Developmental Study

Untapped and Untold: The Hidden Connection between Water and Sustainability in Trinidad and Tobago

2024

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CARIBBEAN WATER AND WASTEWATER ASSOCIATION

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List of Acronyms

ABC	Association of Boards of Certification (now known as Water Professionals International)
CANARI	Caribbean Natural Resources Institute
CapNet UNDP	CapNet United Nations Development Programme
CCLIP	Conditional Credit Line for Investment Projects
CCRIF SPC	Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company
CDB	Caribbean Development Bank
CEC	Certificate of Environmental Clearance
CIMH	Caribbean Institute for Meteorology and Hydrology
CMD	Centre for Manpower Development
COSTAATT	College of Science Technology and Applied Arts of Trinidad and Tobago
CSO	Central Statistical Office
CVQ	Caribbean Vocational Qualification
CWIP	Community Water Improvement Programme
CWWA	Caribbean Water and Wastewater Association
CWUIC SP	Caribbean Water Utility Insurance Collective Segregated Portfolio

List of Acronyms

DESALCOTT	Desalination Company of Trinidad and Tobago
DMA	District Metered Area
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortisation
EMA	Environmental Management Authority
FACRP	Fondes Amandes Community Reforestation Project
FFA-UWI	Faculty of Food and Agriculture, University of the West Indies, St. Augustine Campus
FFOS	Fishermen and Friends of the Sea
GEF CReW+ Project	Global Environment Facility Caribbean Regional Fund for Wastewater Management+ Project
GHG	Greenhouse Gas
GI	Green Infrastructure
GWP-C	Global Water Partnership-Caribbean
HDC	Housing Development Corporation
IDB	Inter-American Development Bank
IMGD	Imperial Million Gallons per Day

List of Acronyms

IPP	Independent Power Producers
IWRM	Integrated Water Resources Management
MALF	Ministry of Agriculture, Land, and Fisheries
MCM	Million Cubic Metres
MPU	Ministry of Public Utilities
NEWT	Nanotechnology-Enabled Water Treatment and Reuse
NGO	Non-Governmental Organisation
NRW	Non-Revenue Water
NSDP	National Social Development Programme
PMA	Pressure Management Area
POS	Port of Spain

List of Acronyms

PPP	Public-Private Partnership
PUC Act	Public Utilities Commission Act
RBC	Royal Bank of Canada
RIC	Regulated Industries Commission
SCADA	Supervisory Control and Data Acquisition System
SDGs	Sustainable Development Goals
SNMR	Surface Nuclear Magnetic Resonance
THA	Tobago House of Assembly
T&T	Trinidad and Tobago
TTBS	Trinidad and Tobago Bureau of Standards
TTEC	Trinidad and Tobago Electricity Commission
UNCCD	United Nations Convention to Combat Desertification
UNESCO	United Nations Educational, Scientific and Cultural Organisation

List of Acronyms

UWI	University of the West Indies
UWI STA	University of the West Indies, St Augustine Campus
WAS Act	Water and Sewerage Act
WASA	Water and Sewerage Authority of Trinidad and Tobago
WBE	Wastewater-Based Epidemiology
WPR	Water Pollution Rules
WRA	Water Resources Agency (WRA)
WRMSS	Water Resources Management Strategy Study
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

1.0 Introduction

Water is intricately embedded in Caribbean nations' socio-economic and environmental fabric, exerting and receiving influence through various interconnected systems. It drives agricultural productivity, supports the tourism sector, underpins public health, and is crucial to the region's vulnerability and adaptive capacity to hydrometeorological hazards such as hurricanes, floods, and droughts. Furthermore, equitable access to potable water resources is closely tied to socio-economic development and environmental justice, making integrated water resources management (IWRM) critical for sustainable development and climate resilience in the region.

The paradox of water abundance and scarcity, particularly in the case of freshwater, is a defining characteristic of Caribbean life. The region's water sector faces the distinctive challenge of managing resources that fluctuate dramatically—periods of excessive water, leading to severe flooding and loss of life, are followed by acute shortages that disrupt businesses, agriculture, and daily activities. This cyclical imbalance underscores the need for robust water management strategies to address both extremes, ensuring resilience and sustainability in these unpredictable conditions.

Though each Caribbean nation faces water security challenges that may be contextually unique, there is a general cognisance by decision-makers in the water sector that there are far more significant similarities in these challenges that warrant a common approach to untangle and solve these issues to ensure all Caribbean people have access to a reliable supply of water and wastewater management services.

This study examines the evolution of the water sector in Trinidad and Tobago, a Caribbean territory that gained independence from Britain in 1962, the same year as Jamaica. While Haiti became the first Caribbean nation to break from colonial rule in 1804, and the Dominican Republic achieved independence in 1844. Trinidad and Tobago's path to self-governance marked a significant milestone in the region's post-colonial development, influencing its approach to managing critical resources like water.

The study documents the evolution of the Trinidad and Tobago water sector from the beginning of its independence, spanning the last sixty (60) plus years. We present findings, recommendations, and lessons that can be applied to other Caribbean nations and small island developing states. These insights aim to improve the sustainability of the water sector, supporting broader, resilient socio-economic development. These recommendations also focus on challenges that will arise from a changing climate, which threatens water availability and will cause significant disruption in the water environment.

The South Oropouche River in Trinidad.
Sara-Jade Govia

Partial aerial view of Port-of-Spain.
Unsplash/Renaldo Matamoro

The following sections critically discuss the water and sanitation sector's institutional ecosystem (the water sector) and its evolution after independence. The document also highlights the availability of water resources and the dynamic between development, availability, and access. The report also explores the growth in demand for water and sanitation services as T&T gained independence and the corresponding infrastructural interventions commissioned to manage the increasing demand over time.

The dialogue then moves on to the sector's governance architecture and how the different actors and structures have changed and work (or do not work) together to secure the country's water resources. To conclude, we propose recommendations and strategies for stabilising and future-proofing the water sector in the context of climate extremes, variability, and change.

2.0 Evolution of the Water Sector

2.1 Water Sector Ecosystem: The Core Players and Skills Working Toward Better Water and Sanitation for Trinidad and Tobago

Water's ubiquitous and cross-cutting nature creates a complex network of physical, institutional, governance, and management processes that ultimately determine its quality, quantity, and accessibility. This section will explore the institutional framework of the water sector ecosystem as it forms the foundation for how water resources are harnessed, utilised, and managed. Understanding these institutional dynamics is critical to effectively addressing water resource management challenges.

The Trinidad and Tobago (T&T) water sector is a complex assortment of systems and interrelated entities with varied and overlapping responsibilities, coverage, and scope. The water sector is characterised by an entire value chain or rather loop, starting with the country's watersheds, its freshwater resources, the water supply system, the management of wastewater, and, for an island nation, the linkage with the coastal environment. The Water Riots of 1903 marked the propensity of water to be a powerful force for mobilising citizens and stimulating action.

The first articulation of the country's system for managing and regulating water was the Waterworks and Water Conservation Act Chap 54:41, enacted in 1944. This Act stipulated the rules and processes for controlling and using water in the country even though multiple managers, custodians, and entities were responsible for water and sanitation (or wastewater). This remained the same at the time of T&T's independence in 1962, where at minimum, twelve (12) organisations were involved in managing the country's water and sanitation services.

In August 1965, the T&T Parliament passed the Water and Sewerage Bill, leading to the enactment of the Water and Sewerage (WAS) Act, Chapter 54:40, on September 1st, 1965. This Act established one of the main water sector stakeholders, the sole service provider of water and sanitation services in the country – the Water and Sewerage Authority (WASA) – a statutory body mandated to carry out the policy of the Government, and which is currently under the portfolio of the Ministry of Public Utilities (MPU). One of the thrusts behind the WAS Act was to consolidate the multiple organisations involved or having responsibility for water supply and wastewater treatment **(as listed in Table 3.1)** into one entity not entirely separated from the central Government and tasked with the execution of Government policy in relation to water and sewerage (Government of Trinidad and Tobago, 1965). A key intended benefit of this move was an amalgamation of technical skills and human resources into one authority. The major powers of WASA as defined by the WAS Act range from:

1. Water supply and regulation of any other suppliers.
2. Rights to water from any source.
3. Conservation, and protection of water resources.
4. Authority to collect and treat wastewater and regulate other operators.
5. Regulators of other persons/companies involved in water and wastewater service provision, for example plumbers and sanitary contractors.
6. Compulsory acquisition of lands to carry out WASA's responsibilities in the Act.

Water engineers at a river in Trinidad.
Adobe Firefly

Table 3.1: List of Entities involved in Water and Sanitation Services before the 1965 Enactment of the Water and Sewerage Act Chapter 54:40 (Trinidad and Tobago Parliament, 1965)

No.	Organisation	Role
1	Oil and Water Board	Abstraction licensing from rivers for industrial and construction purposes of both Government and private entities.
2	Government Water Division	Licensing of private abstraction from groundwater for domestic or industrial uses.
3	Central Water Distribution Authority	Construction, operation, and maintenance of distribution systems for domestic water.
4	Works Department	Drainage, flood control and construction, operation and maintenance of irrigation works.
5	Agricultural Department	Construction and operation of irrigation and drainage.
6	County Councils	Construction, maintenance, and operation of springs, ponds, etc., without pipe-borne supply. Construction, maintenance, and operation of minor pipe-borne supplies and trucking during the dry season.
7	Port-of-Spain (POS) City Council	Winning of water and distribution Operations and maintenance of sewerage and revenue collection in the City of Port-of-Spain (POS).
8	San Fernando Borough Council	Distribution of water and revenue collection in San Fernando.
9	Arima Borough Council	Distribution of water and revenue collection in Arima.
10	Oil Companies	Production and distribution of domestic water for their own needs and industrial purposes.
11	Sanitation Department of Government	Sewerage disposal and environmental sanitation.
12	Private Individuals and Companies	Abstraction of water from rivers and groundwater for their needs.

Quarry pits filled with groundwater in Valencia.
Akil McPherson

Fifty-seven (57) years after the WAS Act, two (2) private water operators were introduced. Both are desalination companies that supply water for the national grid: the Desalination Company of Trinidad and Tobago (DESALCOTT) and Seven Seas Water. Both desalination operators presently produce approximately 20% of the country's total water production. Water entered the national grid from DESALCOTT in 2002 (DESALCOTT, 2022). At the time, it was proposed in the Water Resources Management Strategy Study (WRMSS) to meet the demand for industrial water in Point Lisas (Ministry of Planning and Development, 1999).

At present, DESALCOTT supplies areas out of the Point Lisas Industrial Estate as the plant production exceeds the water demand of the estate. In contrast, the Seven Seas Water plant in Point Fortin was commissioned in 2013 to supply surrounding communities in response to the devastating impacts on life and livelihoods of the 2010 drought (Government of Trinidad and Tobago, 2013) experienced across the region. Apart from these private water operator companies, many other private and public entities abstract, treat, and use water in their operations, including the more prominent beverage manufacturing industry, quarrying sector, and farms.

In wastewater, there are several private entities involved in collecting and treating wastewater across the country. Some of these private wastewater operators provide external services to WASA, while others, for example, the Housing Development Corporation (HDC) or other private developers, provide wastewater services independent of WASA. WASA still regulates these independent wastewater operators via Section 66 of the WAS Act, which indicates that WASA is responsible for approving and regulating all sewerage works. Even though there are Government decisions mandating WASA to take over numerous wastewater facilities from HDC (Sub-Committee of Cabinet, 2020), the transition has not been as anticipated as mechanisms for the adoption remain contentious. HDC and other private operators play a significant role in T&T's water and sanitation sector as they still operate wastewater facilities.

The multiple operators in the water and sanitation sector warrant a discussion on economic regulation. One year after WASA was established, in 1966, an economic regulator was created—the Public Utilities Commission (PUC) Act (Ministry of Public Utilities, 2022; Ministry of Public Utilities, 2022). The PUC gave WASA its first rate increase in 1986 and its last rate increase thirty-one (31) years ago. In 1998, the PUC was replaced by the Regulated Industries Commission (RIC), which became the economic regulator for the water (and electricity) sector. The RIC, by virtue of the RIC Act Chapter 54:73, has responsibility for but is not limited to licensing service providers, prescribing service standards, and setting the principles and methodologies that the service provider would use to determine rates.

Currently, the Second Schedule of the RIC Act stipulates that the RIC regulates the supply and distribution of water and the provision of sewerage services, while WASA remains the only water sector service provider listed in the First Schedule of the Act (Government of Trinidad and Tobago, 1998). In contrast, most independent power producers (IPP) that supply power to the sole electric service provider, the T&T Electricity Commission (TTEC), are listed in the RIC's First Schedule even though the institutional configuration between the IPPs and TTEC is similar to that of WASA and the desalination and wastewater operators.

Considering the number of entities with direct and indirect roles in the water sector, responsibility conflicts and duplication are inevitable. In some cases, there is duplication or overlap of responsibilities, and the governance configuration of these entities is far from ideal. The most striking organisational incompatibility in the water sector ecosystem is the existing placement of water resources management within WASA via Sections 47 to 54 of the WAS Act.

The execution by WASA of these functions is through the Water Resources Agency (WRA), which manages water and licenses private freshwater abstraction. Currently, no water abstraction licensing from coastal or marine environments is done.

The WRA also performs a critical function of monitoring water resources parameters, including but not limited to rainfall, river flow, groundwater levels, and ambient water quality.

The Hollis Reservoir at capacity.
Water and Sewerage Authority (WASA)

Coordination of water resources management in the country has been done since 1910 in the Department of Agriculture, which then evolved to be housed in the Department of Works and Hydraulics in 1948 and then the Drainage Division in the 1950s (Water Resources Agency, Water and Sewerage Authority, n.d). However, in July 1966, a team of Canadian Engineers under M.M Dillon Ltd formed the Water Resources Survey and began training local technicians in collecting, analysing, and publishing hydrological and hydrometeorological data. This modernised the capacity of the country to continue managing its water resources, from which evolved the Water Resources Survey (M. M. Dillon Limited, 1967). In 1971, the Survey was amalgamated within the Ministry of Works as the Hydrology Section, and in 1976 (Water and Sewerage Authority, 2015), it was appended to WASA as the WRA and has been annexed since then, even though WASA as the primary abstractor of the country's freshwater resources is left unregulated in a dichotomy of gamekeeper and poacher.

The conflicting governance configuration for water resources coordination has left the country largely without (i) comprehensive water resource master planning capability, (ii) an understanding of water availability of water and demand across competing uses, and (iii) the ability to set priorities and secure the balancing of water development, conservation and protection to meet existing demand in the short, medium and long terms.

Given the WRA's role in WASA, its priority is to identify and quantify water sources for WASA rather than overarching, national water management and prioritisation of water allocation for specific uses and optimisation of the natural resource. This is contrary to modern water management best practice, which dictates that there should be a separation between the entities that set policy for the water sector, the economic and resource regulation of water, and the provider of water and sanitation services (Organisation for Economic Co-operation and Development, 2009).

Groundwater management in Trinidad and Tobago.
Adobe Firefly

An institutional separation will avoid conflicting policy positions and allow for sustainable, independent, and fair allocation of a resource (water), which is both a common and economic good. An independent, financially self-sufficient institution to manage water resources will have the scope to enforce its legal mandate of making decisions to secure the country's water resources and to be technically sound when presiding over issues of competing uses of water resources. Favourably, an Office of Water Resources Management is on the horizon for Trinidad and Tobago (T&T Newsday, 2022) to provide the much-needed national water management functions, a necessary mechanism for the country's water security.

The Tobago House of Assembly (THA) is also a major player in T&T's water sector ecosystem. The Fifth Schedule of the THA Act Chap. 25:03 places the responsibility for the environment in Tobago with the THA, even though there are no explicit references to water.

Currently, the Division of Infrastructure, Quarries and Urban Development and the Division of Settlements, Public Utilities and Rural Development closely coordinate with WASA on water and sanitation issues.

Arnos Vale (2) Well #4 in Tobago.
Water and Sewerage Authority (WASA)

At the same time, the Department of Natural Resources and Forestry handles watershed management and any related water resources issues. The WRA and WASA also have staff based in Tobago assigned to monitor and manage water and sanitation. It is desirable that more resources and studies/assessments should be specifically assigned to Tobago.

Water transcends all levels of human development either because it is used across sectors, certain sectors sustain it, or sectors may compete against each other for it. As a result of this dichotomy, **many of the following regulators and institutions play a significant role in the water sector ecosystem:**

- **The Meteorological Services Division** of the Ministry of Public Utilities is responsible for weather and climate monitoring, the core inputs for water resource availability. The science of meteorology is crucial to decision-making in the water sector.

