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DRAFT VOINJAMA WATER MASTER PLAN

LIBERIA MUNICIPAL WATER PROJECT

DECEMBER, 2012

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Tetra Tech Contact Information:
Alioune Fall, Chief of Party (AFall@tetratech-lmwp.com)
David Favazza, Senior Technical Advisor/Manager (David.Favazza@tetratech.com)

Tetra Tech
P.O. Box 1397
Burlington, Vermont USA 05401
Tel: 802-658-3890

COVER PHOTO: On Lawazula Road, looking south east towards the center, with two local water vendors, with coolers, selling water to customers in Voinjama

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ACRONYMS AND ABBREVIATIONS

A&E IQC	Global Architecture and Engineering Services Indefinite Quantity Contract
AfDB	African Development Bank
APM	Advanced Participation Methods
CBO	Community-Based Organization
CDA	County Development Agenda
CHF	CHF International
COP	Chief of Party
COTR	Contracting Officer's Technical Representative
cfs	Cubic Feet per Second
DFID	UK Department for International Development
DIG	Development Innovations Group
ECHO	Humanitarian Aid department of the European Commission
EHELD	Excellence in Higher Education for Liberian Development
EMMP	Environmental Monitoring and Mitigation Plan
EPA	Environmental Protection Agency (Liberia)
EWG	Engineering Working Group
GEMS	USAID Governance and Economic Management Support Program
GF	Gender and Facilitation
GIS	Geographic Information System
GoAL WASH	Governance Advocacy and Leadership for Water, Sanitation and Hygiene
GoL	Government of Liberia
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
HCC	Host Country Contracting
ICRC	International Committee for the Red Cross
IEE	Initial Environmental Examination
IIU	Infrastructure Implementation Unit
INGO	International Nongovernmental Organization
ISR	Institutional Strengthening and Reform
IWASH	USAID/Liberia Water, Sanitation, and Hygiene Project
IWRM	Integrated Water and Resources Management
LD	Liberia Dollar
LHS	Liberian Hydrological Service
LISGIS	Liberia Institute of Statistics and Geo-Information Services
L-MEP	Liberia Monitoring and Evaluation Project
LMWP	USAID/Liberia Municipal Water Project
lpcd	liters per capita per day
LWSC	Liberia Water and Sewer Corporation
M&E	Monitoring and Evaluation
MLME	Ministry of Lands, Mines and Energy
MoE	Liberia Ministry of Education

MoF	Liberia Ministry of Finance
MoHSW	Liberia Ministry of Health and Social Works
MoPEA	Ministry of Planning & Economic Affairs
MoPW	Ministry of Public Works
MOU	Memorandum of Understanding
NGO	Non-governmental Organization
NWRSB	National Water Resources and Sanitation Board
NWSHPC	National Water, Sanitation and Hygiene Promotion Committee
O&M	Operation and Maintenance
PMP	Performance Monitoring Plan
PSI	Population Services International
RFP	Request for Proposal
RoSCA	Rotating Savings and Credit Association
SA	Situational Analysis
SDC	Swiss Agency for Development and Cooperation
STA	Senior Technical Advisor
STA/M	Senior Technical Advisor/Manager
STTA	Short-Term Technical Assistance
SWA	Sanitation and Water for All
TWG	Transition Working Group
UL	University of Liberia
UL-PIRE	University of Liberia Pacific Institute for Research and Evaluation
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNMIL	United Nations Mission in Liberia
USAID	United States Agency for International Development
USD	Unites States Dollar
UWSSP	AfDB Urban Water Supply and Sanitation Project
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WSP	World Bank Water and Sanitation Program
WSSC	Water Supply & Sanitation Commission

EXECUTIVE SUMMARY

The Liberia Municipal Water Project (LMWP), funded by the United States Agency for International Development (USAID), will support the design, tendering, execution and operation of water supply infrastructure improvements in the cities of Robertsport, Sanniquellie, and Voinjama. LMWP will assist local and national authorities in developing plans for urban water supply and sanitation improvements, implementing short and medium-term water supply infrastructure improvements, and re-establishing local capability to sustainably operate and maintain the water supply improvements. During the four-year project base period, it is the goal of LMWP to help establish improved water supply access in each city, with infrastructure managed by locally-based entities capable of financially and technically sustaining the service. The improved water systems will provide public health and economic development benefits in the three target cities.

The responsibility for water service provision in urban areas (>5,000 population) and county capitals rests with the Liberia Water and Sewer Corporation (LWSC). The selection of the project's cities was done in consultation with the GOL who identified these three as priority cities for USAID assistance and USAID/Liberia has committed, subject to availability of funds, to support the GOL in improving water supply service in the three cities of Robertsport, Sanniquellie and Voinjama. This document is the Master Plan for the City of Voinjama.

The first major task of the project was the Situational Analysis (SA), designed to inform the subsequent design of appropriate infrastructure, management systems, and capacity building programs. The Master Planning stage is the second major task and precedes the actual detailed design and construction of both institutional and infrastructure systems to improve the level of water service to the City of Voinjama.

Central Voinjama from Kitoma Hill

Former Municipal Water Systems

No portions of the former municipal water treatment and distribution systems were found to be operational. Except for a limited number of components, most of the infrastructure from the previous municipal water system is not salvageable. The former elevated water storage tank and concrete structures at the treatment facilities and intake structure may be salvageable, subject to additional testing. None of the electrical, mechanical, and former distribution system piping and valves are salvageable. The majority of all mechanical and electrical components of the systems have been looted. Historic

information related to the condition of the previous water system, existing well locations, water quality, and other environmental and contextual data is limited due to lost or lack of record keeping.

Other Infrastructure Conditions and Challenges

Electricity from a public grid is not available in Voinjama, nor does any definitive plan to develop a grid-based power system appear to currently exist. Therefore, electrical power for future systems will need to be produced via generators, solar power, or other sources, at least in the short to medium term, and will represent a significant portion of operational costs.

Roadway access will be a significant challenge for the project, particularly during the rainy season when travel is slowed down by impassable roads. Travel challenges will increase operational costs and could delay the timely delivery of fuel and chemicals required for pumping and treatment activities.

The target cities generally lack the municipal infrastructure and service delivery experience that is necessary to support a fully functioning water supply system. Currently, the LWSC does not have any representation in Voinjama – except from a caretaker looking over the remnants of the water system infrastructure. There is a lack of experienced construction firms with water-specific construction experience in Liberia in general, and specifically in the target cities. Development of sustainable technology alternatives is also affected by the remote location of Voinjama resulting in challenges with respect to warranty service and supply of spare parts for maintenance.

Even with these various constraints and challenges the design and construction of a water system to improve access to water services for the residents of Voinjama can be accomplished.

Water Source Options

Although Liberia is fortunate to have high amounts of rainfall, the uneven distribution between the rainy season (April to October) and dry season (November to March) results in temporal fluctuations in surface water flows and quality.

The previously existing municipal water system in Voinjama relied on surface water. The surface water supply watershed (Zeliba River) remains mostly to partially forested. Available information suggests that dry season flows in the Zeliba River can reduce to zero flow for stretches of several days, so it is recommended to restore the previous impoundment system and to keep the withdrawal rate at that of or near the capacity of the previous treatment works. Based on the plans and records from the Gbarnga and Voinjama treatment works, it is estimated that the capacity of the Voinjama WTP was about 433,600 gallons per day (67.3 m^3 per hour[1]).

There is currently a lack of skilled, trained staff to manage, operate, and maintain future infrastructure. Although one of the goals of LMWP is to develop requisite capacity, the current low level of available capacity and need to achieve sustainability reduces the attractiveness of some technological alternatives during the Master Planning process. As noted above, LWSC does not have a presence in Voinjama, with the exception of a caretaker responsible for looking over the former facilities. Due to lower treatment costs, reduced operational complexity, and associated lower technical capacity requirements, the

[1] Republic of Liberia, Public Utilities Authority, Water Supply Project for six Cities, Final Design for Voinjama, by PWL Planning Group, GKW Consulting Engineers & German Water Engineering. Based on 68.4 m3/hr. abstraction rate/intake pump and WTP Capacity, note previous capacity also included 1.1 m^3/hr. backwash losses

utilization of groundwater or the slow sand filtration process may be the most appropriate source option. However, available information on subsurface hydrogeology indicates that obtaining sufficient flow from a groundwater source is unlikely. Therefore it is recommended that Zeliba River be developed as the primary water source for the City of Voinjama. To maintain the quality and quantity of the Zeliba River as the primary water supply source it is also recommend that steps be taken now to protect this source into the future. Proper management of wastewater is also required to reduce contamination of existing wells and hand pumps, which may continue to be used for non-drinking water purposes in the future.

The water quality testing conducted by LMWP and analyzed by US based labs indicated that most parameters tested were in compliance with the World Health Organization (WHO) guideline standards. Exceptions included pH, turbidity, color and iron. The WHO guidelines that are exceeded were not established by health based criteria, but by aesthetic and other criteria.

Recommended Water System and Components

Based on the critical need to limit operating costs and ensure the installed system is operable and sustainable, it is recommended that the previous conventional (rapid sand filtration) treatment process be replaced with a slow sand filtration process. Unlike a conventional treatment system, a slow sand filtration process does not rely on the addition of chemicals to provide treatment, with the exception of chlorine for disinfection. Chlorine is the most commonly used disinfectant for elimination of water borne pathogens.

It is anticipated that the new water treatment plant (WTP) will be located at the site of the previous WTP and utilize the water supply from the Zeliba River. In order to reduce turbidity and manage the iron present in the surface water supply, pretreatment will be provided in the form of river bank filtration, if the subsurface conditions are favorable to draw a groundwater supply that is under the influence of the Zeliba River. Additional pretreatment is recommended to reduce turbidity and this will be accomplished by reusing and modifying the previous sedimentation basin. It is also recommended that aeration be provided to enhance the filtration of the iron in the raw water. The pretreated flow would then be filtered in the slow sand filters, before being chlorinated and pumped into a new distribution system. The chlorination and pumping systems are proposed to be housed in the previous WTP structure. The restoration of the previous WTP will also include offices and maintenance facilities for the system operator.

A new distribution system is required to deliver treated water for consumption. It is initially recommended that the distribution system convey the water to public taps and kiosks that are metered. Dedicated connections would initially be limited to large institutions such as schools and community buildings in order to reduce cost and operational complexity. The distribution system will also include water storage facilities. The previous elevated water storage tank will be used if found to be able to feasibly be restored and capable of providing water to the newly developed sections of Voinjama. The proposed service area will be prioritized to serve areas with the greatest population density and lowest levels of access to improved water supply in order to effectively achieve the project goal of 90% access to improved water[2].

[2] Improved water supply access is defined by LMWP's USAID contract as regular household access to a water source, a distribution system, or a delivery point, which by the nature of its design and construction is likely to protect the water source from external contamination, in particular from fecal matter, and which can be reached by the household in a round trip of 30 minutes or less. Improved water supply sources are: piped water into dwelling, plot, or yard; public tap/standpipe; tube well/borehole; protected dug well; protected spring; or rainwater collection. Unimproved water supply sources are: unprotected dug well; unprotected spring; cart with small tank/drum; tanker truck; surface water (river, dam, lake, pond, stream, canal, irrigation channel); and, bottled water.

The first phase of improvements is herein referred to as **Short Term Projects**. These improvements include the restoration of portions of the WTP to provide bulk water service via a modular approach and installation of "mini water systems" utilizing groundwater to provide limited drinking water supplies in targeted areas. It is anticipated that Short Term Projects would be completed in 2014.

Since the Short Term Projects rely on the water quality of the Zeliba River, it is recommend that when establishing the administration and institutional departments of the water utility in Voinjama, the protection of the Zeliba River watershed should be prioritized.

The **Medium Term Projects** are expected to include the expansion of the WTP with slow sand filtration sized to serve the City of Voinjama and the installation of the distribution system to serve at least 90% of Voinjama's population, with a majority of the distribution system being constructed and placed into service. It is anticipated that Medium Term Project would be completed in 2016.

The Long Term Project recommended includes the following:

- Improvements to Operational and Institutional Capacity to improve sustainability
- Improved delivery of water by converting from public dispensing locations (kiosks and public stand pipes) to more private connections (yard taps and house connections)
- Re-visiting and updating of the Master Plan for Voinjama (recommended every 5 years)
- Implementation and advancement of an Asset Management Plan should occur during construction and just after start of any new facility
- Continuous updating of the Operation and Maintenance (O&M) manuals for the water system, its components, and its operational staff
- Continuous training for the water system staff, as well as the development of a training program to assist other water utilities being developed in Liberia
- Promotion of rainwater harvesting
- Development and implementation of a sanitation master plan
- Develop and implement program for decommissioning existing wells that do not meet acceptable water quality standards, or appropriately indicating and promoting their use for only non-potable water supply

Implementation and Affordability

The proper implementation of an improved water supply can overcome the restrictions and difficulties present in Voinjama, but it will require a strong and properly structured institutional framework. The institutional framework must ensure accountability to well-defined performance measures, incentives to meet performance targets, autonomy at the local level with regard to budgeting and operations, and staff with requisite capacity. In addition, water tariffs must reflect the actual operational costs of the system to ensure financial sustainability, while simultaneously allowing access for the poor. Having the institutional components in place is critical to sustainably providing municipal water services and a service that is both affordable and reliable. Development of an institutional framework is ongoing and is currently being addressed through local and national water steering committees. This Master Plan is focused largely on engineering aspects of the project.

Planning must include regular involvement of stakeholders within Voinjama to ensure their needs are being addressed and that their critical support is maintained during and after the Master Planning process. The general public will likely be interested in the level of service to be provided and the cost for such service. The cost of service will be based on the operational costs of the water system with the goal of

having all operation and maintenance costs be borne by the customers. To assure that an efficient water utility is developed, the development of an operation and maintenance manual and an asset management plan and associated training are required and will be conducted as part of Task 4 of the LMWP project.

The planning effort will also require that USAID secure funding for the capital works phase of the project. The procurement method to solicit construction prices from private contractors will also need to be resolved along with land rights and land ownership issues.

The estimated capital costs and annual operating cost of the various recommended alternatives are outlined in the following table.

Recommended Alternatives for Phased Construction	Alternative	Estimated Capital Costs[3]	Estimated Annual Operating Costs	Estimated Percent of Population Served
Short Term Project	Zeliba River Watershed Protection Program	$48,000	Dependent on type of project developed and if the purchase of land is and can be accomplished	n/a
Short Term Project	Mini Systems located at high yielding wells	$198,000	$60,640	6%
Short Term Project	Restore WTP Site, Construct Slow Sand Filters, and Restore portion of Distribution System with Storage.	$1,510,000	$92,100	8%
Medium Term Project	Restore Water Distribution System to serve all areas	$16,245,000	$200,000 to $241,000	~ 90 to 100%

The ability to carry out implementation of all recommended alternatives and also ensure that the investments are sustainable is heavily dependent on local willingness and ability to pay for ongoing operation and maintenance services. While the initial household survey and focus group analysis gathered important information on this important subject as presented in the Situational Analysis Report, further engagement at the local level is needed to confirm and refine that analysis based on the specific recommendations and expected costs in the Master Plan. However, available information is sufficient to perform initial analysis of affordability.

As noted above, in order for the proposed systems to be sustainable without external subsidies, then at a minimum the cost of operation and maintenance must be recovered via water tariffs. Given currently estimated annual operating costs and water demand, the requisite average cost recovery tariffs are generally within the range of affordability in Voinjama when examined using several different metrics.

The estimated annual water cost per household for water from the proposed systems can be expected to vary as outlined below depending on the short term or long term solutions. These costs also vary as a

[3] The capital costs presented are all components recommended by the described alternative and are independent of cost presented for other alternatives

percentage of median household (HH) income as reported during the household survey. The estimated household monthly net (surplus) income in Voinjama is $31.43, or $377 per year as calculated based on results of the household survey.

- Short Term – Mini System $383 per HH per year 22 % of annual income
- Short Term – Modular Treatment System $175 per HH per year 10 % of annual income
- Medium Term – Slow Sand Filtration $62 per HH per year 4 % of annual income

1.0 MASTER PLAN SCOPE, PROCESS AND FORMAT

The Liberia Municipal Water Project (LMWP), funded by the United States Agency for International Development (USAID), will support the design, tendering, execution and operation of water supply infrastructure improvements in the cities of Robertsport, Sanniquellie, and Voinjama. LMWP will assist local and national authorities in developing plans for urban water supply and sanitation improvements, implementing short and medium-term water supply infrastructure improvements, and re-establishing local capability to sustainably operate and maintain the water supply improvements. During the four-year project base period, it is the goal of LMWP to help establish improved water supply access in each city, with infrastructure managed by locally-based entities capable of financially and technically sustaining the service. The improved water systems will provide public health and economic development benefits in the three target cities.

The project goal is after four years, over 90% of the population in the project cities will have improved water supply access and improved infrastructure will be handed over to locally-based management financially and technically sustaining water supply service.

Improved water supply access is defined by the USAID contract as regular household access to a water source, a distribution system, or a delivery point, which by the nature of its design and construction is likely to protect the water source from external contamination, in particular from fecal matter, and which can be reached by the household in a round trip of 30 minutes or less. Improved water supply sources are: piped water into dwelling, plot, or yard; public tap/standpipe; tube well/borehole; protected dug well; protected spring; or rainwater collection. Unimproved water supply sources are: unprotected dug well; unprotected spring; cart with small tank/drum; tanker truck; surface water (river, dam, lake, pond, stream, canal, irrigation channel); and, bottled water.

Following the Situational Analysis - and informed by its findings, - the master planning process is the main component of the project Task 2 – *Plans for Staged Water Supply and Sanitation Infrastructure Improvements*. Its main objective is to evaluate the existing water needs and systems in Voinjama to identify water infrastructure and system improvements to achieve the project goal of 90% access after four years. Specifically, the Voinjama Master Plan presents options, for consideration by USAID and GOL authorities, of the most cost effective and feasible approaches for:

- Improving water supply access in the short-term;
- Improving water supply access in the medium-term (i.e., through end of the four-year task order); and
- Improving water supply and sanitation access in the long-term (i.e., after the end of the four-year task order).

As part of the Master Plan, the following items are addressed:

- Recommended water sources;
- Development of conceptual water supply and distribution system(s) throughout the city. Systems will be planned by zones based on phased construction and technical feasibility;
- Construction cost estimates for different components (sources, distribution, storage facilities, etc.) segregated in a list of sequential projects that can be funded separately. The Master Plan identifies the sequence in which each component must be implemented, e.g. source, storage and distribution – in that order;

Figure 1-1 Voinjama Vicinity Map

- Estimated operation, maintenance and labor costs;
- Preliminary construction schedule for execution of projects; and
- Initial estimates of ability of Voinjama water system customers to fully cover ongoing operation and maintenance costs via water tariffs.

LMWP key stakeholders include the following: Voinjama Municipal Government and citizens, Liberia Water and Sewerage Corporation (LWSC), Ministry of Land, Mines and Energy (MLME), and Ministry of Public Works. To the extent practicable, input from the stakeholders was solicited during this planning process through exchanges during the monthly Engineering Working Group (EWG)[4] meetings, weekly LWSC meetings, and meetings with the Voinjama Water Steering Committee and National Transition Working Group. This Master Plan will be fully vetted with national and local stakeholders through additional meetings, public and focus group discussions among other methods.

The LMWP and this Master Plan are intended to represent the starting point of an ongoing process. The Master Plan presents a broad range of recommended projects, some of which are critical and some of which are lower priority. It is important to recognize that the recommendations of the LMWP are based on assessment of the existing water management conditions and practices, and on projected water demand growth. Changes in scope, details and phasing of certain projects may be required over time to respond to changes in population growth, new developments, new regulations, emerging technologies, etc. Although this Master Plan maps out major expenditures for the Voinjama water sector through 2031, conditions will change and flexibility is important in terms of infrastructure planning, operations, and management. The Plan should be reviewed and revised as necessary to reflect new initiatives and/or major changes in

[4] LMWP formally established an Engineering Work Group (EWG) consisting of a core group of representatives including LWSC, MLME, and MoPW responsible for assisting with development of design criteria and reviewing technical reports relevant to the planning and design of water supply systems.

priorities or conditions. It is recommended that a complete review and written update be performed at least once every five (5) years.

The format of the Master Plan follows the process diagram presented in the following figure.

Section 2.0 describes water supply challenges, opportunities, and project-specific challenges at the national and local levels and recommendations for addressing them.

Section 3.0 of the Plan provides background information on the existing and projected population estimates and anticipated water demand rates. A complete summary of existing conditions was documented in the May 2012 Situational Analysis Report.

Section 4.0 outlines the water system components, including the potential sources of water, treatment options, storage options, distribution options and pumping systems.

Section 5.0 evaluates and recommends the source of water for the proposed improvements. Based on the proximity of the supply source to the demand centers, the quantity and quality of water available, and any seasonal conditions; the other components of the water system can be evaluated and recommended.

Section 6.0 presents planning-level construction cost estimates, as well as an estimation of the operation and maintenance (O&M) costs for the proposed options. It also contains a summary of the cost-benefit analysis conducted for the proposed improvements.

Section 7.0 summarizes Tetra Tech's recommendations regarding water infrastructure investment needs. The recommendations are categorized as Quick Impact Projects (QIPs), Short Term Projects (first 18 months), Medium Term Projects (18 to 48 months), and Long Term Projects (48+ months).

Section 8.0 outlines the existing sanitation practices in Voinjama, based on observations and the results of the socio economic survey. The impact of providing improved access to drinking water is assessed to describe how it may change the sanitation practices and the amount and type of wastewater generated. The section also outline basic consideration the City should consider as the LMWP project progresses.

Section 9.0 outlines the funding, organizational, procurement and asset management, schedule, and other considerations for the implementation of the project.

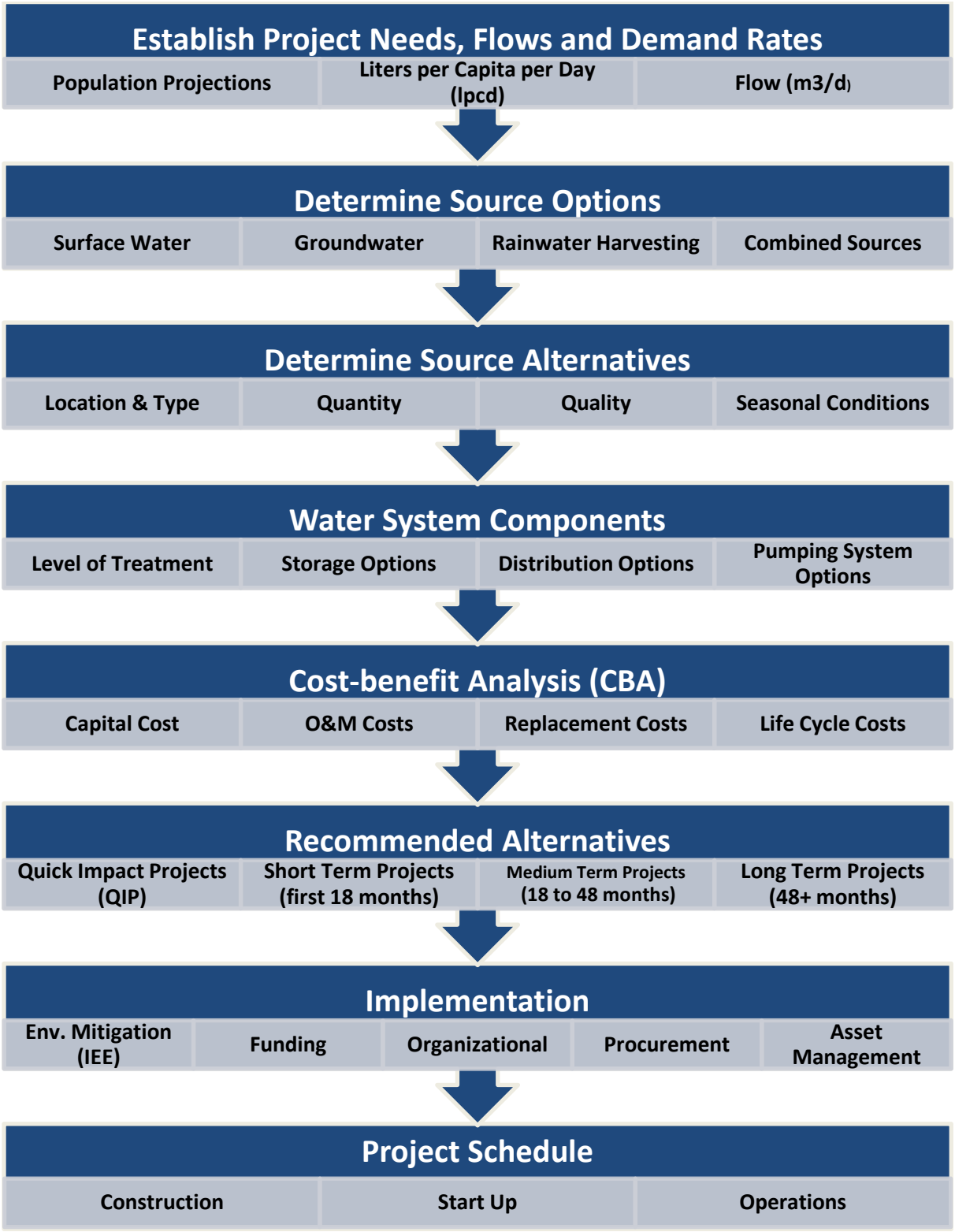


Figure 1-2 Voinjama Master Planning Process

2.0 CHALLENGES AND OPPORTUNITIES

2.1 WATER SUPPLY CHALLENGES

The primary difficulty present in Voinjama is the lack of a currently dependable source of safe drinking water available to the residents. Related challenges include:

- There is no existing municipal water supply, treatment, storage or water distribution system.
- According to the survey of 195 households in Voinjama conducted during the Situational Assessment, only 59% of households reported having regular access to safe drinking water within a 30 minute round-trip of their home.
- Although present water demands are being met by a variety of distributed sources such as dug wells with hand pumps, boreholes, and direct surface water abstraction, quality and quantity issues associated with these sources has resulted in insufficient access to improved water supplies necessary to meet daily needs and protect public health.
- For drinking and cooking purposes, approximately 54% of household survey respondents reported using protected wells with hand pumps or dug wells as the main source of drinking water. No one (0%) reported obtaining water from water vendors. Around 5% of residents get water directly from a surface water source.
- The primary source of water is from wells located throughout the city that are withdrawing water from the contaminated shallow aquifers. Testing conducted by LMWP and reported in the Situational Analysis Report showed that 65% of the 23 source samples from throughout the city indicated coliform presence. The consumption of contaminated water is detrimentally affecting the health of the residents. Twenty Four percent (24%) of the household survey respondents reported that one or more members of their household had diarrhea within the last 30 days. Eleven percent (11%) reported that a household member had contracted dysentery and 17% had contracted typhoid in the last 30 days. Six percent (6%) reported they had a death in the family in the past 12 months, and 58% of those cited the main causes of death being diarrhea.
- The residents have learned to avoid certain hand dug wells due to water quality problems, therefore limiting the number of source to draw water.
- There is no local management structure or agency in place that is equipped or funded to operate or oversee operation of a municipal water supply system.
- There is a lack of coordination at the local and national levels regarding water supply development efforts.
- Voinjama does not possess a reliable source of electricity to provide power for water treatment processes and pumps, and LMWP is not aware of any clear plan or schedule for provision of power from a national grid.
- Voinjama lacks a wastewater and solid waste management system.

- The current methods of wastewater disposal permit wastewater to infiltrate and contaminate the shallow aquifer used to supply hand dug wells, resulting in bacterial contamination as identified by previous LMWP water quality testing.
- The migration of displaced or re-settled persons into and around Voinjama is expected to continue and impact the competition between demand and the supply for a safe drinking water supply.
- Prolonged dry seasons, drought, population increases, and economic needs have heightened competition for scarce water resources resulting in anecdotal reports of conflicts related to water.

2.2 WATER SUPPLY OPPORTUNITIES

There are number of opportunities for the LMWP to improve the water supply situation in Voinjama:

- Good economic prospects via agriculture and mining within the region which would be enhanced by access to safe, convenient, reliable, and affordable water.
- The provision of water to unserved residents.
- The provision of safe drinking water to a large population of Voinjama.
- The possibility to support existing plans to improve and expand the support of the regional industry in Voinjama
- The ability to improve the quality of life by providing enhanced water service.
- The chance to reduce incidences of water borne disease and anecdotally reported conflicts related to the lack of water.
- The prospect to promote an awareness of the importance of a safe water supply.

2.3 PROJECT-SPECIFIC CONSTRAINTS

There are specific constraints and challenges in Voinjama that can affect the development and evaluation of various water system components and alternatives being considered in the master planning process:

- Limited available records of river stage readings indicate the primary water source, the Zeliba River, has low or no flow for prolonged periods during the dry season.
- Collection of necessary survey and field data is hindered by the location of the project in a remote section of Liberia and quality of roadway and other access infrastructure.
- Operation and maintenance requirements may limit consideration of certain alternatives given local capacity limitations.
- Voinjama lacks all the components of an established and reliable municipal infrastructure that are necessary to support a fully functioning water supply system, particularly roadway access and electricity.
- Voinjama and LWSC lack supporting institutions at the local level to finance, maintain, and manage a water supply system.
- Existing water quantity and quality from the most widely used current water source, the shallow aquifer by means of hand dug well, are not adequate and suitable for human consumption.
- Historic information related to the condition of the previous water system and existing well locations is limited due to lost or non-existent records.
- Development of alternatives is impacted by the location of the project and limited availability of spare parts and service for equipment.
- There is a lack of construction firms with experience directly related to municipal water supply infrastructure in Voinjama and Liberia more broadly.

- Few records are available regarding minimum stream flows, seasonal water quality variations, and other environmental and contextual data.
- Voinjama lacks any historic records of previous water use that allow for developing water consumption rates, water use classifications, and the ability to determine average and peak demands for planning purposes.

Figure 2-1 Previous water main exposed by erosion and roadway grading

3.0 DEMOGRAPHICS AND EXISITNG CONDITIONS

3.1 POPULATION ESTIMATE

The population estimates for Voinjama will provide one of the building blocks for projecting water consumption and demand. For planning purposes the LMWP population estimates are forecasted to the year 2031 based on the 2008 Liberia National Census.

The base year (2011) population of Voinjama for the Liberia Municipal Water project is 15,300 which is based on projections from the 2008 National Census.

TABLE 3-1 outlines the current and projected populations based on the 2008 National Population and Housing Census, and growth rates reported by LISGIS:

TABLE 3-1: VOINJAMA POPULATION PROJECTIONS

Basis	
2008 Population[1]	14,453
Growth Rate[2]	1.3%
Projections[3]	
Base Year (2011)	15,300
5 Years (2016)	16,100
10 Years (2021)	17,200
20 Years (2031)	19,600

[1]Per Republic of Liberia 2008 National Population and Housing Census. Populations shown are for city enumeration areas only (data provided by LISGIS).

[2]Growth rate during the period 1984-2008 by county (Lofa - Voinjama), per 2008 Liberia Census Table 4. Population Growth Rates and Average Household Size.

[3]Rounded to nearest 100.

The distribution of the 2008 population is shown in the Figure 3-1 Distribution of Population by 2008 Enumeration Areas.

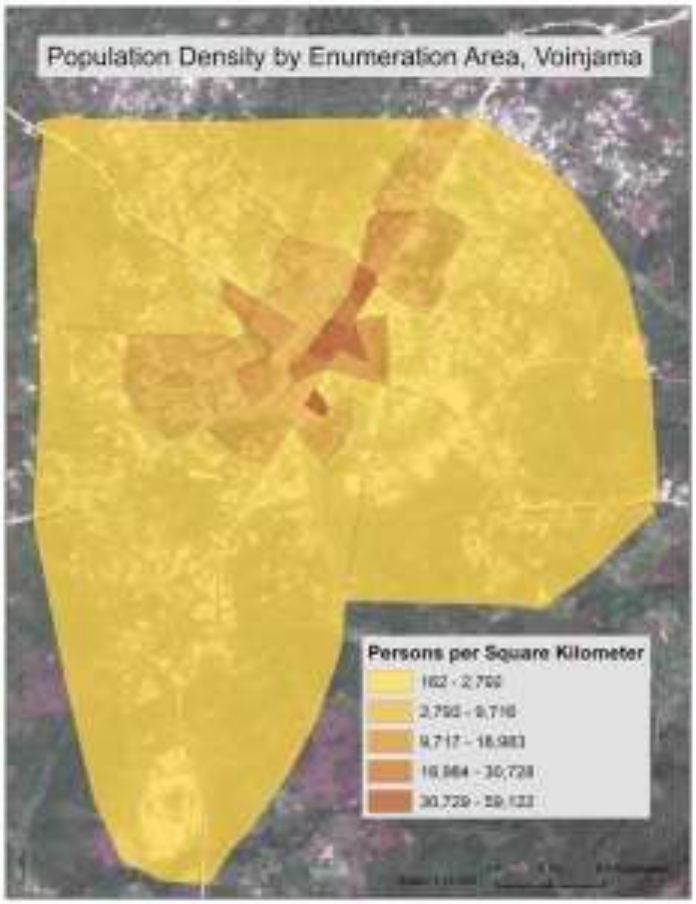


Figure 3-1 Distribution of Population by 2008 Enumeration Areas

3.2 PHYSICAL ENVIRONMENT

3.2.1 Topography

Lying in the north-western corner of the country, Voinjama is the county capital of Lofa County. Lofa is bordered on the east and north by the country of Guinea, to the west by Country of Sierra Leone and on the south by the counties of Gbarpolu and Bong counties. Lofa County is now the second largest County in Liberia. Lofa County and the area surround the developed portion of Voinjama is composed of tropical rain forest including high forest, broken forest and low bush regions.

The county is mountainous in the north and hilly in the south and has an elevation of about 550m, with elevations nearby reaching over 1,000m (1km). Most part of the County is covered by tropical rain forest. It is drained by little rivers. The main rivers in the county include the Lofa, the Mano River which runs from Guinea, and the St. Paul River. These rivers are all discharged into the Atlantic Ocean.

Prior to the war, the region was used for cultivating coffee, cacao, rice, and other crops. The area around the city is largely under cultivation and the county is a major agricultural area of Liberia. Economic activity in Voinjama is currently limited.

The physical geological condition of the area consists of crystalline bedrocks. The rest of the area is covered with layers of laterite, which carries insignificant alluvial deposits that causes huge contamination along the streams.

The iron ore mined in Lofa County is from the Wologissy Mountains. In the 1980s, a Liberian Mining Company signed a deal with the Government to extract the mineral. For that purpose, railways through Mano River Congo was constructed to ease the transportation of the ore to Monrovia port for exportation.

The Zeliba River, which was the main source of water intake constructed for the former treatment facility in the 1980s is located at about a kilometer north the city overlooked by the newly constructed presidential Lodge.

3.2.2 Climate

The climate in Voinjama is tropical, hot and humid, and experiences a dry season and a wet season. The rainy season typically continues from mid- April to mid-October. The dry season will generally begin in November and continue through April. The region is located in the climatic zone of tropical rain forest with dry season between November and April. It has an annual precipitation of about 7.92ft (2.4m).

The range of temperature in Voinjama varies from 24C to 30C (75F to 85F). The wind generally blows from the Northeast during the dry season, but changes to a southwesterly direction during the rainy season.

3.3 LAND USE AND WATERSHED PROTECTION

3.3.1 Land Use Description

Land use classification was undertaken using ERDAS Imagine image analysis software. An algorithm was used to sort the pixels of the satellite imagery into one of 25 classes of reflectance. Based upon the color captured by the satellite, it is possible to classify each pixel as belonging to one group or another. The 25 classes created by the computer were then organized into four main land types using a visual interpretation of the image.

Generally, undisturbed forest is darker and thicker than disturbed forest or shrub land, which allows those two categories to be delineated. Highly disturbed land is typically more reflective. Urban areas often contain highly reflective roofs and beaten tracks, allowing them to be pulled out from the image as separate classes. Once the four classes were determined, a smoothing algorithm was run over each image to remove small clumps and individual pixels that were misclassified. Often, there will be shadows, hillsides, and other landforms that cause a pixel to be incorrectly identified. Smoothing helps mitigate this and create more coherent and useful groups of pixels. When complete, the data was compiled and overlaid onto the mapping to create the land use figures for each city.

Land use classifications have been separated into four categories – primary forest, secondary forest, primary urban and secondary urban. Primary forest describes those areas that are largely undeveloped and have established vegetation in its natural state. These portions of the cities have not been significantly disturbed in any fashion, be it for commercial, residential, agricultural, or other uses. They are shown on the mapping as a dark green. Secondary forest areas, while still composed mainly of natural ground cover, have scattered pockets of development. The vegetation is generally thinner and more scattered. They are usually found on the fringe of the secondary urban areas and are indicated by light green shading.

The primary urban classification highlights those sections of the cities that are most densely developed and are likely to contain the largest populations and/or are the most heavily disturbed. As previously noted in the watershed discussion, these areas are also the most likely to be major sources of surface and groundwater contamination. They are identified on the land use maps as a deep red/maroon color. The sections of the mapping shown in light red have been classified as secondary urban. Secondary urban areas are less populated areas located adjacent to the larger population centers. While still developed, they buildings are more spread out and scattered. This classification can also represent cleared or previously disturbed land that is immediately adjacent to developed urban areas.

Voinjama's land use distribution is nearly split equally amongst three categories – secondary forest, primary urban and secondary urban. They represent approximately one-third each. Similar to Sanniquellie, the majority of the primary urban areas are located along major roadways in the center of the city. The remainder of the primary urban areas are found along secondary roads branching out from the city center. Secondary urban areas are located around the outer perimeter the primary urban sections of the city.

Secondary forest is responsible for thirty-one percent of Voinjama's ground coverage. These areas are scattered throughout the city, generally found along the perimeter and the outer edge of the secondary urban areas. Primary forest areas are found in scattered clusters around the outer perimeter of the city. They are loosely grouped and do not cover large, contiguous stretches of land. Primary forest represents less than ten percent of the total land use in the city. **TABLE 3-2** provides a summary of the land use types in Voinjama.

TABLE 3-2: VOINJAMA LAND USE SUMMARY

Land Use Type	Percentage Within the City Limits
Primary Forest	8
Secondary Forest	31
Primary Urban	27
Secondary Urban	34

3.3.2 Watershed Protection

A watershed represents the land area that contributes to a surface water body — stream, river, lake, etc. The boundaries of a watershed are generally defined by localized high points that direct the flow of water into or away from a given water body. Surface waters represent the collection points in each watershed. Large watersheds comprise many smaller, sub-watersheds that collect and convey water to the larger surface water. As a general rule, rivers often represent the convergence of many smaller watersheds, namely the watersheds associated with feeder streams that contribute to the river.

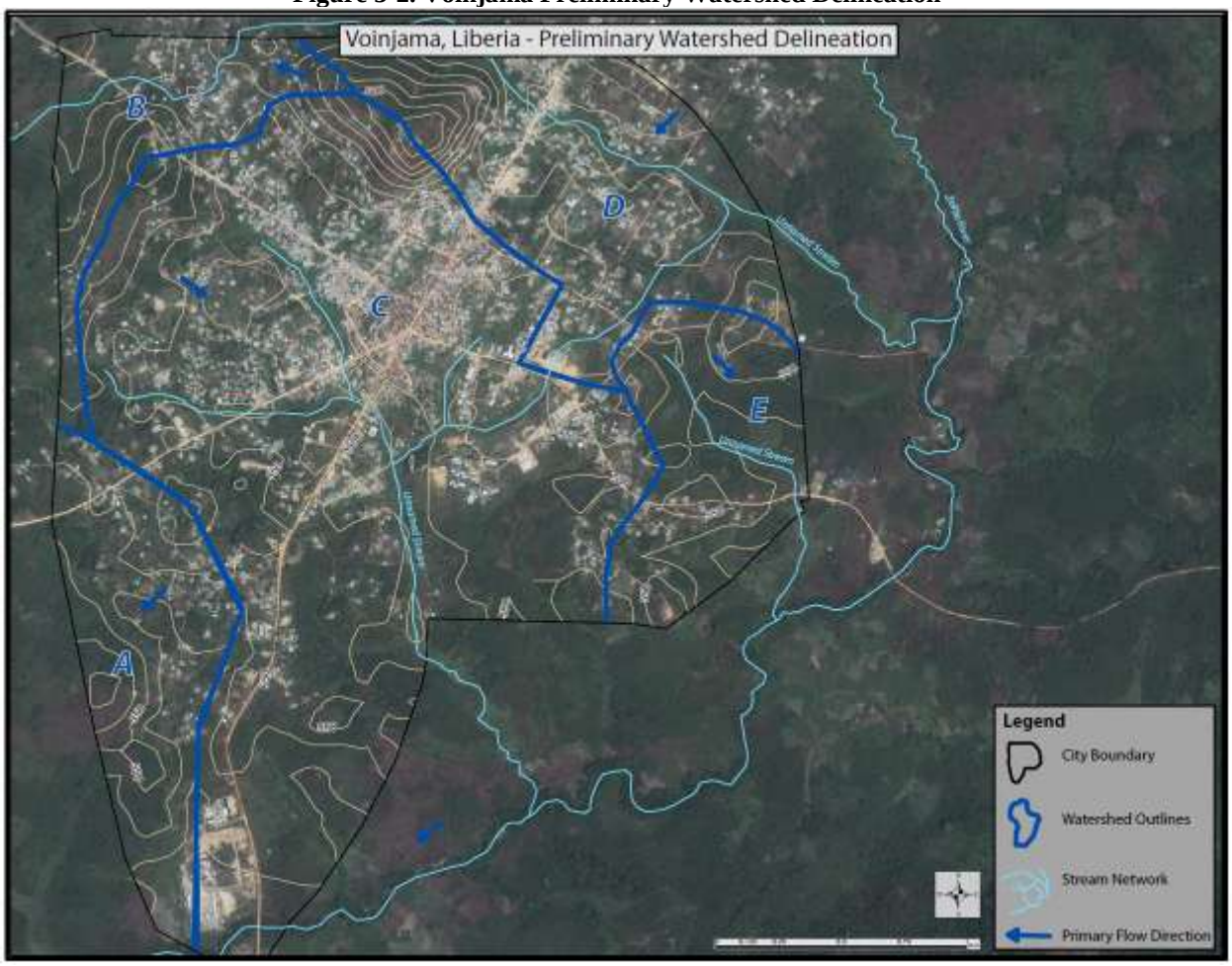
The quality of a watershed is directly related to the predominant land uses within it, and in some cases, upstream of it as well. Surface waters whose watersheds are composed predominantly of undisturbed, forested areas usually contain cleaner water than surface waters whose watersheds are composed predominantly of disturbed, urban areas. Watersheds composed of undisturbed, forested areas are more likely to contain potable surface water sources than watersheds composed of disturbed, urban areas. They are also more likely to have a reliable aquifer system, as rainfall is allowed to naturally percolate through the ground surface to recharge groundwater resources. Conversely, watersheds with large urban developed areas have a higher probability of contamination and have less reliable groundwater sources. Higher contamination rates are due in large part to the higher waste generation rates associated with large population areas. For example, improperly constructed and/or managed latrines can be detrimental to groundwater resources, as leachate from these systems is a significant source of contamination. Solid waste generation and improper waste management are direct sources of contamination for surface waters

as well. Watersheds with higher probabilities for contamination can also directly affect downstream surface water supplies. Contamination allowed to enter upstream sections of feeder streams or rivers will flow downstream and potentially compromise other surface water supplies.

Additionally, watersheds with a high impervious surface/pervious surface ratio lose infiltration of storm water to subsurface aquifers as a result of the impervious surfaces intercepting runoff before it can infiltrate. Non-vegetated surfaces are more susceptible to erosion than are vegetated surfaces. As such, it is important to properly develop land to find a balance between meeting the resource demands of the populations and protecting the water quality of the region's watersheds. Unless the storm water runoff generated by these surfaces is properly managed, it can lead to depleted aquifers, increased erosion that results from unmitigated, concentrated storm water discharges, and impaired surface water quality.

The watersheds shown on Figure 3-2 have been delineated using topographic information provided by LISGIS, information collected during the Scoping and Detailed Analysis visits, and information contained in record documents collected during the Desktop Study. The figures will be updated as additional data is gathered through our ongoing coordination efforts with LISGIS and other agencies.

Figure 3-2. Voinjama Preliminary Watershed Delineation



Voinjama is broken into five major watersheds – A through E. Most of the watersheds either contribute directly to the Zeliba River or flow through secondary surface waters before reaching the river. A number of small, unnamed streams carry water from the hill located at the northern part of the city to the Zeliba River. Many of these streams feed irrigation ditches that are used to provide water to rice patties and other agricultural development. In general, Voinjama's primary drainage pattern trends from northwest to southeast.

Voinjama is the most developed of the three cities included in LMWP and the quality of the surface water bodies is representative of Voinjama's land use distribution. Many are heavily silted, filled with trash and other debris, and are often used as dumping grounds. Downstream quality is better. However, Voinjama's vegetation is not as thick or contiguous as Sanniquellie's and Robertsport's. As a result, visual indicators of compromised water quality tend to be present even on the outskirts of the city. Heavy erosion rates leave the water silted and muddy and trash is still visible in river tributaries.

Proper management of development and forestry activities is crucial to protect the overall quality of any watershed, especially those whose resources are critically important to the people who rely on them. Potential new groundwater sources will be located such that they limit their exposure to sources of contamination such as latrines or grave sites. Local management groups will be educated on the importance of locating water sources outside the zone of influence of potential contamination sources. As the LMWP team advances through the project, we will continue to foster strong working relationships

with other ongoing programs focusing on watershed protection, seek opportunities to protect sensitive resource areas, and pursue responsible development programs.

3.4 INFRASTRUCTURE

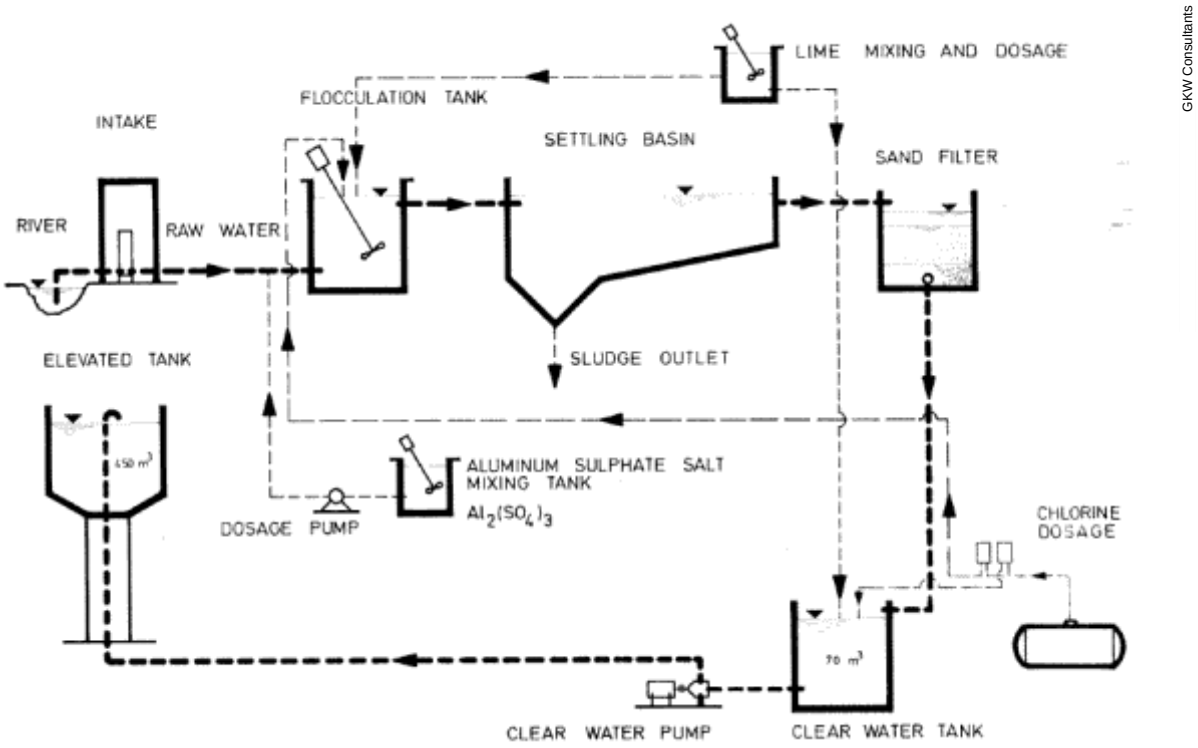
3.4.1 Previous Water Infrastructure (Piped Water)

The former intake structure withdrew the untreated/influent raw water from the Zeliba River and transmitted it to the Water Treatment Plant (WTP) located approximately 350 feet away. The WTP was a conventional filtration treatment facility. The treated water was pumped from the WTP through a dedicated ductile iron transmission main to the elevated water storage tank. All the flow passed through the elevated storage tank before entering the distribution system. The storage tank was elevated to provide adequate pressure to the system and sized to provide the volume required during periods of peak flow. The distribution system was composed of PVC (plastic) pipe. The distribution system purveyed water to customers and users by means of private metered building connections or standpipe kiosks.

The intake structure and associated site are composed of a water control structure, bar screen, and raw water pumps. The water control structure or system extends from the WTP to the intake structure as an elevated foot path or earthen dike, with a height of approximately 1 meter. A steel water control structure spanning the Zeliba River makes up the next component of the water control system. From the steel control structure, an earthen dike extends approximately 0.2 kilometers to an upland area, above the flood plain, on the opposite side of the river. The purpose of the impoundment was to maintain adequate submergence for the vertical lift centrifugal pumps in the intake structure, and to maintain an adequate supply during drought conditions.

The WTP facility was constructed to include chemical storage and application, a coagulation/flocculation basin, a sedimentation basin, two gravity filters, a treated water tank, treated water/effluent discharge pumps, backwash pumps, chlorine storage and application, power generation facilities and fuel tanks, and an office/staff building. Essentially, none of the components and appurtenances of the chemical storage/application and power generation systems remain.

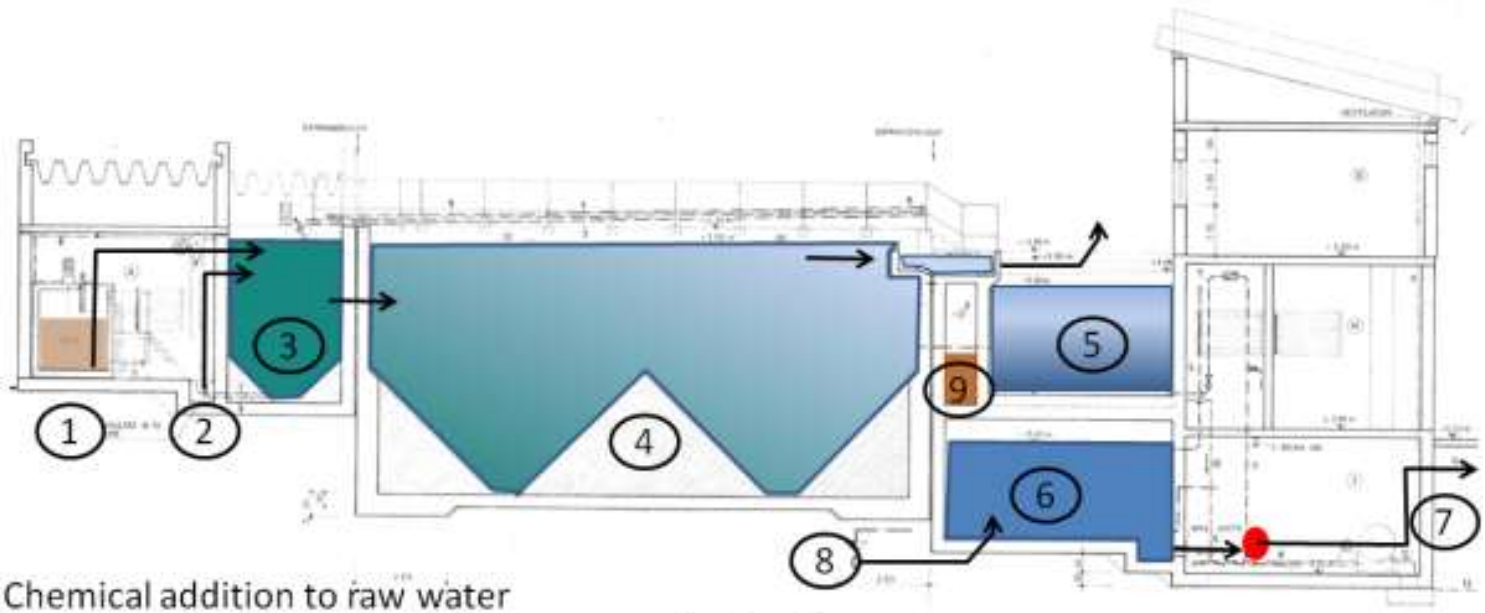
Figure 3-3 Process Flow Diagram for Voinjama Conventional WWTP



A separate concrete building located adjacent to and up-slope of the WTP appears to have housed offices, staff housing and possibly a laboratory. Most of the doors, windows and roof sections of the office building were missing or in a state of disrepair.

