Upscaling Lowland Rice Production to Improve Food Security through Improved Solar Powered Irrigation Practices

AFCIA 2021000017

Implementation Report for the Small-scale Pilot of a Solar Pumping Irrigation System in Bong County (Output 4)

Prepared for:

Climate Technology Centre & Network (CTCN), MoA & EPA

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Upscaling Lowland Rice Production to Improve Food Security through Improved Solar Powered Irrigation Practices

Output 4 Deliverable Report

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Acronyms and Abbreviations

AfDB	African Development Bank
AIICO	Agriculture Infrastructure Investment Company
AWD	Alternate Wetting and Drying
CAC	County Agriculture Coordinator
CAO	County Agriculture Officer
CARI	Competitive African Rice Initiative
CHAP	Community of Hope Agriculture Project
CTCN	Climate Technology Centre and Network
DAO	District Agriculture Officer
DOA	Department of Agriculture
EIA	Environmental Impact Assessment
EPA	The Environmental Protection Agency of Liberia
FAO	Food and Agriculture Organization of the United Nations
FDMC	Fuamah District Multipurpose Co-operative
FED	Food and Enterprise Development Programme
FUN	Farmer Union Network
GAP	Good Agricultural Practices
GIS	Geographic Information System
LIGIS	Liberia Institute of Geo-Information Services
M&E	Monitoring and Evaluation
MoA	Ministry of Agriculture
NDE	National Designated Entity
NGO	Non-Governmental Organisation
PV	Photovoltaic
RAC	Region Agriculture Coordinator
SPIS	Solar Powered Irrigation Systems
SRI	System of Rice Intensification
SWG	Stakeholder Working Group
TA	Technical Assistance
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization (UNIDO)
USAID	United States Agency for International Development
WAAPP	West Africa Agricultural Productivity Program
WARDA	West Africa Rice Development Association
WUA	Water User Association

1 EXECUTIVE SUMMARY

1.1 Background and Objectives of this Report

This report provides an update on work conducted under the Technical Assistance (TA), to introduce Solar Powered Irrigation Systems (SPIS) and a System of Rice Intensification (SRI) to increase rice production in one lowland county in Liberia (Output 4). This covers activities for the implementation of a small-scale pilot solar pumping system in the selected county of Bong County, including:

- Reporting on the visits to site to the pilot area, with pictures, participants and conclusions
- Details of the plans for implementation, including the procurement process, tender evaluation and logistics for construction
- Minutes of discussions with stakeholders throughout the implementation, including revisions to the implementation plans and designs.
- Reporting on the construction works with pictures.

1.2 Pilot Scheme Site Selection

A site for the pilot SPIS scheme was chosen in the selected county of Bong County, following assessment of sites across Lofa and Bong counties against a range of criteria, including:

- Availability of suitable water sources, either:
  - Surface water (river and dam/reservoir)
  - Groundwater (borehole or shallow water-table)
- Existing lowland rice cultivated areas (~10ha)
- Suitable soil types and adequate drainage
- Community interest/motivation
- Labour availability and organisation
- No land ownership issues
- Located near milling facilities and markets
- Good site access from Monrovia and other counties.

Whilst there was no clear favourite, the site assessments were presented to the Stakeholder Working Group Meeting (SWG) on 30th May 2022 and it was agreed to move forward with implementation at the site at Bong Mines A for the pilot scheme, despite some shortcomings regarding water resources and soils. A number of consultation meetings were undertaken with the farmers of the Fuamah District Multipurpose Cooperative (FDMC) to ensure they were fully engaged in the scheme.

Originally targeted for an area of 7.5 ha, the pilot scheme was adjusted down to 5 ha to suit the available budget.

1.3 Implementation Planning

Based on the desk studies and data collected from the proposed site, the Team developed an outline design and procurement plan to implement the pilot project. This design specified the

power and pumping system requirements and the irrigation infrastructure. In addition, the Team outlined the agricultural activities that would be required to initiate rice production, following the intended System of Rice Intensification (SRI). The Team proposed a procurement process, to request proposals from international suppliers and local suppliers/contractors for both the supply and installation of the SPIS equipment at Bong Mines. This was agreed at a meeting with the SWG in November 2022.

1.4 Consultations

Various stakeholder meetings were held during the implementation planning process and concerns raised were incorporated into the designs.

To minimise the cost of implementation and increase the farmers' ownership and commitment to the pilot scheme, it was planned that the community benefitting from the scheme would contribute labour for the construction and security for the equipment. Initially, it had been targeted to have the pilot scheme operating for the first crop during the 2022/2023 dry-season. However, due to contract negotiations and a change in the FDMC leadership, the start of implementation was delayed until a Memorandum of Understanding (MoU) was signed in May 2023, which initiated the implementation work to begin in earnest.

1.5 Procurement

A tender notice was issued to a shortlist of supplier/contractors in October 2022, providing them with the background to the project and instructions for bidding, including the eligibility criteria and an outline bill of quantities. After the deadline for submission of the bids, the Team had received eight offers, which were evaluated to check the tender had been completed correctly, as well as a technical review of the proposals and financial evaluation of the price offered. By ranking the evaluation scores, the preferred bidder was determined as Nation Innovation Systems (NIS) Company from Liberia, who was subsequently called for contract negotiations, to clarify issues raised during the tender evaluation process and negotiate terms of the contract.

1.6 Construction and Commissioning

A contract with NIS was signed on 6th February 2023, but as noted earlier, the finalisation of the design and a change in the FDMC leadership delayed the start of construction until the MoU was signed in May 2023.

Under the supervision of the Team Leader and other experts, the pilot SPIS was installed at Bong Mines following a detailed topographic survey of the entire site and further investigations at the pond. Options for locating the pump were discussed and it was agreed to mount directly in the pond, since other options were expensive or difficult to construct and the level of silt was determined to be insignificant. Based on the topographic survey, the scheme layout was also adjusted to maximise the command of fields suitable for rice production, whilst minimising the need for land levelling. The PV panel support structure was constructed to also provide security fencing and shelter.

As agreed in the MoU, the farmers from the community provided the labour for site clearing and digging of the pipe trenches. The Contractor's technician undertook the pipe laying and jointing, while the pump was installed horizontally on a concrete base, on metal supports, then moved into position in the pond. Once the pump was connected to the supply pipeline, the trenches were backfilled and compacted together with the cabling between the inverter and pump.

Commissioning was delayed due to the unavailability of the control valves to be installed along the pipelines. A defects list from the site inspections identifies areas where the work is incomplete or does not meet the required standards or specifications, and these will be addressed by the contractor during the Defects Liability Period to the satisfaction of the Team and the farmers.

The Contractor is also to provide records of the completion of the construction works, some of which are included in the appendices to this report, but all will be incorporated into the next deliverable, Bong Mines Pilot Scheme - Operation & Maintenance Manual (Output 5).

1.7 Conclusions and Recommendations

An Operation and Maintenance (O&M) Manual and training materials based on the scheme implementation will be further developed in the next deliverable (Output 5) and the key messages presented again to farmers, stakeholders, and officials in future workshops.

Lessons learned from the pilot scheme implementation will help formulate an enabling environment roadmap to scale up the SPIS technology across Liberia and an M&E framework will be developed by the Team (Output 6) for the future Monitoring and Evaluation (M&E) of the scheme's performance by the farmers, MoA and EPA.

2 INTRODUCTION

2.1 Background

Agriculture is a major sector of Liberia employing more than 70% of the population. However, Liberia's agriculture system is predominantly rain-fed, with heavy dependence on consistent rainfall, and climate change is posing serious challenges to all sectors and is threatening the sustainability of agricultural production. This is happening prior to Liberia recovering from 14 years of civil conflict, global recession, Ebola, and now the COVID-19 pandemic.