- **The Environmental Management Authority** is the environmental regulator responsible for water pollution regulation and plays a critical role in approving development based on its environmental impact.

- **The Forestry Division** is a department within the Ministry of Agriculture, Land, and Fisheries (MALF) responsible for managing the country's forest resources. Forests are a crucial input to the water cycle and must be sustainably managed to protect the quality and quantity of freshwater.

- **The Town and Country Planning Division** is the department of the Ministry of Planning and Development that controls the development of all land in the country. Permission to develop land for particular uses is critical for the water sector, as land use can either favour or adversely affect water quality and quantity.

- **The Drainage Division** is a department within the Ministry of Works and Transport with several responsibilities related to reducing and controlling flooding and providing irrigation water for farms. The Division's role in the water sector is specific to mitigating the impact of flooding events on water supply assets (such as intakes) and managing an alternative source of water—stormwater or runoff.

- **The Engineering Division** of the MALF is responsible for providing irrigation water in the water sector, similar to the responsibility of the Drainage Division.

- **The Minerals Division** is the department within the Ministry of Energy and Energy Industries that regulates quarrying in the country. This is significant for the water sector because quarrying can impact water resources when it is not properly managed and rehabilitated.

- **The Public Health Inspectorate** of the Ministry of Health monitors drinking water quality and its impact on human health. It also has some responsibility for regulating the manufacture of products consumed by humans that use water as a raw material.

- **The Institute of Marine Affairs** is a research institute of both marine and related environmental matters. The organisation's role is crucial to T&T's water sector because the country is a small island state, and the marine and terrestrial environments are strongly interconnected.

- **Local government** entities such as regional/city/borough corporations carry out important regulations and enforcement responsibilities regarding land use stipulations and stormwater management.

This list is not exhaustive as many other stakeholders operate, benefit, or influence the country's water sector, including professional associations, academic bodies, and community-based organisations. What the list reflects is that there are actors who have the same or similar functions, there are gaps in responsibilities such as regulation of drinking water quality even though monitoring exists, and there is a pressing need to have a structure for institutional coordination among these actors to optimise management and use of water resources, and to ensure quality control.

Regarding skills in managing water in the country, the Water Resources Management Programme was initially developed as a subset of both the Civil and Environmental Engineering and Environmental and Natural Resource Management undergraduate programmes at The University of the West Indies, St Augustine Campus (UWI STA). Noting the need for a more focused approach, WASA, in collaboration with the College of Science Technology and Applied Arts of Trinidad and Tobago (COSTAATT), developed an Associate degree in Water Resources Management and Technology in 2002. This was further developed into a Bachelor's degree in Water and Wastewater Management, Services, and Technology in 2008. To date, these are the most focused formal training courses offered locally at the undergraduate level in water resources management.

The UWI STA offered an MSc in Water and Wastewater Services Management at the postgraduate level, which was discontinued in 2017. A recently developed undergraduate major in Disaster Risk Resilience for Agriculture and the Environment was offered from September 2022 that addresses aspects of water resources management. Over the years, regional developmental agencies such as Caribbean WaterNet (CapNet UNDP), Global Water Partnership-Caribbean (GWP-C), the Caribbean Water and Wastewater Association (CWWA), and the Caribbean Institute for Meteorology and Hydrology (CIMH) provided capacity-building training.

As WASA began investing in major water supply projects, staff were also locally and internationally trained to manage and maintain these plants (Batchelor, n.d.). WASA also established a Centre for Manpower Development (CMD) between 1975 and 1981 for their water and wastewater operations staff. The status of training in CMD is unknown. However, there are several international (ABC) and regional (CVQ) certification courses being undertaken in partnership with regional professional associations and the National Training Agency, including training for licensed sanitary contractors and plumbers (Gill, n.d.).

2.2 Water Resources: Development of T&T's Natural Stores of Water (Rivers and Aquifers)

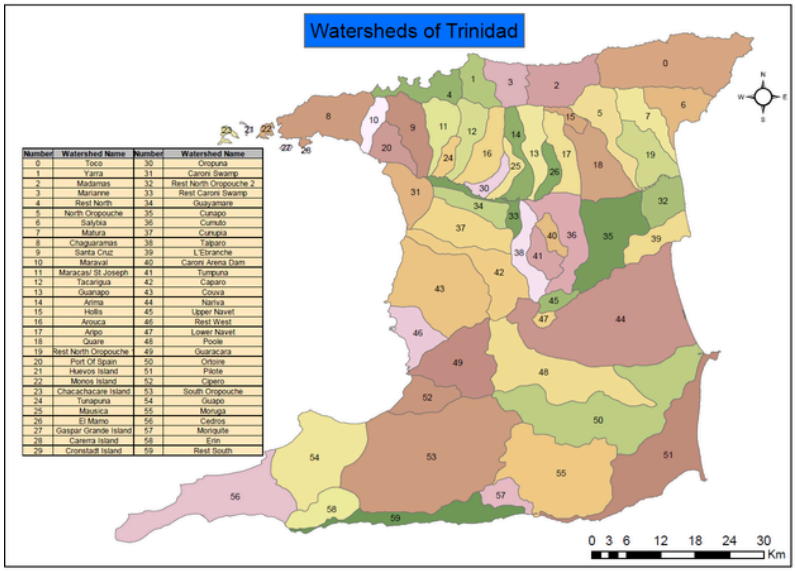
In 1962, the country already had a system of monitoring its water resources, although it was less extensive than required, even at that time. However, a team of local professionals was internationally trained soon after to monitor, interpret and analyse water resources data. These locals formed the earlier versions of the present-day WRA.

Prior to the establishment of WASA, the country abstracted water from its rivers and aquifers to supply a total national production of 50 imperial million gallons per day (IMGD). Seven (7) years before then, water production was recorded at 15 IMGD (Trinidad and Tobago Parliament, 1965), signifying a tripling of water abstraction to support national development.

Today, WASA produces nearly 243 IMGD (Sub-Committee of Cabinet, 2020) of water, approximately five (5) times higher than its independence production, even though the population has only doubled. This demonstrates an exponential increase in the development of water sources around the country.

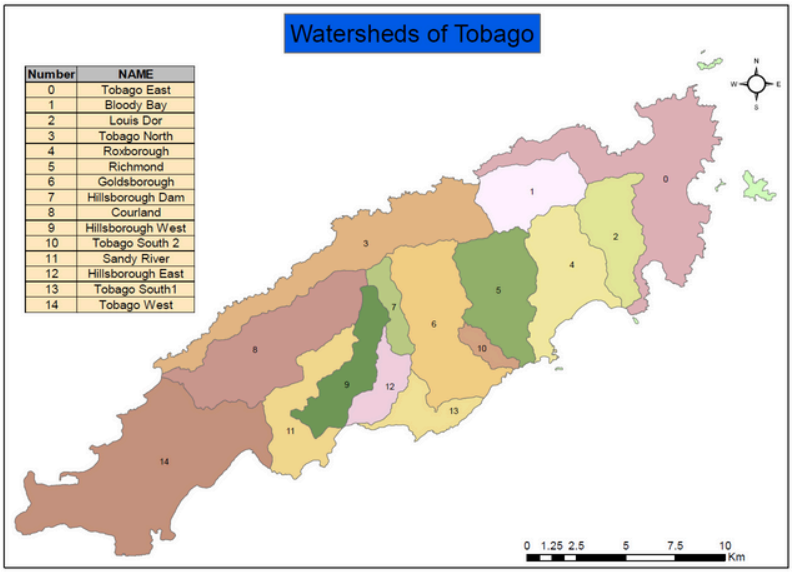
The water resources available in Trinidad and Tobago on account of its rainfall patterns are recorded at 844,800 IMG/year (3,841 million cubic metres, MCM) (United Nations Food and Agricultural Organisation, 2017), which accounts for the dry and wet season variations in water availability. With an approximate T&T population of 1.4 million, T&T has a per capita water availability measure of 2,700 m3/capita/year.

Using the Falkenmark indicator to measure a country's water stress, where the threshold for water stress starts when this water availability drops below 1,700 m3/capita/year (Cosgrove, 2000), T&T is not a water-scarce country. Surface water sources provide most of this water (79%), while aquifers store the remaining 21% as groundwater. The spread of availability and development of these resources differs by watershed, depicted in **Figures 3.1 and 3.2**, and is mainly determined by the spatial pattern of rainfall across both islands **(Figure 3.3)**. As illustrated in the map, the areas with higher availability of water resources are in the north-eastern parts of Trinidad and the central parts of Tobago.



Number	Watershed Name	Number	Watershed Name
0	Toco	30	Oropuna
1	Yarra	31	Caroni Swamp
2	Madamas	32	Rest North Oropouche 2
3	Marianne	33	Rest Caroni Swamp
4	Rest North	34	Guayamare
5	North Oropouche	35	Cunapo
6	Salybia	36	Cumuto
7	Matura	37	Curupia
8	Chaguaramas	38	Talparo
9	Santa Cruz	39	L'Ebranche
10	Maraval	40	Caroni Arena Dam
11	Maracas/ St Joseph	41	Tumpuna
12	Tacarigua	42	Caparo
13	Guanapo	43	Couva
14	Arima	44	Nariva
15	Hollis	45	Upper Navet
16	Arouca	46	Rest West
17	Aripo	47	Lower Navet
18	Quare	48	Poole
19	Rest North Oropouche	49	Guaracara
20	Port Of Spain	50	Orboire
21	Huevos Island	51	Pilote
22	Monos Island	52	Cipero
23	Chacachacare Island	53	South Oropouche
24	Tunapuna	54	Guapo
25	Maususica	55	Moruga
26	El Mamo	56	Cedros
27	Gaspar Grande Island	57	Morigute
28	Carerra Island	58	Erin
29	Cronstadt Island	59	Rest South

Figure 3.1: Watersheds in Trinidad (adapted from WRA's data)



Number	NAME
0	Tobago East
1	Bloody Bay
2	Louis Dor
3	Tobago North
4	Roxborough
5	Richmond
6	Goldsborough
7	Hillsborough Dam
8	Courland
9	Hillsborough West
10	Tobago South 2
11	Sandy River
12	Hillsborough East
13	Tobago South1
14	Tobago West

Figure 3.2: Watersheds in Tobago (adapted from WRA's data)

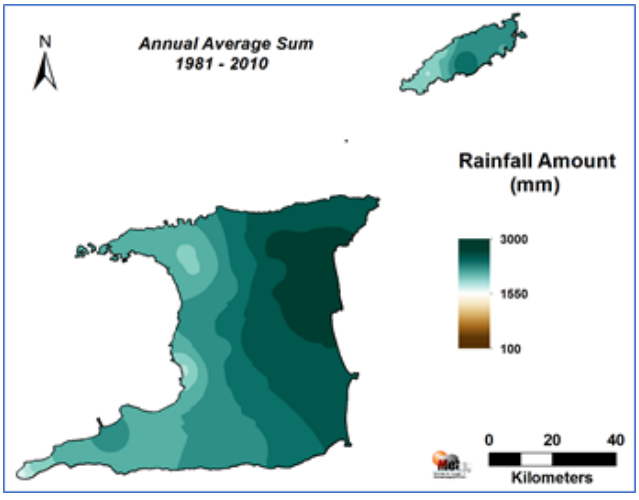


Figure 3.3: Rainfall Distribution across Trinidad and Tobago

Some key watersheds in Trinidad that the country harnessed for national water supply post-independence include the Navet, Caroni, and North Oropouche watersheds. Water was abstracted from these systems to boost the supply at the time from Hollis and numerous groundwater wells and smaller river intakes across Northern Trinidad and some areas of south.

The Navet Water Treatment Plant.
Adobe Firefly

In Tobago, the Courland and Richmond watersheds were similarly developed to augment supply to the island from the Hillsborough watershed. Paradoxically, the sites of water resources development post-independence did not ideally align with the areas of the highest available water volumes nor, in some cases, the demand centres. Instead, water was sent from the areas where water harnessing schemes were implemented to the areas with increased built development, primarily at the residential scale and where industrial and commercial activities were centred.

As a result of this mismatch between the water sources and the demand for that water, the country invested in a proliferation of water transmission and distribution infrastructure, including energy-intensive pumping schemes to get water to the demand centres. The preferable approach would have been to develop localised water sources to supply individual communities and isolate the management of water (sources and supply) within the watershed.

In a similar approach to the development of surface water resources, groundwater usage exponentially increased in the last sixty (60) plus years based on a need to localise the supply of water. Before 1966, wells were drilled for the municipal water supply and private production, often uncoordinated and unregulated (Water Resources Survey, 1972). In some cases, wells augmented the supply from the major surface water facilities, such as in Central Trinidad, while in others, aquifers were tapped to provide water to unsupplied developments, as depicted in **Figure 3.4.** The majority of available groundwater resources are used for public water supply (Ministry of Planning and Development, 1999).

However, there are privately operated water schemes for commerce generation, primarily in beverage manufacturing, quarrying, or construction aggregate processing (Ministry of Public Utilities, 2016). However, there is private water abstraction of surface water sources for farming and quarrying.

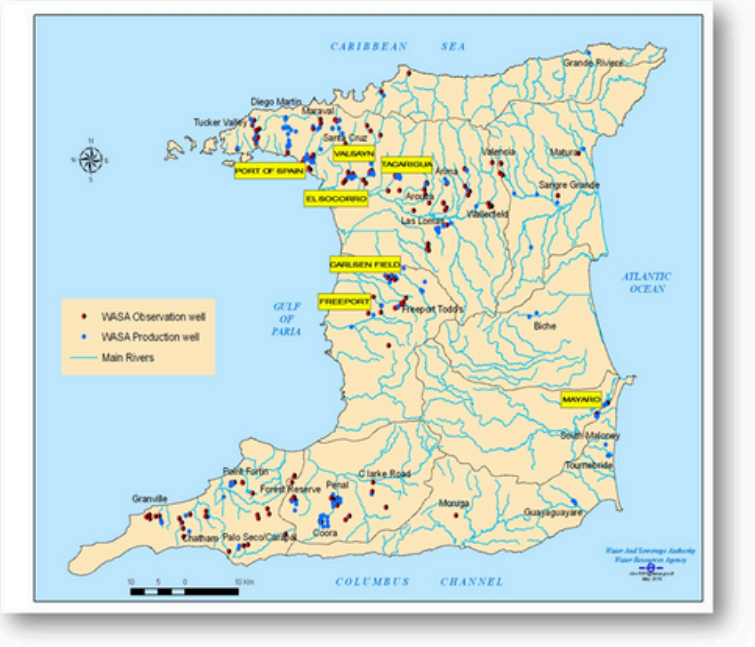


Figure 3.4: Groundwater Wells in Trinidad (Water Resources Agency, Water and Sewerage Authority, 2018)

In 1980, Central American and Caribbean members of UNESCO's International Hydrological Programme met in Jamaica, and WRA was tasked with developing a hydrogeological map for the country. In September 1990, the hydrogeological maps of Trinidad and Tobago were produced. Following this, in the early 2000s, there was a landmark re-assessment of Trinidad's groundwater resources, increasing the volumes of available groundwater previously thought to exist in the country. This study was undertaken by the Earthwater Technology T&T LLC jointly with Lennox Petroleum on behalf of WASA and led to the introduction of the bedrock aquifer concept in T&T.

These bedrock aquifers, unlike the traditional alluvial systems are recharged at considerably higher rates and have high hydraulic conductivity (the measure of how easy water can flow through the subsurface material) due to the heavily faulted characteristics of the rock. Most of the work in Trinidad was exploration, and it was not until nearly fifteen (15) years later that the development of these wells in Tobago moved the bedrock aquifer water from probable to proven. Today, 95% of Tobago's groundwater supply comes from these bedrock aquifers (Govia S., 2020), validating the potential sustainability of this source to meet the growing water demand on the island.

The management of the nation's watersheds is at the interface of water resource availability and its subsequent development. Simply put, how we develop, conserve, and protect land determines the volumes and quality of water the country has and will have available for its people, economy, and ecosystems. In less than two (2) decades, the quality of Trinidad's watersheds has significantly deteriorated, and the areas of this deterioration are closely aligned with population growth. The watershed quality status is primarily determined by the water quality of some of the major watercourses.

The Hollis Reservoir in the dry season.
Water and Sewerage Authority (WASA)

However, environmental conditions, such as habitat assessments, are included in this watershed assessment. **Figure 3.5** depicts some watersheds that have experienced drastic changes: the Nariva, Toco, Chaguaramas, and Cedros watersheds. Of most concern is the continuous worsening of the watersheds that provide or are upstream of the country's major water sources, such as the Courland watershed in Tobago (Genivar, 2009), the Quare watershed feeding the Hollis Reservoir, and the watersheds of the Caroni Basin specifically Aripo, El Mamo, Cumuto, Guanapo, Mausica, Tumpuna **(as illustrated in Figure 3.6)**.

