Final Report

Liberia Energy Project: Evaluation Design for the Water Pipeline Sub-Activity

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Contents

Tables

Figures

ABBREVIATIONS

AfDB	African Development Bank
ERR	Economic rate of return
KII	Key informant interview
LEC	Liberia Electricity Corporation
LWSC	Liberia Water and Sewer Corporation
MCC	Millennium Challenge Corporation
MCHPP	Mt. Coffee Hydropower Plant
O&M	Operations and management
RAP	Resettlement Action Plan

I. INTRODUCTION

Liberia's long civil war from 1989 to 2003, followed by widespread looting, resulted in the destruction of the Mt. Coffee Hydropower Plant (MCHPP) and the entire transmission and distribution network. The MCHPP was Liberia's largest source of power before 1989. The plant was located along the banks of the St. Paul River adjacent to the White Plains water treatment plant, and it fell into disarray due to extensive theft and destruction of its equipment.

In 2015, the Millennium Challenge Corporation (MCC) partnered with the Government of Liberia to help address the country's insufficient access to reliable and affordable electricity. Under MCC's compact with the Government of Liberia, the $202 million Liberia Energy Project aimed to modernize the country's energy network, extend access to electricity, and improve the quality and reliability of the power system. The Liberia Energy Project includes the following four activities, which address the challenges facing Liberia's power sector:

- **Activity 1:** The **Mt. Coffee Rehabilitation Activity,** which has repaired and expanded the MCHPP, providing an installed generation capacity of 88 MW.
- **Activity 2:** The **Capacity Building and Sector Reform Activity,** which will support the creation of an independent regulatory agency, provide management oversight to the Liberia Electricity Corporation (LEC), and strengthen the capacity of the LEC and, potentially, Liberia's Environmental Protection Agency
- **Activity 3:** The **Mt. Coffee Support Activity,** which addresses environmental and social risks associated with the rehabilitation of MCHPP and aims to increase productive uses of electricity.
- **Activity 4:** The **LEC Training Activity,** which aims to improve the capacity of the energy sector workforce through improved training for LEC staff and technicians.

In 2018, MCC contracted Mathematica to conduct impact and performance evaluations of the Liberia Energy Project. This report describes Mathematica's evaluation design for the Mt. Coffee Support Activity (**Activity 3**), which includes a sub-activity to construct a water pipeline from MCHPP to the water treatment plant. The water treatment plant, which supplies purified drinking water to Monrovia, previously received water from the St. Paul River through a decrepit pre-civil war pipeline.

In the chapters that follow, we provide context for the evaluation and describe its planned design in further detail. In Chapter II, we present the program logic, describe the interventions under the pipeline sub-activity, and summarize the existing literature on piped water access in sub-Saharan Africa. In Chapter III, we outline the questions that the evaluation seeks to answer and provide an overview of the evaluation designs and data sources that will enable us to answer these questions. In Chapter IV, we list the key challenges to the evaluation and offer strategies to mitigate them. Chapter V discusses administrative issues.

II. OVERVIEW OF THE WATER PIPELINE SUB-ACTIVITY

In this chapter, we provide context for the evaluation of the pipeline sub-activity by describing the sub-activity's design and the mechanisms through which we expect them to affect outcomes, as set out in the program logic. We also provide an overview of the current status of the sub-activity's implementation and a summary of the existing literature on the state of water supply in Liberia and the benefits of piped water in sub-Saharan Africa.

A. Overview of the water pipeline sub-activity

As part of the Liberia Energy Project's Mt. Coffee Support Activity, MCC aimed to restore and upgrade the raw water pipeline to the White Plains water treatment plant, which was destroyed during the civil war. The $18 million water pipeline sub-activity is expected to improve the Liberia Water and Sewer Corporation's (LWSC's) capacity to serve more than one million customers in and around Monrovia who currently lack an adequate supply of clean water. The gravity-fed pipeline system is expected to reduce the cost of pumping water to the treatment plant, improve raw water quality by substituting a less saline source than the previous location along the St. Paul River, and provide a more consistent supply of potable water. Although the MCHPP was fully rehabilitated in 2018, the rehabilitation of the pipeline is still in progress given that the conceptual design, environmental and social assessment, and feasibility analysis were not carried out while developing the Liberia Compact, but rather were completed two years after the compact entered into force.

The pipeline sub-activity's budget of $18 million (revised from an original estimate of $13.4 million) covers the costs of expanding the original 900 mm pipe to a 1,200 mm pipe with the greater capacity needed to meet the expanding demand for water throughout Monrovia. It also includes funds for an operations and management (O&M) plan, training for LWSC's water treatment plant staff, and procuring additional equipment for the plant. In addition, the budget covers contingency costs and preparing and implementing a Resettlement Action Plan (RAP), which includes constructing or rehabilitating water points (tube wells and borewells) in the communities surrounding the MCHPP.

Development, review, and approval of tender documents and contractor procurement took longer than expected, so the sub-activity finally commenced when the design-build contract was executed on February 12, 2019. At the end of September 2020, the pipeline construction was nearly complete, with some ancillary work—including installing fencing and pressure testing the pipeline—still in process. The RAP has been largely implemented, with a few outstanding issues that require additional compensation to landowners.

