



Caye Caulker Sanitation System

Feasibility Study for Collection and treatment Alternatives

Belize



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Abbreviations

BWS Belize Water Services Ltd

DOE Department of Environment

GPD Gallons per day

GPM Gallons per month



1 Introduction

The GEF CReW+ project is a partnership project financed by the Global Environmental Facility (GEF) that is being co-implemented by the Inter-American Development Bank (IDB) and the United Nations Environment Programme (UNEP) in 18 countries of the Wider Caribbean Region: Barbados, Belize, Colombia, Costa Rica, Cuba, Dominican Republic, Grenada, Guatemala, Guyana, Honduras, Jamaica, Mexico, Panama, Saint Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, Suriname, and Trinidad and Tobago. CReW+ is being executed by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the Organisation of the American States (OAS) and the Secretariat of the Cartagena Convention (CAR/RCU) on behalf of the IDB and UNEP respectively. The project was endorsed by the GEF Chief Executive Officer and Chairperson in November 13, 2019, for an amount of US\$14,943,938. The GEF CReW+ was launched in January 2020.

The aim of this feasibility study is to determine the most viable sanitation solution for Caye Caulker to give orientation to the contractor of the detailed design for the system. Therefore, it is important to determine the design parameters well and to compare different possible solutions in their applicability in the special conditions of Caye Caulker.

The high fluctuation of water consumption throughout the year, the sensitive coastal area, the high groundwater table, and flat terrain influence the feasibility and cost of

the different options. The limited access to qualified staff, spare parts, and service providers on the small island present operational restrictions, especially for highly technological options.

The report shortly introduces the specific conditions of Caye Caulker which impact the requirements a new sanitation system needs to fulfill (Chapter 2). In Chapter 3, data is analyzed to define the design data and specify selection criteria. Chapters 4 and 5 shortly present sewage and treatment options and provide a comparison according to the define selection criteria, including a rough estimate of the capital expenditure. The final Chapter 0 takes the conclusions of the findings and recommends further proceedings.

2 Current situation

The small island of Caye Caulker is divided into a strongly developed southern island with the village of Caye Caulker and a less developed northern island. The Split between the islands is of high touristic and environmental value and needs to be protected. Currently, 2,000 inhabitants and up to 1,000 tourists¹ are served with drinking water from a piped water network. As Caye Caulker does not have a centralized wastewater system, the prevailing sanitation solution are septic tanks at household level. However, as no system for sludge treatment exists, the fecal sludge extracted from the septic tanks is often dumped in the sensitive mangrove areas.² The fluctuating water consumption over the year, the high groundwater level, the environmental and ecological sensitivity of The Split, as well as limited space availability need to be considered in the selection and design of a sanitation solution.

2.1 Caye Caulker

Caye Caulker is a small limestone coral island, located 21 miles northeast of Belize City. Although the island is only about 4 miles long and 1 mile wide, it is the second largest of the Belizean cayes. Caye Caulker island is divided into two by The Split that separates the more developed South Caye Caulker from the North Caye Caulker, which is still relatively low populated.³ However, in the last years water and electricity infrastructure has been implemented in North Caye Caulker; ever since then several development projects have been carried out.

¹ Verbal information of the Chairlady from Caye Caulker

² Verbal information of the Village Council, the DOE and BWSL

³ <https://belize.com/caye-caulker/>

The Split is the islands main tourist concentration point. Therefore, a potential failure in a sewage pipeline connecting the northern and southern island would not only have a negative environmental impact, but also threaten the tourism sector. Therefore, it is the desire of the Department of Environment (DOE) and BWS that two independent sanitation systems shall be proposed for North and South Caye Caulker.

Caye Caulker was primarily a fishing community. Today its economy is mainly tourism-based; and over the past ten years, the population of Caye Caulker has doubled from 1,000 to 2,000 inhabitants.⁴ The number of hotels on the island ranges between 25 and over 50, depending on the information source.⁵ However, in addition to hotels, also hostels, bed and breakfasts and cottages are available accommodations.

In peak season, about 1,000 tourists per day visit the island. This reflects 50 % of the population, and therefore implies large fluctuations of hydraulic and organic load between high and low season. For a proper dimensioning a definition of the basic design data is crucial; therefore, the water consumption data from 2019 to 2022 is being analyzed in the framework of this feasibility study (see 3.1 Effluent standards parameter).

2.2 Groundwater

In Caye Caulker, the groundwater table is high. In the most parts of the southern island, the groundwater is approximately 4 feet under the ground. The center of the island is slightly raised, here the groundwater level is 6 feet below ground. However, in the

⁴ <https://belize.com/caye-caulker/>

⁵ Google.com lists 26 hotels on South Caye Caulker and three hotels on North Caye Caulker; Booking.com lists 54 hotels of a total of 95 accommodations in Caye Caulker; According to Belize.com "there are now approximately 25 hotels on the island"; and the client base of BWS includes 12 hotels.

area called “The Bahía” (north of the airstrip), the water table is only half a foot below ground.

**Figure 1:
Water table in North Caye Caulker**



Source: ©GIZ / AKUT

Also, in North Caye Caulker the water level is less than a foot (20 cm) under the natural ground; only under the road the water table is approximately 2 feet below the ground (Figure 1).

The high groundwater level poses specific challenges. On the one hand, it makes deep excavations difficult and expensive, on the other hand it requires technologies that prevent intrusion of groundwater into the sewage system, but especially prevent the infiltration of untreated wastewater into the groundwater (see Chapter 3).

2.3 Water provision

Belize Water Services Limited (BWS) is the national water and sewerage utility; it serves all the municipalities of the country, including Caye Caulker. The water service network in Caye Caulker was inaugurated in 2010. The distributed drinking water stems from the Caye Caulker Reverse Osmosis Plant, where sea water is converted into drinking water. The desalinization plant has a production capacity of 150,000 GPD.

BWS provided historical data indicating monthly water consumption between January 2019 and February 2022. Based on this data, the average daily consumption was calculated. As per February 2022, BWS had a client base of 871 with an average daily consumption totaling 124,000 gallons per day (GPD).

Data analysis shows that the average daily consumption fluctuates throughout the year. In 2019, February shows the highest daily consumption (125,500 GPD), 25% more than during the year's months with lowest consumption (November: 100,500 GPD).⁶ In 2020, when tourist numbers were strongly reduced due to the impacts of COVID-19, the consumption even halved from 126,000 GPD (January 2020) to 63,000 GPD (October 2020). It can be assumed that short-term tourism peaks on weekends, as well as specific festivities as Easter and the annual Lobster Fest. Therefore, the amplitude between actual daily consumptions may vary even stronger than its monthly average. This fluctuation needs to be considered in the design and is one of the selection criteria (see chapter 3 Design parameters).

Before the piped water system, household-level wells were used as main water source. Many of these wells still exist and during the field visit different interviewed

⁶ Max. monthly average: 125,000 GPD (February 2019); min. monthly average: 100,000 (October 2019).

households confirmed that they use the well water for irrigation and partially even as service water, e.g., to flush the toilets.

2.4 Sanitation

Caye Caulker does not have a centralized wastewater system. The prevailing sanitation solutions are overground septic tanks with soakaway⁷ at household level.⁸ The septic tanks inspected during the field visit appeared to be in good condition. Neither around the septic tanks nor around the soakaways stagnant water was observed. However, DOE and BWS indicated that problems with not sufficiently sealed septic tanks exist in some cases.

**Figure 2:
Septic Tank in South Caye Caulker**



Source: ©GIZ / AKUT

⁷ Covered, porous-walled chamber that allows water to slowly soak into the ground; also known as soak pit or leach pit.

⁸ Although during the field visit no latrines were detected, some interview partners indicated that some families use pit latrines. Specific numbers on latrine use are not available.

Based on inquiries with three building contractors, the general design criteria for septic tanks and soakaways in Caye Caulker were checked. In general terms, the groundwater level in the specific location determines the specification of the septic tank. The septic tank is built above groundwater level, with a total height of 1.5 m. If this height cannot be achieved, the required volume is obtained by a larger footprint. Also, the septic soakaway is implemented above the groundwater level. For greywater (e.g., shower, washing machine) a separate soakaway or filters are implemented.

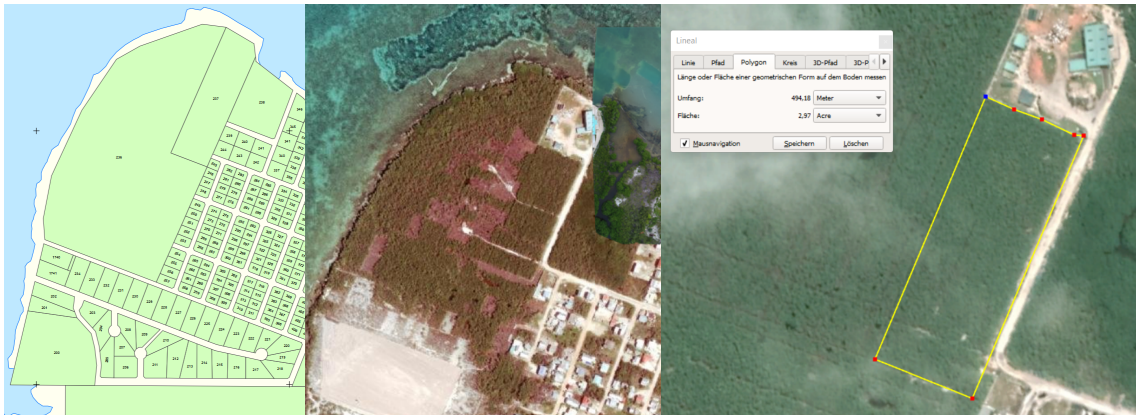
The building contractors assured that the septic tanks on the island are well built. In areas with extremely high groundwater table (i.e., Northern Island and The Bahia), septic tanks protrude about 50 cm, sometimes 1 m, from the ground, while the soakaways about 20 cm. In the central part of the village, where the groundwater level is lower, the standard septic tank protrudes about 25 to 30 cm, whilst the soakaways are implemented level with the ground.

2.5 Potential location for wastewater treatment system

Due to the advanced development of South Caye Caulker, the available space for the implementation of a wastewater treatment system is limited. In the mission, the consultant identified and visited potential locations on the southern and northern island.

On South Caye Caulker the potentially available area is slot 237 with around 3 to 3.5 acres (Figure 3). The owner is the company which is responsible for the garbage management of Caye Caulker. Therefore, the localization is very well suited. Energy and water are directly available at the plant.

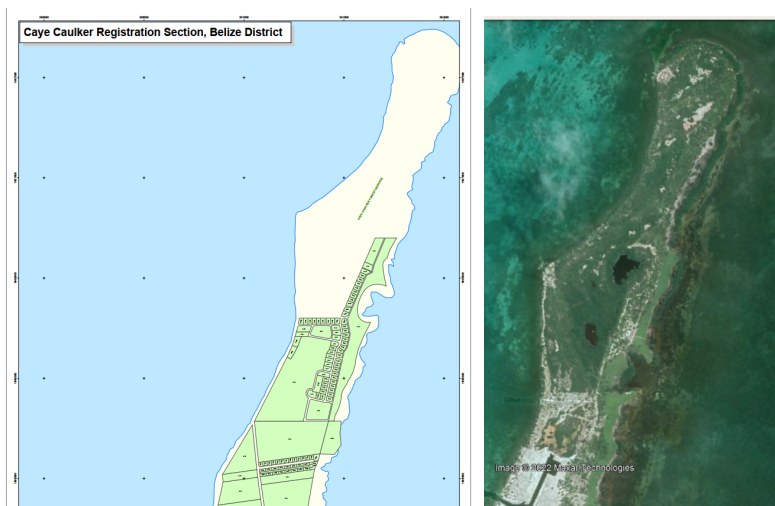
**Figure 3:
Potential location for WWTP in South Caye Caulker**



Sources: left and middle BWS, right google earth

On North Caye Caulker there is an area that is still government-owned and sixty times larger than the necessary area for a wastewater treatment system, and it is located at the northernmost end (Figure 4). As the area is a natural reserve, the area necessary for the wetland would have been to be declared as possible for a WWTP installation. All other areas in North Caye Caulker are private.

**Figure 4:
Potential location for WWTP in North Caye Caulker**



Sources: BWS

3 Design parameters and selection criteria

3.1 Effluent standards parameter

The treated effluent in Caye Caulker must comply with the standard for discharge in Class 1 waters of the Environmental Protection Regulation of Belize from 2009.

This standard defines effluent quality as follows in Table 1.

Table 1:
Effluent standards for the Wastewater Treatment in Caye Caulker according to the Environmental Protection Regulation (2009)

Parameter	Standard
TSS - Total Suspended Solids	30 mg/l
BOD5 - Biochemical Oxygen Demand	30 mg/l
pH	5 - 10 pH units
Fats, Oil and Grease	15 mg/l
Fecal Coliform	200 mpn/100 ml
Floatables	Not visible

Source: ©GIZ / AKUT

The Project has a design horizon of 20 years, the construction is proposed in two stages, the first until 2032 and the second until 2042. The division is proposed to avoid infrastructure which will not be used adequately for many years. The evaluation of alternatives will refer to the first phase. The population projection will be taken as a basis for calculating the volumes of residual water.