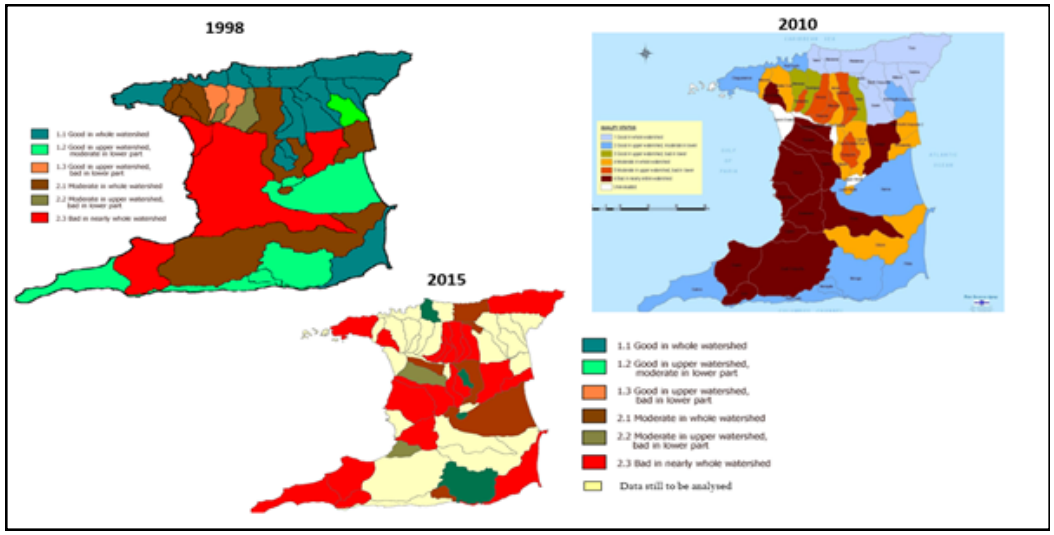


Figure 3.5: Changes in Watershed Quality Status from 1998 to 2015 (Sub-Committee of Cabinet, 2020)

Groundwater is also not spared from the impact of this watershed degradation, as it threatens the quality and quantity of groundwater due to infiltrating contaminants and reduced recharge volumes. The more significant impact of watershed degradation on groundwater availability is encroachment and changes in the permeable surface of groundwater recharge areas.

For example, the concretisation of major watercourses and quarrying for sand and gravel in these recharge areas result in lowered recharge rates for aquifers. There is very little published work in Tobago assessing surface and groundwater resources and the state of Tobago's watersheds.

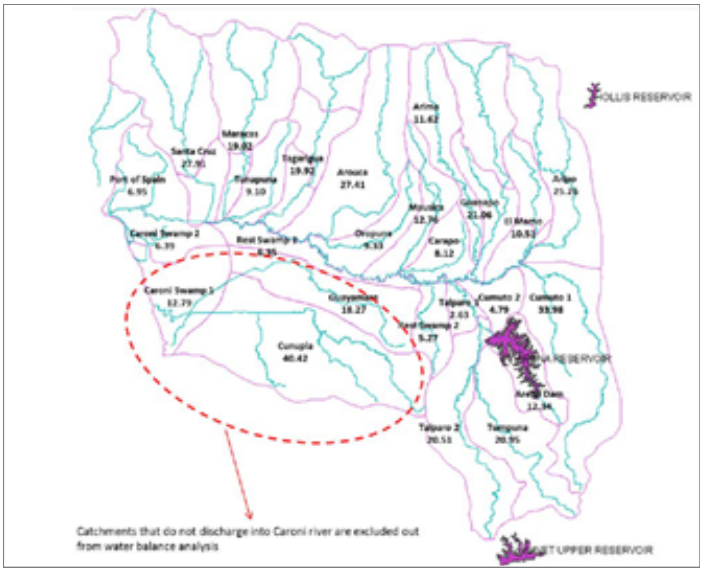


Figure 3.6: Watersheds that Discharge into the Caroni Water Supply System (CPG Consultants, 2013)

One of the main drivers of watershed degradation is improper land use, which impacts water because of a lack of enforcement that manifests in two (2) ways:

1. The activity has approval for the particular location in the watershed. Yet, the conditions of that approval are left unregulated, unmonitored, or unenforced.
2. The activity has no approval in the watershed but continues unhindered.

These scenarios reflect the significant disconnect between land use planning and regulation, which results in the unsustainable development of the country's watersheds for housing, quarrying, agriculture, road networks, manufacturing, and other economic activity. The end result is the country's inability to secure its water resources. Inadequate land use regulation manifests itself in the following ways in T&T:

1. Water pollution from oil spills, sewage, industrial waste, contaminated stormwater runoff, overflow of undersized quarry sedimentation ponds, overuse of pesticides and fertilisers, etc.
2. Rampant untreated solid waste disposal as rivers and land are used as dumping grounds.
3. Soil erosion from improper agricultural and construction practices and forest clearance.
4. Deforestation for various land use activities such as quarrying, housing developments, agriculture, etc.

Blockage at a bridge in the Caparo River.
Sara-Jade Govia

While activities contributing to watershed degradation are all necessary for socio-economic advancement, T&T's challenge is the imbalance between growth in these sectors, the unsustainable way this growth is carried out, and the protection of the country's watersheds.
The balancing act must consider the entire water value chain from the watershed, water stores, water supply, and wastewater treatment at different scales (for the country and each socio-economic activity). Without a comprehensive approach to national planning, there will be spiralling consequences beyond the water sector, such as the loss of the country's biodiversity resources and a gradual decline in the land's natural capacity to buffer against natural disasters such as flooding and coastal inundation.

Another often neglected and undervalued consequence of negative watershed changes is water's cultural and recreational significance in T&T's context. The Caura, Shark, Marianne, Matura, Argyle, and Castara Rivers are the more popular destinations for river limes.

Similarly, many rivers are hubs for religious ceremonies, particularly in the Hindu and Spiritual Baptist faiths. The more popular river celebrations in the country are Ganga Dhaara and the Oshun River Festival. Changes in the quality and quantity of water in these watercourses will impact water's recreational and cultural value. The reduction in the flow of the Lopinot River, another recreational river monitored by the WRA, is one of the more prominent examples of the changing relationship between land use and riverine flow.

Recreational activities at the Matura River in Trinidad.
MC Garcia

Rivers are the pollution pathways to the marine environment and can threaten the viability of these ecosystems. This can be detrimental for T&T, particularly in areas that provide an ecotourism product, such as the coral reef systems and beaches of Tobago, the north coast of Trinidad, and the mangrove swamps of Caroni and Nariva. The IMA reported that the country's marine pollution problem remains predominantly land-based. This not only compromises the water quality at the country's beaches but significantly affects marine ecosystems and compromises fishes that people consume (Institute of Marine Affairs, 2016). The degradation of the marine environment, resulting from the country's management of its watersheds, threatens revenue from ecotourism and fisheries and destabilises the natural resilience provided by coastal resources such as mangroves and coral reefs.

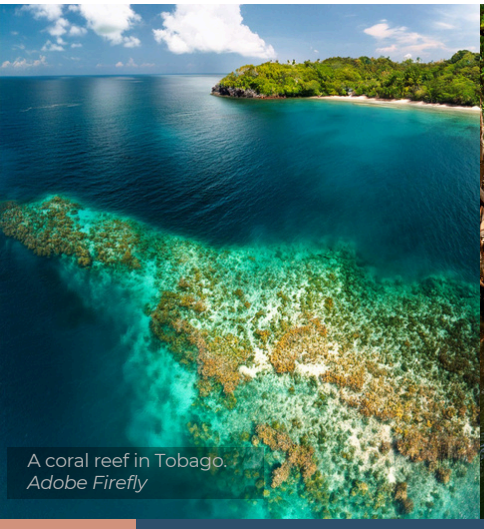
Fishing village in Roxborough, Tobago.
Pexels/Rudi Singh

Maracas Beach, Trinidad.
Pexels/Bhisham Roodal

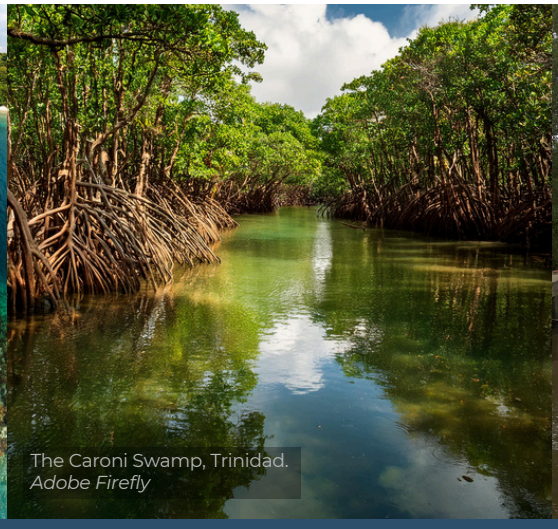
The threat multiplier to the availability and quality of the country's water resources is the current and impending worsening impact of climate change.

The most recent analysis of climate change trends reveals the following:

1. Declining rainfall in Tobago.
2. Increased intense, short-duration rainfall events across both islands.
3. Dry seasons have become 10% drier.
4. Sea level has risen between 1.5 to 3 mm per year (Particip, 2019).



A coral reef in Tobago.
Adobe Firefly



The Caroni Swamp, Trinidad.
Adobe Firefly

River at Woodland in Trinidad.
Sara-Jade Govia

The latest Intergovernmental Panel on Climate Change (IPCC) report suggests that global temperatures can overshoot 1.5°C in the coming decades (Intergovernmental Panel on Climate Change, 2021). Specifically for T&T, the climate models reflect the possibility that by 2100, temperatures will increase by 2.4 – 3.6°C, rainfall will decrease by 22 – 30%, and sea level can rise between 0.75 to 1.26 mm (Particip, 2019). The (Climate Studies Group Mona (Eds.), 2020) validates this projection where Zone 5 (where Trinidad and Tobago lies) will experience the greatest increase in warm days and warm nights of all other zones in the Caribbean. Zone 5 is also most susceptible to drying. This all paints a picture of the declining and unpredictable availability of water resources.

The changing climatic patterns will manifest as more intense extreme events (storms, flooding, drought, etc.) that can undermine water quality and quantity. Flood events as a result of climate change can both damage water infrastructure and increase turbidity levels to the extent of WASA's inability to treat water with the existing infrastructure. Extreme storms and hurricanes can have similar effects to flooding but also result in high winds and landslides that further damage the water supply network and treatment plants. Sea level rise, another impact of climate change, can cause salinisation of ground and surface water sources and, in some cases, can be irreversible. Unlike the other hazards, drought, which can be more frequent and intense due to human-induced climate change, are slow-onset events that reduce the country's available water resources and can further negatively impact watersheds from increased bushfires. T&T has been feeling the impacts of these events, and they will continue to worsen. Fortunately, CCRIF SPC (formerly the Caribbean Catastrophe Risk Insurance Facility) launched the Caribbean Water Utility Insurance Collective Segregated Portfolio (CWUIC SP), a disaster risk management and financing facility to provide some level of coverage, mutual aid, and resilience-building which WASA can access (CCRIF SPC, 2023).

2.3 Growing Water Demand: Supplying Water for the Growth of People, Society and Business

Water demand in T&T, as with all countries, is a function of population size, developmental status, level of industrialisation and consumer behaviour. Upon the establishment of WASA in 1965, total daily water production in Trinidad and Tobago stood at 50 IMGD. In the next ten (10) years, several water-winning projects increased production to 65 IMGD, including:

1. Increased water production at the Navet Water Treatment Plant (WTP) from 6 IMGD in 1966 to 19 IMGD in 1975.
2. The new Courland and Richmond Waterworks, Tobago, was commissioned in 1975, which added a total daily production of 3 IMGD.

With the onset of the oil boom in the 1980s, water production more than doubled, reaching approximately 140 IMGD facilitated by a TT$451Mn investment in water development projects by the Government. These included but were not limited to:

1. Construction of the North Oropouche WTP in 1979 with a production capacity of 10 IMGD.
2. The Northern Range Valley Project, completed in 1980, included the construction of water treatment facilities at Acono, Lluengo/Naranjo, Caura, Aripo, and Guanapo.
3. The commissioning in 1981 of the TT$105 million Caroni Arena Project with a production capacity of 60 IMGD.

The Caroni–Arena Dam.
Sara-Jade Govia

The recession following the oil boom still saw an increase in production but at a much slower rate compared to the previous decade, with a focus on increasing supply to rural areas, such as:

1. The Sans Souci WTP commissioned in 1986.
2. Pt. Fortin and St. Patrick's Water Supply Projects in 1991 and 1994, respectively.
3. In 1991, the construction of the Hillsborough West WTP in Tobago produced 1.2 IMGD.
4. Rehabilitation of Courland Waterworks, increasing production to 3 IMGD in 1994.

As the economy started to recover in the mid to late 1990s, there was further development that included the following:

1. The South Water Project included the upgrade of the Caroni WTP.
2. The North Water Project focused on rehabilitating facilities, mainly in northern areas of the country.
3. The Tobago Water Project focused on developing new groundwater sources on our sister isle.

Over the next couple of decades, both infrastructural development and production continued to increase. In 1997, water production was reported to be 173 IMGD, while in 2015 (Ministry of Planning and Development, 1999), this increased to an estimated 230 IMGD. WASA reports that its production capacity is 243 IMGD (Sub-Committee of Cabinet, 2020), which is the country's most recent publicly available production estimate. Potentially, the country's production capacity may have increased within the last three (3) years through the MPU's Community Water Improvement Program (CWIP), an intervention to install and refurbish water treatment plants and complete well drilling and rehabilitation (Trinidad and Tobago Newsday, 2023) and the execution of a Strategic Action Plan for Water Supply Improvement.

As expected, the increase in production over time shows some relation to the country's demographic transitions. In 1960, according to the Central Statistical Office (CSO), T&T's population was 834,350, while it currently stands at 1,367,510 (CSO, 2024). Following independence, T&T's annual population growth rate was under 2% from 1961 to 1990 and then fell below 1% from 1990 to 2011. The current annual population growth rate stands at 0.4% (World Bank Group, 2024). While T&T's population growth does not follow the global trend of an increased growth rate, the demand for water has significantly increased over time because of changes in household water consumption activities (such as an increase in water faucets in homes), industry, and commerce sectors. This is reflected in Trinidad and Tobago's average daily consumption per capita of 91 imperial gallons (Phillip & Salim, 2023), significantly higher than that of regional counterparts.

Laying of pipes.
Adobe Firefly

Water supply for most of the population is intermittent; however, it is difficult to verify a precise figure given the lack of metering on WASA's network. Estimates of 24/7 fluctuate between 50% to 60% of the population receiving a 24/7 supply.

WASA has also reported that 89 – 90% of the country is covered with pipe-borne supply, while 10 – 11% are serviced via standpipes. WASA estimates that between 5,800 and 6,500 km of pipeline covers the country, which is predominantly PVC, ductile iron, and cast iron. Some of the major transmission pipe-laying projects that occurred post-independence are:

1. Laying of a 54" pipe from Caroni WTP to central and south Trinidad as far as Erin.
2. A 42" transmission main connecting the Caroni WTP to areas in north Trinidad as far west as Westmoorings.

The major WTPs, similarly, have large diameter pipes that convey water to different parts of the island, including a 36" main from Navet WTP, 42" main from North Oropouche WTP, 24" pipe from Hollis WTP, a 12" pipeline from Hillsborough WTP and a 16" main from Courland WTP (Water and Sewerage Authority, 2011). Smaller pipes or distribution mains send water to the customer service connections. The National Social Development Programme (NSDP) contributed to this increased water access in rural communities. Today, the MPU's CWIP also improves WASA's transmission and distribution systems, targeting specific communities.

The country also saw other advancements in water distribution technology, including the introduction of new booster stations, also through the NSDP, which is one of the key strategies to improve WASA's conveyance of water to the demand centres located in the extremities and elevated parts of their network. These booster stations pump water at the required pressure and are energy-intensive. Boosters became a necessary feature of WASA's water supply network as development extended to areas beyond the reach of the existing water production facilities and pipe network.

