Change Division                                                                    | Coordinate and facilitate the integration of a sustainable mechanism that facilitates the development, coordination, implementation and monitoring of policies, sectoral plans, programmes, strategies, and legislation to mitigate as well as adapt to the impacts of climate change.                                                                                                                                                                                                                                                 |
| National Water Commission (NWC)                                                            | Provide piped water supply and sewerage services.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Ministry of Health                                                                         | Monitor drinking and recreational water quality and promote safety and sanitation by risk reduction of Environmental Health hazards.                                                                                                                                                                                                                                                                                                                                                                                                   |
| The Ministry of Local Government and Municipal Corporations                                | Manage minor water supplies and community catchment tanks.                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Forestry Department                                                                        | Protect and improve forests and forest watersheds on crown lands managed by the Agency.                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Rural Water Supply Ltd. (RWSL)                                                             | Assist households and communities in rural areas in obtaining safe drinking water.                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| National Irrigation Commission (NIC)                                                       | Provide agricultural water and drainage services.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| National Works Agency                                                                      | Provide flood water control services around roads, settlements and agricultural lands.                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| National Solid Waste Management Authority                                                  | Manage solid waste in watersheds.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

**The IWRMC shall be responsible for:**

- Making recommendations to the Minister for all IWRM related matters.
- Overseeing the preparation of a comprehensive IWRM framework.
- Coordinating the implementation of land and water management plans/programmes at the macro and micro levels. This will eliminate the overlapping of responsibilities of MDAs which often results in conflicting objectives.
- Reviewing, monitoring and evaluating the implementation of the IWRM framework.
- Identifying financial and technical support for projects and programmes.
- Making recommendations for amendments to existing laws and/or the need for new laws.
- Reviewing periodically the development plans within the context of the IWRM framework.
- Liaising with agencies to obtain relevant data to guide decision making.



- ◆ Recommending incentives for private sector investment for improving land and water resources in Jamaica.
- ◆ Developing criteria and procedures for the establishment of Local Integrated Water Resources Management Committees (LIWRMC), and the integration of existing groups.
- ◆ Reviewing and monitoring the institutional capacities and strengthening of the LIWRMC and Governance Mechanisms.
- ◆ Preparing and submitting progress reports, through the Ministry with portfolio responsibility for Land and Water, to Cabinet.

A dedicated secretariat shall be established to support the work of the IWRMC. The creation of working groups shall be recommended to facilitate the execution of the IWRM framework in areas such as public education, financing, and public-private partnerships. The creation of Local IWRMCs in the 26 WMUs shall also be promoted to allow for full participation of various local stakeholders, included (but not limited to) farmers, churches, NGOs, etc.

*"Participation and continued capacity development will ensure the improved and increased measurement/collection of hydrological data which will lead to improved management of water resources and further refining of future Water Resources Master Plans."*

## BUILDING INSTITUTIONAL CAPACITY

A necessary condition to advance integrated water resources management in Jamaica is that all participating agencies and stakeholders have the institutional capacity to carry out their mandates. As such, the WRA will need to ensure adequate institutional capability in hydrology, water resources assessments, research, and groundwater management. This capacity can be ensured via:

- ◆ Continual staff development and training,
- ◆ Implementation of relevant external and internal projects with international donor agencies (e.g. Pilot Program for Climate Change Resilience and the Inter-American Development Bank, Hope-Yallahs Project, Essex Valley Project and Caribbean Development Bank, Isotope Hydrology projects with the International Atomic Energy Agency, Inter-Basin Transfer study, etc).
- ◆ Acquisition and maintenance of equipment, e.g. e-trackers, radar gauges, water quality metres, well divers, groundwater modelling software, GIS software, remote sensing analysis of satellite data etc.

Participation and continued capacity development will ensure the improved and increased measurement/collection of hydrological data which will lead to improved management of water resources and further refining of future Water Resources Master Plans.

## FUNDING OF THE WATER RESOURCES AUTHORITY

The Water Resources Act states in Part II Section 6 that:

*"The funds and resources of the Authority shall consist of-*

- Such sums as may be provided annually for the purpose in the Estimates of Revenue and Expenditure of Jamaica*
- Sums borrowed by the Authority pursuant to section 8 for the purpose of meeting any of its obligations or discharging any of its functions;*
- All other sums or property which may in any manner become payable to or vested in the Authority in respect of any matter incidental to its functions."*

Historically, the WRA's funding has been from annual government subventions based on review and approval of the budget submitted by the Authority. Budget submissions have usually been severely constrained, with focus on salaries, overhead expenses and routine hydrological data collection of streamflow and groundwater levels. There has been very little (if any) fiscal space provided for equipment acquisition and maintenance, research projects, capacity development or general improvement of the Authority's physical space and data collection expansion for water quality monitoring. While the WRA continues to partner with international donor agencies as previously mentioned to acquire equipment and increase institutional capacity, the maintenance and sustainability of these actions is severely threatened by the limited funding available once the various projects are completed.



**WRA**

WATER RESOURCES AUTHORITY

Revenue for the WRA has historically been relatively small when compared to the subventions received (between 4-6% of the annual budget). Most of the WRA revenue has come from the fees collected from the abstraction licenses and drill permits, along with cost-recovery hydrogeological investigations and reports for various state entities like the National Water Commission, Rural Water Supply Limited, National Housing Trust, and other entities. A major development in the WRA's revenue generation was the implementation of the Volume-Based Fee system, which became effective on April 1, 2018 for all abstractions in Jamaica. This is further discussed in the Demand-Side Management section.

While the VBF is a welcome addition to the WRA's funding regime, there is still a great need for sustainable and intentional funding of water resources management, monitoring and protection. In particular, there is a significant need for the WRA to fund water quality monitoring, abstraction monitoring and enforcement, and expansion of the hydrological network to install new stations and rehabilitate old stations. The funding of the WRA needs to be commensurate with the importance of water to all sectors of Jamaica's governance and operation.

An additional fee which could be considered are water discharge fees, where users would pay a fee to discharge treated effluent into natural waterways. However, this would be implemented by the agencies with mandate for effluent discharge monitoring, as opposed to the WRA. It should be noted that the WRA generally does not endorse effluent discharge into natural waterways, notwithstanding the facilitation provided for same under the NRCA environmental discharge regulations.

## WATER RESOURCES MANAGEMENT ALTERNATIVES

The management of water resources can take various forms, dependent upon the motivation and status of the management implementer. Regulators such as the WRA would often be motivated by the need to ensure equitable water resources for all users, while private sector users might be motivated by the need to reduce expenses and more efficiently use water for greater profit margins. The various alternatives for water resources management can be implemented via supply-side management, or demand-side management.

### SUPPLY-SIDE MANAGEMENT

Supply-side management is the implementation of various measures to increase the available supply of water resources beyond the commonly used groundwater or surface water sources. Four potential options for supply-side management are:

- ◆ Increased Water Storage
- ◆ Rainwater Harvesting
- ◆ Managed Artificial Recharge of Aquifers
- ◆ Desalination

### INCREASED WATER STORAGE

It is estimated that approximately 6,500 MCM/year of water flows to the sea via river discharge and runoff. This is much larger than the estimated reliable safe yield for surface water resources. If water storage capacity can be increased, then much of this water can be conserved for future usage, especially for the use of drought mitigation. Storage capacity could be increased by the use of dams, reservoirs, and microdams. Dams and Reservoirs: Table 58 shows some of the existing dams and reservoirs in Jamaica and their estimated capacity.

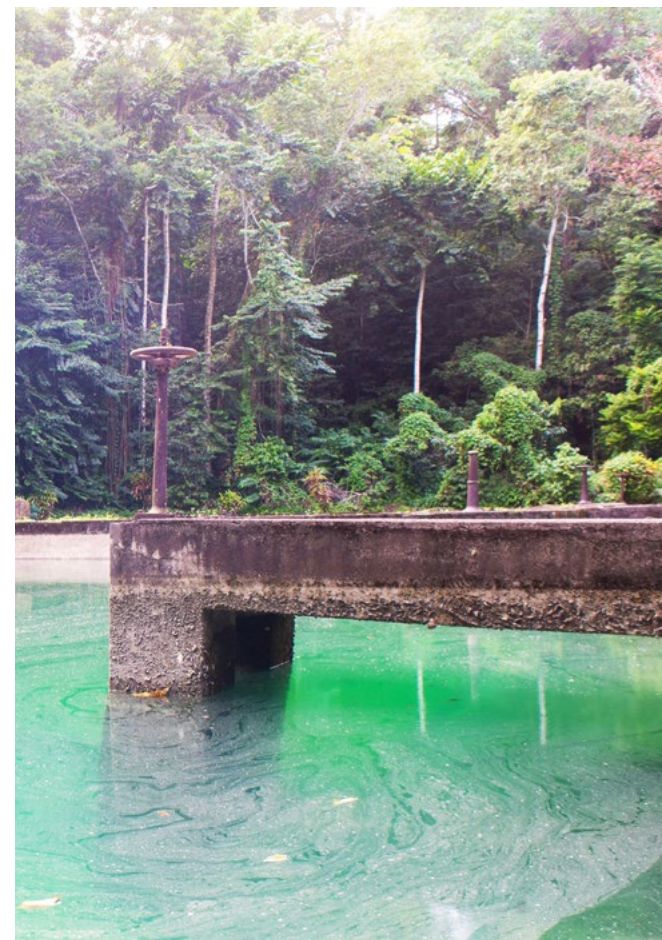


**TABLE 58: EXISTING DAMS AND RESERVOIRS**

| NAME                    | WMU             | RIVER                                   | CAPACITY (MCM)                                               | PURPOSE                                       |
|-------------------------|-----------------|-----------------------------------------|--------------------------------------------------------------|-----------------------------------------------|
| MONA RESERVOIR          | Hope River      | Hope River, Yallahs River               | 3.18                                                         | Domestic Storage                              |
| HERMITAGE DAM           | Wag Water River | Wag Water, Ginger River, Moresham River | 1.74                                                         | Domestic Storage, Hydroelectric generation    |
| RIO COBRE DAM           | Rio Cobre       | Rio Cobre                               | 121.2/year, (licensed abstraction)                           | Irrigation Diversion, Domestic Usage (future) |
| WHITE RIVER DIVERSION   | Dry Harbour     | White River                             | 176.4/year (licensed abstraction)                            | Hydroelectricity                              |
| ROARING RIVER DIVERSION | Dry Harbour     | Roaring River                           | 83.3/year (licensed abstraction)                             | Hydroelectricity                              |
| RIO BUENO DAM           | Dry Harbour     | Rio Bueno                               | 320.65/year (total licensed abstraction for both diversions) | Hydroelectricity                              |
| BLACK RIVER DIVERSION   | Black River     | Black River                             | 202/year (licensed abstraction)                              | Hydroelectricity                              |

Table 59 shows some water storage sites recommended in previous studies (NIC, 1998).

**TABLE 59: PREVIOUSLY RECOMMENDED NIC IRRIGATION STORAGE SCHEMES**

| IRRIGATION SCHEME | WMU         | STORAGE CAPACITY (MCM) |
|-------------------|-------------|------------------------|
| RIO PEDRO         |             | 35.6                   |
| RIO MINHO         | Rio Minho   | 21.5                   |
| MOUNT DAKIN       | Wagwater    | 3.4                    |
| SWIFT RIVER       | Swift River | 5.6                    |
| <b>TOTAL</b>      |             | <b>66.1</b>            |

- Microdams. The NIDMP listed 35 micro-dams that were identified to provide irrigation water. Their storage volumes of ranged from 23,000 to 730,000 m<sup>3</sup>/year. However, combined yield was only 4.7 MCM/year (less than 3% of national surface water yields). Of the 35, only 8 were constructed and only (4) are still operating. The operating ones are (2) in Rhymesbury in Clarendon (2) and (1) each at Bodles in St. Catherine (WMU 19) and Albion in St. Thomas (WMU

17). Those at Rhymesbury are licensed by WRA and operated by NIC. The micro-dams at Shettlewood and Hope Gardens are also operational (filled with water), though not in use.

There is scope for additional water storage in Jamaica. However, further work is needed to:

- Take cognizance of change in energy costs, land use and environmental impacts.
- Obtain critical information such as storage-elevation characteristics for reservoir sites. The ideal sites are on steeper reaches of rivers where large volumes can be stored using minimal area.
- Obtain critical economic considerations on economic cost, loss of land, dislocation and relocation of people and livestock, and environmental issues. A feasibility study was done in 2008 for an expanded dam construction on the Rio Cobre; however this was not implemented as the benefits did not outweigh the costs and impacts.

The most feasible form of increased storage is for municipalities and residents/consumers to ensure their own storage for times of low water availability, via installation of personal tanks and/or underground storage tanks where convenient.

## RAINWATER HARVESTING

Rainwater harvesting, as previously mentioned in the Climate Change Adaptation section of Chapter 7, is the collection and storage of rainwater from roofs and surface catchments to provide water supply for individual households or small communities. The systems need to be designed and operated to prevent contamination that could transmit water-related diseases. Rainwater harvesting is also necessary for enhancing water security following natural disasters, such as tropical storms and hurricanes, where water supply distribution infrastructure may be damaged and remain out of commission for extended periods. It may decrease peak flows, as well as, reduce flooding and damage



resulting from flooding. The system can serve individual households or communities. Household systems typically use the roof to catch water, in an elevated storage tank, and may include a system of pipes to deliver water to indoor taps. Community systems collect rainwater from a large concrete or metal catchment area and transfer it through pipes to a large storage tank. Rainwater harvesting may also be utilized in other sectors, such as agriculture, construction and tourism.

Rainwater harvesting is currently used by approximately 15 percent of households as their main source of water supply, including 31 percent of households in NUSAs. There are 353 community rainwater harvesting tanks that serve NUSAs. Maintaining rainwater harvesting systems is low-cost and does not require advanced technical knowledge. In many parts of the country, it is the least-cost method of delivering reliable water supply, combined with a reliable backup option, such as trucking. Backup supply is most often necessary during periods of drought conditions. Rainwater harvesting is likely to be an attractive water supply option in areas of high rainfall (above 1500 mm annually), but is still used in areas of relatively low rainfall when there is no other option available. The 2019 Water Sector Policy includes a Policy on Rainwater Harvesting as a method of augmenting water supply, and establishes incentives to offset the cost of investment in rainwater harvesting systems.

*"The 2019 Water Sector Policy includes a Policy on Rainwater Harvesting as a method of augmenting water supply and establishes incentives to offset the cost of investment in rainwater harvesting systems."*

### MANAGED ARTIFICIAL RECHARGE OF AQUIFERS

Artificial recharge is defined as the augmentation of the natural replenishment of groundwater in aquifers by artificial means. These means usually involve the injection of water into the aquifer via recharge wells, soak-away pits, or sinkholes. Artificial recharge could be used to:

- Store treated sewage effluent (see reuse of wastewater in Demand-Side management), excess irrigation water and excess storm water runoff for later use. It is important that appropriate treatment processes are employed before recharge.
- Mitigate or control saltwater intrusion into coastal aquifers.

In Jamaica, a pilot project was conducted in the mid-1980s at Innswood, St. Catherine to test the feasibility of artificial recharge. A series of pumping and non-pumping wells were used to monitor the project. Some main findings were that:

- Sinkholes can be used as injection points to recharge karstic limestone aquifers. Over an 18 month period, 4 MCM/year was recharged.
- Groundwater levels in some wells increased by 4-6 metres.
- Chloride concentrations in some wells decreased by 26- 85% (UNEP, 1997).

These findings indicated the possibility that artificial recharge can be used to control saline intrusion. As such, the WRA in partnership with the NWC and the RWSL constructed a Managed Artificial Recharge facility in the Innswood region of St. Catherine, located in the Rio Cobre sub-WMU. Construction was completed in 2016. This facility takes water diverted from the NIC canal, which then flows into settling ponds and then into reed beds for removal of nutrients and potential contaminants. The treated water is then channelled via pipes into various wells and sinkholes in the region to recharge the underlying limestone aquifer. Figure 52 presents a schematic diagram of the site. The main aim of this recharge facility is to reverse saline intrusion and increase the aquifer's safe yield and productivity for sustainable usage. The specific motivation for the MAR was to make up the additional water granted to the NWC for the Western Headworks wells, as a decline in groundwater levels and increase in chloride concentration was noticed during the abstraction from these wells. The WRA is currently monitoring the surrounding wells and has also partnered with the IAEA and NWC to complete an Isotope Hydrology study to determine the facility's effectiveness in combating saline intrusion.

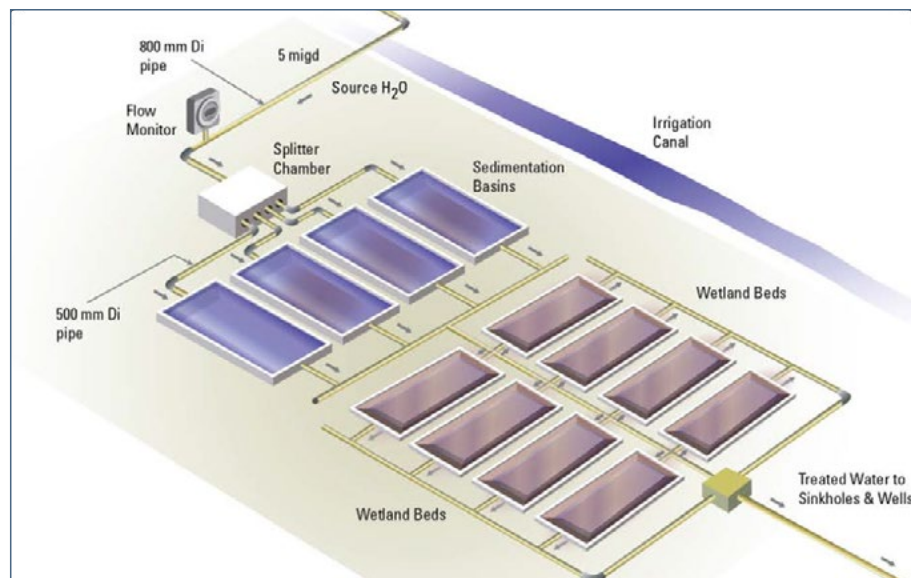


Figure 52: Schematic diagram of Innswood Managed Artificial Recharge Site (Source: NWC)

The success of this initiative provides a template for future MAR facilities in other stressed aquifers. Potential candidates include the Lower Rio Cobre Alluvium Aquifer, and the Rio Minho Limestone Aquifer near Sevens, Clarendon. The Lower Rio Cobre Alluvium Aquifer in particular could be artificially recharged by the use of specially designed infiltration basins, with the recharge water coming from the NIC canal or from treated wastewater from Soapberry Treatment Facility.

