Technical options and construction supervision
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Abbreviations

AC Alternating current
BW Bore well
CAPEX Capital Expenditure
CBA Cost benefit analysis
CBM Community Based Monitoring
CPHEEO Central Public Health and Environmental Engineering Organisation
CPWD Central Public Works Department
DC Direct current
DPR Detailed Project Report
GI Galvanized Iron
GP Gram Panchayat
HDPE High-density polyethylene
HGM Map Hydrogeo-Morphological Map
HP Horsepower
IEC International Electro technical Commission
INR Indian Rupees
IS International Standards
kg Kilogram
LCCA Life cycle cost analysis
lit Liters
LLDPE Linear low-density polyethylene
LPCD Litres per Capita per Day
MB Measurement book
mm millimetre
mtr meters
O&M Operation and Maintenance
PCC Plain cement concrete
PHED Public Health Engineering Department
PV Photovoltaic
RCC Reinforced Cement Concrete
RWS Rural Water Supply
SSD Saturated Surface Dry
SWP Solar Photovoltaic Water pumping
TDH Total dynamic head
TW Tube well
uPVC unplasticized polyvinyl chloride
VWSC Village Water and Sanitation Committee
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4.1. Introduction:

The Swajal scheme is mini pipe water supply schemes preferably with the workable options that are easily planned, erected and installed by community, and are easy in operation and maintenance at local level. The core element of Swajal is enabling the community in choosing its own water supply option which is socially acceptable, economically affordable, environmentally responsible and sustainable. The first step in facilitating the community driven option selection process is to appreciate various technical options available for each sub work of the mini water supply scheme. The existing water supply schemes e.g. hand pumps could be upgraded/retrofitted to be converted in power pump and tank schemes, to ensure running water availability to the community. There are many options to power pumps; one of the emerging options is solar pumps and solar dual pumps depending on site specific conditions. Solar pumping is preferred as it has very low O&M costs & little maintenance and is environmentally responsible.

India has a very good solar radiation of 4 to 7 KWh/square meter per day and highest global solar radiation on horizontal surface. Thus India has the most favourable conditions for solar energy production and consumption. Solar energy is known to be renewable energy and environment friendly technology and therefore should be promoted in order to reduce the burden on conventional energy sources and save earth from Green House gas emissions resulting out of coal burning. All other sectors have already shifted on this option. Hence understand use of it in drinking water sector.

In this section we will look at various options available for source, pumping system, storage tanks, tap stands, private connection and chlorination.

Following table presents various technical options available for each sub work of a pump and tank based water supply scheme.

<table>
<thead>
<tr>
<th>No</th>
<th>Sub Work</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Source</td>
<td>Bore well</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tube well</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dug well</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spring</td>
</tr>
<tr>
<td>2.</td>
<td>Pumps</td>
<td>Electrical surface (Centrifugal) Pump</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrical Submersible Pump</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrical / Solar Dual Pump</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solar surface AC/ DC Pump</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solar Submersible Pump AC/DC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No</th>
<th>Sub Work</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Storage Tank</td>
<td>Zinc Aluminium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LLDPE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RCC</td>
</tr>
<tr>
<td>4.</td>
<td>Chlorination</td>
<td>Bleaching powder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online chlorinator</td>
</tr>
<tr>
<td>5.</td>
<td>Pipe line</td>
<td>HDPE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gi</td>
</tr>
<tr>
<td>6.</td>
<td>Tap Stand</td>
<td>Gi</td>
</tr>
</tbody>
</table>
4.1.2. Appreciating the options:

Each of these options has advantages and disadvantages. There are specific considerations for each option which make them more suitable for a particular context. Following table presents the options for each sub work and its key features and considerations.

a) Source:

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore well IS 2800-1 (1991) : Code of Practice for Construction and Testing of Tube wells/Bore wells, Part 1: Construction</td>
<td>• Mainly in hard strata • Yield and quality need to be certified by the competent authority • It is simple and economical • Existing Bore wells can be retrofitted based on certification of yield and quality</td>
<td>• Location needs to be selected carefully by the Hydro-geologist, and certified for designed yield. • Drilling up to desired depth as prescribed by the competent authority and local conditions • The depth of casing pipe as prescribed by the competent authority.</td>
</tr>
<tr>
<td>Tube well IS 2800-1 (1991) : Code of Practice for Construction and Testing of Tube wells/Bore wells, Part 1: Construction</td>
<td>• Mainly in alluvium strata • Yield and quality need to be certified by the competent authority • Tube well needs to be developed scientifically • As compared to bore well higher cost • Existing Tube wells can be retrofitted based on certification of yield and quality.</td>
<td>• Location needs to be selected carefully by the Hydro-geologist, and certified for designed yield. • Drilling up to desired depth as prescribed by the competent authority • The depth and design of casing pipe as prescribed by the competent authority • Development/ Flushing needs to be carried out until crystal clear water is available.</td>
</tr>
<tr>
<td>Dug well</td>
<td>• In case of shallow aquifer • Yield and quality need to be certified by the competent authority • As compared to bore well it is time consuming and expensive • Higher land requirement • Protection of well is a must to stop any chances of nearby contaminations reaching well water</td>
<td>• In case of collapsible strata construction of weep holes is mandatory, • Trial bores to the recommended depth is mandatory • Multiple choices of construction material, RCC and masonry</td>
</tr>
</tbody>
</table>
During the assessment process identification of the potential sources in the village needs to be identified through collaboration with hydro geologist HGM maps and the community. Community need to be consulted for the traditional water sources, Streams and watershed to understand the natural runoff, percolation and collection patterns.

b) Pumps:

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>• Natural source</td>
<td>• RCC or masonry spring box and storage needs to be constructed</td>
</tr>
<tr>
<td></td>
<td>• Sustainability and seasonality needs to be confirmed</td>
<td>• Water filter needs to be integrated</td>
</tr>
<tr>
<td></td>
<td>• Yield and quality need to be certified by the competent authority</td>
<td>• Pollution protection interventions</td>
</tr>
<tr>
<td></td>
<td>• Need to check catchment for pollution risk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Distance from the habitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Easy and safe accessibility for construction and O&amp;M</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Surface/ Centrifugal IS : 8034</td>
<td>• Reliable electrical supply has to be available</td>
<td>• Surface/ Centrifugal pump installed on the open well</td>
</tr>
<tr>
<td></td>
<td>• Suitable for the Open well</td>
<td>• Operating panel board in the nearby protected place, or on the well itself</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pump-set is installed on the girders</td>
</tr>
<tr>
<td>Electrical Submersible IS : 8034</td>
<td>• Reliable electrical supply has to be available</td>
<td>• Submersible pump installed on the BW/TW/open well</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Operating panel board in the nearby protected place</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• For open well pump-set is installed on the girders</td>
</tr>
<tr>
<td>Electrical Dual Pump IS : 8034</td>
<td>• Reliable electrical supply has to be available</td>
<td>• Used for BW/TW option</td>
</tr>
<tr>
<td></td>
<td>• The depth of ground water varies and combination of hand pump and power pump is better option</td>
<td>• Depending on the ground water level in BW/TW, the Hand pump may be used</td>
</tr>
</tbody>
</table>
### TECHNICAL OPTIONS AND CONSTRUCTION SUPERVISION

