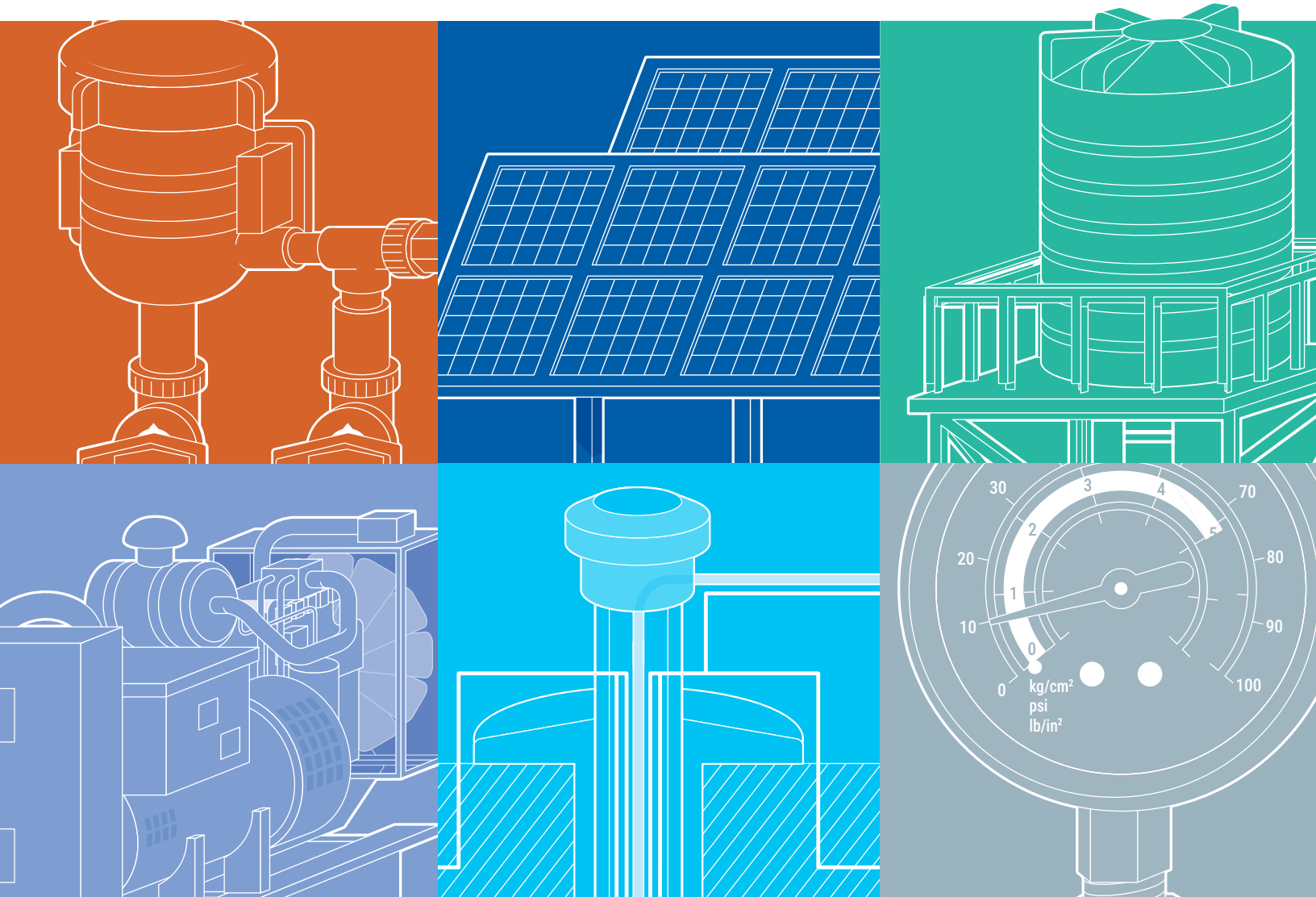
Global Water CENTER

Solar Powered Water Systems:
Operations & Maintenance Guide 2024

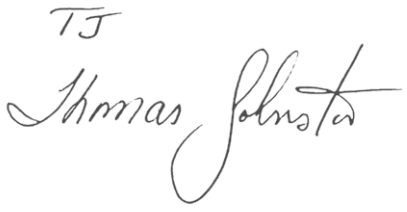


Global Water Center equips leaders to solve the global water crisis together. Through our work with leaders around the world, we identified a critical gap in the operations and maintenance of solar powered water systems.

With a team of globally experienced subject matter experts, we created a resource to support the efforts of those working to fill this gap. The Solar Powered Water Systems: Operations & Maintenance Guide is a practical, user-friendly tool to improve the sustainability of solar powered water systems. We offer this guide freely and encourage its widespread use. Please refer to the back cover for more details on how to use and cite it.

I am grateful to everyone who collaborated on this guide, sharing their expertise to equip operators and technicians for years to come. Together, we've created a resource to keep safe water flowing, not for a moment, but for generations.

Whether you're an operator, technician, or trainer, we hope this guide supports your efforts. If you have questions or need further support, please reach out to us at info@globalwatercenter.org. We look forward to supporting you in your learning journey as we work to solve the global water crisis together.



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Acknowledgements

Thank you to the following individuals for contributing valuable expertise into the development of this guide:

- Lisa Mitchell, Senior Director of Learning Services, Global Water Center
- Heidi Fuller, Director of Training, Global Water Center
- Kogi Chege, Senior Technical Advisor, Global Water Center
- Jessica Mahan, Independent Engineering Consultant
- Alberto Ibanez, Independent Consultant
- Zoe Keone Pacciani, Independent Consultant
- Jake Ward, WASH X Energy Program Manager
- Jordan Deshon, International WASH Engineering, Water Mission
- Thies Timmermans, Design Engineer, Practica

A special thanks to Water Mission for its contributions to the technical content of this publication. To learn more about the organization, visit watermission.org.

The guide was made possible through the generosity and support of The Coca-Cola Foundation.

This guide and the information provided herein should be used for guidance and without any guarantees of accuracy or completeness. Any use of the content provided herein is at your own risk.

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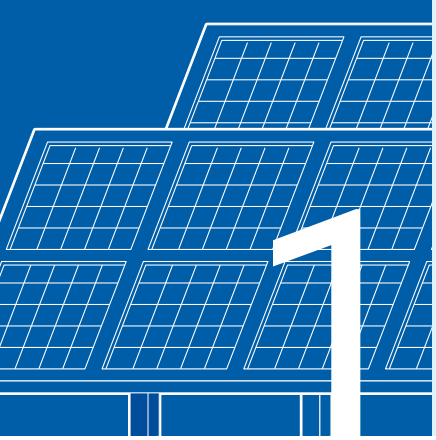


Section 1

SPWS Introduction

1.1 Introduction

Solar-powered water systems (SPWS) power water pumps by converting solar energy to electrical energy. These pumps push water from the source, ideally through a water treatment system, to an elevated storage tank and then downward by force of gravity to where users will collect the water. Some SPWS include an alternate power source, such as a generator or an electrical grid, to extend operating hours or as a backup power source when the solar energy is not sufficient due to weather or season.

The adoption of SPWS is increasing globally as a reliable technology for ensuring a consistent water supply, particularly in rural areas where electrical grid systems are either unreliable or nonexistent. Unfortunately, there are many systems that are no longer operating or are operating below the designed performance. This is in part due to deficient or non-existent ongoing operations and maintenance (O&M) of the systems themselves.

> **In terms of financing, the rural water sector has been historically dependent on...financing [that is] overwhelmingly focused on new capital investment, to the detriment of long-term operation and maintenance of services following initial construction**
>
> (REAL-Water, 2023, p. 25).

Figure 1.1: Steps in SPWS Life Cycle

1.2 Importance of Operations and Maintenance

Routine operations and maintenance (O&M) of solar powered water systems (SPWS) is critical for sustaining safe and reliable water supply. Failure to routinely perform O&M activities will reduce water quantity and quality - potentially harming people who use the water and causing system failure and costly repairs.

To avoid these outcomes proper planning and support for ongoing O&M is required. Planning begins in the design phase during which the system design considers factors to facilitate operations and maintenance (O&M), thereby enhancing the long-term sustainability of the system. For example, if the electrical house is constructed over the wellhead, performing maintenance or replacing the pump will be challenging. Similarly, while positioning the solar panels on a structure elevated off the ground may deter theft, it will also make inspection and cleaning significantly more difficult. In both cases different design choices would better facilitate O&M.

Once a system is designed and installed, there are several reasons why it may stop working or fail to meet performance expectations:

- Lack of ongoing O&M
- Lack of effective management systems
- Failure to clearly define roles and responsibilities
- Lack of funds for training and support for ongoing operations and maintenance
- Component failures due to lack of, or incorrect, maintenance
- Lack of funds for replacing broken parts or parts that are past their lifespan
- Lack of easy-to-use operations and maintenance support tools

Benefits of Ongoing O&M

When SPWS are well designed and constructed, they are simple to operate and maintain. Typical operations and maintenance (O&M) consist of relatively straightforward activities that produce significant results when performed on a regular basis.

These activities typically include providing security, cleaning the solar array, monitoring performance, collecting user fees (if applicable), inspecting all the components, chlorine regulation, making minor repairs, and keeping records. These activities are conducted daily, weekly, quarterly and annually, as explained in other Sections of this guide.

Solar-powered water systems require less O&M than fuel-powered generators. However, many SPWS face challenges due to inconsistent or ineffective O&M practices. Inadequate O&M can lead to system failures and a lack of water availability, often necessitating costly repairs. Ongoing and effective O&M is essential for preventing issues and promptly addressing them when they arise.

When O&M is consistent and ongoing, this:

1. **Prolongs System Lifespan:** Properly maintained systems can operate efficiently for many years, providing a sustainable source of water.
2. **Prevents Water Supply Interruptions:** When the systems are running efficiently and effectively there are fewer interruptions in the water supply to the community.
3. **Saves on Costs:** Routine maintenance reduces repair costs and minimizes downtime, ultimately saving resources for communities and organizations.

1.3 How to Use This Guide

> **There is a strong link between professionalizing the management of rural water supply and improving financing which allows for more competent System Operators and can support improved practices.**
>
> (REAL-Water, 2023, p. 25).

Ineffective or absent operations and maintenance (O&M) is a primary reason many solar-powered water systems (SPWS) fail to deliver consistent and reliable water. While SPWS are highly engineered with complex technical processes, O&M can be relatively straightforward when conducted regularly. However, once a system fails, the technical challenges become significantly greater.

While some components of the SPWS system are standard, most SPWS will have unique components and design features that require tailored O&M management processes. As a result, no one O&M plan or manual will fit all SPWS. Global Water Center has created this guide to be used as a template that can be adapted and tailored to a specific SPWS. An operational SPWS in Kenya is used throughout the guide as an illustrative example.

This guide is designed to be a practical, user-friendly guide to:

- **Support service providers** with the planning, management, and implementation of O&M best practices and processes for SPWS.
- **Provide a detailed and accessible outline** of the standard operations and maintenance practices and processes of SPWS.
- **Support the capacity development** of System Operators and their assistants to effectively operate and maintain SPWS with easy-to-use forms, checklists, and clear instructions.
- **Reinforce best practices** for optimized and efficient functionality of SPWS.
- **Provide usable tools, checklists, and job aids** that support capacity development and professionalization of service providers, technicians, and systems operators.

Capacity Development of O&M Staff

This guide should be used in combination with an O&M training course to support the:

- O&M planning process
- Building of a comprehensive O&M manual specific to your SPWS
- Effective implementation of O&M processes and practices

Capacity development of System Technicians and Operators is required to achieve effective O&M. This guide aims to support this capacity development and to lay the groundwork to formalize the professional roles required to operate and maintain SPWS, increasing the long-term sustainability of the systems.

Intended Audience/Users

A. *Primary:* **Service Providers** – Supported community-based management teams, private enterprises, non-profit organizations, governments, etc.

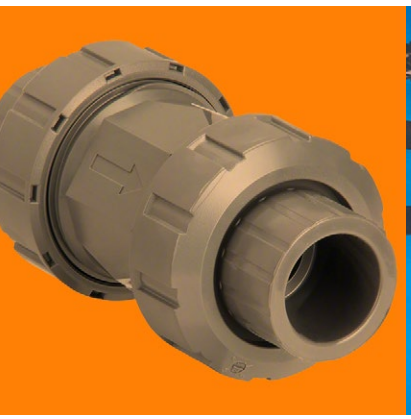
B. *Primary:* **System Operators and Assistant Operators** – Community members or employees of service providers that operate and maintain the system(s) daily.

C. *Secondary:* **Technicians** – Plumbers, electricians, solar PV experts, water quality analysts, etc.

D. *Secondary:* **System Integrators** – managing the integrated IT systems (if applicable)

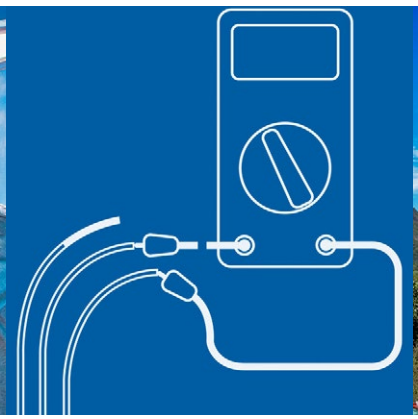
E. *Secondary:* **Donors**

Section	Title	Primary Audience
1	Solar Powered Water Systems	Service Providers & Operators
2	Management of O&M	Service Providers
3	Financial Sustainability	Service Providers
4	Safety Protocols and Practices	Service Providers & Operators
5	Quarterly and Annual Maintenance Tasks	Service Providers & Operators
6	Weekly and Daily Operations and Maintenance Tasks	Service Providers & Operators
7	Toolkit for System Operators	Service Providers & Operators



SOURCE: GRAINGER

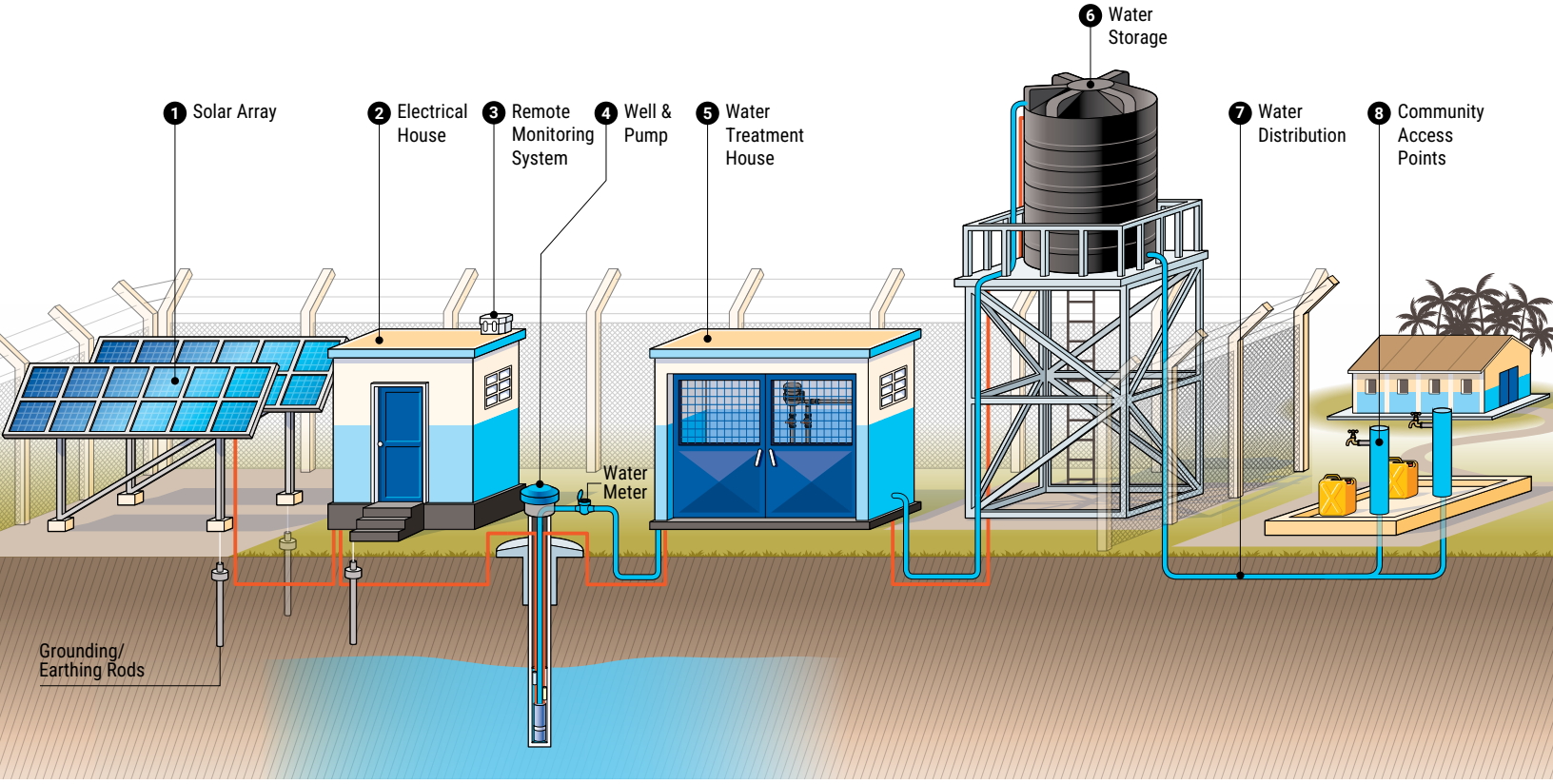
SOURCE: WATER MISSION



SOURCE: GRUNDFOS

SOURCE: WATER MISSION

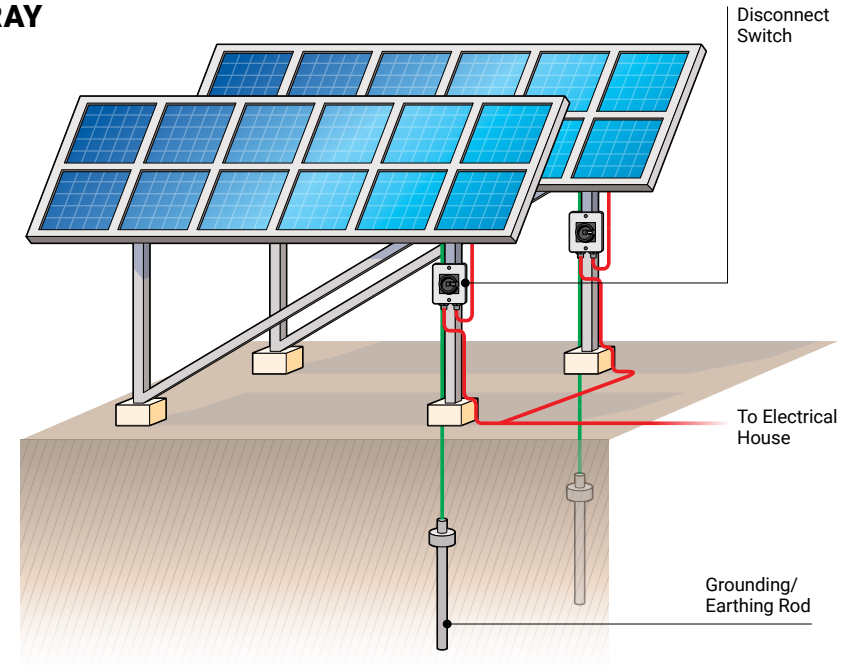
1.4 SPWS Standard Model



	Component	Function
1	**Solar Array**	Main or only source of power. Converts solar energy to electrical energy.
2	**Electrical House**	A building that houses the wiring, conduits, boxes (combiner, controller, inverter), electrical protections, and earthing components to safely connect the solar power to the pump and to control the pump.
3	**Remote Monitoring System**	Track and transmit data to a cloud-based server to allow for remote monitoring of the system.
4	**Well & Pump**	The pump may be in a well, borehole, or surface water body, and runs when connected to a power supply. Submersible pumps are most common for SPWS, but surface pumps may also be used.
5	**Water Treatment House**	A water treatment system to ensure that the water being pumped to the storage tank or directly to taps is safe to drink.
6	**Water Storage**	Water is pumped and stored in protected tanks that are elevated, either using elevated ground or a structure.
7	**Water Distribution**	Pipes run from the storage tanks to collection points in the community.
8	**Community Access Points**	Wherever and however the water users access the water being delivered.

1.5 SPWS Components

A SOLAR ARRAY



Component	Function
Solar Structure	Appropriately positions and secures the solar panels to capture optimal sunlight and prevent theft. May be pole-mounted, roof-mounted, or ground-mounted depending on the system's design. There are advantages and disadvantages to each, particularly related to the ability to clean the solar panels or prevent shading, both of which are ongoing maintenance tasks that optimize power output.
Solar Panels	Converts solar energy to electrical energy. Different classifications based on material and manufacturing technology, such as monocrystalline, polycrystalline, thin film, and bifacial. Solar panels are wired together in "parallel" or "series" depending on the design and power requirements.
MC-4 Connectors	Electrical connectors used to connect solar panels. 

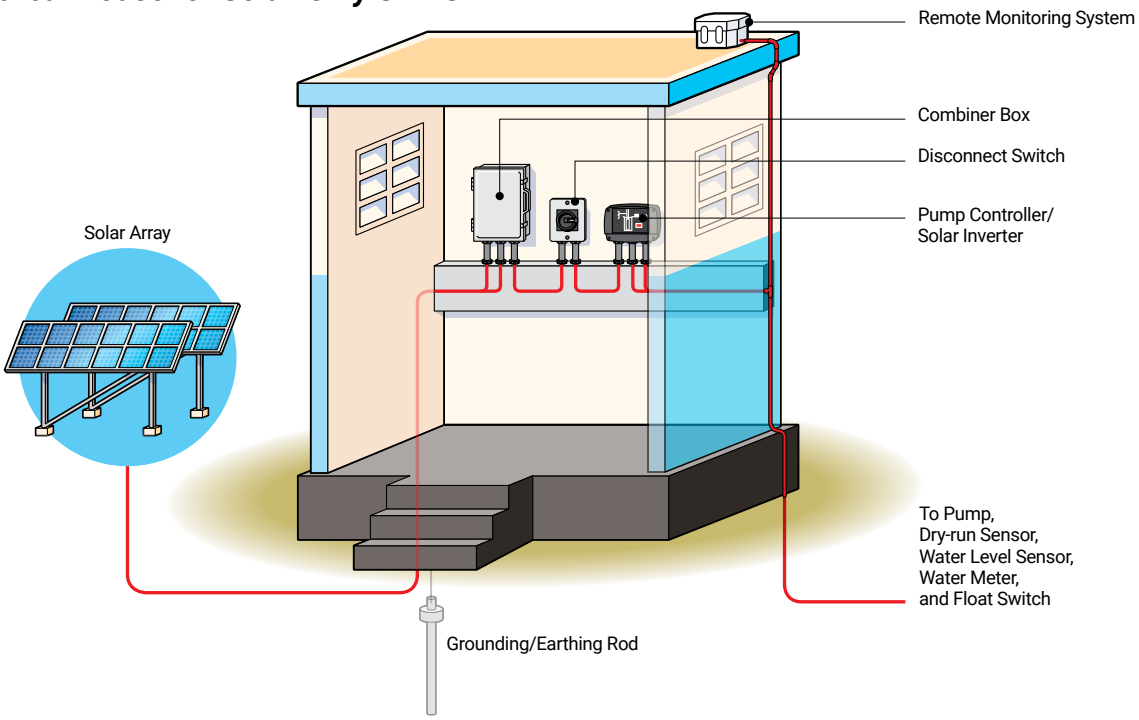
SOURCE: RENOGY

Component	Function
Disconnect Switch	Allows a System Technician to isolate the electrical connection between the solar array and the combiner box when needed.
Cables and Conduit	Wiring and protective sleeve to transport electricity generated from the PV panels to the electrical house.
Grounding Rods * Grounding mechanisms are often forgotten in a SPWS which creates substantial safety risks.	Create a safe and reliable pathway for stray electrical current to prevent electric shock, reduce the risk of fire, prevent damage to sensitive electronic equipment, and play a part in preventing lightning damage if a lightning arrestor is installed. Note: Depending on the design and layout of the SPWS, grounding rods may also be included at other locations, such as the electrical house, water treatment house, or elevated storage tank.

B ELECTRICAL HOUSE

The electrical house contains the wiring, components, and protections needed for the electrical system to safely connect power to the pump and to control it. The exact components inside the electrical room depend on the system design and whether the SPWS is powered by solar-only or by a hybrid system that includes a backup power source.

Electrical House for Solar-Only SPWS



Component	Function
Combiner Box  SOURCE: ATO	Where the individual solar panel wires connect and combine to a singular connection.
Disconnect Switch (2-way)  SOURCE: GRUNDFOS	Allows a System Operator to manually switch between “off” and “on” with a single power source, such as solar.

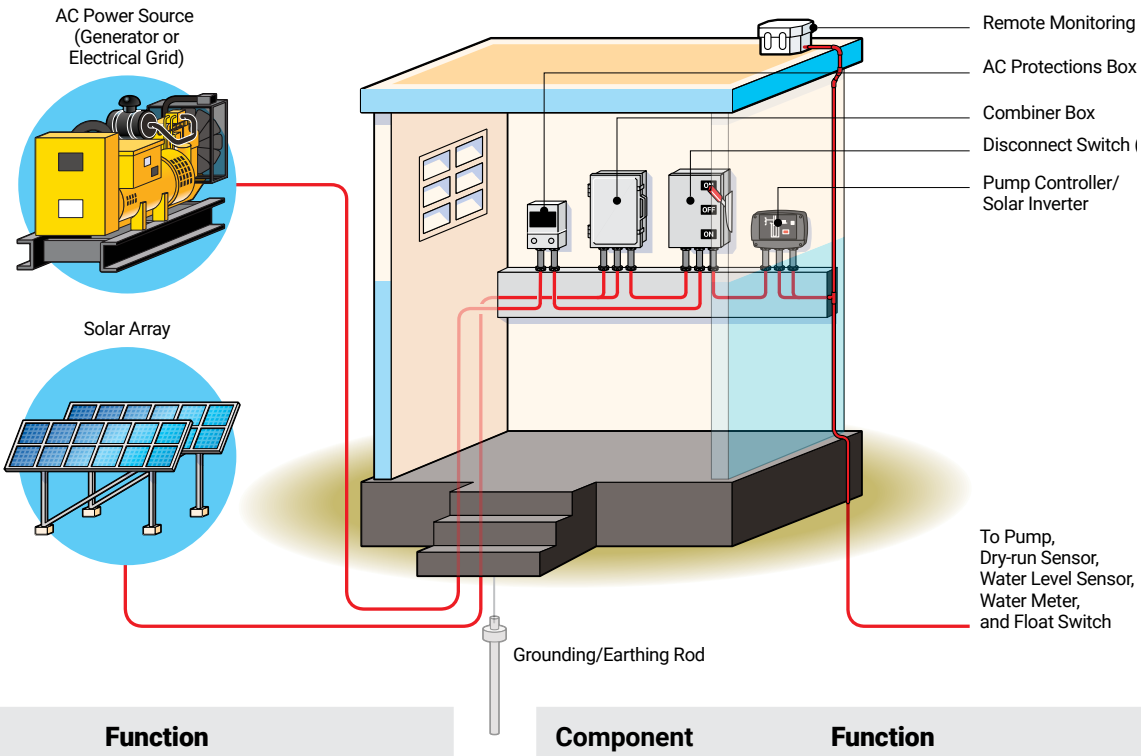
Component	Function
Pump Controller (or Solar Inverter when needed)  SOURCE: GRUNDFOS  SOURCE: GRUNDFOS	Used to switch the pump on and off and connects sensors. Optimizes array output power to best match pump requirements and maintain an effective and reliable water supply. * Depending on the pump type, a solar inverter will be used as the pump controller to convert Direct Current (DC) power from solar to Alternating Current (AC) power for the pump. * Other pumps contain an in-built inverter and do not need a separate solar inverter in the electrical room

Electrical House for Hybrid SPWS

Hybrid SPWS include an alternate power source for supplementary or backup power. This allows the SPWS to operate when the available solar power is not enough to pump water or if the solar array needs repairs.

Diesel generators and electric grids are common backup power sources for SPWS, but batteries may be used in certain contexts as well. Hybrid SPWS are most commonly designed to run on one power source at a time, however some SPWS may use power blending which allows the SPWS to combine power sources.

Note: This guide focuses on non-blended hybrid SPWS using backup AC power. For systems that include batteries or power blending, make sure to consult manufacturer O&M recommendations specific to the equipment being used.



Component	Function
AC Power Source (generator or electric grid)	Alternate power source.
AC Protections Box	Provides protection for the system by cutting off power if there is a power or voltage surge from the generator or grid (AC) power sources.

SOURCE: SOLLATEK

Component	Function
Disconnect Switch (3-way) * Replaces the 2-way disconnect switch in solar-only system	Allows a System Operator to manually switch between "off" and "on" with multiple power sources, such as solar (DC) and generator (AC), using a single power source at a time.

SOURCE: GRAINGER

C MONITORING SYSTEM

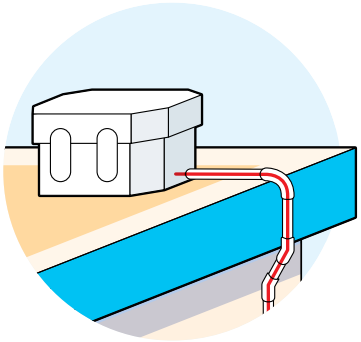
A monitoring system, whereby data is recorded manually or is gathered remotely, is an important component of an SPWS. Monitoring systems include sensors and meters that provide relevant information about the system's performance, such as the quantity and quality of water being transported to storage.

The information provided by these devices can help identify potential issues and troubleshoot problems, enabling the system to return to full operation swiftly. Each SPWS will include sensors and meters specific to that system and may include devices to monitor flow, pressure, water level, water quality, and more.

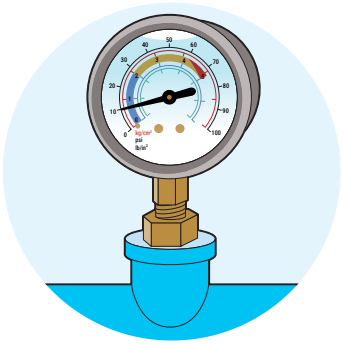
A monitoring system may be manual, automated (remote), or a combination of both. It is best practice to manually record key daily operational data, such as water meter readings, pressure gauge readings, and routine water quality test results.

In some cases, an SPWS may also have remote sensors to monitor data automatically. Remote monitoring systems send data to an online platform so the system performance can be monitored off-site, which aids in identifying potential problems quickly.

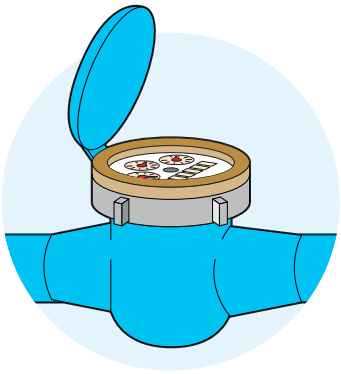
Remote Monitoring System



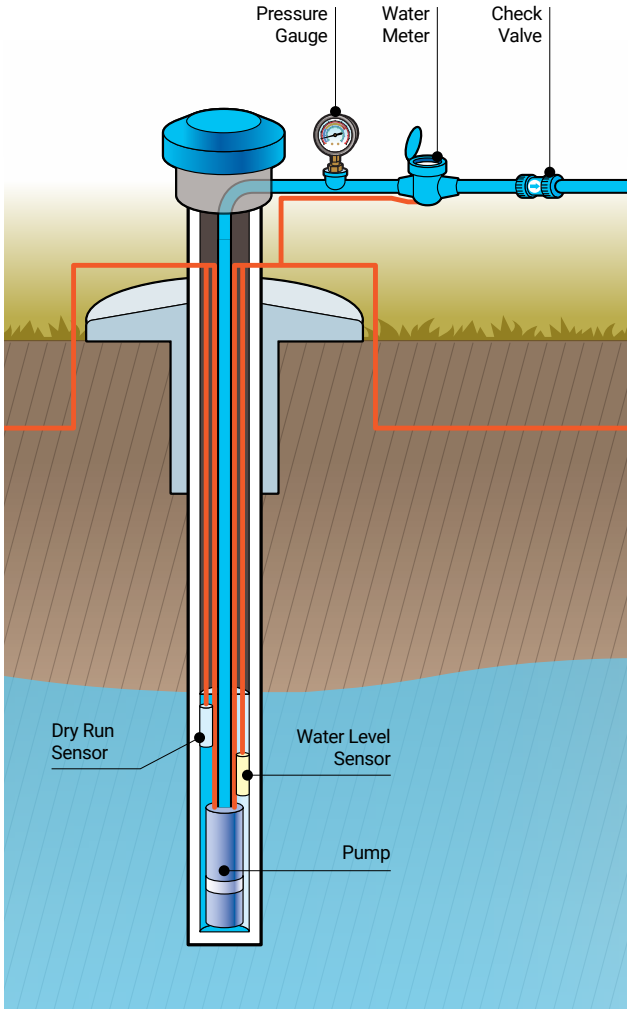
Pressure Gauge



Water Meter



D PUMP AND ACCESSORIES



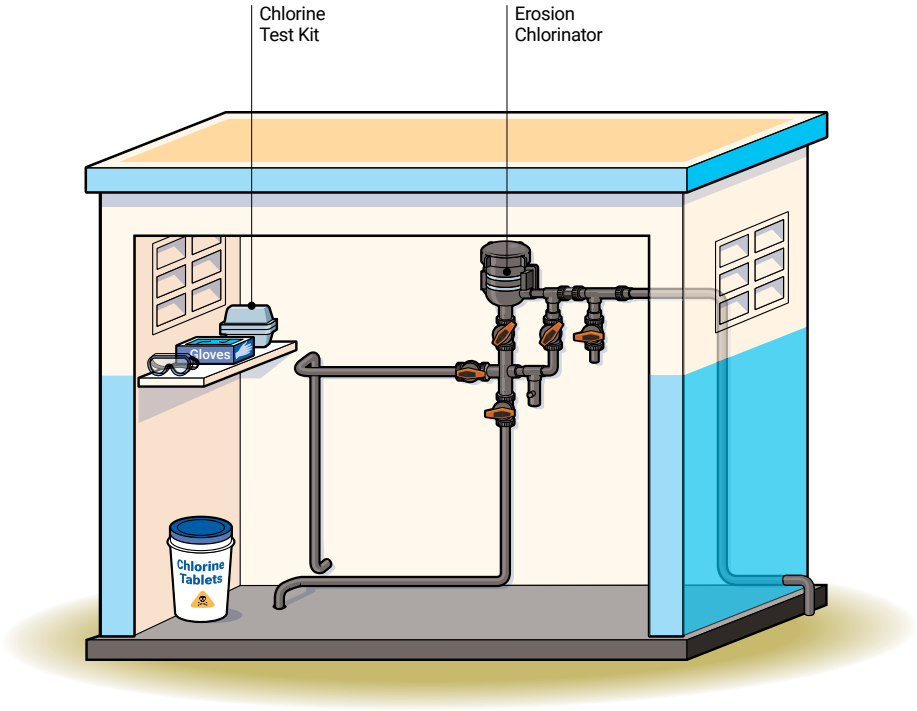
Component	Function
Pump  SOURCE: GRUNDFOS	Converts electrical energy to mechanical energy to move water from one point to another. Submersible pumps are the most common for SPWS.
Dry Run Sensor  SOURCE: WINDANDSUN	Protects the pump by turning the pump off when the water table lowers to a minimum level. Often built into the pump or installed as a stand-alone sensor that is connected to the pump controller.
Water Level Sensor  SOURCE: WINDANDSUN	Monitors the level of the water source. This is most commonly used in boreholes to monitor the water table variations over time.
Pressure Gauge  SOURCE: MEASUREMAN	Measures the outlet pressure of the pump. Often installed upstream of the water meter in the supply line at the wellhead.
Water Meter  SOURCE: MYSENSORS	Measures the volume of water that has been pumped. Often installed in the supply line at the wellhead.
Check (non-return) Valve  SOURCE: GRAINGER	Located downstream of the water meter to prevent backflow of water through the meter and back into the water source.

E WATER TREATMENT HOUSE

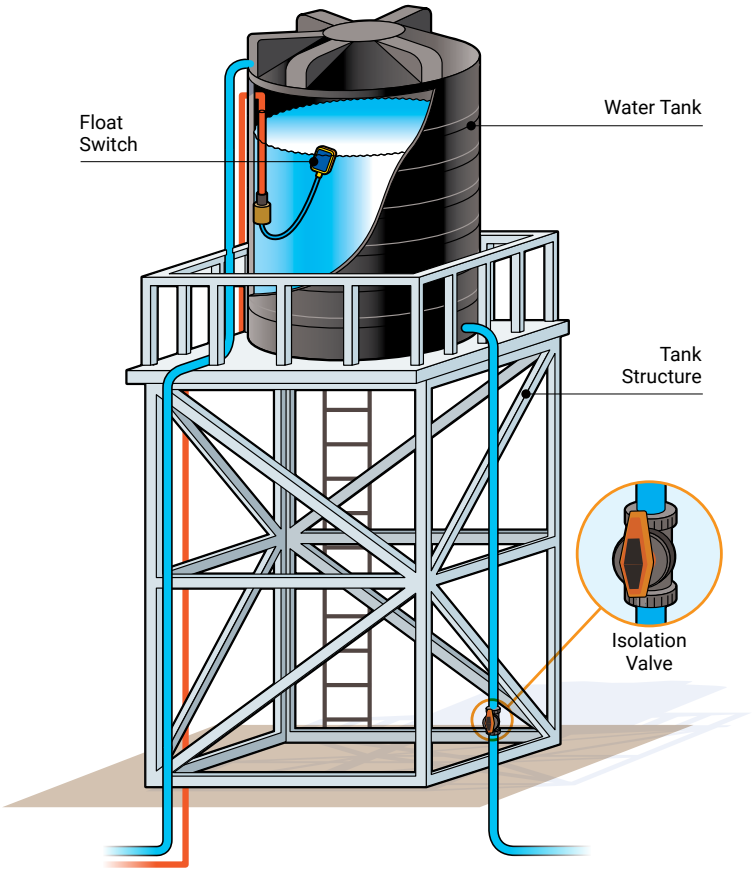
"The primary limiting factor in achieving safely managed drinking water for people in low to middle income countries is fecal contamination"[3] (Greenwood et al., 2024, p.1). Water treatment is therefore a key component of SPWS to ensure the water produced is of high quality and safe to drink. Water quality is essential for good health and all SPWS that produce water intended for human consumption should include an appropriate water treatment method designed to make the water safe for drinking.

In addition to health benefits, water treatment enhances the acceptability of water for end-users, potentially increasing their willingness to pay for it. The exact water treatment method included in SPWS depends on the quality of the source water and the available supply chain for water treatment consumables.

A common water treatment method for disinfection in SPWS is chlorine. Chlorine disinfection can be accomplished with tank chlorinators, in-line dosers, or dosing pumps. However, a full range of water quality tests during the design phase of SPWS is needed to determine the necessary water treatment method. Ongoing water quality testing should be performed routinely during O&M to ensure the water is safe for human consumption. If the quality of the water source or treated water changes, adaptations may need to be made to the treatment method. Improper treatment, such as adding too much chlorine, will impact the health of water users and therefore the acceptability of the water.