## DESALINATION

Desalination is the process by which the salt content of water is reduced sufficiently to make the water fit for specified uses. There are desalination plants in some Caribbean islands including Antigua, Aruba, Bahamas, Barbados, Cayman Islands, Curacao, St. Croix, St. Thomas, and the U.S. Virgin Islands. Desalination is usually implemented in regions where there

are no other water resources available, or where the available water resources are insufficient to meet the existing water demand (i.e. water-scarce regions). Some of the drawbacks of desalination include:

- The capital investment and production cost currently ranges from about US\$600-5,000 per 1000 m<sup>3</sup> (Keller *et al.*, 2000; UNEP, 1997). The high cost has restricted their extensive use.
- Concentrated brine is a by-product of the desalinisation process. The disposal of the brine without causing damage to the environmental effects.
- Desalination is very energy-intensive, and this impacts the scale of production.

Desalination usage in Jamaica has mostly been limited to tourism interests (e.g. Moon Palace Hotels in Ocho Rios, and Secrets Hotels in Jamaica) or industrial/bulk water sale interests (e.g. Kingjam Well in Kingston, Jamaica).

The WRA does not consider desalination to be an essential supply management option for Jamaica at this time. It may become more essential in the future as climate change impacts lessen the availability of freshwater resources, but the major constraints of cost, energy usage and environmental impact would still impact its usage. Future improvements in these constraints would increase the probability of wide-scale desalination in Jamaica.

## DEMAND-SIDE MANAGEMENT

Demand-side management is the application of measures to most efficiently use existing water resources, change the water usage habits of consumers. The measures include more efficient water delivery, processing and agricultural practices, reuse of water, and inter-basin transfers.

## INCREASED WATER USAGE EFFICIENCY

Improved use efficiency in the domestic, agricultural and industrial sectors could improve the water surplus-deficit situation in different areas of the country. The use of hydroponics and drip irrigation would both reduce the amount of water required for irrigation, and lead to expanded agricultural production both in agricultural yield, and in expansion of land area available for agricultural production. For domestic and industrial usage, the reduction of non-revenue water and the improvements in the consumer's water usage



habits would also lead to significant savings in water usage and an increase in the amount of available water. Table 60 shows projections on its impact in Hope River, Rio Cobre and Rio Minho WMUs which are stressed or have the potential to be stressed.

The data indicate that potential beneficial impacts of demand-side management programmes include:

- Improved irrigation efficiencies would increase the projected water surpluses in Rio Cobre and Rio Minho WMUs by 2-3 times.
- Enhanced municipal delivery efficiency with lower unit residential water use in Rio Cobre and Rio Minho WMUs would further increase their water surpluses.
- Increase in municipal water delivery efficiency in Hope River WMU would reduce the apparent 2025 water deficit.
- Reduction of need to increase available water resources despite rise in the 2005-2025 demands.

**TABLE 60: EFFECTS OF DELIVERY EFFICIENCIES AND RESPONSIVE RESIDENTIAL USE ON 2025 DEFICITS**

| SCENARIO                                                                  |                        | DEMAND                  | SELECTED WMUS (MCM) |           |           |
|---------------------------------------------------------------------------|------------------------|-------------------------|---------------------|-----------|-----------|
| NO.                                                                       | DESCRIPTION            |                         | HOPE RIVER          | RIO COBRE | RIO MINHO |
| A: RESOURCES AVAILABLE (BENCHMARKED AT 2005 LEVELO                        |                        |                         | 75                  | 484       | 266       |
|                                                                           | 2005 Irrigation and    | Irrigation Demand       | 0.1                 | 270       | 151       |
|                                                                           | Municipal Efficiencies | Total Demand            | 97                  | 431       | 203       |
|                                                                           |                        | Demand – 2005 Resources | -22                 | 53        | 63        |
|                                                                           | Improved Irrigation    | Irrigation Demand       | 0.1                 | 159       | 87        |
|                                                                           | Efficiencies1          | Total Demand            | 97                  | 319       | 140       |
|                                                                           |                        | Demand – 2005 Resources | -22                 | 165       | 126       |
|                                                                           | Improved Irrigation &  | Irrigation Demand       | 0.1                 | 159       | 87        |
|                                                                           | Municipalefficiencies2 | Total Demand            | 81                  | 303       | 138       |
|                                                                           |                        | Demand – 2005 Resources | -6                  | 181       | 128       |
|                                                                           | Scenario No. 3 plus    | Irrigation Demand       | 0.1                 | 159       | 87        |
|                                                                           | Lower Residential use3 | Total Demand            | 73                  | 294       | 137       |
|                                                                           |                        | Demand – 2005 Resources | 2                   | 190       | 129       |
| 1. Potential irrigation efficiencies given in Chapter 5 (NIC, 1998)       |                        |                         |                     |           |           |
| 2. Municipal delivery leakage losses reduced from 40% to 25%              |                        |                         |                     |           |           |
| 3. Per capita use reduced from 172 to 150 litres/day, leakage losses 25%. |                        |                         |                     |           |           |

## TREATMENT, RECYCLING AND RE-USE OF WASTEWATER

The reuse and recycling of wastewater is becoming more accepted as wastewater treatment technology increases over time. Countries such as Israel and Singapore have proved the viability of using treated wastewater as a resource for domestic, irrigation and industrial purposes. Singapore in particular has blazed the trail with their NEWater which recycles their wastewater into ultra-clean high-grade reclaimed water which supplies up to 40% of their current water demand.<sup>21</sup>

There are currently no formal water reuse or recycling programmes in Jamaica. However there have been local efforts at water recycling – mainly in the bauxite and alumina industry. Furthermore, the Soapberry Wastewater Treatment Plant (operational since 2008) currently treats the corporate area's sewage to the tertiary level, and the treated effluent could be further treated via Ultra Violet radiation to remove coliform bacteria which would further improve the water quality for irrigation and recharge usage. The daily volume of treated effluent from the Soapberry plant is 55,000 cubic metres per day<sup>22</sup> and this is discharged into the Rio Cobre flowing into Hunts Bay. This discharge, once further treated, could replenish the Lower Rio Cobre Alluvium Aquifer and serve as a source of irrigation water within the region.

<sup>21</sup> <https://www.pub.gov.sg/watersupply/fournationaltaps/newater>

<sup>22</sup> [http://www.jamaicaobserver.com/environment-watch/what-a-waste-\\_150238?profile=1123](http://www.jamaicaobserver.com/environment-watch/what-a-waste-_150238?profile=1123)

There is an estimated potential to recycle nearly 70% of the water used within the industrial sector. This would release almost 60 MCM/year for re-allocation– about 2% of the total usable (ground plus surface) water resources of the country and about 7% of the annual demands. Potential re-use opportunities include:

- ◆ Aquifer recharge by percolation of wastewater from homes and housing developments. This contribution is currently small compared to the safe yields. There are also water quality constraints – especially related to usability for domestic purposes.
- ◆ Reuse of industrial wastewater in cooling and manufacturing. For the latter, food quality and safety would constrain application in the food and beverage industry.
- ◆ Irrigation of golf courses with treated wastewater.

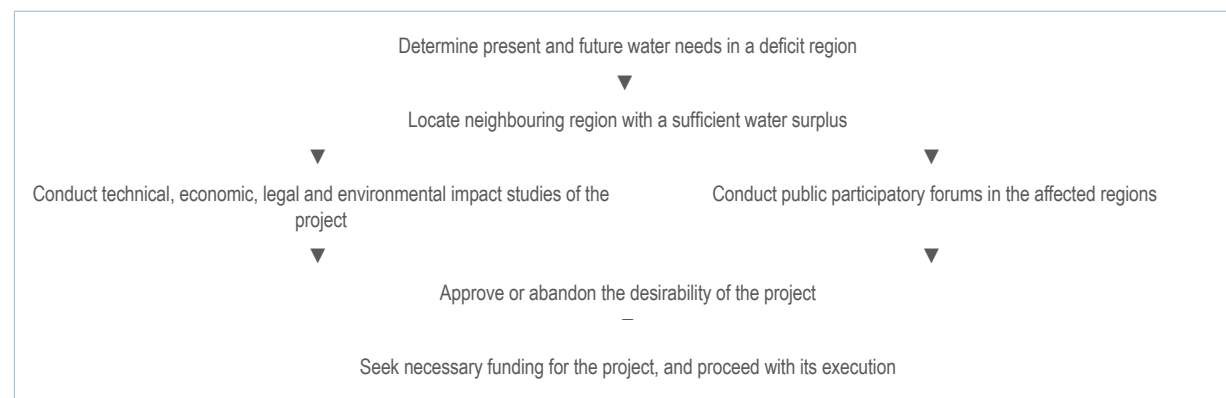
## INTER-WMU TRANSFER

Transfer of water from a hydrologic unit with excess to a unit with need is an established water management practice. In Jamaica, about

50% of KMA potable water supply is sourced from Wagwater, Yallahs and Rio Cobre WMUs. The 1990 WRDMP lists projects that were recommended. The WRA has also prepared a report (N. Hutchings, K. Chambers, 2018) regarding potential Inter-WMU transfers from the Dry Harbour basin into the KMA, considering the Rio Bueno, White River and Laughlands Great River as the main sources of water for the proposed interbasin transfer. Pipelines would be aligned along the existing Edward Seaga Highway, with the final connection point at the proposed NWC Content Water Treatment Facility to be constructed at Damhead on the Rio Cobre.

Despite its importance, neither the 1990 WRDMP nor the Water Resources Act has explicit reference to regulate the transfers. However, both set out priorities of water demands that should be considered in project selection, especially with considerations for reserved resources in the Water Resources Act. Table 61 shows a sequence that may be adopted for consideration of inter-WMU transfer projects.

**TABLE 61: MECHANISMS FOR PLANNING INTER-BASIN TRANSFERS**



## VOLUME-BASED FEE

The Volume-Based Fee is an economic instrument used for quantity and quality management of water resources, and manages demand and provides a return on a valuable and scarce resource. In addition, the fee covers expenditure on data collection; analysis and dissemination of data/information; water resources assessment; floodwater control and mapping. The fees are currently gazetted as follows for the stated usage categories in table 62.

**TABLE 62: VOLUME-BASED FEES AND USES**

| WATER USES                                                                                               | FEES (J\$4.545 M <sup>3</sup> /ANNUM) |
|----------------------------------------------------------------------------------------------------------|---------------------------------------|
| Domestic/Public Supply                                                                                   | 0.1150                                |
| Industrial                                                                                               | 0.1725                                |
| Non-consumptive (including, but not limited to, hydropower, aquaculture, and some recreational purposes) | 0.0920                                |
| Agriculture                                                                                              | 0.1725                                |

The Volume-Based Fee has an additional impact on demand-side management. Since the VBF levies a fee on the licensed abstraction figure even if the actual abstraction is less than the licensed amount, the abstractors are incentivized to adjust their abstraction licenses to their actual usage amounts and thus make more water available to other users. Some abstractors have even relinquished their licenses based on the VBF and associated costs for reserving water rights they no longer use. Table 63 summarises the benefits and shortcomings of water use fees.

**TABLE 63: BENEFITS AND SHORTCOMINGS OF WATER USER FEES**

| SHORTCOMINGS                                                                                          | BENEFITS                                                            |
|-------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| Difficult to adjust abstraction fees over time – as needed to respond to change in supply and demand. | Easier to promote technological innovations for water conservation. |
| Possibility of User Fees being passed on to consumers in higher prices.                               | Lower administration costs for Permit system.                       |
| High water use sectors could experience higher cost. Could be minimised by phasing.                   | Increased charge for water used in ecologically sensitive areas.    |
| Low volume water users may require exemption from Fees                                                | Encourage water conservation and efficient use                      |
| Possible need for enforcement costs.                                                                  | Increased charge for water diminished in quality by effluents.      |
|                                                                                                       | Promote environmental policy and conservation goals                 |
|                                                                                                       | Sources of funding of WRA from charges.                             |
|                                                                                                       | Permit and/or licensing system already in place                     |

## INCENTIVES FOR WATER CONSERVATION

Water conservation can be incentivised through multiple measure. Some of these measures include:

- Installation of meters, increasing block rate structures, seasonal pricing, charge for excess use, and financial incentives such as rebates, subsidised retrofits and water audits
- Education and public information on water conservation and efficiency of use and appeals for voluntary reductions
- Revision and enforcement of plumbing, building and landscaping codes.
- Rationing, limiting the time or quantity of use through “no outdoor water use” or alternate day rules.

Documented benefits include:

- Encouragement of recycling and/or re-circulation.
- Savings from increased industrial water use efficiency and re-cycling or re-use.

Renwick and Green (2000) and Renzetti (2005) found that well designed demand-side management measures can cause reductions in water demand of 15% and more.

## WATER MARKETS

Water markets allow water users such as irrigation associations, municipalities and large industries to trade their water permits – either by sale or by lease. This allows prices to respond to

change in supply and demand. The expectation is that changing prices can provide valuable information to inform users to make decisions regarding production levels, business locations and investments.

Issues that need to be considered in the design of a water permit market include:

- Provision for government oversight of the decentralised trading to ensure that environmental water demands are met and that potential third-party impacts are minimised.
- Allowance for the existing priorities of water use. This may require trade of permits across user groups or assigning differing weights to different water use groups.
- Annex C lists options for water permit charges, as well as alternative water valuation methods, estimates and case studies.

## WATER SHOPS

In recent times, the Government of Jamaica has implemented an initiative to construct water shops as a way to address water shortages in parishes that traditionally suffer from severe drought conditions. The water is trucked to the shops, purified and then made available to residents for free or at a discounted cost. The average amount of water provided at water shops is 16,000 gallons/day (60.56 m<sup>3</sup>/day)

## WATER FUND AND PAYMENT FOR ECOSYSTEM SERVICES

Water Funds are organizations that design and promote financial and governance mechanisms, engaging public, private, and civil society stakeholders in order to contribute to water security through solutions grounded on nature-based infrastructure and sustainable management of watersheds.<sup>23</sup> They contribute to the better governance of water resources; once key stakeholders for good water management have been identified in a watershed area, the

<sup>23</sup> <https://www.fondosdeagua.org/en/the-water-funds/>



Water Fund approaches them and generates the necessary dialogue conditions, sometimes functioning as the bridge between the different sectors. Water Funds offer scientific information for the identification and prioritization of the challenges to be solved, so that decision making is based on science and incorporate the different visions and possible solutions to contribute in the best way to ensure the water security of cities.

The pioneering experience of the Water Funds began in the high Andean wetlands, an ecosystem that harbours many threatened animal species. These wetlands are also essential water sources for cities such as Quito, Ecuador. In the year 2000, TNC and the Municipal Drinking Water Company of the City of Quito (EMAPS) realized that the degree of deterioration of the wetlands put the city's water supply at risk. That concern motivated the creation of the first Water Fund. Other cities were inspired, such as Rio de Janeiro and Espirito Santo, in Brazil; Bogota, in Colombia and Paute and Tunguragua, in Ecuador to adopt this model. The creation of the Latin American Water Funds Partnership in 2011 provided seed capital and technical assistance fundamental for the systematization of the methodology, its refinement and the expansion that we can see in the region today.

Currently, the pioneering model in Latin America has been successfully implemented in many countries, from the United States to China and Africa. In Jamaica, The Nature Conservancy started a preliminary investigation in 2019 to establish a Water Fund for the Kingston Metropolitan Area, with special focus on preserving the Wag Water River WMU and Hermitage Dam therein. The programme was suspended in 2020 due to the COVID-19 pandemic, but is expected to resume post-COVID where feasible.

A similar concept is the Payment for Ecosystem Services, which are incentives offered to farmers/landowners in exchange for managing their land to provide some sort of ecological service. In Jamaica, PES schemes have been considered for application under the Hope-Yallahs Watershed project spear-headed by the NEPA and PIOJ.

*"...the recommended order of allocation is:  
1<sup>st</sup>: Public water demand.  
2<sup>nd</sup>: Non-consumptive demands such as hydro-power and environmental flows.  
3<sup>rd</sup>: Industrial and agricultural water demands."*

## WATER RESOURCES ALLOCATION

The allocation of water resource in Jamaica is guided by Regulations No. 4 of the Water Resources Act. This states that, in evaluating merits of water abstraction and water use applications, WRA shall give regard to:

- The provisions of the WRDMP - including any amendments thereto.
- Any recommendations or representation, pursuant to the publishing of notices of application, made by any other Government agency or department exercising functions in relation to water.
- The priority of the satisfaction of public water supply demands.
- The requirements and financial and technical capabilities of the applicant.
- The requirements of other water users.
- The safeguarding of public health and the environment.
- The requirements of in-stream uses of the water.
- The requirement of land drainage.

## ALLOCATION PRIORITIES

The 1990 WRDMP did not include a priority ranking for water allocation. For decision-making, the 1990 WRDMP:

- Recommended use of surface water over groundwater. Ground water is generally regarded as being more cost effective to develop because of the implication to provide storage and treatment facilities both of which are capital intensive. However, this might need to be re-evaluated in light of the increasing energy cost.
- Defined productive and non-productive sectors as follows:
  - + The productive sectors: agriculture, industry, tourism and hydro-power generation.
  - + The non-productive sectors: domestic, public (non-commercial) service and nature reserves.

