Guyana Society for Biodiversity and Ecosystems (GSBE)

A Review of the Status of the Freshwater Ecosystems in Guyana

Final Report

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ACRONYMS

CCME	Canadian Council of Ministers of the Environment
EDWC	East Demerara Water Conservancy
FAO	Food and Agriculture Organization
GoG	Government of Guyana
GSWC	Georgetown Sewerage and Water Commission
GUYWA	Guyana Water Authority
GWI	Guyana Water Incorporated
IWRM	Integrated Water Resource Management
MMAC	Mahaica – Mahaicony – Abary Conservancy
MoA	Ministry of Agriculture
NDIA	National Drainage and Irrigation Authority
NDS	National Development Strategy
WHO	World Health Organisation
WWF Guianas	World Wildlife Fund Guianas

ABBREVIATIONS

H_2SO_4	sulfuric acid
HCl	hydrochloric acid
km	kilometres
km^2	square kilometres
l/min	liters per minute
m	metres
m^3/yr	cubic meter per year

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1 INTRODUCTION

1.1 Background

Water is an essential substance upon which all life depends. More so, freshwater resources are the lifeblood of any one country. Over the past decades, impacts of climate change such as dry spells, droughts, sea level rise and flooding have put at risk the world's population, critically, developing countries of Africa, Asia, Latin and South America, and small island developing states (SIDS) of the Caribbean region. In addition, increase population sizes places pressure on the improvement of socio-economic state for these countries, and this is typically achieved through agricultural expansions, industrial development, and exploitation of natural resources. These activities result in both exploitation and degradation of freshwater resource systems as a result of overuse, and chemical and other forms of contamination.

Guyana has an abundance of freshwater resources and this include surface and underground water resources (US Army Corps of Engineers 1998). In the coastal zone and hinterland regions of Guyana, relatively large volumes of freshwater are available in close proximity to the local population. The FAO reported in 2015 that Guyana's internal renewable water resources (IRWR) are estimated at 241 km^3/year, with its surface water resources estimated at 241 km^3/year, groundwater resources at 103 km^3/year and the overlap between surface water and groundwater is estimated to be 100 percent (FAO 2015).

Guyana's population for 2018 is estimated at 782,225, with 90% of its population living on the coastal strip. To add, Guyana's national water footprint as it relates to the total amount of freshwater used to produce goods and services consumed by its population is an average of 1548 m^3/yr per capita (Water Footprint Network 2018). The coastal zone accounts for only 10% of the total land area and is just 40 miles across at its widest point (World Population Review 2018). More so, in the coastal zone, most communities rely on groundwater from aquifers for their domestic and industrial supply. Water used in rice and sugarcane cultivation and other agricultural activities is mainly supplied from inland conservancies. In addition, the Capital city of Georgetown has the largest concentration of the country's population of about 240,000 (World Population Review 2018), and a significant amount of its freshwater supply is sourced from the East Demerara Water Conservancy (EDWC). Moreover, most hinterland communities have a heavy dependence on freshwater resources from rivers and other open wetlands for their domestic and agricultural use and for support of mining activities.

Recently, there have been concerns about the status of Guyana's freshwater resources. In the hinterland communities in areas such as the Essequibo, Mazaruni, Cuyuni and Potaro River Basins, this concern is mainly due to the growth and expansion of the mining and logging sectors. There have been reported cases of irresponsible dumping of domestic and industrial wastes and mercury contamination of aquatic ecosystems in areas where mining is predominant. The South-Central part of Guyana, the Rupununi region, is dominated by savannahs where floods and droughts due to seasonal weather conditions put the human populations and their livelihoods at risks. In the coastal areas, mainly in urban zones, poor sanitation and improper waste management from households, commercial and industrial practices, and run-off and leaching of agrochemicals used in crop production serve to compound contamination of freshwater resources in Guyana (US Army Corps of Engineers 1998).

Although Guyana is regarded as an ecological creditor country (Global Footprint Network, 2008) having an abundance of freshwater resources, there are still a number of key concerns about its water resources that need to be addressed to ensure sustainable use of this natural resource. There exists critical scientific data and information gaps on Guyana's freshwater resources particularly on aspects such as water quality, quantity, current and future uses, sectoral demands and human-aquatic ecosystem interaction and impacts. In addition to existing data gaps, available information is highly dated and serves limited purpose with respect to the planning and management of the country's water resources.

As such, it is anticipated that this study will serve as a precursor to a number of scientific and technical investigations of freshwater ecosystems in Guyana to fill existing knowledge gaps and serve as one of the planks on which an integrated management approach can be taken to enable effective management of the country's water resources, as Guyana continues to move towards its green state development agenda.