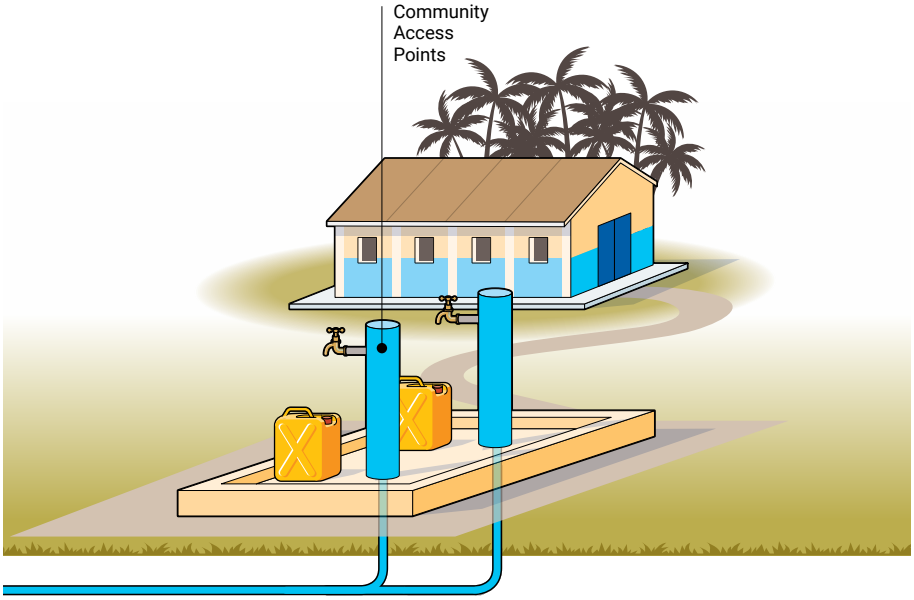
F WATER STORAGE AND WATER DISTRIBUTION



Component	Function
Water Tank	Provides protected storage for the water following treatment and prior to distribution to water users.
Tank Structure	Provides a sturdy foundation for the water tank. In most SPWS, elevated structures are used to allow water to flow by force of gravity from the water tank to the community access points.
Float Switch	Turns the pump off when the water storage tank reaches a maximum level. Installed in the storage tank and connected to the Pump Controller. Note: Depending on the SPWS, a pressure switch or remote water level sensor may be used instead of a float switch to monitor the water level in the tank and to control the pump.
Isolation Valve	Allows the System Operator or Technician to isolate the water tank from the rest of the distribution system in order to repair the water tank or distribution piping.

G COMMUNITY ACCESS POINTS

Community access points are the locations where users collect the water being delivered by the SPWS. There are several types of community access points, which can impact the management and O&M plan for the project.



Component		Function
Water Collection Point * Tap stand or standpipe	 SOURCE: WATER MISSION	Allows water users to collect water, usually with the help of a tap operator. Common in widespread communities where many collection points are needed.
Kiosk	 SOURCE: WATER MISSION	Allows water users to collect water with the help of a kiosk operator. Common in centralized communities or high-traffic areas, such as markets.
Metered Connection * Prepaid or institutional	 SOURCE: GRUNDFOS	Allows water users to collect water using a prepaid card or metered amount. Common where mobile money is accessible or in institutions, such as schools.

Section 2

Management of O&M

2.1 Operations and Maintenance

A solar powered water system (SPWS) is more likely to keep working in the long term if there is ongoing operations and maintenance (O&M) and is staffed with trained and supported personnel.

O&M planning should focus on:

1. Building management processes and practices that support O&M.
2. Training and support for System Operators.
3. Training System Technicians on the specifics of SPWS quarterly and annual maintenance and repair requirements.
4. Accessibility of operations and maintenance tools and supplies.

A. FEASIBILITY OF O&M

The feasibility of sustaining ongoing O&M is dependent on the following:

1. **Comprehensive O&M work plan** – Checklists and schedules that include processes, practices, parts, and supplies.
2. **Clear ownership of the water system assets** – Who owns the assets long-term and what are their responsibilities? *This should be determined before construction of the system begins.
3. **Service delivery model** – Who will be responsible for maintaining the system and what training do they need? Who has the authority to delegate this responsibility? This should be clearly stated in the contracts.
4. **Durability of technology and equipment** – How frequently should system equipment be serviced and replaced? Is system equipment clearly labeled to assist the System Operators and Technicians?
5. **Community engagement** – Have the needs of community stakeholders been included from the start of the project? What training does the community need to support the system and prevent theft and vandalism? Which members were included in the evaluation of the design and installation?

Key stakeholders should be involved in these decisions and their agreement secured before the system's design and installation. During commissioning and handover, reconvening to confirm that agreements, contracts, and trained personnel are in place is essential for the system's long-term sustainability. While the system is being designed and installed, the management team should be working on the O&M work plan and training personnel to ensure all processes are ready and in place at the time of handover.

B. O&M TERMINOLOGY

Routine Operations

Routine operations are the ongoing, day-to-day work required to operate the system to ensure it is delivering water at the capacity it was designed for.

Activities associated with routine operations include, but are not limited to:

- Controlling system parameters
- Conducting inspections
- Monitoring and cleaning of facilities
- Recording water production data

Preventative Maintenance

Preventative maintenance includes inspecting, servicing, and maintaining all system components from source to tap to ensure that the system is operating at its intended and designed performance. Some equipment that is at the end of its service life may warrant overhaul or replacement.

Typically, it includes tasks such as:

- Testing
- Adjusting
- Tightening
- Lubricating
- Cleaning
- Repairing
- Replacing

Reactive or Repair Maintenance

When the system is not functioning as intended or has stopped working, corrective actions or repairs are needed to restore proper operation or service of the equipment. Reactive maintenance is often more costly than preventive and routine maintenance; however, these costs can be significantly reduced through regular operations and preventative measures.

C. KEY ROLES FOR SUSTAINABILITY

The ongoing O&M of SPWS takes a team of people. Management, Operators, and Technicians must all work together to ensure that the SPWS can provide a reliable supply of water to the community.

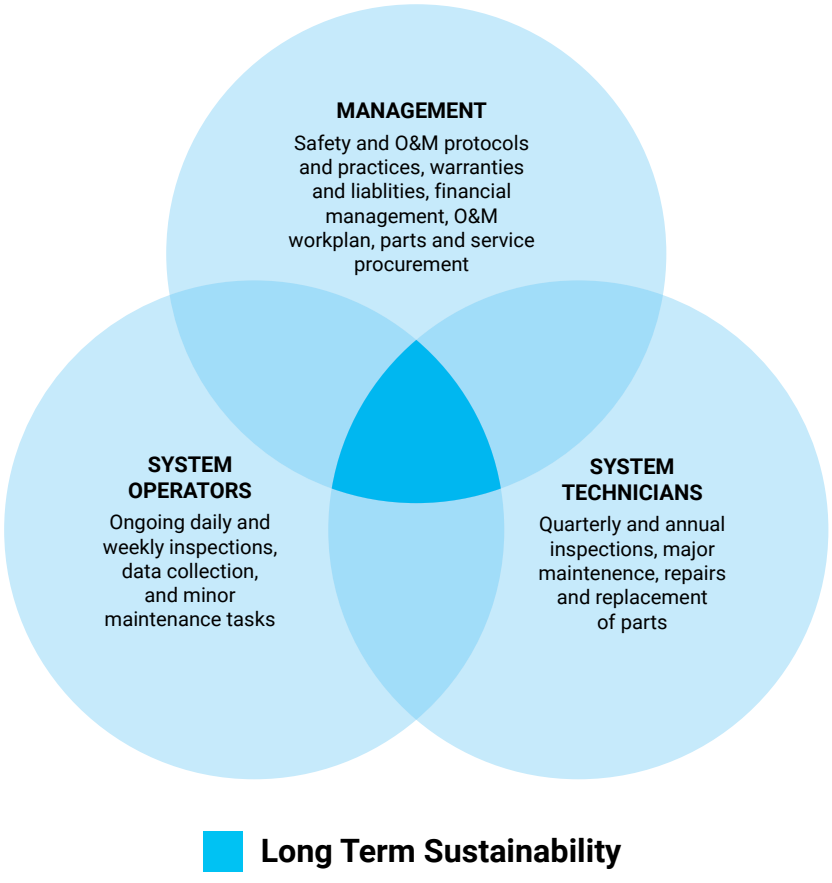


Figure 2.1: When management, Operators and Technicians work together and fulfill their roles effectively, the SPWS will more likely operate for the long term.

D. MANAGEMENT MODELS

Today, primary management models are diverse. Systems are being managed in any of the following ways:

A. Community based management (CBM)

B. Community based management with support

C. Semi-professionalized water enterprises

D. Private sector

E. Public utility

F. Government

From 1990-2010, the predominant model was CBM systems. Since then, there has been an emergence of alternate models with increasing professionalization and aggregation of service areas.

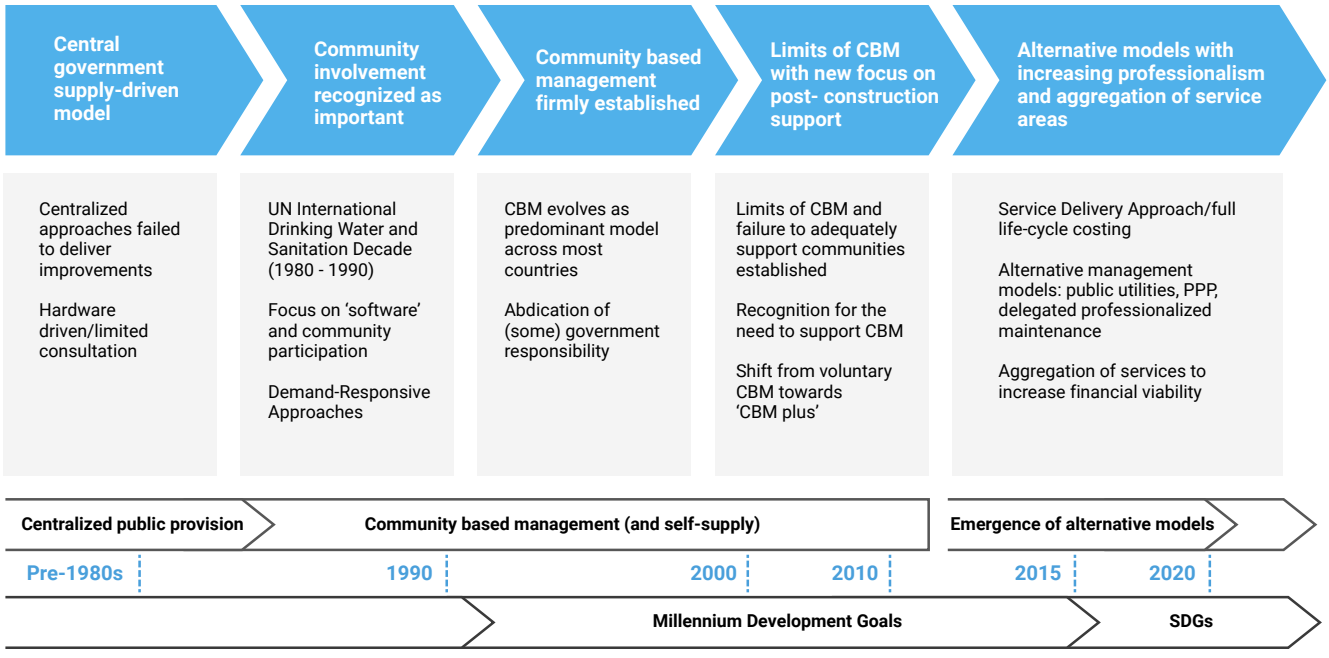
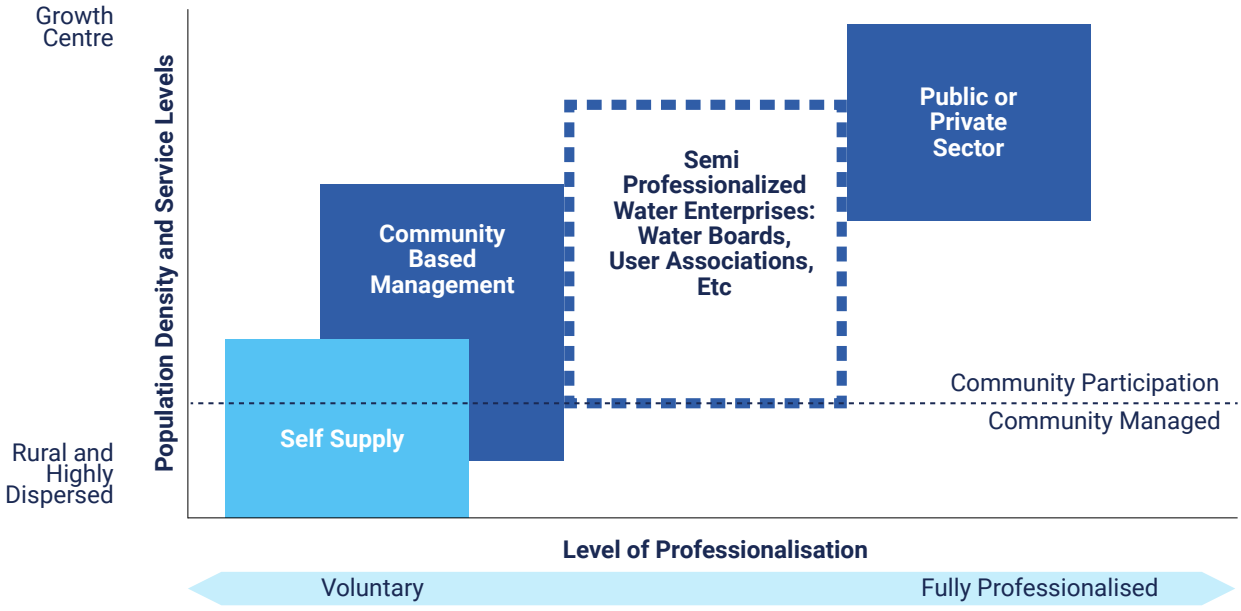


Figure 2.2: Professionalization Movement of Management Models

The figure below illustrates the different models as they relate to population density and level of professionalization. The example system in Kenya is based on a model that falls in the middle of semi-professionalized water enterprises.



SOURCE: ADAPTED FROM RURAL PUBLIC UTILITY O&M IMPLEMENTATION MANUAL - ONE WASH NATIONAL PROGRAM

Figure 2.3: Level of Professionalization increases with increasing Population Density

Think about the best model for long-term sustainability and begin planning with the processes, practices, and tools outlined below. Keep in mind that you may choose to start with one model and later find that another could be more effective.

2.2 Management Processes and Practices

A DESIGN & INSTALLATION DOCUMENTATION – NEW INSTALLATION

Once a system has been installed, the design documentation that should be part of the handover process includes:

1	Site Assessment Report	
2	Design Tool Documentation	
3	Project Layout	
4	As-Built Drawings	
5	Budget	
6	Parts Supplier Contacts and Warranty Information	
7	Specification Documentation for the following:	
	a. Solar Panel Data sheet	
	b. Pump (Ex. Grundfos SQ Flex)	
	c. Pump Controller (Ex. Grundfos CU200)	
	d. Voltage Protection (Ex. AVS 30 Voltage Protection)	
	e. Inverter (if applicable)	
	f. Water Treatment System (Ex. Erosion Chlorinator)	
	g. Remote Monitoring System (Ex. Saltwater Communicator)	

This documentation provides management with a clear record of the component parts and the manufacturer's maintenance and repair guidelines. This information is essential for developing a comprehensive O&M plan and establishing the recommended service agreements and contracts detailed in section 2.3 Management of Parts and Supplies, below.

B SYSTEM DOCUMENTATION – TAKING OVER AN EXISTING SPWS

When a service provider or entity is taking over an existing SPWS, there are several recommendations to consider before entering into an operations and maintenance agreement.

To start, it is imperative to:

A. Obtain a comprehensive list of all the parts, brands of the parts and, if possible, the suppliers
B. Find out exactly how the system was installed
C. Know what the system's current operating functionality is
D. Identify potential failure points that will need to be rectified

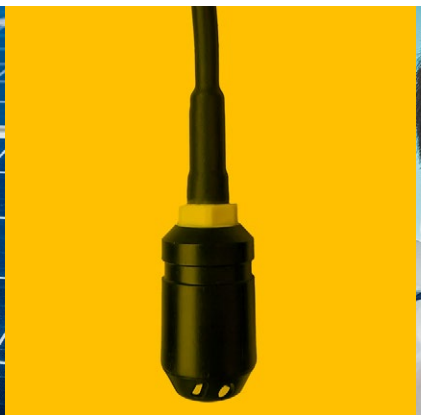
Usually this information is available in the form of a commissioning report, "as-built" or completion document.

However, this will not always be the case. There may also be instances where the system is being handed over by local government or institutions that cannot provide this information. This could happen for various reasons, for example the system may be older and/or the information has been lost.

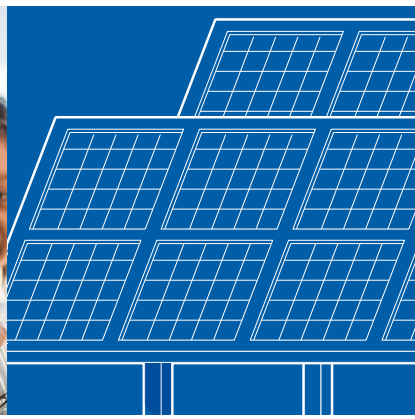
In this case, a thorough system inspection will be necessary, involving an experienced engineer and technician. It is strongly advised that the following parties also attend to validate the findings and provide clarification as needed: local government representatives, the institute or NGO transferring the system, as well as the designer and contractor/builder. During the inspection of the system the following information is gathered:

1. Location information and inspection participants
2. System parameters and components
3. System map
4. Functionality test/operating performance results
5. Socio-economic assessment of the community being served

SOURCE: UNSPLASH


SOURCE: ????


SOURCE: WATER MISSION



The result will be a system inspection report with detailed information regarding the system design, components, operating requirements, and current performance. From this report, an operations and maintenance plan can be built and service agreements written.

C SERVICE AGREEMENTS AND CONTRACTS

Establishing service agreements and contracts with key parties will support accountability of key responsibilities.

1. **Product Suppliers:** Warranty and defect liability arrangement, ideally for periods of two or more years (recommend a minimum requirement of one-year). *This is usually done at the time of equipment purchase and installation by the supplier. Check to make sure that this is the case and, if not, prepare the contract and contact the supplier.
2. **Owner/Service Providers:** Overhaul and replacement of equipment.
3. **System Technicians:** Service delivery arrangement should be established with key responsibilities.
4. **System Operators:** Service delivery arrangement should be established with key responsibilities.
5. **Users/buyers:** A fee amount and schedule with transfer arrangements should be agreed on for covering ongoing costs through a combination of funds.

D. KEY ROLES AND RESPONSIBILITIES

Clearly defined roles and responsibilities ensure individuals know what is expected of them, what tasks they are responsible for, and how their work contributes to the overall goal of providing safe, reliable water to the community.

This clarity also:

A. Reduces confusion, avoids duplication of efforts, and promotes efficiency in task execution.

B. Ensures accountability for work to be done.

C. Facilitates effective communication within teams and across departments by knowing who to approach for specific tasks or information, reducing misunderstandings and promoting collaboration.

A list of typical roles and responsibility areas within an SPWS are as follows:

Service Providers/Owners/Management

- Safety protocols and supplies
- Life-cycle financial planning and management
- Warranties and liabilities
- Record keeping
- Parts procurement, delivery and service arrangements
- Training System Operators
- Data management
- System Operators
- Safe start up and shut down of the system
- Ongoing operations and minor maintenance of all system components from the solar panels through to the user collection point
- Minor repairs
- Daily operations record keeping
- Water quality monitoring
- Fee collection (if applicable)
- Communicate with the System Technician, as needed

System Technicians

- Follow and enforce safety protocols
- Respond to support requests in a timely and effective manner
- Routine system maintenance and corrective actions for repairs
- Analyze system performance
- Support Operators in capacity and confidence on the job
- Regular operations and routine maintenance training for System Operators

E. CAPACITY DEVELOPMENT OF OPERATORS

Sustainable O&M requires trained personnel to operate and maintain the system who understand which activities need to be done, how and when to do them, and when to consult a System Technician.

Developing System Operator competencies (knowledge, skills and behaviors) requires training (both in the classroom and on-the-job) on all operations, maintenance, and minor repair activities.

Ongoing support and reminders of these procedures can be done during follow-up visits by the System Technicians.

- If operating and maintaining a single system, it is recommended that a few individuals are trained based on the System Operator competencies.
- For multiple systems, it is possible to have a tiered approach with Assistant System Operators working under the guidance of a System Operator.

System Operator Competencies

To safely operate and maintain small drinking water systems, a System Operator must have the competence (knowledge, skill, and attitude) to:

- Demonstrate safety protocols during all operations and maintenance procedures.
- Perform common maintenance and routine checks of electrical or fuel powered water supply systems.
- Perform common maintenance and routine checks of water treatment systems.
- Perform common maintenance and routine checks of the storage, distribution system, and water collection point – whether at the household level or at kiosks.
- Troubleshoot issues and perform minor repairs of system components.
- Perform corrective actions to resolve identified issues related to water quantity and distribution.
- Collect and test water samples (E. coli or total coliforms, pH, turbidity, free residual chlorine).

- Interpret water quality testing results and perform corrective actions to resolve issues.
- Accurately complete, manage, and submit data records and monitoring forms.
- Manage fee collections and finances.
- Communicate effectively with community members regarding locally available household water treatment options in case of an absent or failing water treatment system.
- Manage parts procurement and warranties.
- Demonstrate computer skills using Word, Excel, data management software, and email.
- Support and supervise assistant Operators.
- Assist in system design and installation assessments.
- Effectively communicate with System Technicians for issues as required.

F. SAFETY PROTOCOLS AND RISK PREVENTION COMPLIANCE

Protocols and Risk Prevention

It is essential that management provide appropriate training on the correct use of safety equipment and ensure that System Operators and Technicians understand the importance of following safety protocols. Regular safety inspections and audits should also be conducted to maintain a safe working environment for all personnel.

To ensure the safety of System Operators, Technicians, and users, management should:

A. Be familiar with the manufacturers' instructions, product manuals, and other available documentation for the most accurate and detailed safety information and warnings on the various components of the system.

B. Create safety strategies to protect personnel

C. Supply safety equipment to all personnel. *See list below.

D. Provide in-depth training on safety protocols.

E. Create, discuss, and post a safety plan on site in the event of injury, attack, or theft.

Supplies to Support Safety

Supplies to support safety protocols and practices are dependent on the system components and should be provided by management. Safety equipment that could be required include:

1. Personal protective equipment (PPE)

a.	b.	c.	d.	e.
 **Safety glasses**	 **Hard Hats**	 **Gloves**	 **Respirator or Mask**	 **Hearing Protection**

2. Fall protection ladders and harnesses
3. Fire extinguishers and blankets
4. First aid kit
    a. Burns
    b. Cuts
    c. Eyewash
5. Contact info posted on site, in case of emergency

G. DATA MANAGEMENT

Monitoring, documenting data, and reporting to management are vital for the long-term sustainability of a SWPS. This data will show trends and indicate whether issues are starting to arise in the functions and productivity of the system.

Data Collection

System Operators should keep a daily and weekly log, digitally or on paper, while inspecting the system and performing tasks as outlined in Sections 6 and 7.

Management should decide what data to collect, and could include any or all the following:

1	Date/Time/Duration of operation
2	Weather (rainy, sunny, partially cloudy etc.)
3	Average flow rate (calculated based on total volume / duration of operation)
4	Initial and ending water meter value and resulting daily water volume produced
5	Operating pressure
6	Power usage of the pump
7	Chlorine levels at treatment and community access points
8	Storage tank level
9	Any observations such as fault alarms or anything else out of the ordinary
10	If applicable generator/grid power monitoring

**Template checklists and data collection forms will be available. These can be adapted to suit the needs of your team based on the specifics of your system.*

Data Use

Keeping a log helps to:

A. Evaluate that beneficiaries are receiving water in sufficient quality and quantity.

B. Identify issues before they become major problems by noticing trends/ out-of-norm values (ex. steadily decreasing water production).

C. Determine if the SPWS is operating as expected and in a sustainable way.

D. Troubleshoot issues that have appeared and determine what maintenance tasks are needed to address them.

E. Provide evidence of malfunction for product warranties.

F. Keep Operators accountable to management that they are upholding their responsibilities.

Case Study:

A solar powered water system was commissioned 1 year ago.

	Issue:
•	The community's water demand has not changed, but the taps are running dry earlier and earlier in the day
•	It seems water production is going down
•	The Operator calls the System Technician.
	Information Collected:
•	The System Technician asks to see the data logs showing water production, but the Operator informs them that they have not been collecting data for the last three months
•	From the data that was previously collected, the System Technician can see a general downward trend in water production.
•	The System Technician visits the site and notices that regular cleaning of the solar array has not been happening and foliage has also not been cut around the array.
	Lessons Learned:
1.	Solar panels must be regularly cleaned to ensure proper performance.
2.	Ensure that no trees or other objects shade the solar panels.
3.	Daily operator logs are helpful for identifying if a problem exists.
4.	Train operators to follow regular procedures and reporting.

Data Reporting Procedures

Regular submission to management of data reporting logs is necessary to make the data useful for others. This also ensures motivation for Operators to keep collecting the data daily.

Although there is no established best practice, a monthly submission of the logs by the Operators followed by monthly analysis by a System Technician would be ideal. However, this should be decided based on the service contract/management plan. It's advisable to request the data before any issues arise.

Additionally, before a System Technician visits the site, they should review the system's data to analyze and plan the necessary maintenance tasks for their visit.

The data logs should be stored in a safe place for long-term storage – either in the pump house or with the management team – in case they need to be referred to for troubleshooting.

Even with a remote monitoring unit on the system, the Operator logs will help to supplement or cross check the data collected remotely.

2.3 Management of Parts and Supplies

Effective management of parts and supplies is crucial for the ongoing success and sustainability of SPWS. This section provides guidelines and procedures to ensure that all aspects of asset management, theft prevention, supply chain management, and maintenance are addressed comprehensively.

By following these guidelines, the management team can effectively oversee the operations and maintenance of the solar powered water system, ensuring its reliability and sustainability in providing safe drinking water to rural communities.

A. ASSET DATA TRACKING

Objective: Maintain accurate and up-to-date records of all assets to ensure efficient management and accountability.

The following elements should be included in your asset data tracking system:

1. **Inventory System:** Implement an inventory management system (computerized or manual) to record all assets, including solar panels, pumps, electrical components, water treatment materials, and all associated equipment.
2. **Data Recording:** For each asset, record essential information including the make, model, serial number, date of purchase, location, and current condition. Regularly update this information, particularly when new assets are added, or existing ones are repaired or replaced.

3. **Regular Audits**: Conduct periodic audits of all assets to verify the accuracy of records and ensure that no items are missing or unaccounted for. These audits should be scheduled at least bi-annually, carried out by the Operator, and cross checked by the System Technician annually.

SOURCE: KOGI CHEGE (FROM A WATER MISSION PROJECT)

B. THEFT AND TAMPERING PREVENTION

Objective: Implement measures to safeguard assets against theft and unauthorized tampering to avoid system downtime or unnecessary replacement of parts.

Theft is a risk where:

1. There is a lack of ownership.
2. The users have not been consulted in terms of their needs and/or the SPWS that is installed does not provide the required services.
3. SPWS falls into disrepair for long periods of time.
4. The system is installed at a remote location, near international borders or near public places or roads.

The following elements should be considered in planning for theft prevention:

1. **Security Measures:** Hire security to watch over the system. Install security lighting around critical components of the water system, such as the solar array and pump house. Use one-way bolts or security screws to fix the modules onto the frame. Mark the modules with the owner's name or the name of the village.
2. **Access Control:** Restrict access to system personnel only. System Operators should make sure all locks and fencing are kept in good order to prevent access to all site components, including the solar array, pump house, water treatment house, and storage tank.
3. **Community Engagement:** System Operators should engage the local community in safeguarding the system by promoting awareness about the importance of the water system and encouraging the reporting of suspicious activities.

C. SUPPLY CHAIN AND PARTS PROCUREMENT

Objective: Ensure a reliable and cost-effective supply chain for procuring necessary parts and supplies.

The following should be established to allow for smooth procurement of parts when needed:

1. **Supplier Selection:** Establish relationships with reputable suppliers who provide high-quality parts and materials. Verify the reliability and performance history of suppliers before making agreements.
2. **Procurement Process:** Develop a standardized procurement process that includes requesting quotes, comparing prices, and evaluating suppliers. Ensure that all procurement activities are documented and comply with any relevant regulations.
3. **Stock Management:** Maintain an optimal inventory level of essential spare parts to prevent shortages and reduce time for repairs to be completed. Monitor usage patterns and adjust inventory levels, as needed.
4. **Contingency Planning:** Identify alternative suppliers and parts sources

in case of supply chain disruptions. Maintain a list of backup suppliers and keep them informed about potential future needs.

D. WARRANTIES, LIABILITIES, AND REPAIRS

Objective: Manage warranties and repair needs effectively to minimize downtime and repair costs.

1. **Warranty Management:** Keep detailed records of all warranties, including expiration dates and coverage details. Ensure that warranty information is readily available for reference when issues arise.
2. **Claims Process:** Follow the established procedure for filing warranty claims, including documenting issues, contacting the manufacturer or supplier, and providing necessary evidence or reports.
3. **Repair Protocol:** Develop a protocol for handling repairs, including troubleshooting procedures, repair requests, and contractor or technician management. Ensure that repairs are conducted promptly and that quality standards are maintained.
4. **Liability Management:** Understand and document any liabilities associated with the use and maintenance of equipment. Ensure that the management team is aware of their responsibilities and the potential consequences of equipment failure.

SOURCE: WATER MISSION

E. ONGOING OPERATIONS AND MAINTENANCE SUPPLIES

Objective: Ensure that all necessary supplies for routine operations and maintenance are readily available and properly managed.

1. **Operations Supplies:** Data logs, checklists, PPE, and chlorination tablets.
2. **Maintenance Supplies:** Maintain an inventory of essential maintenance supplies such as ladders, brooms, cleaning agents, replacement parts, and tools. Ensure these supplies are in good condition and readily accessible to operators and technicians.
3. **Storage and Organization:** Store maintenance supplies in a clean, dry, and organized manner. Designate specific areas for different types of supplies to prevent confusion and facilitate easy access.
4. **Supply Replenishment:** Monitor usage of maintenance supplies and reorder items before they run out. Set up a replenishment schedule based on usage patterns and anticipated needs.
5. **Training:** Train Operators on the proper use and care of maintenance supplies and equipment. Ensure that they are aware of the importance of keeping supplies in good condition and reporting any issues promptly.

2.4 Support Tools for Managing O&M

To create a comprehensive plan that supports Management Staff, System Operators, and System Technicians in effectively managing, operating, and maintaining SPWS, use the support tools provided below as needed.

A. Management Planning Checklist
B. New System Documentation Checklist
C. System Take Over Assessment Form
D. Service Agreements & Contracts Checklist
E. Roles & Responsibilities
F. Operator Competency Checklist
G. O&M Tasks Overview
H. Data Management Plan
I. Parts Suppliers & Warranties - Major Components

Management Planning Checklist

System Name:	Date:
Management Name(s):	

#	Management Output	Supporting Documents	Person Responsible	Not Started ✓	In Progress ✓	Complete ✓
1	System Information	System Design Documents Checklist (new installation) or System Assessment (taking over)		❑	❑	❑
2	Service Agreements & Contracts	Service Agreements & Contracts Checklist		❑	❑	❑
3	Roles & Responsibilities	Roles & Responsibilities Outline Operator Competency Checklist Operator Tools & Supplies Checklist Technician Tools & Supplies Checklist		❑	❑	❑
4	Safety Responsibilities	Safety Responsibilties Checklist		❑	❑	❑
5	Data Management Plan	Data Management Responsibilities Daily O&M Checklist Daily Water Production Form Daily Maintenance Form Weekly Maintenance Checklist Quarterly Maintenance Checklist Annual Maintenance Checklist		❑	❑	❑
6	Asset Management Plan	Parts Suppliers & Warranties List Weekly Tools & Supplies Inventory Form		❑	❑	❑
7	Financial Sustainability Plan	Financial Sustainability Worksheet		❑	❑	❑

New System Documentation Checklist

System Name:
Management Name(s):
Date:

The following information should be received as part of the handover process for a new SPWS. This documentation provides a clear record of the component parts and the manufacturer's maintenance and repair guidelines.

#	System Document	✓
1	System Assessment Report	❑
2	Design Documentation	❑
3	Project Layout	❑
4	As-built Drawings	❑
5	Project Budget	❑
6	Parts Suppliers & Warranty Information	❑
7	Technical Specifications for Major Components, such as:	
	Solar Panels	❑
	Pump	❑
	Pump Controller (or Solar Inverter, if applicable)	❑
	Electrical Controls & Protections	❑
	Water Treatment Equipment	❑
	Remote Monitoring Equipment	❑

System Take Over Assessment

System Name:	
Management Name(s):	
Date:	

#	Item	Data
A. Location, Participants, & Summary		
Location Information		
A1	System name:	
A2	Village/Town:	
A3	District:	
A4	Region:	
A5	Country:	
A5	GPS Coordinates:	
Inspection Participant Details		
A6	Inspection date:	
A7	Inspector:	
A8	Designer:	
A9	Contractor:	
A10	Handover entity:	
A11	Participants:	
Executive Summary		
A12	System approved for immediate operation?	❑ Yes ❑ No

A13	Recommendations:		
A14	Date of submission:		

#	Item	Inspection/Commissioning Data
B. System Parameters & Components Information		
Solar Array		
B1	GPS Coordinates of solar array:	
B2	Number of panels (total):	
B3	Manufacturer of solar panels:	
B4	Rated power of solar panels (in W, per panel):	
B5	Number of panels (in series):	
B6	Do ALL PANELS in each series have exactly the same rating?	❑ Yes ❑ No
B7	Number of series groups (strings in parallel):	
B8	Total wattage output (STC):	
B9	Total voltage output (STC):	
B10	Spare solar panel information (if available):	
B11	Source circuit (before combiner box) wire size:	
B12	Source circuit wire type:	
B13	Output circuit (after combiner box) wire size:	
B14	Output circuit wire type:	
Well		
B15	GPS Coordinates of well:	
B16	Well depth:	
B17	Casing diameter:	
B18	Static water level:	

B19	Dynamic water level:	
B20	Yield test results (conduct a yield test if more than 1 year since last test):	
B21	Water quality test (obtain water from source and label for testing):	❑ Complete
Pump (remove from well to inspect)		
B22	Pump manufacturer:	
B23	Pump model & serial number:	
B24	Pump capacity (rated flow and pressure):	
B25	Is a warranty available?	❑ Yes ❑ No
B26	Depth of pump installation:	
B27	Pumping installer (if different than contractor named above):	
B28	Is the pump free of damage, dents, dirt, debris, etc?	❑ Yes ❑ No
B29	Is the the safety cable/rope in good condition?	❑ Yes ❑ No
B30	Does the underwater cable splice have mechanical/electrical integrity?	❑ Yes ❑ No
B31	Is the low water sensor unobstructed?	❑ Yes ❑ No
B32	Are all pipe joint sealed and secure?	❑ Yes ❑ No
B33	Is the connect of the water pipe to the wellhead secure?	❑ Yes ❑ No
B34	Is there proper strain relief for the submersible cable at the wellhead?	❑ Yes ❑ No
B35	Is the well cap securely bolted in place?	❑ Yes ❑ No
B36	Is there a pressure gauge installed at the pump?	
B37	Take a picture of the wellhead enclosure.	❑ Complete
Electrical House		
B38	GPS Coordinates of electrical house:	
B39	Pump controller manufacturer:	
B40	Pump controller model & serial number:	
B41	Pump controller current (amperage) Rating:	
B42	Is an operations manual for the pump controller available on site?	❑ Yes ❑ No
B43	Solar inverter manufacturer (if aoolicable):	
B44	Solar inverter model & serial number (if applicable):	
B45	Solar inverter current (amperage) rating (if applicable):	
B46	Solar inverter efficiency (if applicable):	

B47	Is an operations manual for the pump solar inverter available on site?	❑ Yes ❑ No
Pressure Line		
B48	Size and type of pressure line (well to water tank):	
B49	Length of pressure line from well to water tank):	
B50	Total head (elevation change) from ground level at well to water tank inlet:	
Water Storage Tank		
B51	GPS Coordinates of water tank:	
B52	Material of tank tower:	❑ Brick ❑ Metal ❑ Other: _____
B53	Material of water tank:	
B54	Size of water tank:	
B55	Is the overflow screened?	❑ Yes ❑ No
B56	Is a float valve (or other tank-full control) installed?	❑ Yes ❑ No
B57	Is there a tank drain separate from the distribution pipe?	❑ Yes ❑ No
Water Distribution & Community Access Points		
B58	Material of distribution pipe:	
B59	Size (diameter) of distribution pipe:	
B60	Number of distribution lines:	
B61	Number of gate valves installed	
B62	Number of tap stands (if applicable):	
B63	Number of building connections (if applicable):	
B64	Number and type of any other community access points installed:	
B65	Are the community access points in proper working condition?	❑ Yes ❑ No
Operations & Maintenance		
B66	Was Operations & Maintenance training conducted?	❑ Yes ❑ No
B67	If yes, list the participants:	
B68	Operating entity (if applicable):	

B69	Tools available (if any):	
B70	Warranties & Contractor (if any):	
B71	Repairs conducted (if any):	

#	Component	Activity	Results
C. Operating Performance (Functionality Tests)			
C1	Borehole yield	Conduct a yield test on the well if not done in the past year.	
C2	Dry run sensor	Test the dry run sensor (low water probe) to ensure it is functioning.	
C3	Water quality	Obtain a water sample from the water source and after treatment (if applicable) for testing.	Attach water quality report
C4	Solar array	Check that all connections are secure.	
C5		Measure the output .	
C6	Pump	Check pump power consumption and record in power consumption for m3 pumped.	
C7		Measure pump capacity in liters per minute (LPM) against expected.	
C8	Pump controller (or solar inverter)	Check operation of pump controller (and Solar Inverter, if applicable).	
C9		Measure input power.	
C10		Measure output power.	
C11	Piping and water treatment equipment	Check valve functionality. If valves are found to be tight they may need to be lubricated. If they are found to be stuck they may need to be replaced.	
C12	Float switch	Check function of the tank float switch	
C13	Community access points'	Measure the flow rate at each community access point.	Point 1: Point 2: Point 3: Point 4: Point 5:
C14	System pressure	Check pressure in EPAnet or similar software to ensure correct pipe sizing.	