No fencing or other protection to secure the intake structure, WTP, or office building is present. The site is accessible by a dirt road and driveway. The site surface is grassed. Larger trees and vegetation surround the site but have not significantly encroached during the decades of the facility's disuse.

Since plans and other documentation are not available for the previous Voinjama WTP, an evaluation of the dimensions of the similarly sized and configured Gbarnga WTP was conducted. Figure 3-15 illustrates how the influent from the intake structures flows through the coagulation/flocculation tank, the sedimentation basin, and filters, before being chlorinated and pumped into the distribution system. Table 3-8 and Table 3-9 summarize the dimensional size and volumes of these components in the columns on the left and the estimated WTP Capacities based on industry standard design criteria on the right.



1- Chemical addition to raw water
2- Raw water feed from Intake Structure
3- Coagulation and Flocculation Tank
4- Sedimentation basin with hopper bottom
5- Rapid sand filtration basins
6- Chlorine contact clearwell
7- High lift pumps to transfer water to distribution system
8- Chlorine addition for disinfection purposes
9- Filter backwash waste channel

Figure 3-4 Schematic diagram of flow through previous WTP[5]

[5] Based on 1974 design drawings for the City of Gbarnga, Liberia, prepared by GKW Consulting Engineers GmbH, Germany that represents a similar design layout and configuration to the LMWP project cities of Sanniquellie and Voinjama.

Table 3-3 Intake, Flocculation and Sedimentation Basin of Previous WTP

Location & Description[6]	Qty		Design Criteria[7]		Estimate WTP Capacities	
Intake Structure						
Number of Pumps	3					
Capacity	Unknown				Unknown	gpd
Flocculation Basin						
Length	9.2	ft.	Detention Time		318,000	gpd
Width	9.2	ft.	0.5	hours		
Depth to Hopper	9.9	ft.	Velocity		459,000	gpd
Cross Sectional Area	91.5	SF	0.5	feet per min		
Surface Area	85.4	SF	1.5	feet per min	1,379,000	gpd
Volume	845.2	C				
Hopper Shape	Pyramidal					
Hopper Depth	2.7					
# of Hoppers	1					
Volume of Hoppers	42.7	CF				
Total Volume	887.9	CF				
Total Volume	6,641	Gals				
Sedimentation Basin						
Length	39.6	ft.	Detention Time		349,000	gpd
Width	19.8	ft.	4	hours		
Depth to Hopper	8.9	ft.	Velocity		950,000	gpd
Cross Sectional Area	176.4	SF	0.5	feet per min		
Surface Area	784.1	SF	Weir Loading		396,000	gpd
Volume	6,986.2	C	20,000	gpd/LF		
Hopper Shape	Pyramidal		Overflow Rate		564,000	gpd
Hopper Depth	2.7		0.5	gpm/SF		
# of Hoppers	2					
Volume of Hoppers	797.0	CF				
Total Volume	7,783.2	CF				
Total Volume	58,218	Gals				

[6] Based on 1974 design drawings for the City of Baraga, Liberia, prepared by GKW Consulting Engineers GmbH, Germany that represents a similar design layout and configuration to the LMWP project cities of Sanniquellie and Voinjama.

[7] Recommended Standards For Water Works, 2012 Edition, Policies for the Review and Approval of Plans and Specifications for Public Water Supplies - A Report of the Water Supply Committee of the Great Lakes--Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers

Table 3-4 Filters, Chlorination and Summary of Previous WTP

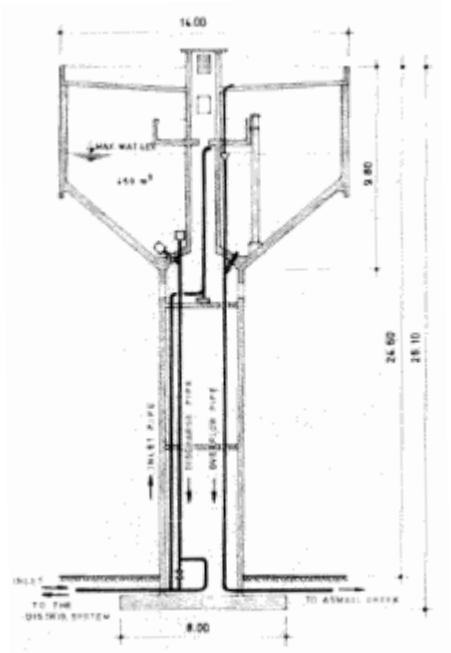
Location & Description[8]	Qty		Design Criteria[9]		Estimate WTP Capacities	
Rapid Sand Filters			Range of Loading Rates			
Number of Basins Total	2		2	gpm/SF	188,179	gpd
Number of Online Basins	1		2.5	gpm/SF	235,224	gpd
Length	13.2		3	gpm/SF	282,269	gpd
Width	4.95		3.5	gpm/SF	329,314	gpd
Surface Area	65.34		4	gpm/SF	376,358	gpd
Chlorine Contact Tank						
Length	16.3	ft.	Detention Time			
Width	23.3	ft.		at flow of	318,000	gpd
Depth	6.9	ft.			89	mins.
Configuration	Baffled					
Surface Area	380.0	SF				
Total Volume	2,633.6	CF				
Total Volume	19,700	gals				
SUMMARY						
Estimated Capacity of Previous WTP =					318,000	gpd
Filter Loading with One Filter on Line =					3.4	gpm/SF
Filter Loading with Two Filters on Line =					1.7	gpm/SF
Projected 20 Year Average Daily Demand =					336,340	gpd
Surplus / (Deficit) WTP Capacity =					(18,340)	gpd

[8] Based on 1974 design drawings for the City of Baraga, Liberia, prepared by GKW Consulting Engineers GmbH, Germany that represents a similar design layout and configuration to the LMWP project cities of Sanniquellie and Voinjama.

[9] Recommended Standards For Water Works, 2012 Edition, Policies for the Review and Approval of Plans and Specifications for Public Water Supplies - A Report of the Water Supply Committee of the Great Lakes--Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers

The route of the underground transmission main from the WTP to the elevated water storage tank could not be determined. No air release valves were located along the route. The physical condition, diameter, types of joints, and methods of restraint of the buried transmission main could not be assessed. The transmission main could be salvageable, depending on the results of investigatory testing, which would include pressure testing.

The 450 cubic meter elevated storage tank is constructed of reinforced concrete and is located on a high point between the WTP and City of Voinjama. Previous reports indicated that the tank was sized to provide firefighting and emergency storage, as well as to meet the daily demands. Like the WTP, the design of the Voinjama elevated storage tank is the same as Sanniquellie's tank in all respects except for overall height. Since the Voinjama tank is located on a taller hill (with respect to the service area) the height of the structure is less. During the visit, the team noted small stones or pieces of concrete striking the concrete apron; therefore a structural evaluation of all elevated storage tanks is recommended. The reinforced concrete tank and the internal piping of the water tank may be salvageable, depending on future pressure testing and structural analysis. The control valves (gates and butterfly valves) within the internal piping are not salvageable.



GKW Consultants

Figure 3-5 Schematic Diagram of Voinjama Elevated Storage Tank

By appearances, the distribution system coverage once extended to the majority of the populated areas, although some older and newer areas of development were not served. Many of the roads showed extensive erosion that resulted in large vertical drops from building stairs to the roadway surface (significantly more than Sanniquellie). At various locations the PVC pipe was observed exposed due to the erosion and/or by the re-grading of the roadways.

Standpipe stations served as the main points of delivery for the previous water distribution system. These stations, frequently referred to as kiosks, are metered concrete structures located to serve selected areas of the city. It is estimated that approximately 20 kiosks were installed throughout the town. The physical conditions of the kiosks varied from poor to good, with many located adjacent to erosion areas and others overgrown with vegetation. Most kiosks lacked several original appurtenances, including the metal access hatch, dispensing taps, meters, and above-grade piping. It was reported that the original distribution system included some private services, but only two private service lines with above-ground meters were observed. In each case the meter was damaged.

Figure 3-6 depicts the former extent of the Voinjama water distribution system.

Figure 3-6 Schematic Diagram of Voinjama Distribution System

No portions of the former water treatment system were found to be operational. Some portions of the former distribution system may be salvageable, pending additional testing. The majority of all mechanical and electrical components at the intake structure and the adjacent water treatment plant (WTP) have been looted. The concrete structures form the shell of the remaining intake and WTP, and are the only potentially salvageable components at these sites.

The reinforced concrete elevated storage tank and the internal piping of the water tank may be salvageable (depending on future pressure testing and structural analysis). The control valves (gates and butterfly valves) within the internal piping are not salvageable.

No portion of the transmission main or distribution system is considered salvageable. Most of the kiosk structures could be salvaged and rehabilitated, if required, but the effort may not be cost-effective.

3.4.2 Current Water Infrastructure: Wells and Hand Pumps

The mechanical features and locations of the wells and hand pumps are best described via the map in

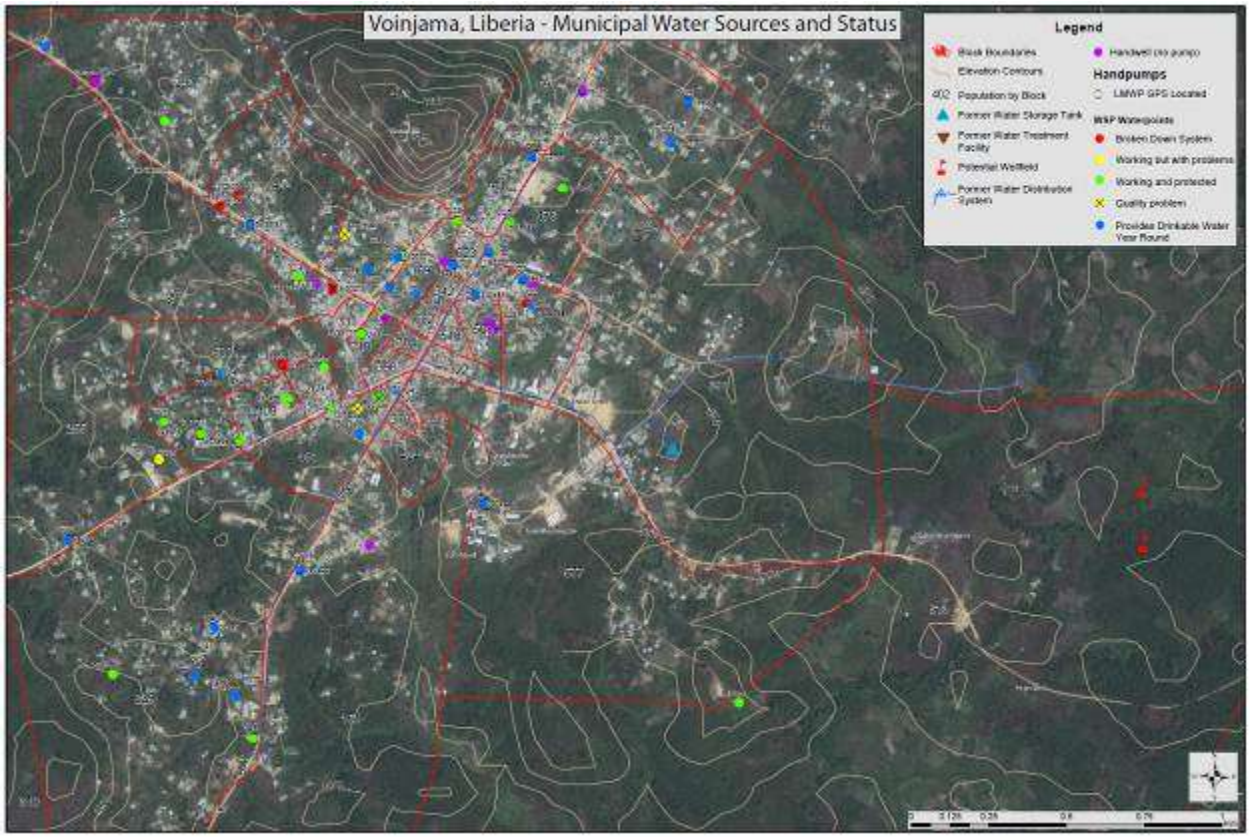


Figure 3-7 Voinjama Municipal Water Sources and Status which summarizes well type, water quality, and functionality.

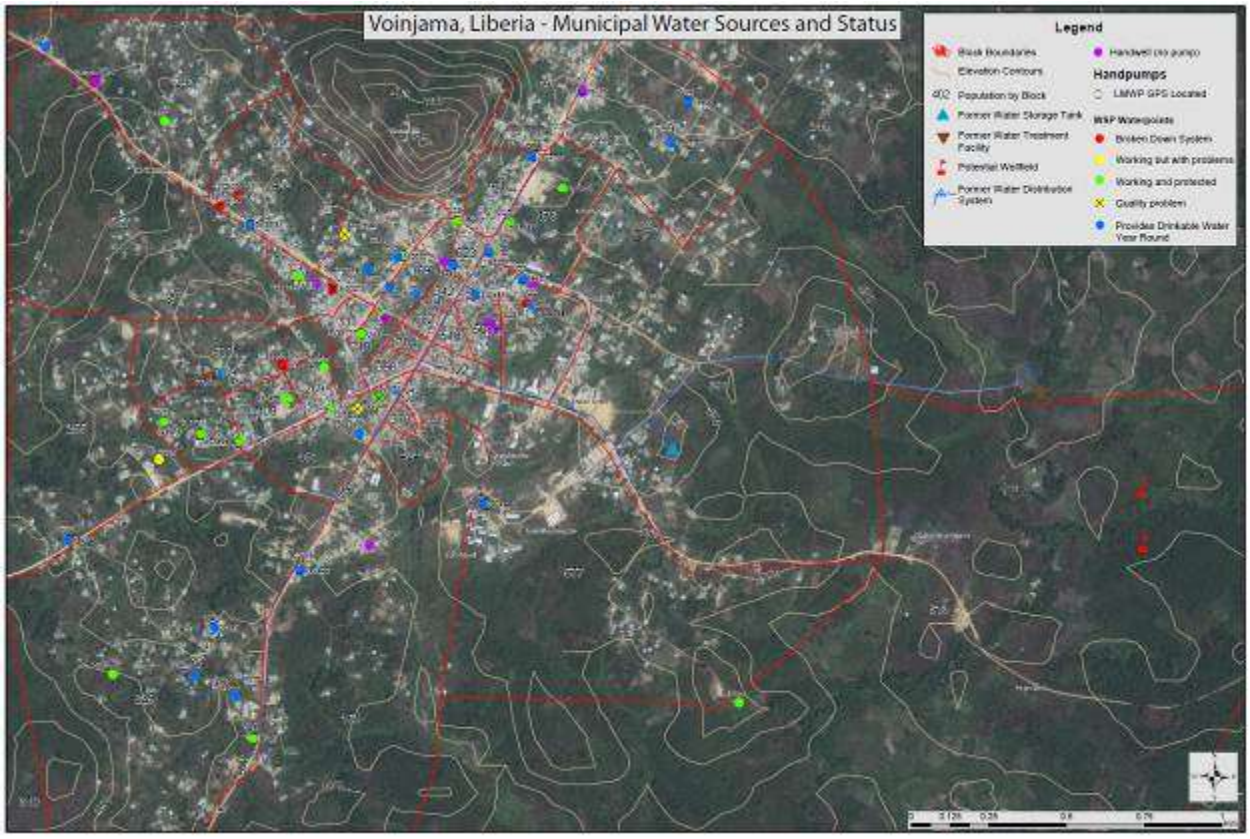


Figure 3-7 Voinjama Municipal Water Sources and Status

Groundwater supplies the majority of water to Voinjama via hand-dug wells with hand pumps. The current regulation of hand pumps is the responsibility of the Department of Public Works. However, they lack the organizational structure, capability and other resources to provide the basic oversight and monitoring of existing hand pumps.

It appears that (1) the quick reaction by the government and donors during the emergency period (following the conflict) to provide wells, and (2) the lack of structure to support the local regulators, permitted wells to be installed without adequate supervision or adherence to the government water supply standards. The immediate response also did not permit construction of wells to be documented and/or inspected. Therefore there was no database of wells until the recent WSP survey was conducted in 2011. The database has been developed and shared with the County Health Teams and Department of Public Works and should be maintained and utilized to track operational conditions, water quality, and water quantity.

The quantity of groundwater produced in Voinjama from hand pumps varies from a year-round supply to no or limited supply during the dry season. It appears that many wells were quickly constructed and that certain well installers were more qualified and experienced, constructing wells that are less likely to run dry. The Government of Liberia (GoL) presently has requirements (The Guidelines for Water and Sanitation Services in Liberia, Oct 2010) regarding the static water level in the well when constructed.

Wells must have a sustainable yield of at least 264 gallons (1,000 liters) per hour. As a proxy guideline for yield, any hand-dug well constructed in the raining season — the period from 1 May to 31 October — must have a static water column of at least 20 feet (6 meters). Any hand-dug-well constructed in the dry season — the period from 1 November to 30 April — must have a static water column of at least 15 feet (4.5 meters).

In the majority of wells in which depth measurements were taken, it appears that the well installers did not comply with the above-noted requirements. It should be noted that these requirements may not have been adopted and in place during the emergency period.

Hand pumps are mechanically operated and experience a wide range of operating conditions — from good to poor to non-functioning. Comparing the conditions observed during the Spring 2011 survey by WSP to LMWP observations made in December 2011 reveals information regarding repairs and breakdowns which indicates the life-cycle of the hand pumps. This information should be considered in future analyses.

In general a person from the nearby community of each well was selected or has taken on the role of caretaker. The informal position could include the responsibilities of repairing the well, collecting fees, and limiting the hours of operation of the well. There was no local supply of spare parts to repair broken hand pumps, which results in pumps remaining unused or degrading to a permanent state of disrepair. There is no evidence of water quality sampling or water quantity measurement.

No formal training is provided to repair or operate the hand pumps. The only training indicated occurred between residents. Experienced and trained residents trained others in the communities.

To address slow recharge rates during the dry season, the caretakers of the wells often decided to manage the hours of operation by chaining the well handle or locking the well gate. Hours of operation were also limited to prevent non-community personnel from using the well. When restricted, the hours of operation usually comprised 2-3 hours in the morning and 2-3 hours in the late afternoon.

Table 3-5 lists the estimated number of Voinjama residents distributed geospatially to the nearest hand pump in an attempt to estimate the number of people who are likely to use a given well as their water source. The table includes a distribution that considers all hand pumps (the "All Wells" column) and a distribution that considers *only* wells characterized as having good quantity and quality by the WSP 2011 survey (the "Good Qty. & Quality" column). Since the number of wells with both good quality and good quantity is limited, the number of persons per well increases. The number of persons estimated per well should be evaluated in light of the Public Works guideline limit of 250 persons per hand pump well.

This analysis only addresses hand pumps and does not consider alternative source such as surface water supplies and water vendors. The analysis does not take into account geographic or other factors that might cause a user to choose a well that is further away than his/her nearest well.

TABLE 3-5: VOINJAMA HAND PUMP POPULATION DISTRIBUTION (PERSONS PER PUMP)								
Well #	All Wells	Good Qty & Quality Wells	Well #	All Wells	Good Qty & Quality Wells	Well #	All Wells	Good Qty & Quality Wells
V01	83	-	V30	254	-	V60	235	-
V02	60	-	V31	166	-	V61	25	182
V03	562	-	V35	317	-	V62	401	-
V05	186	371	V36	120	-	V63	192	-
V06	201	-	V37	288	-	V64	180	-
V07	1,034	1,239	V38	80	368	V65	147	-
V08	50	261	V39	146	177	V66	294	-
V09	102	875	V40	51	62	V67	427	-
V10	350	-	V41	18	-	V68	209	537
V11	353	-	V42	215	-	V69	16	323
V12	335	-	V43	54	-	V70	110	-
V13	373	-	V44	52	94	V72	815	1,451
V14	115	944	V45	19	-	V78	333	599
V15	192	-	V46	45	-	V79	207	-
V16	232	-	V47	60	-			
V17	66	-	V48	236	-			
V18	406	-	V49	231	821			
V20	406	1,035	V50	314	-			
V21	658	-	V51	318	-			
V23	127	181	V52	178	-			
V24	136	-	V53	145	-			
V25	301	-	V54	51	-			
V26	158	-	V55	409	929			
V27	545	1,570	V56	66	518			
V28	237	-	V58	83	-			
V29	472	-	V59	23	-			

The level of protection provided by properly siting the wells installed during the emergency period varied. Many wells installed during the emergency period were observed to be located improperly with respect to existing latrines and graves. In these instances, wells were constructed down gradient of the potential contamination sources. As a direct result, the strong potential exists for the quality of the wells to be compromised. The importance of informing residents of proper well protection practices and maintaining proper offsets from sources of contamination is still critical and present today.

The Voinjama County Health Teams does periodically monitor water quality, but the work is conducted for the entire county and is not systematically recorded by location or parameter. Furthermore, the County Health Teams are often limited in their testing capabilities by a lack of adequate testing materials/mediums.

The supply of water is the primary concern in the improvement of water services to the residents of Voinjama. Additional groundwater exploration should be conducted in areas of high yield. Hydrological investigations are being planned to be conducted as other phases of the Liberia Municipal Water Project progresses to identify and evaluate such area or sites. Potential sites in the Voinjama area may be along the Zeliba River. The potential sites in Voinjama will be identified as part of the hydrogeological survey efforts.

The quality of the existing water and the level of pollutant contaminants also represent a concern.

The pH Scale is an indicator of the acidic or alkaline condition of water. The pH scale ranges from 0-14; 7 indicates the theoretical neutral point. Water with a pH value less than 7 indicates acidity and tends to

be corrosive. With pH greater than 7 the alkalinity can impact the taste of the water and cause scaling in pipes. Generally, groundwater can be impacted by the surrounding soils and bedrock, or from acid rain. The presence of low-pH water increases the potential for water to contain leached metals such as copper, lead, iron, cadmium, and zinc from the well pump and plumbing system. The pH of drinking water itself, however, is not a health concern.

Iron can be present in water in four forms. None are considered a health hazard. The four forms are ferrous iron, ferric iron, iron bacteria, and organic iron. Ferrous iron and ferric iron results in rust particles forming and settling out of the water when exposed to oxygen. Iron bacteria do not cause diseases and occur in soil, groundwater, and surface waters. The bacteria may also grow well on the metal parts of piping and plumbing fixtures of water systems. Organic iron can combine with different naturally occurring materials and can exist as an organic complex. It can be found in shallow wells and surface waters.

Lead can occur naturally in groundwater, but this is typically rare. The significant source of lead in drinking water is generally corrosion of piping, well fixtures or household plumbing systems. The amount of lead in water also depends on: the types and amounts of minerals in the water; how long the water stays in the pipes; and the water's temperature and pH. Infants and children who consume water containing lead in excess of 15 parts per billion could develop delays in their physical or mental growth. Adults who drink this water over many years could develop kidney problems or high blood pressure.

3.4.3 Electrical Power Supply

There is no large-scale power utility operating in Voinjama. In 2011, the Government of Liberia provided a generator during the Independence celebration, which was to be used for public power supply. According to Mr. Robert Gibson, Resident Engineer (MPW) Lofa County, the generator does not have the capacity to supply the entire City power supply. The generator's capacity is about 75KVA. It supplies power to main street lights and a few residents. The inhabitants are not willing to pay for the running, operation, and maintenance of the generator. Some of the inhabitants receive power supply from private generators for a few hours every night. This method constitutes the bulk of the city's power supply, including the power supply for the disused water treatment plant.

The Total Corporation is currently constructing a gas station to supply fuel for the city, which currently has no filling station to supply petroleum product. According to the Resident Engineer of the Ministry of Public Works, there is no plan for future development of the public power supply for now.

The socioeconomic survey indicates that 73% of the respondent's homes have no electricity.

3.4.4 Drainage and Erosion

The City of Voinjama is located below Kitoma Hill; the center is located on higher ground than the surrounding area. The City Centre of Voinjama is located on a hilltop and all quarters of the city are located on sloping ground so that surface waters can drain away easily. There is no flooding of built-up areas. In former times, some sections of the streets close to the main junction at the town Centre were served by underground drainage channels, but these have since eroded away.

In the Centre of Voinjama, the combination of fine-grained soils, steep slopes, high volumes of surface water runoff, and human activity, has in many places lowered the surface of roads and walkways by more than one meter, exposing formerly buried pipes and culverts.

The erosion-related deficiencies cannot be repaired within an emergency program. Indeed, they appear to be more a problem related to road construction than drainage; because of this relationship, the

establishment of proper roadside drainage is being effected through road projects comprising reconstruction and hard-surfacing of roads and walkways.

Few signs of the city's former drainage system remain. Channelized gutters were observed along some portions of the sloped main streets. Extreme signs of erosion and subsequent road re-grading were present throughout the developed portions of the City. The team observed grade differentials as great as 10 feet. Other signs of the erosion include water service pipes penetrating road side banks 4 feet above the current road grade, or doorway entrances and steps that cannot be accessed from the new, lower elevation of the road.

There were signs of culvert repairs being made to respond to emergencies. For example, the culvert on the road in front of the Voinjama High School was washed out and repairs had been completed in May of 2012. Unfortunately, the repair process had stopped for unknown reasons before completion of the work, and the road remains closed.

3.4.5 Solid Waste

There are no known records for the amount of solid waste generated in Voinjama. The lack of records is directly related to the lack of a formalized disposal service. It appears that the current practice is disposal of solid waste via roadside disposal, composting, incineration, or consumption by animals.

The rate of generation of solid waste is most likely on the lower side of the typical range of 0.3 to 0.6 kg/c/d. This low rate of generation is attributable to the lack of commercial activity, which usually contributes waste through the manufacture of goods and packaging. Based on the low-end generation rate and the Voinjama population of 15,100, the anticipated solid waste generated would be approximately 4,530 kg per day, or 1,650,000 kg per year.

Voinjama is one of the towns where people are using private open pits to bury their refuse. The refuse sites are located near the residents' homes. A baseline survey conducted by Tetra Tech showed that 48% of the people interviewed use a garbage pit, 14% use a gazette collection pit, and 38% use "open area."

3.4.6 Wastewater Management

No centralized piped sewage system has ever existed in Voinjama. It appears the majority of residents use pit latrines or "the bush" — a term indicating open defecation in forested areas.

The most likely source of wastewater would be from sources such as hand pumps, kitchens and laundry areas, bathing areas, hospitals, and clinics. The wastewater generated from hand pumps generally would not require treatment, but that generated from kitchen and health facilities may. The anticipated flow rate from these facilities may be estimated as follows:

Kitchen/feeding centers	25 liters per person per day
Hospitals	50-100 liters per day per person

The city of Sanniquellie does not have a sewage treatment plant so it is difficult to quantify wastewater generation of the city. However, the baseline study carried out in these three cities, allows for a breakdown by percentage of the *method* of disposal of the residents. This breakdown is shown in **TABLE 3-6**.

TABLE 3-6: VOINJAMA WASTEWATER DISPOSAL METHODS	
Basic Information	**Voinjama**
Discharge of Grey Water:	
Open Area	85%
Disposal	8%
Drainage System	7%
Others	0%

3.4.7 Transportation Infrastructure

The improvement of roadway in Lofa County appears to be the responsibility of one or two ministries, the Ministries of Public Works and Rural Development. The Ministry of Rural Development is responsible specifically for the construction and maintenance of feeder and farm to market roads. The Ministry of Public Works is responsible for and carries out the implementation and coordination of improvements to all classes of roadways.

Approximately two years ago, the Public Works Ministry along with the Swedish International Development Agency (SIDA) began constructing and rehabilitating several feeder roads in northwestern Liberia.

The continuous maintenance of the roadway from Voinjama to Monrovia would be critical to the proper operation of a water system. During past rainy seasons the portion of the roadway between Voinjama and Gbarnga has frequently been washed out, causing major delays in transport of people and supplies. The portion of road from Gbarnga to Monrovia is anticipated to be improved by mining operations located in Nimba County.

3.5 ONGOING WORK BY OTHERS

Throughout Liberia the USAID IWASH project is working with GoL and its Ministry of Health to rehabilitate water sources such as wells. Their effort includes working to establish and implement fees and charges for water source development, and developing testing and analysis methods to evaluate the groundwater wells.

IWASH is also working with LISGIS and the WSP to develop and maintain a database of hand pump and water point locations and operational status. IWASH is also involved in managing spare pump part inventories and point-of-use water treatment products (Water Guard).

IWASH also works with the Department of Public Works to coordinate practices regarding hand-dug wells and borehole installations.

3.6 INSTITUTIONAL ASSESSMENT

3.6.1 Municipal and County Government Organization and Functional Arrangements

LWSC has no presence in Voinjama. In addition, there is no central power system. Several small power cooperatives operate in the market district, consisting of private shop owners who share power from a generator provided during the preparations for last year's Independence Day Celebration, but are currently inoperative due to equipment failure, with no obvious plans or funding for replacement.

Offices of the Lofa County Supervisor and the Mayor of Voinjama: As with the other municipalities in Liberia, the mayor of Voinjama is appointed by the County Superintendent (CS), who in turn is appointed by the President of Liberia. While the Mayor is an elected post, there has not been a mayoral election since prior to the war. Key governmental functions of the town relevant to LMWP, including health services, education, and the provision of infrastructure services are the responsibility of the Lofa County government.

LMWP has had numerous town meetings chaired by the CS, Assistant Superintendent for Development Planning and other community leaders. In early April 2012, the team discussed the need to establish a Transition Working Group (TWG) at the national level, consisting of national and local government, community and business leaders with the goal of determining how the systems will be managed and overseen. It was determined that local level groups, called Water Steering Committees would be formed in each of the target cities, and send representatives to participate in the national TWG. As of December 2012, the TWG has been established at the national level, including a charter, with local Water Steering Committees established in each project city, including Voinjama. Three meetings have taken place in Monrovia with representatives from Voinjama attending. The TWG is expected to play a critical role in selecting management and oversight options in the coming months and this process is ongoing.

Lofa County Community Health Team (CHT): The CHT performs water quality testing for water points across the county. The team has a substantial number of staff for this purpose, trained by IWASH in testing procedures. However, CHT representatives reported that water testing is quite new to the team, that they are providing more training principally in areas outside of Voinjama. The CHT has not attempted a correlation of epidemiological data on waterborne diseases across the town, but suggested that such an analysis could be useful in identifying health "hot spots" that could help the LMWP in identifying priority areas for quick impact projects.

Lofa County Ministry of Education Office: The Director confirmed that of public schools in the city, all are currently served by hand pumps. Hand pumps are being constructed at these schools by USAID's IWASH Project.

Since one of the concerns of the SA is to determine the ability of public institutions to pay for water services, the team discussed the budgetary process within the county school system. The department does not have an annual budget, except for the payroll of teachers and staff. Any additional expenses, such as payment for repairs, utility bills, etc. require approval of the county board. The Director acknowledged that this is a major challenge she faces, and that this would be a concern if schools were billed for water.

3.6.2 LWSC Current Operation

LWSC effectively has no presence in the town. While there is a former water treatment facility in town it is no longer operational and LWSC does not have a caretaker for that facility on its payroll.

3.6.3 Community Water Management Organization

Since there is no government agency or utility specifically responsible, water services are currently provided through informal community based organizations (CBOs). The degree to which these groups effectively managed their respective pumps varied considerably.

One of the communities visited (near the Administration Building) appears to have a well-organized approach to managing the local hand pump. A caretaker is present during the hours of operation (6–11AM and 4–6 PM) and locks it during off-hours. Members of the community group, (15–20 households) pay a USD 1.50 fee and in return receive a ticket which entitles them to use the well any time

during open hours. Non-members may use the well, but the caretaker typically requires some kind of in-kind contribution (e.g., cleaning the well site).

The *Business Association* consists of proprietors from the business district, which is served by two hand pumps. However, the hand pumps are managed by a volunteer, not the association. The association provides a conduit for collecting payment for repairs when needed, but does not appear to have a high degree of "ownership" of the hand pumps.

The *Public Market Association,* an organization of some 400 members, has taken responsibility in the past for repairing the hand pump that used to serve the market. Funding for repairs was covered by the dues that the association charges its members. Although the hand pump no longer exists since it was removed in conjunction with a road rehabilitation project, this past history indicates that the association views water services as part of its mandate.

The Situational Assessment team also met with the local USAID IWASH project team. IWASH has extensive experience in hand pump installation, although up to this time it has not installed hand pumps within the boundary of the city, although this may be included in the project's SOW in the future.

3.6.4 Private Sector Water Supply Capacity

Aside from individual tradespersons who repair hand pumps and generators, there is very little capacity to operate and maintain water systems in the town. The team met one individual who built his own public latrine and runs it as a business (charging 5 LD per visit).

While there were general limitations on water carriers and suppliers, there is a general understanding that local residents had severe difficulty in obtaining water supplies will require payment on the part of all residents. Most residents will have their children walk significant distances waking up at 5:00 AM daily just to obtain supplies of water from the limited number of wells that are operable during the dry season. There is a general sense that there is a significant willingness to pay for an improved supply of water for all.

3.6.5 Utility Management and Regulation Challenges

The Liberia Water Supply and Sanitation Policy's fifth policy statement encourages Community wellbeing through social and environmental considerations. Those considerations include "Community participation in project planning and design is paramount for the sustainability of the project and shall be encouraged by all proponents."

The challenge is for implementation measures of the Water Supply and Sanitation Policy to become effective. At this writing, the National Water Resources and Sanitation Board (NWRSB) Executive Order has yet to be issued and the Water Supply and Sanitation Commission which is also expected to be formed through Executive Order remains outstanding as well.

The NWRSB will be responsible for WSS Sector Policy, Strategy, Planning, Technical Support, Coordination, M&E, HRD, Capacity Building, Decentralization, Programs, Financing, NGO Support, Management Information Systems (MIS), Donor Coordination, and will ensure the enforcement of standards, regulations and by-laws (including the existing Public Health Laws, chapter 24 of Title 33 of the revised Public Health Law and Section 35, Part IV, related to Drinking Water Quality Standards in the Environmental Protection and Management Law) through the WSSC.

In its new mandate the NWRSB will oversee the Water Supply and Sanitation Commission (WSSC) comprising eminent experts in the fields of Water, Sanitation, Environment, Economy, Finance, Law,

Sociology, and Public Health who will regulate all activities related to Tariffs, Licenses, PPPs, Service Standards, and Water Laws compliance, to be appointed by the President. The NWRSB will also serve as the supervisory arm for the National Water Supply and Sanitation Committee and Hygiene Promotion Committee (NWSSCHP), comprising of service providers on the part of the Government on one hand and PPP on the other.

One major responsibility of WSSC is to issue water service provider licenses meant to ensure that water is provided by local corporations, utilities or private providers to communities and ensuring that all Liberians have access to both clean water and sanitation through autonomous water service providers. Without these policy and regulatory bodies being instituted guidance on how to develop a water supply work group whose goal it is to promote the sale and delivery of clean water will experience difficulties.

LMWP will continue to work with Policy Level Committees to help promote formulation of specific functioning boards, committees and organizations to foster policy, promote regulation and formulate guidance for water supply promotion, investment, production, operations, maintenance, distribution, sales, delivery and payment. With one key statement that "Government would gradually disengage from direct service delivery and play a more active facilitating role"[10] it is clear that local institutions are expected and shall be encouraged to promote local ownership and system operation.

3.6.6 Capacity Building Challenges and Needs

As noted above, a Water Steering Committee has been established to work with the LMWP project and serve as representative to the national TWG and provide input to the process of deciding how the systems will be managed and overseen. However, it should be noted that LWSC is the entity entrusted with responsibility for provision of water to secondary cities.

One of the greatest challenges we envision is establishing a fair water price that achieves cost recovery. People in the community currently receive water services at no or little cost. In some parts of the City, citizens have been asked to contribute the cost of repairing pumps or repairing the well itself but very little is put aside for continued maintenance, flushing the wells, chlorination or the many other needs to make certain that wells are in good order providing good quality water continuously.

We expect to work with the Water Steering Committee on the continuing concerns and needs for water supply service and expansion and its actual cost. The community needs to be assured that the cost of water services is fair and reasonable and is being provided professionally. These capacity building programs will take many forms. For the Water Steering Committee we expect this will include dedicated training that will include both classroom education and perhaps traveling to a pilot community to see how improved water supply has helped that community. In the community we expect not just media information but providing handouts and hygiene education in schools and working with USAID funded IWASH, other donor funded programs and CBO's to promote hygiene, clean water use, hand washing and other initiatives. We will particularly focus on the commercial issues in water that will provide a strong understanding that payment for water use is an inexpensive alternative to the current unprotected water sources.

[10] The Republic of Liberia, Water Supply and Sanitation Policy, Ministry of Lands, Mines and Energy In Collaboration with the Ministry of Health and Social Welfare (MOH), Ministry of Public Works (MPW), Liberia Water and Sewer Corporation (LWSC), UNICEF, WATERAID AND CONSORTIUM OF OxFAM-LED NGOS, April 2009, pg. 17

While currently, water supply regulation is only in its formative stages, our work will help foster concurrent regulatory processes that will determine water tariff based on clear and understood, full cost recovery principals. Our work at the local level will make a strong case that full cost recovery is not only imperative for continued water operation but also affordable and given the right level of local communication, input and accountability is socially acceptable. We will target informal dialogue opportunities to meet these needs.

The most important challenge we face is developing a formal institution that will be ready to manage a water utility once medium-term investments are approved and ready to be implemented, and this process is ongoing within the national TWG. Managing a start-up organization in any field is a challenge but when there is limited managerial, technical or financial knowledge for the nascent utility, that challenge will be magnified. We will seek ways and means to develop this capacity locally as well as determine what short- to medium-term alternatives are available to address capacity deficiencies initially. The longer-term horizon anticipates training and local capacity development to provide continuous management throughout the life of the utility.

3.7 SOCIO-ECONOMIC ASSESSMENT

3.7.1 Objective

The following section presents quantitative and qualitative survey findings for the city of Voinjama. The objective of the survey in Voinjama was to determine both household and commercial willingness and ability to pay for water services. To make this determination, the survey team explored important issues surrounding water, such as current water consumption, household/community concerns regarding water quality and water-borne diseases, desire for improved water, willingness to pay for improved water as well as current household income and expenditures. The survey also gathered information on the basic socio-economic characteristics of the population in Voinjama.

The quantitative baseline survey in Voinjama explored a sample of 374 observations. The survey comprised 155 questions and targeted individual households. The survey sample covered 12% of the city's population, and the respondents were randomly selected to ensure both a statistically valid and representative sample.

For the qualitative survey in the city of Voinjama, the team conducted a total of six (6) focus group discussions, comprising 59 participants, and five (5) interviews of commercial and institutional entities. While the focus group discussions included heads of household[11], women entrepreneurs and protected well caretakers, the information in the household sections of this report refers solely to the responses provided by the heads of household. The Commercial and Institutional Water Consumption and Sanitation Characteristics section includes responses from women entrepreneurs and protected well caretakers, as well as interview answers from commercial enterprises and institutions.

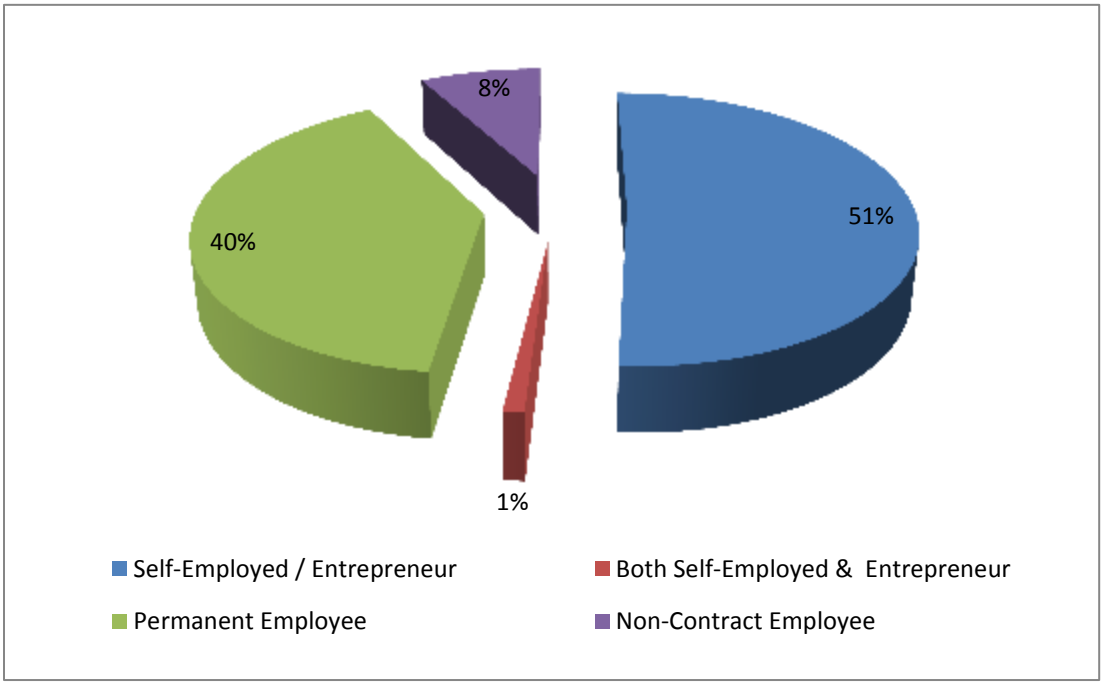
The survey results for the city of Voinjama are presented according to the following sections: socio-economic profile, household water consumption and sanitation characteristics, household health trend characteristics, household financial characteristics, household ability and willingness to pay for water services, water system management, household savings and access to credit, formal financial services, household housing history and quality, and an overview of commercial and institutional water consumption and sanitation characteristics.

[11] The head of household, as the target respondent for this survey, is the person who earns the most money in the household and/or is responsible for the household's financial decisions.

3.7.2 Socio-economic Profile

The quantitative baseline survey in Voinjama involved a sample of 374 observations of which more than half (51%) were self-employed or entrepreneurs, 40% were permanent employees, and a small percentage were non-contract employees (8%) or both self-employed and entrepreneur (1%) (see Figure 3-8[12]). For the qualitative assessment, the team held six (6) separate focus group discussions with 59 total participants, including women entrepreneurs (34% of participants), heads of household (49% of participants) and protected well caretakers (17% of participants).

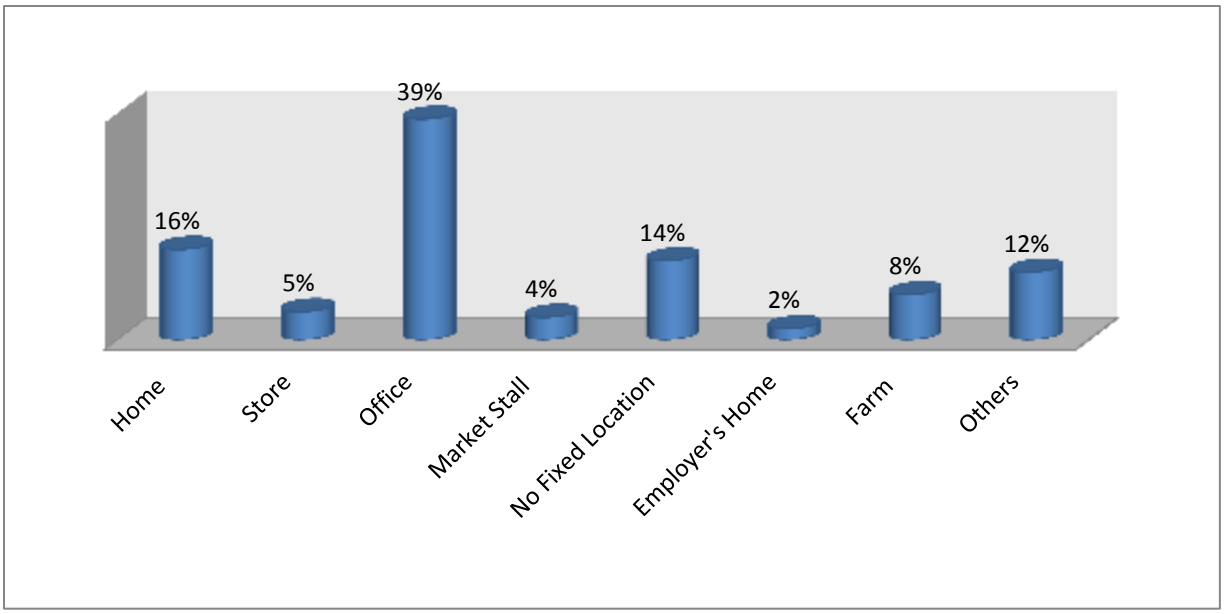
Figure 3-8: Sample Breakdown by Type of Employment, Voinjama



With 55% of the respondents working in services and 35% in trade, the survey team ensured that the quantitative sample was representative of the major economic activities in Voinjama. The remaining respondents worked in agriculture (9%) and in manufacturing/construction (1%). While 16% worked from home, the majority of those surveyed worked in offices (39%).

[12] All figures used in the socio-economic assessment refer to data from the quantitative survey.

Figure 3-9: Sectors of Employment, Voinjama

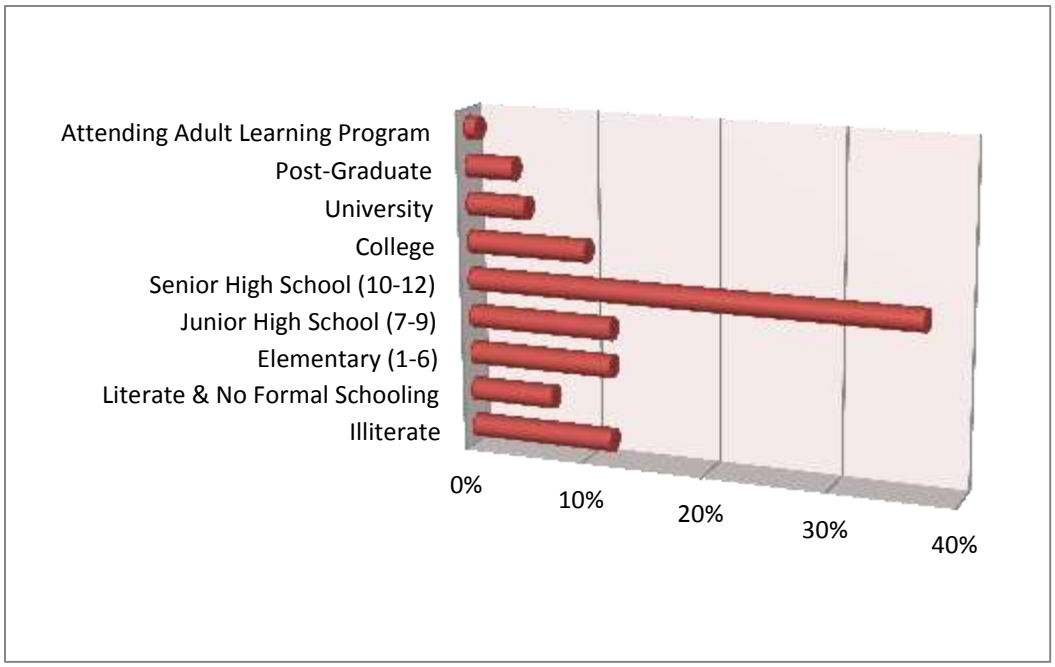


The quantitative sample was comprised of 61% men and 39% women, with an average age of 36 years which reflects the young population of Liberia. More than half of the respondents were married (59%), 20% were single, 13% were cohabitating and the remaining 8% were divorced, separated or widowed. The majority of the respondents were Christian (76%), while 21% were Muslim and 3% were from other religions. For the qualitative assessment, the overall sample of 59 focus group participants was represented by 34% men and 66% women. Of the 29 heads of household surveyed for the focus group discussions in Voinjama, 52% were men and 48% were women.

The study shows that over three-quarters of the quantitative survey respondents (81%) had received some level of education, while 12% were illiterate with no formal schooling. Another 7% were literate but had no formal schooling. By comparison, the national literacy rate in Liberia is 58%.[13] The majority of the respondents had received some secondary education or attended senior high school (37%). Twelve percent (12%) of the respondents had only completed elementary education, and 15% of respondents had received some college education or completed college.

[13] CIA Fact, The World Factbook, https://www.cia.gov/library/publications/the-world-factbook (February 2011).

Figure 3-10: Education Level, Voinjama



Less than half of the quantitative respondents (43%) reported owning their homes, while 46% indicated that they occupied rentals and 11% had free-of-charge housing. Additionally, the majority of homeowners reported holding registered title deeds (66%), which could serve as potential collateral should the households want to borrow in the formal financial sector. The remaining homeowners reported holding an agreement between two parties (15%) or a registered sales contract (8%). Lastly, 11% reported holding no ownership documents.

3.7.3 Household Water Consumption and Sanitation Characteristics

Fifty-three percent (53%) of the quantitative respondents reported having regular access to a water source. Additionally, 59% of the quantitative respondents reported having regular access to safe drinking water within 30 minutes round-trip of their home. For drinking and cooking purposes, less than half of the respondents used protected wells with hand pumps[14] as the main sources of water in the dry[15] (44%) and wet[16] (43%) seasons. Thirty-two percent (32%) used boreholes[17] in the dry season and 28% in the wet season. Eleven percent (11%) used open or hand dug wells[18] as the third main source of water in the dry season and 10% in the wet season. Other sources of potable water included water kiosks/stand posts, private yard taps, bodies of water, and rain harvesting (see Figure 3-11). As the main reason for their choice of potable water source, 50% reported water quality, and 37% indicated convenience. Many focus

[14] A protected well is a well dug by hand with a manually-operated hand pump, an inner lining to prevent the walls from collapsing, a cement cover for security and sanitation purposes, and a drainage system.

[15] The dry season in Liberia is from November until April.

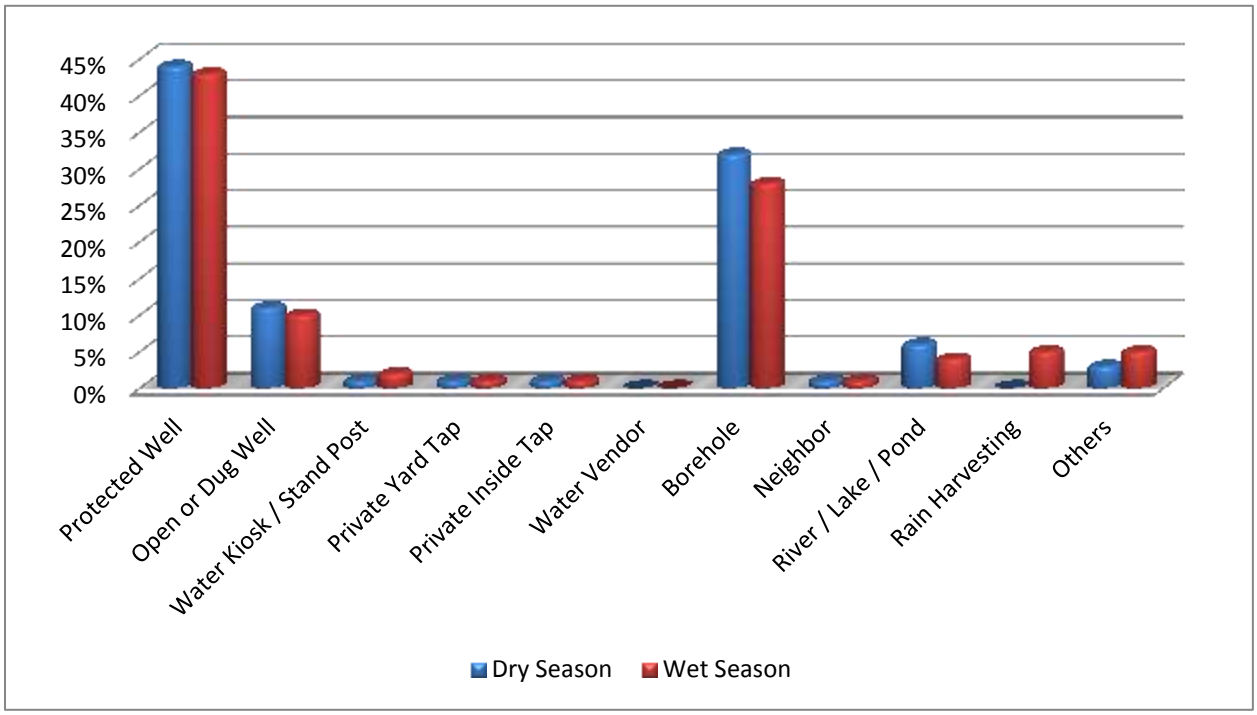
[16] The wet (rainy) season in Liberia is from May until October.

