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

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Bong Mines Pilot Scheme - Operation & Maintenance Manual (Output 5)

Prepared for:

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

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Output 5: Bong Mines Pilot Scheme - Operation & Maintenance Manual

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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
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
PPE	Personal Protective Equipment
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 Manual

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. Specifically, it covers the elaboration and dissemination of training materials and workshops (Output 5), including, as follows:

- A detailed manual on the Operation and Maintenance (O&M) of the technology
- Learn-by-doing workshop with the rice farmers.
- Stakeholder consultations
- Organising training for Municipal and National officers (TBD).

1.2 Operation & Maintenance Manual

Operation & Maintenance (O&M) activities for SPIS predominantly involves the care and preventative maintenance of the solar electrical systems and piped irrigation network, and the repair of these systems, as needed. This report introduces the key components of SPIS, its advantages and risks, and how it can be used to schedule irrigation for the cultivation of crops and record information that will improve water management and ensure that future systems are designed, operated and maintained effectively. It also introduces the System of Rice Intensification (SRI), providing guidelines for farmers on how to plan what to plant (Crop/seed variety), where to plant (Land selection and preparation), methods of planting and transplanting rice seedlings, weed and pest management, application of fertilizers and other chemicals, and water / irrigation management, as well as harvesting, processing and marketing tactics to help maximise the sales of their produce and be successful rice producers. Note, the final output of the TA (Output 6) will formulate a Monitoring and Evaluation (M&E) framework to be used by the farmers and stakeholders to monitor and report on aspects of the scheme, including Agricultural Production, Water Management, Energy Generation and Maintenance Activities.

The long-term sustainability of the SPIS depends on the good design and quality of production and installation of the equipment, but also on the farmers' ability to use it efficiently and maintain the technology. The O&M Manual includes all relevant information that the farmers and county officers may need for effective O&M of the SPIS implemented at Bong Mines for SRI production. The O&M Manual describes what, how and when maintenance activities should be undertaken, and when the assistance of a qualified technician may be required to replace parts or correct defects.

Personal safety of farmers and operators is of paramount concern and the O&M Manual includes simple guidelines to reduce risks and provide protection. Energised electrical systems can be lethal when handled inappropriately and solar panels are energized anytime when the sun is up, so require particular care and planning are required to undertake

maintenance safely. The O&M Manual gives guidance on how and when electrical maintenance activities should be planned, as well as hazards related to the use of chemicals, such as fertilisers, pesticides etc.

The specific guidelines in the O&M Manual cover the following:

- Installation:
  - Electrical Components
  - Supply Pipelines and Laterals
  - Storage Tank
- Routine Maintenance:
  - Solar Panels
  - Pump Controller (Inverter)
  - Pump and Supply Pipeline
  - Storage Tank
  - Distribution System

Although not part of the Bong Mines scheme, the storage tank is included for completeness, since it could be integral to other systems developed in the future.

The information presented is exhaustive and is written in technical English, so the key messages and instructions for the farmers are also presented as simplified guidelines in the Appendices; these posters can be displayed at strategic points within the scheme to ensure the key messages are communicated to everyone (Few farmers are literate and local language translations would provide little benefit). The O&M Manual will be provided as hard copy in full to the farmers at Bong Mines, as well as electronic versions for the EPA and MoA for use at other schemes, as and when the technology is rolled out to other areas of the country.

1.3 Training Workshops

As owners of the pilot scheme, the EPA and MoA officials, as well as the rice farmers from the FDMC and the wider Bong county were invited to an on-site workshop on 14 July 2023, but at that time the scheme was incomplete to enable a practical introduction to and demonstration of the SPIS. Instead, O&M training was given to the farmers from the Fuamah District Multipurpose Co-operative (FDMC) and described the deployment of the technology at Bong Mines and covered the key aspects that will be needed to make efficient use of the technology and for the long-term sustainability of the pilot SPIS:

- **Operation**: A description of how it works and the functionalities of each component.
- **System of Rice Intensification**: Improved rice husbandry practices to broaden the practical skills in rice cultivation, post-harvest processing and management, and the factors to consider for a healthy crop.
- **Maintenance**:
  - When, what and how maintenance activities should be undertaken (e.g. Cleaning solar panels, maintaining the pumping system or the electrical components)
  - When equipment/materials should be replaced

- Where spare parts can be purchased, with estimated prices, delivery times and conditions of guarantees.
- Do's and Don'ts.

A new date will be agreed with EPA/MoA, the SWG and FDMC to complete this awareness raising and training exercise. This workshop will explain the purpose of the project, with its focus on lowland SRI production with solar water pumping system, and why the particular SPIS configuration was selected as appropriate for the site.

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 Manual

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 5, covering four activities, as follows:

Activity 5.1: Preparing a detailed manual on use and maintenance of the technology (Draft, Translation, Final)

Activity 5.2: Organising a learn-by-doing workshop

Activity 5.3: Organising a stakeholder consultation workshop

Activity 5.4: Organising training for Municipal and National officers.

2.3 Introduction to Solar Powered Irrigation Systems (SPIS)

A Solar Powered Irrigation System (SPIS) is like any other irrigation system, except its power source comes from the sun. An SPIS can be divided into three components:

1. **Electrical System**, including:
   - Solar (PV) panels, mounting structures
   - Controller (Usually Maximum Power Point Tracking – MPPT)
   - Pump (DC or AC, variable motor speed and pump volume)
   - Electrical cables
   - Optional extras:
     - Monitoring system (Volume, Timer etc)
     - Alternative energy uses (Rice mill etc)
     - Energy storage (Batteries)
     - Mini-Grids and Hybrid systems
     - Security fencing.
2. **Irrigation System**, including**:**
   - Water storage (Tanks, reservoirs)
   - Distribution network (Pipelines, canals)
   - Application method (Surface, Overhead or Drip)
3. **Agriculture System** including (As described in Section 2.4 Introduction to System of Rice Intensification):
   - Crop/seed variety
   - Land selection and preparation
   - Methods of cultivation:
     - Planting and transplanting
     - Weed and pest management.
     - Application of fertilizers and other chemicals
     - Water / irrigation management
   - Harvesting, processing, and marketing.

Water from the source, such as groundwater (e.g. wells or boreholes) or surface water (e.g. pond, lakes, rivers or reservoirs) is pumped through a rising main to the fields. The energy to drive the pump is provided by the solar panels. In some systems water is stored in an elevated tank to enable irrigation at any time of the day, but the simplest systems only operate when the sun is shining. Based on the preferred method of irrigation for the crop to be grown, the water is applied to the fields either by gravity/flood/surface irrigation, overhead/pressurised sprinklers or through low pressure drip lines to all parts of the irrigated area (See Figure 1).

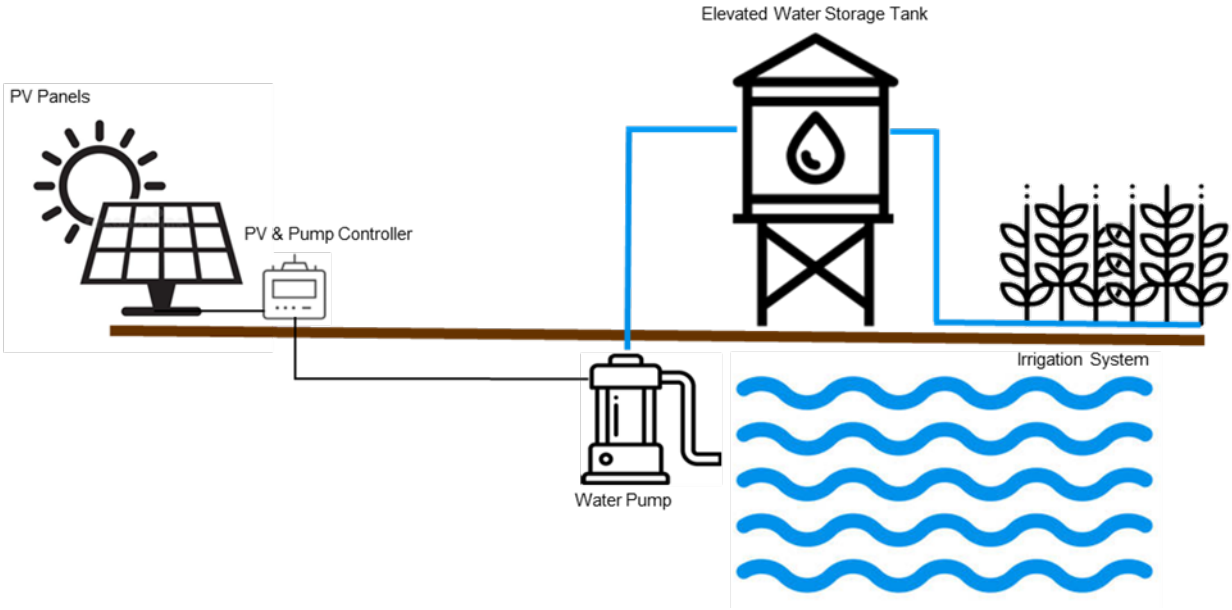


Figure 1: Simple SPIS System

Note, the pilot SPIS at Bong Mines represents the simplest configuration without the elevated water storage.

2.3.1 Advantages and Risks of SPIS

SPIS has been found to be an appropriate application of solar energy for small-scale irrigation, as well as other water-related projects, such as portable water supplies for institutions and communities, and livestock water supply. Some of the advantages and risks are summarised in the Table below.

Advantages	**Risk/Challenges**
Low Operation and Maintenance costs	High Capital Cost
Zero Pollution	Need for innovative financing models or subsidies
Year-round supply increases outputs/income	Limited Servicing Infrastructure
Can be installed anywhere	
Highly reliable technology	Pumping limited to hours of solar radiation
Increasingly more affordable	Water output determined by initial system design
	Need for increased capacity of local technicians and preventative maintenance for users at time of installation and operation

Table 1: Advantage, Risks and Challenges of SPIS

2.3.2 Operation and Maintenance

Operation & Maintenance (O&M) activities for SPIS includes care and preventative maintenance of the solar electrical systems and piped irrigation network, and the repair of these systems, as needed. Some key terminology is provided below:

- **Operation** - Refers to ongoing, recurring day-to-day work involved in the running of a technical facility for the purpose of producing value for the beneficiaries/users (e.g. farmers). Operations activities include:
  - Controlling system parameters
  - Scheduling and conducting inspections.
  - Monitoring and overseeing the facilities and processes.
- **Preventive Maintenance/Servicing** - This refers to routine, recurring work activities required to keep a facility or scheme in such condition that it may be continuously used at its original design capacity and efficiency for its intended purpose. Typically, it includes tasks such as:
  - Adjusting
  - Lubricating
  - Cleaning
  - Replacing components.
- **Diagnostics and Testing** - These are the procedures used to understand a failure when it is not obvious.
- **Corrective Maintenance/Repair** - These repair activities are those necessary to re-establish the proper functioning condition or service of SPIS equipment. It may be planned and/or unplanned.
- **Overhaul** - When equipment at the end of its service-life needs complete restoration to return it to useful condition via appropriate and recommended maintenance.

2.3.3 Irrigation Scheduling

Based on the design, the operators should understand the irrigation schedule (i.e. how much irrigation water must be given to the crop and how often). This depends predominantly on the type of land preparation (dry or wet), type of crop, critical stages of the various growth phases (e.g. active tillering, panicle initiation and flowering), climatic conditions and soil type; for example, during hot, dry and windy conditions a crop will need more water, but some water will be stored in the root zone, which the plants can gradually use each day, therefore it is not necessary to apply water every day. Clay/Loamy soil types have a greater water holding capacity than free draining sandy soils, which will need more frequent irrigation, and some crops need more water than others and different amounts depending on the stage of growth. The irrigation interval has to be chosen to suit the local conditions in such a way that the crop does not suffer water stress (i.e. too little water, leading to wilting) or flooding (i.e. too much water, leading to waterlogging) and should maximise the effective use of water and energy resources to give the greatest yields. By careful management of irrigation schedules, farmers can realize direct savings in water, fertilizer, pesticide, herbicide, and farm labour. Farmers

will see an improvement in quality and quantity of their yields, and therefore an increase in their income.

Regular collection of climatic data, soil properties and crop growth stages are not always possible to make this detailed assessment of water requirements and most farmers will rely on their wealth of experience and simple rules of thumb to schedule irrigation. For the pilot SPIS at Bong Mines the design assumes 1.5 l/s/ha every 4-5 days.

2.3.4 General Care of Crops

Crops must be cared for to protect them from nutrient deficiency, extremes of weather, pests and diseases. Specific details regarding rice production utilising the System of Rice Intensification (SRI) methods are provided in Section 2.4, but farmers are encouraged to engage in the following general practices to improve yields:

- **Soil moisture** - Check to ensure that crops have sufficient water. Soil moisture increases as the pores in the soil become filled with water and air is expelled and can be estimated by pressing a soil sample in the palm of the hand (if the soil is moist the water content will make it sticky and the particles will be held together, if it is dry the soil particles will easily separate) or by sticking a finger into the soil to see if it comes out wet/cool.
- **Mulching** - Apply organic compost, leaves, straw, or well-rotted manure to minimise weed growth and continuously feed the plants with nutrients as they leach into the soil (also aids pest management).
- **Fertilizers** - Chemical or organic fertilizers improve the soil conditions and improve yields (the maximum increase in yield occurs when water and nutrients are managed together). Agrochemicals should be adopted with care to ensure that those used pose no threat to human health or the environment.
- **Weeding** - Weeds compete for space, water and nutrients and can quickly overtake young crop seedlings. Routine weeding by hand or mechanical means is preferable however the usage of herbicides is recommended where there is significant weed pressure.
- **Pests and diseases** - Check for unhealthy soil, diseased plants or an increase in insect activity; early detections can usually be addressed successfully by application of pesticides, based on the type of pests and diseases.
- **Harvest on time** – Rice crops should be harvested at physiological maturity, not at harvest maturity. Physiological maturity indicates when 90 percent of crop turn yellow and remaining is green in colour. Vegetable crops should be harvested as soon as they are mature or they will go to seed (e.g. lettuce, broccoli, cabbage) or become tough and woody (e.g. kohlrabi, turnips, beets). Other crops can be picked over a period of weeks, with frequent picking actually encouraging new growth and increased yields (e.g. peas, Swiss chard, beans, squash, cucumbers).

2.3.5 Record keeping

The key aims for the introduction of SPIS in Liberia is to reduce the dependency on fossil fuels in agriculture at a national level and enhance access to water and sustainable energy.

However, the future roll-out of schemes similar to the pilot at Bong Mines will depend on increased technical knowledge and understanding of SPIS, to ensure that future systems are designed, operated and maintained effectively. Without information on the operation of SPIS, there is a risk that national roll-out may foster unsustainable water use as low energy costs lead to over-abstraction and wasteful water use. To ensure data is collected from the pilot SPIS and other schemes in Liberia, the final output of the TA (Output 6) will formulate a Monitoring and Evaluation (M&E) framework to monitor and report on aspects of the schemes:

- **Agricultural Production**: General details for the scheme to understand the land preparation, cultivation and harvesting activities, with the costs and benefits of these operations determining a case for the sustainability of rice farming (See example below).

General:					
Pilot area name:			**Address:**		
No. of participating farmers:			**Contact Person:**		
Total area:		acres/hectares	**Rice planted season:**		
Rice variety type:	Short/medium/long duration		**Other crops:**		
Pre-Cultivation details:					
Type of land preparation:	Dry/Wet		**Area of land preparation:**		
Labour/cost required for land preparation:			**Total rice planted area:**		acres/hectares
Levelling field:	Good / Fair / Poor		**Source of seed:**		
Seedling numbers/hill or bunch:			**Rice variety name:**		
Transplanting date:			**Seed rate:**		kg/acre
No.of workers/ ha:			**Plant spacing:**		
Labour/cost for transplanting:			**Cost of Seeds:**		
Cultivation details:					
	First weeding date:		**Second weeding date:**		**Subsequent weeding**
No.workers/ha:					
Labor/cost required for weeding:					
Use of Cono weeder:					
Coverage/ha:					
Adoption of new technologies (e.g. usage of young seedling, square planting, LCC and cono weeder etc)					Good/fair/poor
Cost for irrigation:			**Cost of maintenance:**		
Bags of urea applied/ha:			**Other plant protections:**		
Cost of Nutrients:			**Cost of plant protection:**		
Harvesting details:					
Average Tillers (No.of rice plants at PI stage):			**Harvesting date:**		
Average Panicles (No.of plants at harvesting):			**Average grains/panicle (plant):**		
Harvesting labour/cost:			**Harvesting method:**	Reaper/manual	
Total Yield (kg):			**Rice price/kg:**		
Rice Yield (kg/ha):	#DIV/0!		**1000 grains weight:**		
Costs vs Benefits:					
Total production cost:	**0**				
Total income:	**0**				
Net profit:	**0**				

- **Water Management**: Regular and systematic accounting for water pumping and use, ensuring an optimal balance of rainwater, soil moisture and irrigation. Measures of equity, uniformity and timeliness; knowing where and when irrigation is required and applied, to understand the efficiency of water usage.
- **Energy Generation**: Solar energy (kWhr) generation and use for irrigation pumping and any other alternative uses.

