

Groundwater monitoring for mapping aquifers in Belize as a tool for climate change adaptation planning

Upscaling to national level

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Client representative	Marisela Ricardez Garcia
Project manager	Azucena Rodriguez Yebra
Project director	George Woolhouse

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Prepared Azucena Rodriguez Yebra	Approved George Woolhouse	Authorised Nigel Walmsley
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1 Background

1.1 Project summary

In Belize, 56% of the population lives in rural areas where groundwater is a vital source for fresh water and represents almost 95 per cent of the fresh water supply.

Groundwater is also used as a source of drinking water in all districts in Belize, using rural water systems and Belize Water Services Limited (BWSL) wells. However, the existing aquifers and their annual recharge rate have not been quantified.

Increase in demand for fresh water resulting from increasing population, greater economic activity and agricultural expansion are threatening the quality and availability of fresh water. Each year during low rainy seasons exists the possibility of droughts due to low recharge of aquifers.

Transboundary aspects and distribution of population are other factors that affect the water sector. For example, central and northern regions (Orange Walk and Corozal) have much larger populations and higher agriculture zones for water intensive crops, but less water resources.

Although there is a need for groundwater information across the country, the priority area includes the New River watershed. The Nationally Determined Contribution (2022) indicated water resource assessment (especially groundwater) as part of the main actions to be implemented to build resilience.

The results of the prioritization of adaptation technology factsheets for the Water Sector documented in the technologies needs assessment (TNA) for adaptation (National Climate Change Office et al., 2017) include:

- Drought Monitoring System for Northern Belize with Specific Focus on Groundwater Resources;
- Water Efficient Fixtures and Appliances;
- An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize.

The National Hydrological Service (NHS) is leading a process for building an inventory of existing data on groundwater. The objective is to identify and homogenize information that is currently available but spread among different agencies and institutions, and their various departments.

Requests have been made from the executive level of the Ministry (responsible for the NHS) to other ministries for sharing of relevant groundwater data. However, this is still a work in progress. Additionally, the Ministry of Rural Transformation has indicated that they do not geo-reference their wells.

Following the foreseen adaptation actions in the NDC and the TNA for Adaptation for the water sector, the National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management, and the National Hydrological Service (NHS) started conversations to develop a proposal for a Groundwater Monitoring System.

1.2 About this report

The purpose of this report is to provide a cost analysis and financing strategy for the full monitoring system. This is based on the New River groundwater monitoring system design that was carried out during previous activities within Output 4 of the project (see Deliverable 4.6 report). The first part of this report focuses on the description of the upscaling to a national level. After that, an analysis of costs associated with the development, implementation, operation, and maintenance of the system will be completed to account for an implementation at the scale of Belize. This includes the capital cost of network installation; sampling costs for instrumentation, personnel, and logistics; and analytical costs for laboratory, data processing

and storage. All this information is included in this report to provide an overview of the finance strategy.

2 Proposed monitoring system description

This section sets out the proposed monitoring system, upscaling it to a national level. The principles for the development of the system remained as in the initial Northern Belize within the Coastal Plains groundwater province:

1. Relevant to the interests of the users;
2. Targeted to the highest priority areas;
3. Timely reporting of data;
4. Appropriate technology;
5. Adaptable to allow updates/improvements/upscaling;
6. Financially and technically sustainable;
7. Clear institutional roles.

As discussed for the initial system, the upscaling should not be overly ambitious given that Belize presently has no institutional experience with groundwater monitoring and considerable uncertainties still exist in aquifer characteristics. There is also no known well surveys in the rest of the territory which could facilitate the decision on well locations. Once implemented, the systems should be reviewed on a regular basis, preferably annually, in order to review the quality of the data being collected, revisit monitoring priorities and optimise the locations and frequency of monitoring. Lessons learned from the previous monitoring network design should inform the upscaling to the national territory.

2.1 Proposed locations for monitoring

In order to meet the monitoring objectives, locations for monitoring groundwater levels and quality have been identified and are provided Figure 2.1. Note that these are general locations of interest and not specific sites or coordinates, intended to provide a general guide to the likely number and locations of future monitoring interest.

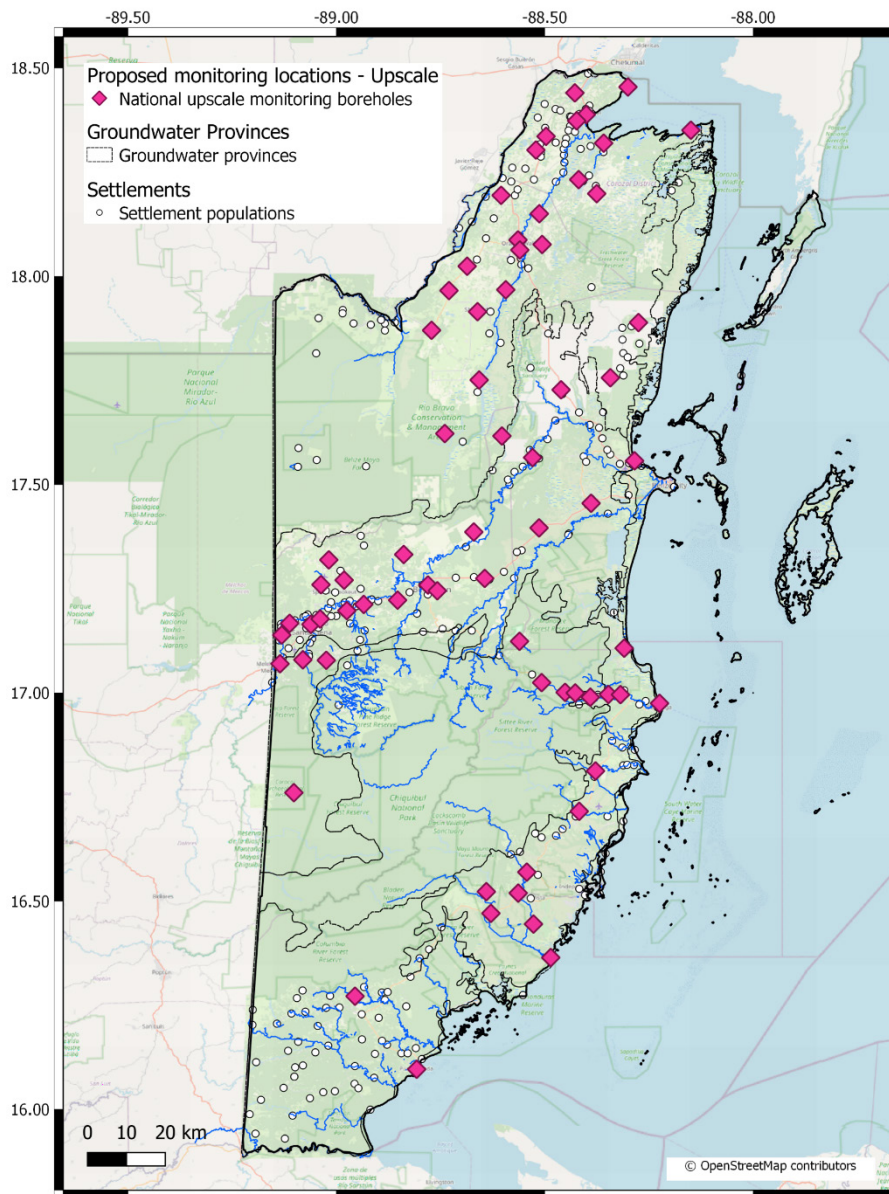


Figure 2.1: Proposed monitoring locations at a national level.

These have been identified on the basis of the following:

- A representative spread of locations across the different groundwater provinces around the country to be able to determine spatial variations in groundwater level changes and water quality changes over time.
- Locations have been selected in reference areas with minimum human disturbance to provide data on natural groundwater conditions to track drought and climate change without human influence.
- Locations have been selected in areas where agricultural development may influence groundwater levels (through abstraction for agriculture) and quality (through application of fertilizers and pesticides).
- Locations have been selected in areas where saline intrusion may pose a risk to public water supply in order to track changes in salinity over time.
- The lack of well surveys around the country has made the identification of existing wells that could be selected more difficult. Due to this, the map of the wells in the country does not show an exact location but an area of interest. These areas of interest will need to be

surveyed and more detailed fieldwork will need to be carried out to identify and confirm whether existing wells are suitable for monitoring or drilling of new boreholes is necessary. This is shown in Figure 2.2 with monitoring wells in all different groundwater provinces, based on population and agricultural development.

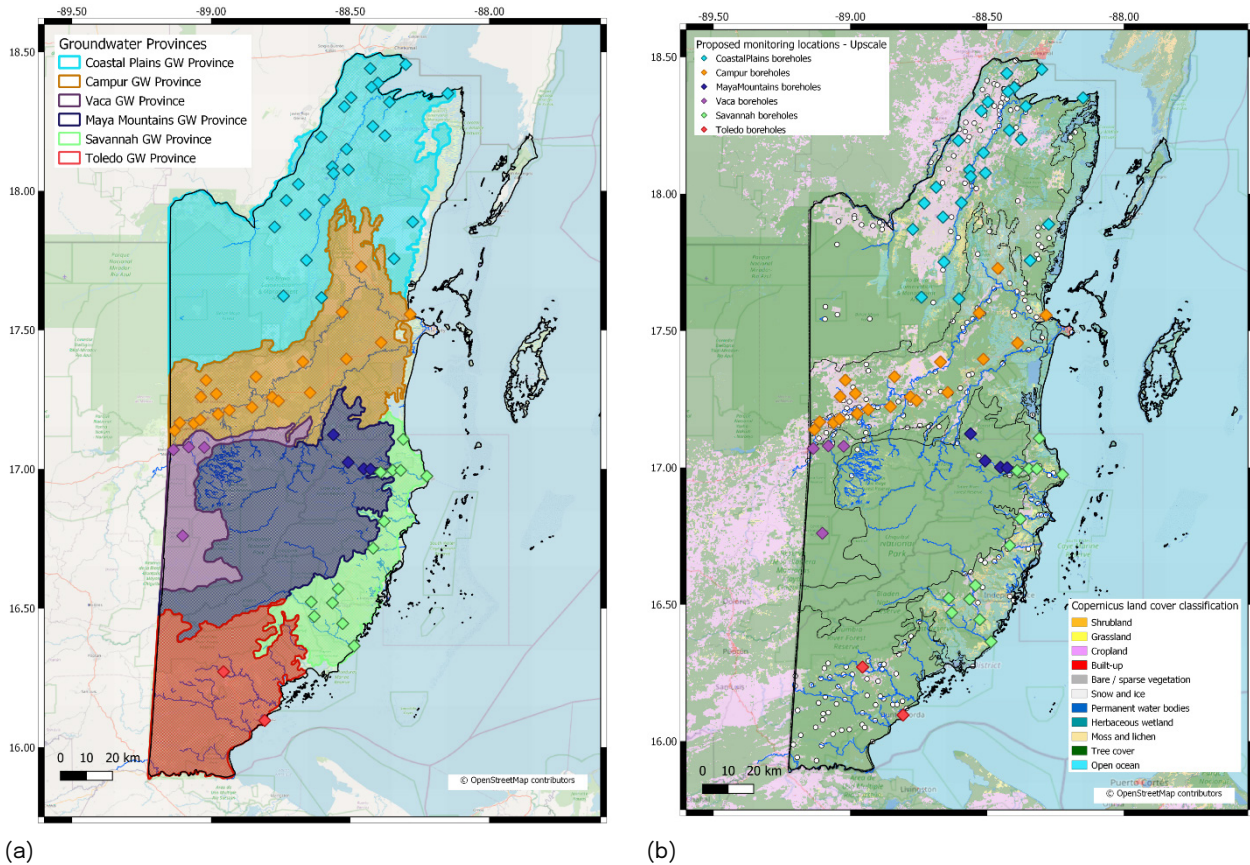


Figure 2.2: (a) Groundwater provinces delimitation and monitoring wells for each province; (b) monitoring boreholes and land cover classification.

A description of each of the groundwater provinces (Hartshorn et al., 1984) and the proposed locations of monitoring wells is given next (north to south). The Coastal Plains groundwater province in northern Belize is not described as this was the basis of the groundwater monitoring design in Output 4.6 (see corresponding report). A prioritisation of these provinces will be carried out in the next phases of the project to facilitate the gradual approach in the monitoring implementation.

As described in previous studies, Campur groundwater province coincides with the *Campur* limestone, so groundwater is available, if the water bearing limestone formations are reached. The location that covers this groundwater province, has large areas of agricultural development and population centres along the Belize River. Based on these agricultural areas and settlement populations, potential monitoring locations have been selected. Figure 2.3a shows these monitoring locations in detail. The Vaca Plateau has no permanent towns or villages, and water is obtained from springs or streams in the Chiquibul drainage basin in this groundwater province. Figure 2.3b shows areas of agricultural development in the northern area of the province, where three monitoring locations have been selected. South of the province, forest and archaeological reserves are present, and natural conditions should be monitored to assess natural conditions without human disturbance, the most suitable location for selected monitoring wells should be decided for this area.

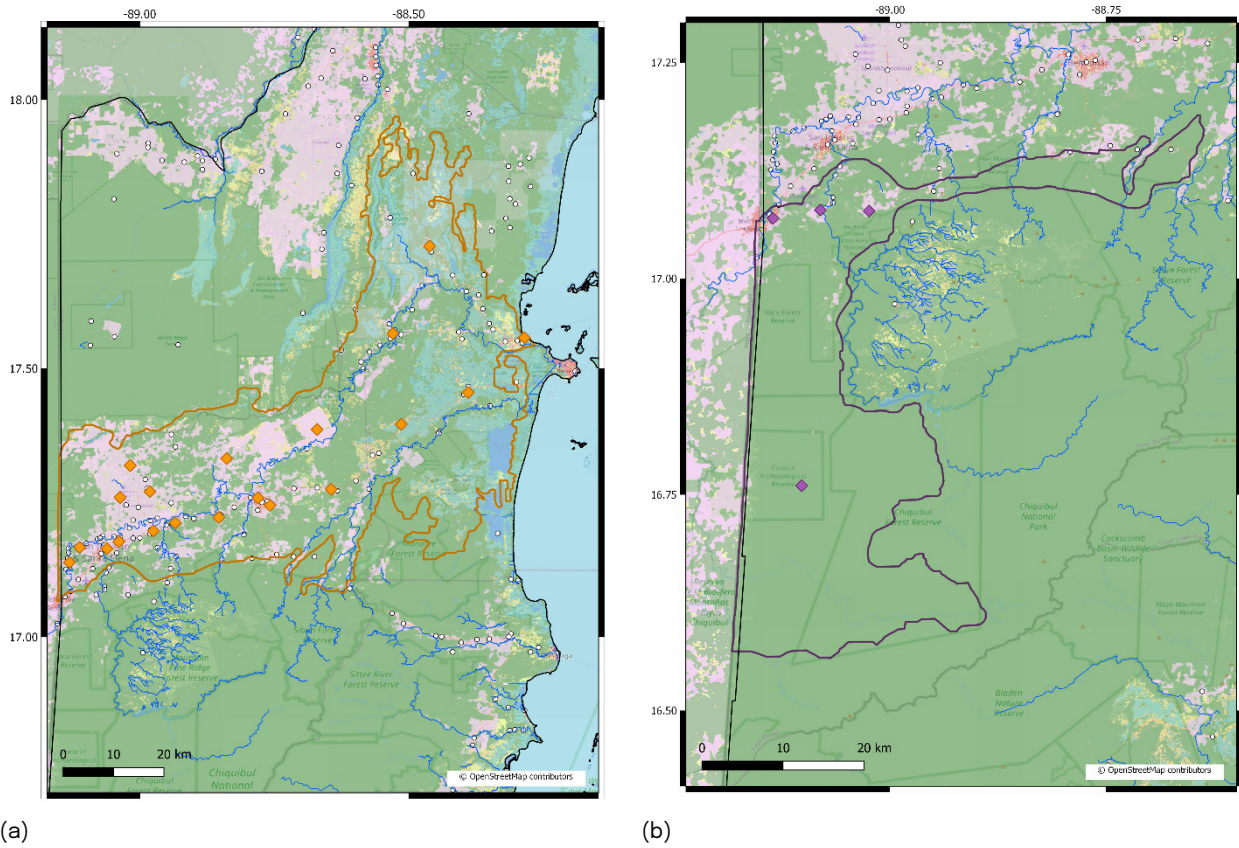


Figure 2.3: (a) Campur groundwater province and location of potential monitoring wells; Vaca groundwater province and location of potential monitoring wells

Due to the geology of the province, there is insignificant amounts of groundwater in the Maya Mountains, so water is taken from permanent streams and rainfall. However, due to areas of agricultural development, northeast of the groundwater province, the area would benefit from the setting up of monitoring wells (Figure 2.4a). Bordering the east of the Maya Mountains groundwater province, the Savannah groundwater province was the subject of a study in 2014 (UNDP, 2014), and it was found that only shallow aquifers were exploited. Deeper aquifer units could potentially also be exploited in future especially where shallow aquifers were brackish or saline. However, the study noted the risk of localised over-abstraction even if the overall level of groundwater exploitation for the province was low. Due to the large number of agricultural development in the province, it is advised that a number of monitoring wells are set up to cover these susceptible zones to monitor potential contaminations and over-abstraction (Figure 2.4b).

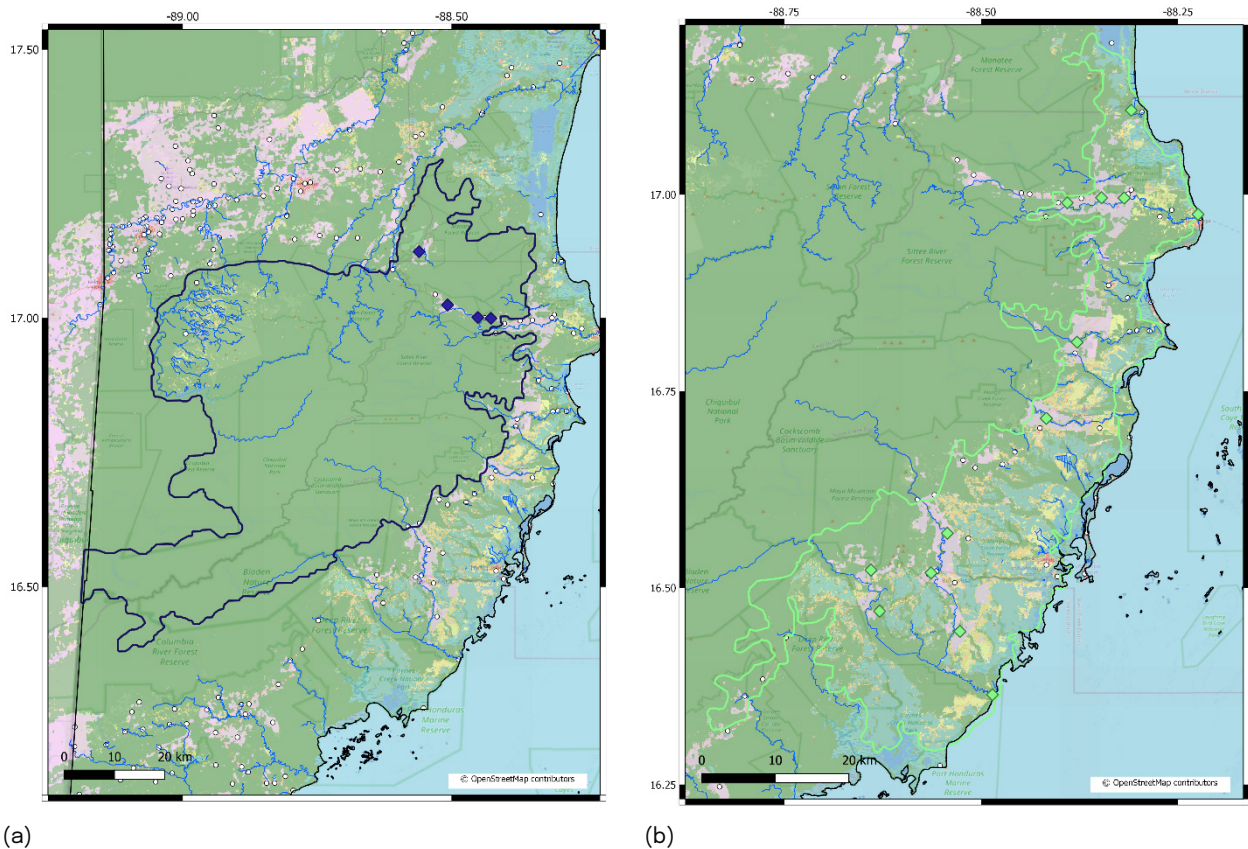


Figure 2.4: (a) Maya Mountains groundwater province and location of potential monitoring wells; Savannah groundwater province and location of potential monitoring wells

In the Toledo groundwater province, there is an apparent abundant supply of groundwater at shallow depths, with 2 major aquifers in the Sepur formation and the underlying Campur limestone. However in this area, there are no major population settlements and agricultural areas are scarce. Therefore, it is proposed to have two monitoring sites, one to assess the groundwater situation in areas where agriculture could impact abstraction and quality, and a site in proximity to the coast to assess salinity (Figure 2.5a).

The Coastal Shelf and Cayes groundwater province extends along the coast of Belize (Figure 2.5b). In this province, a perched freshwater aquifer exists in the extensive sand beaches, particularly along the Southern coastal shelf. Most fresh water is obtained from hand-dug wells or rainwater collection. Monitoring in this area is complicated by the presence of wetlands all along the coast. This has been taken into account and at this stage, no monitoring is proposed as it will need further and detailed study of the area for a suitable approach.

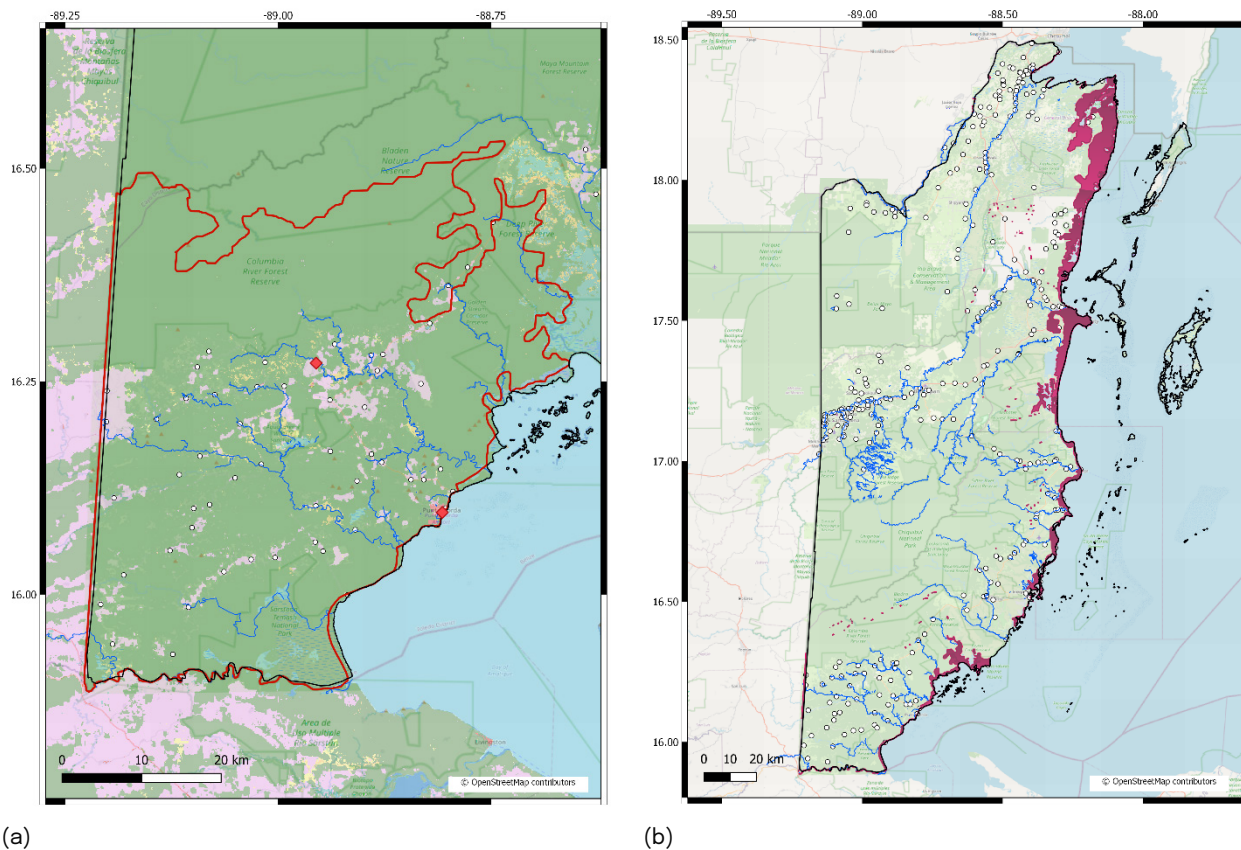


Figure 2.5: (a) Toledo groundwater province and location of potential monitoring wells; Coastal shelf groundwater province

3 Implementation plan

This section sets out the timeline of actions required in order to upscale the monitoring plan from the point of budget approval to the point where groundwater data collection, storage and dissemination is an ongoing regular process at a national scale. A Gantt chart showing the timing of each activity is provided in Figure 3.1 is provided electronically in Appendix A.

Following the implementation plan (Output 4.6) for the monitoring system design of Northern Belize, and using this as a testing site, plan for upscaling to other groundwater provinces is outlined in Figure 3.1. Year 1 of implementation focuses on the prioritisation of groundwater provinces in Belize. This prioritisation followed agricultural intensity in the area and population density, as this will impact on water supply needs. Years 2 to 6 are used to expand the monitoring system, set-up the equipment and continue data collection. More detailed information will be provided in the gradual approach to monitoring in Deliverable 5.3 (Institutional assessment and gradual approach to monitoring implementation).

It is also important to note that surface water and groundwater sources are linked across borders throughout Belize, Mexico and Guatemala. Therefore, plans for upscaling should take into consideration transboundary issues within the water sector. More will be expanded on this topic in Deliverable 5.3 report.

A phased approach dependent on funding and staff availability can also be considered. These phases will be described in the concept note developed in deliverable 5.2.

