

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

D 4.1-4.3 - Stakeholder Working Group  
meeting report (Contract No.  
UNEP/2022/319 (UMOJA #4700023827) RFP:  
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# 1 Introduction

## 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 in these areas.

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)<sup>1</sup> 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 (2017)<sup>2</sup> 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) is implementing a project to develop a Groundwater Monitoring System for the New River Watershed.

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<sup>1</sup> Belize's Nationally Determined Contribution, 2022  
<https://unfccc.int/sites/default/files/NDC/2022-06/Belize%20Updated%20NDC.pdf>

<sup>2</sup> Technology Needs Assessment for Adaptation, 2017  
[https://unfccc.int/ttclear/misc\\_/StaticFiles/gnwoerk\\_static/TNA\\_key\\_doc/3db7d7bbba4c4deebecbc11fd24fb67d/5331353e87a0488e861d1fe6aca1b747.pdf](https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNA_key_doc/3db7d7bbba4c4deebecbc11fd24fb67d/5331353e87a0488e861d1fe6aca1b747.pdf)

## 1.2 About this report

The purpose of this report is to detail the discussions held at the Groundwater Monitoring System Consultation workshop held on March 29<sup>th</sup>, 2023. This report presents a summary of the presentations made to the Stakeholder Working Group (SWG), and details feedback from the SWG on the initial design of the monitoring system. The feedback received provides inputs to advancing Output 4 of the Project- Design a fully integrated groundwater monitoring system that will enable Belize to manage groundwater resources in the New River watershed. Additionally, the report includes a detailed record of the consultation proceedings, including the participants present.

# 2 Stakeholder Working Group- Workshop

## 2.1 Objectives

The workshop set out to:

1. Provide an opportunity for organisation of the SWG to contribute to the design of a groundwater monitoring system for the New River watershed in northern Belize by facilitating discussions on the proposed monitoring system objectives and design options.
2. Provide an update on progress to date of the development of the groundwater monitoring system.

## 2.2 Workshop Structure

The consultation was held over a one-day period and utilised a mix of presentations and breakout group focused discussion to gather input from the SWG. The discussion set out to respond to five key input areas including: the Scope and focus of the monitoring programme; areas to be monitored; intensity of groundwater monitoring; monitoring methods and; data storage and sharing. The workshop agenda is included as **Appendix A Workshop Agenda**.

## 2.3 Participation

SWG members from 8 of the 10 SWG agencies attended the Inception Meeting. Additionally, there was representation from the Sustainable Development Unit. Agencies Present were:

1. Belize Water Services Limited (BWSL);
2. Department of the Environment (DOE);
3. Department of Rural Transformation (DRT);
4. MAMA's Women's Group (MWG);
5. Ministry of Agriculture, Food Security and Enterprise (MAFSE);
6. Ministry of Economic Development (MED);
7. National Climate Change Office (NCCO);
8. National Hydrological Service (NHS) (*Chair*); and,
9. *Sustainable Development Unit (SDU) (Invited Guest)*.

40% of participants at the workshop were female; and 60% were male.

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

## 2.4 Discussion on initial design of groundwater monitoring system

Two working groups were developed to provide feedback on the design areas for the New River ground water monitoring system. Both groups had representation from the varying SWG organisations who were present at the workshop. Generally, there was convergence in the feedback coming from both groups, the results of which are presented below. Intensity of monitoring was the sole area where there were divergent views. One group demonstrated a preference for monitoring at as- short- as- possible intervals. The other group preferred that intensity is informed by the NHS based on the scope and parameters selected.

Table 2.1 summarises inputs from the SWG on the (5) five design areas.