Based on the analysis of water consumption (section 3.2.2) and population (3.2.3) the following values are recommended for the design of the system:

- + Consumption in residential areas: 135 GPD per household
- + Consumption related to tourism: 50 GPD per tourist (currently 1,000 tourists peak)
- + Rate of return: 100% of drinking water consumption is returned as wastewater⁹
- + Household size: 2.85 p.e.
- + Population growth (South Caye Caulker): 2.5% p.a.
- + Population growth (North Caye Caulker): 15% p.a.

Table 2 shows the projected wastewater volumes for 2022, 2032 and 2042, with a total volume of 380,572 GPD in 2042, thereof 221,213 GPD in South Caye Caulker and 159,358 GPD in North Caye Caulker. The wastewater projection per year is provided in Annex 1.

**Table 2:
Projection of wastewater volumes [GPD]**

Year	South Caye Caulker		North Caye Caulker		Caye Caulker (total)	
	Residents	Tourists	Residents	Tourists	Residents	Tourists
2022	90,000	45,000	4,737	5,000	94,737	50,000
2032	115,208	57,604	19,163	20,228	134,371	77,832
2042	147,475	73,738	77,526	81,833	225,001	155,570
2042 (total)	221,213		159,358		380,572	

Source: ©GIZ / AKUT

⁹ Normally, a return rate of 80% is considered, as it is assumed, that a portion of water is used for irrigation purposes. In the case of Caye Caulker, on many properties wells exist and well-water is used for irrigation; in some cases well-water is also used to flush the toilets. Therefore, it seems advisable to consider a return rate of 100%.

3.2 Influent parameters

3.2.1 Raw water loads

Table 3 demonstrates the typical raw water parameter per pe which should be used if there is no better reference. In the case of Caye Caulker, the consultants did not encounter a better or more accurate source to analyze the raw water load to the treatment plant.

Table 3:
Projection of wastewater loads per capita

Parameter	Load	
	number	unit
BOD ₅	50	g/pe,d
COD	100	g/pe,d
SST	60	g/pe,d
TKN	8	g/pe,d
P _{tot}	1	g/pe,d
Total Coliforms	10 ¹⁰ - 10 ¹³	org/pe,d

Source: table 2.24 in von Sperling (2007)

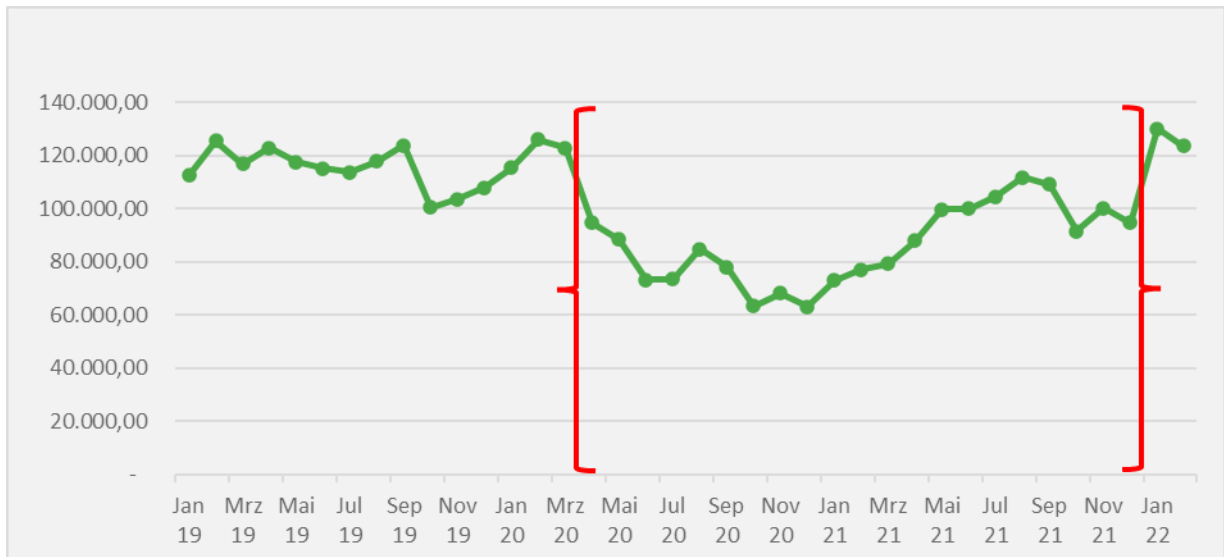
3.2.2 Analysis of water consumption

As pointed out in section 2.1, Caye Caulker is a highly touristic island. The changing number of tourists throughout the year leads to a fluctuating water consumption and wastewater production. To account for a potential increase in tourism over the design period, it is important to identify the specific water consumption related to tourism.

The impact of tourism becomes visible when analyzing the consumption data between January 2019 and February 2022, where from April 2020 on a strong reduction can be noted (Figure 5). This coincides with the start of traveling restrictions related to the COVID-19 pandemic (marked with red brackets).

Although this period must be disregarded, when defining the current daily water consumption, it gives very relevant information on the tourism-related water consumption and will be analyzed in this aspect.

Figure 5:
Daily water consumption [GPD] from 01/2019 to 02/2022



Source: ©GIZ / AKUT, based on data received from BWS

Figure 5 also shows, that in average February is the month of highest water consumption. Also, in February 2022, the consumption seems to be back to pre-COVID-19 values. As this consumption reflects the latest available data, it will be considered as base value for the design.

To receive further detail on the consumption, the data for February 2022 is further analyzed. In a first step, the BWS customer categories are analyzed. Three of the eleven customer categories can be directly associated with hotels: Hotels (HOT), Licensed Hotels (LIH) and Recreation (REC); in February 2022, 11 HOT, 48 LIH and 1 REC were registered. Three categories relate to other commercial activities.¹⁰ Three categories

¹⁰ Business (BUS); Essential Service (ESS); Food Services (FDS).

are specifically related to residential consumption.¹¹ The remaining three categories Government of Belize (GOB), School/Church (S/C) and recreation areas (REC) are considered “other” consumers in the framework of this study.

The analysis of these four types of customers (Table 4) shows that 80% of the customers are considered residential and represent a water consumption of little over 50% of the total volume. Based on this information, the average daily consumption per residential customer or household is 95 GPD.

Whilst the hotels (7% of customers) consume 25% of the total water volume. As the main commercial activity of Caye Caulker is related to tourism, the consultants also assume the consumption of commercial customers to be tourism-related. Thus indicating, that 43% of water consumption can be attributed to tourism. Considering 1,000 tourists in February 2022, the tourism-related consumption is approx. 50 GPD per tourist.¹²

**Table 4:
Daily water consumption per user type (February 2022)**

Type	Customers		Consumption	
	Number	%	GPD	%
Residential	702	81%	66,825	54%
Hotels	60	7%	31,188	25%
Commercial	99	11%	22,684	18%
Others	10	1%	3,049	2%
Total	871	100%	123,746	100%

Source: ©GIZ / AKUT, based on data received from BWS

¹¹ Apartments (APTS); Employee Residential (EMP- BWS), categorized separately since BWS employees get half-rate benefit; Residential (RES).

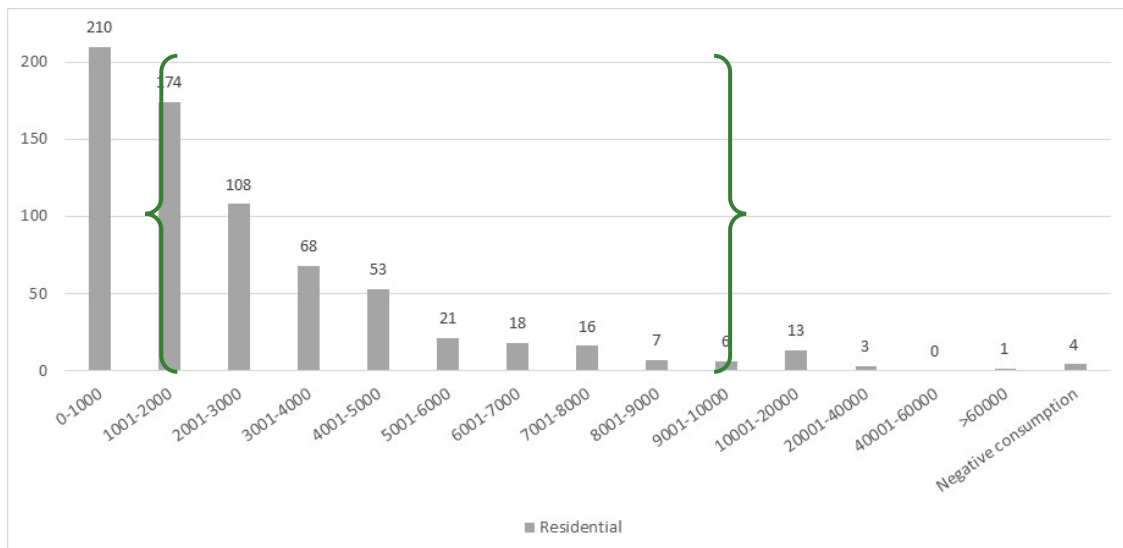
¹² Total tourism-related consumption: 53,872 GPD (tourism: 31,188 GPD plus commercial: 22,684 GPD).

The evaluation of consumers per monthly consumption range gives further information on consumption patterns. Figure 6 shows the number of residential customers per water consumption range, Figure 7 shows the same information of hotels.

Figure 6 shows that in February 2022, 210 (26%) of the residential customers consumed up to 1,000 gallons per month (PGM). Of these readings, 110 show values below 500 GPM or 18 GPD. Even for households with only one member, this is a very low amount. Potential explanations include that respective households are only intermittently habituated, that well water is used in addition to potable water or that water metering is defective.

For the further calculation of the average water consumption per residential customer, the 110 customers with consumption below 500 GPM will be excluded. The imputed customer base is thus 592.

Figure 6:
Number of residential customers per water consumption range [GPM]
(February 2022)



Source: ©GIZ / AKUT, based on data received from BWS

Table 5 indicates that realistic consumptions of residential customers would range between 2,000 and 10,000 GPM; the values are based on realistic minimum and maximum household size and consumption per household member (HHM) in GPD.

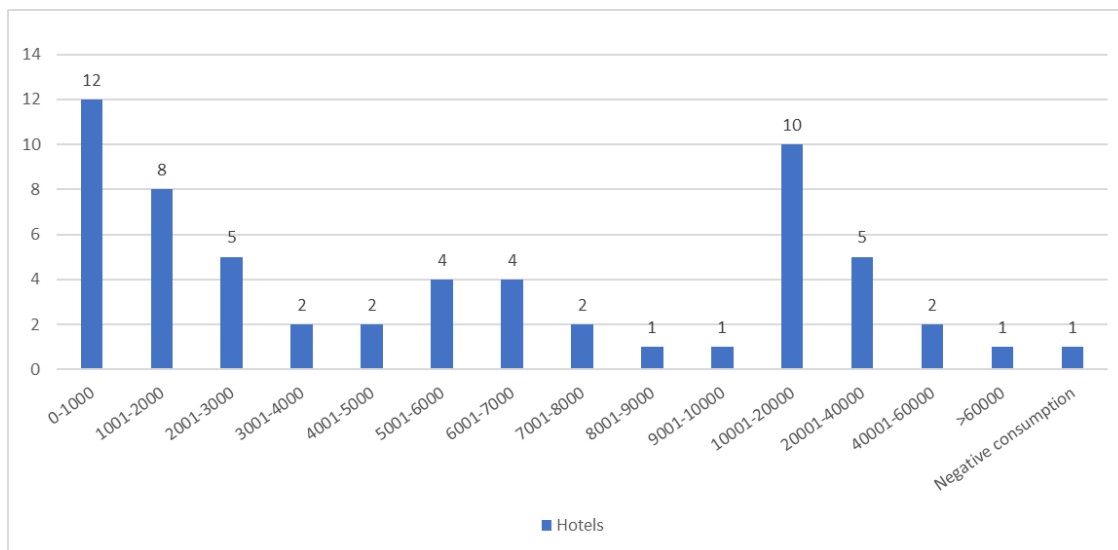
**Table 5:
Realistic consumptions per household**

Household size [HHM]	Consumption per household [GPM]	
	40 GPD	70 GPD
2	2,240 GPM	3,920 GPM
5	5,600 GPM	9,800 GPM

Source: ©GIZ / AKUT, based on data received from BWS

This range is marked with green brackets in Figure 6. The consultants highly recommend BWS to investigate the residential household connections that lie outside of the range. Especially for customers with a monthly consumption below 500 GPM it is recommended to check the water meters, as submetering may result in a significant loss of revenue. Consumptions above 10,000 GPM may indicate commercial use, it is recommended to investigate if an alteration of the customer category is required.

**Figure 7:
Number of Hotels per water consumption range [GPM] (February 2022)**



Source: ©GIZ / AKUT, based on data received from BWS

Figure 7 shows, that in February 2022, 20 (30%) of the hotels consumed less than 2,000 gallons per month (GPM). Values considered low, even for residential customers. Independent of the size of the hotel, the expected consumption would be higher. Potential explanations for the limited consumption include temporary closure, use of well water in addition to potable water or defective water metering. The expected consumption per hotel depends on its size and installations, therefore a general minimum or maximum consumption cannot be established. The consultants recommend BWS to check the individual hotels' consumption against the hotel size, to identify those customers that show potential sub-metering.