The first group uses water as one of its production inputs. The second group uses water as an essential requisite for civilized human existence.

In this Master Plan upgrade, agriculture includes crop irrigation, recreational irrigation, and aquaculture. Public supply includes domestic,



tourism, commercial (offices, banks, etc.) and institutional (schools, hospitals, etc.) usage. Non-consumptive usage includes hydro-power and recreational usage. Environmental flows are reserved as far as possible to remain instream and not used for any consumptive allocation.

The Water Resources Authority historically (pre-1995) allocated water resources in the following order of priority:

1<sup>ST</sup> : Public water demand.

2<sup>ND</sup> : Agricultural demand

3<sup>RD</sup> : Industrial demand

This order of priority facilitates recycling and reuse of water.

Since the promulgation of the Water Resources Act 1995, there has been both national and international developments that necessitated changes in the process governing the allocation of water. One of the developments has been the implementation of IWRM and Vision 2030, which focuses on sustainability of the environment. Consequently the recommended order of allocation is:

1<sup>ST</sup> : Public water demand.

2<sup>ND</sup> : Non-consumptive demands such as hydro-power and environmental flows.

3<sup>RD</sup> : Industrial and agricultural water demands.

This ranking fits in with Schedule 4 of the Water Resources Act and the spirit of the Water Sector Policy. However the framework must also give credence, while satisfying sectorial demands, to the need to safeguard the public interest.

## ALLOCATION MECHANISMS

Water resources allocation is usually made by a combination of administrative and technical decisions influenced by allocation priorities previously mentioned and quantities available as determined by the Safe Yields and existing allocations.

## ADMINISTRATIVE APPROACH

An administrative approach to allocation of water uses legislative measures. In Jamaica, this is done under the provisions of Section 19 of the Water Resources Act. The Act vests authority in WRA to issue water abstraction and water use licences. Pros and cons of this method are that:

- Response to emergency situations such as severe droughts is facilitated.
- Water is not necessarily allocated to the highest valued uses.
- Adjusting allocations to respond to changes in supply and demand is more difficult.
- Decision-making may be perceived to lack transparency and participation.

For public water, existing and proposed measures to safeguard public interest include:

- Delegating OUR, through the OUR Act, to oversee tariffs and service standards. The National Water Commission Act has been amended to permit OUR to license municipal water and sewage providers, set tariffs and service standards, promote competition among service providers, protect consumer interest and advise the Minister on water supply and sewerage services matters.
- Drafting of a Water Supply and Sewerage Services Act. Proposals for regulations include:
- Provision of a generic framework to protect customers and to prevent or correct abuse of market power.
- Promotion of an industry structure that is economically and ecologically sound.
- Provision for equal treatment of service providers - whether private or public.

## MARKET-BASED APPROACH

The market-based approach provides for allocation to be driven by economic instruments such as user fees and the relative value of different water uses. It relies primarily on interactions of buyers and sellers of water rights. Options to introduce market-oriented measure include introduction of:

- Global water use fees or volumetric charges for the right to abstract and use water.
- Publicity campaigns to promote water conservation.

Table 64 indicates some of its advantages and disadvantages.

**TABLE 64: ADVANTAGES AND DISADVANTAGES OF MARKET-BASED APPROACH TO WATER ALLOCATION**

| ADVANTAGES                                                                                             | DISADVANTAGES                                                                                                                 |
|--------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>Ability to adapt allocations rapidly to changes</li> </ul>      | <ul style="list-style-type: none"> <li>Increased difficulty to protect in-stream and</li> </ul>                               |
| <ul style="list-style-type: none"> <li>in supply and demand conditions</li> </ul>                      | <ul style="list-style-type: none"> <li>other environmental water demands</li> </ul>                                           |
| <ul style="list-style-type: none"> <li>Direct compensation to water sellers</li> </ul>                 | <ul style="list-style-type: none"> <li>Less centralised control over water allocations</li> </ul>                             |
|                                                                                                        | <ul style="list-style-type: none"> <li>More difficulty in preventing negative</li> </ul>                                      |
|                                                                                                        | <ul style="list-style-type: none"> <li>negative impacts on third parties</li> </ul>                                           |
| <ul style="list-style-type: none"> <li>Promote more efficient use and conservation of water</li> </ul> | <ul style="list-style-type: none"> <li>Less centralised control over water allocations</li> </ul>                             |
| <ul style="list-style-type: none"> <li>Can be administered by local water user associations</li> </ul> | <ul style="list-style-type: none"> <li>The system may be viewed as excluding or being disadvantageous to the poor.</li> </ul> |

## CHANGING ALLOCATION PRIORITIES

Allocation priorities are not static. Conditions may arise that cause a change in the priorities. These include: resolution of conflicts between competing users interests, response to emergencies in the short-term, and impacts of climate change on water resources in the long-term as per the projections previously mentioned.

## CONFLICT RESOLUTION

The mix of centralised administrative and market-based water allocation system often lead to cloudy areas. There is therefore need for a well-articulated process to resolve conflicts and enforce decisions. Part VI Section 48 subsection 2 of the Water Resources Act states:

*“Until the Authority has been consulted thereon, any matter which involves the supply of water or which*

*affects or may affect surface or underground waters or both, shall not be approved or finally determined by any person, body or agency having authority in that behalf.”*

This clause enables the Water Resources Authority to be the main mediator to facilitate the resolution of any water-based conflict.

## EMERGENCIES

The allocation of water during normal situations can usually be done by normal administrative and market-based mechanisms. However, specials provisions are needed during water shortage emergencies that are associated with events such as droughts. This requires that a responsible agency be vested with the authority to act. WRA is vested with this authority under the Water Resources Act.

## WATER RESOURCES MONITORING

The development of this and prior WRDMPs, the estimated water resources availabilities and all assessments of safe yield and projected impacts of climate change would not be possible without a robust and reliable Water Resources Monitoring network. The hydrological data collected by the network (including precipitation from rain gauges via Met Office, streamflow via stream gauges and groundwater levels from monitoring wells) is essential to sound decision making and future planning. Since all research and assessment is only as good as the data which informs that research and assessment, the maintenance and funding for Jamaica's Water resources Monitoring network must be of a sufficient level to ensure that quality data is collected in proper quantities and frequencies to ensure accurate assessment and research.

## STATUS OF BASIN AND WMU HYDROLOGICAL MONITORING NETWORK

Table 65 shows the number of historical and current streamflow stations and groundwater index wells in each WMU. Data from these stations and wells were used to estimate the available water resources in Chapter 6 of this master plan. They are also mapped on figures 53 and 54. The data indicates that major outflows from 24 WMUs are being collected, with gaps in the Oracabessa-Pagee and New Savannah River WMUs. Water level data is currently monitored at 286 out of 2229 recorded wells.

The optimum size of a monitoring network is usually constrained by availability of human and financial resources (Davar and Brimley: 1990 and



Harmancioglu *et al*: 1998). However, it normally is designed to provide sufficient and accurate information. The network size, most appropriate locations and frequency of sampling can be adjusted as necessary. Table 66 presents recommendations for re-continuations and additions to the monitoring network to provide a more comprehensive monitoring network that provides more data for future analysis.

**TABLE 65: TOTAL STREAMFLOW STATIONS AND MONITORING WELLS PER WMU**

| BASIN                 | WMU                       | CURRENT STATIONS | DISCONTINUED STATIONS | TOTAL STATIONS | GROUNDWATER MONITORING INDEX WELLS |
|-----------------------|---------------------------|------------------|-----------------------|----------------|------------------------------------|
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     | 1                | 0                     | 1              | 2                                  |
|                       | Morant River              | 3                | 0                     | 3              | 7                                  |
|                       | Yallahs River             | 11               | 6                     | 17             | 6                                  |
| KINGSTON              | Hope River                | 1                | 4                     | 5              | 14                                 |
| RIO COBRE             | Rio Cobre                 | 14               | 12                    | 26             | 85                                 |
| RIO MINHO             | Rio Minho                 | 11               | 9                     | 20             | 17                                 |
|                       | Milk River                | 6                | 6                     | 12             | 25                                 |
|                       | Gut River-Alligator Hole  | 4                | 0                     | 4              | 0                                  |
|                       | Black River               | 12               | 12                    | 24             | 39                                 |
| CABARITA RIVER        | Deans Valley River        | 1                | 1                     | 2              | 3                                  |
|                       | Cabarita River            | 6                | 2                     | 8              | 4                                  |
|                       | New Savannah River        | 0                | 1                     | 1              | 1                                  |
|                       | South Negril-Orange River | 2                | 1                     | 3              | 12                                 |
| GREAT RIVER           | Lucea River               | 2                | 3                     | 5              | 2                                  |
|                       | Great River               | 3                | 2                     | 5              | 1                                  |
|                       | Montego River             | 3                | 3                     | 6              | 6                                  |
| MARTHA BRAE           | Martha Brae               | 6                | 5                     | 11             | 16                                 |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River     | 16               | 11                    | 27             | 28                                 |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 | 1                | 9                     | 10             | 0                                  |
|                       | Oracabessa-Pagee          | 0                | 0                     | 0              | 0                                  |
|                       | Wagwater River            | 5                | 8                     | 13             | 8                                  |
|                       | Pencar-Buff Bay River     | 5                | 4                     | 9              | 6                                  |
|                       | Spanish River             | 1                | 4                     | 5              | 0                                  |
|                       | Swift River               | 1                | 3                     | 4              | 1                                  |
|                       | Rio Grande                | 6                | 2                     | 8              | 2                                  |
|                       | Drivers River             | 5                | 1                     | 6              | 1                                  |
|                       |                           |                  |                       |                |                                    |
| <b>TOTAL</b>          |                           | <b>126</b>       | <b>109</b>            | <b>235</b>     | <b>286</b>                         |

**TABLE 66: PROPOSED NEW/REHABILITATED STATIONS FOR WRA MONITORING NETWORK**

| BASIN                 | WMU                       | PROPOSED NEW/REHABILITATED STATIONS                                                                     | PROPOSED MONITORING WELL ADDITIONS        |
|-----------------------|---------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------|
| BLUE MOUNTAIN SOUTH   | Plantain Garden River     |                                                                                                         |                                           |
|                       | Morant River              | Ginger River, Nutts Great River, Duppy River, Morant River near Morant Bay, Negro River, Rozelle Falls  |                                           |
|                       | Yallahs River             | Cane River                                                                                              |                                           |
| KINGSTON              | Hope River                | Constant Spring                                                                                         |                                           |
| RIO COBRE             | Rio Cobre                 | Ferry River, Salt Island Creek, Coleburn Gully                                                          |                                           |
| RIO MINHO             | Rio Minho                 | Bowers River nr Freetown, Rio Minho at Alley                                                            |                                           |
|                       | Milk River                | Hillards River at Springfield                                                                           |                                           |
|                       | Gut River-Alligator Hole  |                                                                                                         | Construction of Exploratory Index Well(s) |
| BLACK RIVER           | Black River               | Broad River at Slipe, Styx River near Lacovia                                                           | Wells in Bull Savannah sub-WMU            |
| CABARITA RIVER        | Deans Valley River        | Robins River, Corn River                                                                                |                                           |
|                       | Cabarita River            | Thicketts River, Cabarita River further downstream                                                      |                                           |
|                       | New Savannah River        | New Savannah River at Delveland                                                                         | Construction of Exploratory Index Well(s) |
|                       | South Negril-Orange River | South Negril River nr Springfield                                                                       |                                           |
| GREAT RIVER           | Lucea River               | Davis Cove nr Davis Cove, Pell River, Island River, Lucea East River, Flint River                       |                                           |
|                       | Great River               |                                                                                                         |                                           |
|                       | Montego River             |                                                                                                         |                                           |
| MARTHA BRAE           | Martha Brae               |                                                                                                         |                                           |
| DRY HARBOUR MOUNTAINS | Rio Bueno-White River     | Pear Tree Bottom, Laughlands Little River (Chester Spring), Roaring River, Turtle River, Milford Stream |                                           |
| BLUE MOUNTAIN NORTH   | Rio Nuevo                 |                                                                                                         | Construction of Exploratory Index Well(s) |
|                       | Oracabessa-Pagee          | Oracabessa River, Pagee River, Crawle River                                                             |                                           |
|                       | Wagwater River            | Wag Water Below Broadgate                                                                               |                                           |
|                       | Pencar-Buff Bay River     | Crooked Gut                                                                                             |                                           |
|                       | Spanish River             | Spanish River Below Chepstow, or Maebeess River before confluence with Spanish River                    |                                           |
|                       | Swift River               |                                                                                                         |                                           |
|                       | Rio Grande                |                                                                                                         | Construction of Exploratory Index Well(s) |
|                       | Drivers River             | Priestmans River, Black River, White River, Drivers River at Manchioneal                                | Construction of Exploratory Index Well(s) |