- **Maintenance Activities**: Details of routine and planned maintenance (as defined in this Manual), emergency repairs and corrective improvements, and overhauls at the end of the equipment lifespan. The costs of technician time and spare parts should also be recorded.

Further details of the M&E Framework will be developed and discussed in the Output 6 Report and at a workshop with the farmers, municipal and national officers.

2.4 Introduction to System of Rice Intensification (SRI)

Liberia has potential for rain-fed and irrigated rice production, and with the abundant water provided by SPIS, farmers can increase production. Also, with the development of the New Rice for Africa (NERICA), especially NERICA-L19 for lowland rice production systems, farmers can increase productivity, profitability and incomes by double cropping of rice. This Manual provides simple, step-by-step instructions on improved rice production techniques with emphasis on a System of Rice Intensification (SRI) to mitigate greenhouse gas emission[1]. It further outlines factors affecting the choice of seed(s) as well as step-by-step guidelines in growing healthy rice.

For successful rice production, as a business, farmers should develop a plan on what to plant (Crop/seed variety), where to plant (Land selection and preparation), how to cultivate (Methods of planting and transplanting, weed and pest management, application of fertilizers and other chemicals, and water / irrigation management) and where to sell the produce (Harvesting, processing and marketing), as described in the following sections.

A summary of typical calendar of crop production activities for rice and agricultural input requirements are shown in Figure 2 and Table 2.

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 2: Rice Production Activities for Typical Dry Season

[1] This SRI guidance is based on the Food and Agriculture Organisation (FAO) Training Guide for Lowland Rice Production for Smallholder Farmers Practical / On-farm Training Curriculum

No	Input Requirements (5 ha)	Quantity
1	Nerica L19	200 kg
2	Nursery trays	Needs 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	2.5-3.0 litres
	Tebuconazole	2.5-3.0 litres
	Carbendazim/Mancozeb (seed treatment)	0.5 kg
9	Cono weeders	2
10	Leaf Colour Chart (LCC)	4

Table 2: Typical Agricultural Input Requirements for Rice

2.4.1 Planning for Production

a) Market Survey

A market survey (or window-shopping exercise) is the process of finding out what type of crop variety people want to buy, establishing the price and what time of year a particular crop can be in surplus or hard to find in the market. The information gathered during this exercise will help the farmer decide on what to plant/cultivate in the coming season, and also when to sell the produce to make more money. The survey should also determine where to obtain the inputs needed to grow the crop (e.g. seeds, tools, agro-chemicals, fertilizers, labour, etc) and their costs.

b) Crop Calendar

A crop calendar is a picture of the rice growing season; it is the timeframe from the fallow (rest), to land preparation, sowing/transplanting and field maintenance up to harvest and storage. By understanding a crop's calendar, farm activities are better planned, and performed at the right time. It is also easier to organize labour and obtain inputs such as seeds and fertilizers in time.

Things to consider in creating a crop calendar:

1) Determine the best date to plant.
2) Determine the time the variety takes from planting to harvest:
   - Short duration: 90 - 120 days
   - Medium duration: 120–140 days
   - Long duration: 160 days or more.
3) Most varieties take 50–55 days from panicle initiation to harvest.

4) Mark on the calendar the date of planting and when each other operation needs to be done (ploughing, weeding, fertilizing, and harvesting) and keep it visible so all farmers understand and are aware of the next activities.

2.4.2 Selection of Seeds/Planting materials

Choose the best seed variety that suit the growing conditions. Farmers should consider using own seed or from the local market, or buying certified seed from a trusted / certified agro-input dealer. The most suitable seed variety is the one that meets the farmer's and consumer's needs. Seed varieties should be selected based on good yield potential, resistance to disease, good cooking qualities, high milling yield, and are suitable for the market. Some factors to consider in selecting a variety:

- **Crop duration**: Short-duration (90 - 120 days); Medium-duration varieties (120–140 days); Long-duration varieties (160 days and longer).
- **Crop height**: Tall (1.4 m and taller); Medium height (1–1.2 m); Short varieties are best suited to level fields especially in irrigated areas.
- **Grain quality**: Aromatic, softness, stickiness, and colour.
- Sort and identify clean and healthy seeds
- Popular lowland rice varieties cultivated in Liberia are NERICA-19 and Suakoko 8, while Suakoko-8 and FARO-15 are particularly suitable for iron toxic areas, such as Bong Mines.

a) Germination test:

A germination test enables the farmer to know whether the seeds are good or not. A simple germination test follows the following method:

- Fill a small cup with soil and add a small amount of water
- Add rice seed (Typically 100 and avoid seed of mixed varieties)
- Cover with a paper towel or wet cloth moist with clean water
- After four to nine days, observe the seeds and see how many have germinated.
- Good quality seeds with high germination percentage (>80%), and without insect damage or contaminants (weed seeds, stones, other seed types) are ideal.

b) Pre-sprouting seeds (seed priming)

The process involves two activities: *soaking* and *incubation*. Well-prepared dry seeds should be soaked in clean water for 24 hours to enable moisture adequate for sprouting to be absorbed. The seeds are then removed from the water and spread on a mat on a slated floor to facilitate the draining of excess water. The seeds are finally incubated by covering them with moist covers for about 48 hours to provide them with the heat necessary for sprouting.

2.4.3 Land Preparation

a) Site selection

For healthy lowland rice production, select fertile lowland rain-fed or irrigated fields with sufficient clay soil with good water-holding capacity (and contains some organic matter, i.e. loamy soil); sandy clay loam and clay soils are most desirable. Check the soil colour and

texture, and check also for worm cast (worm pupu). All these information will help you to select an ideal site for production.

The soils at the pilot SPIS at Bong Mines are sandier than would be ideal for rice production and have a high organic content, which will require careful water management practices.

b) Prepare and Level the Fields

Land preparation involves clearing, tilling or ploughing the soil, and levelling. Farmers can clear their fields using cutlasses, regular hoes, machetes, rakes, etc. Field tillage can be done manually (hoes and shovels) or mechanically (two-wheel power tiller, mini- tractor). Level and well-tilled fields produce healthy crops that give the best yields, since this enables a uniform spread of irrigation water.

c) Construct or Rehabilitate Paddy Bunds and Canals

Bund construction or rehabilitation is important in both irrigated and rain-fed rice farming for the purpose of retaining water in the paddy plot. Make sure that there are water in-lets and out-lets for each “bunded” paddy plot to facilitate proper water management. The standard dimension of a paddy plot is 20m x 20m; but any suitable dimension can be used based on the topography and orientation, and for ease of operations.

The recommended dimensions of rice field bunds:

- Top 30 to 50 cm wide.
- Depth (height) 40 to 50 cm deep/high.
- Base 130 to 160 cm wide.

d) Nursery Preparation and Management for Lowland Rice

Rice seeds can be planted directly or nursed before transplanting in the field. For lowland rice, prepare or build a nursery to support the development of seeds into young seedlings that can later be transplanted in the fields when they are strong enough to cope with field conditions (Note: In general, about 1000 m^2 seedbed nursery is required to transplant a 1 hectare). There are two types of nurseries for lowland rice:

- **Dry bed nursery:** Generally, nursery can be 1.0 meter wide and could be 3.0 – 8.0 meters in length depending on the land size, quantity of seeds and available resources. This ensures ease of maintenance; watering, constant monitoring to identify insect pests; and carrying out regular weeding, etc. The nursery bed should be watered regularly to keep the soil moist but not puddled. Good drainage should be provided to ensure that the nursery is never flooded. Spread the sprouted seeds uniformly on a levelled surface for dry bed nursery.
- **Wet bed nursery**: Select a site with well-drained fertile soil exposed to full sunlight, and conveniently located in an area close to the main field to facilities for efficient watering when needed. Incubate the seeds by covering with polythene bags or palm fronds for another 48 hours for seeds to sprout.

To cultivate rice seedlings in nurseries, the following activities should be undertaken:

- Spread the sprouted seeds uniformly on a puddled nursery bed (wet bed nursery) or on a levelled surface for dry bed nursery.
- Drain the excess water from the nursery bed for about a week, then flood to 2-3cm depth if using wet bed nursery.
- About 5 days after sowing seeds, the nursery beds should be kept flooded to a depth of 2 -3 cm. To prevent weeds and also ensure easy pulling of seedlings, water depth should gradually be increased to a depth of about 5 cm.
- Apply 50 g/m^2 of NPK (15-15-15) fertilizer or apply 5 t/ha of rice husk + bran as mulch/manure.

2.4.4 Planting and Transplanting

To maximise yields, farmers should follow the System for Rice Intensification (SRI) guidelines below:

- Plant/transplant on time, as per the agreed cropping pattern. For the rainfed season, the time of sowing will be between May and June, with transplanting 14-21 days after sowing[2].
- Transplant seedlings in well-puddled (wet season), harrowed (dry season) and levelled paddy plots.
- Transplant one seedling per hill, at a depth of 3–4 cm, and at a spacing of 30cm × 30cm[3].
- Fill the empty spaces within two weeks after transplanting using leftover seedlings from the nursery.

2.4.5 Weed and Pest Management

a) Weed Control

A weed is a plant growing where it is not wanted and in competition with cultivated plants. Weeds compete with crops for water, nutrients and sunlight and will reduce crop yields if left to grow. Good land preparation (clearing, ploughing and levelling) reduces weed growth because most weeds have trouble germinating under water. Also, selecting varieties that have early vigour will establish the crop ahead of the weeds.

Weeding is the removal of any unwanted plants from the fields and should be carried out regularly and on time, according to the farmers' plan. First weeding should take place within 2–3 weeks after establishment and the second weeding another 2–3 weeks later.

There are three common methods of weed management:

- **Manual weeding**: Manual weeding is normally done by pulling out weeds by hands.

[2] Allow rains to be well established before seedling transplanting.
[3] For conventional rice cultivation system, apply direct sown seed at 30–40 kg seed/ha or transplant at a rate of 2–3 seedlings per hill, to a depth of 3–4 cm, and at a spacing of 30cm × 30cm, or 20 x 20 cm when soil is fertile or sufficient fertilizer is available.

- **Mechanical weeding**: Most appropriate for crops transplanted in straight rows and can be undertaken using simple machinery, such as the Cono Weeder. This weeder should be used in the field in both directions, within the rows and between the rows.
- **Chemical weeding**: Use of herbicide technologies can be labour-saving, but there are associated costs and care must be taken for safe handling and to minimise impacts on the environment. Herbicides may be classified as: Selective, Non-selective, Pre-emergent, and Post-emergent herbicides. If used, the following are recommended for lowland rice:
  - Apply Ronstar™ (oxadiazon) 25(EC) or Butachlor 50EC 2-3 days after sowing or just after seeding at the rate of 4–6 litres/ha and 2.5-3 litres/ha respectively.
  - Apply Gramoxone™ (Paraquat) at 2 litres/ha but not more than 24 hours after sowing when weeds have grown in the field.
  - DO NOT spray Gramoxone™ after the germination of paddy seeds, to avoid killing the seedlings.
  - For post-emergence, Bisbyripac sodium @0.5 litres/ha or Propanil + 2,4 – D @ 4-5 litres/ha when the sown crop reaches 21 days after seeding or when the weeds attain 2-3 leaf stage.

b) Pest Control

A pest is any organism that adversely affects the farmer, his crops and livestock, and could be an animal (e.g. rodent, bird etc), plant or pathogen. There are different types of pest control methods including fencing; hand picking, and the use of chemicals / pesticides, etc, but in all cases prevention is the best form of control. The following points outline the most common practices for bird and rodent control:

- **Bird Control:**
  - Erect scarecrows randomly in the field,
  - Scare the birds manually,
  - Use flash tapes or bird scaring tapes diagonally across and around the field.
- **Rodent Control:**
  - Leave an uncropped margin of 1-2 meters around the field and distribute poison (bait) mixed with maize, sorghum, millet or rice in bamboo boxes or containers in the uncropped margins and alleys.
  - Fencing with bamboo or chicken wire mesh, or polythene sheet round the field may deter the rats and grass cutters.
  - Use of local metal traps.

2.4.6 Fertilizer Use

Careful use of fertilizers can significantly increase yields and financial returns by supplying nutrients essential for growth and development to the rice plant. Fertilizers can be applied in the form of organic or inorganic (chemical) compounds or both. Organic fertilizers can be in the form of manure, compost or crop residues, while chemical fertilizers are manufactured, generally from the three key element Nitrogen (N), Phosphorous (P) and Potassium (K). It is

vital to apply the right quantity and at the right time to obtain optimum yields and for environmental protection.

a) Types of fertilizers

There are Straight (single) fertilizers, which supply only one primary nutrient (e.g. N, P or K) to the crop, such as Urea or Muriate of Potash (MOP), or Compound fertilizers, which supply more than one primary nutrient to the crop, such as DAP (46% P: 18% N) and NPK 15-15-15 (15% N; 15% P_2O_5; 15% K_2O).

b) Fertilizer application

Fertilizer should be applied based on the residual nutrients found after soil testing, the expected yield and the type of fertilizer materials available. Farmers should aim to use fertilizer based on the suppliers' recommendations and as detailed in Figure 2 and Table 2 above, which are based on the results of soil analyses on samples taken from Bong Mines (These recommendations may need adjustment for soil types in other areas). Farmers can also make use of Leaf Colour Charts (LCC) for the particular application of Urea, following the instructions on the charts (To be provided).

In situations where it is not possible to conduct soil tests, either due to high cost and unavailability of analytical services or when the crop shows signs of being subnormal in growth, the below recommendations should serve as a guide.

- **General fertilizer recommendation, based on agro ecology:**
  - Humid forest: Apply 60 kg N, 30–60 kg P_2O_5 and 30 kg of K_2O per hectare
  - Savannah: Apply 60–80 kg N, 30–60 kg P_2O_5 and 30 kg K_2O per hectare.
- **Time of application:**
  - Basal Application of Phosphorus and Potassium: Apply P and K within one week before transplanting and work the fertilizer well into the soil.
  - Topdressing of N fertilizer (e.g. urea) - Apply in three equal doses:
    - Deep placement (2–3 cm) at transplanting.
    - Broadcast at about mid-tillering (3–5 Weeks After Transplanting [WAT]).
    - Panicle initiation (i.e. the start of the reproductive phase of rice development, when the head begins to form); 8 WAT for late maturing (cultivars) before or after 150 days or earlier, (6 WAT) for medium maturing varieties.

  Maintain water levels in the field to 3-5 cm at the time of application to ensure efficient use of the applied fertilizer.
- **Methods of fertilizer application:** The fertilizer can be applied in two ways:
  - For small areas in the irrigated area, close the irrigation system and any drainage outlet, then apply the fertilizer between rows. Irrigate and close the canals for about 10 days to facilitate nutrient absorption.
  - Drain the field and apply the fertilizer by broadcasting. The fertilizer should be flooded immediately to prevent denitrification.
- **Topdressing N from straight fertilizers (e.g. urea):** General Recommendations:
  - Use 15 to 20 kg N for every tonne of target (expected) yield.

- Apply in 2 -3 splits for greater or less than 60 Nitrogen per hectare (</> 2.5 bags urea); use more splits for late-maturing cultivars (varieties) >120 DAS.
- Do not apply more than 35 kg N/ha (1½ bags urea) in a single dose (split) to minimize losses.
- Apply 40–60 kg N, 20 kg P_2O_5/ha and 20 kg K_2O/ha.