Table 2.1: SWG feedback on initial design of groundwater monitoring system

No.	Design Area	System Design Inputs
1	<b>Scope and focus of the monitoring programme</b> <ul style="list-style-type: none"> <li>What are the priority variables? (Groundwater level / quality? / Which variables?)</li> </ul>	<ul style="list-style-type: none"> <li>Water levels and water quality should be monitored. Though levels would be easier to monitor, quality is important for many departments.</li> <li>Bacteriology testing should also be incorporated (DoE and Department of Rural Transformation has noted bacteriological issues in the area).</li> <li>Parameters should be in line with those set by Water Quality Programme run by DOE. This programme is supported by a tripartite taskforce (DOE, NHS, Ministry of Health and Wellness (MOHW)).</li> <li>DOE's newly established Protocol for water quality monitoring should be taken into consideration.</li> </ul>
2	<b>Areas to be monitored</b> <ul style="list-style-type: none"> <li>Where are the priority locations within study area? (Coastal / population centres / agricultural / natural)</li> </ul>	<ul style="list-style-type: none"> <li>Coastal Plains; Population centres; areas of high agricultural use.</li> <li>Coastal plains are an important area to monitor salt water intrusion. Rockstone Pond and Consejo are possible areas for monitoring.</li> <li>The changing use of agricultural lands in northern Belize, from sugar care to the water intensive coconut, will necessitate focus on agricultural areas.</li> <li>While transboundary monitoring may be difficult, data sharing agreements can exist to conduct various levels of analysis.</li> <li>An overlay of the presented map by HR Wallingford at the consultation, and the NHS map for planned installation of hydrological stations can provide a clearer picture of the priority areas to be monitored.</li> <li>The sites for installation of four (4) new stations under the National Adaptation Planning (NAP) for Integrated Water Resources Management in Belize project should be considered as areas to be monitored under the ground water monitoring system. These sites were selected based on the combination of target areas for monitoring and the presence of suitable existing wells for monitoring.</li> <li>The four sites are: San Antonio, San Roman, Santa Cruz, Albion Island.</li> <li>Louisiana and Santa Rita Wells can be used for quantity testing, but not quality testing as these well were condemned by the BWSL based on high nitrate levels.</li> </ul>
3	<b>Intensity of groundwater monitoring</b> <ul style="list-style-type: none"> <li>How often should we be monitoring each variable? (Daily / monthly / annually?)</li> </ul>	<ul style="list-style-type: none"> <li>Due to low availability of data, the interval with which data collection occurs should be as short as possible (minutes, seconds) for a at least two years until consistent trends and patterns of natural variability are established.</li> <li>A set frequency was not established but intensity should be based on the variables and parameters set by the NHS (most appropriate defining authority) in terms of what makes sense.</li> <li>Establishing trend levels over time is important especially where rural water systems (RWS) dry up during the dry season.</li> </ul>

No.	Design Area	System Design Inputs
4	<b>Monitoring methods</b> <ul style="list-style-type: none"> <li>● What approaches are most appropriate?</li> <li>● Manual community led water levels vs data loggers (level / multi parameter) / Telemetry</li> <li>● Water quality sample collection and processing</li> </ul>	<ul style="list-style-type: none"> <li>● A hybrid approach should be used (the issue of logger security, vandalism and theft is an identified issue for automated stations). While barbed wire fences and other measures may not bar tampering, it will deter humans.</li> <li>● The NHS currently has automated systems for ground water.</li> <li>● Campbell Scientific is the preferred brand of equipment based on proven longevity and robustness.</li> <li>● Strategic locations should be automated.</li> <li>● Fully automated systems require a GSM signal.</li> <li>● Logged data requires an individual to retrieve data.</li> <li>● Manual e-tape requires a person in the vicinity to collect data.</li> <li>● A lesson learnt form the manual surface water monitoring systems is that community buy-in is important. Community members who monitor the systems are proved with a monthly ninety Belize dollar (\$90BZD) stipend and, bushing fee (\$20BZD).</li> <li>● It is difficult for a system to be fully automated because the system requires maintenance, manual validation, and maintenance.</li> </ul>
5	<b>Data storage and sharing</b> <ul style="list-style-type: none"> <li>● How should the data be licenced and shared? (Free online / by request / cost recovery) (Creative commons license)</li> <li>● What information products are most useful (Data on request? Annual review? Quarterly bulletin?)</li> </ul>	<ul style="list-style-type: none"> <li>● Data should be housed at NHS and not the Central Information Technology Office (CITO).</li> <li>● Processed data to be shared in the form of maps for well drillers to indicate ground water levels in an area, to pinpoint best location for drilling.</li> <li>● The Water Information Systems (WISKI) platform by KISTERS which is currently being used by the DoE and NHS may be a good platform for the monitoring system. This provides a dashboard system that other agencies can utilise to access data.</li> <li>● There should be an annual publication of a newsletter to share information on what data is collected (states levels of water that can be abstracted sustainably).</li> <li>● The University of Belize has comprehensive water quality data (contacts are: Mr. Valladares and Mr. Ake).</li> <li>● The MOHW has data on water quality from wells and lines (contact is: Ari Sosa).</li> <li>● BWS also has data on levels and quality.</li> </ul>

## 2.5 Workshop record

**Date of meeting:** 29/03/23      **Time of meeting:** 9:35am-3:00pm      **Place of meeting:** Belize Biltmore Plaza      **Recorded by:** Tanya Barona & Elishah St. Luce