1.2 Study Aim and Objectives

The primary aim of this review was to conduct a rapid assessment and compile a comprehensive report to describe the status of Guyana's freshwater resources, both surface and ground water, with respect to the parameters:

- Water quality,
- Water quantity,
- Current and future uses,
- Problems and challenges confronting the water sector, and
- Potential for provision of ecosystem services, including livelihood activities.

2 METHODOLOGY

This review was conducted over a period of one month, July 17 to August 18, 2017 with data collected from literature sources such as:

- Books,
- Electronic journal publications,
- Legal and other government documents.
- Reports,
- Reputable websites,

Additionally, interviews were conducted where open-ended questions were utilised as the structure of the interviews. Three (3) sessions were done with two (2) key stakeholders involved in the water resource sector. These agencies were:

- Hydrometeorological Department, Ministry of Agriculture (MoA), and
- The Guyana Water Incorporated (GWI).

3 RESULTS

This section of the report will first provide an overview of the hydrology of Guyana surface and ground fresh water resources taken from two comprehensive literature: The Water Resource Assessment of Guyana (1998) and Customary Water Laws and Practices: Guyana (2010).

Further, this section will discuss the nature of the water resources sector in Guyana with respect to parameters: water quality, water quantity, water uses, problems and challenges confronting the water sector and potential for provision of ecosystems services, and data gaps, each in its respective sections. The information in these subsections was gathered from various sources of available literature in addition to interviews conducted with the resource personnel from two (2) key stakeholders: Guyana Water Incorporated (GWI) and the Hydrometeorological Department, Ministry of Agriculture (MoA).

3.1 Hydrology of Guyana

3.1.1 Surface Water Resources

Guyana occupies 215, 000 km^2 of territory and has a vast network of rivers mainly the Berbice, Demerara, Essequibo, Corentyne (River bordering Suriname) (US Army Corps of Engineers 1998), Abary, Mahaicony, Mahaica, Pomeroon, Waini and Barima rivers which discharge into the Atlantic Ocean (Narayan 2006), together with a host creeks and streams (Janki, 2010) that have many rapids and waterfalls (US Army Corps of Engineers 1998). To add, no official information has been found on what the percentage of the country's territory is dominated by vast network of freshwater water systems.

More so, according to Janki (2010) the Essequibo River drains over half of the country and is a major river by international standards. The Essequibo river flows through the entire length of the country from the southern border to the Atlantic Ocean and its major tributaries include the Cuyuni, Mazaruni, Potaro and the Rupununi rivers. Moreover, Guyana has 14 major drainage basins with six (6) of the rivers forming parts of the country's boundary. In addition, these rivers provide abundant surface water resources with each having marked seasonal differences in flows (US Army Corps of Engineers 1998).

Surface water is extracted from conservancies (reservoirs), shallow streams, canals. The US Army Corps of Engineers (1998) reported that 10 percent (%) of the country's drinking water comes from its surface water. It is worthy to note that the GWI as the water and sewerage services public utility company, did not provide a sound estimation as to validate or dismiss the reported percentage. To add, Janki (2010) stated that the amount of surface water resources in Guyana compares favourably with the level of consumption.

3.1.2 Ground Water Resources

Ground water is the main source of public water supply in Guyana (US Army Corps of Engineers 1998, and Aubrey Roberts, pers. Comm.). It is mostly abundant along the coastal zone and has been the source for public water supply in the city of Georgetown since the early 19th Century. A number of wells have been constructed in Georgetown, along the coastal strip and inland alongside the Demerara river (Guyana Water Authority 1993). Beneath the coastal zone of Guyana, lies three distinct layers of sand: The Upper Sands, A sands and B sands (A and B are separated by clay) (Janki 2010). These are the three distinctive sand aquifers down to 400 m that are being exploited beneath the coastal zone. According to the Guyana Water Authority (1993), groundwater from the Upper Sands is no longer being pumped due mainly to issues relating to quality. However, during this study, the GWI did not report on this matter.

Another key source for groundwater is the White Sands Formation which is located in the southern coastal lowlands regions and northern interior plains region of Guyana. This formation is centred around Linden town and yields moderate to large quantities of freshwater that are available from unconsolidated deposits of sand and sandstone at depths less than 30 m (US Army Corps of Engineers 1998).

In addition, the Takutu Sandstone Formation is the principal aquifer source for the northern savannahs of the Rupununi region and freshwater yields from the formation are moderate. Janki (2010) reported that groundwater is increasingly used in the Amerindian communities and this was reported by the Hydrometeorological Department that there is an increasing number of "boreholes" [number not disclosed] in the hinterland (Vivianna Critchlow, pers.