#### Options

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Submersible AC/DC Solar Panels with IEC 61215 and IEC 61730 specifications</td>
<td>• When electric supply is not available or not reliable&lt;br&gt;• Yield is satisfactory in the source&lt;br&gt;• Head is manageable</td>
<td>• Used for BW/TW/Open well option&lt;br&gt;• Solar panels of appropriate wattage, fixed at easily inaccessible heights&lt;br&gt;• Operating panel board</td>
</tr>
<tr>
<td>Solar Dual Pump Solar Panels with IEC 61215 and IEC 61730 specifications</td>
<td>• When electric supply is not available or not reliable&lt;br&gt;• The depth of ground water varies and combination of hand pump and power pump is better option&lt;br&gt;• In case of problem with the operation of solar pump, hand pump can be used.</td>
<td>• Used for BW/TW option&lt;br&gt;• Solar panels of appropriate wattage, fixed at easily inaccessible heights,&lt;br&gt;• Depending on the ground water level in BW/TW, the Hand pump may be used</td>
</tr>
<tr>
<td>Common points</td>
<td>• Pumps delivering water shall be controlled by the level of water in the storages.</td>
<td>• Level control sensor shall be fitted and ensured that the water in the storage shall not overflow and shall also maintain minimum water level.&lt;br&gt;• As the same storage is being proposed to be in use for 30 years, to have control on use of water in initial years minimum level in the tank shall be set at higher level compared to lowest water level.</td>
</tr>
</tbody>
</table>

#### c) Storage tanks

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE: (LLDPE) Linear Low Density Polyethylene IS : 12701 Rotational Moulded Cylindrical Vertical Water Storage Tank (Double Layer)</td>
<td>• Light weight&lt;br&gt;• Readily available in 100 lit to 10000 lit capacity made up of chemically inert material&lt;br&gt;• Can be installed on the sufficient height and accessible steel structure&lt;br&gt;• Quick installation&lt;br&gt;• Float control can be installed&lt;br&gt;• Reasonable cost&lt;br&gt;• Transportation is easy.&lt;br&gt;• Lid is available and cleaning from inside is possible</td>
<td>• For small habitations storages with 1 to 2 mtr height and diameter are available.&lt;br&gt;• Taken to predetermined height&lt;br&gt;• Inlet, outlet and overflow piping&lt;br&gt;• Compatible with GI/metal piping&lt;br&gt;• Water level indicator to know the level from outside</td>
</tr>
<tr>
<td>Options</td>
<td>Considerations</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>RCC</td>
<td>• Wide range of capacity tanks can be cast in situ.</td>
<td>• RCC structure as per size and shape suitable to the capacity.</td>
</tr>
<tr>
<td></td>
<td>• Skilled job to be done as per design of RCC structures</td>
<td>• It can be on elevated ground or at decided height elevated on RCC columns</td>
</tr>
<tr>
<td></td>
<td>• Comparatively costly for smaller capacities</td>
<td>• Inlet, outlet and overflow piping.</td>
</tr>
<tr>
<td></td>
<td>• Time taking</td>
<td>• Operating valves suitably located</td>
</tr>
<tr>
<td></td>
<td>• Long lasting</td>
<td>• Water level indicator to know the level from outside</td>
</tr>
<tr>
<td></td>
<td>• Needs O&amp;M periodically</td>
<td>• Structure up to top is accessible</td>
</tr>
<tr>
<td></td>
<td>• Costly as compared to HDPE</td>
<td></td>
</tr>
<tr>
<td>Zinc Aluminium</td>
<td>• Wide range of capacity tanks can be installed or quickly assembled on site, at pre-decided height, on a base structure.</td>
<td>• Structure as per size and shape suitable to the capacity.</td>
</tr>
<tr>
<td></td>
<td>• Comparatively costly for smaller capacities</td>
<td>• It can be on elevated ground or at decided height elevated on RCC/masonry footing columns</td>
</tr>
<tr>
<td></td>
<td>• Decent and fresh look</td>
<td>• Inlet, outlet and overflow piping.</td>
</tr>
<tr>
<td></td>
<td>• In built arrangement for storing Rain water.</td>
<td>• Operating valves suitably located</td>
</tr>
<tr>
<td></td>
<td>• Installed quickly as compared with RCC tank</td>
<td>• Water level indicator to know the level from outside</td>
</tr>
<tr>
<td>Common point</td>
<td>• Any selected option shall have minimum storage of 50 % of the demand in a day.</td>
<td>• With the use of level sensor tank water level shall be maintained in such way that it should not overflow and also shall not go dry.</td>
</tr>
<tr>
<td></td>
<td>• It is preferred to start the supply at 65 to 70% of the capacity of the tank.</td>
<td>• In case of more than one tap stands, better choice is to use multiple outlets, right from the tank. It will minimize the operations in the system.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ensure equal pressures on the taps even though they are located at different ground levels.</td>
</tr>
</tbody>
</table>
d) Chlorination

It is most effective system in the context of rural water supply scheme to ensure that water is microbiological contamination free. The details of chlorination process are given in O&M session.

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleaching Powder</td>
<td>• Easily available</td>
<td>• White powder but very unstable at Normal temperature and pressure and reduces chlorine content over a time</td>
</tr>
<tr>
<td>IS : 1065</td>
<td>• Chemically active immediately in solution in water</td>
<td>• Supernatant Water solution is required to be used</td>
</tr>
<tr>
<td></td>
<td>• Chlorine content reduces if kept in open atmosphere</td>
<td>• Calcium residue is to be disposed</td>
</tr>
<tr>
<td></td>
<td>• Needs manual intervention everyday</td>
<td>• Hence a fresh sample shall be more active.</td>
</tr>
<tr>
<td>Online chlorinator</td>
<td>• Compact decent look</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fits online in the given pipeline</td>
<td>Fitted on the installed pipeline from the outlet of the tank leading to Distribution system or stand post.</td>
</tr>
<tr>
<td></td>
<td>• Tablet react with water flow and imparts chlorination to the flowing water</td>
<td>Consists of processing unit and replaceable cartridge</td>
</tr>
<tr>
<td></td>
<td>through pipe line</td>
<td>Tab is used to chlorinate flowing water and consumption is proportional to water flow</td>
</tr>
<tr>
<td></td>
<td>• No manual intervention and power is required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Needs replacement on the complete reduction of the tablet.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Comparatively costly</td>
<td></td>
</tr>
<tr>
<td>HDPE</td>
<td>• Range 16 mm to 1000 mm</td>
<td></td>
</tr>
<tr>
<td>IS : 4984</td>
<td>• Smaller dia. from 16 mm to 63 mm are available in rolls and it involves very</td>
<td>Black in colour, and has no tanning effect.</td>
</tr>
<tr>
<td></td>
<td>less joints</td>
<td>If carefully joint there is a sturdy piping.</td>
</tr>
<tr>
<td></td>
<td>• Jointing in electro fusion method and mechanical compression are available</td>
<td>Open to damage by the heat and heated metal insertion</td>
</tr>
<tr>
<td></td>
<td>both require special tools and equipment.</td>
<td>Rejoining is easy.</td>
</tr>
<tr>
<td></td>
<td>• Chemically inert and long life.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sustains high impact and pressure externally</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sustained Internal pressure is dependent on class of pipe selected.</td>
<td></td>
</tr>
</tbody>
</table>
### TECHNICAL OPTIONS AND CONSTRUCTION SUPERVISION