	NAME	INITIALS	ORGANISATION
<b>ATENDEEES</b>	Ramiro Salinas	RSA	Climate Technology Centre & Network ( <i>Virtual</i> )
	Tennielle Hendy (Chair)	THE	National Hydrological Services, MNRPM (NHS)
	Rhona Lopez	RLO	National Hydrological Services, MNRPM (NHS)
	Ellington Cayetano	ECA	National Hydrological Services, MNRPM (NHS)
	Isani Williams	IWI	National Hydrological Services, MNRPM (NHS)
	Gina Young	GYO	National Climate Change Office, MSDCCDRM) (NCCO)
	Miguel Balan	MBA	Ministry of Agriculture, Food Security and Enterprise (MAFSE)
	Marvin Blades	MBL	Ministry of Agriculture, Food Security and Enterprise (MAFSE)
	Hugo Rancharan	HRA	Belize Water Services Limited (BWSL)
	Beverly Mohammedali	BMO	Belize Water Services Limited (BWSL)
	Kurt Gideon	KGI	Ministry of Rural Transformation (MRT)
	Ismer Ortega	IOR	Ministry of Rural Transformation (MRT)
	Maria Elena Meza	MME	MAMAS Women's Group
	Leroy Martinez	LMA	Ministry of Economic Development (MED)
	Darlene Haylock	DHA	Minister of Sustainable Development, Climate Change & Disaster Risk Management (MSDCCDRM)
	Edgar Eck	EEK	Department of Environment, MSDCCDRM (DOE)
	George Woolhouse	SWO	HR Wallingford
	Azucena Rodriguez Yebra	AYE	HR Wallingford
	Lucien Chung	LCH	HR Wallingford- Consultant
	Elishah St. Luce	ESL	HR Wallingford-Consultant
Tanya Barona	TBA	Consultant	
<b>ABSENT</b>	Minerva Gonzales	MGO	Forest Department

Jorge Nabet	JNA	Forest Department
Adrian Zetina	AZE	Belize Sugar Industry- ASR Group

## MINUTES

Agenda Item 1: Welcome remarks from the National Hydrological Service and the purpose of the workshop	
<b>Info</b>	<p><b>THE:</b> welcomed participants to the Stakeholder Working Group (SWG) Workshop. She noted that branching into groundwater monitoring is new for the NHS and Belize as the focus has always been surface water. The creation of a stakeholder network is useful to developing a monitoring system. Participants were urged to be as open as possible and reminded that all comments are welcomed. The setting called for open discussion.</p>
<b>Discussion</b>	None
<b>Action Items</b>	None
Agenda Item 2: United Nations (UN) Climate Technology Centre and Network (CTCN) introduction	
<b>Info</b>	<p><b>RSA:</b> highlighted that CTCN was establishment in 2013, and functioned as technical mechanism for the United Nations Framework Convention on Climate Change. CTCN was hosted by the United Nations Environmental Programme (UNEP). Past collaboration with the United Nations Industrial Development Organisation (UNIDO) hosted the management unit. CTCN has been supporting countries with financing and technical support for low carbon and climate resilient pathways.</p> <p>CTCN thanks the National Hydrology Service (NHS) and the National Climate Change Office (NCCO) as well as HR Wallingford for undertaking this work in Belize.</p> <p><b>RSA:</b> Thanks the SWG for being present and welcomed active participation.</p>
<b>Discussion</b>	None
<b>Action Items</b>	None
Agenda Item 3: Context of Current Workshop	
<b>Info</b>	<p><b>AYE</b> provided a recap to participants that highlighted the status of the project.</p> <p>Project Objectives:</p> <ul style="list-style-type: none"> <li>● The overall purpose is to design a groundwater monitoring system useful for the National Hydrological Service and government agencies in Belize to identify water supply risks for diverse groundwater users.</li> </ul> <p>The main outputs:</p> <ol style="list-style-type: none"> <li>1. A communications plan and detailed work plan;</li> <li>2. Map stakeholders and establish a stakeholder working group;</li> <li>3. An assessment of groundwater availability and demand;</li> <li>4. <b>Design of an integrated monitoring system that will enable Belize to manage groundwater resources in the priority area;</b></li> <li>5. Establish enabling factors for implementation, including financial, institutional setting and capacity building.</li> </ol> <p><b>Output 4:</b> design of an integrated monitoring system that will enable Belize to manage ground water resources in the priority area:</p> <ul style="list-style-type: none"> <li>● Defining area to be monitored, information needs and monitoring objectives;</li> <li>● Benchmarking and selecting groundwater monitoring technologies;</li> </ul>