#	Item	Result	Notes
D. Community Socio-Economic Assessment			
General Community Information			
D1	Catchment area *(Check all that are present in the system's service area.)*	❑ Villages ❑ Households ❑ Schools ❑ Businesses ❑ Religious Centers ❑ Markets	
D2	Total population:		
Socio-Economic Information			
Interview a random selection of water users			
D3	Are users willing to pay?	❑ Yes ❑ No	
D4	Are users able to pay?	❑ Yes ❑ No	
D5	Average monthly HH income:		
D6	Current water fee (if any, record per HH/jerry can/m3):		
Water Distribution System			
D7	Total number of community access points:		
D8	Number of tap stands:		
D9	Number of yard taps:		
D10	Number of building connections:		
D11	Community Access Point Details *(Copy/record this information for all community access points. Include all types of community access points, such as tap stands, yard taps, HH connections, and institutions.)*	Type of connection:	
D12		GPS Coordinates:	
D13		Number of taps:	
D14		Number of HHs served:	
D15		Hours operational:	
D16		Queue time (if any):	

D17		Flow rate:	
D18		Metered? ❑ Yes ❑ No	
Water Demand (Daily)			
D19	Demand at tap stands:		Total # HHs using tap stands * 6 * 20 L/day
D20	Demand at yard taps:		Total # HHs using yard taps * 6 * 50 L/day
D21	Demand at HH connections:		Total # HHs using building connections * 6 * 100 L/d
D22	Demand from institutions:		
D23	Schools		Day students * 5 L/day Boarders * 50 L/day
D24	Health centers		Outpatients * 5 L/day Beds (inpatient capacity) * 50 L/day
D25	Religious centers/Markets		Assess on case-by-case basis
D26	Total daily water demand:		

Service Agreements & Contracts Checklist

System Name:
Management Name(s):
Date:

#	Contract With	Contract Purpose	✓	Effective Date	
				Start	End
1	Product Suppliers	Warranty and defect liability arrangement, ideally for periods of two or more years (recommend a minimum requirement of one-year). *This is usually done at the time of equipment purchase and installation by the supplier. Check to make sure that this is the case and, if not, prepare the contract and contact the supplier.	❑		
2	Service Providers	Overhaul and replacement of equipment arrangement.	❑		
3	System Technician(s)	Service delivery arrangement should be established with key responsibilities.	❑		
4	System Operator(s)	Service delivery arrangement should be established with key responsibilities.	❑		
5	Water Users	A fee amount and schedule with transfer arrangements should be agreed on for covering ongoing costs through a combination of funds.	❑		

Roles & Responsibilities Guide

System Name:
Management Name(s):
Technician Name(s):
Operator Name(s):
Date:

#	Primary Responsibility	Support
System Management		
1	**Safety Protocols & Risk Prevention** Create safety strategies to protect personel. Provide safety equipment (personal protective equipment). Provide in-depth safety training to all personel.	System Operator System Technician
2	**O&M Workplan** Establish O&M plan for the system. Hire qualified personel. Provide O&M plan to Operators and Technicians.	System Technician
3	**Data Management** Determine what system data to collect and provide forms. Determine the data reporting procedures and frequency. Maintain all sumbitted records.	System Operator System Technician
4	**Management of Parts & Supplies** Establish site security and theft prevention procedures. Implement an inventory system for supplies and spare parts. Maintain a stock of all routine supplies and spare parts. Manage warranties, liabilities, and major repairs. Procure major replacement components.	System Operator System Technician
5	**Financial Management** Establish water fees/tariffs based on life-cycle costing. Establish water fee/tariff collection and deposit procedures. Maintain system financial records. Manage system budget for ongoing O&M and replacements.	Tap Operators (if applicable)

System Operator		
6	**Safety Protocols & Risk Prevention** Follow all safety protocols at all times. Maintain site security at all times. Report safety or security concerns.	System Management System Technician
7	**Routine Operation** Follow established pumping procedures (start up/shut down). Maintain pumping schedule to ensure reliable water supply. Perform water quality testing to ensure safe water.	System Management System Technician
8	**Preventative (minor) Maintenance** Maintain site cleanliness. Perform weekly inspections (as detailed in O&M workplan). Perform minor repairs (as detailed in O&M workplan).	System Management System Technician
9	**Data Recording** Complete data collection forms (as detailed in O&M workplan). Submit forms to Management (as detailed in O&M workplan).	System Management
10	**Repair (major) Maintenance** Assist Technician with quarterly/annual inspections. Assist Technician with minor and major repairs.	System Technician
System Technician		
11	**Preventative (minor) Maintenance** Perform anuual maintenance (as detailed in O&M workplan). Perform quarterly maintenance (as detailed in O&M workplan). Perform minor repairs as needed.	System Operator System Management
12	**Repair (major) Maintenance** Perform major repairs and replacements as needed.	System Operator System Management
13	**Data Recording** Complete data collection forms (as detailed in O&M workplan). Submit forms to Management (as detailed in O&M workplan).	System Management

SYSTEM MANAGEMENT SHOULD CUSTOMIZE THIS FORM PRIOR TO USE

Operator Competency Checklist (General)

System Name:
Management Name(s):
Technician Name:
Operator Name:
Date:

To safely operate and maintain small drinking water systems, a System Operator must have the following competencies (knowledge, skills, and attitude).

* See Operator Competency Checklist (System Operations) for an on-the-job competency check to evaluate Operators.

#	Competency	✓
1	Demonstrate safety protocols during all operations and maintenance procedures.	❑
2	Perform common maintenance and routine checks of electrical or fuel-powered water supply systems.	❑
3	Perform common maintenance and routine checks of water treatment systems.	❑
4	Perform common maintenance and routine checks of storage, distribution, and water collection points, whether at the household level or at kiosks.	❑
5	Troubleshoot issues and perform minor repairs of system components.	❑
6	Perform corrective actions to resolve identified issues related to water quantity and distribution.	❑
7	Collect and test water samples (residual/free chlorine, turbidity).	❑
8	Interpret water quality testing results and perform corrective actions to resolve issues.	❑
9	Accurately complete, manage, and submit data records and monitoring forms.	❑
10	Communicate effectively with community members about water availability and acceptability.	❑
11	Communicate effectively with community members about locally available household water treatment options in case of an absent or failing water treatment system.	❑
12	Assist in system design processes to ensure system meets community needs.	❑
13	Communicate effectively to the System Technician for issues as required.	❑
14	Support and supervise Assistant Operators.	❑

O&M Tasks Overview

System Name:
Managment Name(s):
Technician Name:
Operator Name:
Date:

#	Responsibility	Primary Responsibility	Supporting Responsibility
DAILY			
	Routine operation of water system.	Operator	Management Technician
	Maintain site security and cleanliness.	Operator	Management
	Visually inspect solar panels and electrical boxes.	Operator	Technician
	Check residual chlorine (and turbidity, if applicable).	Operator	Technician
	Complete *Daily Water Production Form* and *Daily Maintenance Form* .	Operator	Management
WEEKLY			
	Check for modifications or animal activity.	Operator	Management
	Perform visual inspections and minor maintenance: *Solar array (wash solar panels), electrical house, wiring and grounding, wellhead, water treatment house, water tank, piping (pressure and distribution), community access points*	Operator	Technician Management
	Complete *Weekly Maintenance Checklist* and *Weekly Tools & Supplies Inventory Form* .	Operator	Management
QUARTERLY			
	Perform visual inspections and major maintenance: *Electrical house and all electrical equipment*	Technician	Operator Management
	Confirm functionality of equipment: *Float Switch, remote monitoring system, sensors (as applicable), water quality testing equipment*	Technician	Operator
	Observe Operator performing water quality tests.	Technician	Operator
	Test water quality: *Residual chlorine, turbidity, bacteria*	Technician	Operator

	Complete *Quarterly Maintenance Checklist*.	Technician	Management Operator
ANNUAL			
	Perform full inspections and major maintenance: *Structures, fencing/gates, lights, electrical equipment and protections, wiring connections, borehole, pump, water treatment equipment, piping, valves, water meter, remote monitoring system, generator (if applicable)*	Technician	Operator Management
	Perform a continuity test. **Every 3-5 years or as required by local regulations*	Technician	Operator Management
	Perform a ground resistance test. **Every 3-5 years or as required by local regulations*	Technician	Operator Management
	Observe Operator performing pumping procedures.	Technician	Operator
	Perform a yield test.	Technician	Operator Management
	Collect water samples for full water quality analysis.	Technician	Operator Management
	Complete *Annual Maintenance Checklist*.	Technician	Management Operator

SYSTEM MANAGEMENT SHOULD CUSTOMIZE THIS FORM PRIOR TO USE

Data Management Plan

System Name:
Management Name(s):
Technician Name:
Operator Name:
Date:

#	Data to Record	Frequency of Data	Form to Use	Submission to Management
OPERATORS are responsible for recording and submitting the following data:				
1	Water Meter Reading	Start and end of all pumping cycles	Daily Water Production Form	Weekly
2	Total Daily Water Production	Daily		
3	Residual Chlorine	Daily		
4	Turbidity (if applicable)	Daily		
5	Weather Conditions (sunny, cloudy, rainy)	Daily	Daily Maintenance Form	Weekly
6	Pumping Pressure	Daily (specifiy set times)		
7	Power (from pump controller)	Daily (specify set times, noon recommended)		
8	Alarms (from pump controller)	Daily (as present)		
9	Maintenance Completed	Daily (as appliable)		
10	Community Feedback	Daily		
11	Completion of Weekly Maintenance Tasks	Weekly	Weekly Maintenance Checklist	Weekly
12	Areas of Concern or Future Repairs	Weekly		
13	Inventory	Weekly	Weekly Tools & Supplies Form	Weekly

TECHNICIANS are responsible for recording and submitting the following data:				
14	Completion of Quarterly Maintenance Tasks	Quarterly	Quarterly Maintenance Checklist	Quarterly
15	Areas of Concern or Future Repairs	Quarterly		
16	Follow Up to be Completed by Operator	Quarterly		
17	Completion of Annual Maintenance Tasks	Annually	Annual Maintenance Checklist	Annually
18	Borehole Yield Test	Annually	Provided by Technician or Hydrogeologist	Annually
19	Full Water Quality Analysis	Annually	Provided by Water Quality Lab	Annually

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Parts Suppliers & Warranties - Major Components

System Name: Newa Community
Management Name(s):
Date:

Type of Equipment	Part Number or Name	Manufacturer	Specifications #	Supplier Contact #	Warranty*	Expected Lifespan
Solar Panels	SPR-P5-525-UPP	Sunpower	1		10-year product 25-year performance	25 years
Pump	11 SQF-2	Grundfos	2		2-year product	7 years
Pump Controller	CU200	Grundfos	3		2-year product	10 years
3-Way Disconnect Switch	32 A Onload Changeover Switch	Havells			2-year product	10 years
DC Combiner Box	IP65-rated electrical enclosure	Misc.			N/A	10 years
	20 kA, 600 VDC Surge Protection	Misc.			N/A	3 years
	15 A, 600 VDC Circuit Breaker	Misc.			N/A	3 years
	15 A Fuses	Misc.			N/A	3 years
AC Protections Box	AVS30 (voltage protection)	Sollatek	4		1-year product	3 years
	20-A, 240 V Overcurrent protection	Misc.			N/A	3 years
	20 kA, 240/480 V Surge Protection	Misc.			N/A	3 years
Water Treatment	Erosion Chlorinator	Water Mission	5			15 years
Remote Monitoring	SatWater Communicator V3	Water Mission	6			10 years

Section 3

Financial Sustainability

Introduction

Financial sustainability is an **essential** component of ongoing operations and maintenance (O&M) and is key to the long-term success of the project. Financial planning should ideally begin during the design phase of the project. This section is included in this manual for reference, training purposes, and to support Service Providers that may be starting a new project or assuming responsibility for the O&M of an existing system.

One of the primary causes of failure in water systems is broken components that remain unrepaired or are not replaced. Comprehensive financial planning for O&M and fund management throughout the life of the project, starting during the design stage and continuing throughout the project's lifecycle, is essential to ensure the system operates successfully over time. It is crucial to establish a financial budget that accounts for ongoing O&M expenses as well as replacement costs for components that will inevitably fail. The key activities that will require ongoing financial resources are:

- Paying someone to perform daily operations and monitoring.
- Paying someone to perform more complex maintenance and repairs.
- Maintaining a consistent supply of treatment consumables (ex.chlorine).
- Maintaining a consistent supply of water quality testing equipment and consumables.
- Providing a consistent supply of alternate power (electrical grid or generator).
- Saving for future equipment, parts and tools replacement(s).

Financial planning for sustainable operations and maintenance (O&M) requires a different mindset and strategy than for design and installation. The design and installation of a SPWS and finances required to support these activities are finite and eventually come to an end. Whereas, O&M requires ongoing financing, as well as forecasting for future expenses to be covered when needed, sometimes years after commissioning and handover of the system.

Global Water Center's Chief Strategy Officer, Pamela Crane-Hoover, explains the difference and explains below how she thinks about the challenges that O&M teams face over the long-term.

> **Planning for design and installation is much like running a construction company. You find a good customer (or community) and research the context, including figuring out what the customer wants and then you design for the reality of their context and to the standards that need to be met. Customer interaction is essential to design a good project, so you work with the customer to design, and then you install what you designed. Post-installation, there might be a check-in or two required for a given period of time during the handover process, but typically within a year the financial responsibilities are done.**
>
> **Ongoing operations and maintenance is a service model. You are not selling exciting new construction or a shiny new car. Instead, you are selling the maintenance that keeps the building stand or the car running, something that few people like to budget for. When you have an operations and maintenance model, the company needs to perform all the maintenance you agree to do so that a water point keeps functioning, and, if it breaks down you must respond quickly so that the water can keep flowing.**
>
> **With construction, you might have a surge of work, but you can also decide to do extra in one month and less in another month. If you are focused on operations and maintenance, water points NEVER go away. You just keep adding them. This requires efficiency with your team to meet the demands of the work and will likely require additional team members as new water points are added. With construction, you do work and move on. But with operations and maintenance, you continue to add water points and systems, and the work continues to expand. When I think of organizations doing construction and adding water points to their O&M, but thinking the O&M is easy, I think they miss the compounding impact that happens over the years because the first few years are relatively so easy.**
>
> **In the following figure, the different colors show water points constructed in each year. The construction team continues to do the same work from year to year, but the O&M team is doing much more work within a short period of time. The process and systems for O&M are so important.**

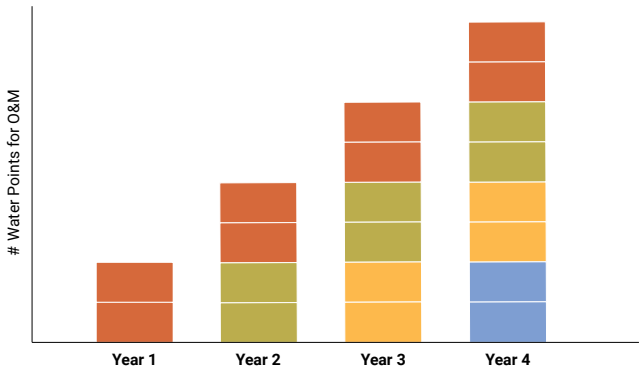


Figure 3.1: Every Year the Number of Systems to Operate and Maintain Increases.

So, the O&M teams must do more (and you must add teams), all while delivering the same quality of service. This is when all of the thinking through systems becomes such a big deal. Also, when you do O&M and you are getting communities to pay for it (through fees, monthly tariffs or other ways), it becomes a big problem if the construction quality of the original work is not good -- because then parts break down too fast, and your financial model does not work. Suddenly the O&M company/ organization cares more about original quality of construction AND must be a better 'business' because of the level of operations they have to run cost-effectively.

3.1 Financial Models

Community Owned: The SPWS is owned by the community and a water fee is charged. The money is collected and is regularly used towards the operating costs, but there is a surplus amount that is accumulated to cover future replacement costs.

Private Entity Owned: The SPWS is privately owned and charges users a water fee while assuming full responsibility for repairs and replacements, regardless of whether the collected water fees are sufficient to cover these costs.

User Subsidized: A portion of the water is used for irrigation, and a fraction of the harvest is set aside to cover SPWS costs. Or, community member who benefits significantly from the SPWS—typically a farmer using the water for agriculture or livestock—covers the full cost of repairs when necessary.

Financed by NGO: All costs are fully financed by an NGO (ex. SPWS in refugee camps, protracted humanitarian crises, etc.).

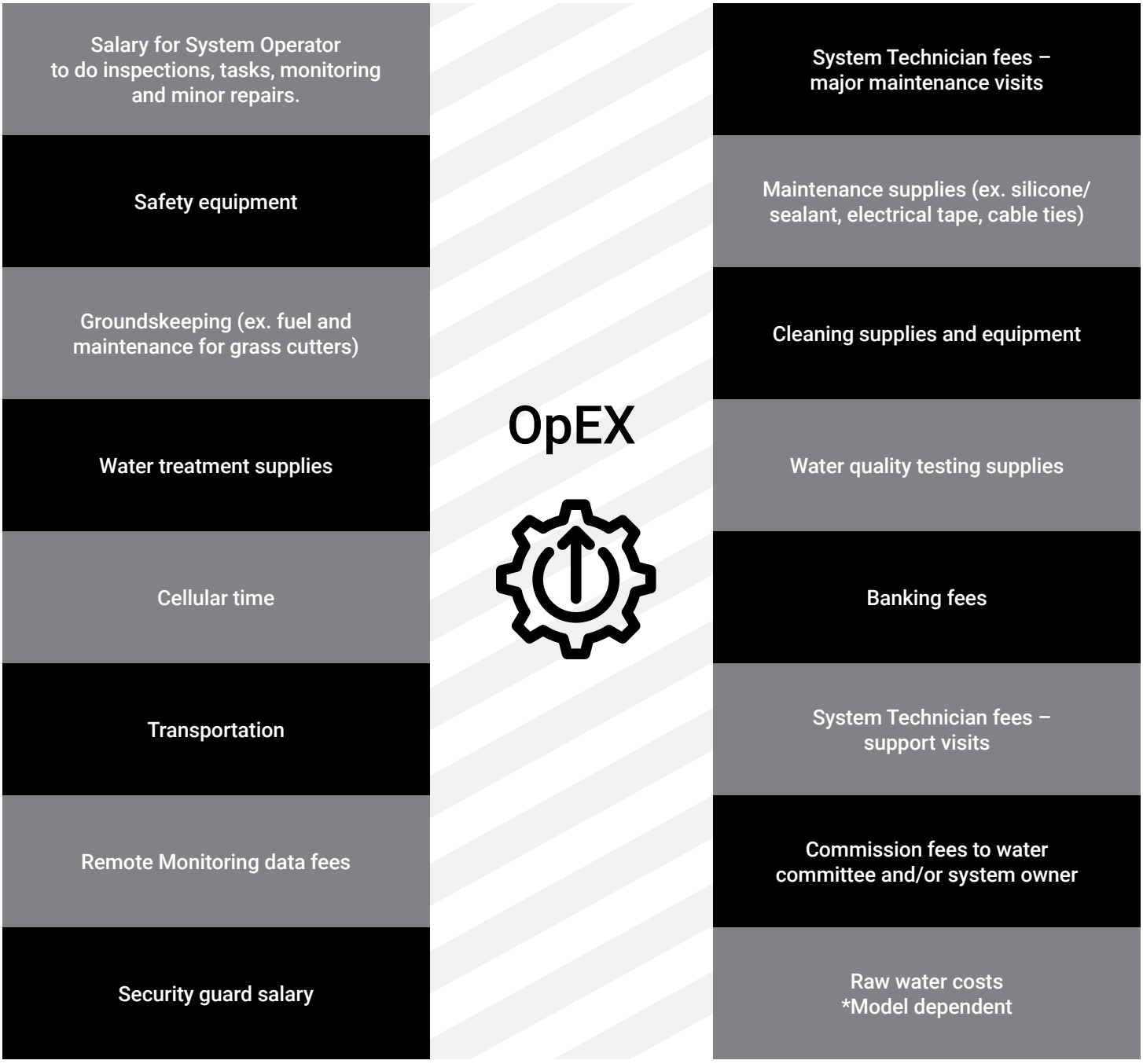
Government Owned: The SPWS is owned and managed by the government. While a water fee is charged, the government covers any deficits through subsidies when necessary.

3.2 Types of Costs

There are two main types of costs associated with SPWS - operational and capital.

A. OPERATIONAL COSTS/EXPENDITURES (OPEX)

These are the costs to operate, maintain, and manage the day-to-day operations and could include:



B. CAPITAL COSTS/EXPENDITURES (CAPEX)

These are the costs to acquire, upgrade, and/or replace the component parts of the system and could include:

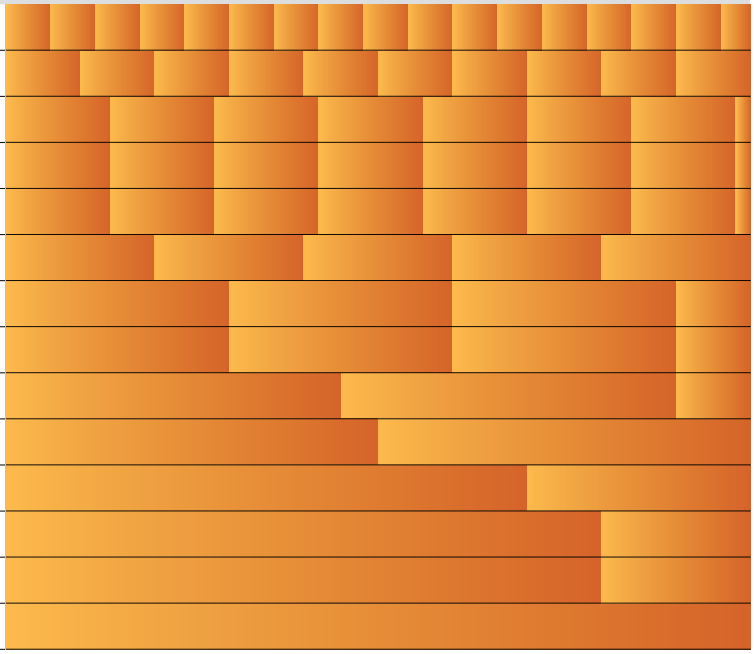
Pump	CapEX 	Tap Stands
Controller		Combiner Box
Inverter (if applicable)		Meter and gauges
Generator		Splice kits
Solar panels		Water Source
Water treatment system		Water tank
Structure		Piping

3.3 Lifespan Costs of the SPWS

Knowing the approximate lifespan of equipment and its replacement costs can help with budgetary planning and saving for such expenses.

If replacement costs are not planned for, the system will eventually go into disrepair when a replacement is inevitably needed. For example, on average pumps last about seven years. This means that to keep the SPWS running long-term, a new pump will be needed approximately every seven years. If funds are not available when the new pump is needed, the SPWS will no longer function, and water will no longer be available to the community. This, in turn, will prevent revenue collection, hindering the ability to cover the other system's costs, as well as the cost of getting the system back up and running.

All system components have different lifespans that should be considered when planning replacement costs. Refer to the table below to see an example list of equipment and its typical lifespan. For financial planning purposes, the costs of each piece of equipment should be researched and listed in a table such as this. These capital costs will impact the overall cost of operating and maintaining the system over time.

Equipment	Typical Lifespan (years)	Approximate Cost (Currency)	Average replacement schedule of equipment over 50 year period
Tap Stands (each)	**3***		
Pump	**3 - 7**		
Controller	**5 - 10**		
Combiner Box	**5 - 10**		
Inverter	**5 - 10**		
Water Treatment	**5 - 15**		
Meters/Guages	**10 - 20**		
Generator	**10 - 20**		
Water Tanks	**15 - 30**		
Solar Panels	**20 - 30**		
Water Source	**30 - 40**		
Buildings	**20 - 60**		
Solar Structure	**20 - 60**		
Piping	**50**		
	Total		

*small parts require more frequent replacement

3.4 How to Calculate the Lifespan Costs

Planning to cover the total costs requires information regarding operational costs, capital or replacement costs, and water usage over time. Once this information is collected there is a calculation tool that will determine the amount of fees that need to be collected.

To help plan for financial sustainability, there is a basic financial sustainability worksheet (FWS) calculation tool that can calculate ongoing project expenses based on:

- Water User Data
- Operational Costs
- Replacement Costs

The information is then used to calculate a breakeven price which determines the fee that must be charged to water users over time to accumulate sufficient funds to cover these costs.

The colored boxes in the example tables below outline the information that must be gathered and inputted to utilize the FSW effectively.

A. USER DATA

General Information	Unit	Value
Est. households in service area	no. households	600
Est. avg. household size (including children)	no. people	5
Est. household population with access to safe water	no. people	3,000
Est. daily water users from outside the community	no. people	0
Additional revenue sources (institutions, e.g.)	-	No
Local currency	-	KES (Kenya)
Foreign currency	-	USD
Avg. monthly household income	KES	45,000
Max household safe water consumption expenditure	%	3%
Exchange rate	KES/USD	460
Container size	L	20
Management committee commission	% total sales	5%
System operator commission	% total sales	0%
Tap operator commission	% total sales	5%

Targets	Unit	Value
Anticipated household penetration	% service area	60%
Anticipated individual safe water purchased	L/person/day	12.0
Anticipated revenue collection efficiency	% total revenue	80%
Anticipated daily production	L/day	21,600

B. OPERATIONAL COSTS

	Operational Costs (OpEx)	Applicable?	Unit	Unit Costs KES	Unit Costs USD	Costs per Month KES	Costs per Month USD	% of total expenditure
Variable	Chlorine (see Additional Calcs tab)	Yes	/m³ water	2	0.02	1,479	9.86	2%
	Fuel (for generators and/or delivery vehicles	No	/m³ water	0	0.00	0	0.00	0%
	Electricity (for water production)	No	/m³ water	0	0.00	0	0.00	0%
	Total commissions		/month	7,200	48.00	7,200	48.00	11%
Fixed	Fixed Salaries (non-commission)		/month	30,000	200.00	30,000	200.00	44%
	Rent		/month	0	0.00	0	0.00	0%
	Water quality testing supplies		/month	1,500	10.00	1,500	10.00	2%
	Cellular airtime		/month	3,000	20.00	3,000	20.00	4%
	Banking fees		/month	1,500	10.00	1,500	10.00	2%
	Transportation		/month	0	0.00	0	0.00	0%
	Routine maintenance and upkeep		/month	4,500	30.00	4,500	30.00	7%
	Support visits (see Additional Cals. tab)	Yes	/month	3,000	20.00	3,000	20.00	4%
	Other expenses		/month	0	0.00	0	0.00	0%
					Total Variable Costs:	8,679	57.86	13%
					Total Fixed Costs:	43,500	270.00	64%
					Anticipated Operational Costs (Variable + Fixed)	52,179	327.86	76%

C. REPLACEMENT COSTS

Replacement Costs	Life Span (years)	Capital Investment KES	Capital Investment USD	Costs per Month KES	Costs per Month USD	% of total expenditure
Water Source (borehole, sump, intake, e.g.)	20	450,000	3,000	1,875	12.50	3%
Structures (enclosures, towers, platform, etc.)	50	900,000	6,000	1,500	10.00	2%
Electrical (wire, switches, controls, etc.)	20	150,000	1,000	625	4.17	1%
Power Supply (solar panels, generators, etc.)	15	300,000	2,000	1,667	11.11	2%
Pump	7	375,000	2,500	4,464	29.76	7%
Water Tanks	30	75,000	500	208	1.39	0%
Tap Stands (concrete, meters, valves, etc.)	3	37,500	250	1,042	6.94	2%
Water Treatment Equipment	15	225,000	1,500	1,250	8.33	2%
Piping	80	600,000	4,000	625	4.17	1%
Other			0	0	0.00	0%
Anticipated Replacement Costs:		3,112,500	20,750	16,256	108.37	24%

D. BREAKEVEN PRICE

Financial Summary	Unit	KES	USD
Method of fee collection (*select from dropdown menu*)	/HH/month	Monthly household fee	
Recommended max water fee	/HH/month	1,800	12.00
Water fee option #1 (OpEx Costs ONLY)	/HH/month	181	1.21
Water fee option #2 (OpEx Costs + Replacement Costs)	/HH/month	238	1.58
Anticipated water fee	/HH/month	**250**	1.67
Anticipated Operational Cost Coverage	%	138%	
Anticipated Replacement Cost Coverage	%	122%	
Anticipated Consumption Expenditure	%	0.4%	
		KES	**USD**
Anticipated Total Revenue	/month	72,000	480
Anticipated operational costs (OpEx)	/month	52,179	330
Anticipated savings	/month	19,821	130
Anticipated replacement costs	/month	16,256	110
Anticipated total costs	/month	68,435	440

Expense Type	% of Expenses
Chemicals + Testing	4%
Commissions & Salaries	54%
Energy Costs	0%
Maintenance	7%
Other OpEx	7%
Support Visits	4%
Replacement Costs	24%

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For this example, in order to break even based on all of the operational and capital costs, each household will have to pay 250 Kenyan shillings per month. If the financial model is based on a fee for volume of water, this can be calculated in the FSW by selecting this method of fee collection.

3.5 Factors that Impact Financial Sustainability

Even with effective planning, covering costs can be challenged in various ways. Here are a few examples.

Challenge: Collected monies are adequate to cover operational costs, but not enough to fully cover replacement costs.

Recommendation: Use both the operational costs and replacement costs to calculate the fee that would be required for full cost coverage and then a plan on how those costs will be covered over time.

Challenge: A community may collect water fees and begin saving money, but it can be challenging to avoid using those funds for other purposes. They might spend the savings on buying livestock, funding microcredit schemes, or similar activities. As a result, when a system failure occurs—possibly years after the handover—the funds needed for repairs may not be readily available or might have been entirely depleted.

Recommendation: Early education/training/awareness of the community and those involved in managing the money on the long-term needs for repairs and costs of the system.

Challenge: Non-paying customers. Even though many formal/informal water operators/utilities have magnetic or lockable isolation valves, they are unable to disconnect customers because access to water is a human right.

Recommendation: There is no easy answer how to manage this situation. Education/training/awareness can be beneficial, but it remains a challenging and common issue that varies significantly depending on the specific context.

Being aware of the factors that can challenge or support financial sustainability can potentially help prevent situations like those highlighted in the examples above.

A. FACTORS THAT CHALLENGE FINANCIAL SUSTAINABILITY

1. *Unsupported* Community Based Management has largely been unsuccessful in providing adequate long-term support for systems. *Lack of availability* of government incentives varies in each country.
2. Government incentive programs that *require immediate returns* – these are challenging for small arrays and micro-consumption.
3. Popular tariff collection options, such as Feed-in-tariff (FIT) and Net Metering (NEM), which require *grid tie in* and therefore do not work for stand-alone power systems.
4. Financial *corruption.*
5. *Misuse of finances* or using collected fees or tariffs for other entities.

B. FACTORS THAT SUPPORT FINANCIAL SUSTAINABILITY

1. **Accountability:** Involvement of national ministries, city council, NGO, private sector, & users.
2. **Support based approach:** NGO support service providers/owners through innovation and strengthening of accountability practices.
3. **Consolidating services:** Increase the size of the service provision area or the number of systems being managed.
4. **High level of cost recovery** (CapManEx).
5. **Performance-based incentives** (ex. Uptimewater.org).
6. **Tax exemptions and subsidies:** Cost reduction with government involvement.
7. **Supporting typical Community Based Management (CBM)** model with government (regulation), public utility provision, or private sector participation.

Effective planning for O&M as a lifelong service to the SPWS is best achieved by considering the context, selecting an appropriate model, accounting for all operations, maintenance and replacement costs, and addressing factors that could affect resource availability over time.

Section 4

Safety Protocols and Practices

Introduction

Proper maintenance and safety procedures and practices protect System Operators, Technicians, and those who are collecting water from the system. Ensuring these safety protocols and practices are embedded in the management, design, installation, and operations and maintenance of SPWS is crucial. Considering and implementing safe practices starting at the design phase will help to eliminate possible electrical and chemical exposures.

There are distinct safety risks and mitigation strategies specific to each area of the SPWS. Safety protocols are effective only when communicated clearly and supported by appropriate training and tools for System Operators and Technicians.

By implementing safety practices and promoting a culture of safety among workers, organizations can significantly reduce the risks associated with working around SPWS and create a safer work environment for their employees.

This section will outline general safety. Within Sections 5 and 6, the specifics regarding safety will be noted and expanded upon as they relate to the different components of the SPWS and specific O&M activities.

4.1 Personal Safety

Maintaining personal safety is the top priority, particularly in remote areas.

Safety Practices:

A. Maintain a clean environment throughout the SPWS and in the surrounding areas of all fenced zones to minimize the risk of insect, rodent, or snake infestations.

B. Ensure all areas are always locked, particularly at night.

C. Post the necessary hazard signs around the SPWS to remind yourself and warn others of the danger.

D. Regularly review the emergency response plan that management has provided in case of injury, attack, or theft.

E. Personal Protective Equipment (PPE) should be used appropriately.

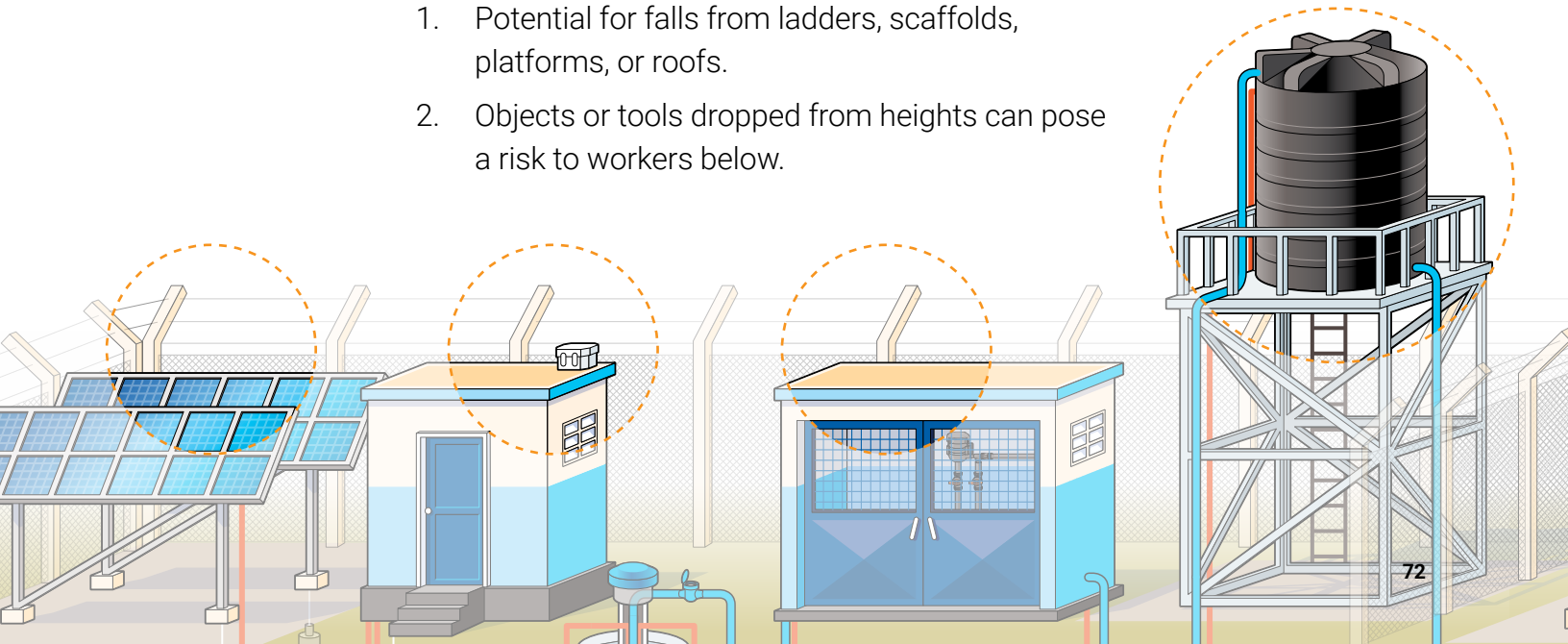
	**Hard hat:** to use when climbing to heights above 2m or when there is danger from above.
	**Hearing protection:** to use when working with loud equipment, like a generator.
	**Eye protection:** to use when working with electrical equipment, treatment chemicals, and when cleaning to protect from dust.
	**Respiratory protection:** to use when working with chemicals like chlorine or fuel (petrol, gas).
	**Gloves:** to use when working with chemicals or fuel.
	**Foot protection:** to be worn on–site at all times.

4.2 Working at Heights

Working at heights presents significant safety risks that can lead to accidents, injuries, or fatalities if proper precautions are not taken.

Safety Hazards:

1. Potential for falls from ladders, scaffolds, platforms, or roofs.
2. Objects or tools dropped from heights can pose a risk to workers below.



Safety Practices:

A. **Fall Protection Systems**

- Use guardrails, safety nets, or personal fall arrest systems (harnesses and lanyards) to prevent falls.
- Ensure that all fall protection systems are properly installed, inspected, and used correctly.

B. **Proper Training**

- Provide training on working at heights, including hazard recognition, fall protection, and emergency procedures.
- Train workers on the safe use of equipment such as ladders, scaffolds, and lifts.

C. **Proper Personal Protective Equipment (PPE)**

- Ensure that workers wear appropriate PPE, such as helmets, gloves, and safety footwear, to protect against falling objects and other hazards.
- Use non-slip footwear to prevent slips on elevated surfaces.

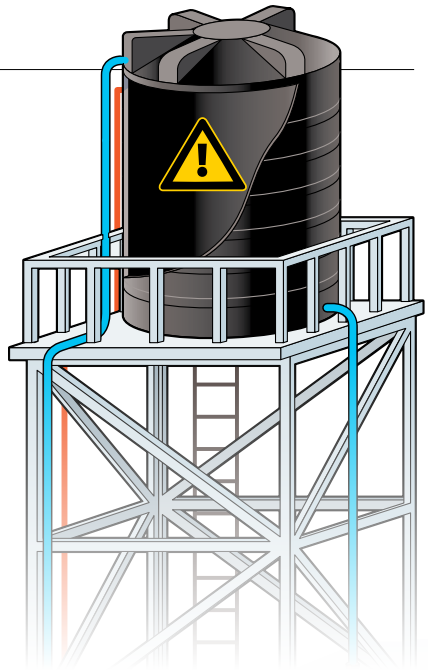
D. **Risk Assessment and Regular Inspections**

- Conduct thorough risk assessments before starting work at heights to identify hazards and implement control measures.
- Involve workers in the assessment process to address concerns and enhance safety awareness.
- Regularly inspect scaffolding, ladders, platforms, and other equipment for safety and structural integrity.
- Conduct pre-work inspections to identify and address potential hazards.

E. **Emergency Preparedness**

- Have emergency rescue and evacuation procedures in place for workers working at heights.
- Ensure that workers are trained in emergency response protocols and how to access emergency services, if needed.

4.3 Confined Spaces



Working in confined spaces presents unique safety risks due to limited access, poor ventilation, and potential exposure to hazardous materials.

Safety Hazards:

1. Asphyxiation
2. Exposure to toxic gases
3. Fire hazards
4. Entrapment

Safety Practices:

A. **Training:** Provide proper training to workers that focuses on hazard recognition, safe entry procedures, emergency response, and the proper use of personal protective equipment (PPE). Ensure workers understand confined space rescue procedures and how to respond to emergencies.

B. **Ventilation and Air Quality:** Ensure adequate ventilation systems are in place to provide fresh air and control exposure to contaminants.

C. **Entry and Exit Procedures:** Establish clear entry and exit procedures, including procedures for communication, monitoring, and periodic checks on workers inside confined spaces.

D. **Personal Protective Equipment (PPE):** Provide appropriate PPE, such as respirators, helmets, gloves, and protective clothing, based on the hazards present.

E. **Buddy System:** Ensure there is another person present when someone is entering confined spaces to maintain communication and coordinate rescue efforts, if needed.

4.4 Electrical Hazards and Safety Practices

All electrical equipment is potentially hazardous and should be treated with EXTREME CAUTION, even when power appears to be OFF.

***Note to management:** Consult an electrician, electrical engineer, or **System Technician** for anything related to the electrical system components, the purpose of these components, and how they work.

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. **Serious injuries and death can be caused by electrical hazards such as arc flash, shocks, burns, falls if shocked, and fires.**

***Solar panels are energized whenever the sun is up** – whether the pumping system is on or not.

Electrical Hazards

High Voltage Exposure
Solar panels generate high voltages, which are dangerous if you are exposed to their voltage or mishandled.

Electrical Arcing
Faulty connections or damaged panels can cause electrical arcing, which can lead to fires, equipment damage, or serious injury.

Lightning Storms
Solar panels and electrical components are vulnerable to lightning strikes, which can cause damage and pose safety risks.

Short Circuits
Incorrect wiring or damaged insulation can cause short circuits, leading to overheating, fires, or system failure.

Loose Wire Connections
Loose or improperly connected wires can cause intermittent electrical faults, overheating, and potential fires.

Damaged Wire Insulation
Insulation failure due to wear, mechanical damage, or environmental factors can lead to exposed live wires and potential shocks.

