

## Appendix

---

A.	Supplemental Literature .....	2
1.	Sustainable Development Goals .....	2
2.	Policy .....	2
3.	Monitoring .....	11
4.	Maps.....	13
5.	African Water Corridor Study .....	15
6.	Case Studies .....	16
B.	Methods Development .....	17
7.	Value search terms .....	17
8.	Values of organizations.....	17
9.	Iteration Images .....	19
10.	Value Cards .....	21
C.	Interview Protocol and Materials .....	22
11.	Part 1 Interview Protocol: Consumers.....	22
12.	Part 1 Interview Protocol: Organizations.....	23
13.	Part 2: Values Activity .....	26
D.	Coding .....	28
14.	RQ1. Stakeholders.....	28
15.	RQ2. Water Management Landscape .....	31
16.	RQ3. Value Sensitive Design .....	34
E.	RQ 1 Supplemental Information .....	35
17.	Literature Review .....	35
F.	RQ2 Supplemental Information .....	36
18.	Practical groundwater management .....	36
G.	RQ3 Supplemental Information .....	37
19.	Value Connections .....	37
H.	RQ4 Supplemental Information .....	38
20.	Recommendation product.....	38

## A. Supplemental Literature

### 1. Sustainable Development Goals

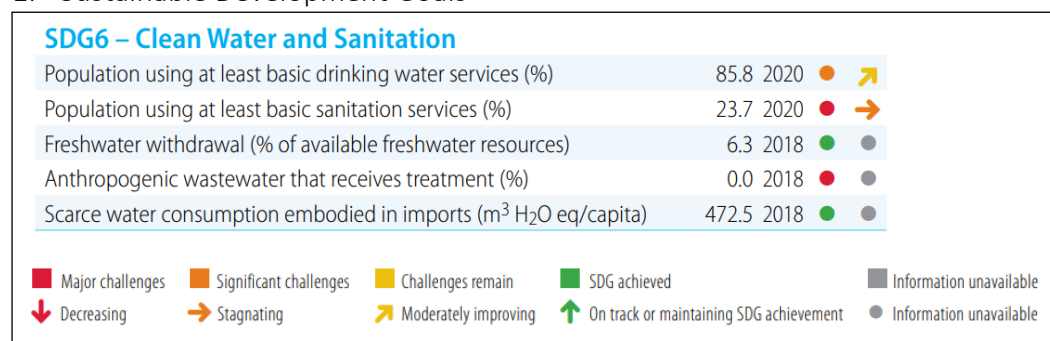


Figure 1. progress on UN SDG 6 for Ghana as of 2022 (United Nations, 2022)

### 2. Policy

Table 1. Summary of significant water resource legislation Ghana (Ebo Yahans Amuah, Afia Boadu, & Solomon, 2022)

Year	Action	Description
1957	Ghana independence	Ghana becomes independent sovereign nation from the United Kingdom
1965	Ghana Water and Sewage Corporation	Responsible for urban and rural water supply
1986		Rural Water Department within GWSC
1992	Constitution of Ghana	Vests control of all water resources in the President of Ghana
1993	Local Government Act	Provision for the administration of districts: district assembly, a municipality or metropolis.
1996	Water Resources Commission Act 522	Established WRC and to be responsible for overall management of Ghana's water resources. By parliament
1998	CWSA Act 564	Established the Community Water and sanitation Agency to be responsible for management of rural and small water supply systems, hygiene education and provision of sanitary facilities
1999	Ghana Water Company Limited Act 461	Urban water supply in control of GWCL as a state-owned limited liability company
2000	Africa Water Vision 2025	
2001	Water Use regulation (L.I. 1692)	Regulates water use for permitting and registering water use through WRC
2006	Drilling license and groundwater regulation (LI 1827)	Requires a person to obtain a drilling license
2007	National Water Policy	provide an effective interface among key stakeholders, integrate and harmonize their activities. By ministry of Works and Housing

2003- 2011	Subsidiary districts	Established 5 national river basin IWRM plans and 4 river basin boards (RBB)
2008	Sharm El-Sheikh Commitments	Accelerating the Achievement of Water and Sanitation Goals in Africa
2011	WRC Groundwater management strategy	
2012	Government of Ghana Integrated Water Resources Management Plan	Created by the WRC
2014	Water Sector Strategic Development Plan	Ministry of Water Resources, Works and Housing
2015	African Agenda 2063	Blueprint created by the African Union for a prosperous global future
2017	Ministry of Water Resources Works and Housing changes to Ministry of Works and Housing. Ministry of sanitation and water resources absorbs the water	Ministry of Sanitation and Water Resources (MSWR) established

Table 2. Ghana National Water Policy (Ministry of Water Resources, Works and Housing, 2007)

Water Resources Management	Urban Water Supply	Community Water and Sanitation
<ol style="list-style-type: none"> <li>1. Integrated Water Resources Management</li> <li>2. Access to Water</li> <li>3. Water for Food Security</li> <li>4. Water for Non-consumptive and Other Uses</li> <li>5. Financing</li> <li>6. Climate Variability and Change</li> <li>7. Capacity Building and Public Awareness Creation</li> <li>8. Good Governance</li> <li>9. Planning and Research</li> <li>10. International Cooperation</li> </ol>	<ol style="list-style-type: none"> <li>1. Water Sources</li> <li>2. Improving Access to Water</li> <li>3. Finance</li> <li>4. Hygiene Education and Environmental Sanitation</li> <li>5. Private Partnerships</li> <li>6. Capacity Building</li> <li>7. Good Governance</li> <li>8. Research and Development</li> <li>9. Monitoring and Evaluation (M&amp;E)</li> <li>10. Emergency and Extreme Events</li> <li>11. Pro-poor Issues</li> </ol>	<ol style="list-style-type: none"> <li>1. Access to Potable Water</li> <li>2. Decentralized delivery of water and sanitation services</li> <li>3. Finance</li> <li>4. Hygiene Education and Sanitation (HES)</li> <li>5. Public Private Partnership</li> <li>6. Capacity Building</li> <li>7. Gender Mainstreaming and Good Governance</li> <li>8. Research and Development</li> <li>9. Operation and Maintenance (O&amp;M)</li> <li>10. Monitoring and Evaluation (M&amp;E)</li> </ol>

Table 3. Water Sector Strategic Development Plan (Ministry of Water Resources, Works and Housing, 2014)

Service packages	Cross Cutting Issues
<ul style="list-style-type: none"> <li>- Urban &amp; Peri-urban Water Services</li> <li>- Rural &amp; Small Towns Water Services</li> <li>- Rural and Small Towns Sanitation &amp; Hygiene Services</li> </ul>	<ul style="list-style-type: none"> <li>- Institutional Capacity Development and Governance</li> <li>- Finance</li> <li>- Water Resource Management</li> <li>- Knowledge Management, Gender and M&amp;E (monitoring and evaluation)</li> </ul>

Table 4. Pra River Basin IWRM (Water Resources Commission, 2012)

Cause	Actions
<b>Problem 1: Inadequate Water supply</b>	
<ul style="list-style-type: none"> <li>• Increasing urbanization due to rapid population growth</li> <li>• High percentage of non-revenue water (over 50%) in urban water supply system due to poor physical infrastructure and pilferages</li> <li>• Inadequate financial resources and logistics for water supply and sanitation (WSS) delivery</li> <li>• Poor maintenance of irrigation infrastructure leading to low water use efficiency</li> </ul>	<ul style="list-style-type: none"> <li>• Improve Operation and Maintenance of existing water infrastructures</li> <li>• Improve efficiency of water use</li> <li>• Build new surface and groundwater infrastructure to meet projected demand up to year 2025</li> <li>• Increase institutional capacity to increase water supply</li> <li>• Promote rainwater harvesting and use of underground dams</li> <li>• Initially recover cost for O&amp;M and later attain</li> </ul>
<b>Problem 2: Land degradation and water quality deterioration</b>	
<ul style="list-style-type: none"> <li>• Land degradation from poor agricultural practices, forest excision for settlements and illegal mining</li> <li>• Deforestation for agricultural land and fuel wood</li> <li>• Fragmented buffer zone policies</li> <li>• Farming along the riverbanks</li> <li>• Point pollution from discharges of waste from mining, industrial and urban centres</li> <li>• Poor urban sanitation practices</li> <li>• Use of chemicals in fishing</li> <li>• Inability to enforce regulations and permit conditions</li> <li>• Limited awareness and knowledge on environmental hygiene</li> <li>• Unregulated peri-urban irrigation practices</li> </ul>	<ul style="list-style-type: none"> <li>• Create awareness and sensitize stakeholders about negative impacts of land degradation</li> <li>• Provide incentives to change behavior and alternatives to lost livelihoods</li> <li>• Implement Buffer Zone Policy</li> <li>• Strengthen institutional capacity to enforce compliance with Regulations</li> <li>• Support MMDAs to enact Byelaws for enforcement of environmental laws</li> <li>• Support MMDAs to rehabilitate, expand and build new waste treatment facilities to meet increasing demand</li> <li>• Enforce Regulations on waste management and pollution control of surface and groundwater resources</li> <li>• Strengthen institutional capacity at all levels for waste management</li> <li>• Implement the Polluter Pays</li> </ul>
<b>Problem 3: Inadequate adaptation to climate change and variability</b>	
<ul style="list-style-type: none"> <li>• Lack of integrated flood management in Development planning</li> <li>• Inadequate coping mechanisms for climate change</li> <li>• Inadequate financing of water resources development and management</li> </ul>	<ul style="list-style-type: none"> <li>• Monitor climate elements and create early warning systems</li> <li>• Promote Community to National level approach to adapting to Climate Change (Adapts)</li> <li>• Develop scenarios for extreme water availability, their impacts and develop corresponding strategies to adapt, cope and achieve water security</li> <li>• Strengthen institutional capacity for adaptation</li> </ul>
<b>Problem 4: Weak institutional capacity</b>	
<ul style="list-style-type: none"> <li>• Inadequate data and information for planning</li> <li>• Limited awareness and knowledge</li> <li>• Inadequately trained and motivated manpower</li> <li>• Inadequate financial resources and logistics</li> </ul>	<ul style="list-style-type: none"> <li>• Create and sustain awareness and sensitize stakeholders on WRM problems, issues and solutions</li> <li>• Intensify education and training at all levels</li> </ul>