In response, the adoption of Solar Powered Irrigation Systems (SPIS) and a System of Rice Intensification (SRI) is being investigated to increase rice yields whilst lowering water usage. Potential benefits of adopting this irrigation technology includes guaranteeing yields in an increasingly dry climate, where there is a lack of natural soil moisture, and reducing energy consumption as a climate change mitigation; whilst also reducing water consumption and avoiding the production of CO_2 and pollution from fossil fuel driven pumps.

2.2 Objectives and Scope of this Report

Against this background, the objective of the Technical Assistance (TA) is to introduce SPIS technology and SRI practices to increase rice production in one lowland county in Liberia (Selected as Bong County), with the intention of later upscaling at a national level. To achieve this, the TA is divided into six outcomes, as follows:

Outcome 1: Analyse the current irrigation and rice cultivation practices in one county of Liberia.
Outcome 2: Design appropriate irrigation and solar water pumping technologies for SRI based farming in the selected county.
Outcome 3: Select an appropriate SPIS technology.
Outcome 4: Pilot a small-scale implementation of the solar pumping system in the selected county.
Outcome 5: Elaborate and disseminate training materials and workshops.
Outcome 6: Formulate an enabling environment roadmap and a M&E framework.

This report provides an update on work conducted to provide Outcome 4, covering five activities, as follows:

Activity 4.1: Choose a plot in the selected county for a small-scale pilot implementation of the selected SPIS.
Activity 4.2: Plan the implementation of the pilot project.
Activity 4.3: Organize an online meeting to discuss the logistics and implementation of the pilot.
Activity 4.4: Route the technology to the selected area.
Activity 4.5: Implement the small-scale project in the pilot area.

3 SITE SELECTION

Eight sites were visited during the site selection exercise as shown in Figure 1 below, including Bong Mines A, Bong Mines B, Gbarnga, Sergeant Kollie Town, Suakoko, Balama, Fietua and Palala.

The criteria used for site selection included:

- Availability of suitable water sources, either:
  - Surface water (river and dam/reservoir)
  - Groundwater (borehole or shallow water-table)
- Existing lowland rice cultivated areas (~10ha)
- Suitable soil types and adequate drainage
- Community interest/motivation
- Labour availability and organisation
- No land ownership issues.
- Located near milling facilities and markets.
- Good site access from Monrovia and other counties.

Based on the field visits and data collected by the Team, three sites were discounted at an early stage due to lack of water resources (i.e. Gbarnga, Suakoko and Fietua), while the remaining sites were assessed according to these selection criteria. This assessment was presented to and agreed at a meeting of the Stakeholder Working Group (SWG) at the end of May 2022, as shown in Figure 1 and Table 1. Whilst there was no clear favourite, it was agreed to progress with the site at Bong Mines A for the pilot scheme, despite shortcomings regarding water resources and soils.

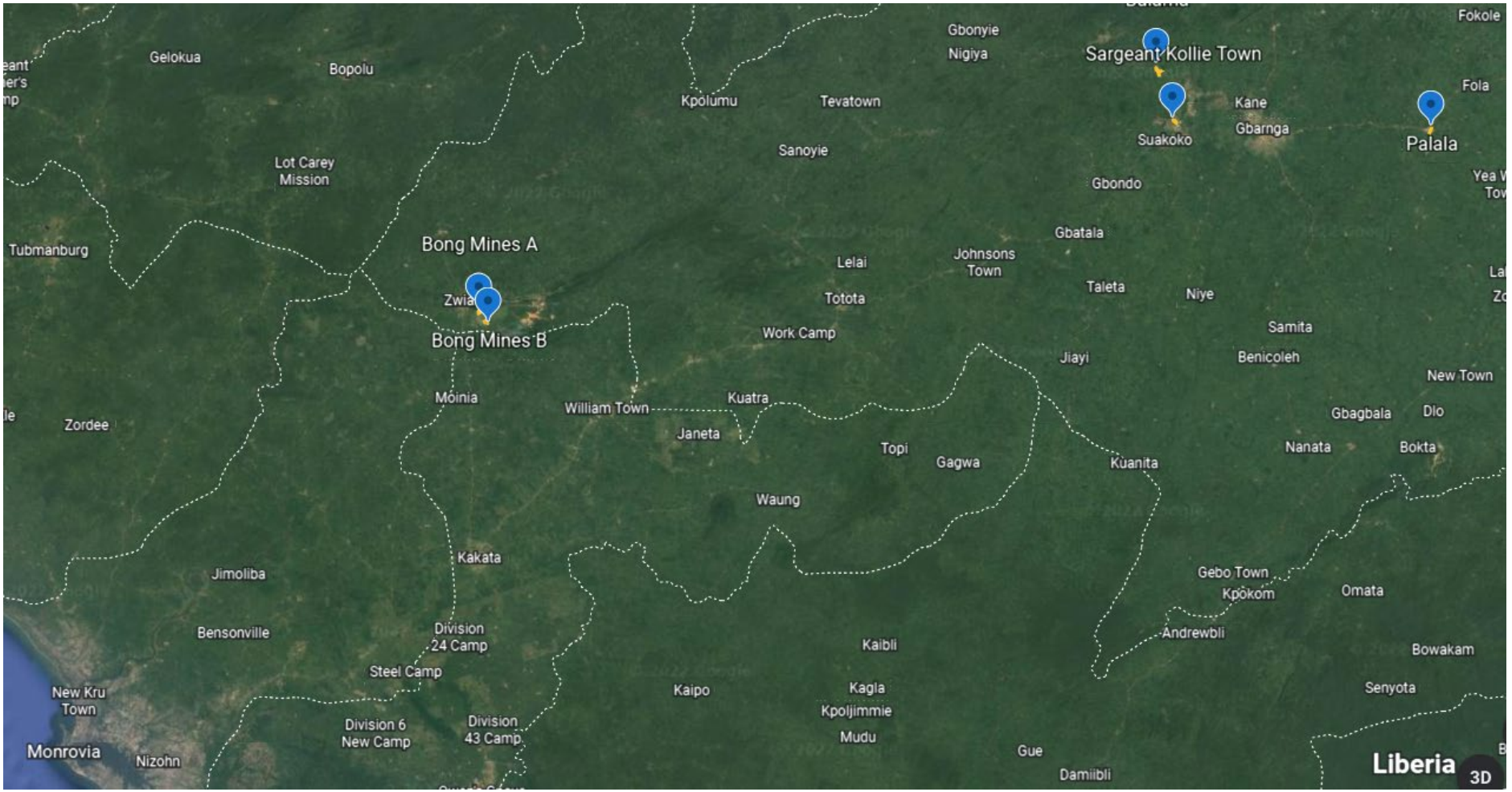

Figure 1: Pilot Scheme Selection: Bong Mines A and B, Sergeant Kollie Town, Suakoko, and Palala