2.4.7 Water / Irrigation Management

No crops will grow well without the regular availability of water, so good water/irrigation management and control is necessary to increase crop yields and grain quality, as well as improve the use efficiency of water use and efficacy of other inputs such as fertilizer, herbicides, and pesticides. To maximize water-use efficiency, the farmers are recommended to do the following:

- Maintain the paddy bunds
- Level the paddy fields
- Puddle the fields where possible
- Use short-duration crops
- Harvest on time.

a) Conventional Irrigation Management

Continuous flooding of water generally provides the best growth environment for rice. After transplanting, water levels should be around 3 cm, gradually increasing to 5−10 cm with increasing plant height and remaining at this level until the field is drained 7−10 days before harvest. Lowland rice is extremely sensitive to water shortage at the flowering stage (i.e. soils drier than the saturation point) and drought at this stage will increase spikelet sterility, producing fewer grains, resulting in yield loss. Therefore, farmers should keep the water level in the fields at a minimum of 5 cm at all times from one week after transplanting or heading to the end of flowering stages or until the grain matures. Any remaining water in the fields should be drained one week before harvesting. For clay soils that shrink when drying out, the moisture levels should be maintained such that cracks should not appear in the field.

b) Alternate Wetting and Drying (AWD)

Alternate Wetting and Drying (AWD) is a water-saving method that lowland rice farmers can apply to reduce their water use in irrigated fields; it can reduce the use of irrigation water by 15-30% compared to conventional irrigation and will not cause any yield decline, so long as the dry period is not too long (i.e. Safe AWD). This practice induces more number of productive tillers especially during the maximum tillering stage. AWD is recommended for the pilot SPIS at Bong Mines, to maximise the utility of the limited available water resources.

Under AWD, the fields are alternately flooded and allowed to dry, with irrigation water applied to flood the fields 1-10 days after the disappearance of ponded water (For the sandier soils evident at the Bong Mines pilot SPIS, this period will be towards the shorter end of this range). For Safe AWD, causing no yield reduction, the perched water level can be monitored using a

perforated tube embedded in the soil; irrigation is applied when the water level drops to 15–20 cm below the soil surface before.

2.4.8 Harvesting

Harvesting the crop on time is very important to maximize yields and grain quality. Rice harvested too early will have many unfilled and immature grains. Immature grains break easily when milled and will not germinate when used for seed. If crops are harvested late, heavy losses will occur through shattering and bird attacks.

Crops should be harvested as follows:

- The crop is ready for harvest when the grains are hard and are turning yellow / brown:
  - Generally about 30–45 days after flowering or a month after 50% flowering
  - Grain moisture should be between 20–22%
  - 80–85% of the grains are straw coloured
  - Grains in the lower part of the panicle are hard/firm, not soft, and not easily broken when squeezed between the teeth.
- Cut the stems with a sickle about 10–15 cm above the ground.
- Lay harvested rice crop in upright position to dry before threshing.

2.4.9 Post-Harvest Management

The following points provide guidance for the farmers for efficient post-harvest activities, to minimise losses and maximise the quality of rice sales.

a) Threshing

- Thresh immediately after harvesting to avoid losses; if available, use a mechanical rice thresher, whacking frames or on a mat or tarpaulin over a concrete floor by flailing (i.e beating rice against the floor or against a stick or drum). Avoid threshing on bare earth floors to prevent the introduction of sand, pebbles and other foreign matter.
- Thresh carefully and avoid de-husking the grains.
- Dry the grains as soon as possible after threshing, on tarpaulins or clean drying pads, and turn or stir the grains at least once every hour when sun-drying to achieve uniformity.

b) Winnowing

- Winnow to separate the chaff and empty grains from the well filled matured grains, with repeated winnowing after drying to further clean the grain.
- Remove any foreign matter from the winnowed grains and store in a cool, dry and clean area, preferably in sealed containers for seed.

c) Drying

- Dry the grains to a safe moisture content of 13–14% using a mechanical drier, if available, or by spreading in a thin layer (2–3 cm thick) on clean concrete floors, mats or tarpaulins and turning periodically. Avoid drying on bare earth floors or road sides, since the quality of rice will reduce with any contamination with sand, stones and other foreign matter.

- Typically allow 2–3 days for sun-drying, depending on the moisture content (On a clear, bright day, sun-drying can last for about 9–10hrs), which will reduce breakage during milling.

d) Storage of Dried Paddy Rice

- In general, it is recommended that rice for food purposes be stored in paddy form rather than milled rice as the husk provides some protection against insects and helps prevent quality deterioration.
- Store the rice in a cool, dry and clean area for as long as possible (i.e. Temperature within 10°F/5.5°C of the average monthly air temperature and below 60°F/15.6°C and relative humidity below 65%).
- Active or passive aeration systems can be designed to maintain rice moisture and temperature at these uniform conditions.
- Only store well cleaned rice.
- Inspect rice regularly (i.e. Weekly) during storage, noting any discoloration or signs of insect infestation and rodents (When necessary and only under the direction of a trained pest control technician, the storage room or the seed stock may be sealed with tarpaulin and treated with fumigants).

e) Milling

Milling is the process of removing the husk or hull from the grain and the bran from the kernel (brown rice). Premium prices will be possible with minimal broken grains, achieved by an efficient milling process.

- Mill the rice in a two-stage milling machine, if available.
- Only mill one pure variety at time.

f) Storage of Milled Rice

- After milling, store when thoroughly dry in clean, dry grain stores.
- Store milled rice in jute or sisal bags or poly bags.
- Stack bags on wooden pallets, raised above the floor, in an air-tight room, free from rodents and roof leakage.

3 SAFETY FOR SPIS OPERATIONS

Personal safety of farmers and operators is paramount, even above the safety of the system. Whilst individuals remain responsible for their own safety, it is important that farmers, operators and technicians evaluate the risks identified in this section of the O&M Manual[4] before proceeding with any work on the system and only do so under an agreed safe method of working. If conditions change, the work should be paused to re-evaluate the risks and if there are ever any concerns, stop and check before proceeding. If in doubt always call a technician.

Any injury, no matter how minor, should be reported and treated by a qualified health professional. Appendix E: Electrical Burns - Identification and First-Aid provides some guidance, but the content in this O&M Manual should never be used in place of qualified medical advice.

3.1 Personal Safety and Personal Protective Equipment (PPE)

Personal safety is of great concern, particularly in remote areas like the Bong Mines SPIS. To ensure safety and reduce risks to farmers, operators and technicians, the following measures should be followed:

- Plan the activities to be undertaken by the personnel prior to starting the work:
  1. List the tasks to be completed.
  2. Identify the specific risks for each task.
  3. Plan methods of working that reduce or eliminate each risk.
  4. Communicate the plans with all personnel involved.
- Ensure a clean environment clearing the area, including a radius around the PV panel fencing, to reduce risks of insect, rodent, or snake infestation.
- Ensure the area is locked at all times, particularly at night.
- Post the necessary hazard signs around the compound to remind yourself and warn others of the dangers.

Personal Protective Equipment (PPE) should be used whenever the risks are assessed to require it, as follows:

- **Gloves** – To be used to protect the hands when working with chemicals (e.g. Fertilizers and pesticides; Always follow the manufacturers' recommendations).
- **Gumboots** - To be used as footwear protection, especially against snakes and other reptiles for ease of movement in bushy areas and during daily cultivation practices.
- **Respiratory protection** – Face masks to be used when working with chemicals especially during mixing of pesticides and spraying periods during pests and disease management.

[4] Based on the Green People's Energy, Practical Operation & Maintenance Manual for Users of Solar-Powered Irrigated Horticulture in Uganda, June 2021

- **Diet** – The person should have proper food before handling with chemicals. Spraying of agro chemicals are not encouraged with empty stomach.
- **Hard Hats** – To be used when climbing to heights above 2 m and when there is a danger of items falling from above (This may be necessary during maintenance of elevated storage tanks, but is unlikely to be the case at the Bong Mines pilot SPIS).

Ideally, the SPIS management (Fuamah District Multipurpose Cooperative) should ensure that appropriate Personal Protective Equipment (PPE) is available for farmers and operatives at all times.

3.2 Electrical Hazards

Energised electrical systems can be lethal when handled inappropriately, even if they appear to be unpowered. Always take extreme care and treat electrical systems with caution. The operating voltage of the SPIS pilot is above 350 Volts Direct Current (DC), which is a serious electrocution hazard, even with dry skin.

Proper maintenance and safety procedures protect both maintenance personnel and individuals using water from the system. A good electrical design will take account of electrical hazards, but safe practices will help eliminate the risk of electrical exposures. Appropriate training of operators and technicians is essential to maintain these safety practices.

A summary of Electrical Safety Rules is provided in the Appendix D andand these should be displayed prominently at the site and all farmers made aware of the contents.

3.2.1 Damaged or Bare Wires

Improperly specified or installed wiring and equipment can be as dangerous as wires with worn or degraded insulation, which may have no visible damage. Be vigilant of all electrical operating equipment, either partially or fully connected and/or powered ON or OFF, and avoid conducting materials or standing water in contact with electrical equipment.

Safe wiring can become unsafe over time. They should be laid and hung to avoid creating a dangerous environment but should be inspected regularly for any damage.

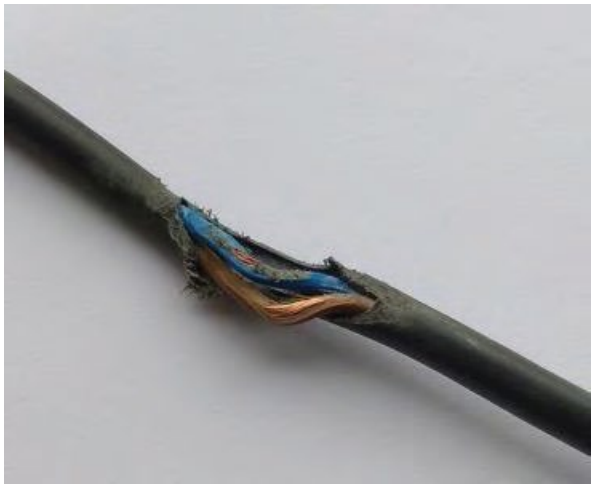


Figure 3: Damaged Insulation Requiring Immediate Replacement

3.2.2 Solar Panels

Solar panels are energized anytime when the sun is up and it is impractical and unsafe to undertake maintenance during night hours, therefore it is essential that the following safety guidelines are followed:

- Do not work in bad weather.
- Do not sit on the solar panels.
- Cover the solar panels while working on them.
- Do not wear metallic jewellery when working around electrical components.
- Never work alone.
- For panels installed at height and not easily reachable from the ground, use a good ladder to reach the panels for cleaning and repairs.
- Wear gloves whenever working on solar panels.

3.2.3 Grounding and Bonding

A grounding and bonding system connects a grounding electrode to all metallic electrical enclosures which can contact electrical conductors in the event of insulation breakdown and is required by the IEC safety standards. A grounding electrode, as included in the system design, creates a protection around energized conductors and equipment, and must be maintained in proper working order to protect farmers, operatives and technicians working near the equipment. Operators should never remove any electrical equipment covers; if removed covers or uninsulated wiring are found, do not touch any components, and immediately contact a technician.

3.2.4 Lightning Storms

Due to the increased risk of shock, SPIS should never be serviced or actively managed during a lightning storm. The pumping system structure and components may attract direct lightning strikes and lightning rods may be provided to disperse the strike through the ground. This creates a physical danger zone around the entire area that receives a lightning strike.

During a storm, quickly move away from the SPIS system and any lightning rods. Always remain outside the fenced solar panel enclosure and pump house when lightning is a threat. Also ensure that no one enters the area during storms. If caught accidentally near the solar panel system during a storm, as a last resort and protective measure only, farmers and other personnel should take up the Lightning Crouch position; place feet together as closely as possible and squat close to the ground without touching the ground with hands.

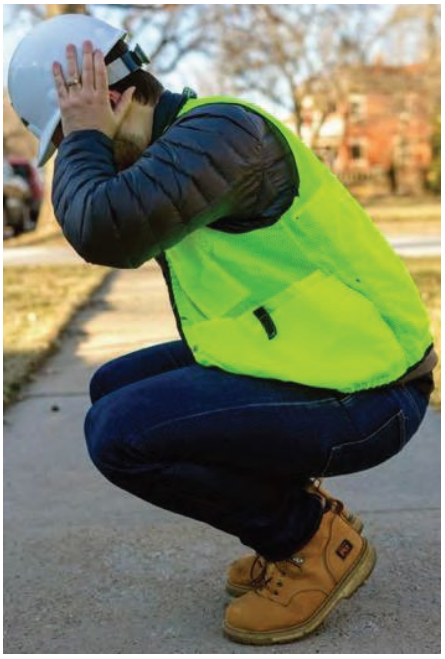


Figure 4: Lightning Crouch Position

3.2.5 Pump Motor Controller

The pump controller should only be opened by a trained technician, since it enables the conversion of the DC electricity coming from the solar panels to the AC voltage that drives the pump motor, as well as providing protection and controls. It is essential that grounding and surge protection be applied to the DC from the solar panels and any alternate electrical sources to prevent damage to the pump controller.

3.3 Chemical Hazards

Safe handling of chemicals is of primary concern and should follow the manufacturers' and suppliers' recommendations at all times. Fertilizers, herbicides and pesticides can contain inorganic chemicals that are hazardous to health, please be careful when handling, always use gloves, eyewear (in case of splash), and a respiratory mask when recommended.

Chemicals should not be stored in the PV panel enclosure or near the SPIS equipment. All such areas should be kept clear of clutter, waste, food and other potential contaminants or invitations for pests to nest or reside inside the enclosure, risking damage to the electrical equipment.

Never climb a ladder with an open container of chemicals.

4 Operation and Maintenance Activities of the System Operator

4.1 General

This section provides details on the installation, operations, and maintenance tasks for each component of the SPIS that are to be performed by the installer, operator and technicians responsible for operation of the system and preventive maintenance. The key tasks are summarised in Appendix B & C as a printable guide to be displayed at the site and kept on record by the system operator.

4.2 Installation Guidelines

The SPIS equipment, both electrical and irrigation components, should be installed by qualified technicians and supervised by engineers, following the recommendations in the suppliers' manual, and according to the design and specifications, such that it provides the required functionality. It is beneficial that the farmers and operators are also involved at this stage to assist with installation of the irrigation system (e.g., pipes, valves etc) to instil a sense of ownership and pride in the system, raise awareness and learn the skills that may be necessary during maintenance and repair activities.

4.2.1 Electrical Components

Always follow the manufacturer's guidelines for installation of PV panels, controllers, and pumps. The following procedure summarises the key stages:

- Assemble all the components of the system (i.e., the solar panels, controller, and pump):
  - Connect the pump outlet to the main delivery pipeline of the irrigation system - Water pumps in an SPIS systems can be surface pumps or submersible pumps, depending on the nature of the water sources to be used (At the pilot SPIS at Bong Mines it is a submersible). Surface pumps are often installed near a water source to suck water into the intake before delivering at pressure into the supply pipeline; they are generally cheaper, but less energy efficient and require attendance of an operator to ensure priming at start-up. Submersible pumps are usually installed for groundwater sources, although they are not limited to this situation, with the advantage that they can be controlled automatically with little attendance by an operator.
  - Incline the solar panels to the optimum angle, such that the radiation falls directly onto the solar panels during the time needed for pumping - The PhotoVoltaic (PV) solar panels converts the sun's radiation into electrical energy for the pump in the SPIS and are usually installed as an array/set of panels on raised supports. Depending on the location in the world, they can be tilted towards the equator, to maximise the efficiency of energy production. (For the pilot SPIS at Bong Mines, the location is close to the equator and the panels have been installed horizontally).