<ul style="list-style-type: none"><li>• Weak capacity of decentralized institutions and civil society groups, (MMDAs, CBOs, NGOs) to perform river basin management tasks</li><li>• Fragmented responsibilities and inadequate coordination of stakeholders' roles</li><li>• Inadequate effective stakeholder participation in water resources planning, development and management</li></ul>	<ul style="list-style-type: none"><li>• Set up Inter-sectoral collaboration and co-ordination committees at District level</li><li>• Provide logistics to enforce Regulations</li><li>• Develop GIS-driven data and information databases on the ecosystems, socio-culture, economics, water cycle, water supply systems, etc.</li><li>• Carry out research into technology development, adaptation, Etc.</li><li>• Monitor and evaluate</li></ul>
---	--

Table 5. Strategic policy objectives, actions and indicators for goals in the water sector (Water Resources Commission, 2012)

Strategic outcome	Action	Delegate	Indicators
<b>1. Strengthen the regulatory and institutional framework for managing and protecting water resources for water security and enhancing resilience to climate change</b>			
1.1 Enhance the policy framework for IWRM	1.1.1 Review the IWRM component of the National Water Policy to address emerging challenges and clarify mandates and roles among stakeholders	WRC + WD/MWRWH	<ul style="list-style-type: none"> <li>– National Water Policy reviewed by 2013</li> <li>– Reviewed National Water Policy receive cabinet approval by end of 2013</li> </ul>
1.2 Enhance the implementation of existing regulations on WRM	1.2.1 Assess and review existing water use- and the drilling license and groundwater development regulations	WRC + WD/WRI/CWSA/ EPA/AGD	<ul style="list-style-type: none"> <li>– Updated versions LI1692 and LI 1827 completed and adopted by 2013</li> <li>– Number of prosecutors/law enforcement personnel trained by 2014</li> <li>– Number of trainings organized or monitoring and inspectorate staff per year</li> </ul>
	1.2.2 Provide capacity building support to AGD and Security services to enforce regulations and permit conditions on raw water	WRC + EPA/AGD	
1.3 Develop and implement additional regulations on Dam Safety and Effluent discharges	1.3.1 Establishment of a Dam Safety Unit	WRC + WD/VRA/GIDA/ EPA/GWCL/MMDAs	<ul style="list-style-type: none"> <li>– Draft Dam Safety Regulations submitted to AGD</li> <li>– by 2013</li> <li>– Dam Safety Regulations adopted by parliament by end of 2013</li> <li>– At least 50% NDSU staff recruited by 2014</li> <li>– Draft effluent discharge regulation prepared by 2014</li> </ul>
	1.3.2 Develop guidelines and regulations for dam safety (including operating rules for floods and evacuation plans)	WRC + WD/VRA/GIDA/MJ-AGD/ EPA/ GWCL/ MMDAs/ NADMO/ GMet	
	1.3.3 Develop regulations for waste water/effluent discharges	WRC + WD/GIDA/ EPA/ GWCL/ MMDAs	
	1.3.4 Develop procedures and operational mechanisms for enforcement of regulations on waste management and pollution control	WRC + EPA/MMDAs/AGD/ GP(police)	
1.4 Ensure the protection and conservation of river basins and wetlands for water security as	1.4.1 Prepare and update national and river basins IWRM plans	WRC + WD/EPA/ MMDAs/RBBs/NGOs	<ul style="list-style-type: none"> <li>– Buffer Zone Policy adopted by cabinet by 2013</li> <li>– Legislative Instrument on Buffer zone developed and approved by Parliament by 2016</li> </ul>
	1.4.2 Establish River Basin Offices and Boards with adequate office accommodation and logistics	WRC + WD +	

well as enhanced resilience and adaptation to climate change	1.4.3 Implement the buffer zone policy for protection and restoration of rivers, water bodies, and wetlands	WRC + WD/EPA/MMDAs/RBBs/NGOs	<ul style="list-style-type: none"> <li>- Number of pilot interventions of the Buffer zone policy initiated by 2014</li> <li>- Functioning climate change resilience and adaptation program for the sub-sector by 2014</li> </ul>
	1.4.4 Formulate legal instruments for buffer zone policy WRC + WD/MJ-AGD/ EPA/	MMDAs/RBBs/NGOs	
	1.4.5 Develop and implement strategic policy framework for rainwater harvesting	WRC + WD/EPA/MMDAs/RBBs/NGOs	
	1.4.6 Incorporate climate change adaptation to water conservation strategies	WRC+WD/EPA/MMDAs/RBBs/NGOs/NADMO	
	1.4.7 Promote ADAPTS concept to climate change adaptation. (The ADAPTS approach to climate change is a bottom – up approach and builds on the needs, priorities and actions of local people and their communities and ensures that adaptation considerations are effectively incorporated into water policies, plans and investment strategies	WRC + EPA/NGOs/RESEARCH INSTITUTIONS/RBBs	
<b>2 Enhance public awareness and education in water resource management issues</b>			
2.1 Strengthen communication campaigns and education to stimulate interest and promote support for WRM-related initiatives	2.1.1 Review and implement IWRM communication strategy (including messages and materials) for increased public awareness and education of IWRM.	WRC + WD/ CWSA/ VRA/ EPA/ GWCL/ MMDAs/ NGOs	<ul style="list-style-type: none"> <li>- Communication Strategy reviewed for 2012-2016</li> <li>- Number of the communication campaigns and education tasks implemented per year.</li> </ul>
	2.1.2 Collate best practices on IWRM and disseminate 'lessons learned' at local, national and international levels	WRC + WD/CWSA/VRA/EPA/GWCL/MMDAs/NGOs	
	2.1.3 Intensify education and training in IWRM at all levels.	WRC+ WD/CWSA/VRA/EPA/GWCL/MMDAs/NGOs/NADMO/ CBOs	
<b>3 Improve access to water resources knowledge base to facilitate water resources planning and decision making</b>			
3.1 Improve data and information management	3.1.1 Support the set-up, rehabilitation, and upgrade the hydrometeorological monitoring networks as well as introduce new technologies for data collection and analysis.	WRC, HSD/GMet/WRI + MWRWH/ MMDA/NNRI	<ul style="list-style-type: none"> <li>- Database on both surface and groundwater upgraded to cover entire country by 2014</li> </ul>

	3.1.2 Implement the “Groundwater Management strategy” nationwide to increase access to accurate groundwater resources information	WRC, WRI + MWRWH/MMDA/NNRI	<ul style="list-style-type: none"> <li>- Recruit at least one GIS/data base expert to manage data base by 2013</li> <li>- At least 2 WRC technical personnel undertake training on water resources assessment, management and development</li> </ul>
	3.1.3 Strengthen water quality monitoring and data assessment including ecological/biological monitoring and further development of water quality guidelines and criteria	WRC + EPA/WRI/GWCL/CWSA/NNRI	
	3.1.4 Monitor Climate Elements and Create Early Warning Systems	WRC + GMet/HSD/WRI/EPA/ NADMO	
	3.1.5 Strengthen human and technical capacities of institutions for data analysis and archiving including GIS-Driven Data and Information Databases on water related information (incl. also ecosystems, Socio-Culture, Economics) and models for analysis and Decision Making.	WRC/MWRWH/GMet/WRI + MMDA/NNRI	
3.2 Promote scientific investigations and research in water resources assessment, management and development	3.2.1 Develop decision support models to assess and manage impacts on quality and quantity of water resources	WRC/GMet/WRI/HSD+WD/MMDA	<ul style="list-style-type: none"> <li>- Number of collaborative/service agreements established for scientific investigations and research on targeted water resources and related issues.</li> <li>- Number of models developed/adopted and utilized for investigations and decision making water resources and related issued.</li> </ul>
	3.2.2 Promote further hydrogeological investigations nationwide	WRC/GMet/WRI/GAEC + WD/MMDA	
	3.2.3 Establish national forecasts for climate change based on global and regional models	WRC/EPA + WRI/GMet/Universities	
	3.2.4 Carry out research on strategies for adaptation to climate change	WRC/EPA +GMet/universities/etc	
<b>4 Improve transboundary and international cooperation in the management of shared water resources</b>			
4.1 Facilitate the development of bilateral and multilateral agreements/ protocols to strengthen cooperation with	4.1.1 Initiate and adopt new protocols with Côte d’Ivoire on the joint management of the (Aby Lagoon-Bia-Tano) basins system and with Togo on shared groundwater resources	WRCMWRWH +/MFA-RI/MJAGD/VRA/MMDAs	<ul style="list-style-type: none"> <li>- Number of bilateral trans-boundary waters agreements with riparian neighbours prepared by 2015</li> <li>- Number of multilateral Transboundary waters arrangements and commitments made.</li> </ul>
	4.1.2 Facilitate the county’s financial contribution, participation and implementation in international programmes and plans (e. g. ECOWAS,VBA, GEF-Volta, GWP/WA and AMCOW)	WRC/MWRWH+WD/MoFEP/MFA-RI/MJAGD/MMDAs	



riparian countries in shared basins			
<b>5 Ensure gender equity in water resources management and planning</b>			
5.1 Ensure gender equity in water resources management	5.1.1 Implement the Gender and Water Resources Management Strategy	WRC+ WD, EPA, MMDA, NGOs, CBOs	<ul style="list-style-type: none"> <li>- Number of the gender equity and sensitivity/responsiveness tasks implemented per year.</li> <li>- Review the Gender Strategy on WRM by 2015</li> </ul>
<b>6 Develop and operationalize a national M&amp;E system to track progress in IWRM implementation</b>			
6.1 Set-up a national M&E system for the implementation of IWRM	6.1.1 Develop indicators	WRC	<ul style="list-style-type: none"> <li>- Functioning and well coordinated M&amp;E units established at River Basin Offices and the WRC Secretariat by 2013.</li> </ul>
	6.1.2 Identify and implement mechanisms for monitoring and evaluation	WRC	

Table 6. National IWRM Programs (Water Resources Commission, 2012)