WRA

WATER RESOURCES AUTHORITY

## Groundwater Monitoring Network

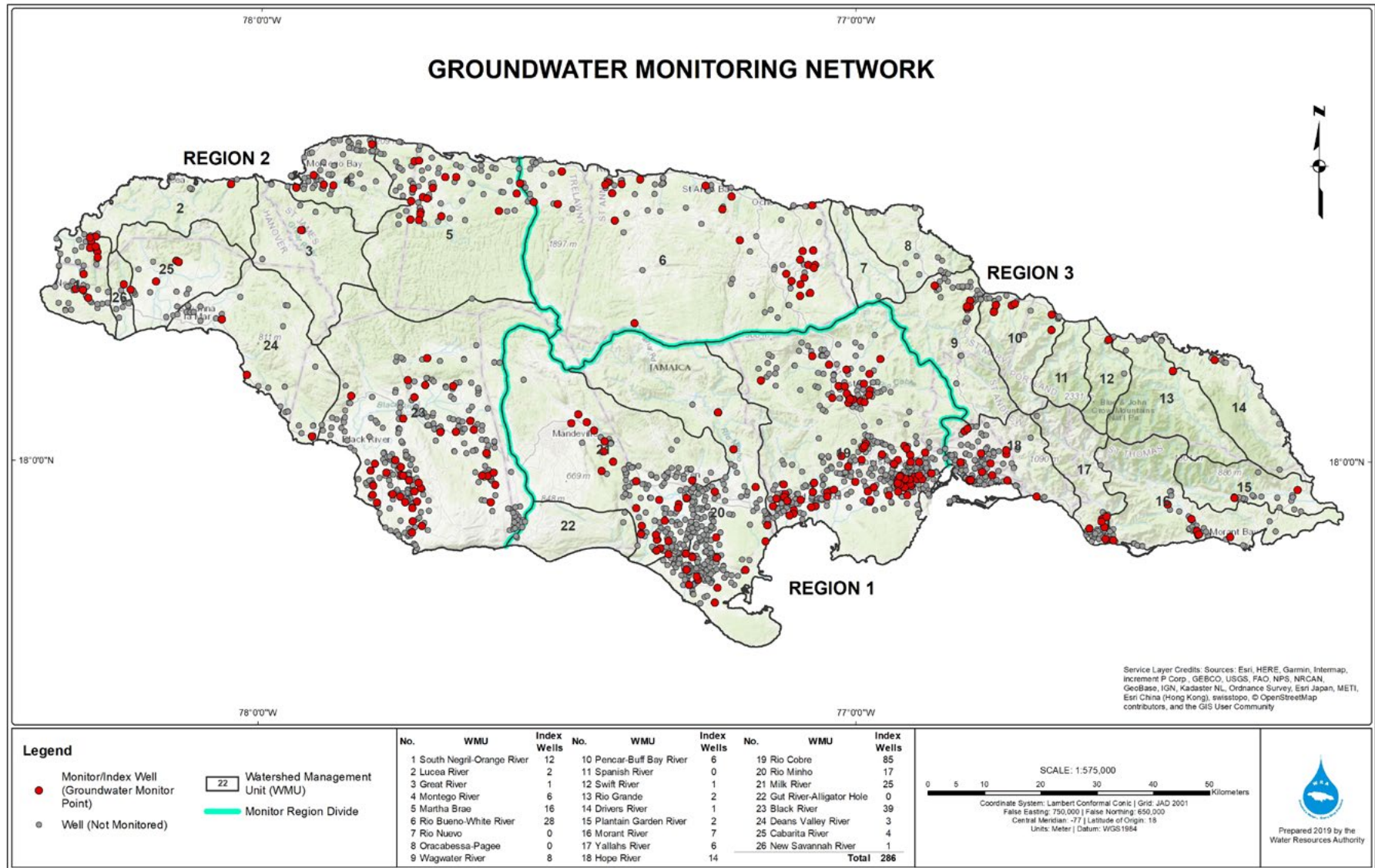


Figure 53: WRA Groundwater Monitoring Network

## Surface Water Monitoring Network

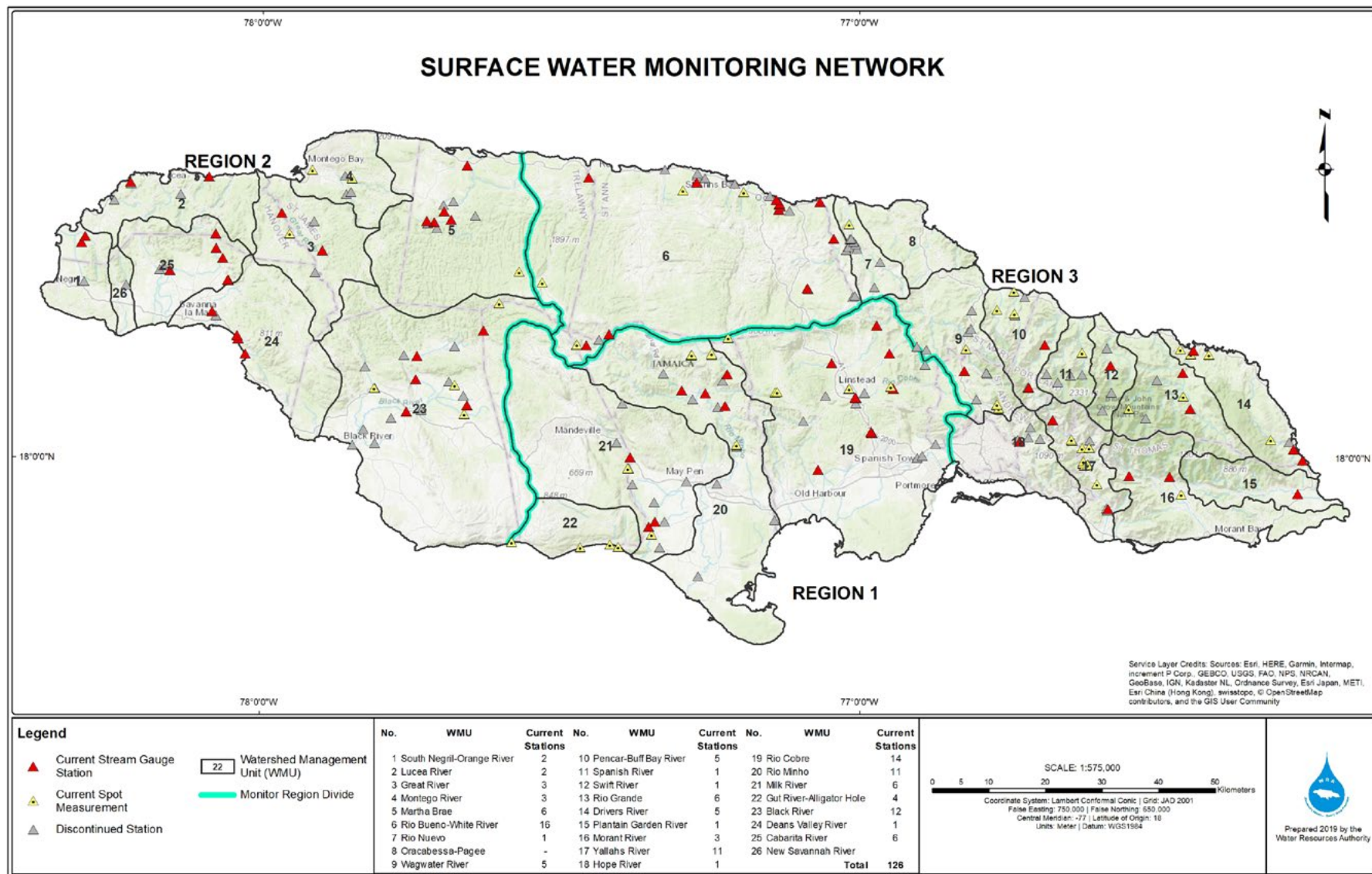


Figure 54: WRA Surface Water Network



WRA

WATER RESOURCES AUTHORITY

## Q90 Streamflow

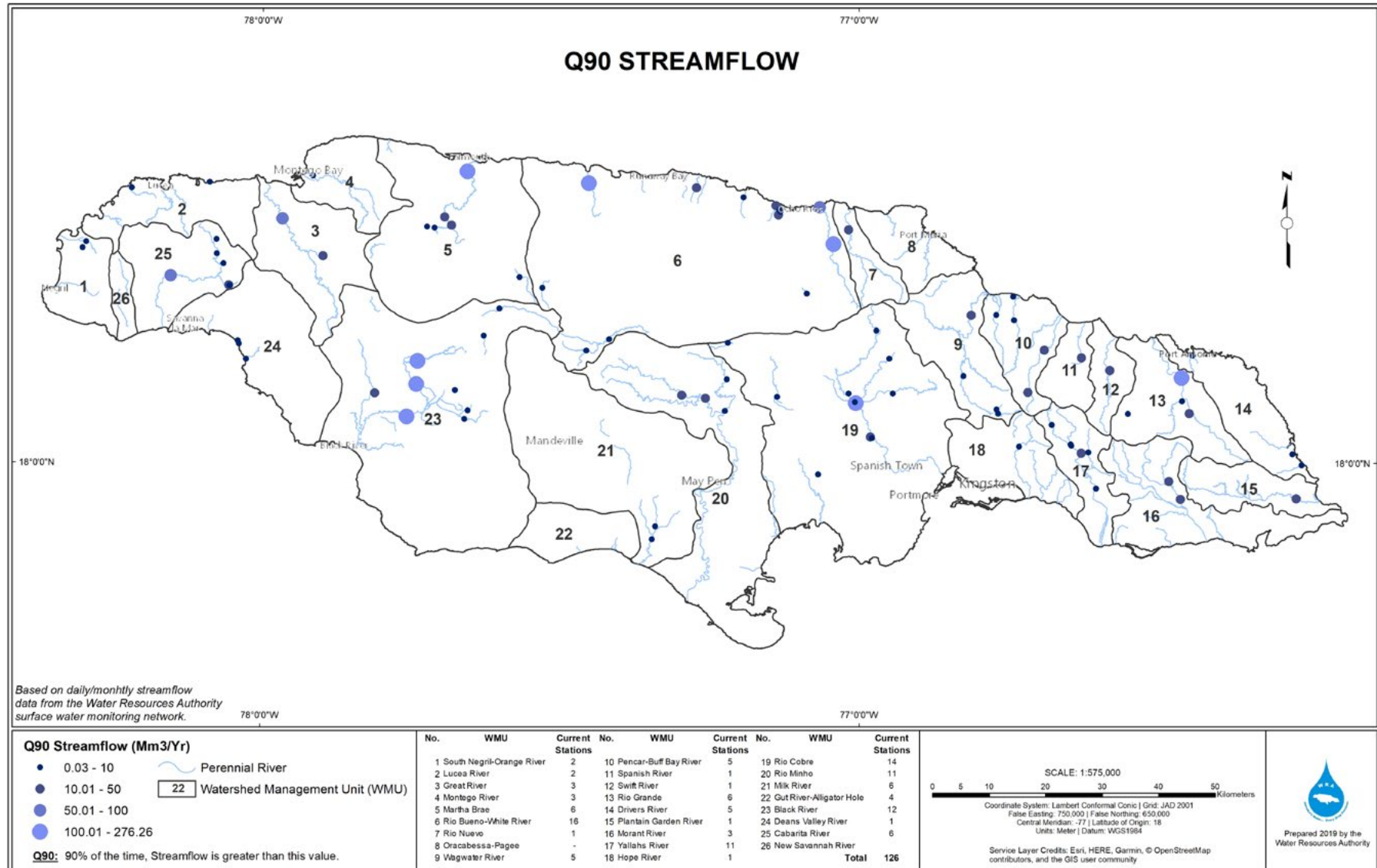


Figure 55: Q90 Flows on Gauged Streams



## DATA PROCESSING METHODS , ADEQUACY AND HYDROLOGICAL MODELLING

Issues that impact data quality and analysis in Jamaica and the WRA include:

- ◆ More evapotranspiration (ET) data to improve water balance calculations in the 26 WMUs. For this report, potential evapotranspiration was estimated using a limited amount of temperature data for only two years, with extrapolation of values from calculated inputs, while actual evapotranspiration was estimated via assumed coefficients that were constant for all WMUs. Additional temperature data over a longer timeframe and a more discrete spatial distribution, along with a more accurate estimation of actual ET from potential ET incorporating differences in WMU climates would improve the reliability of water balance calculations as well as the accuracy and efficiency of predicting irrigation requirements.
- ◆ An assessment of groundwater and well data, and a field inspection of the wells and data sources. Gaps in the data and the uncertain conditions of some of the wells limit the data quality. Additionally, there is a need for the WRA to be able to independently assess actual abstraction (via ultrasonic flow meters) and water quality (both via in-situ WQ metres and laboratory water analysis). The WRA has acquired a number of water quality metres to facilitate in-situ WQ measurements. Funding for maintenance and resupply should be ensured, and a long-term goal for the WRA should be to operate its own water quality analysis.
- ◆ Use of more labour-efficient instrumentation systems, including automation of hydrological data collection to ensure accuracy of the hydrological and water resources data. The WRA has made strides in this arena with the use of radar gauges at over 20 stations with real-time monitoring and Cloud data storage via Stevens Inc. as acquired through the PPCR.

## WATER QUALITY MONITORING AND MANAGEMENT

Some currently critical gaps in the monitoring management of Jamaica's water resources include:

- ◆ Consistent and routine monitoring of the island's ambient water quality (both ground and surface water).
- ◆ A more complete understanding of precipitation and groundwater/surface water flow dynamics, including a more precise determination of the contributions of precipitation to groundwater recharge, precipitation to surface water discharge, groundwater flow to surface water discharge, and groundwater submarine discharge to the marine environment.
- ◆ A more complete understanding of the age of water and travel times for water within the island's hydrosphere.
- ◆ Accurate identification of source pollutants such as nitrates, phosphates, sulphates, sodium, chloride and heavy metals.

*"The WRA must establish and maintain a water quality collection network"*

The Water Sector Goal under Jamaica's Vision 2030 is to *"Ensure adequate and safe water supply and sanitation to support social and economic prosperity and healthy natural environment"*. This stated goal is in sync with the United Nation's Sustainable Development Goal #6 which is to *"Ensure availability and sustainable management of water and sanitation for all"*

The SDG6 indicators that fall under the auspices of the WRA include:

**6.3.2:** Proportion of bodies of water with good ambient water quality,

**6.4.1:** Change in water-use efficiency over time, and

**6.4.2:** Level of water stress: freshwater withdrawal as a proportion of available freshwater resource.

Currently the WRA does not have a sustained water quality data collection network. While the WRA mandates that its abstractors submit water quality data for their abstraction sources twice per year, this data is not regularly returned (though the rate of return has improved significantly in recent years). Furthermore, the frequency of this data is not sufficient for real-time monitoring or trend analysis, and is dependent upon external persons. The WRA's historical WQ database is also reliant on data collected from specific projects (mostly bauxite related) and snapshots such as the Water Quality Atlas. In order to accurately inventorize and assess Jamaica's performance under the SDGs and Vision 2030 WQ goal, as well as to fulfil its mandate, the WRA needs to establish and mainstream a regular water quality collection network.



One crucial factor is that there is currently no established water quality standard for Jamaica. There are the I-JAM Ambient guidelines which are used as *de-facto* standards, but do not have any legislative basis, and the WHO standards are usually utilized for drinking water standards. The WRA is currently (as of 2019) chairing a multi-agency committee to establish standards for environmental and other water quality parameters.

## DESIGN OF MONITORING NETWORK

The proposed water quality sampling network would cover all 26 WMUs in Jamaica, and would be largely based on the existing WRA hydromet network, with most surface water sampling sites at selected WRA stream-gauge stations. There are a few WMUs with no WRA presence, and WQ sampling points for those WMUs would be established. Groundwater sampling sites would be selected from known pumping wells in each WMU as far as possible. Water quality Sampling would include both field data from WQ probes and field kits (pH, Conductivity, DO, Temperature, Alkalinity) and laboratory samples (BOD, TDS, Total Hardness, bicarbonate, chloride, nitrate, sulphate, sodium, calcium, magnesium, potassium, manganese, total and fecal coliform). Other parameters, such as iron, aluminium, heavy metals, etc. may be sampled as needed.

Additionally, the WRA abstraction license conditions require abstractors to test water and submit quality data twice per year for specified parameters. For domestic water supply sources, these were sodium, sulphate, nitrate, chloride, total dissolved solids, faecal coliform bacteria and total coliform. The WRA also requires additional parameters to be analysed for various sources, including calcium, magnesium, potassium,

manganese, iron, ammonia, fluoride, electrical conductivity, hardness, and biochemical oxygen demand.

## MECHANISM FOR IMPLEMENTING POLICY AND LEGISLATION

A Memorandum of Understanding between WRA, NEPA, ODPEM and Ministry of Health on Water Quality Management was signed in November, 2003. The Memorandum previous water quality management practices, including water sampling and monitoring and agreed to:

- ◆ Co-operate with and support each other in co-ordinating their functions, powers and duties in regard to water quality management, using appropriate means to achieve consensus and avoid or expeditiously resolve disputes.
- ◆ Delineated the responsibilities of each agency with respect to water sampling and data compilation for all inland and coastal waters, as well as sewage and industrial effluents.
- ◆ Agreed that the WRA shall have the:
  - + primary responsibility to obtain and compile data concerning the quality of water resources. The other agencies will send their relevant data to the WRA.
  - + Lead with respect to declaration of any area requiring the protection of water resources quality or a Water Quality Control Area, and to the preparation and annual revision of Water Quality Control Plans.

## ISOTOPE HYDROLOGY TECHNIQUES

The use of isotope hydrology would provide a greater understanding of Jamaica's water resources, both in quality and quantity. The evaluation of stable isotopes allows for

the determination of the age and origin of groundwater and surface water, and is also useful for tracing groundwater contamination patterns. It is the only technique available that is capable of differentiating between clean and contaminated groundwater. With the analysis of stable isotopes, it is possible to know and detect the pollution flow even at great distances from the contaminant source. Chemical analysis alone cannot provide the information with the same level of accuracy. The use of isotope techniques (complemented by artificial tracers such as dyes) can result in the determination of transport time of water and pollutants within the water. Isotope Techniques can also provide a measure of the relative contributions/flows from precipitation to groundwater/surface water via the relative measurements of  $^2\text{H}$  and  $^{18}\text{O}$  to create local meteoric water lines. This will better enable the management of groundwater and surface water allocation by providing an accurate estimate of recharge from precipitation on a basin-by-basin scale. Water quality data is essential for interpreting isotope analysis data, and it is therefore a logical decision to establish a stable isotope sampling program alongside a water quality sampling program. Isotope samples could be analysed at the NWC laboratory at Maurescaux Road, which has sourced a Laser Isotope machine from IAEA TC Projects. Future plans could see the WRA establishing its own capacity for water quality analysis, including both laboratory sampling and isotope hydrology sampling.

The overall recommendations for water quality and Isotope monitoring are as follows:

- ◆ Funding for a Water Quality Sampling Budget should be established from the Water Resources Authority Volume-Based Fee Income.



- A Sampling Regime should be designed under the established budget limitations to provide the best coverage of sampling parameters, sample site distribution, and sample campaign frequency.
- The WRA should consider partnering with the UWI Department of Chemistry under this project in the short term (next 1-3 years) to establish a MOU and working relationship for sampling campaigns (students to assist in collecting samples) and sample analysis (including strengthening WRA staff capacity in doing laboratory analysis).
- The WRA should consider partnering with the NWC to establish an MOU for isotope data analysis.
- The WRA should consider establishing its own Water Quality Analysis Laboratory in the medium-to-long term (next 5-10 years).
- A Water Quality Standards Committee should be established with a clear mandate and plan to recommend water quality standards for Jamaica and propose legislation to mandate same.

## PROVISIONS FOR SPECIAL AREAS

### KINGSTON METROPOLITAN AREA

The City of Kingston and urban parts of the parish of St. Andrew are located in Hope River WMU. The current assumptions for water usage are as follows:

- Average daily supply of residential water has been set at 182 litres per person per day (40 imperial gallons per person per day).

- Rate of physical delivery efficiency of municipal water for 2005 was estimated at 60% (KWSP, 2003) i.e. system leakage is 40%.
- Ability to balance the water demands with the supply in the next 10 to 20 years, assuming that the population and industry increase at expected annual rates, and the fraction of unaccounted for water remains the same as the current level.

The 2003 Kingston Water and Sanitation Project (KWSP, 2003) calculated that improvements were made to losses of water due to reservoir overflow and delivery system leakage, the fraction of system losses could be reduced quite feasibly to 25% instead of 40%. This reduction in system losses would facilitate average annual surpluses, even if there are small increases or even no increases in total water supply over the next 20 years. This could assist the water supply situation in periods of drought. There has been a moratorium on new abstractions from the Rio Cobre WMU due to observed pumping depressions below sea-level in wells located in Caymanas, Innswood and Old Harbour, along with associated saline-upconing. The MOU was also influenced by the group pumping test done by WRA in the 1970s in the Upper Rio Cobre where above a certain threshold there was a significant decline in the flow of the Rio Cobre River. In later years as abstraction increased in the upper Rio Cobre the Tulloch Springs were also impacted showing decline in flow.

This moratorium continues to be upheld, until further clarity on aquifer recharge and resource usage can be assessed. Stanley Consultants completed an assessment in 2017 which indicated that the resources in the WMU were still over-exploited.

### LOWER RIO COBRE ALLUVIUM AQUIFER PROTECTION ZONE (APZ)

In 2004, Cabinet declared an Aquifer Protection Zone (APZ) over sections of the Lower Rio Cobre Alluvium Aquifer. This was initially declared a no-build zone; however, conditions were changed to a care-build zone in 2019. The WRA completed a preliminary study on water quality in the designated APZ which indicated that the groundwater in the APZ was in a state of early deterioration due to impacts of saline intrusion, but that impacts from sewage contamination seemed to be less significant at the time of monitoring. This led to the APZ being changed to a care-build zone in 2019. Work will continue to determine whether the region should be declared as a Water Quality Control Zone.