Comm.). However, Janki (2010) stated that the extent of groundwater supplies in the hinterland is not known and it is unclear whether this resource is being used at a sustainable rate.

The US Army Corps of Engineers (1998) stated that small to large quantities of fresh ground water is obtained in the vicinity of the Merum Mountains located in the western part of Guyana. They stated that depth to ground water varies from 10 to 300 meters and that most of the productive ground water zones are fractures. The report also highlighted that minimal information exists on the ground water resource for this aquifer.

Furthermore, throughout the interior, small to moderate quantities of fresh ground water is available from granites, gneisses and sand deposits from various formations called the Trans-Amazonian Granitoids. These types of rocks are scattered throughout Guyana and water is generally available from fracture zones depths ranging from 3 to 150 meters (US Army Corps of Engineers 1998).

In the Southern part of Guyana, in the vicinity of the Kanuku mountains and in the western central part of the country, in the vicinity of the Karanambu area, limited to moderate quantities of fresh ground water is available from metamorphic rocks at depths ranging from 10 to 300 meters. In the north-western coastal region, bordering the Waini River, large quantities of brackish to saline water are available from unconsolidated clay and sand deposits, at depths ranging from 3 to 30 meters (US Army Corps of Engineers 1998). In closing, the Army corps reported that this region [north-western coastal region] is not considered for ground water exploration due to tidal flooding and continuous saturation.

4 WATER QUALITY

The US Army Corps of Engineers (1998) reported that the quality of surface water is a growing concern in Guyana, with biological and chemical contamination being most prevalent along the coast. Contaminations were reported to occur mainly through:

- Inadequate sewage systems in the city of Georgetown to dispose of waste in the Atlantic Ocean,
- Contamination is likely to occur during the wet and dry seasons since open-ditch sewers (pit latrines) and septic tanks may flood during wet rainy seasons and during dry seasons, there may be inadequate flow to flush and dilute the various types of contaminants.

Ground water is suitable for most uses, although biological and chemical contamination of ground water is more common near highly populated areas and in shallow aquifers (US Army Corps of Engineers 1998).

4.1 Surface Water Quality

4.1.1 Main Sources of Contamination

As it relates to the quality of fresh surface water ecosystems in Guyana, the US Army Corps of Engineers (1998) reported that contamination occurs mainly by:

- Improper and inadequate waste disposal;
- Agrochemicals [fungicides, weedicides, pesticides, fertilisers] used in rice, sugarcane cultivation and other small, medium and large scale agricultural activities;
- Heavy metals contamination from the mining of gold, diamond, bauxite, and manganese; specifically: sodium hydroxide [caustic soda] contamination from bauxite production; mercury, cyanide, sulfuric acid (H_2SO_4), and hydrochloric acid (HCl).

To add, mercury is used in gold extraction, significantly by the small-scale gold mining (SSGM) operations, where arsenic (a heavy metal) is generated as a by-product. Major rivers such as the Barima and Essequibo and its tributaries: the Cuyuni, and Mazaruni are mostly polluted by these chemical pollutants generated from gold and diamond mining operations (US Army Corps of Engineers 1998). The misuse of mercury in small-scale gold mining is a major source of water pollution in Guyana. The growth of SSGM in Guyana has increased by 50 % between the years of 2008 – 2013, therefore, doubling the importance of gold production to the Guyanese economy (Legg *et al.* 2015). Legg *et al.* in 2015 stated that based on figures obtained for 2008, the United Nations (UN) estimated that a volume of 15 tonnes/year (range 7.5–22.5 tonnes/year) of mercury was used in Guyana. This is almost doubling the amount used in both Suriname and French Guiana (7.5 tonnes/year (range 3.8–11.3 tonnes/year) for 2008. The authors further stated contamination of freshwater is the most likely important point in the mercury cycle as these water bodies serve as a significant route for the transport of freshly released mercury away from mining sites, as well as being the major site of mercury methylation and biomagnification (Legg *et al.* 2015).

Water quality of surface freshwater systems are also affected by gold mining through increased sedimentation. In particular, gold mining activities release sediments by hydraulic means and alteration (damming and dam failures) of natural water courses. These actions have caused changes to the physical quality of water systems within and around the mined areas by increasing the turbidity of the water, and also disrupts the water supply (Legg *et al.* 2015). The Hydrometeorological Department reported that based on observations, mining [gold] has changed the rivers (no listing was provided), and that the waters are highly turbid (Diana Misir, pers. Comm.).