B. Technical aspects of the water pipeline sub-activity

According to the most recent activity design report, the proposed pipeline is 1,200 mm in diameter and approximately 4.7 km long. It will carry water from the MCHPP to the White Plains water treatment plant and is required to deliver a flow of 0.9 m^3/second to 1.2 m^3/second. As shown in Figure 1, the activity has been split into two segments:

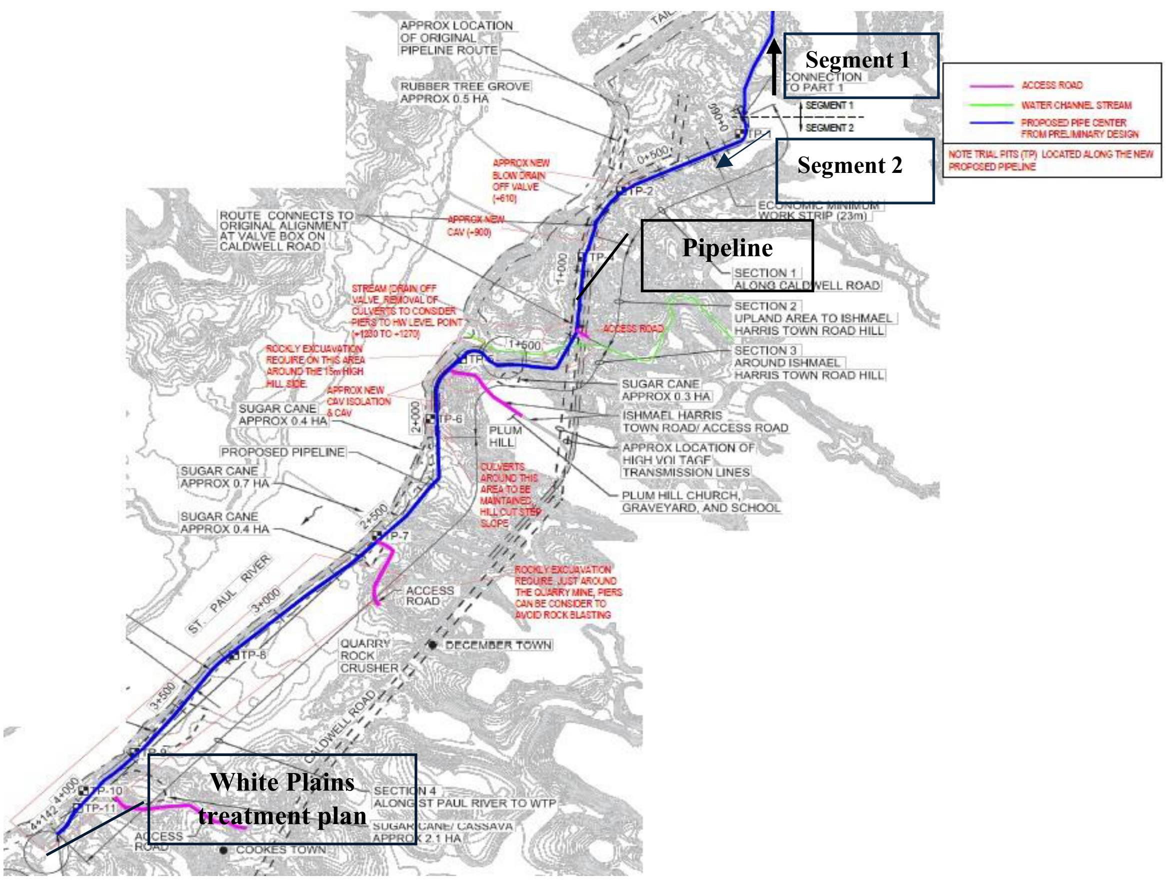
1. Segment 1 involves the provision of a short 0.9 km pipeline within the MCHPP property. This segment will begin at the current blank flanges, situated at the intake chambers of three of the four turbines at MCHPP, and rise to a valve chamber at the end of the LEC construction site for MCHPP. This segment comprises two parts:

- Segment 1A: Steel risers and valve manifold at the dam connection, an over-ground section of steel pipework, and a burst-control valve building
- Segment 1B: Buried pipeline to the boundary of MCHPP

2. Segment 2 involves the provision of a longer 3.8 km pipeline outside the MCHPP property boundary, running along the bank of the St. Paul River to the White Plains water treatment plant. This segment is divided into three parts:

- Segment 2A: Pipeline from the LEC MCHPP boundary to the Pipe Bridge near the treatment plant
- Segment 2B: Pipe Bridge with a steel pipe near the treatment plant
- Segment 2C: Pipeline from the Pipe Bridge to the treatment plant

Figure 1. Schematic of proposed pipeline



Source: Nicholas O'Dwyer (2019).