### SPECIALLY DESIGNATED COMMUNITY DEVELOPMENT REGIONS

Rapid urbanization and population increase in the Kingston Metropolitan Region (KMR) has led to a demand for the development of sustainable communities to provide housing, social, cultural and employment options for the resulting population. To fulfil these demands a range of options were explored which include but not limited to the development of brownfield and greenfield sites, infilling and increase in densities and heights in a wide range of areas. One example of the greenfield sites identified for development was the Bernard Lodge lands which is ideally located in south eastern quadrant of St. Catherine and has been under development pressure for some time. These lands are primarily used for agricultural purposes with several housing and other non-agricultural uses scattered throughout the area. The site is located within the aforementioned Aquifer Protection Zone (APZ) and several concerns



have been raised such as the contamination of wells located on these lands and the fragmentation of agricultural lands. To address the issues and concerns the National Environment and Planning Agency (NEPA) was tasked with the preparation of the Greater Bernard Lodge Master Plan which took in account new urban planning approaches and innovative strategies to optimize the use of these lands in this area and create a resilient and sustainable community based on the following principles (which can be extrapolated to all proposed greenfield developments islandwide):

- 💧 Principle #1: integrated and sustainable community built upon green principles and renewable energy linked with flood protection and adaptation to climate change and sustainable energy mix.
- 💧 Principle #2: compact urban areas intertwined with green spaces at the heart of new neighbourhoods, to ensure a more efficient, effective and more desirable.
- 💧 Principle #3: wide sidewalks to create and enhance the pedestrian environment.
- 💧 Principle #4: Reduce reliance on the automobile and improve opportunities for alternative transportation.
- 💧 Principle #5: Improve the quality of the natural environment and the creation of a just, safe, resilient and city developed along green principles.
- 💧 Principle #6: Provide for a variety of housing forms to help meet the needs of a growing and diversifying population and offer more affordable housing choices.
- 💧 Principle #7: Provide for a diverse and compatible mix of land uses that accommodate employment opportunities for local residents and offer more live and work choices.
- 💧 Principle #8: Sponge City Concept that will encourage additional protection of the aquifers
- 💧 Principle #9: integrated with the existing adjoining communities
- 💧 Principle #10: Crime free through the use of designing out crime and other techniques.<sup>24</sup>

Initiatives such as Managed Artificial Recharge and re-use of treated wastewater effluent may be crucial factors to ensure a reliable water supplies for any proposed greenfield community development, especially in the face of increasing demand and decreasing availability of water due to climate change impacts.

## NON-USAS AND RURAL WATER SUPPLY INITIATIVES

To date, the Rural Water Supply Limited has enhanced access to potable water in rural communities by the implementation of several rural water supply systems as described below:-

### Substantially Completed

- 💧 Montpelier Water Supply System Upgrade, St. James

- 💧 Comma/ Mango Valley Water Supply System, St. Mary
- 💧 Farmers Heights, St. Ann
- 💧 Georgia Water Supply System, St. Thomas
- 💧 Douglas Castle/Macknie Water Supply System, St. Ann
- 💧 Hermitage Water Supply System, St. Ann

### In Progress

- 💧 Portland Cottage Pipeline
- 💧 Gibbs Hill/Maroon Town/Leinster Water Supply System, St. Mary
- 💧 Manchester Municipality

### Wayside Tanks Completed

- 💧 Friendship (St Ann)
- 💧 Spice Grove (Manchester)
- 💧 Keith (St Ann)
- 💧 Coffee Grove (Manchester)
- 💧 Restore (Manchester)
- 💧 Plowden (Manchester)
- 💧 Evergreen (Manchester)
- 💧 Broughton (Manchester)
- 💧 Bamboo Bow (St Ann)
- 💧 Lektion (St Ann)
- 💧 Lodge (St Ann)
- 💧 Minard (St Ann)
- 💧 Silent Hill (Manchester)

These rural water supply systems will benefit approximately nine thousand, five hundred (9,500) residents within the various communities.

<sup>24</sup> "Greater Bernard Lodge Master Plan" National Environmental and Planning Agency

**Rainwater Harvesting Programmes are ongoing with complete rehabilitation of the following:-**

- ◆ Woodlands,
- ◆ Bogdale, and; St. Elizabeth
- ◆ St. Marys
- ◆ Heavy Tree
- ◆ Ebinezer
- ◆ Mt Olivet Manchester
- ◆ Robins Hall, and;
- ◆ Devon
- ◆ Foga, Clarendon

These nine (9) facilities will benefit approximately 3,500 Rural Residents

**Rainwater Harvesting in Schools**

Works carried out at the following schools during the period:-

- ◆ Roehampton Primary
- ◆ Anchovy Primary and High, St. James
- ◆ Mt. Angus;
- ◆ Gayle, and; St. Mary
- ◆ Derry
- ◆ Ferncourt High School, St. Ann
- ◆ Ginger Hill, St. Elizabeth
- ◆ Mt. Olivett, Manchester

**Rainwater harvesting projects were also carried out in the following institutions:**

- ◆ Missionaries of the Poor, Golden Spring, St. Andrew
- ◆ St. Ann's Bay Hospital, and;
- ◆ St. Mary's Infirmary, St. Mary



**Proposed Comprehensive Rural Water Supply Systems Upgrades include:**

- ◆ Portland Cottage/Shearers Heights Water Supply, Clarendon- Pipeline, Relift Station, Storage Tank & Electromechanical equipment
- ◆ Platfield Water Supply, St Mary- Pipeline Installation
- ◆ Tangle River Water Supply, St James
- ◆ Minor Water Supply , Trelawny (Troy, Allsides, WarsoppWarsop)
- ◆ Minor Water Supply, Portland ( Reach, Barracks, Kensington)
- ◆ Wayside Tanks- Manchester, St Elizabeth, Hanover

**Rainwater Harvesting Programme (Catchment Tanks)**

- ◆ Repairs, upgrading and covering of 7 catchments islandwide including Hanover, Westmoreland, St James, Trelawny, Clarendon, St Elizabeth, St Ann and St Catherine.
- ◆ Rainwater harvesting along with installation of solar facilities in approximately 5 selected schools and institutions islandwide including Rennals community's St. Catherine, May Pen Infirmary, health centres, educational institutions and other community based facilities in non-utility service areas



# Recommendations for Projects and Programmes

The 1990 WRDMP identified several gaps in knowledge and information. In the past 30 years, there have been many advances in hydrology and water resources management that can be used to update the WRDMP. These underpinned the deliberations from which these recommendations evolved. The recommendations fall into (3) categories as follows:

- Those that are needed so that WRA may be better equipped to carry out its regulatory functions as mandated by the Water Resources Act,
- Research projects that are needed to improve the knowledge base to enhance sustainable management and provision of water to meet the wide range of demands
- Those that are needed for cost effective development and use of the water resources.

## FOLLOW-UP OF RECOMMENDATIONS FROM 1990 WRDMP AND 2005 DRAFT WRDMP

Tables 67 and 68 shows the water supply projects that were recommended in the 1990 WRDMP for domestic and irrigation water respectively. Most of these projects were not followed through due to costs and infeasibility as deemed by the service providers (NWC and NIC). However, some of these projects have been revived based on changing needs and improved technology. In particular, the establishment of a desalination plant at the Ferry River has been seriously considered by the NWC, and initial plans are under way (July 2021) to implement same. Additionally, the NWC has increased the pipeline capacity for the KMA water supply coming from the Rio Cobre Basin, in preparation for the implementation of the Content Water Treatment plant to be constructed at Dam Head on the Rio Cobre in the near future. The current moratorium on new abstraction in the Rio Cobre basin limits the creation of new wells; however, the use of managed artificial recharge from both excess irrigation flow and recycled wastewater has the potential to facilitate a revision of the moratorium.

**TABLE 67: SUMMARY OF DOMESTIC WATER RECOMMENDATIONS OF 1990 WRDMP AND FOLLOW-UP**

|                                                                                 | # | LOCATION |        | SCHEME                        |                                                                                    | CAPACITY (MCM) | YIELD (MCM/ YR) | DEVELOPMENT COST (US\$ PER) |      | POST-1990 ACTION | 2005 FINDING                                          |
|---------------------------------------------------------------------------------|---|----------|--------|-------------------------------|------------------------------------------------------------------------------------|----------------|-----------------|-----------------------------|------|------------------|-------------------------------------------------------|
|                                                                                 |   | BA-SIN   | WMU    | SOURCE                        | DESCRIPTION                                                                        |                |                 | M³                          | KWHR |                  |                                                       |
|                                                                                 |   |          |        | RIVER/ AQUIFER                |                                                                                    |                |                 |                             |      |                  |                                                       |
| Domestic Water Supply: Kingston Metropolitan Area (KMA) Including St. Catherine | 1 | 1        | 15     | Plantain R (SW)               | Mt. Dakin Dam & Reservoir Treatment Plant at Constant Spring                       | 2.3            | 3.36            | 0.35                        |      | None             | None reported                                         |
|                                                                                 | 2 | 1        | 16     | Yallahs R. (SW)               | Upgrade Mona TP. Increase capacity                                                 |                | 2.6             | 0.08                        |      | None             | Not worth development cost                            |
|                                                                                 | 3 | 3        | 19     | Ferry Sp + UPPER Rio Cobre GW | Mix (1 x Ferry Sp) + (3 x Up. R.Cobre Well Water                                   |                | 3               | 0.26                        |      | Not Feasible     |                                                       |
|                                                                                 | 4 | 3        | 19     | Ferry Sp (s)                  | Desalination of Ferry Sp. Water                                                    |                | 5               | 0.44                        |      | Not now feasible | Not feasible in short term                            |
|                                                                                 | 5 | 10       | 12     | Swift R.                      | Divert SW from Swift R to Yallahs R, treat at Mona TP                              |                | 5.6             | 1.5                         |      | None             | Pre-feasibility study done, but not feasibility study |
|                                                                                 | 6 | 2,3      | 18, 19 | Hope R. and R. Cobre (GW)     | Transfer KMA Plains AI GW to Lr. R. Cobre and R. Cobre Ls Irrigation water to KMA. |                | 5.10.2          | 0.4                         |      | None             |                                                       |
|                                                                                 | 7 | 3        | 19     | R. Cobre (GW)                 | Increase capacity of Pipeline from Up. R. Cobre (3 wells)                          |                | 2.4             | 0.04                        |      |                  |                                                       |
|                                                                                 | 8 | 3        | 19     | R. Pedro SW                   | Construct dam at Harkers Hall                                                      |                |                 |                             |      | None             | Resuscitate.                                          |
|                                                                                 |   | 3        | 19     | R. Cobre (GW)                 | Wells (Cost include Dam) Expand well capacity by 25                                |                | 3.8             | 0.343                       |      | None             |                                                       |

**TABLE 68: SUMMARY OF IRRIGATION WATER RECOMMENDATIONS FROM 1990 MASTER PLAN AND FOLLOW-UP**

|                                                 | # | LOCATION |       | SCHEME                                    |                                                                 | CAPACI-<br>TY (MCM) | YIELD<br>(MCM/YR) | DEVELOPMENT<br>COST (US\$ PER) |      | POST-1990<br>ACTION | 2005 FINDING       |
|-------------------------------------------------|---|----------|-------|-------------------------------------------|-----------------------------------------------------------------|---------------------|-------------------|--------------------------------|------|---------------------|--------------------|
|                                                 |   | BASIN    | WMU   | SOURCE                                    | DESCRIPTION                                                     |                     |                   | M³                             | KWHR |                     |                    |
|                                                 |   |          |       | RIVER/ AQUIFER                            |                                                                 |                     |                   |                                |      |                     |                    |
| IRRIGATION WATER<br>SUPPLY: RIO MINHO           | 1 | 4        | 20-23 | Rio Minho GW                              | Relocation of saline & sand pumping wells                       |                     |                   | 0.018                          |      | Not done            | Not done           |
|                                                 | 2 | 4        | 20-23 | GW and SW                                 | Improve irrigation efficiency                                   |                     |                   |                                |      | Not done            | Not done           |
|                                                 | 3 | 4        | 20-23 | Rio Minho SW                              | Increase pumping from river downstream of May Pen               |                     |                   | 0.026                          |      |                     |                    |
|                                                 | 4 | 4        | 20-23 | Rio Minho GW                              | Install new wells                                               |                     |                   | 0.03                           |      |                     |                    |
|                                                 | 5 |          |       | Run-of-river and Res-<br>ervoir           | Divert Rio Minho flow at North Hall                             |                     |                   | 0.034                          |      | Not done            | Not done           |
|                                                 |   |          |       |                                           | Construct dam & reservoir at Harkers Hall                       | 20                  |                   | 0.44                           |      | Not done            | Not done           |
| IRRIGATION WATER<br>SUPPLY: BLACK<br>RIVER      | 6 |          |       | Black River SW plus GW                    | Diversion from Lacovia to Holland Pumping station<br>at Lacovia |                     |                   |                                |      |                     | Proposal submitted |
|                                                 |   |          |       |                                           | Canals to left Bank of Black R and Broad River                  |                     |                   | 0.035                          |      |                     |                    |
|                                                 |   |          |       |                                           | Canals in Pedro Plains                                          |                     |                   | 0.032                          |      |                     |                    |
|                                                 |   |          |       |                                           | Wells in Pedro Plains                                           |                     |                   |                                |      |                     |                    |
| IRRIGATION WATER<br>SUPPLY: CABARITA            |   |          |       | S. Negril R SW                            | Upgrade and Expansion of Local irrigation scheme                |                     |                   | 0.01                           |      | Not done            | Not done           |
|                                                 |   |          |       | Cabarita R. SW                            | Local irrigation sch.: W of Cabarita                            |                     |                   | 0.014                          |      | Not done            | Not done           |
|                                                 |   |          |       |                                           | East of Cabarita                                                |                     |                   | 0.034                          |      |                     |                    |
| AQUACULTURE<br>WATER SUPPLY: ST.<br>CATHERINE   | B |          |       | Ferry Sp(s)                               | Aquaculture (Up to 252 ha of ponds)                             |                     |                   |                                |      | None                |                    |
| HYDRO-POWER<br>GENERATION: BLUE<br>MOUNTAIN (S) | A |          |       | Yallahs R.                                | Use capacity of, and head in Pipeline for power<br>generation   |                     |                   |                                |      | Not done            | Not done           |
| HYDRO-POWER<br>GENERATION:<br>BLUEMOUNTAIN (N)  |   |          |       | Spanish R                                 | Sites identified                                                |                     |                   |                                |      | Not done            | Not done           |
|                                                 |   |          |       | Swift R                                   | Sites identified                                                |                     |                   |                                |      | Not done            | Not done           |
|                                                 |   |          |       | Rio Grande                                | Sites identified                                                |                     |                   |                                |      | Not done            | Not done           |
|                                                 |   |          |       | R. Grande and Swift,<br>Spanish&BuffBayRs | Multipurpose: Hydropower                                        |                     |                   |                                |      | Not done            | Not done           |
|                                                 |   |          |       |                                           | Multipurpose: Water                                             |                     |                   |                                |      | Not done            | Not done           |



## IMPROVEMENT OF SERVICE DELIVERY FUNCTIONS OF THE WRA

Table 69 shows a list of activities that should be put in place to empower WRA with the tools to improve its functioning under the Water Resources Act. Some of these activities are under way, as previously stated (e.g. Volume-Based Fee).

**TABLE 69: IMPROVEMENT OF WRA SERVICE DELIVERY**

| # | PURPOSE                                               | FOCUS                     | RECOMMENDED ACTION                                                               | TIMEFRAME    | RESPONSIBILITY | STAFF | BUDGET |
|---|-------------------------------------------------------|---------------------------|----------------------------------------------------------------------------------|--------------|----------------|-------|--------|
| 1 | STREAMLINE WATER ALLOCATION                           | Clarify general policy    | . Develop protocol to protect public interest                                    | Medium       | WRA            | x     |        |
|   |                                                       | Manage scarcity           | . Develop protocol to resolve conflict re use during periods of scarcity         | Short-Medium | WRA.           |       |        |
|   |                                                       |                           | . Develop protocol for emergencies                                               | Short-Medium | WRA            |       |        |
|   |                                                       | Inter-Basin/WMU Transfer  | . Identify WMUs with potential and do feasibility analysis                       | Short-Medium | WRA            |       |        |
|   |                                                       |                           | . Develop policy framework                                                       | Short-Medium | WRA            |       |        |
| 2 | IMPROVE DATA MANAGEMENT                               | Update monitoring network | . Do field evaluation to assess adequacy of existing network                     | Short-Medium | WRA            |       |        |
|   |                                                       |                           | . Design automated data collection system                                        | Short-Medium | WRA            |       |        |
|   |                                                       |                           | . Evaluate present, vs use of more labour efficient, instrument system           | Short-Medium | WRA            |       |        |
|   |                                                       |                           | . Determine optimum monitoring sites                                             | Short-Medium | WRA            |       |        |
|   |                                                       |                           | . Determine data collection frequency                                            | Short        | WRA            |       |        |
|   |                                                       | Improve data processing   |                                                                                  | Short        | WRA            |       |        |
| 3 | IMPROVE RESOURCE ASSESSMENT                           | Do Basin/ WMU Studies     | . Do desk-top evaluation of usability of GW and Well Data                        | Short-Medium | WRA            |       |        |
|   | WATER AVAILABILITY BY SUPPLY-SIDE INITIATIVES         | Climate change            | . Identify lead agency.                                                          | Completed    | CCD            |       |        |
|   |                                                       |                           | . Do multidisciplinary study.                                                    | Medium       | WRA            |       |        |
|   |                                                       | Increase SW               |                                                                                  | Long         | WRA            |       |        |
|   |                                                       | Rainwater Harvesting      |                                                                                  | Ongoing      | Multiple       |       |        |
|   |                                                       | Artificial recharge       | . Evaluate results of work by KMA.                                               | Medium       | WRA            |       |        |
| 4 | AUGMENT WATER AVAILABILITY BY SUPPLY-SIDE INITIATIVES | Re-use and Recycle        | . Study possibilities for financial incentives                                   | Medium-Long  | WRA            |       |        |
|   |                                                       |                           | . Design public education campaign                                               | Medium-Long  | WRA            |       |        |
|   |                                                       |                           | . Introduce selected incentives                                                  | Medium-Long  | WRA            |       |        |
|   |                                                       | Efficient Water Use       |                                                                                  |              | WRA            |       |        |
|   |                                                       | Desalination              | . Update periodically data re feasibility of desalination vs traditional sources | Medium       | WRA            |       |        |
|   |                                                       |                           | . Decide on "feasible" cost level.                                               | Medium-Long  | WRA            |       |        |
|   |                                                       |                           | Develop "roll-out" programme.                                                    | Medium-Long  | WRA            |       |        |

| #     | PURPOSE                    | FOCUS                                                      | RECOMMENDED ACTION                                                       | TIMEFRAME    | RESPONSIBIITY | STAFF | BUDGET |
|-------|----------------------------|------------------------------------------------------------|--------------------------------------------------------------------------|--------------|---------------|-------|--------|
| 5     | IMPROVE WQ MANAGE-<br>MENT | Strengthen Monitoring                                      | . Determine WQ parameters to monitor.                                    | Short-Medium | WRA           |       |        |
|       |                            |                                                            | . Design appropriate monitoring schedule                                 | Short        | WRA           |       |        |
|       |                            |                                                            | . Re-design WRA database to include data from 3rd parties                | Short-Medium | WRA           |       |        |
|       |                            |                                                            | . Design protocol to set up WQ Control and Source Protection Zones       | Medium       | WRA           |       |        |
|       |                            |                                                            | . Research cause of salinization of GW and SW in unexpected areas        | Medium       | WRA           |       |        |
|       |                            | Update Regulations                                         | . Develop regulations to implement                                       |              | NEPA          |       |        |
|       |                            |                                                            | "Polluter Pays" Principle                                                |              | NEPA          |       |        |
|       |                            |                                                            | . Set up licensing system to control disposal of industrial effluents    |              | NEPA          |       |        |
|       |                            |                                                            | . Determine human and financial resources needed to do pollution studies |              | NEPA          |       |        |
|       |                            |                                                            | . Design awareness programme to get abstractors to monitor WQ            |              | Multiple      |       |        |
| 6     | IMPROVE WR MANAGE-<br>MENT | Improve existing administrative system                     | . Study water use fees vs volumetric charge for abstraction and use      | Completed    | WRA           |       |        |
|       |                            |                                                            | . Incorporate choice in existing system                                  |              | WRA           |       |        |
|       |                            | Evaluate Demand-Side Approach                              | . Do water use fees & water market study                                 |              |               |       |        |
|       |                            |                                                            | . Do appropriate cost-benefit, financial and socio-economic analysis     |              |               |       |        |
|       |                            |                                                            | . Develop administrative structure for Water Market and User Fee Systems |              |               |       |        |
|       |                            | Facilitate Integrated Water Resource Management            | . Design protocol for multi-sectoral approach to Water Allocation & WQ   |              |               |       |        |
|       |                            |                                                            | . Design decentralised systems                                           |              |               |       |        |
|       |                            |                                                            | . Follow Water Policy                                                    |              |               |       |        |
|       |                            | Secure adequate Funding for WRA                            | . Develop system to fund WRA                                             |              |               |       |        |
|       |                            | Implement policy and legislation                           |                                                                          |              |               |       |        |
| NOTES |                            | WR: Water Resources; WQ: Water Quality; Cons.: Consultancy |                                                                          |              |               |       |        |