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
</table>
| PE100 pipes | PE100 pipes are more preferable | • 'C' value is very good  
• Cheaper than Metal pipes  
| uPVC IS : 4985 | Range 16 mm to 310 mm  
• Class 2,4,6 and 10 kg/sq.cm  
• Solvent cement cold process jointed, chemically inert  
• Comparatively at lower cost per meter  
• Preferable in the underground installations as pipes get tanned in sunlight and convert into brittle material  
• 'C' value is very good  
| Common jointing material is easily available  
• Jointing is very easy  
• Prone to temperature effect  
• Grey colored pipes  
• Available in 6 m lengths  
• Compatible for the metal fixtures  
| GI IS : 1239 | Strong material  
• Range 15 mm to 150 mm dia.  
• Corrosion protection by the galvanization  
• In three categories Light, medium and heavy duty  
• Application both above ground and underground  
• Safe and durable  
• Flow characteristics are slightly less compared to HDPE pipes  
• Costly in comparison with HDPE Pipes  
• Sturdy alignment and not affected by the sunlight and heat exposure  
• Joining various accessories is easy.  
| White colored metal pipes  
• Threaded joints and flanged joints variety in larger diameters are available  
• Reliable piping more suited in Pressure mains.  
• Available in straight length of 6 m  
• All specials are easily available in the market  

### f) Tap stand

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
</table>
| Tap stand | Part of public distribution system  
• Two varieties: 2 tap and 4 tap according to requirement  
• All fittings are manly in GI supported by metal frame  
• Taps: self-closing are preferable  
• Wastage on the stand-posts properly disposed through soak pit or drain.  
| Ground level structure.  
• Soak pit is adjoining to stand-post  
• Hard base CC platform to allow the consumers to fill their utensils with water.
g) Private Connection

<table>
<thead>
<tr>
<th>Options</th>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Connection</td>
<td>• 0.5-inch GI connection.</td>
<td>• 0.5 inch connection.</td>
</tr>
<tr>
<td></td>
<td>• Connection with ferrule and saddle piece.</td>
<td>• Ferrule for water pressure.</td>
</tr>
<tr>
<td></td>
<td>• Connection by trained water person under supervision of VWSC.</td>
<td>• Soak pit adjoining to private connection.</td>
</tr>
<tr>
<td></td>
<td>• All fittings are manly in GI supported by metal frame.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Taps: self-closing are preferable.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Wastage from private connections properly disposed through soak pit or drain.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Considering design aspects provide the individual connection.</td>
<td></td>
</tr>
</tbody>
</table>

Combination of mild steel shaft and consumer tanks is also an option for the water distribution.

4.1.3. Block costs:

In Swajal, GP and community are supposed to choose an option which is affordable to them in terms of capital and O&M costs. Thus it is necessary that community is informed about the capital cost and O&M costs of various options. These costs will have to be worked out for each state considering their schedule of rates. Following table presents the indicative capital and O&M costs of various options.

Indicative block cost:

<table>
<thead>
<tr>
<th>No</th>
<th>Sub Work</th>
<th>Options</th>
<th>Capital Cost (in INR)</th>
<th>O &amp; M Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Source</td>
<td>Bore well</td>
<td>40000</td>
<td>1.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tube well</td>
<td>125000</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dug well</td>
<td>250000</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spring</td>
<td>40000</td>
<td>5%</td>
</tr>
<tr>
<td>2.</td>
<td>Pumps</td>
<td>Solar Submersible AC/ DC</td>
<td>As per MNRE Bench mark Cost</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrical Submersible</td>
<td>28000/HP</td>
<td>1.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrical Surface/ Centrifugal</td>
<td>21000/HP</td>
<td>2%</td>
</tr>
<tr>
<td>3.</td>
<td>Storage Tank</td>
<td>LLDPE</td>
<td>8 to 10 per lit</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RCC</td>
<td>25 per Lit for small capacity for ESR and 14/lit for GSR</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zinc Aluminium</td>
<td>10 to 7 per lit for depending on capacity</td>
<td>1.5%</td>
</tr>
</tbody>
</table>
### Technical Options and Construction Supervision

<table>
<thead>
<tr>
<th>No</th>
<th>Sub Work</th>
<th>Options</th>
<th>Capital Cost (in INR)</th>
<th>O &amp; M Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>Chlorination</td>
<td>Bleaching powder</td>
<td>25 per kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online chlorinator</td>
<td>50,000 including installation, protection cage and cartridge sufficient for 25 lakh liters</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cartridge replacement cost Rs. 5000 for 25 lakh liters/1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Pipe line</td>
<td>HDPE</td>
<td>Diameter wise separately attached</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>uPVC</td>
<td>Diameter wise separately attached</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GI</td>
<td>Diameter wise separately attached</td>
<td>1.5%</td>
</tr>
<tr>
<td>6.</td>
<td>Tap Stand</td>
<td>GI</td>
<td>9701 for two taps</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** All block costs are indicative and they need to be worked out separately as per schedule rates of concerned state in each case.

#### 4.1.4. Solar power based water supply System


Solar power based water supply System is an important aspect of Swajal. It is yet to be mainstreamed as one of the major interventions in rural water supply sector. It has been very useful especially in the remote areas and has enhanced the service delivery for the unreached communities. A separate section of the Solar based schemes is presented below for the in depth understanding of various aspects of the solar based drinking water supply schemes.

**Solar Pumping**

Solar photovoltaic water pumping (SWP) uses energy from solar photovoltaic (PV) panels to power an electric water pump. The entire process, from sunlight to stored energy, is elegant and simple shown in figure 1.

**Advantages of solar pumping**

- SWP systems consume little to no fuel. By using freely available sunlight, they avoid the constraints of weak or expensive rural fuel supply networks.
- Unlike diesel-based systems (i.e., where a diesel generator powers the pump), solar pumping produces clean energy with zero or much reduced exhaust gases and pollutants.
- Solar pumping systems are durable and reliable. PV panels have a design life of over 20 years, and solar pumps have few moving parts and require little maintenance (unlike diesel pumps).
- Solar pumping systems are modular so can be tailored to current power needs and easily expanded by adding PV panels and accessories.
- Properly installed solar systems are safe and low risk due to low system voltage. Adequate protection minimizes fire risk.

**Constraints of solar pumping and mitigation**

- Solar pumping systems have high initial capital costs, which can be discouraging.
• Solar pumps still require some servicing, and specialized technicians/providers may be difficult to access in some areas. This is gradually improving.
• Panel theft can be circumvented by sensitizing communities and providing simple antitheft measures.
• SWP can lead to excessive groundwater extraction because operators face near zero marginal-cost of pumping ground-water.

4.1.5. Life-cycle cost analysis

There are several technically viable options for new pumping systems, generally distinguished by their energy source—diesel pump, wind, solar, etc. Cost-benefit analysis (CBA) is often used to assess the economic merits of alternative investment options. Pumping systems typically have a 20-year lifespan, and over that period they incur various costs, some at the outset, and
others at different times throughout the system lifetime. Consideration of all costs incurred during the system lifetime is often referred to as a life-cycle cost analysis (LCCA). LCCA is particularly important for renewable energy projects because of the high initial investment costs. More conventional options may appear cheaper due to lower initial costs; however, operating costs can be considerable over the project life.

Although pumping systems have myriad costs during their lifetime, a proper LCCA would assess at least four key cost elements:

- Initial costs with capital expenditures (CAPEX) and installation/commissioning. These mostly consist of the acquisition of equipment for the solar pump system: PV panels, pump, control system, pipes and fittings, wiring, etc. Initial costs also include design engineering, system installation, commissioning testing and inspection.

- Operation and maintenance (O&M). Operation costs are labor and energy costs related to a pumping system’s operation. They can vary widely depending on the system’s complexity and duty. Security and managerial costs are also included here. Maintenance costs comprise all costs entailed in keeping the system functional, including routine activities (e.g., cleaning solar panels) and small repairs to faulty components. System design can influence O&M costs through construction quality, components used, and ease of access to spare parts.

- Energy. System energy consumption is often one of the largest cost elements in the LCC, especially if the pump runs more than 2,000 hours per year. Solar pumping systems have lower energy supply costs than conventional systems.