4.2 Monitoring of Surface Water Quality in Guyana

By mandate of the Water and Sewage Act of 2002 (Chapter 30:01: PART III) the Hydrometerological Department is responsible for monitoring the quality of surface and ground fresh water resources in Guyana.

The Hydrometerological Department reported in the interview that quality assessments of fresh surface water have not been continuous mainly because of distance and logistical challenges for the Department to get to the sites for assessments to be done. However, no official data/information was provided by the Department to report on the current quality of the water systems being monitored. Currently, the department is monitoring the following physical parameters on the basis of field visits to the respective hydrological stations. These parameters are:

- pH (WHO standards: 6.5-8.5 pH)
- Conductivity (μS/cm^2) (WHO standards: 5-25 μS/cm^2)
- Temperature (ºC)
- Oxidation Reduction Potential (ORP)
- Dissolve Oxygen (DO %)

It is worthy to note that the Department is not assessing any biological parameters as it relates to the water quality of surface fresh water systems in Guyana (Diana Misir, pers. Comm.). Contrastingly, water quality assessments done by other public and private institutions such as the Guyana Geology and Mines Commission (GGMC), Guyana Environmental Protection Agency (EPA), World Wildlife Funds (WWF) – Guianas (Guyana), Iwokrama International Centre and Conservation International (Guyana), etc., are not reflected in the findings of this report due to challenges in arranging interview sessions with resource personnel from the respective organisations.

Moreover, GWI (established from the merger of GUYWA and GS&WC in 2002) as the water and sewerage services, public utility company monitors the quality of surface water only in communities (listing not provided) where surface water is utilised as a source of potable water. Monitoring is done to ensure that the quality of the water is up to standard for public utility, which is measured against the WHO standard. The quality assessment of the surface water utilised is generally done on a monthly basis, where the physical parameters: pH and turbidity are assessed. There is no systematic testing for heavy metals and biological contaminants. However, in other areas, for instance, the Shelter Belt Treatment Plant (largest surface water plant utilised by GWI), pH and turbidity (results were not provided) are assessed daily by GWI (Aubrey Roberts, pers. Comm.).

4.3 Ground Water Quality

4.3.1 Main Sources of Contamination

As it relates to the quality of fresh ground water ecosystems in Guyana, the US Army Corps of Engineers (1998) reported that contamination of aquifers occurs mainly by:

- Improper disposal of animal and human wastes. This causes biological contamination mostly to shallow aquifers by pathogens.
- Chemical contamination primarily from agrochemicals used in rice and sugarcane cultivation and from other lowlands farm lands on the coastal zone.

In addition, Wright in 2014 reported that contamination of Guyana's Coastal Aquifer is potentially threatened by contamination within the recharge zone and from activities adjacent to wellheads of production wells. Also, spills or seepage of hazardous wastes, petroleum at gas stations/terminals, and other pollutants (not listed) in the recharge zone can enter and contaminate the aquifer. The author mentioned an example of a waste-oil pool in Linden where residents have been dumping waste-oil for the past decade, which likely resulted in the waste-oil migrating into the water table (Wright 2014).

Wright (2014) further noted that data concerning the deeper A and B Sand aquifers along the coast indicated that they are confined and are not contaminated. However, they stated that A Sand aquifer has elevated iron contents, while B Sand aquifer has elevated temperatures and a hydrogen sulphide odour. The report also stated that regardless of this confinement, contamination is still possible from recharge areas, or improperly constructed wells. Fractures (faults) in aquifers generally transport contaminations in a variety of directions. To add, the Hydrometeorological Department reported similarly that hand dug wells (shallow water wells) becomes desiccated in the dry season which serves as a point for surface-ground water interface creating contamination (Vivianna Critchlow, pers. Comm.).

4.4 Monitoring of Ground Water Quality in Guyana

The Hydrometerological Department reported that there are currently no quality assessments for ground water aquifers in Guyana. Although, this is their mandate, at this point, there are no systems in place that allow the Department to assess and thus, monitor the water quality of Guyana's aquifers (Vivianna Critchlow, pers. Comm.).

Moreover, GWI as the water and sewerage services public utility company monitors the quality of ground water only from wells (listing not provided). Similarly, water quality assessments (physical parameters tested were not stated) from wells are generally done on a monthly basis to ensure that the quality of the water is up to standard stipulated by the WHO for public utility (results were not provided) (Aubrey Roberts, pers. Comm.).