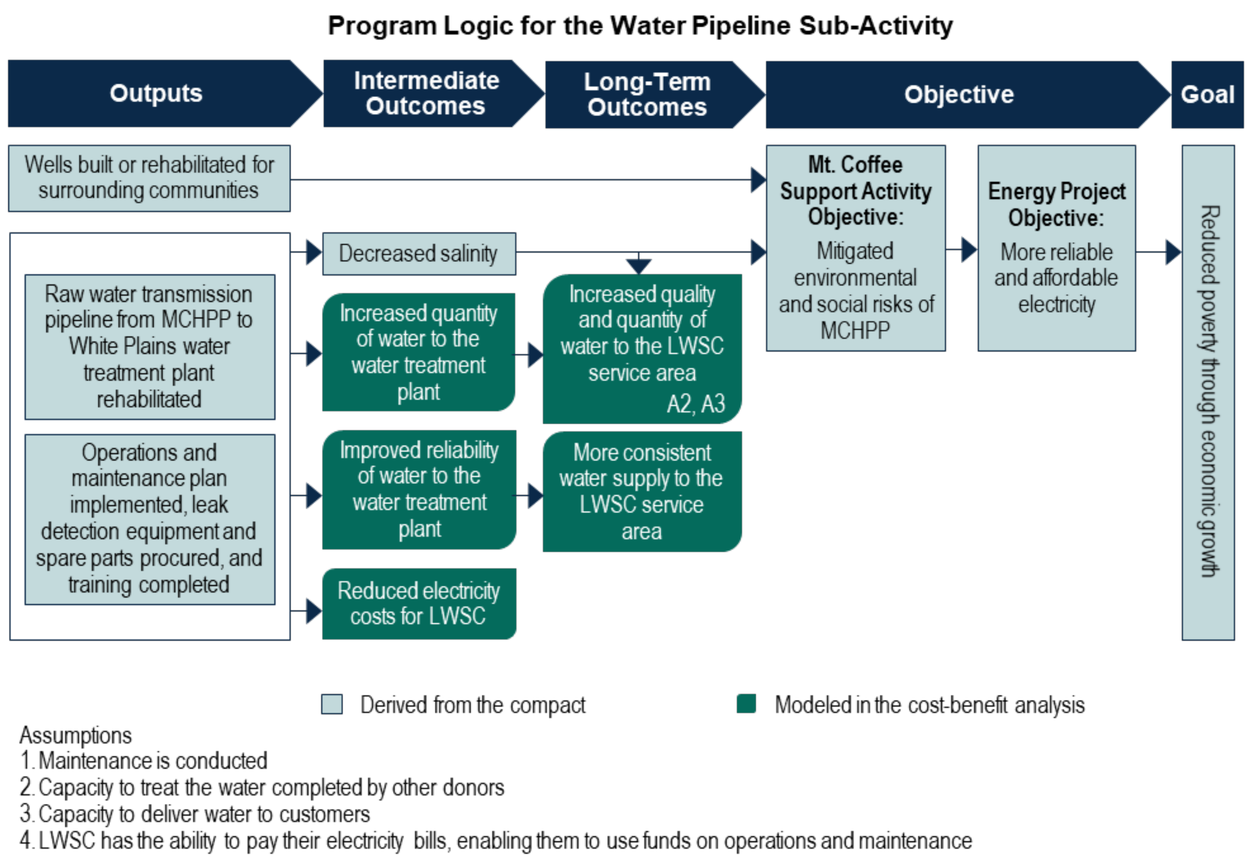
Figure 2. Photos from the construction of the pipeline

C. Theory of change

The program logic (Figure 3) of the pipeline sub-activity guides this evaluation. The program outputs include rehabilitation of the water pipeline, implementation of an O&M plan, training for LWSC staff, procurement of leak detection equipment and spare parts for the pipeline, and completion of the financial management training. Theoretically, these outputs together lead to intermediate outcomes of increased quantity, improved reliability and decreased salinity of water supply to the water treatment plant, and reduced electricity costs for the LWSC due to the gravity-fed pipeline system. In the long term, the increase in raw water supply to the treatment plant, combined with the decreased salinity of raw water, interact to improve the quantity and quality of water supply in LWSC's service areas. Similarly, improved reliability of water to the treatment plant is expected to result in more consistent water supply to LWSC's service areas. Finally, the construction or rehabilitation of wells in the communities surrounding MCHPP addresses the risk of the pipeline limiting access to the St. Paul River as a water source for some of the local communities.

This program logic is contingent on assumptions about regular maintenance of the newly built water pipeline, LWSC's capacity to treat (through donor support) and deliver water to customers, and LWSC's ability to pay for electricity bills (which thereby enables it to use funds allocated to O&M).