Table 1: Site Selection Matrix

Criteria	Site					Comments/Justification for scoring
	Palala	Balama	SKT	Bong Mines A	Bong Mines B	
Availability of suitable water sources:						
• Surface water; river and existing storage (dam/reservoir)	1	2	3	3	4	Bong Mines - Most significant available surface water resources SKT - Dam used by CARI and AfricaRice project Palala - Unknown water source, not visible
• Groundwater	1	2	2	1	1	Bong Mines - Limited groundwater availability SKT potential for shallow well Balama & Palala - Unknown
Existing lowland rice cultivated areas, with potential for increased yields, cropping intensity and/or diversity of crops (i.e. areas out of command for gravity fed irrigation) ~10ha	3	3	4	4	4	Bong Mines - Existing rainfed rice growing area, vegetables in the dry season SKT - Lowland area growing rainfed rice Palala & Balama - Lowland areas, long thin sites
Suitable soil types (i.e. limited iron toxicity) and adequate drainage	3	3	3	2	2	SKT, Palala, Balama - Silt deposits, unknown characteristics Bong Mines - Silty soils, low water holding capacity, potential toxicity
Community interest/motivation in new technologies and cultural practices	1	3	2	3	3	Bong Mines - Significant membership and enthusiasm, FAO training in SRI Balama & SKT - Enthusiastic chairman, limited membership, poor JICA trials Palala - Little enthusiasm shown by chairman
Labour availability and organisation, particularly for equipment security	2	3	2	3	3	SKT predominantly women members, adjacent buildings for storage Palala - Larger group, but details unknown Balama - Pump would be located next to busy road
No land ownership issues	3	4	3	4	2	SKT land granted to co-operative, adjacent to CARI/AfricaRice project to 2023 Palala - Unknown, but assumed granted to the co-operative Bong Mines - Land owned by Dr Suba
Location with respect to milling facilities and markets for inputs (i.e. seeds and agro-chemicals) and produce	3	3	4	4	4	SKT close to Gbarnga, JICA, AfricaRice and CARI facilities Palala - Further away from Gbarnga Bong Mines closely located to Monrovia
Good site access from Monrovia and other parts of the country for construction logistics, demonstration workshop or meetings etc	3	3	4	4	3	SKT simplest and cheapest SPIS system, close to research facilities as demo Bong Mines Site B more costly to install system than Site A due to longer pipe delivery
Total	**20**	**26**	**27**	**28**	**26**	

The pilot project selected for implementation at Bong Mines Site A is summarised below and shown in Figure 2:

- Size: 400 x 200 m, 7.5 ha
- Membership: Part of the Fuamah District Multipurpose Cooperative, Dam 3A and 3B areas
- Water source: Limited surface water resources, available throughout the dry season.
- Soils have high organic content in top surface, predominantly silt/sand with low water holding capacity.
- Pumping distance ~125m.

Figure 2: Selected Bong Mines Site A

The final selected site was presented to the Stakeholder Working Group Meeting (SWG) on 30th May 2022 and agreed to move forward to the next implementation stage.

4 IMPLEMENTATION PLANNING

4.1 Outline Design

Based on the site selection, desk studies and data collected from the proposed site, Figure 3 shows the outline layout design for the selected Bong Mines A site located in Bong County, Liberia, which was developed for tender.

High-Density Polyethylene (HDPE) pipes were initially considered, with 200mm diameter Supply Pipeline (SP) feeding two lateral 150mm diameter Irrigation Pipelines (IPs). The HDPE pipelines were intended to be laid on the ground to give the farmers flexibility to move the alignments according to their requirements. Outlets would be fitted to the IPs to deliver water into a number of field Irrigation Canals (ICs), comprising earth canals that would be excavated by the farmers themselves. It was intended that the ICs deliver water to plots lying either left or right of the outlet, depending on the topography, but following the existing field layout, as developed by previous irrigation developers and the farmers. The plots would drain into Field Drains (FDs) which would discharge into the Secondary Drains (SDs), also to be excavated by the farmers. These drains were existing from previous irrigation developments in the area, but had been poorly maintained.

The SP would be connected to the IPs with a Tee fitting and gate valves would be used to regulate flow into each IP.

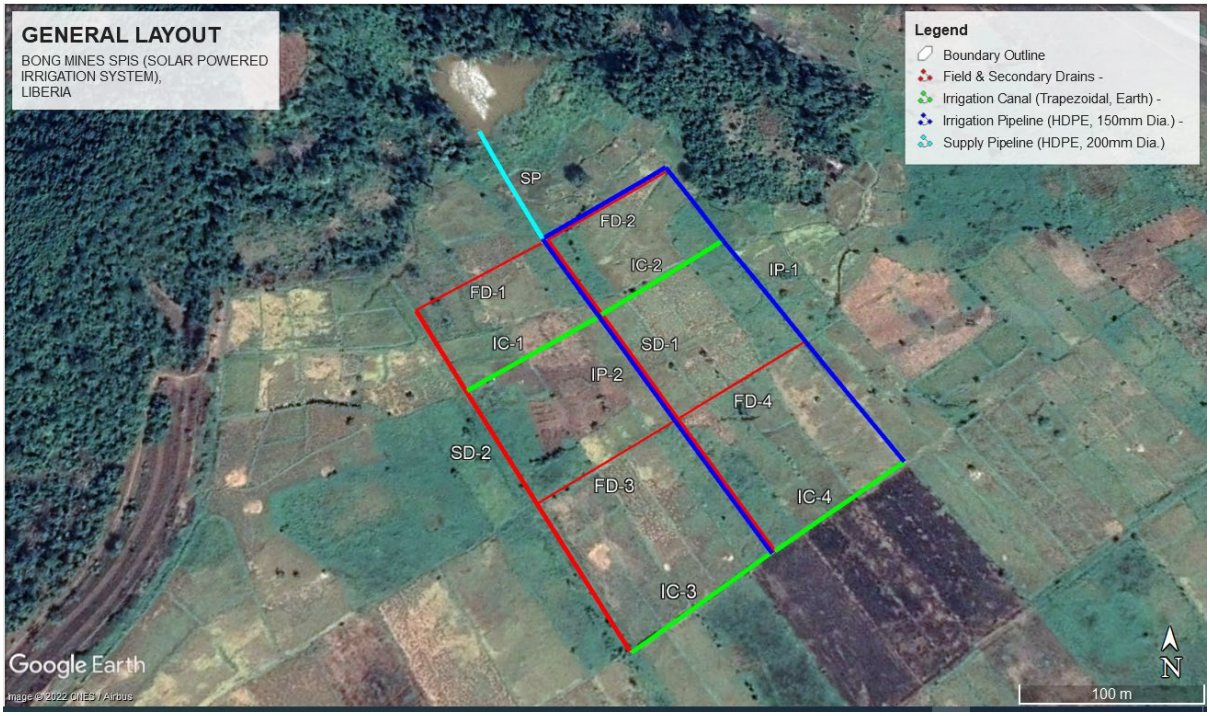

Figure 3: Outline Design of Bong Mines Site A

Below is a summary of the designs and specifications used in the tender for supply and installation of SPIS pilot project in Bong County, Liberia. The full Tender Notice is included as Appendix A.

4.1.1 Pumping System Specification

A simple direct pumping system is to be supplied where a submersible pump is used to pump water from the pond to the irrigated area. No water storage facilities are foreseen. The table below provides an overview of data used in the design of the proposed system:

Table 2: data used in the design of the proposed system

Parameter	Sizing	Comments
Designed water supply	560 m^3/day	Considering the daily max 70 m^3/ha/day water requirement over an area of approx. 8 ha
Pump type	4 kW	Submersible pump
Total dynamic water head	~5m	2-3 m depth of the pond + 1-2 seasonal variation in water level
Pump mounting	-	It is suggested to secure the pump at a reasonable location in the pond and protect it from damage (sediments, etc.) and theft. If required, a shallow well is to be dug to collect filtered water and the pump shall be mounted in this well.
PV size	8 kW	Exact size can vary depending on the rating of individual modules (e.g., 450 W x 12 = 5.4 kW). It is recommended to use module sizes of 350 W or above for achieving higher efficiency levels.
PV mounting	-	The substructure made of aluminium or hot dip galvanized steel is recommended to support the modules and withstand the local weather conditions. It must be sufficiently protected against corrosion for 20 years. Special anti-theft bolts and nuts to match the modules. Provision for earthing.
Controller	-	Depends on the pump model to be supplied.
Piping type	~700m	150-200mm diameter HDPE/uPVC pipe, fittings and valves
Fencing	14' x 48'	It is highly recommended to build a secure fencing for the areas covering the pump and the PV panels, however this is not possible within the limited budget available.

4.1.2 Irrigation Infrastructure

The irrigation system comprises supply and distribution pipework, supplying water through two laterals and irrigation field canals, as summarized in the table below.