Activity	Timeline					
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Testing monitoring system design						
Northern Belize monitoring system installation						
Ongoing data collection activities						
Upscaling						
Prioritisation of other groundwater provinces						
Campur gw province monitoring system installation						
Ongoing data collection activities in Campur						
Savannah and Toledo gw provinces monitoring system installation						
Ongoing data collection activities in Savannah and Toledo						
Vaca and Maya Mountains gw provinces monitoring system installation						
Ongoing data collection activities in Vaca and in the Maya Mountains						

Figure 3.1: Implementation plan for upscaling from years 1 to 6

4 Cost for system set up and operation

4.1 Set up costs

4.1.1 Equipment

The initial setup requires the procurement of essential equipment such as groundwater level monitoring devices, data loggers, and associated installation materials. This would need to be adjusted when the number of automatically monitored sites and manually monitored sites is finally determined. This will also need to be adjusted correspondingly with the gradual approach to implementation. Depending on funding availability, the procurement of equipment, installation materials, and adequate clothing and materials for staff for system at national level could be done initially.

For the manually gauged stations, residents of the respective area will be commissioned to take and record readings using supplied equipment. The main pieces of equipment to be used are:

- Manual Well Dipper - used to measure the static water level in the well.
- Bailer - to collect water sample.
- Water quality probe meter - used to measure basic water quality parameters such as pH.
- Conductivity and Temperature.

As it relates to the automatic stations, the equipment list will comprise the following:

- Water level, conductivity and temperature probes, logger and telemetry equipment. It is understood that NHS prefer the use of Campbell Scientific as a supplier of equipment in order to ensure consistency across monitoring assets.

Equipment needs for NHS technicians will include:

- Portable submersible pump (~ 1 Hp).
- Portable electric power supply.
- Manual Well Dipper - used to measure the static water level in the well.
- Bailer: to collect water sample.
- Water quality probe meter - used to measure basic water quality parameters such as pH.
- Conductivity and Temperature.
- Rugged laptop for field data entry and cellular based internet connection. Rugged smartphone for communications.
- Pickup truck (4WD) to transport personnel and equipment to each site.

4.1.2 Site preparation

Preparing the monitoring sites involves completing basic well information sheets for each location (see report D-4.6, Appendix A), putting in place access and maintenance agreements with landowners. Minor works may be required to ensure proper well construction and retrofitting well heads to facilitate both manual and automatic measurement procedures and installing piezometers at automatic monitoring sites. Installation of dip tubes is recommended in wells or boreholes where submersible pumps are in place.

The drilling of new monitoring boreholes is not recommended unless no alternative is available, due to its high initial cost, and sunk investment. However, the cost set-up have accounted for the potential need for installing a number of boreholes, this could be easily adjusted if the number varies and has been highlighted in our costs for the upscaling of the system. It is also essential to have a survey of existing wells in the country so decisions on whether installation of monitoring boreholes would be necessary. Other aspects of site preparation include checking the accessibility to the site – will there be a need to clear pathways (pedestrian, vehicular) in heavily vegetated areas.

4.1.3 Data Management Infrastructure

To effectively collect, store, and analyse groundwater data, an appropriate data management infrastructure is required. This may involve investing in a centralized database, secure servers, software licenses, and hardware components. Additionally, costs related to data validation, quality control, and backup systems should be considered. Currently, the NHS utilises a data management software (WISKI). The unit may also require an additional desktop computer dedicated for this groundwater monitoring initiative.

4.2 Operational Cost

4.2.1 Monitoring Personnel

Personnel are essential for the regular maintenance and operation of the groundwater monitoring system. For manually read system, the project has considered stipends for community observers and where necessary an access agreement fee for private property owners. The NHS also requires skilled technicians to conduct field visits, calibrate instruments, retrieve, and analyse data, and maintain the overall functionality of the system. The operational costs include salaries, training, and transportation allowances. For the purposes of this groundwater monitoring initiative, it is important to consider the number of personnel necessary to cover monitoring of the whole country. Two (2) additional personnel would be a minimum, four (4) additional personnel would be a medium requirement and six (6) the highest cost but most efficient in terms of time that the monitoring, maintenance and evaluation will take place. They will be recruited by the NHS with backgrounds in hydrogeology and/or hydrometry.

4.2.2 Maintenance and Calibration

Regular maintenance, calibration, repair, and replacement of monitoring equipment are crucial to ensure accurate and reliable data. Budgets should be allocated for periodic servicing, instrument calibration, spare parts, and replacement if necessary. In the table, these annual costs are calculated as the depreciated value for the service life – which is usually 3 to 5 years. Annual fees for site maintenance are also included. This includes vegetation clearing and minor repairs to well head mechanisms.

4.2.3 Data Collection and Analysis

The collected data needs to be processed, analysed, and interpreted for meaningful insights and decision-making. This will involve periodically going out in the field to collect and verify data

points. It is anticipated that field visits will be conducted on a quarterly basis to all sites (manual and automatic). These visits will require finances to cover the cost of accommodation if more efficient for visiting groups of remote sites, fuel, per diem, vehicle maintenance as well as insurance and licencing.

4.3 Summary of costs

These costs reflect three different scenarios, low, medium and high cost, where the number of technicians and vehicles used to maintain the monitoring system are analysed (Table 4.1). Summaries of both capital and operational costs for the proposed upscaling of the groundwater monitoring system are shown in Table 4.2 and Table 4.3. The costing spreadsheets are provided electronically as Appendix B to this report and provide an editable version for any fine tuning of budgets required in future. The costs are summarised as follows:

- 51 manual and 21 automatic sites;
- Quarterly WQ lab analysis for all 72 sites;
- 15 sites analysed for pesticides per year (lower frequency as this is costly and shipping to US required);
- Key assumptions: Use existing boreholes when possible, contingency for drilling new boreholes, replacement of most monitoring equipment at 3 to 5 year intervals, limited pesticide testing due to cost.

Table 4.1: Cost scenarios for upscaling of the monitoring system

	Low	Medium	High
Technicians	2	4	6
Vehicles	1	2	3

The costs presented here will cover the set up and ongoing operation of the groundwater monitoring system resulting in generating time series data of groundwater quality and quantity. It contains costs for a hydrogeologist to be brought onto the staff, and a small amount of external consultancy support to review data and optimise the system. It does not include external consultancy costs associated with any supplementary studies (for example hydrogeological modelling), it is envisaged these will be scoped once data collection has been progressed for a few years.

The costs here are based on 2023 prices and do not include inflation. When the implementation is scheduled it is suggested that adjustment of these costs for inflation is undertaken.

A 20% contingency is recommended to cover uncertainties in the costing estimates such as selection of equipment and unforeseen repair or replacement of equipment. Once the first Phase of the system has been implemented a clearer view of the need for contingency funds will emerge.

Table 4.2: Capital costs for national scale groundwater monitoring system in Belize dollars, to be spread over the course of four years based on phased implementation

Staff (number/vehicles)	CAPEX (BZD) for full system installation at national level		
	Low	Medium	High
Community managed water level monitoring	\$ 269,025	\$ 269,025	\$ 269,025
Automatic water level monitoring	\$ 751,050	\$ 751,050	\$ 751,050
Groundwater monitoring equipment for NHS technicians	\$ 39,350	\$ 78,700	\$ 118,050
Groundwater quality laboratory analysis	--	--	--
Data management	\$ 28,500	\$ 44,500	\$ 60,500
Administrative and logistical	\$ 60,200	\$ 120,400	\$ 180,600
Total costs	\$ 1,148,125	\$ 1,263,675	\$ 1,379,225

Table 4.3: Annual operational costs for national scale groundwater monitoring system in Belize dollars

Staff (number/vehicles)	Annual OPEX (BZD) for national scale monitoring system (2023 costs)		
	Low	Medium	High
Community managed water level monitoring	\$ 95,539	\$ 95,539	\$ 95,539
Automatic water level monitoring (including annualised replacement cost of equipment)	\$ 162,974	\$ 162,974	\$ 162,974
Groundwater monitoring equipment for NHS technicians	\$ 13,403	\$ 26,807	\$ 40,210
Groundwater quality laboratory analysis	\$ 205,200	\$ 205,200	\$ 205,200
Data management	\$ 30,500	\$ 30,500	\$ 30,500
Administrative and logistical	\$ 158,367	\$ 316,733	\$ 475,100
Total costs	\$ 665,983	\$ 837,753	\$ 1,009,523

Appendices

A Implementation plan

Insert implementation plan spreadsheet.

B Capital and operational costs

Insert capital and operational costs spreadsheet for scenarios.

Groundwater monitoring for mapping aquifers in Belize as a tool for climate change adaptation planning

Cost analysis and financing
strategy

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1 Background

1.1 Project summary

In Belize, 56% of the population lives in rural areas where groundwater is a vital source for fresh water and represents almost 95 per cent of the fresh water supply.

Groundwater is also used as a source of drinking water in the cities of the Corozal, Orange Walk, Cayo and Toledo Districts and in some rural areas of Toledo and Cayo. However, the existing aquifers and their annual recharge rate have not been quantified.

Increase in demand for fresh water resulting from increasing population, greater economic activity and agricultural expansion are threatening the quality and availability of fresh water. Each year during low rainy seasons exists the possibility of droughts due to low recharge of aquifers.

Transboundary aspects and distribution of population are other factors that affect the water sector. For example, central and northern regions (Orange Walk and Corozal) have much larger populations and higher agriculture zones for water intensive crops, but less water resources.

Although there is a need for groundwater information across the country, the priority area includes the New River watershed.

The Nationally Determined Contribution (2022) indicated water resource assessment (especially groundwater) as part of the main actions to be implemented to build resilience.

The results of the prioritization of adaptation technology factsheets for the Water Sector documented in the technologies needs assessment (TNA) for adaptation (National Climate Change Office et al., 2017) include:

- Drought Monitoring System for Northern Belize with Specific Focus on Groundwater Resources;
- Water Efficient Fixtures and Appliances;
- An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize.

The National Hydrological Service (NHS) is leading a process for building an inventory of existing data on groundwater. The objective is to identify and homogenize information that is currently available but spread among different agencies and institutions, and their various departments.

Requests have been made from the executive level of the Ministry (responsible for the NHS) to other ministries for sharing of relevant groundwater data. However, this is still a work in progress. Additionally, the Ministry of Rural Transformation has indicated that they do not geo-reference their wells.

Following the foreseen adaptation actions in the NDC and the TNA for Adaptation for the water sector, the National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management, and the National Hydrological Service (NHS) started conversations to develop a proposal for a Groundwater Monitoring System.

1.2 About this report

The purpose of this report is to provide a cost-benefit analysis financing strategy considering national self-funds, private sector participation and climate finance funds alternatives.

2 Introduction

The availability and effective management of fresh water resources in Belize is challenged by many factors including increased demand by productive sectors such as industry and

agriculture; detrimental human practices including pollution and deforestation. Threats posed by climate change through extreme weather events, include increased flood and drought conditions or rising sea levels that increase the risk of saline intrusion of coastal aquifers. These factors have placed severe strain on groundwater resources which is known to be the primary source of supply for rural communities in Belize.

HR Wallingford has been contracted by the UN Climate Technology Centre and Network (CTCN) to commission an assessment of groundwater availability and demand, and to design a fully integrated groundwater monitoring system with priority focus on the New River area in northern Belize. The outputs of this project will assist the National Hydrology Service (NHS) unit of the Ministry of Natural Resources, Petroleum and Mining in developing a national inventory of groundwater quantity and quality.

The Terms of Reference for this assignment also includes the development of a financing strategy to support the sustainability of this monitoring initiative and a feasibility assessment to determine the optimal financing and institutional modalities for replication and upscaling of this pilot.

This document outlines considerations for financing the required capital investments as well as operational expenditures needed to sustain the New River watershed pilot initiative. The document also explores considerations and options for upscaling the initiative to a national level.

This Financing Strategy document references other deliverables within this consultancy including:

- Document 4.6: New River Groundwater Monitoring System Design Report;
- Document 5.1: Groundwater Monitoring for Mapping Aquifers in Belize as a tool for Climate Change Adaptation Planning – Upscaling to a National Level;
- Document 5.3: Groundwater Monitoring for Mapping Aquifers in Belize as a tool for Climate Change Adaptation Planning – Gradual Approach to Monitoring Implementation.

3 Groundwater monitoring system design outline

3.1 New River pilot

The proposed Groundwater Monitoring System is designed to gather water availability, usage and quality data for one of the seven groundwater provinces in Belize – the Coastal Plains groundwater province located within northern Belize in the Orange Walk and Corozal districts where the New River watershed is situated. The system design overview is as follows:

1. Twenty (20) manually operated monitoring stations using existing wells and community field observers to gather data on behalf of NHS related to:
 - a. Weekly monitoring of groundwater levels;
 - b. Weekly monitoring of temperature, conductivity and pH.

NHS working collaboratively with the Environmental Health Department of the Ministry of Health will conduct samples for laboratory analyses on a quarterly basis and maintain a database of groundwater information.

2. Seven (7) automated monitoring stations situated in coastal areas will be managed by NHS to gather data related to water quantity and quality including the tracking of levels of salinity over time.

Further details of the Groundwater Monitoring System are provided in Output document 4.6 – *New River Groundwater Monitoring System Design Report*.

3.2 National level groundwater monitoring initiative

Lessons learnt from the New River Watershed Pilot are intended to inform a scaled-up approach to groundwater monitoring at a national level. Major factors influencing the selection of monitoring stations within the other groundwater provinces include population density, agricultural intensity and the risk of saline intrusion of coastal groundwater sources.

The HR Wallingford study (Output 5.1) recommends a total of 72 monitoring sites across Belize including 51 manual monitoring stations and 21 automatic monitoring stations. The report further advocates the use of existing wells to minimize costs associated with the construction of new boreholes.

4 Groundwater monitoring funding requirements

Costs associated with the start up and continuity of the program relate to the following:

Capital expenditures:

- Site preparation/well rehabilitation works and security;
- Monitoring Field Equipment;
- Vehicle(s) for field transportation;
- Data management hardware and software.

Operational expenditures:

- NHS Monitoring Technicians;
- Stipends for community field monitors;
- Laboratory analyses;
- Administrative costs.

The estimated costs for the pilot monitoring program have been estimated as follows:

Cost category	Year 1 BZD	Subsequent years (expenditure per annum) BZD
Capital investment costs	300,850	-
Operational costs	277,197	288,839 ¹
Replacement costs	-	75,212 ²

¹ Inflation adjustment for year 2 estimated at Belize inflation rate of 4.20% per annum as at September 2023

² Depreciation charged at an average rate of 25% based on an average 4 year asset life

The estimated costs for the upscaled national program were based on scenarios of low, medium and high costs factoring costs related to additional staffing of the NHS and investments in equipment and vehicles (see Document 5.1). The estimated costs based on each of these scenarios are summarized as follows:

	Low	Medium	High
Capital investment costs	BZD 1,148,125	BZD 1,263,675	BZD 1,379,225
Operational costs	665,983	837,753	1,009,523

The report recommends the application of a 20% contingency to account for any variations in estimates. The next section examines financing options for a sustainable program.

5 Sustainable financing for groundwater monitoring

5.1 Context

Like most developing countries within Latin America and Caribbean, the Government of Belize operates within a tight fiscal space characterized by high debt to GDP ratios, rising levels of inflation and modest economic growth. As at December 2022, Belize recorded total public debt of BZD 4.031 Billion amounting to 64.1% of Gross Domestic Product (GDP)³. These constraints limit the ability of the Government to fund needed investments to significantly improve and sustain public services from their core fiscal budgets.

A financially viable and resilient water sector requires the creation of an enabling environment where the true value of water is fully appreciated by all sectors of society. A World Bank report on Scaling Up Finance for Water cites that *“In most countries, the price of water does not reflect its real economic value nor the cost of provision of multiple water services. Water is often not sufficiently considered in investment, economic planning, and policy making. Water as a resource is commonly taken for granted and regularly wasted, threatening human health, and prompting social, environmental, and economic crises triggered by unsustainable approaches”*.⁴

The report goes on to prescribe the need for stronger water governance, institutional reforms, service efficiency, equitable and effective water pricing mechanisms, responsible resource usage, debt and equity financing through loans, capital market operations, public-private partnerships and other financing structures as the means to address the financing gap that exists within the sector.

These principles are embodied within an Integrated Water Resources Management framework (IWRM) which recognizes the need for a multi-sectoral multi-stakeholder approach to the effective management of water resources. The Government of Belize has embraced the concept and principles of IWRM through the development of IWRM policy and legislation which has given rise to the planned establishment of a National Integrated Water Resources Agency (NIWRA). This agency will be vested with the responsibility for the controlling, conserving and ensuring the proper use of water resources across all relevant sectors. The target date set for the full establishment of this entity is 2026.⁵

The funding of Belize’s IWRM institutional set up and specific interventions including the proposed hydrological monitoring program will require a financing strategy that gives recognition to the value of the resource as well as the need for its conservation and protection.

³ <https://www.pressoffice.gov.bz/wp-content/uploads/2023/03/Budget-for-FY2023-2024.pdf>

⁴ Khemka, Rochi, Patricia Lopez, and Olivia Jensen. 2023. Scaling up Finance for Water: A World Bank Strategic Framework and Roadmap for Action. Executive Summary. Washington, DC: World Bank

⁵ <https://med.gov.bz/wp-content/uploads/2023/04/Belize-Med-Term-Dev-Strategy-Action-Plan-2022-to-2025.pdf>

A comprehensive strategy of identifying investment needs; establishing an enabling environment for attracting investment through evidence-based water pricing policies, institutional efficiencies, and de-risking through blended finance arrangements and other public-private partnerships. The mobilization of donor support and concessionary financing from International Financial Institutions (IFIs) will also be critical with respect to providing seed funding to cover required capital investments.

The pricing of water remains fundamental to any financing strategy on water.

The OECD study on Water cites four principles that can be applied to finance water resources management⁶:

Principle	Application and effectiveness
Polluter pays principle	This principle is effective in limiting the levels of pollution around water catchment areas and providing resources for eco-system preservation and restoration. This principle is normally applied through the imposition of pollution taxes, fines and licenses.
Beneficiary pays principle	This principle recognizes that there is a value to be attached to water usage and seeks to ensure that there is a minimum cost recovery related to the production of potable water. This principle is applied through water tariffs directly related to resource usage and encourages water conservation.
Equity	This principle takes into account rights and access to water particularly when pricing of the resource is disproportionate to the users ability to pay. In such cases the use of government subsidies may be necessary to ensure resource affordability by marginalized sectors of society.
Policy coherence	Ensuring policy coherence between competing sectors and users such as agriculture, industry and tourism ensures more cost effective water management through the efficient allocation of budget resources.

These principles can be applied as a prescriptive mix of pricing policies depending on a country's circumstance.

5.2 Water pricing in Belize

The water sector in Belize is largely under-valued and under resourced. There are two primary revenue streams for the provision of water resources – usage tariffs and abstraction licenses fees.

Tariffs for water are set by the Public Utilities Commission (PUC) under the Water Industry Act and the Public Utilities Act. The PUC also provides licenses to water and wastewater service providers. Belize's main water service provider, Belize Water Services Limited (BWS) is regulated by the PUC who approves service rate increases and adjustments.

⁶ OECD(2012) A Framework for Financing Water Resources Management, OECD Studies on Water, OECD Publishing
https://read.oecd-ilibrary.org/environment/a-framework-for-financing-water-resources-management_9789264179820-en#page4

There have been no increases in water tariffs since the formation of the BWS in 2001.⁷ Given recent inflationary pressures, declining revenues and the need for capital replacement and expansion, BWS has proposed the following rate increases in their Annual Review Report 2022:

BWS Annual Review 2022 Report

APPENDIX A – EXISTING AND PROPOSED TARIFFS

Existing Tariffs – All Customers

Usage From	Usage up to	Mainland Water only	Mainland Water & Sewer	Ambergris Caye	Caye Caulker
0	1000	8.72	10.47	25.57	23.46
1001	2000	13.95	18.02	30.22	26.98
2001	3000	15.12	19.76	32.54	29.61
3001	4000	15.69	20.92	34.87	32.50
4001	5000	16.27	22.09	37.19	35.67
5001	6000	17.44	23.25	44.17	39.14
6001	7000	18.60	23.82	52.31	42.96
7001	8000	19.17	24.41	58.11	47.15
8001	-	19.76	24.99	63.93	51.75

Proposed Residential Tariffs

Usage From	Usage up to	Mainland Water only	Mainland Water & Sewer	Ambergris Caye	Caye Caulker
0	1000	8.72	10.47	25.57	23.46
1001	3000	14.29	18.27	31.13	26.60
3001	5000	15.88	20.56	41.93	35.46
5001	8000	18.26	24.11	50.64	42.55
8001	-	19.76	24.99	63.93	51.75

Senior Citizens to receive 10% discount on consumption up to 3000 gallons

Proposed Non-Residential Tariffs

Usage From	Usage up to	Mainland Water only	Mainland Water & Sewer	Ambergris Caye	Caye Caulker
0	1000	8.72	10.47	25.57	23.46
1001	8000	17.31	22.69	47.16	39.71
8001	-	19.96	25.24	64.57	52.27

Proposed Non-Residential Service Fee

Meter Size	Mainland Water Only	Mainland Sewer	Ambergris Caye	Caye Caulker
5/8-Inch	\$5.00	\$6.50	\$10.00	\$10.00
3/4-Inch	\$5.00	\$6.50	\$10.00	\$10.00
1-Inch	\$8.50	\$11.00	\$16.50	\$16.50
1.5-Inch	\$16.50	\$21.50	\$33.50	\$33.50
2-Inch	\$26.50	\$34.50	\$53.50	\$53.50
3-Inch	\$58.50	\$76.00	\$116.50	\$116.50

Figure 5.1: Existing and proposed water tariffs. Source BWS Annual Tariff Review

Rural supplies of potable water are managed through Water Boards who are accountable to Rural Village Councils. The Village Councils in turn fall under the remit of the Ministry of Rural Transformation, Community Development, Labour and Local Government. The Water Boards are responsible for operations and maintenance of the water supply systems; regulating pumping hours; undertaking system expansion; collecting fees; carrying out disconnections. There is no reliable data on tariffs charged and collected by Water Boards and the management of rural systems are quite loosely regulated.

⁷ Belize Water Services Annual Tarriff Review, April 29, 2022
<https://bws.bz/media/ATR2022-Report-Final.pdf>

5.3 Practical considerations for the implementation of a sustainable financing strategy for groundwater monitoring

The mandate of the NHS is to ensure the coordinated management, development, conservation, protection and sustainable use of water resources in Belize. The NHS is therefore proposed as the entity with lead responsibility for groundwater monitoring and maintaining an inventory of groundwater data. The unit is funded primarily through core budgetary allocations to the Ministry of Natural Resources, Petroleum and Mining. Although the NHS has the mandate for providing abstraction licenses, there is no significant revenue stream generated from this activity. The annual budget allocation for the NHS currently amounts to BZD 300,000 per annum.

Given the government’s budgetary constraints, innovative means must be sought to finance both capital and operational expenditures of the pilot New River initiative (Table 5.1) and the scaled-up national level monitoring program (Table 5.2). Recommended approaches to financing the investments and operational activities are tabled below:

Table 5.1: New River pilot monitoring program

Funding Requirement	Timeframe	Funding	Justification
Capital Expenditure	Immediate Term	<p>1. Donor Support through Climate Finance Initiatives including the Green Climate Fund.</p> <p>2. Funding Support from Regional Development Institutions and IFIs including:</p> <p>Caribbean Development Bank (CDB);</p> <p>CARICOM Development Fund (CDF);</p> <p>Inter-American Development Bank (IDB);</p> <p>World Bank through the Global Environment Facility (GEF).</p>	<p>As a critical component of the Belize National Action Plan (NAP) for Water, this initiative contributes directly to climate adaptation and building climate resilience within the water sector.</p> <p>Data collected during the initial phases of this initiative can serve to flesh out climate finance proposals for a more comprehensive program of IWRM support.</p>
Operational Expenditure	Short to Medium Term	<p>Government increased allocations to the NHS to cover required operational costs. This could come in the form of both commensurate increases in fiscal allocations to the Unit as well as resource sharing (personnel, vehicles, laboratory testing) with other collaborating public agencies.</p>	<p>1) The NHS operates primarily on Government budgetary allocations and the creation of additional revenue streams through service provision (ie. developing a mandatory abstraction license fee structure) will not be achieved in the immediate term.</p> <p>2) The pilot monitoring program will be contributing directly towards water sector policy development through evidence based data on resource availability, usage and water quality. This</p>

			inventory of data will also serve to inform the scaled up program for ongoing groundwater monitoring.
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Table 5.2: Expanded national level groundwater monitoring program

Funding Requirement	Timeframe	Funding	Justification
Capital Expenditure	Medium Term	Donor and IFI support as indicated above.	1) The investments required for a scaled up program (low, medium or high) may be beyond the fiscal capacity of the Government. 2) The groundwater monitoring initiative should not be seen as a standalone project but should be viewed within the wider context of IWRM and the reduction of climate related risk.
Operational Expenditure	Medium to Long Term	NHS cost recovery through revenue streams that apply one or more principles of financing water resources management as highlighted in Section 4.1 .	The enabling environment is created for water resources management and water policies are implemented that reflect the true economic value of water and equitable contributions by all sectors.

6 Summary

The Belize groundwater monitoring initiative is a critical component of the Belize’s NAP for water and supports the country’s embrace of IWRM principles. Financing for the initiative must be viewed in the context of water sector climate resilience with approaches to climate finance as a means of attracting initial investment capital that builds the required capacity within the NHS and collaborating agencies.

Longer term sustainable financing will require policy instruments that take into account all water supply related costs and through the implementation of tariffs, taxes, and payments for eco-system services, ensures an adequate measure of cost recovery as a means of funding the institutions that support water resources management in Belize.

Groundwater monitoring for mapping aquifers in Belize as a tool for climate change adaptation planning

Concept note - Climate finance
funds

Document information

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Project manager	Azucena Rodriguez Yebra
Project director	George Woolhouse

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Document authorisation

Prepared Azucena Rodriguez Yebra	Approved George Woolhouse	Authorised Nigel Walmsley
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1 Background

1.1 Project summary

The National Hydrological Service (NHS) of the Ministry of Natural Resources, Petroleum, and Mining and the National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management, are executing a project to design a groundwater monitoring system for the management of aquifers in Belize, focusing on the New River watershed. The project commenced in October 2022 and will complete in September 2023. HR Wallingford Limited is leading the consulting team implementing the project and financial support is provided by the Climate Technology Centre and Network (CTCN).