Figure 3. MCC's logic model for the water pipeline sub-activity (*reformatted by Mathematica*)



D. Literature review

Access to clean water is fundamental to basic household well-being. Yet despite progress in improving water sources in many areas of the developing world, one in three people globally (some 2.2 billion people) still do not have access to safe drinking water (World Health Organization 2019). Liberia lags behind many of its West African neighbors in providing access to high quality water. As of 2015, only 4 percent of urban households in the country had access to piped water on premises and water accessible through public sources is especially poor (WHO and UNICEF 2015). In 2016, researchers selected a random sample of drinking water sources around Monrovia and found that the majority contained fecal indicator bacteria and 22 percent contained nitrates in excess of regulatory standards. They attributed the poor water quality in large part to the prevalence of pit latrines and open defecation in the city (Kumpel et al. 2016)

The literature suggests that increasing the quantity and quality of water through infrastructure improvements can lead to numerous benefits including better health, economic empowerment, a decrease in gender inequality, and environmental risk mitigation (through decreased water salinity):

- **Health.** There is broad consensus that poor quality drinking water increases the risk of diarrheal disease (Wolf et al. 2014). Several studies provide evidence for the health benefits of closer and more reliable access to water sources. One systematic review found that improved water quality is associated with a 17 percent reduction in the risk of diarrheal disease (Cairncross et al. 2010). This protective effect has also been shown to extend to other conditions such as pneumonia (Hennessy et al. 2008), avian influenza (Dinh et al. 2006), and various respiratory illnesses in young children (Luby and Hadler 2008).
- **Economic empowerment.** Studies show that access to improved water sources can greatly increase economic well-being by reducing health care costs and improving time use. Because improved water sources prevent end users from becoming sick, they seek less health care and therefore save money and time. Additionally, time previously spent retrieving water (including time for traveling, waiting in line, and drawing water) can be reallocated towards more productive purposes. As such, the World Bank estimates that the annual economic benefits of improving water supply and sanitation can amount to as much as to 4.3 percent of GDP in sub-Saharan Africa (Hutton 2012). The same study concludes that the benefit of achieving universal piped water access can outweigh the costs by a factor of 2.8.
- **Gender inequality.** Evidence indicates that improving water infrastructure may have gender impacts by reducing costs of retrieving water and the disproportionate incidence of these costs on women and girls. Researchers have shown that these costs include time, caloric expenditure (which is particularly relevant during droughts), and other health and safety risks such as physical attack and injury when fetching water from outside sources. They cite data from the Multiple Indicator Cluster Survey in 44 countries and show that most water carriers are women and children (Sorenson et al. 2011). These costs suggest that improved water sources could potentially reduce gender inequality and confer economic benefits to women (Koolwal and van de Walle 2010).
- **Environmental risk mitigation (through decreased water salinity).** The environmental consequences of excess salinity in the water supply are well documented. Excess salinity

damages the soil, affects irrigation, stunts plant growth, and reduces agricultural yields (Shahid et al. 2018). A 2014 study estimates that annual economic losses associated with salt-induced land degradation amount to $27 billion in lost crop value per year (Qadir et al. 2014). In addition, salinity in the water supply makes it more expensive to treat in making drinking water suitable for human consumption. In this context, infrastructure improvements in LEC’s water transmission pipeline have the potential to reduce environmental risks by reducing salt-water intrusion, although it is unclear how this relates to MCHPP as the logic model indicates.

However, further evidence suggests that the effects of water infrastructure interventions can depend greatly on the section of the water supply system that is targeted. For example, an analysis of public water systems in Nairobi adopted the conceptual framework of “intra-systemic alignment” and “inter-level alignment” to explore how the complex system dynamics of water provision determine the efficacy and beneficiaries of interventions. At the most basic level, the study considered “upstream” systems that deal with large-scale supply and “downstream” systems that deal with distribution and payment. They suggest that, in Nairobi, the upstream interventions have primarily benefited high-income customers and argue that disbursing the benefits of water system investments equitably requires careful attention to alignment of downstream sub-systems (Blomkvist and Nilsson 2017). This framework may prove to be a useful analytical lens for the pipeline sub-activity in Liberia since it would qualify as an “upstream” intervention with limited investment to improve the downstream distribution network.

The proposed evaluation of the White Plains water pipeline sub-activity will add to the evidence base on the impacts of improving water infrastructure in sub-Saharan Africa. In addition, we hope to provide useful information to guide LWSC management, Liberian policymakers, and donors about future investments in the water sector. In this process, we also hope to identify general lessons for MCC on how to maximize the benefits from water infrastructure investments not only in Liberia but also in other countries.

III. EVALUATION DESIGN

In this chapter, we propose an evaluation design that will enable us to answer the key evaluation questions about the water pipeline sub-activity.

A. Evaluation questions and evaluation approach

In Table 1, we list the evaluation questions, summarize our proposed approach to answering them, and outline the data sources that we will use to address each question. The proposed evaluation includes a performance evaluation to assess implementation and whether the water pipeline sub-activity was able to meet the outcomes as set out in the theory of change, as well as a recalculation of the economic rate of return (ERR) and update of the cost-benefit analysis.

We propose a main data collection round in 2021 to answer the primary evaluation questions (Table 2). This approach aligns with MCC's cost-benefit analysis which assumes that the benefits from the sub-activity accrue immediately following completion of the sub-activity in 2021. In this round, we plan to collect documentation and administrative data, and conduct site visits and key informant interviews (KIIs). The data would help us analyze the sub-activity's implementation, assess the outcomes laid out in the program logic, and re-estimate the ERR. We will produce a final report based on data from this round.