The impact of tourism on the water consumption can also be analysed by comparing the consumed water volumes of February 2021 and February 2022. February 2021 establishes one of the peaks of the COVID-19 pandemic with restricted tourism, whilst in February 2022 the consumption values approx. resemble the consumption pre-COVID-19.

**Table 6:
Comparison of daily consumption with and without tourists**

Month	Daily consumption	
	Total	% of February 2022
February 2021	80,057 GPD	65%
February 2022	123,746 GPD	100%
Delta	43,688 GPD	35%

Source: ©GIZ / AKUT, based on data received from BWS

Based on this comparison it can be assumed with high reliability, that 35% of the water consumption on the island is directly related with tourism; whilst 80,000 GPD (65%) can be assumed to be of solely the residential use. Considering the imputed customer base of 562, a **consumption per household of 135 GDP** can be assumed.

Excluding the period affected by COVID-19, the water consumption in the past years has been fluctuating between 100,000 GPD and 125,000 GPD. Considering a residential use of 80,000 GPD, the tourism-related water consumption ranges between 20,000 GPD and 45,000 GPD throughout the year. Considering 1,000 tourists per day in high season, this analysis points to a specific daily water consumption per tourist of 45 GPD. Very proximate to the value of **50 GPD per tourist** determined by the analysis of the hotel and commercial water consumption.

3.2.3 Population projection

The number of inhabitants of Caye Caulker is not officially registered. However, different sources, including BWS (2019) indicate an approximate population of 2,000 inhabitants, with the majority residing on the southern island. As no specific data is available, the consultants take the following assumption for the current population:

- + Population North Caye Caulker (2022): 100
- + Population South Caye Caulker (2022): 1,900

As South Caye Caulker is unevenly populated, the population is distributed according to the following percentages of the total population of South Caye Caulker:

- + Population in Bahia area: 25%
- + Population in Central Area: 75%

As number of tourists the peak value of 1,000 has been established. Based on the limited number of hotels on North Caye Caulker, the consultants establish the following base values:

- + Tourists North Caye Caulker (2022): 100
- + Tourists South Caye Caulker (2022): 900

According to BWS (2019) an annual population growth rate of 5% is assumed, for the increase in tourism numbers no specific value is available and even higher increase in tourism is assumed. As the southern island is already densely populated, in the eyes of the consultants a constant population growth rate of 5% for South Caye Caulker is improbable; whilst with further development of North Caye Caulker population in that part of the island will show higher growth rates. The consultants establish the following respective growth rates to be applied likewise for population growth and increase in tourism, as no better data were available:

- + Growth rate North Caye Caulker (2022): 15%
- + Growth rate South Caye Caulker (2022): 2.5%¹³

Table 7 shows the projected population for 2032 and 2042, with a total population of 7,861 in 2042, with 4,588 inhabitants in South Caye Caulker and 3,273 inhabitants in North Caye Caulker. The population projection per year, based on these design values, is provided in Annex 1.

**Table 7:
Population projection (residents and tourists)**

Year	South Caye Caulker		North Caye Caulker		Caye Caulker (total)	
	Residents	Tourists	Residents	Tourists	Residents	Tourists
2022	1,900	900	100	100	2,000	1,000
2032	2,432	1,152	405	405	2,837	1,557
2042	3,113	1,475	1,637	1,637	4,750	3,111
2042 (total)	4,588		3,273		7,861	

Source: ©GIZ / AKUT

Official information on the average household size is not available for Caye Caulker. Therefore, it is based on the approximate population of 2,000 inhabitants and the 702

¹³ The total projection of 5% was divided in a 2.5% growth rate for South Caye Caulker, which seems a possible growth rate for the Southern Part and a 15% growth rate for North Caye Caulker, as currently the Northern island is almost undeveloped.

residential customers identified in February 2022. The resulting **household size is 2.85** people per household.

**Table 8:
Population projection**

Year	North Caye Caulker		South Caye Caulker	
	Population	% design horizon	Population	% design horizon
2022	200	6%	2,800	61%
2032	810	25%	3,584	78%
2042	3,274	100%	4,588	100%

Source: ©GIZ / AKUT

Table 8 compares the current population and the population projected for 2032 with the projected population for the final capacity (design horizon 2042). It becomes clear that in South Caye Caulker nearly 80% of final capacity will be required in 2032. Therefore, it is recommended to implement the sewage system in one stage. For North Caye Caulker, the implementation in different construction stages is recommended.

3.3 Selection criteria

The selection criteria to be considered in the prioritization of the sewer system and the wastewater treatment system are based on BWS (2019) and have been slightly amended. They include criteria that refer to the topographic and geologic conditions of Caye Caulker, investment and operating costs, as well as the complexity of the system for operation and maintenance.

3.3.1 Selection criteria for sewer system

The first three selection criteria are related to the topography and geology of Caye Caulker and can be considered exclusion criteria.

- + **Unstable soil.** The soil conditions in Caye Caulker are considered unstable. Therefore, the selected sewer system needs to be applicable in unstable soil.
- + **High groundwater.** The high groundwater level influences the cost for excavation, but also the infiltration rate into the sewer system. Therefore, the selected sewer system would preferably be implemented at shallow depth and show low infiltration rates.
- + **Flat terrain.** As Caye Caulker is totally flat, the selected system needs to be adequate for low gradients.

The following two criteria refer to the cost for implementation and operation of the system and inform about the financial feasibility of the system.

- + **Capital expenditure.** The capital expenditure (CAPEX) is the base for calculating the cost-effectiveness of any system. The CAPEX per capita can be especially high for small communities, such as Caye Caulker.
- + **Operating expenditure.** The operating expenditure (OPEX) include costs for operation and maintenance (e.g., energy, replacement parts and staff). Especially, as the total number of permanent residents in Caye Caulker is low, the OPEX are an important selection criterion.
 - **Electricity.**
 - **Number of operators.**
 - **Maintenance costs.** Costs for spare parts and repairs by contracted firms.
 - **Cost for sludge removal from septic tanks.**

The complexity of the system directly influences its operational sustainability.

- + **Complexity of the system.** The higher the complexity of the system, the greater the potential for long down-times in case of failure. Aspects to be considered:
 - **Availability of spare parts and service providers.**

- **Level of training (operators).** The required level of training of operators influences the OPEX. The availability of sufficiently skilled operators may be a restrictive factor.

The remaining three criteria are related to the interaction of the homeowner or customer. Any responsibility outsourced to the customer lacks immediate controllability by the operator and thus proves a potential risk to the reliability of the system. Therefore, in general systems that do not require the customer for operation and maintenance are to be prioritized.

- + **Homeowner (customer) training requirement.** Complex systems that require the involvement of the customer in operation and maintenance may entail specific training. Preference should be given to systems that do not require customer involvement.
- + **Private property access.** Private property access can be critical for installation but also for operation and maintenance of sewer systems. Therefore, preference should be given to systems which do not require access to private properties.

3.3.2 Selection criteria for wastewater treatment system

The first three selection criteria are related to the (touristic) development of Caye Caulker and can be considered exclusion criteria.

- + **Land requirement.** As the available area is limited every treatment system must be checked for its applicability in the case. Especially natural systems must be analyzed critically due to their higher land requirement.
- + **Flexibility to hydraulic and organic load peaks.** The touristic influence makes it necessary to apply systems with a very high flexibility regarding hydraulic and organic load peaks. Natural systems and SBR systems have an advantage here.

- + **Vector and odor problem.** Considering the limited area of Caye Caulker, the wastewater treatment system will be installed in relative proximity to residential areas; therefore, the proliferation of vectors and formation of odors shall be prevented as far as possible.

The following two criteria refer to the cost for implementation and operation of the system and inform about the financial feasibility of the system.

- + **Capital expenditure.** The capital expenditure (CAPEX) is the base for calculating the cost-effectiveness of any system. The CAPEX per capita can be especially high for small communities, such as Caye Caulker.
- + **Operating expenditure.** The operating expenditure (OPEX) include costs for operation and maintenance (e.g., energy, replacement parts and staff). Especially, as the total number of permanent residents in Caye Caulker is low, OPEX is an important selection criterion.
 - **Electricity.**
 - **Number of operators.**
 - **Maintenance costs.** Costs for spare parts and repairs by contracted firms.

The complexity of the system directly influences its operational sustainability.

- + **Complexity of the system.** The higher the complexity of the system, the greater the potential for long down-times in case of failure. Aspects to be considered:
 - **Availability of spare parts and service providers.** Belize does not have an expressive sanitation market; therefore, most specialized maintenance must come from abroad. To guarantee a robust system, it is recommendable to limit requirements for specialized maintenance. Spare parts for critical equipment should be stored to maintain the plant in operation without breakdowns

- **Level of training (operators).** The required level of training of operators influences the OPEX. The availability of skilled operators may be a restrictive factor.
- **Primary Treatment.** The primary treatment is a critical aspect in regard permanent operation and sludge production. A system without a permanent need for raw sludge handling should be chosen.
- **Sludge Generation.** The sludge handling is often a critical aspect in the operation of wastewater treatment plants. Systems which generate a constant need for sludge removal from the plant are not recommendable, as they would cause significant operational costs.
- **Tertiary Treatment.** As the treatment will be situated in a sensitive marine environment, the effluent should be free of chlorine, but it has to be disinfected for touristic reasons.
- **Automatization.** To have a relatively low need for operation it is recommended that the plant should be automatized, but due to the criteria of skill level this automatization should be kept as simple as possible.

4 Sewer: Comparison of options

As discussed in section 2.2, Caye Caulker shows almost flat terrain and extremely high groundwater levels. Due to the lack of slopes, a conventional sewer system would require a very high number of pumping stations, resulting in high investment, and operating costs. Due to the high groundwater table, the system would be exposed to high infiltration rates, thus increasing the water volumes to be transported and treated, further increasing the operating costs. Under these conditions, the implementation of a conventional sewer system cannot be recommended. As alternatives, the consultants propose three different systems:

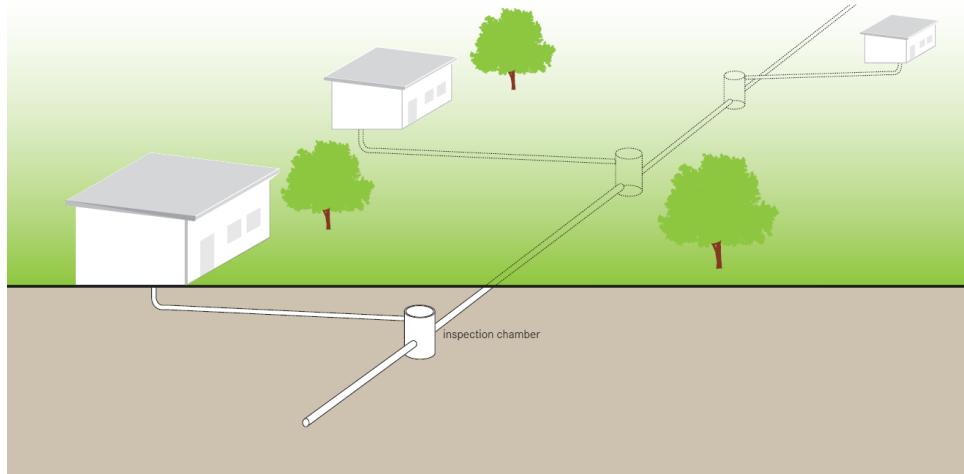
- + Condominial system combined with a pressurized system for the longer transport.
- + Vacuum system; and
- + FLAT system.

As these systems are not standard systems, their general setup and design criteria will be shortly presented in the following sections, before comparing the options.

4.1 Condominial system

Conceptually, the condominial system resembles a conventional gravity sewerage. However, the pipes are usually laid within property lines (i.e., in the back or front yard) where they are not subject to traffic loads. Therefore, the system can be implemented at shallow depth, limiting the required excavation works. Due to the limited depth of the installation, also manholes are generally not required. Instead, inspection chambers or boxes are installed at each junction or significant change of direction.

**Figure 8:
Condominial system**



Source: SSWM (2022)

Design principles for condominial system

The condominial system is designed to ensure a minimum self-cleansing velocity. Therefore, it requires a minimum gradient of 1%, thus showing the same limitation as a conventional gravity sewer, requiring a sufficient slope resulting in a high number of pumping stations due to the flat terrain.

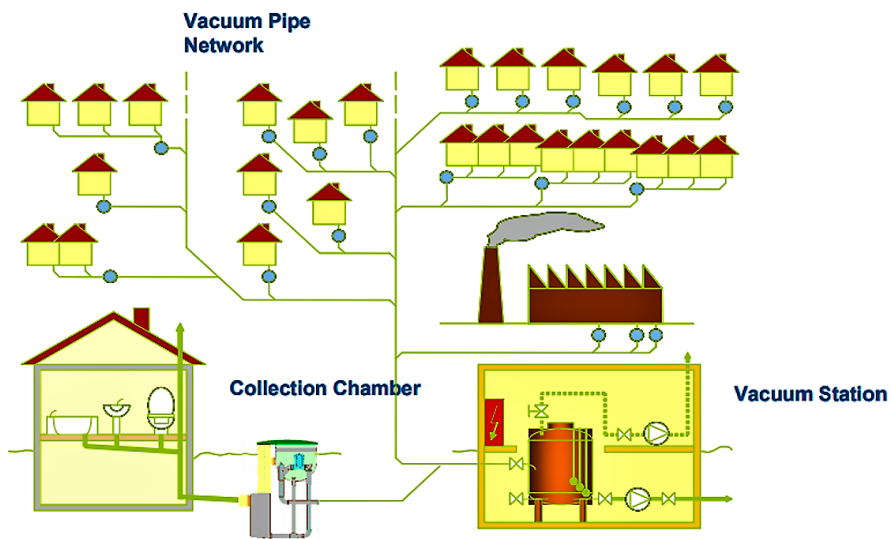
- + Depth on sidewalk: 0.15 m¹⁴
- + Depth at street crossing: 0.75 m
- + Tractive tension: 1 Pa
- + Gradient: 1%
- + Diameter: 100 mm (4")

¹⁴ Due to the particularly high-water table, the consultants adopted the criteria for minimum pipe coverage.