## HYDROLOGICAL RESEARCH PROGRAMME

A Hydrological Research Programme was recommended in the 1990 WRDMP as part of need to continually update the WRDMP. Table 71 summarise the research projects that have been identified.



**TABLE 70: RECOMMENDED HYDROLOGICAL RESEARCH PROGRAMME**

| RANKING                                                 | TYPE               | RESEARCH PROJECT                                                                                                                                           |           |         |                   | COSTS (\$US X '000) |      |            |       |
|---------------------------------------------------------|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|---------|-------------------|---------------------|------|------------|-------|
|                                                         |                    | DESCRIPTION                                                                                                                                                | LOCATION  |         |                   | LEVEL OF EFFORT     |      | OTHERS (1) | TOTAL |
|                                                         |                    |                                                                                                                                                            | BASIN NO. | WMU NO. | EXTENT OF PROJECT | PERSON MONTHS       | COST |            |       |
| 1                                                       | WATER RESOURCE     | Detailed water management plans                                                                                                                            | 3, 4      | 19-22   | Basin-wide        | 72                  | 864  | 75         | 939   |
| 4                                                       | DEVELOPMENT        | Economic valuation of water                                                                                                                                |           |         |                   | 40                  | 480  | 50         | 530   |
| 5                                                       | PLANNING           | Quantity water use by Users (Sectors)                                                                                                                      |           |         |                   | 60                  | 720  | 75         | 795   |
| 2                                                       | RESOURCE           | Determination of aquifer characteristics                                                                                                                   | 7-10      | 1-14    | Basin-wide        | 45                  | 540  | 200        | 740   |
| 3                                                       | EVALUATION         | Water resources assessments                                                                                                                                | 1, 10     | 7-17    | Basin-wide        | 60                  | 720  | 100        | 820   |
| 8                                                       |                    | Contribution of excess irrigation water to GW recharge                                                                                                     |           |         |                   | 30                  | 360  | 100        | 460   |
| 9                                                       |                    | Contribution of leakage to GW recharge                                                                                                                     |           |         | Urban areas       | 40                  | 480  | 100        | 580   |
| 12                                                      |                    | Assessment of quality and safe yields of mineral springs                                                                                                   |           |         |                   | 60                  | 720  | 150        | 870   |
| 13                                                      |                    | Technical, economic and environmental feasibility of desalination for meeting demands                                                                      |           |         |                   | 50                  | 600  | 75         | 675   |
| 14                                                      |                    | Impacts of climate change on water availability                                                                                                            |           |         | Country-wide      | 30                  | 360  | 50         | 410   |
| 6                                                       | WATER USE          | Potential savings from Reuse and recycling                                                                                                                 |           |         |                   | 40                  | 480  | 75         | 555   |
| 7                                                       | EFFICIENCY         | Potential savings from increased irrigation efficiency                                                                                                     |           |         |                   | 40                  | 480  | 75         | 555   |
| 10                                                      | ENVIRONMENTAL FLOW | Determine requirements                                                                                                                                     |           |         | Black River       | 24                  | 288  | 60         | 348   |
|                                                         |                    |                                                                                                                                                            |           |         | White River       | 24                  | 288  | 60         | 348   |
|                                                         |                    |                                                                                                                                                            |           |         | Dunns River       | 24                  | 288  | 60         | 348   |
|                                                         |                    |                                                                                                                                                            |           |         | Negril Morass     | 24                  | 288  | 60         | 348   |
| 11                                                      |                    | Development of an approach to source protection in karst limestone areas, including dye trace and isotope hydrology activities for flow path determination | 3 – 9     |         | Basinwide         | 30                  | 360  | 75         | 435   |
| 15                                                      | WATER QUALITY      | Identification of sources of chloride and sulphate concentrations and possible mitigation measures                                                         |           |         | S. Central        | 40                  | 480  | 120        | 600   |
|                                                         |                    |                                                                                                                                                            |           |         |                   |                     |      |            |       |
|                                                         |                    |                                                                                                                                                            |           |         |                   |                     |      |            |       |
| <b>TOTAL</b>                                            |                    |                                                                                                                                                            |           |         |                   |                     |      |            |       |
| <b>(1): Includes Equipment, Materials, Field Travel</b> |                    |                                                                                                                                                            |           |         |                   |                     |      |            |       |

The total value of the hydrologic research program is US\$ 10.4 million.

The main criterion used to determine the priority was

- importance of the project to minimising the impacts of water scarcity, particularly in the water stressed basins. The projects are expected to have an immediate short-term impact on meeting critical water demands.
- importance of conserving and valuing water, and the water quality and environmental impacts. Black River, White River, Dunn's River, and Negril Morass are listed separately. However they are considered to be of equal importance.

Projects for which the results will have more of a longer-term impact were rated of lowest priority.



# Appendices

## REFERENCES AND BIBLIOGRAPHY

### APPENDIX 1

#### LIST OF LICENCEES IN THE WATER SECTOR

| OFFICE OF UTILITIES REGULATIONS |                                                   |                  |                                                                                                                                                      |
|---------------------------------|---------------------------------------------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| #                               | COMPANY NAME                                      | CUSTOMERS        | AREA LICENCED TO SERVE                                                                                                                               |
| 1                               | Can-Cara Development Limited                      | Water & Sewerage | Western. Spanish Town. The Meadows of Irwin, Irwin St. James.                                                                                        |
| 2                               | Dairy Spring Limited                              | Water            | OchoRios: Eastern boundary- Milford Rvr, gully-Ocho Jnr Sec Sch, Southwest, and southeast – South, Southern boundary: Shaw Park Rvr to DaCosta Drive |
| 3                               | Dynamic Environmental Management Limited          | Water & Sewerage | Vineyards Estate, Bushy Park, Morris Park, Part of Bernard Lodge, Portmore, St. Catherine, Caribbean Estate, Bernard Lodge, Portmore Country Club    |
| 4                               | Four Rivers Development Company Limited           | Water            | Shaw Park Subdivision                                                                                                                                |
| 5                               | Hampstead Citizens Association Benevolent Society | Water            | Hampstead District                                                                                                                                   |
| 6                               | Rose Hall Development limited                     | Water & Sewerage | Rose Hall, Montego Bay                                                                                                                               |
| 7                               | Runaway Bay Water Company                         | Water            | Cardiff Hall, Runaway Bay                                                                                                                            |
| 8                               | Waterwheel Estates Ltd.                           | Water            | Water Wheel Estates Limited, Cave Westmoreland                                                                                                       |
| 9                               | Drax Hall Utilities Limited                       | Water            | Drax Hall East, North Between Mammee Bay and St. Anns Bay                                                                                            |
| 10                              | Everoy H. Chin Company Limited                    | Water            | White Hall Development, St. Mary                                                                                                                     |
| 11                              | Richmond Environmental Service Ltd.               | Water & Sewerage | Richmond Development, St. Ann                                                                                                                        |
| 12                              | Island Homes/St Jago Hills Development            | Water            | St Jago Hills Development, St. Catherine                                                                                                             |
| 13                              | Talawah Investment Limited                        | Water            | Provides service directly to the NWC.                                                                                                                |



## APPENDIX 2

## CROP WATER REQUIREMENT PER GROWING PERIOD

| NAME OF CROP                   | CUMMULATIVE DEPTH<br>(MM)<br>(INCHES) |         | VOLUME/ACRE (YD <sup>3</sup> ) | (M <sup>3</sup> ) | (U.S GALLON)          |
|--------------------------------|---------------------------------------|---------|--------------------------------|-------------------|-----------------------|
| BANANA                         | 1,200 - 1,700                         | 47 - 67 | 6,350 - 9,000                  | 4,855 - 6,881     | 1,282,700- 1,818,000  |
| PEAS, BEANS                    | 300 - 400                             | 12 - 16 | 1,590 - 2,120                  | 1216 - 1621       | 321,180 - 428,240     |
| CABBAGE/ BROCCOLI /CAULIFLOWER | 380 - 450                             | 15 - 18 | 2,010 - 2,380                  | 1537 -1820        | 406,020 - 480,760     |
| CITRUS                         | 900 - 1,000                           | 35 - 39 | 4,760 - 5,293                  | 3639 - 4,047      | 961,520 - 1,069,186   |
| COTTON                         | 700 - 1,000                           | 28 - 39 | 3,705 - 5,293                  | 2832 - 4,047      | 748,410 - 1,069,186   |
| GRAPES                         | 500 - 850                             | 20 - 33 | 2,647 - 4,500                  | 2024 - 3440       | 534,694 - 909,000     |
| PEANUT                         | 500 - 600                             | 20 - 24 | 2,647 - 3,176                  | 2024 - 2428       | 534,694 - 641,552     |
| CORN                           | 500 - 650                             | 20 - 26 | 2,647 - 3,441                  | 2024 - 2631       | 534,694 - 695,082     |
| ONION                          | 350 - 450                             | 14 - 18 | 1,853 - 2,380                  | 1417 - 1820       | 374,306 - 480,760     |
| PEPPER                         | 600 - 750                             | 24 - 30 | 3,176 - 3,970                  | 2428 - 3035       | 641,552 - 801,940     |
| PINEAPPLE                      | 700 - 850                             | 28 - 33 | 3,705 - 4,500                  | 2833 - 3440       | 748,410 - 909,000     |
| IRISH POTATO                   | 500 - 600                             | 20 - 24 | 2,647 - 3,176                  | 2024 - 2428       | 534,694 - 641,522     |
| SUGAR CANE                     | 1,500 - 2000                          | 59 - 79 | 7,940 - 10,586                 | 6070 - 8093       | 1,603,880- 2,138,372  |
| TOBACCO /TOMATO/ WATERMELON    | 400 - 500                             | 16 - 20 | 2,120 - 2,647                  | 1621 - 2024       | 428,240 - 534,694     |
| CALALOO                        | 500 - 600                             | 20 - 24 | 2,647 - 3,176                  | 2024 - 2428       | 534,694 - 641,552     |
| LETTUCE                        | 380 - 500                             | 15 - 20 | 2,010 - 2,674                  | 1537 - 2044       | 406,020 - 534,694     |
| HOT PEPPER                     | 600 - 900                             | 24 - 35 | 3,176 - 4,760                  | 2,428 - 3,639     | 641,552 - 961,520     |
| CARROTS                        | 300 - 380                             | 12 - 15 | 1,590 - 2,010                  | 1216 - 1537       | 321,180 - 406,020     |
| SORREL                         | 400 - 500                             | 16 - 20 | 2120 - 2647                    | 1621 - 2024       | 428,240 - 534,694     |
| YAMS                           | 1000                                  | 39.0    | 5,293                          | 4,047             | 1,069,186             |
| DASHEEN                        | 1500 - 2000                           | 59 - 79 | 7,940 - 10,586                 | 6,070 - 8093      | 1,603,880 - 2,138,372 |
| SWEET POTATO /PUMPKIN          | 300 - 400                             | 12 - 16 | 1590 - 2120                    | 1216 - 1621       | 321,180 - 428,240     |
| FRUIT TREES                    | 1200                                  |         |                                |                   |                       |

## APPENDIX 3

### ESTIMATED DAILY MUNICIPAL AND TOURISM DEMAND -2016

| GROUPS             |       |                           |     | WATER DEMAND, M <sup>3</sup> /DAY |           |            |           |           |
|--------------------|-------|---------------------------|-----|-----------------------------------|-----------|------------|-----------|-----------|
| BASIN              | WMU # | WMU NAME                  | PAR | RESID.                            | COMM./    | TOURISM    | SUB-TOTAL | WMU TOTAL |
|                    |       |                           |     |                                   | INSTI.    |            |           |           |
| I-BLUE MOUNTAINS S | 15    | Plantain Garden           | ST  | 1,417.30                          | 354.3     | 1,008.60   | 2,780     | 2,780     |
|                    | 16    | Morant River              | ST  | 9,177.30                          | 2,294.30  | 5,939.60   | 17,411    | 17,411    |
|                    | 17    | Yallahs River             | ST  | 2,160.10                          | 540       | 280.2      | 2,980     | 5,839     |
|                    |       |                           | KSA | 1,256.30                          | 314.1     | 1,288.80   | 2,859     |           |
| II-KINGSTON        | 18    | Hope River                | KSA | 76,838.10                         | 19,209.50 | 99,908.60  | 195,956   | 214,950   |
|                    |       |                           | KSA | 13,679.20                         | 3,419.80  | 0          | 17,099    |           |
|                    |       |                           | ST  | 350.4                             | 87.6      | 1,456.90   | 1,895     |           |
| III-RIO COBRE      | 19    | Rio Cobre                 | SS  | 74,333.80                         | 18,583.50 | 21,965.30  | 114,883   | 119,499   |
|                    |       |                           | SC  | 3,198.50                          | 799.6     | 0          | 3,998     |           |
|                    |       |                           | CL  | 345.4                             | 86.3      | 0          | 432       |           |
|                    |       |                           | SA  | 93.3                              | 23.3      | 0          | 117       |           |
|                    |       |                           | SM  | 56.2                              | 14        | 0          | 70        |           |
| IV-RIO MINHO       | 20    | Rio Minho                 | CL  | 20,925.10                         | 5,231.30  | 1,681.00   | 27,837    | 28,000    |
|                    |       |                           | SC  | 130.4                             | 32.6      | 0          | 163       |           |
|                    | 21    | Milk River                | CL  | 10,761.50                         | 2,690.40  | 4,875.00   | 18,327    | 55,684    |
|                    |       |                           | MA  | 17,468.90                         | 4,367.20  | 15,521.40  | 37,358    |           |
|                    | 22    | Gut River                 | MA  | 1,694.80                          | 423.7     | 0          | 2,118     | 2,140     |
|                    |       |                           | CL  | 17                                | 4.3       | 0          | 21        |           |
|                    |       |                           | SE  | 0                                 | 0         | 0          | 0         |           |
| V-BLACK RIVER      | 23    | Black River               | SE  | 18,987.90                         | 4,747.00  | 31,379.00  | 55,114    | 59,692    |
|                    |       |                           | WE  | 0                                 | 0         | 0          | 0         |           |
|                    |       |                           | MA  | 2,950.60                          | 737.6     | 0          | 3,688     |           |
|                    |       |                           | TR  | 548.8                             | 137.2     | 0          | 686       |           |
|                    |       |                           | SJ  | 162.9                             | 40.7      | 0          | 204       |           |
| VI-CABARITA RIVER  | 24    | Deans Valley River        | WE  | 8,181.70                          | 2,045     | 30,146.30  | 40,373    | 40,385    |
|                    |       |                           | HA  | 9.5                               | 2         | 0          | 12        |           |
|                    | 25    | Cabarita River            | WE  | 6,326.40                          | 1,582     | 1,008.60   | 8,917     | 9,482     |
|                    |       |                           | HA  | 452.1                             | 113       | 0          | 565       |           |
|                    | 26    | New Savannah              | WE  | 946.1                             | 237       | 1,120.70   | 2,303     | 2,303     |
|                    | 1     | South Negril-Orange River | WE  | 2,693.00                          | 673       | 139,916.90 | 143,283   | 258,560   |
|                    |       |                           | HA  | 1,132.70                          | 283       | 113,861.10 | 115,277   |           |