  - To protect the electrical components, including the solar panels and the pumps, a lightning surge protector should be installed within the array; this provides protection from strikes by harmlessly diverting the electrical charge to ground.
  - Connect the terminals of the panels to the controller and those of the motor of the pump - The controller is the link between the high voltage DC produced by the solar panels and the AC required by the pump at the Bong Mines pilot SPIS (Other installations may use DC motors). It also corrects the fluctuations in power output resulting from variations in sunshine and shade, and regulates the speed of the pump motor, protecting it against over- and under-voltage, reversed polarity (during installation), overload and overheating.
- For submersible pumps, as provided at the Bong Mines pilot SPIS, the pump is submerged and does not need priming, but for surface mounted pumps, with a suction hose, it may be necessary to prime the pump by adding water through the pump before operating.
- Make sure any screens are correctly located around the inlet and are clear of debris and ensure there is no shading of the PV panels.
- Start the pump by pressing the green “Start” button; to stop press the red “Stop” button.

4.2.2 Supply Pipelines and Laterals

Both the supply pipelines (200mm diameter) and laterals (150mm diameter) are constructed from uPVC pipes buried at a minimum depth of 0.6m, so that they are unaffected by cultivation activities or heavy machinery. Nevertheless, farmers should not cultivate within 1m of the pipeline alignments.

A number of valves are located at points along the pipelines in the SPIS, to control the quantity of water flowing and to rotate the supply to different fields; valves are also used to flush the pipelines to clean out any sediments. All mud and other materials should be cleaned from the pipe before laying and connecting any valves, as this could damage the valves when operating. A valve is provided at each outlet riser and at the end of the pipelines to facilitate flushing or with an end plug.

Once the system is substantially complete, it should be tested by pumping water into the system. Ensure that all the valves are open and pump water until all pipelines have been flushed, then close the valves. Once it is established that all the components are functioning properly and the pump is delivering the required flow and pressure at the outlets, the system is ready for use.

4.2.3 Storage Tank

Although not specified at the Bong Mines pilot SPIS, some systems incorporate an elevated storage tank to give greater flexibility on the timing of irrigation applications (The alternative of storing energy in batteries is not cost effective and a security risk). Open tanks also enable fertilisers to be mixed directly into the irrigation water (Fertigation). The mounting structure for the tank must be designed by a structural engineer.

4.3 Routine Maintenance

The following sub-sections provide details of normal operation and regular maintenance activities that should be followed as a general guideline, to supplement the equipment manufacturers' specific recommendations.

4.3.1 Solar Panels

Shading of PV solar panels may occur due to buildings, trees and other vegetation, deposits of dust, dirt or bird and animal droppings, or any other object that can impede the sunlight falling onto the panels. All shading reduces the power output from the panels to the controller and subsequently to the pump.

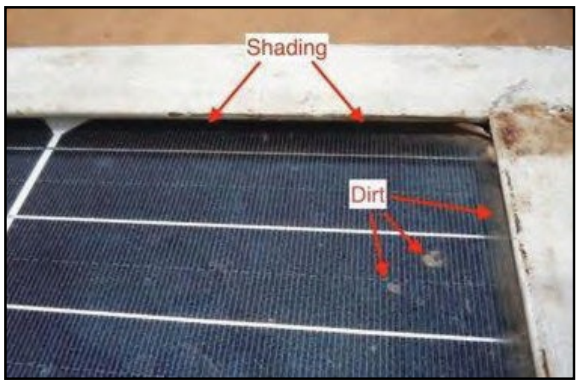


Figure 5: Examples of Shading

The following maintenance activities should be carried out on a regular basis (i.e. Before each daily operation of the pumps, on a weekly basis or as necessary, depending on the level of accumulated dirt or following strong winds or heavy rain that may have caused damage):

- Make a visual inspection of the area to ensure nothing is shading the panels such as vegetation, structures or dirt (Note that shading of only one panel will reduce power from all panels, because of the electrical properties of the connections). Trim or remove any vegetation around the solar panels as well as any erection of structures that will block sunlight.
- Using a soft sponge and water only (DO NOT USE SOAP), wash the panels during the early hours of the day, when it is not yet hot (Remember to remove jewellery, belts, etc. that may scratch the panel surfaces and make sure the ladder you are using is in good repair). Squeegee dry the panels to ensure that water spotting does not occur during drying.

Figure 6: Squeegee for Cleaning Solar Panels

- Check if any panels are cracked. If yes, contact the Technician to request support.
- Check if wiring is exposed, loose/sagging, disconnected or damaged by rodents or animals. If yes, contact the Technician to request support.
- Check if the panel mounting structure is strong and the panels are well attached:
  - Check for cracks or any other sign of weakening or degradation (e.g., corrosion).
  - Check and tighten any loose bolts.
  - If signs of corrosion are evident, repaint the area with anti-corrosive paint.
  - If there are any visible areas of weakness, contact the technician to request support.
- Check the area around the solar panels for trash and debris, spider webs or any other insect nesting (e.g., bees):
  - Remove and dispose of trash and debris.
  - Carefully remove spider webs and insect nests or call a beekeeper or someone who can handle dangerous insects.
- Check that the lightning rod and grounding are secure, taking care of any risks of falling or damaging the solar panels. If there are any visible signs of damage or disconnection, these could be costly or deadly, so contact the Technician to request support.

Figure 7: Earthing/Grounding for Lightning Protection

4.3.2 Pump Controller (Inverter)

The following tasks should be undertaken on a regular basis, before operation:

- Clean the controller/inverter box - Remove dust and cobwebs.
- Repair any holes that may allow insects or rodents to enter and nest, causing serious damage to the equipment.

During operation:

- Record the electrical status indicated by the warning LEDs and the display screen on the controller (e.g. input and output, current and power), if available.
- Note any significant difference from previous/normal recorded data - If the electrical discharge is not in the expected range, contact the Technician.
- Check for the most common alarms (i.e. red LED lights):
  - FAULT - Check that the pump is running, the pressure/flow is in the normal range and there are no unusual sounds. If there is nothing unusual, then it could be that the inverter has an internal error and the Technician should be contacted.
  - WELL/POND DRY - Check the water level in the well/pond and

Contact the Technician under any of the following circumstances:

- The pump is not running - The control systems may need to be re-started. To re-start the system, the operators will need to refer to the re-start procedure in the manufacturers' operating manual, specific to the equipment at the Bong Mines pilot SPIS.
- If inspections of the wiring identifies potential failures, damage or exposed wires - If there appears to be a blown fuse or any blackened areas, indicating an electrical burn, there may be a wiring fault.

4.3.3 Pump and Supply Pipeline

The following checks and maintenance activities should be undertaken relating to the pump and supply pipeline:

- Check there is sufficient water in the well or pond - Level indicators or a simple gauge board can be installed to set the minimum levels required for safe operation.
- Ensure the pump intake is not close to mud or sand that could be entrained into the intake and damage the pump, and check that the screens are not clogged with debris (e.g. leaves, seeds and twigs) - Remove any trash or debris from the area.
- For surface pumps that need priming, ensure the appropriate steps are taken when starting the pump; usually this involves adding water to the pump through the pipes, to enable it to efficiently create the reduced pressures required to draw water from the source.
- On start-up, if meters are available, record the pressure and flow indicated, and the start and stop times to determine the hours of pumping - In case of any abnormalities report to the Technician.
- When running, take note of any unusual noise, vibration and reduced performance of the pump - This may be the result of cavitation (the forming of voids or bubbles within the

pump) or damage to the pump's moving parts. The operator should check and ensure water from the source is sufficient and not drying up and the technician should be contacted.

- Check if the pump, supply pipes or laterals are showing any signs of leaks - Visually inspect connections for any external corrosion, damp ground or puddles along the pipeline routes or erosion of the backfill around the pipes. Due to the high pressure at the pump, repairs to the pipes and fitting will require shutting the system down, therefore contact a qualified Technician to fix any leaks.

4.3.4 Storage Tank

If installed, check and maintain storage tanks as follows:

- Check if the tank, valves or any connections are leaking - Conduct a visual inspection of the tank and its surrounding ground for visible signs of leakage.
- Ensure tank support structure is firm and stable - Note any damage, loose bolts, cracked welds or members, and areas of corrosion (Repaint with rust proofing pain).
- Clean and flush the tank on a quarterly basis, or as needed.
- For any serious issues, contact the Technician to request support.

4.3.5 Distribution System

a) Valves

Valves should be regularly operated to check the ease and range of opening, if the connections are loose or leaking, and to ensure the operating handles are in place. Any issues should be reported to the Technician for further diagnosis; loose connections may be tightened to stop leaking.

b) Irrigation System layout

Operators should regularly conduct a physical walk along the lateral pipes routes between risers to check the following:

- Leakages or any blockages along the lateral pipes, particularly at Tees, bends, risers, valves and at the end plug - Any signs of leakage should be reported and the Technician contacted for guidance.
- In the case of a minor leakages at threaded joints, these can be tightened with thread tape before contacting the Technician for guidance and support.
- For more serious leaks and bursts, a section of pipe may need to be replaced, using a coupler to re-join the new pipe between the two good pipe sections.

5 TRAINING WORKSHOPS

The EPA and MoA, as owners of the pilot scheme, as well as officials and rice farmers from the FDMC and the wider Bong county were invited to an on-site workshop on 14 July 2023, but at that time the scheme was incomplete to enable a practical introduction to and demonstration of the SPIS. O&M training was given to the farmers from the Fuamah District Multipurpose Co-operative (FDMC) and a new date will be agreed with EPA/MoA, the SWG and FDMC to complete this exercise. This future workshop will explain the purpose of the project, with its focus on lowland SRI production with solar water pumping system, and why the particular SPIS configuration was selected as appropriate for the site.

5.1 Objectives

The objective is to raise the awareness of SPIS across the county and build capacity to operate and maintain the pilot scheme. As detailed in the MoU signed by the FDMC and EPA/MoA, once the scheme is complete and handed over, the ownership of the equipment rests with the EPA/MoA, but the FDMC will be responsible for its maintenance and security.

5.2 Participants and Venue

The targeted participants will be the members of FDMC, who will operate the pilot scheme at Bong Mines, as well as other farmers from the county and officials who are interested in employing the technologies elsewhere. A full list of FDMC members who participated in the O&M training is provided in Appendix G: Attendance Records.

The venue will be the SPIS pilot scheme at Bong Mines and the FDMC warehouse.

5.3 Approach and Methodology

Since the target group was predominantly made up of smallholder farmers with minimal literacy and numeracy skills, living and working in rural farming communities, the training approach follows a participatory learning-by-doing approach, designed to be field-based and mainly practical, to enable participants to acquire new and improved skills. In addition to the participatory (learning-by-doing), the training also involves the use of visual presentation and posters.

The training describes the deployment of the technology at Bong Mines and how it could be replicated to neighbouring lands, and covered the following key aspects that will be needed to make efficient use of the technology and for the long-term sustainability of the pilot SPIS:

- **Operation**: A full and detailed description and demonstration of how it works and the functionalities of each component.
- **System of Rice Intensification**: Improved rice husbandry practices to broaden the practical skills in rice cultivation, post-harvest processing and management, and the factors to consider for a healthy crop.

- **Maintenance**:
  - When, what and how maintenance activities should be undertaken (e.g. Cleaning solar panels, maintaining the pumping system or the electrical components)
  - When equipment/materials should be replaced
  - Where spare parts can be purchased, with estimated prices, delivery times and conditions of guarantees
  - Do's and Don'ts.

The sessions were led by an international facilitator, who ensured full participation of individuals in the learning process, and was supported by agricultural and technical personnel from the Consultant's Team, the SWG and contractor. The training sessions were interspersed with group discussions and periods for questions and answers.

5.4 Outcomes and Deliverables

At the end of the training, the participants had gained the following:

- Enhanced knowledge of SPIS technologies, their capabilities and suitability for other areas and crops.
- Practical skills in improved rice cultivation methods, including seed selection, land preparation, sowing, field maintenance, water management, pest and disease control and post-harvest handling and processing techniques
- Operation & Maintenance of the SPIS equipment, including the electrical and irrigation components.

Copies of this O&M Manual will be provided to participants, both electronically and in hard copies, together with the training materials used and the Fact Sheets and posters relating to operator safety, routine maintenance activities and Do's and Don'ts (See Appendices).

Because few rural people are literate in the local languages and dialects in Liberia, it is not considered effective to translate the manual into other languages. Schematic and pictorial representations of the key elements of the O&M Manual may be developed prior to further scaling-up of the project to other provinces of the country.

6 CONCLUSIONS AND RECOMMENDATIONS

This report updates on work conducted under the Technical Assistance (TA) to introduce Solar Powered Irrigation Systems (SPIS) and a System of Rice Intensification (SRI) in Liberia, providing information on the following:

- Introduction to the key components of SPIS, its advantages and risks
- Introduction to the System of Rice Intensification (SRI), providing guidelines for farmers
- Operation and Maintenance (O&M) Manual for the pilot SPIS at Bong Mines
- Learn-by-doing workshop with the FDMC farmers
- Stakeholder consultations
- Organisation of training for Municipal and National officers (TBD).

O&M activities for SPIS predominantly involves the care and preventative maintenance of the solar electrical systems and piped irrigation network, and the repair of these systems. The final output of the TA (Output 6) will formulate a Monitoring and Evaluation (M&E) framework to be used by the farmers and stakeholders to monitor and report on aspects of the scheme, including Agricultural Production, Water Management, Energy Generation and Maintenance Activities.

The sustainability of an SPIS depends on good design, quality equipment and installation, but also on the farmers' ability to use and maintain it efficiently. The O&M Manual describes the installation and routine maintenance, including what, how and when activities should be undertaken, and when the assistance of a qualified technician may be required.

Personal safety of farmers and operators is of paramount concern and simple guidelines to reduce risks and provide protection are also described.

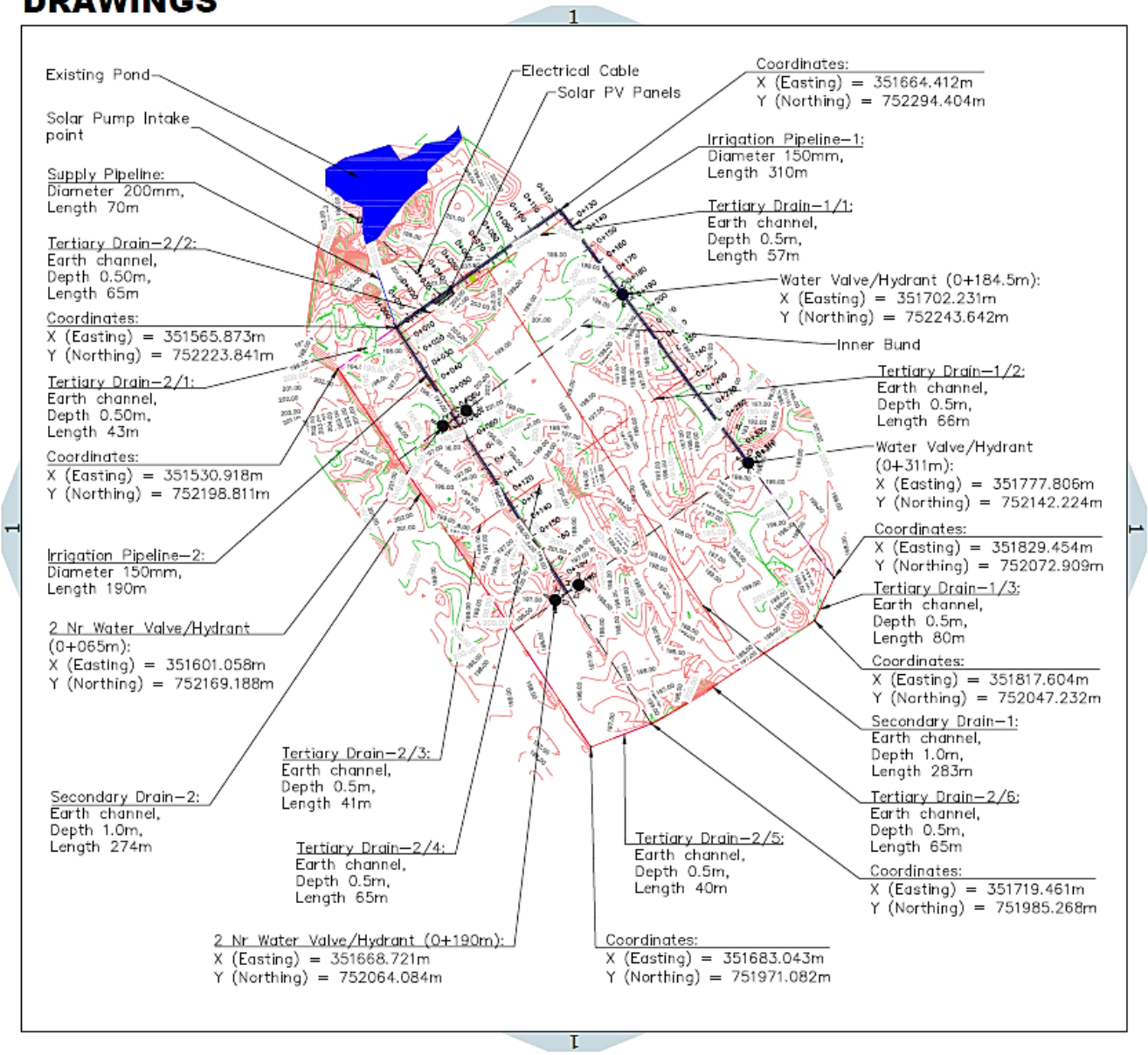
The information presented is exhaustive and technical, so the key messages for farmers are also presented as simplified guidelines in the Appendices, which can be displayed as posters to communicate to everyone. The O&M Manual will be provided as hard copy as well as electronic versions for use at other schemes.