[17] A borehole is drilled into the ground to allow access to groundwater. In some instances, primarily in the case of businesses and institutions, a protected borehole is operated by a submersible pump supplied by a generator.

[18] An open or hand dug well, unlike the protected well, is not operated by a manual hand pump or protected with a cover. Water is typically drawn using a bucket. All hand dug wells are lined to stabilize the walls of the well so that it does not collapse.

group respondents supported the quantitative findings, reporting that they relied primarily on protected wells or hand dug wells for drinking water.

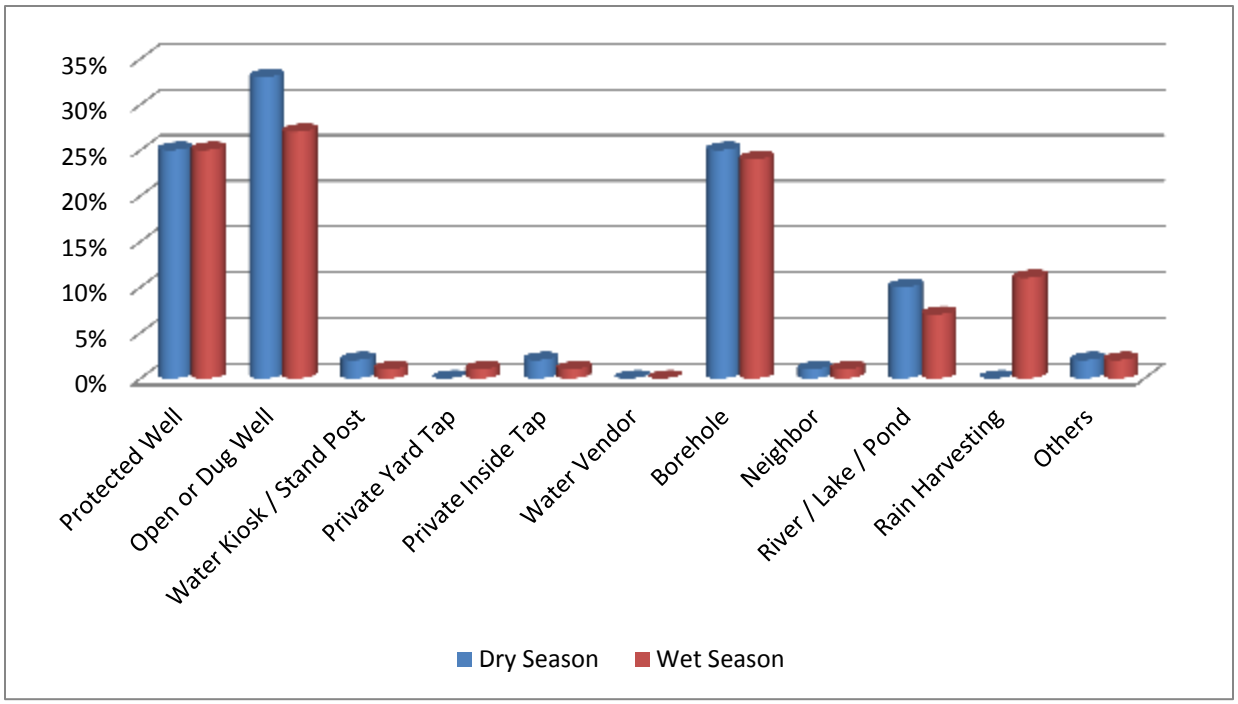
Figure 3-11: Sources of Water for Drinking and Cooking, Voinjama



For bathing and laundry purposes, 33% of the respondents used open or hand dug wells in the dry season and 27% in the wet season. Twenty-five percent (25%) used protected wells in the dry and wet seasons. In the dry season, 25% used boreholes and 24% in the wet season. Only 1% reported buying water from private vendors or water kiosks.

Fifteen percent (15%) used water for small-scale irrigation systems in the dry season and 6% in the wet season. Six percent (6%) used water for livestock feeding in the dry season and 7% in the wet season. Several heads of household that participated in the focus groups also indicated the use of hand dug wells for bathing and laundry.

Figure 3-12: Sources of Water for Bathing and Laundry, Voinjama



To access any water source, the vast majority of the quantitative respondents (77%) walked less than 250 meters within an average of 15 minutes per round-trip plus any waiting time. Waiting times can vary depending on the seasons. If the water level in the protected well is low, there can be extended waiting times. Sometimes children have to leave the jericans[19] in line in the morning and pick them up in the afternoon. Approximately half of the respondents reported that children primarily fetch the water (51%). Forty percent (40%) collected water on a daily basis, while 52% collected water on alternate days. Respondents made up to four (4) trips in the dry season and up to three (3) trips in the wet season in both the mornings and afternoons. While children were usually responsible for fetching water, 56% indicated that the wife was responsible for making decisions regarding water management and consumption in the household.

Despite the fact that the water sources may be close to their home, the qualitative focus group respondents noted that water collection was a very time consuming activity. Most respondents spent anywhere from 15 minutes to three (3) hours per day to fetch water. Unfortunately, the severe dry season had caused many of the protected wells to run dry and, therefore, the wells were unable to keep up with the demand.

For the quantitative assessment, respondents reported that the average household of five (5) (median 5) consumes on average five (5) or on median four (4) jericans[20] of water daily in the dry season for household purposes. Based on reported average consumption and average household size, the per capita usage is estimated to be 20 liters per person per day in the dry season.[21] The consumption drops to an

[19] In Liberia, water is collected using both a 20-liter jerican and one-gallon (US) jug. The respondents indicated they used between 20 and 60 gallons of water per day per household. For the sake of consistency in this report, we are presenting numbers in terms of jericans, and using a conversion rate of 5.3 gallons/jerican.

[20] The use of plastic 20-liter jericans is the most common and feasible way to measure water usage and cost among those who do not have metered connections.

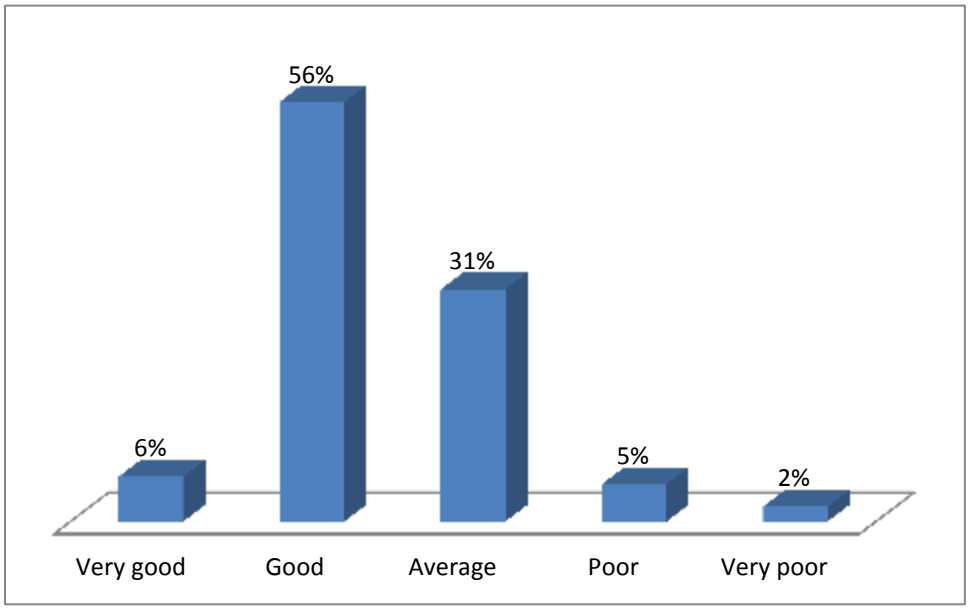
[21] Since one jerican equals 20 liters, we calculated per capita consumption by multiplying 20 liters by the household daily consumption (5 jericans) and then dividing by the average household size (5).

average of four (4) or a median of three (3) jericans in the wet season. Based on reported average consumption and average household size, the per capita usage is estimated to be 16 liters per person per day in the wet season.[22] In comparison to the quantitative survey findings, qualitative survey respondents reported a much larger range of water usage from approximately four (4) jericans to 31 jericans per day per household for drinking, cooking and bathing.

As noted above, reported consumption increases during the dry season. This increase may be due to a number of factors. Many qualitative survey respondents noted that there was a lot of dust during the dry season and, therefore, water was used to reduce the amount of dust around the household. Furthermore, households may resort to using more water for bathing and laundry given the amount of dust circulating. Lastly, households need to fetch more water for gardening in the dry season, which would not be necessary during the wet season because of ample rain. It is worth noting that rainwater used for gardening and other purposes during the wet season may not be taken into consideration when calculating water consumption per jerican, particularly if the rainwater is used immediately without harvesting. During the focus group discussions, however, participants did report rain harvesting as a method of collecting water, thus reducing consumption from protected wells in the wet season.

Regarding water quality, 56% of the quantitative respondents noted that the overall quality of water from their main source of water was "good" (see Figure 3-13). Sixty-eight percent (68%) reported that their water does not have an odor in the dry season, while 79% reported the same in the wet season. In both the dry and wet seasons, 56% reported good water purity. In the dry season, 55% reported that the water tastes good, while 57% reported that the water tastes good in the wet season.

Figure 3-13: Overall Quality of Water from Main Source, Voinjama



The qualitative respondents, on the other hand, reported issues with water quality in the dry and wet seasons. In the dry season, respondents reported the water becomes contaminated with silt when the water level is so low that people have to dig deeper to obtain water. In the wet season, respondents reported that a variety of contaminants and other objects enter the wells as a result of runoff. Those respondents who used unprotected water sources reported that the quality of their water was poor. It is worth noting here

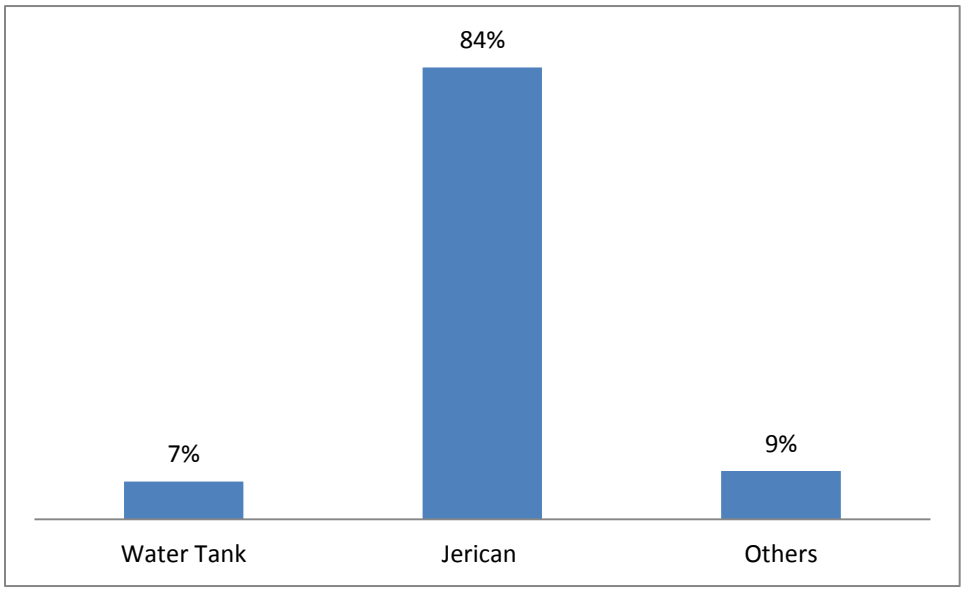
[22] Since one jerican equals 20 liters, we calculated per capita consumption by multiplying 20 liters by the household daily consumption (4 jericans) and then dividing by the average household size (5).

that, during the focus groups and earlier visits, none of the protected well hand pump committees[23] reported testing the water quality on a regular basis. Once the taste or color of the water changes, the community waits for the water level to rise before they recommence pumping water from the well.

Thirty-one pecent (31%) of the quantitative respondents reported that they treat the drinking water all the time, and 23% noted treating the water sometimes. The majority of the respondents who treated the water used chemicals (disinfectants) such as WaterGuard[24] (93%). All focus group respondents reported treating their drinking water with WaterGuard or by boiling or filtration. Several respondents mentioned further treating chlorinated well water with WaterGuard.

Sixty percent (60%) of the quantitative respondents reported owning water storage equipment. Out of the 60% who stored water, 84% reported storing water in jericans. Figure 3-14 below shows the percentage breakdown of household water storage facilities.

Figure 3-14: Household Water Storage Facilities, Voinjama



The city of Voinjama does not have a government or private sector sewage system. However, 9% of quantitative survey respondents have access to a private "sewage system" through the use of a septic tank or soakaway pit. Out of the 9% who reported having access to a private sewage system, only 3% reported paying sewage disposal fees to have the accumulated septic tank periodically emptied.

The quantitative survey findings revealed that 80% of the quantitative respondents did not have an in-house toilet facility, while 32% did not have an outside pit toilet. As to why they do not have a toilet facility inside or outside their home, half of the quantitative respondents (50%) said that they could not afford a toilet facility. Should they obtain a water connection, 70% reported that they would be interested in building a toilet facility. Less than half of the respondents (43%) reported satisfaction with their latrine facility. The vast majority of households discharged grey water in open areas (85%). Almost half reported discharging human and solid waste in garbage pits[25] (48%) and in open areas or elsewhere (38%). All of

[23] Protected well hand pump committees manage protected wells in communities. Their role is to oversee well operations, collect fees, and address maintenance issues.

[24] A household water treatment solution of sodium hypochlorite.

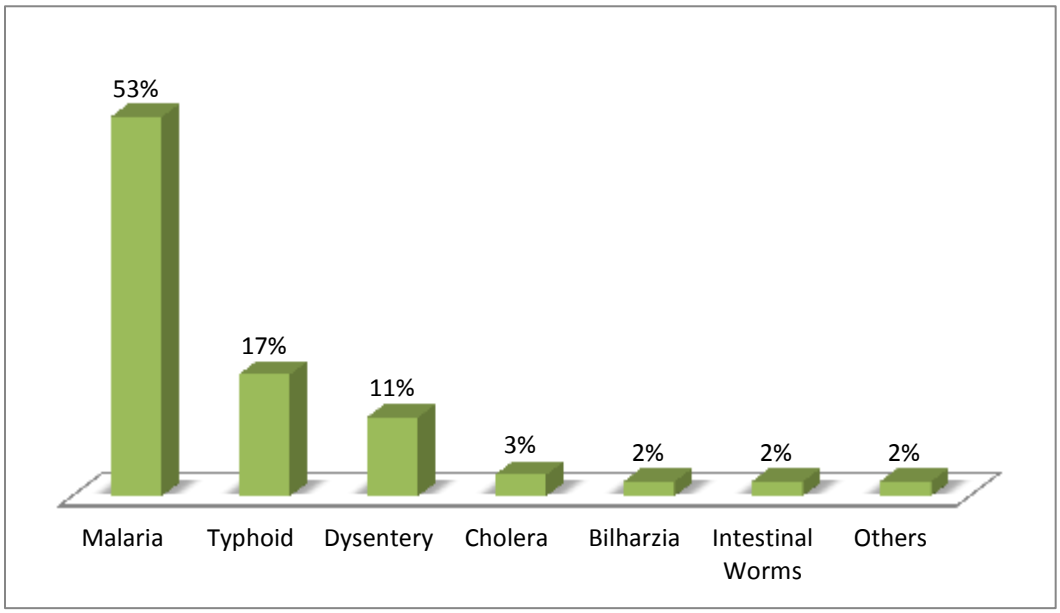
[25] A garbage pit is typically an uncovered hole dug in the ground in a housing compound where residents throw garbage.

the heads of household focus group participants reported having access to sanitation facilities. In the qualitative assessment, 20 respondents out of 29 reported having an outside pit toilet, while five (5) had access to public or shared toilets. Additionally, four (4) respondents had an in-house flush toilet.[26] Approximately half of the 29 respondents indicated the use of a soak pit, garbage pit or sanitation facility to dispose of grey water. Four (4) reported dumping waste water in swamps, creeks or lakes, and three (3) reported recycling grey water through various methods. Of the qualitative respondents, most dispose of feces in latrines or through burying.

3.7.4 Household Health Trend Characteristics

Twenty-four percent (24%) of the quantitative survey respondents reported that one or more members of their household had diarrhea within the last 30 days.[27] Of water-related diseases, more than half of the respondents reported that one or more members of their household had contracted malaria (53%) within the last 30 days. Seventeen percent (17%) reported that one or more members of their household had contracted typhoid and 11% had contracted dysentery within the last 30 days (see Figure 3-15).[28]

Figure 3-15: Water-Related Diseases, Voinjama



Seventy-five (75%) of the quantitative survey respondents noted that the household members who fell ill were above five years old. Of the members who fell ill, 53% fell ill at least once during the last 12 months, and 28% fell ill twice during the past 12 months. Nineteen percent (19%) fell ill more than three (3) times in the past 12 months. Six percent (6%) reported they had a death in the family in the past 12 months with the main causes of death as diarrhea without specifying an illness (58%), malaria (17%), and other reasons (25%).

[26] While most households flush their toilet by pouring water into the toilet bowl, some businesses (i.e. guesthouses) have an elevated tank that allows one to flush a toilet without having to pour water directly into the toilet bowl.

[27] Respondents could not always determine the cause of diarrhea or associate it with a particular disease; therefore, we included a separate question specifically about diarrhea in the questionnaire.

[28] Considering household members could have had more than one water-related disease within the 30-day period, the total cumulative percentage in Figure 22 does not equal 100%.

More than half of the 29 qualitative respondents said they had suffered from dysentery, typhoid or cholera, or that a family member had suffered from diarrhea. Others knew a neighbor or relative that had suffered from diarrhea. Respondents described a cholera epidemic in 2004 and 2005 responsible for cases of both cholera and typhoid in their communities. The afflicted typically seek treatment at the hospital and/or receive medical prescriptions to address their illnesses.

3.7.5 Household Financial Characteristics

The typical household in Voinjama has an average of five (5) members (median 5).[29] On a monthly basis, respondents generated a median income of LD 8,000 / *US 111.11* (13,875 / *USD 192.71* mean) from a primary source. Less than half of respondents earned a secondary source of income resulting in a median of LD 0 / *USD 0* (LD 879 / *USD 12.21*). Similarly, less than half of the respondents reported that their spouse's activities yielded a supplementary income of a median of LD 0 / *USD 0* (LD 2,093 / *USD 29.07* mean). Fewer than half of the heads of households received an income from other sources (LD 0 / *USD 0* median, LD 186 / *USD 2.58* mean*)*, and/or from other family members (LD 0 */ USD 0* median, LD 291 / *USD 4.04* mean*)*.[30] The gross household income was a median of LD 10,500 / *USD 145.83* (LD 17,324 / *USD 240.61* mean*)*.

Total household expenses equaled LD 7,980 / *USD 110.83* median (LD 11,488 / *USD 159.56* mean). Respondents reported that the majority of the household expenses consisted of groceries at LD 4,000 / *USD 55.56* median (LD 4,992 / *USD 69.33* mean*)* and medical expenses at LD 150 / *USD 2.08* median (LD 297 / *USD 4.13* mean). Less than half of the respondents reported paying for water, yielding a median of LD 0 / *USD 0* (LD 114 / *USD 1.58* mean) for water expenses. These figures yielded a net household income (surplus[31]) after expenses of **LD 2,200 / *USD 30.56* median** (LD 5,836 / *USD 81.06* mean).

3.7.6 Household Ability and Willingness to Pay for Water Services

1. Current cost of water at the household level

Overall, 34% of the quantitative respondents reported paying for water from their main source.[32] When asked what they currently pay for water on a monthly basis, survey respondents reported that they paid a median[33] of LD 0 (*USD 0*)[34] and, on average, they paid LD 94 (*USD 1.30*). This is due, in large part, to a

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29 In this report we use both averages and medians for our analysis; when the median (the number at which 50% of the respondents are above and 50% of respondents fall below) is in stark contrast to the average, we have assumed that the average includes some strong outliers and as a result, in those cases, we have used the median as the primary driver for the analysis.

30 Although remittances are common among the low-income population worldwide, only 27% of the sample reported receiving remittances.

31 Please note that the median household surplus is derived from the entire household surplus sample, and not from subtracting total median household expenses from total median household income.

32 Respondents, both quantitative and qualitative, indicated that they obtain water from multiple sources – particularly in the dry season, and the "main source," as noted here is the primary source where the majority of their water is obtained. Respondents also indicated that they obtained water from other sources for washing, cooking, bathing and cleaning (i.e., secondary or tertiary sources).

33 In this report we use both averages and medians for our analysis; when the median (the number at which 50% of the respondents are above and 50% of respondents fall below) is in stark contrast to the average, we have assumed that the average includes some strong outliers and as a result, in those cases, we have used the median as the primary driver for the analysis.

34 The perception, because most respondents in Voinjama do not pay for water by volume consumed, is that they do not pay for the water. However, as noted elsewhere in this section, most respondents pay for water usage, whether as a one-time access fee, or through weekly, monthly, or ad-hoc operation and/or maintenance fees.

perception that, since people are not paying for water by the jericans, their water is free (overall, 64% of respondents perceive they do not currently pay for water). The focus group survey respondents, on the other hand, understood that there was a cost associated with obtaining water, particularly from protected wells.

The protected well installations require regular maintenance and repairs. The costs of the maintenance and repairs are borne either by the institution on the premises of which the well is located, such as the Voinjama high school, or by the residents of the community with access to the well. There are three primary activities incurring costs: 1) ensuring that the area surrounding the well is clean and free of contaminants; 2) treating the well water with chlorine; and 3) repairing the protected well and its associated equipment, when needed. A committee typically manages the maintenance needs of a protected well, and communities in Voinjama use different strategies to meet these needs. In some cases, the committee organizes the community to provide labor for day-to-day maintenance and obtains chemicals free of cost from a non-governmental organization (NGO) or the local hospital to treat the well water. In other cases, the committee collects funds ranging from LD 100 (*USD 1.39*) to LD 250 (*USD 3.47*) on an annual basis or LD 50 (*USD 0.69*) on a monthly basis from each household to cover regular maintenance costs. The majority of the focus group respondents indicated paying on an ad-hoc basis[35] for maintenance, with costs typically between LD 10 (*USD 0.14*) and LD 50 (*USD 0.69*) for minor repairs and chlorination. In the case of major repairs, the committee collects funds in amounts up to LD 300 (*USD 4.17*) per household on an ad-hoc basis. Per the qualitative survey findings, in some cases when a family first moves into a neighborhood, the protected well committee asks the household to pay a one-time fee of LD 250 (*USD 3.47*) for access to the protected well.

In terms of current cost of water in Voinjama, people by and large, as shown by the quantitative survey, perceive that water is free; however, it is clear, from the qualitative findings, that the majority of people pay for water – be that for well operation, maintenance and/or access fees.

2. Willingness to pay for water at the household level

More than half of the quantitative respondents (57%) preferred direct household water connections over shared yard taps (40%) and water kiosks/stand posts (3%) (see Figure 3-16). In terms of price, respondents reported that they would be willing to pay on median LD 10 / *USD 0.14* (LD 15 / *USD 0.21* mean) per jerican of water from a piped household connection**. Since households use a median of 3.5 jericans of water per day,[36] we can extrapolate, based on these findings, that a household would then be willing to pay LD 35 (*USD 0.49)* per day or LD 1,050 (*USD 14.58)* per month on water.[37] The amount of LD 1,050 (*USD 14.58*) represents 10% of the median gross household monthly income in Voinjama. Furthermore, respondents would be willing to pay a median of LD 5 (*USD 0.07)* per jerican for water from a shared** yard tap**. By extension, participants would be willing to spend LD 525 (*USD 7.29)* per month on water from a yard tap.[38] The amount of LD 525 (*USD 7.29*) represents 5% of the median gross household monthly income. Respondents indicated they would also be willing to pay a median of LD 5 (*USD 0.07)* per jerican from** stand posts **and** water kiosks **within 100 meters of their home (see**

[35] Since most of the funds are collected on an ad-hoc basis and depend on the type of repair, we are unable to extrapolate an average cost of maintenance and repairs.

[36] Respondents report their households using 4 (median) jericans per day in the dry season and 3 (median) jericans in the wet season. Since each season spans 6 months, the average between the two seasons, which is 3.5 jericans, is used estimate households' willingness to pay for piped water.

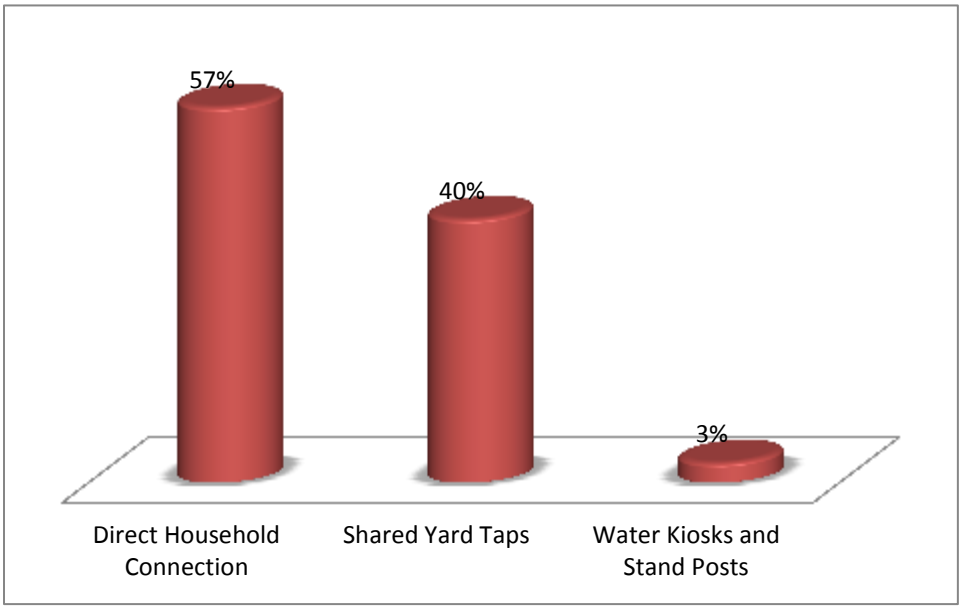
[37] Cost per jerican (LD 10) multiplied by the number of jericans per day (3.5) multiplied by 30 days.

[38] Cost per jerican (LD 5) multiplied by the number of jericans per day (3.5) multiplied by 30 days.

Figure 3-17). Per month, the total comes to LD 525 (*USD 7.29)* on water expenses and equals 5% of the median gross household monthly income.[39] While the willingness to pay expressed by survey respondents indicates a marked increase in the amount households currently pay for water, there are a number of important factors that contribute to the high willingness to pay. These include reducing the amount of time that children spend fetching water, addressing safety issues that children may face in accessing water, reducing instances of water-borne diseases, enjoying more immediate access at the household or neighborhood level, and mitigating conflict between neighbors over access.

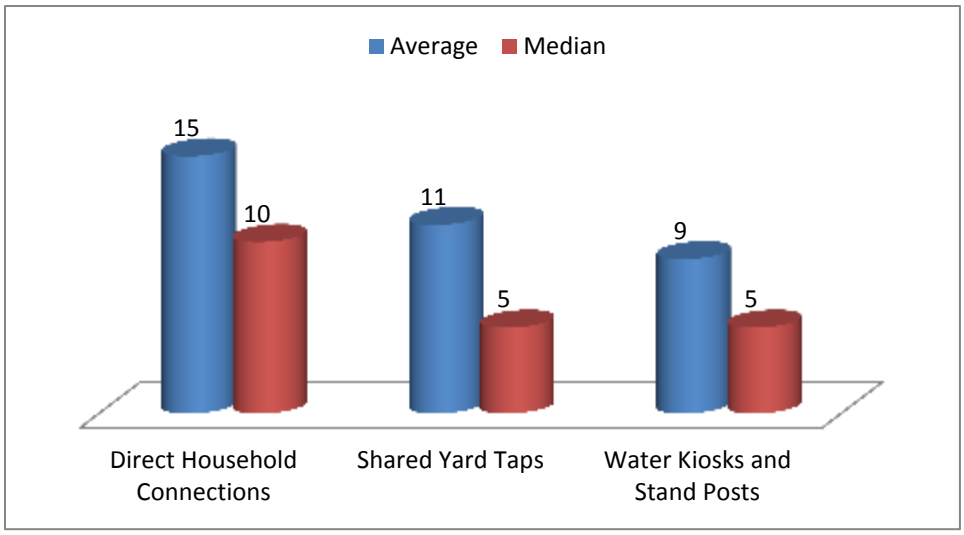
While the quantitative respondents' willingness to pay for water from a piped connection, yard taps, stand posts and kiosks is supported by their ability to afford these services in terms of the median gross monthly household surplus (see the ability to pay section below), we cannot at this time compare the willingness to pay (as expressed in the survey results) to the actual cost of service delivery as there is no existing piped water infrastructure in Voinjama.

Figure 3-16: Preferred Water System, Voinjama



[39] Cost per jerican (LD 5) multiplied by the number of jericans per day (3.5) multiplied by 30 days.

Figure 3-17: Willingness to Pay Per Jerican, Voinjama



Seventy-seven percent (77%) of the quantitative respondents indicated they would be willing to pay **up to a maximum** of LD 2,800 (*USD 38.89*) for a one-time **household connection** fee. In addition, 65% of the quantitative respondents reported that they would be willing to pay ***up to a maximum*** of LD 2,500 *(USD 34.72)* for a one-time registration fee for a shared **yard tap**. It is important to note that the ranges provided for what people would be willing to pay for a *one-time* household or yard connection fee started with the lowest bracket as LD 0 – LD 2,800 (*USD 0 – USD 38.89*) for a household connection, and LD 0 – LD 2,500 (*USD – USD 34.72*) for a shared yard tap connection. The fact that the majority (77% and 65%, respectively) of respondents indicated they would pay within the lowest bracket of possible options provided for a connection fee shows that perhaps this bracket should have been broken down further in the questionnaire, and that the LD 2,800 (*USD 38.39*) and LD 2,500 (*USD 34.72*) are at the high end of the spectrum of what people would actually be willing to pay for these one-time connection fees. As a result, this particular finding should be further investigated in subsequent phases of this program.

The focus groups revealed that most qualitative respondents would consume more water if a safe, reliable source was available. All of the respondents agreed that they use less water due to the scarcity of water. Additionally, all of the 29 qualitative respondents said that they would be willing to pay for safe, reliable water from a water kiosk or stand post within 100 meters of their homes or from a metered water connection. However, they had difficulty articulating an amount they would be willing to pay.

3. Ability to pay for water at the household level

The median household monthly income was LD 10,500 (*USD 145.83*), while the median monthly expenses equaled LD 7,980 (*USD 110.83*). The median gross household monthly surplus for households in Voinjama was **LD 2,200 (*USD 30.56*)**. This surplus amount represents 21% of the median gross household monthly income from which households could potentially draw for spending on an improved water source.[40] As noted above, one can extrapolate that households' willingness to pay ranges from LD 525 (*USD 7.29*) per month, or 5% of the median gross household monthly income for water from a yard tap or water kiosk/stand post, to **LD 1,050 (*USD 14.58*)** per month, or 10% of the median gross household monthly income for water from a piped household connection. With a median gross household monthly surplus of LD 2,200 (*USD 30.56*), the willingness to pay as expressed by the respondents falls within the median gross household monthly surplus.

[40] One must assume that a portion of this surplus income will be used for incidental and/or emergency expenditures.

In the absence of a current, globally accepted standard of what households would be willing to pay for water based on income, this report references a World Bank "5% rule" for comparison purposes. In 1997, the World Bank attempted to set a standard for poor households' ability to pay for water and concluded that "there is an elastic demand for the purchase of water with a cost of less than 5% of a household's income and an inelastic demand where the cost exceeds 5% of the household's income."[41] When comparing the households' willingness to pay for water in Voinjama, the extrapolated monthly costs to obtain water from a yard tap or water kiosk/stand post (i.e. 5% of median gross monthly household median income) is in line with the World Bank standard. While willingness to pay for a household connection was comparatively higher (10%), it should be noted, once again, that this standard remains a source of debate.[42]

In terms of one-time registration fees for a piped water connection, the majority of respondents expressed a potential willingness to pay up to a maximum of **LD 2,800 (*USD 38.89*)** for a household connection and up to a maximum of LD 2,500 (*USD 34.72*) for a yard tap connection. As noted above, most respondents indicated they would pay within the lowest bracket of possible options provided for a connection fee (77% for an individual household connection, 65% for a yard tap). These results indicate the lowest brackets should have been broken down further in the questionnaire. Therefore, LD 2,800 (*USD 38.89*) and LD 2,500 (*USD 34.72*) are most likely at the high end of the spectrum of what people would actually be willing to pay for these one-time connection fees, and this should be further investigated in subsequent phases of this program. While a willingness to pay up to LD 2,500 *(USD 34.72)* and up to LD 2,800 (*USD 38.89*) is greater than the median gross household monthly surplus of LD 2,200 (*USD 30.56)*, the respondents may treat this as an "emergency" expense and may be willing to save for this one-time expenditure as indicated by their willingness to pay. The households with savings and access to informal loans, as revealed by the quantitative survey results, could also use these sources of funding to cover the one-time fee.

4. Conclusion

Despite the fact that 64% of the quantitative respondents perceived that they did not pay anything for water, most of the respondents (79%[43] of quantitative and all 29 qualitative respondents) indicated a willingness to pay for water from an improved source. As noted above, one can extrapolate that households' willingness to pay ranges from a median of LD 525 (*USD 7.29*) per month, or 5% of the median gross household monthly income for water from a yard tap or water kiosk/stand post (as a point of comparison, these findings are in line with the World Bank's 5% standard) to a median of LD 1,050 (*USD 14.58*) per month, or 10% of the median gross household monthly income for water from a piped household connection. With a median gross household monthly surplus of LD 2,200 (*USD 30.56*), the willingness to pay as expressed by the respondents falls within the median gross household monthly surplus. While a default assumption could be that it may be difficult to have people buy-in to a pay-per-use system for a resource they currently perceive to obtain for free, in fact, the quantitative and qualitative assessment results indicate a strong desire for an improved water source, and an ability and willingness to

[41] Littlefair, Kim. "Willingness to Pay for Water at the Household Level: Individual Financial Responsibility for Water Consumption." MEWEREW Occasional Paper No. 26. Water Issues Study Group, School of Oriental and African Studies, University of London. March 1998. Retrieved May 8, 2012 from: http://www.soas.ac.uk/water/publications/papers/file38369.pdf, pages 7-8.

[42] Ibid, "The Bank's approach to estimating levels of [willingness to pay (WTP)] is by application of the 5% rule. This rule commonly assumes that there is an elastic demand for the purchase of water with a cost of less than 5% of a household's income and an inelastic demand where the cost exceeds 5% of the household's income. Winpenny (1994) criticizes such a broad approach to assessing levels of WTP not least because it does not allow for the varying values of water through space and time. Rogerson (1996) agrees with Winpenny by stating that development agencies tend to overestimate the amount individuals are WTP whilst government agencies tend to underestimate. Consequently, Rogerson (1996) advocates further research, but at the household level in order to assess levels of WTP more accurately."

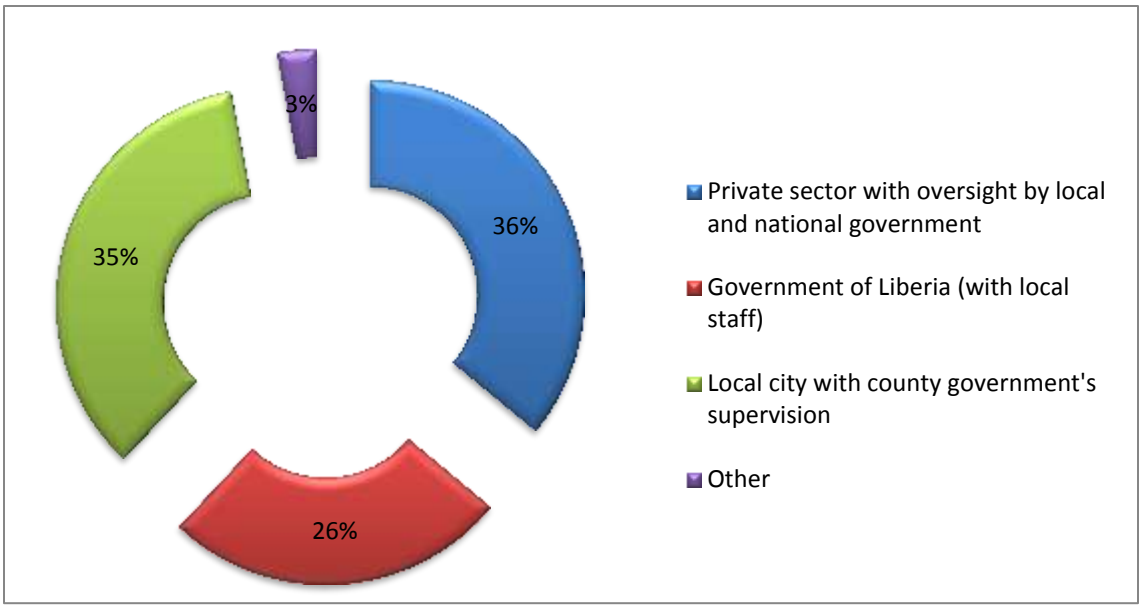
[43] Percentage of respondents willing to pay for a direct household connection.

pay for that water. Based on focus group responses, people can recall the metered water connections of the past and, thus, understand many of the benefits of this type of water connection. As noted above, there are a number of important factors that contribute to the high willingness to pay, including reducing the amount of time that children spend fetching water, addressing safety issues that children may face in accessing water, reducing instances of water-borne diseases, enjoying more immediate access at the household or neighborhood level, and mitigating conflict between neighbors over access.

3.7.7 Water System Management

The survey team asked the quantitative and qualitative respondents their opinion of who should manage the water system. Thirty-six percent (36%) of the quantitative respondents believed the private sector should manage the system with oversight by the local and national government, while 35% believed the local city should manage the system with the county government's supervision. Lastly, 26% believed the government of Liberia with local staff should manage the system (Figure 3-18). As for the qualitative respondents, the vast majority preferred that the private sector manage the water system. However, some believed payment collection would be more effective if the government of Liberia managed the system, thus, contributing to its success.

Figure 3-18: Preferred Entity to Manage the Water System, Voinjama



3.7.8 Household Savings and Access to Credit

1. Effective Demand for Informal Loans

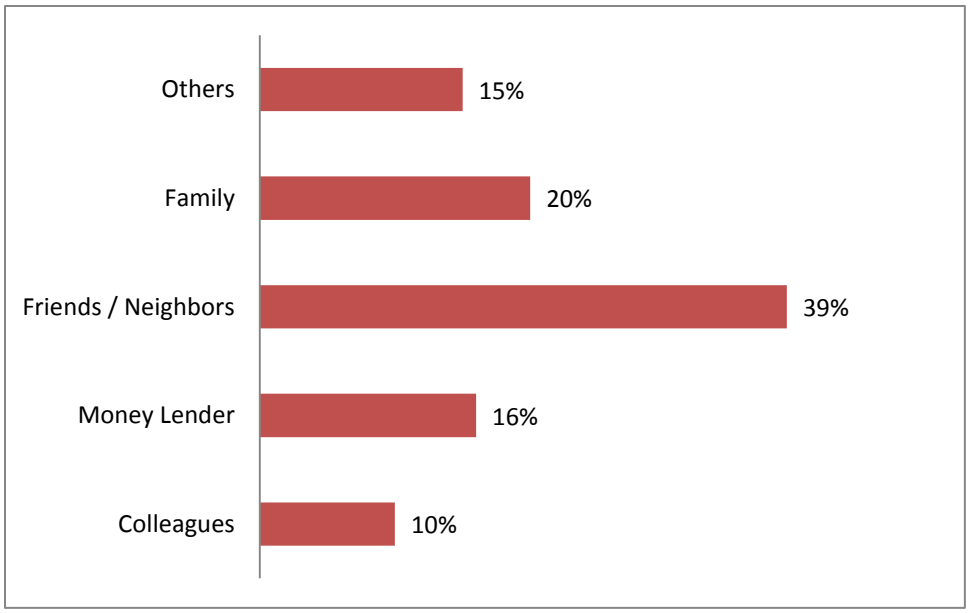
The quantitative survey included questions about the respondents' general use of alternative financial services to reflect how households are able to meet their demands for personal and business financial needs outside of the formal financial sector. Fourteen percent (14%) of the sample reported having requested a loan at some point in the past from an informal source, including family (20%), friends (39%), and moneylenders (16%).

Therefore, while most entrepreneurs reported being self-financed, it is clear that, between loans from Rotating Savings and Credit Associations (RoSCAs)[44] and other informal loans, the use of informal borrowing is a widespread financial management practice used by a fairly sizable percentage of households within the low-income group.

Respondents reported taking out an average of one (1) loan in the past 12 months. The average value of these loans was LD 22,036 / *USD 306.06* (LD 10,000 / *USD 138.89* median) with an average interest rate of 12% (0 median) and a three-month repayment period. Clearly, the interest amount is significantly dependent on the source of the informal loans. Respondents used these informal loans for a variety of purposes, including business (63%), personal (21%), and housing (16%).

[44] RoSCAs are known as Susu in Liberia.

Figure 3-19: Sources of Informal Loans, Voinjama



2. Participation in Informal Groups

In addition to individual loans from family and friends, other informal savings and credit channels, such as RoSCAs, played an important role in household financial management among low-income households. The quantitative survey indicated that 29% of the respondents have participated in informal savings and loans groups. Seventeen (17) members (15 median) generally comprise these informal savings and loan groups. On average, the members of the group make two (2) monthly contributions of LD 2,506 / *USD 34.81* (LD 1,000 / *USD 13.89* median). Additionally, 15% of respondents reported saving an average monthly amount of LD 28,132/ *USD 390.72* (LD 7,920/ *USD 110* median) with informal collectors.

In sum, households in Voinjama have the option of a variety of informal financial services to meet their personal consumption needs, including water and sanitation.

3.7.9 Formal Financial Services

The quantitative survey included an array of questions regarding the availability and use of formal financial services in order to better understand the obstacles that low-income groups face in accessing the financial sector. These questions are critical to help us understand the potential availability of funds for households to pay for a direct water connection and its associated consumption costs. In the absence of a robust microfinance sector, it was not surprising to find that the vast majority of respondents (97%) reported never having requested a formal loan from a bank or other formal financial institution. The main reason for not applying for a formal loan was a fear of the inability to repay (27%), followed by a perception of high interest rates and fees (24%), the lack of need for the credit (16%), and a perception of the difficulty and length of the loan procedures (9%), among others. This trend of avoidance of the formal credit market by low-income groups in Liberia is similar to the behavior low-income earners exhibit around the globe. Of the total sample, only a small percentage (2%) reported that formal financial institutions denied them access to formal loans. The main reason for rejection was a lack of collateral (50%).

Of the 1% who reported taking a formal loan over the past three (3) years, the majority of the respondents (60%) used the formal loans for business purposes, while the rest reported using the loans for personal purposes (40%). None reported using loans for water and sanitation purposes. The majority of this sub-

sample with formal loans (40%) was, at the time of the survey, repaying a loan. BRAC[45] provided all of these loans (100%).

The average size of the most significant formal loans used by the respondents over the past three (3) years was approximately LD 16,288 (*USD 226.22)* with an annual interest rate of 12%.[46] The average installment value was LD 520 (*USD 7.22)* with an average 22-month term. Sixty percent (60%) of the borrowers reported providing a guarantor or co-signer as collateral, followed by using their inventory as collateral (20%). Lastly, 20% reported providing no collateral.

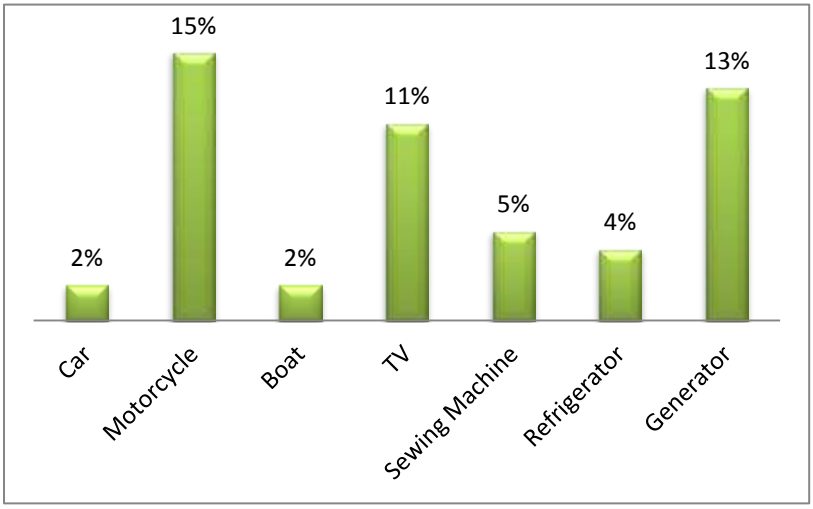
It is important to highlight that, while there is limited use of formal loans among low-income earners, 40% of the respondents report holding a deposit account with a bank. Additionally, the majority of the respondents who did not have a bank account reported an interest in opening one (66%). If personal finances inhibit households from paying for water connections, it is likely that households will depend on the informal sector to secure the funds since people fear their inability to repay a formal loan or that a formal financial institution will reject them.

3.7.10 Household Housing History and Quality

The average age of homes represented in the survey was 11 years, and the average occupancy duration in the dwelling was five (5) years. Out of the 58% who reported building their home, 69% hired laborers to assist in the construction of their homes. Seventy-eight percent (78%) reported the use of personal funds to build their homes.

Respondents reported having an average of four (4) rooms in their home. Close to half of the respondents reported that the majority of their home was built from a mixture of mud and cement (46%), among other materials. Twenty-one percent (21%) had kitchens inside the home, and 68% stated that they used bathroom facilities outside of the home. The majority of the respondents reported living in houses with no electricity (73%). In addition, few households owned significant assets such as motorcycles (15%), televisions (11%) or generators (13%).

Figure 3-20: Household Assets, Voinjama



[45] Microfinance institution founded in Bangladesh in 1972, http://www.brac.net/content/about-brac-liberia.

[46] Respondents indicate taking out multiple loans. The average presented here as the "most significant" represents the loan with the largest monetary value.

3.7.11 Commercial and Institutional Water Consumption and Sanitation Characteristics

Commercial entities, including small and medium enterprises (SMEs), guesthouses and a gas station, indicated they consumed between 38 and 1,590 liters of water daily, depending on the type of business. The institutional users consumed up to 19,000 liters of water daily. With the exception of the hospital that has its own complex water infrastructure, institutional users interviewed relied upon hand dug wells, which had run dry during the dry season, and surface water. Thus, two (2) of the three (3) institutional users were not able to estimate current consumption. All respondents indicated a willingness to pay for an improved water source. Commercial entities were willing to pay a fee for a meter connection and understood that money would be collected every month based on consumption as registered by the meter. Some commercial entities indicated they would be willing to pay between LD 150 (*USD 2.08*) and LD 3,600 (*USD 50*) per month for water. Most respondents indicated that water consumption would increase in the future with ease of access.[47]

The following table provides a breakdown of the six (6) largest commercial and institutional users interviewed as well as their daily water consumption by liters:

TABLE 3-7. Institutional and Commercial Demands, Voinjama

Name	Type of entity	Estimated consumption in liters per day
Tellewonyan Memorial Government Hospital	Institutional	19,000
Free Pentecostal Bible College	Institutional	3,350[48]
Voinjama Multilateral High School	Institutional	1,600[49]
Voinjama Gas Station	Commercial	1,590
National Social Security & Welfare Corporation's Guest House (NASSCORP)	Commercial	1,325
Kingtuma Guest House	Commercial	324[50]

Women-owned SMEs, typically water vendors, obtained at least 38 liters daily from protected wells, while those in food services reported consuming 227 liters daily. The two (2) guesthouses interviewed consumed between 324 and 1,325 liters of water per day. The gas station consumed an average of 1,590 liters daily. Generally, the commercial entities obtained water from a protected well or water tank near their place of business, primarily on institutional compounds, or traveled from well to well to obtain water. The guesthouses rely on protected wells in neighboring communities.[51] It should be noted that protected well caretakers reported that, due to the shortage of water in the dry season, they controlled access to the protected wells by setting hours of operation and by limiting how much water users could draw. This is not the case in the wet season. The protected well caretakers also reported collecting funds in amounts ranging from LD 50 (*USD 0.69*) to LD 300 (*USD 4.17*) on an ad-hoc basis for specific maintenance and repair costs. The gas station, specifically, mentioned it would be willing to pay LD 3,600 (*USD 50*) per month for water. The other SMEs said they would be willing to pay for an improved

[47] Please note that there are no industrial entities present in Voinjama.

[48] Based on 1 liter per student per day and 2 jericans per resident staff with dependents per day.

[49] Based on 1 liter per student per day as there is no sanitary plumbing.

[50] Based on reported use when the elevated tank system was operative.

[51] Previously, the guesthouses obtained water from the United Nations Mission in Liberia (UNMIL), a courtesy no longer available. The guesthouses then invested in a borehole, but the well was drilled improperly, rendering the water level insufficient.

water source but were reluctant to give a maximum amount they would be willing to pay. All commercial entities indicated that water consumption would increase with an improved, accessible source.

The institutional users interviewed included a hospital, a college, and a high school. The hospital indicated that it consumed an average of 19,000 liters of water daily, drawn from its own borehole. The college and high school were unable to estimate their water consumption. The college previously had access to on-site hand dug wells, which had since become dry. Therefore, the college was forced to rely on neighboring protected wells or surface water. The high school had a protected well. The institutional users did not pay directly for water consumption but, instead, incurred related maintenance and operational costs. For example, the hospital purchased generator fuel to operate the borehole and paid salaries for its maintenance staff, while the high school hired security staff to control access to the protected well. The institutions interviewed did not articulate an amount they would be willing to pay for an improved water source; however, the hospital had been connected to the pre-war piped water system and had a line item for water utilities in its budget, indicating it had the capacity to pay for water in the future. Regarding future consumption, the hospital expected consumption to go up with an anticipated increase in out-patient care. The high school is building new dormitories and the college also plans to triple the size of its student body, although it did not provide a specific timeframe. Based on the hospital's and educational institutions' expansion plans, the survey team estimates an additional daily demand of 64,350 liters from these institutions.

Sanitation conditions in Voinjama are poor and, with the exception of the hospital and guesthouses, few respondents had access to a flush toilet. Only two (2) SMEs claimed to have flush toilets at their place of business. Most said they had access to a public facility or private latrine (including in their home when it was located close to their business). The high school provided pit latrines for student use.

3.8 WATER DEMAND

Based on the household survey conducted by LMWP in early 2012 and presented in the Situational Analysis Report, per capita household water use in Voinjama is estimated to be approximately 13.3 liters per capita per day (lpcd), or around 57 to 76 liters per household per day[52]. This value includes water used for all purposes including cooking and cleaning. LMWP assumes that users may initially only obtain drinking water from a new piped supply and continue to rely on existing sources for non-drinking purposes, but eventually transition to utilizing piped water for most demands. Using the above population estimates, the water supply demand for Voinjama was developed considering a steady growth from an expected near "no access" initial level of service demand for piped water of less than 5.3 gpcd (20 lpcd). The projected future level of service is expected to exceed the required "basic access" and provide water within a 30 minute period and at rates greater than the 5.3 gpcd (20 lpcd) consumption demand. A project "goal" of 10 gpcd (38 lpcd) is being used for evaluation purposes in this Master Plan. A long term supply goal of 13 gpcd (50 lpcd) will be used for this master planning document. This rate is consistent with the demand rate utilized in the design of the previous water system for water obtained from public taps. It is important to note that projected flows are presented for conservative long term planning only, based on projected total Voinjama population. Actual demands by year will be dependent on service population, which is expected to be less than the total population. In addition, estimation of increased demand based on transitioning from distributed sources such as hand pumps, vendors, and surface water to piped water supply is difficult in Liberia given the lack of recent precedent for such a transition.

The Voinjama flow demand rate to be used for evaluation as part of this LMWP planning document is intended to increase from the substandard condition to a level exceeding the Basic Access Service Level.

[52] In Voinjama, per capita consumption is estimated to be 11.4 liters per person per day in the dry season (5 jerricans/HH) compared to 15.2 liters per person per day in the wet season (3 jerricans/HH).