<b>National IWRM Action Programs</b>
Review the IWRM component of the National Water Policy to address emerging challenges and clarify mandates and roles among stakeholders
Assess and review existing drilling license and groundwater development regulations
Provide capacity building support to AGD and Security Services to enforce water resources management regulations and permit conditions.
Establishment of a Dam Safety Unit
Develop guidelines and regulations for dam safety (including operation rules for floods and evacuation plans)
Develop regulations for wastewater/effluent discharge
Develop procedures and operational mechanisms for enforcement of regulations on wastewater management and pollution control
Prepare and update national and river basins IWRM plans
Establish River Basin Offices and Boards with adequate office accommodation and logistics
Implement the buffer zone policy for protection and restoration of rivers, water bodies and wetlands
Formulate legal instruments for buffer zone policy implementation
Develop and implement strategic policy framework for rainwater harvesting
climate change adaptation in water conservation strategies (ADAPTS Approach)
Promote community to national level approach to adapting to climate change (ADAPTS Approach)
Implement the reviewed IWRM communication strategy (including messages and materials) for sustained and enhanced public awareness and education on the management of water resources
Collate best practices on IWRM and disseminate 'lessons learned' at local, national and transboundary levels
Intensify education and training in IWRM at all levels
Support the set-up, rehabilitation, and upgrade the hydro-meteorological monitoring networks as well as introduce new technologies for data collection and analysis
Implement the "Groundwater Management Strategy" nationwide under a decentralized stakeholder engagement model for sustained groundwater management in Ghana.
Monitor climate elements and create early warning systems
Strengthen human and technical capacities of institutions for data analysis and archiving including GIS-Driven Data and Information Databases on water related information (incl. also ecosystems, Socio-Culture, Economics) and models for analysis and Decision Making.
Develop decision support models to assess and manage impacts on quality and quantity of water resources
Promote further hydrogeological investigations nationwide
Establish national forecasts for climate change based on global and regional models
Carry out research on strategies for adaptation to climate change
Initiate and adopt new protocols with Côte d'Ivoire on the joint management of the (Aby Lagoon-Bia-Tano) basin systems and with Togo on the Todzie-Aka basin system and shared groundwater resources
Facilitate the country's financial contribution, participation and implementation in international programs and plans (e.g. ECOWAS, VBA, GEF-Volta, GWP/WA and AMCOW)
Implement the Gender and Water Resources Management Strategy
Develop indicators
Identify and implement mechanisms for monitoring and evaluation

\*red highlights indicate areas of interest

## 3. Monitoring

Table 7. Groundwater Monitoring Programs in Ghana

Region	Funding	Ghanian organizations	# Stations	Source
Northern Ghana	CIDA	WRC	42?	(WRC, 2011)
Tano, Ankobra, Pra and Densu river basins	DANIDA/ EU		33	(IGRAC, 2020)
Volta Basin		GAEC- WRC	37	(IGRAC, 2020)
Pra and Densu River Basin		WRI	22	(Council for Scientific and Industrial Research, 2020)

Table 8. Monitoring Databases (SADC, 2022)

Name	Description
Africa Groundwater Atlas	This portal includes a profile of groundwater resources for each country in Africa.
Aquaknow	A list of water datasets.
Hydrogeological maps of Zambia	This page contains several hydrogeological maps of Zambia, at different scales.
Quantitative groundwater maps for Africa	Three maps at the continental scale: aquifer productivity, aquifer flow and storage type, aquifer saturated thickness. IGRAC- British Geological Survey
Africa Groundwater Atlas Country Hydrogeology Maps	Geology and hydrogeology maps of 38 countries in Africa, at a scale of 1:5 million
Global Groundwater Information System	An interactive, web-based portal to access information on groundwater resources across the world.
GRIP – Limpopo	Platform of the Groundwater Resource Information Project for the Limpopo province in South Africa.
Malawi Spatial Data Platform	A public platform for GIS Data to support development in Malawi, including groundwater data.
National Groundwater Archive - South Africa	An online database for viewing and downloading groundwater data in South Africa.
OneGeology	This portal gives access to data from geological data providers around the world.
ORASECOM GIS Server	This platform shares spatial data and maps related to the Orange-Senqu River Basin under the custodianship of The Orange-Senqu River Commission (ORASECOM).
Ramsar Sites Information Service (RSIS)	It provides online information on wetlands that have been designated as internationally important.
SADC Groundwater Literature Archive	A database of documents on groundwater resources in the SADC region.
WHYMAP	Groundwater maps produced under the World-wide Hydrogeological Mapping and Assessment Program.
Water Point Data Exchange (WPDx)	A platform for sharing water point data.

Water Research Commission Knowledge Hub - South Africa	A database of documents, including documents on groundwater resources.
Mine Water Atlas - South Africa	This platform contains groundwater maps of the mineral provinces in South Africa.
ZAMWIS	An information management system for the Zambezi River Basin.
GRAVIS	
GGMN: Global Groundwater Monitoring Network	Use monitoring wells globally to establish database. The GGMN is a “network of networks”, that uses information from existing networks in order to represent a change of groundwater resources at the scale relevant for the regional and global assessment.
Chronicles Consortium	The Chronicles Consortium initiative is collating long term - multi-decadal - records of groundwater levels from around Africa
UNHCR Refugee Site Borehole Data	The UNHCR have an online WASH GIS portal, which includes groundwater data from water boreholes at UNHCR refugee sites, including borehole locations, depths, casing diameters, rest (static) water levels and estimated safe yields.
EAWAG Groundwater Quality information	EAWAG (the Swiss Federal Institute of Aquatic Science and Technology) developed the <b>Groundwater Assessment Platform</b> , with information on geogenic (naturally occurring in groundwater) contaminants. This database includes some measured data on groundwater arsenic and fluoride concentrations, including in Africa.
Groundwater Management Institute	southern African development fund- no maps for ghana

\*red highlights indicate areas of interest

4. Maps

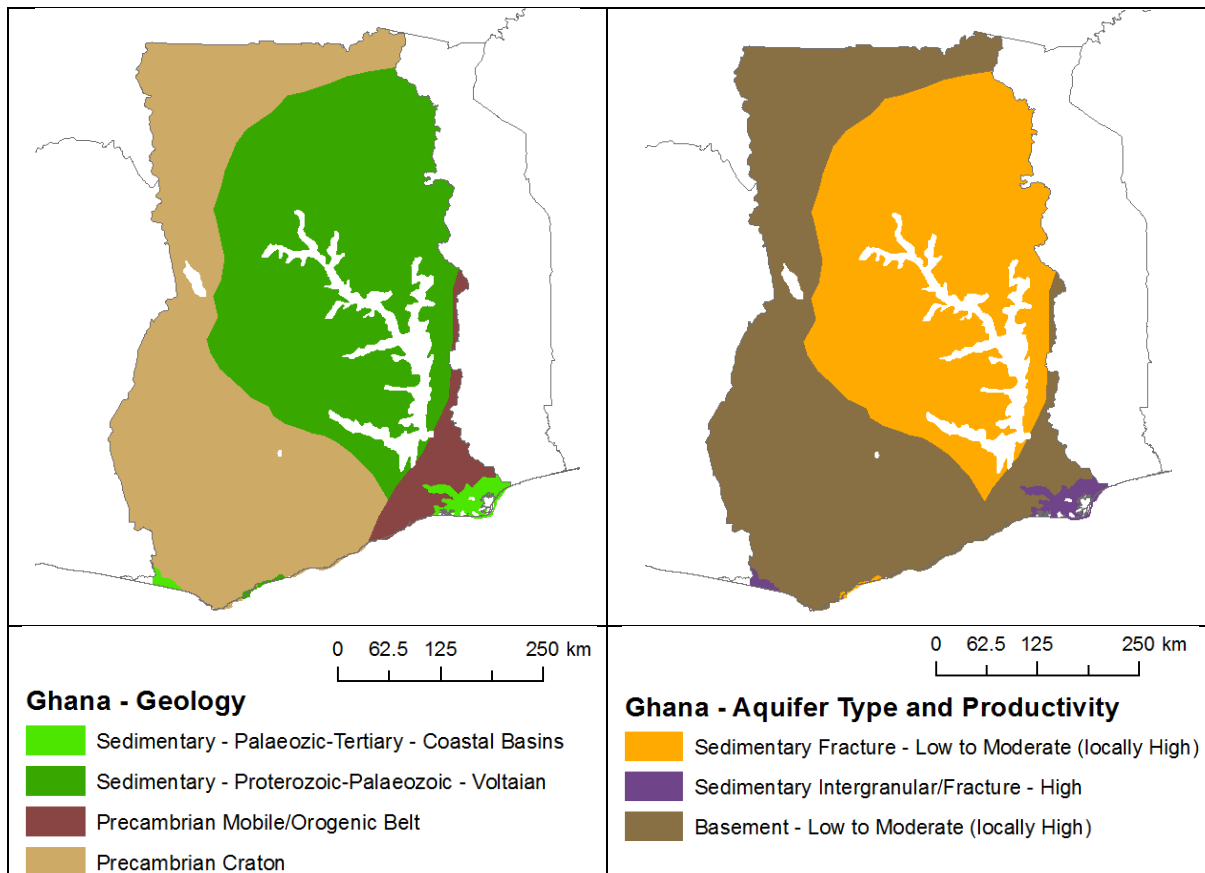


Figure 2. Geology and Aquifer type of Ghana (BGS, 2022)