	<ul style="list-style-type: none"> <li>● <b>Meeting with the SWG to discuss the system;</b></li> <li>● Design a groundwater monitoring system.</li> </ul> <p>Presentation of the system and the implementation plan.</p>
<b>Discussion</b>	None
<b>Action Items</b>	None
<b>Agenda Item 3: Status and trends in groundwater resources of Belize Assessment of water resources in the New River</b>	
<b>Notes</b>	<p><b>GWO:</b> presented to participant.</p> <p>Topic 1: Status and trends in groundwater resources of Belize</p> <p>A summary of the main findings and information gaps from the study carried out as a part of output 3.</p> <ul style="list-style-type: none"> <li>● Water demand (data sources):           <ul style="list-style-type: none"> <li>● municipal 3.5 billion gals (data confidence – high)</li> <li>● domestic 2.5 billion gals (data confidence – moderate)</li> <li>● agricultural 18.5 billion gals (data confidence – low)</li> <li>● industrial 5.5 billion gals (data confidence – low).</li> </ul> </li> </ul> <p>Low confidence figures are sourced from the FAO aqua stats system, which is very old and the breakdown between surface and groundwater demands are based on simple assumptions of the relative areas under irrigation. Figures are difficult to get a hold of. Data from the NHS on industrial consumption was considered, but thought to be underrepresented, highlighting the need for improved data collection on agricultural and industrial water consumption through improved licencing and reporting of industrial water sources.</p> <ul style="list-style-type: none"> <li>● Population growth and water demand           <ul style="list-style-type: none"> <li>● Forecasted 36% population increase from 2020 to 2060</li> <li>● Municipal demand increase from 22.5 - 31 million cubic meter per year in the same time frame</li> </ul> <p>Assumption: per capita demands remain the same over time</p> </li> <li>● Agricultural trends           <ul style="list-style-type: none"> <li>● Increase in the agricultural land over the past 20 years</li> <li>● Simultaneous increase in fertilizer application</li> </ul> <p>Nitrogen loading to the soil is concerning. It's passage through groundwater systems and associated rivers can take years, decades, or millennia to flush through the hydrological system. Even though figures are lacking, there is an indication of intensified agriculture.</p> </li> <li>● Climate change projections           <ul style="list-style-type: none"> <li>● Drier and warmer conditions</li> <li>● High emission scenario shows a drop to less than 80% rainfall at the end of the century</li> <li>● Crop water demand increase</li> </ul> <p>A reduction in rainfall will have implications on ground water recharge. A 10% reduction in rainfall causes a 20% reduction in recharge, depending on how the system responds.</p> </li> </ul> <p>Groundwater is widely used in the following provinces.</p> <ul style="list-style-type: none"> <li>● <b>Coastal Plains</b> (the focus of study)</li> <li>● Campur</li> <li>● Savannah</li> <li>● Toledo provinces</li> </ul>

	<p><b>AYE:</b> presented to participant.</p> <p><i>Topic: Assessment of water resources in the New River</i></p> <ol style="list-style-type: none"> <li>1. Water Resources of the New River           <ul style="list-style-type: none"> <li>● ground water exploitation from:</li> <li>● BWSL, industrial, rural and agricultural via ground water well, private wells, rudimentary water systems, and annual licensed ground water abstraction</li> </ul> </li> <li>2. Assessment of key risks to water resources and hotspot locations           <ul style="list-style-type: none"> <li>● Previously identified at the inception workshop</li> </ul> </li> <li>3. Water Balance Equation <math>P+L=ET+SR+I</math> <ul style="list-style-type: none"> <li>● P- precipitation</li> <li>● L- moisture loss from the soil</li> <li>● ET- Evapotranspiration</li> <li>● SR- surface runoff</li> <li>● I- infiltration to the soil water and ground water</li> </ul> </li> </ol>
<p><b>Discussion</b></p>	<p><i>Topic 1: Status and trends in groundwater resources of Belize</i></p> <p><b>HRA:</b> asked for clarification on the different industries and pointed out that the sum of the values indicate an alarming volume of water that keeps increasing, based on projections.</p> <p><b>GWO:</b> stated that the data on industrial consumption was disaggregated and is uncertain on whether it includes non-consumptive or consumptive industries.</p> <p><b>LCH:</b> reiterated that the data is for industry and noted that he does not think it includes data from Belize Water Service Limited (BWSL). When looking at the make-up of total water usage, the figures somewhat follow global trends, with agriculture being the highest water user, close to 70%, industrial and municipal at 20% and domestic at 10%.</p> <p><b>GYO:</b> asked if the FAO is used as the information source and queried if land mass was used, granted that water usage figures were not precise. Higher accuracy figures can be derived from national data. Given that the presented figures are based on a combination to tier 1 and tier 2 data, national data collected by the National Climate Change Office can be used as tier 1, and global data as tier 2. Additionally, the <b>national climate change policy and strategy master plan</b> was updated and included modelling. The document's projections are more accurate for Belize when compared to that of the World Bank.</p> <p><b>GWO:</b> clarified that inferences were made for land mass, however noted that it does not produce information on changes in crop choice whether water intensive or less water intensive, which is a crucial factor.</p> <p><b>TEN:</b> agrees that the World Bank projections are larger and noted that for domestic data, 195 wells from the Department of Rural Transformation were not covered. Those wells are a combination of domestic, industry, private sector and some eco lodges. Some data for industries is available but inconsistent due to information being voluntarily contributed. When mandated through enforcement and permitting, data will become more consistent and comprehensive to produce a better view of industrial abstraction.</p> <p><i>Caveat: the accuracy of reported abstraction is uncertain because the required bulkhead meters are seldom used. There is pushback from private companies due to high costs that cannot be transferred to customers. The ideal template includes the pump capacity, pump duration, pump frequency (running at full power or half power etc).</i></p> <p>Pump logs are available in the absence of bulkhead data, however complete profiles come at a cost, payable to the Geology Department. The reliability of the data is questionable as some well drillers don't know how to properly record information, while others are not able to conduct proper pump testing (only done for 3 hrs instead of 72hrs).</p>