Electrical Equipment Malfunctions
Faulty electrical equipment (ex. pump motors, controller, inverters) can lead to electrical hazards, overheating, and failure.

Water and Electrical Interaction
Water leakage or spills can come into contact with electrical components, posing a risk of shock or short circuits.

Safety Practices

Limit access to the solar array and electrical house using fencing and locks on all gates and doors.

Ensure grounding systems are properly installed and maintained to protect equipment and personnel.

Conduct routine inspections of panels and connections to check for signs of wear, damage, or corrosion.

Always cover the solar panels while working on them.

Do not wear metallic jewelry while working on the solar array.

Do not work on or work around the solar panels when there is bad weather; NEVER service a SPWS during a lightning storm.

Always work in pairs.

Use a ladder that is in good working condition for cleaning and working on the solar panels.

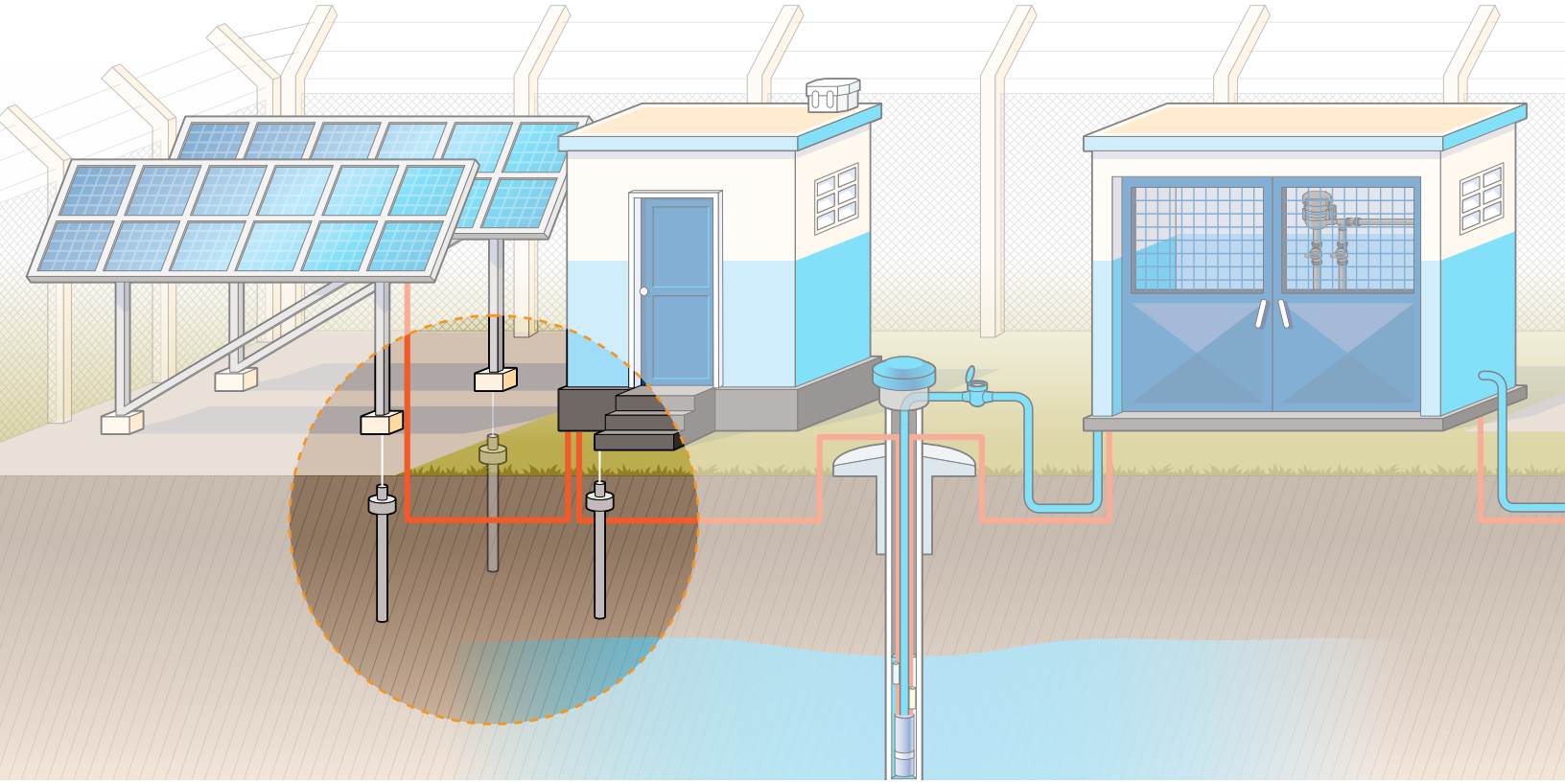
Regularly inspect and maintain electrical wiring, insulation, and connections to ensure that they are secure and in good condition; DO NOT touch loose, damaged, or exposed wires.

DO NOT open or remove the covers on any electrical equipment unless you are a trained System Technician; always call the System Technician for any damage.

NEVER allow water to pool on the floor of the electrical house or near any electrical equipment.

For any damage to the electrical system detected, immediately shut down the SPWS and call the System Technician.

A HAZARDS & SAFETY PRACTICES: GROUNDING AND BONDING



Grounding and electrical bonding protect against electric shock resulting from a conductor contacting exposed metal. Grounding is crucial for the safety of the people working around the system. However, grounding may have been overlooked in the design and installation phase.

Electrical components are insulated with various materials to prevent the transfer of energy outside of the circuit. For protection in the event of insulation breakdown, a connection of a grounding electrode to all metallic electrical enclosures is the method required by the International Electrotechnical Commission (IEC) safety standards.

This requirement means that a grounding electrode must be included in the SPWS design and maintained in proper working order to protect personnel and users of the SPWS. Three grounding rods connect the system to the zero-voltage earth, as shown above. This zero-voltage earth is extended from the ground rods to all the electrical enclosures using bare copper

conductors. The grounding rods effectively connect the electrical enclosures to the zero-voltage earth and make them safe for people to touch. As long as the electrical enclosures remain closed, this connection places a zero-voltage level around all of the electrical equipment.

If an electrical enclosure is opened, the barrier is removed, and the person will be exposed to live equipment and potentially lethal electrical shock.

Opening of the electrical enclosure containing these voltages is only done with qualified System Technicians who understand the procedures and personal protective systems required for this action.

The job of the System Operator is to visually inspect the grounding system to make sure it is secure and there is no detected damage, but not to touch any of it.

If there are any visible signs of damage or disconnection, the Operator must contact the System Technician immediately.

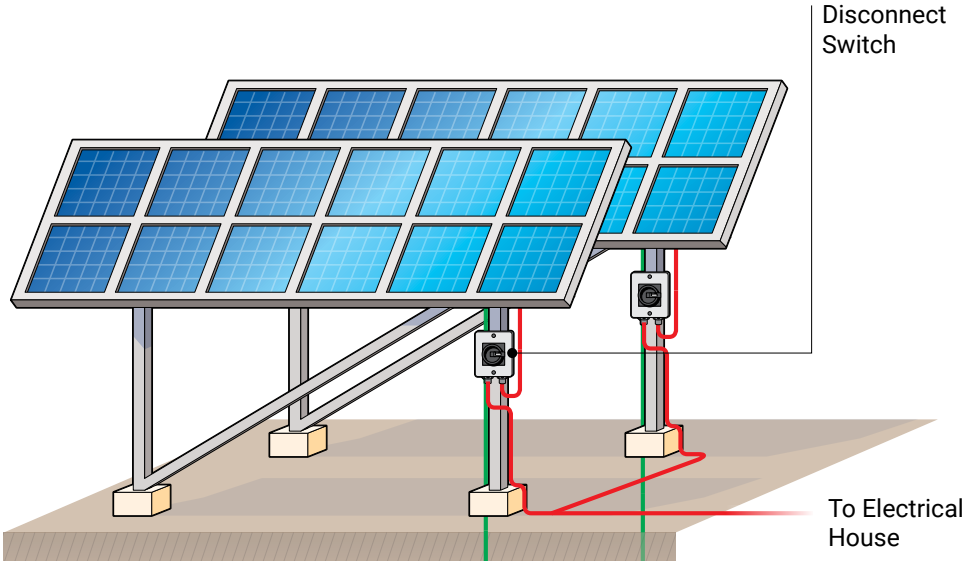
B HAZARDS & SAFETY PRACTICES: LIGHTNING STORMS

NEVER service a SPWS during a lightning storm!

Due to the increased risk of shock, SPWS should never be serviced or actively managed during a lightning storm. The system may attract direct lightning. Lightning rods are intended to ground the lightning strike and disperse it through the ground. This creates a physical danger zone around the entire area that receives a lightning strike during a storm.

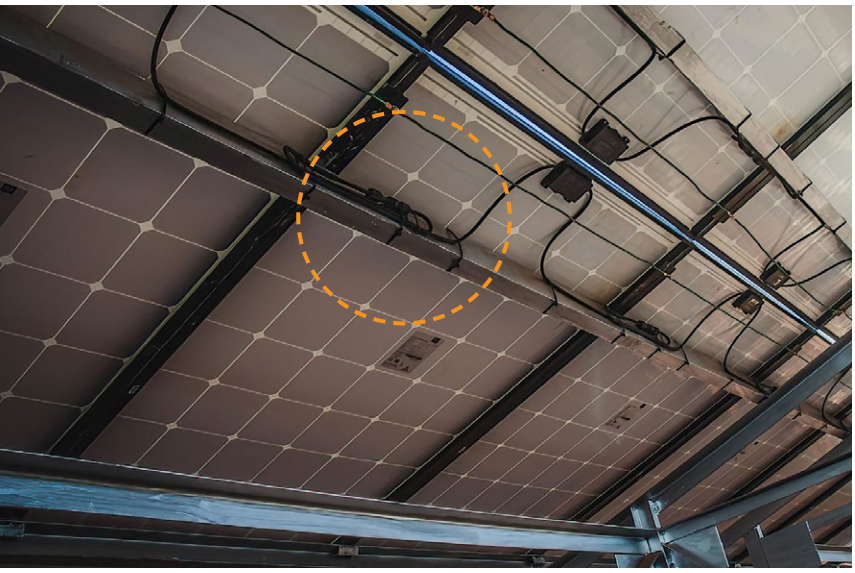
Stay outside the fenced solar panel area and electrical house when lightning is a threat. During a storm, move quickly away from the system and lightning rod and ensure no one enters the system premises.

C HAZARDS & SAFETY PRACTICES: SOLAR PANELS



* Following safety guidelines is crucial when working on or around solar panels.

Solar panels are energized whenever the sun is up – whether the pumping system is on or not – and doing maintenance at night is not safe or practical. A qualified **System Technician** should be involved in all solar array repairs to ensure they are done safely.



MC-4 Connectors: Do not touch
SOURCE: WATER MISSION

The solar panels are connected to the system using MC-4 male and female connectors to ensure they are fully insulated at the panel location. Only qualified electrical technicians, such as the System Technician, can work on the solar panel wiring, MC-4 connectors, or any other part of the system before it passes through the breakers and disconnect switches because these components must be treated as energized equipment.

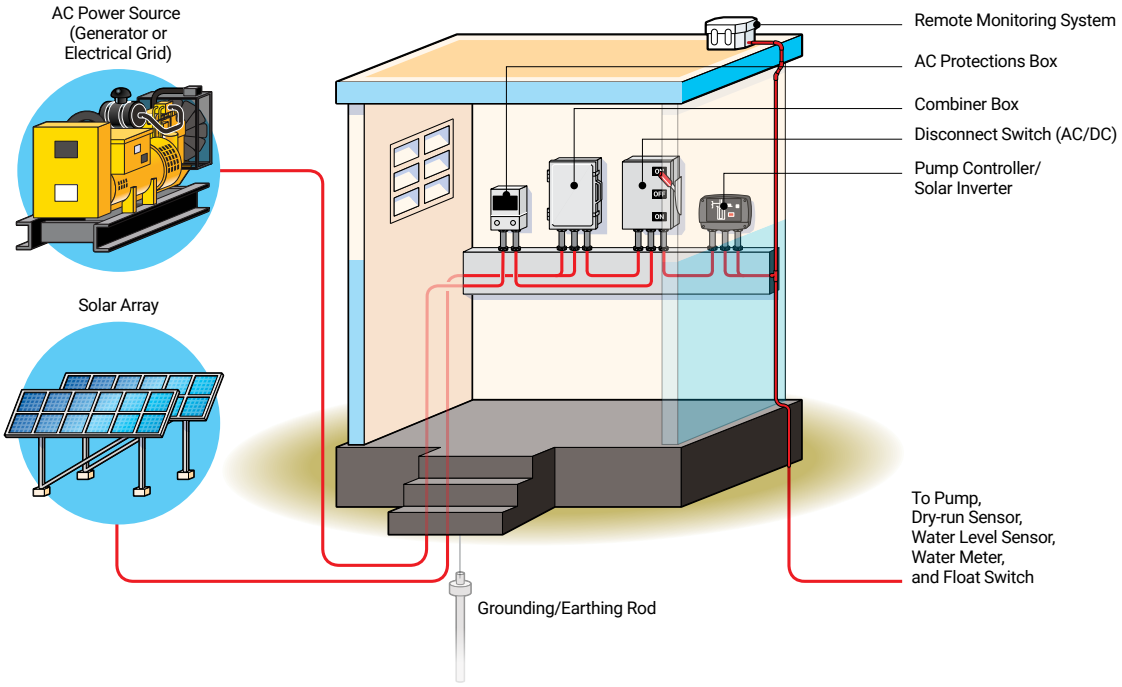
MC-4 Connectors
SOURCE: RENOGY

Never break load or fault currents with the MC-4 connectors. MC-4 connectors are not designed to open when load is flowing through the connector.

It is essential to understand the grounding applied to the solar panels to safely operate the system. Panel frames that are connected mechanically to metal roofs are always connected to the grounding electrode using the required size of wire. In some systems, the negative wire to the panels is grounded at some point to the grounding electrode. The roof, panel frames, and negative wire will have the full string output voltage at any point between these conductive surfaces and the positive conductor of the solar panels, whether the breakers and/or safety switches are closed or not.

Solar panel frames and metal support mounts must be grounded for protection from lightning strikes. This may be done by creating direct contact between the metal frames and the concrete footings. More protection can be added by bonding the solar panel frames to a painted metal support mount and removing the paint at the bolted connections before assembling the structure. If the frames are galvanized metal, no additional bonding to the panels should be needed.

D HAZARDS & SAFETY PRACTICES: ELECTRICAL WIRING



The wires from the solar panels to the disconnect switches/combiner box are continuously energized.

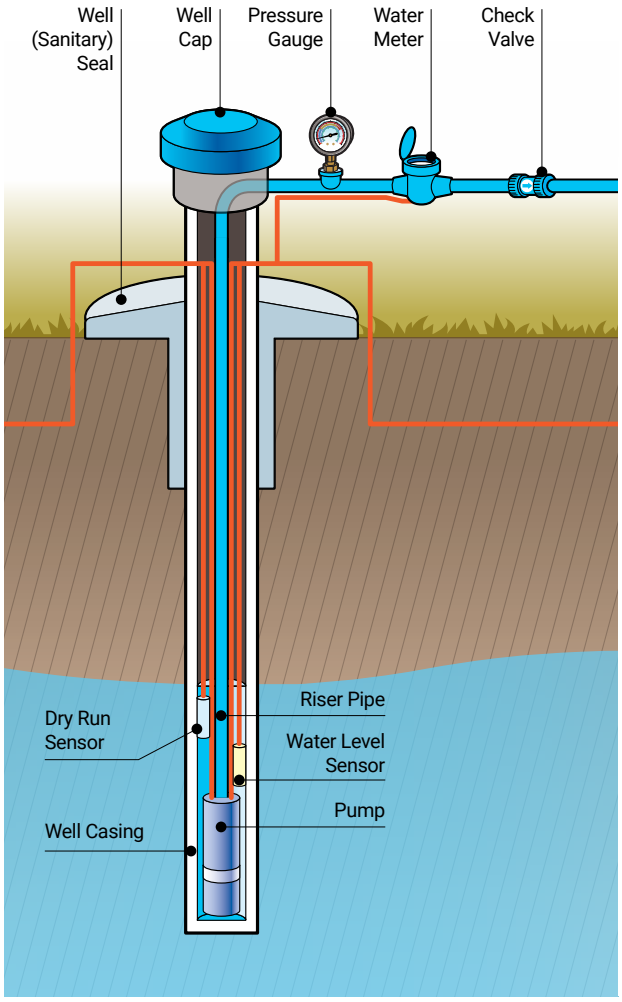
Damage to these wires and their insulation in this area can lead to harmful fault currents or electric shock hazards for people who come into contact with them.

Damage may be caused by unprotected conductor movement due to wind and thermal cycling, as well as contact during panel cleaning and roof repair. Wiring from the solar panels to the disconnect switch/combiner box must be enclosed in conduit to prevent insulation wear in areas exposed to wind, thermal cycling, or damage from animals/rodents.

The wiring must be regularly inspected for potential failure points.

This is particularly crucial for roof-mounted solar arrays, where wires exit near sharp metal roofing edges, penetrate through metal roofing, or are exposed to areas prone to animal or rodent access.

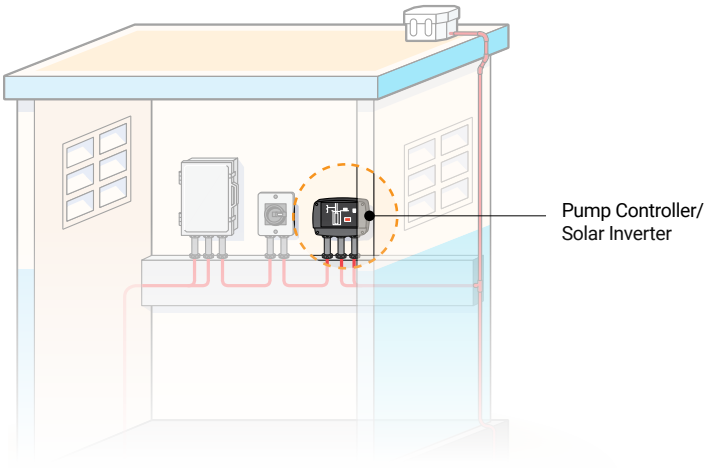
E HAZARDS & SAFETY PRACTICES: PUMP AND WELL CASING



Most SPWS will have a submersible pump located within the well. If the well casing or riser pipe is metal, it is very important to correctly connect the pump wiring to the ground in the well casing.

This system should be tested and remain in place for the life of the well pumping system. If the electrical insulation of the motor breaks down without a grounded system, it can result in lethal voltages near water, causing a hazardous condition for personnel and users of the solar pumping system.

F HAZARDS & SAFETY PRACTICES: PUMP CONTROLLER OR SOLAR INVERTER



The pump controller should only be opened by the System Technician .

SOURCE: GRUNDFOS

The pump controller ensures both protection and control requirements for the pump and is housed inside the electrical house to safeguard it from outdoor elements.

Depending on the pump type, a solar inverter may be used to convert the electricity from the solar panels to power and operate the pump. Other pumps do not need the power converted and therefore just require a pump controller to operate the pump.

It is essential that grounding and surge protection be applied to the direct current from the solar panels and any alternate electrical sources to prevent damage to the pump controller.

Wiring from Pump Controller to Sensors

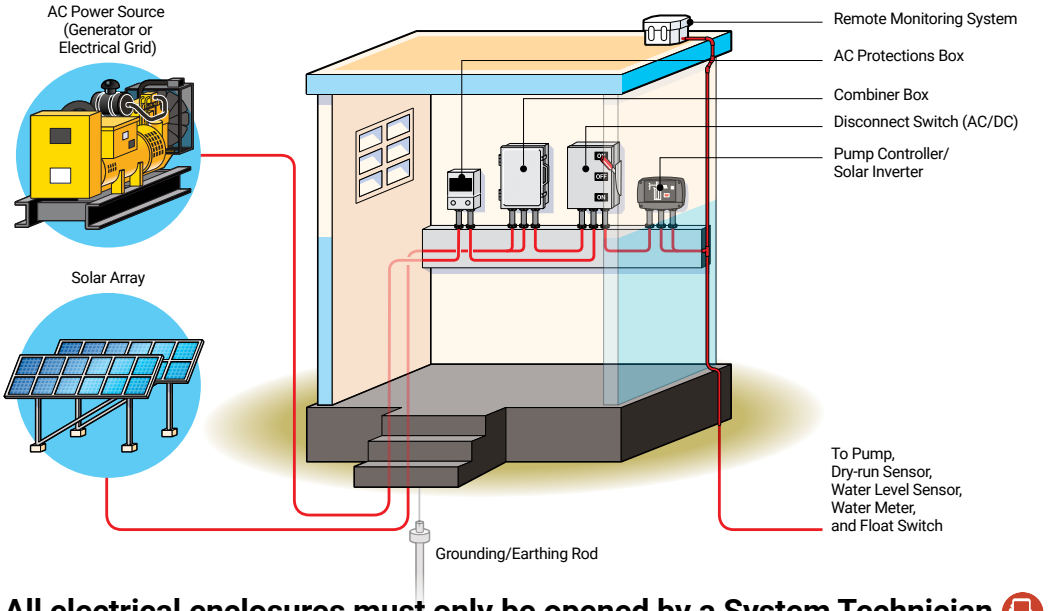
A. The pump controller may have sensor wires running from it to the dry-run sensor. This turns the pump off if the water level in the well decreases too much.

B. The pump controller may have wires running from it to the storage tank for the float switch or pressure switch. This senses the water level inside the tank and can turn the pump off when the tank reaches full capacity.

*Normally, to maintain safety, the voltages on the sensing cables to these switches are lower than the voltages that can cause currents of 1 milliampere (mA).

G HAZARDS & SAFETY PRACTICES: ELECTRICAL HOUSE

The electrical house provides protection for electrical controls and equipment.



All electrical enclosures must only be opened by a System Technician including:

1. Pump controller
2. Combiner box
3. Transfer switch
4. Any other electrical controls or equipment that is enclosed in a protective box

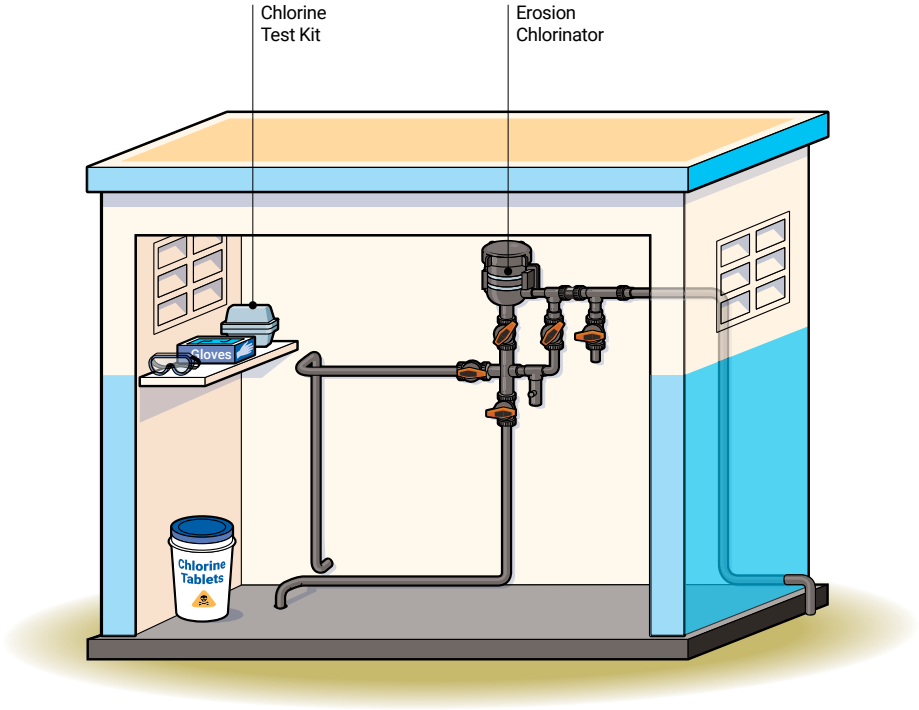
Do not allow water to pool on the floor of the pumphouse. Water is an electrical conductor. This can create a hazardous environment, particularly if damaged or bare wires are lying on the floor. **This hazard and should be reported immediately to a System Technician.**

The electrical house should remain free of clutter, waste, food, and other potential contaminants to prevent pests from nesting inside, which could risk damaging the electrical equipment.

Chemicals should not be stored in the Electrical House.

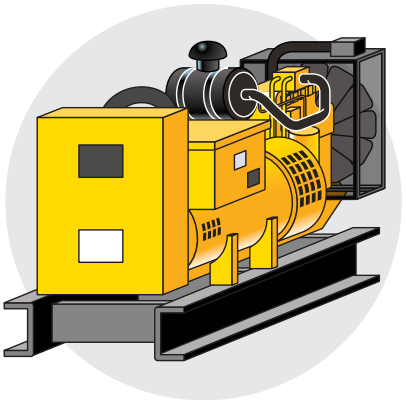
All chemicals must be stored appropriately, away from the well and system equipment.

4.5 Chemical Hazards and Safety Practices



Chemical Hazards:

1. Combining two chlorine products could result in a dangerous chemical explosion.
2. Direct contact with chlorine can be harmful and should be avoided.
3. Chlorine fumes can accumulate in the chlorinator and may be released when draining the chlorinator, removing the cover, or opening the chlorine tablet bucket.
4. Fuel needed for a generator in a hybrid system releases toxic fumes and is highly flammable.



Safety Practices:

A. Never use different chlorine varieties simultaneously.

B. If it is necessary to switch to a new type of chlorine tablet, the chlorinator should also be replaced.

C. Always wear protective gloves, protective eyewear, and a respiratory mask when working with chlorine or fuel.

D. Always perform these actions in well-ventilated areas and avoid inhalation of chlorine or fuel fumes.

E. Chemicals and fuel should never be stored near wells or near electrical equipment because it can cause corrosion or contamination of the water supply.

4.6 Fire Hazards and Safety Practices

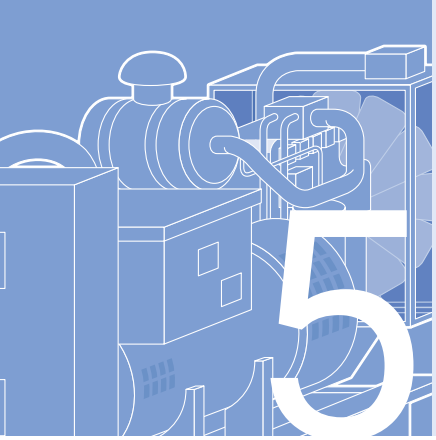
Fire Hazards:

1. Fire is a hazard, particularly when the system has a fuel-based generator as an alternate power source.
2. Due to the electrical wiring of the system, fire is always a risk if the wires are exposed or damaged.

Safety Practices:

A. Never try to put out a fuel fire with water! A bucket with sand should be kept in the pumphouse to soak up fuel spills and to extinguish small fuel fires.

B. Turn off the system and immediately contact a System Technician if any wires are damaged or exposed.



Section 5

Quarterly and Annual Maintenance Tasks

Arc Flash: Arc flash is a flashover of electric current. Light and electricity are released into the air after an arc fault and when it reaches another conductor, or the ground, an explosion occurs creating a wave of heat that can melt and burn anything nearby, including people.

Fault Current: The fault current is the electrical current which flows through a circuit during an electrical fault condition. A fault condition occurs when one or more electrical conductors short to each other or to the ground.

Breaking Load: When the electrical lines are powered they have a load passing through. Opening connections along the path would break this load. MC-4 connectors are not built to handle the impacts caused by breaking load. Use the disconnect switch to break the load.

Electrical Grounding: The process of directing excess electricity to the ground via a wire. Known as a grounding wire, it's an essential safety component in most electrical systems. The grounding wire will discharge excess electricity safely to the ground through a buried rod so that it doesn't cause injuries or fires.

Electrical Bonding: The practice of intentionally electrically connecting all exposed metal items not designed to carry electricity in a room or building as protection from electric shock. Bonding is also used to minimize electrical arcing between metal surfaces with electrical potential differences.

Electrical Conductor: A substance or material that allows electricity to flow through it. In a conductor, electrical charge carriers, usually electrons or ions, move easily from atom to atom when voltage is applied.

Introduction

One of the main causes of failure for water systems is broken system components that go unrepaired or are not replaced. To prevent this from being the cause of failure, the system owner should proactively prepare to repair or replace major components in a timely manner.

Knowing the approximate life and replacement cost of system components can help with preventative maintenance. Planning for the end of the life cycle of specific parts, and replacing them before they break, avoids downtime and costly emergency repair. This is why annual maintenance and monitoring activities are as important as the more regular ongoing maintenance activities.

These major maintenance activities should be performed by a certified System Technician – not the Operator. Although it may not be standard practice, hiring a System Technician to do an in-depth electrical inspection on a quarterly and yearly basis is best practice. The System Technician should notify the System Operator of the site visit with as much advance notice as possible.

It is recommended that the System Operator accompany the System Technician during all maintenance activities to assist, answer questions, and gain a deeper understanding of the system's optimal operation and maintenance.

Note: This section is specific to planned maintenance tasks. If the System Operator detects an issue at any time and contacts the System Technician, then a troubleshooting process should be carried out to determine the issue and how to fix it.

5.1 System Technician Role and Responsibilities

As the System Technician, you are responsible for assessing the overall performance of the solar pumping system, its components, and for verifying the system functionality and conformity to performance expectations.

To fulfill this responsibility, some general tasks include:

- Checking that all job site safety protocols are being followed.
- Checking in on the electrical, environmental, and safety hazard prevention protocols, practices and signage.
- Performing routine system maintenance on the solar array, power conditioning equipment (inverters, generator), system protection mechanisms, and structural systems.
- Checking that the electrical system is still properly wired, the grounding system is working, and the integrity of terminations is intact.
- Measuring and analyzing system performance and operating parameters to assess the equipment's operating condition.
- Reprogramming, adjusting, or configuring inverters and controls for desired set points and operating modes.
- Testing operating voltages to ensure operation is within acceptable limits for power conditioning equipment, such as inverters and controllers.
- Analyzing the chlorine and turbidity testing results carried out by the Operator.
- Identifying and resolving any deficiencies in the storage and distribution system.
- Performing any necessary technical repairs that are beyond the Operator's capacity.
- Supporting Operators to build their knowledge, capacity, and confidence in their job.

5.2 Preparing for a Site Visit

Before conducting the quarterly or annual site visit, several preparations must be made in advance:

Step 1: Call the System Operator

A. Inform them of the date of the visit.

B. Ask if there are any current concerns they have that need to be addressed.

C. Ask if there are any supplies that need to be restocked.

Step 2: Review the design specifications to remind yourself of the system components (ex. Pump type/size, chlorination system etc.) and point in the life cycle of the parts.

Step 3: Review the reporting forms collected throughout the year by the Operator and analyze to determine if there are any issues impacting expected system performance.

A. If the data **indicates a decline** or malfunction in water supply or quality, be ready to perform all necessary maintenance activities to complete the annual maintenance and to identify the cause of the decline.

B. If the data shows that the water supply and quality is **trending as expected**, do each of these maintenance activities to properly maintain the system so that it will continue to supply water consistently.

Step 4: Prepare all tools, materials and consumables required for any maintenance tasks, water quality testing, and restocking the inventory as needed.

5.3 Quarterly Maintenance Tasks

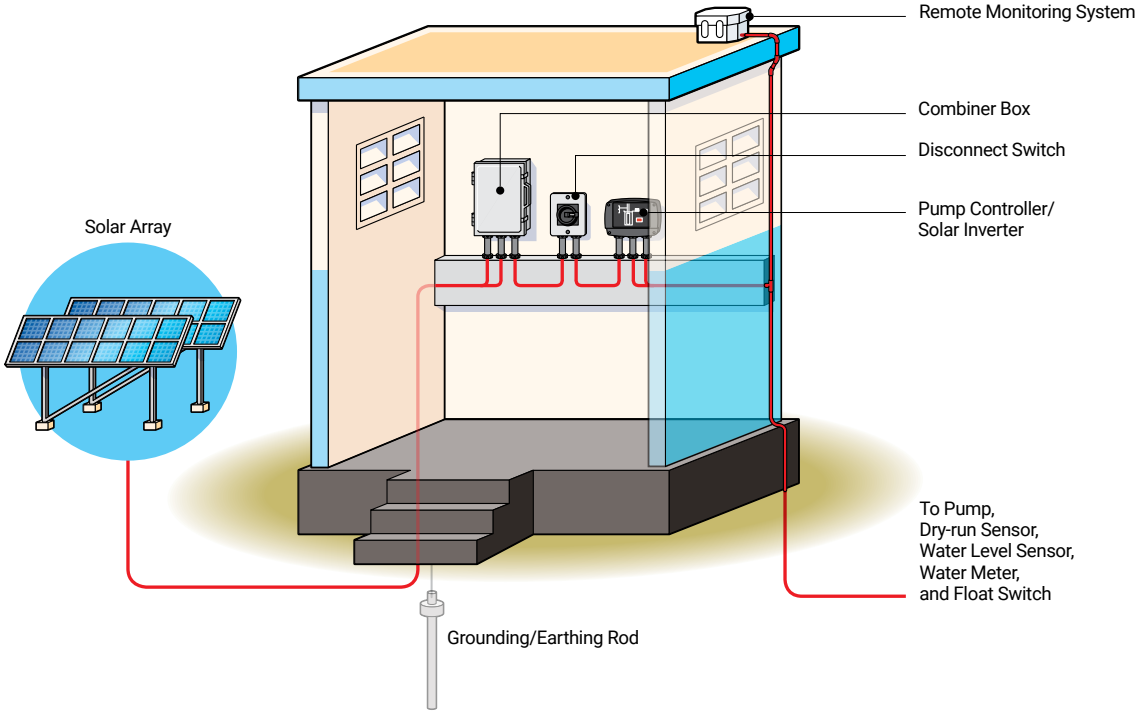
Quarterly inspections are conducted in addition to the daily and weekly inspections performed by the System Operator. These quarterly tasks provide more detailed assessments of electrical connections and enclosures than the daily and weekly inspections.

A. ELECTRICAL HOUSE

Working at heights is a significant risk. Ensure you have a ladder that is in good working order and always have another person with you to hold the ladder.

Water leakage or spills can come into contact with electrical components, posing a risk of shock or short circuits. Do not allow water to pool on the floor. Water is an electrical conductor (electrical energy can travel through it) and this is hazardous, particularly if there are any exposed or even slightly damaged wires.

PPE



Maintenance Tasks:

- Inspect the equipment house for cracks and damage in the roof, walls, foundation, and entryways.
- Look for damaged pipes entering or exiting the equipment house.
- Check for structural damage, such as gapping, and cracks to the foundation, beams, or columns.
- Look for erosion around the foundation.
- Check for leaks in the roof or walls.
- Check for any rotting wood.
- Pick up and dispose of any trash or debris surrounding the equipment house.
- Remove any cobwebs or insect nests found inside or on the outside of the equipment house's structure.
- Check the enclosure lock and replace it if it is broken or missing.

If repairs are needed, either do the repairs with the Operator immediately or communicate with the Operator what needs to be done and when.

If any issues are identified and cannot be resolved by the System Technician, have a qualified individual take corrective action following sound technical and safety procedures.

Reporting

- Record any activities completed and observations that may require attention at a later date, such as potential security concerns or animal activity.
- Record any damage noted, like cracks or rusting.
- Record any repairs that have been made.
- Record any follow up that is required by the Operator.

B. ELECTRICAL EQUIPMENT

Energized systems can be lethal when handled in the wrong way, even if they appear to be unpowered. Always take extreme caution to avoid electric shock hazards.

Solar panels are energized whenever the sun is up – whether the pumping system is on or not – and doing maintenance at night is not safe or practical. Always take extreme care when working around the solar panels.

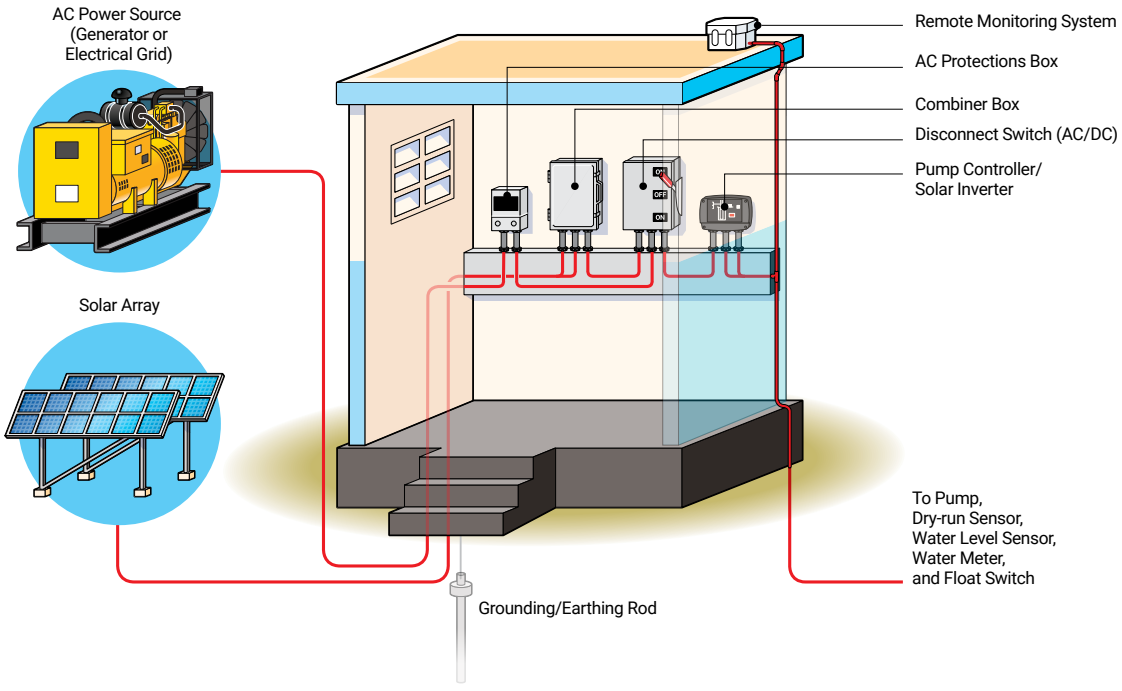
The System Technician will perform inspections of all electrical equipment. The System Operator should accompany the Technician during these tests to assist and gain a better understanding of the Technician's tasks and the system itself.

Working at heights is a significant risk. Ensure you have a ladder that is in good working order and always have another person with you to hold the ladder.

Never do any maintenance on a SPWS during a lightning storm.

Electrical equipment could be comprised of a combination of several components including a pump controller, auxiliary power supply box, combiner box, etc.

PPE



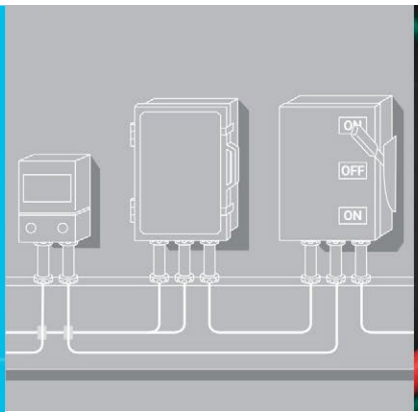
Maintenance Tasks:

- Open the electrical boxes and inspect for signs of:
  a. Corrosion
  b. Insects or dust
  c. Smoke/burns
  d. Presence of water
- After isolating each electrical box from all power sources, check that all wires are firmly secured by gently pulling on each wire.
- If any enclosures have vents or screens, clean the screens so that air flows freely.
- Check equipment mountings on walls to ensure they are properly attached and not in danger of coming off their supports.
- Ensure display screens are clean, and equipment is free from dust and cobwebs.
- Look at connections and seals to ensure they are tight and free from damage.
- Check that the float switch can move freely and function correctly. (*If applicable, verify that the pressure switch properly actuates).
- Inspect any protective equipment, such as dry run sensors, as needed.
- Check the remote monitoring functionality.