4.2 Vacuum sewer system

The vacuum sewerage system (Figure 9) uses differential air pressure and gravity to transport sewage in a network of essentially empty pipes from collection pits to a central collection tank and then to a point of discharge. No manholes or sewer pumping stations are necessary besides the vacuum station, just inspection points for pressure testing. This avoids settling of sludge and no manholes are needed to be cleaned out.

Figure 9:
Vacuum sewer system



Source: SSWM (2022)

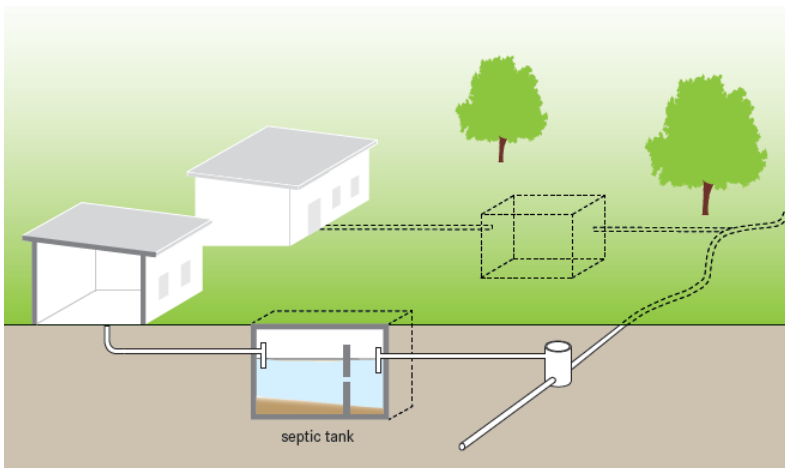
Design principles for vacuum sewer system

- + Depth: Minimum coverage to prevent physical damage, where possible the consultants recommend at least 70 cm
- + Gradient: 0.2%
- + Diameter: 90 to 160 mm
- + Houses per vacuum connection point: 4

4.3 FLAT sewer system

The FLAT system (Figure 10) is a sewerage network for solid-free effluents. Domestic wastewater is pre-treated in septic tanks (at least single chamber), where settleable particles are captured. As the effluent of the septic tanks is free of particles, the system can be designed following the hydraulic principles of a water system and does not require a minimum flow velocity. Therefore, the FLAT system can be installed with smaller diameter pipelines and inflective gradients that follow the topography. Also, as particles that could clog the system are captured in the septic tanks, the system requires few inspection points. Cleaning or flushing points are installed at upstream ends, high points, junctions, or locations with major changes in pipe direction or size.

Figure 10:
FLAT system



Source: SSWM (2022)

Design principles for FLAT system

- + Depth: Minimum coverage to prevent physical damage, where possible the consultants recommend at least 70 cm
- + Diameter: min. 100 mm (4")

4.4 Comparison of sewer options

The technical comparison of the three sewer options is based on the selection criteria established in section 3.3.1. In summary it can be stated that the implementation of the three systems is feasible in the prevailing topographical and geographical conditions. Regarding the remaining selection criteria, the three options show varying strengths and disadvantages. Table 9 provides an overview, details are discussed in the following text.

**Table 9:
Comparison of sewer options (overview)**

Selection criterion	Condominial system	Vacuum system	FLAT system
Feasibility in prevailing topographic and geologic conditions	+	+	+
<i>Unstable soil</i>	+	+	+
<i>High groundwater level</i>	+	+	+
<i>Flat terrain</i>	+	+	+
Capital expenditure	-	0	+
Operating expenditure	0	-	+
<i>Electricity</i>	0	0	+
<i>Number of operators</i>	0	0	0
<i>Maintenance</i>	-	-	+
<i>Sludge removal (septic tanks)</i>	+	+	-
Complexity of the system	0	-	+
<i>Availability of spare parts and service providers</i>	+	-	+
<i>Level of training (operators)</i>	0	-	+

Selection criterion	Condominial system	Vacuum system	FLAT system
Interaction of customer	0	+	-
<i>Customer training requirement</i>	-	+	-
<i>Private property access</i>	+	+	-

+: advantageous / 0: medium / -: disadvantageous

Source: ©GIZ / AKUT, based on BWS (2019)

Table 10 provides an overview on the estimated CAPEX for the three sewer options. Detailed cost estimations are provided in Annex 5B, Annex 6 and Annex 7. Especially due to the elevated number of required pumping stations, the condominium system results to be the most expensive option. The vacuum system is considerably less expensive, its CAPEX representing 58% of the CAPEX for the condominium system. The FLAT system has the lowest CAPEX, approximately a third of the CAPEX required for a condominium system.

**Table 10:
CAPEX for sewer options**

Category	Condominial system	Vacuum system	FLAT system
CAPEX	12,030,446	6,964,824	4,277,298
% of most expensive option	100%	58%	36%

Source: ©GIZ / AKUT

4.4.1 Condominial system

To try to achieve a viable system with the lowest technical input possible the consultants did a preliminary design for all sewers of the condominium system in order to determine the necessary number of pumping stations. The results are presented in Annex 4 for Caye Caulker North and South. Even utilizing very aggressive parameters of design (very low coverage using a pipe on each side of the street) it was not possible to come to a viable number of pumping stations. The preliminary design for the

condominial system indicates that 120 pumping stations¹⁵ are required to adapt the system to the specific conditions of the island (flat topography and high groundwater tables). Apart from impacting on the CAPEX, this would also result in elevated electricity and maintenance costs.

For the effect of the comparison of the systems only South Caye Caulker has been analyzed.

The operation of the condominial system is not a significant issue. The condominial system is commonly used in Latin America and Central America. Local operators will require certain additional training.

Regarding the interaction with the customer, the condominial system requires that customers are trained in the correct use of the system, in order to prevent blockages of the diameter pipelines.

4.4.2 Vacuum system

The vacuum system requires only one vacuum or pumping station, resulting in reduced electricity costs, compared with the condominial system. In case of power failure, the vacuum system can run with only one generator.

Critical aspects for the reliable operation of the system are the vacuum valves and the lack of technical expertise in the region. In case of a failure of just one valve, the system loses pressure and can fail completely. In some cases, the reestablishment of a functional system is not trivial. A very good execution of the system facilitates reestablishment after failure.

Due to the crucial role of the valves, an online control for every valve is recommendable and included in the calculation. Even though it is important to note that a number of

¹⁵ 39 in the northern island and 81 in the southern island.

217 valves leaves enough room for electrical failure, therefore a continuous maintenance is necessary. Without that maintenance the system may accuse failures in situations where the system is working fine; thus, failing in its function of alarming in case of real failures.

Due to the limited number of installed systems in Central America, specialized service is not available in the region, but needs to come from the USA. Therefore, increasing the down-time in case of special technical failures.

4.4.3 FLAT system

The FLAT system requires approximately four pumping stations, thus resulting in low electricity and maintenance costs. Thus, requiring four generators as back-up in the case of power cuts. Additionally, the septic tanks themselves provide storage capacity for several hours in the case of power failure or other malfunctions in the system. As solid-free wastewater is transported, regular blockages are not to be expected, thus limiting the cost for monitoring and pipe cleansing.

The septic tanks are the most critical points of the system. They require maintenance and it cannot be guaranteed that all tanks are completely sealed. To guarantee a fully functional system, the consultants recommend a yearly control of sludge level.

Regarding the complexity, the FLAT system can be considered the most advantageous option. The FLAT system technologically resembles a water supply system; therefore, the required spare parts are locally available and only limited additional training of the operators is required. The very economic execution of the system with a very high flexibility for critical situations and a low-tech maintenance make the system attractive.

As the FLAT system relies on household level septic tanks, this system requires the closest interaction with the homeowners, as they have to permit regular access to their

property for the yearly measurement of sludge levels and the evacuation of septic sludge.

5 Wastewater treatment: Comparison of options

As discussed in section 2.5, available space for the implementation of a wastewater treatment system is limited, especially in South Caye Caulker. As the land requirement for Lagoons or Wastewater Stabilization Ponds (WSPs)¹⁶ exceeds the available area, they are not considered a feasible alternative. There is not industrial activity on the islands; therefore, the wastewater resembles domestic wastewater. However, the very strong variation must be taken into account, as tourists account for about 30% of the consumption of Caye Caulker.

The options for wastewater treatment include technical and natural options. As a general rule the more technical the treatment, the smaller is the required area. However, the more technical treatment options require more operation and maintenance activities. Whilst the performance of natural systems can hardly be influenced by operational measures, for which reason natural systems must be very well designed.

As alternatives, the consultants propose four different systems:

- + Trickling filters;
- + Activated sludge (SBR);
- + Treatment wetland (TW) - French System.

As trickling filters and sequencing batch reactors (SBR) are standard technical options, they will only be shortly introduced. Constructed wetlands or treatment wetlands (TW) are considered a nature-based sanitation solution. Since the first wetland applications

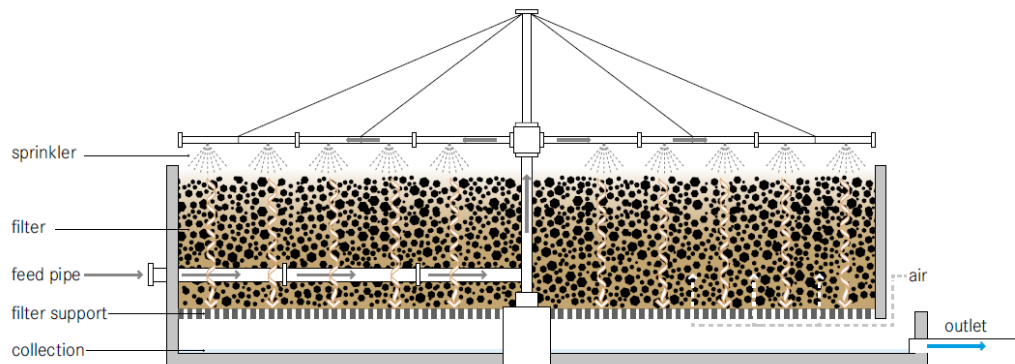
¹⁶ Approximately 40 acres on each of the two parts of the island.

in the 1960s, different types of constructed wetland technologies have evolved. The French System will be presented more extensively.

5.1 Trickling filter

A trickling filter is a fixed-bed, biological reactor that operates under aerobic conditions. Pre-settled wastewater is continuously 'trickled' or sprayed over the filter. As the water migrates through the pores of the filter, organics are degraded by the biofilm covering the filter material. The trickling filter is filled with a high specific surface area material, such as rocks, gravel, shredded PVC bottles, or special pre-formed plastic filter media. A high specific surface provides a large area for biofilm formation. Organisms that grow in the thin biofilm over the surface of the media oxidize the organic load in the wastewater to carbon dioxide and water, while generating new biomass.

Figure 11:
Trickling filter



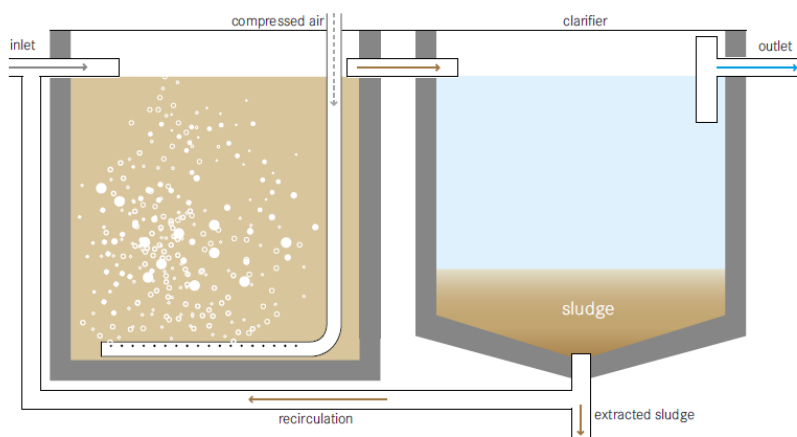
Source: Tilley et al. (2014)

5.2 Activated sludge (SBR)

Activated sludge systems are a biological treatment process widely used worldwide for wastewater treatment. The principle is based on the biochemical oxidation of organic and inorganic compounds from wastewater by means of a diverse microbial population, maintained in suspension in an aerobic environment.