| GROUPS             |       |                       |     | WATER DEMAND, M³/DAY |        |            |           |            |
|--------------------|-------|-----------------------|-----|----------------------|--------|------------|-----------|------------|
| BASIN              | WMU # | WMU NAME              | PAR | RESID.               | COMM./ | TOURISM    | SUB-TOTAL | WMU TOTAL  |
|                    |       |                       |     |                      | INSTI. |            |           |            |
| VII-GREAT RIVER    | 2     | Lucea River           | HA  | 7,564.00             | 1,891  | 91,447.50  | 100,902   | 100,902    |
|                    | 3     | Great River           | SJ  | 3,807.00             | 952    | 5,099.10   | 9,858     | 13,032     |
|                    |       |                       | HA  | 1,130.10             | 283    | 280.2      | 1,693     |            |
|                    |       |                       | WE  | 1,005.00             | 251    | 224.1      | 1,480     |            |
|                    |       |                       | SE  | 1.1                  | 0      | 0          | 1         |            |
|                    | 4     | Montego River         | SJ  | 21,415.40            | 5,354  | 391,621.60 | 418,391   | 418,391    |
| VIII-MARTHA BRAE R | 5     | Martha Brae           | TR  | 6,164.80             | 1,541  | 42,697.90  | 50,404    | 113,400    |
|                    |       |                       | SJ  | 3,597.00             | 899    | 58,499.50  | 62,996    |            |
| IX-DRY HARBOUR MT  | 6     | Rio Bueno-White River | SA  | 19,721.10            | 4,930  | 356,040.00 | 380,691   | 437,689.91 |
|                    |       |                       | TR  | 3,589.40             | 897    | 29,361.80  | 33,849    |            |
|                    |       |                       | SM  | 907.8                | 227    | 17,090.40  | 18,225    |            |
|                    |       |                       | CL  | 996.4                | 249    | 0          | 1,245     |            |
|                    |       |                       | MA  | 2,208.60             | 552    | 784.5      | 3,545     |            |
|                    |       |                       | SC  | 107.3                | 27     | 0          | 134       |            |
| X-BLUE MOUNTAINS N | 7     | Rio Nuevo             | SM  | 2,621.30             | 655    | 14,064.50  | 17,341    | 17,341     |
|                    | 8     | Oracabessa-Pagee      | SM  | 6,459.20             | 1,615  | 21,741.20  | 29,815    | 29,815     |
|                    | 9     | Wagwater River        | SM  | 4,725.70             | 1,181  | 560.3      | 6,467     | 13,241     |
|                    |       |                       | KSA | 4,508.70             | 1,127  | 1,120.70   | 6,757     |            |
|                    |       |                       | SC  | 13.7                 | 3      | 0          | 17        |            |
|                    | 10    | Pencar-Buff Bay R     | PO  | 2,288.80             | 572    | 0          | 2,861     | 6,796      |
|                    |       |                       | SM  | 1,838.10             | 460    | 448.3      | 2,746     |            |
|                    |       |                       | KSA | 10                   | 2      | 1,176.70   | 1,189     |            |
|                    | 11    | Spanish River         | PO  | 568.3                | 142    | 0          | 710       | 710        |
|                    | 12    | Swift River           | PO  | 1,131.30             | 283    | 224.1      | 1,638     | 1,638      |
|                    | 13    | Rio Grande            | PO  | 2,244.50             | 561    | 2,129.30   | 4,935     | 4,935      |
|                    |       |                       | ST  | 0                    | 0      | 0          | 0         |            |
|                    | 14    | Drivers River         | PO  | 6,204.10             | 1,551  | 25,775.60  | 33,531    | 33,569     |
|                    |       |                       | ST  | 30.6                 | 8      | 0          | 38        |            |
| TOTALS             |       |                       |     | 381,154              | 95,289 | 1,531,745  | 2,008,189 | 2,008,189  |

## APPENDIX 4

## LIST OF EXISTING AND PROPOSED GROWTH CENTRES AND CURRENT RANKING

| BASIN              | WMU                    |               | SETTLEMENTS     | NATIONAL PHYSICAL PLAN 1978 – 1998 | PROPOSED DESIGNATION <sup>25</sup> | CURRENT SETTLEMENT RANKING |
|--------------------|------------------------|---------------|-----------------|------------------------------------|------------------------------------|----------------------------|
| X-BLUE MTN S       | Oracabessa-Pagee River | St. Mary      | Port Maria      | Sub-Regional                       | Regional Centre                    | 19                         |
|                    | Pencar-Buff Bay River  | St. Mary      | Annotto Bay     | District Centre                    | Sub-Regional                       | 23                         |
|                    | Morant River           | St. Thomas    | Morant Bay      | Sub-Regional                       | Regional Centre                    | 15                         |
|                    | Morant River           | St. Thomas    | Yallahs         | District Centre                    | Sub-Regional                       | 43                         |
| III- RIO COBRE     | Rio Cobre              | St. Catherine | Portmore        | No Designation                     | Regional Centre                    | 3                          |
|                    | Rio Cobre              | St. Catherine | Guys Hill       | District Centre                    | Sub-Regional                       | 29                         |
| IV- RIO MINHO      | Rio Minho              | Clarendon     | Chapleton       | District Centre                    | Sub-Regional                       | 24                         |
|                    | Milk River             | Clarendon     | Kellits         | District Centre                    | Sub-Regional                       | 42                         |
|                    | Rio Bueno-White River  | St. Ann       | Alexandria      | District Centre                    | Sub-Regional                       | 48                         |
| VI-CABARITA RIVER  | Deans Valley River     | Westmore-land | Darliston       | District Centre                    | Sub-Regional                       | 50                         |
|                    | Deans Valley River     | Westmoreland  | Savanna-la-mar  | Sub-Regional                       | Regional Centre                    | 5                          |
| VII- GREAT RIVER   | Great River            | St. James     | Anchovy         | District Centre                    | Sub-Regional                       | 39                         |
|                    | Great River            | St. James     | Cambridge       | District Centre                    | Sub-Regional                       | 73                         |
| VIII- MARTHA BRAE  | Martha Brae            | St. James     | Maroon Town     | District Centre                    | Sub-Regional                       | 105                        |
|                    | Martha Brae            | Trelawny      | Falmouth        | Sub-Regional                       | Regional Centre                    | 14                         |
| III-RIO COBRE      | Rio Cobre              | St. Andrew    | Lawrence Tavern | No Designation                     | Sub-Regional                       | 67                         |
| I-BLUE MOUNTAIN S. | Yallahs River          | St. Andrew    | Mavis Bank      | District Centre                    | Sub-Regional                       | 92                         |
|                    | Rio Bueno-White River  | Trelawny      | Albert Town     | District Centre                    | Sub-Regional                       | 96                         |
|                    | Black River            | St. Elizabeth | Junction        | District Centre                    | Sub-Regional                       | 22                         |
|                    | Black River            | St. Elizabeth | Treasure Beach  | District Centre                    | Sub-Regional                       | 126                        |

<sup>25</sup> Draft National Settlement Strategy 2016\*



## APPENDIX 5

### IRRIGATION REQUIREMENT PER CROP PER PARISH FOR 2016, 2030'S, 2050'S AND 2080'S

| IRRIGATION REQUIREMENT 2016 |                                             |                  |             |      |                   |
|-----------------------------|---------------------------------------------|------------------|-------------|------|-------------------|
|                             |                                             | TOTAL CULTIVATED | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                             |                                             | AREA (HA)        | AREA (HA)   | KC   | M <sup>3</sup>    |
| WESTMORELAND                | SUGARCANE                                   | 7,534            | 5725        | 1.25 | 13,352,697        |
|                             | Banana/Plantain                             | -                | -           | 1.1  | 0                 |
|                             | Vegetables, Legumes, Condiments and Cereals | 24,483           | 979         | 1.0  | 794,936           |
|                             | Other Tubers, Yam, Potato                   | 11,573           | 694         | 0.9  | 311,828           |
|                             | Fruit                                       | 7,089            | 425         | 0.85 | 116,114           |
|                             | Rice                                        | 13.6             | 13.6        | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                          | <b>50,678.35</b> | <b>7823</b> |      | <b>14,575,575</b> |
| HANOVER                     | SUGARCANE                                   | -                | 0           | 1.25 | 0                 |
|                             | Banana/Plantain                             | -                | 0           | 1.1  | 0                 |
|                             | Vegetables, Legumes, Condiments and Cereals | 9,785            | 391         | 1.0  | 21,111            |
|                             | Other Tubers, Yam, Potato                   | 7,581            | 455         | 0.9  | 0                 |
|                             | Fruit                                       | 4,909            | 295         | 0.85 | 0                 |
|                             | Rice                                        |                  | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                          | <b>22,274.40</b> | <b>1141</b> |      | <b>21,111</b>     |

| IRRIGATION REQUIREMENT 2016 |                                             |                   |             |      |                   |
|-----------------------------|---------------------------------------------|-------------------|-------------|------|-------------------|
|                             |                                             | TOTAL CULTIVATED  | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                             |                                             | AREA (HA)         | AREA (HA)   | KC   | M <sup>3</sup>    |
| ST. JAMES                   | SUGARCANE                                   | -                 | 0           | 1.25 | 0                 |
|                             | Banana/Plantain                             | 248               | 20          | 1.1  | 35,363            |
|                             | Vegetables, Legumes, Condiments and Cereals | 11,205            | 448         | 1.0  | 432,578           |
|                             | Other Tubers, Yam, Potato                   | 7,624             | 457         | 0.9  | 177,201           |
|                             | Fruit                                       | 6,612             | 397         | 0.85 | 83,458            |
|                             | Rice                                        |                   | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                          | <b>25,687.99</b>  | <b>1322</b> |      | <b>728,600</b>    |
| TRELAWNY                    | SUGARCANE                                   | 2,286             | 1737        | 1.25 | 7,837,538         |
|                             | Banana/Plantain                             | -                 | 0           | 1.1  | 0                 |
|                             | Vegetables, Legumes, Condiments and Cereals | 13,987            | 559         | 1.0  | 1,056,191         |
|                             | Other Tubers, Yam, Potato                   | 84,704            | 5082        | 0.9  | 5,607,298         |
|                             | Fruit                                       | 8,637             | 518         | 0.85 | 397,823           |
|                             | Rice                                        |                   | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                          | <b>109,613.41</b> | <b>7896</b> |      | <b>14,898,850</b> |
| ST. ANN                     | SUGARCANE                                   | -                 | 0           | 1.25 | 0                 |
|                             | Banana/Plantain                             | 79                | 6           | 1.1  | 16,474            |
|                             | Vegetables, Legumes, Condiments and Cereals | 35,379            | 1415        | 1.0  | 2,637,859         |
|                             | Other Tubers, Yam, Potato                   | 18,243            | 1095        | 0.9  | 1,249,488         |
|                             | Fruit                                       | 2,818             | 169         | 0.85 | 144,350           |
|                             | Rice                                        |                   | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                          | <b>56,518.81</b>  | <b>2685</b> |      | <b>4,048,171</b>  |

| IRRIGATION REQUIREMENT 2016 |                                             |                  |             |      |                  |
|-----------------------------|---------------------------------------------|------------------|-------------|------|------------------|
|                             |                                             | TOTAL CULTIVATED | IRRIGATED   |      | IRRREQ (YEARLY)  |
|                             |                                             | AREA (HA)        | AREA (HA)   | KC   | M <sup>3</sup>   |
| ST. MARY                    | SUGARCANE                                   | -                | 0           | 1.25 | 0                |
|                             | Banana/Plantain                             | 267              | 21          | 1.1  | 42,205           |
|                             | Vegetables, Legumes, Condiments and Cereals | 15,910           | 636         | 1.0  | 778,605          |
|                             | Other Tubers, Yam, Potato                   | 11,060           | 664         | 0.9  | 390,822          |
|                             | Fruit                                       | 7,013            | 421         | 0.85 | 141,988          |
|                             | Rice                                        |                  | 0           | 1.15 |                  |
|                             | <b>GRAND TOTAL</b>                          | <b>34,248.33</b> | <b>1742</b> |      | <b>1,353,620</b> |
| PORTLAND                    | SUGARCANE                                   | -                | 0           | 1.25 | 0                |
|                             | Banana/Plantain                             | 153              | 12          | 1.1  | 7,473            |
|                             | Vegetables, Legumes, Condiments and Cereals | 6,593            | 264         | 1.0  | 73,160           |
|                             | Other Tubers, Yam, Potato                   | 10,169           | 610         | 0.9  | 50,065           |
|                             | Fruit                                       | 9,441            | 566         | 0.85 | 14,260           |
|                             | Rice                                        |                  | 0           | 1.15 |                  |
|                             | <b>GRAND TOTAL</b>                          | <b>26,355.56</b> | <b>1452</b> |      | <b>144,958</b>   |
| ST. THOMAS                  | SUGARCANE                                   | 2,906            | 2209        | 1.25 | 3,431,124        |
|                             | Banana/Plantain                             | 15               | 1           | 1.1  | 734              |
|                             | Vegetables, Legumes, Condiments and Cereals | 10,811           | 432         | 0.8  | 159,054          |
|                             | Other Tubers, Yam, Potato                   | 3,836            | 230         | 0.9  | 40,734           |
|                             | Fruit                                       | 5,084            | 305         | 0.85 | 36,797           |
|                             | Rice                                        |                  | 0           | 1.15 |                  |
|                             | <b>GRAND TOTAL</b>                          | <b>22,652.77</b> | <b>3177</b> |      | <b>3,668,443</b> |

| IRRIGATION REQUIREMENT 2016 |                                             |                  |             |      |                   |
|-----------------------------|---------------------------------------------|------------------|-------------|------|-------------------|
|                             |                                             | TOTAL CULTIVATED | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                             |                                             | AREA (HA)        | AREA (HA)   | KC   | M <sup>3</sup>    |
| KSA                         | SUGARCANE                                   | -                | 0           | 1.25 | 0                 |
|                             | Banana/Plantain                             | -                | 0           | 1.1  | 0                 |
|                             | Vegetables, Legumes, Condiments and Cereals | 6,525            | 261         | 1.0  | 286,399           |
|                             | Other Tubers, Yam, Potato                   | 1,757            | 105         | 0.9  | 72,008            |
|                             | Fruit                                       | 2,011            | 121         | 0.85 | 63,749            |
|                             | Rice                                        |                  | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                          | <b>10,292.76</b> | <b>487</b>  |      | <b>422,156</b>    |
| ST. CATHERINE               | SUGARCANE                                   | 3,730            | 2834        | 1.25 | 14,394,458        |
|                             | Banana/Plantain                             | 49               | 4           | 1.1  | 13,832            |
|                             | Vegetables, Legumes, Condiments and Cereals | 17,535           | 701         | 1.0  | 1,737,961         |
|                             | Other Tubers, Yam, Potato                   | 9,215            | 553         | 0.9  | 877,145           |
|                             | Fruit                                       | 4,329            | 260         | 0.85 | 321,302           |
|                             | Rice                                        |                  | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                          | <b>34,857.57</b> | <b>4352</b> |      | <b>17,344,698</b> |
| CLARENDON                   | SUGARCANE                                   | 6,212            | 4721        | 1.25 | 23,240,297        |
|                             | Banana/Plantain                             | 7                | 1           | 1.1  | 3,252             |
|                             | Vegetables, Legumes, Condiments and Cereals | 33,708           | 1348        | 1.0  | 3,240,645         |
|                             | Other Tubers, Yam, Potato                   | 24,436           | 1466        | 0.9  | 2,276,977         |
|                             | Fruit                                       | 2,808            | 168         | 0.85 | 196,441           |
|                             | Rice                                        |                  | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                          | <b>67,171.93</b> | <b>7704</b> |      | <b>28,957,612</b> |



| IRRIGATION REQUIREMENT 2016 |                                              |                   |             |      |                   |
|-----------------------------|----------------------------------------------|-------------------|-------------|------|-------------------|
|                             |                                              | TOTAL CULTIVATED  | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                             |                                              | AREA (HA)         | AREA (HA)   | KC   | M <sup>3</sup>    |
| MANCHES-TER                 | SUGARCANE                                    | -                 | 0           | 1.25 | 0                 |
|                             | Banana/Plantain                              | -                 | 0           | 1.1  | 0                 |
|                             | Vegetables, Legumes, Condi-ments and Cereals | 54,293            | 2172        | 1.0  | 4,024,396         |
|                             | Other Tubers, Yam, Potato                    | 47,878            | 2873        | 0.9  | 3,279,544         |
|                             | Fruit                                        | 5,487             | 329         | 0.85 | 283,500           |
|                             | Rice                                         |                   | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                           | <b>107,657.54</b> | <b>5374</b> |      | <b>7,587,440</b>  |
| ST. ELIZA-BETH              | SUGARCANE                                    | 4,234             | 3218        | 1.25 | 10,157,924        |
|                             | Banana/Plantain                              | -                 | 0           | 1.1  | 0                 |
|                             | Vegetables, Legumes, Condi-ments and Cereals | 60,463            | 2419        | 0.8  | 3,103,737         |
|                             | Other Tubers, Yam, Potato                    | 27,936            | 1676        | 0.9  | 1,209,402         |
|                             | Fruit                                        | 35,201            | 2112        | 0.85 | 1,018,277         |
|                             | Rice                                         |                   | 0           | 1.15 |                   |
|                             | <b>GRAND TOTAL</b>                           | <b>127,833.23</b> | <b>9425</b> |      | <b>15,489,340</b> |