The Caroni Water Treatment Plant.
Adobe Firefly

Service reservoirs or treated water storage facilities are also a key characteristic of WASA's transmission and distribution system. WASA uses these service reservoirs to either i) ensure sufficient pressure where a tank is typically situated at an elevated location and water flows by gravity to the demand centre or ii) meet the daily peaks in demand when WTPs are not consistently operating at efficient levels.

Over the years, WASA has also complemented its system by introducing the supervisory control and data acquisition (SCADA) systems for parts of the water system (Kenter 2010), including the Caroni North Oropouche, Navet, and Hollis WTPs. WASA's SCADA can:
i) increase operational efficiency to reduce operating costs, ii) provide performance data and enable better regulatory reporting, iii) provide an alert system to staff to anticipate service delivery issues, and iv) optimise the transmission and distribution of water.

However, there is a lack of maintenance, and the design is not properly integrated to maximise the benefit of SCADA. There may also be similar or alternatives to SCADA that should be investigated to leverage advancements in technology to improve service and reduce its operating cost. This may have been the thrust behind WASA’s recently established Operational Control Centre to monitor and control its processes and network (T&T Guardian, 2024).

Physical water loss in Trinidad and Tobago due to leaky pipes and old water infrastructure.
Adobe Firefly

Over the years, water infrastructure has focused primarily on increasing production and expanding the network to increase coverage across the country. Simultaneously, there has been minimal focus on the maintenance and modernisation of the existing and expanded assets, leading to the country's high non-revenue water (NRW) today.

The country's NRW level is approximately 293 imperial gallons per connection (Janson, Burkhard, & Jones, 2021). Contextually, this equates to 40 to 50% of total water production.

NRW is all the water that WASA produces that it receives no revenue for – it is water that is lost due to physical losses (leaks, no pressure management) and commercial losses (overconsumption that is not billed due to no metering and illegal connections).

NRW is a major obstacle to providing continuous water supply (24/7) to the population and is ultimately symptomatic of inadequate proactive and strategic maintenance and modernisation of the supply infrastructure. The system is primarily unmetered; supply is not isolated but comes and goes without control (no district-metered areas), and there is minimal management of pressures, which results in a highly pressurised network that is constantly emptied and refilled due to the scheduling of supply. This combination, paired with a system of billing for water that is not based on actual usage, gives rise to exceedingly high losses, which, for the most part, cannot be accurately quantified or located.

WASA made its introductory attempts to manage NRW in 2002 when it configured the first district metered area (DMA). WASA also reorganised its Water Loss Control Department, and in 2005 the Maraval and Maloney DMAs were conceptualised and established (Peters & Balfour, 2014). On March 7th, 2023, the Government of Trinidad and Tobago and the Inter-American Development Bank (IDB) signed a loan agreement to finance the Trinidad and Tobago National Water Sector Transformation Program to reduce NRW as 1 of 3 components in this intervention (Inter-American Development Bank, 2022).

2.4 Modernising Sanitation: Expansion of Wastewater Collection and Treatment Systems across the Country

Wastewater in T&T is a combination of liquid or water-carried waste generated from anthropogenic activity and often includes greywater or stormwater. It can further be classified into i) domestic wastewater, which is discharged from residences and commercial institutions, and ii) industrial, which is wastewater from industrial processes. Untreated wastewater contains toxic compounds (Sonune and Ghate 2004) and can have deleterious effects on human life or the environment if left untreated (Ibiam and Igewnyi 2012). Therefore, it must be safely and thoroughly treated, often at significant costs, to avoid adverse effects on ecosystems and people.

The Water Pollution Rules, 2019 (WPR), which took effect on October 10th, 2019, is the primary regulatory instrument addressing liquid effluent discharge into the environment. These replace previous standards of the Trinidad and Tobago Bureau of Standards (TTBS) in the discharge of effluent from different processes into the environment. In January 2023, the Ministry of Public Utilities (MPU) and the TTBS developed national wastewater reuse standards (TTS 664:2022) with a focus on agricultural and other uses as part of the GEF-CReW+ project (Trinidad and Tobago Bureau of Standards, 2023).

In 1950, the Sangre Grande Hospital, a privately owned facility, introduced the first WWTP in Trinidad and Tobago, marking the beginning of wastewater treatment in the country.
It was not until 1966, however, when Lock Joint (America Ltd.) completed a million-dollar, island-wide wastewater extension project that the state got involved in wastewater treatment. This was a seriously ambitious project at the time that included the installation of over 320 kilometres of street sewers and 5,000 manholes in San Fernando, Arima, and Port-of-Spain. After this, multiple privately owned and state-owned treatment plants were established in Trinidad and Tobago.

In 1972, a major wastewater report on Tobago by Attas and Defour Consulting Engineers recommended the establishment of wastewater treatment facilities in three (3) regions of Tobago. Following this, the Scarborough WWTP was commissioned and completed in 1994 (Water and Sewerage Authority, 2022).

Beetham Wastewater Treatment Plant outfall.
Water and Sewerage Authority (WASA)

Wastewater Treat Plant in Trinidad and Tobago.
Adobe Firefly

As it stands, WASA is responsible for collecting and treating wastewater in Trinidad and Tobago. There are forty-four (44) WWTPs owned by WASA and eighteen (18) contracted wastewater treatment facilities (plants and lift stations). These plants collectively serve 30% of the population with centralised sewage collection and treatment, while 64% of the population utilise on-site septic systems and 6% pit latrines.

Over 200 wastewater treatment facilities exist in the country, and as of 2020, WASA has been operating 62 of these facilities with approximately 560 km of sewer mains (Sub-Committee of Cabinet, 2020). The other existing facilities are privately owned or state-owned by various organisations. Many of these are currently abandoned and being assimilated by WASA, particularly in the San Fernando and Malabar regions, where wastewater upgrades and expansion works have been completed.

The major wastewater facilities and related catchments that exist in both islands are:

1. Port-of-Spain – collected and treated at the Beetham WWTP. WASA formerly contracted a private operator for operations and maintenance but has since taken over.
2. Arima – collected and treated at the Malabar WWTP.
3. Chaguanas – served by several packaged WWTPs.
4. San Fernando – collected and treated at the San Fernando WWTP.
5. Scarborough - collected and treated at the Scarborough WWTP.
6. Southwest Tobago Wastewater System – collected and treated at the Bon Accord and Samaan Grove Waste Stabilisation Ponds.

The Malabar and Maloney WWTPs are considered to be two (2) of the most important WWTPs as these catchments drain into the Caroni River, upstream of the Caroni WTP, which provides water for 67% of the population of Trinidad and Tobago (WASA n.d.). In the surrounding areas, various wastewater treatment facilities have been abandoned and overflowed into various drains, including La Florissante, La Resource, Lillian Height, Lynton Gardens, and Santa Monica. These plants would have been decommissioned and rerouted to the new Maloney or Malabar WWTP (Inter-American Development Bank, 2011).

The construction of the new Malabar WWTP replaced the previous Malabar WWTP, Arima WWTP, and several smaller plants previously installed by residential housing developers. It is rated to meet the 2035 forecasted population of 108,630 (Water and Sewerage Authority, n.d.). The new plants follow similar processes as the Beetham WWTP but also included the use of chlorination after the UV disinfection stage (McTaggart, Stevens, & Singh, 2007).

A similar project to the Malabar WWTP was undertaken in the southern part of Trinidad. The new San Fernando WWTP replaced all existing facilities within the project's boundaries. This involved the decommissioning and demolition of 20 functional and abandoned lift stations and WWTPs. Approximately 223 km of sewers were installed as well as the construction of seven (7) lift stations and 11,964 sewer service connections to properties. This plant is rated to meet the needs of the year 2035 forecasted population of 111,600 (Water and Sewerage Authority, n.d.).

WASA has actively attempted to address the ongoing concerns of improper wastewater management in both islands. It initiated efforts in 2015 to adopt and refurbish over one hundred and fifty (150) WWTPs within private land developments with the intention to integrate these smaller systems into larger, regional WWTPs (WASA 2015). As of 2018, through this adoption programme, WASA adopted twelve (12) facilities from the HDC out of the new total of 72 facilities now owned and operated by the HDC (CReW+ 2020). From now on, all facilities constructed and those to be built by the HDC are proposed for eventual adoption by WASA.

A major constraint remains the unwillingness of private housing developers to pay for wastewater operations and maintenance in their developments. The issue stems from the adoption process, where private developers, through assessments and feasibility studies conducted by the New Services Department of WASA, are required to design and implement systems for water access and wastewater management before receiving approvals. Once these approvals are granted and all other approvals are completed, WASA can adopt the facility if the developer requests it.

However, the adoption process requires clear guiding policies with defined roles and responsibilities. The current arrangement creates significant ambiguity where the expectation of adoption has not materialised. Over 200 privately packaged WWTPs are either abandoned or functioning ineffectively (EMA 2019). Wastewater flow projections indicate that by 2035, wastewater flow will be approximately 700,000 m3/day for Trinidad and 30,000 m3/day for Tobago (GENIVAR, 2009). This signals the potential for considering wastewater as an alternative source of water.

The (Sub-Committee of Cabinet, 2020) report recommended the establishment of a Wastewater Division, signalling the government's intent to enhance its focus on wastewater services and management. This requires policy, operational, and organisational changes, which must soon follow for any meaningful transformation to occur. Additionally, the Beetham and San Fernando WWTPs were identified as potential options for water reuse through public-private partnerships (PPP) arrangements in collaboration with the MPU and WASA.

3.0 Review of the Governance Architecture of the Water Sector

Water sector governance is the institutional, policy, socio-economic, administrative, and legal instruments that dictate how water is managed. It explains how these instruments work together or in isolation, resulting in decisions made in the water sector and the system of holding people accountable for those decisions. This section will explore the institutional structures, the enabling environment, and the role of the public and non-governmental entities in managing the country's water and sanitation.

3.1 Institutional Challenges Affecting the Water Sector Ecosystem

Trinidad and Tobago faces severe challenges in the water sector despite the country's economic peaks and the investment made in infrastructure works and water management strategies. According to an assessment of several public water utilities published by the World Bank, the most suitable starting place for this spiral in water and sanitation services is the absence of or limited regulation that results in very low tariffs and collection of those tariffs **(Figure 3.7)**. While in the case of T&T, the Government has continuously filled the large gap between WASA's revenue and operating expenses, the reality is this has made the utility - which was established to have some level of independence – heavily reliant on the national treasury.

The subsidisation by the Government of water and sanitation services has not been simultaneously tied to performance targets. As a consequence of this limited regulation, where the rates do not accurately reflect the true cost of service, and there are no gazetted service standards (only in draft), the customers and utility have nosedived into the present-day situation of (i) a consumer and utility culture that does not value water resources, (ii) infrastructure and management practices that are archaic, (iii) absence of accountability in the provision of services and throughout the utility, and (iv) a debt-riddled institution that has a serious problem of customer, shareholder, supplier, and even employee mistrust.

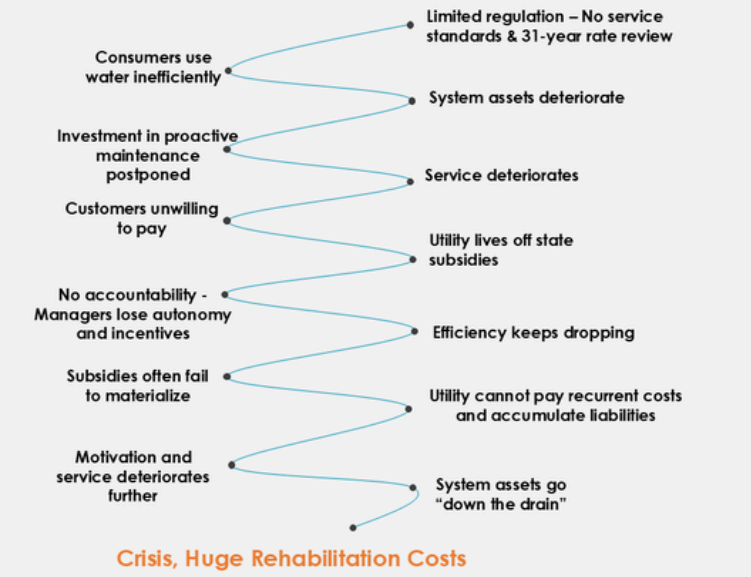


Figure 3.7: Spiral of Decline of T&T's Water and Sanitation Sector (Adapted from the World Bank (Baietti, 2006))

Aerial view of a community in Trinidad and Tobago showing WASA water supply tanks.
Unsplash/Renaldo Matamoro

There have been several attempts to address the water sector's institutional challenges, which have mainly focused on WASA with insufficient emphasis on addressing the problems within and between other stakeholders that comprise the water sector ecosystem. One of the more popular interventions in WASA was the Severn Trent Management Contract with WASA in the 1990s, an Interim Operating Agreement expected to move into a more long-term agreement, which never materialised.

The main reasons for the Severn Trent arrangement not delivering the results, with lessons learnt for future transformation approaches, is because it was not universally approved in the Parliament, which meant one administration had plans to implement a long-term arrangement beyond its term without seeking broader, national approval for the Severn Trent intervention.

One of the two (2) objectives of the Severn Trent contract was to bring efficiency gains. However, WASA's system was not set up to collect critical management data, which made it extremely difficult to define efficiency improvement targets that can be robustly tied to a financial contract. The high contract value, therefore, reflected this risk of uncertainty and ambiguity in the deliverables of Severn Trent. The second objective of the Severn Trent arrangement was to bring private capital to improve the infrastructure; however,
the return for this fund-raising in the form of a concession required some level of transfer of ownership to the private partner, which the WAS Act did not allow for (Ifill, 2019).
This was further compounded by the low tariffs with no plans to revise it.

Following the Severn Trent agreement, the World Bank financed the WRMSS in 1999, undertaken by DHV Consultants, Delft Hydraulics, and Lee Young and Partners. The objective of the WRMSS was to recommend approaches to implement Integrated Water Resources Management (IWRM), a globally recognised concept of managing water and the water environment (land and related resources) to meet a country's social and economic needs and does not comprise ecosystems. The following are the WRMSS recommendations and the country's progress in implementing them.

Table 3.2: Strategies of the WRMSS and Status of Recommendations

Recommendation (Ministry of Planning and Development, 1999)	**Status**
Establishment of a Water Resources Management Authority with relevant legislation and institutional coordination.	Water resources management functions remain in conflict, being housed within WASA, and there is no detailed legal instrument for water resources management. The Cabinet approved a national IWRM Policy in December 2022, which prescribes the separation of water resources management functions from WASA as a policy implementation action. The legal and institutional changes are underway.
Demand-side measures through metering, reduction of losses, public education and incentives to conserve and efficiently use water resources.	The majority of WASA's customer base (residential) remains unmetered. While there have been metering pilots in certain communities, such as Palmiste, Bon Air Gardens, and Valsayn North, there has not been a strategic, national effort to reduce water losses, and the tariff has remained unchanged since 1993. The NRW reduction component of the 2023 IDB-financed loan should materialise in increased metered water connections. There have been numerous public education campaigns by several water sector stakeholders, including the Adopt a River Programme.
Better management of watersheds, water quality, ecological flows, and flood control.	Watersheds continue to be threatened, and no documented methodology for determining or monitoring ecological flows exists. Three (3) major basin studies have been conducted in Caroni, Caparo, and South Oropouche. A US$10 million Adaptation Fund grant administered by the Development Bank of Latin America (CAF) will implement the recommendations of the South Oropouche River basin study (Development Bank of Latin America, 2023). Holistic action in other watersheds still needs to be taken. The Water Pollution Rules were updated in 2019 to more accurately affect the polluter pays principle. However, they do not target non-point sources of water pollution, which is still a major problem.
Supply-side measures to meet growing water demand include sustainably using groundwater, localising supply sources, and meeting agricultural water demand.	Much emphasis has been placed on developing water sources and increasing supply, including constructing two (2) desalination plants, several surface water intakes and plants, and multiple groundwater wells drilled. The supply of irrigation water continues to be challenged.
Develop data management and institutional capacity-building, including adequately financing and staffing these institutions.	There have been some improvements in monitoring water resources parameters across the country and a few isolated projects to introduce technology in the water sector, such as SCADA. The Operational Control Centre will enable more effective monitoring. However, there is still a need for integrating that technology and applying the data and information to drive water sector management decisions. There is no research and development in the water sector and very little connection between academia and industry.

There have been several attempts at the Cabinet-level to address the institutional challenges of the water sector. In 2002, the Cabinet appointed a Committee led by the Chairman of the Standing Energy Committee to i) develop a master plan of long-term projects in water supply, wastewater & drainage, ii) design a financing strategy for the plan, iii) re-model WASA to execute this master plan and iv) detail an approach to developing human resource capacity, technical and information systems and facilitate private sector involvement (Barnes, 2002).