	<p>From the presentation, the transboundary aspect is underrepresented in water availability. Belize shares an aquifer with Mexico up to Merida. Many challenges are faced in the north with high intensity agricultural areas and Mennonite communities near the border. Validation of flow indicates a south and south-eastern flow toward the Caribbean Sea. While the aquifer may be large it acts as a sponge. Contamination goes both ways and excessive abstraction in Mexico can result in saltwater intrusion on the Belize end, which even with mitigative measures is hard to control.</p> <p><b>GWO:</b> noted that the sum total abstraction from the New River data was 0.5 million cubic meters per year and highlights the importance of implementing regional scale ground water monitoring to quantify water movement and explore different scenarios of potential outcomes of reduced recharge on the Mexican side and impacts to flow.</p> <p><b>EEK:</b> supported what was said previously as it relates to data needs and shared that he recently attended a conference by the Yucatan Peninsula Water Council. Understanding the geology of karst regions for Belize and the peninsula has a huge influence on water resources when looking at underground rivers and caves. Studies of that area shows a line of salt water inside the peninsula, which has influenced the results of water quality monitoring programs in Belize. Therefore, transboundary issues relating to Belize needs to be identified.</p> <p>Proactive action is recommended as the status quo has remained unchanged for 25 years, with the same issues still being discussed. Continued collaboration with key agencies (hydrology and geology services) needs to continue. Additionally, the DoE is targeting industries and developments that release effluent and recommends obtaining a licence and maintaining certain standards before releasing into waterways. Other areas look at the reuse of water and determining point source pollution through refined studies.</p> <p>Additionally, the rate and structure with which development is occurring has to be accounted for as this will impact the discussion occurring in this forum.</p> <p>Point sources of pollution is easier to monitor so there is a focus on that area, however, there is needs to identify non- point sources.</p> <p><b>LCH:</b> asked EEK to share a copy of the presentation from the Yucatan Peninsula Water Council.</p> <p><i>Topic 2: Assessment of water resources in the New River</i></p> <p><b>TEN:</b> asked about water balance in terms of a scenario where input values are unknown, (what is used for calculation). The purpose of the question was for the clarification of terminology to other participants. Identification of missing parameters is important to allow for justification as to why certain directions are taken. Consultancy documents are peer reviewed and validated, which leverages needs, for example, capacitating the Meteorological Service with equipment.</p> <p><b>AYE:</b> responded that calculations from past papers written on similar types of aquifers provides values for calculations.</p> <p><b>GWO:</b> added that by looking at river flow statistics 530 million cubic meters per year was estimated at Tower Hill, which accounts for 25% of rainfall in the catchment upstream. This is taken as a ballpark figure of the proportion that make it to the New River.</p> <p><b>LCH:</b> further simplifies the equation by stating that the exercise is done to determine how much water actually ends up in the aquifer and how much water is available for abstraction. Essentially, the volume not undergoing evapotranspiration, assumingly ends up in the aquifer.</p>
<p><b>Action Items</b></p>	<ol style="list-style-type: none"> <li>1. Request presentation from Yucatan Peninsula Water Council and share with LCH, (Person responsible, EEK).</li> <li>2. Review data from the national climate change policy and strategy master plan for CC modelling data (Person responsible, GWO).</li> </ol>

Agenda Item 4: Update on progress to date: Groundwater monitoring system initial design options	
<b>Notes</b>	<p>AYE: presented to participant.</p> <p>Topic1: Groundwater monitoring framework</p> <p><b>Ground Water Quantity</b></p> <p>Monitoring systems:</p> <ul style="list-style-type: none"> <li>● No systematic monitoring of groundwater globally;</li> <li>● Best indicator of the condition of the resource;</li> <li>● Impact of climate change;</li> <li>● Long term trends of over exploitation;</li> <li>● Sustainable management of groundwater resources;</li> <li>● Long-term data collection - groundwater models and forecast trends.</li> </ul> <p>Monitoring objectives:</p> <ul style="list-style-type: none"> <li>● To investigate the impact of local drawdowns on groundwater levels;</li> <li>● To investigate the impact of climate change (droughts/ changes in precipitation) on groundwater resources;</li> <li>● Monitor levels along the river to investigate the interaction between a river and aquifer;</li> <li>● To characterise the deep groundwater system and investigate the impact of climate change on deeper groundwater resources.</li> </ul> <p>Information requirements:</p> <ul style="list-style-type: none"> <li>● Who wants to be informed;</li> <li>● What types of information;</li> <li>● For what purpose;</li> <li>● How accurate;</li> <li>● How frequent;</li> <li>● In what form.</li> </ul> <p><b>Ground Water Quality</b></p> <p>Monitoring systems:</p> <ul style="list-style-type: none"> <li>● Groundwater directly extracted and used untreated as drinking water for rural populations;</li> <li>● Contamination with faecal bacteria, agrochemicals, industrial waste disposal, and environmental contaminants; naturally occurring chemicals;</li> <li>● To assess threats and provide an early warning system;</li> <li>● Impact of climate change and human activities on groundwater quality;</li> <li>● Saline intrusion.</li> </ul> <p>Monitoring objectives</p> <ul style="list-style-type: none"> <li>● To observe seasonal and long-term trends on in situ and ex situ parameters;</li> <li>● To observe the long-term trend of pesticides;</li> <li>● To investigate the impact of tidal influences on water quality, including rising sea level.</li> </ul> <p>Information requirements</p> <ul style="list-style-type: none"> <li>● Reference monitoring;</li> <li>● Protection monitoring;</li> <li>● Pollution containment;</li> <li>● Determination of fresh-saline interface;</li> </ul>