In addition, we propose a final sustainability check in 2025. We will leverage the fact that we will be in country for other MCC evaluations to efficiently assess the maintenance and sustainability of the pipeline sub-activity. This will supplement our final evaluation findings for evaluation questions 2, 3, 4, and 6. These results will be captured in the endline evaluation report for Activities 1 and 2.

Table 1. Overview of evaluation questions, evaluation approach, and data sources

Evaluation questions	Evaluation methodology	Data sources
1. Did implementation of the water pipeline sub-activity go according to plan?	Performance evaluation of the sub-activity's implementation using KIIs, document reviews, and site visits	• KIIs with staff at MCC, MCA-Liberia, LWSC, water treatment plant, MCHPP, Bergstan Africa (pipeline designer), Nicholas O'Dwyer (engineering agency), and Denys (construction contractor). • Documents from LWSC, water treatment plant, Bergstan Africa, and Denys. Documents include work plans, schedules, reports, and media. • Site visit to meet stakeholders, observe implementation and operations.
2. To what extent, if any, has the water pipeline increased the supply of water to the White Plains treatment plant, improved the reliability and quality of water supply, and	Performance evaluation using document reviews, KIIs, and pre-post analysis of administrative data (as available) during the final round and sustainability check	• Reports from MCHPP and the water treatment plant related to water flow and quality. • KIIs with staff at MCA-Liberia, LWSC, water treatment plant, engineers from Nicholas O'Dwyer, and Denys. • Administrative data on water supply and water quality from the treatment plant.

reduced risks associated with salt-water intrusion?		
3. Has the new pipeline design led to a reduction in electricity costs now that water is gravity fed at no cost?	Performance evaluation using document reviews and pre-post analysis of administrative data during the final round and sustainability check	• Administrative data from water treatment plant, LWSC, and MCHPP. We will assess financial data and costs of transporting water to the treatment plant.
4. What is the status of the existing water network? To what extent can it accommodate the increased supply? Will the water pipeline improve the ability of LWSC to meet a growing demand for water?	Performance evaluation using KIIs at during the final round and sustainability check	• KIIs with staff at MCA-Liberia, water treatment plant, LWSC, World Bank, and African Development Bank (AfDB).[1] • Documents from LWSC, World Bank, AfDB.
5. What is the cost-benefit analysis of the pipeline? (Recalculation and justification.)	Re-estimation of the ERR: Analysis of the model, with suggested revisions and justification during the final round	• Administrative data on rate of water transported to the treatment plant, water transportation costs, demand for potable water, water supply costs, treatment plant operational costs, and amount of water billed and payments received.
6. Is the asset being maintained?	Performance evaluation using a document review, KIIs, and administrative data (as available) during the final round and sustainability check	• Reports from LWSC on the implementation of the O&M plan. • Administrative data on maintenance costs. • KIIs with staff at MCA, LWSC, and the water treatment plant.

B. Data sources

We will conduct a performance evaluation to answer overarching questions related to project design, implementation quality, progress, fidelity, and timing of the water pipeline sub-activity, along with deviations from plans and the reasons for modifications. The evaluation's analysis will also address questions related to asset maintenance, sub-activity outcomes, successes and challenges and their causes, and lessons learned that will be important for Liberia and other countries implementing similar projects.

Data for the evaluation will come from project documentation, administrative data, site visits, and KIIs. We will review documents and assess relevant materials such as project designs, work plans, progress reports, monitoring and evaluation reports, media articles, timelines, and schedules to gain a full understanding of the design, implementation, and outcomes of the water pipeline sub-activity, including water flow and quality. Design plans, work plans, and timelines will serve as benchmarks against progress reports to assess implementation progress and quality related to increasing the pipeline's capacity and improving water salinity. We plan to review progress reports from Denys, the implementation contractor, as well as other stakeholder agencies involved in this pipeline work—Bergstan Africa (pipeline designer), MCHPP, White

[1] The World Bank and the African Development Bank have investments in LWSC's water transmission network to support distribution from the White Plains water treatment plant to Monrovia.

Plains water treatment plant, LWSC, and MCA-Liberia. We will begin the document review in early 2021 and continue to collect relevant documentation throughout the evaluation period from 2021 to 2025.

The evaluation will also draw on quantitative administrative data to assess the outcomes related to water flow, pipeline capacity, water quality, and related costs. Administrative data will be requested on a regular basis from the LWSC so that we can assess outcomes for the final report in 2021.. Below is a preliminary list of indicators that we will track in the administrative data.[2]

- **Pipeline capacity**. We will collect data from MCHPP and the water treatment plants on indicators related to water flow to assess if water supply has increased due to the pipeline. We will also assess any variations in water supply, such as seasonal variations, delays, and so on.
- **Water quality**. We aim to use water quality data from the water treatment plant, including measures related to water salinity, sediment, and other impurity levels, to assess if the pipeline reduced salt-water intrusion and improved water quality.
- **Customer consumption**. We will assess aggregated customer data over time to track the number of LWSC customers and understand growth in water consumption.
- **Costs.** We will try to collect data from administrative records at the water treatment plant and LWSC on the costs of transporting water to the plant, treating raw water, and supplying water to Monrovia.