Table 3: Summary of Irrigation Infrastructure

Component	Quantity
Irrigation Infrastructure	
200mm dia. Supply Pipeline (From Pump to Irrigation Distribution) PE PN6	92 m
150mm dia. Irrigation Pipelines (Distributing to Earth Canals) PE PN6	622 m
Elbows, Tees, End caps, Valves, etc	1
Irrigation canal excavation	400
Drainage excavation	912
Miscellaneous	
Transport and logistics	
Civil & earth works (To be provided by community contribution)	
Installation, testing and commissioning	

The Team also produced an Engineer's Estimate for the cost of the pilot scheme, to ensure that it could be implemented for the available budget.

4.2 Rice Cultivation Activities and Inputs

A number of activities must be undertaken, following the intended System of Rice Intensification (SRI) good agricultural practices, before rice cultivation can take place. These are illustrated in Figure 4 and will be elaborated in the next report and materials prepared for Output 5 of the TA (Bong Mines Pilot Scheme - Operation & Maintenance Manual); this will be disseminated to the farmers, citizens of Bong County and Municipal/National officers through training materials and workshops.

At the time of initial planning for the pilot scheme implementation, it was targeted to have the pilot scheme operating for the first crop during the 2022/2023 dry-season, as shown in Figure 4. However, due to issues relating to the community's contribution (See Section 4.3), the start of implementation was delayed.

The Team also identified the agricultural inputs and tools required for the first season of rice production (See Table 2). Requirement of some inputs are based on local availability (e.g. organic manure) and some need based. There are two ways of raising nursery seedlings; by using nursery trays or raising nursery in the field by spreading poly sheets. Provision of these inputs was not budgeted in the Response Plan or the Consultant's proposal, but the Team made efforts to find donors able to provide to the scheme. The Team met with various stakeholders, private sector and organisations to secure the provision of some of these inputs, including rice seed from AfricaRice (Courtesy of Dr Akintayo) and organic manure from Bangladesh Rehabilitation Assistance Committee (BRAC), while the Cono Weeder and Leaf Colour Charts (LCCs) will be provided under the TA. The remaining inputs will need to be provided by the farmers' co-operative and/or the MoA.

Table 4: Summary of Seasonal Agricultural Input Requirements

Sl.No	Input Requirements (5 ha)	Quantity
1	Nerica L19	200 kg
2	Nursery trays	Need based
3	Organic manure	Based on availability
4	Urea	22 bags
5	DAP	12 bags
6	MOP	8 bags
7	Herbicides:	
	Butachlor	12-13 litres
	Bisbyripac sodium	2.5 litres
8	Pesticides	
	Emamectin Benzoate	2.5 - 3 litres
	Tebuconazole	2.5-3 litres
	Carbendazim/Mancozeb (seed treatment)	0.5 kg
9	Cono weeders	2 No.
10	LCC scales	2 No.

Activities	January				February				March				April				May				June	
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2
Land preparation 1	X	X																				
Application of organic manure			X																			
Land preparation 2			X																			
Application of full dose of P			X																			
Levelling				X																		
Nursery preparation				X	X																	
Planting						X	X															
Gap filling								X	X													
Need based N as per LCC											X		X			X						
Application of Potash											X					X						
Mid season drainage											X	X										
Weeding by Cono weeder										X	X	X	X									
Pest and Diseases Management										X			X									
Bird scaring																		X	X	X	X	
Pre harvest operations																			X	X		
Harvest																					X	X

Figure 4: Agronomic Practices for Rice Cultivation

4.3 Community Contribution

To minimise the cost of implementation and increase the farmers' ownership and commitment to the pilot scheme, it was agreed that the community benefitting from the scheme should contribute labour and tools during the construction period. The community's contribution was estimated to require approximately 240 man-days of labour to complete the clearing and excavation of pipeline trenches (excluding land preparations, which were considered part of the normal operations of the scheme).

Since the pilot scheme site is somewhat secluded and distant from the nearest habitation, the community would also need to agree to the provision of 24/7 security to minimise the risk of theft of the equipment.

Various consultations were undertaken with the farmers, with the attendance of the MoA and other members of the SWG, to agree these community contributions and sign a Memorandum of Understanding (MoU) to define the roles and responsibilities of each of the concerned parties (See Section 5).

Whilst the intention of this process had been to fast-track the procurement of the pilot scheme, a number of delays were incurred, particularly during the negotiations and finalising a contract with the preferred bidder, including a number of clarifications and changes to the design and specification of materials and equipment (See Section 5 Consultations for details). However, a change in the leadership of the FDMC resulted in a significant delay to the start of implementation.

4.4 Fast-Track Procurement

In order to meet the deadline for completion of the pilot schemes before the 2022/23 dry season, allowing for planting of rice seedling nurseries in the 3rd week of January 2023, it was proposed to fast-track the procurement process. The Consultant's Team followed a process, identifying and requesting proposals from international suppliers, to benchmark the prices for supply of the required SPIS equipment, and local suppliers/contractors for both the supply and installation of the SPIS at Bong Mines. A Tender Notice, including the outline design and equipment specification, was circulated to the international and local firms with a deadline for submission of tenders, allowing time for them to make a site visit and request clarifications (See Section 6 Procurement for further details), with the key stages summarised in Figure 5.

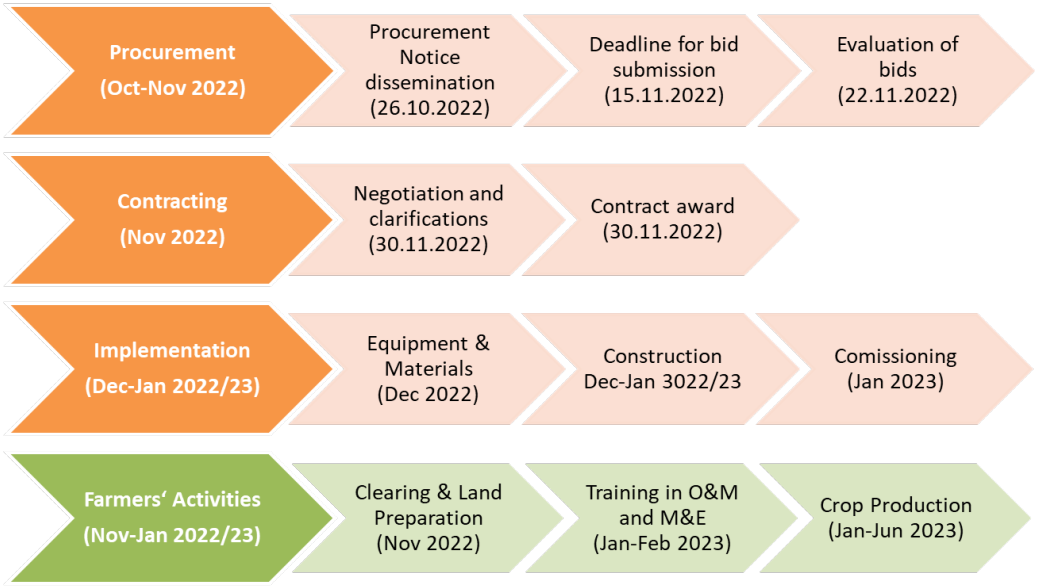

Figure 5: Fast-Track Procurement Activities

Whilst the intention of this process had been to fast-track the procurement of the pilot scheme, a number of delays were incurred, particularly during the negotiations and finalising a contract with the preferred bidder, including a number of clarifications and changes to the design and specification of materials and equipment (See Section 6 for details).

5 CONSULTATIONS

5.1 Meetings

Following the planning and design process, a meeting was held with the SWG to discuss and agree the implementation plan; this took place on 2nd November 2022, when it was agreed to proceed with the plans as outlined above, including the procurement strategy and process, community contributions to the construction, and the programme of agricultural activities in preparation for the start of irrigated rice cultivation in the next dry season (See Appendix E: Minutes of Meetings).