Later, in 2003, the Cabinet established a Technical Committee led by the Permanent Secretary of the Ministry of Public Utilities and the Environment, who developed a 3-Year Action Plan to effect this master plan. The 3-Year Action Plan focused on employing technology, pipe materials, and digitalisation to support a state-of-the-art sector.
This Committee recommended adopting universal metering, developing localised water supply sources and a national water grid with adequate pressures, providing centralised wastewater, and creating a knowledge-based workforce (Bartholomew, 2003).

In 2004, another Cabinet committee drafted a Water Sector Strategic Plan that recommended the completion of a Water and Wastewater Master Plan, the implementation of the 3-Year Action Plan, allowing WASA to apply for a tariff increase, the refinancing of WASA's existing debt and managing future expenses, completion of the revisions to the WAS Act and investment in cheaper, more reliable sources of water (Subcommittee of the Standing Committee on Energy, 2004).

A technical team developed a short-term programme in 2006 for the financial restructuring of WASA. This programme proposed i) short-term projects in water production, treatment, transmission & distribution, and wastewater, ii) the outsourcing of a metering programme and the reduction of non-revenue water as a core activity for WASA, iii) the construction of impounding reservoirs in Moruga and North Oropouche, and iv) interim structure for immediate delivery of priorities (Julien, 2006). The latest Cabinet intervention was in 2020, with the establishment of another sub-committee of Cabinet that put forward a strategy to get WASA to deliver on its mandate.

In 2009, WASA hired a Canadian firm, Genivar, to develop a water and wastewater master plan to re-engineer water and wastewater infrastructure. In addition to the engineering interventions, this master plan recommended several institutional strengthening and best practice approaches for the sector and further reinforced earlier recommendations under the WRMSS to revise the WAS Act and create a Water Resources Management Authority. This master plan not only proposed transformation actions for WASA but also looked at the wider sector, recommending the following:

1. Building the capacity of local suppliers in the water sector to conduct pipeline and sewer repairs, maintenance of wastewater systems, engineering design, and construction management.
2. Training and certification of water and wastewater operators.
3. Community involvement to build support for the master plan and manage local services in their communities, specifically devolving responsibilities to local authorities.
4. Creation of a water quality regulator (Genivar, 2009).

Coastal community near a bay in Tobago.
Angelika/Pixabay

In 2016/2017, WASA engaged Safege under the Inter-American Development Bank's (IDB) wastewater expansion loan to recommend strategies for improving the corporate governance of WASA. Safege prepared a suite of reports for WASA on a legal framework for a new corporate structure for WASA (a draft of a revised water and wastewater services Act), a governance arrangement, policy and agreement, recommendations for implementing corporate governance practices, a Board charter and a transformation roadmap for WASA.

Several of the recommendations in these reports refer to strengthening the governance arrangement between WASA, which was proposed to move from a statutory authority to a state-owned enterprise with a sole shareholder – the Government. Based on the experience of other state-owned water utilities, Safege recommended that expectations and priorities of the water utility should be formalised by the appropriate government entity in the form of a Statement of Corporate Intent (Safege, 2017). Water sector governance continues to be an unresolved morass for every administration.

The approval of a US$80 million loan by the IDB on December 14, 2022, for a Trinidad and Tobago National Water Sector Transformation Programme is another significant step towards improving the country's water supply and enhancing water security. This loan is the first operation financed through a US$315 million conditional credit line for investment projects (CCLIP) that has three (3) components:

1. Water Stabilisation and Improvement (US$44 million) – construction, refurbishment, and upgrading of WTPs, drilling and equipping of wells, and rehabilitation of booster stations in selected locations across the country.
2. Water Sector Transformation (US$2.74 million) – mainstreaming of gender, climate, and disaster resilience, as well as institutional strengthening to implement IWRM and improve MPU's technical oversight capacity.
3. Network Optimisation (US$31 million) – reducing NRW through a co-management performance-based contract.

The remaining funding (US$2.6 million) will cover project management expenses. This Programme is expected to improve service quality, continuity, and access to water for over 1.2 million people (Inter-American Development Bank, 2022). In September 2024, WASA announced a new executive structure to support its ongoing transformation efforts.

3.2 Changes to the Enabling Environment

Water and sanitation in Trinidad and Tobago.
Adobe Firefly

The enabling environment of the water and sanitation sector comprises all the policies, legislation, and financing structures that allow for developing the country's water resources to meet the needs of people, the planet, and profit. The primary legal instruments in the sector are considerably outdated, having been drafted either before independence (Waterworks and Water Conservation Act) or immediately after independence (WAS Act).

These pieces of legislation do not recognise the various institutions that have emerged across the decades, nor does it give the flexibility and innovation to deal with impending threats to the water and sanitation sector, such as climate change, watershed degradation, shifting national economic drivers and the evolving systems of regulation (economic, resource, public health and environmental).

In the mid-1990s, the Environmental Management Act was passed, which established an environmental regulator, the EMA. One of the main legal mandates on water from this Act is the regulation of water pollution, which was more clearly defined in 2007 through the Water Pollution Rules. In 2017, after the EMA's fixed penalty system for breaches in the Water Pollution Rules was legally challenged by Fishermen and Friends of the Sea (FFOS), a revised Water Pollution Rules 2019 was enacted to adhere to the polluter pays principle and adequately reflect the environmental damage caused by water pollution. This watershed moment for the country's water sector fuelled greater accountability by the regulator and polluters. It is the impetus for considerable change in how some of the country's major point source polluters manage their liquid waste.

The Certificate of Environmental Clearance (CEC) Rules, 2001 also has an impact on the water environment as it is a process that stipulates how the environmental impact (including on water) of development activities should be assessed and then managed. The intention is that this CEC process will bring the required coordination among other national authorities responsible for regulating natural resources or activities that can impact natural resources, such as minerals regulation, municipal corporations, forestry, and urban and rural land use planning.

Major flaws in the CEC process are that several activities are impacting the environment that were grandfathered in, and the process relies heavily on the developer to be transparent about their activities. Inter- and intra-agency coordination needs to be significantly strengthened and bolstered by a modernised, integrated system for tracking development applications and monitoring the footprint of the environment. Even when development is approved, do the entities responsible for enforcement, such as the regional corporations, have the institutional capacity and power to conduct monitoring and enforcement activities?

The role of local government reform becomes critical here. Most importantly for water and sanitation, the impact of development needs to be accounted for in the context of the broader watershed and cumulative consequences (of each built development or activity in a watershed) on the already overburdened water and wastewater infrastructure.

The most evident manifestation of the uncoordinated regulation of land use is in the development of the country's hillsides, most blatant in the Northern Range. This is significant for water because the mountain ranges are the head or source of the country's more prolific rivers and aquifers, and if the land is not protected and deforestation rates increase, this directly threatens the volumes and quality of water that flows downstream to water treatment plants, farmers, mangrove systems, coral reefs, and seagrass beds.

Tobago has had greater success in protecting its hillsides and watersheds, with the Tobago Main Ridge remaining one of the oldest forest reserves in the western hemisphere.

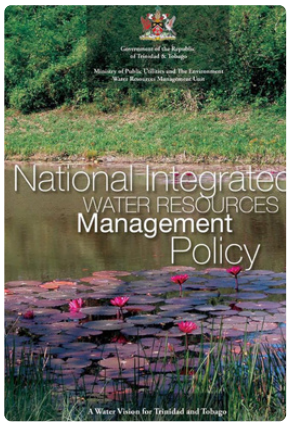
Aerial view of hillside farming in Trinidad and Tobago.
Unsplash/Renaldo Matamoro

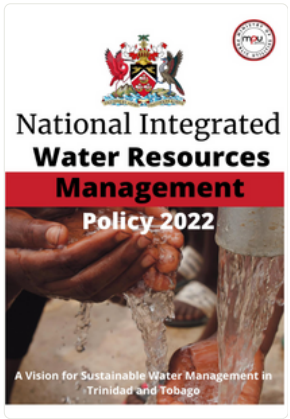
Unsustainable hillside development also causes more frequent flooding, particularly when the developed surfaces and natural drainage system is concretised or made impermeable. This situation results in a much shorter runoff time for the high quantities of water after the typical wet season rainfall events, resulting in flash flooding and flood events that are more frequent and off the scale. While there have been attempts to stop hillside development through moratoriums, this has yet to be sustained and fit-for-purpose building codes and enforcement remain key problems for balancing watershed protection with land utilisation.

After the WRMSS, the country made a significant stride to adopt international best practices in water with the enactment of the National IWRM Policy (2005). This policy articulated several intentions and commitments of the Government on how water would be prioritised, developed, conserved, and protected to meet existing and future demands. It focused on each element of the water supply chain, from the water environment to water resource allocation, water treatment and supply infrastructure, wastewater collection and treatment, stormwater management, or flood control. The policy also connected the dots between freshwater resources and the coastal waters, specifically wetlands, and made the linkages between data, research and development, and effective management of the country's water.

The National IWRM Policy defined a strategy that the Government intended to follow in setting up the proper institution to effect IWRM and coordinate among the many entities involved in water, as well as strengthen the capacity of these institutions to perform their own functions.

Following the approval by the Government of the National IWRM Policy, 2005, a Water Resources Management Bill was drafted to effect the policy prescriptions and set up an authority to manage the water resources. Unfortunately, the conflict of WASA retaining responsibility to manage the country's water resources remains unaddressed even though it is the largest abstractor of water (Parliament of the Republic of T&T, 2012).





In 2016, the Government signalled its intent to update the 2005 National IWRM Policy and remove water resources management functions from WASA. Following the revision of the policy in 2017, cabinet approval for a new policy was given in December 2022.

The National IWRM Policy 2022 has set a national goal to manage water resources and the water environment to support the country's socio-economic development. It prescribes the instruments to enhance water sector governance, establish water resources management legislation and an Office of Water Resources Management (OWRM), methods to strengthen inter-agency coordination and collaboration, modern management approaches and strategies for the sector to adapt to climate change. The Policy is the country's articulation of collaboration and collective ownership of the nation's water resources and water environment to safeguard existing and future users, and it does this through a detailed responsibility matrix (Ministry of Public Utilities, 2022).

Financing and investment are one of the more neglected structures in the enabling environment for water, as there is limited scientific evidence on the opportunity cost for the mismanagement of watersheds, ecosystems and water resources. Ideally, payments made for natural resource regulation, such as water pollution fees and water abstraction, should cover the cost of (i) rehabilitating the damage and/or (ii) protecting the ecosystems that sustain the resource.

The RIC also regulates the water abstraction rate, which is considerably lower than the water and wastewater tariff and certainly does not account for payment for losses from not having that water available for the environment, recreation, cultural purposes, or other socio-economic uses. While the payment for water pollution breaches is more aligned with the polluter-pay principles and based on the contaminant load, similar to the water abstraction fees, a transparent financial structure does not exist for, at minimum, a portion of the funds to be invested back into the watershed either for protection or rehabilitation.

Drone shot of inactive quarry pits in Valencia, Trinidad.
Akil McPherson

The quarrying sector is the loudest warning alarm for the disconnect between economic instruments to protect and conserve the environment and the structure to return these investments. In 2010, the Ravine Sable River within the Caparo watershed overflowed its banks and spilled into an adjacent, under-regulated red sand quarrying operation. The remnants of the pond remain today and are presumed to be groundwater-fed, indicating that the quarrying depth likely exceeded sustainable environmental limits. Unrehabilitated, abandoned quarry operations litter the foothills of the Northern Range, for example, in the communities of Valencia. The paradox is that quarrying activities are located in Trinidad's groundwater-prolific zones since gravel is the supreme groundwater conduit and prime material for aggregate quarry operators. This imbalance in natural resource exploitation between quarrying for aggregate and securing freshwater epitomises how water is a cross-cutting, national development matter to be prioritised for people and the economy.

In 2000, the Government established a Green Fund, which is capitalised via a 0.3% levy on the gross income of all companies operating in the country. Organisations, including a statutory body, a not-for-profit company, a non-governmental organisation, and a community group can access the Green Fund. The projects that the Green Fund finances are focused on remediation, conservation, reforestation, and environmental education. The balance as of September 2020 was TT$7.63Bn (Office of the Auditor General, 2021), and $400Mn has allegedly been spent to date (Javeed, 2022) on the projects in the aforementioned focus areas that have benefitted the water and sanitation sector.

WASA is a recipient of Green Fund resources, which are being channeled through the Adopt a River Programme, which involves public and private entities and citizens in better management of watersheds. However, there is a greater need to expedite transparent and justified access to the Green Fund to further protect and restore the country's natural environment.

Financing in the water and sanitation sector is structured where the Government covers the majority of operating expenses and total capital works, as depicted in **Figure 3.8 and Figure 3.9.** This has been the status quo because water and wastewater tariffs have remained low for the past thirty-one (31) years. In fact, a regional benchmarking study revealed that WASA's balance sheet position with a negative EBITDA (earnings before interest, taxes, depreciation, and amortisation) margin, negative net income margin, negative return on assets, and negative equity is an outlier when compared to other water utilities in the Caribbean (Janson, Burkhard, & Jones, 2021). This reflects that the financing arrangement for the water sector through Government subsidies is untenable and must be addressed.

In 1998, the country attempted to recover some of its expenses with the application of a water improvement rate under the Waterworks and Water Conservation Act, and then in 2011. This rate aims to add a premium to the water bill of agricultural, industrial, or commercial customers who materially benefit from improvements to the water infrastructure in their area.

While there have been a few areas declared as water improvement areas, the industrial and commercial customers of the Point Lisas Industrial Estate are charged this water improvement rate for the improved supply they receive from the DESALCOTT plant.
The same, however, does not apply to the industrial and commercial customers of Point Fortin, where the Seven Seas desalination plant is located. Nor the industrial and commercial customers who benefit from a desalination supply outside of Pt. Lisas.
The main barrier to tracking these customers is WASA's lack of metering both on its network and for its customers.

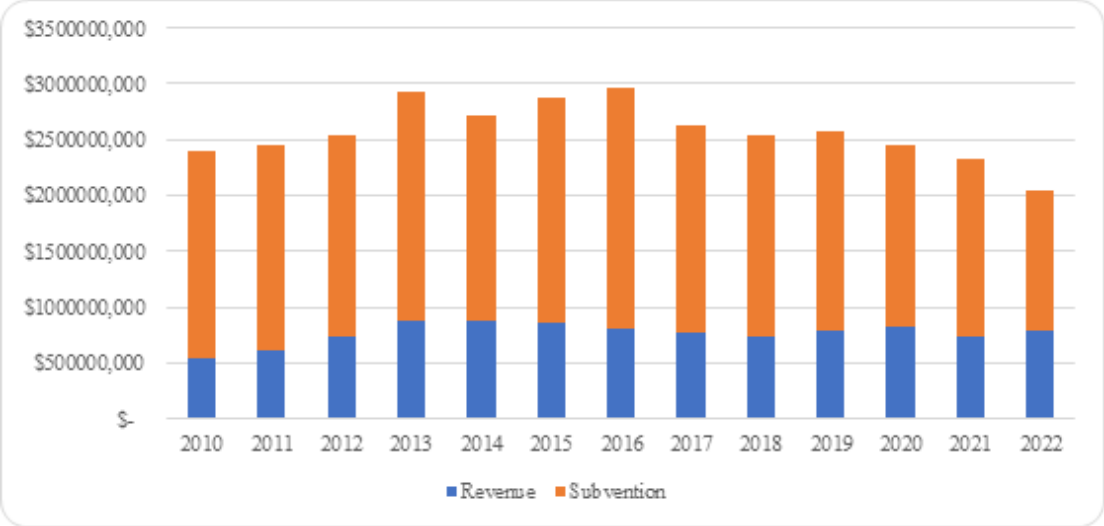


Figure 3.8: WASA's Revenue against Government Subvention from 2010 – 2022 (Ministry of Finance, 2011 - 2022)

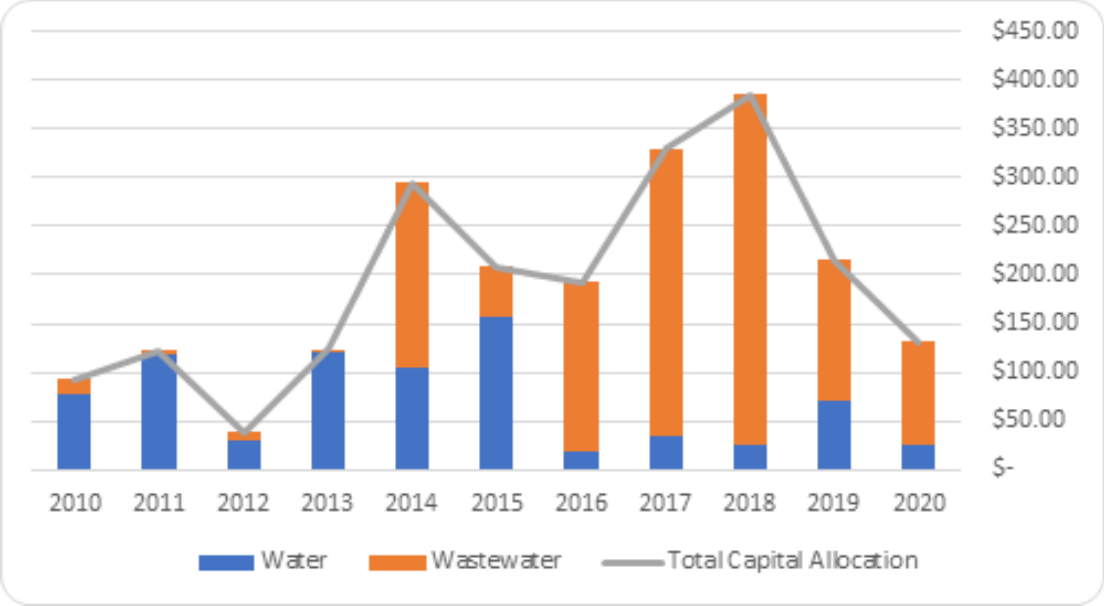


Figure 3.9: Government Capital Investment in Water and Wastewater from 2010 – 2020 (Ministry of Finance, 2011 – 2020)

3.3 Rise of NGOs and Shifting Public Perception and Practices

Water resources occupy a special place among other natural resources. It is the most widely distributed substance on our planet. Particular importance must be placed on freshwater; without it, human life is impossible, and any other known substance cannot be substituted (Shiklomanov, 1998).