O&M training was given to the FDMC farmers covering operation, SRI and maintenance Do's and Don'ts. A new date will be agreed with all stakeholders to complete this awareness raising and O&M training aspect of the TA to further explain the purpose of the project, its focus on lowland SRI production and SPIS, why the site and configuration was selected and how it can be replicated in other areas.

APPENDICES

Appendix A: As-Built Drawings and Equipment Manufacturer's Details

DRAWINGS



CARES Limited

CARES

LEGEND

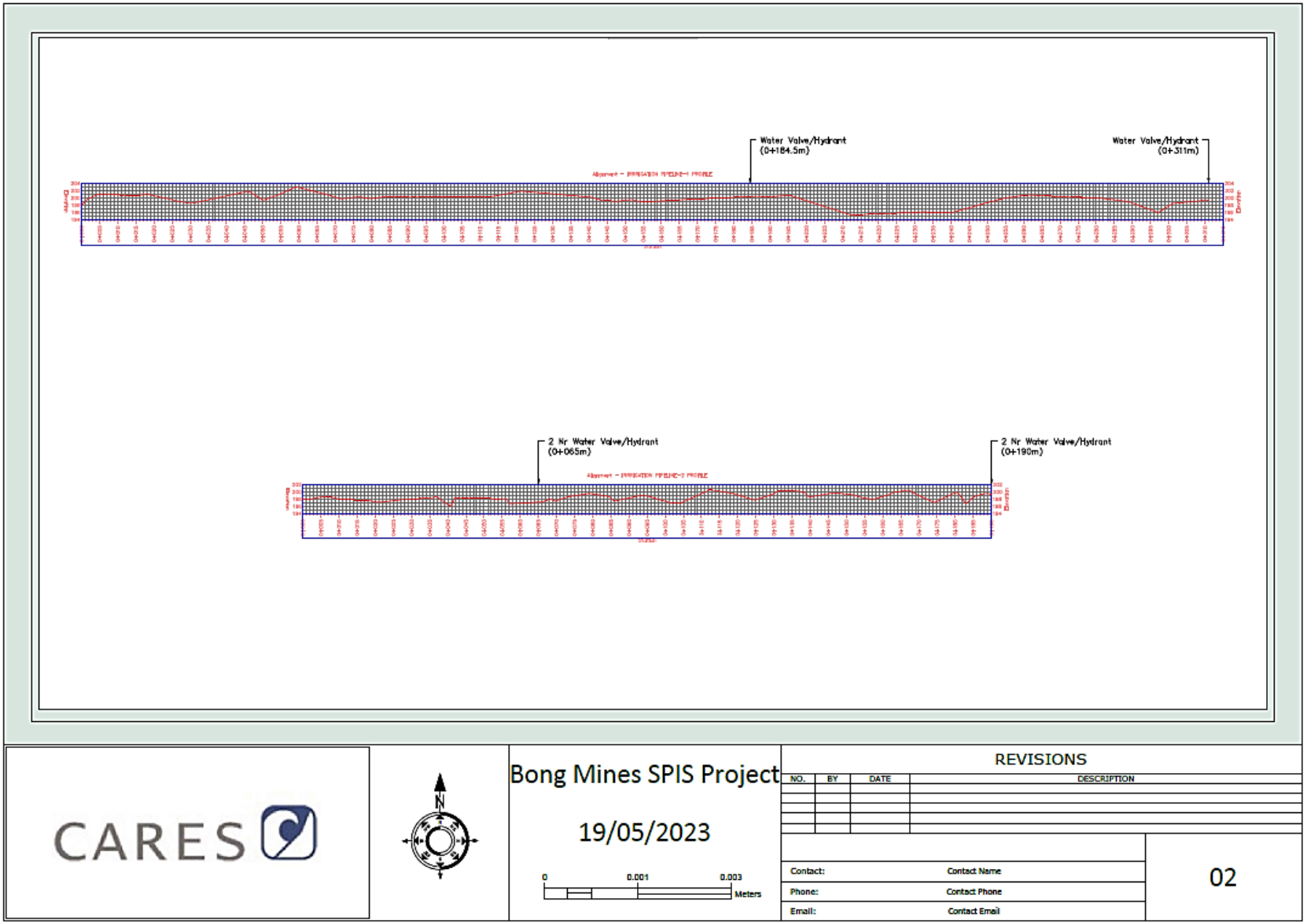
KEY MAP

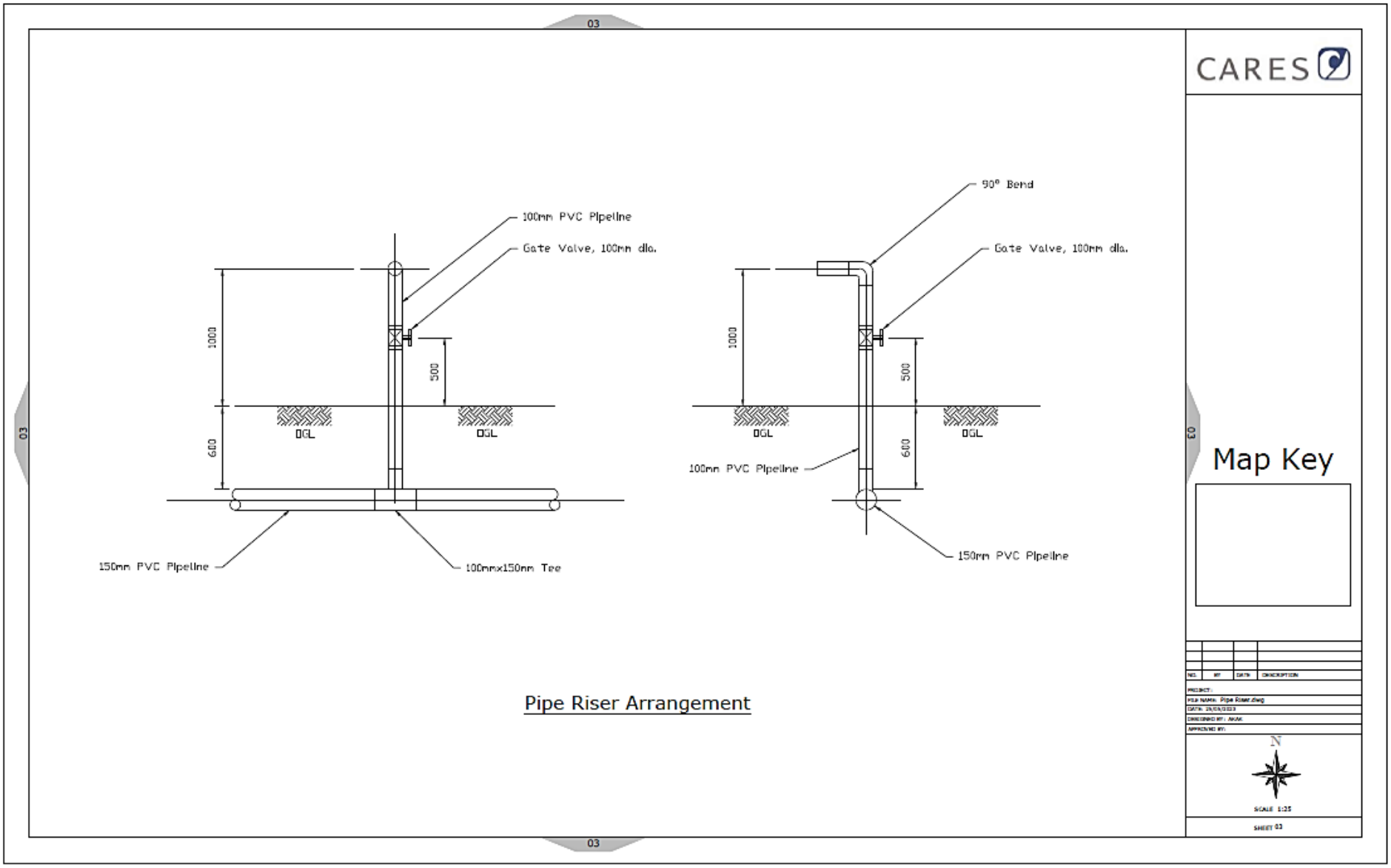
N

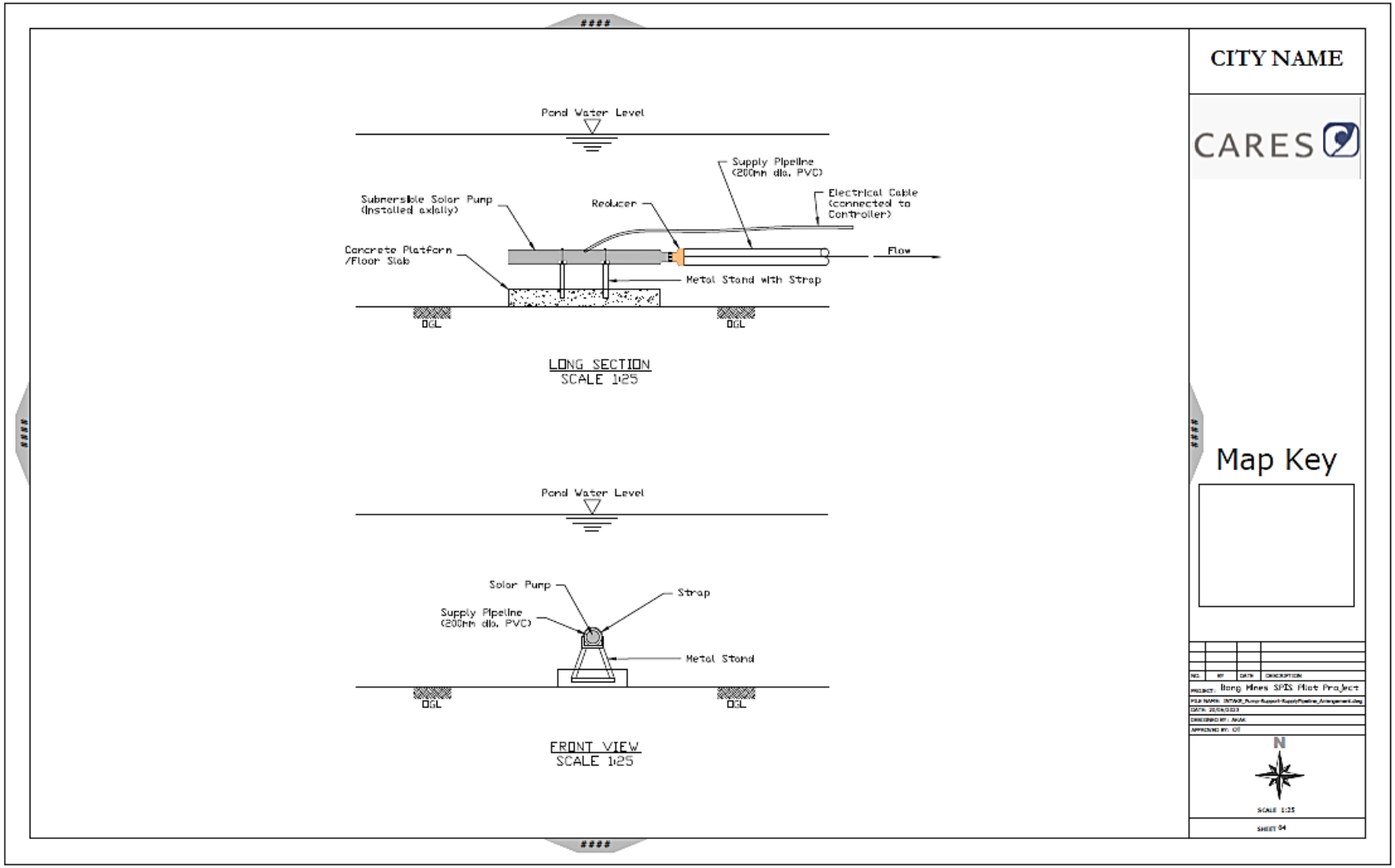
SCALE	SHEET NUMBER
As shown	01
PLOT DATE	
19/05/2023	

FILE NAME

Bong Mines SPIS Project


Water Valve/Hydrant
(0+184.5m)
Water Valve/Hydrant
(0+311m)
2 Nr Water Valve/Hydrant
(0+065m)
2 Nr Water Valve/Hydrant
(0+190m)
Bong Mines SPIS Project
19/05/2023
0
0.001
0.003
Meters
REVISIONS
NO.
BY
DATE
DESCRIPTION
Contact:
Contact Name
Phone:
Contact Phone
Email:
Contact Email
02

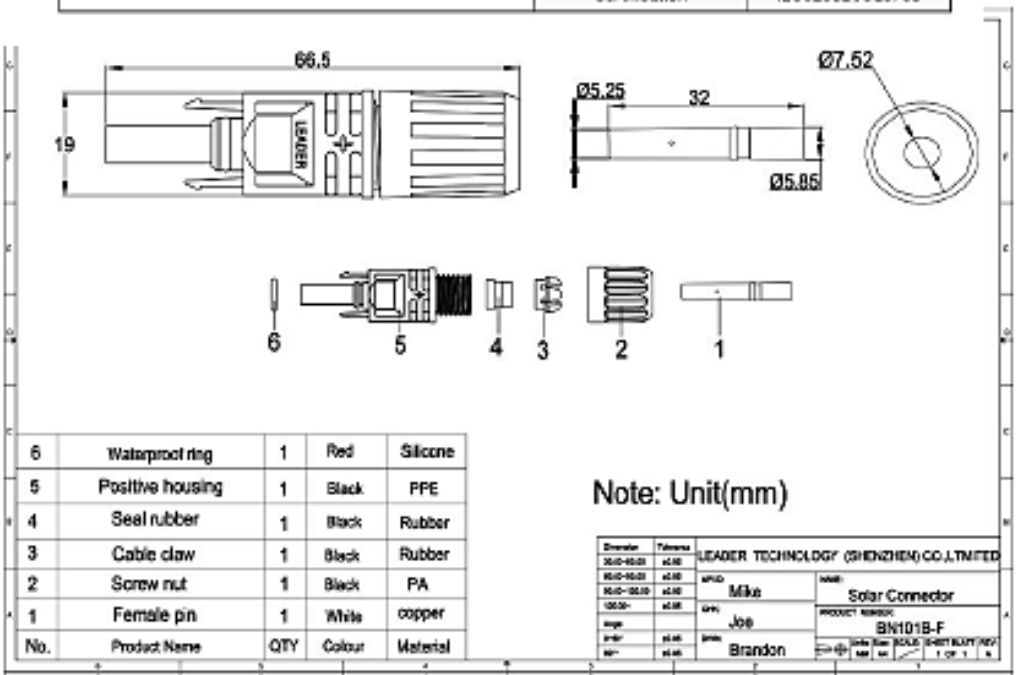

03
100mm PVC Pipeline
Gate Valve, 100mm dia.
1000
500
600
OGL
OGL
150mm PVC Pipeline
100mmx150mm Tee
90° Bend
Gate Valve, 100mm dia.
1000
500
600
OGL
OGL
100mm PVC Pipeline
150mm PVC Pipeline
Pipe Riser Arrangement
CARES
Map Key
N
SCALE 1:25
SHEET 03