5.2 Site Visits and Community Engagement

Further meetings were held on site with the representatives and members of the FDMC, with the MoA and members of the SWG present on some occasions, and later with the tenderers and preferred contractor. The purpose of these meetings was to raise the farmers' awareness of the SPIS project, and the roles and responsibilities defined in a draft Memorandum of Understanding (MoU), as well as collect further data for completing the design and pricing of the scheme. There were technical concerns raised regarding the water source and the quality of water and its potential impact on the pump operation. Various meetings took place during the period December 2022 to May 2023, with representatives from the MoA and the SWG attending to clarify and resolve the issues raised (See Appendix E: Minutes of Meetings).

Concerns were raised by the community regarding the capacity and suitability of the pond water supply for the pilot scheme, since it had been indicated by some farmers that the pond was shallow, with a deep layer of silt on the bottom. This would have impacted the operation and durability of the pump and alternative intake solutions were considered, including an infiltration gallery and deep pump sump located at the edge of the pond. However, through further discussions, site visits, surveys and investigations, it was determined that the pond bottom was not deeply silted and the water depth was sufficient for horizontal installation of the submersible pump. The pond was noted never to be completely dry, even at the end of subsequent dry seasons, and it was considered that it benefits from recharge from groundwater through the surrounding sandy soils and from surface runoff from the hillside and the watercourse.

At the end of February 2023, the FDMC had an election for a new leadership, which further delayed the start of the implementation work as the new leadership took charge and understood their responsibilities under the draft MoU; this had been discussed with the previous leadership, but had not been signed. Concerns were also raised regarding the capacity of the farmers to provide the labour required for implementation, so the Team were able to renegotiate and address this by making allowances in the MoU. On 24th May 2023, the MoU was finally signed, which initiated the implementation work to begin in earnest.

During construction every effort was made to maintain engagement through regular communications with the community and to ensure farmers located adjacent to the scheme were fully involved and compensated for any impacts on their fields during construction.

Figure 6: Signing the MoU with the FDMC

6 PROCUREMENT

6.1 Tendering Process

In order to pilot a small-scale implementation of the solar pumping system in Liberia, the Consultant undertook a fast-track tendering process, notifying a shortlist of known international suppliers and local contractors and evaluating their bids. This chapter describes the process from publishing the tender notice to signing the contract with the highest scoring bidder.

6.1.1 Tender notice

A tender notice was issued to a shortlist of supplier/contractors in October 2022 (Appendix A: Tender Notice). The tender notice provided a brief background of the project and instructions to bidder, listed the eligibility criteria and the bid documentation, and included the description of project, irrigation system and pumping system as well as the bill of quantities template and the project timeline.

The eligibility criteria for companies included:

- Experience of supplying SIP systems: At least 3 projects of similar size and scope
- Financial capacity: Company should be operational and solvent for more than 1 year
- Local partner in Liberia qualified to execute the local works and providing the after-sales services (if required in future).

The bidder documentation to be submitted included:

- Evidence of presence in Liberia directly or indirectly through a local partner that can provide required support
- Data sheets and other information material for each major item (modules, inverters, batteries, supports, pumps, etc.)
- Warranty declarations and authorization letters issued by the respective Manufacturer
- Implementation plan including organization of works, statement for quality assurance, implementation schedule
- Bill of Quantities (BoQ) based on system proposed by the bidder.

The bidders were required to fill in the bill of quantities template included in the tender notice. The bill of quantities listed the following categories of items: equipment costs, irrigation structure costs and other costs.

The bidders were informed of the deadline for the submission of the bids and could ask questions. They were also encouraged to make a site visit to assess the local conditions and particular logistics and access issues.

6.1.2 List of tenderers

After the deadline for submission of the bids, the consultant received eight offers. The bidding companies and their country of origin are listed in the following table.

Table 5: Bidding Companies

Company name	Country
EcoPower Liberia	Liberia
Dizengoff Ghana Ltd	Ghana
GNP Engineering Services	Ghana
Protergia Nigeria Limited	Nigeria
Renova Energy Construction and Trade INC	Sierra Leone / Canada
Nation Innovation Systems (NIS) Company	Liberia
Go Solar	Liberia
BizSolutions 360	Liberia / USA

6.2 Evaluation and Selection of Contractor

6.2.1 Evaluation

An evaluation procedure was put in place to award scores to all the bids. The evaluation consisted of three levels: Completion check, Technical evaluation, and Financial evaluation. Each of them is described in the following sub-sections.

a. Completion check

The completion check consisted of ensuring the existence and reviewing of the following documents:

- Evidence of presence in Liberia directly or indirectly through a local partner that can provide required support
- Data sheets and other information material for each major item (modules, inverters, batteries, supports, pumps, etc.)
- Warranty declarations and authorization letters issued by the respective Manufacturer
- Implementation plan including organization of works, statement for quality assurance, implementation schedule
- Bill of Quantities (BoQ) based on system proposed by the bidder.

The details of the completion checks can be found in Appendix F: Tender Evaluation.

b. Technical evaluation

The following table shows the technical specifications used for evaluation.

Table 6: Technical Specifications for Evaluation

A	General Requirements		
No.	**Description**	**Unit**	**Specification**
1	Layout	Item	
2	Output	Item	400/230VAC, 50 Hz
3	Option to connect generator	Item	
4	Warranty	Item	Min 2 years
5	Guarantee assignment	Item	Yes
6	Transport and logistics	Item	Yes
7	Installation, testing and commissioning	Item	Yes
8	DLP	Item	
9	Related Experience of SIP System	Item	3 projects of similar size
10	Local Partner in Liberia	Item	Yes
B	**Photovoltaic Modules**		
	Electric Data		
No.	**Description**	**Unit**	**Specification**
1	Rated power at standard temperature conditions	W	350 or Greater
2	Peak Power (Pmax)	W	
3	Peak voltage (Vmax)	V	
4	Peak system voltage (Vsmax)	V	
5	Peak current (Imax)	A	
6	Short circuit current (Isc)	A	
7	No load voltage (Voc)	V	
8	A/°C-diagram	Item	
9	Temperature power coefficient (%/K)	K	-0.35%/K
10	Nominal cell operation temperature (NOCT)	°C	
11	U-I functions at 25°C and other temperatures and radiation	Item	
	General Data		
12	Min/max operational temperature	°C/°C	-40°C … +80°C
13	Min/max ambient temperature	°C/°C	-40°C … +45°C
	Standards		
14	Connection terminal	Item	DIN VDE 0126-5
15	Wiring, plug connector	Item	EN 50521
16	Modules general	Item	IEC 61215; IEC 61730; IEC 61701; IEC 61721; EN 50380
	Certificates		
17	Modules	Item	IEC 61215; IEC 61730
18	Test report by a certified and licensed laboratory	Item	IEC 17025
19	Product certification unit/authority	Item	Acc. to EN 45011
20	CE conformity (or equal)	Item	yes
21	Tier 1 Certification	Item	yes