5 WATER QUANTITY

The Hydrometerological Department (2017) reported that the quantity of surface water is largely affected by climatic and weather conditions of Guyana (wet and dry seasons coupled by the consequences of climate change: droughts and heavy rainfall), as quantity changes with seasons (Diana Misir, pers. Comm.).

5.1 Surface Water Quantity

The quantity of surface water is measured on a monthly basis by the volume discharged in liters per minute (l/min). The Hydrometerological Department currently has sixty-one (61) surface water-level monitoring stations of which sixteen (16) monitor water levels continuously with water level recorders, ten (10) operate manually and thirty (30) using Frog Loggers (automatic stations) to transmit water level data from the East Demerara Water Conservancy (EDWC) (Guyana. Ministry of Agriculture 2016 and Diana Misir, pers. Comm.). To add, no official data/information was provided by the Department to report on the current quantity of the water systems being monitored. However, this data is only for official use by the government, and external agencies must pay a stipulated fee to the Department to be given access to the raw data (Diana Misir, pers. Comm.).

Furthermore, in January 2016, The Ministry of Agriculture published on their website that in collaboration with its National Drainage and Irrigation Authority (NDIA) they have been closely monitoring the water levels and maintaining national conservancies and canals in the main *agricultural* Administrative Regions: 2, 3, 4, 5, 6, and 10, because of the persistent condition of very little to no rainfall (Guyana. Ministry of Agriculture 2016). They stated that low water levels (measurements and period of assessment not stated) were reported in the Manikuru (Main Canal) and Tapakuma, Golden Fleece, Ituribisi, and Mainstay Water Conservancies in Region Two. In Region Three, the water level was reported to be low in the Boerasirie Water Conservancy, while in Region Four, there was insufficient water at Belfield, Cove and John, Hope Dochfour, and Cane Grove canals. Meanwhile in Georgetown, at GWI's shelterbelt location on Vlissengen Road, pumping has been reduced by more than 50 percent. In Region Six at Crabwood Creek they reported that there is insufficient water (no specific description of quantity/condition) causing the irrigation pumps to inoperable (Guyana. Ministry of Agriculture 2016).

5.2 Monitoring of Surface Water Quantity in Guyana

By mandate of the Water and Sewage Act of 2002 (Chapter 30:01: PART III) the Hydrometerological Department is responsible for the monitoring of surface and ground quantity in Guyana.

In addition, the main institutions dealing with irrigation and potable water management are:

- The NDIA, created in 2004, is in charge of the maintenance and delivery of irrigation water countrywide. The NDIA works with the conservancies' boards, water users' associations (WUAs), farmers groups and local government bodies to maintain irrigation and drainage systems in an operational and efficient manner (FAO 2015).
- The GWI, which is in charge of the drilling of wells and delivery of portable water countrywide (FAO 2015). Furthermore, the GWI as the water and sewerage services public utility company, measures the quantity of surface water in terms of flow from their twenty (25) treatment plants throughout Guyana. The flow of water is measured in meters per second (m/s) or meters per hour (m/h).

Moreover, the Hydrometerological Department does not monitor the quantity of surface water extracted for various uses throughout Guyana (Diana Misir, pers. Comm.) and GWI reported the same (Aubrey Roberts, pers. Comm.). Therefore, besides the monthly measurements of surface water discharge and flows from GWI treatment plants, there are no other detailed monitoring of surface water quantity in Guyana.

5.3 Ground Water Quantity

The Water & Sewerage Act of 2002 mandates the Hydrometeorological Service to monitor and manage Guyana's groundwater resources (aquifers) and to develop and operate a national groundwater resources data base. However, this sub-section within the Water Resources Section of the Hydrometerological Department did not have any staff, reported in its Annual Report of 2015 (Guyana. Ministry of Agriculture 2016). As such, there is no up-to-date quantifiable data available on the status of the quantity of Guyana's groundwater ecosystems (aquifers) (Vivianna Critchlow, pers. Comm.). To add, forms for license to abstract water and permission to drill wells are usually reviewed by the Ministry of Agriculture before approvals are granted (Guyana. Ministry of Agriculture 2016).

However, this study found that from that point forward (2015), the Ground Water sub-section of the Department now has a hydrologist, but still no monitoring of ground water resources has been commenced (Vivianna Critchlow, pers. Comm.). Moreover, because GWI abstract ground water to provide their public utility service, the company has accepted a role in monitoring the flow of fresh ground water from their wells.

6 FRESHWATER ECOSYSTEM SERVCIES

This section gives an overview of general ecosystem services provided by freshwater as described in the report "Freshwater Ecosystem Services: Ecosystems and Human Well-being: Policy Responses" by Aylward *et al.* in 2005. It also serves as a preamble to the following chapter as the services presented in this section are described in terms of uses (direct benefits), both current and future, derived from freshwater ecosystems in Guyana.