This important project will help Belize to sustainably manage groundwater resources in the face of a changing climate and human pressures on the resource.

The main outputs include:

1. A communications plan and detailed work plan;
2. Stakeholder mapping and establishing a stakeholder working group;
3. An assessment of groundwater availability and demand, nationally and with a particular focus on the New River watershed;
4. Design of an integrated monitoring system that will enable Belize to manage groundwater resources in the priority area of the New River watershed;
5. Development of an implementation plan on the enabling factors for implementation, including financial, institutional setting and capacity building.

1.2 About this report

This report presents a concept note for accessing climate finance for developing a groundwater monitoring system for Belize. It is based around the main elements of the Green Climate Fund Concept Note template, but is generic in its presentation to facilitate its reshaping to meeting the submission requirements of a range of climate financing sources. The total grant funding request is substantially smaller than the smallest category of GCF project which is the Micro at less than 10 million USD. This concept note could therefore be expanded to include other objectives relevant to sustainable management of water and land resources, or included as a component of a GCF concept note under development in the GCF Country Programme for Belize. Alternatively this concept note could be adapted to suit other funding opportunities and funded in stages depending on the ceiling amount of grant funding available on a case by case basis.

Where text is highlighted in yellow it has been left for completion by the project proponent.

2 Concept note

Project/Programme Title:	Groundwater monitoring for climate resilient Integrated Water Resources Management in Belize
Country(ies):	Belize
National Designated Authority(ies) (NDA):	National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management.
Accredited Entity(ies) (AE):	[REDACTED]
Date of first submission/ version number:	[YYYY-MM-DD] [V.0]
Date of current submission/ version number	[YYYY-MM-DD] [V.0]

A. Project/Programme Summary (max. 1 page)			
A.1. Project or programme	<input checked="" type="checkbox"/> Project <input type="checkbox"/> Programme	A.2. Public or private sector	<input checked="" type="checkbox"/> Public sector <input type="checkbox"/> Private sector
A.3. Is the CN submitted in response to an RFP?	Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> If yes, specify the RFP: -----	A.4. Confidentiality¹	<input type="checkbox"/> Confidential <input type="checkbox"/> Not confidential
A.5. Indicate the result areas for the project/programme	<p><u>Mitigation</u>: Reduced emissions from:</p> <input type="checkbox"/> Energy access and power generation <input type="checkbox"/> Low emission transport <input type="checkbox"/> Buildings, cities and industries and appliances <input type="checkbox"/> Forestry and land use <p><u>Adaptation</u>: Increased resilience of:</p> <input type="checkbox"/> Most vulnerable people and communities <input checked="" type="checkbox"/> Health and well-being, and food and water security <input type="checkbox"/> Infrastructure and built environment		

¹ Concept notes (or sections of) not marked as confidential may be published in accordance with the Information Disclosure Policy ([Decision B.12/35](#)) and the Review of the Initial Proposal Approval Process ([Decision B.17/18](#))

	<input checked="" type="checkbox"/> Ecosystem and ecosystem services		
A.6. Estimated mitigation impact (tCO₂e over lifespan)	None direct Potential mitigation benefits for any resulting reduction in fossil fuel powered groundwater abstraction	A.7. Estimated adaptation impact (number of direct beneficiaries and % of population)	Indirect beneficiaries 100% of population through improved groundwater monitoring and resulting sustainable use and protection of water resources
A.8. Indicative total project cost (GCF + co-finance)	Amount: USD 2,762,000	A.9. Indicative GCF funding requested	Amount: USD 2,460,000
A.10. Mark the type of financial instrument requested for the GCF funding	<input checked="" type="checkbox"/> Grant <input type="checkbox"/> Reimbursable grant <input type="checkbox"/> Guarantees <input type="checkbox"/> Equity <input type="checkbox"/> Subordinated loan <input type="checkbox"/> Senior Loan <input type="checkbox"/> Other: specify _____		
A.11. Estimated duration of project/ programme:	6 years	A.12. Estimated project/ Programme lifespan	25 years (noting that the monitoring system should continue indefinitely)
A.13. Is funding from the Project Preparation Facility requested?²	Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> Other support received <input type="checkbox"/> If so, by who:	A.14. ESS category³	<input type="checkbox"/> A or I-1 <input type="checkbox"/> B or I-2 <input type="checkbox"/> C or I-3
A.15. Is the CN aligned with your accreditation standard?	Yes <input type="checkbox"/> No <input type="checkbox"/>	A.16. Has the CN been shared with the NDA?	Yes <input type="checkbox"/> No <input type="checkbox"/>

² See [here](#) for access to project preparation support request template and guidelines

³ Refer to the Fund's environmental and social safeguards ([Decision B.07/02](#))

<p>A.17. AMA signed (if submitted by AE)</p>	<p>Yes <input type="checkbox"/> No <input type="checkbox"/></p> <p>If no, specify the status of AMA negotiations and expected date of signing:</p>	<p>A.18. Is the CN included in the Entity Work Programme?</p>	<p>Yes <input type="checkbox"/> No <input type="checkbox"/></p>
<p>A.19. Project/Programme rationale, objectives and approach of programme/project (max 100 words)</p>	<p>Belize relies significantly on groundwater resources, serving crucial roles in domestic, agricultural, and industrial water supplies, while also supporting wetland and river ecosystems. Future climate projections indicate a hotter and drier climate, leading to a diminished natural recharge of groundwater aquifers.</p> <p>To address this, a comprehensive monitoring system for water quality and quantity in Belize's groundwater aquifers will be initiated. The project's initial focus will be on northern Belize, where groundwater challenges are most pressing, and then building on this to expand the system to a national scale.</p> <p>Combining funding from the Green Climate Fund (GCF) and in-kind contributions from the Government of Belize, the project will be carried out through collaboration between the National Hydrological Service (NHS) of Belize, the National Climate Change Office, and pertinent stakeholders in the water sector.</p>		

2.1 Project Information

2.1.1 Project/Programme Title

Groundwater monitoring for climate resilient Integrated Water Resources Management in Belize.

2.1.2 Project/Programme rationale, objectives and approach of programme/project

Groundwater resources in Belize are a vital source for domestic, agricultural and industrial water supplies, as well as sustaining wetland and river ecosystems services. Historically, groundwater has been perceived as an unlimited resource, and monitoring has not been carried out. However, this is now changing as increasing exploitation and pollution coupled with a changing climate is already increasing the stress on the resource. Belize is projected to experience a drier and hotter climate in future, reducing the natural recharge of groundwater aquifers.

This project will provide systematic monitoring of the groundwater aquifers throughout Belize for water quality and quantity. This will equip the government of Belize with the tools and information to manage the resource sustainably in the face of a changing climate and increasing human pressures. It will begin by focussing on northern Belize where groundwater issues are highest priority, then upscale to national level and continue to support the system as it becomes fully institutionalised and sustainable.

The project will be executed by the National Hydrological Service (NHS) of Belize, the government agency mandated with the management of Belize's freshwater resources, working with the National Climate Change Office and relevant water sector stakeholders.

2.1.3 Context and baseline

Belize has seven groundwater provinces, defined based on hydrogeological characteristics, shown in Figure 2.1. These are the Coastal Plains; the Coastal Shelf and Cayes Province; the Vaca Plateau Province; the Campur Province; the Maya Mountains Province; the Toledo Province; and the Savannah Province. The Coastal Plains province is the most heavily exploited for domestic, agricultural and industrial water supplies, as well as sustaining wetland and river ecosystems services. Groundwater is widely used in this province and a survey of wells by the NHS identified around 400 wells and boreholes, although this is likely to be a substantial underestimate. Groundwater use has increased steadily over the preceding decades and is the main water source in the Coastal Plains.

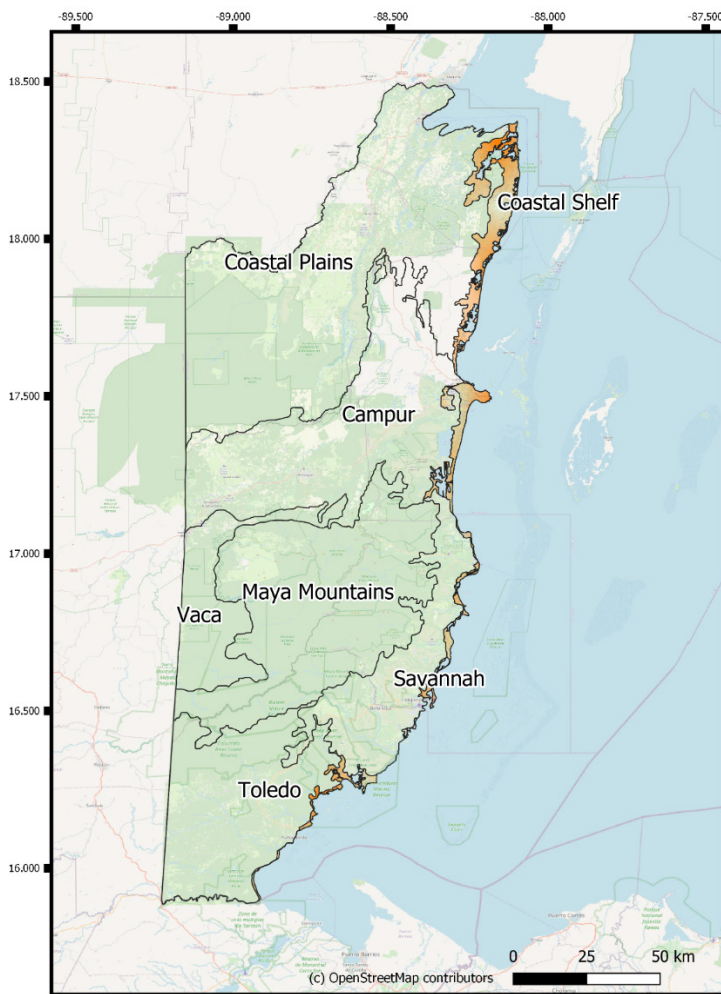


Figure 2.1: Belize groundwater provinces (Coastal Shelf province shaded for clarity)

Exploitation and pollution of groundwater through increased groundwater use and agricultural intensification is placing the resource under increasing stress, as evidenced by rising nitrate concentrations and salinity in coastal areas. Recent drought events have exacerbated this stress causing low flows and eutrophication in the New River in northern Belize in 2019 and more recently in 2021.

The impact of climate change on groundwater can manifest itself in terms of changes in recharge, baseflow, sea water intrusion of coastal aquifers or increased evapotranspiration under dry conditions and high temperatures. Nevertheless, the direct impacts of climate change related to observed changes in groundwater level, storage, and quality is difficult to determine in Belize due to a lack of information and or data availability. As such, the extent to which groundwater resources have already been affected by climate change is not known.

Notwithstanding, Belize’s groundwater resource is one of the country’s largest sources of fresh water and plays a central part in sustaining ecosystems and enabling human adaptation to climate variability and change. The strategic importance of groundwater for water and food security has intensified under climate change as more frequent and intense climate extremes (droughts and floods) have increased variability in precipitation, soil moisture and surface water. This is evidenced by the increased use of unregulated wells for food production across Belize.

The change in frequency, intensity, and patterns in rainfall, as well as change in temperature has implication for replenishment of groundwater storage. Aquifer recharge occurs through the infiltration of precipitation into the subsurface, through the soils, past baseflow and into the aquifer as well as via interaction with surface water bodies. Changes in global climate are expected to affect the hydrological cycle, altering surface water levels and groundwater

recharge to aquifers with various other associated impacts (e.g., sea level rise which leads to saline intrusion of coastal aquifers) on natural ecosystems and human activities. Although the most noticeable impacts of climate change are changes in surface-water levels and quality there are also potential effects on the quantity and quality of groundwater. In Belize, the latest CMIP6 climate change projections indicate hotter and drier conditions are likely in future (see Figure 2.2) which would be expected to reduce groundwater recharge, and increase groundwater demand especially for agriculture. This underlines the urgent need for enhanced monitoring of the resource.

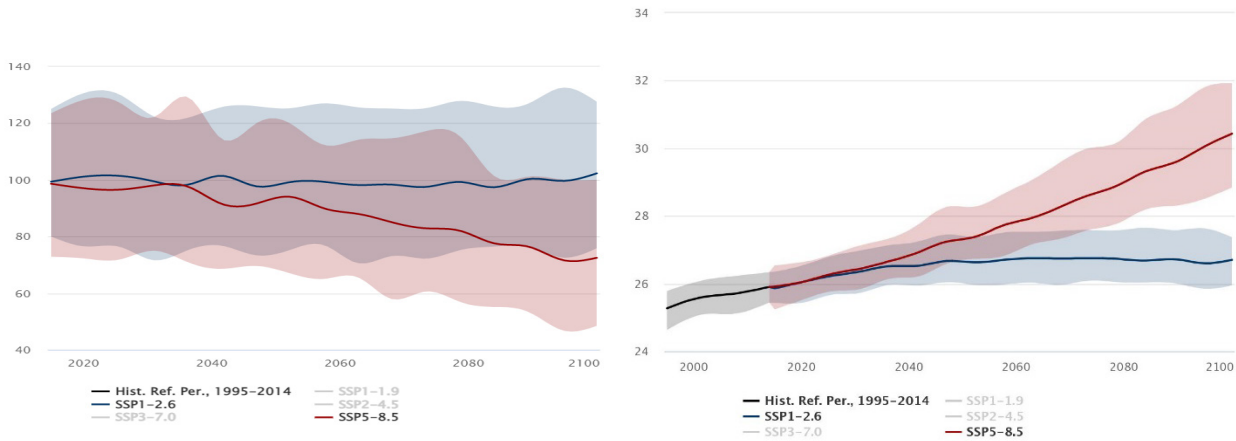


Figure 2.2: Projected Belize Annual Average rainfall expressed as a percentage of the baseline average (left) and Mean-Temperature in degrees Celsius (right) for 2020-2100 (Reference Period: 1995-2014), SSP1-2.6 & SSP5-8.5, Multi- Model Ensemble (World Bank, 2022)

At present no environmental groundwater level or quality monitoring is carried out, making it difficult for the government of Belize to make informed water management decisions in terms of regulating groundwater exploitation and managing the impacts of drought events. This is due to a combination of financial and technical capacity constraints within the NHS.

Efforts have been made to advance Integrated Water Resources Management in Belize, but financial constraints have slowed progress. This is evidenced by the development of the National Integrated Water Resources Act of 2010, which assigned the legislative responsibility to the Minister of Natural Resources to protect, control, allocate, and manage the sustainable use of the water resources in Belize. It also provides for the establishment of the National Integrated Water Resource Authority (NIWRA), charged with the responsibility of administering the specific functions enshrined under this Act. The NIWRA Act commenced on September 1, 2015 with limited implementation occurring. To date, only 1 of the 5 prioritized actions identified in the Integrated Water Resources Management Policy and Plan have been adopted and this is largely due to financial challenges.

This project concept contributes towards and is rooted in Belize’s climate response actions and is consistent with the goals and objectives of several national policies and strategies. This includes The National Adaptation Strategy to address climate change in the Water Sector 2009, the National Climate Change Policy, Strategy and Action Plan 2015 and Belize’s National Determined Contributions (NDC) under the UNFCCC.

2.1.4 Project/Programme description

The project will deliver a functional and sustainable groundwater monitoring system at national level for Belize. The system will collect, manage and disseminate groundwater level and quality information, with the capacity development and technical support to ensure the sustainability of the system. The system will use both manual data collection through engagement with community observers as well as automatic stations.

The National Hydrological Service has demonstrated a commitment to groundwater monitoring, designing a monitoring system for northern Belize and for upscaling this at national level. As an initial suggestion, this project would be broken into three phases as follows:

- Phase 1 (Year 1) - Implementation of groundwater monitoring system design for northern Belize.
- Phase 2 (Years 2, 3 and 4) - Upscaling of groundwater monitoring system to all areas of Belize based on prioritisation of remaining groundwater provinces.
- Phase 3 (Years 5 and 6) - Ongoing support to the optimisation and sustainable operation of the monitoring system at national level.

These three phases are complemented by a programme of ongoing technical support, capacity development and dissemination activities to maximise the usefulness of the system.

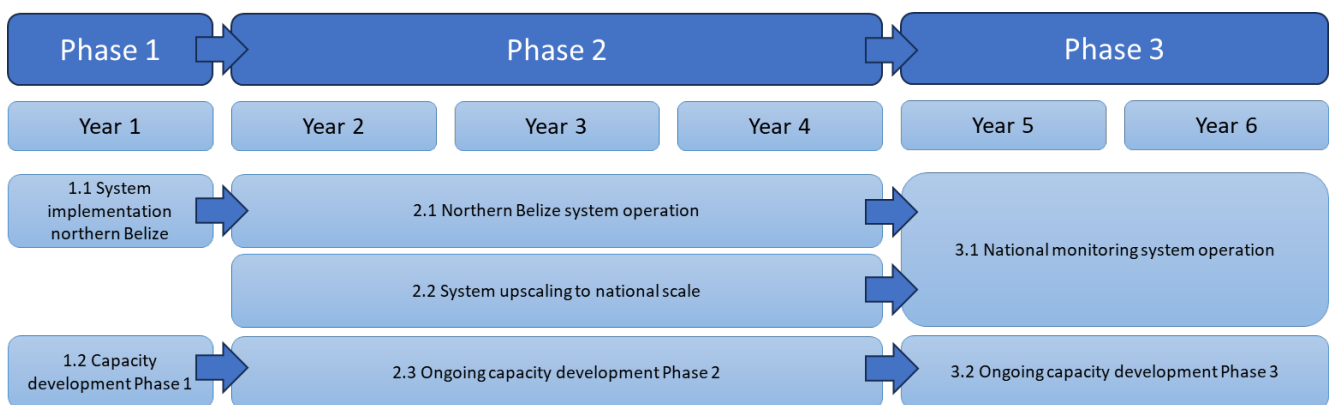


Figure 2.3: Summary of project phases

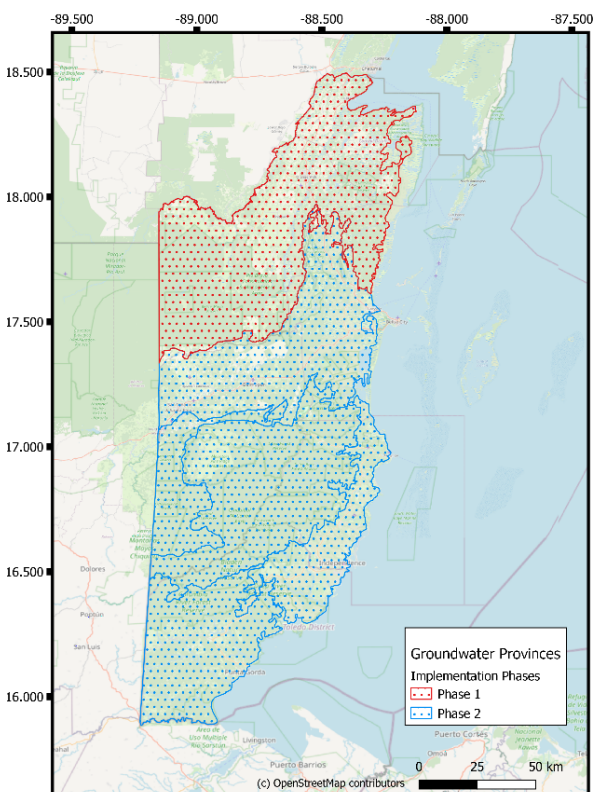


Figure 2.4: Map of groundwater provinces coloured by implementation phase

Each Phase consists of components as follows:

Phase 1 Components:

Component 1.1: Commissioning manual and automatic groundwater stations

This component will see the recruitment of groundwater monitoring technicians and a groundwater technical specialist to form a Groundwater Unit within the National Hydrological Service, supported by capacity development activities under component 1.2.

This component will engage with well owners at 18 identified monitoring locations to set up regular monitoring of water level and basic field water quality parameters by community observers (well owners or nominated representatives). Equipment and training will be provided to the community observers on data collection and transmission to the NHS central office. Community observers will provide data weekly to the NHS office where it will be quality assured and entered into the NHS hydrometric database. Quarterly field visits will be carried out to liaise with well owners, maintain equipment and collect water quality samples for field and laboratory analysis. Water quality sampling will allow tracking of seasonal and long-term trends in water quality in both standard parameters such as nitrates as well as trace contaminants such as pesticides and herbicides which are a concern in agricultural areas.

Automatic groundwater monitoring stations for groundwater level, temperature and conductivity will be installed in 7 priority locations with telemetry feeding data in near real time into the NHS hydrometric database. Quarterly field visits will be carried out to maintain and calibrate equipment and collect water quality samples for field and laboratory analysis.

A hydrometric database will be set up and maintained at the NHS central office and linked to the automatic station telemetry systems, as well as manual input of data sent in from community observers. Capacity development of NHS staff to QA, enter, maintain and interpret the datasets will be carried out, including the development of protocols and standard operating procedures for data entry. It will provide for the development of information products based on the data collected, and engagement with data users and decision makers to facilitate the use of data for informed water sector planning and operational decision making.

Component 1.2: Ongoing operational support, capacity development and knowledge management

This component addresses the need to ensure that data is reliable and is turned into actionable information to support decision making in the water sector. A programme of ongoing training and hands on technical support will be deployed to ensure the technical capacity is maintained and institutionalised over time, and that the data and information produced is reliable and relevant. It will include formal and on the job training for NHS staff and community observers, independent data review and analysis and the development of information products including annual hydrological summaries and drought monitoring bulletins. In order to ensure the long-term financial sustainability of the system, a study will be carried out on the feasibility of revenue streams from a variety of funding sources.

Phase 2 components

Component 2.1: Technical review of Phase 1, detailed upscaling plan and implementation of groundwater monitoring system at the scale of Belize

The implementation of the groundwater monitoring system in northern Belize (the coastal plains groundwater province) will be reviewed and used to inform the detailed implementation plan for the upscaling of the system to national level. This will include experience on the operational procedures developed in Phase 1, technology utilised as well as the institutional capacity and engagement with communities.

The system upscaling will take place based on a prioritisation of the remaining groundwater provinces. Based on population density and the presence of agricultural activities the Campur and Savannah provinces are likely to require a higher density of monitoring locations than the

Vaca, Maya Mountains and Toledo provinces and are therefore recommended for the early part of the upscaling component.

This component will require setting up approximately 30 locations for community groundwater monitoring and about 15 automatic monitoring locations. It will include the necessary equipment, staff and capacity development. The systems for data collection, management and reporting developed in Phase 1 will be used as the basis for the upscaled national system.

Component 2.2: Operation of northern Belize monitoring system for three years

Once stations for the northern Belize system are operational this component will conduct a programme of water quality sampling and analysis, ongoing site and equipment maintenance and liaison with well owners. Following this three-year period, the operational processes and monitoring regime will be reviewed and optimised, and the lessons taken into the operational management of the national scale system once it is in place at the end of Phase 2.

Component 2.3: Ongoing operational support, capacity development and knowledge management

This component will include continued training and hands on technical support to ensure data is timely and relevant. It will include formal and on the job training for NHS staff and community observers, independent data review and analysis and the development of information products including annual hydrological summaries and drought monitoring bulletins.

Phase 3 components

Component 3.1: Operation of national groundwater monitoring system for two years and planning for long term sustainability

Once all stations across Belize are operational this component will operate the monitoring system by conducting a programme of water quality sampling and analysis, ongoing site and equipment maintenance and liaison with well owners. Following this two-year period, the operational processes and monitoring regime will be reviewed and optimised, and fully institutionalised and embedded into the work programme of the National Hydrological Service of Belize.

Component 3.2: Ongoing operational support, capacity development and knowledge management

This component addresses the need to ensure that data is reliable and is turned into actionable information to support decision making in the water sector. A programme of ongoing training and hands on technical support will be deployed to ensure the technical capacity is maintained and institutionalised over time, and that the data and information produced is reliable and relevant. It will include formal and on the job training for NHS staff and community observers, independent data review and analysis and the development of information products including annual hydrological summaries and drought monitoring bulletins.

2.1.5 Expected project results aligned with the GCF investment criteria

Impact Potential

This project will enhance the adaptative capacity of the government of Belize to effectively manage groundwater resources in a changing climate. This will, in turn, safeguard groundwater-dependent farmers, business and household water supplies from increasing frequency and severity of droughts and saline intrusion into coastal aquifers as a result of climate change. It will also support the monitoring of transboundary aquifers shared with Mexico in northern Belize.

Agriculture makes up 8% of GDP in Belize and supports 20% of the labour force⁴ and consumes an estimated 70 million cubic metres of water annually⁵. Water is used primarily for irrigation, and changes in climate are leading to increased interest in using irrigation for crops previously rain-fed such as sugar cane. The projected hotter and drier climate in future is likely to continue the trend towards increased agricultural water demand. This will increase pressure on water resources and underpins the need for improved water resources management.

Around 57%⁶ of Belizeans depend on groundwater resources for drinking water, through the national water utility Belize Water Services Limited (BWSL), private supplies, or the Rudimentary Water System (RWS) managed at village level. Groundwater dependent water supply systems will be made more resilient by the improved data and information on groundwater quality and quantity collected through this project. Population growth alone is projected to increase domestic water demand by a third by 2060. This project will result in positive impact on all groundwater dependent sectors and users in the medium to long term, by securing sustainable groundwater resources and avoiding degradation of the resource.

The project will also engage around 50 community groundwater observers across Belize, who will be trained in groundwater measurement and support the work of the NHS. This will raise awareness of groundwater management at community level, coupled with the ongoing role of the NHS in community level awareness and education to facilitate the improved valuation of groundwater resources.

Improved groundwater management will also benefit ecosystems services provided by groundwater fed watercourses, such as the New River in northern Belize. This river is used for recreational, tourism and amenity purposes.

Paradigm shift potential

This project represents a step change in the monitoring of climate variability and change on Belize's vital groundwater resources. To date groundwater has been regarded as an infinite resource which can be abstracted without consequence. This is not the case, as is being increasingly evidenced through recent events such as the 2019 drought in which groundwater fed watercourses such as the New River suffered from eutrophication due to low flows and high nutrient loadings.