In its conventional version (Figure 12), the activated sludge system is composed of two units: aeration tank (aerobic reactor) and a secondary sedimentation tank. In the aerobic reactor, biochemical reactions take place to remove organic matter and, under certain conditions, nitrogen. The substrate present in raw sewage is used by the biomass for its development. The sedimentation of solids (biomass) occurs in the secondary sedimentation tank, resulting in a final clarified effluent. The solids settled in the secondary sedimentation tank are almost entirely recirculated to the aerobic reactor, except for a fraction extracted from the system. The purpose of sludge recirculation is to maintain a specific biomass concentration in the aerobic reactor and the purpose of excess sludge disposal is to control the age of the sludge so that the system works satisfactorily.

Figure 12:
Conventional activated sludge



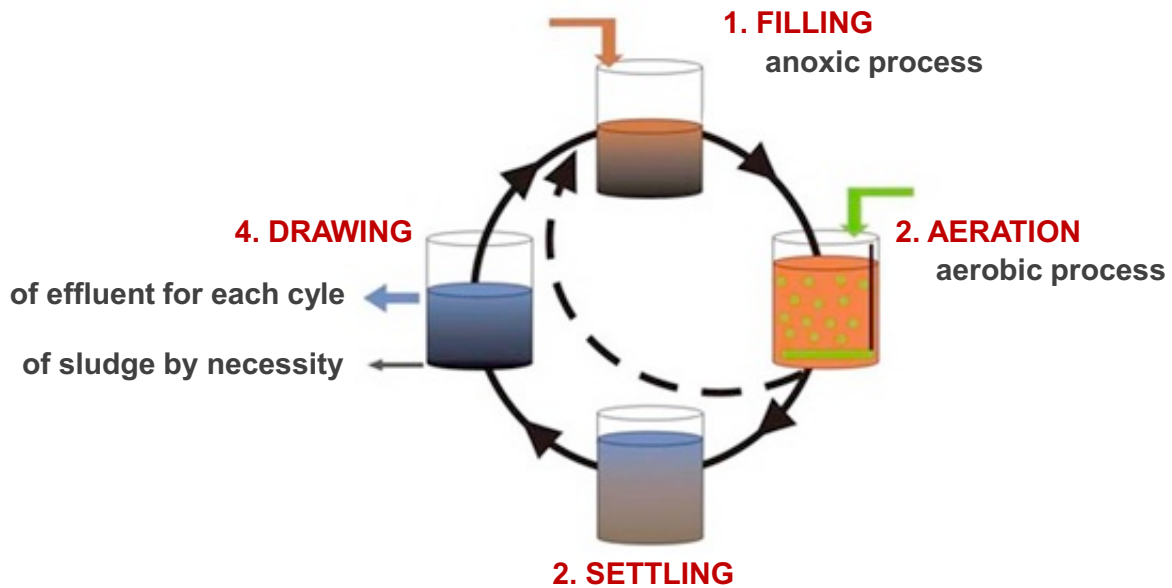
Source: Tilley et al. (2014)

Hydraulic and organic load peaks are a challenge for the conventional activated sludge system because changes in flow and velocity can affect the efficiency of biomass sedimentation in the secondary unit. This means that the clarified effluent could carry biomass (sludge) and the system's efficiency would be affected. For this situation, a solution is the use of Sequential Batch Reactors (SBR).

The SBR is a special variant of the activated sludge process, which has been widespread in recent years and has the same degradation principles observed in conventional activated sludge systems. The main difference is that the SBR reactor has as its principle that all treatment steps are carried out in a single tank (primary sedimentation, biological oxidation, and secondary sedimentation). For these steps to be possible, an SBR is operated in cycles that begin with the filling of the reactor with raw wastewater and end with the removal of clarified effluent. Cycle times can be adapted to respond to flow variations, ensuring treatment efficiency as well as energy savings.

Each cycle (Figure 13) of an SBR is normally divided into four phases: (1) **Filling** phase, when the pre-treated wastewater is added to the reactor, while also keeping mixing conditions so that the microorganisms are exposed to substrate, but maintaining anoxic processes (denitrification with reduced BOD₅); (2) **Aeration** phase, when the aerators are kept on to ensure the biological processes of treatment (oxidation of BOD₅ and nitrification); (3) **Settling** phase, with separation of the clarified effluent from the formed biomass; (4) **Drawing** phase, when the clarified effluent is removed, which may be followed, at certain intervals, by the removal of excess sludge.

Figure 13:
Sequential Batch Reactor phases



Source: ©GIZ / AKUT

In addition to the ability to absorb hydraulic and organic load peaks, SBR type reactors are more compact and allow complete operational control by automation, even facilitating the biological removal of nutrients. For these reasons, the consultants propose the sequencing batch reactors (SBR) as a modification to be analyzed.

5.3 Treatment wetland - French System

The so-called **French Filter** has revolutionized the concept of communal wastewater treatment in France and other European countries since the 1990s. Currently more than **4.000 French Wetland Systems** are being used in France only attending population ranges from 200 to 6,000 person equivalents.

The “**Classical**” **French Wetland System** combines the “**French Filter**” as **1. Stage for raw wastewater treatment** with a **vertical sub-surface flow wetland** as **2. Stage** (figure 1). The need for two stages is due to the cold **climatic conditions** in combination with advanced treatment demands. Therefore, **vertical flow sub-surface wetlands** were used in Europa already before the development of the **French Wetland System**, especially because of their high nitrification potential, but as secondary treatment, according to Figure 1, it was previously dependent on classic pre-treatment technologies with own needs on design and own challenge of maintenance.

The **French Wetland System** solved this obstacle in an exemplary way: **replacing classic pre-treatment technologies with a French Filter**, a Wetland with a very **high efficiency in retaining and degrading suspended solids and organic matter of raw wastewater** (primary sludge). This sludge, retained on the surface is **degraded by strictly aerobic processes (oxidation)**, without odor or release of Greenhouse gases and without need for manipulation. The dry product can pile up to a height of 15 to 20 cm before it needs to be removed, which lasts 10 years or more.

As mentioned before, the “Classical” French Wetland System (Figure 14) is composed of:

- + **1. Stage: French Filter.** Composed of three separate areas with gravel as filter material for the retention of solids on its surface and biological activated filtration with DBO/COD removal of the effluent.
- + **2. Stage: Vertical sub-surface flow wetland.** Typically divided into two areas, with coarse sand as filter material, to complete removal of organic matter and nitrification of the pre-treated effluent.

**Figure 14:
French Wetland System¹⁷**



Source: ©GIZ / AKUT

Since 2000, the concept of the **French Wetland System** was introduced and researched in **warm climates**, including Caribbean states¹⁸, Brazil¹⁹ and Peru²⁰. The investigations in **warm climates show a much higher potential of the 1. Stage**, which allows subsequent adaptation of the concept:

- + The efficiency of the 1. Stage reaches 80 to 90 % COD/BOD removal, and the nitrification process occurs partially. That means that in a warm climate conditions the French Filter as single stage already meets highest treatment requirements.
- + Where even higher effluent treatment efficiency is required, post-treatment can be guaranteed by less sophisticated technologies such as horizontal flow sub-surface wetlands or maturation pond, depending on the treatment objective.
- + Regarding the treatment of raw wastewater sludge, the warm temperatures allow its accelerated decomposition. This means, that the sludge needs less rest time for stabilization, allowing to use only two instead of three areas (33% reduction in area).

¹⁷ Left: WWTP for 800 inhabitants in Spain; 1. Stage with three areas for the treatment of raw wastewater and 2. Stage with two areas mainly for the nitrification of the pre-treated effluent. Right: Pilot wetland plant at UNALM University in Lima/Peru (background) and cones of raw waste water, effluent of 1. Stage and effluent of 2. Stage of the Classic French System (foreground).

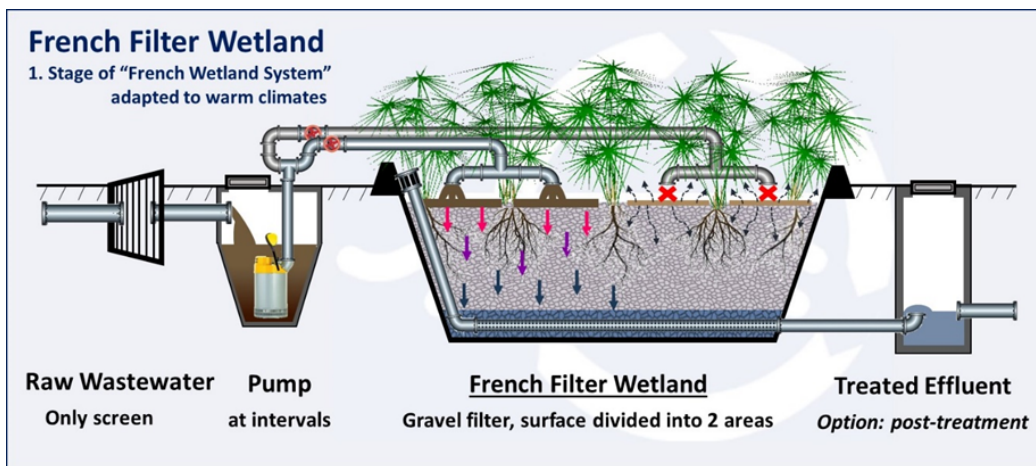
¹⁸ French IRSTEA institute (Prof. Pascal Molle).

¹⁹ UFMG University (Prof. Marcos von Sperling).

²⁰ UNALM University (Prof. Rosa Miglio).

According to the studies cited, the **adaptation of the 1. Stage** of the classic French Wetland System with a comparatively smaller area (2 instead of 3 areas) was **effective for single stage treatment of raw wastewater in warm climates** (80 - 90% COD and TSS removal and partial nitrification) and at the same time **primary sludge is co-treated**. Figure 15 shows the layout of such **French-Filter as single stage**.

Figure 15:
French Wetland System (schematic)²¹



Source: ©GIZ / AKUT

As shown in Figure 16 the **primary sludge is treated on the first stage by natural aerobic decomposition, somewhat comparable with a compost system**.

²¹ Approved as a single stage of raw wastewater treatment in a warm climate conditions, divided into two areas, ensuring frequent surface rest and complete drying and mineralization of deposited sludge.

Figure 16:
French Wetland System - treatment of raw sewage solids²²



Source: ©GIZ / AKUT

Finally, it is important to mention that **emerging plants or macrophytes**, species adapted to the climate and conditions of abundance of water and nutrients, grow very quickly and **after a few weeks of initiation of the process cover completely the surface of the filter and the discharge points** (Figure 17).

Figure 17:
French Wetland System - species of macrophytes²³



Source: ©GIZ / AKUT

²² Intermittent use of two beds in a rate of two to four days allows for complete aerobic decomposition.
²³ French Filter to treat the raw sewage in Florianópolis / Southern Brazil with different species of macrophytes and after 3 months of operation.

In accordance with the cited studies and the growing worldwide demand on nature-based sanitation solutions, **the French-Filter is seen currently as one of the most promising treatment technologies for raw wastewater in warm climate conditions**, because of the **extremely low operating costs** and **very high and stable treatment performance, including efficient effluent and sludge treatment**.

For the case of Caye Caulker a conservative number for dimensioning the treatment is 1.8 m² /pe. This leads for south Caye Caulker to a total area necessity of 2.2 acre (bae 2042) already considering an additional area of 20 % as surrounding area.

5.4 Comparison of wastewater treatment options

The technical comparison of the four technology options for wastewater treatment is based on the selection criteria established in section 3.3.2. The land requirement for Lagoons exceeds the available area; therefore, this alternative is excluded. Trickling filters and SBR reactors have the smallest footprint. The available space is sufficient for a treatment wetland French (see "Treatment wetland - French System"). Therefore, a very robust, low maintenance and operation option which complies totally with the effluent standards is available. For a better general understanding of the situation, all options will be analyzed shortly.

Regarding the remaining selection criteria, the four remaining options show varying strengths and disadvantages. Table 11 provides an overview, details are discussed in the following text.

Table 11:
Comparison of wastewater treatment options (overview)

Selection criterion	Trickling filters	SBR	CW French system
Land requirement	+	+	0
Flexibility to hydraulic and organic load	-	+	+
Vector and odor problem	0	+	+
Capital expenditure		0	0
Operating expenditure	0	-	+
<i>Electricity</i>	0	-	+
<i>Number of operators</i>	-	-	+
<i>Maintenance</i>	0	-	+
Complexity of the system	0	0	+
<i>Availability of spare parts and service providers</i>	0	-	+
<i>Level of training (operators)</i>	0	-	+
<i>Primary treatment</i>	-	+	+
<i>Sludge generation</i>	-	0	+
<i>Tertiary treatment - disinfection</i>	+	+	+
<i>Automatization</i>	+	0	+

+: advantageous / 0: medium / -: disadvantageous

Source: own, based on BWS (2019)

5.4.1 Trickling filter

Trickling filters are a very robust treatment option. They have a low energy need and a relatively low maintenance necessity (for a technical system). Critical points of the treatment are:

- + **Primary treatment.** When a primary settlement is used, there is a need for the treatment of raw primary sludge. Imhoff tanks would be a good option for the pretreatment, but they have typically a depth of over 4 m build into the ground. With the very high groundwater levels this is an economic challenge.

- + **Sludge generation.** The system produces primary sludge and secondary sludge which must be treated. An option to overcome this critical point could be sludge mineralization beds.
- + **Flexibility to hydraulic and organic load.** The treatment must be designed for high season and will be very low loaded during low season. During low-season nitrification will increase and affect the biofilm (see below).
- + **Low alkalinity.** The very low alkalinity of the water in Caye Caulker may affect the biofilm negatively. As nitrification will lower the pH further, this can lead to a loss of biomass and therefore to a loss of the treatment efficiency.