We visited the site to observe the pipeline's construction in November 2019, and we plan to visit again when the pipeline is completed in 2021 and to observe the maintenance and sustainability of the sub-activity in the post-compact period. The site visits will expand our understanding of on-site challenges that cannot be fully captured or conceptualized without an in-person presence. Our next visit will provide an opportunity to ask more in-depth questions and to deepen our understanding of the water pipeline sub-activity outcomes such as water flow, quality, and utility operating costs. We envision visiting the pipeline construction sites, the offices of MCHPP, the water treatment plant, and LWSC. During the site visits, we will ask key stakeholders to walk us through key features of the pipeline's implementation. We will schedule site visits to coincide with KIIs.

We will use the KIIs to collect targeted information on implementation and maintenance to further inform our analysis. We have already had interactions with key stakeholders at MCC and MCA-Liberia and will continue to work with these stakeholders to identify relevant information. We also anticipate interviewing staff from the water treatment plant, LWSC, Bergstan Africa, Denys, and MCHPP. The qualitative interviews with pipeline engineers will assess the extent to which the pipeline was able to increase water flow and improve water quality. We had preliminary discussions with stakeholders in November 2019 and aim to conduct interviews in 2021 and during the sustainability check in 2024. KIIs will also gather respondents' perceptions

[2] We have requested LWSC to provide data on a list of indicators (shown in the Appendix). LWSC has yet to confirm whether data on these indicators are available and can be shared with us.

of the existing water infrastructure, especially related to (1) its ability to increase water provision in and around Monrovia as a result of the increased supply to the treatment plant through the water pipeline, and (2) the challenges of operating and maintaining the pipeline given LWSC's financial constraints.

C. Analysis plan

We will answer the evaluation questions by integrating and triangulating findings from the various data sources. For the document review, we will systematically organize, screen, and categorize materials by source and topic to better understand how the documents relate to water pipeline implementation and outcomes. This will also enable us to identify relevant themes that emerge from the materials. We will review new documents as they become available to track implementation and monitor developments related to the sub-activity.

We will use administrative data to investigate how the pipeline may have influenced water supply, reliability, quality, and other outcomes. We will analyze trends in key outcomes by examining monthly or yearly measures related to raw water transported, various measures of costs, and amount of potable water supplied and billed. For example, we plan to track LWSC's water supply in and around Monrovia over time, LWSC's customer base, and the cost of supplying water. Once we have preliminary results, we will seek feedback from key stakeholders, including possible explanations for detected trends and inflection points.

Finally, we will analyze data from the site visits and KIIs to acquire stakeholders' perspectives on the water pipeline implementation, the pipeline's effects in terms of reducing salt-water intrusion into the treatment plant, and the existing water supply infrastructure's ability to absorb increased water from the treatment plant and serve additional customers. We will analyze data from the KIIs to understand the respondents' perspectives, identify new information, confirm patterns or findings, and detect divergent experiences. For analyzing the qualitative data, we will develop a detailed coding strategy that aligns with the evaluation questions and conduct a thorough content analysis of the transcripts. We will use NVivo or similar qualitative data analysis software to code the transcripts, and then we will review and organize resulting codes into themes that are present across multiple respondents. We will identify consistent and differing themes across respondents. Finally, we will use these emerging themes to compare findings against other data sources, noting commonalities and discrepancies for further inquiry.

Once we have analyzed each data source, we will triangulate findings to identify trends and relationships, confirm patterns or findings, and detect discrepancies or disparate experiences.

D. Cost-benefit analysis

MCC has conducted a cost-benefit analysis to estimate the ex-ante ERR for the water pipeline sub-activity. As part of the evaluation, we will update the ERR estimate using data collected for the evaluation, and we will prepare the ex-post ERR in 2021, immediately after the end of the water pipeline sub-activity. Below, we describe MCC's ex-ante ERR model, including the ERR model components and critical assumptions. We include a short discussion of our proposed approach for updating the ERR.

ERR model and assumptions

The primary beneficiaries of the water pipeline sub-activity are the LWSC customers in and around Monrovia, who are expected to receive adequate and more reliable water given increased supply to the treatment plant. The benefit is calculated as the value of increased consumption of 11.48 million cubic meters of water per year, which is more than double the baseline level of consumption estimated in the ERR model.[3] This is the primary source of benefits from the construction of the new pipeline and the model. The model assumes that the current LWSC water distribution infrastructure has the capacity to transmit the increased volume of water from the White Plains treatment plant to the end users (albeit at a higher cost due to the need to increase the strength of the supply flow), and that there will be sufficient demand the year after the pipeline construction is completed to absorb the additional water available.

The ERR model's cost of water provision to Monrovia from Mt. Coffee includes costs of transporting water to the White Plains water treatment plant, treating raw water at the plant, transporting water from the treatment plant to Monrovia, and supplying water to consumers in Monrovia.

The net benefits of the pipeline sub-activity are calculated by comparing the total benefits and costs with and without the pipeline. The net benefits are calculated for a 20-year period, as is customary for MCC investments. The resultant ex-ante ERR was estimated at 16.93 percent, which is higher than the 10 percent threshold MCC uses for making investment decisions.