Pond Water Level
Supply Pipeline
(200mm dia. PVC)
Submersible Solar Pump
(Installed axially)
Reducer
Electrical Cable
(connected to
Controller)
Concrete Platform
/Floor Slab
Flow
Metal Stand with Strap
OGL
OGL
LONG SECTION
SCALE 1:25
Pond Water Level
Solar Pump
Strap
Supply Pipeline
(200mm dia. PVC)
Metal Stand
OGL
OGL
FRONT VIEW
SCALE 1:25
CITY NAME
CARES
Map Key
Ilong Mines SPIS Pilot Project
N
SCALE 1:25

Specification Of Solar Products

EQUIPMENT MANUFACTURER'S DETAILS

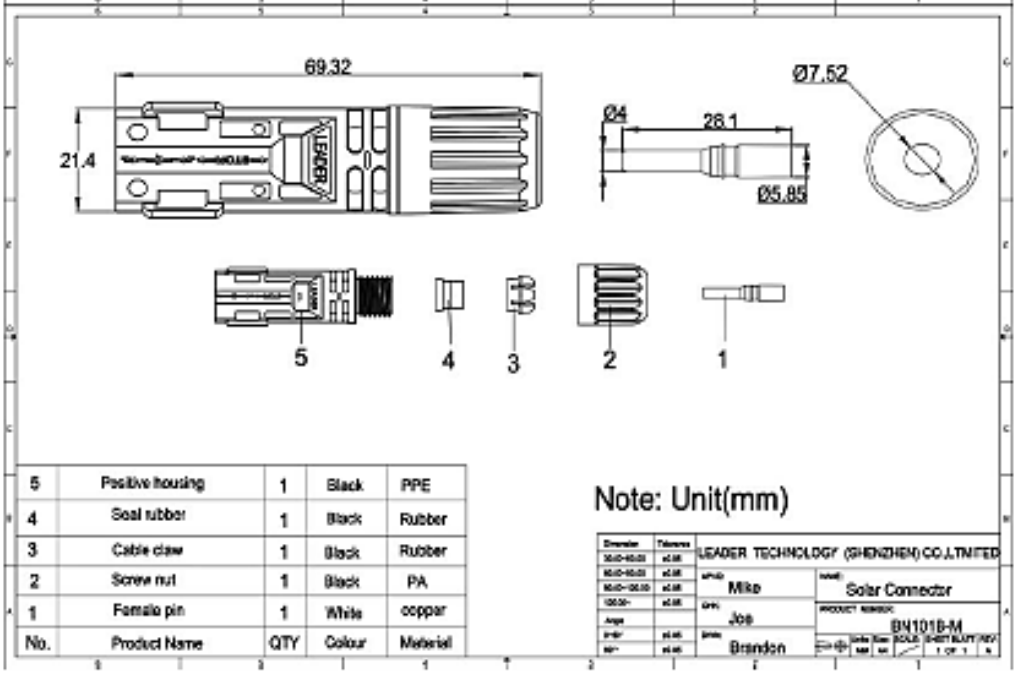
Product NO.	PV-BN101B-S6
Insulation material	PPO/PC
Rated voltage	TUV1500V/UL1500V
Rated current-2.5mm²	35A (14AWG)
Rated current-4mm²	40A (12AWG)
Rated Current-6mm²	45A (10AWG)
Test voltage	6KV(50Hz,1Min)
Contact material	Copper, Tin-plated
Contact resistance	Less than 0.35 mΩ
Degree of protection	IP68
Ambient temperature	-40°C up to +90°C
Certification	IEC62852 /UL6703



No.	Product Name	QTY	Colour	Material
6	Waterproof ring	1	Red	Silicone
5	Positive housing	1	Black	PPE
4	Seal rubber	1	Black	Rubber
3	Cable claw	1	Black	Rubber
2	Screw nut	1	Black	PA
1	Female pin	1	White	copper

Note: Unit(mm)

LEADER TECHNOLOGY (SHENZHEN) CO.,LTD	
APVD: Mike	NAME: Solar Connector
CHK: Joe	PRODUCT NUMBER: BN101B-F
DRWN: Brandon	SCALE: SHEET 1 OF 1 REV: A



No.	Product Name	QTY	Colour	Material
5	Positive housing	1	Black	PPE
4	Seal rubber	1	Black	Rubber
3	Cable claw	1	Black	Rubber
2	Screw nut	1	Black	PA
1	Female pin	1	White	copper

Note: Unit(mm)

LEADER TECHNOLOGY (SHENZHEN) CO.,LTD	
APVD: Mike	NAME: Solar Connector
CHK: Joe	PRODUCT NUMBER: BN101B-M
DRWN: Brandon	SCALE: SHEET 1 OF 1 REV: A

PRYSMIAN

A brand of the Prysmian Group

TWIN FLEXIBLE PV SOLAR CABLES

SLIM SOLAR TWIN PV

Cable description

Twin power cables - 600V/1000V AC – 900V/1800V DC
PV1-F cable to 2 PfG 1169/08.07

Application

Domestic PV system wiring

Approvals

2 PfG 1169/08.07

Behaviour in flame and fire

Fire Performance: IEC60332-1
Smoke Density: IEC 61034, EN 50268-2
Content of halogen acid gas: IEC 60754-1, EN 50267-2-1

Temperature range

Maximum operating temperature: +125 °C
Minimum operating temperature: -40 °C

Flexibility

Flexible Class 5

Resistance to

Chemical exposure: Excellent

Mechanical impact: Light

Water exposure: Good

Solar radiation and weather exposure: Excellent

Cable design

Conductor:
Stranded Tinned copper conductor to IEC60228-2

Insulation:
XLPO
Colours: Red, Black

Sheath:
XLPO
Colour: Black

Markings:
Standard cable print on top of the sheath

Sizes & pack lengths available:
4 mm² & 6 mm² in 100 m plastic reels

Installation conditions

In free air
In conduit
External building with protection

Prysmian Australia Pty Ltd | Ph: 1300 300 304 | Fx: 1300 300 307 | E-mail: sales.au@prysmiangroup.com | www.prysmiancable.com.au
Prysmian New Zealand Ltd | Ph: (09) 827 3109 | Toll Free: 0800 492 225 | E-mail: sales.nz@prysmiangroup.com | www.prysmiancable.co.nz
Connect with us: Prysmian Australia and New Zealand

TWIN FLEXIBLE PV SOLAR CABLES

PRYSMIAN

Physical & electrical characteristics

4 mm² Twin Solar Cable		
	Item	Specification
Conductor	Cross-section area (mm²)	4 mm²
	Material	Stranded tinned copper
	Size (mm)	52/(0.30±0.008)
	Strand OD (mm)	2.45±0.05
Insulation	Material	Electron-beam cross-linked materials
	Nominal OD (mm)	3.65±0.15
	Colour	Red, Black
Sheath	Material	Electron-beam cross-linked materials
	Nominal OD (mm)	4.85±0.20 x 10.0±0.40
	Colour	Black

6 mm² Twin Solar Cable		
	Item	Specification
Conductor	Cross-section area (mm²)	6 mm²
	Material	Stranded tinned copper
	Size (mm)	78/(0.30±0.008)
	Strand OD (mm)	3.0±0.05
Insulation	Material	Electron-beam cross-linked materials
	Nominal OD (mm)	4.30±0.15
	Colour	Red, Black
Sheath	Material	Electron-beam cross-linked materials
	Nominal OD (mm)	5.55±0.20 x 11.6±0.50
	Colour	Black

Technical data

	Nominal voltage	Test voltage	Temperature rating	Ambient temperature	
4 mm² Twin Solar Cable	U°/U=600/1000V AC, 900/1800V DC	6500 V, 50 Hz, 5 min	-40°C up to +125°C	(-40°C up to +120°C): >25 years	
6 mm² Twin Solar Cable	U°/U=600/1000V AC, 900/1800V DC	6500 V, 50 Hz, 5 min	-40°C up to +125°C	(-40°C up to +120°C): >25 years	
	Max. conductor temperature	Bending radius	Conductor resistance	Insulation resistance	UV resistant
4 mm² Twin Solar Cable	+120°C	≥ 6 x cable OD	≤ 5.09 Ω / km at 20°C	≥ 10^{14} Ω .cm at 20°C	>720h
6 mm² Twin Solar Cable	+120°C	≥ 4 x cable OD	≤ 3.39 Ω / km at 20°C	≥ 10^{14} Ω .cm at 20°C	>720h

Fire performance: IEC60332-1
Smoke density: IEC61034, EN50268-2
Halogen acid gas emission: IEC60754-1, EN50267-2-1
Certificate: TUV

Prysmian Australia Pty Ltd | Ph: 1300 300 304 | Fx: 1300 300 307 | E-mail: sales.au@prysmiangroup.com | www.prysmiancable.com.au
Prysmian New Zealand Ltd | Ph: (09) 827 3109 | Toll Free: 0800 492 225 | E-mail: sales.nz@prysmiangroup.com | www.prysmiancable.co.nz
Connect with us: Prysmian Australia and New Zealand

Appendix B: Operations and Maintenance Guidelines

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
General	Routinely check the proper operation of the system from the pump to the end use through the outlet valves. Continuously check the irrigation pipelines for any leaks.	Follow the agreed pumping schedule for the scheme. Note: Normal operation will not require intervention of the technician, but failure of any cut-off switch or fail-safe may require the farmer to follow manual schedules determined for each site or contact the technician.
Pond/Water source	Record water level before starting pumping in the morning and at the end of irrigating for the day.	If water levels have dropped below minimum operating levels then do not operate the system until they have recovered.
Solar Array	Check if solar panels need to be washed. Check for shade on the panels such as vegetation or structures.	Clean of any dirt/debris on panel surface and note any resulting damage. Any cracks in the panels should be reported to the technician for support. Cut down/trim any form vegetation that may be shading the panels. Always maintain a clean facility.
Controllers / Inverters, etc.	Clean protective box. Check for any warning lights or alarms. Monitor the controller temperature. Record electrical device LED status, input and output voltage, current and power if available on controller and/or inverter. Check for any damage from rodents or animals.	In case of any loose or broken wires, contact the technician. In case of any alarms, switch off system and contact technician for support. Any sign of overheating, stop operations and contact the technician immediately. Report any damages to the technician for support.
Pump	Check for any debris around the pump. Record pumping times and pressures (if meters available).	Clean the pump intake and keep it free of debris. Any unusual pump noise, stop operations and contact the technician immediately.
Pipelines	Are any pipes exposed? Are any valves leaking? Are any pipes leaking? (i.e Wet ground along pipeline routes) Are any connections leaking?	Based on the kind of pump use, in case of submersible pumps that are not movable, bury the pipes, in case of surface pumps or pumps that shall be moved, ensure when pumping that it is aligned well. Tighten the valves with a thread tape and report to the technician. Tighten the pipe section leaking with a thread tape then report to the technician. For major connection leakages, close the system and contact the technician immediately.
Water meter (if available)	Record water meter reading at the beginning and end of each pumping cycle.	Records to be used for maintenance cycles and charging for water to farmers.
Distribution System (Irrigation layout)	Walk through the system to check equal and fair distribution of water up to the last outlet in the system.	Flush the system lines to ensure no clogging, or debris along the distribution laterals.

Appendix C: Farmer Do's and Don'ts

Do's:

- Regular checking and cleaning of the solar panels.
- Routine walk of the irrigation system checking out mains, sub mains and the laterals that are functional.
- Regular maintenance of the fields to keep away weeds and pests such as birds and animals.
- Minimize shading by trimming trees or grass surrounding the solar panels or where they shall be placed.
- Maintaining a tidy and clean area surrounding the scheme.
- Safe custody of pumping equipment especially for portable pumping systems.

Don'ts

- Repair the pump if it stops working.
- Repair any of the electrical accessories for the pumping systems.

Appendix D: Summary of Electrical Safety Rules

	Energized systems can be lethal when handled inappropriately even if they appear to be unpowered. Always take extreme care and treat electrical systems with extreme caution!
	Although proper grounding helps remove shock hazards, System Operators and users of the SPIS should never remove any electrical equipment covers. If removed covers or uninsulated wiring are found, do not touch these components and immediately contact a trained technician for support. **Certified Technician Contact Details:** **Nation Innovation Systems** **Tel: +231 77 098 2730 or +231 88 638 6645**
	Never service the SPIS during a lightning storm!
	Solar panels have unique characteristics that make them difficult to work on safely. Adhering to safety guidelines is of utmost important since solar panels are energized anytime the sun is up. Doing maintenance during night hours is not safe or practical!
	Never disconnect MC-connectors to break load or fault currents. Do not disconnect MC-4 connectors because they are not designed to interrupt any electrical current!

Appendix E: Electrical Burns - Identification and First-Aid

The table below provides some guidance on the diagnosis and first-aid to be provided in the case of electrical burns. The content should never be used in place of qualified medical advice and any such injury, no matter how minor, should be reported and treated by a qualified health professional.

Contacts for nearest Health Professional:

Name: Erasmus O.S Tiawan, Bong Mines Hospital

Tel: 0776032986 (Liberia).

Injury	Signs	First-Aid
First-Degree Burns	• Red • Painful to touch • Skin will show mild swelling	• Apply cool, wet compresses, or immerse in cool, fresh water. Continue until pain subsides. • Cover the burn with a sterile, non-adhesive bandage or clean cloth. • Do not apply ointments or butter to burn; these may cause infection. • Over the counter pain medications may be used to help relieve pain and reduce inflammation. • First-degree burns usually heal without treatment. However, if a burn covers a large area of the body or if the victim is an infant or elderly, seek emergency medical attention.
Second-Degree Burns	• Deep reddening of the skin • Pain • Blisters • Glossy appearance from leaking bodily fluids • Possible loss of some skin	• Immerse in fresh, cool water, or apply cool compresses. Continue for 10 to 15 minutes. • Dry with clean cloth and cover with sterile gauze. • Do not break blisters. • Do not apply ointments or butter to burns; these may cause infection. • Elevate burned arms or legs. • Take steps to prevent shock: Lay the victim flat, elevate the feet by about 12 inches and cover the victim with a coat or blanket. Do not place the victim in the recovery position if a head, neck, back, or leg injury is suspected, or if it makes the victim uncomfortable. • Seek further medical treatment. Do not attempt to treat serious burns unless advised by a trained health professional.
Third-Degree Burns	A third-degree burn penetrates the entire thickness of the skin and permanently destroys tissue. • Loss of skin layers • Often painless except from the patches of 1st and 2nd degree burns surrounding. • Skin is dry and leathery or may appear charred or have patches that appear white, brown or black.	• Cover burns lightly with sterile gauze or clean cloth. (Don't use material that can leave lint on the burn). • Do not apply ointments or butter to burns; these may cause infection. • Take steps to prevent shock: Lay the victim flat, elevate the feet by about 12 inches. Keep the person warm and comfortable and watch for signs of shock. • If the face and head are burned, have the victim sit up and watch closely for possible breathing problems. If they are lying down, do not place a pillow under the victim's head, as this may close the airway. • Elevate the burned area higher than the victim's head whenever possible. • Immediate medical attention is required. Do not attempt to treat serious burns unless you are a trained health professional.