	Guarantee		
22	Product guarantee	Item	10 years for product and 25 year performance guarantee
23	Output guarantee 12 years, min. power output (% of nominal power)	Item	>90%
24	Output guarantee 25 years, min. power output (% of nominal power)	Item	>80%
25	Cost of free replacement at installation site in case the min. output ratings fall short	Item	yes
	Features		
26	Brand, Type, Model	Item	
27	Cell dimensions (L/W)	mm	
28	Module dimensions (L/W/H)	mm	
29	Weight of Module	Kg	
30	Kind of glass	Item	
31	Country of Origin	Item	
C	**Pump and Controller**		
No.	**Description**	**Unit**	**Specification**
1	Warranty	Item	min 5 years
2	Brand name, model, type	Item	
3	Head	meter	5
4	Flow Rate	m^3/h	93
5	Power	kW	4
6	Efficiency	%	
7	Enclosure Class	Item	IP 66
8	Submersion	Item	Yes
9	Standard	Item	CE, IEC/ EN 61702
10	Protection	Item	Reverse polarity, overload, over temperature
11	Country of Origin	Item	
D	**Irrigation Infrastructure**		
1	200mm dia, Pipeline	Item	200mm dia. Supply Pipeline (From Pump to Irrigation Distribution) PE PN6
2	Pipeline	Item	150mm dia. Irrigation Pipelines (Distributing to Earth Canals) PE PN6
3	elbows, tees, etc.	Item	Elbows, Tees, End caps, Valves, etc.
E	**Cables**		
1	Brand name	Item	
2	Size	Item	1x [4 / 6 / 10] mm^2
3	Insulation	Item	copper, double insulation for min 1000V, type C2 (high flame resistance), AN3 (high UV resistance)
4	Max operation temperature	Item	at least 90°C in continuous use.
F	**Mounting Structure**		
1	Footing	Item	Concrete
2	Structures	Item	Galvanized
G	**Fencing**		

The details of the technical evaluation can be found in Appendix F: Tender Evaluation.

c. Financial evaluation

The following table shows the breakdown of the financial evaluation of the bid per category.

A	**Equipment Costs**
1	Solar panels (Total Power)
2	Mounting + cabling + accessories
3	Solar pump + controller
4	Soft starter (depending on the pump model and starting current requirement)
5	Shallow well to collect filter water and operate the pump in this well
B	**Irrigation Infrastructure**
1	200mm dia. Supply Pipeline (From Pump to Irrigation Distribution) PE PN6
2	150mm dia. Irrigation Pipelines (Distributing to Earth Canals) PE PN6
3	Elbows, Tees, End caps, Valves, etc
4	Irrigation canal excavation
5	Drainage excavation
C	**Other costs**
1	Transport and logistics
2	Civil & earth works (To be undertaken by the farmers)
3	Installation, testing and commissioning
D	**Miscellaneous costs included by bidder**
1	Port clearing
2	Contingency
3	Security
4	Insurance, Permits, Safety,
5	Office Supplies, Camp, Fencing pump solar equipment
6	Unforeseen payments payoffs to checkstops govt officials local officials Hidden costs of business that always happens. Border travel visas for foreign workers
7	VAT 16%
8	Other Taxes

The details of the financial evaluation can be found in Appendix F: Tender Evaluation.

6.2.2 Selection of the preferred bidder

The following table shows a summary of the evaluation of the bids, with a ranking and indication of the preferred bidder as NIS Company from Liberia, who was subsequently called for contract negotiations. The evaluations concluded that NIS passed the completion check by ensuring all the required documents were attached. Few minor clarifications were required for the technical aspects of the bid to reach a satisfactory level (e.g. Layout of the system,

Warranties, Cable specifications, installation is mentioned but commissioning was missing, flow rate at 5 meter head and mounting structure) and the financial offer was the lowest bid value of US$ 27,568.

Table 7: Summary of Evaluation of Bids

Vendor Name	EcoPower	Dizengoff	GNP	Protergia	Renova	NIS Company	GoSolar	B360
Bid Value	$185,180	$107,492	$57,290	$39,457	$93,935	$27,568	$34,719	$62,461
Evaluation Remarks	PV Watts Required: 350 watts or above PV watts offered: 270 watts. Not matches the requirement	No Technical data provided. Only provided financial data against items in the BOQ	PV Watts Required: 350 watts or above PV watts offered: 160 watts. Not matches the requirement	Preliminary Matches with few clarifications required.	No data provided, except handbook of Pumps. No other details provided.	Preliminary Matches with few clarifications required	No Technical data provided. Only provided financial data against items in the BOQ	Pump size and discharge mismatches Pump size required: 4 kW Pump size offered: 4 HP (2.9 kW)
Ranking				2		1	3	

6.3 Negotiations and Contract Award

The preferred bidder, Nation Innovation Systems (NIS), was invited to a meeting with the TA Consultants on 3rd January 2023, to clarify issues raised during the tender evaluation process and negotiate terms of the contract. The key points are summarised below:

Table 8: Clarification of Key Issues raised during Tender Evaluation

No	Clarification Required	Clarifications Provided
1.	Layout of the system	General Layout (Drawing) of the overall system provided.
2.	Warranties	All major equipment will have manufacturers' warranties as follows: • Solar panels and controller: Manufacturers' warranties (25 years) • Pump: Manufacturer's warranty (2 years) • Any problems with the system installation as a whole will be covered by NIS (2 years). • Warranty certificates will be provided after installation of pump.
3.	Cable specifications	It was confirmed that cables would be buried in protective conduits and they would match or exceed the minimal requirements for the pumps, controller and panels.
		Detailed technical specifications and datasheets were provided of the cables and MC4 connectors that will be used in the project.
4.	Commissioning	It was confirmed that NIS agrees to the scope of works, including successful commissioning of the project.
5.	Flow rate at 5-meter head	It was confirmed that the pump proposed by NIS will give the required flow rate at 5-meter dynamic head.
6.	Details and layout of mounting structure	It was confirmed the structures to be hot-dipped galvanized steel pipes, welded on site rather than bolted as a security measure
		It was confirmed that the support structure would incorporate a raised concrete and crushed rock base platform to provide a dry space for security staff and avoid drainage issues.
7.	Controller	It was confirmed that a controller/Inverter is included in the tender price and will be installed within a lockable security cabinet.
8.	Fencing	It was confirmed that fencing would be provided to the PV panel support structure as an added security measure.
9.	Implementation Schedule	A work plan, providing details on each phase of installation (i.e. Supply, Installation, Commissioning etc).would be provided upon signing the contract or receipt of order.
		It was confirmed that commencement would be on signature of the contract and completion of any necessary groundworks by the farmers (whichever is later).
10.	Training	It was confirmed that commissioning and basic operations training would be provided to farmers and officials on site.

A draft contract was drawn up and shared with NIS for comment, with various clarifications and changes made to the terms and conditions, and payment schedule, before signature on 6th February 2023 (See Appendix G: Contract for Supply and Installation of SPIS Pilot Project).

7 CONSTRUCTION AND COMMISSIONING

7.1 Design Development

7.1.1 Site Topographic Survey

Topographic survey was conducted on 10th, 11th and 14th May 2023, using RTK (real time kinematics) equipment. Survey data for the first two days were analysed but were found to be inadequate to cover the 5 hectares of land required for the pilot scheme. After full analysis, the final design layout and sections were produced in CAD drawings (see Section 7.1.3).

7.1.2 Pump Intake Arrangements

a. Options

As part of the reconnaissance survey on 9th May 2023, three options for situating the pump chamber were discussed: (1) A concrete sump outside the main pond at the foot of the hill, (ii) An infiltration pond adjacent to the main pond (An area where NIS had started excavating), and (iii) Inside the main pond at the deepest point. The issues for each of these options were considered as follows:

Table 9: Options for Pump Intake Location

Option	Pump Chamber Position	Benefits	Issues arising
1	Outside existing pond (at foot of hill)	Construction works would be done easier in firm ground with minimum dewatering and access for maintenance would easy.	• Faster method to utilise pre-cast concrete manhole rings and a backhoe or more and stronger labourers to do the excavation. • High cost of excavation and concrete construction, above the available budget.
2	Inside small dug rectangular pond by Contractor	Small pond acts as infiltration gallery to filter water from main pond, due to concerns over water quality.	• Access to the chamber may be difficult during maintenance. • Excavation in saturated sand proved to be very challenging, especially as rains were approaching, and this option was eventually abandoned.
3	Inside existing pond (at foot of hill)	This was the original intention, due to simplicity, speed and ease of construction.	• Concerns raised about the depth of water and silt deposits were addressed during surveys that measured the depth (approx. 2m) and confirmed bed was not deeply silted. • Access to the deepest point will be problematic, but adds security (NIS also indicated that technicians could complete maintenance). • No extra cost incurred and fastest option.