The pre-program ERR depends on several other assumptions. First, the ERR assumes that the consumer willingness to pay used in the model captures the true valuation for water consumption by Liberian consumers. The benefit calculation relies on the willingness to pay figures derived from the Ayslbat et al. (2013) study on willingness to pay for water in sub-Saharan Africa and LWSC's tariff rates in 2018. Second, the ERR calculations estimate that the larger pipeline will increase LWSC's water supply capacity from 5.52 million cubic meters to 17 million cubic meters in the first year after the pipeline sub-activity is completed (completion is expected to occur in the fifth year of the compact). Third, the model assumes that LWSC will be paid for 70 percent of the water supplied to Monrovia, with the remaining water lost to leaks or theft. Note that this estimate is based on experiences from Lusaka, Zambia, where only 50 percent of water is paid for by customers. Fourth, the model assumes that the cost of supplying water from the water treatment plant to consumers in Monrovia would double from the current U.S. $0.04 to $0.08 per cubic meter of water supplied because the strength of water flow will have to increase to supply more water with the current infrastructure. Our evaluation will try to assess the validity of these assumptions, and we will update these assumptions based on data gathered for the evaluation.

[3] The increased amount of water consumed is valued using a consumer surplus approach relying on the willingness to pay estimate from Ayslbat et al. (2013), and the estimated service costs for supplying water in Monrovia.

Recalculating ERR

The proposed implementation analysis and performance evaluation will enable us to assess the main assumptions underlying the ERR model for the water pipeline sub-activity. Our approach to updating the ERR calculations will involve revising the cost and benefit estimates and the assumptions, to the extent updated data are available. Based on the planned evaluation, we expected to be able to update the following parameters of the ERR model: cost of treating raw water, the amount of water supplied to consumers in Monrovia, growth in water demand, cost of supplying water from the White Plains water treatment plant to Monrovia, and service costs (or tariffs).

E. Report timeline

Table 2 shows the schedule we envision for data collection, analysis, and report submission, based on the sub-activity's implementation and the proposed data collection timeline. We will produce a report for the final round in September 2021. Instead of a standalone report for the sustainability check, we will incorporate this round's findings into the final evaluation report of Activities 1 and 2 of the compact, which received the bulk of funding for the compact. We expect to deliver this report in January 2025.

Table 2. Data collection, analysis, and report submission timeline

Data collection round	Timing of data collection	Data analysis	First draft report expected	Final draft report expected
Final	January–April 2021 (Documentation collection and qualitative activities)	May–June 2021	July 2021	September 2021
Sustainability check	January–April 2024 (Documentation collection and qualitative activities)	May–June 2024	July 2024	January 2025

IV. CHALLENGES AND MITIGATION STRATEGY

We anticipate challenges related to the availability and quality of administrative data, changes to project design, delays, and implementation constraints. As we identify the potential challenges for the proposed evaluation, we discuss potential mitigation strategies and we do not expect any challenges to pose an insurmountable barrier for the evaluation.

Administrative data quality and availability. The evaluation team may face issues with data access and data availability from the entities involved in the water pipeline sub-activity. To address this challenge, our evaluation team will work closely with MCC and MCA-Liberia to build rapport with other key stakeholders. When possible, we will also travel to Liberia as necessary to meet with stakeholders in person to obtain data and documents that are easier to obtain in country. We will ensure a good working relationship with stakeholders, which will help us make data requests that are practical and can be efficiently carried out, especially as administrative data are needed post-compact. The evaluation will also depend upon the availability of reliable administrative data on indicators such as water flow, water quality, operational efficiency, and financial health. It is possible that administrative data on these indicators may be incomplete or of insufficient quality to address these evaluation questions, particularly given that staff can go months without payment and there is not a strong data collection, storage, and usage culture in Liberia. Note that we have already made a formal request for data. We recognize that the potential lack of availability and poor quality of administrative data can pose a challenge to this evaluation. We will mitigate this risk by supplementing administrative data with interviews from key stakeholders and other implementation documents.

Reluctance of respondents to share information about sensitive aspects of project implementation. The performance evaluation also relies on interviews with key informants who may hesitate to talk about some aspects of the sub-activity, especially around design, implementation, and maintenance. We will mitigate this risk by ensuring the confidentiality of the KIIs and making sure respondents are aware of data safeguards. Senior members of the Mathematica research team will conduct these interviews.

Changes to the water pipeline design and implementation timeline. The stability of the water pipeline design and implementation plan is important for our proposed evaluation design and data collection activities. To mitigate the effect on the evaluation of potential changes to project design and implementation delays, we will document any substantive modifications to water pipeline design and implementation plans, reframe questions in our qualitative interview guides, and incorporate those findings into our analysis.