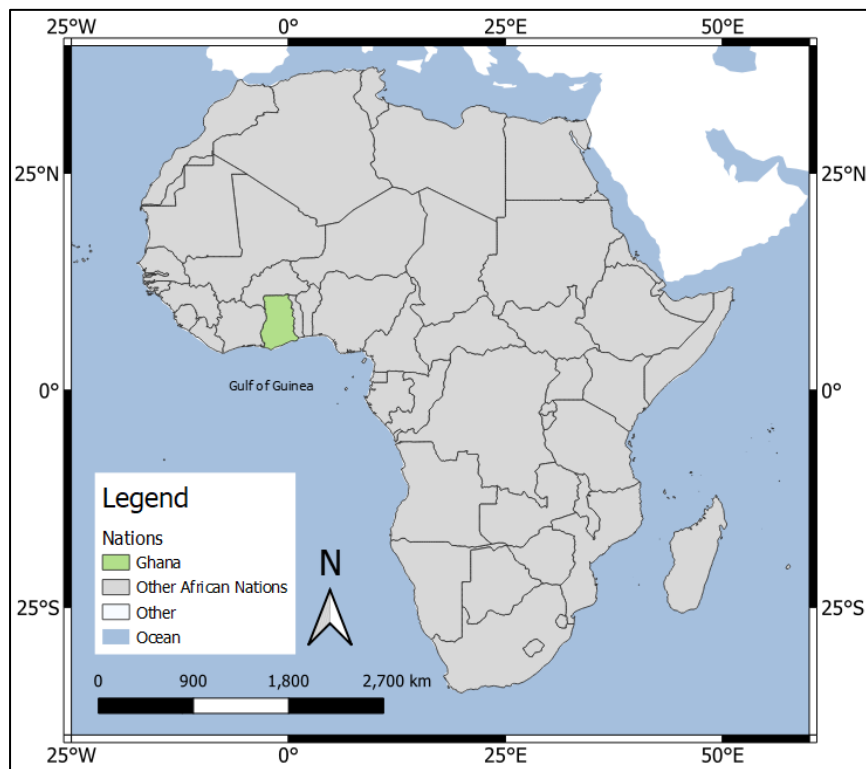


Figure 3. Ghana in reference to Africa

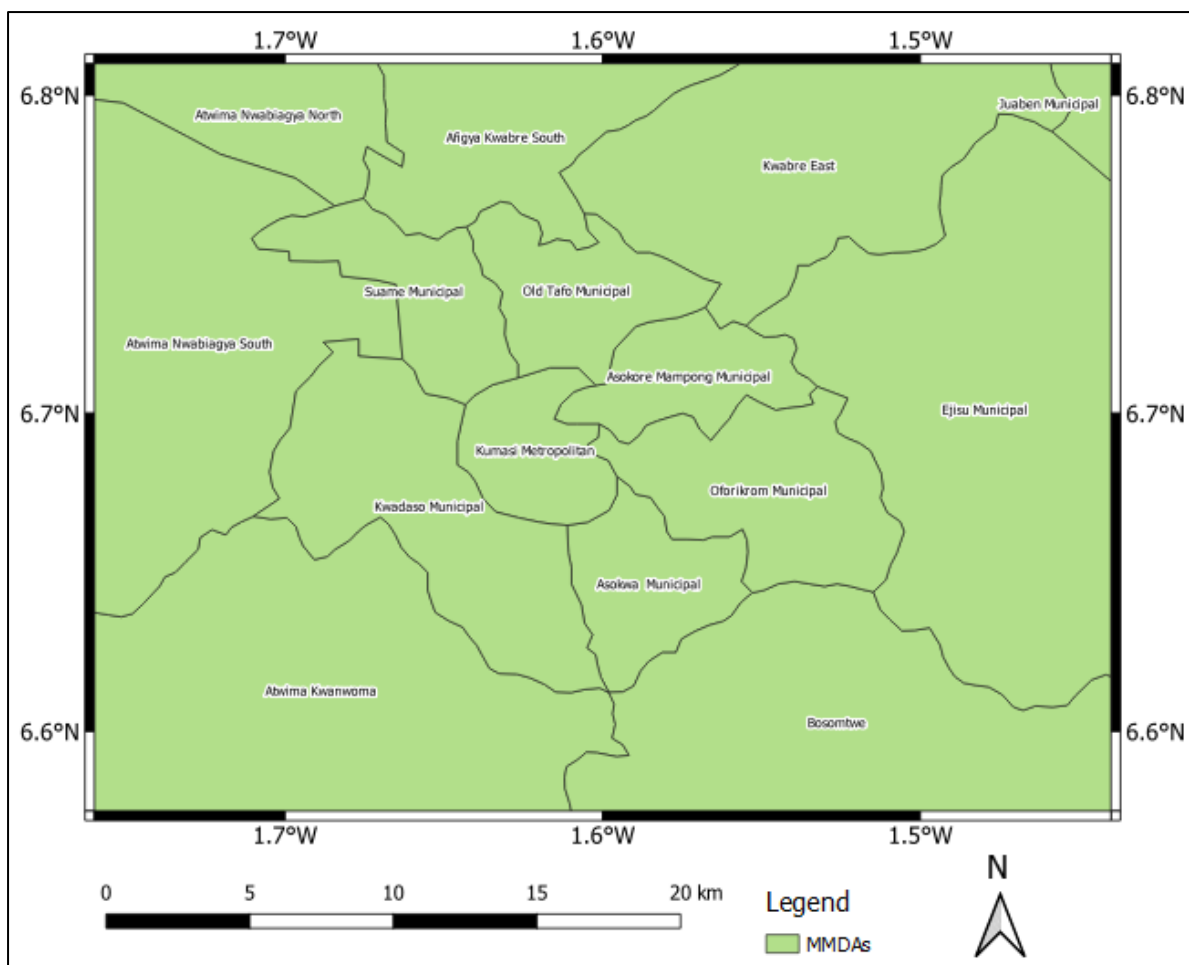


Figure 4. MMDAs in the greater Kumasi area

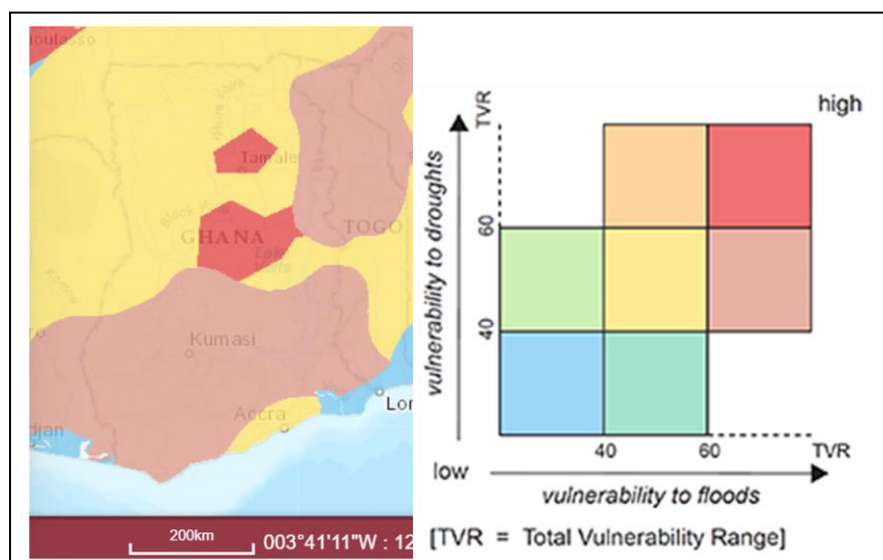


Figure 5. Flood and drought vulnerability (BGR, 2022)

5. African Water Corridor Study

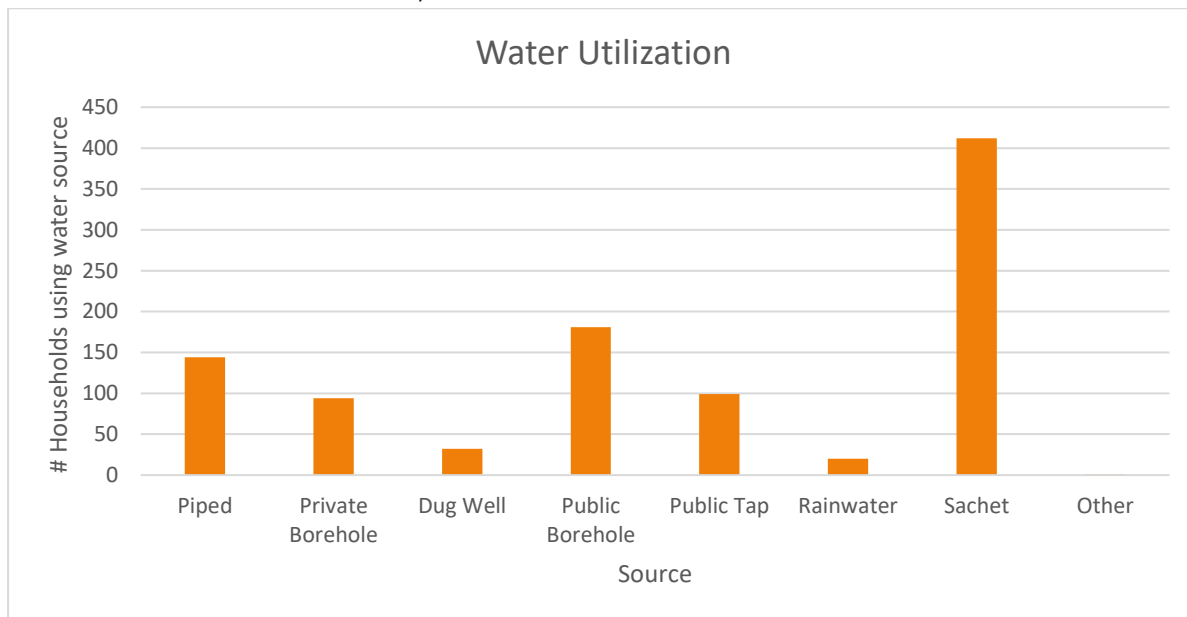


Figure 6. Water utilization from the AWC study

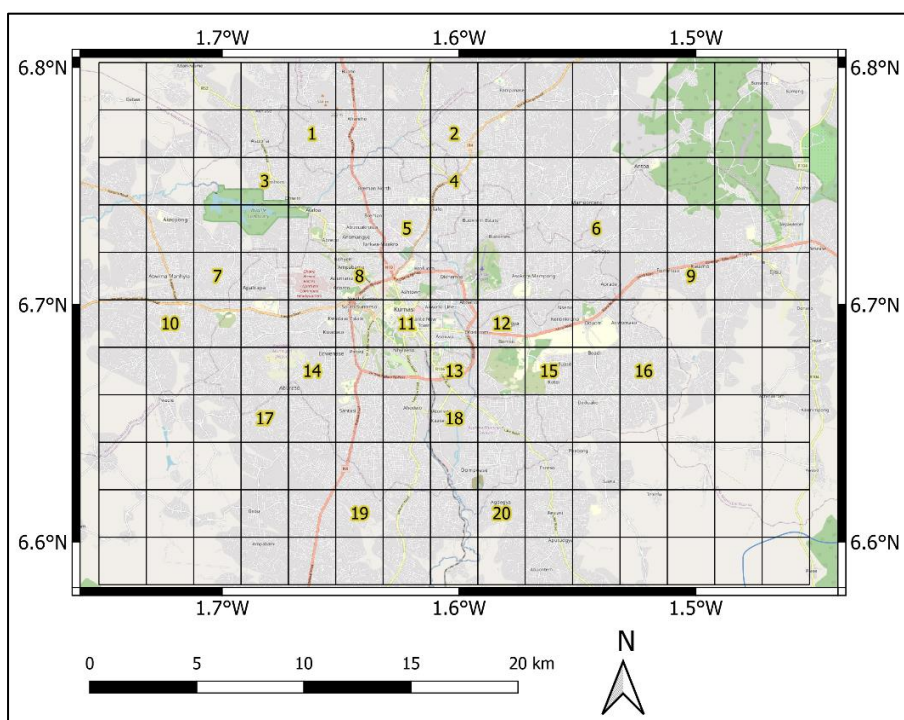


Figure 7. Survey grid for preliminary water use study. Numbers indicate sample location identifiers on the grid

## 6. Case Studies

Table 9. Community Management Models in Sub Saharan Africa (Obosi, 2020)