- Capital replacements. Some major parts of a pumping system have a shorter design life time than that of the overall system (often 20 years), requiring capital replacements along with the associated costs. The pump, for example, often needs to be replaced after 7–10 years.

### 4.1.6. Major system components

A solar pumping system consists of PV modules, a pump set, a storage tank, electronic components, and interconnected cables shown in below figure 2. Electronics normally include an inverter, power conditioner or pump controller, controls/protections, and water sensors. These are described in more detail below:

**Fig. 2. Basic elements of a solar pumping system**

![Diagram of a solar pumping system](source)

**Source:** Zhuhai MNE Technology Co., Ltd.
PV modules

The energy and power for driving an SWP system comes directly from an array of solar modules of the correct size and specification. The elementary component of a solar module is the solar photovoltaic (PV) cell. The cell directly converts solar radiation into electric current, through the photoelectric effect. The ratio of electric power produced to radiation received is the solar PV cell’s efficiency. For example, if a cell generates 0.15 kW of power for each kW received from the sun, its efficiency is 15%. The semiconductor materials most commonly used in commercial PV cells are crystalline silicon where each PV cell has a single silicon crystal; or polycrystalline modules, where each cell has multiple crystals. Mono-crystalline modules are more efficient than polycrystalline ones (16–17% compared to 14–16% in commercial applications).

Pumps and motors

Pumps physically lift water from source to point of use/storage. Technological progress has radically improved pump performance over the years, with pumps now available for pumping ranges up to 500 meters deep.

Water pumps are driven by electrical motors, which convert electrical energy (produced, in the case of solar pumping, by PV panels) into mechanical energy. Most motors typically run on either direct current (DC), where the electrical flow does not switch direction periodically in the wires; or alternating current (AC), where it does.

DC motors are appealing for solar pumping because PV modules producing direct current can be directly coupled to the motor with limited power conditioning. This makes them an economical option for systems with low water demand and a short cable distance between the PV panel array and the motor. For long-distance cabling, however, low-voltage DC motors are not suitable because of power loss in the cable. DC motors are currently not available beyond the 5 kW thresholds.

AC motors can be used in larger SWP systems, although they require a DC/AC inverter.

Solar pumping systems use two main types of pumps: Submersible and centrifugal.

4.1.7. Solar Dual Pump system

Considering the limitations of human efforts in fetching water from the deeper levels in bore wells and to provide household water supply in the hand pump dependent habitations a dual pump system can be used. In this system 1 HP submersible pump is installed in the bore well in addition to the hand pump cylinder, to pump the water to storage tank for providing household tap water supply. Advantage of annular space available surrounding 95 mm reducer cap of the
cylinder in the bore well of 150 mm dia (150-95 = 55 mm. diametrically 27.5 mm on both side of the reducer cap) is taken to insert another riser pipe of submersible pump. Considering radial clearance of 27.5 mm, 25 mm dia HDPE pipe is used as a riser pipe of submersible pump. Solar panels of 900 watt capacity are provided for the energization of 1 HP submersible pump.

Operation of pump is controlled by the pump controller with float switch of tank, which switches on the pump when the water level reaches to a particular set level in the tank and switch off the pump when tank gets filled. Hence overflow is restricted.

Also pump itself has in built dry run protection controls.

**Details of the solar energy based Dual Pump scheme –**

- Installation of 1 HP Solar submersible pump with the help of 32 mm dia HDPE pipe in the bore well/tube well in addition to the hand pump in the bore well and it is energized with the help of 900 watt solar panels installed in the vicinity of the bore well.

- A special water chamber is used for this purpose. It facilitates installation of hand pump cylinderand submersible pump with their independent riser pipes.

- Water pumped by the solar submersible pump is stored in a LLDPE tank of 5000 Liters. This tank is mounted on the galvanized steel structure of 3 mtr height. Location of tank is decided at the most elevated place in the habitation to get the water distributed by gravity.

- A separate connection of GI bend is taken from the special water chamber, which is mounted below the regular water chamber of the hand pump.

- Lower end of this GI bend inserted in the special water chamber, which is mounted with a GI nipple to hold the HDPE riser pipe of submersible pump with proper sealing and nut bolting.

- Another outer end of this GI bend is connected to tank through the rising main.

- Existing Bore well / Tube well (Yield not less than 2000 Liters per Hour.) can be used

- Rising main from the bore well to tank.

- Distributions from the tank to individual tap connections and/or to common public stand post.

**Highlights of the System**

- Each of the schemes can meet the drinking requirement of 250 persons
- The novelty of the innovation is that electricity supply is not required, batteries are not required.
- No electricity charges.
- Fully automatic– No need of man power / operator
- Practically no maintenance required.

**Key factors of success of this scheme**

1. Effortless pumping.
2. Assurance of 24 X 7 water supplies.
3. Five years free maintenance by the contractor.
4. Security of water due to 5000 litres storage tank.
5. Arrangement of special water chamber for easy removal of hand pumps for the maintenance, without disturbing submersible pump.

**4.1.8. Solar system design considerations**

The conceptual design of solar pumping systems is best accomplished by analysing the following
seven key parameters which are described below-

1. Water demand

The design capacity of the solar water system depends primarily on water demand, measured in m³/day or litres/day.

Potable water for human consumption in a village/town is estimated from population size and daily per capita water consumption. For example, if the system is to serve a population of 2,000 and the supply standard is 40 litres per capita per day, then system design capacity should be at least 8,000 litres/day or 8 m³/day. Similarly, water demand for livestock will depend on livestock type and quantity.

2. Water source

Fresh water is generally obtained through open sources or surface water, such as rivers, streams, and dams; or protected ground water sources such as bore holes and wells. Each is characterized with respect to security of supply, water quality, and replenishment. In general, groundwater is preferred for potable water.

In assessing surface water sources, the following aspects must be carefully considered:

- Water availability and pumping levels. Accounting for seasonal variations is critically important, since some sources may dry up, while others may be prone to flooding and high risk. Water level may vary considerably between seasons, affecting pumping head.

- Water quality. Debris, silt, and sediment can cause damage to the pump if not properly screened at pump intake.

Groundwater is a commonly used water source. Groundwater is contained in aquifers, natural underground water reservoirs accessed by wells or bore holes. A pumping test is conducted to evaluate the amount of water that can be pumped from a particular aquifer. The test determines the maximum yield (in m³/hr) as well as the drawdown, or depth to which the water level in the borehole will fall for a given yield and duration (yield per meter of drawdown), while being dynamically replenished by the aquifer. Obviously, a low drawdown is desirable.

Water demand that exceeds an aquifer’s yield can lead to over pumping. Over pumping is evident from deeper drawdown. This can lead to precipitation of heavy metals and oxidation of iron compounds, potentially causing infiltration of nitrate and pesticides in the water and the formation of ochre, which may clog the pump. This vicious cycle leads to increased service costs for the pump, a need for water treatment, longer-term aquifer depletion, and possibly reduced aquifer life.

3. Design flow rate

In conventional engineering design, a pump’s design flow rate is derived by dividing the daily water demand by the total number of pumping hours in a day. Solar pumping applications, however, use the number of peak sun hours to estimate the daily pumping hours. For example, in a solar resource that averages 7.0 kWh/m²/day, peak sun time is 7 hours/day. For a daily water requirement of 70 m³/day, the design flow rate is 70,000 litres/day/7 hours/day = 10,000 litres/hour. The design flow rate should not exceed the maximum water source pumping rate or yield. The design flow rate is used for future water pressure drop calculations and pipe sizing.