Appendix F: Workshop Presentations and Training Materials


UN environment programme
CTCN
CLIMATE TECHNOLOGY CENTRE & NETWORK
MINISTRY OF AGRICULTURE
LIBERIA
Integrity – Service - Inclusion
EPA
Technical Assistance for Upscaling Lowland Rice Production to Improve Food Security through Improved Solar Powered Irrigation Practices in Liberia
Bong Mines Pilot SPIS
Operations & Maintenance Learn-by-doing/On-site Workshop
14 July 2023

Agenda

- Welcome
- Purpose of the Project
- Pilot Scheme Selection
- SPIS Components, Design & Implementation
- **Site Visit** : Learning-by-doing
- Operation & Maintenance Activities
- Questions and Answers
- Next Steps/Programme
- AOB

Purpose of the Project

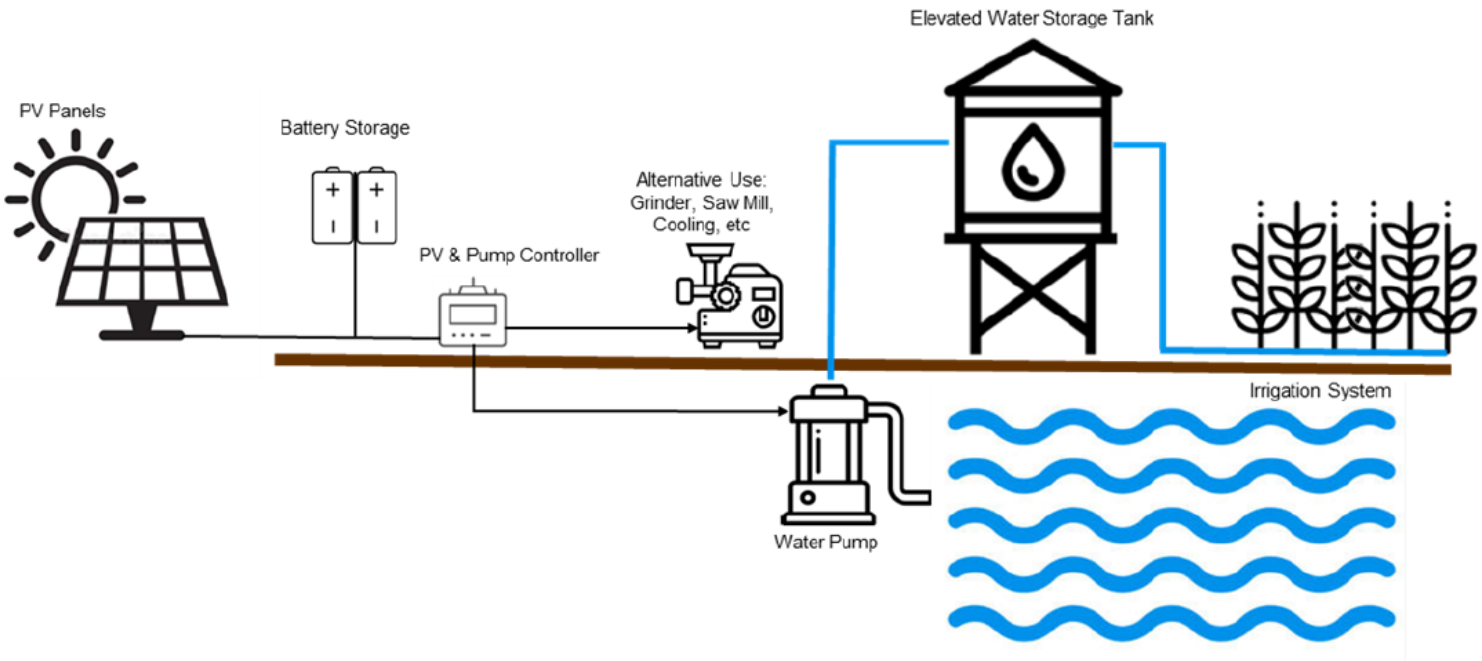
The aims of this project are to introduce Solar Powered Irrigation Systems (SPIS) and practices to intensify rice cultivation and production in one lowland county in Liberia, with the intention of upscaling the technology as an adaptation measure to climate change at a national level.

The expected impacts are to increase the resilience of the county to provide food security, whilst also increasing the access to renewable energy and reducing the reliance on carbon based fuels.

Pilot Scheme Selection

- Stakeholder Working Group (SWG) established to make decisions on the design of the SPIS and ensure these align with Liberian strategic priorities
- Joint site visits with Ministry of Agriculture (MoA) to sites across Bong and Lofa counties
- Assessment based on agreed multiple selection criteria
- Positive reasons for selecting Bong Mines:
  - Availability of stored surface water
  - Existing rainfed rice growing area
  - Motivated farmers co-operative with access to land
  - Ease of access to Monrovia and other counties.
- Limiting factors:
  - Sandy/Silty soils and water, with high iron content, and remote location.

SPIS Components & Design



SPIS Components & Design

Electrical Component


The Solar Panel


The Controller


The Solar Pump

Irrigation Component


Storage


Distribution


Application

Agriculture Component


Crop/Variety


Inputs usage


SRI methods

Design depend on multiple factors, including:

- Available water resources
- Soils, crop/variety choice and agricultural production processes
- Climate (sunshine, rainfall, temperature & wind)
- Other potential energy uses
- Farmer's skills and available budget.

Electrical Component

Equipment:

- Photo-voltaic (PV) panels - Generates electrical power
- Mounting structure - Supports panels and provides security
- Controller - Controls and monitors the power to the pump
- Pump - Delivers water from the pond into the irrigation system.

Recommended for Bong Mines Pilot:

- Basic standalone system to start, with option for alternative energy uses (Rice mill etc) in the future
- Security shelter and fencing.

Irrigation Component

Storage

Distribution

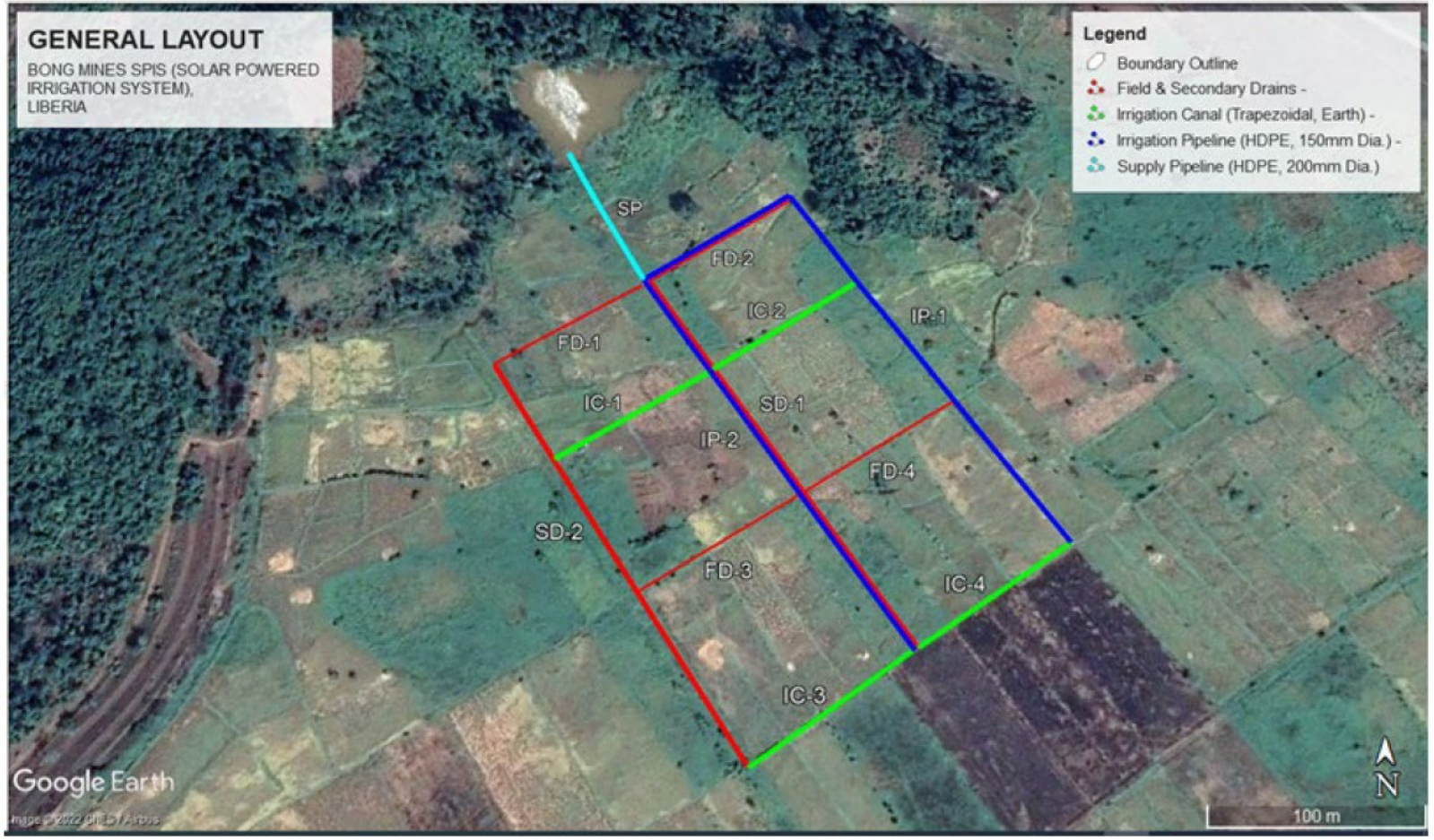
Application

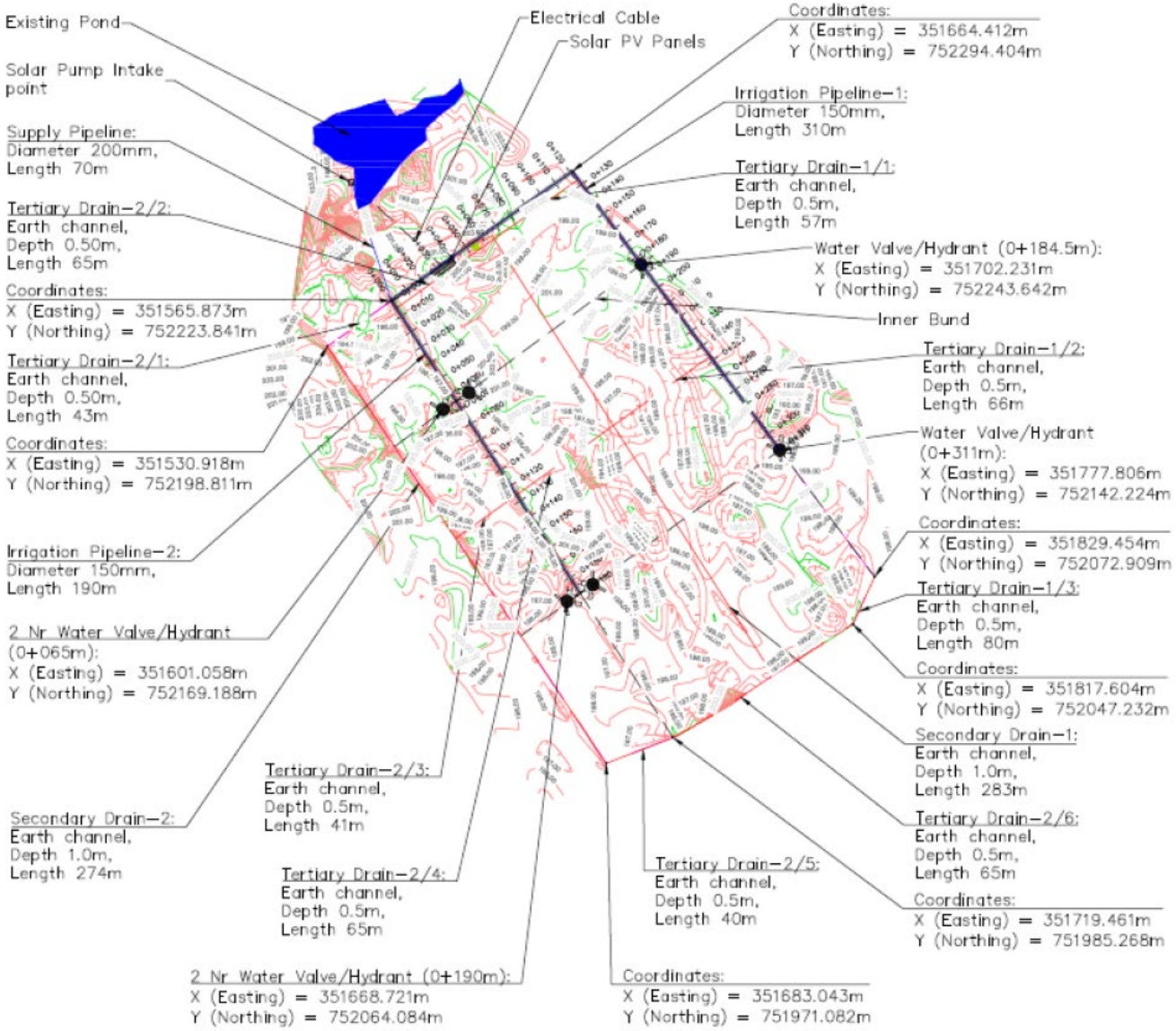
Equipment:

- Natural pond - Existing water storage
- Supply pipeline - Short distance, low head
- Lateral pipelines - Distributes water to all parts of the scheme
- Risers & Valves - Delivers water where and when needed
- Drainage - Removes excess water.

Recommended for Bong Mines Pilot:

- Insufficient budget for elevated storage
- Short distance from water source to field
- Surface/Flood application for rice in flat areas (furrows for vegetables elsewhere)
- Utilise existing drainage.


GENERAL LAYOUT
BONG MINES SPIS (SOLAR POWERED IRRIGATION SYSTEM), LIBERIA
Legend
Boundary Outline
Field & Secondary Drains -
Irrigation Canal (Trapezoidal, Earth) -
Irrigation Pipeline (HDPE, 150mm Dia.) -
Supply Pipeline (HDPE, 200mm Dia.)
SP
FD-2
IC-2
IP-1
FD-1
IC-1
SD-1
IP-2
FD-4
SD-2
FD-3
IC-4
IC-3
Google Earth
N
100 m


Existing Pond
Solar Pump Intake point
Supply Pipeline:
Diameter 200mm,
Length 70m
Tertiary Drain–2/2:
Earth channel,
Depth 0.50m,
Length 65m
Coordinates:
X (Easting) = 351565.873m
Y (Northing) = 752223.841m
Tertiary Drain–2/1:
Earth channel,
Depth 0.50m,
Length 43m
Coordinates:
X (Easting) = 351530.918m
Y (Northing) = 752198.811m
Irrigation Pipeline–2:
Diameter 150mm,
Length 190m
2 Nr Water Valve/Hydrant (0+065m):
X (Easting) = 351601.058m
Y (Northing) = 752169.188m
Secondary Drain–2:
Earth channel,
Depth 1.0m,
Length 274m
Electrical Cable
Solar PV Panels
Tertiary Drain–2/3:
Earth channel,
Depth 0.5m,
Length 41m
Tertiary Drain–2/4:
Earth channel,
Depth 0.5m,
Length 65m
2 Nr Water Valve/Hydrant (0+190m):
X (Easting) = 351668.721m
Y (Northing) = 752064.084m
Coordinates:
X (Easting) = 351664.412m
Y (Northing) = 752294.404m
Irrigation Pipeline–1:
Diameter 150mm,
Length 310m
Tertiary Drain–1/1:
Earth channel,
Depth 0.5m,
Length 57m
Water Valve/Hydrant (0+184.5m):
X (Easting) = 351702.231m
Y (Northing) = 752243.642m
Inner Bund
Tertiary Drain–1/2:
Earth channel,
Depth 0.5m,
Length 66m
Water Valve/Hydrant (0+311m):
X (Easting) = 351777.806m
Y (Northing) = 752142.224m
Coordinates:
X (Easting) = 351829.454m
Y (Northing) = 752072.909m
Tertiary Drain–1/3:
Earth channel,
Depth 0.5m,
Length 80m
Coordinates:
X (Easting) = 351817.604m
Y (Northing) = 752047.232m
Secondary Drain–1:
Earth channel,
Depth 1.0m,
Length 283m
Tertiary Drain–2/6:
Earth channel,
Depth 0.5m,
Length 65m
Coordinates:
X (Easting) = 351719.461m
Y (Northing) = 751985.268m
Tertiary Drain–2/5:
Earth channel,
Depth 0.5m,
Length 40m
Coordinates:
X (Easting) = 351683.043m
Y (Northing) = 751971.082m

Agriculture Component

Crop/Variety

Inputs usage

SRI methods

Systems of Rice Intensification:

- Crop/seed variety
- Land selection and preparation
- Methods of cultivation:
  - Planting and transplanting
  - Weed and pest management
  - Use of fertilizers and other chemicals
  - Water / irrigation management.
- Harvesting, processing and marketing.

Recommendations for Bong Mines Pilot:

- Upto 3 seasons: Rice – Rice – Vegetables
- Nurseries and transplanting of rice
- Mechanised weed control
- Leaf Colour Charts
- Alternate Wetting & Drying.