Table 3-8 Level of Water Service[53]

Service Level	Consumption Demand	Access Measurement	Consumption Needs	Hygiene Needs	Level of Health Concerns
No access	Quantity collected often below 1.3 gpcd (5 lpcd)	More than 1000 m or 30 minutes total collection time	Cannot be assured	Not possible (unless practiced at source)	Very high
Basic access	Average quantity unlikely to exceed 5.3 gpcd (20 lpcd)	Between 100 and 1000 m or 5 to 30 minutes total collection time	Should be assured	Hand washing and basic food hygiene possible; laundry/ bathing difficult to assure unless carried out at source	High
Intermediate access	Average quantity about 13 gpcd (50 lpcd)	Water delivered through one tap onsite (or within 100m or 5 minutes total collection time	Assured	All basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access	Average quantity 26 gpcd and above (100 lpcd+)	Water supplied through multiple taps continuously	All needs met	All needs should be met	Very low

http://www.who.int/water_sanitation_health/diseases/WSH03.02.pdf

[53] Table was derived from *Domestic Water Quantity, Service, Level and Health* (WHO/SDE/WSH/03.02), World Health Organization, 2003. Available online: http://www.who.int/water_sanitation_health/diseases/WSH03.02.pdf

Table 3-9 LMWP Proposed Improvement to Service Level

Present		Immediate Need		Project Goal		Long Term
No Access Service Level	→	Basic Access Service Level	→	Improved Access Service Level	→	Approx. Intermediate Access Service Level
1.3 gallons per capita·day		5.3 gpcd		10 gpcd		13 gpcd
5 lite per capita·day		20 lpcd		38 lpcd		50 lpcd

Table 3-10 Population and Demand Flow Projections[54]

Year	Populations	Residential Demand		Residential Flow		Non Residential Flow		Total Daily Flow	
	(persons)	(gpcd)	(lpcd)	(gpd)	(m3/d)	(gpd)	(m3/d)	(gpd)	(m3/d)
2008	14,543								
2011	15,100	1.3	5	19,700	70	6,310	22	26,010	92
2012	15,300	1.3	5	19,900	80	6,370	26	26,270	106
2013	15,500	5.3	20	82,200	310	26,310	99	108,510	409
2014	15,700	5.3	20	83,300	320	26,660	102	109,960	422
2015	15,900	6.4	24	101,300	380	32,420	122	133,720	502
2016	16,100	7.5	28	120,400	460	38,530	147	158,930	607
2017	16,300	8.6	33	139,900	530	44,770	170	184,670	700
2018	16,500	9.7	37	159,800	610	51,140	195	210,940	805
2019	16,700	10.8	41	180,200	680	57,670	218	237,870	898
2020	17,000	11.9	45	202,300	770	64,740	246	267,040	1,016
2021	17,200	13.0	50	223,600	850	71,560	272	295,160	1,122
2022	17,400	13	50	226,200	860	72,390	275	298,590	1,135
2023	17,600	13	50	228,800	870	73,220	278	302,020	1,148
2024	17,900	13	50	232,700	880	74,470	282	307,170	1,162
2025	18,100	13	50	235,300	890	75,300	285	310,600	1,175
2026	18,300	13	50	237,900	900	76,130	288	314,030	1,188
2027	18,600	13	50	241,800	920	77,380	294	319,180	1,214
2028	18,800	13	50	244,400	930	78,210	298	322,610	1,228
2029	19,100	13	50	248,300	940	79,460	301	327,760	1,241
2030	19,300	13	50	250,900	950	80,290	304	331,190	1,254
2031	19,600	13	50	254,800	970	81,540	310	336,340	1,280

[54] Projected flows are presented for conservative long term planning only, based on projected total Voinjama population. Actual demands by year will be dependent on service population, which is expected to be less than the total population.

These values are used for planning purposes to evaluate the potential of water supplies to sustain long-term needs and in selecting the water system components to be incorporated in the water improvements for Voinjama. **Figure 3-21** presents the projected annual residential, non-residential and total daily flows for the City of Voinjama. The residential flows are based on populations and expected demand rates. The non-residential flows are estimated based on the following percentages of estimated residential demand: 20% unaccounted for water, 5% industrial, 3% commercial, 2% institutional, and 2% emergency.

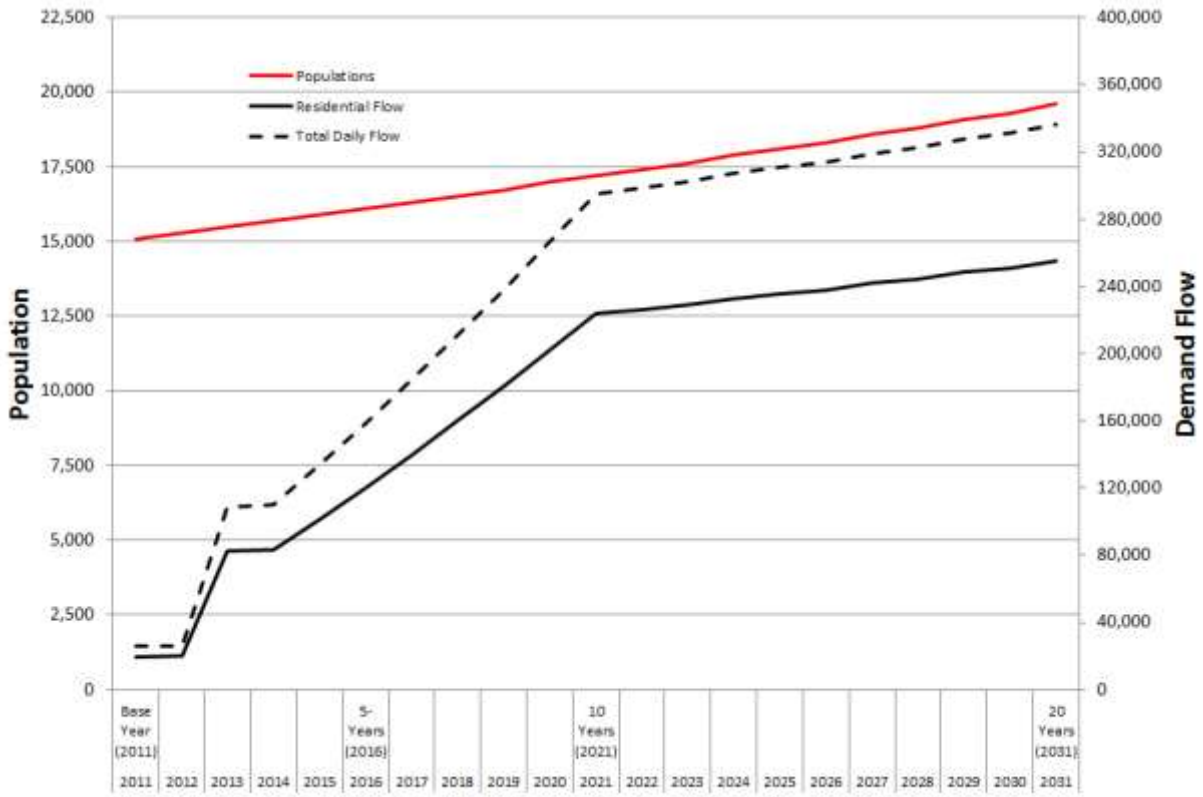


Figure 3-21 Population and Demand Flow Projections

3.9 POTENTIAL SERVICE AREAS

A series of geospatial evaluations were conducted to assess the area of needs in Voinjama and the potential project approach based on the availability of water improved water supplies. The first geospatial evaluation was conducted for the wells in Voinjama based on the results of the pump testing, the recharge capacity of the well, the estimated capacity of the individual wells, and the reported operating status by user (from the WSP survey). A theoretical service area for each well was established based capacity of the well, estimated demand per capita, and population density as follows:

- Determine estimated capacity of the well (gallons per day)
- Determine demand rate (gallon per capita per day)
- Divide the well capacity by the per capita demand rate to yields the number of people each well can serve number of persons for each well)

- Divide the number of people per well by the population density (estimated from Liberia census enumeration data) to yield the service area size of each well (km^2).
- Plot the service area of each well as a circle with the well in the center to show the approximate coverage area for each well.
- Additional evaluation of the operating status (all wells versus wells reported as good quality and quantity per WSP survey results from interviewing users or care takers) can be used to assess the actual use of each well based on WSP usage.

This analysis was used to develop the following figure. The estimated service areas are shown by the circular "bubbles". The service areas are only applied to WSP wells with both good water quality and quantity (year round use). The estimated coverage areas of the wells with good quality and quantity appears to limit the amount of Voinjama that can be served (if the wells are considered protected and improved sources).

The second geospatial evaluation was based on the findings for the socioeconomic survey and the responses the question (Q110) of household having "regular access to an improved water source with a 30 minute round trip." Some of the data from the socio economic results had to be parsed to eliminate respondents, who apparently reside outside of the city limits. The overall percentage of Voinjama respondents indicating that they have regular access to an improved water source with a 30 minute round trip was 59%. A review of the parsed data indicated a consistent response in the various communities, with the exception of 30% in the Guinea Road community and 87% in the Lawulazu Road community. The remaining communities were all within 10% of the city average. This would indicate the following

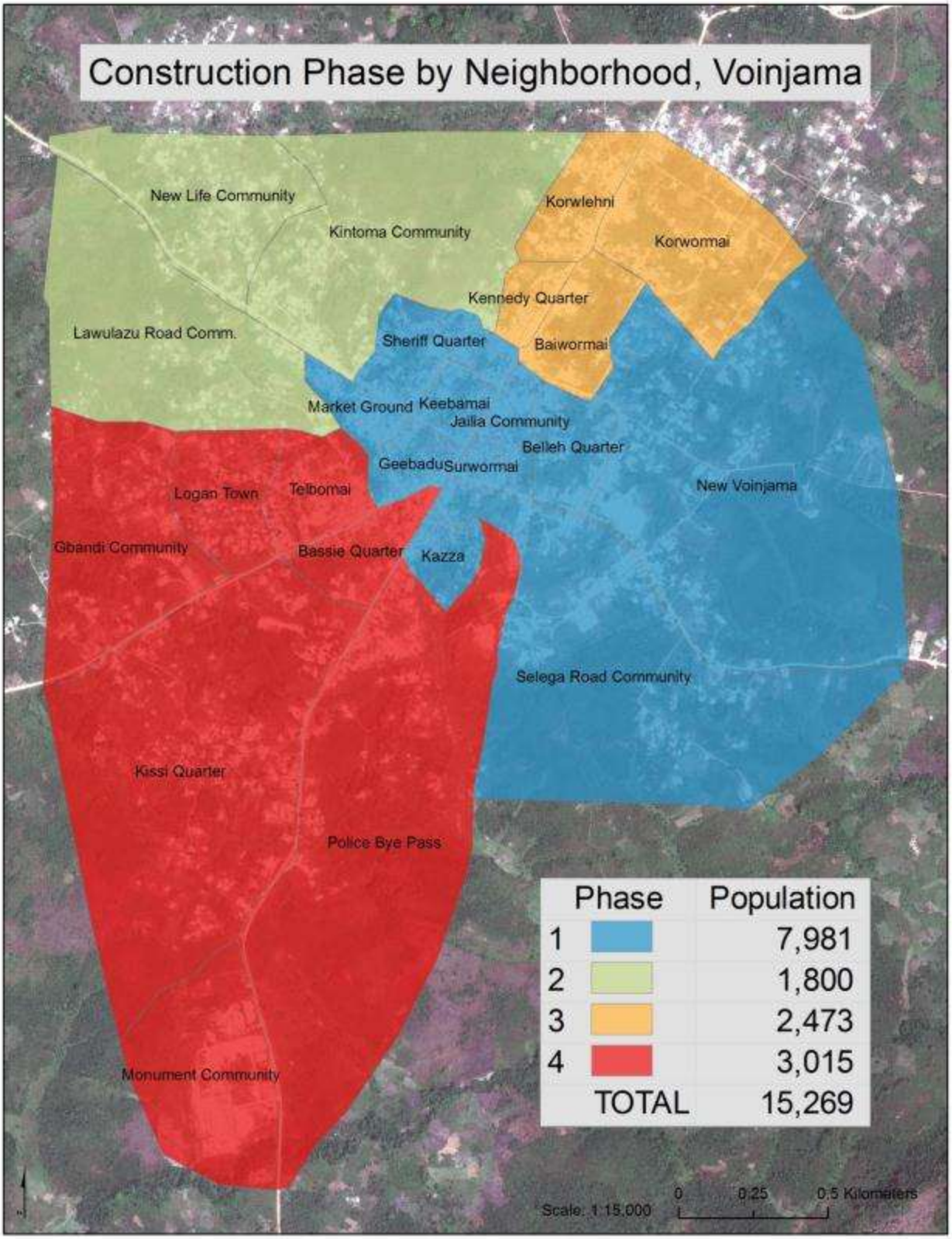
- The less than average access to water in the Guinea Road community.
- The better than average access to water in Lawuzula Road community.
- The consistent level of access in the other portion of Voinjama

Figure 3-22 Estimated Coverage from Wells Reported with "Good Quality"

The third geospatial evaluation was based on the assumptions that water drawn from shallow aquifers via the hand dug wells would not be compliant with WHO standards, and the largest source of water would be from the previous water supply source the Zeliba River. The priority was therefore the address the areas with large population in a systematic development of water distribution. Table 3-11 shows the progress of the services area by enumeration areas.

Table 3-11 Community Population, rankings & potential phased development

Enumeration Area Community Name	Total Population	Pop. Ranking	Population Served in Phase 1	Population Served in Phase 2	Population Served in Phase 3	Population Served in Phase 4
Sherriff Quarter	1,261	1	1,261	1,261	1,261	1,261
Keebamai	1,193	2	0	0	1,193	1,193
Geebadu	992	3	992	992	992	992
Kintoma Community	926	4	0	926	926	926
Market Ground	842	5	842	842	842	842
Surwormai	832	6	832	832	832	832
Logan Town	807	7	0	0	0	807
Kazza	794	8	794	794	794	794
Kennedy Quarter	704	9	0	0	704	704
Korwlehni	694	10	0	0	694	694
New Voinjama	690	11	690	690	690	690
Telbomai	669	12	0	0	0	669
Kissi Qtr. & Monument Com.	629	13	0	0	0	629
Korwormai	599	14	0	0	599	599
Lawulazu Road Community	582	15	0	582	582	582
Selega Road Community	577	16	577	577	577	577
Jailia Community	508	17	508	508	508	508
Bassie Quarter	491	18	0	0	0	491
Baiwormai	476	19	0	0	476	476
New Life Community	292	20	0	292	292	292
Belle Quarter	292	21	292	292	292	292
Gbandi Community	255	22	0	0	0	255
Police Bye Pass	164	23	0	0	0	164
Totals	15,269		6,788	8,588	12,254	15,269
Percentages			44%	56%	80%	100%


Construction Phase by Neighborhood, Voinjama
New Life Community
Kintoma Community
Korwlehni
Korwormai
Kennedy Quarter
Lawulazu Road Comm.
Sheriff Quarter
Baiwormai
Market Ground
Keebamai
Jailia Community
Belleh Quarter
Geebadu
Surwormai
Logan Town
Telbomai
New Voinjama
Gbandi Community
Bassie Quarter
Kazza
Selega Road Community
Kissi Quarter
Police Bye Pass
Monument Community
Phase
Population
1
7,981
2
1,800
3
2,473
4
3,015
TOTAL
15,269
Scale: 1:15,000
0
0.25
0.5 Kilometers

4.0 POTENTIAL WATER SYSTEM COMPONENTS

Outlined below are the water system components relevant to the various infrastructure improvement options being considered:

- Groundwater Supply Options
  - Existing Hand Pumps
  - Bore Holes
- Surface Water Supply Options
  - Zeliba River and other Small Stream
  - Lake Teleh
  - River Bank Filtration
- Pumping Power System Options
  - Solar Power
  - Wind Power
  - Dedicated Generators
- Water Treatment Options
  - Chlorination
  - Water Treatment Processes
  - Managed Water Treatment Systems
  - Packaged Water Treatment Systems
- Storage Options
  - Existing Water Storage Tank
  - Mini Tank-Zonal Nodes
  - Private Tanks
- Water Distribution Options
  - New Distribution Network

4.1 GROUNDWATER SUPPLY OPTIONS

The feasibility of developing a groundwater supply in Voinjama appears to be limited based on the record information and the pending hydrogeological study findings (anticipated to be completed in January 2013), existing practices and water quality conditions. Given initial encouraging data on the water quality in Zeliba River, and its previous use as a water supply for Voinjama, utilization of surface water is the preferred option. However, this will require the restoration and possible modification of the impoundment facilities (water control structure and berm).

Figure 4-1 African Geological, Groundwater Depth and Aquifer Production Maps [55], indicates Liberia is located in a basement complex area, and has generally shallow depths to groundwater. The figure also indicates the yields are typically low to moderate.

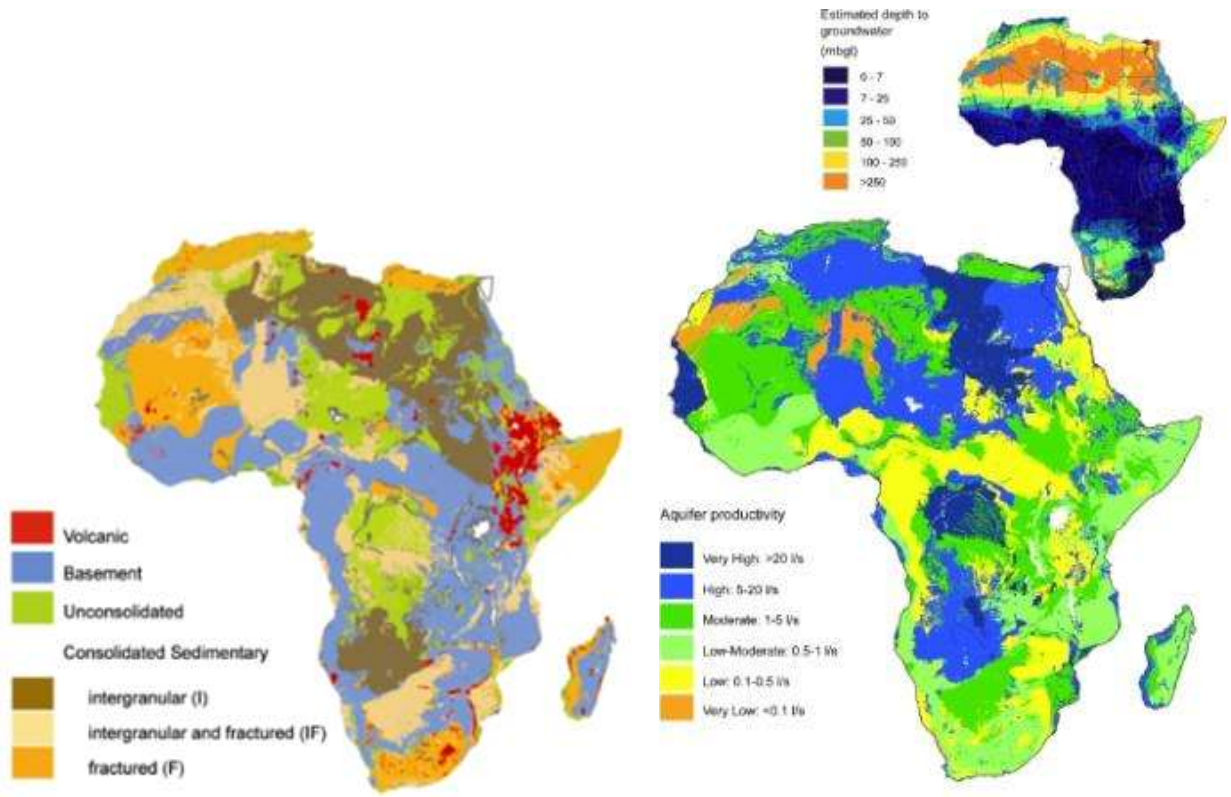


Figure 4-1 African Geological, Groundwater Depth and Aquifer Production Maps

A desk and field investigation of groundwater was conducted to determine if a groundwater supply could be located and developed as a means of serving Voinjama's drinking-water needs. Even though the previous system was based on a surface water supply, the current operation and sustainability factors favor a groundwater supply. A groundwater supply would most likely require less treatment and be a less costly source of water. The supply of a groundwater source appears limited: according to the Liberia "Feasibility Study for Manual Drilling – Mapping of Favorable Zones" by the GoL notes (page 18)

> *"Most of the country is formed by geological units which are not favorable because of the nature of the bedrock, but can be covered by an important alteration layer, exploitable by manual drillings."*

Discussions with well drillers with experience in Voinjama indicates that when drilling and searching for groundwater, fissures in the bedrock are not always productive, but some groundwater can be found in the

[55] "Quantitative maps of groundwater resources in Africa" by IOPselect, A M MacDonald1, H C Bonsor, B É Ó Dochartaigh1 and R G Taylor, 19 April 2012

weathered bedrock. The drillers also indicated that crystalline-bedrock-drilled wells are likely to provide a good quality groundwater source. They indicated the yields from a bedrock well could potentially be in the range of 34 to 60 gpm. The drillers interviewed indicated that a series of wells is a potential solution to the problem of water supply in the city. But all these projections appeared to be optimistic and based on locating large capacity water carrying features that could include fractures in bedrocks or weathered bedrock interfaces.

The World Bank's Water and Sanitation Program (WSP) was developed to locate, map, and inventory the hand pumps in Liberia. The WSP field program used smartphone technology to locate and describe the water points. The survey used GPS and produced information regarding the operation of the hand pumps, the water quantity, and the water quality. Interviews with local residents were conducted to gather quality and quantity information. In some areas, best professional judgment was used in assessing the conditions.

Depletion of water levels during the dry season was evident. Many wells were dry and unusable, other wells supplies were quickly depleted and showed limited recharge capacity during the managed hours of the hand pump.

At each well, the team used one of two pump testing methods, depending on the conditions. Most commonly, the team used a submersible pump connected to an electrical generator, combined with PVC pipes and a flow meter for measuring the discharge from the well. Under these circumstances, the team would first remove the small concrete manhole and use the manhole to lower the pump assembly. Each cover was mortared after the pump test to restore protection of the well.

The team used a second method of pump test when they encountered a well with a water column too short to accommodate the submersible pump; the submersible pump's intake was approximately one foot up from the bottom of the pump. In this case, the team used the existing hand pumps to discharge well-water into containers of known volume.

The pump tests involved the pumping of a single well with no associated observation wells. The purpose of a pump test is to obtain information on well yield, observed drawdown, and specific capacity, i.e., the yield divided by the drawdown. Depending on the results obtained, the test data can also be used to make some reliable estimates of groundwater performance and characteristics.

Community well caretakers were approached no later than one day before the pump test was to be performed, in order to obtain permission to pump the well and to allow time for the caretaker to alert the residents. In general, this practice was successful in preventing residents from drawing down the well before the arrival of the team and in maximizing the collection of the water by residents during execution of the test. The pump tests were composed of two phases; the draw down period, during which water was removed from the well via pumping, and the recovery/recharge period, during which no additional water was pumped from the well, but measurements were taken of the height of the water column so as to determine the rate of inflow from the surrounding groundwater. Listed below are some general findings of the pump tests conducted in the three cities during the DA trips.

- Most wells were pumped dry (or to a level in which the hand pump or submersible pump could not operate) before the planned 45 minute draw down period, even when the flow rate was as low as 3 gallons per minute (gpm).
- Some wells had limited capacity that resulted in draw down periods of only several minutes.
- Many wells showed minimal recharge in the 30+ minute recovery/recharge periods.
- Due to the extremely low flow produced by the selected well and the limited capacity available resulting from the dry season conditions, the pumps tests could not be conducted at an equilibrium condition in which the inflow to the well matched the outflow from the well. Due to the low yield

conditions present, the capacity of the wells observed during the DA trips are estimated based on volume pumped during each test and the estimated number of draw-fill cycles that can occur in 24 hours.

The dry conditions during the 2012 dry season appears to confirm the results presented in the findings of the "Water Supply Project for Voinjama" conducted by German consultants in the 1970's, which stated

> *"Study proved that an appropriate quantity of groundwater cannot be caught applying methods which are reasonable from the economic point of view."*

This was based on a weighted average of 72 liters per day person with water dispensed from public taps and private service connections. The then future demand was for a 1,276 cubic meters per day water system demand.

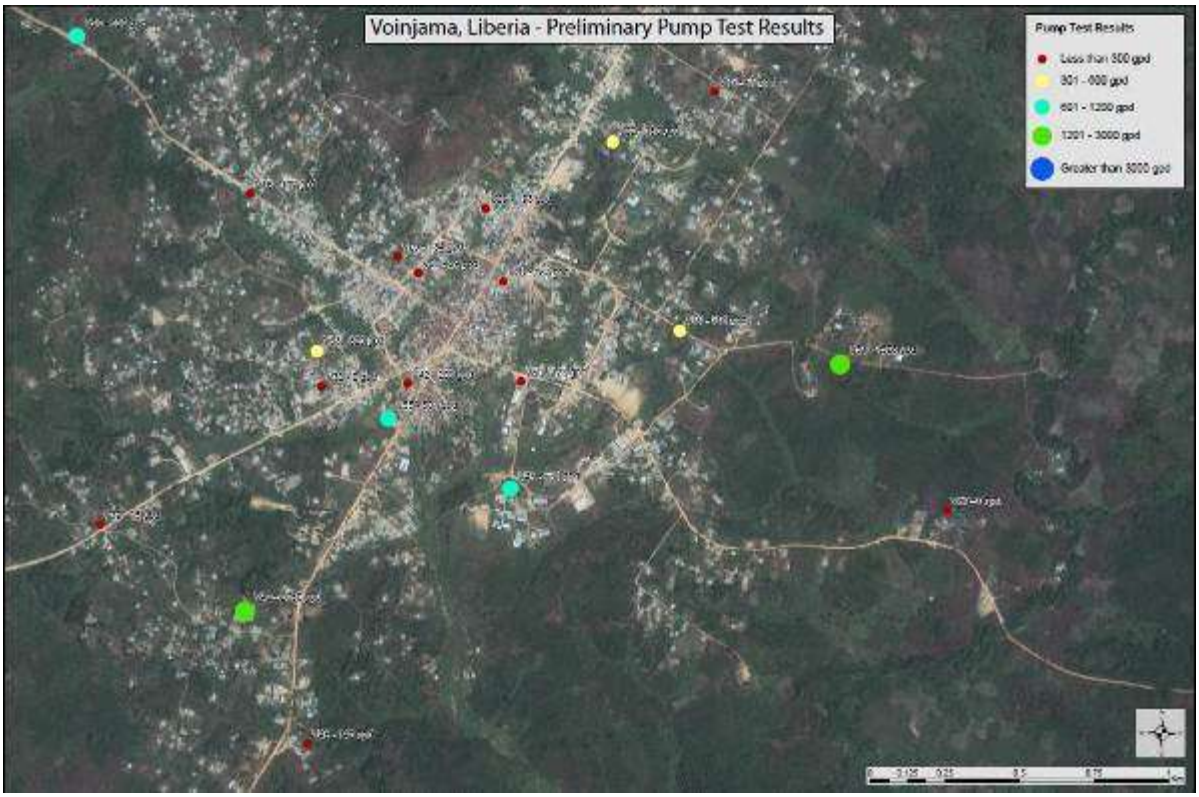
TABLE 4-1 lists the minimum, average, and maximum well characteristics and test results observed and calculated from the pumps tests in Voinjama, during the Detailed Analysis Trip.

TABLE 4-1: SUMMARY OF VOINJAMA PUMP TESTS

Voinjama Well Characteristics	Units	Average	Minimum	Well #	Maximum	Well #
Pump Duration	Minutes	22.60	2.50	V08	49.25	V51
Recharge Duration	Minutes	33.60	28.00	-	54.25	-
Depth of Well	Feet	31.57	14.50	V56	46.00	V05
Depth Pumped Down	Feet	3.95	0.20	V08	11.13	V46
Depth Recovered	feet	0.63	0.12	V08	2.75	V51
Volume of Water Pumped	gals	206.20	0.00	V32 V57	746	V46 V58
Average Flow Rate Pumped	gpm	10.24	2.35	-	24.08	-
Volume Recovered in Recharge Period	gals	38.04	6.45	V08	145.43	V51
Recovery Rate	gpm	1.12	0.21	V08	4.16	V51
Estimated Time to Recover	Min	1413.99	55.31	V40	6031.13	V46
Estimated Time to Recover	Hours	23.57	0.92		100.52	
Estimated # of Draw-Fill Cycles per Day	per day	4.15	0.24	V46	26.03	V40
Estimated Daily Capacity of Well	gpd	453.99	0.00	V32 V57	2750.12	V40

Presented in **TABLE 4-2** are the estimated capacities of the selected wells that were pump tested in Voinjama. Both well #V32 and #V57 were found to be dry and could not be pump tested. Figure 4-2 is a map indicating the wells' locations and capacities.

TABLE 4-2: VOINJAMA INDIVIDUAL PUMP TEST RESULTS			
Voinjama LMWP Well #	**Volume of Water Pumped (gals)**	**Estimated Number Of Draw-Fill Cycles per Day**	**Estimated Daily Capacity of Well (gpd)**
V02	181.63	2.09	380
V05	106.39	0.61	65
V08	11.73	2.51	29
V09	127.40	1.05	134
V15	137.54	1.29	177
V20	310.99	0.50	157
V29	18.60	10.36	193
V32	0.00	0.00	0
V33	16.45	1.69	329
V40	96.41	26.03	2,750
V46	746.33	0.24	140
V49	191.59	2.36	631
V50	384.85	0.37	120
V51	390.36	3.86	1,508
V55	346.90	1.73	601
V56	59.56	10.45	622
V57	0.00	0.00	0
V58	745.80	0.78	581
V42	45.22	4.62	209



Liberia Municipal Water Project

Figure 4-3 Voinjama Pump Test Results

The sum of the Estimated Daily Capacity for the 19 wells pump tested is approximately 8.630 gpd, which represents an average of about 450 gpd. The 19 wells tested represent approximately 30% of number of estimated in the City of Voinjama. The number of residents the tested wells can serve depends on the consumption rate during the dry season. It is assumed that the consumption rate will vary based on the availability of water. **TABLE 4-3** indicates the Voinjama population that can be served at varying consumption rates. While the consumption rate to be used in the design of LMWP improvement is still being developed for approval by the Engineering Working Group, the likely consumption required is approximately 15 gallons per person per day.

TABLE 4-3: VOINJAMA INDIVIDUAL PUMP TEST RESULTS		
Number of Wells Pump Tested	19	
Daily Volume (Pump Tested)	8,630	Gallons Per Day
Est. Total Number of Wells	60	
Projected Theoretical Daily Volume	27,300	Gallons Per Day
Est. 2011 City Population	15,100	

Consumption Rate		Served Population	
gcpd	**lcpd**	**Persons**	**% of City Pop.**
1	3.8	27,300	181%
2	7.6	13,650	90%
3	11.4	9,100	60%
4	15.2	6,825	45%
5	19.0	5,460	36%
15	56.9	1,820	12%
20	75.8	1,365	9%

4.2 EXISTING HAND PUMP WELLS

The majority of Voinjama residents obtain a portion of their water supply from wells. As noted above, for drinking and cooking purposes, approximately 80% household survey respondents reported using protected wells with hand pumps or dug wells as the main source of drinking water. Due to water quality concerns identified by the users, including the aesthetics and bacteriological contamination, many residents do not consume the groundwater directly. Roughly a third of the survey respondents (31%) reported treating their drinking water all the time, and 23% said they treated the water sometimes. The vast majority of the respondents (93%) who treated their water used chemicals (disinfectants) such as WaterGuard.

The hand pumps are mostly placed over and draw from hand dug wells of varying total and water columns depths. Only a few (3-4) hand pumps were observed to be located above a bore hole. The supply of a groundwater source appears limited based on the Liberia "Feasibility Study for Manual Drilling – Mapping of Favorable Zones" by the Government of Liberia which notes (page 18)

> *"Most of the country is formed by geological units which are not favorable because of the nature of the bedrock, but can be covered by an important alteration layer, exploitable by manual drillings."*

Listed below are some general findings of the groundwater in Voinjama's hand dug wells during the March 2012 Detailed Analysis (DA) visit:

- Most shallow hand dug wells were pumped dry (or to a level in which the hand pump or submersible pump could not operate) before the planned 45 minute draw down period of the pump test was completed, even when the flow rate was as low as 3 gallons per minute (gpm).
- Many wells were visually observed as adversely impacted resulting in poor aesthetic quality, apparently to the shallow aquifer conditions.
- Many wells showed minimal recharge.
- Due to the extremely low flow produced by the tested hand dug wells and the limited capacity available resulting from the dry season conditions, the pump tests could not be conducted at an equilibrium condition in which the inflow to the well matched the outflow from the well.

The water quality of the groundwater from the Voinjama hand dug wells generally had a pH less than the minimum standard range of 6.5 to 8.5, indicating an acidic nature to the sampled water.

The continued use of hand pumps for non-consumptive use may reduce the demand on the planned potable water system, but would likely impact the sustainability of the new system if users continue to use the free source that is likely to be substandard and unprotected.

4.3 SUBSURFACE DAMS

Subsurface dams function as underground dams to control and impound additional groundwater in a defined area. They are often located at an ephemeral stream or wetland to increase the elevation of the water table and to increasing the volume of stored water. This modification of the groundwater is generally conducted in arid and rural regions. Construction methods include installation of impermeable barrier by either grouting, slurry wall, sheet steel, mix-in-place, clay and concrete.

The advantages to subsurface dams as compared to the more tradition surface dams include:

- Traditional surface water dams include both safety structural concerns
- Subsurface dams are not impacted by evaporative losses.
- Subsurface dams are capable of recharging to shallow groundwater aquifers
- Subsurface dam can provide a storage volume for precipitation that may be lost as runoff/groundwater migration.
- The installation of wells on the upstream side can provide additional water supply to the service area.

The disadvantages include:

- The requirement to toe or key the base and lateral sides of the dam into lower permeability soils or bedrock
- Another concern in the design and operation of the barrier system is to fluctuation of the water table that could adversely impact water quality such as salinity levels
- The volume the barrier can retain is dependent on the natural soil condition characteristics especially the effective porosity on the upstream side of the subsurface dam

Further consideration of subsurface dam applications is not considered likely for the Voinjama setting but is dependent upon many factors including the conditions found during the hydrogeological study and if contractors experienced in this procedure can be located. Other factors would include the identification of potential sites, environmental impacts, construction costs, and the ability to monitor the system.

4.4 HYDROGEOLOGICAL STUDY

To determine the hydrological conditions in the Voinjama area, the LMWP is contracting with Favour Consult Limited of Nigeria is to carry out a hydrogeological study by January 2013 and test drilling (depending on study results) in Voinjama. The hydrogeological study will be comprised of a desk study and groundwater exploration program, before any test well drilling, in order to detect the most likely productive locations.

The desk study evaluated the watersheds and sub-watersheds that are contributory to the study areas which included:

- Watershed size (area)
- Present land use
- Stream flow characteristics
- Ranking of watersheds or sub water sheds for a groundwater exploration program on the basis of land use and watershed size
- Analyze the data from remote sensing platforms to delineate subsurface areas of fracturing and faulting

A groundwater exploration program will be conducted to locate potential high yield well sites. This will include:

- Evaluation of Voinjama environment to observe the geological surficial conditions and topography.
- Geophysical field survey (Conduct vertical electrical soundings) to identify optimal areas for test well drilling

The desk study and field effort results are expected to indicate the aquifers underlying Voinjama are unconfined and occur in rather limited discrete pockets. The limited amount of groundwater availability depends primarily on the geology of being located on the basement complex. It is further expected the crystalline rocks underlying Voinjama appear to have no primary porosity, and limited fractures or faults. Therefore no permeability and supply of groundwater from the bedrock is considered very limited, but this must be confirmed by the hydrogeological study.

Since the ancient rocks of Liberia occupy stable continental shield areas, it would be expected that a thick overburden, probably as much as 60 m as in other places in Africa, would have developed. However, prolonged erosion has removed much of the old overburden. The thickness of the overburden (regolith) is limited and is rather thin, usually not more than 20 m. The overburden is seen as earthy, lateric material at road cuttings. Alluvial deposits comprising poorly sorted slits, sand and gravels was detected in the floodplains and stream channel and identified as source of groundwater.

Groundwater is in Voinjama is likely only to be found where secondary porosity has developed in the unconsolidated overburden created by weathering and/or joints in the rock and in the alluvium associated with the several rivers and swamp lands that occur in the project area.

The permeability of the overburden depends on the extent of the fracturing and the clay content. In the soil zone, permeability is usually high but groundwater does not exist throughout the year and dries out soon after the rains. Beneath the soil zone the rock is often highly weathered and clay rich so permeability is low. Towards the base of the weathered zone, near the fresh rock interface, the proportion of clay

reduces significantly. This horizon consisting of fractured rock is more permeable, allowing water to move freely. Areas of deep overburden are suspected to indicate underlying joints and fractures.

The field exploratory work is expected to include vertical electronic soundings (VES) to determine potential location with higher groundwater yields. The actual yield cannot be determined until test wells are drilled and tested.

4.5 SURFACE WATER SUPPLY OPTIONS

The surface water alternatives for Voinjama are limited and were assessed from field conditions and observations during the scoping and detail analysis visit. Given the limited number or lack of large streams, there is a scarcity of water resources in the Voinjama area of adequate capacity other than the Zeliba River. These factors limited the list of surface water supplies to the Zeliba River as the most likely viable option. The area appears to include many small streams that are likely perianal and are without flow in the dry season. A lack of mapping and stream flow data significantly impacts the evaluation and development of these smaller streams.

Surface water in Voinjama and the surrounding areas of Lofa County is driven primarily by precipitation. The rainy season typically continues from mid- April to mid-October. The dry season will generally begin in November and continue through April. The region is located in the climatic zone of tropical rain forest with dry season between November and April. The natural undeveloped setting of the tropical forest, the watershed area and the small streams that feed the Zeliba River provides a valuable natural water source that should be protected.

4.5.1 Zeliba River

The residents in Voinjama presently use surface waters, from the Zeliba River and other small streams, on a limited basis (5%) for household cooking use. At the previous intake/impoundment structure, Zeliba River flows within defined banks at normal flows. The smaller streams in the area are shallow and less than 5 to 10 feet in width.

The quality of the surface water is anticipated to vary between the flow conditions of the dry (October to May) and wet seasons (June to September) but untreated water is likely not safe for consumption without disinfection, if not additional treatment.

The intake structure at the Zeliba River is located about 1.4 miles (2.3 kilometers) from the center of Voinjama. The following map indicates the watershed of the Zeliba River that is located above the previous Water Treatment Plant site. The Zeliba River watershed was derived from a three arc-second digital elevation model from USGS HydroSHEDS using the Voinjama water treatment plant location as the watershed outlet. The approximate watershed is 102 square kilometers.[56]

[56] GKW Final Voinjama Design Report

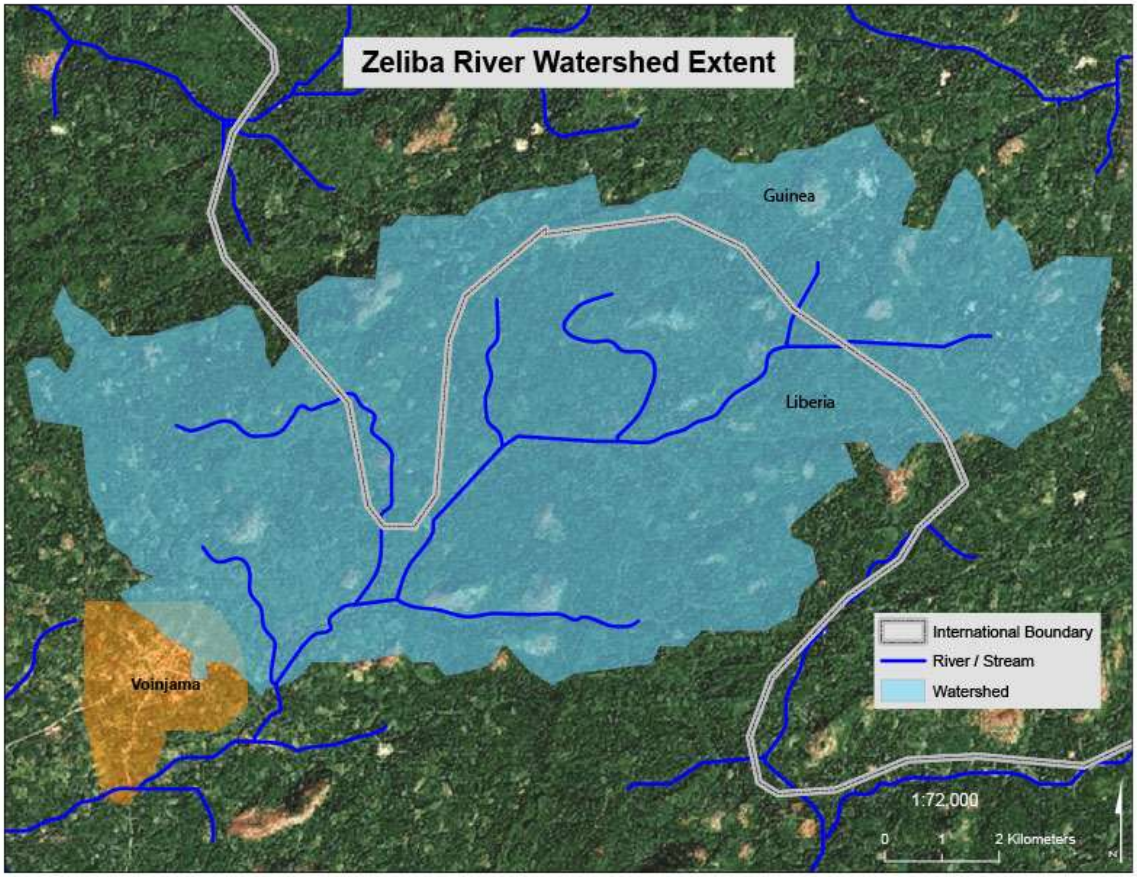


Figure 4-4 Zeliba River Watershed

Maintaining the environmental quality of the Zeliba River watershed is critical to ensuring the sustained quantity and quality of water the surface stream is capable of providing. Maintaining the natural environmental setting and vegetation of the land area within the watershed must be protected and maintained. The watershed and its ability to supply relatively clean water to the Zeliba River was the foundation of the previous water system. The importance of watershed protection is also true for the other streams located in Lofa County. Implementing previous recommendations to protect critical watersheds remains a vital action for the City of Voinjama and LWSC. Providing watershed protection is a supportive step Voinjama can take to support the development of the water systems. The appendix material includes a recommended bylaw the City could enact and enforce. It is anticipated that implementation of watershed protections can be incorporated in the institutional efforts in developing a water utility in Voinjama or any city in Liberia.

To address the availability of discharge information the LMWP team conducted three steps to further evaluate the surface water quantity in Voinjama. They consisted of :

1. Review of raw record data provided by Liberia Hydrological Services
2. Field efforts to measure stream flow during detail analysis visit
3. Evaluation of other flow data

Review of Raw Record Information – The raw information provided by the Liberia Hydrological Service cover the majority of the period from 1973 to 1981, and ranged from hand written notes, submitted field records to typed monthly values summarized with monthly averages as well as minimum

and maximum monthly values. Each month recorded stage depths. Selected months indicated this depth was in centimeters. Other months included the corresponding discharge rate for the recorded stage. But the units of discharge were not documented. From this information a stage discharge relationship was developed to convert the stage depths to discharge rates of unknown units, the historic information plotted, and an evaluation of minimum monthly flows developed.

The raw data indicated that there was two independent stream gauging station located on the Zeliba River. They were simply identified as #1 and #2. Gauge #1 was abandoned in February of 1978, and Gauge #2 continued to be read and records are available until 1981. Some intermittent data is also available for 1987 and 1988. The location of either station is not known; therefore the watershed areas cannot be determined.

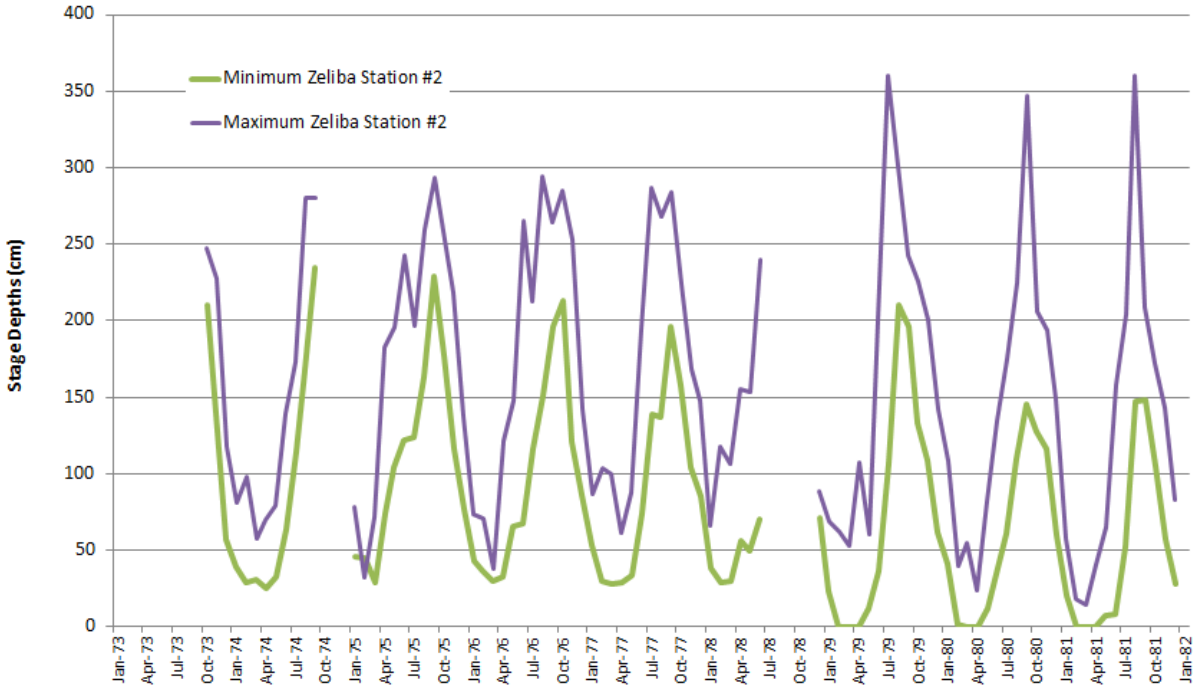


Figure 4-5 Zeliba River Stage Readings 1973-1981

Figure 4-5 Zeliba River Stage Readings 1973-1981, shows the seasonal minimum and maximum values for an 8 year period. It also indicates periods of low flow. Past observations of no flow was also documented[57] to have no flow for a two (2) day period in 1973, even though the river readings indicated a longer period. The low flow periods is the likely reason that an impoundment system was incorporated in the previous design.

Figure 4-6 Range of Monthly Stage Readings, 1973-1981, indicates that most no flow and low conditions occur from February to May.

[57] "Water Supply Project for Six Cities, Final Design for Voinjama"

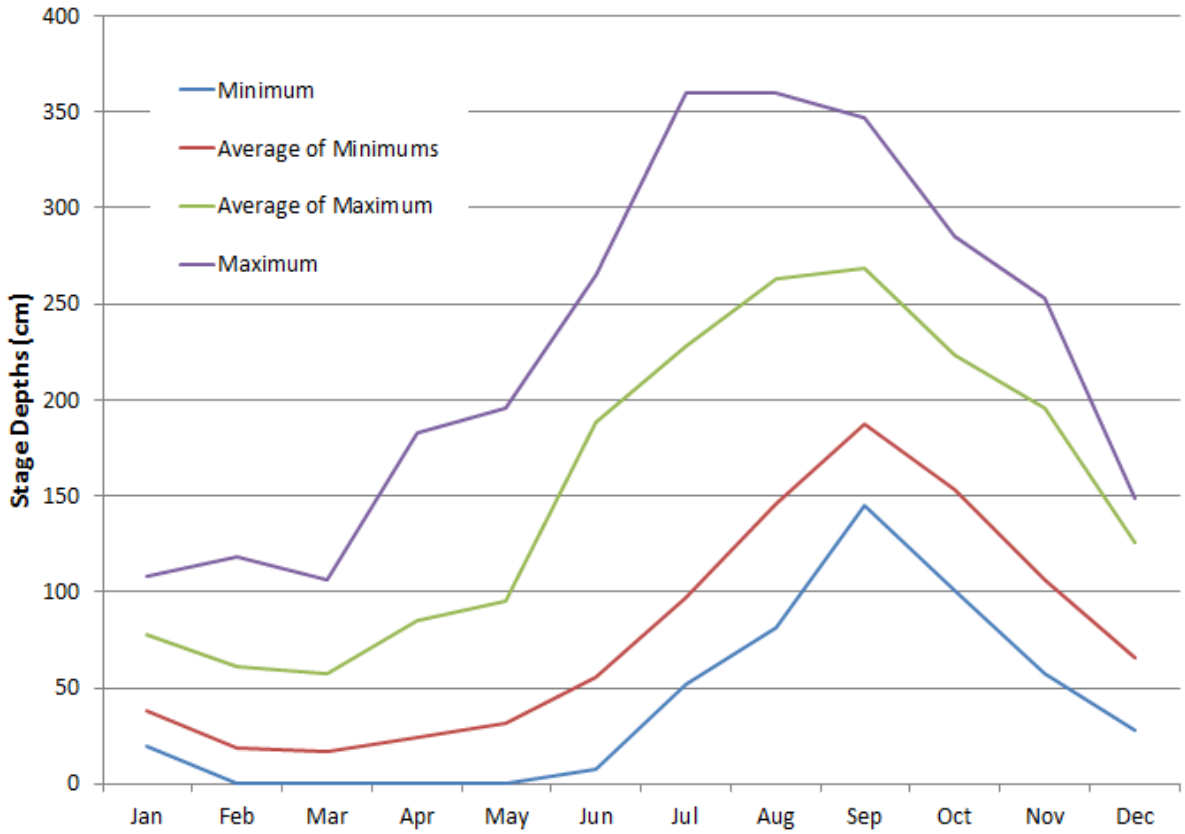


Figure 4-6 Range of Monthly Stage Readings, 1973-1981

Table 4-4 Historic Low Flow Periods[58]

Year	1973	1974	1975	1976	1977	1978	1979	1980 #	1981	1982	1983	1984	1985	1986	1987 +	1988 +
Number of Days with No to Low Flow*	20	-	-	-	-	-	46	40	74	-	-	-	-	-	32	65

* denotes Low flows are days with readings below 10 cm; # denotes estimated completion of WTP; and + denotes periods of inconsistent reporting

Table 4-4 Historic Low Flow Periods, indicates no to low flow may not occur every year, but can occur for prolong periods if dry conditions appear to have occurred. No historic meteorological data was located to correlate to these periods.

The preliminary evaluation of record stream discharge rates raised concerns about the quantity and quality of the data. Concerns are warranted due to but not limited to the following factors:

[58] "Water and Sanitation Policy" by the Ministry of Land, Mines and Energy, Table 2

- The available record flow data is extremely limited, with gaps and a lack of detail.
- The available data was not organized or summarized.
- There are no records to indicate if the previous water system did or did not have raw water supply issues.
- The quality of the stream flow data is questionable.
- The actual minimum annual flows may not have been recorded
- A recent reliable historic and continuous record is not available.
- The design population of 19,600 is greater than the previous (1979 study) design population of 8,600 persons.[59]
- Prolong periods of no to low flow represents as significant design challenge.

The impounded area was described in past reports on the Voinjama WTP design. The knowledge of the previous system was used to develop a rough estimate of the potential area of the new impoundment. The previous impoundment had the following characteristics:

- Impounded area and volume included the Zeliba River and 2 tributaries which totaled 2.6 km in length of stream
- Average depth of water in the impounded area was estimated at 60 cm = 0.6 meters
- Total water surface area impounded = 350,000 m^2

To provide an estimated area and volume to satisfy these criteria, one meter contours were extracted from the three arc-second digital. Using the contour line above the site of the water treatment plant as a reference point for simulating the depth of water, areas could be interpolated and estimated. This produced a surface area of 537,413 m^2. The 2.6 km upstream extends from the water treatment plan was also measured and marked for reference. The following figure provides a conceptual estimate of the impoundment based on the limited wide scale topographic information available.