4. Water storage

Most solar pumping systems require water storage capacity to improve performance and reliability. Reliability is improved when a storage tank is used to store water extracted during sunshine hours to meet water needs at night, or in the event of cloudy weather or system downtime.
In general, SWP tanks should be sized to store at least a 2–3 days of water supply (daily demand \((m^3/\text{day}) \times 3 \text{ days} = \text{storage volume (m}^3)\)). Field survey data indicate that many SWP storage tanks are too small, and experience water overflows in the daytime and shortages in the evening. Optimal tank sizing must account for the hourly water demand pattern as well as possible supply variations in the tank.

5. Total dynamic head

In pumping systems, “head” refers to the height to which water must be pumped relative to its normal level (e.g., underground). Total dynamic head (TDH) or total pumping head is the sum of three components (figure 3).

Dynamic water level (DWL) is the depth of the surface of the aquifer. This gradually increases due to drawdown, hence the term “dynamic.”

Discharge head corresponds to the height above the ground of the water surface inside the storage tank (usually 5–10 m). This water is discharged to users through gravity, thus the name “discharge.”

Friction head accounts for the friction of the water against the inside of the pipes (both vertical and horizontal). It is typically 10% of the DWL plus discharge head.

A pumping test can provide information on the DWL and the discharge head, whereas the friction head can be more accurately obtained from head loss charts for pipes at the required flow rate and pipe characteristics.

6. Location of PV panels

Although not critical to the initial system sizing, PV panels should be installed close to the pump and water source, equator-facing, at optimal tilt angle to the horizon, and unshaded in any part of the solar array for the solar day. Panels should generally be situated in a secure and safe location. These issues can be fine-tuned during final design and installation, but for purposes of preliminary design, it is conceivable that the solar array would not be closely located to the pump, and thus longer array cables are required, with possible energy losses. This scenario calls for a high allowance for power loss in array cables.

7. Solar resource

Solar insolation is a measure of the cumulative irradiance received on a specific area over a period of time. It is a measure of energy (rather than power), normally expressed in kilowatt-hours \((\text{kWh/m}^2/\text{day})\). The characteristics of the solar resource at the site are critical to system design. Sunshine reaches the earth through radiation. Solar irradiance is the power of solar radiation received per unit area. Irradiance is the instantaneous measurement of power, in watts or kilowatts per square meter \((W/m^2\) or \(\text{kW/m}^2\)).
Irradiance is affected by the angle of sun, and at any time of day it is highest when a solar module is perpendicular to the incident sun rays. Since the sun’s position in the sky changes during the day, irradiance increases during the morning until noon (when it is highest), and then decreases until sunset, since the sun’s rays must penetrate more of the atmosphere to reach the earth.

Solar insolation is effectively equal to the area under the solar irradiance curve. Peak sun hours per day are just another term for solar insolation and are always measured in kWh/m²/day.

Solar resources vary from area to area. As Figure 4 illustrates, solar radiation is generally higher in regions near the equator. Factors that affect the amount of solar radiation on a particular area include latitude, prevalence of cloudy periods, humidity, atmospheric clarity, and seasonal variations.

4.1.9. System installation

In a PV system, the “balance of system” or BOS refers to all hardware components other than the main components. In a solar pumping system, the main components are the PV panels, pump, and pump controller, with the BOS comprising the PV array mounting structure, cables/wires, switches, fuses, piping, water meters, data loggers, etc. Installation and related services, on the other hand, include engineering design, transport to site, site preparation, installation services, commissioning, training, and maintenance. The BOS installation and related services can account for 30–50% of total capital costs, and are an important part of setting up a solar pumping system.

Installation

Key considerations of equipment installation procedures include –

Array location. Maximized solar energy production depends on panel location and orientation. Panels should be equator-facing, with panel tilt predetermined based on latitude and local weather conditions to maximize incident insolation and facilitate panel cleaning during the rainy season. Shading at any time of day should be avoided. Because many solar pumping systems are located in remote areas, the risk of vandalism and theft can be significant, and panels should not be easily accessible by the public. If the use of trees and vegetation for shielding is deemed acceptable, then adjustment to sizing may be required if this reduces the amount of available solar radiation due to shading, especially in early morning and late afternoon. This should be decided before installation.

Safety standards. PV systems present a unique combination of hazards and risks, which must be addressed by sound design and specifications followed by proper installation, operation, and maintenance of the system. In large pumping systems, high-voltage DC arrays require special cabling, switch gear, and clear labelling.
**Equipment protection.** Protecting equipment against faults on both the DC and AC sides requires careful attention to earthing design and protective components. Risk of lightning damage is addressed by grounding (giving electrical lightning surges a direct path to the ground that bypasses valuable equipment) and by installing lightning arrestors and surge protectors.

Another major risk is that of vandalism and theft. Measures to curb this risk include:

- Build community ownership.
- Locate the solar array in a populated area with regular foot traffic.
- Fence the array to make access more difficult.
- Arrange for security guards.
- Install motion-detecting sensors and alarms whenever possible.
- Spot-weld bolts or use tamper-proof bolts, screws, and fasteners.

Use anti-theft array mounting frames. These metallic structures hold the panels and are designed to withstand strong winds.

Commissioning immediately follows installation and refers to the process of “handing-over” the system to the client, i.e., ensuring that all system components have been properly installed, are in good condition and that the system is operating as expected. Commissioning comprises three main elements: documentation, inspection, and testing.

### 4.1.10. Operation and maintenance

After the system has been installed and commissioned, focus shifts to O&M throughout its lifetime. System operation can be optimized by closely monitoring and recording key system parameters (data logging), enabling operators to assess system performance or demand changes.

One crucial aspect of maintenance is warranties, usually against defective components or poor work-man ship. The Defect Liability period of 5 years, any items that fail, are not installed to standard, or are damaged by natural calamities must be corrected on site at cost to the contractor/supplier/ installer.

Sustainability of solar SWP has been a challenge in many countries and especially in rural areas, with systems failing often within a short time after commissioning due to lack of proper O&M. It is therefore increasingly common for communities to establish comprehensive maintenance contracts with suppliers during warranty periods, and it is a good practice to extend such contracts beyond the warranty period. Suppliers should further secure system sustainability by training system operators, namely on basic plumbing skills useful for repairing leakages in the pipe network and on handling the advanced inverters and sensors common in modern solar pumping systems.

Since solar panels have no moving parts that could be affected by rust or break down, solar power requires very limited maintenance, other than regular dusting.
Option selection

Introduction:
Selection of an appropriate option for drinking water supply arrangements by the community itself is the single most important step in Swajal scheme cycle. Sustainability of sources, water supply systems and water quality management is directly linked to community selecting an appropriate option.

Various aspects need to be considered while selecting an option. First of all the source has to be sustainable in terms of giving water of desired quantity and quality in all seasons for the design life of the water supply system. It also has to be socially acceptable.

Community should select a system option which they would be able to technically operate and maintain, and would be able to afford the costs of O&M. At the same time GP also should be able to bear the capital and O&M cost contribution. Step by step process will have to be facilitated to inform community about the implications of various options to help them to arrive at an informed choice.

Overall the option selected by community has to be social acceptable, technically appropriate, financially affordable and environmental responsible.

Social acceptability:
This is a demand-led process. The option will have to be acceptable to the community considering their water demand and other social & cultural issues if any. Care should be taken to ensure the service delivery to the marginalized groups in the village. Women’s participation and their say in the process are important and should be decisive.