	<ul style="list-style-type: none"> <li>● Determination of natural parameters.</li> </ul> <p>Case Study</p> <p>Groundwater monitoring progress around the world shows 33 countries producing written reports and 41 countries producing maps.</p> <p><b>GWO:</b> presented to participant.</p> <p>Topic 2: Groundwater monitoring system preliminary design</p> <p>Preliminary system design includes:</p> <ul style="list-style-type: none"> <li>● Area to be monitored;</li> <li>● Objectives of monitoring and variables to be monitored;</li> <li>● Monitoring locations;</li> <li>● Monitoring methodology: existing / new wells. Manual vs automated approaches;</li> <li>● Data collection and dissemination systems;</li> <li>● Cost considerations.</li> </ul> <p>Potential approach using a combination of methods</p> <ul style="list-style-type: none"> <li>● Automated monitoring sites ~5 high priority monitoring locations;</li> <li>● Manual monitoring sites ~20 medium priority locations.</li> </ul> <p>It is essential that the system will produce useful data for water and land management to ensure the sustainable utilisation and protection of Belize’s water resources.</p>
<p><b>Discussion</b></p>	<p><i>Topic 1: Groundwater monitoring framework</i></p> <p><b>LMA:</b> asked if any considerations were given to the financial aspect of monitoring that will require personnel, equipment lab analysis etc.</p> <p><b>GWO:</b> stated at the current stage of the project the team is determining the cost budling blocks for the systems to develop a cost model for each approach including monitoring water level, manual costs models, telemetry cost models and the different variables, to be able to present cost option. This will be complied in the next steps after the workshop.</p> <p><i>Topic 2: Groundwater monitoring system preliminary design</i></p> <p><b>???:</b> asked where the repository will be housed.</p> <p><b>GWO:</b> responded by saying the National Hydrological Service has the Water Information Systems by (WISKI) management software on the servers.</p> <p><b>GYO:</b> asked what did the site selection process incorporate, and if the presented map represented the selected 25 locations was divided into high and medium priority sites. Additionally, are the presented points related to the NHS proposed network for installing hydrological stations for surface water?</p> <p><b>GWO:</b> Noted that sites were not assigned a priority level and added that pre-existing well locations were used. The approach considered areas where monitoring was found to me most useful and then filtered to determine where monitoring was possible. Furthermore, the map presented may need to incorporate the 4 locations under the GCF project.</p> <p><b>AYE:</b> responded that the proposed well locations are not related to the proposed surface water stations network.</p>

	<p><b>LCH:</b> added that the existing wells selected must be good wells. This means that they are operational but not in use. Things to consider includes how well the well is developed, does it reflect the water movement, etc. There are limiting factors as to what wells can be utilized.</p> <p><b>TEN:</b> shared that well drilling is a costly venture. Groundwater monitoring prefers deep boreholes to capture as much of a system’s variability. To drill an 800 ft well is not realistic with minimal funding, therefore, while not the preferred option, geo-resistivity is considered to provide further insight. Infrastructure in the form of hand pumps (2), that remain unused for over 10 years, from the Ministry of Rural Transformation is available. A caveat that explains the rationale for not adhering to required standards needs to accompany outputs.</p> <p>The Caribbean International Brewery has the deepest artesian well at 750 ft, while another privately owned deep well is in Consejo.</p> <p><b>IOR:</b> informed that the Ministry of Rural Transformation has two drill rigs, each with different capacities (140ft &amp; 500ft).</p> <p><b>HRA:</b> indicated that BWSL wells exist in Santa Rita and Louisiana that are not being used due to high nitrate levels. Also, feasibility studies have been conducted to connect Consejo and the free zone. In addition to these studies, a well may potentially be established in the Chan Chen village to reduce pumping costs.</p>
<b>Action Items</b>	None
<b>Agenda Item 5: Breakout Groups: Discussion on initial design of groundwater monitoring systems</b>	
<b>Notes</b>	<p><b>GWO:</b> divided the participants into two groups.</p> <p><b>Group 1-LCH</b></p> <ul style="list-style-type: none"> <li>● Hugo Rancharan</li> <li>● Leroy Martinez</li> <li>● Miguel Balan</li> <li>● Ellington Cayetano</li> <li>● Kurt Gideon</li> <li>● Maria Elena</li> <li>● Edgar Eck.</li> </ul> <p><b>Group 2- ESL</b></p> <ul style="list-style-type: none"> <li>● Beverly Mohammedali</li> <li>● Darlene Haylock</li> <li>● Marvin Blades</li> <li>● Isani Williams</li> <li>● Ismer Ortega</li> <li>● Gina Young.</li> </ul> <p>Questions for discussion</p> <ol style="list-style-type: none"> <li>1. Scope and focus of the monitoring programme</li> <li>2. Areas to be monitored</li> <li>3. Intensity of groundwater monitoring</li> <li>4. Monitoring methods</li> <li>5. Data storage and sharing.</li> </ol>
<b>Discussion</b>	Discussion occurred among member of each of the two groups.
<b>Action Items</b>	None
<b>Agenda Item 6: Breakout groups: Wrap up.</b>	