The project will catalyse the paradigm shift from little to no effective monitoring of groundwater resources to a structured and sustainable monitoring system providing the data and information for science led management of water resources. This project will underpin the ability of the government of Belize to develop the policy and regulatory base for the sustainable management of groundwater resources, leading to long term climate responsive planning in the water sector. This will result in the long-term improvement of water resources management in Belize.

Sustainable development potential

The monitoring of groundwater resources underpins the effective and evidence-based management and protection of water resources for the long term sustainability of the resource. Sustainability co-benefits exist for all water dependent sectors, for the health and wellbeing of communities dependent on groundwater for domestic and agricultural use, and critically for the groundwater dependent rivers and wetlands which provide ecosystems services throughout Belize.

This project supports Sustainable Development Goal 6 (SDG6) and more specifically targets 6.4 "substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater", 6.5 "implement integrated water resources management at all levels, including through transboundary cooperation as appropriate" and 6.6 "protect and

⁴ World Bank, 2023, Based on International Labor Organisation data
<https://databank.worldbank.org/source/world-development-indicators>

⁵ FAO AQUASTAT

⁶ HR Wallingford, 2023, Status and trends in the groundwater resources of Belize. FWR6741 RT006. R02-00

restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes”.

Needs of recipient

The Government has been executing IWRM through the National Hydrological Service which is the hydrology arm for the government tasked to execute data collection for hydrology such as but not limited to: collect data on the quantity, quality, hydrological forecasting variability of water resources and more recently, implementation of IWRM. Nevertheless, in addition to issues related to climate and inadequate planning and management, human resources and data collection/regularization constraints have delayed progress and increased the vulnerability of the resource.

Based on recent trends in increasing water exploitation, extreme events including the drought of 2019 and eutrophication issues in the New River in northern Belize, and future projections, groundwater resources in Belize are at a critical moment and action is required now to avoid degradation of the resource, and set Belize on the path to sustainable water resources management.

These issues underline the need for climate finance to give the NHS the tools and resources it requires to overcome these challenges and take a step change in the approach to monitoring and management of the resource.

Country ownership

Water resources management has been recognised as a priority area for climate action by the government of Belize. This concept note is rooted in Belize’s climate response actions and is consistent with the goals and objectives of several national policies and strategies including:

- The National Adaptation Strategy to address climate change in the Water Sector 2009: The National Adaptation Strategy to address climate change in the Water Sector proposes five key adaptation actions, namely: establishment of an IWRM agency; strengthening existing institutional and human capacities in the water sector; formalize the legal mandate and operation of the National Climate Change Committee; strengthen trans-boundary watershed management.
- The National Climate Change Policy, Strategy and Action Plan 2015: The Government of Belize (GOB) is cognizant that climate change is already having a negative effect on the social, economic, and productive sectors; the physical environment including land and water, and infrastructure; as well as the sustainability of natural resources. The Climate Change Policy, Strategy and Action Plan highlights the need for adaptation planning and supports Belize’s efforts to strengthening its resilience to the effects of Climate Change. In addition, due to the cross-sectoral nature of Climate Change impacts, the document guides the efforts of the Government of Belize to augment the governance and coordination mechanisms required for the management of Climate Change in Belize.
- National Determined Contributions (NDC) 2021: Water Resources management is identified as a priority sector of Belize’s NDC. Main actions to be implemented to build resilience in the sector include the design and implementation of an IWRM programme in watersheds; enhance protection of water catchment (including groundwater resources); develop water conservancy management systems; conduct water resource assessment (especially groundwater); develop flood controls and drought monitoring; improve trans-boundary cooperation regarding water resources; strengthen the human resource capacity in the water sector strengthen the compliance monitoring capacity of staff; undertake water policy reform.

Efficiency and effectiveness

The design of the groundwater monitoring system has taken careful consideration of cost effectiveness through selection of appropriate technology and groundwater sampling variables, site selection and sampling frequency.

The system uses a combination of manual (70%) and automatic (30%) sampling methods. Manual sites are operated by community groundwater observers for a small stipend with technical support from the NHS. This provides a cost-effective data collection method and has the co-benefit of raising awareness of groundwater at the community level. Automatic systems provide more direct control by the NHS and finer resolution data, but at a higher capital cost.

The system design collects basic groundwater quality parameters (low cost) more frequently than trace pesticides (high cost), balancing the costs with the need to keep a high-level oversight on pesticide risks in priority areas.

The system is designed to make maximum use of existing wells and boreholes for monitoring, minimising the costs and redundancy risks associated with drilling bespoke monitoring boreholes.

The balance of automatic and manual systems, and the sampling regime will also be optimised during the phased implementation to ensure that these reflect the data needs and other practical issues (such as equipment failure and repair) as they arise. It is also important to note that the transition from manual to automatic stations will be strategically carried out as deemed appropriate. As the National Hydrological Service (NHS) gains proficiency in the operation and maintenance of automatic stations, there will be a gradual shift in the balance between automatic and manual systems. The aim is to achieve the greatest benefit from groundwater data for the lowest operational cost and risk while ensuring accuracy and access to data.

2.1.6 Engagement among the NDA, AE, and/or other relevant stakeholders in the country

This concept note has been developed as part of a study to design a groundwater monitoring system for the management of aquifers in Belize, focusing initially on the New River watershed and then national scale monitoring. This was implemented by the National Hydrological Service (NHS) of the Ministry of Natural Resources, Petroleum, and Mining and the National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management with funding from the United Nations Climate Technology Centre and Network (CTCN). As part of this study, technical reviews were carried out on the present status of groundwater data and information, trends in exploitation and the potential impacts of climate change. Groundwater monitoring system alternatives were considered and a design developed.

As part of this process, a stakeholder working group for the study was convened with members from the following organisations:

- National Hydrological Service (NHS)–Chair;
- National Climate Change Office (NCCO);
- Department of the Environment (DOE);
- Ministry of Agriculture, Food Security, and Enterprise- Extension service (MAFS&E);
- Department of Rural Transformation (DRT);
- Forest Department (FD);
- Belize Water Services Limited (BWSL);
- Ministry of Economic Development (MED);
- Belize Sugarcane Industry-ASR Group;
- Women Group - MAMAS Group- Orange Walk.

Three face-to-face workshops and one virtual workshop were held over the course of the study, and the perspectives of these stakeholders fed into the design of the monitoring system. There is already a high level of collaboration between the NHS and DoE on water data collection and management, and a shared recognition of the importance of the sustainable management of groundwater resources in a changing climate.

2.2 Project financing information

2.2.1 Financing by components

Component/Output	Indicative cost (USD)	GCF financing		Co-financing		
		Amount (USD)	Financial Instrument	Amount (USD)	Financial Instrument	Name of Institutions
Phase 1 Component 1.1	373,000	330,000	Grant	43,000	In kind	Government of Belize
Phase 1 Component 1.2	60,000	60,000	Grant			
Phase 2 Component 2.1	423,000	380,000	Grant	43,000	In kind	Government of Belize
Phase 2 Component 2.2	586,000	500,000	Grant	86,000	In kind	Government of Belize
Phase 2 Component 2.3	120,000	120,000	Grant			
Phase 3 Component 3.1	1,080,000	950,000	Grant	130,000	In kind	Government of Belize
Phase 3 Component 3.2	120,000	120,000	Grant			
Indicative total cost (USD)	2,762,000	2,460,000		302,000		

Costing assumptions:

- In kind financing includes new government positions in National Hydrology Service, does not include current staff time inputs to project.
- Costings do not include project management funding (required for grant reporting, M&E and other management requirements as stipulated by the grant funder).

2.2.2 Justification of GCF funding request

Belize is a small developing state situated in the central American region. It is a member of the Caribbean Community (CARICOM) and a member of small island developing states (SIDS). It is recognised as a highly vulnerable country to the current and negative projected impacts of climate change. Among small states, Belize ranks 3rd for susceptibility to natural disasters and 5th at risk for climate change⁷. Between 1930 and 2016, the country has been hit by 16 major tropical cyclones, or one every five years on average, which affected 287,670 people and caused US\$635 million in losses. Belize has a small economy of which the main sectors include tourism, agriculture, utilities and services which are highly reliant on natural resources and sensitive to climate change. The Belizean economy suffered a severe impact from the COVID-19 pandemic, resulting in a significant escalation of the country's debt burden, reaching as high as 104 percent

⁷ IMF (2016) "Small States' Resilience to Natural Disasters and Climate Change - Role for the IMF" <https://www.imf.org/external/np/pp/eng/2016/110416.pdf>

of the Gross Domestic Product (GDP). On the heel of the COVID-19 pandemic and the aftermath of Hurricane Lisa in November 2022, the Government of Belize has indicated that not having access to low-cost financing for resilience building and recovery from the COVID-19 pandemic is a major hindrance to Belize's achieving its targets to the sustainable development goals, NDCs and national adaptation agenda.

Belize's Updated Nationally Determined Contribution (NDC) (2021) estimates finance required to achieve the updated NDC targets is at USD1,906 million for 2030. A finance gap of USD1,645 million is estimated after accounting for the already mobilised resources, a substantial gap due to the limited public financial resources.

The NDC identifies the enhanced monitoring of water resources as an adaptation priority with a funding gap of USD 11 million. To close the financing gap Belize has developed a Climate Finance Strategy aimed at mobilising resources, from domestic, international, public and private sources. The GCF country programme for Belize identifies water resources as a priority sector aligned with GCF results areas under the adaptation. GCF support is pivotal to achieving a step change in the ability of the government of Belize to monitoring its water resources and manage water sustainably for the benefit of people, the economy and its fragile ecosystems in the face of a changing climate.

2.2.3 Sustainability and replicability of the project (exit strategy)

The project provides for a six-year implementation process in which the system is scaled up in an incremental manner, taking lessons learned in early Phases through to later Phases. At the end of the project the NHS will be running a fully functioning technical and financially sustainable monitoring system at national scale.

Technical sustainability has been maximised through the adoption of both automatic and manual monitoring approaches, which de-risks the issues associated with the maintenance and operation of complex automatic monitoring equipment. The lessons from Phase 1 installation and operation of equipment will be carried through, allowing for optimisation of the technology.

Financial sustainability has been addressed through the development of a sustainable funding model for the monitoring system based on the transition towards the licencing of groundwater abstraction to generate a revenue stream for the ongoing funding of the system without recourse to central government grants, or development assistance. Over the five-year period of this project, abstraction licencing will progress and scale up forming a revenue stream for the sustainable financing of the system.

This will provide an opportunity for lessons to be drawn across the region and more widely on the sustainability of monitoring systems, and the opportunity to replicate these in other geographies where similar issues persist.

2.3 Optional supporting sections

1. Map indicating the location of the project/programme
2. Diagram of the theory of change
3. Economic and financial model with key assumptions and potential stressed scenarios
4. Pre-feasibility study
5. Evaluation report of previous project
6. Results of environmental and social risk screening

Groundwater monitoring for mapping aquifers in Belize as a tool for climate change adaptation planning

Gradual approach to monitoring
implemenatation

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Client representative	Marisela Ricardez Garcia
Project manager	Azucena Rodriguez Yebra
Project director	George Woolhouse

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1 Background

1.1 Project summary

In Belize, 56% of the population lives in rural areas where groundwater is a vital source for fresh water and represents almost 95 per cent of the fresh water supply.

Groundwater is also used as a source of drinking water in the cities of the Corozal, Orange Walk, Cayo and Toledo Districts and in some rural areas of Toledo and Cayo. However, the existing aquifers and their annual recharge rate have not been quantified.

Increase in demand for fresh water resulting from increasing population, greater economic activity and agricultural expansion are threatening the quality and availability of fresh water. Each year during low rainy seasons exists the possibility of droughts due to low recharge of aquifers.

Transboundary aspects and distribution of population are other factors that affect the water sector. For example, central and northern regions (Orange Walk and Corozal) have much larger populations and higher agriculture zones for water intensive crops, but less water resources.

Although there is a need for groundwater information across the country, the priority area includes the New River watershed.

The Nationally Determined Contribution (2022) indicated water resource assessment (especially groundwater) as part of the main actions to be implemented to build resilience.

The results of the prioritization of adaptation technology factsheets for the Water Sector documented in the technologies needs assessment (TNA) for adaptation (National Climate Change Office et al., 2017) include:

- Drought Monitoring System for Northern Belize with Specific Focus on Groundwater Resources;
- Water Efficient Fixtures and Appliances;
- An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize.

The National Hydrological Service (NHS) is leading a process for building an inventory of existing data on groundwater. The objective is to identify and homogenize information that is currently available but spread among different agencies and institutions, and their various departments.

Requests have been made from the executive level of the Ministry (responsible for the NHS) to other ministries for sharing of relevant groundwater data. However, this is still a work in progress. Additionally, the Ministry of Rural Transformation has indicated that they do not geo-reference their wells.

Following the foreseen adaptation actions in the NDC and the TNA for Adaptation for the water sector, the National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management, and the National Hydrological Service (NHS) started conversations to develop a proposal for a Groundwater Monitoring System.

1.2 About this report

The purpose of this report is to provide an analysis of institutional setting, this includes the identification of key agencies, their responsibilities, synergies, and possible limitations in the implementation of the groundwater monitoring system. Also explores the gradual approach in monitoring implementation.

2 Analysis of institutional setting

2.1 Institutional Assessment

The National Hydrological Service (NHS), a governmental division under the Ministry of Natural Resources, is tasked with the collection and evaluation of hydrological and water resources data for Belize. Additionally, the NHS issues permits for groundwater drilling and licenses for water abstraction.

Furthermore, the NHS is entrusted with upholding the government's water policy, ensuring the organized and harmonized utilization of Belize's water resources. This includes conserving and safeguarding these resources for the well-being of both current and future generations of Belizeans. The ultimate goal is to guarantee the public access to a secure, sufficient, and dependable water supply in Belize.

The main objectives of the NHS include:

- **Data collection:** Gather information on Belize's natural water resources, focusing on quantity, quality, and variability.
- **Hydrological investigations:** Conduct investigations essential for engineering and various water resources projects, including urban and rural water supply, agricultural irrigation and drainage, hydro-electricity, bridges, and highway drainage.
- **Publication:** Produce publications containing hydrological and water resources data, beneficial for water users.
- **Government advisory role:** Advise the government on watershed management, environmental issues, and disasters like floods, droughts, and water pollution.
- **Planning:** Coordinate the development of the National Water Master Plan, National Water Safety Plan, and Vulnerability profile.
- **Quality control:** Oversee the formulation of the National Water Quality Control Plan.

Hydrological monitoring in Belize commenced in 1965 with an agricultural evaluation of the Belize River Valley's potential conducted by the British Overseas Development Agency. Presently, the NHS operates a network of manually read surface water level stations on the river network, and has some experience in deployment of automatic monitoring systems. However, the NHS does not monitor groundwater resources. The exploitation of groundwater for potable supply, agriculture and industry has increased, placing increasing pressure on the resource. This underlines the need for the NHS to expand its monitoring to cover groundwater for the sustainable management of the resource going forward.

2.2 Staffing

The National Hydrological Service operates with a relatively small but dedicated team of professionals, primarily comprising public officers employed through the Ministry of the Public Service. At the core of this team is the Principal Hydrologist, serving as the Head of the Unit and a vital point of contact for the service. Accompanying the principal hydrologist is a Data Analyst, responsible for in-depth data analysis critical for informed decision-making. Supporting these key roles are Hydrological Technicians and a Clerk, who play crucial roles in the day-to-day operations and data management.

Given the specialized nature of hydrological work and the growing demands of water resource management, there is a perpetual need to expand the team with qualified technicians. The service consistently seeks to hire skilled professionals who can contribute to the field of hydrology and hydrometry. This ongoing recruitment effort is essential to bolster the capacity of the National Hydrological Service, ensuring its ability to effectively carry out its multifaceted responsibilities and meet the ever-evolving challenges in water resources management in Belize.

2.3 Ministerial Roles

The National Hydrological Service (NHS) in Belize plays a pivotal role in water resource management and, as a result, maintains active and collaborative interactions with various line ministries within the government. One of the primary ways in which the NHS interacts with other ministries is through policy alignment and coordination. Given its responsibility for enforcing the government's water policy, the NHS collaborates closely with ministries related to agriculture, environment, infrastructure, and disaster management to ensure that their activities align with the overarching water management goals. A diagram summarising the linkages between the NHS and users of their data and departments influencing decision making from NHS is shown in Figure 2.1.

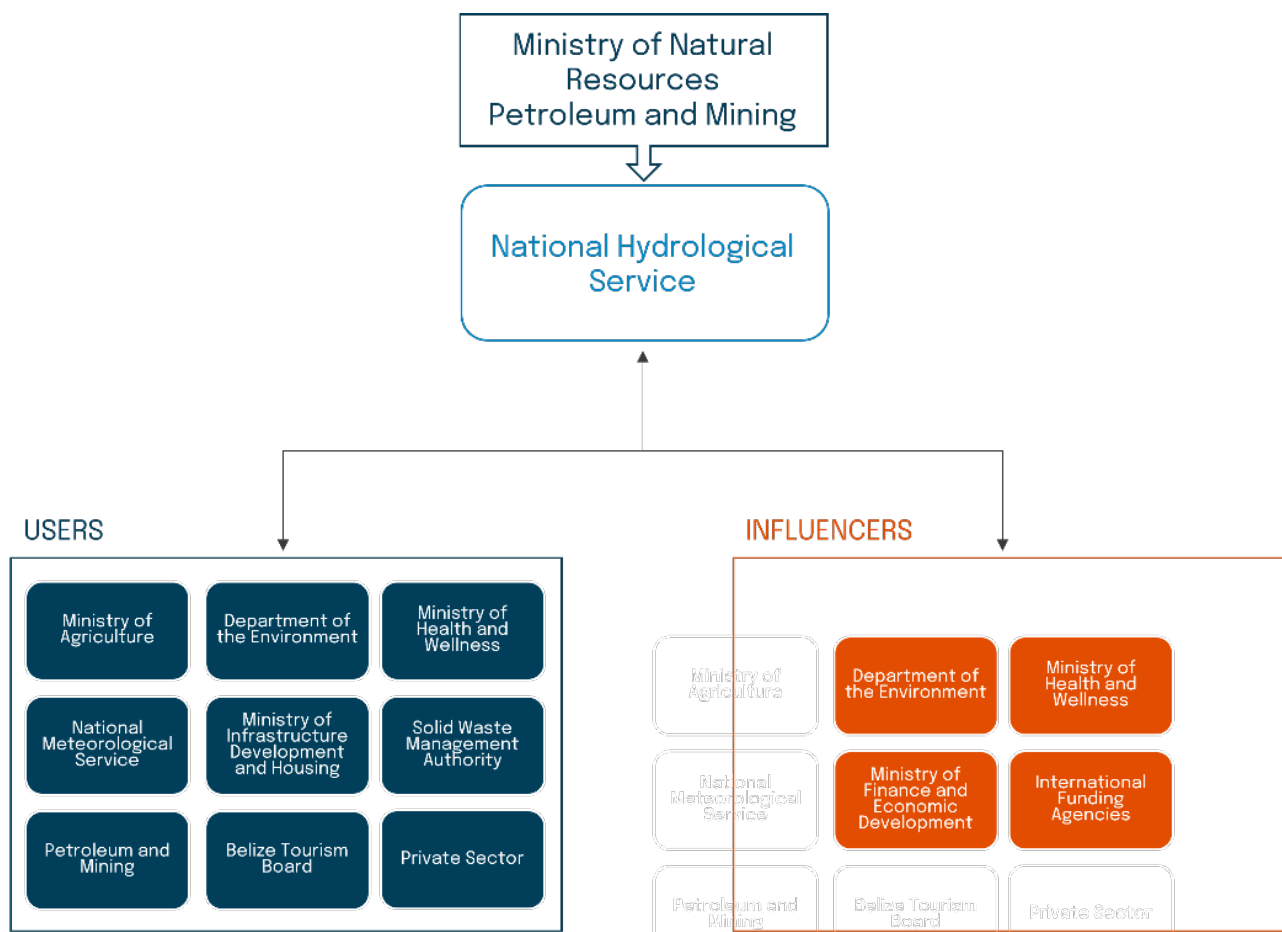


Figure 2.1: Institutional assessment diagram

As an example, in the realm of infrastructure development, the NHS should collaborate with the Ministry of Infrastructure Development and housing and other related ministries. For projects such as bridges and highways, where proper drainage systems are essential, the NHS should provide valuable hydrological insights. By working hand in hand, these ministries ensure that infrastructure projects are designed and implemented in ways that are both functional and environmentally sustainable, taking into account the complex dynamics of water flow and drainage.

Additionally, in the agricultural sector, the NHS should interact closely with the Ministry of Agriculture. The data and analyses that can be provided by the NHS are instrumental in shaping agricultural policies and practices. This collaboration is especially vital for irrigation and drainage projects, where the efficient use of water resources is paramount. By sharing expertise and data, these ministries optimize agricultural practices, promoting sustainable farming techniques that conserve water and enhance agricultural productivity.

Furthermore, the NHS liaises with the Department of Environment to address environmental concerns and promote conservation efforts. By providing valuable data on water quality and quantity, the NHS aids in the formulation and implementation of environmental policies. Together, they work towards safeguarding Belize's natural water bodies and ecosystems, ensuring their vitality for future generations.

In times of disasters, such as floods or droughts, the NHS collaborates with the National Emergency Management Organization (NEMO). Timely and accurate hydrological data provided by the NHS is invaluable for disaster preparedness and response efforts. By sharing this critical information, it enhances NEMO's capacity to mitigate the impact of disasters and protect the lives and livelihoods of Belizean citizens.

Figure 2.2 summarizes the interactions the NHS has with other line ministries. Its interaction with them are categorized under four (4) roles - advisory, regulatory, emergency and financial.

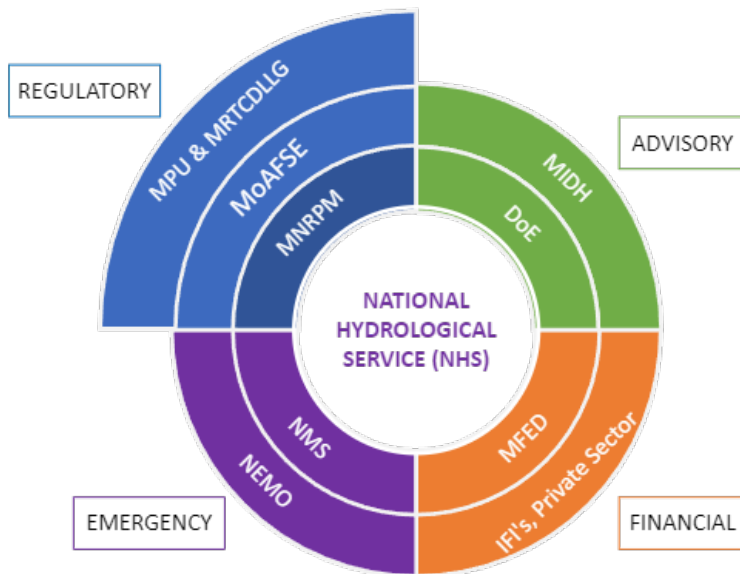


Figure 2.2: Interactions between NHS and other institutions

- MAFSE: Ministry of Agriculture Food Security and Enterprise.
- MNRPM: Ministry of Natural Resources Petroleum and Mining.
- MPU: Ministry of Public Utilities.
- MRTCDLLG: Ministry of Rural Transformation, Community Development, Labour and Local Development.
- MIDH: Ministry of Infrastructure Development and Housing.
- DoE: Department of Environment.
- NMS: National Meteorological Service.
- NEMO: National Emergency Management Organization.
- MFED: Ministry of Finance and Economic Development.
- IFI's: International Funding Institutes.

In summary, the NHS serves as a cornerstone for inter-ministerial collaboration in Belize in the field of hydrology and water resources management, fostering synergy among various government bodies. Through these interactions, the NHS contributes significantly to the holistic and sustainable development of the country, ensuring the responsible use and preservation of Belize's water resources.

2.4 Institutional collaboration in the context of groundwater monitoring

The planned groundwater monitoring system will be led and operated by the NHS, and will support the NHS in delivering its mandate. In addition the system will need to be guided by the requirements of the users identified above to ensure it is meeting the needs of stakeholders from across the water sector.

Moving forward it is recommended that the NHS should convene a technical steering group on groundwater resources made up of representatives from the following agencies:

- MAFSE: Ministry of Agriculture Food Security and Enterprise.
- MRTCDLLG: Ministry of Rural Transformation, Community Development, Labour and Local Development.
- DoE: Department of Environment.
- NMS: National Meteorological Service.
- Belize Water Services Limited (BWSL).

Through periodic technical meetings, the NHS can share insights from the data it is collecting, lobby other agencies and seek feedback on data requirements.

The NHS should also promote and raise awareness of the monitoring system amongst government agencies, and also the wider public through its outreach activities, and at regional and international fora. This will help raise the profile of groundwater management as a key issue for Belize, stimulate demand for data and information, and help secure funding opportunities for investment in groundwater management interventions.

The NHS should make groundwater data freely available in principle, in order to maximise its uptake. A clear metadata catalogue of data holdings should be available on the NHS website with information on the general location of monitoring stations, duration, frequency and monitored variables to facilitate user requests for data and information. The NHS typically actions requests for data and information manually, and should maintain a record of all data requests to track user requirements. A clear licencing policy for data is recommended in order to avoid liability and maintain clarity on the conditions of use. In the UK hydrometric data is increasingly provided under an Open Government Licence (see for example this UK government web based database and associated licence conditions (database: <https://environment.data.gov.uk/hydrology> licence: <https://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/>))

3 Gradual approach to groundwater monitoring

3.1 Implementation plan

Upscaling of the groundwater monitoring system is planned to be taken place in stages with a testing phase first through the installation of the Northern Belize monitoring system as shown in Figure 3.1, followed by upscaling to other groundwater provinces.

Activity	Timeline					
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Testing monitoring system design						
Northern Belize monitoring system installation						
Ongoing data collection activities						
Upscaling						
Prioritisation of other groundwater provinces						
Campur gw province monitoring system installation						
Ongoing data collection activities in Campur						
Savannah and Toledo gw provinces monitoring system installation						
Ongoing data collection activities in Savannah and Toledo						
Vaca and Maya Mountains gw provinces monitoring system installation						
Ongoing data collection activities in Vaca and in the Maya Mountains						

Figure 3.1: Implementation plan for upscaling from years 1 to 6

3.1.1 Testing monitoring system design

The monitoring system installation, and data collection during years 1 to 3 in Northern Belize will serve as a test for the upscaling to the rest of the country. Note that data collection activities will continue after the testing period for all groundwater provinces in the country. The implementation plan is only showing the installation and initial testing of the system with the goal of achieving a full functioning monitoring system in Belize.