Other points considered include:

- Availability of ready-made precast concrete rings with suitable size to house the submersible solar pump.
- Location of pump intake should be in a reasonable distance from the PV farm.

b. Design Choice

It was agreed to adopt Option 3 for design of the intake, to mount the submersible pump directly in the pond, since the other options became too expensive and it was determined from the surveys that there was sufficient depth of water and insignificant level of silt at the bottom, which could damage the pump.

c. Final Intake Design

From the above considerations, the final design of the intake was based on a simple arrangement, mounting the submersible pump on supports in the main pond and raised from the bottom, above any risk of sediment entrainment, as shown in Figure 6.

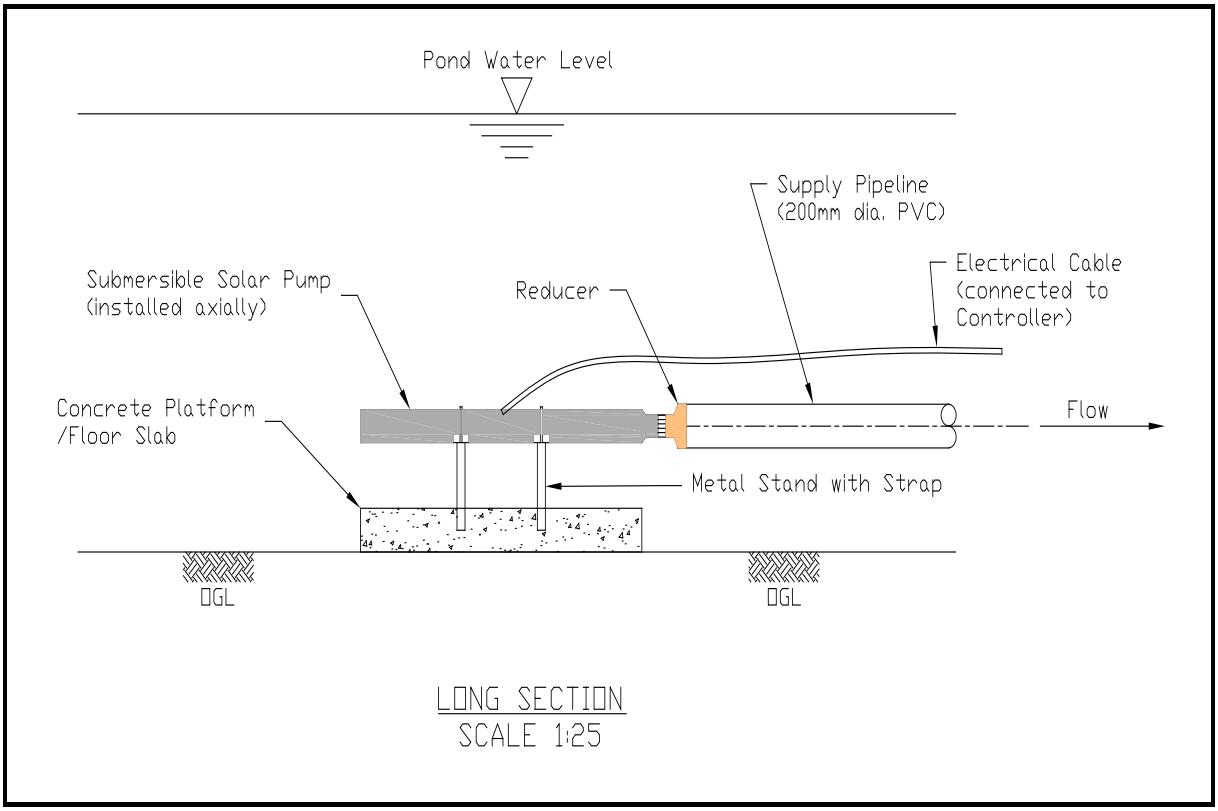

Figure 7: Long section view of Intake (Pump-Supply Pipeline Arrangement)

7.1.3 Farm Layout

As described under Section 4.1, the outline of the layout design comprised supply and distributing made of HDPE (high-density polyethylene) material, with the pipes laid on the ground to give the farmers greater flexibility. However, the Contractor made changes to the preliminary outline design and presented a layout drawing as indicated in Figure 7 with the pipes changed to PVC (Polyvinyl Chloride) that were to be buried in trenches.

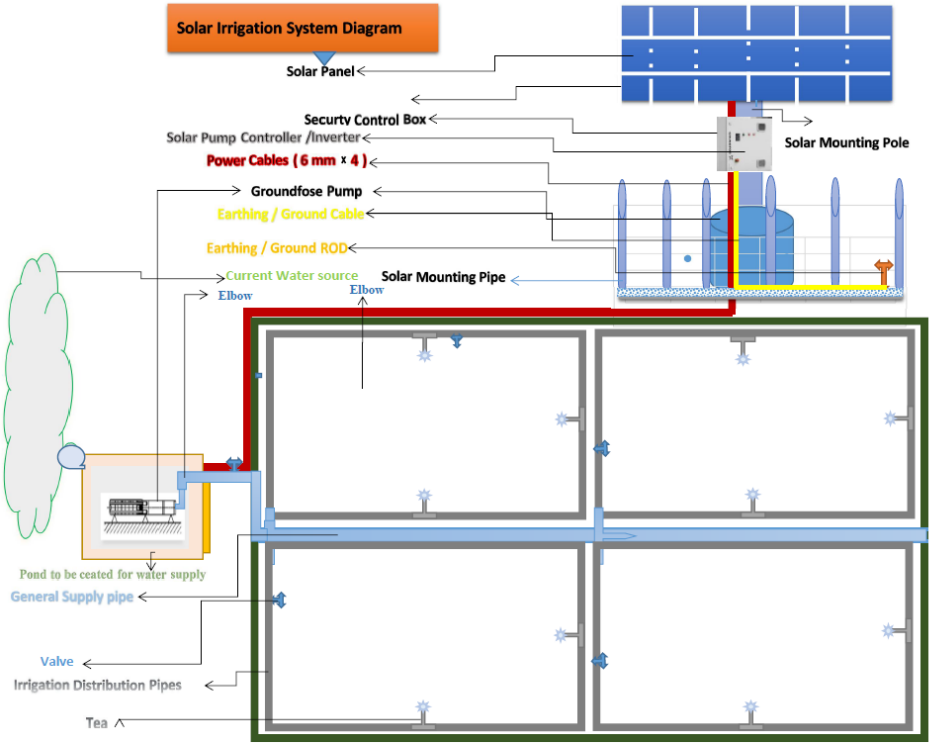

Figure 8: Contractor's modified Layout Drawing

The layout was finalised after field topographic survey and design as indicated in Figure 8. The full final drawings are attached as Appendix B: Drawings.