	<b>Kenya</b>	<b>Tanzania</b>	<b>Nigeria</b>	<b>Malawi</b>	<b>Ghana</b>
<b>Region</b>	<i>East Africa</i>	<i>East Africa</i>	<i>West Africa</i>	<i>Southern Africa</i>	<i>West Africa</i>
<b>Operation</b>	<i>Informally/ independently</i>	<i>Unmonitored</i>	<i>Informal</i>	<i>Unmonitored</i>	<i>Managed public/ private partnership</i>
<b>Role of state</b>	<i>Inspector/ prefect</i>	<i>Active mediator</i>	<i>Passive mediator</i>	<i>Benevolent</i>	<i>Benevolent</i>
<b>Water sources</b>	Community operated kiosks; shallow wells and boreholes; natural sources i.e. rain water, rivers, lake, ponds; and vendors	Community operated kiosks; shallow wells and rivers; vendors and mosques	Community operated kiosks; shallow wells and boreholes; natural sources- rainwater, rivers, lake, ponds, and vendors	community operated kiosks; natural sources; shallow wells and boreholes	Community operated kiosks; shallow wells and boreholes
<b>Role of the state</b>	Regulation, Ltd. infrastructure development; collecting fees and registration of WSPs	Mobilization of community and partners; infrastructure development	Mobilization for infrastructure development	Mobilization of community and partners; infrastructure development	Mobilization of community and partners; infrastructure development
<b>Membership</b>	Local community groups; community-based organizations' (CBOs); institutions. Welfare associations/ Organized groups	People living a given radius; individuals and NGOs	People living a given radius; individuals	People living a given radius initiative of the community	People living a given radius initiative of the community
<b>Public Private Partnerships</b>	Donors, community, state; WSP	Donors; WSPs; water utilities; NGOs; Community liaison unit; political party leadership, local authority	Consultants; NGOs; local Government authorities; Local community water committees; donors	Donors, NGOs; center for community organization and development; water board; WSP; local community/ WUAs	Donor, community, state



## B. Methods Development

### 7. Value search terms

Table 10. search terms used in Scopus science

Keywords	Search Yield	Considered for review	Analyzed	Chosen
(TITLE-ABS-KEY ( groundwater ) AND TITLE-ABS-KEY ( "value sensitive design" ) )	0			
(TITLE-ABS-KEY ( water ) AND TITLE-ABS-KEY ( "value sensitive design" ) )	5	2	2	1 (B)
(TITLE-ABS-KEY ( "value sensitive design" ) ) AND ( water )	29	15	5	2 (B and C)
( TITLE ( "value" ) AND TITLE-ABS-KEY ( "integrated water management" ) )	4	1	1	1 (D)

### 8. Values of organizations

Table 11. values of Ghanaian organizations

Organization	Values
<b>Ministry of Sanitation and Water Resources</b> (Ministry of Sanitation and Water Resources, 2018)	Accountability <sup>1</sup> Competence Excellence <sup>2</sup> Impact and Outcome Driven Sustainability Transparency <sup>3</sup>
<b>Ministry of Works and Housing</b> (Ministry of Works and Housing, 2022)	Accountability <sup>1</sup> Equity Excellence <sup>2</sup> Integrity <sup>4</sup> Quality Assurance <sup>2</sup> Time Consciousness Transparency <sup>3</sup>
<b>Minerals Commission</b> (Minerals Commission Ghana, 2021)	Integrity <sup>4</sup> Professionalism <sup>5</sup> Service Excellence <sup>2</sup> Team Work <sup>6</sup>
<b>Water Resources Commission</b> (WRC, 2022)	Being Responsible Hardworking Honesty Punctuality Respect for others Teamwork <sup>6</sup> Transparency <sup>3</sup>
<b>Council for Scientific and Industrial Research- Water Research Institute</b> (CSIR, 2011)	Commitment Customer satisfaction Dedication to duty Loyalty to quality assurance <sup>2</sup>
<b>African Water Corridor</b> (TU Delft, 2022)	Water as a basic human right Multidisciplinary science Learning/ teaching

<b>Ghana Water Company Limited</b> (GWCL, 2019)	Quality and excellent customer service <sup>2</sup> Urgency in service delivery Continuous improvement and innovation. Health care and safety of stakeholders High ethical and professional standards
<b>Ghana Geological Services Authority</b> (GGSA, 2022)	Professionalism <sup>5</sup> Integrity <sup>4</sup> Result Continuous improvement Collaboration Openness Innovation

1. accountability; 2. Excellence/ quality; 3. Transparency; 4. Integrity 5. Professionalism 6. Teamwork