5.4.2 Activated sludge (SBR)

The treatment is very robust and very flexible to shock loadings. By adjustment of the cycle time, the treatment can be adopted to low season and even hydraulic overload of up to 30% can be dealt with.

Critical points are:

- + **Level of training (operators).** Activated sludge plants need a constant operation and a good understanding of the system, at least by a superior from distance to orientate the operation.
- + **Sludge generation.** The system produces secondary sludge which needs to be treated. An option to overcome this critical point could be sludge mineralization beds.
- + **Energy consumption.** The energy consumption of SBR reactors is relatively high. The second highest consumption of the mentioned treatment options.
- + **Maintenance costs.** SBR reactors have relatively high maintenance costs. The option has the second highest maintenance costs.

Sequencing Batch Reactors are the best technical option in the given conditions and system would be the consultants' primary choice, in case that the land requirement of natural treatment in constructed wetlands exceeded the available land.

5.4.3 Treatment wetland - French System

As expressed in Table 11 the only critical point of treatment wetlands for the situation is the available area, since the wetlands have a higher land requirement, they are critical for these cases. It could be seen that the available land is enough to implant a treatment wetland. The system has by far the lowest energy, operation, and maintenance costs. especially as the sludge remains on the wetland as indicated.

Lagoons and wetlands are considered extensive technologies, which require a larger area, but they have significantly less dependence on electromechanical equipment, less complexity of operation and maintenance, better landscape integration and low operating costs compared to technical solutions. Almost most important for the situation is the capacity of natural systems to absorb peaks in organic load and hydraulic load.

Coming to the conclusion that wetland perfectly attends the needs, with a footprint which is possible in the given situation

6 Cost and financial aspects

6.1 CAPEX

The estimates below are based on benchmark costs. The BWS costs are a cost base provided by BWS, as the consultants have no access to specific costs in Belize. But as the provided costs seemed very high for the given situation, the consultants decided to calculate all costs based on experience with construction in Brazil, Peru and Nicaragua and costs from system providers to enable a comparison between solutions.

The general results of the study are shown in Table 12 **Error! Reference source not found.** The results are based on the detailed costs shown in Annexes 5a - 7. The layout of the Condominial system is shown in Annex 4.

Table 12: Cost overview (South Caye Caulker)

Category	BWS cost (USD)	AKUT cost (USD)
Sewer system		
Condominial system ²⁴	27,101,281	12,030,446
Vacuum system ²⁵	n/a	6,964,824

²⁴ BWS cost base in Annex 5A, Akut Cost base in Annex 5B

²⁵ Annex 6

FLAT system ²⁶	n/a	4,277,298
Wastewater treatment system²⁷		
Treatment wetland - French System	n/a	1.087.467,50

6.2 OPEX

The consultants evaluated the possibilities to develop an OPEX estimation.

Table 13: Components of OPEX cost

Component of OPEX	BWS cost (USD)
Equipment maintenance	3% of CAPEX equipment
Energy costs	Dependent on how many water is produced and how many connections are producing at the same moment - not significant in the total evaluation
Civil works maintenance	1% of CAPEX civil works
Operation	2 persons of good qualification
Final sludge disposal and grit removal	2 cm / year x 0,8 m ² ,pe = 0,16 m ³ /year , pe
Equipment maintenance	3% of CAPEX equipment
Civil works maintenance	1% of CAPEX civil works
Energy costs	4-5 kWh/a.pe
Operation	about 1 day per week of 1 person

Table 13 show the mayor components for an OPEX evaluation. In this case Table 13 it has been impossible to transform the mentioned components in Table 13 for a number of reasons:

- The difference etween the cost estimation on the cost base BWSL or AKUT is too large to allow obtain a reasonable cost fot the maintenance of equipment and civil works.
- As no specific haydraulic dimensioning for the sewer has been carried out, it is impossible to determine the exact energy consumption.
- As the sludge disposal in Landfills is not common practice in Belize, there are no costs for the sludge removal, furthermore the possibility of reuse of th sludge might be

²⁶ Annex 7

²⁷ Annex 8

possible in 10 years, as the Sanitation Policy for Belize foresees a regulation for the reuse of sludge.

6.3 Financing and Tariff aspects

For sure the wastewater solution for Caye Caulker is much more expensive than an equivalent solution on the mainland. The high touristic importance of Caye Caulker and the very sensitive localization directly at the reef makes the provision of sanitation for Caye Caulker a high priority aspect. It should be analyzed how much of this financial burden can be attributed to the residents of Caye Caulker and how much should be attended by a cross financing with other areas of Belize or as well with grants from the government of Belize.

Currently the water tariff in Caye Caulker is about 2,3 times more expensive than on Belize mainland (see Figure 18). A wastewater tariff only paid by the islanders would be in the same range probably and represent a severe social problem especially for persons how do not live from tourism.

Figure 18 - Water tariff in Belize

Water Only Mainland	Water & Sewer Belize City, Belmopan	Water & Sewer San Pedro
Consumption Blocks:	Consumption Blocks:	Consumption Blocks:
0 - 1000 \$8.72	0 - 1000 \$10.47	0 - 1000 \$25.57
1001 - 2000 \$13.95	1001 - 2000 \$18.02	1001 - 2000 \$30.22
2001 - 3000 \$15.12	2001 - 3000 \$19.76	2001 - 3000 \$32.54
3001 - 4000 \$15.69	3001 - 4000 \$20.92	3001 - 4000 \$34.87
4001 - 5000 \$16.27	4001 - 5000 \$22.09	4001 - 5000 \$37.19
5001 - 6000 \$17.44	5001 - 6000 \$23.25	5001 - 6000 \$44.17
6001 - 7000 \$18.60	6001 - 7000 \$23.82	6001 - 7000 \$52.31
7001 - 8000 \$19.17	7001 - 8000 \$24.41	7001 - 8000 \$58.11
> 8000 \$19.76	> 8000 \$24.99	> 8000 \$63.93
Minimum Bill for Consumption less than 1000 US gallons \$8.72	Minimum Bill for Consumption less than 1000 US gallons \$10.47	Minimum Bill for Consumption less than 1000 US gallons \$25.57
Water Only Caye Caulker		
Consumption Blocks:		
0 - 1000 \$23.46		
1001 - 2000 \$26.98		
2001 - 3000 \$29.61		
3001 - 4000 \$32.50		
4001 - 5000 \$35.67		
5001 - 6000 \$39.14		
6001 - 7000 \$42.96		
7001 - 8000 \$47.15		
> 8000 \$51.75		

Source: <https://www.bws.bz/our-rates.html#>

The consultants recommend strongly to use a cross subsidizing scheme in order to bring the specific burden for the islanders to an affordable level. In conversations with the islanders it could be perceived that there is a clear understanding the a sanitation solution is highly necessary and there is a willingness to pay for the service, but it could be perceived as well, that nobody had the slightest idea of the costs which had to be expected.

7 Conclusion and recommendations

Based on the comparison of collection system options, the consultants recommend the Vacuum system for sewerage, and for the wastewater treatment plant, constructed wetland. The key determining factors of this recommendation are:

The Condominial System is not viable technically and economically (81 pumping station South Caye Caulker). The only way to reduce the number of pumping stations would be to choose significantly deeper sewers. Even by that, the number of pumping stations would be very significant.

The FLAT system has clearly the lowest CAPEX and is very suitable to be built in a step-by-step approach. A large disadvantage of the system are the septic tanks. It cannot be guaranteed that the tanks are watertight, and DOE expressed clearly that the sweet water lens below Caye Caulker is important to maintain. Another aspect is the necessary maintenance of the septic tanks on private ground, as well as the fact that still the homeowners have a direct responsibility directly for the system, whereas they must pay a wastewater tariff. That would need an accompanying phase during implementation.

Even though the Vacuum system is technically the most promising solution, it has to be seen critically that the system needs qualified implementation and qualified maintenance. Therefore, it is necessary to guarantee well trained operators. **It must be mentioned that the implementation bares a risk due to the need of special equipment and knowledge in O&M, this aspect must be taken seriously into account when choosing the solution.** Even the system providers recognize this fact as a critical point. But the mentioned aspects for the other systems make the vacuum system appear the best solution in the given situation.

Both systems FLAT and Vacuum can be installed in unstable soils, in high ground water table conditions and in flat terrain.

The vacuum system has the advantage of only one point for energy provision, therefore the system is a bit less vulnerable to hazardous situations.

As expressed above the Treatment wetland seems by far the most suitable solution for treatment as:

- It complies with the effluent standards,
- It is possible to be installed in the given area,
- It is the simplest treatment option regarding O&M,
- It has the lowest energy and sludge handling costs,
- It has the lowest equipment costs.

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Annex 1: Population and volume of wastewater projection - Caye Caulker

Table 14:
Population projection

Year	South Caye Caulker		North Caye Caulker		Growth rate	
	Residents	Tourists	Residents	Tourists	% south	% north
2022	1,900	900	100	100		
2023	1,948	923	115	115	2.5%	15%
2024	1,996	946	132	132	2.5%	15%
2025	2,046	969	152	152	2.5%	15%
2026	2,097	993	175	175	2.5%	15%
2027	2,150	1,018	201	201	2.5%	15%
2028	2,203	1,044	231	231	2.5%	15%
2029	2,259	1,070	266	266	2.5%	15%
2030	2,315	1,097	306	306	2.5%	15%
2031	2,373	1,124	352	352	2.5%	15%
2032	2,432	1,152	405	405	2.5%	15%
2033	2,493	1,181	465	465	2.5%	15%
2034	2,555	1,210	535	535	2.5%	15%
2035	2,619	1,241	615	615	2.5%	15%
2036	2,685	1,272	708	708	2.5%	15%
2037	2,752	1,303	814	814	2.5%	15%
2038	2,821	1,336	936	936	2.5%	15%
2039	2,891	1,369	1,076	1,076	2.5%	15%
2040	2,963	1,404	1,238	1,238	2.5%	15%
2041	3,037	1,439	1,423	1,423	2.5%	15%
2042	3,113	1,475	1,637	1,637	2.5%	15%
Total 2042	4,588		3,273			
	7,861					

**Table 15:
Volume wastewater projection**

Year	South Caye Caulker		North Caye Caulker		Total (GPD)
	Residents	Tourists	Residents	Tourists	
2022	90,000	45,000	4,737	5,000	144,737
2023	92,250	46,125	5,447	5,750	149,572
2024	94,556	47,278	6,264	6,613	154,711
2025	96,920	48,460	7,204	7,604	160,189
2026	99,343	49,672	8,285	8,745	166,045
2027	101,827	50,913	9,527	10,057	172,324
2028	104,372	52,186	10,957	11,565	179,081
2029	106,982	53,491	12,600	13,300	186,373
2030	109,656	54,828	14,490	15,295	194,270
2031	112,398	56,199	16,664	17,589	202,850
2032	115,208	57,604	19,163	20,228	212,202
2033	118,088	59,044	22,038	23,262	222,431
2034	121,040	60,520	25,343	26,751	233,655
2035	124,066	62,033	29,145	30,764	246,008
2036	127,168	63,584	33,517	35,379	259,646
2037	130,347	65,173	38,544	40,685	274,750
2038	133,606	66,803	44,326	46,788	291,522
2039	136,946	68,473	50,974	53,806	310,199
2040	140,369	70,185	58,621	61,877	331,052
2041	143,879	71,939	67,414	71,159	354,390
2042	147,475	73,738	77,526	81,833	380,572
Total	221,213		159,358		380,572