[59] "Water and Sanitation Policy" by the Ministry of Land, Mines and Energy, Table 2 , Page 28

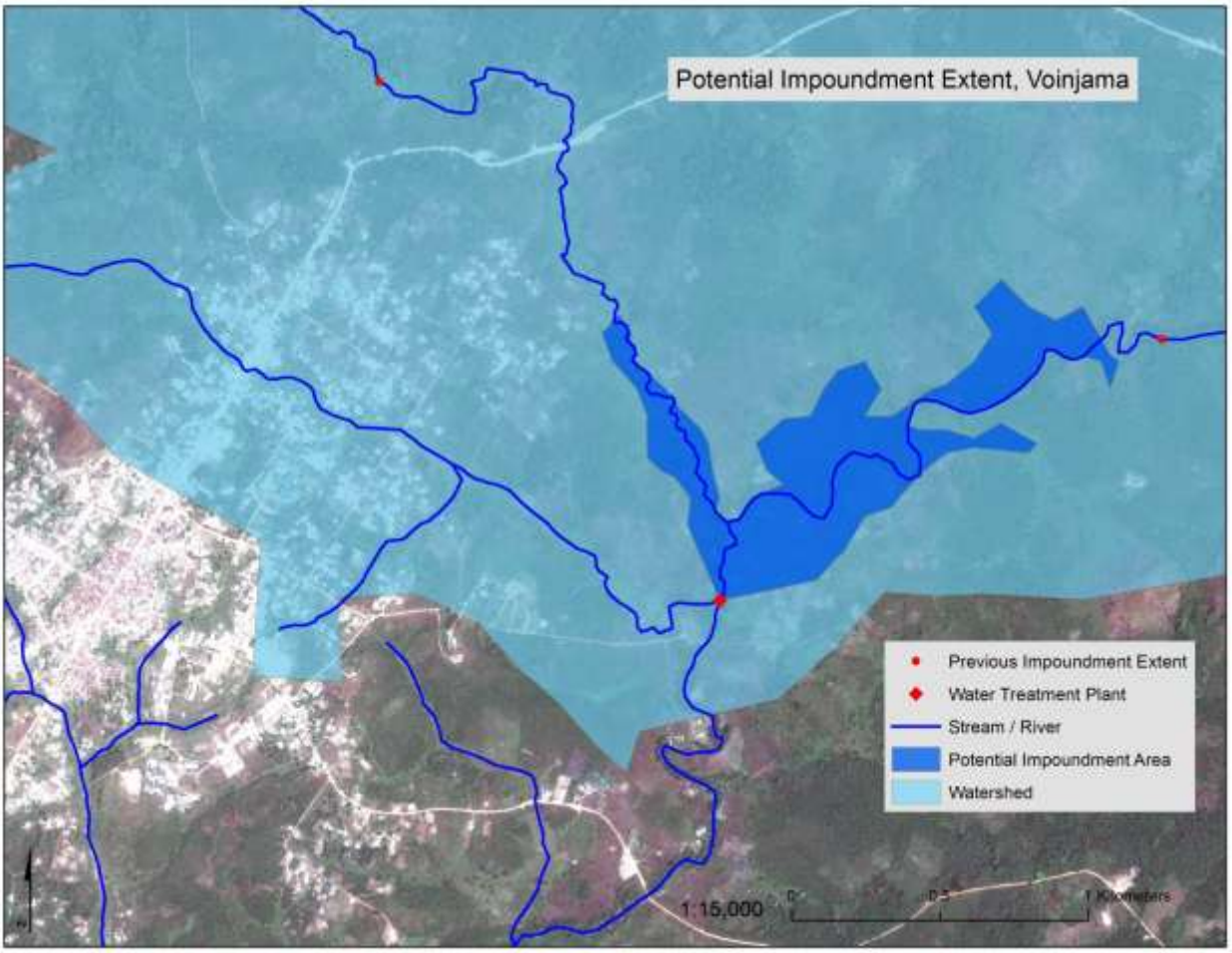


Figure 4-7 Estimated Impoundment Area

Field Efforts to measure minimum flow in February and March 2012. The LMWP team conducted stream gauging and water quality sampling at the previous intake on the Zeliba River during the Detailed Analysis (DA) visit (February to March 2012) to determine the characteristic and current flows and to make preparations and arrangements for additional monitoring throughout the year. The purpose of the monitoring is to determine or estimate the low flow conditions in the previous surface water sources. Measuring the quantity of water carried by a surface water body during periods of low flow allows for the determination of the body's yield.

Quantity: The initial observation upon arrival for the Detailed Analysis there was no flow to minimal flow observed in the Zeliba River. The intake structure at the Zeliba River is located about 1.5km from the center of Voinjama. Even with "no flow" the depth of water in the river permitted recreational swimming. A large amount of fallen trees and vegetation, both upstream and down was observed in the river channel, which could be causing backwater conditions. To further investigate the flow conditions, stop logs were installed over a two day period in the three bays formed by the existing control structure. Upon completion of the stop logs, Bay #1, closest to the Intake Structure, had 2.5 inch of freeboard (height of weir crest above water level) and a width of opening of 6'-5 ½"; Bay #2 had an average of 1'-3 ½" of freeboard and a width of opening of 11'-6"; and Bay #3 had an average 1'-3 ½" of freeboard and a

width of opening of 11’-7½”. The depth from the bench mark in the Intake Structure (chisel mark “V” on metal rail) to the water surface was 15’-6½”.

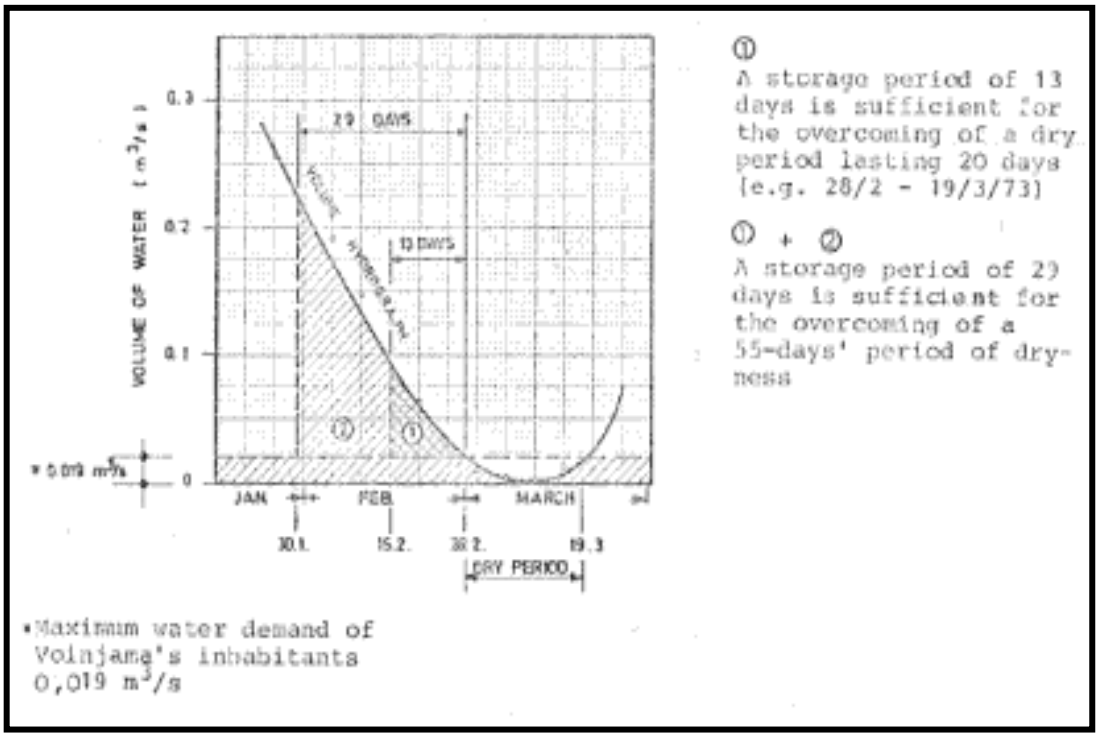


Figure 4-8 Hydrograph for Zeliba River from Previous Design Report

No change or rise in the level occurred behind the stop logs for several days to confirmed that there was no flow to trace flow in the Zeliba River. This is consistent with the findings of the “Water Supply Project for Voinjama” conducted by German consultants in the 1970’s. It also notes the catchment area of the watershed at the intake structure is approximately 102 km2.

4.5.2 River Bank Filtration

Due to the sub surface conditions in Voinjama in the vicinity of the previous intake structure and WTP site it is anticipated that river bank filtration could be accomplished near the Zeliba River and other surface waters that are near and connected with alluvial materials. Alluvial conditions and manual sand mining operations were observed neat the previous WTP site at the Zeliba River. Siting would be limited to areas that include:

- Alluvial conditions
- Provide for easy excavation
- Provide for easy handling of groundwater during construction.
- Shallow depth to groundwater

The abstraction and withdrawal of groundwater under the influence of surface water can often incorporate the indirect supply source while taking advantageous of river bank filtration. River bank filtration processes water as the raw water migrates through the alluvial material banks of the surface.

River bank filtration provides physical treatment by removing and straining suspended particulates while using the alluvial soil as the filter media. Biological treatment can occurs when soil microorganisms remove and organic material and chemical nutrients, in a process similar to a slow sand filter. Chemical treatment can take place when alluvial soils react with soluble chemicals in the water. The efficiency of the system depends on the concentration of the polluting contaminants, the hydraulic conditions and the chemical composition of the in situ bottom sediment of the river or surface water source.

The other advantages of a river bank configuration include:

- Provides a level of treatment
- Improves the microbiological quality of the water
- Is effective in aerobic and anaerobic conditions
- Requires little maintenance and is easy to operate

While the disadvantageous include:

- Can lead to adverse impact associated with over pumping
- Potential to foul bank filter interface that can lead to a slow reduction in production capacity
- Potential aquifer pollution impacts from the reintroduction of heavy metals from the benthic sediment layer

4.5.3 Rainwater Harvesting

Rainwater harvesting practices are in place throughout Liberia, although less than 5% of household survey respondents in Voinjama indicated that they use rainwater as their primary source of drinking water. Rainwater harvesting is time-tested practice that preceded systems that rely on well drilling equipment and piped water supplies. In many parts of the world, rainwater collection remains a large contributor in meeting the daily water requirements.

Rainwater harvesting generally consists of:

- A collection area (usually a roof, to reduce the amount of cross-contamination)
- Piping, gutters, downspouts, or channels, and a method to divert the “first flush” containing potential contaminants
- A storage tank or cistern. Storage tanks or cisterns are commonly constructed of concrete, plastic or fiberglass, and can be located below-ground if desired.
- A system to distribute the water
- Filtration (in some systems)

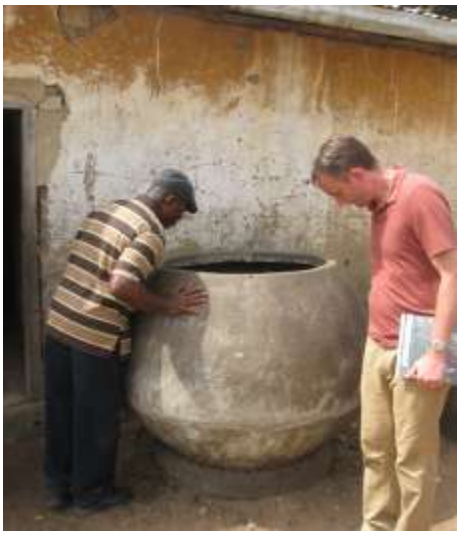


Figure 4-9 Evidence to historical rainwater harvesting practices in central Voinjama

Although evidence of limited the rainwater harvesting was observed in Voinjama, the amount of storage required as determined by both the amount of rain, and the frequency of measurable rainfall indicated that rainwater harvesting is not

feasible. Although the practices of rainwater harvesting by individuals should be supported since it could reduce the demand on any municipal water system.

4.6 LIBERIAN WATER QUALITY SAMPLING

Concerns were raised with the reported elevated levels of certain parameters by the first rounds of water sampling. The March 2012 MOH analysis of samples taken in Sanniquellie, Voinjama and Robertsport revealed levels of iron, fluoride, nickel, manganese, mercury, and lead, which initially indicated concentrations higher than the WHO and/or Ministry of Health drinking water guidelines, but additional investigations were conducted. Subsequent testing by the MoH in June and July 2012, as well as by the MPW's National Standard Lab in July 2012 reported similar results for these parameters even though the site conditions indicated that these pollutants should not reasonably be present. The analytical method available and used by these laboratories is a spectrophotometer. The spectrophotometer relies on the absorption or reflectance in the light beam that is at or near the ultraviolet-visible spectral region. With the addition of specific reagent to the water samples the device measures the spectrum of the light beam to determine the concentration of the parameter. The presence of color, turbidity and other pollutants can interfere with the readings.

During the July 2012 sampling effort in the City of Robertsport, identical sample were taken from eight sample sites. The collected samples were independently analyzed by the MoH lab, the MPW National Standard Lab, and a US based (Alpha Analytical of Westborough MA). The purpose of the additional collection rounds is to develop more data and quality control purposes. The 8 sample sites included:

Surface Waters:	Fasa Creek
Groundwater:	Well # R01, R06, R11, R12, R16, R17, and R18

A review, by parameter indicates the following

- pH – general consistent readings from lab to lab
- Copper – general consistent readings from MOH Lab to National Standards Lab, but the US based Alpha Labs results were significantly less
- Fluoride - general consistent readings from MOH Lab to National Standards Lab, but the US based Alpha Labs results did not detect any concentrations
- Iron and Manganese - general consistent readings from MOH Lab to National Standards Lab, but the US based Alpha Labs results were either at non-detectable levels but when detected at greater concentrations
- Mercury and Lead - general consistent readings from MOH Lab to National Standards Lab, but the US based Alpha Labs results at non-detectable levels
- Nickel- the MOH results from March and June were consistent with the National Standards from July. Unfortunately the MOH lab was not equipped to test this parameter in July so a comparison

The US-based lab used a more advanced testing method, GC mass spectrometry, to analyze the split samples. This equipment is not likely to be available in Liberia. Based on these results, it was recommended that analysis of samples in the short term be considered to include shipping to the US. A summary of the US analyzed results indicate the following:

- Copper was present in four of the seven groundwater samples, from 0.014 mg/l to 0.053 mg/l as analyzed by the US based lab. These samples are greater the Liberian water quality standard of "not detectable" stated by the MoH Lab, but well below the WHO standard of 2 milligrams per liter

- Fluoride, Nickel and Mercury were not found to be present in any of seven groundwater samples analyzed by the US based lab.
- Iron was present in five of the seven groundwater samples, and three of the five samples were greater than the Liberian water quality standard of 0.3 mg/l stated by the MoH Lab.
- Lead was present in one of the seven groundwater samples, at 0.003 mg/l as analyzed by the US based lab. This sample is well less than Liberian water quality standard of <0.1 mg/l stated by the MoH Lab.
- Manganese was present in five of the seven groundwater samples, at concentrations below 0.05 mg/l as analyzed by the US based lab. These samples are less than Liberian water quality standard of <0.1 mg/l stated by the MoH Lab. The MoH results indicate that this parameter could be seasonal or diluted at higher flow rates in the wet season.

4.7 WATER QUALITY EVALUATION – PHYSICAL/CHEMICAL

The water quality analytical information presented in the main body of the Voinjama Master Plan is based on the results of the US base labs for samples collected in September 2012. For comparison purposed the results from the other labs are presented only in the appendix material. The need to take the additional steps in using a lab outside of Liberian should present the need for a reliable and accurate means to measure water quality as the water systems in Liberia are restored.

The September 2012 results are summarized in the following table. Four parameters showed elevated levels and are described below. The water samples tested in Voinjama were generally in compliance with the WHO health based standards, except for those noted. The WHO sets various health based standards as a safeguard to protect public health. These standards are performance objectives, established based on their judgment of safety and a risk assessments of water borne hazards. The WHO guidelines also include additional standards that are not based on health concerns. The results of the infield pH testing and the water quality analysis from the US lab are shown in the following table. Outlined below is a summary of the values outside of the listed WHO guidelines or warrant consideration.

- **pH -** The water quality of the surface and groundwater tested in the field indicates Voinjama sources generally had a pH less than the recommended range of 6.5 to 8.5, indicating an acidic nature to the sampled water. The deviation from the WHO guidelines for pH is not a violation of health based guideline. The WHO has set non-health based guidelines based on other consideration such as treatability of the water and the aesthetic value of the water. The recommendation a pH range is primary needed for treatment purposes. Waters with pH levels outside of the range can be consumed. Many drinks other drinks are readily purchased and consumed. For examples, many sodas, tonics and juices have pH values of 3+/-.

The low pH level was initially measured during the March 2012 Detailed Analysis visit by the Ministry of Health (MoH) Lab in Monrovia. Similar levels were measured again by the MoH lab in June 2012. In July 2012, the low pH was again confirmed by the MoH lab as well a portable field pH meter that was calibrated using pH standards of 4.0 and 7.0.

If treatment is not required for other water quality reasons, then it is not recommended to raise the pH level in Voinjama. It is recommended that the existing pH levels be used unless required to conduct other treatment that require the adjustment of pH for process purposes. To raise the pH level, only to be within the WHO range, will be likely result in a water system that is not sustainable. A significant effort to add a chemical such a lime to raise the pH would represent a significantly impact the operation effort and cost to supply water. The cost of the lime and its reliable delivery is anticipated to be cost prohibitive. The cost of hydrated Lime is approximately$65 per day or $23,500 per year

based on a cost of $9.00 per 25 kg bag of hydrated lime.[60] [61] The provision of a lime chemical addition system could be incorporated in a design that restores or replaces the previous water treatment system, but would like require the need for at least one additional staff member to operate and maintain the system, estimated at $7,500 per year.

- **Color -**Color is a non-health based guideline and is 15 color units. The amount of color in water is generally associated with the presence of organic matter and can be influenced by the amount of iron, manganese and other metals. The level in Zeliba River is slightly greater than the recommended guideline. The levels in Zeliba River could be considered for use without treatment, and would be anticipated to improve with treatment.

- **Turbidity -** Although not detected above the recommended guideline, the level of turbidity should be considered since it is likely to vary seasonally and with runoff. Turbidity is the result of suspended particles that obstructs light from passing through the sample. While the limit is not a health based limit, turbidly can be related to the level of bacterial since bacteria and viruses can be attached to particulates. Turbidity causes interferences of disinfection. Turbidity can also result in consumer complaints when cloudiness occurs. Water utilities should try to provide water that has turbidity of at least less than 5 NTU or lower.

- **Iron -**Iron was detected in the surface waters of the Zelilba River at levels greater than the guideline of 0.3 parts per million (ppm, or mg/l). Iron can be present in water in four forms. None are considered a health hazard but can significantly impact the aesthetic quality of the water. The four forms are ferrous iron, ferric iron, iron bacteria, and organic iron. Ferrous iron and ferric iron results in rust particles forming and settling out of the water when the water is exposed to oxygen. Iron bacteria do not cause diseases and occur in soil, groundwater, and surface waters. The bacteria may also grow well on the metal parts of piping and plumbing fixtures of water systems. Organic iron can combine with different naturally occurring materials and can exist as an organic complex. It can be found in shallow wells and surface waters.

    - The level of iron from two Zeliba River samples 0.64 and 0.68 mg/l. The third sample bottle was damaged in transport.
    - It is anticipated that the majority (near 100%) of iron is dissolved and in the ferrous form
    - Iron can be managed by removal by means of adsorption (green sand filter) or filtration (of ferric iron), or by sequestering (chemical addition of sequestering agents).
    - Dissolved (ferrous) iron can be oxidized in to a settable and filterable ferric form iron by means of oxygen/aeration, chlorine or potassium permanganate.
    - The oxidation of ferrous iron to ferric is more efficient at certain pH and temperature levels. Iron is oxidized most efficiently and quickly between pH 7.0 and 8.0. High temperatures also enhance a quicker oxidation process.
    - The amount of oxidizing agent ranges from 0.14 mg O_2 per mg ferrous (Fe^{2+}), 0.62 mg Cl_2 per mg $Fe^{2+,}$, and 0.91 mg $KMnO_4$ per mg $Fe^{2+,}$ to be oxidized.
    - If the elevated level of iron is not removed in the WTP, the addition of chlorine for bacteria disinfection purposes will convert any ferrous iron to ferric which will likely result in the deposition of iron in the storage tank and distribution pipe. The deposited material would then require to be periodically flushed to limit and control dirty water episodes associated with its re-suspension during period of high flow or reverse flow conditions.

[60] According to LWSC operation costs

[61] Based on CO_2 = 5 mg/l, Alkalinity = 30 mg/l and Mg = 30 mg/l, pilot testing would be required to confirm application rate and costs

Table 4-5 Physical / Chemical Water Quality Sampling Results

Sample Site	Units	Zeliba	Zeliba	Zeliba	V18	V40	V49	V35	V37	WHO 4th Edition Guidelines	Non Health-Based Guideline Established
Date		9/24/2012	9/25/2012	9/25/2012	9/25/2012	9/25/2012	9/25/2012	9/25/2012	9/25/2012		
pH		6.47	6.33	6.2	4.66	5.68	5.24	5.14	4.91	6.5-8.5	NH
Color	cu	30	20	25						15	NH
Turbidity	TU	2.4	3	3.1	2.4	0.2		1.4		5	NH
Conductivity	µS	18	19	19	35	97	45	33	76		-
Total Dissolved Solids (TDS)	ppm	128	100	72	100	36	76	60	56	600	NH
Ca & Mg (Hardness)	ppm	NT	5	5.6	5.5	34.7	10.5	NT	10.3	150	NH
Alkalinity	ppm	22	12	14	14	32	20	18	16		-
Potassium	ppm	NT						NT			-
Chlorine	ppm	0.07	0.12	0.12	0.03	0.04	0.04	0.02	0.02	5	
Chloride	ppm					3.1	5.1	1	12.2	250	NH
Fluoride	ppm									1.5	
Iron	ppm	NT	0.68	0.64	0.08			NT		0.3	NH
Sulfate	ppm	2	3	2	2	2	2	2	1	250	NH
Nitrate	ppm				1.8	4	2.4	0.8	2.9	50	
Nitrite	ppm									3	
Copper	ppm	NT			0.021	0.005	0.008	NT		2	
Manganese	ppm	NT	0.015	0.013	0.02	0.039	0.022	NT	0.082	0.4	
Mercury	ppm	NT						NT		0.006	
Cyanide	ppm	NT				0.001		NT		0.05	
Nickel	ppm	NT						NT		0.07	

Table 4-5 Physical / Chemical Water Quality Sampling Results

Sample Site	Units	Zeliba	Zeliba	Zeliba	V18	V40	V49	V35	V37	WHO 4th Edition Guidelines	Non Health-Based Guideline Established
Lead	ppm	NT		0.001			0.003	NT	0.037	0.01	
Sulfide	ppm	NT	NT	NT	NT	NT	NT	NT	NT	0.05	
Zinc	ppm	NT	0.006	0.011	0.035	0.009	0.016	NT	0.01	4	NH
Chromium, Trivalent	ppm	NT						NT			-
Solids, Total Suspended	ppm		6	5	8						-
Nitrogen, Ammonia	ppm			0.103						1.5	NH
Phosphate, Total	ppm										-
Surfactants, MBAS	ppm										-
Chromium, Hexavalent	ppm	NT						NT			-
Arsenic, Total	ppm	NT			0.003			NT	0.006	0.01	
Boron, Total	ppm	NT		0.03		0.04		NT		2.4	
Cadmium, Total	ppm	NT						NT		0.003	
Chromium, Total	ppm									0.05	
Silver, Total	ppm	NT						NT			-
Vanadium, Total	ppm	NT						NT			-

Notes: NT indicates Not Tested, Empty entries indicate results less than parameter detection limits, Shaded entries exceed guidelines, NH indicates no health based guideline has been established.

4.8 WATER QUALITY EVALUATION - BACTERIALOGICAL

The WHO has set standards for both Total Coliform and Escherichia coli (E. coli.) Safe drinking water should be absent of both Total Coliform and E. coli. E.Coli is an indicator of fecal contamination. Total Coliform includes a wide range of bacteria that includes E. coli; Klebsiella and Enterbacter, and occurs both in wastewaters and natural waters. Both kinds of bacteria can be treated and inactivated with chlorination.

It would be anticipated that both bacteria would be found to some level in surface water supplies. It is less likely that E. coli would be present in groundwater sources if the proper construction and protection measures are in place.

The most common health implication from drinking bacterially contaminated water is gastrointestinal illness including diarrhea. Gastrointestinal illness is usually non-life-threatening in normal healthy adults, but can limit the daily functions and productivity of the infected person. The risk of death from bacterially contaminated water and gastrointestinal illness increases among vulnerable groups such as infants, the elderly, and individuals with suppressed immune systems.

During the March 2102 Detail Analysis trip to Voinjama, bacteriological testing was conducted using an absent-present test method, i.e., a method which indicates only the presence of bacteria, as opposed to the quantity of bacteria. The method consists of collecting a water sample in a sterile plastic bag and combining the sample with a mixture of nutrients and reagents. With the addition of the nutrients and reagents, the sample becomes yellow. If total coliform is present in the sample, the color of the sample will change to green or blue/green within a 48-hour holding time. If *E. coli* is present, the blue/green water sample will fluoresce (glow) when exposed to UV light in a dark room. Samples were drawn during the pump testing of the wells to obtain a flushed and representative sample.

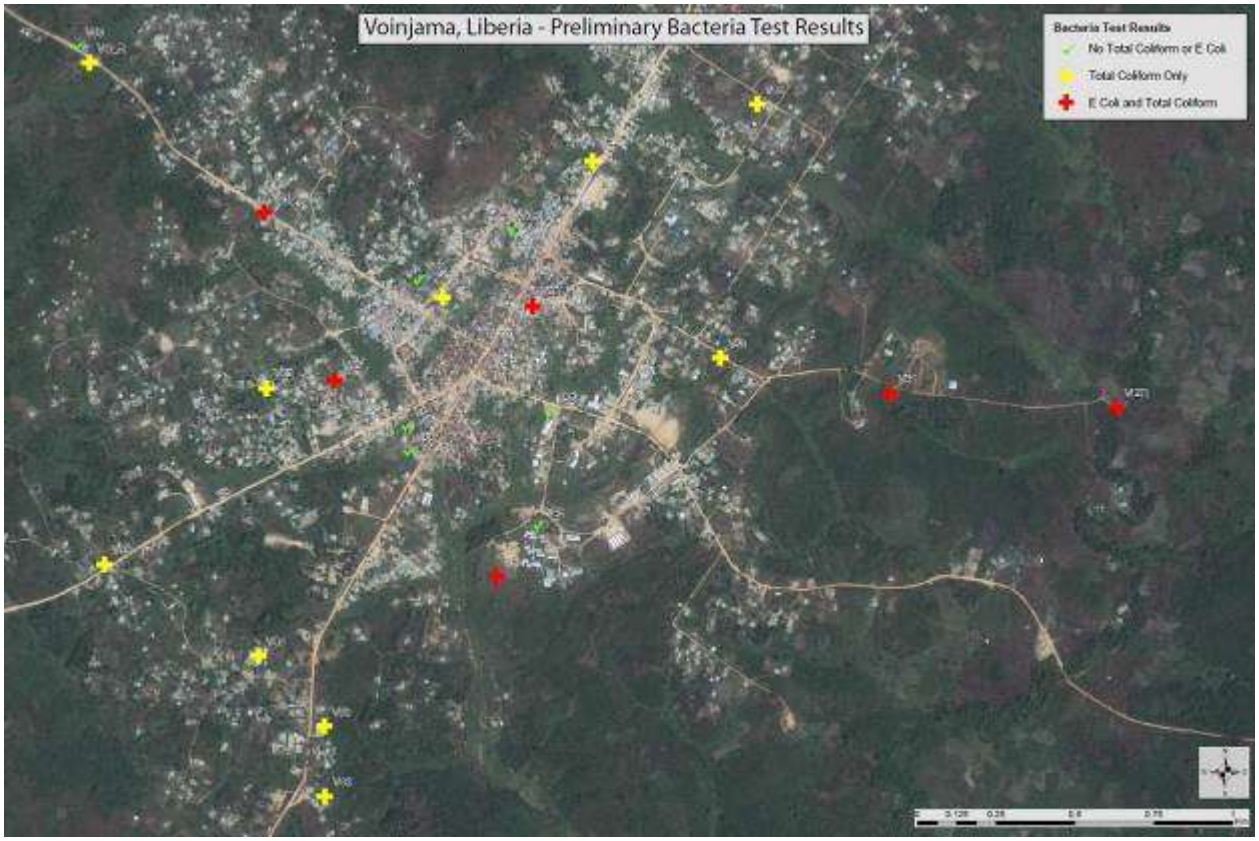
The series of fecal/total coliform testing on the wells and surface water in Voinjama demonstrated total coliform contamination in 17 of the 28 samples taken from surface and groundwater supplies. Fecal Coliform was detected in 7 of the 28 samples

TABLE 4-6: VOINJAMA BACTERIA RESULTS

Parameter	Total Sampled	Total Coliform Present	E Coli Present
Surface Water Samples			
Intake – Zeliba River	1	1	1
Creek at Lawazula Road	1	1	0
Groundwater Samples			
Wells	23	15	6

Due the high presence of Total Coliform and to a lower presence of E. Coli, the conclusion can be drawn with reasonable certainty that the vast majority of wells show signs of contamination. Water from the wells in Voinjama should not be considered potable until treated.

Figure 4-10 Voinjama Bacteriological Test Results



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In September of 2012, the County Health Team (CHT) was requested to conduct additional sampling to quantify the level of bacterial contamination. The Zeliba River and three (3) well were tested and all were absent of Total Coliform. The hand pumps were composed of both shallow hand dug wells and bore hole-drilled wells. The results also reported a consistent 0.1 mg/l of Free Chlorine in all surface water and groundwater samples. The quality of the results could be questioned based on the consistent presence of free chlorine. While chlorine could be present in if the well was recently treated, chlorine would not be expected in the Zeliba River sample. Conversely, Total Coliform would be expected in the surface water bacteriological sample but none was reported.

4.9 WATER TREATMENT OPTIONS

In the quantitative survey, about one quarter of the respondents (28%) reported treating their drinking water all the time, and 31% said they treated the water sometimes. The vast majority of the respondents who treated their water used chemical disinfectants such as WaterGuard. Water quality testing performed by LMWP indicated that most wells have coliform bacteria present. Given widespread water quality concerns, relatively low levels of household water treatment, and strong local demand for piped water supply, continued reliance on wells and direct collection of surface water is not recommended. Although point of use treatment such as WaterGuard should continue to be promoted during the interim, the medium term goal of LMWP is to move to a piped water supply that provides disinfected water.

The goal of water treatment is to protect public health by purveying a safe and reliable drinking water supply. In general, surface water supplies require treatment processes that are more complex than the treatment processes for groundwater supplies, in order to remove the expected higher levels of combined organic and inorganic contaminants. In general groundwater typically possesses better quality than surface waters, but as previously noted the use and consumption from the existing groundwater supply in Voinjama indicates the shallow aquifer is susceptible to contamination. This is most likely from infiltration of sanitary and other wastewaters, but more important the quantity of groundwater is limited

The preliminary design of treatment for Voinjama will be based on the following primary considerations: water quality, water demand, required staff capacity, cost, safety and reliability.

4.9.1 Chlorination

To provide disinfection, chlorine is commonly added to water supplies at the source, a distribution node, or storage tank. It can be added using any of several different methods. The water source characteristics determine the estimated amount of chlorine required for disinfection and other treatment purposes.

Based on a conservative application of 10 mg/L of chlorine to the raw water, a total daily demand of chlorine is estimated for various water demands shown in the following table.

Table 4-7 Chlorination Quantities by Type

Populations	Daily Flow	Chlorine Application	Chlorine Required	Hypochlorite Required	Storage	12% Bleach	Storage
(persons)	(gpd)	(mg/l)	(Lb./day)	(Lb./day)	(lb.)	(gpd)	(gal)
15,100	26,010	10	3	5	600	3	360
16,100	158,930		14	20	2,400	14	1,680
17,200	295,160		25	36	4,320	25	3,000
19,600	336,340		29	42	5,040	29	3,480

Chlorine can be directly applied in the form of different chemicals such as calcium hypochlorite or bleach, or a chlorine solution can be generated and injected on-site from chlorine gas.

Calcium hypochlorite can be provided in a powdered or solid/tablet form that will provide approximately 70% of its weight as chlorine. Therefore Voinjama would require about 42 pounds of high test hypochlorite (HTH) daily. The application rate would increase as both the population and daily water demand increase. Dry chlorine can be simply but possibly inefficiently cast into the water, or added by means of in-line chlorinator. More advanced application methods require solution tanks, mixers, and chemical feed pumps. Outlined below are annual costs for consumption of chlorine tablets and the associated labor to apply chlorine tablets. The cost of the equipment, piping, and appurtenance is dependent upon the type and number of source waters and the complexity of the application (from manual casting of powder to chemical application systems). The cost of capital for the chemical application system can be incorporated into the cost estimate for the selected project alternatives. Table 4-8 is presented to describe the magnitude of O&M costs associated with the addition of chlorine using tablets.

Table 4-8 Chlorine Tablet Estimated Costs

	QTY	Unit	Unit Cost		Annual Cost
Chlorine Tablets	42	Lb./day	15.0	per pound	$229,950.00
Labor	4	hr./day	15.0	per hour	$21,900.00
O&M Costs					$251,850.00

Liquid bleach is generally available at a commercial grade of 12% (120,000 mg/l) as sodium hypochlorite. Liquid bleach will degrade and lose its concentration and potency over time at a rate of 20% each year, but the rate of degradation will increase when stored at temperatures greater than 20 degrees Celsius. Liquid chlorine application requires chemical feed pumps that withdraw directly from chemical vessels or totes.

Chlorine gas can be provided as one ton cylinders (907 kilogram containers) or as 150 pounds upright tanks/ bottles (68 kg). The handling and transportation of chlorine gas represents a safety hazard. Severe security and safety hazards associated with the gaseous chlorine can occur from accidental events and sabotage. The application of gaseous chlorine requires scales, evaporators, and regulators to inject the chlorine gas into the water flow. The previous water system used this method.

Another alternative source of chlorine could include on-site generation of chlorine. On-site generation generally includes a direct current power source that converts a salt water solution to a hypochlorous acid. In addition to the power supply source, the process requires a supply of saturated brine and softened water.

The previous options imply the application of chlorine at a central location such as a single supply or from the treatment plant, but another option for consideration is to add the chlorine at storage node tanks prior to consumption by the residents of Voinjama. At these sites in a distribution system the selection of the form of chlorine would be limited to the application of calcium hypochlorite due to storage and safety concerns.

If private storage tanks play a role in the water system improvements education should be provided regarding the concerns of safe drinking water and the practices of applying calcium hypochlorite to the water supply. The application of chlorine in a private tank would not eliminate the need to maintain a residual concentration to provide protection for public stand posts.

When chlorine is added to the water system an ongoing practice of monitoring for free chlorine in the system should be conducted using colorimetric methods.

The option of utilizing chlorine as calcium hypochlorite is recommended to improve the level of water service in Voinjama. Calcium hypochlorite is more cost effective and easier to perform for a simpler disinfection system. The recommendation of calcium hypochlorite is consistent with current LWSC practices of chlorination. The use of powdered calcium hypochlorite was observed in field visits to Kakata. The operators would mix a “day solution” and apply the chlorine solution to the water withdrawn from Kakata’s borehole number 2.

The use of chlorine bleach could be an alternative depending on the application and location.

The option of chlorine gas and on-site generation is eliminated from further consideration as a source of water due to complex system requirements, and significant O&M efforts and electricity requirement.

4.9.2 Water Treatment

As documented in prior reports and LMWP analysis, the surface water and groundwater in the Voinjama area requires treatment if it is intended to be used as a drinking water supply. The modification of the previous WTP to provide slow sand filtration and chlorination water treatment process could likely be used with sufficient provision of adequately train operators, and adequate financial and administrative support.

Listed in the Appendix Material are two tables, the first outlining possible treatment processes that could be applied in Voinjama and the second outlining the removal methods for specific contaminants.

In general, the selection of a simple and low cost treatment system is highly preferred over more complex and resource-intensive treatment options due to requirements in terms of labor and capacity, chemicals, and maintenance. The factors favoring the simpler treatment option include:

- Lack of experienced operators
- Fewer operation and maintenance requirements
- Lack of the components of an established and reliable municipal infrastructure that are necessary to support a fully functioning water supply system
- Lack of well-established supporting mechanisms to finance, maintain, and manage a water supply system
- Difficulty to supply spare parts and equipment vendor service
- Lack of power available from an electrical grid.
- Lack of experienced in-country support services and sub-contractors to assist in maintenance of the treatment system

4.9.3 Conceptual Slow Sand Filtration Process

Based on the need for a simple treatment process, the development of a conceptual slow sand filter was developed for implementation in Voinjama. Slow sand filtration is accomplished by passing raw water from the source through sand medium by gravity at a relatively low application rate. The low filtration rate, coupled with the use of small size of sand gradation, results the removal of particles from the raw water in the top layer of the sand bed. The surface of the bed forms a biological-active layer, called "schmutzdecke", consisting of organic and inorganic debris and particulate matter in which biological activity is stimulated. The schmutzdecke forms and provides an additional filtration layer, physically screening smaller particles, and the biological activity degrades some organic matter. Particulate (solids, algae, bacteria, etc.) can be removed through bio-adsorption and attachment to the sand grains.

Once the filter's head losses increase to a certain level due to the binding or clogging of the filter media, the filter is drained and the top 10 to 20 mm of media is scraped off, cleaned and stockpiled on-site, and then the filter is put back in service. In Liberia, it is expected that the labor-intensive process of removing the media would be performed manually given the availability of low cost labor and concerns regarding maintaining and powering equipment needed to accomplish this task mechanically. Each operation run of slow sand filter lasts weeks to months, depending on the raw water quality and flow rates. The operation and scraping cycle can be repeated many times, usually over a period of several years, until the sand

reaches a minimum depth of about 0.5 m. Then the sand will be replenished with the stockpiled sand to restore the original depth. This operational procedure is called resanding. A filter with new media typically has a ripening period which may last several days to allow the schmutzdecke form and the effluent water quality improve.

Compared with other treatment technology, slow sand filtration has the advantages and disadvantages listed below:

Advantages:

- Simple, easy to operate and maintain
- Low construction/operation cost
- Gravity flow through the process system, minor or no power consumption
- No requirement of coagulation pretreatment
- Low head loss and long run time

Disadvantages:

- Low filtration rate
- Large footprint, generally only applicable in small communities
- Has no or very low removal for dissolved components and colloids. Only applicable for raw waters which has good quality and low turbidity levels of less than 10 units
- Labor intensive

Water Quality

Slow sand filtration is only effective for certain source water quality. High content of suspended solids and precipitate will clog the filter and shorten the length of filter runs. Table 4-9 summarizes the recommended limits of source water quality parameters. Based on field observation in both the dry and wet seasons, the raw water quality Zeliba River is considered to be at or above these with these limits, therefore additional pretreatment step may need to be employed. Additional analytical testing by a US based laboratory is planned to confirm these observations as part of the final design.

Table 4-9 Recommend Influent Concentrations for Slow sand Filters

Parameter	Recommended Limit
Turbidity	<10 NTU
True Color	<10
Algae	<200,000/L
DO	> 6mg/L
Iron	< 1 mg/L
Manganese	< 1 mg/L

*turbidity must not be attributable to colloidal clay

Slow sand filtration generally removes particulates from the water. Typical treatment performance of slow sand filtration is presented in Table 4-10. Based upon the observed raw water quality and the anticipated performance of the slow sand filtration process, it is anticipated that the treated water quality will comply with WHO standards.

Table 4-10 Approximate Effluent Quality from Slow sand Filters	
Parameter	Effluent Concentration or Reduction Capacity
Turbidity	<1.0 NTU
Coliforms	1 to 3 log units
Enteric Viruses	2 to 4 log units
Giardia cysts	2 to 4+ log units
Total organic carbon	<15% to 25%
Biodegradable dissolved organic carbon	<50%

Filter Design Criteria

A sand filter generally consist of filter structure, sand bed, gravel support layer, underdrain and other configurations such as a filter-to-waste system.

1) Flow rate: typically the nominal rate is 45-150 gpd/ft^2 of sand area (1.8-6.1 m^3/day/m^2)

2) Filter media: cleaned and washed sand free from foreign matter. Effective size shall be between 0.15 and 0.30 mm. Maximum uniformity coefficient is 2.5.

3) Sand Bed: minimum initial depth is 0.76 m (30 in.). Minimum depth before resanding is 0.48 mm.

4) Gravel Support: 0.38 -0.6 m deep. Consists of five layers of various size gravels.

5) Underdrains: includes both main drain and an adequate number of lateral underdrains.

6) Depth of water on filter beds: 0.9-1.8 m minimum.

Pretreatment Considerations

Pretreatment provision can be provided to reduce the level of iron and turbidity levels from the source water (if it is not attributed to colloidal clay particles). To address the anticipate turbidity levels from the surface water supply of the Zeliba River, the use of river bank filtration and pre sedimentation was considered. The river back filtration will rely on the insitu filtering properties of the alluvial material located along the surface water body. River bank Filtration has been documented to reduce turbidity levels by 2 to 3 logs.[62] [63] In addition to the river bank filtration, the previous water treatment plant structure can be restored to remove additional silt and suspended particle, and to oxidize the ferrous iron. It is recommended that a cascade aeration towers be placed prior to the sedimentation tank, and the slow sand filters. It also is recommended that the sedimentation basin be equipped with tube settlers to enhance

[62] Evaluation of Riverbank Filtration as a Drinking Water Treatment Process [Project #2622], from http://www.waterrf.org/ExecutiveSummaryLibrary/90922_2622_profile.pdf

[63] Riverbank filtration for control of microorganisms: Results from field monitoring, www.elsevier.com/locate/watres

removal. If the turbidity is associated with colloidal[64] clays then the reduction of turbidity would require more comprehensive treatment such as the addition of an alum coagulant.

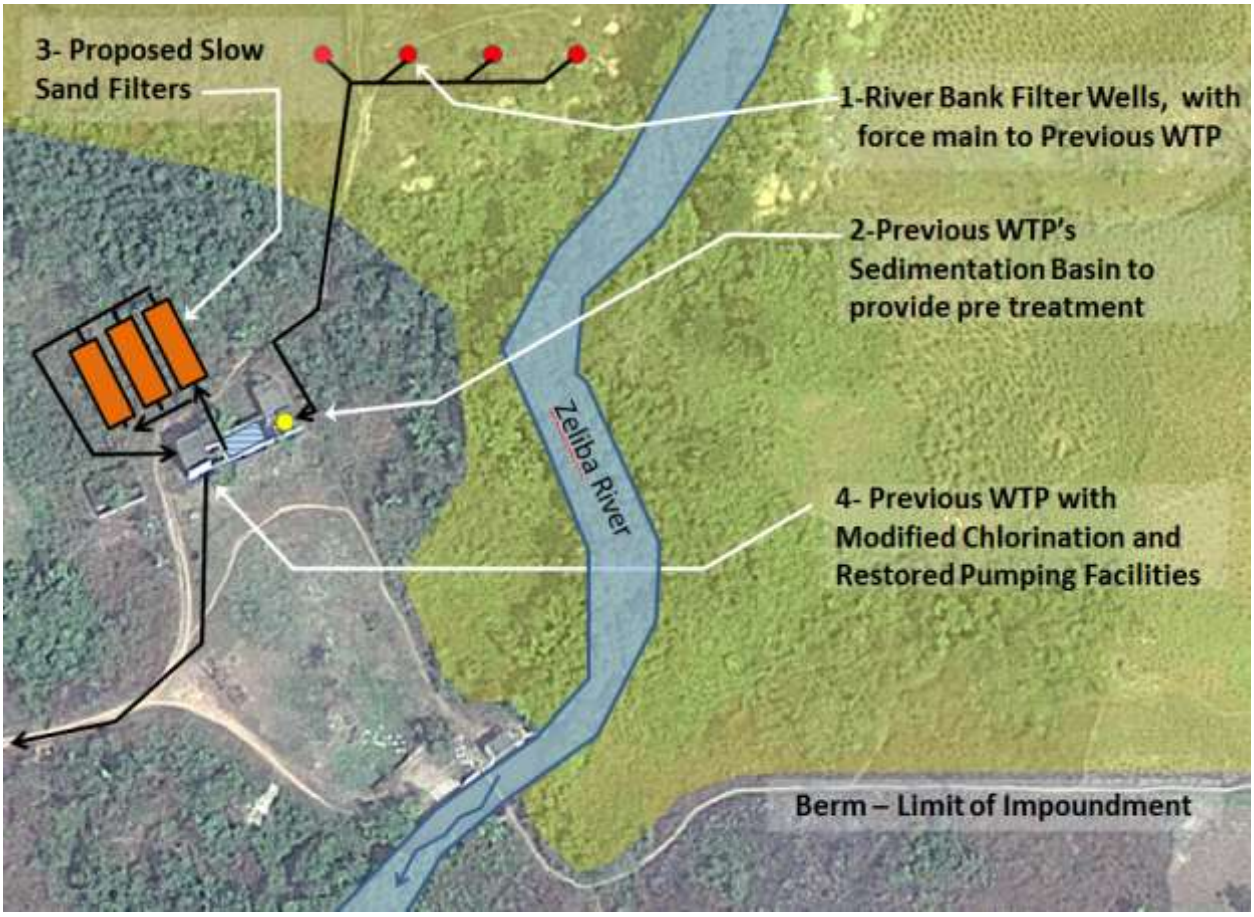


Figure 4-11 Conceptual Layout of River Bank Filtration, Pretreatment and Slow Sand Filters

Figure 4-11 Conceptual Layout of River Bank Filtration, Pretreatment and Slow Sand Filters shows the potential location of river bank filtration wells located in an area known to be mined for sand by locals. The raw water could be pumped to the previous WTP to be aerated. The flow could also be placed in the previous sedimentation to remove settable material before being sent to the new slow sand filters. The filtered water could then be chlorinated and pumped to the distribution, by new facilities installed in the previous treatment plant.

Figure 4-11 Conceptual Layout of River Bank Filtration, Pretreatment and Slow Sand Filters also shows the approximate location of the berm used to impound water for use during low to no flow conditions. The waters of Zeliba River were impounded by placing wooden stop logs across the river's channel at the site of the previous intake and water control structure. Stop logs would cause the water level to rise within the channel and with a 35 hectare area that would be flood

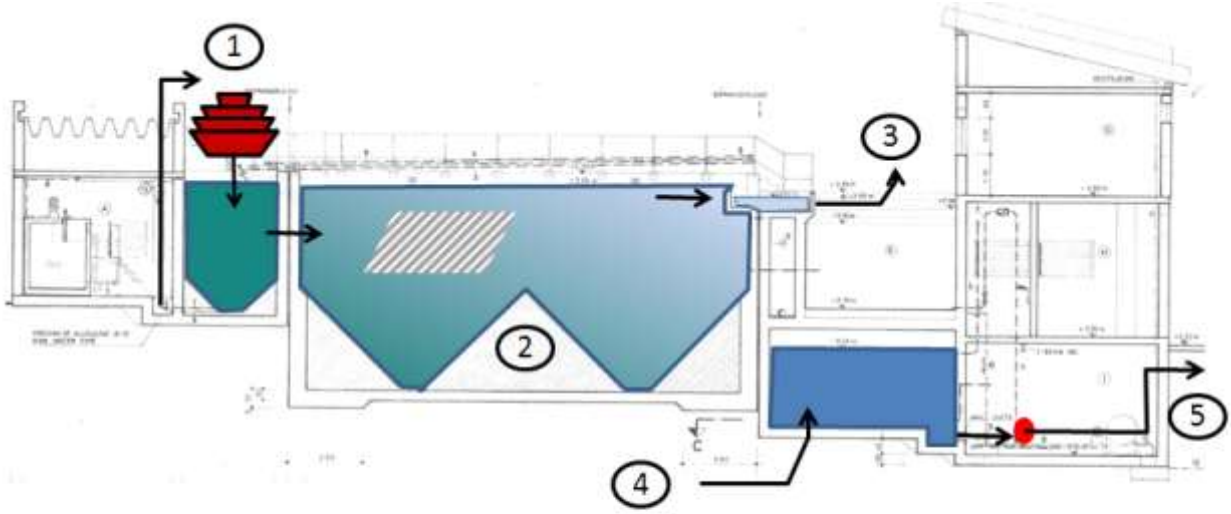
[64] Colloidal materials are solids of a particle size that are not truly dissolved and do not settle readily from the liquid

Slow sand Filter Sizing

The long term water demand is estimated at 300,300 gpd (275 m^3/day) for the city of Voinjama. Evaluating various filter rates in the below table indicates the application of the estimated demand would result in a range of filter sizes based on application rates of 1.8, 3.2 and 6.2 $m^3/day/m^2$. This results in filters ranging from 184 to 631 square meters. It is initially anticipated that 2 filters would be online and a third filter is available when needed for maintenance or filter ripening. Without the ability to conduct long term and seasonal pilot testing the size of the slow sand filter beds presented for comparison purposes based on the projected flows.

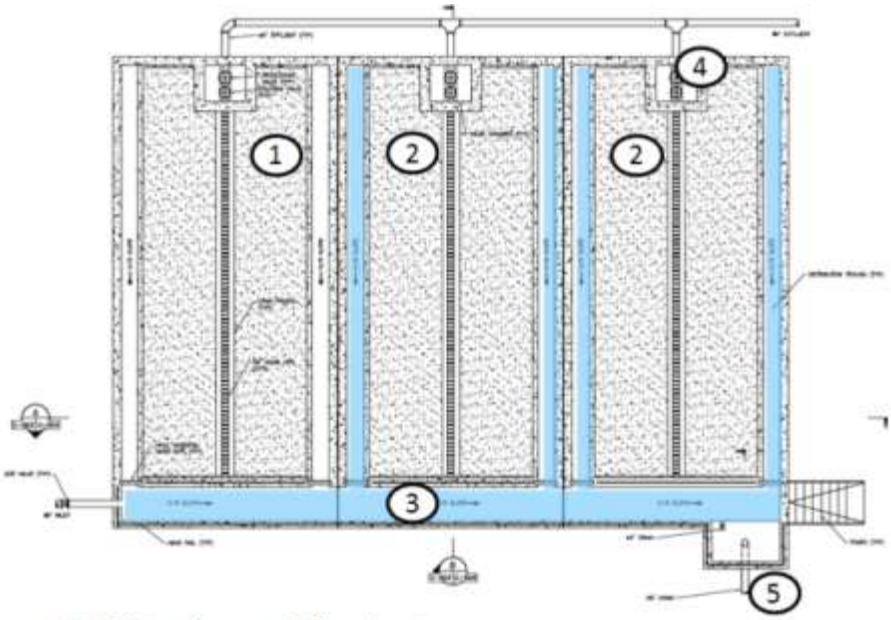
Table 4-11 Filter Size Comparison

Filter Rates	Year	Total Daily Flow		Required Surface Area	Filter Details	Length/Filter		Width/Filter	
$m^3/day/m^2$	-	(gpd)	(m3/d)	(m2)		(m)	(ft)	(m)	(ft)
1.8	2,011	26,010	92	52	3	8.83	29	2.94	10
	2,016	158,930	607	338	lengths to 1 width	22.52	74	7.51	25
	2,021	295,160	1,122	624		30.59	101	10.20	34
	2,031	336,340	1,280	712		32.68	108	10.89	36
3.2	2,011	26,010	92	29	# of Online Filters	6.60	22	2.20	7
	2,016	158,930	607	190	2	16.88	56	5.63	19
	2,021	295,160	1,122	351		22.95	76	7.65	25
	2,031	336,340	1,280	400		24.49	81	8.16	27
		-	-						
6.2	2,011	26,010	92	15		4.74	16	1.58	5
	2,016	158,930	607	98		12.12	40	4.04	13
	2,021	295,160	1,122	181		16.48	54	5.49	18
	2,031	336,340	1,280	207		17.62	58	5.87	19



1- Raw water feed from river bank filtration wells, to aeration at previous WTP
2- Restored sedimentation basin with tube settlers to enhance settling
3- Settle water gravity flow to slow sand filtration
4- Slow sand filter effluent to restored clear well and modified chlorination system
5- Restored pump room to transfer water to distribution system

Figure 4-12 Conceptual Modifications to Previous WTP



1- Offline slow sand filter basin
2- Online slow sand filter basin, media shown
3- Influent channel to distribute flow to basins
4- Effluent box from slow sand filter
5- Overflow chamber

Figure 4-13 Conceptual Layout of Slow Sand Filters in Plan View

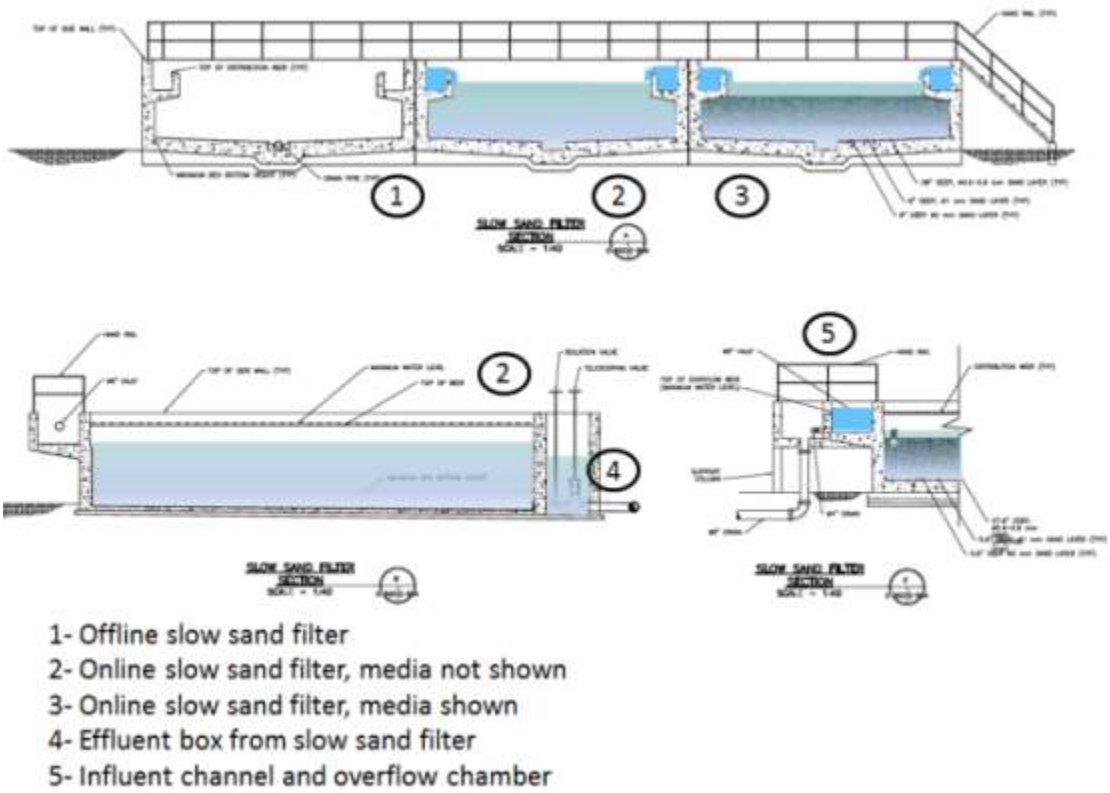


Figure 4-14 Conceptual Cross Sections of Slow Sand Filters

4.9.4 Packaged Water Treatment Systems

To address the provision of clean and sustainable water during and after emergencies, portable packaged treatment systems have been developed. These treatment systems are designed for local water conditions and water quality and can include a combination of pretreatment/pre-filtration, mechanical filtration, carbon filtration, reverse osmosis (RO) filtration, ultra-filtration (UF), and ultra-violet (UV) treatment. Individual units can produce up to 31,500 gallons per day ($5m^3$ per hour) of drinking water from source water with up to 750 mg/l of Total Dissolved Solids (TDS) and turbidity of 250 NTU.