SPIS Implementation

Procurement by comparison of selected suppliers' tenders:

- One company or consortium to supply and install entire system
- Procurement notice: Scope of work, specifications, timeframe and instructions
- Evaluation of qualifications, experience and financial offer
- Negotiation and clarifications, leading to a contract award with….

Nation' Innovation System
Mount Barclay, Johnsonville, Montserrado, Liberia

Farmer/Community Activities:

- Memorandum of Understanding with farmers to agree activities
- Site clearance, pipeline trench excavation and backfilling
- Seasonal activities: Land preparation, maintenance and security.

Supplier/Contractor Activities

- Supply and transportation of solar equipment and materials to site:

- Laying and jointing of pipelines:

- Panel frame support foundations and steelwork:

Supplier/Contractor Activities

- Pump support concrete works:

- Installation of SPIS pump, controller and cabling:

- Commissioning and testing.

Site Visit

Learning-by-Doing

Operation & Maintenance Activities

O&M for SPIS includes care and preventative maintenance of the electrical systems and irrigation network, and repairs, as needed.

- **Operations** - Daily tasks to run the scheme to be of value to the farmers. Operations activities include:
- **Preventive Maintenance/Servicing** - Routine, recurring activities required to keep equipment in good working order.
- **Diagnostics and Testing** - Procedures used to understand a failure.
- **Corrective Maintenance/Repair** - Works necessary to re-establish functioning after a problem or failure.
- **Overhaul** - Restoration of equipment at the end of its service-life.

Good O&M avoids the need or minimizes the costs of expensive repairs.

Operations Activities

The following will all help maximise production and profits:

- Planning for Production - Crop calendar
- Selection of Seeds - Buy from trusted/certified dealers
- Land Preparation - Clearing, tilling or ploughing, and levelling
- Planting and Transplanting - Spacing of 30cm × 30cm
- Weed and Pest Management - ConoWeeder in both directions
- Fertilizer Use - Optimise usage with Leaf Colour Chart
- Water Management - Alternate Wetting and Drying (1-10 days)
- Harvesting - When grains are hard and turning yellow/brown
- Post-Harvest Management - Threshing, winnowing, drying etc
- Record Keeping - Monitor and evaluate (Next Training)

Safety for SPIS Operations

- Personal safety of farmers and operators is paramount, even above the safety of the system.
- Evaluate the risks before proceeding with any work on the system.
- Ensure that appropriate PPE is available for farmers and operatives at all times.
- **Electrical Hazards**:
  - PVs operate at high voltage - Electrocution risk
  - Damaged or bare wires - Report, Don't Touch
  - Never remove any electrical equipment covers
  - Never work on the SPIS during a lightning storm.

- **Chemical Hazards** - Follow the manufacturers'/ suppliers' recommendations for fertilizers and pesticides.

Routine/Regular Maintenance

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
General	Routinely check the proper operation of the system from the pump to the end use through the outlet valves. Continuously check the irrigation pipelines for any leaks.	Follow the agreed pumping schedule for the scheme. Note: Normal operation will not require intervention of the technician, but failure of any cut-off switch or fail-safe may require the farmer to follow manual schedules determined for each site or contact the technician.
Pond/Water source	Record water level before starting pumping in the morning and at the end of irrigating for the day.	If water levels have dropped below minimum operating levels then do not operate the system until they have recovered.
Solar Array	Check if solar panels need to be washed. Check for shade on the panels such as vegetation or structures.	Clean of any dirt/debris on panel surface and note any resulting damage. Any cracks in the panels should be reported to the technician for support. Cut down/trim any form vegetation that may be shading the panels. Always maintain a clean facility.

Routine/Regular Maintenance

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
Controllers / Inverters, etc.	Clean protective box. Check for any warning lights or alarms. Monitor the controller temperature. Record electrical device LED status, input and output voltage, current and power if available on controller and/or inverter. Check for any damage from rodents or animals.	In case of any loose or broken wires, contact the technician. In case of any alarms, switch off system and contact technician for support. Any sign of overheating, stop operations and contact the technician immediately. Report any damages to the technician for support.
Pump	Check for any debris around the pump. Record pumping times and pressures (if meters available).	Clean the pump intake and keep it free of debris. Any unusual pump noise, stop operations and contact the technician immediately.
Water meter (if available)	Record water meter reading at the beginning and end of each pumping cycle.	Records to be used for maintenance cycles and charging for water to farmers.

Routine/Regular Maintenance

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
Pipelines	Are any pipes exposed? Are any valves leaking? Are any pipes leaking? (i.e Wet ground along pipeline routes) Are any connections leaking?	Based on the kind of pump use, in case of submersible pumps that are not movable, bury the pipes, in case of surface pumps or pumps that shall be moved, ensure when pumping that it is aligned well. Tighten the valves with a thread tape and report to the technician. Tighten the pipe section leaking with a thread tape then report to the technician. For major connection leakages, close the system and contact the technician immediately.
Distribution System (Irrigation layout)	Walk through the system to check equal and fair distribution of water up to the last outlet in the system.	Flush the system lines to ensure no clogging, or debris along the distribution laterals.

Do's & Don'ts

What can you do yourself?

- Clean the panels when dirty or dusty
- Cut away any plants blocking the sun from the panels
- Check cleanliness of water coming out of the tank visually and clean or replace the filter if necessary
- **Monthly:** Clean or flush the tank to ensure water is clean
- **Weekly:** Check the system for leaks, corrosion, damages, dust or insects

When to call in a technician

- Leaks in the pipes or the tank
- Open wires in the system
- The pump runs dry
- The pump has strange noises and vibrations
- Water is not released evenly across the field
- Controller shows flashing diodes indicating an error

Questions and Answers

Next Steps/Programme

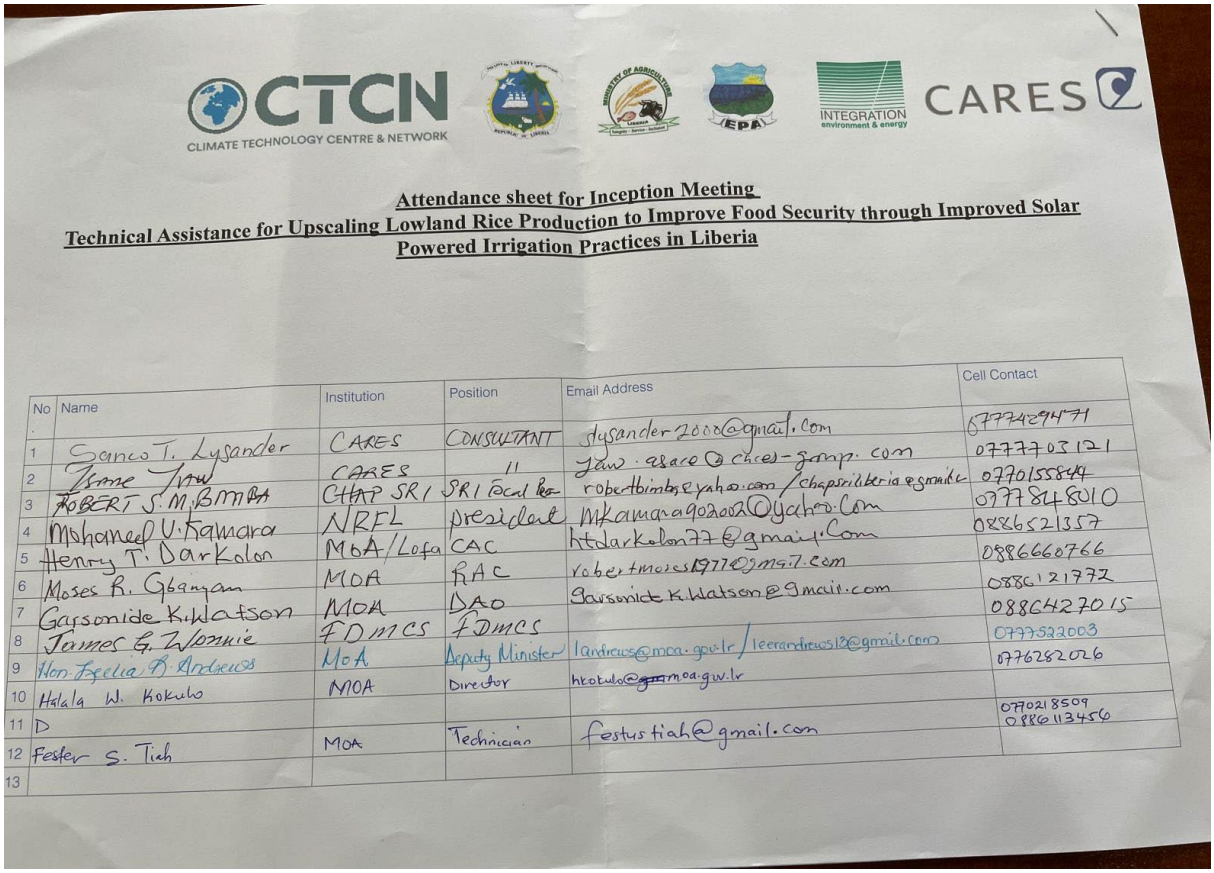
- Developing a Monitoring & Evaluation (M&E) Framework
- Further Training for farmers, stakeholders and officials
- Workshops and further consultations on the Enabling Environment Roadmap for future roll-out of SPIS nationwide.

Remaining Deliverables (Outputs 4, 5 & 6)

- SPIS Pilot Scheme Installation Report (Output 4)
- Operation & Maintenance Manual, including materials for "Learn-by-doing" workshop with farmers (Output 5)
- Monitoring & Evaluation Framework and Enabling Environment Roadmap (Output 6)
- CTCN Closure and Data Collection Report (September 2023)


Thank you!

Appendix G: Attendance Records



CTCN
CLIMATE TECHNOLOGY CENTRE & NETWORK

CARES

INTEGRATION environment & energy

Attendance sheet for Inception Meeting

Technical Assistance for Upscaling Lowland Rice Production to Improve Food Security through Improved Solar Powered Irrigation Practices in Liberia

No	Name	Institution	Position	Email Address	Cell Contact
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3	ROBERT S.M. BIMBA	CHAP SRI	SRI Focal Per	robertbimba@yahoo.com / chapsriliberia@gmail.c	0770155849
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7	Garsonide K. Watson	MOA	DAO	garsonide.k.watson@gmail.com	0886121772
8	James G. Wonnie	FDMCS	FDMCS		0886427015
9	Hon. Cecelia B. Andrews	MoA	Deputy Minister	landrews@moa.gov.lr / leeandrews13@gmail.com	0777522003
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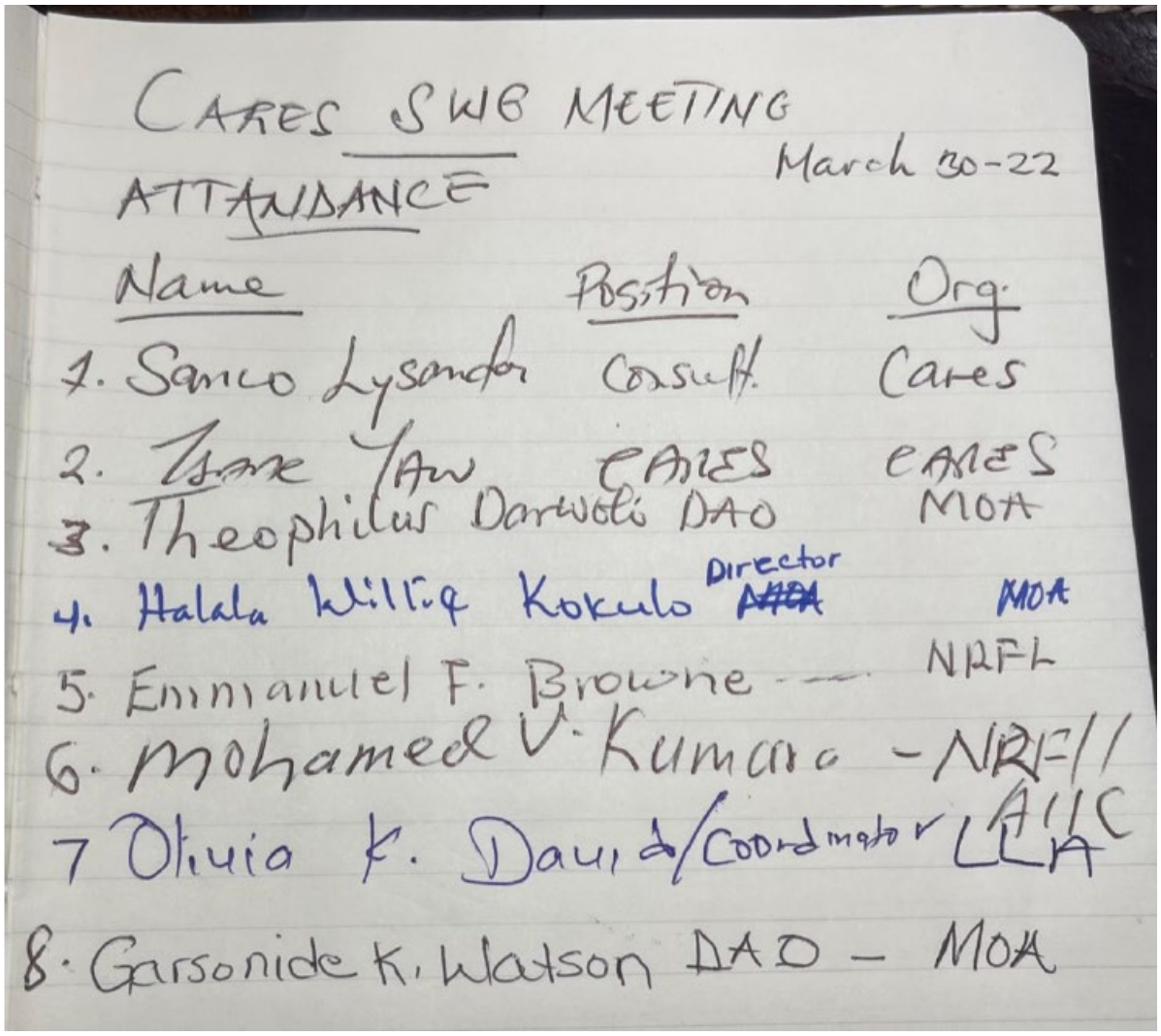
11	▷				
12	Fester S. Tiah	MOA	Technician	festustiah@gmail.com	0770218509 0886113456
13					

Online Attendees

Online Attendees Oliver Taylor (CARES)	Nadege Trocellier (CTCN)	Chris Kabah (EPA)
Matthew Baker (CARES)	Rajendra Uprety (CARES)	Dagnoko, Mariatou (FAOLR)
Yalun Jin (INTee)	George Oboli (CARES)	DMT (Guest)
Sanco Lysander (CARES)	Adolphus (Guest)	Theophilus Baah (Guest)
Balamurugan Pandian (CARES)	Frankie Eckersley-Carr (INTee)	Anthony Kullie (Guest)
Jobson Momo (Guest)	James S.Dolo (Guest)	Roosevelt Reeves (MoA)
Halala Kokulo (MoA)	Akintayo, Inoussa (AfricaRice - Liberia)	Tom-Wesley Korkpor (Guest)

STAKEHOLDER WORKING GROUP - 30th March 2022



CARES SWG MEETING

March 30-22

ATTANDANCE

	Name	Position	Org.
1.	Sanco Lysander	Consult.	Cares
2.	Isaac Yaw	CARES	CARES
3.	Theophilus Darwolo	DAO	MOA
4.	Halala Willie Kokulo	Director ~~AHEA~~	MOA
5.	Emmanuel F. Browne		NRFL
6.	Mohamed V. Kumara		NRFL
7	Olivia K. David	Coordinator	LLA/C
8.	Garsonide K. Watson	DAO	MOA

Online Attendees

Oliver Taylor (CARES)	Nadege Trocellier (CTCN)	Balamurugan Pandian (CARES)
Matthew Baker (CARES)	Rajendra Uprety (CARES)	Anthony Kullie (Guest)
Yalun Jin (INTee)	James S.Dolo (Guest)	Akintayo, Inoussa (AfricaRice - Liberia)