Technical Appropriateness:
In the context of natural resource base of a village, various options will have to be evaluated to check their appropriateness. This is linked to the various engineering aspects and their considerations as mentioned in the session plan on Technical Options. In this process there might no difference in perception of community, which will need to be objectively addressed and resolved. The bottom line is that the system proposed has to deliver the desired level of service for the designed life. The role of the technical agency is vital in helping community understanding the appropriateness.

Economic affordability:
The scheme is ultimately to be managed by GP/ VWSC with community participation. Capital cost and O&M cost implications of each option needs to be appreciated by community and that should lead to selection of an option for which they are both willing and also able to pay.

Environmental responsibility:
Each option will have some environmental implications, may it be in terms of ground water or energy consumption or climatic variability/ risks. Environmental responsibility needs to be considered specifically with reference to the sustainability.
Process of option selection:

<table>
<thead>
<tr>
<th>STEP</th>
<th>PROCESS</th>
<th>PROPOSED TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gathering Information</td>
<td>Calculation of demand for drinking water</td>
<td>• Social Mapping</td>
</tr>
<tr>
<td></td>
<td>Review of available sources and facilities and its utilisation potential</td>
<td>• Scheme Walk</td>
</tr>
<tr>
<td></td>
<td>Identification and quantification of requirement</td>
<td>• Seasonality</td>
</tr>
<tr>
<td></td>
<td>Finalization of requirements about new sources and facilities</td>
<td>• Resource Mapping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Drinking Water Budgeting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Technical inputs</td>
</tr>
<tr>
<td></td>
<td>Listing of the most feasible options based on above information</td>
<td>• Documenting of Tools</td>
</tr>
<tr>
<td></td>
<td>Consolidation of details of each option - capital cost, O&amp;M cost,</td>
<td>• Technical input on source and demand calculation</td>
</tr>
<tr>
<td></td>
<td>water tariff rate, pro’s and con’s</td>
<td>• Technical input for sub work options</td>
</tr>
<tr>
<td></td>
<td>Finalization of appropriate option in Gram Sabha</td>
<td>• Option selection</td>
</tr>
<tr>
<td></td>
<td>Approval of Village action plan in Gram Sabha</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Submission of Village action plan to PHED/ZP along with community</td>
<td></td>
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<tr>
<td></td>
<td>contribution</td>
<td></td>
</tr>
</tbody>
</table>

A. Gathering Information

i. Calculation of demand for drinking water:

Deciding the demand of water for the village and calculating the capacity of the scheme

Water demand for the village is decided by the two parameters:

a) Rate of water supply per capita per day

In rural area per capita water supply is provided as stipulated below:

<table>
<thead>
<tr>
<th>Use</th>
<th>Need for water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking</td>
<td>3 Ltr</td>
</tr>
<tr>
<td>Kitchen</td>
<td>5 Ltr</td>
</tr>
<tr>
<td>Washing of utensils</td>
<td>7 Ltr</td>
</tr>
<tr>
<td>Personal hygiene</td>
<td>10 Ltr</td>
</tr>
<tr>
<td>Bathing</td>
<td>15 Ltr</td>
</tr>
<tr>
<td>Total</td>
<td>40 Ltr</td>
</tr>
</tbody>
</table>

b) Population

For deciding the population and water demand, following things are necessary:

- Data of historical population as per census for minimum 5 decades
- PRA in the village will give current details of the
number of houses/households in the village and the average family size of household

- Data from the annual census done by the GP
- If no historical data of last 5 decades census is available, work out projected population for 30 years ahead by multiplying 2.25 to the present population
- Water supply amenity design shall be based on the above projected population
- Rate of water supply shall be taken as 40 Lit per capita per day.
- Consider 15% as the losses in the system and update the above demand for deciding the source capacity.

There are two methods for calculating the projected population:

a. Arithmetic method
   \[ P_n = P_p + \frac{S_n}{n} \]
   \( P_n \) = Projected population
   \( P_p \) = Present population
   \( N \) = No. of Decades
   \( S_n \) = Sum of the arithmetic increases

b. Incremental increase method
   \[ P_n = P_p + nX + \frac{n(n+1)}{2}Y \]
   \( P_n \) = Projected population
   \( P_p \) = Present population
   \( N \) = No. of Decades
   \( X \) = Increase
   \( Y \) = Incremental increase

**Total Water Demand**

Assume a village is having a population in 2018 as 1000
Village population in 2048 will be \( 1000 \times 2.25 = 2250 \)

Rate of water supply = 40 LPCD
Drinking water Demand = \( 2250 \times 40 \)
= 90000 lit/day
Losses in the system 15% = 13500 lit/day
Total demand = \( 103500 \) lit/day

Above demand of 103500 lit/day needs to be considered in the planning and designing of the scheme.

**ii. Review of available sources, facilities and its utilisation potential**

Each village will have some existing infrastructure in the form of hand pumps, power pumps, and in some cases old storage structures etc.

The information generated during PRA exercise needs to be used for augmenting the new project. The specific consideration for each sub work is presented in earlier session on Technical Options. For the old infrastructure in addition to these considerations the physical status of each sub work, its design life and year of construction needs to be looked at before taking a decision about using old infrastructure. If the physical status is not up to the mark and if the remaining design life is minimal, the selection of such option may not be done.

Since in Swajal the village selection criterion is non-availability of pipe water supply scheme, the issue of using old infrastructure will be limited.

Finalization of the option would be aligned with the water demand, existing usable facilities and the proposed new facilities for all sub works.

**B. Option Finalization:**

Formulation of scheme options and ranking:
Based on the options available for each sub work, formulate the options for schemes as follows:

**Scheme A:** Source + storage type + pipe option + chlorination system + tap stand locations
Source + storage type + pipe option + chlorination system + tap stand locations. There can be multiple scheme options like scheme B, C etc.

Work out capital and O&M cost of for each scheme option. It can be worked on the basis of block costs prevalent at the time.

Also for each option, work out the GP contribution in capital cost which is 10% of total capital cost of the scheme. GP should decide the share in the O&M cost and based on that community will bear the remaining amount in the O&M cost and the community contribution in O&M can further be converted in HH water tax.

C. Village Action Plan

Gram Sabha Approval:

Present the information in Gram Sabha for approval of preferred option.

Make a resolution in Gram Sabha and GP to present the report of the selected option to PHED/RWS for finalization of DPR.

The template for the option selection report (Village action Plan) is attached in workbook.
4.3.1. Relevance of construction supervision

The water supply schemes are designed for a particular life. The design includes the specifications for all sub works of water supply schemes and also for the construction material to be used during the construction. Monitoring the quality of both construction material and each sub work as per the design specifications is expected and non-negotiable. Non-adherence to the specifications and quality leads to compromised performance of the scheme and also reduces the expected life of the scheme. It also leads to excess O&M costs for the scheme and ultimately increases the burden on the consumers. Service delivery below desired service level and high burden of cost can make schemes non functional. It is necessary to do proper construction supervision to ensure sustained service delivery for designed life of the scheme.

Core of the Swajal scheme is a community ownership. The engagement of community and GP/VWSC during construction phase is essential to ensure transparency and ownership.

The following sections look at first the checklists of quality assurance of construction material, followed by check list for construction supervision of sub works i.e. Source (dug well, bore wells and springs), solar pumps and panels, electrical pumps, storage structures, pipelines, tap stands and soak pits.

4.3.2. Quality assurance of construction material

Cement, steel, sand & aggregate, is the basic construction materials of the water supply scheme. Along with those solar pumps, electrical pumps, solar panels are also the basic construction material for water supply scheme to be taken up under Swajal. The basic checklists for quality assurance of the construction material are presented below.