The units can be set up on a temporary or long-term basis. The systems are commonly mounted on trailer units which allow the system to be towed. They can be powered by a generator unit or solar panel arrays.

Presented below is an outline of the estimated capital cost for a series of treatment facility installations powered primarily by solar panels with an auxiliary generator unit. The single table includes the cost of an ultra-filtration (UF) treatment process and a reverse osmosis (RO) treatment process but excludes the cost of the surface water intake, bore holes, site work, and associated distribution and storage costs. Also included are the basic operation and maintenance annual costs.

Table 4-12 Package Treatment Plant Estimated Costs

Capital Costs	Capacity/Unit	Capacity	Treatment	#Units	Unit Cost	Costs
	gpd	gpd				
Package WTP Units	9,000	300,300	RO Option	42	$170,000.00	$7,140,000.00
			UF Option		$48,000.00	$2,016,000.00
Generators					$5,000.00	$210,000.00
Annual Labor Cost			Superintendent	2	$8,000.00	$8.00
			Chemist	3	$5,500.00	$16,500.00
			Operators	20	$4,000.00	$80,000.00
			Maintenance	6	$4,000.00	$24,000.00
			Laborers	12	$3,000.00	$36,000.00
Annual O&M Supplies			UV Light Replacement		$150.00	$6,300.00
			UF Module Maintenance		$3,000.00	$126,000.00
			Filter Replacement		$50.00	$2,100.00
			Chlorine Supply		$400.00	$16,800.00
			RO Membranes		$350.00	$14,700.00
			RO Descaling Supplies		$4,500.00	$189,000.00
			Filter Media Replacement		$100.00	$4,200.00
			Fuel		$4,380.00	$183,960.00
Annual Operating Cost			RO Option			$573,568.00
			UF Option			$495,868.00
Annual Replacement Costs	2%	Rate	RO Option			$671,249.98
	10	Life , years	UF Option			$203,292.85
Annual Costs			RO Option			$1,244,817.98
			UF Option			$699,160.85

4.10 STORAGE OPTIONS

4.10.1 Existing Elevated Storage Tanks

The previous Voinjama water system contained an elevated storage tank with a capacity considered to be 450 cubic meters constructed of reinforced concrete that served the distribution system. The elevated storage tank was fed by the high lift pumps located at the WTP site.

The elevated storage tank will need to be cleaned, repaired and disinfected prior to returning to service if the component is determined to be integral to the Voinjama water system improvements. The site of the elevated storage tank is presently overgrown with vegetation that will be required to be clear and the sites secured, and lacks provision for security and access. The scope of the repairs will be based on a detailed inspection of the concrete structures and the level of effort to rehabilitate the structures and their appurtenances. The structural integrity of the elevated storage tanks will need to be conducted by a qualified structural engineer to determine if the no empty storage tank will be able to safely hold the re-introduction of treated or untreated water.

The volume of a storage tank is typically determined based on three components.

- Equalization Volume
- Volume Needed Fire Flow (if determined to be required during the design process)
- Volume for Emergency Storage

The following table outlines the storage time provide if the existing elevated storage tanks are rehabilitated and restored to service, and the daily flow increases. The previous ground storage tanks that served the low and high service areas did not provide any volume for needed fire flow demands. The storage tanks provide the volume that allows the distribution system to float of the pressure provided and to meet peak hourly demands.

Table 4-13 Durations of Storage in Elevated Tank

Year	Description	Daily Flow		Existing Storage Volume		Storage
		(gpd)	(m3/d)	(gal)	(m3)	(days)
2011	Base Year (2011)	26,010	92	118,400	450	4.55
2016	5-Years (2016)	158,930	607			0.74
2021	10 Years (2021)	295,160	1,122			0.40
2031	20 Years (2031)	336,340	1,280			0.35

The estimated 15 meters or 50 vertical feet from the base of the elevated storage area to the finish grade at the elevated storage tank site indicates 20 psi of static pressure is available at this location. A cursory review of the key or well-known areas in Voinjama indicates the majority of the town is located below the elevated storage tank site. This simplified evaluation does not address the head loss condition and pipe loss between sites. The elevated sections of Voinjama,

near New Life Community appears to be beyond the limits of the elevated storage tank, but does represent a location for an at grade reservoir if additional capacity is needed. An at grade tank is generally less expensive to construct. The addition of a second tank also provides redundancy and can improve the level of pressure in the distribution system.

Table 4-14 Comparison of Elevations throughout Voinjama

Location	Approximate Elevation (ft.)	Difference in Elevation with Respect to Elevated Storage Tank (ft.)*
Est. Base of Storage Volume	1935	
Grade at El. Storage Tank	1840	-95
Water Treatment Plant	1740	-195
Superintendent's Complex	1845	-90
New Police Barracks	1800	-135
Tellewoyan Hospital	1810	-125
Center of City	1820	-115
Market Area	1785	-150
Voinjama High School	1787	-148
Kormah Shepherd Academy	1806	-129
Lawazula Road Hill	1860	-75
New Life Community, North of Lawazula Road	1880	-55
Top of Kitoma Hill	2015	80

*(+) denotes a higher elevation and, (-) denotes a lower elevation in comparison to storage volume, elevation are estimated based on mean sea level datum

4.10.2 Mini Tanks/Zonal Nodes

Smaller storage facilities can be provided as a zonal node approach to reduce the requirements for system-wide elevated storage. The service area can be segmented into zones to ensure the resident's distance from a protected water supply does not exceed 30 minutes round-trip. This criterion can be developed in the definition of the zonal nodes and the location of zonal small storage tanks. From the small tanks, a smaller distribution system can provide service to local public stand posts or private yard and house connections. The small storage tanks and zonal systems can be developed independently to control pressures to protect individual communities from service breaks in the event of excessive demands from other communities. The small tank storage can maintain storage for peak demand for the community service area. This type of distribution system and tank configuration is also flexible and would permit chlorine to be added or boosted at each small tank location. In this configuration the use of calcium hypochlorite can be considered as a cost-effective method of chlorination.

As mentioned, it is recommended that the small storage tanks be sized to store to provide for the total daily demand for each community zone served, but the final volume should consider the supply source constraints. This could be greater than the half day (50%) storage used in more developed water systems. The excess storage is recommended due to the inconsistent power supply and other restrictive operational

issues. When the system is operational with a proven, long-term operating record, this value could be reduced. The tank elevation and the expected operational range should provide adequate pressure for the one-story structures located throughout Voinjama.

Also, it is recommended to maintain a residual pressure at the public stand post of 15 psi.

4.10.3 Private Tanks

If individual private tanks become a conventional component of the water system, then residents could be trained to add chlorine powder to their tanks to provide chlorine residual. The overall system would be required to continue adding chlorine at some location to provide a chlorine residual at the public stand posts. The use of private tanks would also require the need for back flow prevention devices. The simplest backflow device is the use of an air gap. The air gap and other back flow device would safe guard against cross contamination from the private to the main distribution system. The back flow preventer would reduce the risk of a contaminated private tank's contents from be siphoned back into the main Voinjama supply system during periods of unusually low pressure (such as during a water main break).

The option of utilizing the previous elevated storage tank, small tank zonal nodes, or a combination of the two should be included for the immediate solution to improve the level of water service in Voinjama.

The option of private water storage tanks is eliminated from further consideration as a means of storage in the water due the risk of relying on private participation and the inability to identify and coordinate with specific potential location of private service connection at this stage of the master plan.

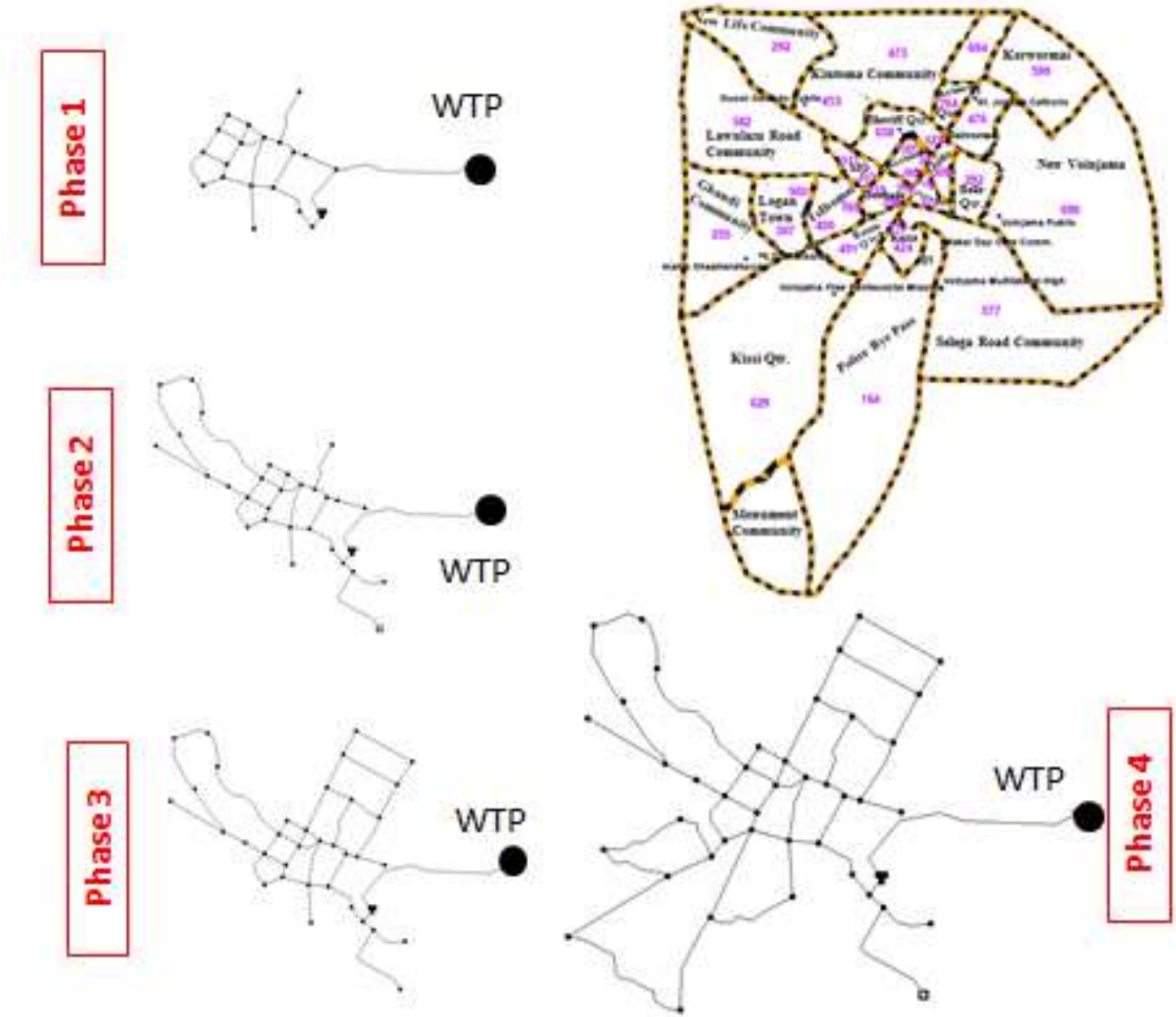
4.11 WATER DISTRIBUTION OPTIONS

The previous water distribution system was determined to be unsalvageable. No mapping of the distribution system was available for review or reference, but by various observations it appears the previous distribution system coverage once extended to the majority of the populated areas. The new pipe is proposed to follow the existing roadways and be located in the shoulder of the road. At various locations the PVC pipe of the former water system was exposed due to the erosion and/or re-grading of the roadways.

A hydraulic analysis of the new distribution system will be performed as part of the design stage to evaluate system pressures and velocities under the initial normal demands of 10 gallons per day per person (38 lpcd) residential flow, plus 20% unaccounted for water, and an additional percentage for nonresidential flow for the areas of coverage. The evaluation will be conducted to determine the requirements and conditions of the population and demands at the end of the study period. A looped system will likely be incorporated as much as possible to provide a level of redundancy to sustain the level of service.

The general progression of the construction of the new distribution based on the survey results is present in the series of images shown in the following figure.

Figure 4-15 Potential Phased Development of Voinjama Distribution System, based on no access, and feed from WTP



4.12 PUMPING POWER SYSTEMS OPTIONS

Due to the lack of a grid power supply, alternative power system needs to be developed to provide power for pumping of surface waters, groundwater, or treated water to the storage tanks or to the residents directly. The list of alternative power supplies includes:

- Independent electrical generator units
- Solar Power
- Wind Power

4.12.1 Independent Electrical Generator Units

Essentially all of the electricity used in Voinjama is from generator units owned and operated by private residents or businesses. The previous water system was also powered by an onsite generator located at the treatment plant. If properly sized, installed, and operated, a dedicated generator unit can provide power for the needed pumping and treatment.

Fuel cost and management would represent the single largest operational cost if generators are used for the project. Proper containment practices to safeguard the fuel from becoming a source of contamination at wells are critical. Due to the widespread use of portable generators in Liberia sufficient capacity to maintain and operate the units is expected to be present.

Table 4-15 Electric Generator for Pump Costs

Description	Qty.	Unit	Unit Cost	Cost	
Diesel generator	1	LS	$3,000	$3,000	
Generator house	1	LS	$6,000	$6,000	
Submersible pump set	1	Each	$2,000	$2,000	
Fencing	1	LS	$1,500.00	$1,500.00	
Individual Generator and Pump Set				$12,500.00	
(excludes bore hole, site work, storage and distribution)					
Annual Operation and Maintenance Cost					
Annual Replacement Costs	2%	Rate	20	Life , years	$760.00
Fuel Cost	$5.00	per Gal	8	hour/day	$8,760.00
	0.6	gph Fuel			
Miscellaneous Repairs					$500.00
Labor	1	hr./day	$15.00	per hour	$5,475.00
O&M Costs					$15,495.00

Derived from Unicef WASH Technology Information Packages

4.12.2 Solar Power

Advances in solar power technology have made solar a viable alternative energy option for water pumping. Several configurations of solar power devices may be viable. These configurations include the following:

Table 4-16 Solar Power for Pump Operation Alternatives

Components	Water service
Base Option: pump, switch box & Solar Panels	Only when solar panels are in operation
Addition of Storage Tank	Storage to provide service at night, when solar energy is inadequate
Addition of Backup Generator Unit	Alternate power source when solar energy source is not available or is inadequate
Addition of Backup Batteries	Alternate power source when solar energy source is not available

Solar radiation generally arrives at a maximum power density of about 1 kilowatt per square meter (1kW/m2), but the actual recoverable rate depend on the geographical location, amount of cloud cover, hours of sunlight per day, and the efficiency of the solar panels. The size of the solar panel array and system is based on the several factors including the population, flow rate, and total dynamic head for the pump. To estimate the flow the method used was based on a population of 19,600 persons in Voinjama and maximum coverage rate of 30,000 gallons per solar powered pump system, therefore twelve (12) installations are conservatively recommended. This will provide limited contingencies for expansion and for one of the solar pump systems to be out of service at a time. The evaluation can also be translated from a borehole application to a pumping facility located at a centralized location such as the previous water treatment plant.

Presented below is an outline of the estimated capital cost for a typical pump installation powered by a dedicated generator. It excludes the cost of the bore hole, site work, and associated distribution and storage costs. Also included are the basic operation and maintenance annual costs.

Table 4-17 Solar Power for Pump Costs

Capital Costs	QTY	Unit	Unit Cost	Cost	
Solar Panels, Peak watts, 20% cont.	576	peak watt	$2.50	$2,250.00	
Stand and Foundation for Panels	1	LS	$2,000.00	$2,000.00	
Solar pump	1	Each	$2,000.00	$2,000.00	
Fencing	1	LS	$1,500.00	$1,500.00	
Individual Solar Pump Set				$7,750.00	
(excludes bore hole, site work, storage and distribution)					
Operation and Maintenance Cost					
Annual Replacement Costs	2%	Rate	10	Life , years	$810.00
Labor	1	hr./day	$15.00	per hour	$5,475.00
O&M Costs					$6,285.00

Derived from Unicef WASH Technology Information Packages

The application of solar power at the WTP is also an appropriate setting. The previous WTP was equipped with a 80KVA[65] diesel fueled generator unit. The estimated capital cost to restore the previous system is about $25,000 to $30,000. The annual O&M cost of fuel is projected to be about $415,000 per year.[66]

The costs of a solar power system at the WTP will have a higher capital outlay and a low operating cost. In addition to the benefits of lower operating cost on the sustainability of the system, the solar power system also address concerns of a reliable fuel delivery to Voinjama. The lack of a reliable and consistent supply of fuel to the Kakata outstation has significantly crippled its operations for periods of months. The labor cost to operate the solar system is estimated to be offset with the cost of labor to operate the diesel generator unit.

4.12.3 Wind Power

While various styles of wind mills have been developed to generate energy, the scope of this evaluation is based on "lifting" windmills for pumping purposes. This approach reduces the loss of efficiency in converting mechanical power to electrical power and then back to mechanical power to transport the water. The traditional U.S. windmills have evolved over time but still provide the same service. The estimated cost of a traditional blade windmill, excluding the cost of the bore hole/well and the tower and support structure, is approximately $17,000 to $20,000 USD. The capacity for a windmill to lift water is based on wind speed, the diameter of the rotating blades, system inefficiencies, and the height the water is to be lifted. The below tables indicates the gallons per hour that can be pumped during light wind conditions.

Figure 4-16 Windmill powering well in Buchanan, Grand Bassa County

Table 4-18 Windmill Pumping Capacities

Size of Cylinder, Inches	Capacity (gallons per hour)		Elevation in Feet to Which Water Can Be Raised					
			Diameter of Windmill					
	6 ft.	8 ft. to 16 ft.	6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.
1 7/8"	3,000	4,320	120	175	260	390	560	920
2"	3,120	4,560	95	140	215	320	460	750
2 1/4"	4,320	6,240	77	112	170	250	360	590
2 1/2"	5,400	7,800	65	94	140	210	300	490
2 3/4"	6,360	9,240	56	80	120	180	260	425
3"	7,680	11,280	47	68	100	155	220	360
3 1/2"	10,560	15,360	35	50	76	115	160	265

[65] Final Design Report by GKW Consultants

[66] Based on 6 gallon per hour fuel consumption rate for a 80 KVA generator and $7.50 per gallon, excluding an labor cost

Table 4-18 Windmill Pumping Capacities

Size of Cylinder, Inches	Capacity (gallons per hour)		Elevation in Feet to Which Water Can Be Raised					
			Diameter of Windmill					
	6 ft.	8 ft. to 16 ft.	6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.
3 3/4"	-	17,520			65	98	143	230
4"	13,680	19,920	27	37	58	86	125	200
5"	21,600	31,200	17	25	37	55	80	130
6"	-	45,000		17	25	38	55	85

Pumping capacities shown are approximate, based on the mill set on the long stroke, operating in a 15 to 20 mile-an-hour wind. The short stroke increases elevation by one-third and reduces pumping capacities by one-fourth

Ref http://aermotorwindmill.com/Sales/CommonQuestions.asp

Even though a wind-powered hand-dug well was observed in the City of Buchanan, in Grand Bassa County, Liberia, wind power has been eliminated as an option for the short and medium term due to the lack of adequate wind records to properly select the types and size of equipment, the possible lack of power during prolonged windless periods, and the lack of widespread usage and experience with this technology in Liberia.

4.12.4 Gravity Feed

A preliminary evaluation indicated that large scale gravity is not feasible in Voinjama. It appears that the nearest elevated land mass is approximately 2 miles from the city center. The ridge of mountains is south easterly from Voinjama. The steep ridge line appears to be able to provide only a limited watershed area, and the location and presence of streams is unknown.

5.0 ALTERNATIVE FORMULATIONS

A comprehensive water supply strategy for Voinjama included the identification of water source capacities, water treatment options, power supply options, water storage options, and distribution system options.

The following consideration was the components to meet the initial water demand of 5 gpcd (20 lpcd), a project goal of 10 gpcd (38 lpcd), and the long-term projected demand of 13 gpcd (50+ lpcd). Based on available capacity and other constraints, emphasis is put on alternatives that utilize simple technology capable of future expansion and improvement with increasing demand and revenue.

The use of a surface water source was determined to be the most feasible option, due to several factors:

- Past water supply practices
- Observed poor water quality from groundwater sources
- The relative high water quality of surface water present, and
- The low possibility of contamination in the watershed area where human activity is less-intense.
- The current practice of using surface waters as drinking water sources

With the selection of the Zeliba River as the preferred water supply source, the development of alternative was conducted to take advantage of the elevated supply source. The approach also needs to consider the withdrawal limitation of the Zeliba River, and the current access to water supply sources.

The short term recommendation is to provide service through metered public kiosks or public stand pipes. Certain facilities such as administration buildings, hospitals and possibly larger commercial users would be served by dedicated metered service connections. The distribution system will be designed to allow the conversion from the metered public dispensing location to more private house connections or private yard taps as the water utility becomes further developed

5.1 NO ACTION ALTERNATIVE

Voinjama is not presently served by a reliable water system. The present situation is unacceptable due to the lack of water, the poor quality of drinking water that is characterized as unsafe, and the heavy reliance on hand-dug wells that were often constructed improperly but out of necessity during the emergency period. The current situation represents a threat to public health from contaminated water sources.

Evaluation of the No Action Alternative (No Action Plan) includes:

<u>Short and Medium Term (2012-2015)</u>

- Continued water deficit
- Chronic vulnerability to dry seasons and drought conditions via continuously depleting the aquifer
- Continued health issue due to consumption of contaminated groundwater from the shallow source aquifer
- Continued risk of social uncertainty and conflict
- Loss of productive time spent fetching water that could be spent at work or school

Long-term (2016-2031)

- Continued water deficit
- Acute vulnerability to dry seasons to droughts
- Advancing depletion of the shallow aquifer
- Heightened risk of social uncertainty and conflict
- Additional health concerns resulting from worsening water quality
- Highly constrained economic development potential

The No Action Alternative is eliminated as an option because it fails to meet basic access levels, maintains a perilous condition, and does not improve the access to a protected water supply to the City of Voinjama necessary for protecting public health and promoting economic development.

5.2 SOURCE ALTERNATIVE #1: RESTORATION OF PREVIOUS TREATMENT WORKS

This alternative represents the general restoration of the previous intake structure at the previous water plant site. The source waters would be from the Zeliba River. The intake structure improvement would include upgrades to the previous water control structure, new screens, pumps, controls, and force main. The intake structure is anticipated to discharge to a treatment facility located on or near the previous WTP site. Treatment is required due to the level of turbidity and bacteriological conditions in the Zeliba River.

5.3 SOURCE ALTERNATIVE #2: RIVER BANK FILTRATION

This alternative was described in Section 4.9.3. This option includes the use of river bank filtration that would withdraw groundwater from the alluvial and water bearing material from a well field installed near the previous WTP and the Zeliba River. While the river bank filtration would be drawing on groundwater under the influent of the surface water of the Zeliba River, it is anticipated that an improved raw water source could be achieved. The river bank filtration system is anticipated to discharge to a treatment facility located on or near the previous WTP site. Treatment is anticipated to be required due to influences of the surface waters.

5.4 TREATMENT ALTERNATIVE #1: RESTORATION OF PREVIOUS TREATMENT WORKS

This alternative represents the general restoration of the previous water system. The treatment system would include a conventional water treatment system with chemical addition, coagulation, flocculation, sedimentation, rapid sand filtration, and chlorination before the treated waters are pumped to the distribution system and storage. The power supply, distribution and storage alternatives are being considered separately and independently from this source water and treatment works alternative. The proposed treatment work, offices maintenance shop and laboratory would be located at the previous site and include the restoration of the previous WTP structures.

The lab facility should be equipped to conduct both basic water quality testing and those tests that are need to be per in situ. The Voinjama water should have at its disposal and use its own equipment and facilities for routine laboratory testing necessary to ensure proper operation.

The laboratory equipment selection shall be based on the characteristics of the raw water source, the complexity of the treatment process involved, and the capacity of the lab technician. Laboratory test kits which simplify procedures for making one or more tests may be acceptable. Analyses conducted to determine compliance with drinking water regulations must be performed in an appropriately equipped laboratory. The laboratory should be capable of verifying adequate quality assurances and for routine calibration of equipment provided.

It is recommended to provide the laboratory with sufficient bench space, adequate ventilation, adequate lighting, storage room, and a laboratory sink. Since the proposed Voinjama facility will be rely on surface water as its supply the proposed lab should be capable of testing, analyzing and monitoring the following parameters-

- Microbiological testing (most probable number method such as Aquatest ™, or the Compartmentalized Bag ™)
- Turbidity (nephelometric turbidimeter)
- pH meter (with temperature and specific conductivity)
- Iron and manganese (iron to a minimum of 0.1 milligrams per liter, and manganese to a minimum of 0.05 milligrams per liter)
- Free and Total chlorine

For more advance water quality testing it is recommended that improvement also be made in the currently LWSC laboratory in Monrovia.

The offices would be capable of housing the superintendent, operational management, accountant, billing and customer services. The offices would be equipped with chairs, desk, file storage, computers and other office features needed to operate and manage the treatment works, the distribution system, billing and collection practices.

The maintenance shop would be located and sized to hold and secure the stock and supplies to operate the entire water system. The maintenance shop would also have a supply of tools and equipment for the maintenance and repair of the treatment work, water storage, water distribution, and possible vehicle maintenance.

5.5 TREATMENT ALTERNATIVE #2: MODIFIED TREATMENT WORKS

This alternative was described in Section 4.9.3. This option includes the restoration of portions of the previous WTP to provide pretreatment, chlorination and pumping services; and the installation of slow sand filters. The application of slow sand filters is recommended since it represents a simpler treatment process that does not rely on the supply and application of chemicals. Not including chemical addition in the treatments work is advantageous due to constraint associated with the reliable supply and also reduces operational cost in an attempt to make the system more sustainable. Certain pretreatment steps, include the use of river bank filtration and tube settlers are incorporated to reduce the level of turbidity anticipated to be present in the raw water from the Zeliba River. As previously noted low turbidity levels are required for proper operation of the slow sand filters.

The modified treatment works would also house the offices, maintenance and laboratory. It is expected that these facilities would be consistent with those described above.

5.6 TREATMENT ALTERNATIVE #3: PACKAGED WATER TREATMENT PLANTS

This alternative include a series of 42+ packaged WTPs would be sited either at a central location or at multiple decentralized locations depending on the selection of supply sources. It is anticipated that the entire population would be served by this treatment process. Due to the high level of treatment that can be provided by package units, the effluent water quality may be the most improved of the alternatives considered. The alternative was outlined in Packaged Water Treatment Systems Section.

5.7 POWER ALTERNATIVE #1: ONSITE DIESEL GENERATOR UNIT

This alternative represents the installation of an onsite generator powered by diesel fuel. This option will required the constant supply of diesel to power the WTP treatment work and for pumping. The power system will include fuel storage as well as the generator unit. An 80KVA generator is anticipated to be required to support the electrical needs of the treatment works.

5.8 POWER ALTERNATIVE #2: SOLAR POWER

This alternative includes the installation of a solar collection and storage system to power the treatment works. The capacity of the system is also 80 KVA. The solar system will require to be sited near the WTP and in an open area without large vegetation to limit the casting of shadow to reduce the productivity of the system. The solar collection panel array will be located within the perimeter fencing of the WTP. The system will also require having storage batteries to allow for 24 hour per day pumping and WTP operations, and in both power alternative backup system would be required.

5.9 STORAGE ALTERNATIVE #1: PREVIOUS ELEVATED WATER TANK

This alternative includes the restoration of the previous concrete storage tank, as well as a ductile iron transmission main from the WTP to the tank site, located on the road to the WTP. The structural integrity of the reinforced concrete tank would need to be assessed to determine if the structure is still capable of safely holding 450 cubic meters of water after decades without use and maintenance.

This alternative limits the service area of the distribution system due to the fixed height of the tank. The pressures provide by the distribution system is directly dependent on the hydraulic grade line set by the water level inside the tank. To provide service to elevated sections of Voinjama, not previously served, will require additional pumping. An example of such an area is to the west of Kitoma Hill in the North West quadrant of Voinjama.

The use of the previous elevated water tank depend on at least two critical issues

- Its ability to serve the present service area, based on its height and location in the service area (to be determined by engineering survey of town topographical conditions at the high and low points in previous and newly settled areas)
- The structural integrity and operational condition of the previous (to be determined before or during construction by filling the structure)

The possibility of restoring the previous elevated water storage tank is based on the use similar elevated storage tanks as well as the planned restoration of others. The LWSC water system in its outstation of Kakata presently uses an elevated water storage tank of the same design. While the Kakata water system is presently operated intermittently due to fuel shortages, it was indicated that when powered the boreholes would pump groundwater to the elevated tank that appears to be similar physical condition (interior piping and valves repaired) to the Voinjama tank. An African Development Bank project (Buchanan, Zwedru and Kakata) has indicated in discussions that they plan to restore the elevated tank in Buchanan and Kakata (Zwedru is unknown, no plans have been provided to date for review by the AfDB

project). Visits have been made to the Kakata and Buchanan system and the conditions of the elevated tanks have observed. Past documents has also indicates that the previous Zwedru water included a similar elevated water tank[67].

5.10 STORAGE ALTERNATIVE #2: NEW AT-GRADE WATER TANK

This alternative includes the siting and installation of a new storage tank, as well as a ductile iron transmission main from the WTP. As noted above the area elevated to the west of Kitoma Hill and could be used to site a new storage tank. Preliminary analysis indicates that an at-grade tank could be sited. For preliminary comparison purposes a 50' diameter by 50' tall tank is being considered. The height of the new tank could be adjusted along with the pumping system at the WTP to serve elevated sections not previously connected. It is anticipated that one acre will be required within certain elevation constraints to site the new storage tank.

A new storage tank may be required to serve newly populated areas, beyond the previous water service area. The new facility may be required to increase the hydraulic grade line of the town's distribution system.

5.11 STORAGE ALTERNATIVE #3: DUAL STORAGE TANKS

This alternative is a combination of the previous two storage alternatives. This alternative, by provide two storage tanks, located on nearly opposite ends of the distribution is advantageous. The added volume provides additional storage that would allow the system to provide more emergency storage and have more capacity to operate a flushing program to maintain water quality with the distribution system. By having two storage facilities located at the limits of the service area would provide better control and a more consistent water pressure for customers connected. This could be accomplished if the tanks are hydraulically connected and operate to allow each to float off of the distribution system demand and WTP's supply.

This option is most feasible only if both storage tanks can operate at or near the same hydraulic grade line in the distribution system.

5.12 DISTRIBUTION SYSTEM ALTERNATIVE #1: ACCESS TO IMPROVED WATER SUPPLY BASED ON SOCIO ECONOMIC SURVEY RESULTS

This alternative is based on the development of a distribution system composed of 6 to 8 inch PVC water mains, gate valves, hydrants (for air release and flushing) and appurtenances. The phased development of the distribution was to prioritize areas of need based on the socio economic survey of respondent's access to improved water sources. The phased approach addressed the city center, areas of needs, certain important sites to the community such as hospitals and administration buildings. The phases of construction was developed to obtain the project of goal of access to improved water by 90 % of Voinjama's population, and then for 100 %.

5.13 DISTRIBUTION SYSTEM ALTERNATIVE #2: BASED ON NO CURRENT ACCESS TO IMPROVED WATER SUPPLY SOURCES

This alternative is based on the development of a distribution system composed of 6 to 8 inch PVC water mains, gate valves, hydrants (for air release and flushing) and appurtenances. The phased development of this alternative was previous described in Section 3.9 , and address areas with the greatest population.

[67] Main Report – Emergency Rehabilitation Project Report, by GKW Consult in 2005

The phased approach addressed the city center, and certain important sites to the community such as hospitals and administration buildings.

6.0 COST ESTIMATES

Estimates outlined in this master planning document are intended to provide a theoretical level of data for evaluation and development of the recommended plan. They are considered preliminary estimates since they have been developed based only on a conceptual level of detail design or scheme. This level of design effort is which is consistent and constant with the current Master Planning phase of the LMWP project scope.

Cost estimates were developed using water system component designs, unit selection, sizing, upgrades, other infrastructure information provided by LWSC and other engineering sources. Local labor rates used wherever possible. The amount of data provided was limited.

Current difficulties associated with estimating construction and operation cost of water system components include:

- No large scale water construction project has been designed or constructed in more than 30 years.
- The current African Development Bank Project (in Monrovia, Kakata, Buchanan and Zwedru) has completed conceptual designs and estimates, but the designs are presently be reviewed before the projects are tendered. The current schedule is for the AfDB project to be tendered in December 2012 or January 2013.
- Until the AfDB project or the LMWP's Voinjama project is tendered and bid are solicited, For 30 years, no construction contractors have prepared pricing for large scale water projects in Liberia.
- Without the track record of submitted bid prices various key construction factors have not been completely determined and addressed. These factors include the cost associated with travel to and the supply of material to Liberia for non-Liberian water contractors, the cost of access remote sites (outside of Monrovia), and other unknown difficulties and costs of performing work in Liberia.

The cost estimates in this master plan are based on 2012 United States dollars.

6.1 CAPITAL COST ESTIMATES OF IMPROVEMENT ALTERNATIVES

Listed below are a series of tables that estimated for preliminary evaluation purposed the capital cost required for each alternative previously described.

The first set of two (2) tables represent the estimated capital cost to either restore the existing intake structure, and construct a river bank filtration system near the previous WTP site.

Table 6-1 Source Alternative #1, Restore Intake Structure

#	Source Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
1	Restore Intake Structure	Restore Intake Pump Systems	3	Intake Pumps & Controls, ~125 gpm @ 60'TDH	$30,000	$90,000	$268,500
		Restore Intake Structure Building & Components	1	~12' x ~28' 2 story concrete structure	$24,000	$24,000	
		Restore Weir and Water Control Structure	1	~30LF 4'ht ogee weir and ~100LF of 12' ret. Walls	$22,000	$22,000	
		Improve Impoundment Area Berm	1,500	LF of Berm	$65	$97,500	
		Force main to WTP	350	LF DICL water main	$100	$35,000	

Table 6-2 Source Alternative #2 River Bank Filtration[68]

#	Source Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
2	River Bank Filtration	River bank filtration wells & pumps	4	-8" wells, 50' deep w/ ~125 gpm at 60' TDH each	$65,000	$260,000	$390,000
		Control Building for wells	1	~12' x ~28' 2 story concrete structure	$75,000	$75,000	
		Force main to WTP	550	LF DICL water main	$100	$55,000	

[68] At this time it is not known if the restoration of the earth berm is required with the River Bank Filtration withdrawal approach, therefor the cost is not included

The following two (2) tables outline the various line item improvements to provide treatment and their associated capital costs. The treatment options include the restoration of the previous Water Treatment Plant (WTP), and the construction of new slow sand filters. The slow sand filters options do include restoration of the previous sedimentation tanks to provide pretreatment to reduce the turbidity level. The previous WTP structure will also be used to house chlorination and effluent pumping and clearwell.

Table 6-3 Treatment Alternative #1, Restore Previous Treatment Works

#	Treatment Alternative	Components	Qty.	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
1	Restore Previous Water System	Restore Pre Treat Chemical Feed	1	Alum, Lime, Ferric = 3 Chemical Feed Systems	$36,000	$36,000	
		Rehabilitated WTP tanks	1	Floc (8'x8'x12') and Sed Basins (40'x20'x20')	$30,000	$30,000	
		Restore Filters	2	Rapid Sand Filters (14'x5'x10' each)	$14,000	$28,000	
		Sludge Piping	500	LF DICL water main	$100	$50,000	
		Restore WTP structures and rooms	1	- 2 story conc structure, ~7,500 SF total	$220,000	$220,000	
		Chlorination System	2	Chlorine Gas, chlorinators/evaporators	$150,000	$300,000	$1,434,400
		High Lift Pump System	3	Pumps & Controls, ~125 gpm @ 150'TDH	$50,000	$150,000	
		Back Wash Pump System	2	Pumps & Controls, ~1200 gpm @ 40'TDH	$40,000	$80,000	
		Restore Offices	1	Office, Lab, Work Shop, 4,000 SF total	$400,000	$400,000	
		Work Vehicles	3	work vehicles	$30,000	$90,000	
		Perimeter Fencing	1,260	-4' masonry wall topped w/ 6' wire fence & razor wire	$40	$50,400	

Table 6-4 Source Treatment #2 Modified Treatment Works

#	Treatment Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
2	Pretreat in Previous WTP Slow Sand Filters Restored Chlorination & High Lift Pump Systems	Rehabilitated WTP tanks	1	Floc (8'x8'x12') and Sed Basins (40'x20'x20')	$30,000	$30,000	$3,472,500
		Restore WTP structures and rooms	1	- 2 story conc structure, ~3,500 SF total	$220,000	$220,000	
		Sedimentation Basin Improvements	400	SF - Tube Settlers	$120	$48,000	
		Sludge Piping	700	LF DICL water main	$100	$70,000	
		Slow Sand Filters	3	each filter ~100' by 35' in size	$750,000	$2,250,000	
		Conc Slab for Sand Cleaning & Handling	1	on grade slab, 100' by 220'	$220,000	$220,000	
		Chlorination System	1	Hypochlorite HTH solution	$60,000	$60,000	
		High Lift Pump System	3	Pumps & Controls, ~125 gpm @ 150'TDH	$9,500	$28,500	
		Restore Offices	1	Office, Lab, Work Shop, 4,000 SF total	$400,000	$400,000	
		Work Vehicles	3	work vehicles	$30,000	$90,000	
		Perimeter Fencing	1,400	-4' masonry wall topped w/ 6' wire fence & razor wire	$40	$56,000	

The following two (2) tables outlines the various line item improvements to provide power to the water utility. The option includes r onsite diesel generators, solar generation and a modified combination of both to provide redundancy and lower operating costs.

Table 6-5 Power Alternative #1 Diesel Generator

#	Power Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
1	On Site Generator	Diesel Generator Set	2	- 80 KVA, Diesel fueled and accessories	$180,000	$360,000	$360,000

Table 6-6 Power Alternative #2 Solar Power

#	Power Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
2	Solar Power System	Solar Array, battery storage and controls	1	- 80 KVA	$2,200,000	$2,200,000	$2,380,000
	Backup Generator	Diesel Generator Set	1	- 80 KVA, Diesel fueled	$180,000	$180,000	

The following three (3) tables outline the capital cost to provide storage within the distribution system. The option include restoration of the previous elevated storage tank (if tested and determined feasible) , the installation of a new storage facility (depending on engineering survey of the service area, including the newly populated and settled areas), and combined option of provide a restored and a new storage facility.

Table 6-7 Storage Alternative #1, Previous Elevated Storage Tank

#	Storage Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
1	Previous Storage Tank	New Transmission Main to Storage	5,300	LF, 8 inch DICL water main	$100	$490,000	$690,400
		Restore Elevated Storage Tank and Site	1	-450 cubic meter elevated concrete pedestal tank	$150,000	$150,000	
		Perimeter Fencing	260	-4' masonry wall topped w/ 6' wire fence & razor wire	$40	$10,400	

Table 6-8 Storage Alternative #2, New Storage Tank

#	Storage Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
2	New Storage Tank	New Transmission Main to Storage	10,300	LF, 8 inch DICL water main	$100	$1,360,000	$1,602,600
		New Elevated Storage Tank and Site	1	Metal Stand Pipe, ~50' dia. By ~50' ht.	$550,000	$550,000	
		Land Purchase	1	Acre	$5,000	$5,000	
		Perimeter Fencing	440	-4' masonry wall topped w/ 6' wire fence & razor wire	$40	$17,600	

Table 6-9 Storage Alternative #3, Previous and New Storage Tanks

#	Storage Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
3	Previous Tank plus a New Storage Tank	New Transmission Main to Storage	12,500	LF, 8 inch DICL water main	$100	$1,360,000	$1,983,000
		Restore Elevated Storage Tank and Site	1	450 cubic meter elevated concrete pedestal tank	$150,000	$150,000	
		Land Purchase	1	Acre	$5,000	$5,000	
		New Elevated Storage Tank and Site	1	Metal Stand Pipe, ~50' dia. By ~50' ht.	$550,000	$550,000	
		Perimeter Fencing	700	-4' masonry wall topped w/ 6' wire fence & razor wire	$40	$28,000	

The following table outlines the capital cost to provide distribution system throughout the City of Voinjama.

Table 6-10 Distribution System

#	Distribution Alternative	Components	Qty	Description	Unit Cost (USD)	Cost (USD)	Alternative Cost Estimate (USD)
1	Service Areas	Phase 1 Distribution System	23,600	LF, 6 to 8 inch PVC water main	$80	$1,888,000	$5,472,000
		Phase 2 Distribution System	15,500	LF, 6 to 8 inch PVC water main	$80	$1,240,000	
		Phase 3 Distribution System	12,200	LF, 6 to 8 inch PVC water main	$80	$976,000	
		Phase 4 Distribution System	17,100	LF, 6 to 8 inch PVC water main	$80	$1,368,000	

6.2 OPERATIONAL COST ESTIMATES

The water utility developed through the institutional phase of the Liberia Municipal Water Project would be responsible for operating the system as efficiently as possible, keeping in mind that the primary objective is to provide a continuously reliable source of drinking water to its customers. The annual labor costs are based on approximately 240 hours per year per staff member and the estimated daily rate for the various categories of work. The allocation of staff is based on the estimate staffing for each alternative. The base staffing for future water utility is included under the treatment work alternatives. Staffing related to the distribution system, power supply and storage facility are listed under the applicable alternatives to estimated level required.

Table 6-11 Estimated Annual Labor Cost per Alternative

		Staffed Positions							
#	Alternative	Superintendent	WTP Operators	Chemist	Maintenance	Distribution Operator	Accountant	Billing	Cost
W1	Restored intake Structure	0	0.5	0	0.5	0	0	0	$4,920
W2	River Bank Filtration	0	0.5	0	0.5	0	0	0	$4,920
T1	Previous Treatment Works	1	5	2	2	0	2	3	$76,800
T2	Modified Treatment Works	1	5	2	2	0	2	3	$76,800
T3	Package Treatment Works	1	15	3	8	0	2	3	$157,200
P1	Onsite Diesel Generator	0	1	0	1	0	0	0	$9,840
P2	Solar Power	0	1	0	1	0	0	0	$9,840
S1	Previous Storage Tank	0	0	0	0.5	0	0	0	$3,000
S2	New Storage Tank	0	0	0	0.5	0	0	0	$3,000
S3	Dual Storage Tanks	0	0	0	0.5	0	0	0	$3,000
D	Distribution System	0	0	0	0	5	0	0	$19,200
	Daily Rate	$30.00	$16.00	$25.00	$25.00	$16.00	$25.00	$20.00	

The estimated labor cost of the source alternative is approximately the same between the restored intake structure and the river bank filtration. The operation of the treatment alternative will require chemical costs. The primary chemical required for all alternatives is chlorine for disinfection purposes. Hypochlorite is used for consistency, although if the previous water treatment plant is restored the option of chlorine gas (previously use form of chlorine), despite the safety concerns. The previous conventional

treatment system will also require alum for coagulation and flocculation purposes. Other chemical may also be needed if the previous system is restored and would represent an additional operational cost above that indicated.

Table 6-12 Estimated Annual Chemical Cost by Alternatives

		Estimated Chemical Cost					
#	Task	Population Served	Total Daily Flow	Hypochlorite Required	Alum	Chemicals Package WTPs	Cost
		Person	gpd	lb/d	lb/d		
0	No Action	0	-	0	0	0	$0
T1	Previous Treatment Works	19,600	336,340	42	578	0	$161,100
T2	Modified Treatment Works	19,600	336,340	42	0	0	$76,650
T3	Package Treatment Works	19,600	336,340	42	0	$170,000	$246,650

Notes:
Based Chlorine = 10 mg/l; Alum = 35 mg/l; Cost of Chlorine = $12 per pound; Cost of Alum = $5 per Pound

A large operational cost for most Liberian water system appears to be related to the cost of fuel. The fuel costs are broken down by diesel fuel to power generators need for treatment and pumping; and for the estimated gasoline cost to supply the vehicle fleet for the utility. The fuel costs are estimated based on $7.50 per gallon of diesel and $6.00 per gallon of gasoline.

The operation of the water utility will require various types of supplies. Office and computer supplies will be required for the utility to purchase new equipment; track labor hours, costs and benefits, conduct meter readings, issue bills, and evaluate tariff rates. Spare parts include consumables such as oils, lubricants and other supplies are needed for the day to day of the utility. Tools are needed for the maintenance of the treatment works, vehicles and operation of the distribution system. Piping and fittings will be need in the distribution system to repair leaks, and to extend pipelines, as well as with the treatment plant.

Table 6-13 Estimate Annual Fuel Cost by Alternatives

		Estimated Fuel Cost					
#	Task	Required Power	Required Power	Fuel Demand	Vehicle Use	Vehicle Fuel	
		KW	KVA	gph	(mi/yr)	(gal/year)	
P1	Onsite Diesel Generator	55	80	6	30,000	1,670	$404,220
P2	Solar Power	55	80	0	30,000	1,670	$10,020

Table 6-14 Estimated Annual Supply Costs by Alternatives

		Estimated Cost of Supplies					
#	Task	Office Supplies	Spare Parts	Tools	Pipe and Fitting	Vehicular	Cost
0	No Action	$0	$0	$0	$0	$0	$0
T1	Previous Treatment Works	$8,000	$8,000	$900	$1,000	$4,000	$21,900
T2	Modified Treatment Works	$8,000	$6,000	$700	$1,000	$4,000	$19,700
T3	Package Treatment Works	$12,000	$40,000	$5,000	$5,000	$15,000	$77,000
P1	Onsite Diesel Generator	$0	$8,000	$500	$0	$0	$8,500
P2	Solar Power	$0	$5,000	$500	$0	$0	$5,500
S1	Previous Storage Tank	$0	$2,000	$0	$0	$0	$2,000
S2	New Storage Tank	$0	$2,000	$0	$0	$0	$2,000
S3	Dual Storage Tanks	$0	$4,000	$0	$0	$0	$4,000
D	Distribution System	$0	$5,000	$0	$7,000	$0	$12,000

The various types of operation and maintenance costs are summarized by alternatives in Table 6-15 Summary of Annual Operating Costs by Alternatives, and can be consider for either source alternative (restored intake or river bank filtration).

Table 6-15 Summary of Annual Operating Costs by Alternatives		
#	Task	Summary of O&M Cost by Alternative
T1	Previous Treatment Works[69]	$264,720
T2	Modified Treatment Works[70]	$178,070
T3	Package Treatment Works	$480,850
P1	Onsite Diesel Generator	$422,560
P2	Solar Power	$25,360
S1	Previous Storage Tank	$5,000
S2	New Storage Tank	$5,000
S3	Dual Storage Tanks	$7,000
D	Distribution System	$31,200

Based on the various types of alternatives (source/treatment, power, and storage), they were compiled in systematic combinations. Due to the high annual operating cost and its impact on sustainability, the package treatment alternative was discounted from further consideration. The remaining alternatives created 12 possible scenarios. The estimate annual operating costs were developed for these scenarios and they are ranked according to cost in Table 6-16 Ranking of Scenarios by Estimate Annual Operating Costs. Of the 12 possible scenarios, a range of 5 were selected for further evaluation and consideration.

The four selected scenarios do not include options that are powered by diesel generators. When the operational cost of the diesel fuel along with the logistical uncertainties of supplying fuel to remote locations the use of diesel generators were considered to be infeasible and too costly. The cost of diesel fuel nearly matches all other operating costs (labor, chemical and supplies) and essentially would result in the doubling of user fees. The sharp increase in operating cost associated with diesel generation made this power alternative an unsustainable approach.

[69] Include O&M cost associated with source alternatives (restored intake or river bank filtration)

[70] Include O&M cost associated with source alternatives (restored intake or river bank filtration)

Table 6-16 Ranking of Scenarios by Estimate Annual Operating Costs

Treatment Alternatives	Power Alternatives	Storage Alternatives	Estimated Annual Operating Cost	Scenarios recommended for further consideration
T2	P2	S1	$239,630	Scenario A
T2	P2	S2	$239,630	Scenario B
T2	P2	S3	$241,630	Scenario C
T1	P2	S1	$326,280	Scenario D
T1	P2	S2	$326,280	No
T1	P2	S3	$328,280	Scenario E
T2	P1	S1	$636,830	No
T2	P1	S2	$636,830	No
T2	P1	S3	$638,830	No
T1	P1	S1	$723,480	No
T1	P1	S2	$723,480	No
T1	P1	S3	$725,480	No

To evaluate the scope of the selected scenarios, the present worth cost to the capital costs plus 20 years of the operating costs were determined. Since the capital costs are a one-time current cost and the operating costs are associated with a 20 year period, the operating costs were discounted at 2% rate (P/A. 2%, 20 years = 16.35)

Table 6-17 Present Worth Values of Scenarios

Scenario	Alt(s)	Capital Cost of Alternative	Capital Cost of Scenario	Annual Operating Costs of Alternatives	Annual Operating Costs of Scenarios	Present Worth
A	T2	$3,862,500	$12,224,900	$178,070	$239,630	$16,143,000
	P2	$2,200,000		$25,360		
	D1	$5,472,000		$31,200		
	S1	$690,400		$5,000		
B	T2	$3,862,500	$13,137,100	$178,070	$239,630	$17,055,000
	P2	$2,200,000		$25,360		
	D1	$5,472,000		$31,200		
	S2	$1,602,600		$5,000		
C	T2	$3,862,500	$13,517,500	$178,070	$241,630	$17,468,000
	P2	$2,200,000		$25,360		
	D1	$5,472,000		$31,200		
	S3	$1,983,000		$7,000		
D	T1	$1,702,900	$10,065,300	$264,720	$326,280	$15,400,000
	P2	$2,200,000		$25,360		
	D1	$5,472,000		$31,200		
	S1	$690,400		$5,000		
E	T1	$1,702,900	$11,357,900	$264,720	$328,280	$16,725,000
	P2	$2,200,000		$25,360		
	D1	$5,472,000		$31,200		
	S3	$1,983,000		$7,000		

Listed below are the "per capita costs" associated with both the capital and operating costs developed for the scenarios. The capital cost per capita is related to the funding of the capital cost of the projected which is anticipated to be funded by USAID. The operating cost per capita is related to the funding of the annual operating cost for each scenario which is anticipated to be funded by the connected users in the establishment of a sustainable water system.