Reporting

- Record any observations of disrepair, wear, and any issues of concern.
- Record any repairs made.
- Record any follow up required by the Operator.

SOURCE: MYSENSORS



SOURCE: ANTONIO AVANTI ON PEXELS.COM

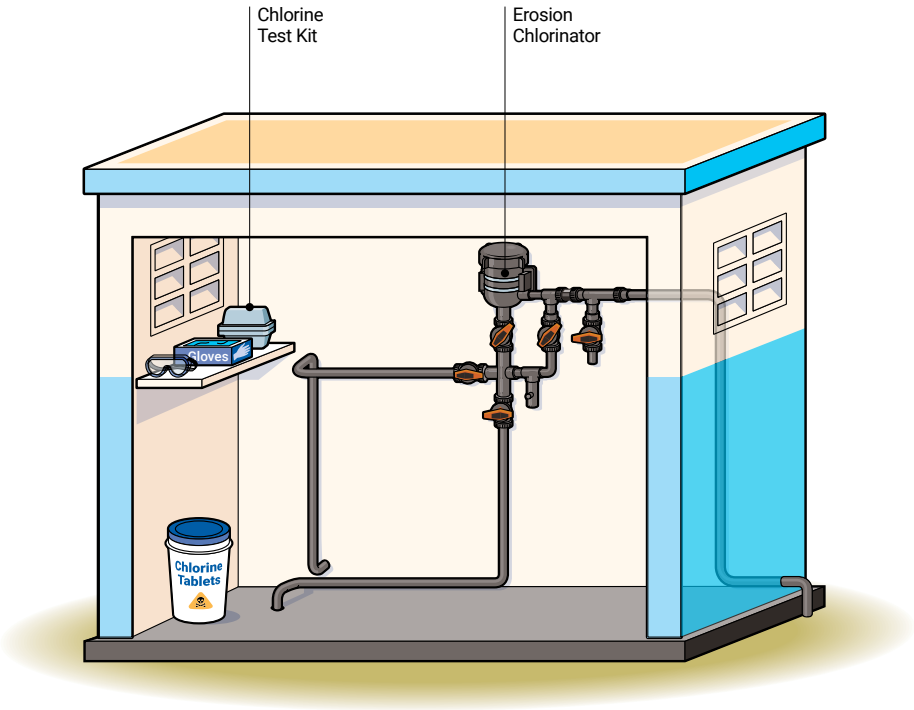
SOURCE: GRAINGER

C. WATER TREATMENT HOUSE

Always wear eye protection, respiratory protection, and gloves when working with chlorine. Direct contact with chlorine or chlorine fumes can be harmful and should be avoided. Chlorine fumes can accumulate in the treatment equipment and may be released when draining the chlorinator, removing the cover, or opening the chlorine tablet bucket.

The combination of chlorine products could result in a dangerous chemical explosion. Always make sure to consistently use the correct chlorine product.

PPE



Maintenance Tasks:

- Check that chlorine is stored safely.
- Check that the test kit is in good working order.
- Observe the Operator performing the tests to check their methods and to cross check the results.

Tests

- E. coli (fecal coliform bacteria)
- Total coliform
- Free chlorine
- Turbidity

Reporting

- Record test results.
- Record any signs of disrepair or wear that may need attention in the future.
- Record any repairs that have been made.
- Record any follow up that is required by the Operator.

Hach Chlorine Color Wheel test: Check the free and total chlorine and observe the System Operator performing the tests.

SOURCE: WATER MISSION

5.4 Annual Maintenance Tasks

A. STRUCTURAL INSPECTIONS

The System Operator should conduct regular inspections of the structures throughout the year. The System Technician should perform the same visual and hands-on inspections from a fresh perspective.

Working at heights is an extreme risk. Ensure you have a ladder that is in good working order and always have another person with you to hold the ladder.

Maintenance Tasks

- Check the condition of fences, gates, and locks for security and address any issues if security is found to be compromised.
- Check the electrical house walls, floor, and roofing for cracks, damage, rust, animal nests, and overall cleanliness.
- Check the area around the wellhead.
- Check that the water treatment chemicals are properly stored.
- Check the condition of the lights and electrical sockets.
- Ensure cleanliness in all areas is sufficient.
- Check the condition of the storage tank and structure.
- Check the taps.
- Make any structural repairs that are required.

Reporting

- Record any signs of disrepair or wear that may need attention in the future.
- Record any repairs that have been made.
- Record any follow up that is required by the Operator.

Water treatment house: Visually inspect all enclosures for damage, cleanliness, and proper storage of any chemicals.

SOURCE: KOGI CHEGE (FROM A WATER MISSION PROJECT)

B. SOLAR PANELS AND STRUCTURE

Although most solar panels are designed to last a long time, they may need to be replaced before reaching the end of their expected lifespan.

Solar panels are energized whenever the sun is up – whether the pumping system is on or not – and doing maintenance at night is not safe or practical. Always take extreme care when working around the solar panels.

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. Serious injuries and death can be caused by electrical hazards such as arc flash, shocks, burns, falls, and fires.

Never do any maintenance on a SPWS during a lightning storm.

Working at heights is an extreme risk. Ensure you have a ladder that is in good working order and always have another person with you to hold the ladder.

PPE

Solar array for the Newa Community Project (Kenya).
SOURCE: WATER MISSION

Maintenance Tasks

- Check cleanliness of the panels.
- Check the clamps or bolts that connect the panels to the structure.
- Check for cracks and rust.
- Tighten bolts at all connection points.
- Check that all the wiring connections are secure.
  **Never break load or fault currents with the MC-4 connectors. MC-4 connectors are not designed to open when the load is flowing through the connector.*
- Make repairs as needed.

Tests

- Check the electrical measurements of the panels to determine if replacement is necessary.
- Conduct an operational test and calibrate the irradiation sensor as needed.

Reporting

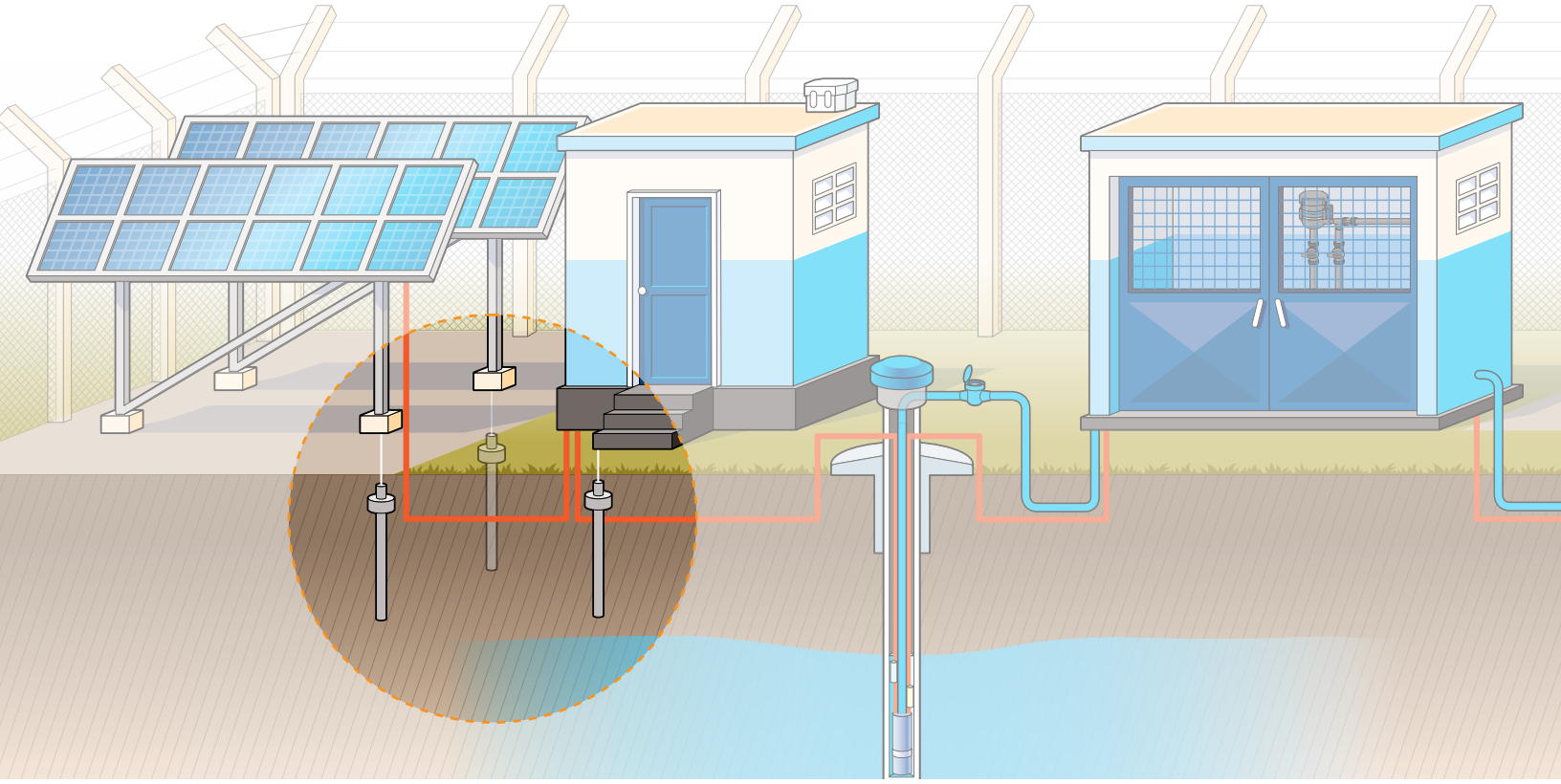
- Record test results.
- Record if cleaning has not been completed and discuss this with the Operator.
- Record any signs of disrepair or wear that may need attention in the future.
- Record if any loose parts were detected and review with the Operator to ensure they complete the checks weekly.
- Record if follow up is needed, by whom, and by when.

C. GROUNDING AND BONDING

The System Operator is expected to conduct inspections throughout the year; however, it is beneficial to have a System Technician's fresh perspective for the visual and hands-on inspections.

Grounding and electrical bonding protect against electric shock resulting from a conductor coming into contact with exposed metal. Grounding is crucial for the safety of the people working around the system.

PPE



Maintenance Tasks

- Check for signs of corrosion, damage, or loose connections in grounding wires, electrodes, and bonds.
- Check that all grounding connections are tight and secure.
- Clean up the earth chamber from any debris and dust.

Tests

To be done at least every 3-5 years, or as recommended by the manufacturer or local regulations.

- Continuity test: Ensure that all parts of the grounding system are electrically continuous.
- Ground resistance test: Measure the resistance to ground. Typically, a value of 5 ohms or less is desired, but local codes may specify different limits.

Reporting

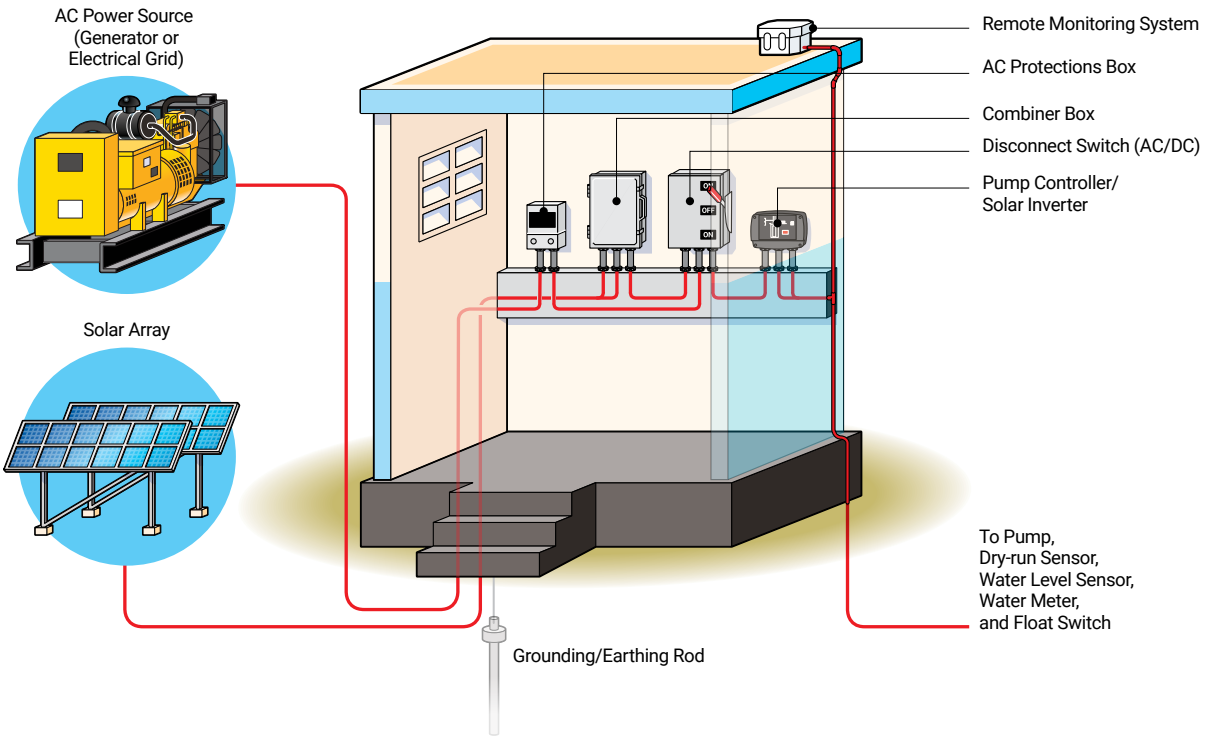
- Record test results.
- Record repairs that have been completed.
- Record any follow up that is required by the Operator.

D. ELECTRICAL BOARDS, SWITCHES, CABLES, CONTROL BOX/INVERTER

All electrical equipment is potentially hazardous and should be treated with EXTREME CAUTION even when power appears to be OFF.

Electric shocks can be lethal. Always take extreme care when working around the solar panels and any electrical equipment and wiring. Disconnect power before opening electrical equipment doors.

PPE



For the electrical boards, switches, cables, and control box or inverter, carry out the following tasks and consult the equipment specifications for any manufacturer-recommended checks.

Maintenance Tasks

- Check cleanliness.
- Check for proper seals around doors and conduit.
- Check that covers are properly closed and sealed.
- Check labelling and identification.
- Tighten cables and connection points.
- Document the inspection results.

Tests

- Check the condition of electrical boards, switches, cables, control box/inverter to ensure they are operational.
- Check electrical protections (fuses and surge) with visual and functional tests.
- Complete a measurement inspection to measure the magnitude of the electric current including current, voltage, resistance, and power. Compare the results with the expected outputs.
- Complete a thermography inspection to identify temperature changes in operations, heat flows through equipment, and temperature comparisons for various components and areas.
- Observe the Operator performing the shutdown, start up and change over procedures to ensure these are being done correctly.

Reporting

- Record test results.
- Record any signs of disrepair, wear that may necessitate future repairs, or any other issues of concern.
- Record any repairs that have been completed.
- Record any follow up that is required by the Operator.

Electrical House for Newa Community Project (Kenya)

SOURCE: WATER MISSION

E. GENERATOR (IF APPLICABLE)

The System Operator is expected to conduct inspections throughout the year; however, it is beneficial to have a System Technician's fresh perspective for the visual and hands-on inspections.

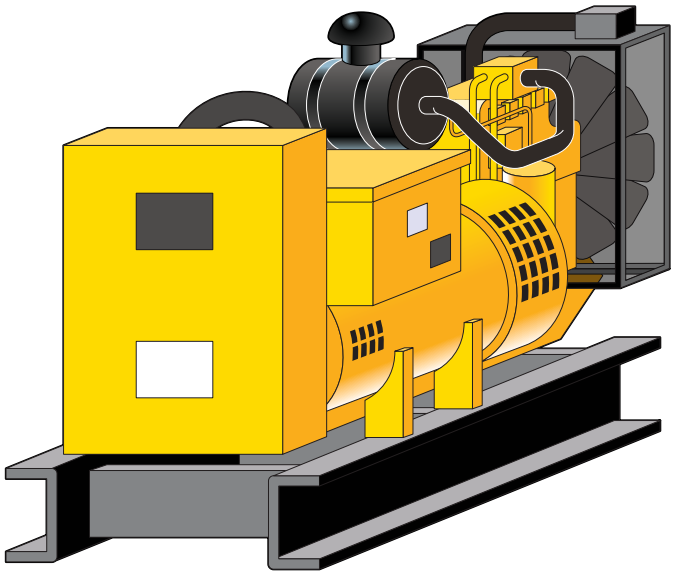
Fire is a hazard, particularly when the system has a fuel-based generator as an alternate power source.

Due to the electrical wiring of the system, fire is always a risk if the wires are exposed or damaged.

PPE

Maintenance Tasks

- Look for any signs of damage or blockages in the exhaust system.
- Ensure all electrical connections are secure and free of corrosion.
- Change engine oil and filter, as needed.
- Change fuel filter, as needed.
- Inspect and replace coolant, as needed - check for any leaks.
- Inspect and replace air filters, as needed.
- Check the radiator for blockages or dirt and clean, as needed.



Tests

- Conduct a load test to ensure the generator is operating properly.
- Ensure all safety features and alarms are functioning properly.
- If applicable, check the condition of the battery/ batteries and clean the terminals, as needed.

Reporting

- Record any signs of disrepair, wear that may necessitate future repairs, or any other issues of concern.
- Record any repairs that have been completed.
- Record any follow up that is required by the Operator.

F. REMOTE MONITORING

Maintenance Tasks

- Review the data logs from the remote monitoring system and/or Operator logs for any potential issues with the sensors.

Tests

- If the data indicates a potential issue with a sensor, test the sensor to confirm functionality.

Reporting

- Record test results.
- Record any signs of disrepair, wear that may necessitate future repairs, or any other issues of concern.
- Record any sensor issues that have been identified and/or solved.
- Record any follow up that is required by the Operator.

Remote Monitoring System for Newa Community Project (Kenya)

SOURCE: WATER MISSION

G. WELLHEAD, BOREHOLE AND YIELD TEST

Any foreign material entering the well can pose serious health risks to users, potentially leading to illness or even death, and can cause significant damage to the equipment.

Maintenance Tasks

- Check the water table levels.
- Examine the borehole casing for signs of corrosion, damage, or leakage.
- Ensure that the borehole structure is stable and that there are no concerns about possible collapse.
- Examine the wellhead components, including the seal and discharge pipes, for any damage or leaks.
- Check that the area is clear of any debris around the well head and ensure that the area is secure and well-maintained.

Tests

- Perform a yield test to check the flow rate and overall performance of the borehole.
- Compare the test results with the original specifications to ensure that it is operating efficiently.

Reporting

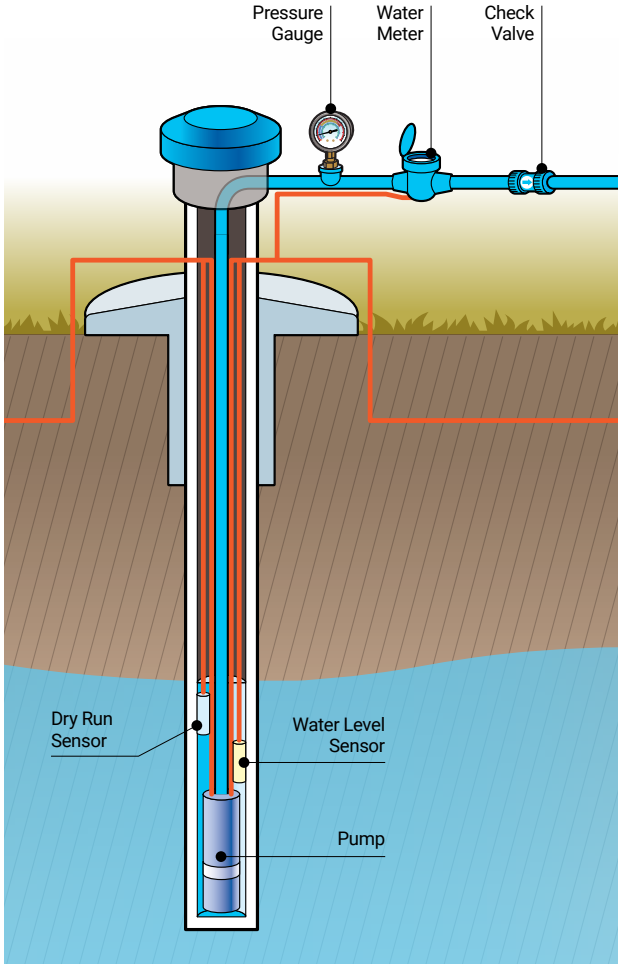
- Record test results.
- Record any signs of disrepair, wear that may necessitate future repairs, or any other issues of concern.
- Record any repairs that have been completed.
- Record any follow up that is required by the Operator.

Wellhead with borehole cover at Newa Community Project (Kenya). Inside is the well with submersible pump, accessories, and piping.

SOURCE: WATER MISSION

H. PUMP MAINTENANCE

Most problems that occur with submersible pumps are electrical and can be fixed without having to pull the pump from the well.



Grundfos submersible pumps. Always follow manufacturer recommendations for maintenance and troubleshooting.

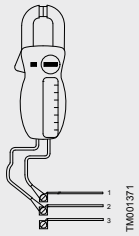
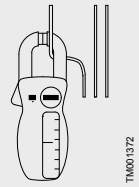
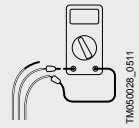
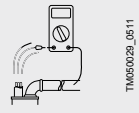
SOURCE: GRUNDFOS

Maintenance Tasks

- Review the pump test data and Operator logs for any potential performance issues of the pump.
- If there are indications of pump decline, always make the above ground checks first before pulling the pump from the well.

  **See Figure 5.1 below for what ground checks to conduct. The way in which to do these checks are dependent on the pump, so check the pump specifications.*

9.2 Preliminary tests

Test	How to measure	What it means
Supply voltage 	With a voltmeter set to the proper scale, measure the voltage at the control box or starter. On single-phase units, measure between line and neutral. On three-phase units, measure between the legs (phases).	When the motor is under load, the voltage must be within ± 10 % of the value stated on the nameplate. Larger voltage variation may cause winding damage. Large variations in the voltage indicate a poor power supply and the pump must not be operated until these variations are corrected. If the voltage constantly remains high or low, the motor must be changed to the correct supply voltage.
Current 	With an ampmeter set to the proper scale, measure the current on each power lead at the control box or starter. See section for motor amp draw information. Current must be measured when the pump is operating at a constant outlet pressure with the motor fully loaded.	If the amp draw exceeds the listed service factor amps (SFA), or if the current imbalance is greater than 5 % between each leg on three-phase units, check the following: • Burnt contacts on motor-protective circuit breaker. • Loose terminals in starter or control box or possible cable defect. Check winding and insulation resistances. • Supply voltage too high or low. • Motor windings are shortened. • Pump is damaged, causing a motor overload.
Winding resistance 	Turn off power and disconnect the submersible drop cable leads in the control box or starter. With an ohmmeter, set the scale selectors to Rx1 for values under 10 ohms and Rx10 for values over 10 ohms. Zero-adjust the ohmmeter and measure the resistance between leads. Record the values. Motor resistance values can be found in section Insulation resistance and ohm value chart. Cable resistance values are in section Insulation resistance and ohm value chart.	If all the ohm values are normal, and the cable colors correct, the windings are not damaged. If the ohm value is less than normal, the motors may be shorted. If the ohm value is greater than normal, there is a poor cable connection or joint. The windings or cable may also be open. If some of the ohm values are greater than normal and some less, the submersible drop cable leads are mixed. To verify lead colors, see resistance values in section Insulation resistance and ohm value chart.
Insulation resistance 	Turn off power and disconnect the submersible drop cable leads in the control box or starter. With an ohmmeter or megohmmeter, set the scale selector to Rx 100K and zero adjust the meter. Measure the resistance between the lead and ground (discharge pipe or well casing, if steel).	For ohm values, refer to section Insulation resistance and ohm value chart.. Motors of all hp, voltage, phase and cycle duties have the same value of insulation resistance.

- If the ground check results are showing that there are issues:

  a. Remove the pump for cleaning

  b. Inspect it for wear and tear

  c. Evaluate whether it needs to be replaced. If so, follow replacement procedures as per the manufacturer.

Tests

- Test for voltage, current, resistance and power.

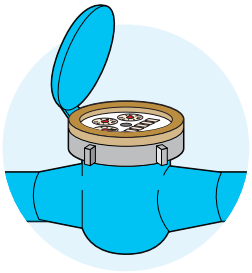
  **Two instruments are needed for these checks: a multimeter to test for voltage, current and resistance, and an ohmmeter for testing power.*

Reporting

- Record test results.
- Record any signs of disrepair, wear that may necessitate future repairs, or any other issues of concern.
- Record any repairs that have been completed.
- Record any follow up that is required by the Operator.

Figure 5.1: Troubleshooting steps for Grundfos 11-SQF-2 pump.

I. WATER METER



The main measuring instrument is the totalizing water meter that displays cumulative water volume.

PPE

Maintenance Tasks

- Check the cleanliness around the area.
- Check the connection points where the meter is installed.
- If the meter is not accurate, replace it.

Tests

- Record the water meter reading before and after pumping a specific volume of water.

  **Additional sensors, such as well-depth or water quality sensors, may be installed on a case-by-case basis. Maintenance and operation for these sensors will depend on the specific models installed and should follow the manufacturer's recommendations.*

Reporting

- Record test results.
- Record any signs of disrepair, wear that may necessitate future repairs, or any other issues of concern.
- Record any repairs that have been completed.
- Record any follow up that is required by the Operator.

Close up of water meter face: Test the meter to ensure it is accurate.

SOURCE: ASSUREDAUTOMATION.COM

Wellhead (inside borehole cover) with piping and safety rope for submersible pump, water meter, and accessories for water level sensor.

SOURCE: KOGI CHEGE (FROM A WATER MISSION PROJECT)

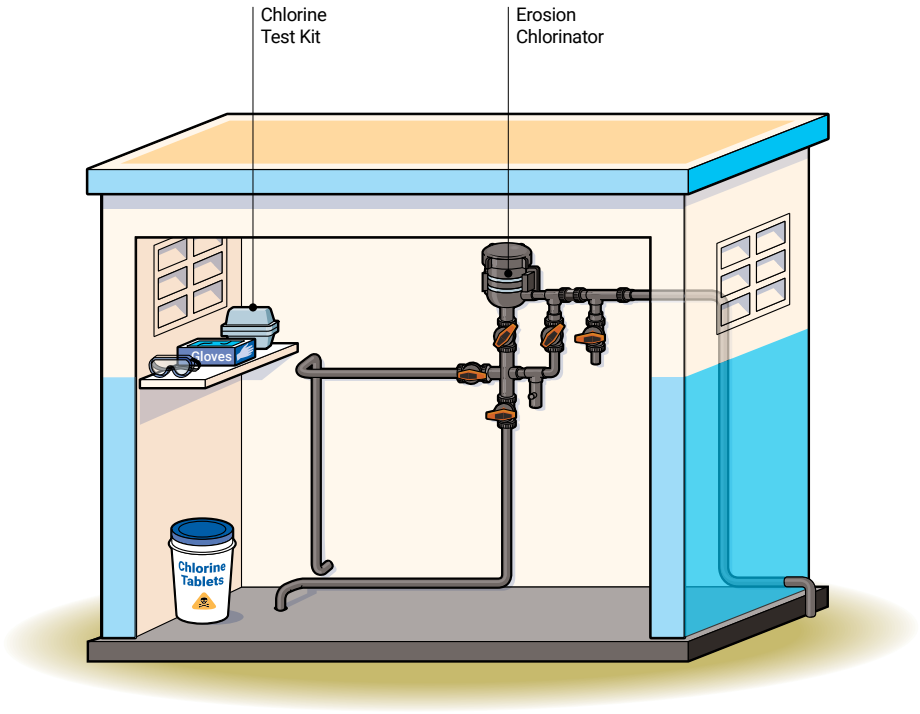
J. WATER TREATMENT HOUSE

The main measuring instrument is the totalizing water meter that displays cumulative water volume.

Chlorine must always be stored in the water treatment house. NEVER in the electrical house.

Always wear eye protection, respiratory protection, and gloves when working with chlorine. Direct contact with chlorine or chlorine fumes can be harmful and should be avoided. Chlorine fumes can accumulate in the treatment equipment and may be released when draining the chlorinator, removing the cover, or opening the chlorine tablet bucket.

PPE



Maintenance Tasks

- Check that all the chemicals are stored in the water treatment room and not anywhere near the electrical room.
- Check the valves of the treatment system

Ideally, a **System Technician** should visit the site **quarterly** and test water quality for turbidity, chlorine residual, E. coli, and conductivity at the point of leaving the treatment system as well as at the furthest collection point in the community.

The water quality testing requirements are much more comprehensive during the annual visit. The raw source water should be tested to determine if anything has changed across the year. The treated water should undergo testing for both standard and non-standard parameters. Each test should be done at the following water points:

1. The point of departure from the treatment system.
2. At the tap closest to the safe storage tank,
3. At the tap at the collection point furthest from the tank.

Tests

All the biological, chemical, and acceptability aspects or parameters should be tested according to the schedule on the following page:

Erosion Chlorinator and chlorine test kit at the Newa Community Project (Kenya)

SOURCE: WATER MISSION

Health Related Standards

Aspect/ Parameter to Test For	**WHO Standard**	**Daily/ Weekly** (Operator)	**Quarterly** (Technician)	**Annually** (Technician) *Raw Water and Treated Water
E. coli	0 CFU/100mL			*
Total Coliforms	0 CFU/100mL			*
Chlorine, Free	0.2mg/L to </ 0.5mg/L			*
Turbidity	</ 1.0 NTU			*
Copper	</ 2.0 mg/L			*
Nitrate	</ 10 mg/L			*
Nitrite	</ 1 mg/L			*
Fluoride	</ 1.5 mg/L			*
Arsenic	</ 0.01 mg/L			*

Acceptability Related Standards

Aspect/ Parameter to Test For	**WHO Standard**	**Daily/ Weekly**	**Quarterly**	**Annually** (Technician)
Chlorine, Total	</ 5 mg/L			
pH	6.5 - 8.5			*
Conductivity	</ 1,000 uS/cm			*
Alkalinity	80 -4 00 mg/L			*
Hardness	</ 250 mg/L			*
Iron	</ 0.3 mg/L			*
Manganese	</ 0.4 mg/L			*

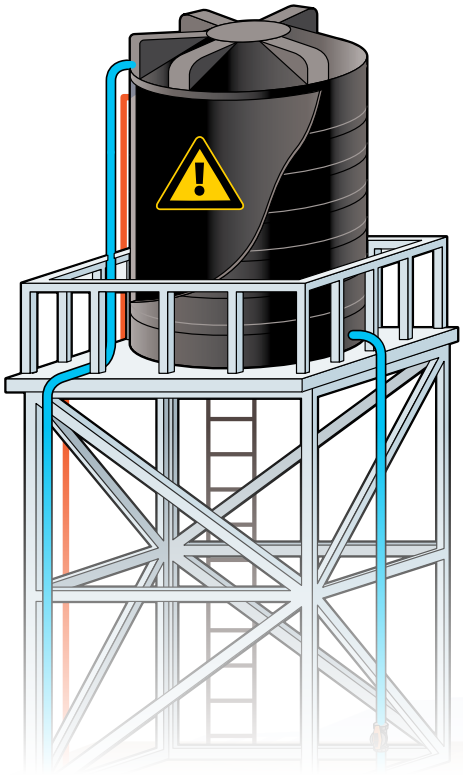
Note: The tables above outline the drinking water quality standards or limits set by the World Health Organization (WHO). These standards should be applied in the absence of country or national drinking water quality regulations. If national standards exist and are more stringent than those set by WHO, the national standards should take precedence.

Reporting

- Record test results
- Record any signs of disrepair, wear that may necessitate future repairs, or any other issues of concern.
- Record any repairs that have been completed.
- Record any follow up that is required by the Operator.

K. WATER STORAGE AND DISTRIBUTION

The inside of a storage tank is a confined space. Working in confined spaces presents unique safety risks due to limited access, poor ventilation, and potential exposure to hazardous materials. Follow safety practices.



Elevated water storage tank at the Newa Community Project (Kenya)

SOURCE: WATER MISSION

Maintenance Tasks

- Check the entire length of the pipe system for visible leaks, damage, or exposed pipes.
- Check with the Operator if any point of the pipe had to be reburied and, if so, ask to be shown the location(s) to check that it is buried correctly.
- Ensure that all connections and fittings are securely tightened.
- Check the storage tank for any signs of damage or contamination.
- Check the taps, particularly at the furthest from the storage tank.
- Repair any pipe, connections, or valves that are damaged or re-bury any exposed pipe sections.

Tests

- Verify that all valves are operating correctly.
- Check that the float switch is operating correctly.

Reporting

- Record test results
- Record any signs of disrepair, wear that may necessitate future repairs, or any other issues of concern.
- Record any repairs that have been completed.
- Record any follow up required by the Operator.

Community access point (tap stand) at the Newa Community Project (Kenya

SOURCE: WATER MISSION

5.5 Checklists and Reporting Forms

A. Technician Tools and Supplies Checklist

B. Quarterly Maintenance Checklist

C. Annual Maintenance Checklist

D. Operator Competency Assessment Form

Technician Tools & Supplies Checklist

System Name:	
Technician Name:	
Operator Name:	
Date:	

Item #	Quantity	Item	Purpose	✓
Quarterly Tasks				
1	1 pair	Foot protection (protective shoes)	Personal protective equipment	❑
2	1	Hard hat	Personal protective equipment	❑
3	1	Eye Protection	Personal protective equipment	❑
4	1	Respiratory protection	Personal protective equipment	❑
5	1 pair	Gloves	Personal protective equipment	❑
7	1	Writing utensil (pen/pencil)	Data recording	❑
8	1	*Quarterly Maintenance* Form	Data recording	❑
9	1	Toolbag	To hold all tools and supplies	❑
10	1	Ladder	Inspecting solar array and structures	❑
11	1 set	Adjustable wrenches	Tightening bolts, as needed	❑
12	1 set	Insulated screwdriver set	Opening electrical boxes, tighten wires	❑
13	1	Chlorine Test Kit with Reagents	Testing residual chlorine	❑
14	1	Turbidity Test Kit (if needed)	Testing turbidity	❑
15	1	Bacteria Test Kit (or sample bags)	Testing total and fecal coliforms	❑
Annual Tasks (the following are needed *in addition* to the above for annual mainenance tasks)				
16	1	*Annual Maintenance* Form	Data recording	❑
17	1	Multimeter **Voltage greater than system, 1000 V is best.*	Checking electrical measurements	❑
18	1	Irradiance meter, if applicable	Checking irradiation sensor	❑
19	1	Piezometer or water level sensor	Measuring water table	❑
20	1	Tape measure	Measuring water table or equipment	❑
21	1	Borehole camera **highly reccomended*	Inspecting borehole and casing	❑

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Quarterly Maintenance Checklist

System Name:	
Technician Name:	
Operator Name:	
Date:	

Prepare for the Site Visit	
1	Call the System Operator: a) Inform them of the date of the visit b) Ask if there are any current concerns that need to be addressed c) Ask if there are any supplies that need to be restocked
2	Review the design specifications to remind yourself of the system components (ex. Pump type/size, chlorination system etc.) and the current point in the life cycle of the parts.
3	Review the reporting forms collected throughout the year by the Operator and analyze to determine if there are any issues impacting expected system performance. a) If the data indicates a decline or malfunction in water supply or quality, be ready to perform all annual maintenance activities and to identify the cause of the decline. b) If the data shows that the water supply and quality is trending as expected, perform all annual maintenance activities so the system will continue to supply water consistently.
4	Prepare all tools, materials and consumables required for any maintenance tasks, water quality testing, and restocking the inventory as needed.

Maintenance Task		**✓**	**Notes**
A. Electrical House			
A1	Check for structural damage.	❑	
A2	Check for damaged pipes entering or exiting.	❑	
A3	Check for erosion around the foundation.	❑	
A4	Check for leaks in the roof and walls.	❑	
A5	Check for rotting wood.	❑	
A6	Check for and remove waste and debris.	❑	
A7	Check for and remove cobwebs or insect nests.	❑	
A8	Check the door lock. Replace if needed.	❑	

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

B. Electrical Equipment				
B1	Check inside all electrical boxes for corrosion, insects, dust, smoke/burns, or water intrusion.	❑		
B2	Check that all wires are firmly connected (isolate each electrical box first).	❑		
B3	Clean the vents and screens on all electrical boxes.	❑		
B4	Check that all electrical equipment is properly and securely mounted to the wall/supports.	❑		
B5	Check that display screens are clean and remove any dust or cobwebs.	❑		
B6	Check the seals around enclosure covers and wire entrances to ensure they are tight.	❑		
B7	Check that the float switch is functioning.	❑		
B8	Inspect protective equipment (e.g., dry run sensor), as needed.	❑		
B9	Check that the remote monitoring system is functioning.	❑		
C. Water Treatment House				
C1	Check that chlorine is stored safely.	❑		
C2	Check that water quality testing equipment is functioning.	❑		
C3	Observe the Operator performing water quality tests to confirm proper procedure.	❑		
C4	Test the residual chlorine at the closest and farthest community access point.	❑	Chlorine (ppm)	
C5	Test the turbidity at the closest and farthest community access point.	❑	Turbidity (NTU)	
C6	Test for bacteria (total and fecal coliforms) at the closest and farthest community access point (or collect samples to be sent to off-site water quality lab).	❑	Total Coliforms (CFU/100 mL) Fecal Coliforms (CFU/100 mL)	

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Additional Comments

Follow Up Items for Operator

x _____ _____
Technician Signature Date

x _____ _____
Operator Signature Date

SUBMIT TO SYSTEM MANAGEMENT

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Annual Maintenance Checklist

System Name:	
Technician Name:	
Operator Name:	
Date:	

Prepare for the Site Visit	
1	Call the System Operator: a) Inform them of the date of the visit b) Ask if there are any current concerns that need to be addressed c) Ask if there are any supplies that need to be restocked
2	Review the design specifications to remind yourself of the system components (ex. Pump type/size, chlorination system etc.) and point in the life cycle of the parts.
3	Review the reporting forms collected throughout the year by the Operator and analyze to determine if there are any issues impacting expected system performance. a) If the data indicates a decline or malfunction in water supply or quality, be ready to perform all annual maintenance activities and to identify the cause of the decline. b) If the data shows that the water supply and quality is trending as expected, perform all annual maintenance activities so the system will continue to supply water consistently.
4	Prepare all tools, materials and consumables required for any maintenance tasks, water quality testing, and restocking the inventory as needed.