9. Iteration Images

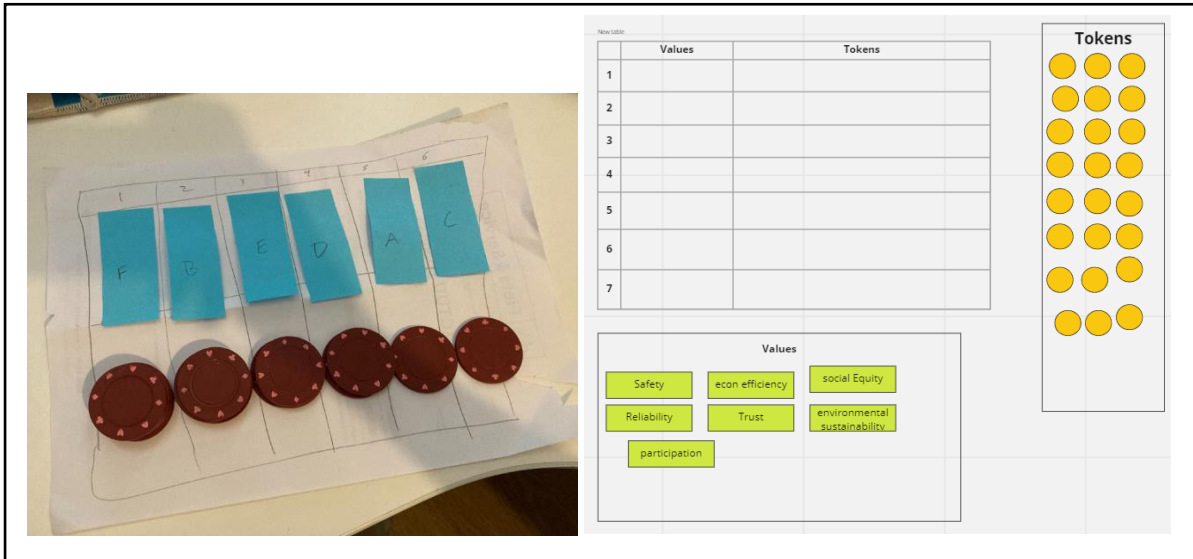


Figure 8. Draft 1 physical and Miro version

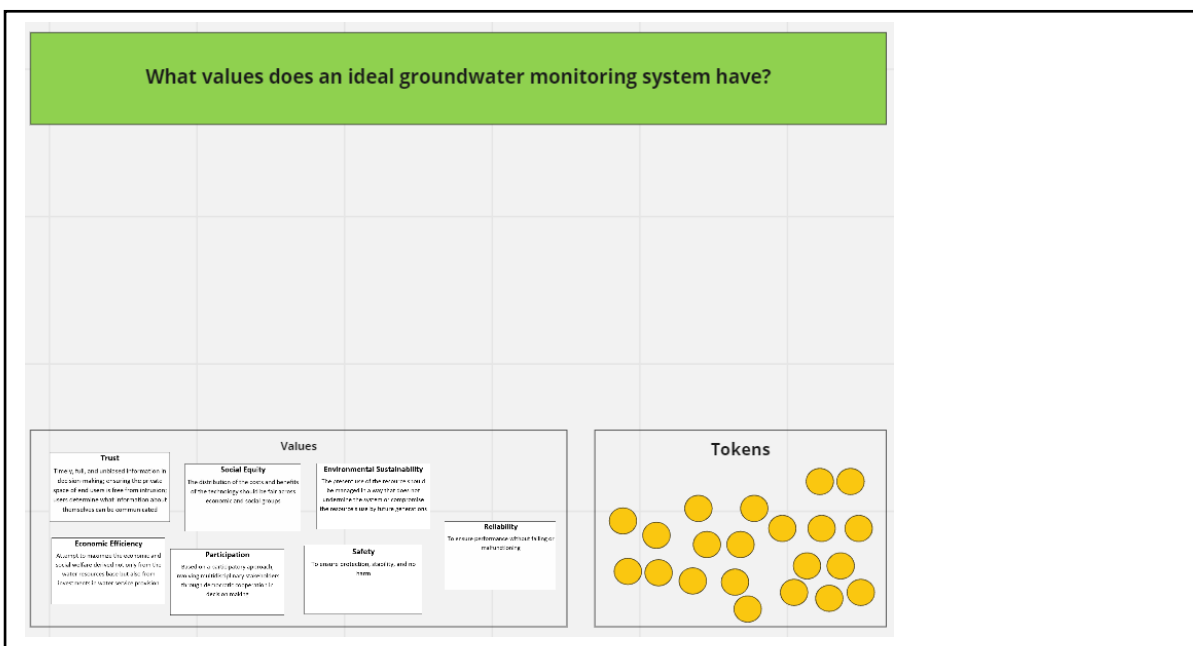


Figure 9. version 2 on miro with definitions

Final Interview Tool

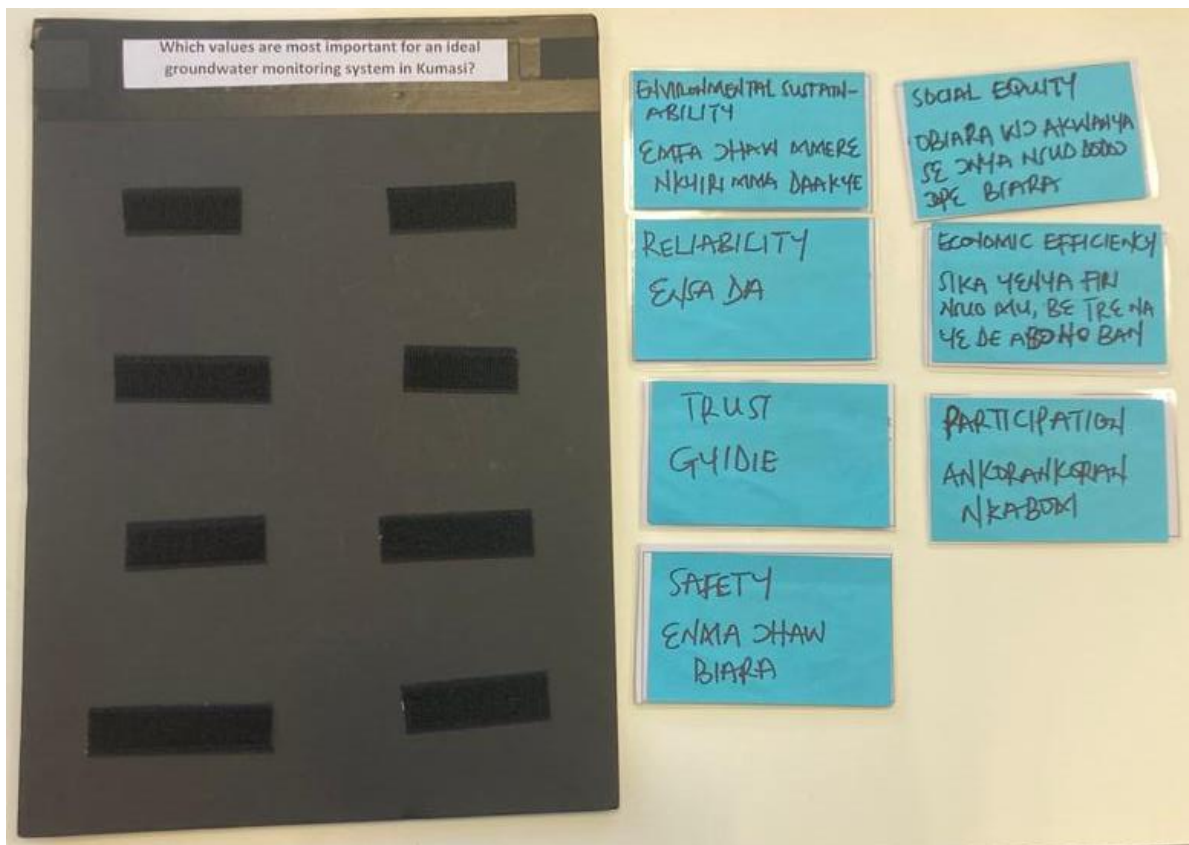


Figure 10. Values activity board and cards

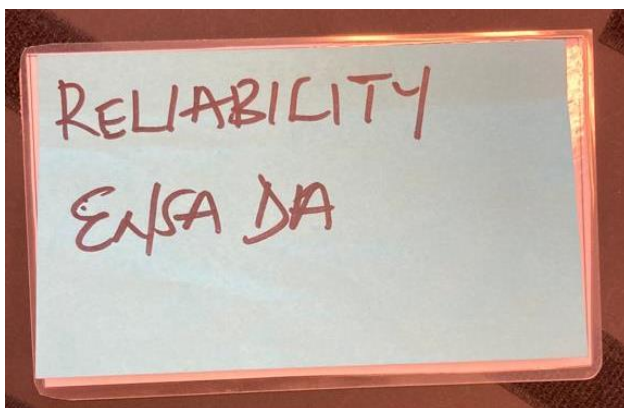


Figure 11a. Front side (twi)

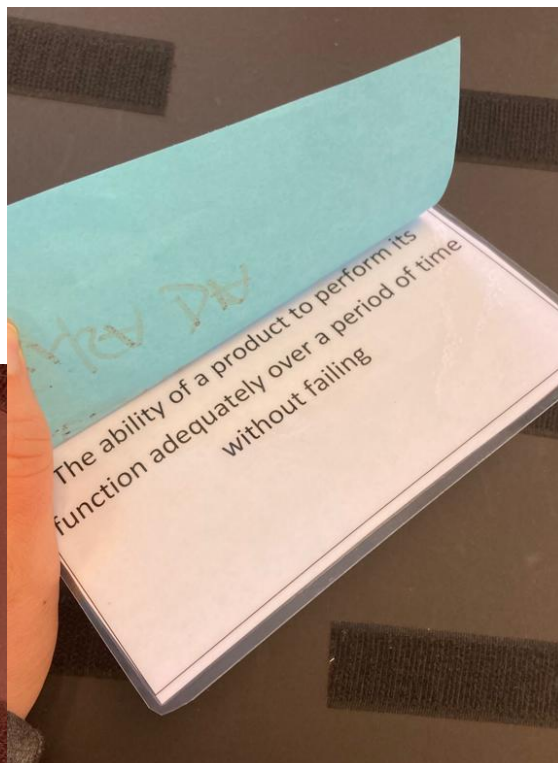


Figure 11b. back side (English)

## 10. Value Cards

Table 12. Value Cards front and back

<p>ECONOMIC EFFICIENCY</p> <p>SIKA YENYA FIRI NUO MU, BE TRE NA YE DE ABONO BAN</p>	<p>ENVIRONMENTAL SUSTAIN- ABILITY</p> <p>EMFA JHAW MMERE NKHIRI MIMA DAAKYE</p>
<p>PARTICIPATION</p> <p>ANKORANKORAN NKABOXI</p>	<p>RELIABILITY</p> <p>ENSA DA</p>
<p>SAFETY</p> <p>ENMA JHAW BIARA</p>	<p>SOCIAL EQUITY</p> <p>OBIARA KID AKWANYA SE NYA NUO DODO JPE BIARA</p>
<p>TRUST</p> <p>GYIDIE</p>	

## C. Interview Protocol and Materials

---

### 11. Part 1 Interview Protocol: Consumers

Ok we are now recording. There are three parts of this interview: first I will be asking you general information about your relationship to groundwater, then you will complete a values activity. At the end of the interview, you will be debriefed about your experience and given the opportunity to ask questions and provide additional comments.

#### **General information**

##### Groundwater Use

1. Do you use groundwater?
  - a. If yes- why?
  - b. If no- why not?
2. If yes to using groundwater...
  - a. If so, from private borehole, public borehole or well?
  - b. Is borehole manual or mechanized?
3. Are you satisfied with your groundwater? Why or why not?
  - a. Quantity and quality?
4. Do you track your groundwater use? Why or why not?
5. Would you be willing to have your water consumption monitored?
  - a. Why or why not?
  - b. What is preventing you from doing so?
6. Is there anything else you'd like to tell me about your experience with using groundwater here in Kumasi?

#### **Post Problem introduction**

*The next part of the interview is focused on groundwater management. Last year, there was a master thesis study from the TU Delft which identified an increase in groundwater use in recent years.*

7. Who should be in charge of tracking groundwater? Why?
8. If Kumasi were to track groundwater, how would you like to be involved?
9. If there were to be a groundwater monitoring system in Kumasi, is there anything that would encourage you to be involved?

## 12. Part 1 Interview Protocol: Organizations

### Introduction

Thank you for meeting with me today- I really appreciate your time. Before we begin with the interview, we need to go over the informed consent forms from which I will read. If you have any questions, please let me know and I'll be happy to answer them.

### Informed Consent

*Read the informed consent.*

If you understand and agree to the conditions, I just read to you, please sign at the end of the page and I will do the same.

There are a couple of items I need you to go over in this checklist. If you agree to the items listed here, please initial next to the item and if you have questions about anything, please ask.

### Questions

Ok thank you for filling out the form as it ensures both you and my university that this procedure is following the ethical guidelines, I reported on prior to beginning this study. With the permission you've just given me, I will begin the recording now. Is that, ok?

### Introduction

Ok we are now recording. There are three parts of this interview: first I will be asking you general information about your organization related to groundwater, then you will complete a values activity. At the end of the interview, you will be debriefed about your experience and given the opportunity to ask questions and provide additional comments.

### General information

#### Initial

1. Can you tell me the name of the organization you work for?

*Ok it is important, moving forward in the interview that you respond from the perspective of this organization- not your personal views. You need to speak on behalf of your organization. Is that, ok?*

2. What can you tell me about your organization and its role in groundwater management in Kumasi?

- a. *Groundwater management definition- planning, implementation, and operation involved in the provision of safe and reliable groundwater supplies to consumers*
- b. *Projects; goals; initiatives; supporting organizations;*
- c. *What are the responsibilities? What are the main activities?*

3. What is your organization's view on the status of groundwater management in Kumasi?

- a. *Do you think groundwater management is going well? What can be improved?*

#### Ghana Water Company Supplement

1. What are the main problems/concerns the GWCL encounters when supplying water to the inhabitants of Kumasi?
  - a. *Consistency? Quality? Billing? Maintenance? Communication?*
2. How does the GWCL manage these problems/concerns?

3. How is the policy of the GWCL determined? Are the users involved?

### **Post Problem introduction**

*The next part of the interview is focused on groundwater management. Last year, there was a master thesis study from the TU Delft which identified an increase in groundwater extraction in recent years.*

4. Are you aware of attempts to monitor groundwater levels in Kumasi either currently or in the past?
  - a. *If yes*- what was the result? What were the challenges involved? Who were the stakeholders involved? How was it funded? Why was it not sustained?
5. Does your organization have any intentions or plans for monitoring groundwater levels in the future?
  - a. *Yes*- can you tell me a bit about it?
    - i. *Such as: deadlines; goals; technical implementations*
  - b. *If yes*- Has your institution collaborated with another institution to monitor groundwater?
    - i. *If Yes*, what was your role and how was it organized?
  - c. *No*- Does your organization have an interest in monitoring groundwater levels in Kumasi? Why or why not?
6. How if at all, would your organization like to be involved in monitoring groundwater levels in Kumasi?
  - a. *If yes*, would groundwater management be a priority for your organization?
  - b. Development and review of groundwater monitoring framework for Kumasi
  - c. Provision of funding
  - d. Provision of monitoring equipment and logistics
  - e. Training and Research
  - f. Data collection on groundwater quality and uses (variations)
  - g. Data collection on groundwater availability
  - h. Communication and coordination
  - i. Interpretation and publication of data

### **Collaboration**

7. Are you aware of existing collaborations for groundwater monitoring in Kumasi?
  - a. *Governments; individuals; researchers; non-profits*
8. Who are your key collaborators in groundwater management and what does that collaboration look like?
  - a. What do these projects look like? How do you collaborate?
9. What institutions will need to be involved to make groundwater monitoring successful?

### **Design**

*This is the last section of the introductory material before we move on to the activity. The next few questions are about goals or ideas you might have of groundwater monitoring in Kumasi.*

### Norms



*Answer in terms of capabilities, activities, properties, attributes, functions, institutions involved, scale, scope, technology involved, costs, ect*

1. What does ideal groundwater monitoring look like to your organization?
2. What do you see as the biggest opportunity in establishing groundwater monitoring?
  - a. What are the institutional components already in place that can contribute to a system?
3. What do you see as the biggest obstacle in establishing groundwater monitoring in Kumasi?
4. What could your organization contribute to a groundwater monitoring system in Kumasi?