6.1 Human Well-being and Fresh Water

Ecosystem services are defined as the benefits provided to people, both directly and indirectly, by ecosystems (in this case freshwater) and biodiversity. Aylward *et al.* in 2005 stated that fresh water is a ''provisioning'' service as it refers to the human use of fresh water for domestic use, irrigation, transportation and power generation.

Fresh water ecosystems generally provide cultural, regulating, and supporting services that contribute directly and indirectly to human well-being through recreation, scenic values, and maintenance of fisheries. These are further described below.

6.1.1 Provisioning Services

- Water (quantity and quality) for consumptive use: domestic, agriculture and industrial.
- Water for non-consumptive use: transport/navigation and generating of electrical power.
- Aquatic organisms for food and medicines (Aylward *et al.* 2005).

6.1.2 Cultural Services

- Recreation for instance: sport fishing
- Tourism: river viewing
- Existence values such as personal satisfaction from free-flowing rivers (Aylward *et al.* 2005).

6.1.3 Regulatory Services

- Maintenance of water quality through natural filtration and water treatment (Aylward *et al.* 2005).

6.1.4 Supporting Services

- Role in nutrient cycling (Aylward *et al.* 2005).

7 CURRENT AND FUTURE USES OF FRESHWATER RESOURCES

Fresh water resources in Guyana are mainly used in domestic, industrial, and agricultural uses (US Army Corps of Engineers 1998). Other potential and future uses of water resources are discussed.

7.1 Domestic Uses

The US Army Corps of Engineers (1998) reported that nationally, about 90 % of the domestic water supply comes from ground water sources, whilst the remaining 10 % comes from surface water. Further, Georgetown has a demand of 20 million gallons per day with about 8 million being sourced from surface water and about 12 million from ground water (US Army

Corps of Engineers 1998). For the coastal zone, surface water is supplied by the East Demerara Water Conservancy (EDWC) (US Army Corps of Engineers 1998) which is located in the Administrative Region 4, Demerara-Mahaica (WWF Guianas 2012).

The EDWC extends between the Mahaica and Demerara Rivers, inland from the Atlantic Coast, with an approximate length of 72 km (WWF Guianas 2012). The EDWC has a capacity of holding 336.7 km^2 equalling to 100 billion gallons of water (WWF Guianas 2012) where domestic water supply has a third priority for the use of surface water supplied by this conservancy (US Army Corps of Engineers 1998). This is because, the conservancy supplies an extensive network of drainage canals which generally leads to agricultural lands (WWF Guianas 2012). Therefore, in periods of short water supply (direct precipitation) into the system, irrigation and transportation demands must be met first (US Army Corps of Engineers 1998). Excess water from the conservancy can then be used for domestic supply (US Army Corps of Engineers 1998).

7.2 Industrial Uses

The supply of water for industrial purposes (mostly in manufacturing) comes from both surface and ground water sources. Industrial uses accounts for about 40 % of the ground water supply (US Army Corps of Engineers 1998). As it relates to future use of water, the US Army Corps of Engineers (1998) reported that the demand for ground water will increase for industrial purposes which would be directly related to the decline in supply of surface water (Seulall 2013). The decline of surface water supply is predominantly linked to dry spells or droughts. Recent episodes of dry spells or droughts experienced in Guyana were between:

– 1997-1998: The El Niño phenomenon was one of the most severe, if not the most severe, in Guyana’s history.

Gold mining is practiced through hydraulic dredging of the rivers and land dredging where river water is also used to wash the dredged materials to extract the gold (US Army Corps of Engineers 1998). It was estimated that this El Niño resulted in gold export, Guyana's most lucrative export, declining by 40% during that period, since the rivers were dried up preventing gold to be mined (Seulall 2013).

- May 2009 – Feb 2010: meteorological drought also caused concerns in agriculture community, and
- Sept 2012 - Jan 2013 dry spells: some agriculture areas in Guyana were water stressed (Seulall 2013).

It can therefore be expected, given the reoccurrence of dry spells or droughts in the country, developers in the industrial sector will be or are more inclined to invest in wells (ground water) to secure a constant supply of fresh water for their respective manufacturing processes.