Annex 2: Comparison of wastewater collection system options

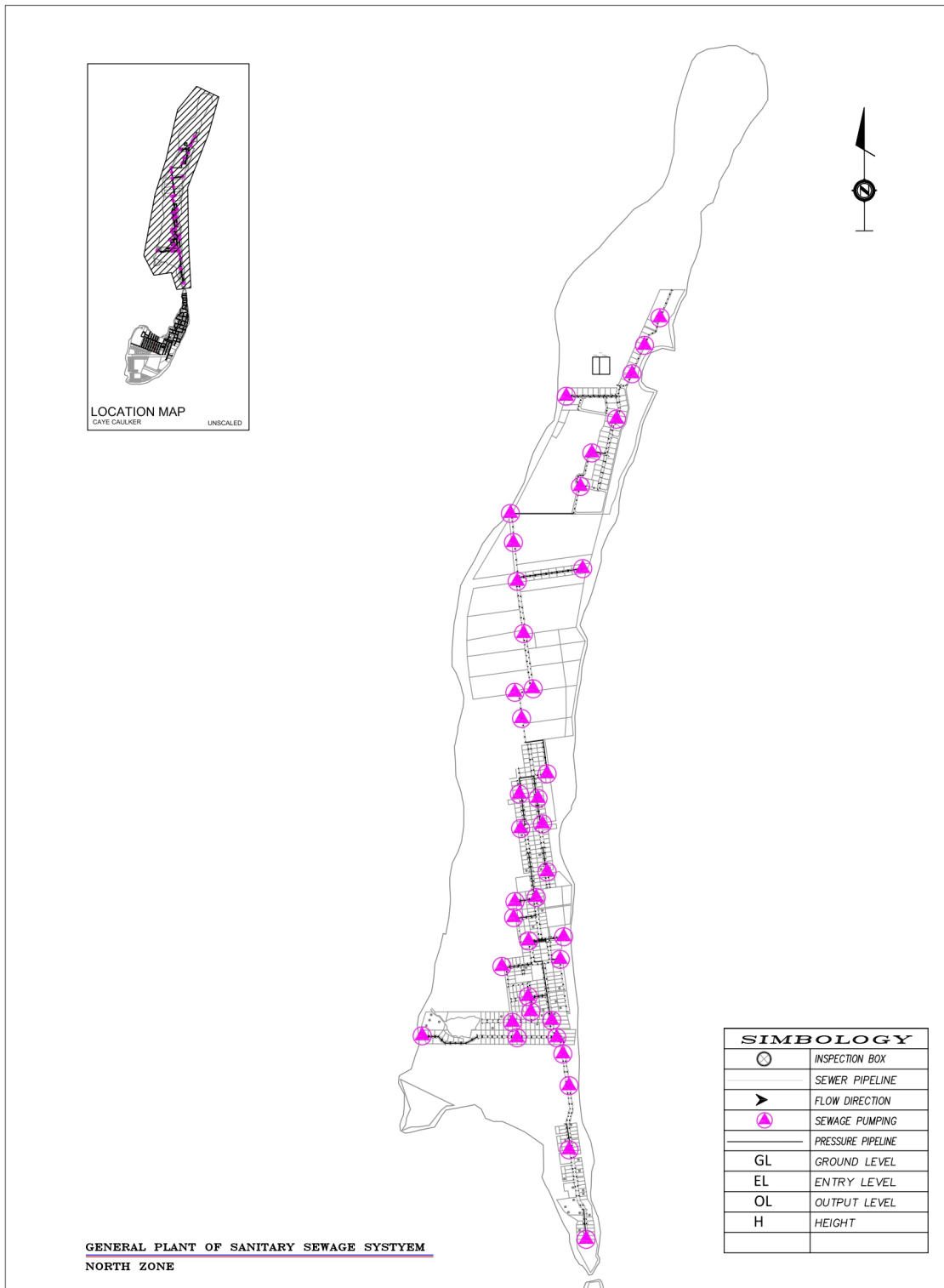
Category	Condominial system	Vacuum system	FLAT system
Feasibility in prevailing topographic and geologic conditions			
<i>Unstable soil</i>	Feasible	Feasible	Feasible
<i>High groundwater level</i>	Feasible	Feasible	Feasible
<i>Flat terrain</i>	Feasible	Feasible	Feasible
Capital Expenditure	Medium	Medium to high	Low to medium
Operating expenditure			
<i>Electricity</i>	High demand	Medium demand	Low demand
<i>Number of operators</i>	Two operators required for preventative maintenance	Two operators required for preventative maintenance	Two operators required for preventative maintenance
<i>Sludge removal (septic tanks)</i>	Not required	Not required	Required
Complexity of the system	Collection Chamber is a critical point due to the small diameter, higher number of pumps	Valves can present a technical problem due to obstruction, therefore leading to failure	Pretreatment unit to be installed or used existing pretreatment unit
<i>Availability of spare parts and service providers</i>	Available in country	Available in USA	Available in country
<i>Level of training (operators)</i>	Medium level of training is required for O&M Staff.	High level of training required for O&M	Low level of training required for O&M
Interaction of customer			
<i>Customer training requirement</i>	Training or education required for homeowner due to smaller diameter and possibility of blockage	No significant training or education required for homeowner.	Some training or education required for homeowner.
<i>Private property access</i>	No access necessary	No access necessary	Access to septic tanks required

Annex 3: Comparison of wastewater treatment options

Category	Trickling Filters	Activated Sludge (SBR)	Treatment wetland - French System
Land requirement	1-2 acres on each side of the island.	1-2 acres on each side of the island.	0.8 m ² /pe.
Flexibility to hydraulic and organic load	Critical to shock loads for the secondary clarifier	SBR is one of the most flexible systems for shock loading due to the batch operation.	With high retention times, flow and load peaks are well tolerated
Vector and Odor Problem	Potential for vector and odor problems.	No significant issues	Limited potential for problems
Capital expenditure	High	Moderate	Moderate
Operating expenditure	Moderate.	Relatively high.	Low cost
<i>Electricity</i>	Relatively low power requirement	High power requirement	Very low power requirements
<i>Number of operators</i>	One operator required	One operator required	Part-time operator required (25%)
<i>Maintenance</i>	Moderate	Relatively high	Low
Complexity of the system			
<i>Spare parts and service providers</i>	Limited availability (in the region)	Availability only outside of region (USA)	Full availability in country
<i>Skill level required to Operate</i>	Moderate. Regular Operator attention is needed.	Moderate skill level for day-to-day operation but qualified supervision needed in order to react to changes.	Operational simplicity. Minimal skills required.
<i>Primary Treatment</i>	Needs primary treatment	No primary treatment needed	For this type of wetland, no
<i>Sludge generation</i>	Generates less sludge than activated sludge, but primary sludge has to be stabilized.	Sludge dewatering needed; sludge is stabilized.	No separate sludge treatment needed; sludge treated in the French System
<i>Tertiary treatment</i>	suitable for UV disinfection	suitable for UV disinfection	Retention of helminth eggs, suitable for UV disinfection

<i>Automatization</i>	Easy to automatize for control purposes	Easy to automatize for control purposes and automatization is a pre-condition for the process.	Almost no need for automatization besides flow metering and switching of beds
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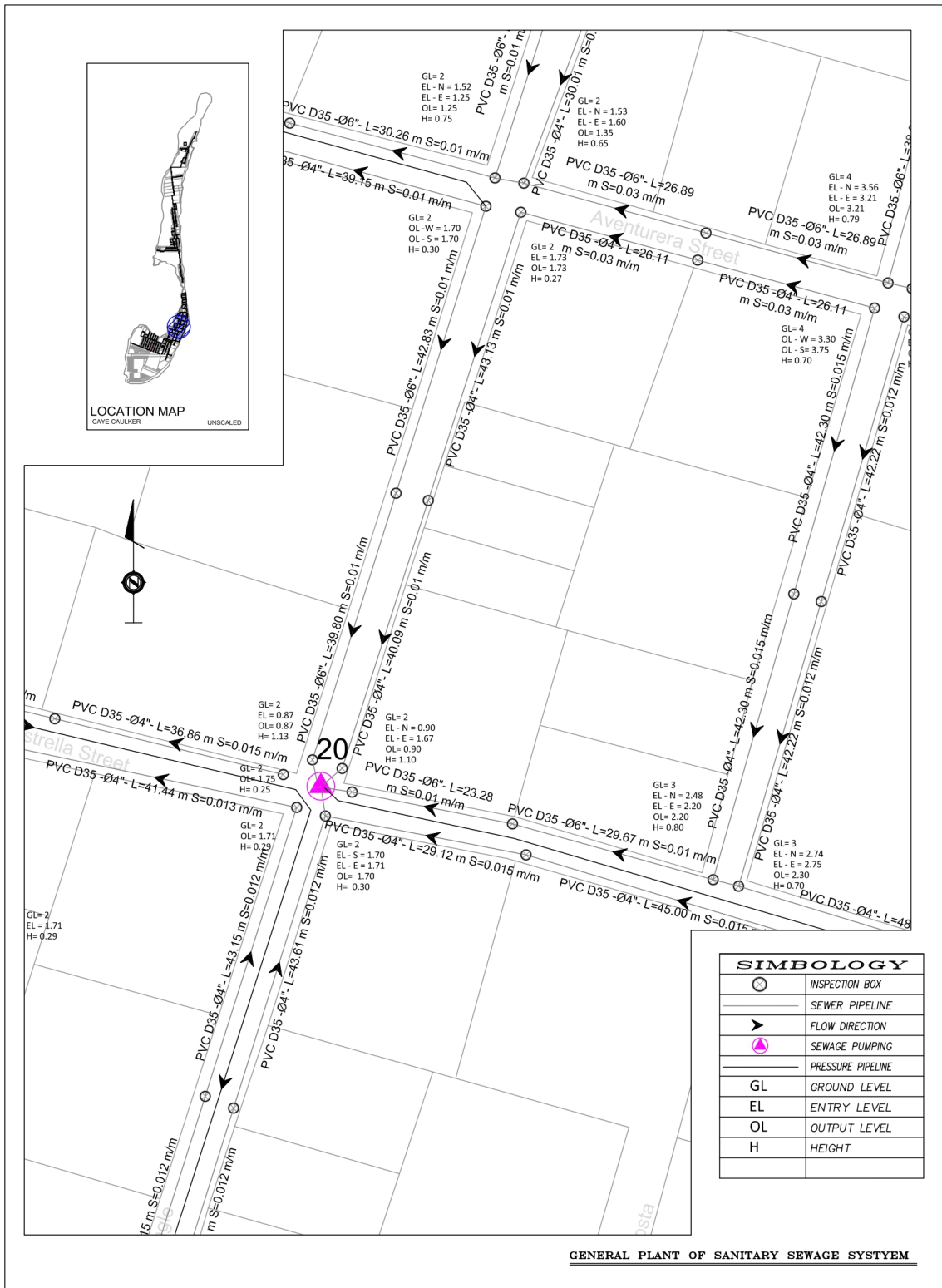
Annex 4: Layout for condominal system





SIMBOLOGY	
○	INSPECTION BOX
—	SEWER PIPELINE
➤	FLOW DIRECTION
▲	SEWAGE PUMPING
- - -	PRESSURE PIPELINE
GL	GROUND LEVEL
EL	ENTRY LEVEL
OL	OUTPUT LEVEL
H	HEIGHT

GENERAL PLANT OF SANITARY SEWAGE SYSTEM
SOUTH ZONE



Annex 5: Cost estimation for condominal system - South

Annex 5A: Cost estimation for condominal system - BWS cost base

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
1	Preliminary activities				2,029,549.93
101	Mobilization! preconstruction survey and demobilization	L.S.	1.00	731,527.00	731,527.00
102	Schedule	L.S.	1.00	18,000.00	18,000.00
103	Labor & material bonds	L.S.	1.00	209,007.64	209,007.64
104	Insurance	L.S.	1.00	418,015.29	418,015.29
105	Coordination / Project management & construction progress management	L.S.	1.00	90,000.00	90,000.00
106	Permits	L.S.	1.00	5,000.00	5,000.00
107	Quality control	L.S.	1.00	18,000.00	18,000.00
108	Health and safety	L.S.	1.00	4,500.00	4,500.00
109	Temporary facilities	L.S.	1.00	18,000.00	18,000.00
110	Environmental protection & temporary controls	L.S.	1.00	10,000.00	10,000.00
111	Grades and lines	L.S.	1.00	15,000.00	15,000.00
112	Equipment start-up & performance testing	L.S.	81.00	5,000.00	405,000.00
113	Cleaning	L.S.	1.00	7,500.00	7,500.00
114	Record drawings	L.S.	1.00	40,000.00	40,000.00
115	Operation & maintenance manuals	L.S.	1.00	40,000.00	40,000.00
2	Sanitary sewers				8.772.089!65
201	100 mm Dia. DR35 PVC	m	17,609.26	150.00	2,641,389.00
202	150 mm Dia. DR35 PVC	m	4,530.07	165.00	747,461.55
203	200 mm Dia. DR35 PVC	m	868.86	185.00	160,739.10
205	Sewer System Leakage Testing	L.S.	1.00	100,000.00	100,000.00
206	Sheeting and Shoring! and Well Point Dewatering System	L.S.	614.00	5,000.00	3,070,000.00
207	600 mm Dia. Sanitary Inspection box 0.25m - 1m in Depth	ea.	617.00	2,800.00	1,727,600.00
208	1200 mm Dia. Sanitary Manhole 1m - 1.75m in Depth	ea.	60.00	3,500.00	210,000.00

Ite m	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
209	Home connections	ea.	766.00	150.00	114,900.00
3	Pumping stations				11.933.176!60
301	50 mm dia. forcemain	m	2,509.32	90.00	225,838.80
302	100 mm dia. forcemain	m	2,230.51	100.00	223,051.00
303	150 mm dia. forcemain	m	0.00		
304	200 mm dia. forcemain	m	865.56	155.00	134,161.80
305	Forcemain pressure testing. 81 sites	L.S.	81.00	3.125,00	253.125,00
306	Clearing. Vegetation removal and Grubbing. and Topsoil Stripping (81 PS sites). Remove material from site and dispose at approved location (written approval from landowner and minimum 50 meters away from water body)	L.S.	81.00	5.000,00	405.000,00
307	Excavate and Remove and dispose of site. gravel. rocks. sand and silt	L.S.	81.00	5.000,00	405.000,00
308	Supply and Install PS Concrete Base-slab for PS	L.S.	81.00	5.000,00	405.000,00
309	Supply. Transport. Place and Compact Select Native Fill Material to Subgrade (81 sites). Granular material availability on Caye is limited. refer to Mitchell Moody Geotechnical Investigation	L.S.	81.00	12.000,00	972.000,00
310	Supply and Install and Commission Pumping Station (incl Control Panel and electric connection)	ea.	81.00	100.000,00	8.100.000,00
311	Sheeting and Shoring. and Well Point Dewatering System	L.S.	81.00	10.000,00	810.000,00
4	Earthworks				195.498.16
401	Excavate. transport. place and compact berm material (select native excavated material)	m ³	8,886.28	22,00	195.498,16
5	Provisional works				836.030.58
501	Engineering during construction	L.S.	1.00	836.030,58	836.030,58
Budget estimate					24.637.528.92
Budget estimating contingency					2.463.752.89
Total					27.101.281.81