| IRRIGATION REQUIREMENT 2030S |                                              |                  |             |      |                   |
|------------------------------|----------------------------------------------|------------------|-------------|------|-------------------|
|                              |                                              | TOTAL CULTIVATED | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                              |                                              | AREA (HA)        | AREA (HA)   | KC   | M <sup>3</sup>    |
| WESTMORE-LAND                | SUGARCANE                                    | 7,534            | 5725        | 1.25 | 18,485,396        |
|                              | Banana/Plantain                              | -                | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condi-ments and Cereals | 24,483           | 979         | 1.0  | 1,152,225         |
|                              | Other Tubers, Yam, Potato                    | 11,573           | 694         | 0.9  | 494,540           |
|                              | Fruit                                        | 7,089            | 425         | 0.85 | 218,671           |
|                              | Rice                                         | 14               | 13.6        | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                           | <b>50,678.35</b> | <b>7823</b> |      | <b>20,350,832</b> |
| HANOVER                      | SUGARCANE                                    | -                | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                              | -                | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condi-ments and Cereals | 9,785            | 391         | 1.0  | 19,096            |
|                              | Other Tubers, Yam, Potato                    | 7,581            | 455         | 0.9  | 0                 |
|                              | Fruit                                        | 4,909            | 295         | 0.85 | 0                 |
|                              | Rice                                         |                  | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                           | <b>22,274.40</b> | <b>1141</b> |      | <b>19,096</b>     |
| ST. JAMES                    | SUGARCANE                                    | -                | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                              | 248              | 20          | 1.1  | 54,347            |
|                              | Vegetables, Legumes, Condi-ments and Cereals | 11,205           | 448         | 1.0  | 757,341           |
|                              | Other Tubers, Yam, Potato                    | 7,624            | 457         | 0.9  | 383,396           |
|                              | Fruit                                        | 6,612            | 397         | 0.85 | 198,299           |
|                              | Rice                                         |                  | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                           | <b>25,687.99</b> | <b>1322</b> |      | <b>1,393,383</b>  |

| IRRIGATION REQUIREMENT 2030S |                                             |                   |             |      |                   |
|------------------------------|---------------------------------------------|-------------------|-------------|------|-------------------|
|                              |                                             | TOTAL CULTIVATED  | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                              |                                             | AREA (HA)         | AREA (HA)   | KC   | M <sup>3</sup>    |
| TRELAWNY                     | SUGARCANE                                   | 2,286             | 1737        | 1.25 | 10,511,133        |
|                              | Banana/Plantain                             | -                 | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 13,987            | 559         | 1.0  | 1,612,455         |
|                              | Other Tubers, Yam, Potato                   | 84,704            | 5082        | 0.9  | 9,160,328         |
|                              | Fruit                                       | 8,637             | 518         | 0.85 | 703,277           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>109,613.41</b> | <b>7896</b> |      | <b>21,987,193</b> |
| ST. ANN                      | SUGARCANE                                   | -                 | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                             | 79                | 6           | 1.1  | 22,657            |
|                              | Vegetables, Legumes, Condiments and Cereals | 35,379            | 1415        | 1.0  | 3,939,046         |
|                              | Other Tubers, Yam, Potato                   | 18,243            | 1095        | 0.9  | 1,974,851         |
|                              | Fruit                                       | 2,818             | 169         | 0.85 | 224,309           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>56,518.81</b>  | <b>2685</b> |      | <b>6,160,863</b>  |
| ST. MARY                     | SUGARCANE                                   | -                 | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                             | 267               | 21          | 1.1  | 60,637            |
|                              | Vegetables, Legumes, Condiments and Cereals | 15,910            | 636         | 1.0  | 1,199,523         |
|                              | Other Tubers, Yam, Potato                   | 11,060            | 664         | 0.9  | 607,755           |
|                              | Fruit                                       | 7,013             | 421         | 0.85 | 216,783           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>34,248.33</b>  | <b>1742</b> |      | <b>2,084,698</b>  |

| IRRIGATION REQUIREMENT 2030S |                                             |                  |             |      |                  |
|------------------------------|---------------------------------------------|------------------|-------------|------|------------------|
|                              |                                             | TOTAL CULTIVATED | IRRIGATED   |      | IRRREQ (YEARLY)  |
|                              |                                             | AREA (HA)        | AREA (HA)   | KC   | M <sup>3</sup>   |
| PORTLAND                     | SUGARCANE                                   | -                | 0           | 1.25 | 0                |
|                              | Banana/Plantain                             | 153              | 12          | 1.1  | 15,819           |
|                              | Vegetables, Legumes, Condiments and Cereals | 6,593            | 264         | 1.0  | 205,831          |
|                              | Other Tubers, Yam, Potato                   | 10,169           | 610         | 0.9  | 217,702          |
|                              | Fruit                                       | 9,441            | 566         | 0.85 | 128,464          |
|                              | Rice                                        |                  | 0           | 1.15 |                  |
|                              | <b>GRAND TOTAL</b>                          | <b>26,355.56</b> | <b>1452</b> |      | <b>567,816</b>   |
| ST. THOMAS                   | SUGARCANE                                   | 2,906            | 2209        | 1.25 | 5,940,874        |
|                              | Banana/Plantain                             | 15               | 1           | 1.1  | 1,519            |
|                              | Vegetables, Legumes, Condiments and Cereals | 10,811           | 432         | 0.8  | 396,431          |
|                              | Other Tubers, Yam, Potato                   | 3,836            | 230         | 0.9  | 101,279          |
|                              | Fruit                                       | 5,084            | 305         | 0.85 | 93,155           |
|                              | Rice                                        |                  | 0           | 1.15 |                  |
|                              | <b>GRAND TOTAL</b>                          | <b>22,652.77</b> | <b>3177</b> |      | <b>6,533,258</b> |
| KSA                          | SUGARCANE                                   |                  | 0           | 1.25 | 0                |
|                              | Banana/Plantain                             |                  | 0           | 1.1  | 0                |
|                              | Vegetables, Legumes, Condiments and Cereals | 6,525            | 261         | 1.0  | 581,999          |
|                              | Other Tubers, Yam, Potato                   | 1,757            | 105         | 0.9  | 146,483          |
|                              | Fruit                                       | 2,011            | 121         | 0.85 | 125,123          |
|                              | Rice                                        |                  | 0           | 1.15 |                  |
|                              | <b>GRAND TOTAL</b>                          | <b>10,292.76</b> | <b>487</b>  |      | <b>853,605</b>   |



| IRRIGATION REQUIREMENT 2030S |                                             |                   |             |      |                   |
|------------------------------|---------------------------------------------|-------------------|-------------|------|-------------------|
|                              |                                             | TOTAL CULTIVATED  | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                              |                                             | AREA (HA)         | AREA (HA)   | KC   | M <sup>3</sup>    |
| ST. CATHERINE                | SUGARCANE                                   | 3,730             | 2834        | 1.25 | 20,115,063        |
|                              | Banana/Plantain                             | 49                | 4           | 1.1  | 20,277            |
|                              | Vegetables, Legumes, Condiments and Cereals | 17,535            | 701         | 1.0  | 2,709,875         |
|                              | Other Tubers, Yam, Potato                   | 9,215             | 553         | 0.9  | 1,494,586         |
|                              | Fruit                                       | 4,329             | 260         | 0.85 | 562,468           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>34,857.57</b>  | <b>4352</b> |      | <b>24,902,269</b> |
| CLARENDON                    | SUGARCANE                                   | 6,212             | 4721        | 1.25 | 31,375,097        |
|                              | Banana/Plantain                             | 7                 | 1           | 1.1  | 4,681             |
|                              | Vegetables, Legumes, Condiments and Cereals | 33,708            | 1348        | 1.0  | 4,649,538         |
|                              | Other Tubers, Yam, Potato                   | 24,436            | 1466        | 0.9  | 3,594,471         |
|                              | Fruit                                       | 2,808             | 168         | 0.85 | 332,199           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>67,171.93</b>  | <b>7704</b> |      | <b>39,955,986</b> |
| MANCHESTER                   | SUGARCANE                                   |                   | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                             |                   | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 54,293            | 2172        | 1.0  | 6,047,375         |
|                              | Other Tubers, Yam, Potato                   | 47,878            | 2873        | 0.9  | 5,313,079         |
|                              | Fruit                                       | 5,487             | 329         | 0.85 | 475,065           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>107,657.54</b> | <b>5374</b> |      | <b>11,835,519</b> |

| IRRIGATION REQUIREMENT 2030S |                                             |                   |             |      |                   |
|------------------------------|---------------------------------------------|-------------------|-------------|------|-------------------|
|                              |                                             | TOTAL CULTIVATED  | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                              |                                             | AREA (HA)         | AREA (HA)   | KC   | M <sup>3</sup>    |
| ST. ELIZABETH                | SUGARCANE                                   | 4,234             | 3218        | 1.25 | 13,981,680        |
|                              | Banana/Plantain                             |                   | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 60,463            | 2419        | 0.8  | 4,418,090         |
|                              | Other Tubers, Yam, Potato                   | 27,936            | 1676        | 0.9  | 1,926,787         |
|                              | Fruit                                       | 35,201            | 2112        | 0.85 | 1,730,303         |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>127,833.23</b> | <b>9425</b> |      | <b>22,056,860</b> |

| IRRIGATION REQUIREMENT 2050S |                                             |                  |             |      |                   |
|------------------------------|---------------------------------------------|------------------|-------------|------|-------------------|
|                              |                                             | TOTAL CULTIVATED | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                              |                                             | AREA (HA)        | AREA (HA)   | KC   | M <sup>3</sup>    |
| WESTMORELAND                 | SUGARCANE                                   | 7,534            | 5725        | 1.25 | 17,036,957        |
|                              | Banana/Plantain                             | -                | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 24,483           | 979         | 1.0  | 832,006           |
|                              | Other Tubers, Yam, Potato                   | 11,573           | 694         | 0.9  | 310,992           |
|                              | Fruit                                       | 7,089            | 425         | 0.85 | 129,921           |
|                              | Rice                                        | 14               | 13.6        | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>50,678.35</b> | <b>7823</b> |      | <b>18,309,876</b> |

| IRRIGATION REQUIREMENT 2050S |                                             |                   |             |      |                   |
|------------------------------|---------------------------------------------|-------------------|-------------|------|-------------------|
|                              |                                             | TOTAL CULTIVATED  | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                              |                                             | AREA (HA)         | AREA (HA)   | KC   | M3                |
| HANOVER                      | SUGARCANE                                   |                   | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                             |                   | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 9,785             | 391         | 1.0  | 260,033           |
|                              | Other Tubers, Yam, Potato                   | 7,581             | 455         | 0.9  | 181,784           |
|                              | Fruit                                       | 4,909             | 295         | 0.85 | 56,978            |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>22,274.40</b>  | <b>1141</b> |      | <b>498,795</b>    |
| ST. JAMES                    | SUGARCANE                                   |                   | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                             | 248               | 20          | 1.1  | 53,441            |
|                              | Vegetables, Legumes, Condiments and Cereals | 11,205            | 448         | 1.0  | 728,533           |
|                              | Other Tubers, Yam, Potato                   | 7,624             | 457         | 0.9  | 366,779           |
|                              | Fruit                                       | 6,612             | 397         | 0.85 | 183,070           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>25,687.99</b>  | <b>1322</b> |      | <b>1,331,823</b>  |
| TRELAWNY                     | SUGARCANE                                   | 2,286             | 1737        | 1.25 | 11,004,153        |
|                              | Banana/Plantain                             |                   | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 13,987            | 559         | 1.0  | 1,719,362         |
|                              | Other Tubers, Yam, Potato                   | 84,704            | 5082        | 0.9  | 9,844,552         |
|                              | Fruit                                       | 8,637             | 518         | 0.85 | 759,194           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>109,613.41</b> | <b>7896</b> |      | <b>23,327,261</b> |

| IRRIGATION REQUIREMENT 2050S |                                             |                  |             |      |                  |
|------------------------------|---------------------------------------------|------------------|-------------|------|------------------|
|                              |                                             | TOTAL CULTIVATED | IRRIGATED   |      | IRRREQ (YEARLY)  |
|                              |                                             | AREA (HA)        | AREA (HA)   | KC   | M3               |
| ST. ANN                      | SUGARCANE                                   |                  | 0           | 1.25 | 0                |
|                              | Banana/Plantain                             | 79               | 6           | 1.1  | 23,265           |
|                              | Vegetables, Legumes, Condiments and Cereals | 35,379           | 1415        | 1.0  | 4,076,737        |
|                              | Other Tubers, Yam, Potato                   | 18,243           | 1095        | 0.9  | 2,063,726        |
|                              | Fruit                                       | 2,818            | 169         | 0.85 | 241,195          |
|                              | Rice                                        |                  | 0           | 1.15 |                  |
|                              | <b>GRAND TOTAL</b>                          | <b>56,518.81</b> | <b>2685</b> |      | <b>6,404,923</b> |
| ST. MARY                     | SUGARCANE                                   |                  | 0           | 1.25 | 0                |
|                              | Banana/Plantain                             | 267              | 21          | 1.1  | 74,696           |
|                              | Vegetables, Legumes, Condiments and Cereals | 15,910           | 636         | 1.0  | 1,611,640        |
|                              | Other Tubers, Yam, Potato                   | 11,060           | 664         | 0.9  | 1,069,476        |
|                              | Fruit                                       | 7,013            | 421         | 0.85 | 483,696          |
|                              | Rice                                        |                  | 0           | 1.15 |                  |
|                              | <b>GRAND TOTAL</b>                          | <b>34,248.33</b> | <b>1742</b> |      | <b>3,239,508</b> |
| PORTLAND                     | SUGARCANE                                   |                  | 0           | 1.25 | 0                |
|                              | Banana/Plantain                             | 153              | 12          | 1.1  | 21,837           |
|                              | Vegetables, Legumes, Condiments and Cereals | 6,593            | 264         | 1.0  | 285,480          |
|                              | Other Tubers, Yam, Potato                   | 10,169           | 610         | 0.9  | 369,051          |
|                              | Fruit                                       | 9,441            | 566         | 0.85 | 221,603          |
|                              | Rice                                        |                  | 0           | 1.15 |                  |
|                              | <b>GRAND TOTAL</b>                          | <b>26,355.56</b> | <b>1452</b> |      | <b>897,971</b>   |



| IRRIGATION REQUIREMENT 2050S |                                             |                  |             |      |                   |
|------------------------------|---------------------------------------------|------------------|-------------|------|-------------------|
|                              |                                             | TOTAL CULTIVATED | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                              |                                             | AREA (HA)        | AREA (HA)   | KC   | M3                |
| ST. THOMAS                   | SUGARCANE                                   | 2,906            | 2209        | 1.25 | 7,516,349         |
|                              | Banana/Plantain                             | 15               | 1           | 1.1  | 2,065             |
|                              | Vegetables, Legumes, Condiments and Cereals | 10,811           | 432         | 0.8  | 593,347           |
|                              | Other Tubers, Yam, Potato                   | 3,836            | 230         | 0.9  | 173,343           |
|                              | Fruit                                       | 5,084            | 305         | 0.85 | 159,528           |
|                              | Rice                                        |                  | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>22,652.77</b> | <b>3177</b> |      | <b>8,444,632</b>  |
| KSA                          | SUGARCANE                                   |                  | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                             |                  | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 6,525            | 261         | 1.0  | 767,315           |
|                              | Other Tubers, Yam, Potato                   | 1,757            | 105         | 0.9  | 206,174           |
|                              | Fruit                                       | 2,011            | 121         | 0.85 | 188,074           |
|                              | Rice                                        |                  | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>10,292.76</b> | <b>487</b>  |      | <b>1,161,563</b>  |
| ST. CATHERINE                | SUGARCANE                                   | 3,730            | 2834        | 1.25 | 22,395,892        |
|                              | Banana/Plantain                             | 49               | 4           | 1.1  | 23,012            |
|                              | Vegetables, Legumes, Condiments and Cereals | 17,535           | 701         | 1.0  | 3,155,455         |
|                              | Other Tubers, Yam, Potato                   | 9,215            | 553         | 0.9  | 1,817,196         |
|                              | Fruit                                       | 4,329            | 260         | 0.85 | 706,756           |
|                              | Rice                                        |                  | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>34,857.57</b> | <b>4352</b> |      | <b>28,098,311</b> |

| IRRIGATION REQUIREMENT 2050S |                                             |                   |             |      |                   |
|------------------------------|---------------------------------------------|-------------------|-------------|------|-------------------|
|                              |                                             | TOTAL CULTIVATED  | IRRIGATED   |      | IRRREQ (YEARLY)   |
|                              |                                             | AREA (HA)         | AREA (HA)   | KC   | M3                |
| CLARENDON                    | SUGARCANE                                   | 6212              | 4721        | 1.25 | 34,391,388        |
|                              | Banana/Plantain                             | 7                 | 1           | 1.1  | 5,290             |
|                              | Vegetables, Legumes, Condiments and Cereals | 33,708            | 1348        | 1.0  | 5,347,032         |
|                              | Other Tubers, Yam, Potato                   | 24,436            | 1466        | 0.9  | 4,180,272         |
|                              | Fruit                                       | 2,808             | 168         | 0.85 | 398,305           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>67,172</b>     | <b>7704</b> |      | <b>44,322,287</b> |
| MANCHESTER                   | SUGARCANE                                   |                   | 0           | 1.25 | 0                 |
|                              | Banana/Plantain                             |                   | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 54,293            | 2172        | 1.0  | 6,965,090         |
|                              | Other Tubers, Yam, Potato                   | 47,878            | 2873        | 0.9  | 6,470,332         |
|                              | Fruit                                       | 5,487             | 329         | 0.85 | 583,904           |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>107,657.54</b> | <b>5374</b> |      | <b>14,019,326</b> |
| ST. ELIZABETH                | SUGARCANE                                   | 4,234             | 3218        | 1.25 | 15,690,439        |
|                              | Banana/Plantain                             |                   | 0           | 1.1  | 0                 |
|                              | Vegetables, Legumes, Condiments and Cereals | 60,463            | 2419        | 0.8  | 5,321,597         |
|                              | Other Tubers, Yam, Potato                   | 27,936            | 1676        | 0.9  | 2,355,436         |
|                              | Fruit                                       | 35,201            | 2112        | 0.85 | 2,263,018         |
|                              | Rice                                        |                   | 0           | 1.15 |                   |
|                              | <b>GRAND TOTAL</b>                          | <b>127,833.23</b> | <b>9425</b> |      | <b>25,630,490</b> |

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(Footnotes)

1 Draft National Settlement Strategy 2016\*







# **Water Resources Authority**

Jamaica's Water ... Every Drop Precious