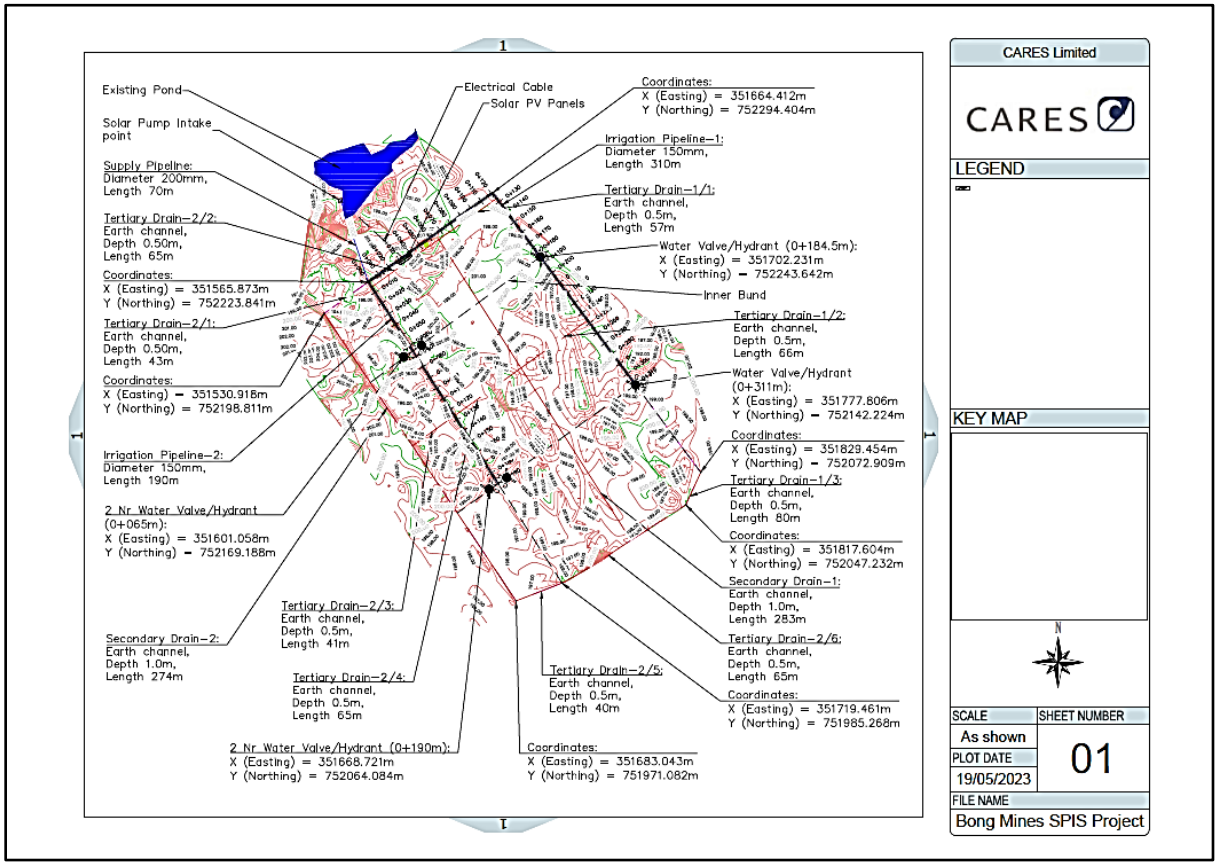

Figure 9: General Design Layout – Bong Mines Site A

7.1.4 PV Support Structure and Compound

The PV support structure, as designed by the Contractor, shows how the PV panels are installed to provide security fencing and shelter (Figure 9 and Figure 10).

Figure 10: Installed PV Pannels with fencing and gate

Figure 11: Installed PV Pannels providing shelter

7.1.5 As-built Details

Table 10: As-built Data

Parameter	Sizing	Comments
Pump Type	7.5 kW	GrundfosX SP 30-8 Submersible pump – MS6000 motor with sand shield
Pump Discharge	30 m^3/hr	Rated flow
Pump Dynamic Head	61 m	Rated head
Pump mounting	-	Can be installed vertically or horizontally
PV Panel type	1133 mm x 2256 mm (3.8' x 7.5')	ASTRONERGY 525W~545W Monocrystalline PV Module CHSM72M(DG)/F-BH Series (182)
PV size	12.6 kW	Rating of individual module is 525 W (i.e., 525 W x 24 = 12.6 kW).
PV mounting	-	The substructure made of hot dip galvanized steel to support the modules and withstand the local weather conditions.
Controller	-	
Piping type	~590m	150-200mm diameter uPVC pipe, fittings and valves
Fencing	(14' x 48')	A secure fencing for the areas covering the PV panels.

7.2 Construction Activities

7.2.1 Community Labour

After signing the MoU, the farmers of FDMC commenced clearing the fields and excavation of pipe trenches.

Figure 12: Group of farmers in the community ready for site clearing and digging of trenches.

Figure 13: Part of cleared Pilot site

7.2.2 Pipe Laying

PVC pipes were conveyed from the Contractor's shop in Monrovia to Bong Mines Site A.

Figure 14: Offloading of pipes at site.

Figure 15: Laying of pipelines.

Figure 16: Jointing pipes with glue

Figure 17: Irrigation Outlet with Control Valve

7.2.3 PV Panel Support/Enclosure

Figure 18: PV Panels offloaded at site

Figure 19: PV panels installed on Support structure.

7.2.4 Pump Installation

The pump is installed horizontally on a concrete base, secured on two metal supports which are embedded in the slab, as shown in Figure 6 and Figure 19. The base was cast on the pond shore, then moved into a suitable position at the bottom of the pond. Once firmly seated on the pond floor, the solar pump was connected to a 200mm diameter PVC Supply Pipeline (SP) which was then submerged and backfilled in the pipe trench (Figure 20 and Figure 21). The long sectional view of the final intake arrangement is shown in Figure 6, with the full drawings in Appendix B: Drawings.

Figure 20: Solar pump mounting platform cast in concrete with two embedded metal supports, ready to be moved into pond

Figure 21: Connecting Solar Pump to Supply Pipeline

Figure 22: Lowering the Solar Pump/SP into the pond

7.2.5 Controls and Cabling

The pump controller/inverter is mounted in the enclosure under the panels and in a locked cabinet (Figure 22), while all cabling is buried in the same trenches as the pipelines.

Figure 23: Support showing Controller inside security cage.

7.3 Commissioning Tests

Commissioning is the process of configuring and verifying that all the SPIS components in the scheme are properly installed and optimized per the expected performance requirements.

Figure 24: Water Flow at Irrigation Outlet

The recommended minimum testing involves the following:

Solar PV Installation

- Visual inspection to ensure mechanical integrity and correct wiring:
  - Civil works, foundations of PV module mounting structure
  - Check all electrical connections.
- Systematic compliance checks performed on each component of the system, performed in a non-energised state.
  - Verification of the correct polarity and electrical continuity
  - Open circuit voltage/Short circuit current.
- Testing of instrumental circuits, testing of circuit breakers, etc:
  - Setting of all alarm thresholds on the equipment.
  - Completion and functional verification of the earthing system.
- Testing of appliances and energisation of cables:
  - PV Modules
  - LV Cabling
  - Controller/Inverter
- Verification of the nominal power of the installed system as the sum of the nominal power of all the installed modules.

Irrigation System

- Visual inspection to ensure integrity and connectivity:
  - Pipe cover
  - Leaks.
- Functional verification of pump operation:
  - Flow and pressure
  - Valve operation.
- Equity of water delivery and uniformity of water application.

Commissioning was delayed due to the availability of the control valves to be installed along the pipelines.

7.4 Manuals, plans and training.

The following details are also to be provided by the Contractor to record the completion of the construction works; some of the details are included in the appendices to this report, but all will be incorporated into the next deliverable, Bong Mines Pilot Scheme - Operation & Maintenance Manual (Output 5):

- Technical data, certificates and test protocols, catalogues, installation, operation, and maintenance manuals of PV modules, inverter, pump
- Daily, weekly, monthly, yearly maintenance programme
- As-built drawings
- Training of operators
- Part lists all major items (PV modules, inverter, pump) with manufacturer, part number.
- Contacts (address, email, phone, web, etc) of supplier, manufacturer.

7.5 Defects List

The defects or snags list is created after the commissioning and final inspections of the scheme once the construction works are substantially complete. It identifies specific areas where the work does not meet the required standards or specifications, and may include items such as damaged finishes, missing or incorrect fixtures, faulty installations, or any other defects that need attention. The Defects List for the scheme is attached in Appendix H: Defects List. These

will need to be addressed by the contractor during the Defects Liability Period to the satisfaction of the Team and the farmers.