Table 6-18 Capital Cost per Capita of Scenarios

Scenario	Capital Cost of Scenario	Estimated Service Population	Cost per Capita (USD$/person)
A	$12,224,900	19,600	$624
B	$13,137,100		$670
C	$13,517,500		$690
D	$10,065,300		$514
E	$11,357,900		$579

Table 6-19 Operating Cost per Capita of Scenarios

Scenario	Annual Operating Costs of Scenarios	Estimated Service Population	Cost per Capita (USD$/person)
A	$239,630	19,600	$12
B	$239,630		$12
C	$241,630		$12
D	$326,280		$17
E	$328,280		$17

6.3 COST-BENEFIT ANALYSIS

The cost-benefit analysis is used to evaluate and rank the financial value of various solutions. A properly conducted and accurate cost-benefit analysis is capable of assessing alternatives and scenarios with respect to the increase in the public's welfare from a financial perspective. The financial perspective is on the key factors in selecting and developing a sustainable water system. The Voinjama cost-benefit analysis was developed based on the estimated value of an effective water system, and the present worth of the estimated capital and operational costs for the various alternatives being considered.

The benefit of a water system is primarily based on the anticipated improvements provided by a safe and protected source. The primary advantage is anticipated to be the improvement to the public health especially that associated with the impacts of diarrheal diseases. This is calculated through the decrease in: direct health care costs; miscellaneous expenditure associated with health care issues; loss of income by the household providers; loss of education value for sick children; loss of income associated with parents who care for sick children in lieu of work;; the loss of time spent fetching water; and the loss associated with decreased life expectancy.

Table 6-20 Summary of Benefit Costs/Values

Parameter	Value	
Demographics		
City Projected Population	19,600	persons
Average Household Size	5.0	persons per household
Estimated Number of Households	3,920	households
Health Care Cost - associated with diarrheal disease		
Unit Cost - per visit	5.00	visit per case
Unit Cost - per day	15.00	per day of hospitalization
Time -	1.00	outpatient visit per episode
Time -	5.00	days for hospitalization cases
Distribution of Treatment-	0.90	outpatient visit
Distribution of Treatment-	0.10	hospitalization cases
Estimated Occurrence	2.00	times per person per year
Estimated Outpatient Medical Cost	$176,400	per year
Estimated Hospitalization Cost	$58,800	per year
Other Direct Expenditures Cost		
Transportation Cost per visit	1	per visit
Estimated percent of patients using transportation	80%	
Estimated Transportation Costs	$31,360	per year
Lost Income due Illness		
Days out of work due to Outpatient episode	3	days per episode
Days out of work due to Hospitalization episode	7	days per episode
Percent of Population in Work Force	40%	
Estimated Daily Income	7	per day
Income Lost due to Outpatient episode	$296,352	per year
Income Lost due to Hospitalization episode	$76,832	per year
Loss of Education Value		
Percent of Population in Schooling	35%	

Table 6-20 Summary of Benefit Costs/Values		
Estimated Value of Education (minimum wage)	4	per day
Ed. Value Lost due to Outpatient episode	$148,176	per year
Ed. value Lost due to Hospitalization episode	$38,416	per year
Lost Income from Parent due to Child Illness		
Percent of Population in Child Age	30%	
Estimated Loss of Parent Income (minimum wage)	4	per day
Ed. Value Lost due to Outpatient episode	$127,008	per year
Ed. value Lost due to Hospitalization episode	$32,928	per year
Lost Convenience Time spent Collecting Water		
Time lost per household	1	hours per day
Time lost per person	0.1	hours per day
Value of Conv. Time (minimum wage)	4	per day
Estimated value of Lost Conv. Time/household	$1,907,740	per year
Estimated value of Lost Conv. Time/person	$953,870	per year
Cost Summary		
Sum of Losses per year	$3,847,882	per year
Value of Loss of Life		
Estimated Current Life Expectancy	55	Years
Estimated Projected Life Expectancy	65	Years
Estimated Increase to Years of Income Production	5	Years
Estimated Productive Days per Year	200	days per year
Estimated Loss Income	$54,880,000	
Project term and cost		
Life of Project	20	Years
Estimated Cost associated with lack of water system (Present Worth, 20 years, 2%)	$117,792,871	

The costs to construct and to operate the various alternatives have also been estimated. These costs were summarized and calculated using present value (based on a 20 year term and 2% interest rate).

The below table adjusts the benefit value of the improved water system based on the population to be served. The table also indicates if the proposed alternative complies with the project goal of 90% access

to an improved water supply access. Alternatives that do not comply with this project goal are still presented because certain alternative may be considered as part of a phased construction approach.

Table 6-21 Cost to Benefit Ratio Comparison of Scenarios

Scenario	Alternative	Description	Population Served	Benefit Cost	Alternative PW of O&M Cost	Benefit - Cost Ratio	Ranking	Recommended Scenario
A	T2	Modified Treatment Works	19,600	$117,792,871	$16,143,000	7.30	2	YES
	P2	Solar Power						
	D1	Distribution System						
	S1	Previous Storage Tank						
B	T2	Modified Treatment Works	19,600	$117,792,871	$17,055,000	6.91	4	
	P2	Solar Power						
	D1	Distribution System						
	S2	New Storage Tank						
C	T2	Modified Treatment Works	19,600	$117,792,871	$17,468,000	6.74	5	
	P2	Solar Power						
	D1	Distribution System						
	S3	Dual Storage Tanks						
D	T1	Previous Treatment Works	19,600	$117,792,871	$15,400,000	7.65	1	
	P2	Solar Power						
	D1	Distribution System						
	S1	Previous Storage Tank						
E	T1	Previous Treatment Works	19,600	$117,792,871	$16,725,000	7.04	3	
	P2	Solar Power						
	D1	Distribution System						
	S3	Dual Storage Tanks						

The benefit values and the alternative cost are directly compared to each other and ratio is determined (Benefit Value / Alternative Cost). Based on the input into the benefit values, the alternative's benefit : cost ratios can be compared and ranked. All five selected scenarios ranking consistently, with ratios ranging from 6.74 to 7.6.

The recommended scenario for improve the access to an improved water source in Voinjama is Scenario A. The recommended scenario includes:

- Modification of the treatment plant to provide pretreatment of flow from either directly from the Zeliba River or from river bank filtration (dependent upon hydrogeological site conditions and study result)
- Construction of slow sand filters
- Modifying the previous works to provide chlorination and pumping
- Construction of a new distribution system with metered public dispensing locations
- Provision for storage facilities, either by the previous elevated water tower or a new facility (dependent on current service area and condition of previous facility)

6.4 ECONOMIC SUSTAINABILITY

The supply of an improved source of water can be inadequate or restricted due to challenges such as power outages, source depletion, and delay in receiving chemicals for treatment or spare parts and replacement equipment. A water system must support its customers and provide services and a product that is both affordable and reliable. The planned approach within the improved Voinjama water system must balance the need to provide water services with the local ability and willingness to pay for services, which is critical to ensuring that such systems are sustainable. Without ensuring full cost recovery or adequate subsidies, the systems put in place are likely to enter into a spiral of poor maintenance leading to equipment and system failure. While tariff structures must ensure full cost recovery, they also must ensure that the poorest customers have access to a basic level of service via a "lifeline" tariff. It is expected that the tariff structure will include cross-subsidies where the larger water users pay more per volume than low-volume users.

The construction of the distribution system to provide the conveyance of water from the source or treatment to the customer is typically substantial capital cost of system. Therefore, the cost effectiveness of extending the distribution system is typically reduced as the distribution network extends into less densely developed areas where it costs more to extend service on a per capita basis.

In order to reduce costs and barriers to access, the initial supply of water in the short term is expected to be solely via public kiosks located throughout the city with locations to be determined during design. The medium and longer term goal is to transition from kiosks to private yard taps and private house connections.

LMWP will provide a detailed analysis on sustainability once the options have been finalized. The will include detailed financial analysis based on system cost, customer base and revenues and operation and maintenance costs projections. However, an initial analysis regarding the financial feasibility as currently outlined is presented below.

In order for the proposed systems to be sustainable without external subsidies, then at a minimum the cost of operation and maintenance must be recovered via water tariffs. The following table presents a preliminary analysis which demonstrates that given currently estimated annual operating costs and water demand, the requisite average cost recovery tariffs are generally within the range of affordability in Voinjama when examined using several different metrics. First, the estimated monthly water cost per household for water from the proposed systems can be expected to vary as the system develops.

Although this represents a large portion of available household income, it appears reasonable when compared to the estimated household monthly net (surplus) income which was also calculated based on results of the household survey.

Table 6-22 Voinjama Water System Initial Affordability Analysis

Scenario	Annual Operating Costs (USD)	Estimated Population Served	Expected Volume Sold (gpd)	Expected Per Capita Demand (gpcd)[1]	Estimated Monthly Water Cost per Household (USD)	Monthly Cost as Percentage of Median Household Income (%)[2]	Household Monthly Net (Surplus) Income (USD)[3]	Estimated Avg. Tariff per Jerrican volume equivalent (USD/5.2 gal)[4]	Current Robertsport Vendor Rate per Jerrican (USD/5.2 gal)[5]
A[6]	$239,630	19,600	336,400	17.2	$7.13	5.0%	$31.43	$0.0101	$0.25
B	$239,630	19,600	336,400	17.2	$7.13	5.0%	$31.43	$0.0101	$0.25
C	$241,630	19,600	336,400	17.2	$7.19	5.0%	$31.43	$0.0102	$0.25
D	$326,280	19,600	336,400	17.2	$9.71	6.8%	$31.43	$0.0138	$0.25
E	$328,280	19,600	336,400	17.2	$9.77	6.8%	$31.43	$0.0139	$0.25

[1]includes non-domestic usage such as commercial, industrial and other.

[2]Per Situational Analysis, total reported median monthly gross household income in Voinjama was $145.83.

[3]Per Situational Analysis, a median net household income (surplus) after expenses of $31.43.

[4]Per Situational Analysis, respondents indicated they would also be willing to pay a median of LD 5 (*USD 0.07)* per jerican from stand posts and water kiosks within 100 meters of their home

[5] Per Situational Analysis, Voinjama residents do not purchase water by the jerrican, but the current vendor rates in Robertsport are 20 LD ($0.30) per jerrican sold in Fanti Town neighborhood and 15 LD ($0.20) per jerrican in Grassfield. Assume an average rate of $0.25 USD/jerrican.

[6] Recommended scenario

[75] Operational Costs, Estimate household cost and percent of household income could be less if the solar power system is used more than the 50% contribution level used in Scenarios C, D and E.

7.0 RECOMMENDATIONS OF SELECTED ALTERNATIVES

Outlined below are the recommendations for the planned improvements to the City of Voinjama's water supply access needs.

The sequenced recommendations prioritize the supply of water to residents, to important city sites and to high population areas. The implementation of these alternatives is anticipated to achieve the 90% access to an improved water supply source.

The ability to concentrate on the supply of water is possible due to the water quality present in Zeliba River, but an important short-term recommendation is the establishment of regulations and administration to protect the source quality of the surface water supply, i.e., to protect the Zeliba River watershed area.

7.1 SHORT-TERM PROJECTS

7.1.1 Develop Mini Systems at Selected High Yielding Wells

The Mini System Water Scheme would consist of a developed water source (either a high-yielding hand-dug well or borehole), a submersible pump with an associated power source, an overhead storage tank, kiosk or stand posts, and piping to connect all facilities. Maintenance and operation costs will be minimized in order to create a cost-recoverable system. The high yield wells that are proposed to be developed into water sources are presented hereafter with their accompanying location in the project cities. They are selected primarily because of their yield and their suitability to provide potable water supply. Preliminary estimates for Mini System are approximately $55,500 per site. Based on the estimated capacity of wells pump tested high yield wells are considered to be those greater than 1,000 gpd.

Table 7-1 Mini System, Proposed Locations

Project City	Estimated Number of Wells to be Developed	LMWP Well Number & Community	Estimated Capacity (gpd)	Estimated Capacity (gpm)
Voinjama	3	V 18 located in Kintoma Community	9,511	6.6
		V 35 located in Telboma Community	6,594	4.5
		V 40 located in Kissi Quarter Community	2,750	1.9

7.1.2 Establish Modular WTP Improvements

The development of the short term project was developed based on various factors such as scheduling and implementation constraints. The reconstruction of the entire WTP with a significant portion of the distribution system would not be capable to be completed in the short term phase of the project. The implementation of the funding and procurement could also be difficult for the anticipated newly created water utility and agencies. Therefore the proposed larger scaled treatment works and water system was divided into the both the short term and medium term projects.

In the short term project, the goal of the modular WTP improvement is to construct portion of the works that will also be used in the medium term effort, but will initially provide a facility from which the new water utility could be based and operate from. The modular facility improvements would include restoration of the offices, laboratory and maintenance areas so the water utility can support the operation of the mini systems and WTP efforts. The modular WTP improvement would also include the restoration of portion of the previous tanks and system to operate as down sized slow sand filter. This can be a valuable tool for the new water utility to learn the operations of a smaller facility, and to obtain performance information on the slow sand filtration of the waters from the Zeliba River. The water from the modular treatment works could also be supplied to the City.

Focusing on the short term recommended components will allow for a quicker construction period that will lead to an earlier implementation of a water service area and utility. The implementation of this recommendation would include:

- Restore office building at existing WTP site. The restored office would be used for administration, billing, maintenance shop and basic lab work.
- Restored Intake Structure with a solar powered submersible pump sized for the proposed modular WTP. (unless test well drilling phase of the hydrogeological study determines river bank filtration can provide the yield and is feasible)
- Install a stream gauging station for Liberia Hydrological Services as part of intake structure work
- Modify the mixing tank and sedimentation basin (with tube settlers) to provide pretreatment by means of aeration and sedimentation to reduce turbidity levels. This improvement would also be used in the medium term project.

- Construct slow sand filters from the previous rapid sand filter. The use of the previous tankage will save construction cost since these down sized filters would not be used as the system develops, but the operation of slow sand filters will be valuable in the capacity building of operators in the functions of slow sand filter and their performance on raw waters from the Zeliba River.
- Provide chlorination and storage of treated effluent.

It is recommended that basic laboratory work, such as temperature, pH, and chlorine residual testing is performed by the lab located at the restored WTP site. This lab facility should be equipped to conduct both basic water quality testing and those tests that are need to be per in situ. The Voinjama water utility should have at its disposal and use its own equipment and facilities for routine laboratory testing necessary to ensure proper operation.

The laboratory equipment selection shall be based on the characteristics of the raw water source, the complexity of the treatment process involved, and the capacity of the lab technician. Laboratory test kits which simplify procedures for making one or more tests may be acceptable. Analyses conducted to determine compliance with drinking water regulations must be performed in an appropriately equipped laboratory. The laboratory should be capable of verifying adequate quality assurances and for routine calibration of equipment provided.

It is recommended to provide the laboratory with sufficient bench space, adequate ventilation, adequate lighting, storage room, and a laboratory sink. Since the proposed Voinjama facility will be rely on surface water as its supply the proposed lab should be capable of testing, analyzing and monitoring the following parameters-

- Microbiological testing (most probable number method such as, Aquatest ™, or the Compartmentalized Bag ™)
- Turbidity (nephelometric turbidimeter)
- pH meter (with temperature and specific conductivity)
- Iron and manganese (iron to a minimum of 0.1 milligrams per liter, and manganese to a minimum of 0.05 milligrams per liter)
- Free and Total chlorine

For more advance water quality testing it is recommended that improvement also be made in the currently LWSC laboratory in Monrovia.

The offices would be capable of housing the superintendent, operational management, accountant, billing and customer services. The offices would be equipped with chairs, desk, file storage, computers and other office features needed to operate and manage the treatment works, the distribution system, billing and collection practices.

The maintenance shop would be located and sized to hold and secure the stock and supplies to operate the entire water system. The maintenance shop would also have a supply of tools and equipment for the maintenance and repair of the treatment work, water storage, water distribution, and possible vehicle maintenance.

7.1.3 Establish Protective Measures for the Zeliba River Watershed

The degradation of natural resources and the resultant in the loss of soil fertility, deforestation and other environmental changes can contribute to the declining capacity of water resource that represent drinking

water supplies. Portion of Liberia, such as Lofa County and Voinjama contain valuable forest resources, but indications are much of the forest is being lost to cultivation. While forests can represent a cultural to the residents of the area, this resource areas also provide forest-dependent residents with the capacity to harvest edible and medicinal plants, wild meat, fruits, honey, shelter, firewood and many other goods.

On a global scale, all forests play a crucial role in climate regulation and constitute one of the major carbon sinks on earth. But on a local level the natural forest that makes up the watershed above the Zeliba River intake structure is critical component to both the quantity of water available and just as importantly the quality of the surface water.

The protection of the forest that makes up the limited watershed of the surface streams and creeks in Voinjama should be valued as a resource in the control of stream flow and water quality. The current sources of drinking water would be significantly and adversely impacted if the current watershed is altered. Alteration of the watershed area would decrease the quantity of water that is available and degrade the quality of the water.

Along with the administration and institutional establishment of the water utility in Voinjama, the protection of the Zeliba River watershed should be prioritized.

7.1.4 Short Term Capital Costs

Table 7-2 Short Term Projects Capital Costs outlines the capital cost broken down by city and by the water system components. Also included in the table is a brief description of each component of the water system , along with the capacity or quantity of the water system component. The table includes cost for short term projects that include:

- Watershed Protection
- Stream Gauging
- Mini Systems
- Initial Modules of Water Treatment Plants with relatively low capacity, to provide training and capacity building of treatment operators, provide an initial supply of drinking water with limited distribution, act as a pilot of the slow sand filtration process, and provide a base for a new water utility.

These capital costs and others presented represent the best estimate for the alternatives developed during the master planning process. These costs are expected to change as they are refined during the design process. Therefore for planning purposes a contingency of 20 percent is recommended and was applied to all capital costs.

It should be noted that a database of water improvement cost for similar work in Liberia was not located and could not be developed since such activities have not occurred in several decades. It is expected that the African Development Bank (AfDB) projects will be issued and actual bids will be received in the first quarter of 2013. It is recommended that this process be monitored and the results be obtained and assessed to determine the construction cost environment and condition present for Liberian water improvement projects and refine our estimates accordingly. Given the rapid changes occurring in Liberia's development since the conclusion of the conflict, change and volatility could be expected in construction costs.

Table 7-2 Short Term Projects Capital Costs

Water Utility Component	Cost & Descriptions
Establish Watershed Projection Program with the administration and institutional establishment of the water utility in Robertsport. The protection of all three watersheds should be prioritized. On each local level, the watersheds are a critical component to both the quantity of water available and just as importantly the quality of the surface water. The current sources of drinking water would be significantly and adversely impacted if the current watershed is altered. Alteration of the watershed area would decrease the quantity of water that is available and degrade the quality of the water.	$40,000 Catchment Area Estimated 102 km2
Groundwater – Mini Systems The Mini Systems will utilize a developed and existing water source (either a high-yielding hand-dug well or borehole) and add submersible pump with an associated power source, overhead storage tank, kiosk or stand posts, and piping to connect all facilities. Any pipe installed for distribution could be sized for future water distribution system improvements. The elevated storage tanks could also be incorporated into future kiosks to provide local storage to cover any operational outages associate with the startup of the new system. The Mini Water Systems would include the components and design features as outlined in the Quick Impact Conceptual Report.	Mini System Unit Price ~$55,500 per mini system Estimated Number of Mini System = 3 $166,500
Stream Gauging Stations Install stream gauging stations at or near proposed intake structures, capable of transmitting reading to remote locations.	$120,000
Treatment For Voinjama the restoration of an administrative office, a lab, and a maintenance space in the previous WTP buildings and work vehicles is also required. The installation of perimeter fencing will also be required to secure the previous system sites.	$550,800 Cost of Chlorination included in Mini System Costs
Initial Modules of Treatment Plants for Pilot Studies For preparation of the medium term projects in Voinjama down sized treatment plants are proposed to (1) act pilot plants for the second phase of works treatment plants, (2) as a training location of water treatment plant operators and (3) to provided treated water to city residents. The scope of this pilot plants would include:	
Restoration of the intake structure with solar powered pumps and batteries.	$75,000
Restoration of force main from intake to WTP (350 LF in Voinjama) [to be retained for future use in medium term project]	$35,000
Installation of a gravity aeration system. [to be retained for future use in medium term project]	$40,000

Table 7-2 Short Term Projects Capital Costs

Water Utility Component	Cost & Descriptions
Restoration of the previous coagulation and sedimentation tanks for pretreatment. [to be retained for future use in medium term project]	$30,000
Conversion of the two Rapid Sand Filter to Slow Sand Filters (Flow rate based on existing foot print (~9 m2 each) and slow sand loading rates (1.8 to 6 m3 per day per m2 ~ 4,000 to 14,000 gpd per unit, Use 12,000 gpd	$28,000
Chlorination to be provided via an inline erosion type of chlorinator.	$7,000
Master metering for influent [to be retained for future use in medium term project] and effluent flows	$10,000
Laboratory restoration, furnishing and supplies. [to be retained for future use in medium term project]	$50,000
Sand Cleaning area [to be retained for future use in medium term project]	$220,000
Tools, Supplies and Stock Materials	$70,000
No pumping to distribution system, transmission main or elevated storage is proposed as part of the reduced sized treatment plant. Only storage would include temporary storage of treatment water for collection. ~ 12,000 gal	$22,000
Subtotal of Cost to be incorporated into Medium Term Project [71]	$455,000
Subtotal for Down Sized Treatment Plant	$587,000
Short Term Project Improvement Cost	$1,463,300
Contingency Allowance (20%)	$292,700
Total	$1,756,000

7.1.5 Short Term Project Operating and Maintenance Costs

Table 7-3 Mini System O&M Costs outlines estimated costs to operate the recommended short term mini system projects. The costs include labor associated with the staffing the water utility. It should be note in some case the cost of one half of position was accounted for in the mini system, for example one superintendent labor was assigned to mini system and the other half applied to the modular WTP, since one superintendent could manage both. The chemical cost is limited to the use of chlorine to disinfect. The cost of supplies for both administrative and operation activities are also presented.

Table 7-4 outlines estimated costs to operate the recommended short term Gravity Feed Water System in Robertsport and the Modular WTP systems in Voinjama.

[71] Therefore an estimated $905,000 could be subtracted from Medium Term Cost for Sanniquellie and Voinjama WTP improvements that are also presented in the Medium Term Project costs to avoid duplication of cost of short term improvement to be retained.

Table 7-5 Summary of Short Term O&M Costs combines the operational cost of the mini system and the other short term projects. A sensitive analysis is also include that outlines how the cost per household ($/HH) varies as the water consumption rate changes based on the gallons per day per capita (gpcd). The price per gallon appears to provide a more consistent comparison value. The cost of fuel has been identified as the largest cost of operation for the longer term project, as much as 50% of all operating costs, when diesel generators were included.

Table 7-3 Mini System O&M Costs

Water Utility Components	**Cost and Descriptions**
Staffing Includes: Water Utility Superintendent; Operators of the Treatment works and distribution system; chemist for the lab; maintenance staff; and an accountant and billing position.	$37,920 7.5 positions
Chemicals With the selection of mini system and slow sand filtration, the chemical use is anticipated to be limited to sodium hypochlorite for disinfection	$5,500 3 lbs. per day
Fuel Fuel cost is related to fuel to vehicle use.	$10,200
Supplies Supplies are expected for various departments of the water utility including office supplies, spare parts, tools, pipes & fittings, and vehicular supplies.	$7,200
Mini System Operation and Maintenance Cost	$60,640
Estimated City Population	15,300
Estimated Supplied, gpd	9,750
Supply per Capita, gpcd	10.0 gpcd (38 lpcd)
Estimated service population	975 persons
Estimated Percent Coverage by Short Term Project	6%
Estimated Number of Person per Households	5
Est. Number of Households served	195
Approximate Cost per Household ($/HH/yr.)	$310 per HH/yr.
Cost per gallon Comparison ($/gallon)	$0.0170 per gallon

Table 7-4 Modular Treatment Plant O&M Costs

Water Utility Components	**Cost and Description**
Staffing Includes: Water Utility Superintendent; Operators of the Treatment works and distribution system; chemist for the lab; maintenance staff; and an accountant and billing position.	$60,360 12.5 positions
Chemicals With the selection of the modular slow sand filtration, the	$5,500

chemical use is anticipated to be limited to sodium hypochlorite for disinfection	3 lbs. per day
Fuel Fuel cost is related to fuel to small generator use and vehicle use.	$11,160
Supplies Supplies are expected for various departments of the water utility including office supplies, spare parts, tools, pipes & fittings, and vehicular supplies.	$15,100
Modular WTP O&M Costs	$92,095
Estimated City Population	15,300
Estimated Supplied, gpd	12,000
Supply per Capita, gpcd	10.0 gpcd (38 lpcd)
Estimated service population	1,200 persons
Estimated Percent Coverage by Short Term Project	8%
Estimated Number of Person per Households	5
Est. Number of Households served by Short Term Project	240
Approximate Cost per Household Comparison ($/HH/yr.)	$383 per HH/yr.
Cost per gallon Comparison ($/gallon)	$0.0210 per gallon

Table 7-5 Summary of Short Term O&M Costs

Short Term O&M Costs	$152,735
Estimated City Population	15,300
Estimated Supplied, gpd	21,750
Supply per Capita, gpcd	10.0 gpcd (38 lpcd)
Estimated service population	2,175 persons
Estimated Percent Coverage by Short Term Project	14%
Estimated Number of Person per Households	5
Estimated Number of Households served by Short Term Project	435
Approx. Cost per Household Comparison ($/HH/yr.) at 10 gpd/capita	$350 per HH/yr.
Approx. Cost per Household Comparison ($/HH/yr.) at 5 gpd/capita	$175 per HH/yr.
Cost per gallon Comparison ($/gallon)	$0.0192per gallon

7.2 MEDIUM-TERM PROJECTS

7.2.1 Establish Modular WTP Improvements

The Medium-Term Recommendations are to further improve the treatment works and to provide for distribution and storage of water to cover the majority of the City of Voinjama to serve a minimum of 90% of the population. The selection of the site is based on the selection of the Zeliba River as the primary water source for the City of Voinjama. The planned improvements at the WTP include the following:

- Utilize the restored office building at existing WTP site conducted under the short term project.
- Complete the restoration of Intake Structure started in the Short Term Project with screens and pumping system (unless test well drilling phase of the hydrogeological study determines river bank filtration can provide the yield and is feasible)
- Restore and improve upon the impoundment berm and water control structure as needed to retain a volume of water for use during low to no flow periods.
- Utilize the modified mixing tank and sedimentation basin (with tube settlers) to provide pretreatment with aeration and sedimentation to reduce turbidity levels
- Construct slow sand filters and sand cleaning facilities
- Modify the previous WTP to provide chlorination and effluent pumping
- Provide a solar power with a backup generator unit.
- Replace transmission main to previous elevated tank
- Restore elevated storage tank, replace pipes and valves
- Install Distribution system with metered public kiosks to dispense water in a phased approach to address priority areas

7.2.2 Medium Term Capital Costs

Table 7-6 Medium Term Capital Costs, outlines the capital cost broken down by city and by the water system to further advance the improved access to water and to achieve the project goals of 90% access to an improved water supply source in Voinjama.

Table 7-6 Medium Term Capital Costs

System Component	Cost and Description
Watershed An allowance of funds for the continued support of the Watershed Projection Program	$20,000 Catchment Area Estimated 102 km2
Source For Voinjama, the source improvement will draw from the Zeliba Rivers. The withdraw will either be directly from the river from the previous intake structure or from a new river bank filtration component depending on test well results. The improvement to the Voinjama intake structure will also require the restoration of the previous impoundment area and berms to store water for period of no flow or extreme low conditions in the Zeliba River. The need to determine if impoundment improvements are not knows at this time.	$268,500 Previous Intake72 Or $390,000 River Bank Filtration
Treatment For Voinjama, the treatment improvement will include pretreatment (aeration and sedimentation) at the previous WTP, new slow sand filters, plus chlorination and pumping to the storage/distribution systems from the previous WTP facilities. A	$3,472,500

[72] Includes impoundment improvements to handle extreme low flow or no flow conditions in the Zeliba River for a prolong period as designed as part of the previous water system

master meter will be installed at the WTP. The purpose of the pretreatment and the slow sand filters is to reduce the turbidly and iron level in the raw water. The addition of chlorine is address bacteriological issues associated with the raw water source. The restoration of the WTP will also include offices, laboratory and maintenance space.	336,340 gpd
Power Supply	
The power supply needs are associated with the raw water pumping, chemical addition pumping of chlorine, treated raw pumping, and that of the administrative office, laboratory and maintenance space. The aeration, sedimentation and slow sand filter treatment will not require electrical power. The recommended power supply is to use solar power.	$2,200,000 80 KVA
Storage	
For Voinjama, the previous elevated water tank will be used unless it determined that it is either not salvageable or does not meet the current need to serve the new service area. In Voinjama, if the elevated New Life Community located to the north west portion of the city is included in the new distribution system's service area, then the previous elevated water tank is not likely tall enough to provide the hydraulic grade line to service this community located on the opposite side of Voinjama.	$690,400 Previous El. Tank Or $1,602,600 New Storage Tank Or $1,983,000 Previous & New Tanks
Distribution System	
The distribution system is anticipates to include 6" to 8" Poly Vinyl Chloride (PVC) mains, laid out in in a looped configuration when possible to provide both redundancy and improved service pressures. Some Cement Lined Ductile Iron (CLDI) pipe may be used to provide need protection based on specific site conditions. Hydrants will be located through the system for flushing and other purposes. The intent of the hydrants is not to provide fire protection. Hydrants will be located at high points to act as manual air releases, and at low points for flushing and draining the mains. Gate valves will be located at intersections and throughout the system to allow sections to be isolated and to control the direction of flow for maintenance purposes. The distribution mains will be buried with approximately 4' of cover along the road way shoulders. At utility crossings such as culverts, the main will be placed above the culvert if feasible. The distribution will include service connection to public metered kiosks with taps, with limited private service connections to key government, community and hospital sites expected at this stage.	$5,472,000 68,400 LF
Medium Term Project Improvement Cost	From $12,123,400 To $13,537,500
Contingency Allowance	$2,707,500
Planning Cost for Medium Term Projects	$16,245,000

Table 7-7 presents the operational cost for the immediate startup of operation (estimated as 2016) and for the end of the study period (2031). The change in operational cost is associated with the chemical costs that increase with the increase in the supply and demand of the growing service population.

Table 7-7 Medium Term Project O&M Costs

Water Utility Components	Cost and Descriptions	
Staffing Includes: Water Utility Superintendent; Operators of the Treatment works and distribution system; chemist for the lab; maintenance staff; and an accountant and billing position.	$113,760 23.5 positions	
Chemicals [73] With the selection of mini system and slow sand filtration, the chemical use is anticipated to be limited to sodium hypochlorite for disinfection	$36,500 to $76,650 20 to 42 lbs. per day	
Fuel Fuel cost is related to fuel to small generator use and vehicle use.	$11,160	
Supplies Supplies are expected for various departments of the water utility including office supplies, spare parts, tools, pipes & fittings, and vehicular supplies.	$39,200	
Slow Sand Filter WTP and Water Systems Costs [74]	$200,620	$240,770
Estimated City Population	16,100	19,600
Estimated Supplied, gpd	158,900	336,340
Supply per Capita, gpcd	10	10
Estimated Percent Coverage by Short Term Project	90+ %	90+ %
Estimated Number of Person per Households	5	5
Est. Number of Households served by Short Term Project	3,220	3,920
Approximate Cost per Household Comparison ($/HH/yr.)	$62	$61
Cost per gallon Comparison ($/gallon)	$.0035	$0.020

7.3 LONG-TERM PROJECTS

Assuming the Short-Term and Medium-Term recommendations are adopted, the Long-Term recommendations include:

- Further improvements to Operational and Institutional Capacity to improve sustainability
- Improved delivery of water by converting from public dispensing locations (kiosks and public stand pipes) to more private connections (private stand pipes and house connections)
- Re-visiting and updating of the Master Plan for Voinjama (recommended every 5 years)

[73] Chemical Cost are variable cost dependent on the production rate and the amount of chemical required.

[74] Two conditions presented to represent cost at startup (say 2016) and end of period (2031)

- Implementation and advancement of an Asset Management Plan
- Continuous updating of the O&M manuals for the water system, its components, and its operational staff
- Continuous training for the water system staff
- Development of a training program to assist other water utilities being developed in Liberia
- Promotion of rainwater harvesting

8.0 SANITATION

8.1 INTRODUCTION

Over the past decades, researchers have shown that improper sanitation practice is one of the major factors contributing to the spread of diseases (communicable diseases and non-communicable diseases). Hence, examining the sanitation condition of populated areas is an imperative and key factor in ensuring that diseases are prevented.

The WHO defines sanitation as "[T]he provision of facilities and services for the safe disposal of human urine and faeces."[75] The definition is often expanded, however, to include the promotion of hygiene through prevention of human contact with wastes[76].

The sanitation condition of a particular region is influenced by factors such as population, occupations of the people concerned, types and numbers of functional industries, number and types of institutions, education level of the people, household income, the type of medical services available, etc.

Municipal wastewater, which is 99% liquid, consists of suspended and dissolved solids, both organic and inorganic, and includes large numbers of microorganisms[77]. Wastewater treatment is provided to minimize the detrimental effect to the receiving environment. In order to minimize the sanitation threats posed by wastewater, plans for an improved wastewater system must be formulated and applied in accordance with the characteristics of the wastewater being generated.

Furthermore, in the formulation and application of improved water supply, it is necessary to integrate provision of water supply and sanitation facilities with sanitation and hygiene promotion activities to ensure sustainability of the infrastructure and correct and consistent hygiene behaviors to reduce waterborne diseases[78].

8.1.1 Purpose of the Study

The purpose of this study is to review the planning, implementation, and operation of water, sanitation, and environmental health programs in the city of Voinjama. To this end, the LMWP team:

1. Reviewed the work of other agencies in the sector (WASH, UL-PIRE, LWSC, NCL Eng. Ltd., etc.);
2. Reviewed standard materials/literature on sanitation; and
3. Conducted field study on the sanitation status of the city.

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[75] World Health Organization (2012). Sanitation. Retrieved from www.who.int/topics/sanitation/en/.

[76] Wikipedia (24 October 2012). Sanitation. Retrieved from http://en.wikipedia.org/wiki/Sanitation.

[77] Municipal Program Development Branch, Alberta Environment (April 2000). *Guidelines for Municipal Wastewater Irrigation*. Retrieved from http://environment.gov.ab.ca/info/library/7268.pdf.

[78] United States Agency for International Development (2009). *Environmental Guidelines for Small Scale Activities in Africa, 2nd Ed*. Retrieved from http://www.encapafrica.org/egssaa.htm.

8.1.2 Scope of the Study

The information presented in this report is limited to the city of Voinjama and will focus on sanitation as regards wastewater, also known as septage. For purposes of this study, wastewater will include and be limited to:

- Toilet Wastes – comprising urine, feces, and flushed water. Toilet waste is also known as blackwater.
- Greywater – defined as wastewater from domestic activities such as laundry, dishwashing, cooking, and bathing.
- Trade Wastes – wastes generated from commercial processes or operations. Trade waste is also known as industrial wastewater

8.2 CURRENT SANITATION STATUS OF VOINJAMA

Information in this section has been obtained or extrapolated from the Water Services and Willingness to Pay Market Assessment and Baseline Survey, performed by the University of Liberia Pacific Institute for Research and Evaluation (UL-PIRE) in April of 2012. In general, the survey reveals that the current status of sanitation in Voinjama is not conducive to promote public health. There are no proper wastewater channelization programs or facilities in place and most inhabitants must resort to "the bush" for urination and defecation. Additionally, as will be shown in this section, the morbidity and mortality rates for waterborne, water-washed, water-based, and water-related diseases in Voinjama are a cause for concern. Given the widely recognized correlation between inadequate sanitation and disease[79,80,81], it is valid to say that the lack of proper sanitation practice in Voinjama is a prominent factor contributing to the poor health of the inhabitants.

8.2.1 Sanitation Practices Employed

No centralized piped sewage system has ever existed in Voinjama, however, four types of sewage disposal methods are being practiced. These include:

1. Greywater Disposal Methods:
   a) Drainage Systems: Some users pour greywater into the city's drains and ditches;
   b) Surface Wetting: Describes wasting of water onto open soil;
2. Blackwater Disposal Methods/Facilities
   a) "The Bush": This term applies to the practice of open defecation in forested areas of the community.
   b) Pit Latrine: One of the most widely used sanitation technologies in the developing world, a pit latrine consists simply of a chamber dug into the soil and covered with a concrete slab containing

[79] United Children's Fund (17 June 2003). Water, Sanitation, and Hygiene – Common Water- and Sanitation-Related Diseases. Retrieved from http://www.unicef.org/wash/index_wes_related.html.

[80] World Health Organization (2012). Sanitation. Retrieved from www.who.int/topics/sanitation/en/.

[81] Nath KJ, Bloomfield SF, Jones M (2006). Household water storage, handling and point-of-use treatment. A review commissioned by the International Scientific Forum on Home Hygiene; published on http://www.ifh-homehygiene.org

an opening for excreta. A small superstructure is usually built on top of the slab to afford privacy to users.[82]

c) Flush Toilets: comprising both pour-flush and lever-flush toilets, flush toilets are better at preventing odors than pit latrines but require a constant source of water.[82]

Table 8-1 lists the number and percentage of houses with access to sanitation facilities. Table 8-2 tallies the number and percentage of households practicing certain methods of greywater disposal. Table 8-3 and Table 8-4 provide an idea of the morbidity and mortality of certain water-related diseases.

Table 8-1: Households with Access to Sanitation Facilities, By Type of Facility (n=374)[83]

Facility	Number of Households with Access	Percentage of Households with Access
Pit Latrine	2,705	69%
Flush Toilet	824	21%

Table 8-2: Households Practicing Methods of Greywater Disposal, By Method (n=298)[84]

Method	Number of Practicing Households	Percentage of Practicing Households
Open Area (Surface Wetting)	3,254	83%
Drainage Systems	236	6%
Other	432	11%

Table 8-3: Households Reporting a Disease in the Household within the Previous 30 Days, By Disease (n=374)[85]

Disease	Percentage
Diarrhea	24%
Malaria	53
Typhoid	17
Dysentery	11
Cholera	3
Bilharzia	2
Intestinal Worms	2
Others	2

[82] Tilley, Lüthi, et al. and Eawag-Sandec (2008). Compendium of Sanitation Technologies. Retrieved from http://www.wsscc.org/node/831.

[83] University of Liberia Pacific Institute for Research and Evaluation (2012).Liberia Willingness and Ability to Pay Baseline Survey, Appendix B, Question 109

[84] University of Liberia Pacific Institute for Research and Evaluation (2012).Liberia Willingness and Ability to Pay Baseline Survey, Appendix B, Question 141

[85] University of Liberia Pacific Institute for Research and Evaluation (2012).Liberia Willingness and Ability to Pay Baseline Survey, Appendix B, Question 143

Table 8-4: Households Reporting a Death (6%) in the Household within the Previous Year, By Cause (n=374)[86]		
Disease	**Number of Households Reporting a Death from Named Disease**	**Percentage of Households Reporting a Death from Named Disease**
Diarrhea	137	58%
Malaria	40	17%
Typhoid	15	6%
Others	59	25%

While a causal relationship cannot be established exclusively from these data, it is reasonable to assume that the lack of appropriate disposal of greywater and blackwater is contributing to the burden of the disease described in Table 8-3 and Table 8-4.

8.2.2 Generation Rates for Wastewater and Night Soil

In a discussion of the possible long-term sanitation facility planning for Voinjama, it is instructive to estimate the current wastewater flow volumes. Calculations for wastewater generation are often performed to estimate the flow burden on a wastewater collection system. Given that there is no wastewater collection system in Voinjama, one may instead consider the wastewater as that portion of the water demand which *would* reach a wastewater collection system, were such a system in place. Thus such a calculation would include water for cleaning dishes, showering, etc., but exclude water for fire suppression, irrigation, etc.

Recall the three kinds of wastewater from Section 8.1.2:

1. Blackwater: The liquid volume contribution of urine is commonly a negligible fraction of the water contributed by toilet flushing. Therefore, blackwater will be calculated according to an estimated 0.6 gallons per flush[87,88]. During the "no access" period (that is, when users have access to less than 5 gallons/person/day), one flush per person per day will be assumed. During all other periods, two flushes per person per day will be assumed. The contribution will be restricted to that portion of the population which has access to a flush toilet.

2. Greywater: wastewater is often calculated as a percentage of water consumption – usually between 60 to 85 percent.[89] To be conservative, LMWP will assume 85% of the residential water demand is converted to wastewater. The greywater portion of the wastewater will then be the wastewater minus the blackwater.

3. Trade Wastes: There is currently very little industry in Voinjama. The commercial enterprises which exist are mostly restaurants, small convenience stores/shanties, and lodges. One can assume that the wastewater generation rate for such enterprises parallels the wastewater generation rates for domestic

[86] University of Liberia Pacific Institute for Research and Evaluation (2012).Liberia Willingness and Ability to Pay Baseline Survey, Appendix B, Question 147

[87] Waterwiki.net (20 Dec 2009). Pour-flush latrine. Retrieved from http://waterwiki.net/index.php/Pour-flush_latrine.

[88] Tilley, Lüthi, et al. and Eawag-Sandec (2008). Compendium of Sanitation Technologies. Retrieved from http://www.wsscc.org/node/831.

[89] Tchobanoglous, Burton, and George and Metcalf & Eddy (1991). *Wastewater Engineering: Treatment, Disposal, and Reuse, 3rd ed.* Mcgraw-Hill.

users, given that the greywater contributions from these enterprises should be similar to the contributions in a domestic setting (i.e., bathing, cooking, laundry, etc. as opposed to wastewater from metal processing or other heavy industry activities). Thus, trade waste will be calculated as a percentage of the commercial, industrial, and institutional water demand.

Additionally *night soil* (i.e., feces) is generated at an average rate of 0.5 lbs/person/day, [90] and will be calculated as well.

Using the base year of 2011, and the calculated water demand values from [INSERT REFERENCE TO THE POPULATION AND FLOW RATE TABLE], one finds the current wastewater flows as shown in Table 8-5.

Table 8-5: Wastewater Flow Estimates for 2011

Population	15,100
Percentage with Access to Flush Toilet	21%
Residential Water Flow (gpd)	19,900
Residential Wastewater Flow (gpd)	16,915
Residential Blackwater Flow (gpd)*	2,093
Residential Greywater Flow (gpd)°	14,822
Trade Wastes (gpd)†	1,675
Total Wastewater Flow	18,590
Total Night Soil Generation (lb./day)	7,550

**Calculated as (0.66 gal/flush)(1 flush/person/day)(3,700persons)(42%)*
°Calculated as (Residential Wastewater Flow) – (Residential Blackwater Flow)
†Calculated as (Institutional Wastewater + Commercial Wastewater + Industrial Wastewater) = (.85(2%+3%+5%))(Residential Flow)*

8.2.3 Changes in Generation Rates for Wastewater and Night Soil as a Result of LMWP

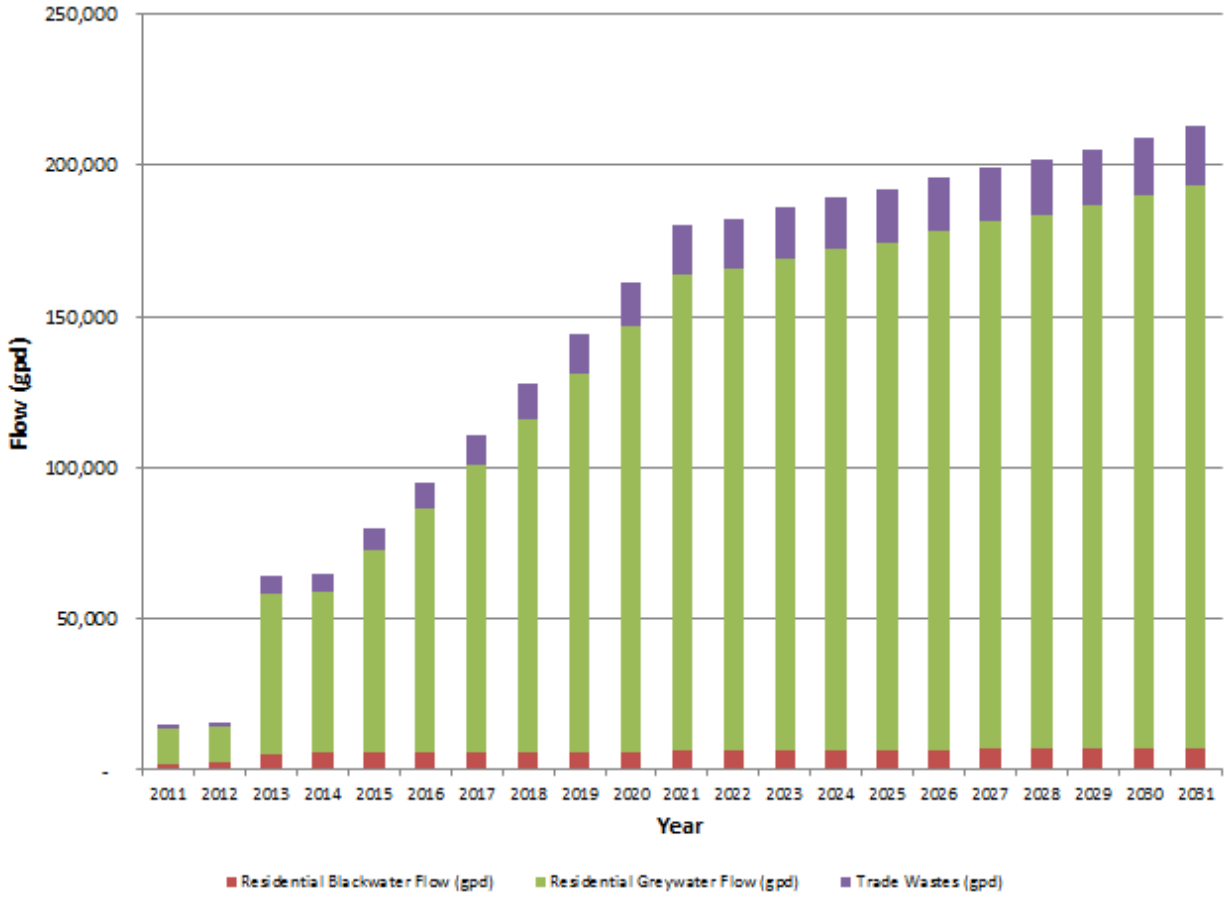
Using these calculations along with the data from Voinjama's population projections, one can project wastewater generation rates through year 2031. Table 8-6 and Figure 8-1 illustrate such a projection. Note that in the table, once water supply exceeds 5 gpd, two flushes per person are assumed. Note also that the table assumes the percentage of inhabitants with access to flush toilets remains constant throughout the 20 year period; the projections will be adjusted to display sensitivity to different sanitation options in future sections.

[90] Fry, L. John (1973). *Methane Digesters for Fuel Gas and Fertilizer*. Woods Hole, Massachusetts. The New Alchemy Institute.

Table 8-6: Projected Wastewater Flow Estimates (No Changes in Sanitation Technology)

Year	Population	Percentage with Access to Flush Toilet	Residential Water Flow (gpd)	Residential Wastewater Flow (gpd)	Residential Blackwater Flow (gpd)	Residential Greywater Flow (gpd)	Trade Wastes (gpd)	Total Wastewater Flow (gpd)	Night Soil Generation (lb./day)
2011	15,100	21%	16,300	13,855	1,733	12,123	1,386	15,241	6,250
2012	15,300	32%	16,600	14,110	2,682	11,428	1,411	15,521	6,350
2013	15,500	32%	68,400	58,140	5,449	52,691	5,814	63,954	6,450
2014	15,700	32%	69,500	59,075	5,533	53,542	5,908	64,983	6,550
2015	15,900	32%	85,400	72,590	5,660	66,930	7,259	79,849	6,700
2016	16,100	32%	101,700	86,445	5,745	80,700	8,645	95,090	6,800
2017	16,300	32%	118,400	100,640	5,829	94,811	10,064	110,704	6,900
2018	16,500	32%	136,600	116,110	5,956	110,154	11,611	127,721	7,050
2019	16,700	32%	154,300	131,155	6,040	125,115	13,116	144,271	7,150
2020	17,000	32%	172,500	146,625	6,125	140,500	14,663	161,288	7,250
2021	17,200	32%	192,400	163,540	6,252	157,288	16,354	179,894	7,400
2022	17,400	32%	195,000	165,750	6,336	159,414	16,575	182,325	7,500
2023	17,600	32%	198,900	169,065	6,463	162,602	16,907	185,972	7,650
2024	17,900	32%	202,800	172,380	6,589	165,791	17,238	189,618	7,800
2025	18,100	32%	205,400	174,590	6,674	167,916	17,459	192,049	7,900
2026	18,300	32%	209,300	177,905	6,801	171,104	17,791	195,696	8,050
2027	18,600	32%	213,200	181,220	6,927	174,293	18,122	199,342	8,200
2028	18,800	32%	215,800	183,430	7,012	176,418	18,343	201,773	8,300
2029	19,100	32%	219,700	186,745	7,139	179,606	18,675	205,420	8,450
2030	19,300	32%	223,600	190,060	7,265	182,795	19,006	209,066	8,600
2031	19,600	32%	227,500	193,375	7,392	185,983	19,338	212,713	8,750

Figure 8-1: Projected Wastewater Flow Estimates (No Changes in Sanitation Technology)



It is apparent that the majority of the increase in wastewater is projected to come from the increase in residential greywater. Trade waste increases proportionally but is numerically less significant. Blackwater remains nearly constant, doubling between 2012 and 2013 and thereafter increasing only as a linear function of population.

Table 8-6 demonstrates that night soil generation rates are expected to increase only as a linear function of population.

From these data, the need for improved sanitation facilities which parallel the improved water access becomes clear. Future sanitation efforts should address not only the currently inadequate facilities for disposal and treatment of human waste, but the anticipated increase in greywater flow. These factors will be taken into consideration in Section 8.3: PROPOSED METHODS FOR ADDRESSING CHANGES IN SANITATION STATUS.

8.3 PROPOSED METHODS FOR ADDRESSING CHANGES IN SANITATION STATUS

There are many options for the provision of improved sanitation[91] facilities in developing countries. These options can be divided into two categories: on-site systems and piped conveyance systems. In the near future, sanitation improvements in Voinjama will most likely be composed of on-site systems such as pit latrines, pour-flush latrines, or septic tanks. As Voinjama continues to develop, more traditional wastewater collection and treatment systems should be considered.

8.3.1 Simple Pit Latrine

Simple Pit Latrines are already in use in Voinjama and as such are evaluated here. However, they are unlikely to be able to handle the increase in grey water predicted in Section 8.2.3.

The standard pit latrine should meet a number of requirements:

- Lining – may be concrete, brick, stone, mortar, or rot-resistant timber. Lining the pit helps to prevent collapse of the pit and is necessary unless other excavations in the area, such as shallow wells, have proven self-supporting for a number of years.
- Floors – the base of the pit latrine should be smooth, level, and impervious, with an upper surface at least 6" above ground level to prevent rain and surface water from entering the latrine. In the case of Voinjama, where flooding is heavy, a height of 1 ft. above ground level is likely more appropriate.
- Slab – the slab that covers the pit should be made out of cement-based material with squat holes large enough to limit fouling of edges but not so large that children are afraid to use the latrine. A squat hole often has a maximum recommended width of 7" and a minimum recommended length of 14".
- Tight-Fitting Lid – this is placed over the squat hole to reduce odors and prevent attraction of insects. The lid must be easily removable but sturdy.
- Superstructure – a walled and roofed structure should be constructed atop the concrete slab to provide privacy and shelter during rain.
- Proper Location – a latrine should be located in an area convenient to its users and on slightly raised ground to avoid flooding during rain events. It should also be located at least 100 feet from any water source, and downstream of any nearby water sources if possible, so as to prevent contamination.
- Proper Volume – the latrine should be sized in accordance with its design life and number of users. However, most pits are designed to contain at least 70 ft^3, with a minimum depth of 10 feet and a minimum diameter of 3 feet.
- Proper Disposal Behaviors – all types of solid cleansing materials can be discarded into the pit, although they may shorten the life of the pit and make pit emptying more difficult. Whenever possible, solid cleansing materials should be disposed of separately. A small amount of greywater in the pit may facilitate degradation, but too much greywater can shorten the life of the pit.

[91] The WHO and UNICEF define an improved sanitation facility as one that hygienically separates human excreta from human contact. Examples include flush toilets, connection to a piped sewer system, connection to a septic system, flush / pour-flush to a pit latrine, ventilated improved pit latrines, pit latrines with slabs, and composting toilets. (http://www.wssinfo.org/definitions-methods/watsan-categories/)

Though quite possibly the simplest sanitation facility in terms of construction, the simple pit latrine produces untreated sludge for which there is currently no mechanism for emptying and treating in Voinjama. For densely populated areas like Fanti Town, moving from pit to pit when one pit fills presents a problem of space and of creating multiple contamination sources in the community. Furthermore, pit latrines are dangerous in areas prone to heavy rains and flooding, which may cause the pits to overflow and spill raw sewage onto the ground surface.