3.1.2 Upscaling

During Year 1, and while the northern Belize monitoring system is installed, a prioritisation of groundwater provinces in Belize should take place. It is suggested that this prioritisation takes into account population density and agricultural land (Figure 3.2).

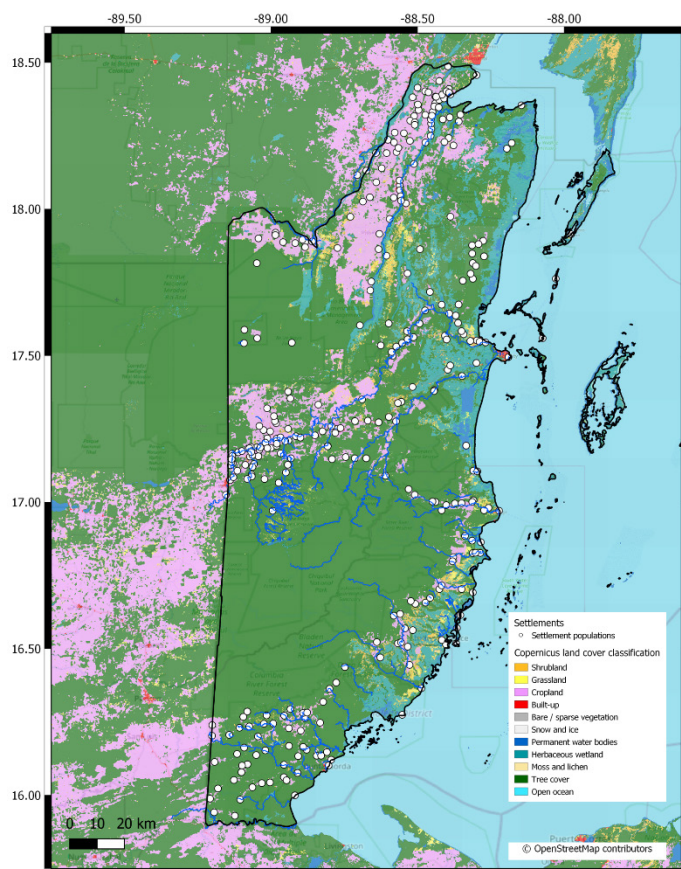


Figure 3.2: Agricultural areas and population settlements in Belize

This will aid the identification of hotspots and priority areas. Once the installation of the monitoring system has been completed and tested during the first year, lesson learned can be taken into account when beginning the installation of the monitoring systems in other provinces.

Based on an initial prioritisation considering agricultural land and population, we recommend the installation of these systems starting from the following groundwater provinces:

1. Campur – Beginning of year 2 installation;
2. Savannah – Mid-year 2 installation;
3. Vaca and Maya Mountains – Year 4 installation.

For the above groundwater provinces, we are suggesting a period of 2 years of ongoing data collection for reviewing and testing. This will bring a better understanding of the systems and therefore, improvements, if needed, can be implemented after these initial 2 years of data collection. This will progress the collection of data and will improve data analysis as well as future decision making.

The gradual approach to the installation of the monitoring system in Belize is expected to be completed in 6 years, depending on funding availability. This could also be done more rapidly if external funding can be secured and the upscaling made a priority. A phased approach dependent on funding and staff availability can also be considered. These phases were described in the concept note developed in Deliverable 5.2.

3.2 A note on transboundary issues

Transboundary aquifers are defined as groundwater that transfers through the borders of one country to others (Wada and Heinrich 2013). The shared boundary normally increases the challenges associated with assessment and management of aquifers. Physical assessments are not enough—social, economic, political, cultural, and historical variables play an equally significant role in the assessment of the aquifer to understand its complexities (Sanchez and Eckstein, 2020).

Transboundary groundwater is a key component of water security (Rivera et al., 2023), particularly for arid or drought-prone areas in the world, where these aquifers face common issues. To ensure sustainable water management, including water security (sustainable access to water, sufficient quantity and quality), strengthening institutional capacity, improving data and information exchange, and involving diverse groups of stakeholders, is vital (Albrecht et al., 2017).

It is also important to highlight that a strong scientific and technical knowledge is needed for a better understanding of transboundary issues. However, there are challenges identifying the appropriate transboundary groundwater management units, where transboundary implications are important (i.e., active groundwater flow across the international border, presence of well fields or pollution, etc.). Issues will need to be addressed from communication among those countries sharing surface or groundwater catchments, exchanging of data and information and appropriate policies addressing transboundary aquifers.

Belize has transboundary aquifers (and river watersheds) with Mexico and Guatemala (see Figure 3.3). The movement of water across the national borders, changes due to exploitation of groundwater in both countries and loadings of pollutants is not quantified at present. Moving forward, Belize should work collaboratively with its neighbours to encourage the sustainable exploitation of resources and avoidance of pollution for the mutual benefit of all.

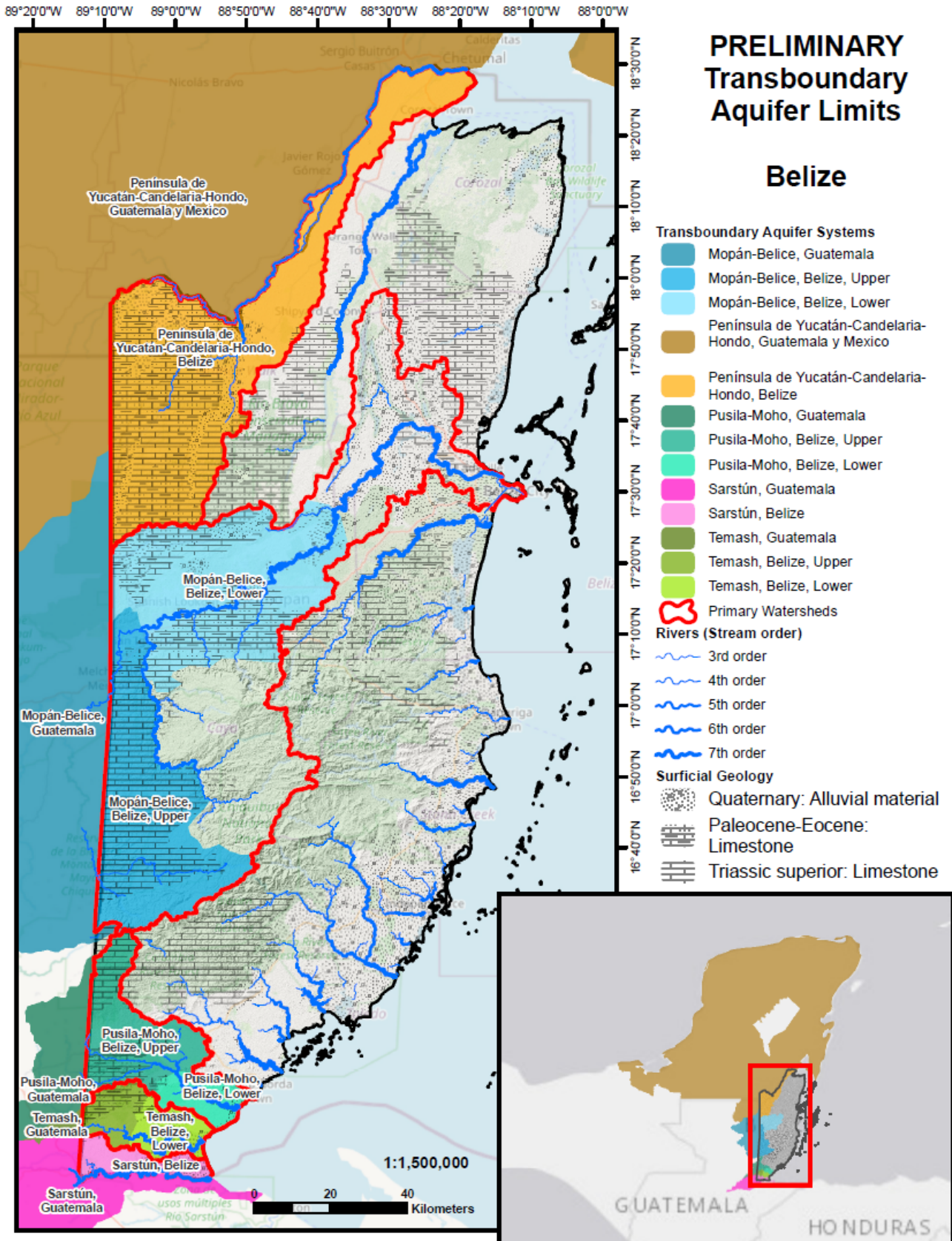


Figure 3.3: Belize preliminary transboundary aquifers map (source: NHS)

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Groundwater monitoring for mapping aquifers in Belize as a tool for climate change adaptation planning

Groundwater monitoring system
consultation report

Document information

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Project manager	Azucena Rodriguez Yebra
Project director	George Woolhouse

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Prepared Emily Strathdee	Approved Azucena Rodriguez Yebra	Authorised Nigel Walmsley
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- A Workshop Agenda
- B Sign-in Sheet
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1 Introduction

1.1 Project summary

The National Hydrological Service (NHS) of the Ministry of Natural Resources, Petroleum, and Mining and the National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management, are executing a project to design a groundwater monitoring system for the management of aquifers in Belize, focusing on the New River watershed. The project commenced in October 2022 and will complete in September 2023. HR Wallingford Limited is leading the consulting team implementing the project and financial support is provided by the Climate Technology Centre and Network (CTCN).

This important project will help Belize to sustainably manage groundwater resources in the face of a changing climate and human pressures on the resource.

The main outputs include:

1. A communications plan and detailed work plan;
2. Stakeholder mapping and establishing a stakeholder working group;
3. An assessment of groundwater availability and demand, nationally and with a particular focus on the New River watershed;
4. Design of an integrated monitoring system that will enable Belize to manage groundwater resources in the priority area of the New River watershed;
5. Development of an implementation plan on the enabling factors for implementation, including financial, institutional setting and capacity building.

1.2 About this report

The purpose of this report is to detail the discussions held at the Groundwater Monitoring System workshop held on September 6th 2023, carried out under Output 5 of the project. This report presents a summary of the presentations made to the Stakeholder Working Group (SWG), and details feedback from the SWG on the design, costing and institutional arrangements of the monitoring system. The feedback received provides inputs to finalising the 5th, and final output of the Project- Design a fully integrated groundwater monitoring system that will enable Belize to manage groundwater resources in the two priority areas. Additionally, the report includes a detailed record of the engagement proceedings, including the participants present.

2 Stakeholder Working Group – workshop

2.1 Objective

The workshop set out to provide an opportunity for SWG organisations to understand and provide feedback on the design of a groundwater monitoring system for the New River watershed in northern Belize. This was to be done by introducing the monitoring system scope, costs, implementation plan and how the system could be scaled up nationally.

2.2 Workshop structure

The session was held over a one-day period and utilised a mix of presentations and open group guided discussion to gather input from the SWG. The final discussion of the day set out to respond to final queries or concerns with the proposed design, financing options and plans for scaling up of the Groundwater Monitoring System presented to the SWG during the day. Notably,

earlier discussions were robust and meant that there was insufficient time for participants to engage in the interactive game organised to round off the morning workshop session. The workshop agenda is included as Appendix A Workshop Agenda.

2.3 Participation

SWG members from 6 of the 10 SWG agencies attended the Inception Meeting. Agencies Present were:

1. Belize Water Services Limited (BWSL);
2. Department of the Environment (DOE);
3. Ministry of Agriculture, Food Security and Enterprise (MAFSE);
4. Ministry of Economic Development (MED);
5. National Climate Change Office (NCCO); and
6. National Hydrological Service (NHS) (*Chair*).

42% of participants at the workshop were female; and 58% were male.

The participants' list can be found in Appendix B Sign-in Sheet.

2.4 Key takeaways from the workshop session

The following are key elements that the Consulting firm has taken away from the discussions that took place during the Workshop session:

1. Consideration will be made to strike a balance between automated and manual monitoring sites. The ideal location of the stations, and the pros and cons of both approaches, will be considered in finalising the consultancy outputs.
2. Consideration will be made to ensure that the groundwater monitoring system capitalises on potential collaborations between the DoE and NHS for facilitation of data collection at stations already installed along the New River.
3. Where financing is concerned, the fairness route for changing perceptions that utilising a public resource is without cost was identified as critical and should be a theme in public relations campaigns around the establishment of groundwater monitoring systems.
4. In sourcing resources to cover CAPEX funding needs, grant funding is to be considered. However sustainable financing needs to be factored into the phased implementation of the Groundwater monitoring system. Therefore, a finance strategy needs to be developed to transition into a longer-term sustainable program.
5. A lot of groundwork on licensing fees needs to occur. Equally important is the need to undertake science-led public relations campaigns to inform and introduce tariffs for extraction.
6. Plans for upscaling should consider the transboundary issues within the water sector. This is because surface water catchment and groundwater sources are linked across borders.
7. Maintaining a flexible costing plan at the national scale should include assumptions that present ranges for costing to inter alia, consider shifts between automated and manual stations. Contingencies should also be reflected in costs.

2.5 Workshop record

Date of meeting:	Time of meeting:	Place of meeting:	Recorded by: Elishah St. Luce and Tanya Barona
06/09/23	9:43am-2:30pm	Belize Biltmore Plaza	
	NAME	INITIALS	ORGANIZATION
ATTENDEES	Tennielle Hendy (Chair)	THE	National Hydrological Services, MNRPM (NHS)
	Rhona Lopez	RLO	National Hydrological Services, MNRPM (NHS)
	Kaeem Lino	KLI	National Hydrological Services, MNRPM (NHS)
	Marleny Dominguez	MDO	National Hydrological Services, MNRPM (NHS)
	Dr. Lennox Gladden	LGL	National Climate Change Office, MSDCCDRM (NCCO)
	Gina Young	GYO	National Climate Change Office, MSDCCDRM (NCCO)
	Miguel Balan	MBA	Ministry of Agriculture, Food Security and Enterprise (MAFSE)
	Andy Che	ACH	Ministry of Agriculture, Food Security and Enterprise (MAFSE)
	Justino Palomo	JPA	Ministry of Economic Development (MED)
	Hugo Rancharan	HRA	Belize Water Services Limited (BWSL)
	Beverly Mohammedali	BMO	Belize Water Services Limited (BWSL)
	Edgar Ek	EEK	Department of Environment, MSDCCDRM (DOE)
	George Woolhouse	SWO	HR Wallingford
	Azucena Rodriguez Yebra	ARO	HR Wallingford
	Lucien Chung	LCH	HR Wallingford - Consultant
	Ian McMillan	IMC	HR Wallingford - Consultant
	Elishah St. Luce	ESL	HR Wallingford - Consultant
ABSENT	Minerva Gonzales	MGO	Forest Department
	Jorge Nabet	JNA	Forest Department
	Adrian Zetina	AZE	Belize Sugar Industry - ASR Group
	Elsa Cardinez	ECA	Department of Rural Transformation,
	Maria Elena Meza	MME	MAMAS Women's Group

MEETING MINUTES

Agenda Item 1&2: Welcome remarks from the National Hydrological Service and introduction to the purpose of the workshop and agenda	
Notes	<p>GWO: welcomed participants to the final Stakeholder Working Group (SWG) Workshop, listed agenda items to be covered and provided a recap of project objectives since inception in November 2022 to November 2023.</p> <p>The five main project phases/outputs:</p> <ol style="list-style-type: none"> 1. A communications plan and detailed work plan; 2. Map stakeholders and establish a stakeholder working group; 3. An assessment of groundwater availability and demand; 4. Design of an integrated monitoring system that will enable Belize to manage groundwater resources in the priority area (New River area Northern Belize); 5. Establish enabling factors for implementation, including financial, institutional setting and capacity building and upscaling to the national level. <p>The purpose of the workshop will help with achieving output five and aimed to:</p> <ul style="list-style-type: none"> ● Update stakeholder working group (SWG) on the proposed groundwater monitoring system design and seek feedback; ● Discuss options for implementation and financing, upscaling to a national level; ● Discuss institutional roles and setting. <p>Introduced the financial expert Ian Mc Millan.</p> <p>IMC: thanked GWO for the opportunity to work on the project. Identified himself as an Economist/Financial Specialist by training but referred to himself as an Applied Economist. He outlined that he aimed to offer a pragmatic solution to the urgent need for monitoring groundwater, from a standpoint of extensive knowledge living in Belize and working with government and quasi-government organizations.</p>
Discussion	None
Action Items	None
Agenda Item 2: United Nations (UN) Climate Technology Centre and Network (CTCN) introduction	
Notes	<p>GWO: stated that Maricela Ricardez Garcia was unable to present and asked LGL to say a few words.</p> <p>LGL: noted that it is a natural fit for the NCCO to support the groundwater monitoring initiative. The groundwater monitoring project is embraced because the work of the Consultants goes beyond paperwork and ensures tangible outputs that are beneficial to people. CTCN works on a cyclical basis. Belize has approached the CTCN previously under a different initiative; however, this groundwater network provides a second opportunity to access resources. The National Hydrological Service has pointed out that the issue of monitoring is important. The scope of this groundwater monitoring work is currently small, however, the opportunity for upscaling through the CTCN exists via the technological mechanism for the secretariat.</p>
Discussion	None
Action Items	None
Agenda Item 3:	
<ul style="list-style-type: none"> ● Groundwater monitoring system design for northern Belize; ● Benefits of groundwater monitoring; ● Proposed system specification (data collection/management/dissemination); ● System implementation schedule of activities. 	
Notes	<p><i>Topic 1&2: Groundwater monitoring system design for northern Belize & benefits of groundwater monitoring</i></p> <p>GWO: presented to participants.</p> <ul style="list-style-type: none"> ● Why is groundwater important in Belize? (Recap of key points from investigations under output 3): <ul style="list-style-type: none"> ● Northern Belize shallow aquifers are highly exploited; ● Population rise from 2010-2022 (20% & 30% in Orange Walk and Corozal); ● 75% agricultural land expansion; ● Groundwater recharge supports the New River and wetland ecosystems; ● Trends and future projections (lower rainfall, increased temperatures, increased demands, increased pollution);

	<ul style="list-style-type: none"> ● Lack of detailed figures on quality, quantity and current exploitation. <p>Monitoring allows managers to get a handle of the resource and allows for structure in planning and decision making for the sustainable use of groundwater.</p> <ul style="list-style-type: none"> ● Types of information needed to effectively manage groundwater: <ul style="list-style-type: none"> ● Groundwater occurrence and aquifers properties; ● Groundwater use; ● Supporting information. <p>Data exists in two forms: baseline data and time variant data of which the latter is the focus of the monitoring program.</p> <ul style="list-style-type: none"> ● Groundwater monitoring objectives focus on two aspects: quality & quantity. The program can: <ul style="list-style-type: none"> ● Identify how droughts affect groundwater and how they develop over time; ● Track impacts of extraction; ● Focus on shallow aquifers; ● Determine pollution impact. ● Groundwater monitoring approach: <ul style="list-style-type: none"> ● Manual stations (weekly community observer data, quarterly technician checks); ● Automated stations (data loggers, quarterly technician checks). <p><i>Topic 3&4: Proposed system specification (data collection/management/dissemination) & System implementation schedule of activities.</i></p> <p>GWO: presented to participants.</p> <ul style="list-style-type: none"> ● Data Collection/Testing/Dissemination: <ul style="list-style-type: none"> ● Manual data; ● Data loggers; ● Field and laboratory analysis; ● Care and attention to detail (fieldwork/instrument recalibration); ● Data must then be processed and analysed to allow the information to be meaningfully interpreted; ● Websites, reports, downloading of data. ● A data product example as seen on the UK Centre for Ecology and Hydrology website which depicts groundwater stations, river stations, etc. The example is an easy and interactive portal which can be released to decision makers to better understand the groundwater situation. NHS WISKI platform exists. Questions to ask; how will this be useful for decision makers, how reporting will occur? In addition to an online portal. Periodic study of droughts can be done to gain a better understanding of what is going on. ● Implementation Plan: <ul style="list-style-type: none"> ● Year 1: aim to have the system up and running. ● Year 2-3: continuity phase. <p>There needs to be periodic review of data coming in to assess the quality of the data. After year 1 it can be determined what works, what doesn't, what is useful, what to downscale or upscale and what can be adopted moving forward. A staggered implementation plan to upscale can be adopted which allows experience from northern Belize to be applied moving south.</p> ● Cost for: <ul style="list-style-type: none"> ● 18 manual and 7 automated sites; ● Quarterly water quality lab analysis for all 25 sites; ● Five sites analysed for pesticides per year (this action is costly and shipping to US required). <p>CAPEX - \$300,850 BZD</p>
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	<p>OPEX - \$277,179 BZD Key assumptions: Use existing boreholes, replacement of most monitoring equipment at 3-to-5-year intervals, limited pesticide testing due to cost.</p>
<p>Discussion</p>	<p><i>Topic 1&2: Groundwater monitoring system design for northern Belize & benefits of groundwater monitoring.</i></p> <p>EEC: asked why the automated monitoring sites were located near the coast and noted that inland sites can also produce critical information as salinity can also be detected at those sites. To date this parameter has been a major concern for agriculture and nearby communities. The DoE takes weekly manual reading and as a system is already in place.</p> <p>Collaborations and partnerships already exist. The DoE is improving the monitoring stations, with automated stations along the New River. These not only look at the hydrological monitoring but also are tested for water quality. At least at the 4 stations there will be a gamut of parameters monitored.</p> <p>GWO: noted that the rationale behind coastal sites is to serve as an early warning system for salt intrusion and to detect rapid fluctuations in salinity. With the monitoring station option, field parameters can be assessed. It was noted that lab analysis and pesticide analysis are sophisticated and can be costly to undertake.</p> <p>LCH: stated that high tech equipment can stop working and essentially become a white elephant. It is noted that the Campbell equipment is most reliable and suggested that at the start of the monitoring programme, manual stations can be utilised and a transition to automated after year 2 or 3 can occur when the automated stations are validated to be reliable, and the team becomes comfortable with it.</p> <p>RLO: reiterated the same as above on a shift from manual to automated, however added that the NHS does not want to get rid of manual stations because they serve as a cross reference that automated equipment is functioning properly, as these can fail. Manual data checks are necessary to validate and for data correction. The NHS has tried Steven's and other brand loggers in the past but is leaning toward the use of Campbell Scientific. It was noted that this would require training of technicians to allow for effective use.</p> <p>EEC clarified that the question on manual versus automated stations was not to suggest an elimination of manual stations but instead to point out that there are currently 400 existing wells, whose primary use was human consumption. There has been an apparent switch to predominantly agricultural use. This is because of the availability of potable water in new areas. Information on current well use can show how priorities have shifted.</p> <p>Additionally, the baseline information presented by GWO does not account for geology and land use changes, which also needs to be considered in the baseline.</p> <p>JPA: suggested that it is better to cost both options and the transition from Manual to Automated. JPA added that moving forward with digital transformation (automated stations) is better and noted that both options require training.</p> <p>LGL: stated that manual stations, require human interventions that are already stretched thin. To move toward being efficient, it would make practical sense to focus on automated stations paired with interdepartmental collaborations (DoE, National Meteorology Service (NMS), and MAFSE) to share data sets from other existing automated stations. This is beneficial to grasp a holistic view of the groundwater situation. The NMS is moving away from manual stations.</p> <p>Considerations for larger scale projections need to be considered as it is best to match and source resources. Historically, considerations have been for short to medium term, however water management requires long term planning. In looking at a wider scope, there is more that is required for the management of the resource. Funding agencies may be willing to fund scaling up of monitoring systems. The piecemeal approach sometimes gets pushed aside. Water resources have been flagged as a top priority in Belize.</p> <p>THE: shared that manual stations remain relevant for the NHS. Automated loggers tend to fail and require some form of manual verification. With thirty years of experience in data collection, history has shown the benefits of validating fluctuating data that would have otherwise been discarded. Additionally, automated stations are expensive to operate, loggers are often infested with ants and various sealing methods have successfully rectified this issue, thus affecting the quality of data. The CAPEX for automated stations is the Department's entire annual budget and is thus unrealistic to implement fully.</p> <p>Manual stations allow for community engagement and support, as well as by-in and ownership. While the stipend paid is meagre, data collectors do not hesitate to report</p>

	<p>instances of flash flooding which would otherwise go undetected due to the quickness with which these can occur. Belize Water Services Limited (BWSL) takes readings from a manual station, this collaborative support is crucial as there is no department funding available.</p> <p>Automated data is quicker and occurs in real time, however, this form of raw data needs to be validated for quality assurance. Multiple factors need to be considered such as potential glitches, location, cost, maintenance etc. when considering automated stations.</p> <p><i>Topic 3&4: Proposed system specification (data collection/management/dissemination) & System implementation schedule of activities.</i></p> <p>None</p>
Action Items	None
<p>Agenda Item 4:</p> <ul style="list-style-type: none"> ● System cost estimates; ● Cost and scope of upscaling to the national level. 	
Notes	<p><i>Topic 1: System Cost Estimates.</i></p> <p>IMC: presented to participants.</p> <p>Key focus: How will this system be paid for and how will it be sustained without having to go back to the government to request for additional resources like salaries?</p> <p>Strategic objective: The model is based on a sustainability framework. (What is being proposed will require political will).</p> <p>Legislative and Institutional Framework in place:</p> <ul style="list-style-type: none"> ● National Integrated Water Resources Act (NIWRA); ● Water Resources Administration (WRA); ● The effectual power of Statutory Instruments. <p>Operational Modalities:</p> <ul style="list-style-type: none"> ● Design Principles: <ul style="list-style-type: none"> ● Community/CSO-Based/Public Sector Partnership Model; ● Key Attributes: <ul style="list-style-type: none"> – Cost Effectiveness; – Model Sustainability; – Community Ownership; – Participatory Inputs; – Environmental Educational Tool. ● Formal Establishment of a Groundwater Monitoring Unit (GMU) under the NHS. ● Design Targets: <ul style="list-style-type: none"> ● Operationalization Target Start Date: April 1st, 2024; ● Funding Approval Targets: <ul style="list-style-type: none"> – CAPEX (\$ 400K, 20% contingency): February 28th, 2024; – OPEX (\$ 300- 500K, 15% contingency): October 31st, 2023 (needs to be a recurring line item, the needs to be proposed to relevant minister). <p>To garner interest from funders, putting forward a \$ 10-20 million project makes sense. Hence a national project is something to look at.</p> ● Funding Model Assumptions: <ul style="list-style-type: none"> – CAPEX: Potential Grant Funded (Yr. 0, Bi & Multilateral development partner solutions); – OPEX: GOB Funded (Yr.'s 1-3, WRA Tariff Based streams thereafter). <p>Tariff regime set up for all licenced well owners. There are illegal wells operating below the radar. There needs to be a rationalisation (some form of bar code). The reason for this is that users are extracting, and this needs to be paid for in a negligible manner. A rate setting method needs to be justified and categories established. The OPEX indicates the desire to ensure</p>