4.3.3. Quality parameters for construction material

Most important materials required for construction in Rural Drinking Water schemes are;

- Cement and admixtures
- Course and fine & aggregate (sand)
- Stone and Brick
- Water

4.3.3.1. Cement and admixtures

- Cement shall be conforming to IS 269:1965.

4.3.3.2. Stone

- Freshly quarried stone of specified size along with chips shall be used.
- Stones shall be thoroughly washed and shall be used in Saturated Surface Dry (SSD) condition.
4.3.3.3. Water

• Water quality is important for good construction. It should be of potable grade for mortar and concrete mix.
• Ample water shall be available for curing.

4.3.3.4. Steel

Steel conforming to following Indian Standards shall be used and shall be in consonance with the structural design drawings:

• 462–1960 Mild steel or Medium tensile steel
• 1786-1961 Cold twisted bars
• 1139 Deformed Steel bars

4.3.3.5. Pipes

• Select the pipes as per relevant specifications required for the work. G.I., HDPE, u-PVC shall be as per relevant IS Codes. For lowering, laying and jointing of pipes relevant IS codes shall be referred.
• For allied items such as excavation, refilling, dewatering (if required), bedding, hydraulic testing, etc. and disposing extra excavated stuff working practices in the region are to be followed, however, overall guidance is given in CPHEEO manual and CPWD standard specifications.

4.3.4. Component wise Construction, supervision

Swajal scheme is predominantly a groundwater based simple mini pipe water supply scheme. Selected technical option and further approved in the Gram Sabha is proposed to be implemented. Implementation is the responsibility of the RWS/PHED of the State. For supervision they shall be abide by the procedures followed in the departmental specifications. However, during implementation GP authorities shall be taken into confidence and allow them to participate the supervision. It is advisable to implementing authorities to involve the GP to make a note of visible checks. In this section the checklist for construction supervision for each sub work is presented.

4.3.4.1. Water Source Components

i. Specifications to be followed as per Design and Drawing
a) Open/Dug well –
   Depth and diameter of excavation
   Height, thickness and material of lining/steining
b) Bore well/ Tube well –
   Depth and Diameter of drilling
   Depth, diameter and type of casing pipe
c) Spring –
   Dimensions as per the design and drawing
   Water filter as per specification

ii. Steps of implementation
a) Open/Dug well –
   • Site clearance and lineout
   • Trial bore and yield test as prescribed by competent authority
   • Excavation with due strata classification and protection
   • PCC footing, lining and steining and parapet wall
   • Vents, back filling, ramming and drains
b) Bore well and tube well –
   • Site clearance and lineout
   • Drilling, casing and flushing
   • Capping, clamping and clearing

   c) Spring
   • Site clearance and lineout
   • Excavation with due strata classification and protection
   • PCC footing and construction of spring box and filter as per design

iii. Common Indicative check List for Monitoring of all civil works
• Check site clearance and layout. Layout should be as per drawing and design.
• Entries of receipt and issue of all material received at site shall be recorded in the stock register.
• Excavated material shall be stalked separately at safe distance from work site.
• Certify that the excavation work is completed as per drawing/ design.
• Dimensions of foundation PCC
• Taking measurement of work daily and recording of the same
• Weekly check of stock register and labor attendance.
• Joints do not overlap and vents are left during construction.
• Height and securing of parapet wall as due
• Back filling and ramming completed as required.
• Certify that construction work is completed as per drawing/design.

4.3.4.2. PUMPHOUSE, PUMP, TOOLS AND ELECTRICAL FITTINGS

i. Component Specifications to be followed as per design and estimate
  
a) Solar panels-
  - Make and capacity of panels
  - Connections of the panel

b) Pump set-
  - Make and capacity of pump sets
  - Make of the valves and other fittings

  c) Electrical fittings-
  - Make and capacity of electrical fittings

ii. Steps during implementation

  a) Solar panels-
     • Site clearance and layout
     • Structural erection/ fabrication
     • Fitting of panels and testing
     • Electrical fittings and connections

  b) Pump set-
     • Fitting of pump set
     • Pipe fitting, electrical connections
     • Pump testing

4.3.4.3. DOs and DON’Ts

Before starting the work, most important step is to organize a village meeting and read out the approved/sanctioned plan and work schedule. Explain the villagers, steps in the plan and timeline as described in the estimate or plan.

<table>
<thead>
<tr>
<th>Dos</th>
<th>DON'Ts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site clearance, layout and erection</strong></td>
<td>Do not start erection of solar panels if site is not levelled</td>
</tr>
<tr>
<td>Remove shrubbery, undergrowth and any garbage</td>
<td></td>
</tr>
<tr>
<td>Fill and level the work site</td>
<td></td>
</tr>
<tr>
<td>Give proper layout</td>
<td></td>
</tr>
<tr>
<td>Check soundness of fabrication</td>
<td></td>
</tr>
<tr>
<td><strong>Solar panel fitting</strong></td>
<td></td>
</tr>
<tr>
<td>Assemble solar panels as per design</td>
<td>Do not force panels and levers</td>
</tr>
<tr>
<td>Fitting of all panels and levers</td>
<td>Solar panels should not be far away from Bore well/Tube well to avoid current losses.</td>
</tr>
<tr>
<td>Fencing of the solar unit</td>
<td></td>
</tr>
<tr>
<td>Testing of solar panels</td>
<td>Solar panel should be located under the tree</td>
</tr>
<tr>
<td>It should have proper foundation as the steel structure of solar panel has to withstand against the wind of 150 Km/hr velocities</td>
<td>Don’t locate it on exposed rocks</td>
</tr>
<tr>
<td>Pump set and fittings</td>
<td></td>
</tr>
<tr>
<td>Install and fit the pump set only through agency fitter</td>
<td>Do not loose fit any of the components</td>
</tr>
</tbody>
</table>
4.3.4.4 Indicative check List for Monitoring of Solar Panels and Pump Set

- Panels, pumps, fittings, tools, etc. are recorded in stock register and marked.
- Testing of solar panels and pump set in front of dealer representative and Site Engineer.

4.3.4.5 Pipelines (Rising Main and Distribution System)

i. Component Specifications to be followed as per Design and Drawing
   a) Pipes - Type of pipes
      Make, mark and thickness of pipes
      Fittings like bends, T, clamps, caps, etc.
   b) Valves - Types of valves
      Make and mark of the valves and other fittings

ii. Steps during implementation

Pipes and valves - These will be laid and fitted together. Rising main and distribution system can be done in stretches or simultaneously as per local conditions and resource mobilization.

- Pipes of different types, sizes and their numbers
- Valves and other fittings
- Lineout with clear instructions for specific locations
- Stock register, labor attendance and measurement book
- Excavation, leveling, cleaning and layering
- Particular care at critical locations
- Laying and fitting of pipeline
- Fitting of different valves
- Testing, checking and backfilling

iii. Indicative check List for Monitoring of Rising main and Distribution system

- Check with the help of tube level that the bottom level of trench is maintained properly.
- Ensure that work is properly detailed at the critical locations. Check that all measurements are recorded in measurement book (MB).
- Hydraulic Testing of pipeline and valves along with operation of each valve, pressure at discharge points and ensure there are no leakages.

4.3.4.6 Storage tanks

Depending on the topography of the area and land availability two types of tanks are constructed in water supply schemes. First is ground service reservoir and second is elevated service reservoir.