#### Design Requirements

*Answer in terms of software, infrastructure, tools, programs, collaborations, ..these can be technical or non-technical*

1. Ideally, how would your organization like to keep track of groundwater levels?
  - a. Does your organization have a technology in mind to monitor groundwater levels?
  - b. What kind of benefits would you like to see in groundwater monitoring?
2. Does your organization have any design requirements that you would like to see for groundwater monitoring in Kumasi?

### 13. Part 2: Values Activity

Ok now we are at the second part of the interview which is the Values Activity.

This activity will focus on answering the question: **Which values are most important for an ideal groundwater monitoring system in Kumasi?**

In order to answer that question, I have these Values Cards for you. (*hand over stack*) there are seven values in the deck and on each card is the name of a value with a definition. The first thing you are going to do it review the cards and then place them on the table so that the front side is facing up. You can arrange them any way you'd like.

*Participant places cards*

Ok now that you have reviewed the cards, I also have tokens. There are 21 tokens. For the activity, you are going to place tokens on the value card to answer the question above. So the more tokens you put on a value, **the more important it is for your organization's view of ideal groundwater monitoring**. You must use all the tokens and are free to distribute them in any way you would like.

\*it is important here to note that you are looking at your organization's view of ideal groundwater **monitoring for water level**- not the quantity or quality of groundwater itself

\*if you have a question about meaning of card- answer to the best of your ability and we will go over your interpretations of the cards at the end

*Interviewee places tokens*

### Recapping

Ok now we are at the last section of the interview. Before we move on, I am going to take a photo of your worksheet and record the results. In the final part of the interview, I'll be asking about your responses and motivations for such responses. The theory behind this is to translate values into design requirements. For example, for the design of a cup to be safe (value) it must be insulated (design requirement) so that it is not too hot to hold.

I will be asking about your top two and bottom two ranked values. Lets start with the top...

1. What does [value] mean to you in relation to groundwater monitoring?
  - a. Was there something in the provided definition that was particularly interesting to you?
2. What would groundwater monitoring need to do/be in order for this value to be realized?
3. Why did you rank it [number] in relation to the other values?

### Supplementary follow up questions

Value	Related concepts	Follow up Questions
<b>Economic Efficiency</b>	<i>Cost- effectiveness</i> <i>Economic efficiency</i>	Minimizing costs for who? Affordability
<b>Environmental Sustainability</b>	<i>Environmental sustainability</i> <i>Non-anthropogenic values</i> <i>Sustainability</i>	Longevity- what time frame do you think of? Data as a resource
<b>Participation</b>	<i>Communication</i> <i>Cooperation</i> <i>Democratic participation</i> <i>Managerial accordance</i> <i>Multidisciplinary</i> <i>Stakeholder involvement</i>	Centralized v decentralized? Scope- household level v regional What groups need to be involved?
<b>Reliability</b>	<i>Reliability</i> <i>Responsibility</i>	Time frame of reliability- how can this be operationalized? What period of time is ideal?
<b>Safety</b>	<i>Safety</i> <i>Security</i>	Health is implicit- did you think about that? Would you want to monitor for quality simultaneously? Who is safe? What risks would need to be mitigated to be safe?
<b>Social equity</b>	<i>Distributive justice</i> <i>Social equity</i> <i>Social sustainability</i>	Accessibility
<b>Trust</b>	<i>Trust</i> <i>Disclosure</i> <i>Privacy</i> <i>Procedural justice</i>	Private v public ownership How would data need to be handled to establish trust?

### Extra Values

4. Was there a value important to your organization that was not listed here?
  - a. If yes what and why? Repeat Qs 1-x
5. Is there anything else you'd like to add about anything we discussed today?

### Conclusion

That concludes the interview. Thank you for your participation. Again, the results of the study will be anonymized, and your name will not be included in any way from the publicly published report. I will stop the audio recording now.

## D. Coding

---

The tables in this section describes how the interviews were coded. If a code was directly stated in an interview, the description will say “direct quote”. Otherwise, the details of the code can be found in the description.

### 14. RQ1. Stakeholders

To answer the first research question, each stakeholder group was coded for being mentioned, describing their role in groundwater management and what they would contribute to groundwater monitoring. Additionally, discussion of collaborations with other organizations were coded as well.

Table 13. Mentioned stakeholders

Group	Stakeholder code	Description
Domestic Consumer	Caretaker	Direct quote
	Households	Household consumers of groundwater
	Husband	Direct quote
	Interviewee	Interviewee; hostel; household; husband
	Landlord	Landlord and/or owner of the interviewee's property
Commercial Consumer	Hostel	Hostels on the KNUST campus
Training and Research	Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED)	Direct quote
	Council for Scientific and Industrial Research- Water Research Institute (CSIR-WRI)	Direct quote
	Expert	Includes any mention of nonspecific academic or expert groups
	KNUST	Affiliates of KNUST, researchers, students, staff
	TU Delft	Direct quote
	RWESCK	Direct quote
Service Providers	CWSA	Direct quote
	Borehole Companies	Direct quote
	GWCL	Direct quote
	Hydrogeologist	Direct quote
	Sachet	Direct quote
Regulation	Assembly	Direct quote
	Geological Services	Direct quote
	Committee Members	Direct quote
	EPA	Direct quote
	Hydrological Services	Direct quote
	Ministry of Health	Direct quote
	GIDA	Direct quote
	Ministry of Sanitation and Water Resources	Direct quote
	Government	Direct quote
	PURC	Direct quote
	WRC	Direct quote
Chief	Direct quote	
External	Foreign Investors	Describes external companies from other countries
	NGO	Direct quote
	I don't know	Respondent did not know what actors to name

Table 14. Are you willing to be involved in groundwater monitoring?

Code	Description
Yes	Respondent says yes
No	Respondent says no
Yes, under a condition	Respondent provides conditions under which they would contribute

Table 15. Tasks

Task	Description
Advise policy	Advising policy
Data collection	Collecting data Going to site Offering data
Lead	Offering to lead efforts
Partner	Partnering with lead
Research	Research based on data Modeling tasks
Technology Development	Develop tools to monitor
Tools	Offer tools to monitor Offer services to monitor
Community participation	Participate in community group

## 15. RQ2. Water Management Landscape

Table 16. Management View

Code	Definition
No management	Interviewee states there is no management, that management does not exist, or that they do not have it
Poor management	Any negative comments about water management related to lack of data, poor quality, poor distribution, leadership and lack of regulation.
Positive management	Any positive comments about water management

Table 17. Groundwater Access Type

Category	Code	Definition
Type	Boreholes	Direct quote
	Well	Direct quote
Access	Private	Direct quote
	Public	Direct quote
Mechanism	Manual	Direct quote
	Mechanized	Direct quote

Table 18. Satisfaction with Groundwater

Category	Code	Definition
Overall	Satisfied (Y)	Direct quote
	OK (OK)	Direct quote
	Not satisfied (N)	Direct quote
	Conditional (C)	n/a
Quantity	Satisfied (Y)	Direct quote + Readily available Flows well Doesn't dry up
	OK (OK)	Direct quote
	Not satisfied (N)	n/a
	Conditional (C)	Good except for the dry season
Quality	Satisfied (Y)	Direct quote+ Eat and drink with it
	OK (OK)	Direct quote
	Not satisfied (N)	Salty Poor taste Do not drink it Visually turbid Feel itchy after bathing
	Conditional (C)	Treat it before using Filter before using Quality samples taken to lab Chemical treatment Disinfection

Table 19. Groundwater Management Components

Code	Definition
Adequate supply	Discussions of the ubiquitous availability of groundwater in Kumasi
Ease of drilling	No limitations on drilling "anyone can drill"
Caretaker	Direct quote
Expensive Borehole	Affordability is a barrier to having a private borehole Expenses of materials
Groundwater to supplement pipes	Discussion of users who use groundwater as a supplement to groundwater
Heterogenous distribution	Discussions of groundwater availability being unevenly distributed in the country
Hydrologist	Direct quote
Neighbor interference	Drilling in neighboring areas impacting each other
Poor borehole construction	Description of poor techniques in borehole drilling Shallow wells Insufficient materials No survey
Poor piped distribution	Discussions of piped water through GWCL not providing access to all areas
Proper construction	Description of protocol to design a sustainable borehole
Sharing data	Discussions of drilling sharing data with others
Sharing private borehole access	Discussion of neighbors allowing others to use their private borehole
Septic tank	Direct quote
WRC permitting	Discussion of permits and/or registering of borehole with the WRC

Table 20. Challenges

Name	Definition
Capacity	Relates to human resources capacity to complete tasks
Collaboration	Limitations and/ or challenges on individuals, groups or organizations working together
Funding	Insufficient or non-existent funds to complete tasks
Infrastructure	Lacking physical monitoring infrastructure
Lack of awareness	Limited awareness among individuals of groundwater management
Lack of Regulation	Limited regulation and following regulations for groundwater
Leadership	Undefined leader and unknown roles for a groundwater monitoring project



Table 21. Designs

Category	Code	Definition
Collaboration	Accessible	Discussions about equal access, distribution and accessibility regardless of socio-economic status, language or location
	Community Participation	Involving community members in design
	Decentralized system	Local focus, or discussions of decentralizing the management of data
	Education	To share information Education Learning
Functions	Consumption Levels	Informing users of their groundwater consumption
	Timely data	Discussing endurance of the data tool over time and how often data is collected over time
	Cost effective	Ensuring costs are affordable Cost associated with the monitoring will ensure longevity of tool
	Flood protection	Device to monitor can aid in flood warning
	Low maintenance	Device requires low in person maintenance activities
	Quality data	Gathering data on water quality through monitoring
	Regulation	Instituting more regulations in design
	Service Provision	Providing maintenance, assistance or other services to consumers who are a part of the monitoring
	Large scale	Need to data points over a large-scale area for accurate measurements
Spatial targeting	Target particular areas based on groundwater use	
Technology	Data Repository	Database for all groundwater monitoring points
	Device	A device to monitor groundwater
	Models	Create model for the aquifer in the monitoring region
	Telemetry	Use of telemetry to collect data remotely
	Aquifer recharge	Direct quote
	Mobile technology	Use mobile technology to collect data
	Open data	Direct quote
	Pilot test	Discussions of a test phase prior to full scale

## 16. RQ3. Value Sensitive Design

Table 22. Value descriptions

<b>Value</b>	<b>Description</b>
Participation	Direct quote
Trust	Direct quote
Reliability	Direct quote
Safety	Direct quote
Environmental Sustainability	Direct quote
Social equity	Direct quote
Economic Efficiency	Direct quote

Table 23. Parent and Contributing Values

<b>Value</b>	<b>Description</b>
Parent	A value which absorbs other values in the explanation
Contributing	A value listed as a contributing value to another value.