	<p>sustainability of systems and programs. It must be paid for, but who pays, taxpayers?</p> <p>IMC presented a proposed phased approach to establishing the groundwater monitoring system in what is called 'Zone 1'. The proposed approach considers a five-year implementation period as follows.</p> <p>Year 0:</p> <ul style="list-style-type: none"> ● Get all approvals and ducks in order during a 6–9–month period. ● Sourcing of funds. <p>Year 1:</p> <ul style="list-style-type: none"> ● Commencement of operation. ● Training is required as of April 1, 2024. There will be a 6-month period where persons from the community will be identified and trained based on the ratio of automated to manual stations. New data will likely not be collected until October 2024. ● The Water Resource Authority (WRA) will be actively seeking institutional strengthening. Multilateral and bilateral interest will be sought after (target only the ones with demonstrated interest in Belize of which there are only a few). ● A properly worded funding document is required (with development phases listed). ● Soliciting of resources from the above sources, will assist in institutional capacity building of WRA. <p>Year 2:</p> <ul style="list-style-type: none"> ● Begin collection of baseline data. ● Hold conversations on what rate is to be applied. ● This is expected to be a contentious year since the concept of an individual or company paying for water that they sourced themselves is not easily accepted. ● The consultation process should commence at the midpoint of year 2. Consultations should demonstrate the tariff structure and broadcast to people the planned approach and potential costs for water extraction. ● Implementers should anticipate friction when telling people why they need to pay for the water being extracted. ● The agreed rate will generate a lot of discussions and attention in the media. <p>Year 3:</p> <ul style="list-style-type: none"> ● All licensees should have some form of metering system that cannot be tampered with. ● Commencement of the consultation process. ● The consumer, particularly commercial and industry, should have an idea of what their bill would look like. ● The need for rate adjustments may arise (there are cycles to setting rates, BWS in the past had a 5-year cycle, this has now shifted to every year). <p>Year 4:</p> <ul style="list-style-type: none"> ● Actual collection of tariffs. <p>Year 5:</p> <ul style="list-style-type: none"> ● Formal system evaluation. <p>Establishing a tariff-based regime: There is no money in monitoring but there is in extraction.</p> <p>Design Principles:</p> <ul style="list-style-type: none"> ● Adoption of familiar user category classifications of: <ul style="list-style-type: none"> ● Domestic (room for exemptions); ● Commercial; ● Industrial. ● Incorporation of Exempt categories under the NIWRA: <ul style="list-style-type: none"> ● Cognizance of Demand and Supply Elasticities regarding Groundwater extraction impact. (this may determine tariff will incentivize of disincentives consumption extractions and thus can dictate and control use). ● Non-Inflationary nor Market-Distortionary in application.
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	<p><i>Topic 2: Cost and scope of upscaling to the national level.</i></p> <p>ARO: presented to participants potential options for scaling up based on the following characteristics:</p> <p>Enabling factors to implementation:</p> <ul style="list-style-type: none"> ● Upscaling to a national level; ● Finance strategy; ● Institutional assessment; ● Feasibility analysis; ● Training with relevant entities in the sector. <p>Proposed monitoring location:</p> <ul style="list-style-type: none"> ● Relevant to the interests of the users; ● Targeted to the highest priority areas; ● Timely reporting of data; ● Appropriate technology; ● Adaptable to allow updates/improvements/upscaling; ● Financially and technically sustainable; ● Clear institutional roles; ● Spread of locations across the different groundwater provinces around the country; ● Reference areas with minimum human disturbance; ● Areas where agricultural development may influence groundwater levels; ● Areas where saline intrusion may pose a risk to public water supply. <p>Groundwater Provinces:</p> <ul style="list-style-type: none"> ● Campur; ● Vaca; ● Maya mountains; ● Savannah; ● Toledo province; ● Coastal shelf; ● Coastal Plains. <p>Implementation Plan Period: 1-6 years (51 manual and 21 automated sites).</p> <p>The assumed cost is for:</p> <ul style="list-style-type: none"> ● 51 manual and 21 automated sites; ● Quarterly water quality lab analysis for 72 sites; ● 15 sites analysed for pesticides per year (costly and shipping to US required). <p>Rough cost estimates are based on the following:</p> <ul style="list-style-type: none"> ● CAPEX – Low \$670,725 BZD, Medium \$764,525 BZD, High \$858,325 BZD; ● OPEX – Low \$570,583 BZD, Medium \$665,553 BZD, High \$760,523 BZD. <p>Draft idea on how to upscale https://www.nytimes.com/interactive/2023/08/28/climate/groundwater-drying-climate-change.html.</p>
<p>Discussion</p>	<p><i>Topic 1: System Cost Estimates.</i></p> <p>HRA: stated that a classic example can be seen in the Belize River Valley area in which there were nine (9) villages with rudimentary water systems (RWS). Through a specific funding project, the company aimed to supply potable water to the area switching from a flat rate to using a tariff structure at rates seen in Belize City. Initially there was some resistance, however, buy-in was achieved. Nevertheless, this was slow and took between 2-3 years. Actions to achieve this included one on one conversations, advertisements and required someone to champion the initiative (such as a chairperson). There was also a recognised need for a shift by communities since people were facing health issues with using water supplied by the RWS.</p>

There is currently no distinction between domestic and commercial tariffs as rates are the same, however differences were seen in the installation costs. HRA suggested that the Department of Rural Transformation revisits the flat rate charge for potable water in villages to a more manageable figure. There is a need to revisit the legislation as it relates to RWS. There is no confirmation on whether this has commenced or not.

HRA also suggested that a portion of groundwater monitoring costs be billed under the current BWSL tariff regime.

LGL: suggested that BWSL may be able to share experiences with tariffs. A new metering system (smart meter) installation moves toward a draconian approach has been implemented by the Department of Rural Transformation. Water meters are not negotiable. If a person doesn't want a water meter installed, they will not be connected. This is based on the recognition that the application of a flat rate for water use in rural areas is unsustainable. MAFSE should be able to provide examples of how they have faced push back in establishing charges to farmers.

LCH: added that the buy-in to the BSW River Valley project was easier to achieve due to issues with the wells drying up seasonally. In looking at charging for the extraction of groundwater the question of value comes in question. With a tariff regime, will the water table produce more efficiently and continuously? This is not known and cannot be guaranteed. How can tariffs be justified in terms of value to the user? Communication campaigns need to take this into account.

To get political and public buy-in, the approach must rest on science. Use science to show water availability in aquifers, and recharge rates, annually, when possible. This demonstrates a finite resource which mandates regulation. Getting the science right will take time.

Agreed to the suggestion of having a portion of groundwater monitoring costs be billed under the current BWSL tariff regime but noted that some offices are under financial constraints.

THE: noted that there is misinformation related to NIWRA resulting in resistance from people when they believe that freedom is curtailed. Groundwater extraction is currently free, but expectations to monitor, manage and ensure future use are high. There is a lot of documentation currently in place that relates to the legislation, institutional architecture, a financial sustainability plan, and documentation on phasing in the financing/tariff regime, with a suggested rate of one thousandth of a cent.

The existing water policy considers the user pay and the polluter pay principle. The policy is built on water being a finite resource. It also recognises that groundwater recharge is a slow process. The Savannah groundwater province was assessed, but results were not definitive. The Independence well, which is the source of piped water to Placencia, is giving issues, resulting in water needing to be trucked into the village. The issue of fairness is again raised, when the heaviest users are not recycling, or implementing water efficient fixtures, and are essentially paying the same rate for an unlimited water supply.

THE is happy to hear this group echoing the same sentiments identified by the NHS as it provides validation. All documents were developed from as far back as 2014 but have only minimally progressed forward. To ensure minute progress, the lower hanging fruit, the easiest funded aspects, are prioritized and targeted. There is a need to update and put a package together to represent the true reality of the situation the country is facing in relation to groundwater, to advance further and more rapidly.

The current GCF project uses Africa as an example and justification because the relevant science does not exist in Belize. Groundwater is looked at in all projects now and a groundwater monitoring unit is necessary.

Transboundary considerations still exist. While it would be ideal to sign an agreement that obligates upstream countries to allow 'x' amounts of cubic meters to flow into Belize, the transboundary issues provide limitations. Obstacles that can be addressed are therefore the focus, however the larger, harder issues are on the back burner but still very much alive.

Collaboration/Water Resources Administration are extremely taxing on limited staff. Documentation exists on what this should look like, how it should function, the expertise needed, technical staff etc. There has been an instituted, but now defunct, Water Advisory Council that included the Chief Environmental Officer, Chief Agriculture Officer, Chief Forest Officer, Chief Climate Change Officer, Head of Rural Development, Public Utilities Commission, Principal Hydrologist (NHS), Chief Meteorologist, etc. A total of 15 government divisions made up the council whose function was to aid in water resource administration. The council had a terms of reference which included looking at applications, determining what was demanded, what would be allowed, what was considered over extraction and determining a contingency, however, the exercise

	<p>showed that it was impossible to determine when the aquifer capacity was unknown. The absence of knowing the water resource availability made the group go defunct. This derailed the process.</p> <p>The Water Rights Administration, a smaller group, includes the Department of Rural Transformation, DoE, Hydrology, and where necessary BWSL. This group is responsible for deciding on giving well permits, and abstraction licenses. This is still a formal group. While the process is extensive, limitations in resources and time, prevents members from conducting site visits. Responsibility therefore falls on the NHS, to carry out due process. Findings are shared with the various agencies for input or objection. This, however, is rarely realised by the established deadline, resulting in the NHS moving on.</p> <p>THE reiterated that all documentation exists, but the challenge is in moving forward with the implementation. The NHS adapts to suit reality. There exists a 20-question community engagement strategy that references the legislation which would aid with the buy-in of a tariff regime, zoning as described by the consulting team, and identifying the national authority to address issues like large eco resorts paying flat rates in rural communities with RWS. The NIWRA legislation, once properly instituted, can eliminate some of the issues currently being faced with extraction. A lot of the current issues with water regulations, is the inability to respond to those asking who the ultimate authority for water regulation is. The establishment of the NIRWA will help to address some of the issues that are currently faced.</p> <p>IMC: stated that sensitisation is required and will not be achieved overnight. Benefits need to be conveyed to everyone. Revenue would be primarily generated from commercial users and industry. The conversation will be very political; however, the goal is to advance the principle of fairness. Buy-in would take place over 2 to 3 years. (Understanding what it is, what it means to the country on a whole, what is the aim).</p> <p>Under the tariff regime it is not necessary to account for what it costs to monitor but certainly to offset the costs of monitoring. Getting a loan for CAPEX is understandable but to ask the taxpayer to subsidise an extracted resource does not result in fairness. There must be an understanding that fairness is what is needed. Therefore, OPEX must be a budget line item. The process should be data driven. This includes ensuring data collection, proper financial analysis (how much it costs on the dollar) and an economic analysis and assessing the footprint on aquifer. The kinks can be worked out in the pilot phase.</p> <p><i>Topic 2: Cost and scope of upscaling to the national level.</i></p> <p>EEC: noted that the transboundary issue was not mentioned in plans for upscaling the groundwater monitoring system. EEC asked whether costs included contingencies and the need for drilling of boreholes.</p> <p>ARO: pointed out that it is difficult to plan for transboundary issues as it falls outside the scope of the current initiative, but the suggestion will be considered for integration in the final deliverable.</p> <p>It was also pointed out that Most wells are in Northern Belize and therefore scaling up will not be too expensive. 25 wells are proposed to monitor in the New River watershed, whereas 72 are proposed for the rest of the country.</p> <p>Contingency costs are included in the cost estimate especially where there is potential need to drill boreholes.</p> <p>Projected execution costs are low, due to the existence of boreholes. However, costs can easily go up, depending on the number of automated monitoring sites that are decided on and a need to drill boreholes.</p> <p>THE: requested that the document produced indicate that the projected cost is an estimate and subject to change over time. THE requested that there is a disclaimer that the 72 proposed country wells are an estimate.</p>
Action Items	ARO to Ensure inclusion in the document that costs are subject to change over time and based on a proposed number of well nationally.
Agenda Item 5: Institutional Assessment	
Notes	<p>LCH: presented the potential institutional makeup of the groundwater monitoring system to participants.</p> <p>An organogram was put forward as follows:</p> <ul style="list-style-type: none"> ● Regulatory (policy, regulation, monitoring): <ul style="list-style-type: none"> ● MAFSE: Ministry of Agriculture Food Security and Enterprise; ● MNRPM: Ministry of Natural Resources Petroleum and Mining; ● MPU: Ministry of Public Utilities;

	<ul style="list-style-type: none"> ● MRTCDLLG: Ministry of Rural Transformation, Community Development, Labour and Local Development. ● Advisory (technical, monitoring, infrastructure): <ul style="list-style-type: none"> ● MIDH: Ministry of Infrastructure Development and Housing; ● DoE: Department of Environment. ● Emergency (flood, drought, data): <ul style="list-style-type: none"> ● NMS: National Meteorological Service; ● NEMO: National Emergency Management Organization. ● Financial (project planning and funding, human resources, equipment): <ul style="list-style-type: none"> ● MFED: Ministry of Finance and Economic Development; ● IFI's: International Financial Institutions.
Discussion	<p>THE: suggested the inclusion of the Department of Rural Transformation under the advisory (technical) role. This department helps if there is a need to find a groundwater source.</p> <p>Indicated that the DoE requests information from the NHS specifically for surface water to determine flow and hydrological assessments done on New River on turbidity etc.</p> <p>The relationship between the NMS and the NHS is not stable, but it currently functions.</p> <p>As it relates to the financial category, there should be a public/private partnership agreement, to aid in financial support, where corporate entities assume corporate social responsibility to e.g., monitor a portion of a river. This exists as a legal document which stipulates obligations of partners party to the agreements. One example is seen under a collaboration with NHS and BWSL to monitor a river/water level station at the BWSL Double Run facility. Other interest has been noted from other companies like Santander. Another example of such partnership is seen in the River Valley Area (Mussel Creek Bermuda Landing bridge, Lemonal) where community members participated in preparation efforts for their water supply.</p> <p>The Ministry of Tourism approached the NHS due to increased occurrences of flash floods at the Aktun Tunich'il Muknal Cave site. The interest was in early warning systems and costs to implement such a system.</p> <p>GWO: asked: as it relates to the institutional roles with groundwater monitoring systems, who pays for what? Is there a government policy or environmental data sharing charging to be considered?</p> <p>GWO: gave an example in the UK where there is a move toward free data sharing, placed on portals etc. historically. A disadvantage is that it is harder to track and determine use of data.</p> <p>THE responded that there have been discussions on cost recovery mechanisms, however currently there is no charge for hydrological data. Data requests often come through her. Requests are asked to be forwarded to RLO's email. There is no charge for data sharing. The sector is not profitable. Although a charge may be considered for quality checked data.</p> <p>The Fisheries and Forestry Departments charge a fee to research/research entities who request data.</p>
Action Items	None
Agenda Item 6&7: Summary of the day and close of workshop/Final remarks	
Notes	<p>GWO: Thanked all participants for sharing time and expertise, provided summary points of the day's activities, and listed next steps.</p> <ul style="list-style-type: none"> ● Summary points: <ul style="list-style-type: none"> ● There was robust discussion on a balance between automated and manual monitoring sites. The ideal location of the stations, and the pros and cons of both approaches will be considered in finalising outputs. ● There was discussion on potential collaborations between the DoE and NHS for facilitation of data collection at stations already installed along the river. ● Where financing is concerned, the fairness route for changing minds when utilising a public resource is identified as critical. Under the sustainability theme, the theory, institutional architecture and legislations is already in place, however implementation is lacking. ● The institution for CAPEX -grant funding, ongoing sustainable financing needs to be considered, finance strategy needs to be developed to transition into a longer-term sustainable program.

	<ul style="list-style-type: none"> ● A lot of groundwork on license fees needs to occur equally the need to do science led public relations. ● In the discussion of upscaling the transboundary issues were raised as surface water catchment and groundwater sources are linked across borders. ● Maintaining a flexible costing plan at the national scale should include assumptions that are clear ranges. Contingencies should also be reflected in costs. ● Priority should be placed on the need-to-haves and not the nice-to-haves. ● There is a general move towards open data rather than cost recovery. ● Next Steps: <ul style="list-style-type: none"> ● Integrate feedback from the workshop: <ul style="list-style-type: none"> – A costing and financing strategy; – Concept note to attract financing; – Institutional arrangements; – Implementation plan for upscaling to national level; – System manual. <p>THE: Thanked the Consulting team for the short but long ride and showed appreciation for the work, effort and expertise displayed in producing deliverables. THE was grateful for the relief provided to her team. Special thanks were given to GYO and LGL from the NCCO, and the very responsive and dedicated stakeholders. THE promised that the documents would be used for advancements in water resources, and not left in a corner.</p>
Discussion	<p>BMO: offered that BWSL has monthly data from its groundwater sources. The data is shared with the Ministry of Health. This is done as a mandate under the Water Industry Act. It is possible to share data with private sources however, when this is done, there is need to sign a non-disclosure agreement.</p> <p>THE: sought clarification on the reference to the number of Technicians listed in the presentations. The rationale is to ensure that documents submitted reflect the same, or similar information in terms of justification of the groundwater unit. The proposal from the NHS is three persons to cover the technical aspect.</p> <p>IMC: confirmed that two technicians were costed in the cost estimate. IMC further committed to working with NHS to ensure that numbers align.</p>
Action Items	<p>IMC to ensure the number of Technicians costed align with needs identified by NHS.</p>

Appendices

A Workshop Agenda

A.1 Stakeholder Working Group –Workshop

A.1.1 Groundwater monitoring system design

Date and Location:

9:15am Belize City 6th September – **Belize Biltmore Plaza** (Mile 3, Philip Goldson Highway, Belize City).

Workshop agenda

Time	Activity	Facilitator
9:15 – 9:30	Participant registration.	
9:30 – 9:40	Welcome remarks from National Hydrological Service.	Tennielle Hendy (NHS)
9:40 – 9:50	Introduction to the purpose of the workshop and agenda.	George Woolhouse
9:50 – 9:55	UN Climate Technology Centre and Network (CTCN) introduction.	Marisela Ricardez Garcia (CTCN)
9:55 – 10:45	<ul style="list-style-type: none"> ● Groundwater monitoring system design for northern Belize; ● Benefits of groundwater monitoring; ● Proposed system specification (data collection/management/dissemination); ● System implementation schedule of activities. 	George Woolhouse/ Azucena Rodriguez Yebra/Lucien Chung
10:45 – 11:00	Break.	
11:00 – 12:00	Interactive game (“ <i>Before the drought</i> ”).	Azucena Rodriguez Yebra
12:00 – 13:00	Lunch.	
13:00 – 13:30	<ul style="list-style-type: none"> ● System cost estimates; ● Cost and scope of upscaling to the national level; ● Q&A. 	Ian McMillan Azucena Rodriguez Yebra George Woolhouse
13:30 – 13:45	<ul style="list-style-type: none"> ● Comments and discussion. 	Elishah St Luce/Lucien Chung
13:45 – 14:00	<ul style="list-style-type: none"> ● Final remarks. 	Azucena Rodriguez Yebra
14:00 – 14:15	Summary of the day and close of workshop.	George Woolhouse

*Consulting team (when not specified)

B Sign-in Sheet



Workshop: Belize groundwater monitoring consultation workshop

REGISTRATION FORM

Name:	Position:	Organisation:	Telephone and E-mail:
Andy Che.	Extension officer.	MAFSE	636-6357 andy.che@agriculture.gov.bz
Miguel Bolon	District Ag. Coordinator	Ministry of Agriculture	691-0689 Miguel.bolon@agriculture.gov.bz
Justino Palomo	Project Dev Specialist	Ministry of Economic Dev	615-9454 justino.palomo@med.gov.bz
Brendan H Chiquedde	LAB SUPERVISOR	Belize WATER SERVICES	600-2899 beverly.mohamedali@bwsl.com.bz
EDGAR Ek	Deputy Chief Governmental Officer	Department of the Environment	deputy@environment.gov.bz



Name:	Position:	Organisation:	Telephone and E-mail:
Rhonda Lopez Willemus	DATA ANALYST	National Hydrological Service	610-5091 hydroanalyst@naturalresources.gov.bz
Gina Young	NDC Facilitator	National Climate Change Office	613-0662 ndc.coord@environment.gov.bz
Lennex Gledhill	Chief Climate Change Office	MCCO	coord.cca@environment.gov.bz
Kareem Lino	Hydrological Technician	National Hydrological Service	614-8884 lino.kareem@gmail.com
Marleny Dominguez	Under study Data Analyst	National Hydrological Service	621-8135 MDominguez@naturalresources.gov.bz

C Photos



Groundwater monitoring for mapping aquifers in Belize as a tool for climate change adaptation planning

Groundwater monitoring system
manual - NHS field technicians

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Project manager	Azucena Rodriguez Yebra
Project director	George Woolhouse

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Document authorisation

Prepared	Approved	Authorised
Azucena Rodriguez Yebra	George Woolhouse	Nigel Walmsley

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1 Background

1.1 Project summary

The National Hydrological Service (NHS) of the Ministry of Natural Resources, Petroleum, and Mining and the National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management, are executing a project to design a groundwater monitoring system for the management of aquifers in Belize, focusing on the New River watershed. The project commenced in October 2022 and will complete in November 2023. HR Wallingford Limited is leading the consulting team implementing the project and financial support is provided by the Climate Technology Centre and Network (CTCN).

This important project will help Belize to sustainably manage groundwater resources in the face of a changing climate and human pressures on the resource.

The main outputs include:

1. A communications plan and detailed work plan;
2. Stakeholder mapping and establishing a stakeholder working group;
3. An assessment of groundwater availability and demand, nationally and with a particular focus on the New River watershed;
4. Design of an integrated monitoring system that will enable Belize to manage groundwater resources in the priority area of the New River watershed;
5. Development of an implementation plan on the enabling factors for implementation, including financial, institutional setting and capacity building.

1.2 About this report

This report is a manual for the operation of the groundwater monitoring system for the New River area (as defined by the Coastal Plains groundwater province) designed as part of Output 4 above.

It provides a manual for the NHS technicians to help identify monitoring sites, preparing sites for monitoring, collecting data and quality assurance.

2 Groundwater Monitoring for NHS Field Technicians

This section of the manual is intended for National Hydrological Service staff as a guide to the following aspects of operational groundwater monitoring in the Coastal Plains groundwater province of northern Belize.

2.1 Purpose and scope of groundwater monitoring in the Coastal Plains groundwater province

2.1.1 Purpose of the groundwater monitoring scheme

Groundwater is a vital source of water supply in northern Belize for municipal, domestic, agricultural, and industrial purposes, sustaining health, livelihoods, and economic activities. However, the monitoring and management of groundwater is limited, and the resource is facing several challenges including:

1. Limited licensing and reporting of groundwater abstraction leading to uncertainty over the sustainability of groundwater exploitation with respect to aquifer health, environmental flows in rivers; and wetlands;

2. Agricultural development and the application of agrochemicals which have the potential to contaminate groundwater;
3. Climate change projections which indicate warmer and drier conditions in the future, reducing groundwater recharge and increasing the risk of groundwater depletion and saline intrusion, coupled with sea level rise.

These issues have been highlighted in recent drought events and the eutrophication of the New River in 2019. Groundwater and surface water resources are likely to be closely linked in some areas, and the transboundary nature of the aquifer systems extending into southern Mexico and Guatemala adds further dimensions of complexity to the system.

At present, there is no systematic monitoring of groundwater level and quality in Belize, and such a system is required to provide data for the effective and evidence-based management:

Drought

During droughts groundwater levels are expected to drop, and it is vital to understand how aquifers are responding to low rainfall. To investigate this, boreholes that are not affected by abstraction need to be monitored. This allows the impact of abstraction to be separated from the impact of drought. It is important to look at seasonal trends when assessing the impact of drought.

Water resource monitoring

If abstraction is greater than recharge, then groundwater levels will reduce over time. Water resource monitoring of boreholes allows us to assess changes in water level resulting from over-abstraction and help identify ecological sites, groundwater abstraction sites and rivers that may be impacted. Water resource monitoring boreholes need to be close to abstraction points.

Pollution

There are many types of pollutants which can be dangerous to human health that can be found in groundwater resources. For example, the presence of bacteria, such as E-Coli can indicate that water is not suitable for human consumption, or nutrients, such as nitrate or phosphate which can cause damage to surface waters. Additionally, dangerous chemicals, such as pesticides and organic compounds (e.g. oil-based products) or naturally occurring toxic elements (e.g. arsenic) can also be found in groundwater. We need to monitor for these to protect rivers, people, crops and wildlife.

Saline intrusion

Seawater can contaminate fresh water supplies. Although not necessarily toxic, saline water can affect the taste of water and at higher concentrations it is dangerous to people and wildlife. Salinity can increase over time due to sea-level rise, as a consequence of climate change, or from temporary effects such as hurricanes and over-abstraction from coastal boreholes.

2.1.2 Scope of the groundwater monitoring scheme

The proposed monitoring system in this report provides a basis for the structured collection of groundwater level and quality data across the northern Coastal Plains groundwater province. The NHS is the lead agency for implementing and operating the monitoring system, working collaboratively with other agencies including the Department of Environment, especially on water quality issues. Twenty manually operated and seven automatic monitoring stations are proposed for the long-term monitoring of groundwater level and quality, as shown in Figure 2.1. The use of existing wells is proposed to minimize capital costs. Table 2.1 provides a summary of the measurements required to be taken at different monitoring sites.