7.3 Agricultural Uses

Agriculture requires intensive irrigation. Along the coastal zone of Guyana, water for irrigation of agricultural fields is generally supplied by several conservancies using reservoirs, canals and other irrigation ditches. Each major administrative region has a water conservancy which supplies fresh surface water to surrounding agricultural fields (US Army Corps of Engineers 1998). These are:

- The East Demerara Water Conservancy (EDWC) supplies Region 4 (WWF Guianas 2012).
- The Mahaica – Mahaicony – Abary (MMA) Conservancy spans from the Mahaicony River to the Berbice River in Region 5 and it has a storage capacity of 609 million cubic meters (WWF Guianas 2012).
- The Essequibo Coast lakes (inland permanent fresh water lakes) and other wetlands located in Region 2, Pomeroon-Supenaam. Offtake from these lakes is through water withdrawal for domestic, industrial and agricultural uses. There is extensive rice cultivation on the Essequibo Coast and because of this, the lakes are managed as reservoirs (WWF Guianas 2012).

7.4 Freshwater Aquaculture

Aquaculture of shellfish and finfish for food and ornamental fish in both brackish and freshwater is expanding and thriving (Guyana NDS).

7.5 Hydropower

Currently there exists no hydropower plants in Guyana. However, a total of sixty-seven (67) potential sites have been identified to developed plants along major rivers and tributaries such as the Essequibo, Demerara, Berbice, Potaro, Cuyuni, Mazaruni, Barima, New River, Moco-Moco, and Rewa, etc. (Guyana Energy Agency 2018). This includes the Amaila Falls Hydropower Project (AFHP) located on the Kuribrong River in West Central Guyana and about 250 km southwest of Georgetown.

7.6 Transportation

Inland waterways are used for transportation by the logging and mining industry. Significantly, the Indigenous population use the rivers for local transportation. More so, Guyana has about 6,000 km of navigable waterways. The Essequibo, Demerara and Berbice Rivers are navigable by oceangoing vessels for 80, 100 and 150 km, respectively. There also exists major ports in the towns of Bartica, Parika, Georgetown, Linden and New Amsterdam (US Army Corps of Engineers 1998).

7.7 Recreation

Main recreational activities associated with fresh surface water resources are:

- Boat rides along the Essequibo River,
- Day and packaged tours to Kaieteur Falls, Orinduik Falls, and Baganara island, Baracara Falls, Marshall Rapids, Saxacalli Beach,
- Sport fishing adventure to Rockstone (The Rockstone Fish Festival), Kurupukari on the Essequibo River,
- Fishing Expedition to Simoni Lake, Bat Creek, Rupununi and Rewa Rivers.

Manmade and natural wetlands in Guyana are also worthy to explore to serve as potential sites for ecotourism (livelihood activities), for instance, in the North-West Wetlands located in the north-western portion of Guyana, and the North and South-Central Wetlands (the Rupununi wetlands) (WWF Guianas 2012).

7.8 Water Export

The GWI plans to explore the options of exporting raw and treated water from Guyana for commercial and industrial purposes (Aubrey Roberts, pers. Comm.).

8 PROBLEMS AND CHALLENGES CONFRONTING THE FRESHWATER SECTOR

Key problems and challenges confronting the fresh water sector in Guyana include:

– Diversion and abstraction of surface water

As reported previously, the damming of waterways done in mining, logging and for other industrial uses, influences the supply of water to other stakeholders (water users). In particular, this is conflicting with the Indigenous communities in the hinterland regions that are in close proximity to mining sites because these activities create water stress in the communities due to the interruption of the natural seasonal flow variations.

– Over abstraction of groundwater

This may cause a continued decline in ground water levels and consequently, aquifers being depleted (Guyana Water Authority 1993).

– Illegal construction of boreholes (any well, excavation or any artificially constructed or improved underground cavity).

This allows for usage of ground water in an unsustainable manner, since there is no monitoring of water quantity utilised, resulting in future shortages (Janki 2010).

– Water Pollution

Increased turbidity and chemical contamination from mercury, cyanide and other chemical wastes (petroleum and related products: fuels & lubricants) as a result of mining, is a major threat to freshwater ecosystems (surface and ground waters) and its biological resources.

Legg *et al.* in 2015 reported on a study that was conducted between 2005 and 2009 where sediment samples collected from areas covering northern, central and southern (Essequibo River basin) Guyana were assessed for levels of mercury contamination. The study found that samples taken from active and historically mined areas which included Mahdia (central Guyana), Arakaka, Mathew's Ridge and Port Kaituma (north-western Guyana) had a mean (± standard deviation) mercury concentration of 0.229 ± 0.223 µg/g, which is above CCME quality guidelines.