A healthy watershed is, in many ways, one of the most fundamental requirements for a successful human population to thrive. Not only does it provide a medium for nutrient cycling, carbon storage, erosion/ sedimentation control, increased biodiversity, and soil formation, but it also acts as a wildlife movement corridor and flood control and reduces the effects of climate change and other natural disasters. Arguably, and most importantly, watersheds improve water quality as natural landscapes filter pollutants, which also leads to an economic benefit as less investment would be necessary to ensure that water is potable (US EPA).

An aerial view of several communities nestled amidst the surrounding mountain landscapes in Trinidad. *Unsplash/Renaldo Matamoro*

Trinidad's Northern Range contains some of the country's most important watersheds, but these watersheds are being degraded primarily due to urban development, unsustainable agricultural practices, and quarrying (Pantin & Krishnarayan, 2003). Although the state is responsible for forest management and reducing degradation, it is difficult for the state to keep up with the pace of these threats (Lum Lock & Geoghegan, 2006). This has led to a rise in the interest of NGOs in protecting these watersheds.

NGOs such as the Fondes Amandes Community Reforestation Project (FACRP), the Maracas Valley Action Committee, the Caura Valley Village Council, the Cashew Gardens Community Council, the Guanapo Community and Environmental Development Organisation, and Anse Fromager Ecological and Environmental Protection Group arose as strong community advocates for protection of watersheds.

Fondes Amandes Community Reforestation Project (FACRP)

One of the earlier community groups advocating for better water management is the FACRP. Fondes Amandes is a hillside community in St. Ann's, western Northern Range, adjacent to an important reservoir serving Port-of-Spain. The Fondes Amandes residents have been particularly affected by the degradation of the surrounding lands. Typically, subsistence farmers in the 1970s and 1980s these residents experienced hardships when, during the dry season bush, fires raged, leading to excessive soil erosion as well as flooding during the rainy season, which resulted in heavy siltation of the river and water works (Lum Lock & Geoghegan, 2006). In 1991, the Jaramogis (the representative for the Fondes Amandes community) developed a community reforestation plan to rehabilitate the watershed, and WASA allowed the community to utilise land owned by the utility for this.

By 1999, the FACRP was established, with the main objectives of the project being the restoration of the watershed through the planting of trees, the prevention of further deforestation from bushfires, and the improvement of the quality of life of the communities. The NGO has transformed what was once fire climax grassland into an impressive 30-hectare organic agro-forestry project as of 2006, and to this day, it continues to work towards achieving its goals (Lum Lock & Geoghegan, 2006).

Fishermen and Friends of the Sea (FFOS)

Another NGO of note in Trinidad and Tobago is FFOS. They were formed in the late 1990s and became a non-profit organisation in 2000. Their mission is “to promote sustainable development, sound environmental management, accountability, consultation, transparency and community empowerment throughout the Caribbean and the wider world.” (FFOS, 2022) This organisation holds authorities accountable and has, in many cases, filed legal proceedings for the benefit of the country.

FFOS challenged the Government of T&T over the Water Pollution Fees Regulations.
This was a lengthy and bureaucratic process spanning over a decade that reached the Privy Council. Prior to the ruling, T&T's polluters, big or small, had a fixed penalty of TTD 10,000 per year to pay. The FFOS argued that this was unlawful and large industrial or petrochemical polluters requiring a water pollution permit from the EMA pay the same annual permit fee as a small pig or cattle farmer with only 20+ animals, regardless of the quantity or toxicity of their pollution. The FFOS believed that the payment should be more representative of the level of pollution caused by the individual/ body. The FFOS won, causing the Water Pollution (Fees) Regulations, 2007, to be revoked. This led to the creation of The Water Pollution (Fees) Regulations, 2019 where payment for pollution is calculated based on the volume and the pollutant load (Hilson, 2018).

The Cropper Foundation

The Cropper Foundation is another non-profit organisation that has made strides in water resource management. The organisation, founded in the year 2000, is committed to addressing environmental and resource management issues with a particular focus on sustainable development. Its primary mission is to influence policy and governance while building human and material capacity for environmentally sustainable and equitable development (CARI-BOIS, 2022). With this at the fore, the foundation has partnered with numerous communities in Trinidad to alleviate the effects of anthropogenic and natural environmental calamities.

In 2019, the Cropper Foundation worked with the residents of Acono in the Maracas St. Joseph Valley to highlight and address the destruction of the Acono River and its native aquatic life arising from 50-year-long intensive quarrying activities. Immense levels of sedimentation released into watercourses also caused flooding problems in lower-lying areas. Further, gentrification and increased population density in the community meant that the same water supply had to be distributed among more residents, leading to water supply challenges. Cropper Foundation also worked with residents of Valencia to address flooding, empowering residents with the tools to bring flooding issues to the relevant bodies through the most efficacious channels (Eron Melville, 2020).

The Caribbean Natural Resources Institute (CANARI)

The Caribbean Natural Resources Institute (CANARI) is another non-profit technical institute founded in 1989 with extensive experience in research, policy influence, and capacity building for participatory natural resource governance in the Caribbean.
Royal Bank of Canada (RBC) blue water project, which ran from 2012-2014, was one of their notable initiatives in the water sector. Its goal was to improve the community-based management of watersheds in Trinidad and Tobago.

Strategies employed in this project included training workshops on communication, watershed protection, and organisational management for community stewardship, as well as the development and dissemination of materials that bring environmental awareness on watershed protection, shining light on the importance of access to clean and safe drinking water. Publications and documentation for public knowledge also arose out of the initiative (CANARI, 2022).

T&T was also the birthplace of the Caribbean's only professional association of practitioners in water, wastewater, and solid waste, the CWWA. In 1991, CWWA was established as a regional NGO through an Act of T&T's Parliament to advance the science and practice of water and waste management, provide education and training in these sectors, and provide a platform for the study, research, and development in the sector. The CWWA has provided advocacy for water and sanitation in the region and has a membership that comprises professionals, utilities, and corporate entities working within the Caribbean.

One of the major drivers for the genesis of some of these NGOs is the protection of water by building the awareness of the citizens of T&T on matters of water and watersheds. Citizen awareness gradually decreased as the water supply became centralised, meaning most of the water used across the country would come from only a few sources (Sitzenfrei & Rauch, 2014), and people began to rely more on WASA. An example is the Caroni WTP, which services Trinidad's North, Western, Central, and Southern regions (CPG Consultants, 2013).

Citizen's ownership of water changed. In contrast, generations ago, water was sourced locally from standpipes or clean rivers and springs. Water collection was a hub for community gatherings, and people were more protective of their water sources. While the community spirit of water guardianship is rare, it still exists today in communities that rely on localised sources of water, such as Caura and Maracas/St. Joseph. This change from localised to centralised water supply has resulted in a lack of guardianship, apathy for the persistent poor service, and lowered value for the country's water resources. Not only in Trinidad and Tobago but in many countries, people seem to take tap water for granted (Randolph & Troy, 2008).

In 2003, a study was conducted in Trinidad and Tobago on the willingness to pay for utility services. The survey sought to ascertain domestic consumers' perceptions of the quality and price of utility services and of service providers in the water and electricity sectors. The survey results highly imply that many users, in evaluating their willingness to pay, consider only the private benefits that accrue in wastewater upgrades rather than the public benefits.

Increased environmental awareness is required to underscore the necessity of wastewater treatment and, in turn, stimulate demand for enhanced sanitation facilities. Enhanced public awareness is also needed on the role or connection between their activities, watershed management, and water coming into their taps. This should be a campaign at all scales for all users of water. The 2003 study also indicated that many users are unsatisfied with the quality and reliability of the water that they are supplied with, leading to the prominence of other sources of drinking water (Regulated Industries Commission 2005).

In the last sixty (60) plus years, there has been a marked change in how populations consume water locally and internationally, where a new mode of drinking water arose: the bottled water industry. This industry has drastically shifted the water market and solid waste sector due to its contribution to the massive increase in single-use plastics.
The demand for bottled water has steadily increased through the last few decades, leading this industry to become the fastest non-alcoholic beverage sector (Ferrier, 2001). Quite a few factors have influenced customers' change in preference; one of these factors is dissatisfaction with tap water's organoleptic characteristics (taste, odour and sight) (Abrahams & Jordan, 2000). Another factor is the public perception that bottled water is healthier (or cleaner), which may seem paradoxical as tap water quality in most countries has improved throughout the last few decades as more and better technologies are implemented (Doria, 2006). The influence of marketing and the media cannot be understated in relation to the demand for bottled water.

There has been a significant increase in the amount of financial investment these bottled water companies pay toward improved and increased marketing campaigns (Olson, 1999) and visibility in their corporate social responsibilities. The private sector's efficiency and business techniques give the bottled water industry a significant head start in positioning bottled water as the premium (and even sole) choice for drinking water. In some respects, the bottled water market may not even be considered competition with the water utility, which has a monopoly over tap water. There is potential for this market share to shift away from the water utility with the continued rise of bottled water and even an increase in water tankers as an alternative source of water, albeit not always a legal one in several cases in T&T.

4.0 A Vision for Future Water and Wastewater Management in Trinidad and Tobago and Lessons for the Caribbean

Recognising that the T&T water and sanitation sector has considerable work to do to get the provision of services into the 21st century, despite the significant capital investment and operating contributions made by the national treasury, there will be two (2) stages of moving forward:

i) equilibrium to address the challenges that remain and accumulate from the past 60 years, and ii) future-proofing to deal with the uncertainties of providing water and sanitation services in the situation, environment, and climate that lies ahead for the country.

4.1 Recommendations for Equilibrium: Addressing the Challenges of the Past

Water and sanitation in Trinidad and Tobago.
Adobe Firefly

To a large extent, the solution to stabilising the water and sanitation sector is the inverse of the problems articulated in the discourse above. There are several sectoral benchmarks and targets that can help the country signpost where it needs to be, and one of them is the United Nations' Sustainable Development Goals (SDG).

SDG 6 – Clean Water and Sanitation for All has several indicators that track a country's progress toward that goal. **Figure 3.10** depicts T&T's progress to SDG 6 and the areas that require attention
(UN Water, 2023).

Based on this SDG 6 assessment, T&T is relatively well placed in terms of access to safely managed drinking water, with 100% of the population having access to drinking water. This is notably higher than the regional percentages for Latin America and the Caribbean, which stand at 75% for access to safely managed drinking water and 49% for safely managed sanitation services at the basic level (UN Water, 2023).

Sanitation coverage, not recorded in **Figure 3.10** but reported in the wastewater section, is 30% of the population, while 64% utilize on-site septic systems and 6% pit latrines. T&T also reported that 88% of water bodies have good ambient water quality, which is the highest in the region and significantly higher than the regional average (57%). NRW requires urgent attention and stands at 50%, one of the highest in the region, only surpassed by Jamaica and Guyana (Janson, Burkhard, & Jones, 2021).

IWRM implementation in T&T is underway and is currently at a medium-low level. However, this is consistent with the regional average. This section will put forward the interventions in order of priority, which can be done sequentially to move the country and its citizens closer to better water and sanitation services.

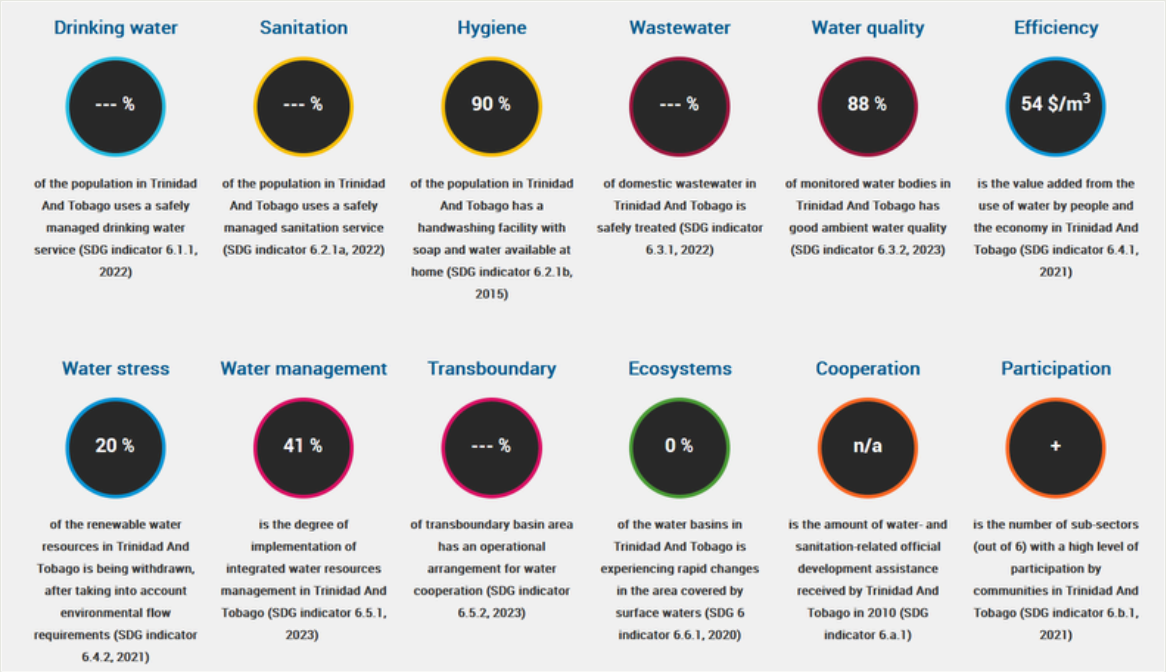


Figure 3.10: T&T's Progress to SDG 6 (UN Water, 2023)

4.2 Reconfiguring the Water Sector Ecosystem

It is proven in many other territories that managing water must be a coordinated and integrated effort between all layers of government and society – the IWRM approach. The water sector is akin to a living organism that requires all its organs (stakeholders) to work for it to be functional (provide water for people and the economy). The focus must therefore be both on WASA but equally on the other entities that make up this ecosystem.

The regulators and entities responsible for managing and/or monitoring the country's natural resources (land, ecosystems, minerals, agriculture, etc.) must collaborate in their decision-making, and the system for this coordination must be institutionalised.
In some countries, the portfolio for water is placed under the Office of the Prime Minister, while in others, it is under the responsibility of the Ministry of National Security.

There are a few options for T&T; however, the objective is to integrate water resources planning into national planning. This is not solely a piece of a national development strategic planning exercise but is a cornerstone that requires a paradigm shift in the thinking and operations of public entities that have national responsibilities to recognise that water is fundamental to supporting and growing the country.