The current global pandemic, COVID-19. The COVID-19 pandemic has disrupted travel and workplans for many international projects. We recognize that it may still not be possible for our staff to travel in 2021 to conduct site visits and KIIs due to the pandemic. Mathematica is currently adjusting workplans on our ongoing projects to adapt to this situation and we will draw on that experience to move to remote data collection or subcontract a local data collection firm to conduct interviews and site visits, if necessary. We will work closely with MCC to monitor the COVID-19 situation in Liberia and will decide on these alternative approaches together. If we engage local data collectors to conduct the site visits and interviews for us, our team would prepare detailed interview and data collection guides, conduct virtual training, and oversee the quality of data collection using techniques such as remotely participating in on-ground interviews, daily check-ins with consultants, and ongoing review of audio files and pictures from the site visits.

IV. ADMINISTRATIVE

A. Summary of Institutional Review Board (IRB) requirements and clearances

Mathematica is committed to protecting the rights and welfare of human subjects by obtaining approval from an IRB for relevant research and data collection activities. IRB approval requires three sets of documents. The first document is a research protocol, in which we (1) describe the purpose and design of the research, and (2) provide information about our plans for protecting study participants—including their confidentiality and human rights—and how we will acquire consent for their participation. The second document is copies of all data collection instruments and consent forms that we plan to use for the evaluation. The third document is a completed IRB questionnaire that provides information about the research protocol, how we will securely collect and store our data, our plans for protecting participants' rights, and any possible threats to participants resulting from any compromise of data confidentiality. We anticipate the IRB review of this study to qualify for expedited review because it presents minimal risk to participants. IRB approval is valid for one year; we will submit annual renewals for approvals for subsequent years as needed.

We will also ensure that the study meets all U.S. and local research standards for ethical clearance, including submitting our study for approval by Liberia's ethical review committee. We will coordinate with our consultant and data collection partner to submit to the required local agency the full list of required materials, including a description of the methodology, the instruments and enumerator manuals, a community awareness plan, the timeline, the budget, and a dissemination plan.

B. Data access, privacy, and file preparation

Mathematica will ensure confidentiality of all respondents, including confidentiality of participating in the data collection, confidentiality of personally identifiable information, and other sensitive data. For the primary qualitative data to be collected under this evaluation, the Mathematica team will ensure the safe handling and transfer of electronic files and ensure that they are stored on Mathematica's secure server. Data files will be accessible only to project team members who clean or analyze the data. If needed, electronic data files will only be shared among team members using a secure file transfer system, such as a file transfer protocol, file exchange website (FX site), or a SharePoint site. All files with sensitive information, including those for secondary data analyses and document review, will be stored in a designated encrypted project folder, which is secured with AES 256-bit encryption.

After producing and finalizing the reports, we will prepare corresponding users' manuals, and codebooks for the qualitative data according to the most recent guidelines set forth by MCC. We will work with MCC's Disclosure Review Board to find a mutually agreeable solution regarding the necessity and potential to create public use data files for transcripts of our KIIs. Public use data files will be free of personal or geographic identifiers that would enable unassisted identification of individual respondents and we will remove or adjust data that introduce reasonable risks of deductive disclosure of the identity of individual participants.

C. Evaluation team roles and responsibilities

Our team will contribute our extensive experience and expertise to meet MCC's evaluation needs. Program manager **Dr. Candace Miller** will be responsible for managing the team and delivering high quality products to MCC. **Ms. Poonam Ravindranath, Ms. Kristine Bos,** and **Mr. Matt Spitzer** will support the collection of high quality data and analysis. **Mr. Jeremy Page** will oversee the collection and analysis of administrative data. **Dr. Arif Mamun** will provide quality assurance on all deliverables.

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APPENDIX

List of indicators requested from LWSC

- Pipeline capacity of the rehabilitated pipeline from Mt. Coffee to the water treatment plant
  - Capacity of the rehabilitated pipeline
  - Amount of water flowing through the rehabilitated pipeline
  - Outages in the water flow through the rehabilitated pipeline

- Water quality
  - Turbidity of the water flow through the rehabilitated pipeline
  - Salinity of the water flow through the rehabilitated pipeline
  - Turbidity of the water flow from the treatment plant to Monrovia service areas
  - Salinity of the water flow from the treatment plant to Monrovia service areas

- Customer consumption (in Monrovia)
  - Capacity of LWSC transmission and distribution network
  - Water production at the treatment plant after treatment
  - Continuity of service
  - Total water consumption
  - Residential water consumption
  - Commercial/industrial water consumption
  - Institutional and other water consumption
  - Total number of customers
  - Number of residential customers
  - Number of commercial/industrial customers
  - Number of institutional and other customers
  - Metering level

- Revenue and costs of supplying water (in Monrovia)
  - Unit operational cost for water
  - Operational cost of water supply to the treatment plant (include all costs)
  - Operational cost of water treatment at the treatment plant (include all costs)
  - Operational cost of water supply to Monrovia (include all costs)
  - Operational cost of water provision to Monrovia customers (service costs/tariffs)
  - Electrical energy costs of transporting water to the treatment plant
  - Electrical energy costs of treating raw pipeline water at treatment plant
  - Maintenance costs of the rehabilitated pipeline
  - Non-revenue water
  - Total water revenue
  - Residential water revenue
  - Commercial/industrial water revenue

    - Institutional and other water revenue

- Collection ratio

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