## E. RQ 1 Supplemental Information

## 17. Literature Review

Table 24. Literature review for RQ1

Search term	Search Yield	# Considered for review	#analyzed	# chosen
TITLE-ABS-KEY ( ghana AND groundwater AND monitor )	3	1	1	1
TITLE-ABS-KEY ( ghana AND groundwater AND kumasi )	14	2	1	1
TITLE-ABS-KEY ( ghana AND groundwater ) AND ( LIMIT-TO ( SUBJAREA , "SOCI" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) OR LIMIT-TO ( DOCTYPE , "re" ) OR LIMIT-TO ( DOCTYPE , "ch" ) )	45	5	3	2
TITLE-ABS-KEY ( kumasi AND water ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )	149	8	8	7

\*Conducted on 4 July 2022

## F. RQ2 Supplemental Information

## 18. Practical groundwater management

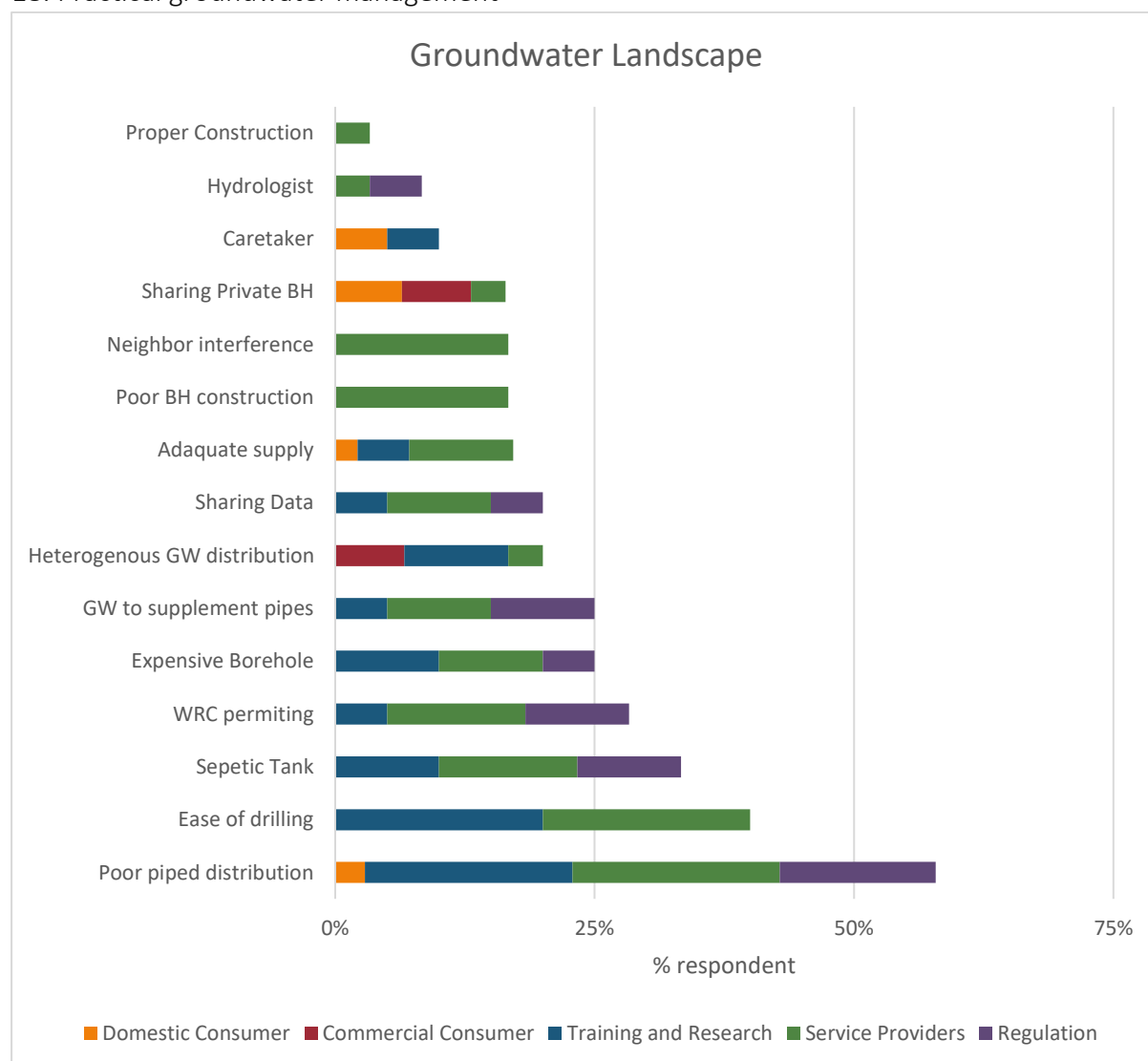


Figure 12. Components of groundwater management in Kumasi

## G. RQ3 Supplemental Information

## 19. Value Connections

Table 25. Value connection pairs

Value Pair		# Connections
Participation	Trust	6
Participation	Reliability	4
Participation	Safety	4
Economic Efficiency	Participation	3
Participation	Social equity	3
Reliability	Trust	3
Safety	Trust	3
Environmental Sustainability	Participation	2
Reliability	Safety	2
Environmental Sustainability	Reliability	1
Environmental Sustainability	Safety	1
Environmental Sustainability	Trust	1
Social equity	Trust	1

## H. RQ4 Supplemental Information

## 20. Recommendation product

**Program A: Multistakeholder Involvement**

A.1 Establish periodic meetings for stakeholders to voluntarily participate in a groundwater monitoring program							
1	Collaboration	6	Challenges	16	Participation	24	Citizen involvement
3	Readiness	12	Values	21	Regular meetings	25	Peer learning
2	Consumers	13	IWRM concepts	23	Field integration	29	Participant diversity
A.2 Delegate leadership of the advisory board to the WRC in collaboration with members of the Pra River Basin Management Board							
1	Collaboration	6	Challenges	14	Monitoring	24	Citizen involvement
3	Readiness	12	Values	16	Participation	25	Peer learning
4	Key stakeholders	13	IWRM concepts	23	Field integration	29	Participant diversity
A.3 Utilize informal networks of pre-established relationships between stakeholders to share organization activities							
1	Collaboration	8	Existing infrastructure	16	Participation	25	Peer learning
3	Readiness	12	Values	21	Regular meetings	26	Social Learning
4	Key stakeholders	13	IWRM concepts	23	Field integration	30	In- group messenger
A.4 Outsource collaboration oversight to external social scientist or communication specialist							
1	Collaboration	6	Challenges	13	IWRM concepts	23	Field integration
3	Readiness	9	Value profiles	16	Participation	27	External facilitator
5	Management	10	Importance v agreement	19	Training scheme		
A.5 Provide round table discussion on developments in monitoring and education							
1	Collaboration	6	Challenges	16	Participation	25	Peer learning
3	Readiness	12	Values	17	Incentives	28	Openness
4	Key stakeholders	13	IWRM concepts	24	Citizen involvement	29	Participant diversity

### Program B: Technical Development

B.1 Involve groundwater experts to develop groundwater monitoring technology							
3	Readiness	13	IWRM concepts	22	Public data	29	Participant diversity
7	Design requirements	14	Monitoring	23	Field integration	30	In- group messenger
11	Technical experts	15	Technology		#N/A		#N/A
B.2 Engage experts from institutions such as KNUST, WRI and GAEC in collaboration with TU Delft							
3	Readiness	11	Technical experts	19	Training scheme	25	Peer learning
7	Design requirements	14	Monitoring		#N/A		#N/A
8	Existing infrastructure	15	Technology		#N/A		#N/A
B.3 Create groundwater models and pilot studies before integration of a monitoring system into a community							
1	Collaboration	6	Challenges	16	Participation	24	Citizen involvement
3	Readiness	12	Values	21	Regular meetings	25	Peer learning
4	Key stakeholders	13	IWRM concepts	23	Field integration	29	Participant diversity
B.4 Utilize existing data sources and borehole infrastructure							
1	Collaboration	8	Existing infrastructure	15	Technology	24	Citizen involvement
3	Readiness	11	Technical experts	20	Local government		#N/A
4	Key stakeholders	14	Monitoring	23	Field integration		#N/A
B.5 Set up mechanism for technical working group to share results, updates and needs from monitoring development at collaboration meetings							
1	Collaboration	7	Design requirements	15	Technology	23	Field integration
3	Readiness	8	Existing infrastructure	16	Participation	25	Peer learning
4	Key stakeholders	11	Technical experts	21	Regular meetings	27	External facilitator

### Program C: Education Campaign

C.1 Implement a water education program for consumers in regions with high groundwater use							
6	Challenges	13	IWRM concepts	19	Training scheme	26	Social Learning
7	Design requirements	16	Participation	24	Citizen involvement	28	Openness
8	Existing infrastructure	17	Incentives	25	Peer learning	30	In- group messenger
C.2 Facilitate education campaign with KNUST graduate students speaking at gatherings of water users							
3	Readiness	12	Values	19	Training scheme	25	Peer learning
6	Challenges	16	Participation	21	Regular meetings	28	Openness
11	Technical experts	17	Incentives	24	Citizen involvement	30	In- group messenger
C.3 Integrate grade schools in environmental education program							
3	Readiness	8	Existing infrastructure	18	Replacement	24	Citizen involvement
6	Challenges	16	Participation	19	Training scheme	28	Openness
7	Design requirements	17	Incentives	21	Regular meetings	29	Participant diversity
C.4 Schedule regular community meetings with groundwater consumers to discuss water use and offer technical advice for water related concerns							
2	Consumers	7	Design requirements	17	Incentives	24	Citizen involvement
3	Readiness	12	Values	19	Training scheme	25	Peer learning
6	Challenges	16	Participation	21	Regular meetings		
C.5 Integrate assembly men and committee members as leaders to establish relationship with community							
2	Consumers	8	Existing infrastructure	17	Incentives	28	Openness
3	Readiness	12	Values	20	Local government	30	In- group messenger
6	Challenges	16	Participation	24	Citizen involvement		

### Integration

Integrate the three programs when a groundwater monitoring program is ready to be applied							
1	Collaboration	8	Existing infrastructure	16	Participation	21	Regular meetings
3	Readiness	12	Values	19	Training scheme	23	Field integration
4	Key stakeholders	13	IWRM concepts	20	Local government	27	External facilitator