Maintenance Task		**✓**	**Notes**
A. Structural Inspections			
A1	Check the condition of fences, gates, and locks for security.	❑	
A2	Check all walls, floors, and roofing for cracks, damage, rust, and animal activity/nests.	❑	
A3	Check the area around the wellhead for damages, leaks, and animal activity/nests.	❑	
A4	Check that water treatment chemicals are properly stored.	❑	
A5	Check the condition of all lights and electrical sockets.	❑	
A6	Check the condition of the water storage tank and structure.	❑	
A7	Check the taps at community access points.	❑	

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

A8	Check for and remove waste and debris.	❑	
B. Solar Array			
B1	Check the solar panels for dust or debris.	❑	
B2	Check all clamps and bolts to ensure the solar panels are securely mounted.	❑	
B3	Check the solar structure for cracks or rust.	❑	
B4	Check that all wiring connections are secure.	❑	
B5	Check the electrical measurements of the solar panels to ensure functionality.	❑	
B6	Check the functionality of the irradiation sensor, if applicable.	❑	
C. Grounding and Bonding			
C1	Check for corrosion, damage, or loose connections in grounding wires.	❑	
C2	Check that connections at the grounding rod(s) are tight and secure.	❑	
C3	Check for and remove debris and dust in the earthing chamber, if applicable.	❑	
C4	Perform a continuity test. **Every 3-5 years or as required by local regulations*	❑	
C5	Perform a ground resistance test. **Every 3-5 years or as required by local regulations*	❑	
D. Electrical Equipment			
D1	Check for dust or dirt on all electrical equipment.	❑	
D2	Check for proper seals around wire entrances and conduit.	❑	
D3	Check that all electrical covers properly close and seal.	❑	
D4	Check that all electrical equipment and wiring is properly labelled and identified.	❑	
D5	Tighten cables and wire connections.	❑	
D6	Check that all electrical equipment is functioning properly.	❑	
D7	Check that all electrical protections (fuses and surge) are functioning properly.	❑	

D8	Complete a measurement inspection (current, voltage, resistance, power).	❑	
D9	Complete a thermography inspection.	❑	
D10	Observe the Operator performing start up, shutdown, and change over procedures.	❑	
E. Generator (if applicable)			
E1	Check the exhaust system for damage or blockages.	❑	
E2	Check all electrical connections are secure and free of corrosion.	❑	
E3	Check engine oil and filter, as needed.	❑	
E4	Change fuel filter, as needed.	❑	
E5	Checks for leaks in the coolant system. Inspect and replace coolant, as needed.	❑	
E6	Inspect and replace air filters, as needed.	❑	
E7	Check the radiator for blockages or dirt. Clean as needed.	❑	
E8	Conduct a load test to ensure the generator is operating properly.	❑	
E9	Ensure all safety features and alarms are functioning properly.	❑	
E10	Check the condition of the battery and clean terminals, as needed.	❑	
F. Remote Monitoring			
F1	Review all data logs for potential issues with the remote monitoring system or sensors.	❑	
F2	Test the sensors to confirm functionality, as needed.	❑	
G. Well & Pump			
G1	Check the water table levels (static water level).	❑	
G2	Examine the borehole casing for corrosion, damages, or leaks.	❑	
G3	Ensure the borehole structure is stable without concern of collapse.	❑	
G4	Examine the wellhead for leaks or damage, including the well seal and discharge pipes.	❑	

G5	Check around the wellhead for waste or debris.	❑	
G6	Perform a yield test to check the flow rate and performance of the borehole.	❑	
G7	Compare the test results with the borehole's original yield test results.	❑	
H. Pump Maintenance			
H1	Review the yield test data and Operator logs for any potential performance issues.	❑	
H2	If there are indiciations of pump decline, test the voltage, current, resistance, and power.	❑	
H3	If the electrical tests indicate an issue, remove the pump for cleaning, inspect for damage, and evaluate if the pump needs to be replaced.	❑	
I. Water Meter			
I1	Check the piping connections around the water meter.	❑	
I2	Test the water meter to ensure it is reading accurately.	❑	
J. Water Treatment House			
J1	Check that all chemicals are properly stored in the water treatment house.	❑	
J2	Check the valves of the treatment system for damage, leaks, and functionality.	❑	
J3	Collect water samples to perform all biological, chemical, and physical water quality tests.	❑	
K. Water Storage and Distribution			
K1	Check the length of the pipe system for leaks, damage, or exposed pipes.	❑	
K2	Ask the Operator to show you any areas where the pipe has been reburied.	❑	
K3	Check that all pipe connections and fittings are securely tightened.	❑	
K4	Check that all valves are operating correctly.		
K5	Check the storage tank for signs of contamination.	❑	
K6	Check that the float switch is operating correctly.	❑	

Additional Comments

Follow Up Items for Operator

x _____ _____
Technician Signature Date

x _____ _____
Operator Signature Date

SUBMIT TO SYSTEM MANAGEMENT

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Operator Competency Assessment (System Operations)

System Name:
Technician Name:
Operator Name:
Date:

This question/answer checklist is to be used by the Technician to train and evaluate the Operator. While Operator training may cover even more topics, these are the key competencies that the Operator must be able to demonstrate to effectively start up, operate, and shut down the water system. The Operator should correctly answer and demonstrate these competencies.

* See Operator Competency Checklist (General) for all job competencies related to the Operator role.

#	Competency	Pass	Fail	N/A
1	What do you do before starting the solar-powered water system? *Answer: Make sure all valves are in the proper position (includes at the wellhead, pipeline, water treatment, and water storage tank).*	❑	❑	❑
2	How do you start the solar powered water system? *Answer: Turn the Disconnect Switch to "On/Solar/DC" and turn the pump on using the button on the pump controller. Never plug/unplug wires.*	❑	❑	❑
3	How do you shut the solar-powered water system down? *Answer: Turn off the pump using the button on the pump controller and turn the Disconnect Switch to "Off". Drain the chlorinator. Never plug/unplug wires.*	❑	❑	❑
4	How do you switch to generator (AC) power? *Answer: Turn the pump off using the button on the pump controller and turn the Disconnect Switch to "Off". Turn the generator on and wait two minutes. Turn the Disconnect Switch to "On/Generator/AC" and turn the pump on using the button on the pump controller.*	❑	❑	❑
5	How often should you check the solar panels for dust and dirt? *Answer: Every day.*	❑	❑	❑
6	How often should you wash the solar panels? *Answer: At least once per week, but as often as needed to keep them clear of dust and dirt.*	❑	❑	❑

D OPERATOR COMPETENCY ASSESSMENT FORM PAGE 2

7	Why is it important to keep the solar panels clean? *Answer: Dust and dirt on the solar panels will reduce the amount of power, which means less water will be produced. Even the smallest amount of dust (or shading from vegetation) can have a significant impact on water production.*	❑	❑	❑
8	How do you test the chlorine? *Answer: Use the Chlorine Test Kit (or chlorine test strips) to measure the residual chlorine.*	❑	❑	❑
9	What should the residual chlorine be coming out of the tap? *Answer: The residual chlorine should be 0.2-0.5 ppm at the community access points under normal conditions.*	❑	❑	❑
10	What should the residual chlorine be exiting the water treatment system? *Answer: The residual chlorine should be 0.5-0.8 ppm at the water treatment system under normal conditions. (If the water distribution network is large, it may need to be higher, such as 1.2-2.0 ppm).*	❑	❑	❑
11	What do you do if the water at the tap does not have least 0.2 ppm? *Answer: Adjust the amount of chlorine during water production.*	❑	❑	❑
12	How do you increase or decrease the chlorine level? *Answer: Turn the chlorine control valves on the chlorinator (clockwise to increase counter-clockwise to decrease).*	❑	❑	❑
13	Why is having the proper chlorine level important? *Answer: Low chlorine levels increase the risk of microbial contamination, making the water unsafe to drink. High chlorine levels cause a strong smell and taste. Significantly high levels of chlorine can be unsafe.*	❑	❑	❑
14	What should you do with the chlorinator every time you shut down the solar powered water system? *Answer: Drain the chlorinator.*	❑	❑	❑
15	Why is draining the chlorinator important? *Answer: Draining the chlorinator prevent over-chlorination and the build up of chlorine fumes inside the chlorinator.*	❑	❑	❑
16	How do you drain that chlorinator? *Answer: After the pump has been turned off and water has stopped flowing through the chlorinator, open the drain valve.*	❑	❑	❑
17	How do you complete the *Daily Water Production* form? *Answer: Record the water meter reading at the start and end of each pumping session, the residual chlorine at the closest and furthest community access point, and the total water produced (at the end of the day).*	❑	❑	❑

18	How do you take a water meter reading? *Answer: Read the dial on the face of the water meter. Record the number and the units.*	❑	❑	❑
19	How do you complete the Daily Maintenance form? *Answer: Record the weather conditions, pumping pressure, power, alarms (if present), and any key notes, observations, or activities performed.*	❑	❑	❑
20	How do you take a power reading? *Answer: The power is displayed digitally on the pump controller. Record the number and units.*	❑	❑	❑
21	How do you know if there are any alarms? *Answer: Alarms are displayed on the pump controller as red LED lights.*	❑	❑	❑
22	What are the most common pump alarms you might encounter? *Answer: The most common alarms are WELL DRY, TANK FULL, and FAULT.*	❑	❑	❑
23	What do you do if the water system stops working or there is a problem? *Answer: Shut down the system and contact the System Technician and System Management.*	❑	❑	❑

x _____ _____
Technician Signature Date

x _____ _____
Operator Signature Date

SUBMIT TO SYSTEM MANAGEMENT

Section 6

Daily & Weekly Operations & Maintenance Tasks

6.1 System Operator Role & Responsibilities

An Operator's job is to keep the clients, or users, satisfied with the water service by ensuring that:

- The water system is pumping enough water to meet the demand.
- The water is available when needed.
- The water is safe for human consumption
- The distribution system provides water to all collection points.
- Repairs are completed quickly so that downtime is short.
- Professionalism is practiced at all times.

Daily and weekly tasks are needed to meet these requirements. This section is dedicated to outlining what an Operator should be doing daily and weekly to meet their responsibilities.

6.2 Daily Tasks & Reporting

The Operator's main daily responsibility is to ensure that the water system provides safe water and functions properly. This includes conducting daily inspections, maintenance, and reporting to keep everything running smoothly and operating at maximum capacity.

Refer to the ***Daily O&M Checklist*** for more details.

One benefit of these daily checks is that they help the Operator become familiar with the system, making it easier to spot any issues quickly. If there is a problem, it is the Operator's responsibility to fix it or contact the System Technician right away to get the system up and running again as soon as possible.

Keep Thorough Records

Keeping thorough and accurate records is a fundamental part of operating the SPWS effectively. Water production records should include detailed information about the duration of pumping, volume of water pumped, and

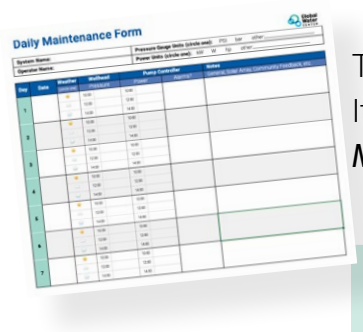
water quality. These records are important for monitoring the system's performance and identifying any potential issues before they become major problems.

Keeping detailed records helps to:

A. Ensure that the system is functioning optimally and provides a clear history of operations that can be referenced if any adjustments or repairs are needed.

B. Track trends and make informed decisions about scheduling and maintenance, enhancing the reliability and efficiency of the water system.

C. Support the smooth operation of the system and contributes to a more sustainable and resilient water supply for the community.



This section outlines the tasks to be completed in each area of the SPWS. It includes a list of items that should be reported, along with either the ***Daily Maintenance Tasks*** form or the ***Daily Water Production*** form.

If any issues require a System Technician, contact them immediately.

Energized systems can be lethal when handled in the wrong way, even if they appear to be unpowered. Always take extreme care and treat these systems with caution.

Never do any maintenance on a SPWS during a lightning storm.

A. OPERATION - SYSTEM STARTUP, SHUTDOWN, AND CHANGEOVER

Starting up and shutting down the pump and water treatment equipment is usually part of daily operations. Therefore, the System Operator must receive comprehensive training and supervised practice on these procedures. The electrical system should only be shut down by the Operator in an emergency. Any maintenance or repairs requiring a shutdown of the electrical or solar system should be performed by a qualified System Technician.

By carefully following startup/shutdown procedures and staying responsive to community feedback, System Operators play a key role in providing reliable access to safe drinking water for everyone. *Refer to Section 7 for step-by-step instructions.

Follow Proper Procedures

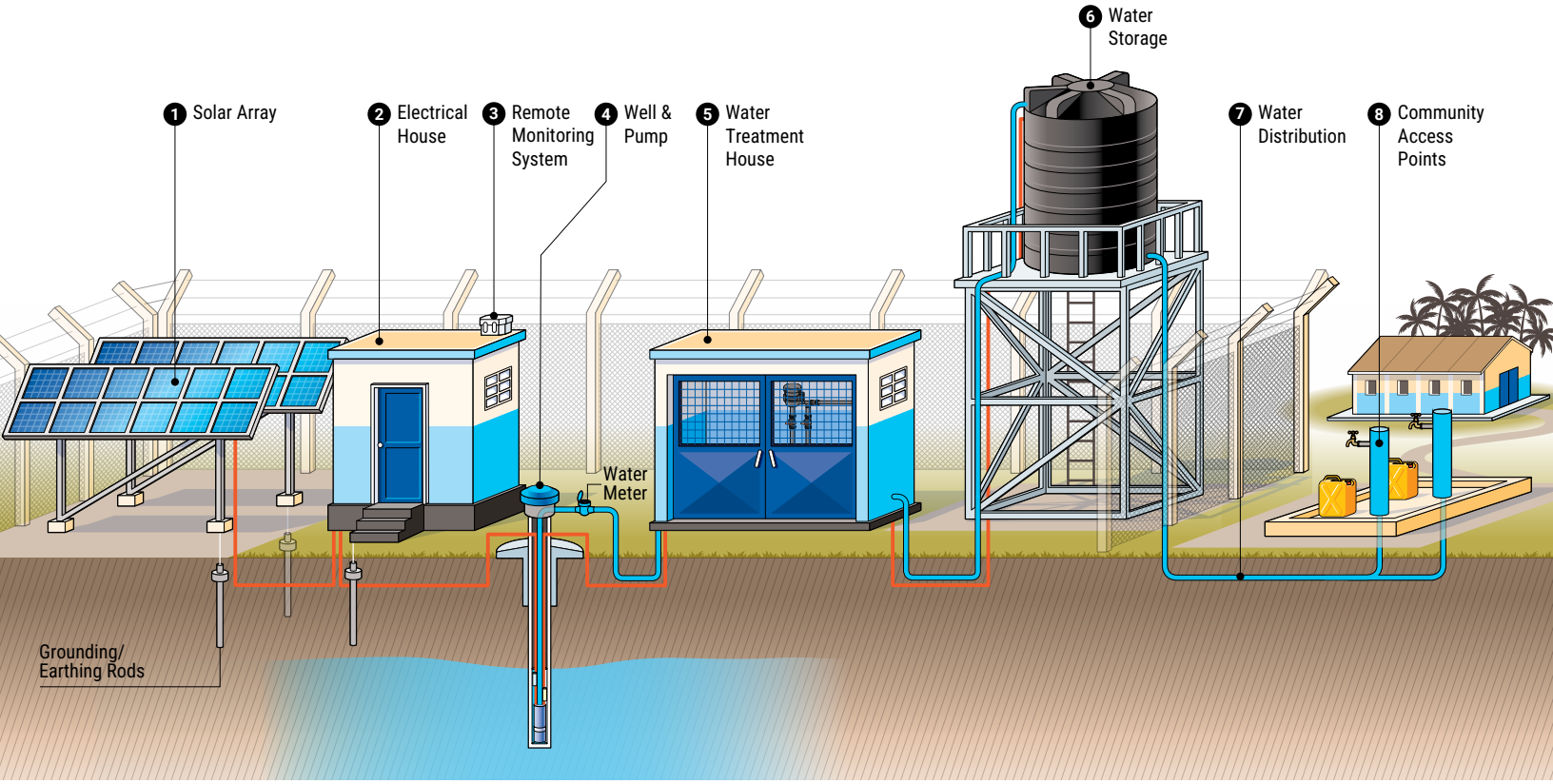
Adhering to the specific steps provided for startup and shutdown is vital for the system's optimal performance. Each system is unique, and following the exact procedures helps prevent issues and ensures that the water system runs smoothly.

Maintain a Schedule

Maintaining a consistent schedule for operating the water system is essential. Following a regular startup and shutdown routine helps ensure that there is always enough water available for everyone in the community. Regular operation not only meets daily water needs but also supports the system's overall health and longevity.

Additionally, it is important to be prepared to adjust the water distribution schedule based on feedback from the community. Regularly visiting the community and talking with residents will provide valuable insights into their water needs and help to inform any necessary adjustments to the schedule. This ensures that the system continues to meet the community's needs effectively.

B. GENERAL MAINTENANCE



Any unauthorized access to the site can lead to serious harm due to electrical hazards and fall risks.

PPE

Maintenance Tasks

- Make sure all fence gates and doors are securely closed and locked to restrict access to the site, as appropriate.
- Check the areas inside and around the solar array, electrical house, wellhead, water treatment house, and storage tank for waste and debris.
- Remove and dispose of all waste and debris. This is important to ensure that insects, rodents, and snakes do not disturb regular operation or cause physical harm.

Reporting

Daily Maintenance Tasks form

- Document any completed tasks and observations that may require attention later, such as potential security concerns or animal activity.

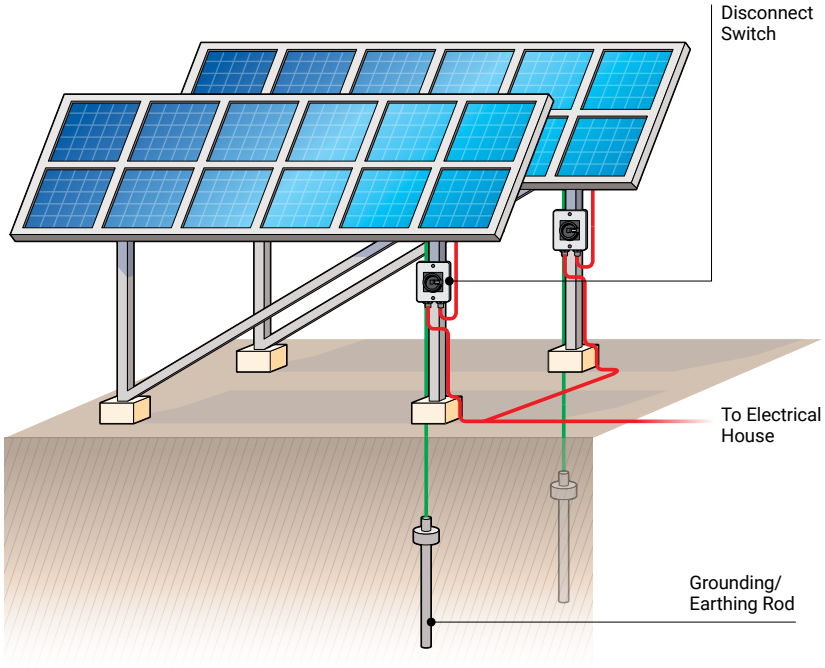
Solar array and site example

SOURCE: WATER MISSION

Solar array

SOURCE: WATER MISSION

C. SOLAR ARRAY



Electric Shock Hazards can be lethal. Always take extreme care when working around the solar panels and any electrical equipment and wiring. *Solar arrays are always energized when the solar panels are exposed to sunlight.*

While proper grounding can help to remove shock hazards, Operators and users of SPWS should never remove any electrical equipment covers.
If removed covers or uninsulated/loose/frayed wiring are found, DO NOT touch. Immediately contact the System Technician for support.

Working at heights is an extreme risk. Ensure you have a ladder that is in good working order and always have another person with you to hold the ladder.

PPE

Maintenance Tasks

- Visually inspect the surface of the solar panels for debris, such as leaves, twigs, insect poop, or other organic material. Carefully remove any debris on the solar panels. Use a sturdy ladder or long-handled, soft brush if necessary.

- Visually inspect the surface of the solar panels for dust or dirt to determine if cleaning is required. In most cases, solar panels need to be cleaned weekly. However, seasonal weather patterns and effects such as increased dust in the dry season, may require additional cleaning. Clean the solar panels whenever necessary.

** *Task instructions available in Section 7.*

- Visually inspect the solar panels for any damage, cracks, or broken glass, especially if any debris was found on the surface of the panels. Broken panels will need to be replaced to maintain system performance.

If any damage is detected, contact the System Technician.

Reporting

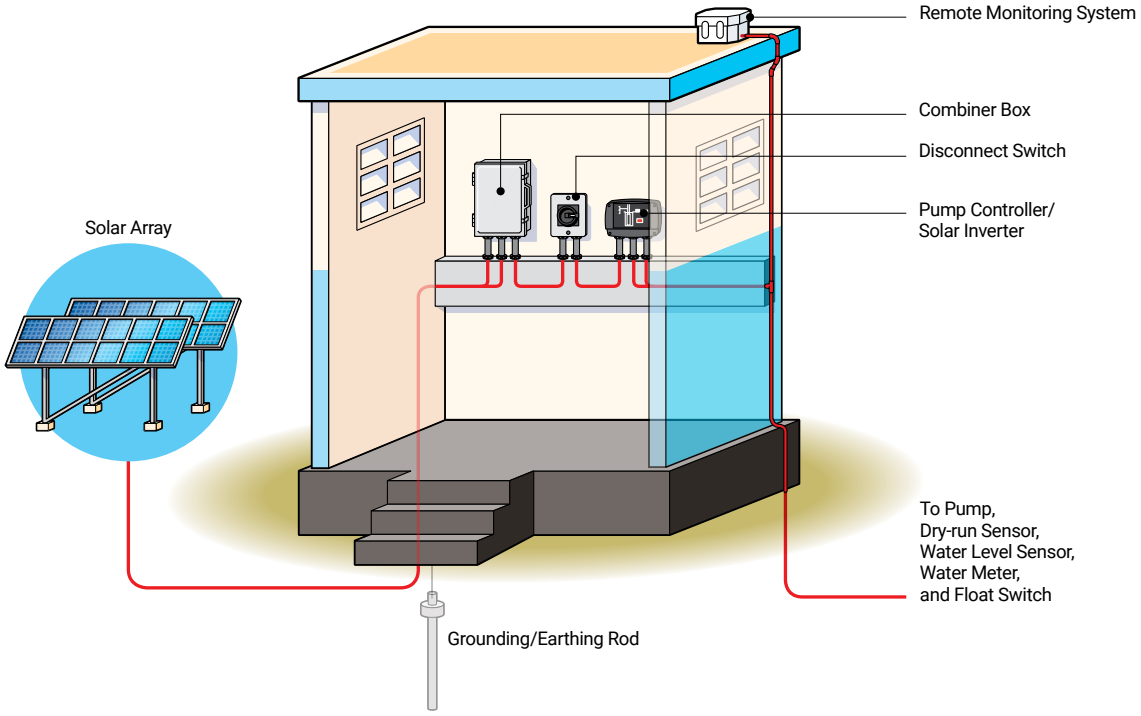
Daily Maintenance Tasks form

- Record the weather conditions (sunny, cloudy, raining, etc.).

- Record any damage found on the solar panels, including the type of damage and which panel(s) is/are affected.

Solar array for the Newa Community Project (Kenya).
SOURCE: WATER MISSION

D. ELECTRICAL HOUSE



Water leakage or spills can come into contact with electrical components, posing a risk of shock or short circuits. Do not allow water to pool on the floor. Water is an electrical conductor (electrical energy can travel through it) and this is hazardous, particularly if damaged or bare wires are lying on the floor.

DO NOT open any electrical equipment boxes.

If required, contact the System Technician .

PPE

Maintenance Tasks

- Check that all electrical boxes and cabinets have covers on them and that the covers are tightly closed.

Reporting

Daily Water Production form

- Record the pumping start time (when the pump is turned on) and end time (when the pump is turned off).

- If two different power sources are used during the day, make sure to record the start and end time for each power source.

Daily Maintenance Tasks form

- Record the electrical parameters from the pump controller.

If the electrical parameter(s) is/ are out of the expected range, contact the System Technician.

** *Task instructions available in Section 7.*

- Record any alarms from the pump controller (if present).

** *Task instructions available in Section 7.*

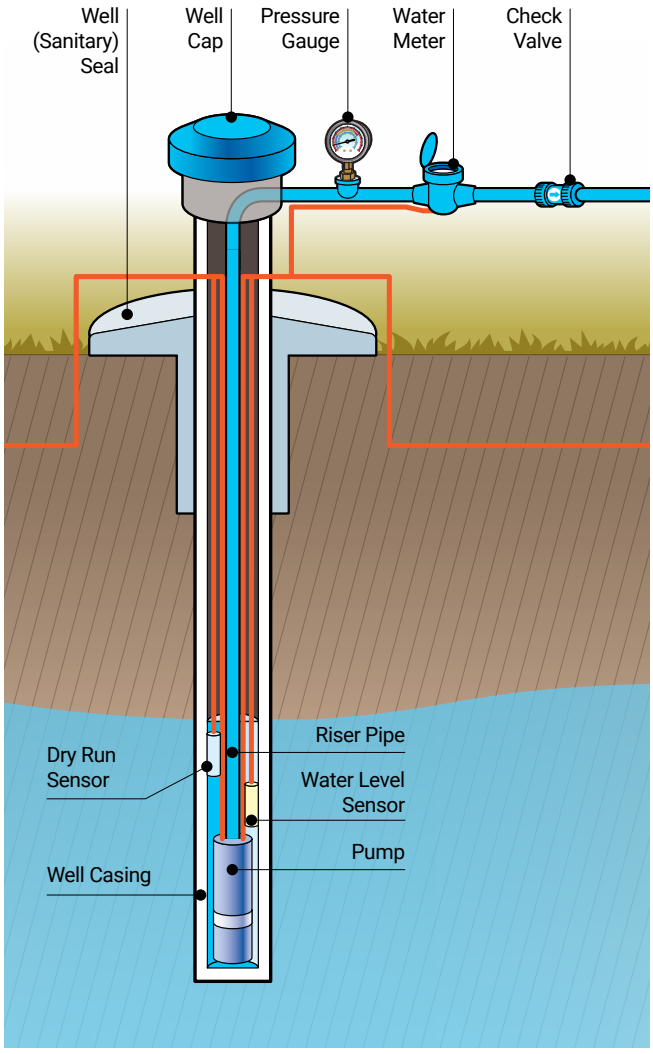
Electrical House for Newa Community Project (Kenya).

SOURCE: WATER MISSION

E. WELL & PUMP

Any foreign material entering the well can cause sickness or death of users and severe damage to the equipment.

PPE



Maintenance Tasks

- Check for leaks in the piping and connections at the wellhead.

** *Task instructions available in Section 7.*

Reporting

Daily Water Production form

- Record the water meter readings at the start of pumping (before the pump is turned on) and at the end of pumping (when the pump is turned off).
- If two different power sources are used during the day, make sure to record the start and end water meter readings for each power source.

Daily Maintenance Tasks form

- Record the pump pressure at the same time of day.

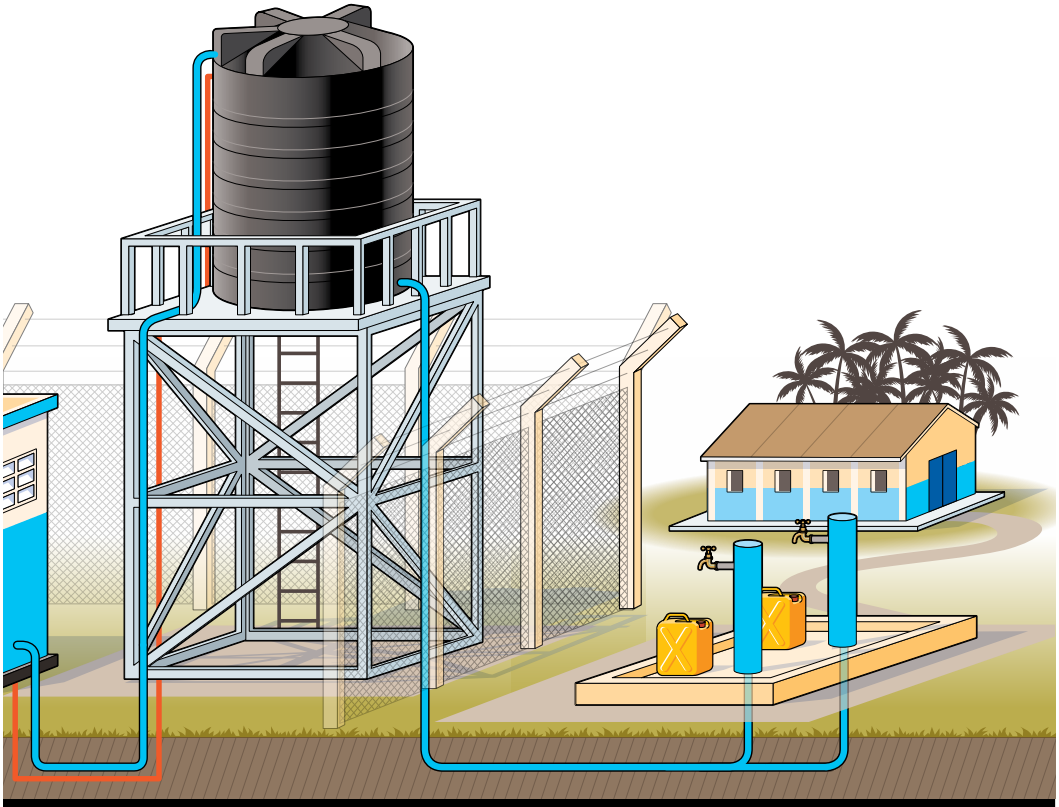
** *Task instructions available in Section 7.*

If the pressure is out of the expected range, contact the System Technician.

Wellhead (inside borehole cover) with piping for submersible pump and water meter (pressure gauge not pictured).

SOURCE: KOGI (FROM WATER MISSION PROJECT)

F. WATER STORAGE TANK, DISTRIBUTION, AND COMMUNITY ACCESS POINTS



The inside of a storage tank is a confined space. Working in confined spaces presents unique safety risks due to limited access, poor ventilation, and potential exposure to hazardous materials.

PPE

Maintenance Tasks

- Check the water tank for signs of overflow. This can be done by walking around the tank and looking for water stains on the side of the tank, wet areas or pooling water on the ground, or soil erosion near the base of the tank structure.
- Test the chlorine residual at two community access points (the one that is closest to the water storage tank and also the furthest).

** *Task instructions available in Section 7.*

- Test the turbidity at two community access points (the one that is closest and the one that is furthest from the water storage tank. (If applicable)

* *This is applicable if the treatment method uses filtration or if the water source is at risk for high turbidity (> 5 NTU) based on the raw water test results.*

** *Task instructions available in Section 7.*

Reporting

Daily Water Production form

- Record the chlorine test results
- Record the turbidity test results (if applicable).

Daily Maintenance Tasks form

- Record any community feedback received while walking between community access points, such as a lack of water, low flow, or color/odor in the water.

Elevated water storage tank at the Newa Community Project (Kenya)

SOURCE: WATER MISSION

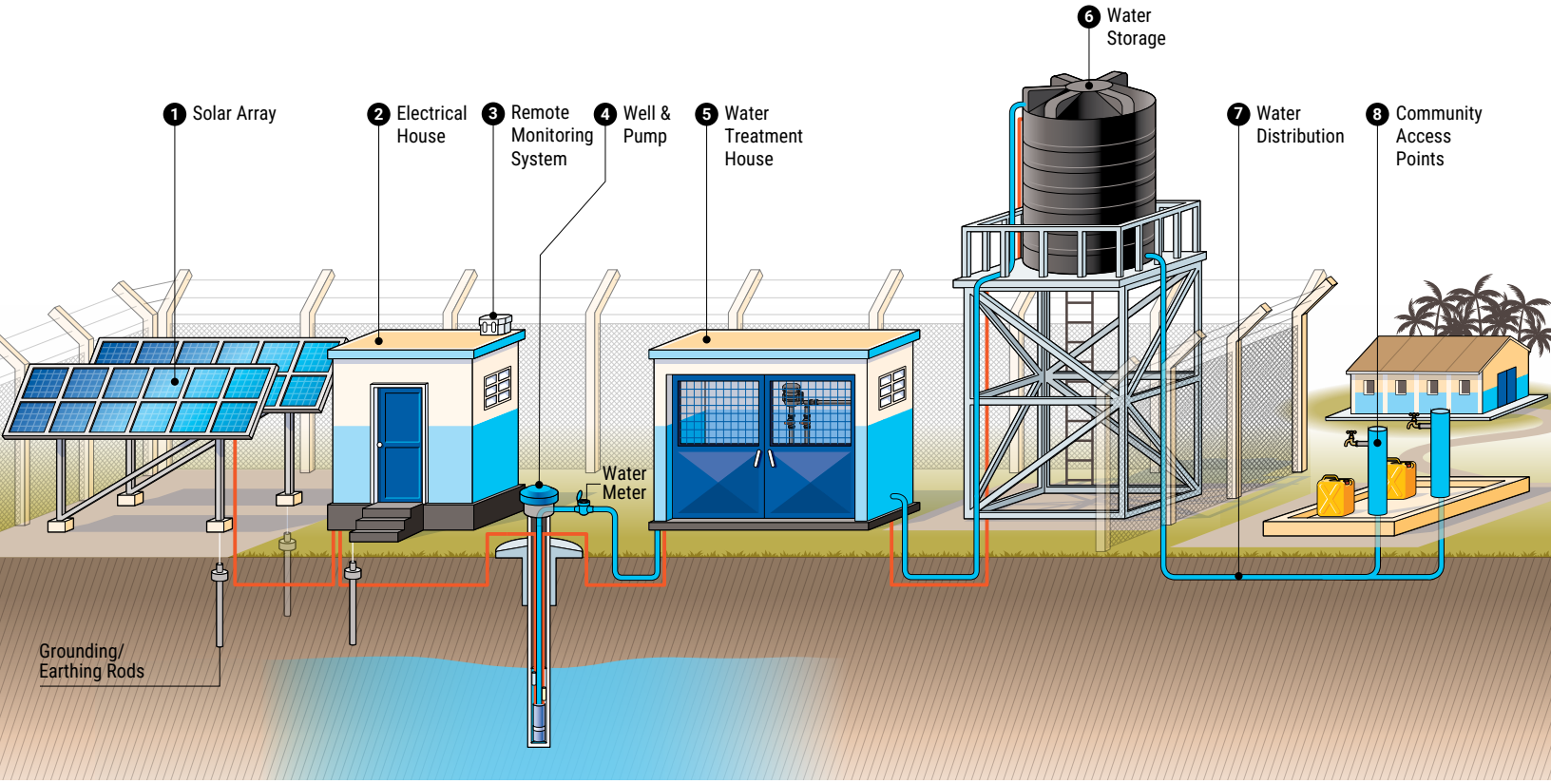
Community access point (tap stand) at the Newa Community Project (Kenya)

SOURCE: WATER MISSION

6.3 Weekly Tasks and Reporting

Weekly maintenance checks involve more thorough inspections and tasks performed in addition to the daily checks. Doing daily and weekly checks will help to keep the system in good order and operating at maximum capacity.

A key aspect of these weekly checks is becoming familiar with the system and all its components, allowing the Operator to quickly identify any issues or malfunctions. If there are issues, they can be addressed immediately to ensure that the system is working again as quickly as possible.



A. GENERAL SITE

Any unauthorized access to the site can lead to serious harm due to electrical hazards and fall risks.

Any unauthorized tampering of the system could impact the system's performance or lead to system failure.

PPE

Maintenance Tasks

- Check the system for unauthorized modifications, including the addition of a generator, grid power, lighting fixtures, or cell phone charging stations.
- Check all locks, fence gates, and fencing to ensure site security. Make sure unauthorized people cannot enter the site to modify the system, climb on arrays or structures, throw rocks near the solar panels, or perform gardening or farming activities near the system or near the buried electrical cables.
- All fencing should be inspected to ensure there are no missing sections or holes, that no digging has taken place underneath it, and that support poles are not broken.
- Replace or repair locks as needed.
- Check the site for animal activity. This could include insects, rodents, goats, cows, etc. that are making homes in the electrical house, water treatment house, electrical enclosures, or conduit. Animals may also dig near wiring or pipes, or otherwise damage system components.

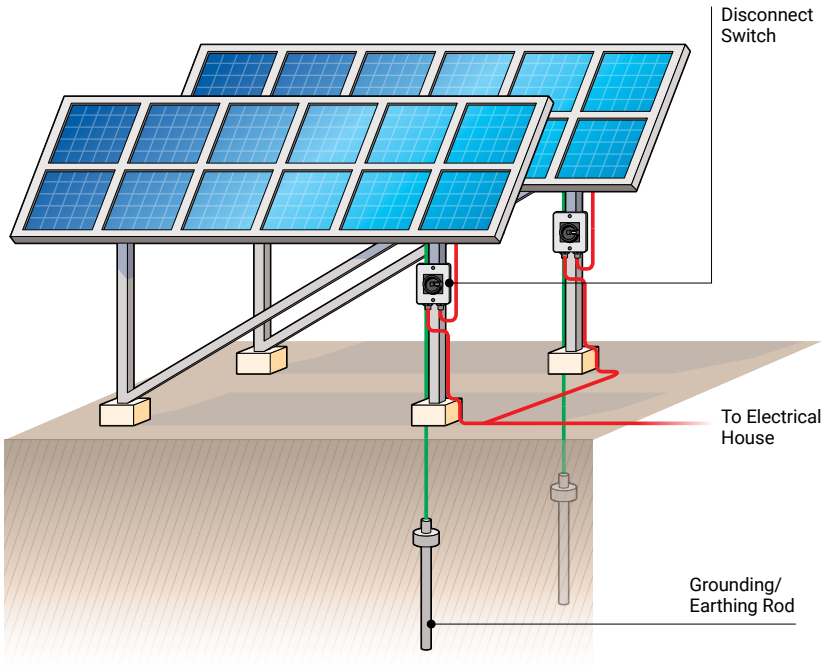
Reporting

Weekly Maintenance Tasks form

- Record any unauthorized modifications to the system
- Record any repairs that were made to locks, fence gates or fencing, and record any repairs or security concerns that are still present.
- Record any animal activity, actions taken, or any concerns that still need to be addressed.

Irreparable remote monitoring system due to bee infestation. Make sure to regularly check for signs of animal activity to avoid this situation.

SOURCE:



B. SOLAR ARRAY

In addition to doing these tasks weekly, these maintenance tasks should also be performed after any major storms

Electric Shock Hazards can be lethal. Always take extreme care when working around the solar panels and any electrical equipment and wiring. *Solar arrays are always energized when the solar panels are exposed to sunlight*

Although proper grounding helps remove shock hazards, Operators and users of SPWS should never remove any electrical equipment covers. If removed covers or uninsulated/loose/frayed wiring are found, DO NOT touch. Immediately contact the System Technician for support.

Working at heights is an extreme risk. Ensure you have a ladder that is in good working order and always have another person with you to hold the ladder.

PPE

Maintenance Tasks

- Clean the solar panels.

** *Task instructions available in Section 7.*

- Check for any source of shading on the solar panels, such as vegetation or structures, and remove it. Even small amounts of shading, including shading on just one panel, can cause significant reductions in the power output of the panel array. Trim or remove vegetation around the solar panels and any structures that will block sunlight.

- Check for spider webs, bird nests, or other insects on the solar panels or structure. Carefully remove webs and nests. If necessary, call a beekeeper or someone who can handle dangerous insects.

Use a soft cloth with water (no soap) to clean the surface of the solar panels.

SOURCE: UNICEF

- Check that the solar panels are securely mounted to the solar structure. Check and tighten any loose bolts.

* *If the structure or panels remain insecure after tightening or if you are unable to tighten the bolts properly,* ***contact the System Technician*** *to request support.*

- Visually inspect all wires and conduits for any signs of loose connection or damage.

** *Task instructions available in Section 7.*

- Check that all electrical boxes are closed, sealed, and properly mounted.

** *Task instructions available in Section 7.*

- Visually inspect the grounding system for missing or corroded connections.

** *Task instructions available in Section 7.*

- Visually inspect the solar structure.

If there are any visible cracks or signs of weakness, contact the System Technician.