To add, for the Indigenous and local communities downstream from mining, the problems are related to contamination of the food chain, especially fish which is an integral part of their diet and a main source of protein, and pollution of rivers that are used as a source of domestic water supply. Further, Legg *et al.* in 2015 reported that the GGMC in 2001, performed a survey of the Potaro River, and found that 57% of carnivorous fish sampled had mercury levels above the maximum WHO guideline concentration (0.5 μg/g).

Also, untreated human and animal wastes, agricultural and industrial wastes threaten both ground and surface waters by means of surface run-off and leaching (GoG NDS).

– Climate change

Rising temperatures will disrupt the hydrological cycle with the result that rainy seasons may be shorter and more intense, while dry seasons may be longer (Narayan 2006). The reduction and/or changes on the precipitation pattern (this can result long dry spells and severe droughts), can diminish the recharge of aquifers, causing available groundwater restriction. Another expected impact is the increase in demand and decrease in the surface water availability that will cause the population and business sector to turn to aquifers as its main source.

Another expected consequence is the rise in sea level. A rise in sea level will inundate rivers, wetlands and lowland areas (surface water ecosystems) on the coastal zone of Guyana which is located below sea level (Narayan 2006). This can be accompanied by saline intrusion of the coastal sand aquifers through direct movement of sea water (Guyana Water Authority 1993, Narayan 2006 and Vivianna Critchlow, pers. Comm.).

– Management of water resources

- Lack of a coordinated and integrated management approach to freshwater resources of Guyana. Although the Water and Sewage Act of 2000 describes the establishment of a National Water Council which would have the responsibility for the management of water resources all across the country; to date, this body does not exist.
- Guyana lacks a National Strategy on Integrated Water Resource Management (IWRM).

- Institutional constraints on the capacity of organisations to act, and lack of human resources. For instance, the lack of technical personnel at the Hydrometeorological Department to lead in data collection, analysis and publication of information for freshwater resources in Guyana.

9 DATA GAPS

Significant data gaps exist for ground fresh water resources in Guyana, when compared to surface water. These are represented below.

- Groundwater (aquifers) level (groundwater level monitoring),
- Rate of groundwater abstraction from all aquifers,
- Rate of recharge of aquifers,
- Availability of water resources from ground and surface water sources,
- Estimated national water demands for various sectors,
- Groundwater hydrochemistry (water quality) for all aquifers,
- Biological analysis (Total coliform and *E. coli* assessment) of surface and ground water, and
- Water pollution (contamination) monitoring for ground and surface water.

10 RECOMMENDATIONS AND CONCLUSIONS

Key recommendations include:

- The establishment of the National Water Council (as described in the Water and Sewage Act of 2000) and a strategic plan that will serve to address issues around water resources throughout the country.
- The creation of a National Water Policy which will set out a vision for the development and management of all water resources in Guyana.
- The creation and implementation of a National Strategy on Integrated Water Resource Management (IWRM) which is a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives. This is critical for the management of the major conservancies, particularly the East Demerara Water conservancy given the high dependency of it to irrigate the vast majority of agricultural activities that takes place on the coast, and to supply potable water to Georgetown, to augment the groundwater supply (FAO 2015).
- Proactive cooperation among various sectors using and monitoring (for instance: GGMC and EPA conduct water quality assessments of major water-ways in the Mining Districts) freshwater resources for collaborative management to help maintain public health, food security, social, environmental and economic stability, and to help build sustainable peace. More awareness, public consultation and public participation are critical, especially in the mining sector to avoid user conflicts with the Indigenous communities throughout Guyana.
- An integrated use of surface and groundwater resources must be considered in water use planning. Importantly, in events of water scarcity the solution is based on factors such as: societal awareness, better knowledge on the characteristics of aquifers and effective management actions.
- The implementation of a groundwater monitoring system as a matter of priority, since these data form the basis for all water resource planning. Moreover, critical measurements should include: water levels, water quality and rate of abstraction.

- Establishment of more public and private accredited analytical laboratories to do biological and chemical analysis of water and sediments across Guyana.
- Banning of mercury in the mining sector through the Minamata Convention to which Guyana signed in Japan in October 2013. The gradual phasing out of mercury use in the artisanal mining sector may be a more appropriate approach that can be considered to prospectively eliminate mercury contamination of the water resources and the environment.
- Given that the Hydrometeorological Department is responsible for all surface and groundwater monitoring and management, institutional capacity building for its staff is critical for them to become equipped in hydrology and effective water resource management.
- More sectoral and site-specific assessments, residential, commercial and ecological risk assessments, and clean-up of contaminated sites, especially in Georgetown and along the coast where chemical spills, commercial, industrial and agricultural source discharge is not being actively monitored by authorities and polluters required to pay for the clean-up and monitoring.

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