<p><b>Notes</b></p>	<p><b>LCH:</b> Presented a summary of group 1’s responses</p> <ol style="list-style-type: none"> <li>1. Scope and focus of the monitoring programme           <ul style="list-style-type: none"> <li>● Monitoring of water levels and water quality</li> <li>● Bacteriology testing should also be incorporated (DoE and Rural transformation has noted bacteriological issues plaguing the area)</li> </ul> </li> <li>2. Areas to be monitored           <ul style="list-style-type: none"> <li>● All three (Coastal / population centres / agricultural / natural)</li> <li>● While transboundary monitoring may be difficult, data sharing agreements can exist to conduct various levels of analysis</li> </ul> </li> <li>3. Intensity of groundwater monitoring           <ul style="list-style-type: none"> <li>● Due to low availability of data, the interval with which data collection occurs should be as short as possible (minutes, seconds) for a at least two years until consistent trends are establish.</li> </ul> </li> <li>4. Monitoring methods           <ul style="list-style-type: none"> <li>● A hybrid approach (the issue of logger security, vandalism and theft was discussed. While a fence barbed wire and other measures may not bar tampering, it will deter humans)</li> <li>● Campbell Scientific is the prefer brand in terms of longevity and robustness</li> <li>● Fully automated systems require a gsm signal.</li> <li>● Logged data requires an individual to retrieve data</li> <li>● Manual e-tape requires a person in the vicinity to collect data</li> </ul> </li> <li>5. Data storage and sharing           <ul style="list-style-type: none"> <li>● Data to be house at NHS (not CITO, echoed by multiple group members)</li> <li>● Processed data to be shared in the form of maps for well drillers to indicate ground water levels in an area, to pinpoint best location for drilling</li> <li>● Annual publication of a newsletter, to share information on what data is collected (states levels of water that can be abstracted sustainably)</li> </ul> </li> </ol> <p>Funding options were all centred around external funding, which is not sustainable and would require some internal source. The challenge with internal fund generation is seen in difficulties by consumers to meet bill payments which are already low. A violation of human right will not promote cancelling access to water, however examples of flow limiting mechanisms are utilized in other countries.</p> <p><b>ESL:</b> Presented a summary of group 2’s responses</p> <ol style="list-style-type: none"> <li>1. Scope and focus of the monitoring programme           <ul style="list-style-type: none"> <li>● Monitoring of levels and quality was the general consensus</li> <li>● Well production</li> <li>● Parameters should be in line with those set by Water Quality Programme run by DOE. This programme is supported by a tripartite taskforce (DOE, NHS, Ministry of Health and Wellness (MOHW)).</li> <li>● DOE’s newly established Protocol for water quality monitoring should be taken into consideration.</li> </ul> </li> <li>2. Areas to be monitored           <ul style="list-style-type: none"> <li>● An overlay of the presented map and the hydrology service’s hydrological station map of what currently exists can provide a clear picture of what area should be monitored.</li> <li>● Four new stations under the GCF National Adaptation Planning (NAP) for Integrated Water Resources Management in Belize. project</li> <li>● Monitor parameters to be characterized can piggy back on areas to be monitored.</li> </ul> </li> </ol>
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	<ul style="list-style-type: none"> <li>● Changes in crop type in the north will mean agricultural area should be prioritised for quality and quantity monitoring.</li> </ul> <p>3. Intensity of groundwater monitoring</p> <ul style="list-style-type: none"> <li>● A set frequency was not established but intensity should be based on the variables and parameters set by the NHS (most appropriate defining authority) in terms of what makes sense.</li> <li>● Establishing trend levels over time is important especially where rural water systems dry up during the dry season</li> </ul> <p>4. Monitoring methods</p> <ul style="list-style-type: none"> <li>● NHS currently has automated systems for ground water.</li> <li>● Strategic locations should be automated</li> <li>● A lesson learnt form surface water monitoring systems is community buy in through a \$90 stipend and bushing fee.</li> <li>● It is difficult for a system to be fully automated because the system requires maintenance, manual validation, and maintenance.</li> </ul> <p>5. Data storage and sharing</p> <ul style="list-style-type: none"> <li>● The WISKI platform by KISTERS is currently being used by the DoE and NHS. This provides a dashboard system that other agencies can utilise</li> </ul>
<p><b>Discussion</b></p>	<p><b>LHS:</b> Shared that SIRD I has an irrigation master plan that involves using water from the New River to funnel through canal systems to irrigate farms. This is not recommended as the river is still on life support from 2019.</p> <p><b>TEN:</b> Informed that a publication existed in the past (The Water Resources report). The NHS currently has a draft for publication but requires review and is not exactly up to standard where they would like it to be).</p> <p>Additionally, the SIRD I masterplan needs to be revisited based on the need for an aquifer investigation.</p> <p>Shared that funds are generated through collection of annual fees from well abstraction licences.</p> <p><b>EST:</b> Shared that changing crop type, from sugar cane to coconuts, in the north is something to monitor. There is approximately 5000 acres of coconut cultivated land. This is a marked increase from the previous 150 acres in the past. This leads to a shift in nitrate levels. While the frequency application of fertilizer may be less than sugar the quantity can potentially be the same. Furthermore, pesticides is concerning with the new crop type.</p>
<p><b>Action Items</b></p>	<p>None</p>
<p><b>Agenda Item 7: Next steps for the project</b></p>	
<p><b>Notes</b></p>	<p><b>AYE:</b> presented to participant.</p> <p>The next steps include</p> <p>Finishing the design of the ground water monitoring system</p> <ul style="list-style-type: none"> <li>● Monitoring stations (amount and location)</li> <li>● Parameters to be monitored (including data format)</li> <li>● Monitoring frequency</li> <li>● Technologies for each monitoring objective</li> <li>● Access to data</li> <li>● Data analysis and treatment</li> <li>● Evaluation procedures</li> <li>● Reporting procedures</li> </ul>