Water must shape national development and is the common denominator for T&T to achieve social and economic prosperity. Achieving this level of harmonisation requires a strong focus on improving coordination among land use planning entities, custodians of the country's natural resources, major users of water, and the entities with power and influence to deliver change (community groups and NGOs).

Between 2012 and 2013, the WRA initiated an IWRM Stakeholder Forum and presented a Position Paper on institutionalising the coordination required for IWRM. This will be a meaningful foundation for moving forward with the required coordination. In addition, institutional strengthening for these entities to be more effective at their role is critical to ensuring that all the inputs to sustaining the water cycle are secured. This requires a concerted effort to modernise the legal instruments used by these entities, build the skill sets of the people in these organisations and implement the systems that would rely on data to make coordinated decisions for the benefit of securing water.

One of the more urgent actions for better governance is the separation between the entities responsible for setting policies for water, managing water resources, regulating water rates, and providing water and sanitation services. The missing institution among these actors needed for T&T is an entity to independently manage water resources and the legal instrument that gives powers and sets out the framework to properly manage land and other resources to safeguard watersheds from degradation, protect riverine buffer zones and groundwater recharge areas all toward securing the country's water resources.
The legal instrument should also, articulate the financing structure to ensure that fair revenue streams can be generated and then invested back into building the capacity of the institutional arrangement and preserving the country's water resources. The major benefits of setting up an autonomous manager of water resources are:

1. Deliver an updated and accurate quantification of water resources and analysis of water demand with climate change projections, which will be used for decision-making.
2. Undertake climate-resilient master planning to allocate, conserve, and develop water resources based on sound science.
3. Fair and equitable regulation of all users of water (utility, agriculture, industry, etc.) and transparent setting of water allocation priorities.
4. Coordination of all water-related matters – flood management, irrigation development, drought mitigation, pollution management, land use planning and development, etc.
5. Enable financial self-sufficiency of a water resources management institution where abstraction and other fees can finance the operating expenses of equitably and scientifically managing the country's water resources and can be invested back into training, research, and development.
6. Transparent allocation of financial resources earned from water resource abstraction can be appropriately directed to investments in rehabilitating and protecting the physical environment that safeguards water quality and quantity.
7. Free WASA to focus on its core function of water and sanitation service provision and have a system of accountability for WASA to optimise and conserve the water resources it abstracts.

An aerial view of planted crops.
Unsplash/Renaldo Matamoro

The new governance architecture for water should also carve out a space for NGOs, academia, professional associations and societies of commerce, businesses, farmers, quarry operators, etc. As stakeholders with sufficient power and influence, these groups should have a platform to contribute to developing and transforming the country's water and sanitation sector. A structured two-way channel should allow for contribution and feedback on managing water, including during water-related emergencies. In addition, because of the national economy, there is much room for private-public partnerships that will bring the efficiency and capital required to deliver material change in the sector.

4.3 Strategic Infrastructure and System Upgrades for Water Quality and Quantity

Given the state of the country's watersheds, primarily due to poor ambient water quality, there must be a national effort to improve the quality of the country's freshwater resources. This will have multiple direct and indirect benefits, one of the most material being, improvements to the marine environment if riverine water quality improves. Improving water quality involves stronger action to clamp down on point sources of pollution, and neglect of wastewater treatment facilities is high up on the list of contributing activities. WASA is responsible for managing the country's wastewater. However, it is not solely in charge of reversing the problem. In keeping with the IWRM approach, addressing the wastewater problem must also involve the land use planners and developers to facilitate a more robust approval process that stipulates codes of practice for the construction, operation, and maintenance of wastewater facilities.
The system change should also focus on enforcement and penalties/sanctions that inhibit breaches.

The issue of non-point source pollution must also be given equal importance, which potentially requires a long-term public education and awareness campaign, establishing building codes and standard operating procedures that encourage zero to minimal discharge of wastewater, and adopting the circular economy concept. This is at all levels of society – agricultural, residential, commercial, and industrial. Wastewater reuse at the non-utility scale is, therefore, a beneficial strategy to promote. It can possibly have a greater uptake for the developed reuse standards and complement the Water Pollution Rules, 2019.

One of the urgent, no-regret projects in the sector is optimising the production and delivery of water throughout the country toward a continuous (24/7) water supply. With a non-revenue water (NRW) quantification that ranges between 40 to 50% of production, it is unwise to continue investment in water supply without tightening the losses on the system. This reduction in NRW requires the immediate installation of a system to monitor flows and pressures throughout the entire water supply network, from water abstraction points to production facilities, transmission pipelines to distribution systems, and finally, the exit points – customers.

Metering, tied into the Operational Control Centre, will allow WASA and the customer to manage water based on data and not intuition. The benefits of this type of system, particularly for WASA, are extensive, including greater accountability in the level of service WASA provides and better succession planning for the human resources involved in WASA's operations. The NRW reduction strategy is not simply to fix the leaks in the system but allows for a more strategic, proactive, and long-lasting approach to addressing the root of these leaks – inaccurate pressures, inadequate management/monitoring data, and ad hoc investment in asset installation, upgrade, and maintenance.

The gold standard for network management uses the District Metered Area (DMA) or Pressure Management Area (PMA) approach, which isolates supply areas based on factors such as topography or connections. This allows the utility to control the flows and pressures throughout these more manageable clusters of the network and can deliver uniformity in supply with respect to pressure and flows. It can bring greater accuracy in quantifying and locating losses on the system. Adopting the DMA/PMA approach is critical to modernising and improving water supply service delivery.

Optimisation of the production and delivery of both water and sanitation services also involves enhancing the technology required to better manage the system and capitalise on limited resources. Urgent technological advancements needed for the water sector are the increased application of digital technology (such as machine learning and artificial intelligence) to rewire organisational processes and upgrade and explore more fit-for-purpose tools, goods, and equipment, including proactive maintenance of these assets. Technology that reduces energy usage utilises renewable sources, reduces pumping, allows for more water storage, automates plant operations, and enables redundancy and interconnectivity of the system are all necessary for optimising service delivery.

The introduction of standardised rainwater harvesting techniques is another grassroots, cost-effective technology required in the water sector for both residential and agricultural uses to collect water safely without becoming a public health hazard. This should be a standard design of all built development.

It is now generally accepted at the global level that the management of water resources must extend beyond engineered interventions and approaches to include complementary nature-based solutions and principles of the circular economy, particularly regarding wastewater treatment and reuse. This has been the focus of recent times by numerous local NGOs such as the IAM Movement, who, in collaboration with UWI St. Augustine Campus, are investigating the efficacy of vetiver grass in removing micro-toxins from liquid effluents and watershed rehabilitation. Regional projects funded by developmental agencies are also advancing water and wastewater management in the Caribbean. One such example in relation to T&T is the GEF CReW+ Project, which aims to implement innovative, technical, small-scale solutions in the Caribbean using an Integrated Water and Wastewater Management (IWWM) approach and building on the sustainable financing mechanisms that were piloted through the Caribbean Regional Fund for Wastewater Management.

4.4 Financing the Water Sector and Linking to Performance

At the start of the spiral of decline for water utilities, there is little to no regulation, resulting in low tariffs. Today, no single product in T&T is being sold at 1993 prices.
The delay in adjusting the water and sanitation service rates must be resolved as this will not only send the proper price signals for the true value of water as both a service and a natural resource but will concurrently establish a system that can hold the service provider accountable for set performance targets and service standards. From this perspective, the increases in water and wastewater rates must be tied to the formalisation of standards that incur some level of sanctions for the service provider.

A detailed focus and subsequent rollout of a revised rate structure should result in customers paying for services they receive, which is the main rationale for customers in agreeing to an accountability tool, i.e., metering. This would move customers away from paying based on the archaic system of property value to payment based on usage and service. The revised tariff structure should be independently determined to ensure that it does not reflect the costs of inefficiency but also provide the water utility with available financing to undertake ring-fenced capital projects first tied to efficiency improvements (stabilising the service) and then move on to growth and advancements (future-proofing).

The country should also focus on a financing structure to protect water resources and ensure that fees for water abstraction and water pollution adhere to sound environmental principles. Financing other sectors intrinsically linked to water must also be prioritised starting with solid waste. In T&T, no financing structure covers the collection and disposal of solid waste, which is fully covered by the Government.
To promote a culture of responsible environmental behaviour, a system must be instituted in the country that allows the solid waste sector to cover its operating expenses in the first instance with a phased approach to financing capital works. This capital programme should follow the waste hierarchy of reduce, reuse, and recycle based on T&T's waste characterisation and align with the national policies launched in 2024 addressing how solid waste will be managed across the country.

Notwithstanding, no-regret projects in the solid waste sector should be fast-tracked, such as installing engineered landfills in Trinidad and Tobago and remediating the existing sites to avoid further environmental degradation. This must be coupled with a sustainable livelihoods programme modelled against the circular economy.

A critical measure for national buy-in to the revision of the financing arrangements for sectors that have historically been undervalued or unvalued is enabling transparency.
Data on key national performance indicators of the responsible entities in the water and sanitation sector should be published in real-time. Examples of these indicators can include a real-time and accurate record of the level of water service provided to each community, production from each source of water, wastewater treated from each facility, annual reports, and independent financial audited statements. The indicators should also be used to drive behaviour change among all stakeholders.

An example of river sedimentation in Trinidad and Tobago.
Adobe Firefly

Another form of transparency that the country should be undertaking is the creation of consumer groups and a platform for other advocacy groups to ventilate and even address the issues facing consumers. These groups can be mutually beneficial as they can be a two-way channel to spread accurate information between WASA and the community.

They also allow for a structured system of obtaining independent feedback on service provision and can be a powerful catalyst for better community relations and building of public trust between WASA and the consumers.

In addition, these groups can assist WASA with resolving water and wastewater issues in their community and can help engender guardianship for water and the water environment, eventually inculcating a stronger appreciation for the value of water.

The Adopt a River Programme has covered significant ground in involving communities and corporate entities in watershed management. It should strengthen its approaches to engage citizens and other sects of society in protecting and conserving water resources.

4.5 Future-Proofing the Sector: Dealing with the Uncertainties

The uncertainty of the future of the water sector demands significant planning and strategic interventions to ensure that there is in-built resiliency for a resource crucial to the country's socio-economic advancement. While some experts predicted that the world would likely face a pandemic, the exact timing, scale, and impact of that pandemic was uncertain – until 2019, when COVID-19 hit. As the water sector moves from a state of equilibrium to maturity (or expansion), predicting, assessing, scanning, and planning for risks at the scale of COVID-19 is a fundamental step in future-proofing.

The three (3) top risks the Caribbean water and sanitation sector will likely face are environmental supply chain risks, technology disruption, and climate change (Govia S., 2022). Risk management can deliver a deeper analysis of the weaknesses in the sector and recommend mitigation measures to reduce the shock and build resilience to possible changes. A WASA Board Committee on Risk is one of the initial interventions the sector can adopt to help move risk management from a corporate function to a discipline in all the projects, strategies, and policies the country adopts. While the Board Committee will focus on WASA, it is highly likely that this team will unearth risks to the broader water sector and can recommend approaches to managing that risk.

Improving the current systems and increasing efficiency would increase the ability of the sector to absorb more shock in managing uncertainty. The continued implementation of IWRM will also aid in building water resilience for the future (Mahabir, 2015). No-regret upgrades that improve the quality and safety of infrastructure that delivers water, collects sewage, and stormwater are critical to designing a sector that can withstand uncertainty. This approach will capitalise on a closed-loop system for water manufacturing (treating water and wastewater) and ensure infrastructure is more resilient to damages by floods, landslides, drought, sea level rise, and other extreme events, which will become more prevalent as human-induced climate change impacts worsen. Indeed, building resiliency to other natural hazards, such as earthquakes, is critical. WASA should consider participating in CWUIC SP and accessing other instruments to reduce its disaster risk.

The launching pad for future-proofing the sector should be a publicly agreed-upon climate risk-informed (i) water resources master plan, and (ii) water and wastewater master plan. The country already has a solid foundation of a water and wastewater master plan prepared by Genivar in 2009. The aforementioned master plans should be 20–30-year guiding documents, even considered a social contract, to prioritise and sequence investments in the water sector beyond political regimes. As a result, parliamentary approval of such a plan should be acquired as a national document mutually agreed upon by the country's decision-makers for building resiliency in the water and sanitation sector.

The resources to deliver a water and wastewater master plan will be quite economically taxing, and the state will need support to bring capital, efficiency, and innovation to the water and sanitation sector. This is where the involvement of the private sector would substantially improve the chances of achieving these goals. The success of PPPs in the water and sanitation sector (and other development areas) has been globally proven. These PPPs can help transfer risks (budget, schedule, operations, etc.), facilitate off-balance sheet borrowing and fund-raising in times of limited national capital, and deliver efficiency in services. However, PPPs require extensive due diligence to be clear on risks, data systems to measure performance, and public transparency from procurement to contract closure.

One of the main contributors to climate change is the unsustainable consumption of energy and the continuous usage of fossil fuels for power that emit various greenhouse gasses.
A shift away from fossil fuels and using renewable energy can mitigate climate change. Nationally, while the focus has been on mitigation of climate change, i.e., reducing greenhouse gas (GHG) emissions because of its high GHG per capita, T&T, as a small island developing state is extremely vulnerable to climate impacts and should be aggressively adapting to climate change, specifically in a sector that will be the most significantly and detrimentally affected - water. A climate risk-informed water resources master plan will build national capacity to balance fluctuating water supply and demand in a changing climate.

New and improved technologies will also aid in resilience building. There have been significant improvements in computers in speed and storage, processing data faster, and application of algorithms to help with holistic water resource management (Shiklomanov, 1998). Various companies are now producing household leak detection devices that will aid in detecting water leaks and reducing the vast amounts of NRW at the consumer level in T&T. The introduction of nanotechnology-enabled water treatment and reuse (NEWT) poses an exciting opportunity for improved water treatment, drinking water quality, and optimisation of alternative sources of water (reuse). Technologies like NEWT can enable access to affordable, adequately treated water by developing automated transformative and decentralised modular treatment systems, increasing efficiency, reducing costs, and minimising waste products.

WASA's operations should shift to a closed-loop factory that generates water and reuses its by-products (reuse water) to meet the principles of the circular economy. Solar-powered water technology is also gaining momentum, and T&T can explore solar-driven desalination (where expansion is considered for this source), solar-based disinfection, and photocatalytic degradation of disruptors or nitrate reduction to molecular nitrogen by bimetallic catalysts (Alvarez, 2021). This will prove beneficial, particularly in rural areas where less investment would be needed for new centralised water supply infrastructure. The role of self-supply technologies such as solar-powered water pumps and rainwater harvesting, which has already been undertaken in several communities across the country, such as Cumaca, is also relevant for future-proofing the water sector.

There have been advancements in real-time monitoring of water and wastewater operations. The emerging discipline of wastewater-based epidemiology (WBE) is a new approach that can give comprehensive health information on communities. This means monitoring searches for biomarkers in wastewater, which could be harmful chemicals or biological compounds that would indicate the health of a community and emerging threats that that community may be facing. This technology has been used in the COVID-19 pandemic in various countries to give an expression of the level of infection (Ahmed, 2020). T&T's adoption of these approaches will benefit both the immediate sector and provide an early warning system for public and environmental health crises.

T&T also needs to adopt cost-effective technology as it explores and harnesses its water resources. There are a number of geophysical techniques based on the principles of geoelectrics, electromagnetics, seismic, gravity, and magnetics, which are used in the exploration of geological structures, in particular, to discover georesources as well as boreholes and borehole measurements to help identify groundwater systems and their dynamics. A new discipline called hydrogeophysics has been formed and is growing fast (Torres-López et al. 2015). Efforts for the direct detection of groundwater led recently to a new technique: Surface Nuclear Magnetic Resonance (SNMR), which can directly measure the presence of water in the subsurface (Davis, Skibbe, & Müller-Petke, 2019).

The water-energy nexus is highly influential in the T&T context, and the links between water and electricity are many and varied and encompass the production, transportation, and consumption of these resources. Simply put, without adequate water, many of our most common means of energy generation will not be able to meet the demand (Hamiche, Stambouli, & Flazi, 2016). This reliance on water for energy will not diminish in the near future and further highlights the importance of proper water resource management. The research and piloting of hydrogen energy (de Miranda, 2019) in T&T can be a game changer for the water sector. On the 12th of April 2022, it was announced that the NewGen plant would be constructing the world's largest clean hydrogen-producing company of its kind in Trinidad (NewGen, 2022). Several methods are used to create hydrogen fuel, the most common being natural gas reforming (a process that requires water for cooling) and electrolysis of water (DOE 2022).