At manually operated sites community groundwater observers will be employed to take measurements of groundwater level, temperature, conductivity and pH once a week and report this back to the NHS. Site visits will be carried out by NHS staff quarterly to manually collect data on groundwater level, and temperature, conductivity and pH using a handheld meter. They will also inspect the well and take a water quality sample for laboratory analysis.

At automatic sites, temperature, water level, and conductivity probes and dataloggers are proposed to provide continuous monitoring of these variables, with data collected at 15 minute intervals (for the first year). Automatic monitoring is proposed in coastal areas where salinity is considered to be a risk factor. Site visits will be carried out by NHS staff quarterly to manually collect data on groundwater level, and temperature, conductivity and pH using a handheld meter. They will also inspect the well and take a water quality sample for laboratory analysis. They will also download the readings from the data loggers.

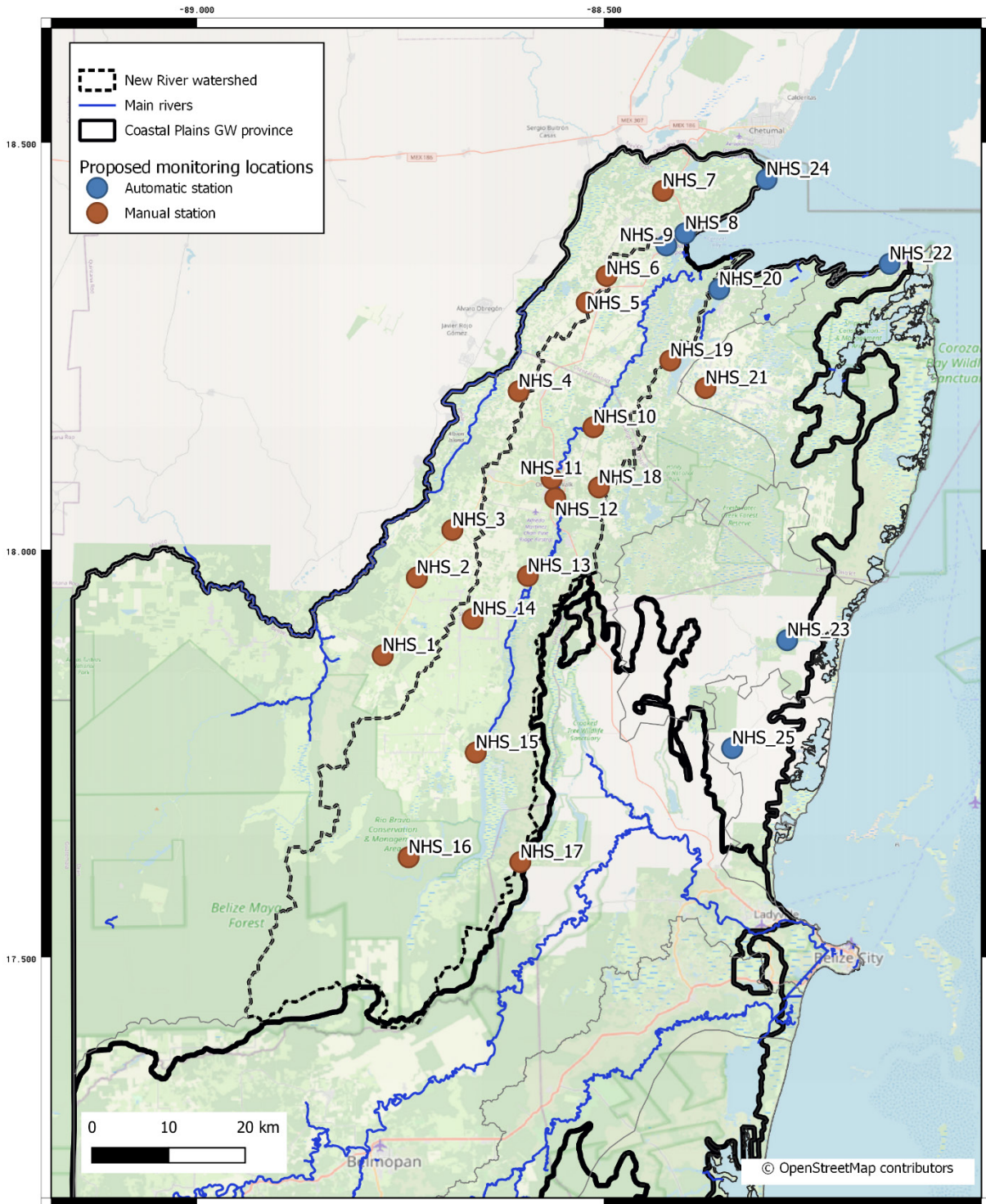


Figure 2.1: Map of proposed monitoring locations

Table 2.1: Summary of the measurements required to be taken at different monitoring sites

Monitoring site type	Number of monitoring sites	NHS Site visit to monitoring station	Water level monitoring method	Field parameter monitoring method	Standard water quality laboratory analysis	Trace chemicals water quality laboratory analysis
Manual	20	Quarterly (year 1) then review. Inspect well. Collect well level and field parameters using a handheld meter. Take water quality sample.	Weekly. Community representative collects water depth data using a well dipper.	Weekly. Community representative collects temperature, conductivity, and pH data using a handheld meter.	Quarterly (year 1) then review. Sample collected by NHS during the site visit.	Five sites sampled per year. Sample collected by NHS during the site visit. Adjust sampling depending on findings.
Automatic	7	Quarterly (year 1) then review. Inspect well. Collect well level and field parameters using a handheld meter. Take water quality sample.	15 minute (year 1), then review. Water level, temperature, and conductivity probe with logger.		Quarterly (year 1) then review. Sample collected by NHS during the site visit.	

2.2 Selecting suitable wells and boreholes for groundwater monitoring

Proposed monitoring locations were identified on the basis of providing a representative spread of locations across the monitoring area to be able to determine spatial and temporal variations in groundwater level changes and water quality changes over time:

- Some locations were selected in reference areas with minimum human disturbance to provide data on natural groundwater conditions to track drought and climate change without human influence.
- Some locations were selected in areas where agricultural development may influence groundwater levels (through abstraction for agriculture) and quality (through application of fertilizers and pesticides).
- Some locations were selected in areas where saline intrusion may pose a risk to public water supply in order to track changes in salinity over time.

The drilling and commissioning of new observation boreholes is expensive and represent a large sunk cost if in future the location of the observation well is found to be sub-optimal. Therefore, the use of existing wells for monitoring water levels is recommended at this stage. In future, once several years of data have been collected and evaluated, a case for investing in new monitoring boreholes may be stronger. Other potentially suitable wells may exist which are not in the NHS survey data. The Ministry of Agriculture’s BAIMS database of farms indicates many farms

utilise wells as their water source (although not the specific location of the wells themselves), and this may be a basis to target additional areas for well surveys in the future.

Therefore, most locations were identified to coincide with the existing wells surveyed by the NHS. However, not all locations have existing wells within the NHS well survey database, and in such cases some fieldwork has been carried out to identify suitable nearby wells. An initial prioritisation has been carried out as part of this study, and further, more detailed fieldwork and engagement with well owners will be carried out to confirm their suitability for monitoring.

The criteria for selecting an existing well to be part of the monitoring system include the following:

Essential criteria for manual stations

1. The well is accessible (physically/legally) and is likely to remain so;
2. The risk of vandalism, damage or other unplanned alterations to the well are low (for example dumping of garbage);
3. The owner of the well is willing to agree periodic access by NHS staff for monitoring activities (periodic water quality sampling/checking of probes and loggers);
4. The owner of the well is willing to take periodic water level readings or permit a nominated person to do so;
5. The well is suitable for water quality sampling (i.e. good contact between the well screening and the surrounding aquifer and ability to purge the well for sampling);
6. The well is suitable for water level monitoring, i.e. it can reliably be manually dipped to obtain water depth measurements;
7. The groundwater table is likely to remain above the base of the well during periods of extended drought so the well is not at risk of drying out;
8. The well is clear of debris such as garbage or other potentially hazardous waste which could cause blockages and damage equipment.

Additional essential criteria for automatic stations

9. The risk of vandalism or theft of equipment is manageable, and any protection measures can be installed (such as fences and signage);
10. The well is suitable for water level monitoring, i.e. a probe can be easily installed and removed without disrupting well operations, in the case of drilled boreholes.

Further considerations

11. Is the well located near any potential sources of pollution/contamination which are not representative of the aquifer in general (e.g. proximity to soakaways/land fill etc), unless these are a specific monitoring objective?
12. Is the well located near any significant groundwater abstractions which may impact on groundwater level measurements? – unless cone of depression of abstraction well needs to be determined;
13. Are the well construction and performance details known (geology, well screen, yield)?

2.2.1 Main types of well encountered in northern Belize and implications for monitoring

This section discusses the main types of well encountered and implications for monitoring, based on the NHS well survey and fieldwork conducted by the project team.

Private open wells

Private open wells (Figure 2.2) are typically less than 10m deep and if clean, maintained and not susceptible to drying out during the dry season or periods of drought are likely to be suitable candidates for community based monitoring, or the deployment of loggers if dip tubes are installed and are not likely to be subject to damage.



Figure 2.2: Example of a private open well with a suction pump in Belize

Private boreholes

Private boreholes may be used for domestic, agricultural or industrial purposes, and examples are shown in Figure 2.3. These may be suitable for monitoring using both manual approaches and loggers if the headworks allow dipping and the installation of loggers. If a submersible pump is present in the borehole then a dip tube will be required to prevent entanglement of the dipper or logger cable. Any pumping regime will need to be recorded as pumping may affect groundwater levels in the borehole and recovery of the borehole after pumping will need to be studied.



Figure 2.3: Example of private boreholes in Belize

Community handpumps

Handpumps are present in many communities across northern Belize, such as the ones in Figure 2.4. Those which are still in use are not suitable for monitoring as the headworks do not allow dipping of the well. However, if the handpump is no longer used or is damaged and does not require rehabilitation then they could be used for monitoring (manual or data logger) if the pumping mechanism is removed and the head capped off. Presumably, engagement with community representatives and the authority responsible for the handpumps would be required to secure permission for conversion to a monitoring borehole.



Figure 2.4: Example of community handpumps

RWS boreholes

RWS boreholes (Figure 2.5) are used to supply raw water to community scale water supply systems across northern Belize. Those which are actively in use could be used for monitoring, but would require engagement with the village water board and care must be taken not to interfere with the production of the borehole.



Figure 2.5: Example of Rural Water Supply (RWS) boreholes

2.2.2 Considerations when commissioning new monitoring boreholes

In the case where a new borehole must be commissioned, as there are no suitable boreholes or wells in the vicinity, the following design is proposed in Figure 2.6. The design includes a standard headworks design, with removable cover, dip tube and vented cap. The top of the borehole casing can be used as the datum to take measurements from.

The Environment Agency (the non-departmental public body responsible for the protection and enhancement of the environment in England) have published standards for drilling in the UK. These should be considered and are found in '*Guidance on design and installation of groundwater quality monitoring points*' (Fretwell et al., 2006).

It should be noted that the driller carrying out the design and work is responsible for the construction of the borehole.

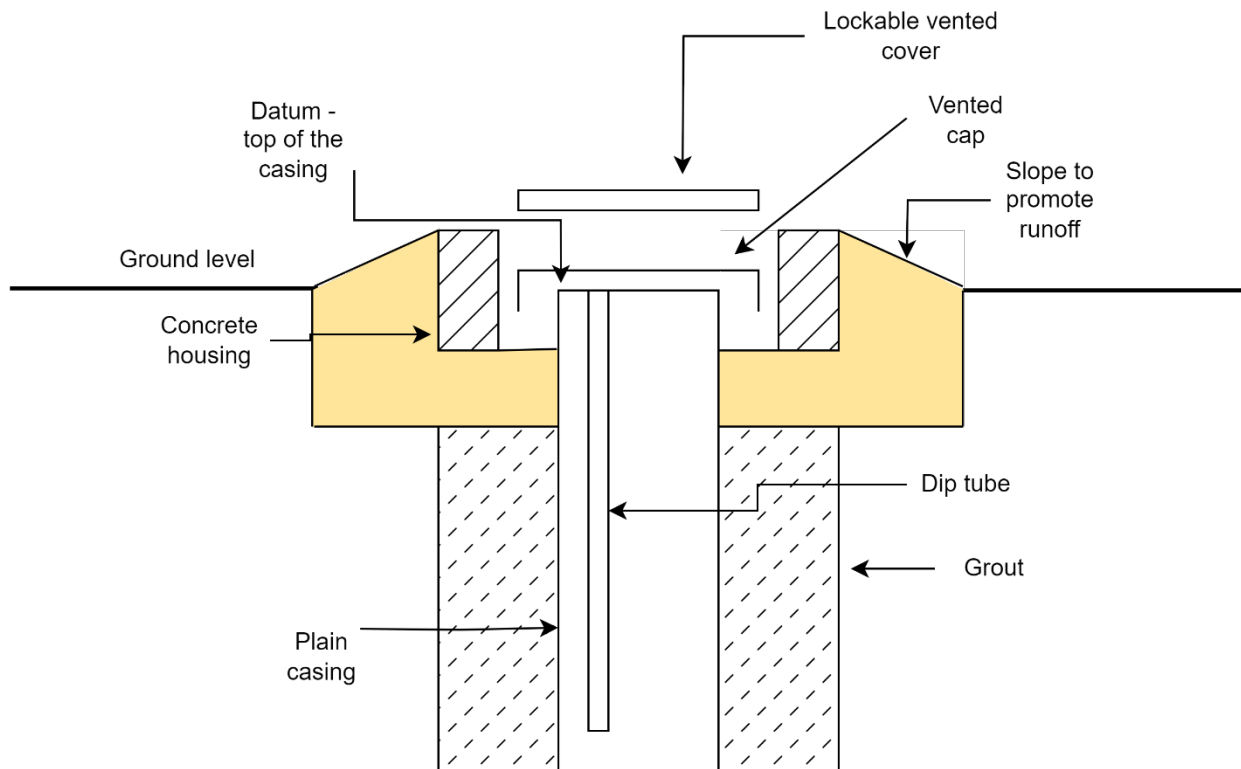


Figure 2.6: Example borehole with headworks

Source: Adapted from Fretwell et al. (2006)

2.3 Preparing wells and boreholes for monitoring and installation of equipment

Once a well or borehole has been identified as suitable for monitoring, a well information sheet should be completed for the site. This provides the basic information on the well or borehole which should be stored on file in the office. A template well information sheet is provided in Appendix A. It is important that the unique identification code assigned to the well or borehole is consistent with the convention and not duplicated (for example if a monitoring borehole is no longer required, its reference should not be re-used for new monitoring boreholes).

If possible the borehole or well should be clearly marked to allow technicians to confirm they have located the correct well during field visits.

2.3.1 Preparing of sites for manual data collection

Community observers and NHS technicians are required to use a dip meter and handheld water quality meter to measure water level, temperature, pH and conductivity.

The community observers and NHS technicians must be able to access the well and use this equipment safely, accurately and reliably.

For preparing sites for manual data collection:

1. The datum for reading the water level must be clearly and permanently marked at the top of the well or borehole. For large diameter open wells this may require construction of a bracket or similar which can be marked as the well datum against which water levels are measured. For boreholes it is typically the top of the casing.

2. If a submersible pump is present then a dip tube should be installed to prevent the dip meter getting tangled with the pump cable.

2.3.2 Preparing of sites for installation of automatic monitoring equipment

Automatic sites must be set up so that the water level, temperature and conductivity can be logged at 15 minute intervals. The site must also be accessible to allow NHS technicians to be able to carry out manual measurements and calibrate and check equipment.

In addition, for automatic sites:

1. The datum for reading the water level must be clearly and permanently marked at the top of the well or borehole. For large diameter open wells this may require construction of a bracket or similar which can be marked as the well datum against which water levels are measured. For boreholes it is typically the top of the casing;
2. If a submersible pump is present then a dip tube should be installed to prevent the dip meter and transducer getting tangled with the pump cable;
3. A transducer and logger must be set up following the manufacturer's instructions;
4. A suitable level of security is required to make sure that damage or theft of equipment does not occur. This could include the installation of a lockable vented cover (see Figure 2.6) or a locked fence;
5. Phone signal is required if telemetry is used to transmit data back to a central location;
6. The equipment is generally low power, so can obtain the power supply from small replaceable batteries or from a small solar panel.

2.4 Field measurement procedures

2.4.1 Before site visit procedures

Before going to site it is important to prepare and make sure the person responsible is ready for fieldwork. This will ensure the success of the work and maximise their productivity at the site. The options for monitoring groundwater quality and levels manually are outlined in Figure 2.7.

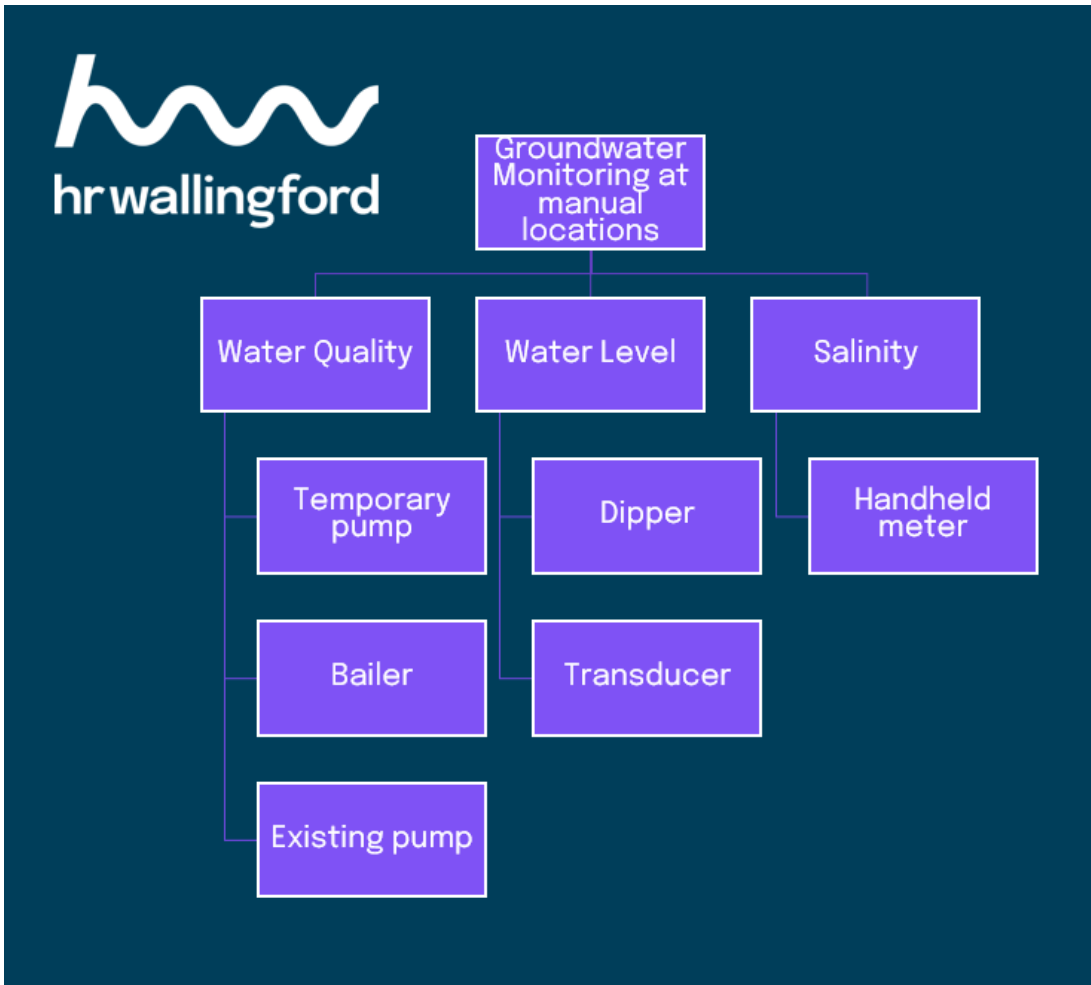


Figure 2.7: Options for monitoring groundwater quality and levels manually

Equipment

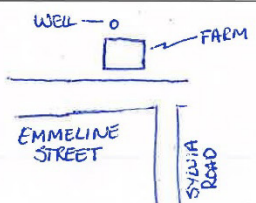
- Wear protective clothing suitable for the site;
- Check equipment is working;
- Pack spares (bottles, batteries, pens);
- A laptop will be required when visiting automatic sites.

Site review

- Prior to arriving at the site review the borehole data sheet to allow a better understanding of the work that will be undertaken. A blank copy is found in Appendix A and an example is provided in Figure 2.8.



Groundwater Monitoring Well Information Sheet

Location/Ownership			
Well Name:	EMMELINE STREET BOREHOLE		
Form completed by:	JO SMITH	Well/Borehole Reference:	NHS-101
Date of Assessment:	10/26/2023	Type of well (e.g., farm well, town water supply):	FARM WELL
Well address:	PANKHURST FARM, EMMELINE STREET, DAVISON TOWN, BELIZE	Directions to Well:	TURN LEFT AT END OF SYLVIA ROAD.
Co-ordinates	Northing 17°11'26.81"N	Westing -88°21'54.77"W	Sketch of location of well 
what3words			
Ownership details	Name:	ANN JOHN	
	Phone:	+501 12345678	
	Email:	-	
	Address:	AS ABOVE	
	Well use: (e.g., "used daily to supply farm")	FARM & SURROUNDING HOUSES	
	Purge volume (litres):	4900 L	
Well construction details:			
Depth	15m		
Diameter	80cm		
What is the water level and how is it measured (e.g. datum)?	WATER LEVEL IS 1.75m MEASURED FROM DATUM → TOP OF WELL CASING		
Pump installed/type/power?	NO PUMP		
Yield (e.g., "goes dry regularly")	WELL OWNER REPORTED IT HAS NOT DRIED OUT IN 30 YEARS	Is there a way of getting a WQ sample?	BAILER OR SAMPLE PUMP.
Can the well be dipped?	YES	Is the well easily accessible?	YES
Are there any Health and Safety Risks?	TREE ROOTS NEAR WELL ARE TRIP HAZARD	Well construction date:	~1991

Add photos below of the well/pump/location etc. overleaf

1

Figure 2.8: Example of Well Information Sheet

2.4.2 On-site procedures

Good practices

When working on-site it is important to adhere to the following good working practices:

- Work safely and report risks to appropriate staff member;
- Poor data is worse than no data;
- Compare new data with previous data;
- Record information;
- Reference and follow your company's Health and Safety protocol.

Other information to collect on site

- Data must be recorded in the Groundwater Monitoring Field Report shown in Appendix B. An example of a Groundwater Monitoring Report is found in Figure 2.9;
- Check well conditions;
- Check community observer equipment;
- Any calibration or maintenance checks carried out should be recorded.

Groundwater Monitoring Field Report

Visited by:	JO SMITH		
Name of agency:	NHS	Date of visit:	10/26/2023
Location:	EMMELINE STREET	Well identification no.:	NHS-101
Notes on condition of the well (e.g. choked; damaged; flooded):	WELL IN GOOD CONDITION		
Notes on condition of equipment:	EQUIPMENT IS WORKING.		
Any other comments (e.g. weather, pump running):	/ NO PUMP.		

Water Level

Please complete the water level manual parameters on site. If the site also has automatic monitoring equipment, please complete water level automatic parameters.

Water Level - Manual

Instrument used:	DIPPER NO. 04		
Water level from previous field visit:	1.29m		
Manual measurement of water level (from datum in meters):	Reading 1:	Reading 2:	Reading 3:
	1.14	1.25	1.15

Water Level - Automatic

Instrument used:	TRANSDUCER NO. 04.
Water Level at time of visit (m):	1.15
Data file downloaded to:	NHS LAPTOP 01
File name:	NHS-07-07/23-10/23

Water Quality

Please complete the water quality field parameters on site and take a water sample to send to the laboratory for further tests.

Water Quality - Field Parameters

Purge carried out?:	NOT POSSIBLE		
Method used:	Sample Pump	<input checked="" type="radio"/> Bailer	Existing Pump
Instrument used (e.g. handheld meter no.):	HANDHELD METER NO. 05		
Depth of sample collection (from datum in m):	3.5m		
Parameter:	Reading 1:	Reading 2:	Reading 3:
pH:	7.1	7.1	7.2
Temperature (°F):	68.0	68.1	68.0
Conductivity (µS/cm):	1300	1150	1280

Water Quality - Laboratory Samples

Method used:	Sample pump	<input checked="" type="radio"/> Bailer	Existing pump
Depth of sample collection (from datum in m):	3.5m		
Sample no.:	ES142004		

Figure 2.9: Example of NHS Technician Groundwater Monitoring Field Report

2.4.3 Water level

Water level needs to be monitored to observe changes due to droughts and abstraction. The static water level will be manually recorded weekly using a dipper by a community representative or continuously automatically logged using a transducer.

Quarterly a NHS technician will either verify manual sites by carrying out dipping at these wells or boreholes or visit automatic sites to download data from a transducer. However, it is recommended that when visiting an automatic site it is valuable to also use a well dipper to take a manual reading both before and after you download the data for cross-referencing.

Well dipper

- Test the dipper prior to the field visit by unscrewing the weighted end of the probe to expose the inner electrode and complete the circuit by immersing the end in water.
- Discern if there is a pump in the borehole or well:
 - If there is no pump in the borehole or well, lower the probe down the borehole or well;
 - If there is a pump, determine if the pump is running or not. If the pump is running, turn off the pump:
 - It is important the water levels have returned to their static level after the pump has been used. This can be done by testing the water level at 5 minute intervals until the change in depth is less than two inches per dip.
- Lower dipper into the borehole, well or dip tube until the buzzer sounds. When lowering the dipper try to reduce wear by running the tape over softer materials such a piece of wood or your hand to prevent it rubbing on the top of the casing.
- When this happens, pull the tape back slowly out of the water until the buzzer stops. The point where the buzzer stops is the water level.
- Use your fingers to mark the position on the tape against a fixed reference point on the borehole casing. Always ensure to measure against the same reference point – this should be recorded on the Groundwater Monitoring Field Report.
- Read off the level to the nearest centimetre.
- Record the dipped level, time of measurement.
- Repeat the process, as a check.