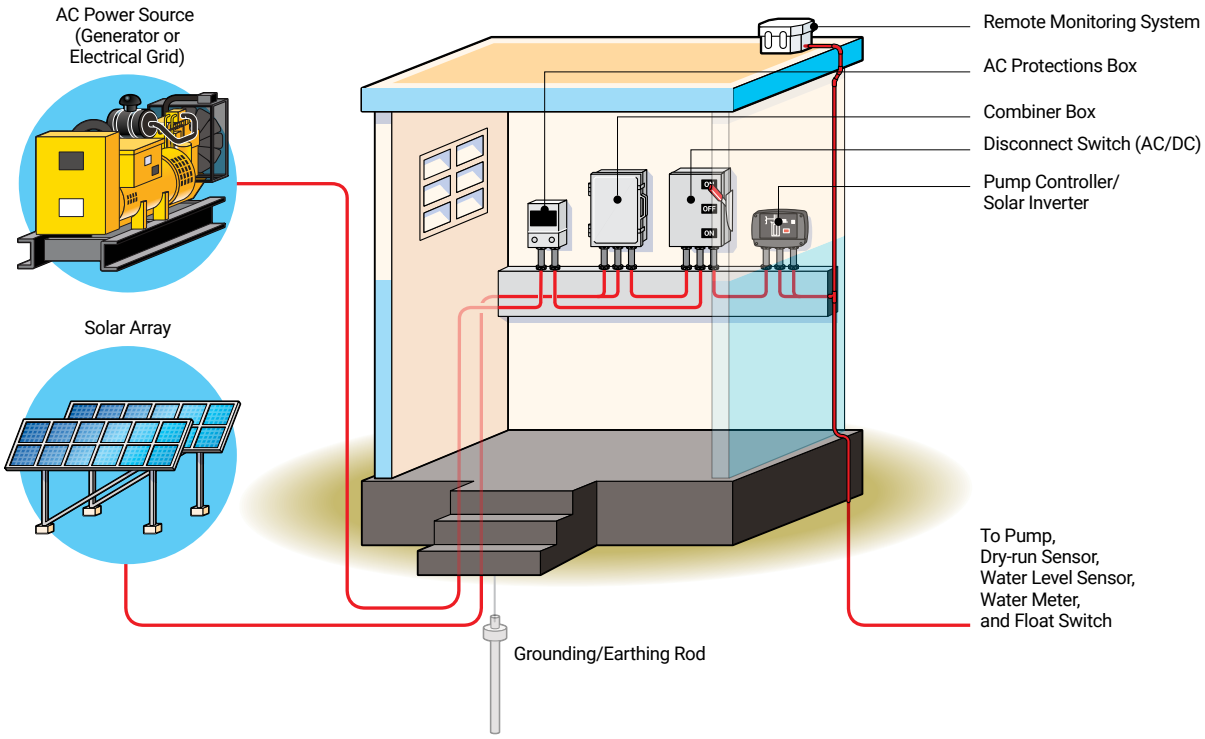
** *Task instructions available in Section 7.*

Reporting

Weekly Maintenance Tasks form

- Document all completed activities, such as cleaning panels or removing bird nests, along with any unusual observations and the location of these observations.

C. ELECTRICAL HOUSE



Working at heights is an extreme risk. Ensure you have a ladder that is in good working order and always have another person with you to hold the ladder.

Water leakage or spills can come into contact with electrical components, posing a risk of shock or short circuits. Do not allow water to pool on the floor. Water is an electrical conductor (electrical energy can travel through it) and is hazardous, particularly if damaged or bare wires are lying on the floor.

Although proper grounding helps remove shock hazards, Operators and users of SPWS should never remove any electrical equipment covers. If removed covers or uninsulated/loose/frayed wiring are found, DO NOT touch. Immediately contact the System Technician for support.

PPE

Maintenance Tasks

- Visually inspect the structure, including the walls, foundation, roof, and entrances and exits of all conduits.

- Clean all electrical boxes and equipment using a dry cloth to gently wipe the outside to remove dust and cobwebs.

- Check that all electrical boxes are closed, sealed, and properly mounted.

** *Task instructions available in Section 7.*

- Visually inspect all wires and conduits for any signs of loose connection or damage.

** *Task instructions available in Section 7.*

- Visually inspect the grounding system.

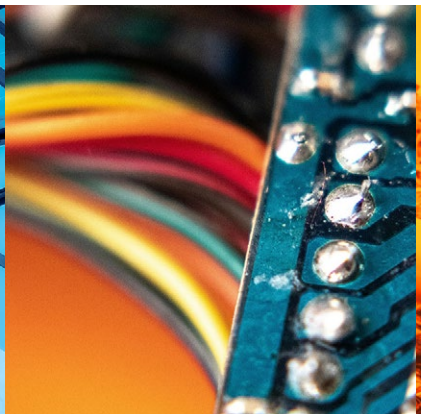
** *Task instructions available in Section 7.*

Reporting

Weekly Maintenance Tasks form

- Record anything observed that is unusual with specifics about the observation and the location.

SOURCE: WATER MISSION



SOURCE: BRIAN WANGENHEIM ON UNSPLASH

SOURCE: WATER MISSION

SOURCE: MEASUREMAN

D. WELL & PUMP

Any foreign material entering the well can cause illness or death for users and severe damage to the equipment.

PPE

Maintenance Tasks

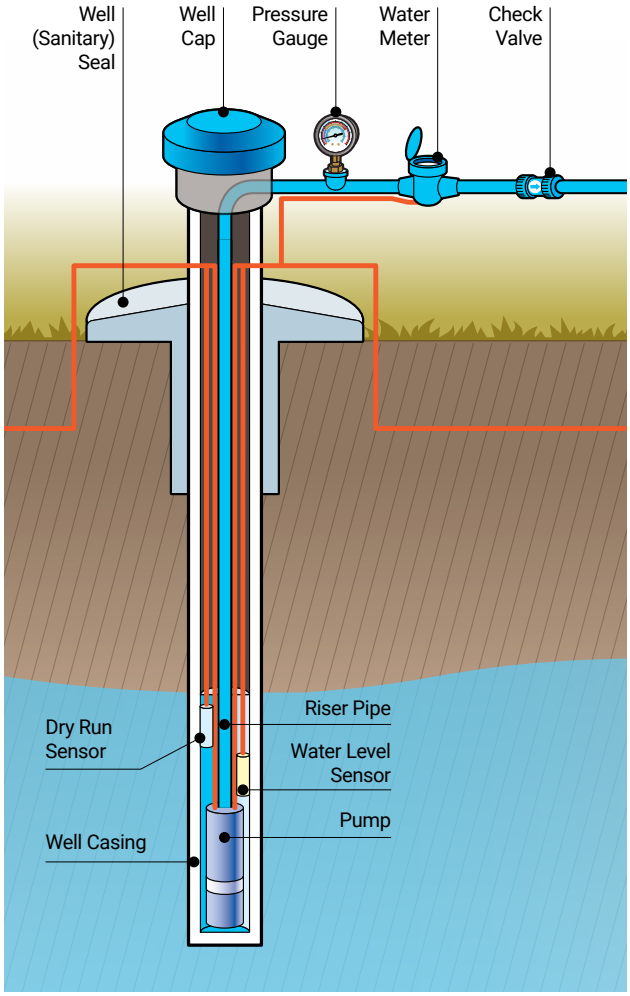
- Check that the wellhead is sealed and undamaged, including the well cap and piping.
- Check that the support cable/safety rope holding the pump in the borehole is still securely connected at the top of the wellhead.
- Visually inspect all wires and conduits for any sign of loose connection or damage.

** *Task instructions available in Section 7.*

- Clean the area using a dry cloth. Gently wipe the components to remove dust and cobwebs.

If there are any visible signs of damage, WARNING: this could expose users to harmful bacteria and cause serious illness. Contact the System Technician to request support.

If the wellhead has been damaged,there is a possibility that dirt, insects,or animals have entered the well, and it may need to be flushed. This is a serious problem. Report it to the System Technician immediately.

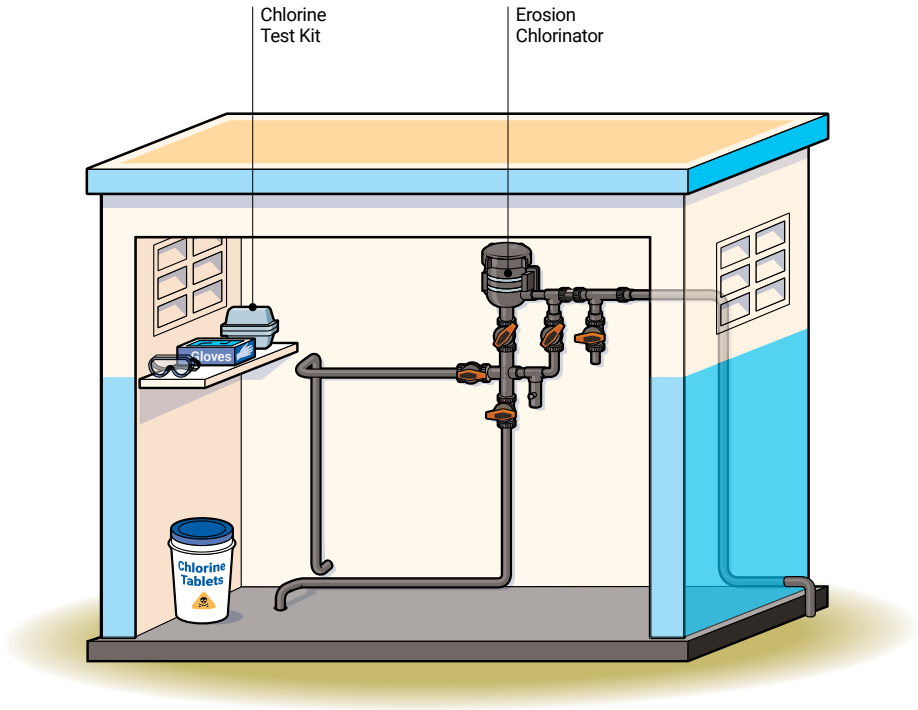


Reporting

Weekly Maintenance Tasks form

- Record anything observed that is unusual about the location and description.

E. WATER TREATMENT HOUSE



Working at heights is an extreme risk. Ensure that you have a ladder that is in good working order and always have another person with you to hold the ladder.

Chlorine must always be stored in the water treatment house. NEVER store chlorine in the electrical house.

Always wear eye protection, respiratory protection, and gloves when working with chlorine. Direct contact with chlorine or chlorine fumes can be harmful and should be avoided. Chlorine fumes can accumulate in the treatment equipment and may be released when draining the chlorinator, removing the cover, or opening the chlorine tablet bucket.

Combining two chlorine products could result in a dangerous chemical explosion. Always make sure to consistently use the correct chlorine product.

PPE

Maintenance Tasks

- Visually inspect the structure, including the walls, foundation, roof, and entrances and exits of all piping and conduits.
- Clean all components using a dry cloth to gently remove dust and cobwebs.
- Check for leaks along all piping, pipe connections, valves, and water treatment equipment.

** *Task instructions available in Section 7.*

- Check and refill water treatment chemicals, as needed.
- Ensure water treatment chemicals are properly stored, and the room is ventilated.

Reporting

Weekly Maintenance Tasks form

- Record any observations that are out of the ordinary with the exact location and description.

Erosion Chlorinator and chlorine test kit at the Newa Community Project (Kenya)

SOURCE: WATER MISSION

F. PRESSURE LINE

This includes the piping between the pump and water storage tank. These checks require the System Operator to walk the pressure line from the pump to the water tank, making these checks along the way.

The pressure line is under high pressure and therefore MOST repairs will require a shutdown of the pumping system. The Operator should check it weekly to identify any problems and request the assistance of the System Technician, when necessary.

PPE

Maintenance Tasks

- Check for exposed pipes.

** *Task instructions available in Section 7.*

- Check for leaks along the pipe and at all valves, pipe connections, and fittings.

** *Task instructions available in Section 7.*

- Check for damage (cracks or bends along the pipe and on any valves).

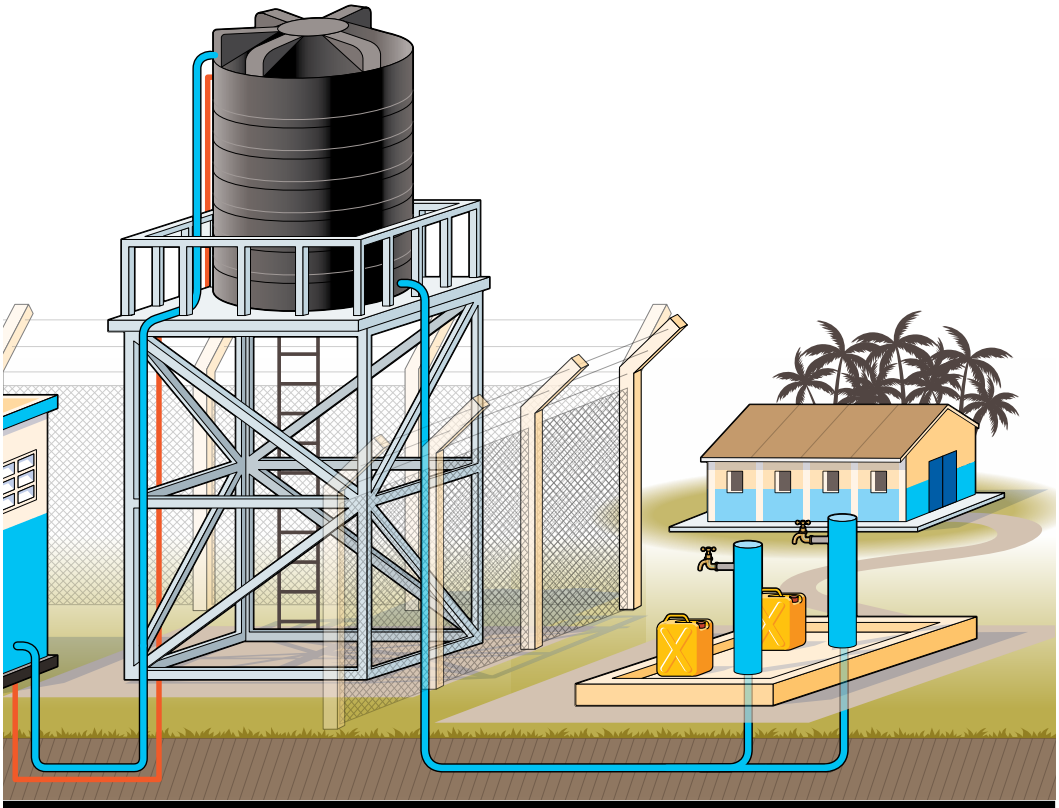
If there are any valves or pipes that are damaged or leaking, or any other issues are identified, contact the System Technician to request support.

Reporting

Weekly Maintenance Tasks form

- Record any observations that are out of the ordinary with the location and description.

G. WATER STORAGE TANK, DISTRIBUTION, AND COMMUNITY ACCESS POINTS



The storage tank is a confined space and should never be entered.

PPE

Maintenance Tasks

- Ensure that the lid on the water tank is secure and not damaged or missing. If the lid is absent, replace it.

If the lid is damaged contact the System Technician to fix or replace it.

- Visually inspect the water tank for any signs of cracking, damage, or leaks. Inspect the ground around the base of the water tank for wet areas or pooling water on the ground.

- Visually inspect the tank structure or tank stand for signs of damage, leaking or leaning.

- Check for exposed pipes.

** *Task instructions available in Section 7.*

- Check for leaks along the distribution pipe and at all valves, pipe connections, and fittings, including the entrance/exit to the water tank and at the isolation valve on the outlet of the water tank.

** *Task instructions available in Section 7.*

- Check if the taps at the community access points are loose or leaking. If so, tighten the fittings carefully to ensure that they are snug. Take care not to overtighten to reduce thread quality and risk further leakages.

If the tap still leaks, contact the System Technician to replace the tap.

- Check if the taps at community access points are stuck, blocked, or have missing handles and if the community access point is damaged or leaking.

If yes, contact the System Technician.

- Check that water is flowing at all community access points with good flow and pressure. For good pressure, you should be able to fill a 20 L container in no more than 2-3 minutes. Low pressure could indicate a leak in the distribution line or low water level in the water tank.

- Talk to community members at each community access point to gather feedback on how the water system is working (Is there enough water? Is the water acceptable? etc.)

Reporting

Weekly Maintenance Tasks form

- Record any observations that are out of the ordinary with the location and description.

- Record any community feedback received while walking between community access points, such as a lack of water, low flow, or color/odor in the water.

H. INVENTORY OF CONSUMABLES AND SPARE PARTS

There should be a supply of consumables and commonly needed materials for minor maintenance on hand. Any consumables required for the quarterly or annual site visit should be brought by the System Technician.

Maintenance Tasks	Reporting
• Check supplies and spare parts.	*Inventory List*
** *Task instructions available in Section 7.*	• Record which stock needs to be replenished.

6.4 Quarterly & Annual Maintenance Tasks

Quarterly inspections should only be performed by a System Technician who can safely isolate the system electrically. The maintenance tasks are included here so that you are aware of them and what should be done.

These inspections are in addition to the daily and weekly inspection lists and do not replace those tasks. The quarterly tasks provide more detailed inspections of electrical connections and enclosures than the daily and weekly tasks.

A. QUARTERLY - ELECTRICAL EQUIPMENT

Electrical equipment could be comprised of a combination of several devices including a pump controller, auxiliary power supply box, combiner box, etc.

The System Technician will perform inspections of all electrical equipment. Accompany the Technician during these maintenance tasks to assist as well as learn about what the Technician is doing to better understand the system.

Maintenance Tasks (for the System Technician)

- Open the enclosure and inspect for signs of:
  - Corrosion
  - Insects or dust
  - Smoke/burns
  - Presence of water
- After isolating the component from all power sources, check that all wires are firmly secured by gently pulling on each wire.
- If any enclosures have vents or screens, clean the screens so that air flows freely.
- Check the equipment mountings to walls to ensure that they are properly attached and not in danger of coming off their supports.
- Ensure that display screens are clean, and equipment is free from dust and cobwebs.
- Look at connections and seals to ensure that they are tight and free from damage.
- Check that the float switch can move freely and function correctly.
- Verify that the pressure switch properly actuates (system dependent).
- Check any protective equipment, such as dry run sensors, as you are able.
- Check the remote monitoring functionality.

B. QUARTERLY - ELECTRICAL HOUSE

The System Technician should examine the structure of the house with a fresh set of eyes. Accompany the Technician during these maintenance tasks to assist as well as to learn about what the Technician is doing to better understand the system. If repairs are needed, they can be done together, or the Technician may show you what needs to be done and you can complete it later (ex. Painting rust spots).

Maintenance Tasks (for the System Technician)

- Inspect the equipment house for cracks and damage in the roof, walls, foundation, and entryways.
- Look for damaged pipes entering or exiting the equipment house.
- Check for structural damage such as gapping and cracks to the foundation, beams, or columns.
- Look for erosion around the foundation.
- Check for leaks in the roof or walls.
- Check for any rotting wood.
- Pick up and dispose of any waste or debris surrounding the equipment house.
- Remove any cobwebs or insect nests found inside or on the outside of the equipment house's structure.
- Check the enclosure lock and replace the lock if it is broken or missing.

If any issues are identified and cannot be resolved by the System Technician, have a qualified individual take corrective action following sound technical and safety procedures.

C. QUARTERLY - WATER QUALITY

While water quality testing is a daily task for the Operator, the System Technician will conduct tests quarterly at the storage tank, at the tap nearest to the storage tank, and at the tap farthest from the storage tank. Accompany the Technician during the maintenance tasks and do the water quality tests along with the Technician to check your own methods and to cross check the results.

Always wear eye protection, respiratory protection, and gloves when working with chlorine. Direct contact with chlorine or chlorine fumes can be harmful and should be avoided. Chlorine fumes can accumulate in the treatment equipment and may be released when draining the chlorinator, removing the cover, or opening the chlorine tablet bucket.

Combining two chlorine products could result in a dangerous chemical explosion. Always make sure to consistently use the correct chlorine product.

Maintenance Tasks (for the System Technician)
• Check that chlorine is stored safely.
• Check that the test kit is in good working order.
• Observe the Operator performing the tests to check their methods and to cross check the results.

Tests (by both you and the System Technician)
• E. coli
• Total coliform
• Free chlorine
• Turbidity

D. ANNUAL MAINTENANCE TASKS

The annual maintenance and monitoring activities will be done by the System Technician, as described in Section 5. The System Operator should accompany the Technician as these maintenance tasks are completed.

A. Structural inspections (buildings, fences, gates, etc.)
B. Solar panels and structure
C. Grounding/earthing
D. Electrical boards, switches & cables
E. Control box/inverter
F. Generator
G. Borehole and yield test
H. Pump maintenance or replacement (if there are issues)
I. Water quality (source water and treated water)
J. Remote monitoring
K. Water supply system (meter, pipes, storage tank, taps)
L. Inventory of spare parts

6.5 Checklists and Reporting Forms

A. Operator Tools & Supplies Checklist

B. Daily O&M Checklist

C. Daily Water Production Form

D. Daily Maintenance Form

E. Weekly Maintenance Checklist

F. Weekly Tools & Supplies Inventory

Operator Tools & Supplies Checklist

System Name:	
Operator Name:	
Date:	

Item #	Quantity	Item	Purpose	✓
Daily Tasks				
1	1 pair	Foot protection (protective shoes)	Personal protective equipment	❑
2	1	Hard hat	Personal protective equipment	❑
3	1	Eye Protection	Personal protective equipment	❑
4	1	Respiratory protection	Personal protective equipment	❑
5	1 pair	Gloves	Personal protective equipment	❑
7	1	Writing utensil (pen/pencil	Data recording	❑
8	1	*Daily Water Production* Form	Data recording	❑
9	1	*Daily Maintenance* Form	Data recording	❑
10	1	Ladder	Inspecting solar array and structures	❑
11	1	Chlorine Test Kit with Reagents	Testing residual chlorine (water quality)	❑
12	1	Turbidity Test Kit (if needed)	Testing turbidity (water quality)	❑
Weekly Tasks(the following are needed *in addition* to the above for weekly mainenance tasks)				
13	1	Soft (non-abrasive) sponge/cloth *or* long-handled soft brush	Washing solar panels	❑
14	1 bucket	Clean water (no soap!)	Washing solar panels	❑
15	1	Squeegee (or dry, clean cloth)	Washing solar panels	❑
16	1	Broom	Removing cobwebs, debris, etc.	❑
17	1	Dry, soft cloth	Wiping components/removing dust	❑
18	1	Wrench or screwdriver	Tightening bolts, as needed	❑
19	1	Pipe wrench	Tightening pipe fittings, as needed	❑
20	5	Chlorine tablets	Refilling treatment, as needed	❑

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Daily Maintenance Tasks Form

System Name:
Operator Name:
Date:

Task	Complete? ✓	Form for Reporting
Routine Operation		
Follow the proper pumping procedures.	❑	
Maintain a consistent pumping schedule.	❑	
General Site		
Keep all doors and fenced gates closed and locked.	❑	*Daily Maintenance Tasks* Form
Check for and remove all waste or debris.	❑	*Daily Maintenance Tasks* Form
Solar Array		
Record the weather conditions (sunny, cloudy, raining).	❑	*Daily Maintenance Tasks* Form
Check the surface of the solar panels and remove debris.	❑	*Daily Maintenance Tasks* Form
Check the solar panels for dust or dirt. Clean if necessary.	❑	*Daily Maintenance Tasks* Form
Check the solar panels for damage, cracks, or broken glass.	❑	*Daily Maintenance Tasks* Form
Electrical House		
Check that covers are tightly closed on all electrical boxes.	❑	
Record pumping times (start and end).	❑	*Daily Water Production* Form
Record electrical paramaters from pump controller.	❑	*Daily Maintenance Tasks* Form
Record any alarms (if present) from pump controller.	❑	*Daily Maintenance Tasks* Form
Well & Pump		
Record water meter readings (start and end).	❑	*Daily Water Production* Form
Record pump pressure (at same time each day).	❑	*Daily Maintenance Tasks* Form
Check for leaks in the piping and connections.	❑	*Daily Maintenance Tasks* Form
Water Tank, Distribution, & Community Access Points		
Check water tank for signs of overflow.	❑	*Daily Maintenance Tasks* Form
Check residual chlorine (and turbidity, if applicable).	❑	*Daily Water Production* Form
Record any community feedback.	❑	*Daily Maintenance Tasks* Form

Daily Water Production Form

System Name:	**Water Meter Units (circle one):** cubic meters litres gallons cubic feet
Operator Name:	

Day	Date	Solar				AC				Total Daily Water Production	Water Quality	
		Time		Meter		Time		Meter			Closest Tap	Farthest Tap
		Start	End	Start	End	Start	End	Start	End			
1											Chlorine (ppm) Turbidity (NTU)	Chlorine (ppm) Turbidity (NTU)
2											Chlorine (ppm) Turbidity (NTU)	Chlorine (ppm) Turbidity (NTU)
3											Chlorine (ppm) Turbidity (NTU)	Chlorine (ppm) Turbidity (NTU)
4											Chlorine (ppm) Turbidity (NTU)	Chlorine (ppm) Turbidity (NTU)
5											Chlorine (ppm) Turbidity (NTU)	Chlorine (ppm) Turbidity (NTU)
6											Chlorine (ppm) Turbidity (NTU)	Chlorine (ppm) Turbidity (NTU)
7											Chlorine (ppm) Turbidity (NTU)	Chlorine (ppm) Turbidity (NTU)

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Daily Maintenance Form

System Name:	**Pressure Gauge Units (circle one):** PSI bar other:_____
Operator Name:	**Power Units (circle one):** kW W hp other:_____

Day	Date	Weather (circle one)	Wellhead Pressure		Pump Controller Power		Pump Controller Alarms?	Notes General, Solar Array, Community Feedback, etc.
1			10:00		10:00			
			12:00		12:00			
			14:00		14:00			
2			10:00		10:00			
			12:00		12:00			
			14:00		14:00			
3			10:00		10:00			
			12:00		12:00			
			14:00		14:00			
4			10:00		10:00			
			12:00		12:00			
			14:00		14:00			
5			10:00		10:00			
			12:00		12:00			
			14:00		14:00			
6			10:00		10:00			
			12:00		12:00			
			14:00		14:00			
7			10:00		10:00			
			12:00		12:00			
			14:00		14:00			

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Weekly Maintenance Checklist

System Name:	
Operator Name:	
Date:	

Task	✓	Notes
General Site		
Check all doors, fence gates, and fencing.	❑	
Check for unauthorized modifications to the system.	❑	
Check the area for animal activity.	❑	
Solar Array		
Wash the solar panels.*	❑	
Check for and remove all sources of shading on the panels.	❑	
Check for and safely remove spider webs, bird nests, or other insects.	❑	
Check that the solar panels are securely mounted to the solar structure. Tighten loose bolts.**	❑	
Check that all electrical boxes are closed, sealed, and properly/securely mounted.	❑	
Visually check for disconnected, loose, or damaged wiring.*	❑	
Visually check the grounding system for loose, missing, or corroded connections.*	❑	
Check the solar structure for damage, cracks, or rust.*	❑	
Electrical House		
Visually inspect the structure for damage or cracks (walls, foundation, roof, conduit entrances).	❑	
Gently wipe the outside of all electrical boxes with a dry cloth to remove dust and cobwebs.	❑	
Check that all electrical boxes are closed, sealed, and properly/securely mounted.	❑	
Visually check for disconnected, loose, or damaged wiring.	❑	

Visually check the grounding system for loose, missing, or corroded connections.	❑	
Well & Pump		
Check that the wellhead is sealed and undamaged, including the well cap and piping.	❑	
Check that the support cable (safety rope) is securely connected at the top of the wellhead.	❑	
Visually check for disconnected, loose, or damaged wiring.	❑	
Clean the area using a dry cloth. Gently wipe the components to remove dust and cobwebs	❑	
Water Treatment House		
Visually inspect the structure for damage or cracks (walls, foundation, roof, conduit entrances).	❑	
Gently wipe all components with a dry cloth to remove dust and cobwebs.	❑	
Check for leaks along all piping, pipe connections, valves, and water treatment equipment.	❑	
Check and refill water treatment chemicals, as needed.	❑	
Check that water treatment chemicals are properly stored, and the room is ventilated.	❑	
Pressure Line		
Check for exposed pipes.	❑	
Check for leaks along the pipe and at all valves, pipe connections, and fittings.	❑	
Check for damage (cracks or bends along the pipe and on any valves).	❑	
Water Tank, Distribution, & Community Access Points		
Ensure that the lid on the water tank is secure and not damaged or missing.	❑	
Visually inspect the water tank for cracking, damage, or leaks.	❑	
Visually inspect the tank structure or tank stand for damage, leaking or leaning.	❑	
Check for exposed pipes.	❑	

Check for leaks along the distribution pipe and at all valves, pipe connections, and fittings.	❑	
Check if the taps at the community access points are damaged, loose, or leaking.	❑	
Check if the taps at community access points are stuck, blocked, or have missing handles.	❑	
Check that water is flowing at all community access points with good flow and pressure.	❑	
Community Feedback		
Gather feedback from community members at each access point (Is there enough water? Is the water acceptable? etc.)	❑	

Any Other Comments?

x _____ _____

Operator Signature Date

SUBMIT TO SYSTEM MANAGEMENT WITH *DAILY WATER PRODUCTION* FORM

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

Weekly Tools & Supplies Inventory Form

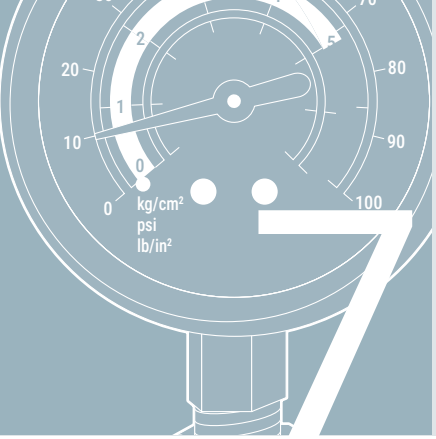
System Name:	**Date:**
Operator Name:	

#	Item	Minimum Needed	Quantity on Hand	Restock ✓	Repair ✓	Replace ✓	Notes
1	Foot protection (protective shoes)	1 pair per person		❑	❑	❑	
2	Hard hat	1 per person		❑	❑	❑	
3	Eye protection	1 pair per person		❑	❑	❑	
4	Gloves (nitrile, disposable)	50 pairs		❑	❑	❑	
5	Writing untensils (pens/pencils)	3		❑	❑	❑	
6	Ladder	1		❑	❑	❑	
7	Chlorine Test Kit	1		❑	❑	❑	
8	Free chlorine reagents	50 satchets		❑	❑	❑	
9	Turbidity Test Kit (if applicable)	1		❑	❑	❑	

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM

10	Chlorine tablets *Or other water treatment	10 tablets		❑	❑	❑	
11	Soft (non-abrazive) sponge *Or long-handled soft brush	1		❑	❑	❑	
12	Bucket (for clean water)	1		❑	❑	❑	
13	Squeegee	1		❑	❑	❑	
14	Soft cloth (dry and clean)	2		❑	❑	❑	
15	Tool bag	1		❑	❑	❑	
16	Adjustable wrenches *Set with various sizes	1 set		❑	❑	❑	
17	Screwdrivers *Set with various sizes	1 set		❑	❑	❑	
18	Pipe wrench *Or channel-lock pliers	1		❑	❑	❑	
19	Broom			❑	❑	❑	
20	Shovel	1		❑	❑	❑	
21	Fuses *Sizes depend on system	3 each		❑	❑	❑	

THIS FORM SHOULD BE CUSTOMIZED BEFORE USE BY SYSTEM MANAGEMENT TO MATCH THE SPECIFICS OF THE WATER SYSTEM



Section 7

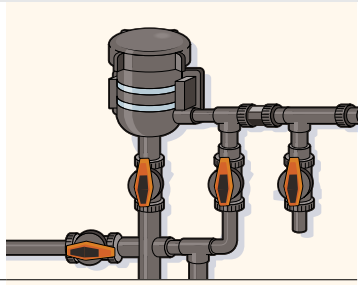
Support Tools for Operators

7.1 How to Start Up, Shut Down and Switch Power Sources

A. SOLAR ONLY: HOW TO START UP

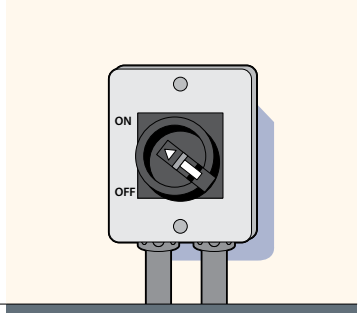
1 Open valves at the chlorinator. Adjust valves to their correct open position to allow water to flow through the chlorinator.

**Refer to the water treatment system manual for the correct positions.*

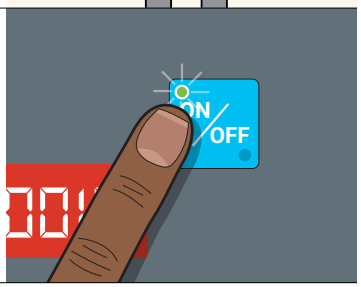


2 Turn the power supply on by:

- First, check if the sun appears to be providing sufficient energy to the solar panels (has the sun risen, is it shining, and are the solar panels clean?)
- Second, turn the 2-way disconnect switch to the “ON” position.

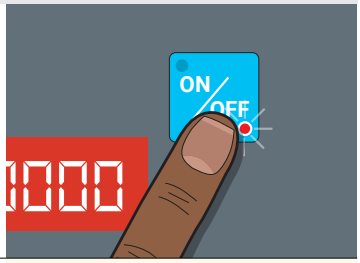


3 Turn the pump on at the pump controller. Monitor the power input information and any other relevant data that appears.

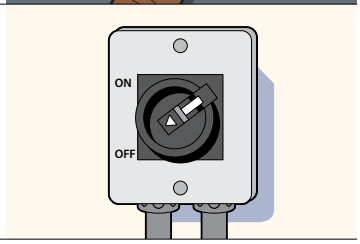


B. SOLAR ONLY: HOW TO SHUT DOWN

1 Turn the pump off at the pump controller unit.



2 Shut off the power supply by turning the 2-way disconnect switch to the “OFF” position.



3 Close valves at chlorinator. After the water has stopped flowing through the system, adjust the valves to their correct shutdown position to prevent a buildup of chlorine in the water.

**Refer to the water treatment system manual for the correct positions.*

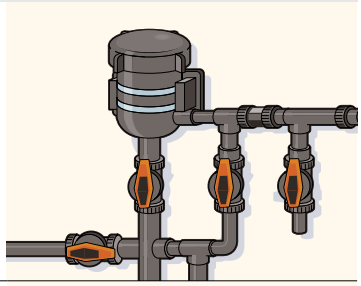
Pump Controller (left) and Erosion Chlorinator (right) for Solar-Only SPWS at Mutulani Community Project (Kenya)
SOURCE: KOGI CHEGE (FROM WATER MISSION PROJECT)

2-way Disconnect (left) and Pump Controller (right) at Mutulani Community Project (Kenya)
SOURCE: KOGI CHEGE (FROM WATER MISSION PROJECT)

C. HYBRID: HOW TO START UP

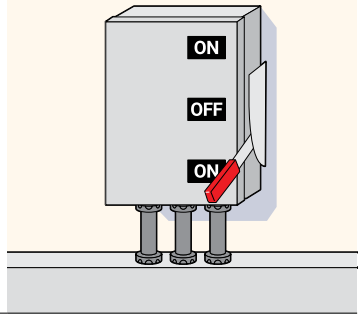
1 Open valves at the chlorinator. Adjust valves to their correct open position to allow water to flow through the chlorinator.

**Refer to the water treatment system manual for the correct positions.*



2 Turn the power supply on by:

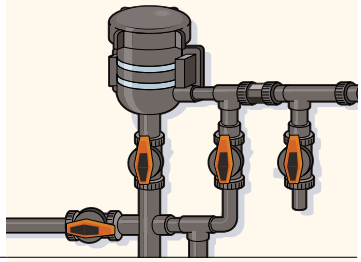
- First, check if the sun appears to be providing sufficient energy to the solar panels (has the sun risen, is it shining, and are the solar panels clean?).
- Second, turning the 3-way disconnect, or “transfer”, switching downwards to the DC Solar position.



If the alternate power is a grid:

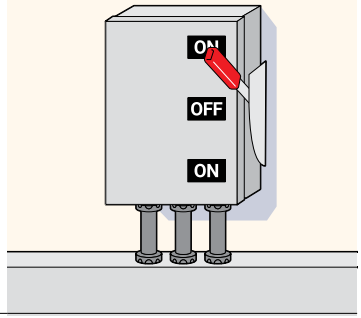
1 Open valves at the chlorinator. Adjust valves to their correct open position to allow water to flow through the chlorinator.

**Refer to the water treatment system manual for the correct positions.*



2 Turn on the AC grid power supply by:

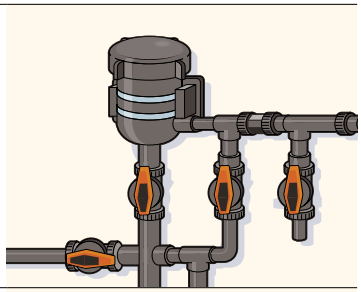
- Pushing the disconnect switch upwards to the AC position.



If the alternate power is a generator:

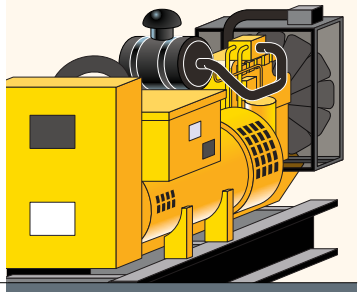
1 Open valves at the chlorinator. Adjust valves to their correct open position to allow water to flow through the chlorinator.

**Refer to the water treatment system manual for the correct positions.*

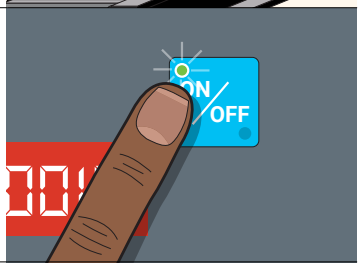


2 Turn on the diesel/petrol generator:

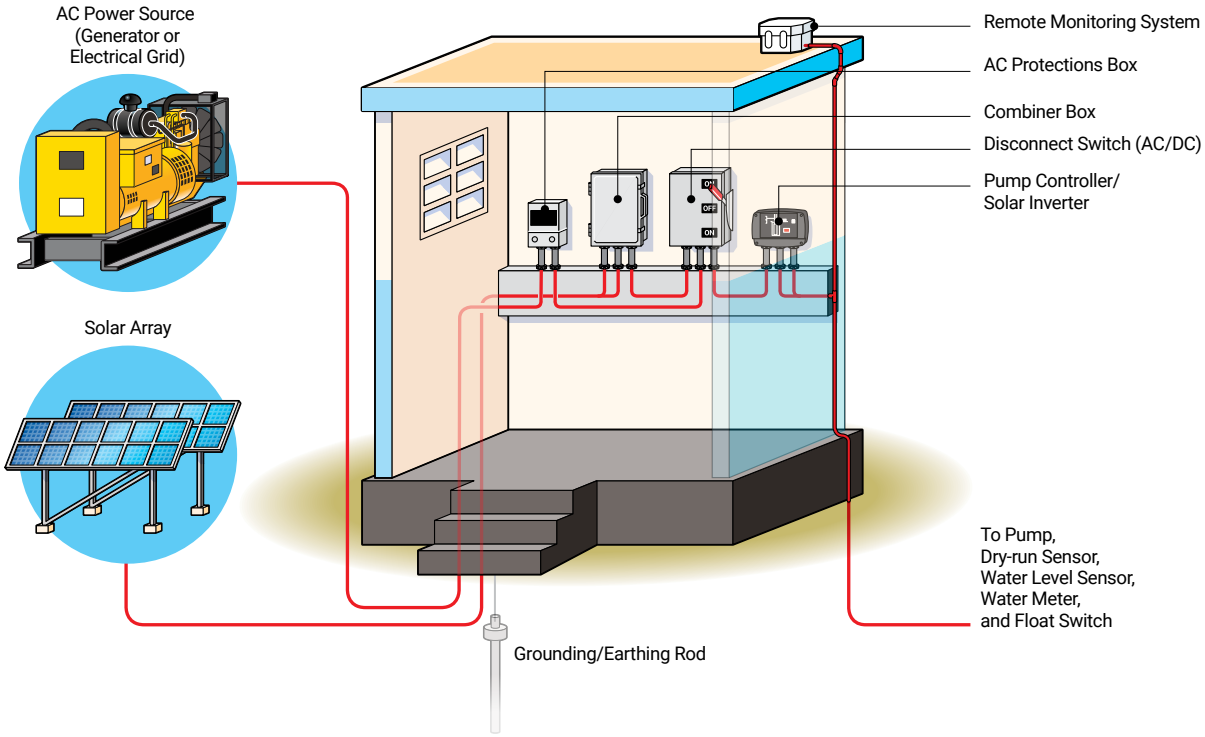
- First, start the generator according to the product manual startup procedure.
- Second, turn the disconnect switch to the AC/Generator position.