	<ul style="list-style-type: none"> <li>● Communication channels</li> <li>● Implementation plan</li> </ul> <p><b>Output 5: Financing, institutional settings and capacity building</b></p> <ul style="list-style-type: none"> <li>● Required budgets for monitoring objectives</li> <li>● Finance strategy</li> <li>● Institutional assessment</li> <li>● Feasibility analysis</li> <li>● Briefing relevant entities</li> </ul> <p>Gender Analysis Process (to ensure outputs are gender inclusive)</p> <ul style="list-style-type: none"> <li>● Outputs must be gender-responsive</li> <li>● Gender perspective incorporated into the development of the groundwater monitoring system</li> <li>● Differential risks between men and women</li> <li>● Potential gender participation gaps</li> </ul>
<b>Discussion</b>	None
<b>Action Items</b>	Share Meeting reports and presentations with participants.
<b>Agenda Item 8: Summary of the day and close of workshop</b>	
<b>Notes</b>	<p><b>GWO:</b> Thanked all participants for sharing time and expertise. The common thread of sustainable water management was highlighted, and the level of collaboration appreciate. Reports and slide decks for the workshop will be shared with participants.</p> <p>A virtual meeting will likely occur in May to achieve final approval on design. Progression thereafter will lead to project completion in August 2023.</p>
<b>Discussion</b>	None
<b>Action Items</b>	None

## Appendices

### A Workshop Agenda

## Stakeholder Working Group - Workshop

### Groundwater monitoring system consultation

#### Date and Location:

9:15 am Belize City - **Belize Biltmore Plaza** (Mile 3, Philip Goldson Highway, Belize City)

### Workshop agenda

Time	Activity	Facilitator
9:30 – 9:45	Welcome remarks from National Hydrological Service and purpose of the workshop	Tennielle Hendy (NHS)
9:45 – 10:00	UN Climate Technology Centre and Network (CTCN) introduction	Ramiro Salinas – (CTCN)
10:00– 10:45	Status and trends in the groundwater resources of Belize Assessment of water resources in the New River	George Woolhouse / Azucena Rodriguez Yebra (Consulting team)
11:00 – 12:00	Update on progress to-date: Groundwater monitoring system initial design options	George Woolhouse / Azucena Rodriguez Yebra (Consulting team)
13:00 – 14:00	Breakout groups: Discussion on initial design of groundwater monitoring system	Lucien Chung Elishah St. Luce (Consulting team)
14:15 – 14:45	Breakout groups: Wrap up	Lucien Chung Elishah St. Luce (Consulting team)
14:45 – 15:00	Next steps for the project	Azucena Rodriguez Yebra (Consulting team)
15:00 – 15:15	Summary of the day and close of workshop	George Woolhouse (Consulting team)

## B Sign-in Sheet

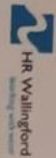
**Workshop: Belize groundwater monitoring consultation workshop**

**REGISTRATION FORM**

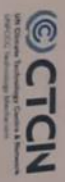
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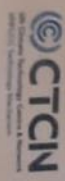
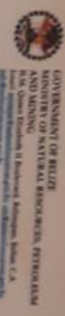
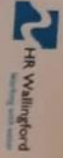
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C Photos



We design smarter, more resilient solutions across both the natural and built environment to help everyone live and work more sustainably with water.

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