Various storage materials
- HDPE tanks
- Zinc Aluminum tanks
- RCC tanks

Storage Reservoir or Water Tank and Fittings

i. Component Specifications to be followed as per design and estimate

a) Reservoir/ tank -
   Depth and width of excavation
   Plinth, pillars, beams, etc.
   Height, radius, thickness and type of construction
   All the material should be as per specification

b) Fittings -
   Outlets and valves
   Fabrications and fencing

ii. Steps during implementation

a) Reservoir/ tank -
   - Site clearance and lineout
   - Excavation and grading of excavated material
   - PCC, foundation in RCC or masonry and leveling
• Pillars, beams, reservoir/ tank construction in RCC

b) Fittings-
• Outlets, valves and other fittings
• Ladder, drains, fencing, filling and ramming
• Filling the reservoir/tank and testing

iii. Indicative check List for Monitoring of Reservoir/ tank and Fittings
• Check with the help of tube level a) PCC, b) plinth and c) slab of the reservoir/ tank.
• Testing of reservoir/tank, pipeline and valves along with operation of each valve and ensure that there are no leakages.

4.3.4.7. Tap stand

i. Components Specifications to be followed as per design and estimate
a) Stand-posts –
   Foundation and construction dimensions
   Number of taps per stand-post

ii. Steps during implementation
a) Stand-posts –
   • Laying proper foundation for the stand posts
   • Ferrule in conformity number of taps
   • Testing of all stand-posts before construction
   • Providing drain and soak pit for safe disposal of water
   • Stock register, labor attendance and measurement book

iii. Indicative check List for Monitoring of stand posts
• Testing of taps for operation and ensures that there are no leakages and has desired discharge.

4.3.5. Construction scheduling and timeliness

Each approved project DPR contains the work plan. It gives the list of activities and proposed time for completion of each activity. It is necessary the teams responsible for the construction supervision understand the work schedule and are able to monitor the time and flow.

The sample work plan is presented below:

<table>
<thead>
<tr>
<th>No</th>
<th>Activity</th>
<th>Start Date</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bore well drilling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Installation of solar pump and panels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Construction installation of storage tank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Construction of tap stand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>.....</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The schedule for construction should be publically displayed and regularly monitored.

4.3.6. Role of community, GP/VWSC in construction supervision

Community Based Monitoring (CBM)

Community Based Monitoring (CBM) is an important aspect of the Swajal Pilot. Community based monitoring (CBM) ascertains community ownership of the works and transparency in the process. People come to know about the scheme, get an opportunity of closer involvement that being their right. Site Supervisor / Site Engineer shall be open-minded so that people get an opportunity of involvement in the process. The most important principle of the CBM is that the “People are owners of the scheme and external actors are facilitators”.

Implementation responsibility is with the RWS/PHED as per the programme guidelines. However, community shall be involved in the Process of implementation right from the initial stages. They shall be allowed to identify every milestone achieved.
Community Based Monitoring actually starts with Participatory Planning. It is expected that following planning steps should be done in participatory manner.

- Water quantity and quality survey/assessment should be conducted by respective departments and it should be ensured that its reports are taken on record.

- Choice of source should be finalized by the Village Water Supply Committee or the Village Panchayat in consultation with Water Supply Department. This shall be done with due reference to the suggestions/recommendations of the test reports.

- Source should not be located in water logged area. If the survey is conducted during dry season it may not be possible to identify the water logged areas; however, the villagers can make out the same.

- Source should not be in close proximity of polluting areas and pollution sources. Such locations shall be discarded. In case the options available are limited the selected location of the proposed source shall be away from existing latrines, drains/gutters, garbage dump which should be duly shifted to farther locations.

CBM is useful to understand local issues and solutions, and is also helpful in mobilizing resources, resolving conflicts, working as per schedule, etc.

- The first move shall be reading out the scheme document in the village meeting and its public display. This shall help the people to understand the scheme and also trigger interest in the same.

- Discuss the implementation plan in details. Using the input received from the people, prepare the final implementation plan along with the construction schedule.

- Explain the nature of community based monitoring to the people. The specifics proposed during each of the stages shall be explained using charts, tables, etc. specifically prepared for CBM.

- Discussions shall be held with the current Village Water Supply Committee members, or with the Panchayat members and ask for nominations as public monitors. Women should be involved in the CBM.

- Prepare a stage wise schedule of community based monitoring and check list. Explain the role of public monitors including that of the VWSC/ Panchayat members.

- Conduct community based monitoring as per the pre conceived schedule. Prepare brief notes and share with all VWSC/ Panchayat members. Whenever possible share the same in village meetings.

- Site Engineer shall be necessarily present during the community monitoring as counter-part of Government representative and patiently listen to the suggestions of the people.

- Some of the important aspects of CBM will include monitoring of quality & quantity of material procured, specifications and quality of work, construction schedule and status of achievement of various mile stones, records namely stock register, measurement book and labor attendance, and testing of specific work components. The component wise details are already presented in the earlier sections.

- Community representatives shall be interested to know the service level equalization achieved in all the Tap stands. Flow and pressure equity on all tap stands shall be ensured with technical intervention to counter the uneven ground levels in each place. Community will be interested to ensure the working time of tap stands at all locations shall be equal.
Annexure: Benchmark costs for Off-grid Solar PV Systems and Grid Connected Rooftop Solar Power Plants

(i) Solar Pumps

<table>
<thead>
<tr>
<th>Pump Capacity (HP)</th>
<th>Benchmark Costs (Rs./HP)</th>
<th>General Category States</th>
<th>North Eastern States/Hill States/ Island UTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 3 HP, DC</td>
<td>8500</td>
<td>95000</td>
<td>17500</td>
</tr>
<tr>
<td>3 HP - 5 HP DC</td>
<td>75000</td>
<td>85000</td>
<td>16500</td>
</tr>
<tr>
<td>3 HP - 5 HP AC</td>
<td>80000</td>
<td>84000</td>
<td>15400</td>
</tr>
<tr>
<td>&gt;3 HP - 5 HP AC</td>
<td>65000</td>
<td>71000</td>
<td>14100</td>
</tr>
</tbody>
</table>

(ii) Solar Lighting Systems

<table>
<thead>
<tr>
<th>System</th>
<th>Benchmark Costs (Rs./Wp)</th>
<th>General Category States</th>
<th>North Eastern States/Hill States/ Island UTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Lamps</td>
<td>250</td>
<td>275</td>
<td></td>
</tr>
<tr>
<td>Solar Street Lights</td>
<td>300</td>
<td>330</td>
<td></td>
</tr>
<tr>
<td>i. With Lead Acid battery</td>
<td>435</td>
<td>475</td>
<td></td>
</tr>
<tr>
<td>ii. With Li-Ion battery</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(iii) Standalone Solar Power Plants/Packs

<table>
<thead>
<tr>
<th>Capacity (kW) Battery Backup (hrs)</th>
<th>Benchmark Costs (Rs./Wp)</th>
<th>General Category States</th>
<th>North Eastern States/Hill States/ Island UTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 10</td>
<td>6</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>68</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Above 10 and up to 25</td>
<td>6</td>
<td>90</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>92</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>61</td>
<td>67</td>
<td></td>
</tr>
</tbody>
</table>

(iv) Grid Connected Rooftop Solar Power Plants

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Benchmark Costs (Rs./Wp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 1 kW and up to 10 kW</td>
<td>60</td>
</tr>
<tr>
<td>Above 10 kW and up to 50 kW</td>
<td>55</td>
</tr>
</tbody>
</table>

2. The above benchmark costs are inclusive of total system cost and its installation, commissioning, transportation, insurance, five year AMC/CMD, and applicable taxes.

(Shobhit Srivastava)
Scientist-C

To
All Concern

Copy to Dir. (NIC) to upload this on the Ministry’s website.
Ministry of Drinking Water and Sanitation
Government of India,
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CGO Complex Lodhi Road,
New Delhi - 110003
https://mdws.gov.in/