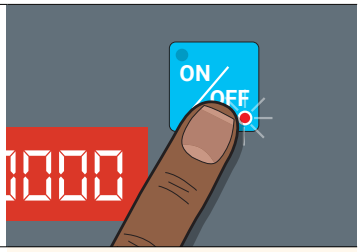
3 Turn the pump ON at the pump controller. Monitor the power input information and any other relevant data that appears.



D. HYBRID: HOW TO SHUT DOWN

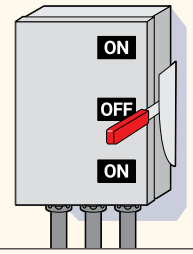


1 Turn the pump off on the pump controller.



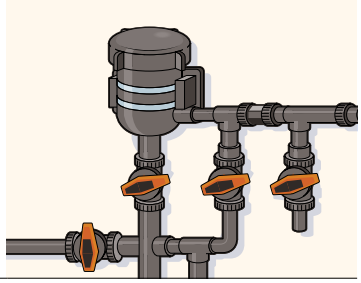
2 Shut off the power supply by turning the 3-way disconnect, or "transfer", switch to the "OFF" position.

If using a diesel/petrol generator, shut down the generator according to the product manual shutdown procedure.



3 Close valves at the chlorinator. After the water has stopped flowing through the system, adjust valves to their correct shutdown position to prevent a buildup of chlorine in the water.

**Refer to the water treatment system manual for the correct positions.*

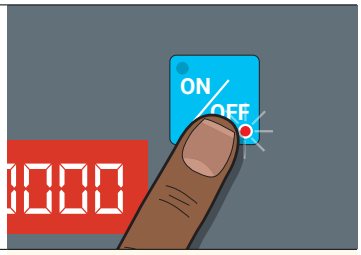


3-way Disconnect (middle) and Pump Controller (right) at the Newa Community project (Kenya)
SOURCE: WATER MISSION

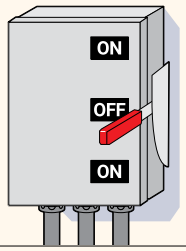
E. HYBRID: HOW TO SWITCH FROM SOLAR TO ALTERNATE POWER

In certain situations, it may be necessary to switch the power source from solar to the generator or grid system following these steps:

1 Turn the pump off on the pump controller.

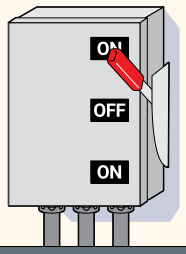


2 Turn the 3-way disconnect switch to the middle "OFF" position.

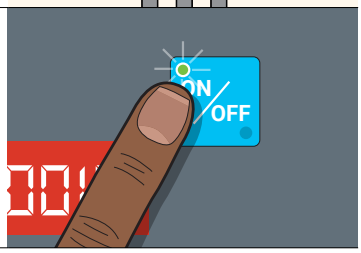


3 Turn the 3-way disconnect switch to the upwards "AC" position.

**NOTE: Let the pump sit for 2 minutes because the voltage rush may damage the pump.*



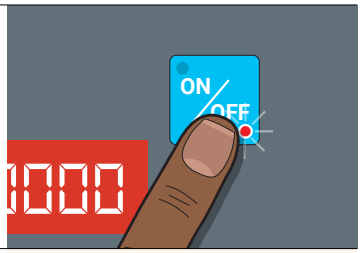
4 Start the pump on the controller.



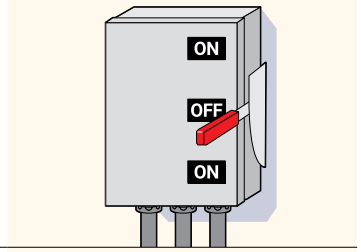
F. HYBRID: HOW TO SWITCH FROM ALTERNATE POWER TO SOLAR

In certain situations, it may be necessary to switch the power source from the generator or grid system to solar using the following steps:

1 Turn the pump off on the pump controller.

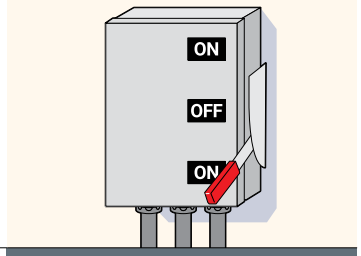


2 Turn the 3-way disconnect switch to the middle "OFF" position.

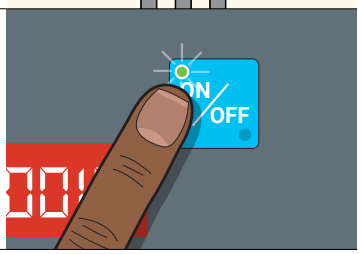


3 Turn the 3-way disconnect switch to the downwards "DC" position.

**NOTE: Let the pump sit for 2 minutes because the voltage rush may damage the pump.*



4 Start the pump on the controller.



3-way Disconnect (middle) and Pump Controller (right) at the Newa Community project (Kenya)
SOURCE: WATER MISSION

7.2 How to Clean Solar Panels

Be sure to wash during the early hours before it gets too hot.

1. Remove jewelry, belts, etc. that may scratch the panels.

2. Organize your supplies:
   - A soft, non-abrasive sponge or cloth to avoid damaging the panels.
   - A bucket of clean water with NO SOAP.
   - A ladder, if needed.
   - A squeegee or tool to remove the excess water to prevent spotting.

3. If possible, attach the cloth to a long-handled brush to reach the edges of the panels more easily.

4. Gently wipe the surface of the solar panels to remove all dust and dirt.

5. Run water from top slope to bottom so that the dust and dirt run off the panels.

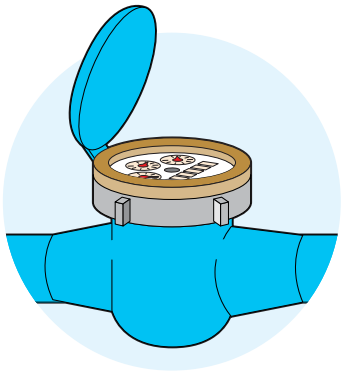
6. Remove the excess water with a squeegee or dry cloth to avoid residual spots.
   **Residual soap or water spots will impact the power output of the panels.*

Use a soft cloth with water (no soap) to clean the surface of the solar panels.
SOURCE: UNICEF

7.3 How to Perform Daily Data Recording

A. READING THE WATER METER

All water meters display a “meter reading,” which is the volume of water that has passed through the pipes since the meter was installed.



Instructions

1. Before starting the pump, record the meter reading under “Meter Reading: Start” on the *Daily Water Production* form.

2. After stopping the pump, record the meter reading under “Meter Reading: End” on the *Daily Water Production* form.

   **If you use two different power sources during the day, make sure to record the start and end water meter readings for each power source.*

Close up of water meter face. Test the meter to ensure it is accurate.

B. READING THE PRESSURE GAUGE

Pressure gauges are commonly installed at the wellhead to measure the pump pressure. The pump pressure should be recorded at least once per day at a consistent time.

Instructions

1 Record the pump pressure every day at noon.

This can be changed per system. Recording at the same time per day is important, but what time matters less. For SPWS, noon is a great time for data recording.

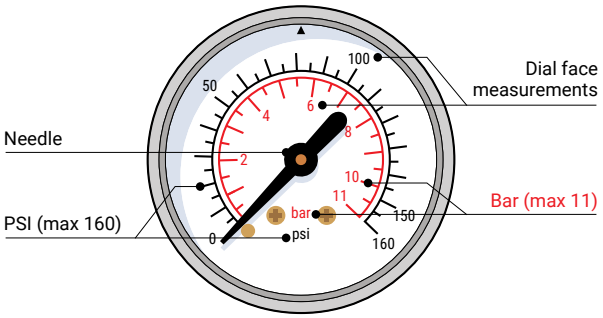
2 View pressure on the pressure gauge (indicated by the needle).

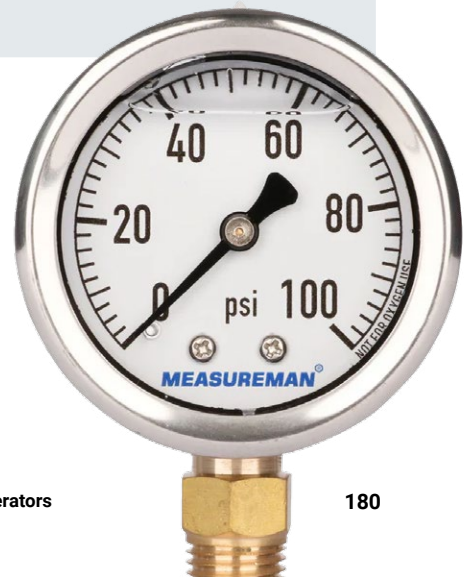
3 Record the number and units (PSI is most common) on the *Daily Maintenance Tasks* form.

4 On the form, check for readings that differ significantly from other daily recorded data.

The "expected range" will vary for each system and refers to the typical pressure readings that are observed. For instance, if the daily pressure averages around 8 Psi and then suddenly drops to 4 Psi, this signals a problem that needs to be addressed promptly.

If the pressure is outside the expected range, contact the System Technician .

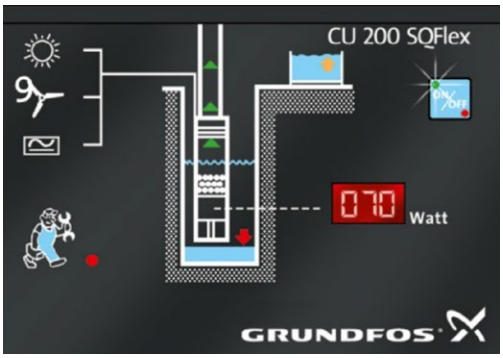




C. READING ELECTRICAL DATA ON THE PUMP CONTROLLER

Electrical data will be available on the LCD screen on the front panel of the pump controller. Typically, this electrical data includes power readings. The voltage and current may also be available depending on the equipment installed.

The pump controller for this system is: *Grundfos CU200*



Instructions:

1. Electrical parameters should be recorded at least once per day at a consistent time. For this system, record the power every day at noon.

2. View the front panel of the pump controller to find the power display (digital output of red numbers).

3. Record the power and the units (kilowatts or watts) on the *Daily Maintenance Tasks* form.

4. Check for readings that differ significantly from other daily recorded data.

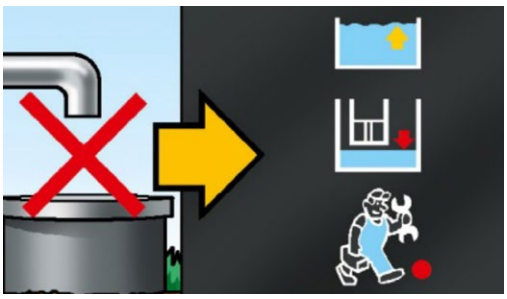
   The "expected range" varies for each system and refers to the typical power readings that are observed. For instance, if the power usually records around 1.4 kW but suddenly drops to 0.6 kW, it indicates a problem that needs immediate attention.

If the electrical parameters are not in the expected range, contact the System Technician .

D. READING ALARMS ON THE PUMP CONTROLLER

Alarms will appear as LED status lights on the front panel or LCD screen of the pump controller.

The pump controller for this system is: *Grundfos CU200*



Instructions:

1 Check for alarms on the pump controller

- After turning the pump on.
- At any time during the day if the pump unexpectedly turns off.
- If there is no water flowing when the pump is on.

2 View the front panel of the pump controller to see the alarms (LED lights). The most common alarms are:

a. TANK FULL (yellow UP arrow in tank):

b. WELL DRY (red DOWN arrow in well): **Contact the System Technician**

c. FAULT (red LED light by technician figure): Check to see if the pump is running.

3 I**f the pump is running,** the pressure is showing in normal range, and there are no unusual sounds, **contact the System Technician** to help determine the cause of the fault (there could be an internal error in the pump controller).

4 If the pump is not running, the system may need to be re-started. To re-start the system, first follow the system shutdown procedure to ensure that the pumping system is off. Then follow the startup procedure.

**Check the troubleshooting guide for any other solutions.*

When in doubt, contact the System Technician.

7.4 How to Perform Daily Water Quality Tests

The System Operator is responsible for performing daily water quality tests to ensure that the water being produced is safe for human consumption.

A. TESTING FOR CHLORINE RESIDUAL

The Hach Chlorine Color Wheel

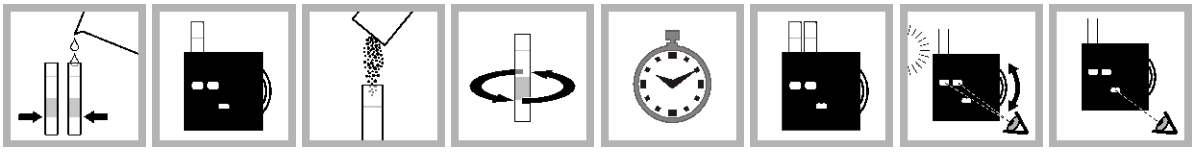
Chlorine is used as a disinfectant for water treatment, meaning that it inactivates pathogens such as bacteria and viruses to make the water safe for human consumption. Too little chlorine will leave dangerous pathogens in the water. Too much chlorine will make the water unacceptable to the consumer.

The chlorine residual (or "free chlorine") should be tested daily by the System Operator at two different community access points: the one closest to the water storage tank and the one farthest from the water storage tank.

Chlorine residual goal: 0.2-0.5 mg/L

The chlorine test kit used at this system is the *Hach Chlorine Color Wheel*

Test procedure — Free or total chlorine (0–3.4 mg/L Cl2)



	Instructions:
1	Fill two tubes to the first line (5mL) with the water sample.
2	Put one tube into the left opening of the color comparator box.
3	Add one DPD (Free) chlorine powder pillow to the second tube only.
4	Swirl to mix. A pink color develops.
5	Read the result within 1 minute.
6	Put the second tube with the powder into the color comparator box.
7	Hold the color comparator box in front of the light source. Turn the color disc to find the color match.
8	Read the result in mg/L in the scale window.

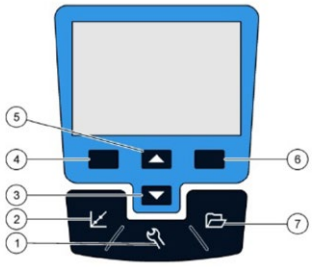
B. TESTING FOR TURBIDITY

Turbidity refers to the cloudiness of water, or the amount of physical dirt found in the water. When the turbidity of the water is above 1 NTU the capacity of chlorine to disinfect the water is reduced. So, turbidity should be monitored for systems that use filtration or have concerns with turbidity based on the yearly raw water quality tests.

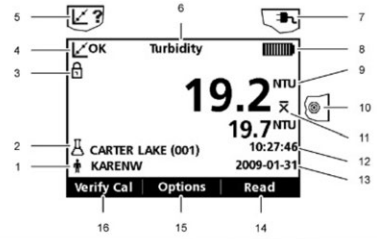
The turbidity should be tested daily by the System Operator at two different community access points: the one closest to the water storage tank and the one farthest from the water storage tank.

Turbidity goal: < 1 NTU

The turbidity test kit used at this system is the *Hach 2100Q Portable Turbidimeter*



1 **SETTINGS** key: select menu options for setting up the meter	5 **UP** key: scroll through menus, enter numbers and letters
2 **CALIBRATION** key: shows calibration screen, start calibration, select cal options	6 **RIGHT** key (contextual): read turbidity sample, selects or confirms options, opens/jumps to sub-menus
3 **DOWN** key: scroll through menus, enter numbers and letters	7 **DATA MANAGEMENT** key: view, delete or transfer stored data
4 **LEFT** key (contextual): access for calibration verification, cancels or exits the current menu screen to the previous menu screen	



1 Operator identification	9 NTU (Nephelometric Turbidity Unit) or FNU (Formazin Turbidity Unit)
2 Sample identification	10 Reading mode: Rapidly Settling Turbidity (Target icon)
3 Stability or display lock indicator	11 Reading mode: Signal Average (X-bar icon)
4 Calibration status indicator (Calibration OK=pass)	12 Time
5 Calibration status indicator (Calibration ?=fail)	13 Date
6 Parameter title	14 Read (contextual: OK, Select)
7 AC power icon	15 Options (contextual)
8 Battery icon	16 Verification calibration

Instructions

1. Use the glass vial that has been provided to collect a water sample from the community access point. Securely close the vial.
2. Wipe the outside of the glass vial to remove all water spots and fingerprints.
3. Open the cap on the turbidimeter, insert the glass vial and securely close the cap.
4. Turn on the turbidimeter by pressing the blue power button.
5. Press the “Read” button and wait for the result to display on the screen.
6. Record the turbidity using the *Daily Water Production* form.

7.5 How to Perform Weekly Visual Inspections

Weekly maintenance checks require visual inspections of several areas of the system.

A. STRUCTURE INSPECTION

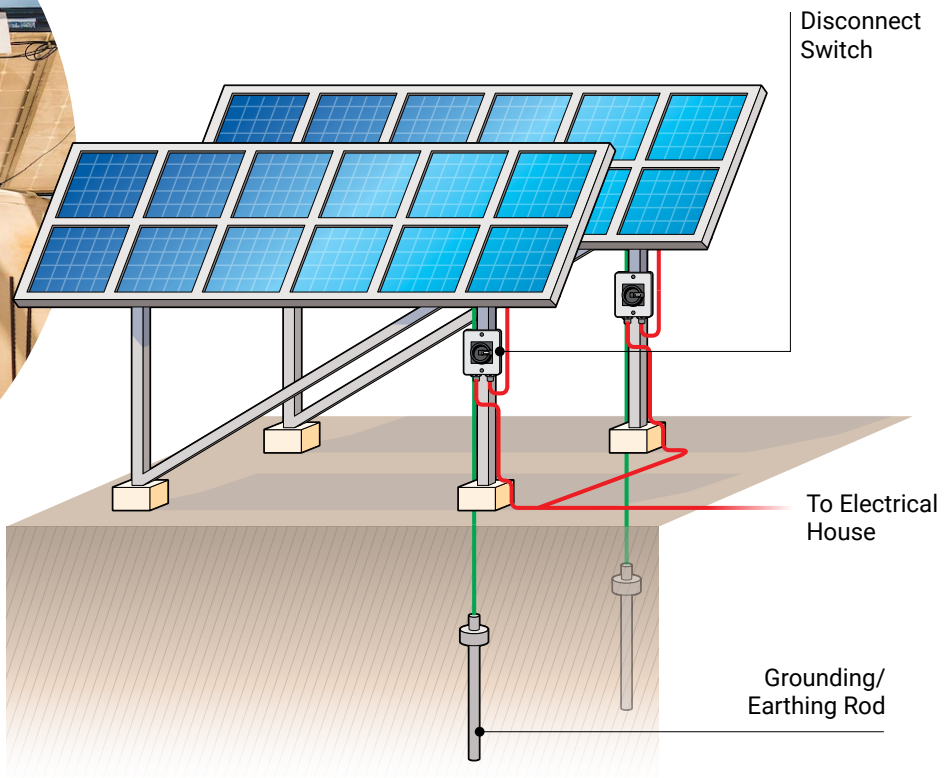
Solar structure inspections should check for:

1 Signs of damage, cracks, corrosion, or rust.

2 Signs of leaning. Look at the whole structure from all sides to determine if the structure or panels are leaning in any one direction.

Actions: If there are signs of rust or corrosion, brush the area to remove the corrosion and repaint the area with an anti-corrosive paint to prevent further weakening or corrosion. If there are any signs of damage or leaning, **contact the System Technician** .

SOURCE: WATER MISSION



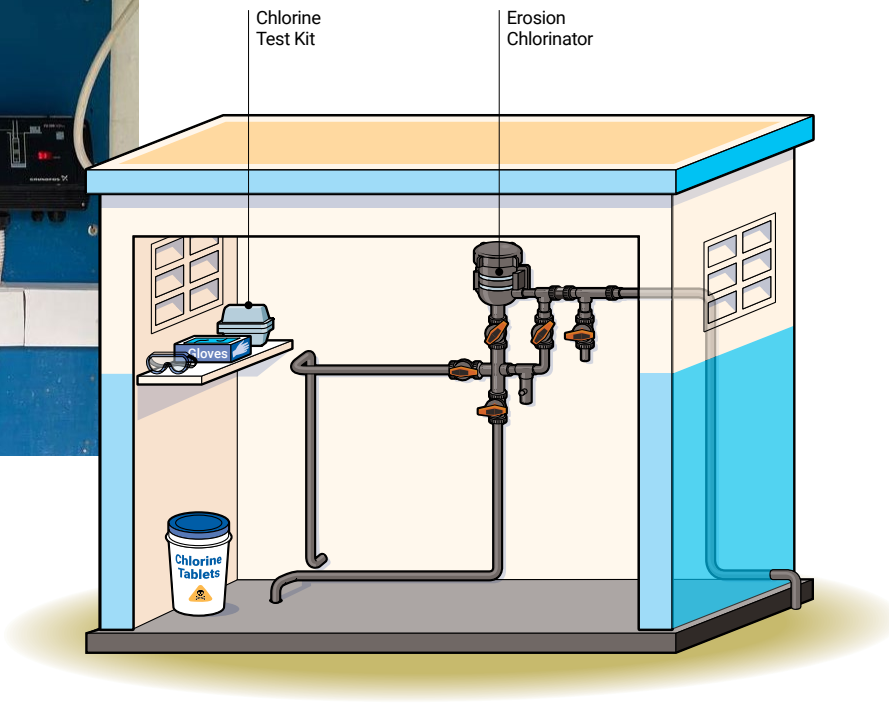
Electrical house and water treatment house inspections (exterior and interior) should check for:

1 Signs of cracks or damage in the walls, foundation, or roof.

2 Check for signs of damage at the entrances or exits of conduits.

Repairs: Repair minor cracks or issues on the foundation or walls with mortar.

Depending on the problem, roof damage may require replacement or repair of roofing material. For roof damage or other serious signs of damage, **contact the System Technician** .

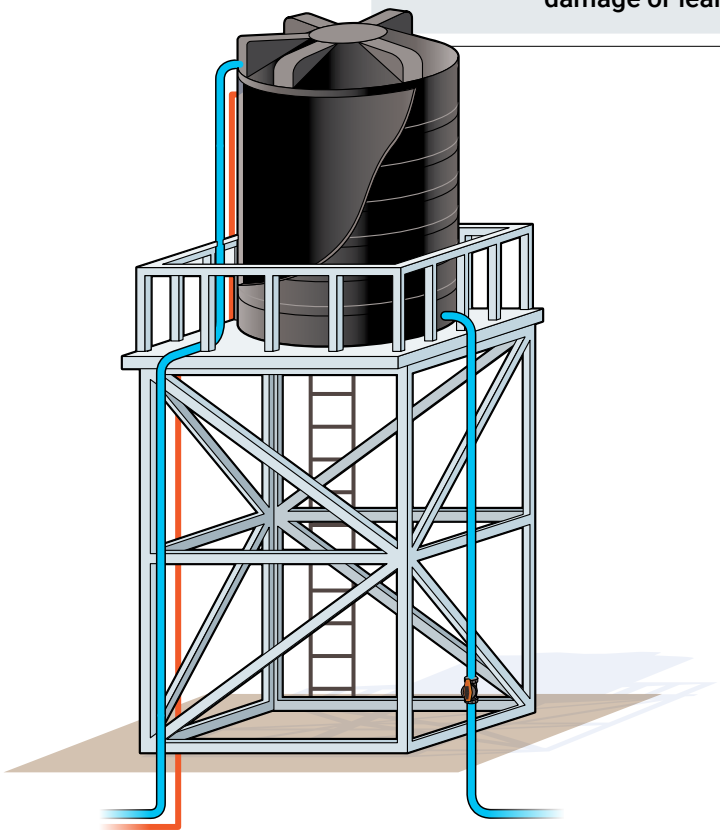


Water storage structure inspections should check for:

1 Signs of damage, cracks, corrosion, or rust.

2 Signs of leaning. Look at the tank structure and tank from all sides to determine if the structure or tank are leaning in anyone direction.

Actions: If there are signs of rust or corrosion, brush the area to remove the corrosion and repaint the area with an anti-corrosive paint to prevent further weakening or corrosion. If there are any signs of damage or leaning, **contact the System Technician** .



B. ELECTRICAL BOXES AND EQUIPMENT INSPECTION

Check for the following:

1. All electrical boxes and equipment have covers that are securely shut.

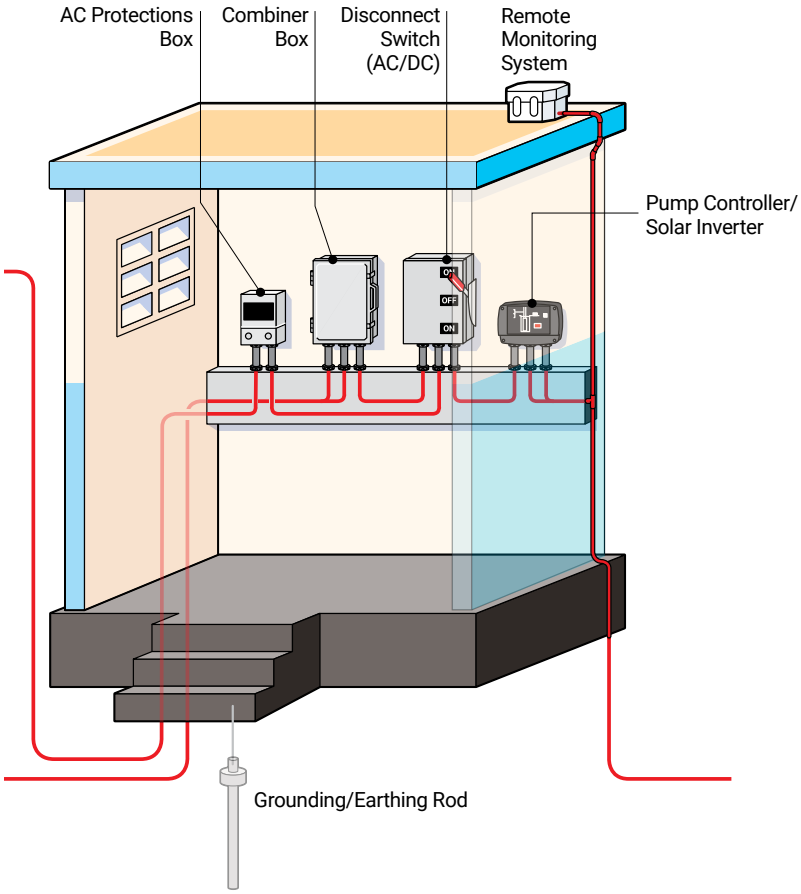
2. All electrical boxes are securely mounted to the wall.

3. All electrical boxes are sealed. This means there are no gaps around where the cover closes or where wires/conduits enter. There should be no holes or areas that allow you to see inside the box. If there are, this means water, dirt, insect, or rodents could enter and cause serious harm.

4. No signs of damage or electrical burns (blackened areas).

If any signs of damage are found, contact the System Technician .

If any holes are found, plug the hole until the System Technician can repair it.



C. WIRING AND CONDUIT INSPECTION

Check for the following:

1. All wires and conduits should be neatly routed and secured to surfaces using cables ties and support clamps. shut.

2. All wires and conduits should be held securely in place when entering/exiting electrical boxes or equipment. There should be no gaps between the wires or conduits and the wall of the electrical box or equipment.

3. There should be no disconnected, loose, or frayed wires.

4. There should be no damaged or exposed wires. The wire insulation should be fully intact and undamaged.

5. All conduits should be undamaged and conduit connections should be secured, tight, and sealed to prevent entrance of water, dirt, or insects.

6. All buried wires and conduits should be properly covered and marked so that erosion or digging does not expose or damage the wires.

If there are any issues or damage found, contact the System Technician .

D. GROUNDING SYSTEM INSPECTION

Check for the following:

1. The grounding rods look secure in the ground and there has been no erosion or shifting in the area.
2. There are no visual signs of damage to the grounding rod.
3. The connection of the grounding wires to the ground rods look secure, with no corrosion, damage, or loose connections.
4. Check that the lightening arrestor is secure (if applicable).

If there are any visible signs of damage or disconnection, WARNING these could be deadly or costly!* ***Contact the System Technician to request support.*

E. PIPING LEAKS AND EXPOSURE INSPECTION

During the inspection, walk the pressure line from the pump to the tank as well as all distribution pipes between the storage tank and community access points, checking for the follow items:

1. Visible leaks or signs of leaks along all piping, pipe connections, and valves. (signs of leaks include wet ground or pooling water).

Actions: If a pipe shows signs of leakage from a crack or damage, contact the System Technician to repair or replace the pipe.

- If a valve or pipe connection is leaking, tighten the fittings carefully to ensure the fittings are snug. Take care not to overtighten the fittings, which could reduce the thread quality and risk further leakages.

  If the fittings still leak,* ***contact the System Technician.*
- If any leaks are found on the pressure line (between the pump and water storage tank), repairs will require a shut down of the pumping system.

2 Look for any exposed pipe. This includes sections not properly covered and buried or where erosion or digging has exposed the pipe.

Actions:

- **If any pipes are exposed, re-bury the pipe by carefully re-digging the trench around and beneath the pipe, burying the pipe, and covering it again with dirt.**
- **Check the area for visible signs of leaks to ensure the pipe has not been damaged while it was exposed.**

If the pipe has been damaged, contact the System Technician .

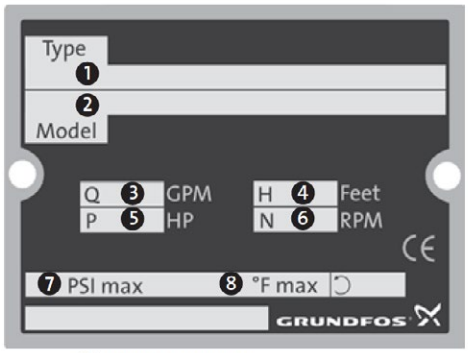
7.6 How to Perform Weekly Inventory

A. IDENTIFYING PART NUMBERS

All project equipment should be clearly labelled by the manufacturer with a part number, type, or model. This data is important to keep track of equipment and to request warranty or troubleshooting support from the manufacturer, when needed.

Here is an example of how to read a Grundfos pump label:

Reading the Pump Nameplate



1. Type designation
2. Model, material number, production code
3. Gallons per minute at rate RPM
4. Head in feet at nameplate flow
5. Pump horsepower
6. Rated RPM
7. Maximum PSI
8. Maximum fluid temperature

B. CHECKING INVENTORY

Use the *Consumables, Tools, and Spare Parts Inventory List* to perform a weekly inventory of all necessary project consumables, equipment, tools, and consumables.

1. Check and count all available stock of equipment, tools, water treatment chemicals, etc.
2. Compare the available stock with the “minimum required” to determine if any parts need to be ordered.
3. Note any parts that need to be ordered.
4. Make note if any tools or equipment are damaged or need servicing.

Consumables, Tools and Spare Parts Inventory List

Item	Quantity	Notes
Hard Hat		
Gloves		
Respirator or Mask		
Eye Protection		
Ear Protection		
Ladder		
Screwdrivers		
Pliers		
Cleaning Cloths		
First Aid Kit		
Multimeter		
Log Book (Extra Checklists and Forms)		
Chlorine Treatment Chemicals		
Turbidity Tubes		
Free Chlorine Test Kit		
Free Chlorine Reagent Packets		
Other...		

7.7 Troubleshooting Issues

Troubleshooting issues that come up while operating and maintaining systems is a core part of the System Operator's role. The troubleshooting processes depend on the specific components of the system because of the product brands and types involved.

These troubleshooting tables, below, are only a quick guide for common problems that may be encountered with a solar pumping system. Reference should be made to the manufacturer manuals for comprehensive troubleshooting procedures.

A. HOW TO USE THE TROUBLESHOOTING TABLES

1. Go through the tables to find the issue that needs troubleshooting.
2. The Checks column is listed in order of process.
3. Once you do the check, read the Actions column and perform the suggested action.
4. Then, check to see if the issue continues. If it is not resolved, continue with the next Check/Action.
5. If the issue persists once you have done all the Checks and Actions that seem appropriate– **Call the System Technician**  **immediately.**

B. TROUBLESHOOTING PUMP ISSUES

Pump Issues			
Issue	**Possible Cause**	**Check**	**Actions**
Pump does not start/run.	Power supply to the pump has been cut off by the float switch or dry-run protection.	Check if the tank-full light appears on the pump controller. Check if the source-low light appears on the pump controller.	Tank is full – the pump will come on with water use. The pump will come on when source recharges. **If this happens regularly, inform management as there may be an issue with the borehole.*
	No or low power reaching the pump controller.	Check that the main disconnect switch is in the proper "On" position. Check if the solar panels are clean.	Turn the disconnect switch to the appropriate "On" position. Clean the solar panels.
	If the above does not solve the issue, **contact the System Technician** The problem could be incorrect wiring of the solar panels, a failed connection between the solar panels and pump controller, a tripped circuit breaker or burned-out fuse, or a fault dry-run sensor, all of which will require the assistance of the **System Technician** to diagnose and remedy.		
Pump attempts to start at intervals (will start to run or just vibrate).	Low power reaching the pump controller.	Check if the solar panels are clean.	Clean the solar panels.
	Pump or pipe is clogged or blocked.	Check if water output is discolored or silt laden, or if there is any obvious sign of blockage.	**Contact the System Technician** to pull out pump to clean the pipes.
	If the above does not solve the issue, **contact the System Technician** The problem could be that the pump wiring is incorrect or that there are loose or failed connections, all of which will require the assistance of the **System Technician** to diagnose and remedy.		

Pump Issues			
Issue	**Possible Cause**	**Check**	**Actions**
Pump runs but no water is delivered.	Surface valves are shut.	Check if any valves are closed.	Open all valves.
	Broken riser pipe.	Check pipes by listening near the borehole for any unusual sounds like dripping, gurgling or knocking of air.	**Contact the System Technician** to pull out the pump and replace worn out pipes.
	Solar power is not strong enough for pump to run.	Check if the solar panels are clean. Check if there is a passing shadow or if the weather is overcast.	Clean the solar panels. Wait for the shadow to pass or for the weather to improve.
	If the above does not solve the issue, **contact the System Technician** The problem could be that the pump wiring is incorrect, the check valve is faulty, the pump suction is blocked, or the pump/motor coupling is broken, all of which will require the assistance of the **System Technician** to diagnose and remedy.		
Pump runs but the flow rate is lower than expected.	Leaking riser pipe or supply pipe.	Check pipes by listening near the borehole, for unusual sounds like dripping, gurgling, knocking.	**Contact the System Technician** to replace worn-out pipes and fittings.
	Pump or pipe is clogged with mud.	Check if water output is discolored or silt laden.	**Contact the System Technician** to either unclog the pipes or pull out the pump to unclog.
	The valves at the wellhead or in the supply pipe are partially closed or clogged.	Check if any valves are closed. Check if any valves are clogged.	Open all valves. Clean valves or **contact the System Technician** to replace the valves.
	If the above does not solve the issue, **contact the System Technician** The problem could be that the pump wiring is incorrect or there is insufficient power reaching the pump controller , all of which will require the assistance of the **System Technician** to diagnose and remedy.		

Pump Issues			
Issue	**Possible Cause**	**Check**	**Actions**
Pump starts and stops too frequently.	Leaking check valve.	With the pump off, listen for water running back into the well and check the water flow meter to see if it is running backward.	Replace the check valve.
	The float switch in the storage tank is installed incorrectly.	Check if the float switch is installed properly to allow full draining and filling.	Adjust the float switch- **contact the System Technician** for assistance if needed.
	Water level in the well is dropping,	Check for faults on the pump controller that would indicate the dry-run sensor is stopping the pump or check remote monitoring data (if available) to determine if the water level in the well is dropping too low.	Wait for the water source to recharge – if the issue is recurring, **contact the System Technician** to determine if over-pumping is occurring.
Pump pressure has increased.	Fully or partially closed valves or partially blocked pipe along pressure line (between pump and tank).	Walk the transmission line to see if there is an obvious problem. Ensure all valves are fully open.	**Contact the System Technician** to fix pipe damage. Open all valves.
		If there is a filtration system included in water treatment, check the filters.	If filters are clogged, replace.

C. TROUBLESHOOTING ELECTRICAL COMPONENTS ISSUES

Electrical House Issues		
Issue	**Possible Cause**	**Action**
Disconnect switch is over-heating.	The current reaching the switch is higher than it is rated for.	**Contact the System Technician .**
Pump controller (or solar inverter) is over-heating.	The ventilation on the pump controller is blocked due to dust.	Regularly check and clean the ventilation (and cooling fins, when present) to promote cooling.
Solar inverter isolation fault.	A short-circuit in the inverter due to moisture, damage to wire insulation, faulty installation, loose wire connections.	Ensure the inverter is sealed properly, including the cable glands where the wires enter the inverter. **Contact the System Technician .**
Solar inverter does not restart after grid fault (if connected to electrical grid).	A voltage peak during the fault triggered a system outage.	**Contact the System Technician .**

D. TROUBLESHOOTING TANK ISSUES

Tank Issues		
Issue	**Possible Cause**	**Action**
Tank is overflowing.	The float switch may be defective.	**Contact the System Technician .**
Connections to or from the tank are leaking.	The gasket may be deteriorating.	**Contact the System Technician .**
Tank is leaning or the tank stand is damaged.	Physical damage.	**Contact the System Technician .**

E. TROUBLESHOOTING WATER ACCEPTABILITY ISSUES

Water Acceptability Issues		
Issue	**Possible Cause**	**Action**
Taste and odor complaints.	Long retention time of water in tank. Growth of algae or other organisms inside tank. Contaminant entry (into tank or break in distribution piping). Leaching from materials (coating on pipes or inside tank). Source water quality, such as high levels of hydrogen sulfide.	**Contact the System Technician .**
Water tastes of chlorine, complaints of high levels of chlorine during testing.	Chlorine dosage is too high.	Test chlorine levels at all distributions points. Lower dosing, as needed. If the problem continues, **contact the System Technician .**
Red water.	Metals uptake from metal surfaces (if metal piping). Iron or manganese in water.	**Contact the System Technician .**
Water appears turbid, has visible sediment, or a light tan color.	Storage tank is contaminated or rusty.	**Contact the System Technician .**
	Change in water source quality or surface water is entering and influencing the well.	**Contact the System Technician .**
	If there is a filtration system included in water treatment, check the filters.	If filters are clogged, replace them.

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Please cite this report as follows:

Global Water Center. (2024). Solar Powered Water Systems Operations and Maintenance Guide. https://globalwatercenter.org