Annex 5B: Cost estimation for condominal system - AKUT cost base

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
1	Preliminary activities				361,446.39
101	Mobilization, preconstruction survey and demobilization	L.S.	1.00	32,500.00	32,500.00
102	Labor & material bonds	L.S.	1.00	91,716.39	91,716.39
103	Insurance	L.S.	1.00	32,500.00	32,500.00
104	Coordination / Project management & construction progress management	L.S.	1.00	46,800.00	46,800.00
105	Permits	L.S.	1.00	3,250.00	3,250.00
106	Shop drawings	L.S.	1.00	9,720.00	9,720.00
107	Health and safety	L.S.	1.00	2,925.00	2,925.00
108	Temporary facilities	L.S.	1.00	11,700.00	11,700.00
109	Equipment start-up & performance testing	L.S.	120.00	1,000.00	81,000.00
110	Commissioning	L.S.	1.00	12,960.00	12,960.00
111	Training	L.S.	1.00	6,500.00	6,500.00
112	Cleaning	L.S.	1.00	4,875.00	4,875.00
113	Record drawings	L.S.	1.00	15,000.00	15,000.00
114	Operation & maintenance manuals	L.S.	1.00	10,000.00	10,000.00
2	Sanitary sewers				6,58,989.65
201	100 mm Dia. DR35 PVC	m	17,609.26	150.00	2,641,389.00
202	150 mm Dia. DR35 PVC	m	4,530.07	165.00	747,461.55
203	200 mm Dia. DR35 PVC	m	868.86	185.00	160,739.10
204	Sewer System Leakage Testing	L.S.	1.00	32,500.00	32,500.00
205	Sheeting and Shoring, and Well Point Dewatering System	L.S.	614.00	2,500.00	1,535,000.00
206	600 mm Dia. Sanitary Inspection box 0.25m - 1m in Depth	ea.	617.00	1,000.00	617,000.00
207	1200 mm Dia. Sanitary Manhole 1m - 1.75m in Depth	ea.	60.00	3,500.00	210,000.00
208	Home connections	ea.	766.00	150.00	114,900.00
3	Pumping stations				2,917,151.60
301	50 mm dia. forcemain	m	2,509.32	90.00	225,838.80
302	100 mm dia. forcemain	m	2,230.51	100.00	223,051.00

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
303	150 mm dia. Forcemain5	m	0.00	135.00	0.00
304	200 mm dia. forcemain	m	865.56	155.00	134,161.80
305	Forcemain pressure testing, 120 sites	L.S.	81.00	500.00	40,500.00
306	Clearing, Vegetation removal and Grubbing, and Topsoil Stripping (81 PS sites), Remove material from site and dispose at approved location (written approval from landowner and minimum 50 meters away from water body)	L,S,	81,00	300.00	24,300.00
307	Excavate and Remove and dispose of site, gravel, rocks, sand and silt	L,S,	81,00	2,000.00	162,000.00
308	Supply and Install PS Concrete Base-slab for PS	L,S,	81,00	2,000.00	162,000.00
309	Supply, Transport, Place and Compact Select Native Fill Material to Subgrade (81 sites), Granular material availability on Caye is limited, refer to Mitchell Moody Geotechnical Investigation	L,S,	81,00	1,000.00	81,000.00
310	Supply and Install Lifting Davit Concrete Bases	L,S,	1,00	1,300.00	1,300.00
311	Supply and Install and Commission Pumping Station (incl Control Panel)	ea,	81,00	18,000.00	1,458,000.00
312	Sheeting and Shoring, and Well Point Dewatering System	L,S,	81,00	5,000.00	405,000.00
4	Earthworks				195,498.16
401	Excavate, transport, place and compact berm material (select native excavated material)	m ³	8,886,28	22.00	19,498.16
5	Electrical works				648,000.00
501	Supply and Install Overhead Power Cable from nearby Pole mounted Transformer (within 100 meters of PS) to Pumping Station Power and Control Panel, Complete final terminations and testing (circuit test, megger test, arc flash test, grounding etc.)	each	81,00	8,000.00	648,000.00
6	Provisional works				196,392.79

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
601	Engineering during construction	L,S,	1,00	196,392.79	196,392.79
Budget estimate					10,936,769.80
Budget estimating contingency					1,093,676.98
Total					12,030,446.78

Annex 6: Cost estimation for vacuum system - AKUT cost base - South Caye Caulker

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
1	Preliminary activities				541.169.68
101	Mobilization, preconstruction survey and demobilization	L.S.	1.00	100,000.00	100,000.00
102	Labor & material bonds	L.S.	1.00	57,784.89	57,784.89
103	Insurance	L.S.	1.00	115,569.79	115,569.79
104	Coordination / Project management & construction progress management	L.S.	1.00	90,000.00	90,000.00
105	Permits	L.S.	1.00	5,000.00	5,000.00
106	Shop drawings	L.S.	1.00	4,815.00	4,815.00
107	Quality control	L.S.	1.00	18,000.00	18,000.00
108	Health and safety	L.S.	1.00	4,500.00	4,500.00
109	Temporary facilities	L.S.	1.00	18,000.00	18,000.00
110	Environmental protection & temporary controls	L.S.	1.00	10,000.00	10,000.00
111	Grades and lines	L.S.	1.00	15,000.00	15,000.00
112	Equipment start-up & performance testing	L.S.	1.00	30,000.00	30,000.00
113	Commissioning	L.S.	1.00	30,000.00	30,000.00
114	Training	L.S.	1.00	10,000.00	10,000.00
115	Cleaning	L.S.	1.00	7,500.00	7,500.00
116	Record drawings	L.S.	1.00	15,000.00	15,000.00
117	Operation & maintenance manuals	L.S.	1.00	10,000.00	10,000.00
2	Sanitary sewers				129.750.00
201	Home connections	ea.	865.00	150.00	129,750.00
3	Vacuum system				5.541.892.00
301	90 mm dia. forcemain	m	12,696.00	100.00	1,269,600.00
302	110 mm dia. forcemain	m	100.00	120.00	12,000.00
303	125 mm dia. forcemain	m	1,170.00	130.00	152,100.00
304	160 mm dia. forcemain	m	1,000.00	155.00	155,000.00
305	Sheeting and Shoring, and Well Point Dewatering System	L.S.	191.00	5,000.00	955,000.00
306	Connections to vacuum valve and pit	L.S.	191.00	7,860.00	1,501,260.00

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
307	Control system - bus		14,966.00	2.00	29,932.00
308	Excavate and Remove Bedrock and dispose of site	L.S.	191.00	5,000.00	955,000.00
309	Supply and Install PS Concrete Base-slab for Vacuum point	L.S.	191.00	1,000.00	191,000.00
310	Vacuum station	L.S.	1.00	321,000.00	321,000.00
4	Earthworks				122,115.97
401	Excavate! transport! place and compact berm material (select native excavated material)	m ³	5,550.73	22.00	122,115.97
5	Electrical works				12,000.00
501	Supply and Install Overhead Power Cable from nearby Pole mounted Transformer (within 100 meters of PS) to Pumping Station Power and Control Panel. Complete final terminations and testing (circuit test! megger test! arc flash test! grounding etc.)	each	1.00	12,000.00	12,000.00
6	Provisional works				115,809.79
601	Engineering during construction	L.S.	1.00	115,809.79	115,809.79
Budget estimate					6,331,659.03
Budget estimating contingency					633,165.90
Total					6,964,824.93

Annex 7: Cost estimation for FLAT system - AKUT cost base

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
1	Preliminary activities				414,144.44
101	Mobilization, preconstruction survey and demobilization	L.S.	1.00	116,924.00	116,924.00
102	Labor & material bonds	L.S.	1.00	33,406.81	33,406.81
103	Insurance	L.S.	1.00	66,813.63	66,813.63
104	Coordination / Project management & construction progress management	L.S.	1.00	90,000.00	90,000.00
105	Permits	L.S.	1.00	5,000.00	5,000.00
106	Quality control	L.S.	1.00	18,000.00	18,000.00
107	Health and safety	L.S.	1.00	4,500.00	4,500.00
108	Temporary facilities	L.S.	1.00	18,000.00	18,000.00
109	Environmental protection & temporary controls	L.S.	1.00	10,000.00	10,000.00
110	Grades and lines	L.S.	1.00	15,000.00	15,000.00
111	Equipment start-up & performance testing	L.S.	4.00	1,000.00	4,000.00
112	Cleaning	L.S.	1.00	7,500.00	7,500.00
113	Record drawings	L.S.	1.00	15,000.00	15,000.00
114	Operation & maintenance manuals	L.S.	1.00	10,000.00	10,000.00
2	Sanitary sewers				2,713,366.67
201	90 mm dia. forcemain	M	12,696.00	100.00	1,269,600.00
202	110 mm dia. forcemain	M	100.00	120.00	12,000.00
203	125 mm dia. forcemain	M	1,170.00	130.00	152,100.00
204	160 mm dia. forcemain	M	1,000.00	155.00	155,000.00
205	Sewer System Leakage Testing	L.S.	1.00	50,000.00	50,000.00
206	Sheeting and Shoring, and Well Point Dewatering System	L.S.	133.33	5,000.00	666,666.67
207	Inspection valves	ea.	50.00	500.00	25,000.00
208	Home connections	ea,	766.00	500.00	383,000.00
3	Pumping stations				432,000.00
301	160 mm dia. forcemain	m	2,000.00	155.00	310,000.00

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
302	Forcemain pressure testing, 81 sites	L.S.	1.00	500.00	2,000.00
303	Clearing, Vegetation removal and Grubbing, and Topsoil Stripping (81 PS sites). Remove material from site and dispose at approved location (written approval from landowner and minimum 50 meters away from water body)	L.S.	1.00	2,000.00	8,000.00
304	Excavate and Remove and dispose of site, gravel, rocks, sand and silt	L.S.	1.00	2,000.00	8,000.00
305	Supply and Install PS Concrete Base-slab for PS	L.S.	1.00	1,000.00	4,000.00
306	Supply, Transport, Place and Compact Select Native Fill Material to Subgrade (81 sites), Granular material availability on Caye is limited, refer to Mitchell Moody Geotechnical Investigation	L.S.	1.00	2,000.00	8,000.00
307	Supply and Install and Commission Pumping Station (incl Control Panel and electric connection)	ea.	4.00	18,000.00	72,000.00
308	Sheeting and Shoring, and Well Point Dewatering System	L.S.	1.00	5,000.00	20,000.00
4	Earthworks				195,314,73
401	Excavate, transport, place and compact berm material (select native excavated material)	m ³	8,877.94	22.00	195,314.73
5	Preliminary works				133,627,26
501	Engineering during construction	L.S.	1.00	133,627.26	133,627.26
Budget estimate					3,888,453,10
Budget estimating contingency					388,845,31
Total					4,277,298,41

Annex 8: Cost estimation for wastewater treatment South Caye Caulker - AKUT cost base

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
1	Preliminary activities				99,999.14
101	Mobilization, preconstruction survey and demobilization	L.S.	1.00	17,500.00	17,500.00
102	Labor & material bonds	L.S.	1.00	3,049.14	3,049.14
103	Insurance	L.S.	1.00	17,500.00	17,500.00
104	Coordination / Project management & construction progress management	L.S.	1.00	33,600.00	33,600.00
105	Permits	L.S.	1.00	1,750.00	1,750.00
106	Shop drawings	L.S.	1.00	525.00	525.00
107	Health and safety	L.S.	1.00	2,100.00	2,100.00
108	Temporary facilities	L.S.	1.00	8,400.00	8,400.00
109	Commissioning	L.S.	1.00	700.00	700.00
110	Training	L.S.	1.00	3,500.00	3,500.00
111	Cleaning	L.S.	1.00	2,625.00	2,625.00
112	Record drawings	L.S.	1.00	5,250.00	5,250.00
113	Operation & maintenance manuals	L.S.	1.00	3,500.00	3,500.00
2	Wastewater treatment plant (1 phase)				871,184.00
201	Excavate, transport, place and compact berm material (select native excavated material)	m ³	7,168.00	22.00	157,696.00
202	Construct cast in place concrete inlet chamber including all gates! bar screen and gratings	L.S.	1.00	60,000.00	60,000.00
203	Supply and install geomembrane and geotextiles for waterproofing	m ²	7,884.80	15.00	118,272.00
204	Supply and install granular material for wetland	m ³	7,168.00	25.00	179,200.00
205	Plants for wetland	each	28,672.00	3.00	86,016.00
206	Distribution system and piping	unit	1.00	100,000.00	100,000.00
207	Intermediate pumping station	unit	1.00	30,000.00	30,000.00
208	Disinfection equipment	unit	1.00	100,000.00	100,000.00
209	Electrical installation	unit	1.00	40,000.00	40,000.00
3	Provisional works				17,423.68

Item	Description	Unit	Quantity	Unit cost (\$USD)	Amount (\$USD)
301	Engineering during construction	L.S.	1.00	17,423.68	17,423.68
Budget estimate					988,606.82
Budget estimating contingency					98,860.68
Total					1,087,467.50

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