Green Infrastructure (GI) is also worthy of consideration as it is gaining significant global attention as an intervention for addressing the complex challenges of water management. The GI approach refers to the natural or semi-natural systems that provide services for water resources management with equivalent or similar benefits to conventional (built) “grey” water infrastructure (UNEP, I.; TNC, W., 2014). GI has been effective in water supply regulation (including drought mitigation), water quality regulation, and moderation of extreme events (floods). Noting the vulnerability of T&T to the impacts of climate change along with the status of watershed degradation, implementation of GI can serve as an effective and economically viable alternative to engineered interventions.

Perhaps the most impactful but long-term strategy for future-proofing the water sector is behavioural change. Considering high water consumption levels and the country's watershed degradation status and percentage of NRW, an increased proclivity towards efficient usage, management, and conservation of water resources has the potential to significantly address many of the challenges in the water sector. The application of behavioural economics to cost-effectively solve development challenges such as health care, resource consumption patterns, agricultural practices, and poverty is an emerging trend. Behavioural interventions are backed by data and sustained communication on a long-term vision with the targeted audience.

The paradigm shift required for better water management in T&T will be most effective if supported with an approach that normalises sustainable water use and conservation habits. Citizens will use water wisely and value the environment that sustains that water when it is commonplace to do that and when it is frowned upon to waste water and degrade watersheds. Behavioural interventions must, therefore, be designed with this long-term state of play in focus. The vision for improved attitudes and behaviours about water must be framed within and linked to an overarching approach to building national pride. Therefore, behavioural economic strategies should focus on all users of water, with several campaigns targeting different categories of users such as households, all business sectors, academics, professionals, and WASA.

Finally, because behavioural interventions rely on data, information transparency is critical. Real-time dissemination of data (such as core operations of the utility, individual and national consumption, weather, etc.) and publications on the state of water and the water environment should be available to the public as part of a knowledge and awareness building approach, giving them the tools they need to value and use water wisely.

Overall, moving the country towards a water-secure future requires education and training of the public and corporate society, as well as the generation of a skilled workforce that can take T&T's water and sanitation sector to the future. All the technologies and approaches mentioned require increased competence in operations, maintenance, and repair of water and sanitation infrastructure. In addition, support staff such as finance, communications, and data specialists, as well as many other trained professionals, are required for the operations of the water utility and a proposed OWRM. This cadre of professionals can be the agents of transformational change to educate and build awareness of our efforts to achieve long-term water stability.

Water is an indispensable resource and commodity that cannot be replaced and impacts every aspect of life. Trinidad and Tobago must implement a long-term strategy integrating cutting-edge technology and environmental sustainability. This imperative is particularly vital in our twin-island nation and the Caribbean region, where climate change impacts have proven to be and are projected to be among the most severe. We must begin immediately taking steps to harness our water resources strategically and sustainably. Establishing a collaborative execution platform is paramount to ensuring the achievement of this crucial goal.

5.0 References

Abrahams, N. H., & Jordan, J. (2000). Joint Production and Averting Expenditure Measures of Willingness To Pay: Do Water Expenditures Really Measure Avoidance Costs? *Am. J. Agric. Econ. 82(2)*, 427–437.

Ahmed, W. e. (2020). First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: A proof of concept for the wastewater surveillance of COVID-19 in the community. *Science of The Total Environment 728*.

Alvarez, P. J. (2021). *Nanotechnology - Enabled Water Treatment A Perspective for Distributed Treatment in Developing Countries*. FAO Caribbean.

Baietti, A. ,. (2006). *Characteristics of Well-Performing Public Water Utilities. Water Supply and Sanitation*.

Barnes, B. e. (2002). *The Way Forward: WASA. Cabinet-appointed Committee Report*.

Bartholomew, A. e. (2003). *3-Year Action Plan on the Water Industry*.

Batchelor, D. e. (n.d.). *Staff training for water supply projects in the West Indies*.

CANARI. (2022). Retrieved from https://canari.org/who-we-are/.

CARI-BOIS. (2022). Retrieved from Environmental News Network: https://www.caribois.org/about/the-cropper-foundation/.

CCRIF SPC. (2023, September 19). *Caribbean Water Utilities to Access Parametric Insurance Coverage Against Extreme Weather Events*. Retrieved from CCRIF: https://www.ccrif.org/news/caribbean-water-utilities-access-parametric-insurance-coverage-against-extreme-weather-events?language_content_entity=en.

Climate Studies Group Mona (Eds.). (2020). *State of the Caribbean Climate*. Produced for the Caribbean Development Bank.

Cosgrove, W. J. (2000). *World Water Vision. Making water everybody's business*.

CPG Consultants. (2013). *Caroni River Basin Study Hydrological Study and Storage Option Assessment Caroni Water Treatment Plant Upgrade*.

CSO. (2024). *Population Statistics*. Retrieved from https://cso.gov.tt/subjects/population-andvital-statistics/population/.

Davis, A. C., Skibbe, N., & Müller-Petke, M. (2019). First Measurements Of Surface Nuclear Magnetic Resonance Signals In A Grounded Bipole. *Geophysical Research Letters 46*.

de Miranda, P. E. (2019). Hydrogen Energy. *Science And Engineering Of Hydrogen-Based Energy Technologies*.

DESALCOTT . (2022, April 11). Retrieved from https://desalcott.com/.

Development Bank of Latin America. (2023, October 9). *CAF is implementing a USD 10 million project for flood relief in Trinidad and Tobago*. Retrieved from CAF: https://www.caf.com/en/currently/news/2023/10/caf-is-implementing-a-usd-10-million-project-for-flood-relief-in-trinidad-and-tobago/.

Doria, M. F. (2006). Bottled Water versus Tap Water: Understanding Consumers' Preferences. *IWA Publishing. Journal of Water and Health 4 (2)*, 271-276.

ESL. (2022). *ESIA for the T&T National Water Sector Transformation Program*. Retrieved from https://www.mpu.gov.tt/wp-content/uploads/2022/10/ENVIRONMENTAL-AND-SOCIAL-ASSESSMENT.pdf.

Ferrier, C. (2001). *Bottled Water: Understanding a Social Phenomenon*. World Wide Fund for Nature (WWF).

FFOS. (2022). *Fishermen And Friends Of The Sea*. Retrieved from What We Do: https://ffostt.com/about-us/what-we-do/.

Genivar. (2009). *Development of a Water & Wastewater Master Plan & Policy for Trinidad and Tobago*.

Gill, I. (n.d.). Presentation on Water Utility Operator Training: Trinidad and Tobago Perspective.

Government of Trinidad and Tobago. (1965). Water and Sewerage Act Chap. 54:40, Section 9(1). *Laws of the Government of Trinidad and Tobago*.

Government of Trinidad and Tobago. (1998). Regulated Industries Commission Act Chap. 54:73. *Laws of the Government of Trinidad and Tobago*.

Government of Trinidad and Tobago. (2013, April 11). *Statement by Environment Minister at the opening of the Point Fortin Desalination Plant*. Retrieved from http://news.gov.tt/content/statement-environment-minister-opening-point-fortin-desalination-plant#.

Govia, S. (2020). Using Geology to Meet T&T's Water Demand. Geological Society of Trinidad and Tobago. *Hammer Magazine, Issue 1, Quarter 1 2020*.

Govia, S. (2022). The Top 3 Risks Facing the Caribbean Water and Sanitation Sector. *Future Proof, Issue 1, April 2022*.

Hamiche, A. M., Stambouli, A. B., & Flazi, S. (2016). A Review Of The Water-Energy Nexus. *Renewable And Sustainable Energy Reviews 65*.

Hilson, C. (2018). The Polluter Pays Principle in the Privy Council: Fishermen and Friends of the Sea (Appellant) v The Minister of Planning, Housing and the Environment (Respondent) (Trinidad and Tobago). *Journal of Environmental Law*, 507-517.

IDB Invest. (2021). *Project Disclosure for Advisory Services Projects*.

Ifill, K. (2019). *Performance-Based Contracting: The Severn Trent Case*.

Institute of Marine Affairs. (2016). *State of the Marine Environment Report*.

Inter-American Development Bank. (2011). *Trinidad and Tobago Wastewater Infrastructure Rehabilitation Program (TT-L1018): Orphan WWTPs In The Maloney Sewerage Region*.

Inter-American Development Bank. (2022, December 14). Project Profile: TT-L1055. Washington DC.

Intergovernmental Panel on Climate Change. (2021). *Climate Change 2022: Impacts, Adaptation and Vulnerability*.

Janson, N., Burkhard, L., & Jones, S. (2021). *Caribbean Water Study: IDB Technical Note No. IDB-TN-2320*. Inter-American Development Bank.

Javeed, A. (2022). Green Fund gets refreshed mandate. *Trinidad Express Newspaper*.

Julien, K. e. (2006). *Report on the Short-Term Programme and the Interim Structure for WASA. Cabinet-Appointed Committee*.

Lum Lock, A., & Geoghegan, T. (2006). *Rewarding community efforts to protect watersheds: Case study of Fondes Amandes, St. Ann's, Trinidad and Tobago*.

M. M. Dillon Limited. (1967). *Trinidad Water Resources Survey: 2nd Interim Report on Staffing and Organisation of Water Resources Agency*.

Mahabir, S. (2015). IWRM Working In Trinidad And Tobago: A Benefits Analysis Of The Adopt A River Programme. *Caribbean Water and Wastewater Association*. https://cwwa.net/wp/wpcontent/uploads/2019/04/IWRM_working_in_Trinidad_and_Tobago_An_analysis_of_the_Adopt_A_River_Programme.pdf.

McTaggart, M., Stevens, G., & Singh, K. (2007). New Beetham Wastewater Treatment Plant – A First Step towards Modernizing Wastewater Treatment in Trinidad and Tobago. *Proceedings of the Water Environment Federation 2007 (11): 6352-6368. Water Env*.

Ministry of Finance. (2011 – 2020). *Estimates of Development Programme (2011 – 2020)*. Government of Trinidad & Tobago.

Ministry of Finance. (2011 - 2022). *Estimates of Revenue and Expenditure of Statutory Boards and Similar Bodies and the THA (2011-2022)*. Government of Trinidad & Tobago.

Ministry of Planning and Development. (1999). *Water Resources Management Strategy Study: Main Report*. Government of T&T.

Ministry of Planning and Development. (1999). *Water Resources Management Strategy Study: Annex 1 Water Resources Planning 1B Trinidad – Measures and Strategies*. Government of T&T.

Ministry of Planning and Development. (1999). *Water Resources Management Strategy Study: Annex 17 Action Plan*. Government of T&T.

Ministry of Public Utilities. (2016). *State of the Water Sector*.

Ministry of Public Utilities. (2022, April 12). Retrieved from https://www.mpu.gov.tt/our-history/.

Ministry of Public Utilities. (2022, November 10). National Integrated Water Resources Management Policy. Port-of-Spain: Government of the Republic of Trinidad and Tobago.

NewGen. (2022). *Newgen Energy Ltd*. Retrieved from https://newgenenergyltd.com/author/newgen-energy-ltd/#:~:text=Trinidad%20and%20Tobago%20is%20already,the%20Point%20Lisas%20Industrial%20Estate.

Office of the Auditor General. (2021). *Report of the Auditor General of Public Accounts of the Republic of T&T for the Financial Year 2020*. Government of Trinidad & Tobago.

Olson, E. (1999). *Bottled Water: Pure Drink or Pure Hype?* New York: Natural Resources Defence Council (NRDC).

Organisation for Economic Co-operation and Development. (2009). *Private Sector Participation in Water Infrastructure: OECD Checklist for Public Action*.

Pantin, D., & Krishnarayan, V. (2003). *Incentives for watershed management in Trinidad: results of a brief diagnostic*. Caribbean Natural Resources Institute.

Parliament of the Republic of T&T. (2012). *8th Report of the Joint Select Committee on Ministries, Statutory Authorities and State Enterprises on Water Resources Agency*.

Particip. (2019). *Vulnerability and Capacity Assessment Report Trinidad and Tobago.*

Peters, E. J., & Balfour, K. D. (2014). Water Losses And The Potential Of Reducing System Pressure: A Case Study In Trinidad. *The West Indian Journal Of Engineering 37*.

Phillip, M., & Salim, S. (2023). *20-Year Domestic Water Demand Forecast for T&T*. Retrieved from https://www.mpu.gov.tt/crwlc2023/files/talks/20%20Year%20Domestic%20Water%20Demand%20Forecast%20for%20TT%20-%20Shehnaaz%20Salim.pdf.

PWC. (2013). *PWC Budget Memorandum*. Port of Spain: PWC.

Randolph, B., & Troy, P. (2008). Attitudes to Conservation and Water Consumption. *Environmental Science and Policy*.

Safege. (2017). *Trinidad and Tobago Corporate Governance Services for the Multi-Phase Wastewater Rehabilitation Program (Phase 1)*.

Shiklomanov, I. A. (1998). *World Water Resources A New Appraisal and Assessment for the 21st Century*. Paris: United Nations Educational, Scientific and Cultural Organization.

Sitzenfrei, R., & Rauch, W. (2014). Investigating Transitions of Centralized Water Infrastructure To Decentralized Solutions – An Integrated Approach. *Procedia Engineering 70*, pp. 1549-1557.

Sub-Committee of Cabinet. (2020). *Report of the Cabinet Sub-Committee Appointed to Review the Operations of WASA and to Determine the Strategy for enabling the Authority to Achieve its Mandate*.

Subcommittee of the Standing Committee on Energy. (2004). *Water Sector Strategic Plan: Laying the Foundation*.

T&T Guardian. (2024, July 9). *WASA unveils state-of-the-art operational control centre*. Retrieved from https://www.guardian.co.tt/news/wasa-unveils-stateoftheart-operational-control-centre-6.2.2046713.2151f35da6.

T&T Newsday. (2022, October 7). *Gonzales: Water Resource Management Office to be set up*. Retrieved from https://newsday.co.tt/2022/12/07/gonzales-water-resource-management-office-set-up/.

Trinidad and Tobago Bureau of Standards. (2023, January 22). TTS 664:2022, *Wastewater Reuse – Agricultural and other Applications – Requirements*. Retrieved from TTBS: https://gottbs.com/product/tts-6642022-wastewater-reuse-agricultural-and-other-applications-requirements/.

Trinidad and Tobago Newsday. (2023, October 13). *Minister: Improved water supply coming in 2024*. Retrieved from Newsday: https://newsday.co.tt/2023/10/13/minister-improved-water-supply-coming-in-2024/.

Trinidad and Tobago Parliament. (1965, August 6). Debates of the House of Representatives. *Hansard Report*. Government Printery.

UN Water. (2023, December 8). *Latin America and the Caribbean*. Retrieved from SDG6 Data Portal: https://www.sdg6data.org/en/region/Latin%20America%20and%20the%20Caribbean.

UN Water. (2023, December 8). *SDG 6 Data Portal*. Retrieved from https://www.sdg6data.org/en/country-or-area/Trinidad%20and%20Tobago#anchor_6.1.1.

UNEP, I.; TNC, W. (2014). Green infrastructure: guide for water management.

United Nations Food and Agricultural Organisation. (2017). *Aquastat Database*.

Water and Sewerage Authority. (2015). *WASA 50 Years and Beyond – Summary Study Guide*.

Water and Sewerage Authority. (2011). *National Quiz Secondary Schools Competition: Supplement 2*.

Water and Sewerage Authority. (2022). *Wastewater*. Retrieved from https://www.wasa.gov.tt/WASA_AboutUs_history1.html#:~:text=Lock%20Joint%20(America%20Ltd.),and%20Port%2Dof%2DSpain.

Water and Sewerage Authority. (n.d.). *WASA Multiphase Wastewater Rehabilitation Program - Malabar Wastewater Project Details*. Retrieved from https://www.wasa.gov.tt/WASA_Wastewater%20Rehab_Malabar2890Details.html.

Water and Sewerage Authority. (n.d.). *WASA Multiphase Wastewater Rehabilitation Program - San Fernando Wastewater Project Details*. Retrieved from https://www.wasa.gov.tt/WASA_Wastewater%20Rehab_SanFernando2890DetailsPg2.html.

Water Resources Agency, Water and Sewerage Authority. (2018). Map of Trinidad's Groundwater Wells.

Water Resources Agency, Water and Sewerage Authority. (n.d). *Movement of Water Resources Management Function to the Ministry of the Environment and the Formation of the Water Resources Management Authority: Strategic Issues*.

Water Resources Survey. (1972). *Annual Data Report*.

World Bank Group. (2024). *World Development Indicators*. Retrieved from https://datacatalog.worldbank.org/search/dataset/0037712.

Notes

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