Transducer

- The manufacturer will provide a set of detailed instructions.
- Take manual reading using a well dipper as detailed above – check it is broadly similar to last dip.
- Retrieve groundwater data using the instrument or data logger software onto laptop – check latest value against manual reading.
- Inspect equipment to check if the installation is operating properly.
- To recalibrate the logger take a further manual reading using a well dipper as detailed above.
- Lower transducer to depth where it is calibrated with the manual reading.

2.4.4 Water quality preparation: purging

Modern groundwater quality monitoring protocols require a large volume of water to be purged before a sample is taken so that the sample is representative of the aquifer.

Where a borehole has an existing pump or sample pump it is advised that three times the water volume in the borehole is purged before a sample is collected. The volume is found by measuring the depth of the borehole and the depth to water, along with the radius of the borehole. Subtract the depth of the water from the depth of the borehole to give 'h' and then calculate the

volume of a cylinder, as shown in Figure 2.10. This value then needs to be multiplied by three to find the volume that needs to be purged. This value should be recorded on the Well Information Sheet (Appendix C) for future reference.

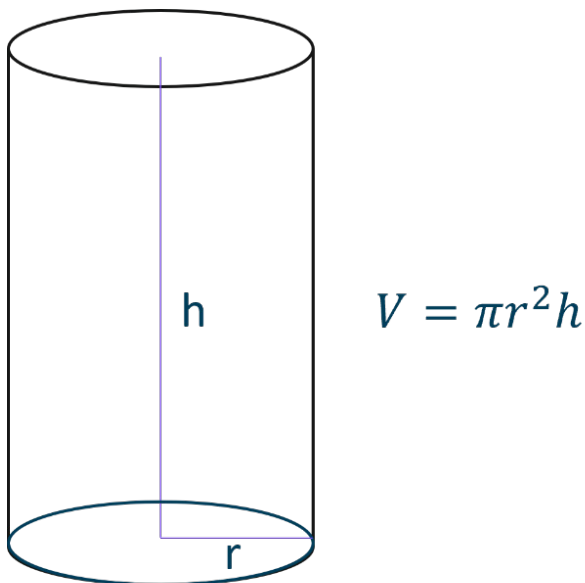


Figure 2.10: Volume of water in borehole

For boreholes with a low yield, it may not be possible to entirely purge the borehole before taking a sample, so take a note of the water volume removed before sampling so it can be considered when the results are analysed.

It may also not be possible to purge the borehole or well at all, and in this case a bailer is usually used to collect the sample. A note of this must be made so this can be taken into account when the results are analysed.

2.4.5 Water quality preparation: collecting samples

Prior to taking groundwater quality samples the borehole or well must be prepared by purging, as outlined in Section 2.4.4. Water samples can then be collected by either using a sample pump, a bailer or an existing pump, as described below.

Sample pumps

- Read manufacturer's instructions and follow all safety rules.
- Sample pumps are small, portable, generator powered and come attached to a hose so they can be lowered into the borehole to the required depth. It is important to make sure that the pump is sufficiently below the water level to avoid it becoming exposed when the water begins to draw down.
- Collect water sample from tap or open pipe in the specified container.

Bailers

- Read manufacturer's instructions and follow all safety rules.
- A bailer consists of a tube made of stainless steel or plastic that has a ball valve at bottom and is weighted so it will sink.
- Check the well or borehole is free from any obstruction and is open.
- Drop the bailer down the well on a string and allow it to fill up.
- Make a note of depth the sample has been collected from on the Field Report.

- Pull sample to the surface.

Existing pumps

- Read manufacturer's instructions and follow all safety rules.
- Collect water sample from tap or open pipe in the specified container.

2.4.6 Water quality (in field testing)

The field parameters to be recorded in the field are temperature, conductivity and pH. This will be recorded weekly by a community representative, and will be verified quarterly by a NHS technician. This data will be collected using a handheld meter:

- Prior to taking groundwater quality measurements the sample must be collected as described in Section 2.4.5.
- Please refer to the manufacturer's instructions on calibration and use of the handheld meter.

2.4.7 Water quality (in laboratory testing)

Water samples to be tested in the laboratory will be collected by a NHS technician.

- Read laboratory instructions and follow all safety rules. An example of the information a laboratory might provide can be found in Appendix C.
- Collect sample as described in Section 2.4.5 and complete relevant forms and labels from the laboratory.
- Some samples:
 - may need to be treated for future analysis and preservation during transport;
 - may need to be kept cold;
 - may require aseptic conditions, such as samples for bacteria.
- Send off to laboratory, following instructions from laboratory.

2.5 Data submission and data quality assurance

2.5.1 Data submission

Community observers must submit their completed Groundwater Monitoring Field Reports to the NHS technician at their quarterly visit. These results will then be compiled and the data entered into the database.

2.5.2 Data quality assurance

Data quality assurance, begins in the field, with general checking. To eliminate human and instrument error, NHS technicians and community observers can repeat measurements at least twice. It is also beneficial to compare the data collected to previous site measurements as this allows the field staff to make a judgement on whether the results are reasonable or not, depending on recent weather conditions.

Data management is proposed to be carried out by the NHS utilizing existing licenses for Water Information Systems by KISTERS (WISKI). Data will be entered into the database and flagged for inconsistencies. Data quality assurance will be carried out by the NHS Hydrological Analyst, working with the monitoring technicians. It is important to look out for steps in data from automatic sites after calibration or drifting in automatic measurements. An external consultancy is proposed annually to review data collected over the course of the year and recommend technical improvements. Once one full year of data has been collected, it may be appropriate to recruit a Hydrogeologist to provide data interpretation and derived products.

A regular public briefing twice per year is recommended to give an update on groundwater status and trends, and this frequency may be increased during periods of drought where a closer interest in groundwater management is required.

3 References

Brassington, R. (1988) *Field Hydrology*. Chichester: John Wiley.

Fretwell, B., R. Short, J. Sutton (2006) *Guidance on the design and installation of groundwater quality monitoring points*. Science Report SC020093. Bristol: Environment Agency.

Groundwater Monitoring Guidance Manual (2001). Commonwealth of Pennsylvania, Department of Environmental Protection.

Appendices

A Groundwater Monitoring Well Information Sheet

Location/Ownership			
Well Name:			
Form completed by:		Well/Borehole Reference:	
Date of Assessment:		Type of well (e.g., farm well, town water supply):	
Well address:			Directions to Well:
Co-ordinates	Northing	Westing	Sketch of location of well
what3words			
Ownership details	Name:		
	Phone:		
	Email:		
	Address:		Well use: (e.g., "used daily to supply farm")
			Purge volume (litres):
Well construction details:			
Depth			
Diameter			
What is the water level and how is it measured (e.g. datum)?			
Pump installed/ type/power?			
Yield (e.g., "goes dry regularly")		Is there a way of getting a WQ sample?	
Can the well be dipped?		Is the well easily accessible?	
Are there any Health and Safety Risks?		Well construction date:	

Add photos below of the well/pump/location etc.

B Groundwater Monitoring Field Report

Visited by:			
Name of agency:		Date of visit:	
Location:		Well identification no.:	
Notes on condition of the well (e.g. choked; damaged; flooded):			
Notes on condition of equipment:			
Any other comments (e.g. weather, pump running):			

Water Level

Please complete the water level manual parameters on site. If the site also has automatic monitoring equipment, please complete water level automatic parameters.

Water Level - Manual

Instrument used:			
Water level from previous field visit:			
Manual measurement of water level (from datum in meters):	Reading 1:	Reading 2:	Reading 3:

Water Level - Automatic

Instrument used:	
Water Level at time of visit (m):	
Data file downloaded to:	
File name:	

Water Quality

Please complete the water quality field parameters on site and take a water sample to send to the laboratory for further tests.

Water Quality - Field Parameters

Purge carried out?:			
Method used:	Sample Pump	Bailer	Existing Pump
Instrument used (e.g. handheld meter no.):			
Depth of sample collection (from datum in m):			
Parameter:	Reading 1:	Reading 2:	Reading 3:
pH:			
Temperature (°F):			
Conductivity ($\mu S/cm$):			

Water Quality - Laboratory Samples

Method used:	Sample pump	Bailer	Existing pump
Depth of sample collection (from datum in m):			
Sample no.:			

C Water Quality Parameters

Table D.2: Water quality parameters - Sampling containers and pre-treatments required

Parameter Group	Parameter	Sample Container	Sample Pre-treatment
General	Temperature	On-site analysis	On-site analysis
	Suspended Solids	1	None*
	Conductivity	On-site analysis	On-site analysis
	pH	On-site analysis	On-site analysis
	Dissolved Oxygen	2	7
	Dissolved Solids	1	None*
Nutrients	Ammoniacal Nitrogen	3	8
	Total Oxidised Nitrogen	3	8
	Total Phosphorus	4	None*
Organic Matter	Chemical Oxygen Demand	3	8
	Biochemical Oxygen Demand	2	4°C, Dark
Major Ions	Sodium	3	None*
	Potassium	3	None*
	Calcium	3	None*
	Magnesium	3	None*
	Carbonates and Bicarbonates	1	None*
	Chloride	1	None*
	Sulphate	1	None*
Other Inorganics	Silica	1	None*
	Fluoride	1	None*
	Boron	1	None*
Metals	Cadmium	3	9
	Mercury	4	9
	Zinc	3	9
Organics	Pesticide (Indicator)	5	4°C, Dark
	Synthetic Detergents	1	None*
	Organic Solvents	1	4°C, Dark
	Phenols	5	8
Microbiological	Total coliforms	6	4°C, Dark
Biological	Chlorophyll 'a'	1	4°C, Dark
NOTES: <i>Containers:</i> 1. 1000 millilitre polyethylene bottle 2. Special BOD bottle (normally 300 millilitre) 3. 500 millilitre polyethylene bottle 4. 100 millilitre glass bottle 5. 1000 millilitre glass (or Teflon) bottle with Teflon lined caps 6. Strong thick-walled, screw-capped glass bottle (300 millilitre capacity). Only good quality will maintain a good seal after multiple sterilisations in an autoclave <i>Preservation:</i> 7. Samples for dissolved oxygen analysis are fixed by adding 1 ml of manganous sulphate solution, 1 ml of alkaline iodide-azide solution and 1 ml of concentrated sulphuric acid to the sample and mixing. Care should be taken to ensure that no air is added to the sample during this process. 8. Samples should be acidified with 2 ml of concentrated sulphuric acid 9. Samples should be acidified with 2 ml of concentrated nitric acid. *None: Ideally, all samples should be kept cool and in the dark after collection. If this is not possible, then at least samples for BOD, coliforms, chlorophyll, pesticides and other organics that are likely to volatilize MUST be kept at 4°C, and dark. Remaining samples can have no preservation.			

Groundwater monitoring for mapping aquifers in Belize as a tool for climate change adaptation planning

Groundwater monitoring system
manual - Community
representatives

Document information

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Document authorisation

Prepared Emily Strathdee	Approved Azucena Rodriguez Yebra	Authorised Nigel Walmsley
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1 Background

1.1 Project summary

The National Hydrological Service (NHS) of the Ministry of Natural Resources, Petroleum, and Mining and the National Climate Change Office of the Ministry of Sustainable Development, Climate Change, and Disaster Risk Management, are executing a project to design a groundwater monitoring system for the management of aquifers in Belize, focusing on the Coastal Plains groundwater province. Further information on the purpose of the groundwater monitoring system can be found in Appendix C.

1.2 About this manual

This document is a manual for community observers for the collection of groundwater level and water quality information as part of the groundwater monitoring system for the Coastal Plains groundwater province.

Community observers are persons who are tasked with collecting groundwater data from wells and boreholes and reporting this data back to the NHS.

2 Groundwater Monitoring for Community Observers

Community groundwater observers will be tasked to take measurements of groundwater level, temperature, conductivity and pH once a week and report this back to the NHS. NHS technicians will also visit the site and meet with the community observers on a quarterly basis to collect completed field reports, check and calibrate equipment, resolve any issues with data collection and inspect the condition of the well or borehole.

This manual covers the following activities:

- Preparing for a site visit;
- Collecting and recording data at the well or borehole;
- Reporting the data to the NHS for permanent storage.

2.1 Step 1: Preparing for a site visit

Before going to site it is important to prepare and make sure the person responsible is ready for fieldwork. This will ensure the success of the work and maximise their productivity at the site.

Collect and check equipment

- Wear protective clothing suitable for the site.
- Check groundwater dipper and handheld water quality probe to ensure they are working and calibrate probe if necessary. NHS technicians will be able to calibrate the water quality probe and check the condition of the dipper during their quarterly visits to the site.
- Pack spares (bottles, batteries, pens).

Review the well information sheet

Each well or borehole in the monitoring system will have had a well information sheet completed which summarises the important information about the well or borehole, such as its location, construction, owner, pumping equipment etc. This information sheet should have been completed by an NHS technician when the well or borehole was added into the monitoring system. Before travelling to the site review the well information sheet to allow a better

understanding of the work that will be undertaken. A blank copy is provided in Appendix A and an example is provided in Figure 2.1.



Groundwater Monitoring Well Information Sheet

Location/Ownership			
Well Name:	EMMEUNE STREET BOREHOLE		
Form completed by:	JO SMITH	Well/Borehole Reference:	NHS-101
Date of Assessment:	10/26/2023	Type of well (e.g., farm well, town water supply):	FARM WELL
Well address:	PANKHURST FARM, EMMEUNE STREET, DAVISON TOWN, BELIZE		Directions to Well: TURN LEFT AT END OF SYLVIA ROAD.
Co-ordinates	Northing	Westing	Sketch of location of well
	17°11'26.81"N	-88°21'34.77"W	
what3words			
Ownership details	Name:	ANN JOHN	
	Phone:	+501 12345678	
	Email:	-	
	Address:	AS ABOVE	
	Well use: (e.g., "used daily to supply farm")	FARM & SURROUNDING HOUSES	
	Purge volume (litres):	4900 L	
Well construction details:			
Depth	15m		
Diameter	80cm		
What is the water level and how is it measured (e.g. datum)?	WATER LEVEL IS 1.75m MEASURED FROM DATUM → TOP OF WELL CASING		
Pump installed/type/power?	NO PUMP		
Yield (e.g., "goes dry regularly")	WELL OWNER REPORTED IT HAS NOT DRIED OUT IN 30 YEARS	Is there a way of getting a WQ sample?	BAILER OR SAMPLE PUMP.
Can the well be dipped?	YES	Is the well easily accessible?	YES
Are there any Health and Safety Risks?	TREE ROOTS NEAR WELL ARE TRIP HAZARD	Well construction date:	~1991

Add photos below of the well/pump/location etc. overleaf

Figure 2.1: Example of Well Information Sheet for a fictional well

2.2 Step 2: Data collection from well or borehole

General good practices

When working on-site it is important to adhere to the following good working practices:

- Work safely and report risks, damaged equipment or other health and safety concerns to the NHS - Do not put yourself at undue risk when collecting data.
- Do not attempt to dip or take water samples from wells or boreholes containing submersible pumps unless there is a dip tube, as the dipper cable or bailer cable may become tangled with the pump and cabling.
- Poor data is worse than no data - check how data compares to previous data and whether it is within expected ranges.
- Record supplementary information on anything which may affect results, for example heavy rainfall.
- Reference and follow the National Hydrological Survey's Health and Safety protocol.

Recording of data

Data must be recorded in the Groundwater Monitoring Field Report shown in Appendix B. An example of a Groundwater Monitoring Field Report is provided in Figure 2.2.



Groundwater Monitoring Field Report
Community Representative

Groundwater Monitoring Field Report

Each time a groundwater monitoring well is visited a field report should be filled out.

General Information

Visited by:	JO SMITH		
Date of visit:	10/26/2023	Pump running:	Yes / <u>No</u>
Location:	EMMELINE STREET	Well identification no.:	NHS-101
Notes on condition of the well (e.g. choked with debris; damaged; flooded):	WELL IN GOOD CONDITION		
Notes on condition of equipment:	EQUIPMENT IS WORKING		
Any other comments (e.g. weather):	✓		

Water Level

Instrument used:	DIPPER NO. 04		
Water level from previous field visit:	1.29m		
Manual measurement of water level (from datum in meters):	Reading 1:	Reading 2:	Reading 3:
	1.14	1.25	1.15

Water Quality

Purge carried out?:	NOT POSSIBLE		
Method used:	Sample Pump	<u>Bailer</u>	Existing Pump
Instrument used (e.g. handheld meter no.):	HANDHELD METER NO. 05		
Depth of sample collection (from datum in m):	3.5m		
Parameter:	Reading 1:	Reading 2:	Reading 3:
pH:	7.1	7.1	7.2
Temperature (°F):	68.0	68.1	68.0
Conductivity (µS/cm):	1300	1150	1280
Any other comments:	✓		

1

Figure 2.2: Example of Community Representative Groundwater Monitoring Field Report for a fictional well

2.2.1 Collecting water level data

Water level needs to be monitored to observe changes due to droughts and abstraction. The static water level will be manually recorded weekly using a dipper by a community observer.

Quarterly, an NHS technician will verify manual sites by carrying out dipping at these wells or boreholes.

Well dipper

- Test the dipper prior to the field visit by unscrewing the weighted end of the probe to expose the inner electrode and complete the circuit by immersing the end in water.
- Discern if there is a pump in the borehole or well:
 - If there is no pump in the borehole or well, lower the probe down the borehole or well;
 - If there is a pump, determine if there is a dip tube installed to allow the well or borehole to be safely dipped. If there is no dip tube contact NHS to arrange for one to be installed;
 - If there is a dip tube installed determine if the pump is running or not. If the pump is running, turn off the pump:
 - It is important that the water levels have returned to their static level after the pump has been used. This can be done by testing the water level at 5 minute intervals until the change in depth is less than two inches per dip.
- Lower the dipper into the borehole, well or dip tube until the buzzer sounds. When lowering the dipper try to reduce wear by running the tape over softer materials such a piece of wood or your hand to prevent it rubbing on the top of the casing.
- When the buzzing happens, pull the tape back slowly out of the water until the buzzer stops. The point where the buzzer stops is the water level.
- Use your fingers to mark the position on the tape against a fixed reference point on the borehole casing. Always ensure to measure against the same reference point – this should be recorded on the Groundwater Monitoring Field Report.
- Read off the level to the nearest centimetre or inch (depending on the type of dipper).
- Record the dipped level and time of measurement.
- Repeat the process, as a check.

2.2.2 Water quality preparation: purging

Purging is the process of pumping water out of a well, allowing water from the aquifer into the well. Purging ensures that water quality samples are representative of the groundwater in the aquifer rather than well water which may be different. It is not always possible to purge a well or borehole, and samples can be taken without purging the well, although this should be noted in the Field Report. Please refer to the Well Information Sheet to find out whether the well should be purged or not and if so, the volume that should be purged prior to collection and sampling:

1. Where a borehole has an existing pump or sample pump it is advised that the well is purged. The volume that should be purged is recorded on the Well Information Sheet.
2. For boreholes with a low yield, it may not be possible to entirely purge the borehole before taking a sample, so take a note of the water volume removed before sampling so it can be considered when the results are analysed.
3. It may not be possible to purge the borehole or well at all, and in this case a bailer is usually used to collect the sample (please see Section 2.2.3).

2.2.3 Water quality preparation: collecting samples

Prior to taking groundwater quality samples the borehole or well should be prepared by purging, as outlined in Section 2.2.2 if practicable. Water samples can then be collected by either using a sample pump, a bailer or an existing pump, as described below.

Samples should be collected into a clean plastic or glass container and the readings taken using the handheld meter as soon as possible. The container should be rinsed out once with sample water to remove any potential contaminants prior to taking the readings.

Existing pumps

If a pump is present in the well then the sample can be collected from the pump outlet in a clean container after the pump has been run to purge the well. The handheld probe can then be used to take the readings of water quality.

Bailers

A bailer consists of a tube made of stainless steel or plastic that has a ball valve at the bottom and is weighted so it will sink. Bailers have different designs depending on the manufacturer, so follow any specific instructions for the make and model used.

Bailers are required where there is no pump in the well or borehole. It is not advisable to use a bailer where a pump is present in the well as it may become tangled in the pump cable:

- Check that the well or borehole is free from any obstruction and is open.
- Drop the bailer down the well on a string and allow it to fill up.
- Make a note of depth the sample has been collected from on the Field Report.
- Pull sample to the surface.

Sample pumps

Sample pumps are small, portable, generator powered and come attached to a hose so they can be lowered into the borehole to the required depth. It is important to make sure that the pump is sufficiently below the water level to avoid it becoming exposed when the water begins to draw down. Refer to the specific manufacturer's instructions and follow all safety rules.

2.2.4 Water quality (in field testing)

The field parameters to be recorded in the field are temperature, conductivity and pH. This will be recorded weekly by a community representative and the data will be collected using a handheld meter:

- Prior to taking groundwater quality measurements the sample must be collected as described in the section above.
- Use the handheld meter to collect the temperature, conductivity and pH reading from the sample container. Ensure that these are taken as soon as possible after collecting the sample as the temperature will be affected by the air temperature.
- Check the readings against the previous field report and note down any unexpected differences.
- Ensure that the units of measurement are correctly recorded.
- If data is suspect, note this on the Field Report and check the calibration of the instrument.
- Please refer to the manufacturer's instructions on calibration and use of the handheld meter.

2.3 Step 3: Data submission

Community observers must give their completed Groundwater Monitoring Field Reports to the NHS technician at their quarterly visit. Where the NHS requires data more frequently, the NHS may request field reports are posted to the NHS office.

3 References

Brassington, R. (1988) *Field Hydrology*. Chichester: John Wiley.

Fretwell, B., R. Short, J. Sutton (2006) Guidance on the design and installation of groundwater quality monitoring points. Science Report SC020093. Bristol: Environment Agency.

Groundwater Monitoring Guidance Manual (2001). Commonwealth of Pennsylvania, Department of Environmental Protection.

Appendices

A Groundwater Monitoring Well Information Sheet

Location/Ownership			
Well Name:			
Form completed by:		Well/Borehole Reference:	
Date of Assessment:		Type of well (e.g., farm well, town water supply):	
Well address:			Directions to Well:
Co-ordinates	Northing	Westing	Sketch of location of well
what3words			
Ownership details	Name:		Well use: (e.g., "used daily to supply farm")
	Phone:		
	Email:		
	Address:		
			Purge volume (litres):
Well construction details:			
Depth			
Diameter			
What is the water level and how is it measured (e.g. datum)?			
Pump installed/ type/power?			
Yield (e.g., "goes dry regularly")		Is there a way of getting a WQ sample?	
Can the well be dipped?		Is the well easily accessible?	

Are there any Health and Safety Risks?		Well construction date:	
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Add photos below of the well/pump/location etc.

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B Groundwater Monitoring Field Report

Each time a groundwater monitoring well is visited a field report should be filled out.

General Information

Visited by:			
Date of visit:		Pump running:	Yes / No
Location:		Well identification no.:	
Notes on condition of the well (e.g. choked with debris; damaged; flooded):			
Notes on condition of equipment:			
Any other comments (e.g. weather):			

Water Level

Instrument used:			
Water level from previous field visit:			
Manual measurement of water level (from datum in meters):	Reading 1:	Reading 2:	Reading 3:

Water Quality

Purge carried out?:			
Method used:	Sample Pump	Bailer	Existing Pump
Instrument used (e.g. handheld meter no.):			
Depth of sample collection (from datum in m):			
Parameter:	Reading 1:	Reading 2:	Reading 3:
pH:			
Temperature (°F):			
Conductivity ($\mu S/cm$):			
Any other comments:			

C Purpose of groundwater monitoring in the Coastal Plains groundwater province

Groundwater is a vital source of water supply in northern Belize for municipal, domestic, agricultural, and industrial purposes, sustaining health, livelihoods, and economic activities. However, the monitoring and management of groundwater is limited, and the resource is facing several challenges including:

1. Limited licensing and reporting of groundwater abstraction leading to uncertainty over the sustainability of groundwater exploitation with respect to aquifer health, environmental flows in rivers; and wetlands;
2. Agricultural development and the application of agrochemicals which have the potential to contaminate groundwater;
3. Climate change projections which indicate warmer and drier conditions in the future, reducing groundwater recharge and increasing the risk of groundwater depletion and saline intrusion, coupled with sea level rise.

These issues have been highlighted in recent drought events and the eutrophication of the New River in 2019. Groundwater and surface water resources are likely to be closely linked in some areas, and the transboundary nature of the aquifer systems extending into southern Mexico and Guatemala adds further dimensions of complexity to the system.

At present, there is no systematic monitoring of groundwater level and quality in Belize, and such a system is required to provide data for the effective and evidence-based management:

Drought

During droughts groundwater levels are expected to drop, and it is vital to understand how aquifers are responding to low rainfall. To investigate this, boreholes that are not affected by abstraction need to be monitored. This allows the impact of abstraction to be separated from the impact of drought. It is important to look at seasonal trends when assessing the impact of drought.

Water resource monitoring

If abstraction is greater than recharge, then groundwater levels will reduce over time. Water resource monitoring of boreholes allows us to assess changes in water level resulting from over-abstraction and help identify ecological sites, groundwater abstraction sites and rivers that may be impacted. Water resource monitoring boreholes need to be close to abstraction points.

Pollution

There are many types of pollutants which can be dangerous to human health that can be found in groundwater resources. For example, the presence of bacteria, such as E-Coli can indicate that water is not suitable for human consumption, or nutrients, such as nitrate or phosphate which can cause damage to surface waters. Additionally, dangerous chemicals, such as pesticides and organic compounds (e.g. oil-based products) or naturally occurring toxic elements (e.g. arsenic) can also be found in groundwater. We need to monitor for these to protect rivers, people, crops and wildlife.

Saline intrusion

Seawater can contaminate fresh water supplies. Although not necessarily toxic, saline water can affect the taste of water and at higher concentrations it is dangerous to people and wildlife. Salinity can increase over time due to sea-level rise, as a consequence of climate change, or from temporary effects such as hurricanes and over-abstraction from coastal boreholes.

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HR Wallingford
Howbery Park
Wallingford
Oxfordshire OX10 8BA
United Kingdom

+44 (0)1491 835381

info@hrwallingford.com

www.hrwallingford.com



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