Although different types of pits are common in most parts of the world, a well-designed pit-based system with appropriate transport, treatment and use or disposal, is still very rare. This system is one of the least expensive to construct (capital cost) however the maintenance costs may be considerable, depending on the depth of the pit and how often it must be emptied. If the ground is appropriate, i.e. good absorptive capacity, the pit may be dug very deep (e.g. >5m) and can be used for several years (up to 30 years) without emptying[92].

Schematics of the Simple Pit Latrine can be seen in Figure 8-2 and Figure 8-3.

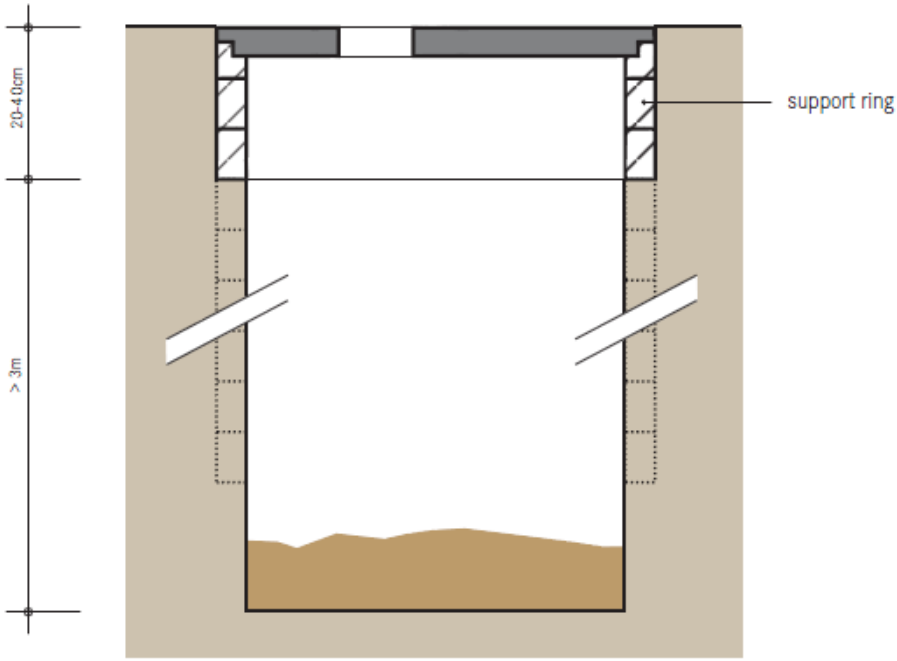


Figure 8-2: Simple Pit Latrine[92]

[92] Tilley, Lüthi, et al. and Eawag-Sandec (2008). Compendium of Sanitation Technologies. Retrieved from http://www.wsscc.org/node/831.

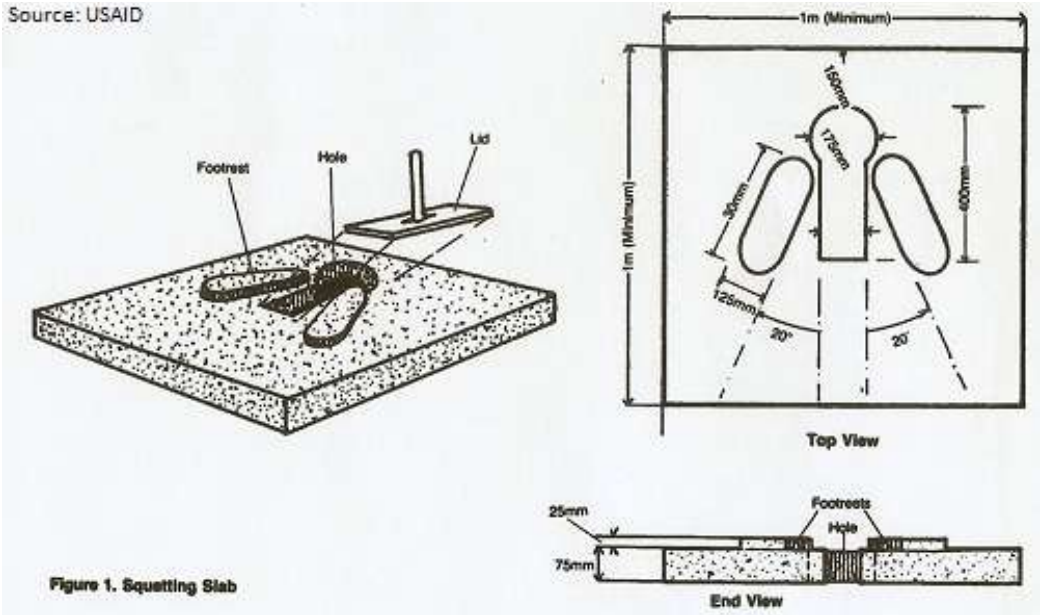


Figure 8-3: Squatting Slab[93]

8.3.2 Ventilated Improved Pit (VIP) Latrine

A VIP Latrine is virtually identical to the simple pit latrine with the addition that the superstructure includes a pipe attached to the reservoir of the pit and extending through the top of the superstructure. Air currents created by wind or differential heat between the pipe and the pit draw odors through the vent, which is screened to prevent the entrance and escape of flies. Figure 8-4 provides an illustration.

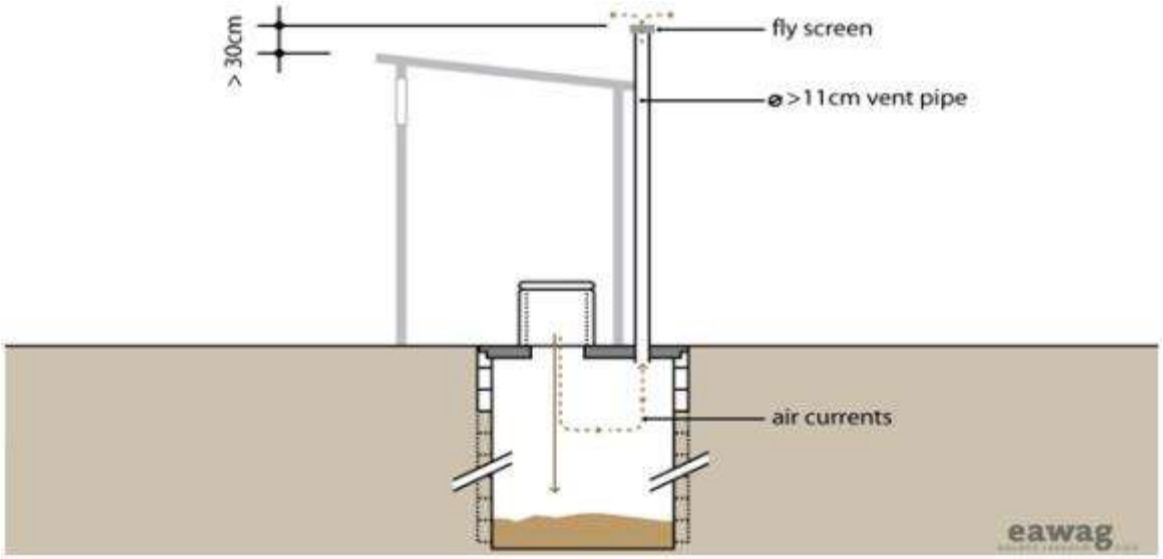


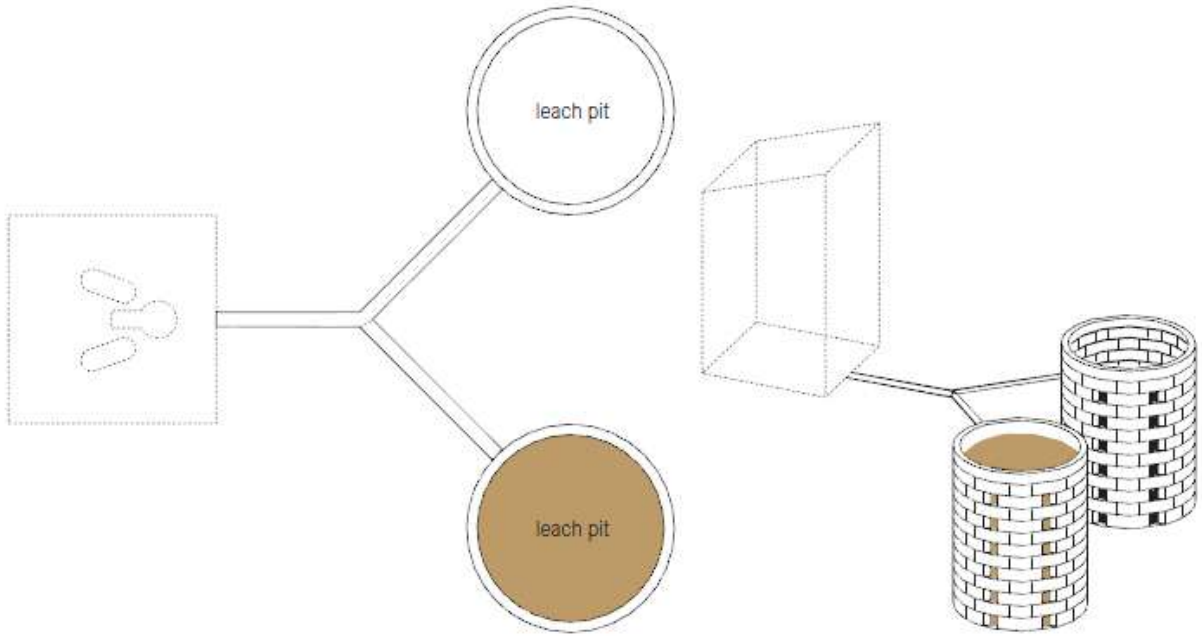
Figure 8-4: Ventilated Improved Pit Latrine[94]

[93] Pit Latrine Slab and Platform Design. "A Layman's Guide to Clean Water." www.clean-water-for-laymen.com/pit-latrine.html

8.3.3 Twin Pits for Pour-Flush Latrines

The previous sanitation options do not allow for the free input of greywater, which is a sanitation challenge that is expected to arise with the increase in water access.

Twin Pits for Pour-Flush latrines allow for the co-management of greywater and blackwater. See Figure 8-5 for a schematic of this method.



[95]

Figure 8-5: Twin Pits for Pour-Flush Latrine

The scheme includes the general structure of a latrine as normal, but diversion pipes lead to two pits dug side-by-side, at least 3 feet apart, and lined for their full depth. Alternatively, the structure can be placed over the pit that is currently in use and moved to the second pit once the first pit is full. While one pit is being used, the other pit is resting and decomposing. The pits should be sized to accommodate two years' worth of volume, over which period the resting pit will transform into a safe, inoffensive, soil-like material (called humus) that can be excavated manually. As effluent leaches from the pit, fecal organisms are removed with an efficiency that depends upon the soil matrix. Again, the pits should be located at least 100 feet from any water source. It is additionally recommended that the pits be sited at least 3 feet from any structural foundation, as leakage can deteriorate structural supports.

The major drawback of this intervention is the susceptibility to overflow during rainy seasons. If pits cannot be constructed with sufficient strength and capacity to weather the rainy season, this solution should not be implemented in Voinjama.

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[94] Tilley, Lüthi, et al. and Eawag-Sandec (2008). Compendium of Sanitation Technologies. Retrieved from http://www.wsscc.org/node/831.

[95] Tilley, Lüthi, et al. and Eawag-Sandec (2008). Compendium of Sanitation Technologies. Retrieved from http://www.wsscc.org/node/831.

8.3.4 Septic Tanks and Soakaway Systems

One on-site sanitation option that allows for commingling of blackwater and greywater and which provides a level of protection against flooding is the septic tank. Septic tanks are currently in use in Voinjama but are confined mostly to guest houses. Septic tanks are often connected to a soakaway pit, also called a leach field, for filtering of liquid waste. See Figure 8-6 for a schematic.

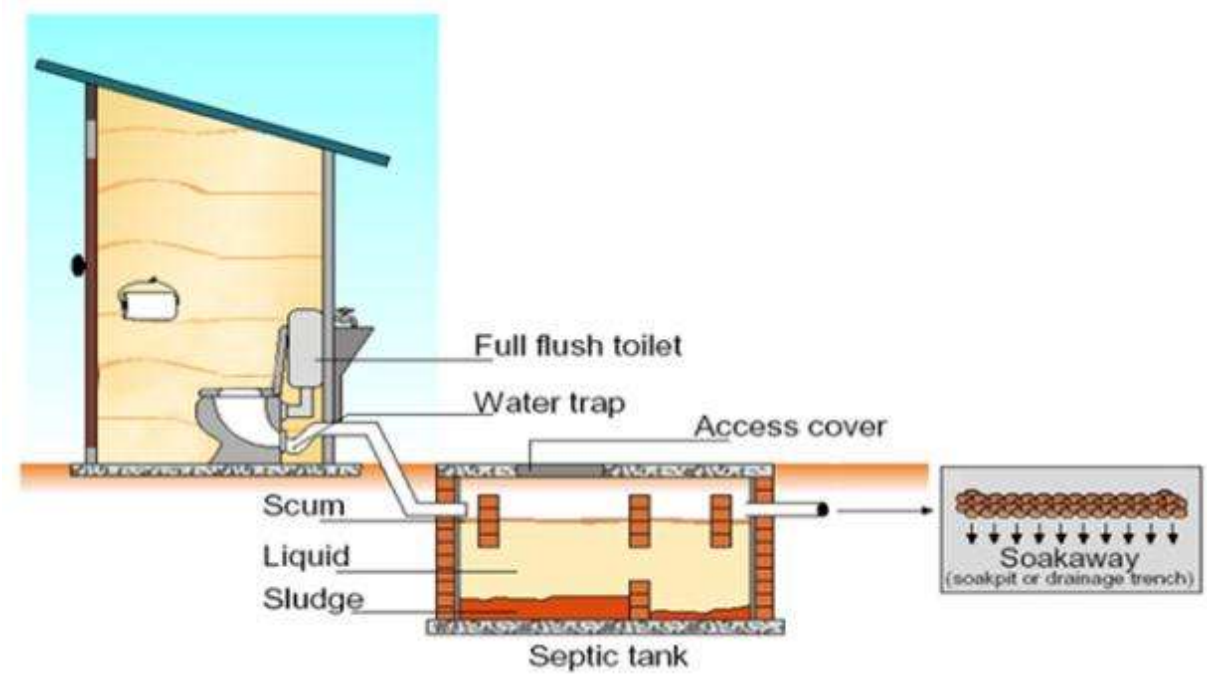

Figure 8-6: Septic Tank and Soakaway

Several resources are available for the proper sizing and design of a septic tank, but the operation remains consistent; liquid flows into the tank and heavy particles sink to the bottom, while scum floats to the top. Solids are degraded anaerobically but must be removed by a vacuum truck at least once every two years, though frequency will depend on size, number of users, efficiency of decomposition, etc. This requirement may prove problematic for Voinjama as this practice is not currently in place.

Table 8-7: Comparison of the Proposed Disposal Methods[96]		
Disposal Method	**Advantages**	**Disadvantages**
Simple Pit Latrine	• Simplest construction • Lowest capital cost • Small land area required	• Cannot accept greywater • Flies and odors normally present • Low reduction in BOD and pathogens • Sludge requires secondary treatment and/or appropriate discharge • Costs to empty; may be unfeasible to empty in the Voinjama environment.
VIP Latrine	• Simple construction • Low capital cost • Reduces flies and odors as compared to pit latrine	• Cannot accept greywater • Low reduction in BOD and pathogens • Sludge requires secondary treatment and/or appropriate discharge • Costs to empty; may be unfeasible to empty in the Voinjama environment.
Twin Pits for Pour-Flush Latrine	• Accepts greywater • Virtually unlimited design life because pits are used alternately • Excavation of humus is easier than excavation of fecal sludge • Potential for use of humus as soil conditioner • Flies and odors significantly reduced compared to pits without water seal • Low capital costs • Moderate reduction in pathogens	• Excreta require manual removal • Clogging is frequent if bulky anal cleansing material is used
Septic Tank and Soakaway	• Accepts greywater • Long service life • No problems with flies or odors if used correctly • Low capital costs	• Low reduction in pathogens, solids and organics • Effluent and sludge require secondary treatment and/or appropriate discharge • Costs to empty; may be unfeasible to empty in the Voinjama environment.

8.3.5 Centralized Wastewater Treatment Options[97]

As Voinjama continues to develop, and especially if piped house connections become more prevalent in the city, the need for a collection system and a centralized wastewater treatment system will become more pronounced.

Wastewater stabilization ponds (WSP) are a low-cost, low-maintenance treatment option that can be appropriate for developing nations.[98,99] These are manmade water bodies that are filled with wastewater

[96] Tilley, Lüthi, et al. and Eawag-Sandec (2008). Compendium of Sanitation Technologies. Retrieved from http://www.wsscc.org/node/831.

[97] Much of the information in this section has been adapted from: Eawag-Sandec (9 Aug 2011). Waste Stabilization Pond. Retrieved from www.akvo.org/wiki/index.php/Waste_Stabilization_Pond.

[98] Bogh, Prüss, et al. (2002). *Healthy Villages: A Guide for Communities and Community Health*. Retrieved from www.who.int/water_sanitation_health/hygiene/settings/hvchap4.pdf.

and treated by naturally occurring processes. WSPs can be used as single, standalone units, but are most effective when combined in series of three or more. See Figure 8-7 for a schematic.

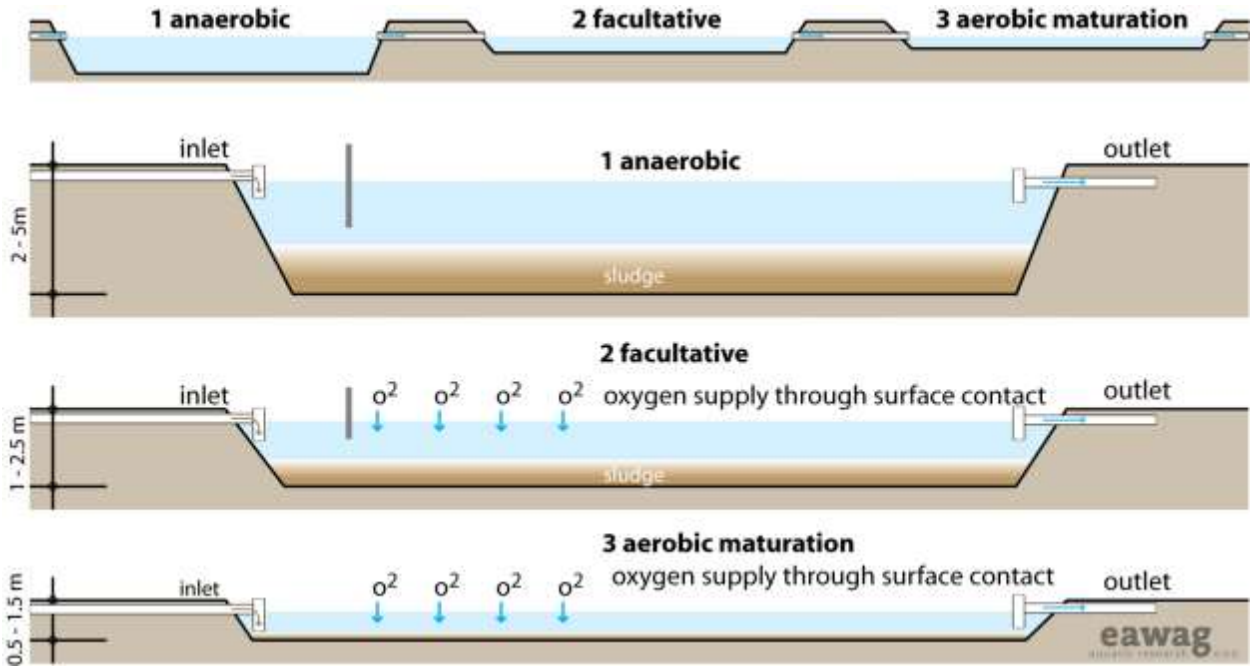

Figure 8-7: Schematic of Waste Stabilization Ponds (Eawag/Sandec)

The traditional sequence begins with an anaerobic pond, built do a depth of between 6 and 15 feet with a detention time between 1 and 7 days. In this stage, anaerobic bacteria degrade the waste, removing up to 60% of the biological oxygen demand (BOD).

The anaerobic effluent becomes influent for the shallower facultative pond, where aerobic processes occur on the top layer while solids accumulate on the pond bottom and digest through anaerobic means. Facultative ponds are usually built to a depth between 3 and 8 feet, with detention times ranging between 5 and 30 days. Anaerobic and facultative ponds in sequence can achieve BOD reductions up to 75%.

Finally, any number of aerobic ponds (also called maturation, polishing, or finishing ponds) can provide a final level of treatment. These ponds are shallow (usually 1.5 to 5 feet in depth) to allow for sunlight penetration. Aerobic ponds are designed to remove pathogens as opposed to BOD, and can be effective at removing nitrogen and phosphorus as well if used in combination with algae and/or fish harvesting.

As mentioned, maintenance requirements for WSPs are low compared to conventional treatment plants. Pre-treatment with grease traps and screens can further decrease maintenance requirements by preventing solids, garbage, and scum-forming grease. Ponds must be desludged once every 10 to 20 years.

Though WSPs require a large land area, Voinjama's low population density and heavy forestation suggests ample, uninhabited regions exist for development. Ideally, the WSPs would be sited in low-lying areas to facilitate gravity flow of wastes to the eventual treatment site. The proximity to surface waters that do not impact water supply sources provides a possible discharge point as well, provided that effluent is sufficiently treated. See Figure 8-8 for vacant land areas within which WSPs could possibly be

[99] Varón, Miguel Peña (July 2004). Waste Stabilization Ponds. International Water and Sanitation Center. Retrieved from http://www.sswm.info/sites/default/files/reference_attachments/VARON%202004%20%20Waste%20Stabilistion%20Ponds.pdf.

investigated and potentially developed (note that the entire area within the boundary would not be used – the boundary merely encompasses uninhabited, near-coast areas). Table 8-8 provides some pros and cons of WSPs.

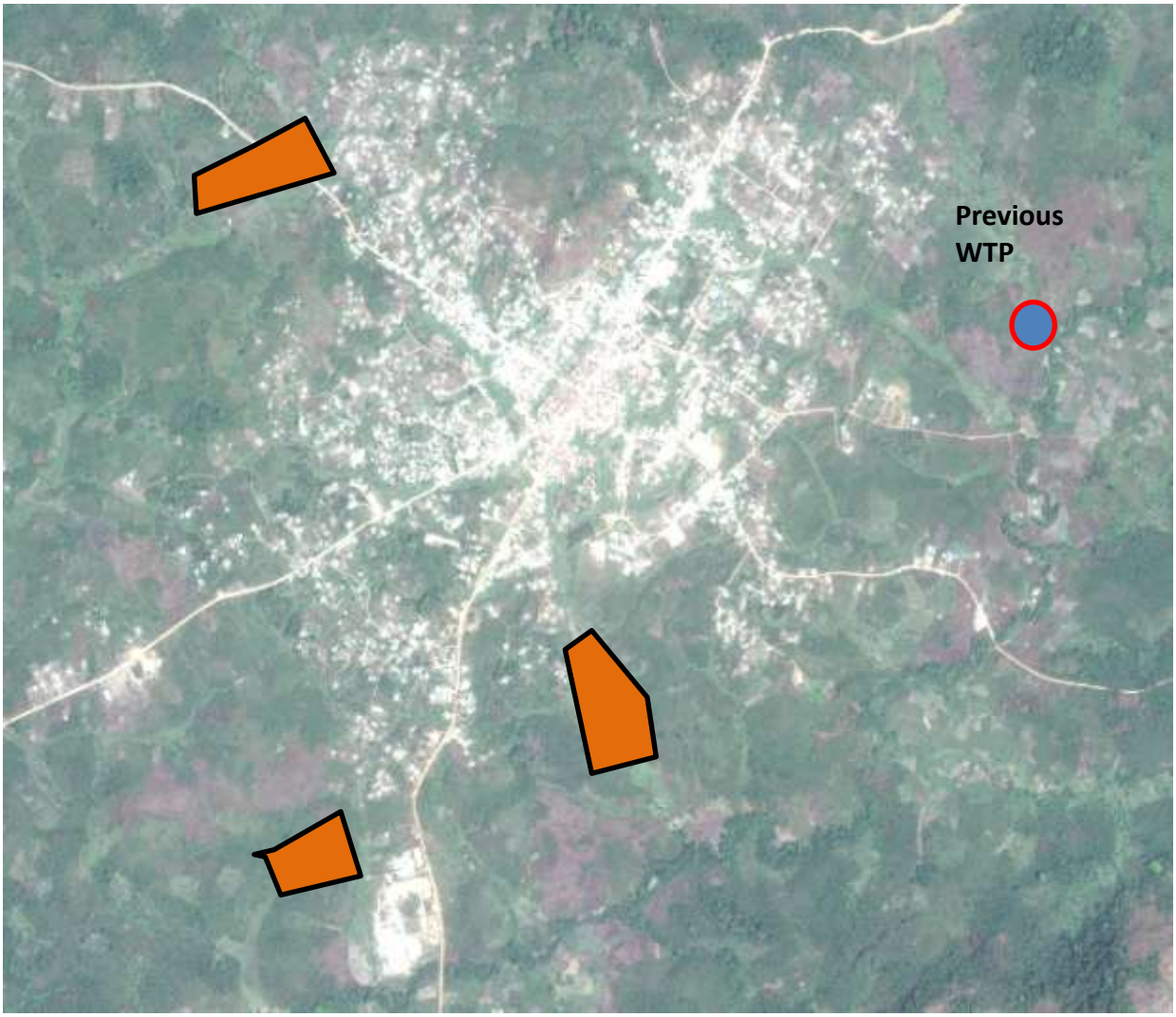

Figure 8-8: Possible Areas for Wastewater Stabilization Ponds in Voinjama

Table 8-8: Advantages and Disadvantages to Wastewater Stabilization Ponds*	
Advantages	**Disadvantages**
• No electrical requirement • Low maintenance effort and cost • Low capital cost compared to conventional WWTP • Feasible for treatment of a wide range of wastewater composition and strength • Possibility of nutrient recovery (Nitrogen, Phosphorus, and Potassium) for irrigation or aquaculture	• Likely to provide lower quality effluent than conventional, well-maintained WWTP. • Uncovered – may require additional depth or protection to prevent flooding during rainy season • Health and safety hazard if not properly fenced
**Information adapted from Lettinga, 2001. Foresti, 2001. Zeeman and Lettinga, 1999. Jim Field, 2002.*	

8.4 HOUSEHOLD WILLINGNESS TO PAY FOR IMPROVED SANITATION[100]

Voinjama does not have a sewage collection system. However, 21% of the respondents have access to a private sewage system through the use of a septic tank or soakaway pit, and only 3% of respondents reported paying for sewage disposal fees to have the accumulated septic tank periodically emptied.

When asked why the household was without toilet facilities, 50% of respondents chose "Cannot afford it" as their reason, while 36% reported not having the space to build one. The remaining 11% claimed it was the landlord's responsibility.

Should they obtain a water connection, 70% of households reported they would be interested in building a toilet facility. This implies a moderate demand for sanitation services, while the other responses indicate a lack of funds and space. It is also likely that there is a lack of expertise concerning the construction of toilet facilities, especially in regard to the improved sanitation facilities described in Section 8.3.

While quantifying the amount of money users are willing to pay for adequate sanitation facilities is not possible from existing data, it can be surmised from the survey responses that upfront capital costs are prohibitive. In the immediate future, construction of on-site sanitation facilities will most likely require action from the donor community or at least considerable subsidy. The possibility of micro-loans should be explored.

If and when a collection and centralized treatment system is constructed, sanitation fees may be included as a portion of the water bill, as is common in the developed world.

8.5 IMPROVING HYGIENE BEHAVIOR AND SANITATION PRACTICES

As previously mentioned, interventions in the water sector have the greatest impact when coupled with interventions in the sanitation sector, accompanied by sanitation and hygiene promotion activities.[101] To

[100] Information in this section is taken from University of Liberia Pacific Institute for Research and Evaluation (2012).Liberia Willingness and Ability to Pay Baseline Survey, Appendix B, Questions 136-142.

[101] United States Agency for International Development (2009). *Environmental Guidelines for Small Scale Activities in Africa, 2nd Ed.* Retrieved from http://www.encapafrica.org/egssaa.htm

that end, future sanitation efforts should include hygiene and sanitation outreach activities as described in this section.

To avoid duplication of efforts, LMWP will work in coordination with the WASH program to support their outreach and education activities. The Steering Committees in particular should be fully engaged in sanitation and outreach activities. The following section, offset in block quotes, is excerpted from the USAID Liberia WASH website, and describes ongoing activities at the National, County, and Community and Household levels:

> **National Level**
>
> Work with Ministry of Health and Social Welfare (MOHSW), Ministry of Public Works (MPW), civil society groups, and private firms to fill gaps and reinforce the Behavior Change Communication Strategy.
>
> Develop guides and materials for WASH-friendly schools and clinics…
>
> **County Level**
>
> Train members of the county health teams (CHTs) on improved hygiene behaviors…
>
> Work with the MOHSW to consolidate disease surveillance, the mapping of water points, and routine water quality monitoring at the county level, and to use this data to advocate for evidence-based infrastructure and behavior change interventions.
>
> Facilitate distribution and promotion of water/sanitation/hygiene products to the county and district level.
>
> **Community and Household Level**
>
> Conduct research on household hygiene practices; consumer preferences and usage patterns; level of investment in latrines; access to construction materials, local producers, and latrine designs and costs information[. Perform] trials of "doable actions", and use this information to develop [messages on health status] to supplement health-based messages from UNICEF's Participatory Hygiene and Sanitation Transformation (PHAST) programs[,] which are [currently] used in Liberia.
>
> Community mobilization to eliminate open defecation — test participatory demand-driven non-subsidized approach (i.e. Community-Led Total Sanitation.)
>
> Train community members in management of their water supply and storage systems and public, shared, and household latrines.
>
> Train entrepreneurs in pump repair and maintenance and latrine construction using sanitation options manual. Link these trainings to demand creation.[102]

Implementing behavior changes such as those described in the previous excerpt can be difficult. People are unlikely to adopt new practices without clear communication regarding their benefits. UNICEF states that "Promoting behavioral change is a gradual process that involves working closely with communities, studying existing beliefs, defining motivation strategies, designing appropriate communication tools and finally encouraging practical steps toward positive practices."[103] By teaming with WASH in the aforementioned interventions, LMWP hopes to cement behavioral change, thereby maximizing the health benefits of its infrastructure improvements.

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[102] USAID (15 Sep 2012). Water, Sanitation, and Hygiene Program (WASH). Retrieved from http://liberia.usaid.gov/node/51.

[103] UNICEF (5 Mar 2012). Water, Sanitation, and Hygiene – Hygiene Promotion. Retrieved from http://www.unicef.org/wash/index_43107.html.

8.6 RECOMMENDATIONS

8.6.1 Onsite Systems

With the improvement of the drinking water system, wastewater flows are expected to increase slightly as a larger proportion of inhabitants gain access to flush toilets. Table 8-9 and Figure 8-9 provide wastewater projections assuming an approximately linear increase in access to flush toilets from the current level (21%) to 100% access by 2025. The stakeholders in Voinjama should be aware and consider steps needed to address this impact from restoring the water system.

In the near-term, actors in the sanitation sector should consider investing in the construction of twin pit pour-flush latrines for the residents of Voinjama. This low-cost, low-maintenance intervention is well suited for handling the expected influx of greywater while improving the current level of sanitation facilities and providing a cradle-to-grave process for the management of human waste. Though septic tanks and leachfields provide the additional benefit of protection against flooding, their construction is more involved and the septic tanks must be emptied by vacuum truck – a costly practice of unknown feasibility in Voinjama. To protect against the hazards of flooding, the pits must be appropriately sited, lined, and sized to limit and accommodate for infiltration.

Table 8-9: Projected Wastewater Flow Estimates (Increased Access to Flush Toilets)

Year	Population	Percentage with Access to Flush Toilet	Residential Water Flow (gpd)	Residential Blackwater Flow (gpd)	Residential Greywater Flow (gpd)	Trade Wastes (gpd)	Total Wastewater Flow (gpd)	Night Soil Generation (lb./day)
2011	15,100	21%	16,300	2,640	12,123	1,386	16,148	6,250
2012	15,300	27%	16,600	3,089	11,428	1,411	15,928	6,350
2013	15,500	32%	68,400	7,103	52,691	5,814	65,608	6,450
2014	15,700	38%	69,500	8,053	53,542	5,908	67,502	6,550
2015	15,900	44%	85,400	9,097	66,930	7,259	83,286	6,700
2016	16,100	49%	101,700	10,104	80,700	8,645	99,449	6,800
2017	16,300	55%	118,400	11,138	94,811	10,064	116,013	6,900
2018	16,500	61%	136,600	12,284	110,154	11,611	134,049	7,050
2019	16,700	66%	154,300	13,375	125,115	13,116	151,605	7,150
2020	17,000	72%	172,500	14,492	140,500	14,663	169,654	7,250
2021	17,200	77%	192,400	15,740	157,288	16,354	189,383	7,400
2022	17,400	83%	195,000	16,915	159,414	16,575	192,904	7,500
2023	17,600	89%	198,900	18,234	162,602	16,907	197,743	7,650
2024	17,900	94%	202,800	19,592	165,791	17,238	202,620	7,800
2025	18,100	100%	205,400	20,856	167,916	17,459	206,231	7,900
2026	18,300	100%	209,300	21,252	171,104	17,791	210,147	8,050
2027	18,600	100%	213,200	21,648	174,293	18,122	214,063	8,200
2028	18,800	100%	215,800	21,912	176,418	18,343	216,673	8,300
2029	19,100	100%	219,700	22,308	179,606	18,675	220,589	8,450
2030	19,300	100%	223,600	22,704	182,795	19,006	224,505	8,600
2031	19,600	100%	227,500	23,100	185,983	19,338	228,421	8,750

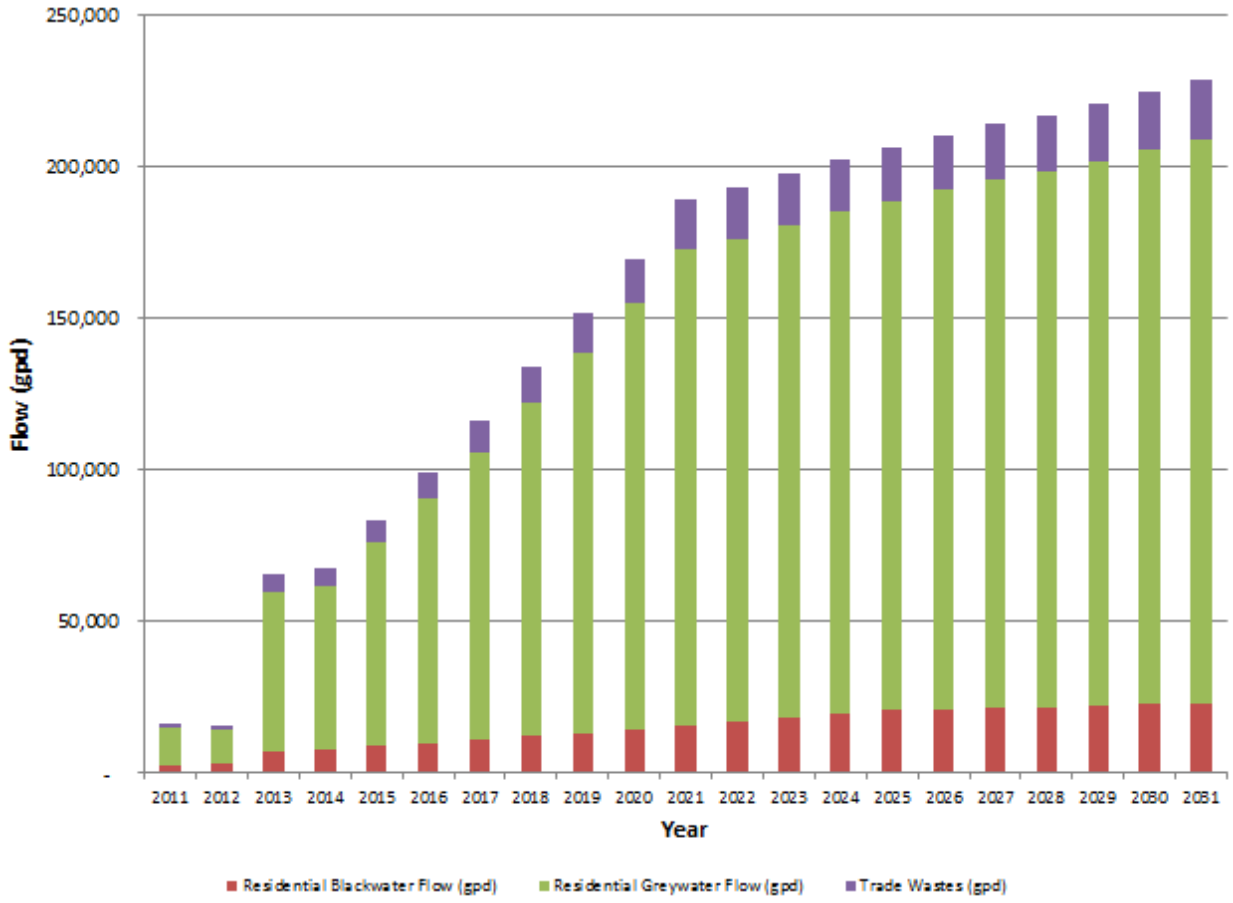

Figure 8-9: Projected Wastewater Flow Estimates (Increased Access to Flush Toilets)

When compared with Figure 8-1 and Table 8-6 one sees that the total flow has increased slightly as a result of the increase in blackwater flow, while trade wastes and greywater production have remained stable.

For successful implementation of these systems, several additional steps must be taken, including:

4. Determination of willingness to pay/acceptability to the community must;
5. Selection of appropriate sites for latrines
6. Arrangement of microfinancing or implementation of subsidies;
7. Exploration of management options (community toilets, household toilets, pay toilets);
8. Generation of standard designs and specifications;
9. Approval of builders for the construction of the facilities;
10. Determination of a full cycle plan for the deposition and sale of the latrine output (humus); and

11. Promotion of appropriate use through education.

All activities should be coordinated with iWASH so as to produce a unified course of action and to make proper, synchronized use of the outreach activities.

Section 8.3.5 clearly recommends the use of waste stabilization ponds, for reasons elucidated in that section. Successful implementation of these systems will include several steps:

12. Feasibility studies
13. Sanitation master plans
14. Agreement upon the site for the WSP;
15. Land acquisition for agreed-upon site;
16. Design and construction of a reticulation network;
17. Determination of tariff rates and payment schemes for sewer services;
18. Performance contracts/management arrangements between LWSC and local government units;
19. Quality criteria for effluent and measurement schedules;
20. Generation of designs and specifications;
21. Acquisition of environmental permits;
22. Retention of construction contractors with appropriate building methods and experience;
23. Construction and operation; and
24. Outreach and education concerning proper use of the system and health benefits of system use.

All activities should be coordinated with iWASH so as to produce a unified course of action and to make proper, synchronized use of the outreach activities.

9.0 IMPLEMENTATION

9.1 ORGANIZATIONAL

The various parties anticipated to be involved in the efforts to improve the access to water for the City of Voinjama, as outline in this report could those in the below table. Also presented in the table are the roles, tasks and responsibilities of those parties.

Table 9-1 Implementation Roles and Responsibilities

Role	Part	Tasks and Responsibility

Technical and Institutional Support	Tetra Tech through its Liberia Municipal Water Project (LMWP)	• Prepare Master Plan
		• Prepare Construction Documents
		• Presentations of Master Plan and Documents to
		  ○ Steering Committee
		  ○ USAID
		  ○ LWSC
		• Revise Report and Bid Documents to address comments from Stakeholders
		• Assist in tendering for construction services
		• Provide engineering service during construction
		• Provide Institutional development support and guidance, develop MOU regarding operational and regulatory responsibility
		• Provide engineering support regarding startup operations

Donor and Financial	United States Agency for International Development (USAID)	• Review Master Plan and Bid Documents • Obtain capital cost financing
Local Entities	City of Voinjama & Steering Committee	• Review Master Plan and Bid Documents
Operator	Liberia Water and	• Review Master Plan and Bid Documents

	Sewer Corporation (LWSC)	• Enter MOU regarding operation and oversight responsibility • Implement Institutional changes • Tender bid documents • Take over operation of new water utility

9.2 STAKEHOLDER INPUT AND PUBLIC INVOLVEMENT

A driving principle in the LMWP and in this Master Plan is collaboration and integration with, local parties, local government, and stakeholders in the Liberia water sector (LWSC, MOH, and MPW). Some of the important components of this document are derived from collaboration with these parties. Additional comments, discussions and input from the interested parties and stakeholders are anticipated to be received during the review and comment period.

9.3 FUNDING

The cost associated with the Voinjama recommendation outlined in this master plan can be categorized as either capital costs or operation and maintenance cost. Capital costs for infrastructure projects, such as this water system, are generally one time large costs. Capital costs are typically associated with the construction of new water system components or the restoration of aging water system components. Restoration capital cost should not be mischaracterized with typical repair and small rehabilitation efforts by a water utility. Capital costs are generally covered by the water utility borrowing monies from lenders.

Operation and maintenance costs are associated with the daily, monthly and annual operation of the water utility. Some of the large O&M costs are associated with labor, chemicals and fuel/power. Other O&M cost can be associated with computer and office supplies, insurance, tools and equipment, and the procurement of specialized services by outside contractors.

It is intended that the capital cost associated with the proposed water system improvements will be covered by the USAID, but ongoing operation and maintenance costs should be fully recovered through user tariff charges.

9.4 PROCUREMENT

The procurement for the project is presently anticipated to be conducted by the Liberia Water and Sewer Corporation (LWSC) with technical and additional support provided by Tetra Tech's Liberia Municipal Water Project (LMWP) team or another GoL entity agreed to with USAID . It is anticipated that the project will be solicited and awarded by the LWSC or any other entity agreed to with USAID. The LMWP team will assist LWSC or the selected entity, since they have not presently had significant procurement experience with construction projects of this scale relative to water supply, treatment and distribution projects. The LMWP is expected to assisted in the following tasks:

- Distribution of bid documents
- Attend pre bid meetings

- Respond to questions submitted by potential bidders
- Receipt of bid proposals
- Review of bid proposals and cost
- Review of References
- Execution of contract

USAID's preference is to utilize host country procurement mechanisms for construction of works under LMWP. Significant capacity building is needed before LWSC is capable of procuring major capital works itself. However, procurement policies promulgated by the Government of Liberia do have strong implementation requirements and are being supported by the Infrastructure Implementation Unit (IIU) within the Ministry of Public Works, which provides procurement support to other agencies of the government.

LMWP conducted an assessment to determine the feasibility of using host country contracting mechanisms for procurement of construction services under LMWP. The assessment developed the findings and recommendations that have been reported to USAID in separate documents.

Progress is being made to bring about improvement through implementation of some of these recommendations, including the LWSC recruitment of a Procurement Manager and provision of better accommodation and equipment for the LWSC Procurement Unit. With these expected improvements within LWSC, the support offered by PPCC and the help that the Project's procurement expert will provide, it should be possible to bring procurement practices of LWSC into compliance with the law by the end of the present calendar year.

The suggested capacity building measures and any involvement by the LMWP in these measures have not been provided for in the Project's budget and additional help from USAID may be needed.

9.5 ASSET MANAGEMENT

Asset management is the framework widely being used to pursue and achieve sustainable infrastructure. An asset management process is the practice of managing infrastructure capital assets (inventory) to lessen the expense of being responsible for and operating and maintaining the water system components including source, treatment, storage, distribution, and administration.

Asset management is a developing practice with the goal of maintaining a desired level of service that the management, operators, and customers should expect from their assets. The future Voinjama water utility customers should expect the lowest possiblelife-cycle cost for the operation, maintenance, rehabilitation, repair, or replacement of a component of the water system. An asset management system will help ensure life-cycle costs are kept to a minimum and funds available for the water system are used efficiently.

Many proponents consider the four fundamentals of a sustainable water system to be better management, full cost pricing, water conservation, and watershed awareness. Better management at the local or facility level involves asset management, environmental management systems, and capacity development. Full Cost Pricing is needed to reliably recover all of the costs of construction, operations, and maintenance from water price. Water Conservation, water quantity, and water quality issues are inextricably linked to sustainability the level service provided. Watershed Awareness is an approach that focuses on stakeholders and activities located within hydraulic boundaries as a means to address water quality and

quantity concerns. Asset Management programs are not intended to be developed to address all four fundamentals, but can be an important tool in supporting better management and full cost pricing.

Asset management programs require good data collection and maintenance on the age, condition and criticality, and life-cycle costs of system components. The program also requires operations and maintenance (O&M) and capital replacement plans based on cost-benefit analyses. While the planning is the most effective tool, the gathering and inputting of all the data can be done best when a new water system is created.

The benefits of asset management include:

- Extended asset life and avoidance of premature loss of capital purchases
- Reduction in operational and capital expenditure costs
- Meet consumer demands with a focus on system sustainability
- Establishment of water tariffs based on sound operational and financial planning that are justifiable to the customer base
- Budgeting focused on activities critical to sustained performance
- Improved responses to complaints from customers
- Preparation for emergencies

Asset management is focused on maintaining continuous awareness of five fundamental conditions of the water system as listed below. These conditions should periodically be assessed as part of the administration of the asset management program.

- Which assets or components of the system are critical to sustained performance?
- What is the current condition of the critical components of the water system?
- What is the expected "sustainable" level of service required from the water system?
- What are the minimum and expected life-cycle costs?
- What are the utility's long-term funding options and strategy?

An asset management program can be developed for a new municipal water system such as Voinjama, a rural water system, or an existing larger water system such as Monrovia. There are distinct advantages to starting an asset management program with a new water system, one of which is the collection of operational data over the life of the equipment.

It is recommended that the establishment of any new water system in Voinjama include the establishment and practice of an asset management program. The US EPA offers free asset management software, known as "Check Up Program for Small Systems (CUPSS)." It is available for download and with supporting information at the following internet address:

http://water.epa.gov/infrastructure/drinkingwater/pws/cupss/index.cfm

The website notes that

> *"CUPSS is a free, easy-to-use, asset management tool for small drinking water and wastewater utilities. CUPSS provides a simple, comprehensive approach based on EPA's highly successful Simple Tools for Effective Performance (STEP) Guide series. Use CUPSS to help you develop:*
> - *A record of your assets*
> - *A schedule of required tasks*
> - *An understanding of your financial situation*

- *A tailored asset management plan"*

An alternative free program is the"Total Electronic Asset Management System (TEAMS)" developed by the Maryland Center for Environmental Training (MCET). Asset management software is available for purchase as well.

9.6 OPERATIONS AND MAINTENANCE MANUAL

The operations and maintenance (O&M) manual is a documents that contains references and record information regarding the details of the water system constructed. The O&M manual describes the general mechanical operation and chemical functions of a water treatment facility, along with the necessary manufacturer materials for maintenance and repair of equipment. The manual also clearly outlines the responsibilities of the various staff members of the water utility. The manual is meant to be periodically updated as the staff structure and the water system each evolves over time

The operations manual can be used as a guidance document for the water system staff and personnel during training sessions. The manual will provide specific instructions as to the daily testing and operation of the facility and day-to-day tasks, which must be accomplished to meet the operational objectives.

O&M manual typically contains the following information:

- Introduction to water system, source watersheds, and facilities(s).
- Water Quality Standards
- Responsibilities of operations and supervision personnel
- Description of facility operations and hydraulics
- Description of facility equipment and relationships
- Common operating problems and solutions
- Chemical applications
- Laboratory testing and operator responsibility
- Power conditions, sequencing and general operation
- Shut-down procedures
- Records and daily logs to be completed
- Calculations for chemical usages and dosages
- Schematic diagrams of flow within the facility
- System maintenance requirements and instructions

An O&M manual should be prepared after each major improvement or institutional change in the water system. A draft sample copy of an O&M Manual is presented in the Appendix. This will constitute the basis for the capacity building documents and other materials to be developed for LWSC.

9.7 LAND OWNERSHIP

The implementation of some the recommendation is this Master Plan will require that land ownership be determined and the consideration of real estate needs. The local government officials, LWSC, and the

steering committee for the LMWP should be engaged in land ownership and real estate needs early in the implementation phase of this plan.

The layout of much of the raw water main, WTP improvements and storage tank are located on the previous sites. This should reduce the need to address land ownership or rights issues as it is understood that the former facilities are under public ownership. The layout of the distribution network is anticipated to follow the shoulders of existing roadways. Access to certain lands may be needed in perpetuity to support the operations and maintenance of the water system.

9.8 SANITATION PLANNING

There has never been and there are no current plans for a sanitary sewage collection system in Voinjama. There is also no solid waste collection and disposal system in place. The solid waste is either cast out as littered to be washed away during the periods of heavy rain, or accumulated into piles for burning.

The majority of residential human waste is discharged to either to latrines or openly cast to the ground. When a sanitation master plan is developed it is recommended that the sanitary waste collection system should initially be situated in decentralized locations throughout the city. Latrines should be located to protect to water sources, by providing provide horizontal offsets and properly designed and constructed. Latrine areas or other properly sited facilities should also include exterior facilities to wash clothing. It is anticipated that any future developed sanitary collection system in Voinjama would increase the water usage.

9.9 SCHEDULE

In order to implement the master plan, the table below was developed to sequence and list the major steps required.

In the near-term, the schedule shows the completion of the ongoing planning stage of the LMWP. The subsequent short term project phase includes the construction of the treatment works and the Phase 1 of the Distribution System. The supply of water to these areas is projected to be done by constructing public stand posts. The later stage of the project is to restore the water treatment plant and begin the transition to private house connections and yard taps.

A key benefit of this approach is that a large portion of the distribution system can be quickly restored to improve access to a large portion of Voinjama that include the more populated areas. This initial water system is considered to be simple to operate and does not require a large amount of chemicals. Since the short term water system is simple to operate it is also anticipated that the initial cost of operation will be low and recoverable through billing users.

Table 9-2 Recommended Voinjama Master Plan Implementation Schedule

Stage	Date	Liberia Municipal Water Project	City of Voinjama and Steering Committee	USAID	Liberia Water & Sewer Corp.
Planning Stage	Sept 2012	Submit Master Plan to • City of Voinjama Steering Committee • LWSC • USAID			
	Oct 2012	Conduct presentation of Master Plan Report to Steering Committee and LWSC	Steering Committee to attend presentation of Master Plan Report	Review Process	LWSC to attend presentation of Master Plan Report
	Nov 2012		Provide Comments	Provide Comments	Provide Comments
	Jan 2013	Respond to comments and Finalize Report	Acceptance of Report	Acceptance of Report	Acceptance of Report
Short Term Project Stage	Feb 2013	• Finalize Phase I (Alt #2) and II (Alt #4) Construction Bid Documents (plans, specs and estimate) and submit for review • Assist Voinjama and LWSC with Institutional development process and implementation	Begin institutional development process		Review and comment on Construction Bid Documents Begin institutional development process
	Mar 2013	Revise Bid Documents based on comments	Implement Watershed Protection Program for the Zeliba River		
	Mar 2013	Assist LWSC to Tender Bid Documents to solicit construction services		Secure capital funding	Tender Bid Documents to solicit construction services
	May 2013	Start Construction of Phase 1 to Serve Areas #1 and #2			
	Feb 2014	Complete Construction of Phase I and II			
	March 2014	Operational Start Up of Phase I and II water	Begin obtaining water from new		Start Operation of new water

Table 9-2 Recommended Voinjama Master Plan Implementation Schedule

Stage	Date	Liberia Municipal Water Project	City of Voinjama and Steering Committee	USAID	Liberia Water & Sewer Corp.
		system	water distribution system		distribution system
Medium Term Project Stage	May – June 2014	Finalize Phase III (Alt #5) Construction Bid Documents (plans, specifications and estimate			Review and comment on Construction Bid Documents
	Aug - Sept 2014	Revise Bid Documents based on comments			
	Oct – Nov 2014	Assist LWSC to Tender Bid Documents to solicit construction services		Secure capital funding	Tender Bid Documents to solicit construction services
	Dec 2013 to Jan 2014	Start Construction of Phase III			
	April to May 2015	Complete Construction of Phase III			
	May - June 2015	Operational Start Up of Phase III water system	Begin obtaining water from new water treatment plant		Start Operation of new water treatment plant.
Long Term Projects	2016+				Convert from public to private connections
	2017		Review planning efforts		Update of the Master Plan every 5 years
	2017				Asset Management Plan
	2017				Develop training program to assist other water utilities
	Ongoing				Promotion of rainwater harvesting

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov