Solar Powered Water System for Mlangali Subvillage

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1 Project Contact Information

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2 Project Profile

2.1 Project Title

Solar Powered Water System for Mlangali Subvillage

2.2 Project Type

A solar powered submersible pump water distribution system will be constructed with compliance from the village water committee. The water will be pumped into a tank near a church and vocational school and then distributed to a spigot area with multiple spigot heads. The solar panel system will be attached on the roof of the church.

2.3 Project Implementing Organization

Organization:	St. Paul Partners
Function:	Project oversight
Primary Contact:	Hanael Gadwe
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2.4 Project Location

Region:	Iringa, Tanzania
District:	Iringa Rural
Village:	Mgela
Subvillage:	Mlangali

2.5 Project Beneficiaries Information

This project will provide clean water to the people of Mlangali subvillage which presently has no consistent supply of potable water available. The subvillage currently has a population of 600 people.

2.6 Project Budget

Total Cost:	$	18,560
Already Invested:	$	8,000
In-kind Contribution:	$	1,010
Cost:	**$**	**9,550**

3 Executive Summary

3.1 Existing Situation

3.1.1 Village Overview

Mgela village, located about 12 km northwest of Iringa Town, is divided into four subvillages: Kidete, Luganga, Mapinduzi, and Mlangali. It is surrounded by farmland and the Ruaha River to the southwest. The village is comprised of 4000 people (39% male, 61% female). The Mgela School is located at the center of the village in Luganga and provides an education to 672 students from all the subvillages. The Mgela Water Committee handles all the village's water issues and is comprised of 12 members, with representation from each subvillage. Mlangali subvillage has a population of 600 people (42% male, 58% female). A vocational school is located near the center of the subvillage along with the church and pastor's house. For Mlangali, there are three existing sources of water for the village: a river pump system, hand dug holes, and donkey carriages.

3.1.2 River Pump System

The river system is used by the whole village as well as Kiwele, a village to the northwest of Mgela. The existing river pump system for Mlangali can be seen in Figure 1.

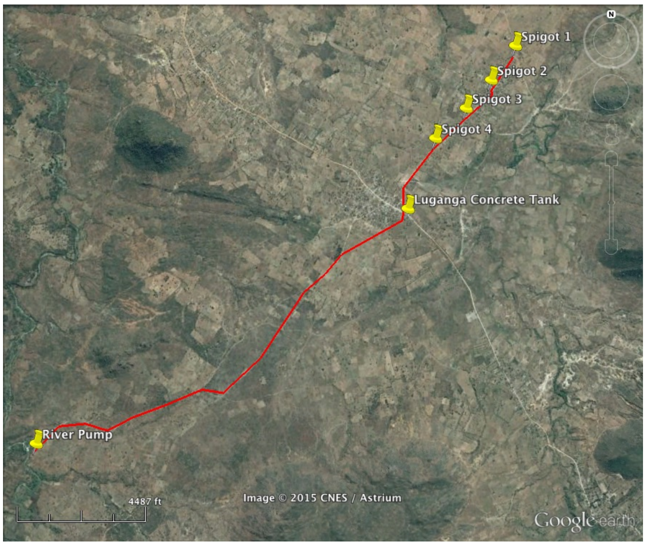
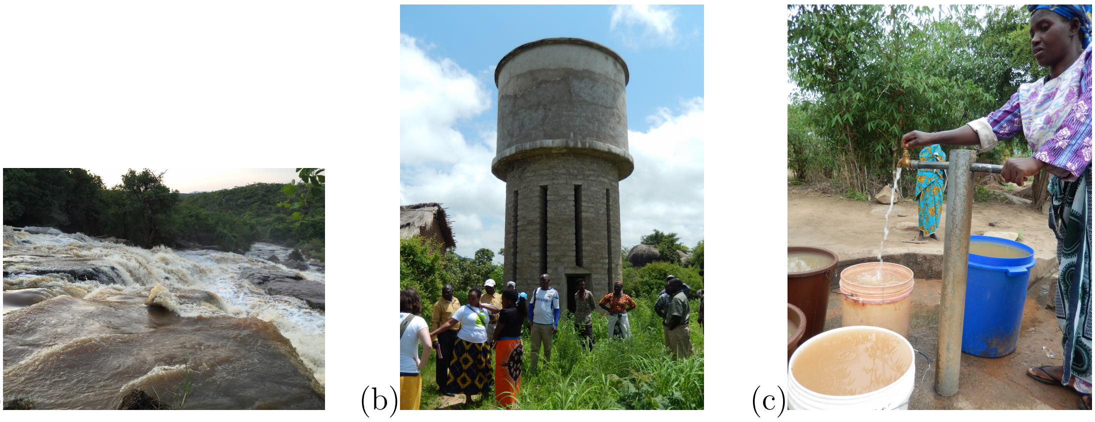


Figure 1: Satellite Imagery of the Existing River Pump System

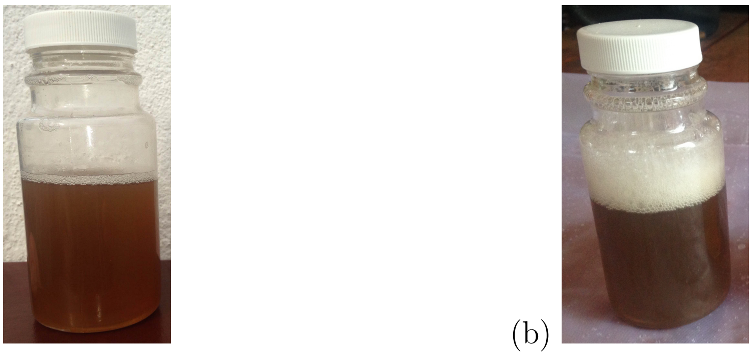
The river system works by pumping water from the Ruaha river with a 25 hp motor to the Luganga concrete tank. The tank is 45,000 L, but due to sedimentation from the river, only 30,000 L are usable. To fill the tank, the water committee must raise 40,000 Tsh ($22) to buy the diesel to power the motor. Once the tank is full, they turn a valve that disperses the water to the subvillages. For Mlangali, there are four spigots for the water to flow to, however, currently only two are operational. To get the water from the spigot, a trusted villager sits by the spigot and collects 100 Tsh ($0.05) for each 20 L bucket the person wants to fill up. The trusted villager then gives the money to the water committee for them to use towards diesel and other expenses. When the spigots are not being used they have a lock box to stop people from getting water without contribution. The components for the river system can be seen in Figure 2.



(a) (b) (c)

Figure 2: The components of the existing pump system supplying water to Mlangali subvillage consists of (a) river water pumped to a (b) 45,000 L concrete tank where it is then gravity fed to (c) four spigots spanning the length of the subvillage

The river in which the village is pumping from has a large supply to support the whole village, however, the system which is in place has problems. Due to a lack of funds, the water committee can only use the pump 2-3 times per month, making it an unreliable source of water. Another problem is the area in which they are pulling water out of the river is standing water right before a waterfall, allowing bacteria and pathogens to grow more easily.



(a) (b)

Figure 3: Water Tests for the operational (a) spigot 2 and (b) spigot 3

With no treatment of the water and taking it from a still area, there is no prevention for water born diseases. This can be seen in the water tests conducted on the working spigots (Figure 3). The other problem with this system is that it was constructed in 2000 with no maintenance or replacement of any kind, making the layout and condition of the piping questionable.

3.1.3 Hand Dug Holes

For times when the river system is not available, there are five hand dug holes spread throughout the subvillage which hold water. They are only available during the rainy season as they catch rainfall and agricultural runoff. These holes are steep to get to and do not protect against animals. The water test from one of the two holes visited (Figure 4) reveals a dark black color indicating a high level of contamination. Sedimentation is clearly visible confirming the water coming from these holes are not safe to drink. An example of a hole can be seen in Figure 5 (a).

Figure 4: Water Test for a hand dug hole

3.1.4 Donkey Carriages

In the dry season there are times when the river pump system is not available and the hand dug holes have dried up. When this happens, the villagers sometimes turn to donkey carriages (Figure 5 (b)). These carriages travel 5 kilometers to the river and fill up 20 L buckets with river water. They transport the buckets back to Mlangali and the villagers can buy a bucket for 500 Tsh ($0.27). If a villager cannot pay for the donkey carriage, then the only other option is to walk to the river themselves to get water. Going to the river to fill up buckets is very time consuming and costly for the villagers. The water is taken from the same river as the river pump system concluding that the water quality from this source is equivalent to that of the river pump.

(a)  (b) 

Figure 5: Other water sources for the subvillage are (a) hand-dug holes and (b) donkey carriages

3.2 Organization Background Information

Estabilished in 2002, St. Paul Partners (SPP) is a 501c3 non-profit organization that provides drinking water to the people of Tanzania, specifically in the Iringa Region. The vision of SPP is to "assist and enable the Tanzanian people to obtain universal access to safe water, community by community." To accomplish this vision, SPP works with other organizations to help implement projects in Tanzania. Some partner organizations include H2O for Life, Bega Kwa Bega, and Water to Thrive.

3.3 Program Objectives

- Provide potable water for the population of Mlangali subvillage (600 people)
- Implement a sustainable water system with distribution at the local church
- Educate and train workers on the maintenance and operation of solar powered system
- Educate and train workers on the maintenance of the distribution system

3.4 Program Deliverables

- Install solar powered pump into the existing borehole
- Install solar system on the church roof
- Install a sim tank near the pastor's house with concrete pad
- Install a concrete spigot area for community access
- Run piping from pump to sim tank and from the sim tank to concrete spigot area

3.5 Impact Goals

- Improve water quality in Mlangali
- Easy/close access to water
- Separate from current river system and its operations
- Increase health of students and villagers

3.6 Implementation Plan

Based on the current design plan, there are several components that need to be installed in the village of Mlangali. These pieces are the pump, solar panels, controller, tank, spigots, piping, and wiring (Figure 6). A suggested location for each part is provided in this implementation plan, but the exact location of each will be chosen by the villagers and the water committee in Mlangali.

- Pump
  - A Lorentz PS600 HR-04 submersible 1 horsepower pump will be purchased from Davis & Shirtliff and placed in the current borehole
  - Pump should be placed below 50 meters from the surface
  - Lorentz Well Probe sensor installed to avoid dry pumping
- Solar Panels
  - The iron stand for the solar panels should be attached to the roof of the new church, with the 6 Dayliff 160W solar panels facing northwest
- Controller
  - The Lorentz PU600 HR-07 submersible pump controller should be placed somewhere secure and indoors, preferably on the inner southwest corner of the new church building
- Tank
  - A concrete pad 1 meter tall should be constructed in a shady area on the south side of the pastors house, near the road
  - A 10,000 liter tank will be placed on top of the pad
- Spigots
  - A concrete basin will be constructed on the grassy area in front of the new church building, similar in design to the current spigot basins already in place throughout the village
  - 3 spigots will be attached to pipe coming out of the concrete basin, allowing for multiple people to fill buckets at one time
- Piping
  - Pipe will run from the borehole in the field through a 1 meter deep trench dug along the road to the tank where it will enter through the top of the tank
  - Pipe will attach to the bottom of the tank and run underground to the spigot basin
- Wiring
  - Wire will run from the solar panels to the controller, and from the controller to the pump
  - A trench should be dug from the controller to the spigot basin to allow the wire to reach the trench the pipe is placed in, which it can follow to the pump

After this system is installed and operational, the option of adding additional solar panels and a battery system can be investigated.

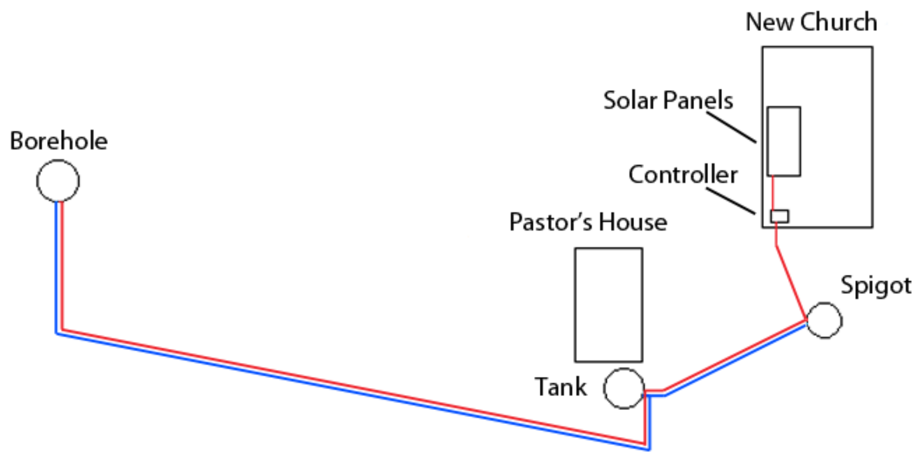


Figure 6: Detailed Layout of the Proposed Project Components

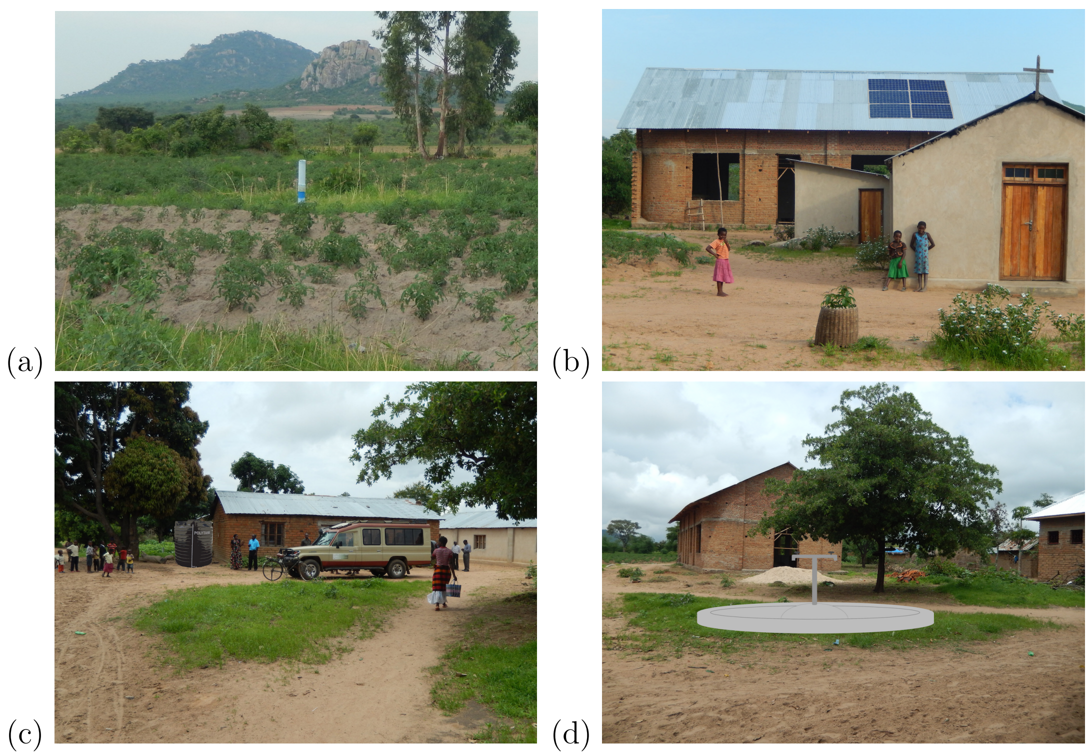


Figure 7: The components of the proposed system will include (a) the borehole and (b) the solar panels (c) the tank location and (d) the spigot area

3.7 Project Site

In 2011, a 90 m deep borehole was drilled in a crop field near the church by St. Paul Partners. The proposed project site will include this existing borehole and the area located by the church and pastor's house. The location of the tank was decided based on its proximity to the vocational school and church. The distance between the farthest point of the subvillage to the proposed location is about 0.5 km, making the location optimal. The underground piping from the borehole to the proposed location is approximately 350 meters with a increase in elevation of 10 meters. A layout of the piping can be seen in Figure 8. The piping will be placed next to the road to minimize the impact on the farmers fields that lay in between the borehole and the church.

Figure 8: Satellite Imagery of the Proposed Water System Piping Layout

4 Construction Process

A borehole has already been drilled and cased with 4 inch PVC casing. Borehole yields have also already been tested, and a recovery rate of approximately 13 liters per minute was determined. Therefore, the digging of trenches, laying of pipe, construction of concrete pad, pump and controller implementation, and solar panel wiring remain to be completed.

The trenches from the borehole to the SIM tank will be dug by the Mlangali villagers. This is a large portion of their in-kind contribution to the system. A level switch will be installed in the SIM tank to control the turning on and off of the pump. The concrete spigot area will be designed like the current spigot areas as shown in Figure 2 (c). This will make it a smooth transition for the villagers to switch to the new water system because it will look like something they are already familiar with. The current water distribution system from the river will not be touched with this proposal. This will allow the villagers to continue getting water while the new system is under construction. Also, if anything were to happen to the new water system, the old system would still be functional as a back up.

5 Project Sustainability

To ensure the long-term sustainability and success of this project, it is crucial to involve the community and local water committee during the entire process. Maintaining the villages full participation in the development and construction process is the basis of the Saint Paul Partners approach. For SPP, participation stems from the recognition of, ownership of and involvement in their own development process. In order to promote the feeling of personal investment, the community will contribute room and board for drilling technicians, locally available materials such as sand and bricks, and contribute unskilled labor for the construction of the solar pumping and storage system. Additionally, the Mgela water committee will be expected to maintain an account with sufficient funds for repairs of the water system following the initial construction. Based on the lifetime of the pump and necessary security for the solar panel and controller, a minimum of $1,600 (2.8M Tsh) must be collected each year by the committee; this averages to about 35 Tsh per 20 liter bucket, well under the 100 Tsh villagers must currently pay for river water. We therefore suggest charging 50 Tsh per 20 liter bucket, with the additional scope of eventually doubling the solar panels and adding to the system to allow for more hours of pumping with these extra funds.

6 Project Budget

Table 1: Solar Pump System Costs

Description	Unit	Quantity	Unit Cost (TZS)	Unit Cost (USD)	Cost (USD)
DAYLIFF Solar Panel 160W, 24V	panel	6	440,000	244.14	1,470.00
LORENTZ PS600 HR-04 Submersible Pump C/W 0.7kW Motor	pump	1	3,128,000	1,737.78	1,740.00
LORENTZ PU600 HR-07 Submersible Pump Controller	controller	1	1,734,000	963.33	960.00
LORENTZ Well Probe Sensor	sensor	1	144,500	80.28	80.00
4 mm^2 Flat Submersible Drop Cable	meter	60	13,000	7.22	430.00
Wire Pump to Panels	meter	400	6,500	3.61	1450.00
Iron Stands for Solar Panels	-	1	90,000	50.00	50.00
Cable Joint Large	-	1	30,000	16.67	17.00
Connecting Accessories	-	1	400,000	222.22	220.00
Labor for Plumbing	-	1	1,200,000	666.67	670.00
Labor for Solar Panels/Electrician	-	1	140,000	77.78	80.00
			Material Cost:		6417.00
			Labor Cost:		750.00

Table 2: Tank and Spigot Costs

Description	Unit	Quantity	Unit Cost (TZS)	Unit Cost (USD)	Cost (USD)
10,000 L Storage Tank	tank	1	700,000	388.89	390.00
HDPE 32mm Class D Pipe	150m roll	3	229,400	127.44	380.00
Pipe Fittings	-	3	15,000	8.33	25.00
Cement	bag	20	17,000	9.44	190.00
Sand/Gravel	lorry	2	100,000	55.56	110.00
Coarse Aggregates	lorry	2	100,000	55.56	110.00
Stones	lorry	1	100,000	55.56	60.00
Bricks	lorry	1	200,000	111.11	110.00
SPP Oversight and Training	-	1	1,000,000	555.56	560.00
Transport for pipe	trip	1	340,000	188.89	190.00
Transport for tank	trip	1	340,000	188.89	190.00
Labor for Digging Trench	meter	345	3,500	1.94	680.00
Labor for Concrete Work	-	1	600,000	333.33	330.00
			Material Cost:		1935.00
			Transport Cost:		380.00
			Labor (In-kind):		1010.00

Table 3: Yearly Maintenance Costs

Description	Unit	Quantity	Unit Cost (TZS)	Unit Cost (USD)	Cost (USD)
Pump Replacement	pump	1	1,564,000	868.89	870.00
Security	guard	1	1,314,000	730.00	730.00
			Maintenance Cost:		**1,600**

Table 4: Summarized Costs

Description	Cost (TZS)	Cost (USD)
Drilling	13,600,000	8,000
Pipe and Tank	3,153,200	1,800
Solar	11,546,500	6,440
Labor	4,147,500	2,320
Total Cost	**33,447,200**	**18,560**
Already Invested	(13,600,000)	(8,000)
In-Kind Contribution	(1,807,500)	(1,010)
Cost of Project	**17,039,700**	**9,550**

7 Appendix

7.1 Additional Input

With the current design and conditions, this system will produce approximately 5,000 liters of water in a 6 hour period of sunlight. This system was designed around the recharge capacity of the borehole, which was found through a water test performed by a local engineer. Given this recharge rate and the maximum amount of sunlight that can be obtained in a day, the most water that could be removed from the well was 5,000. For the village of Mlangali this falls short of the 20 liters per person per day goal, which for a village of 600 people would mean a water supply of 12,000 liters per day. As water cannot be removed from the well any faster than the recharge rate allows, the only other option is to pump for a longer period of time.

If it is determined that the well can supply water at the rate it is expected to while maintaining a stable water level, additional components can be added to the system to enable more pumping hours. Additional solar panels should be added to charge batteries. These batteries would power the pump in hours of low sunlight and through the night, increasing the water supply to a potential 20,000 liters if the total pumping time was set to 24 hours. It is recommended that if this option is pursued, panels and batteries should be added in stages to insure that the water level is stable at each increase in draw from the water table.

7.2 Matlab Code/Calculations

7.2.1 Determining Diameter and Pump Size for the System

```
% MLANGALI CALCULATIONS %

g=9.81;
rho=1000;
d=.032; %1 inch pipe (32 mm)
nu=1.31*10^(-6);
p1=0;    %location 1 is in the well, location 2 is at the tank
p2=0;
z1=0;
z2=48;
l=345;
kl=50;
h=1;   %height of tank
cpw=5; %cost per watt

%RECOVERY RATE

%rr=0.000044717; % m^3 per second
rr=0.000217; % with steady state data from pump test
mdot=rr*rho;
a=((d/2)^2)*pi;
```

```
v=rr/a;
re=v*d/nu;
if re<2300
        fprintf('\nFlow is laminar. \n \n');
        f=64/re;
else
       fprintf('\nFlow is transient. \n');
       f=.036;   %http://www.lmnoeng.com/moody.php
end

%HORSEPOWER CALCULATIONS

w=mdot*g*(((v^2)/(2*g))*(f*l/d+kl)+(p2-p1)/(rho*g)+(z2+h)-z1);
hp=w*0.00134102209;
head=w/(mdot*g);
fprintf('Required power is: \n');
fprintf('%s watts \n',num2str(w));
fprintf('%s horsepower \n \n',num2str(hp));
fprintf('Total head is %s  \n',num2str(head));
```

7.2.2 Determining Solar Panels for the System

The number of panels found for the 1 hp pump was found to 5 from the following equation. However, to account for variability in the sunlight hours, an additional panel was added.

$$\# \text{ of panels} = \frac{Watts_{total}}{Watts_{panel}}$$

Where: $Watts_{total}$ = total watts required
$Watts_{panel}$ = number of watts per panel

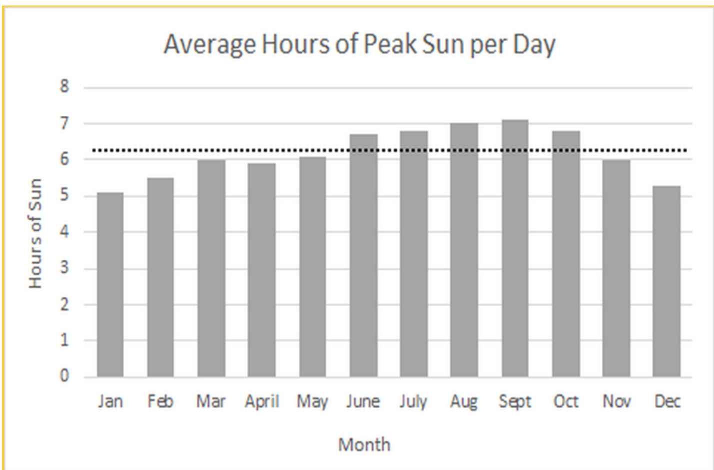


Figure 9: Average Peak Sunlight Hours per Day

7.3 Borehole Pump Test

Time hour:minutes	Time decimal hours	Water level FOOT	Water level METER	Time sec to pump 22 Liter	YIELD LITERS PER HOUR	YIELD GAL PER HOUR	LPM	liters
13:00	13.00	25	7.6	21.51	3682	973	61.4	
13:02	13.03	30	9.1	21.6	3666	969	61.1	122.47
13:04	13.07	35	10.6	22.75	3481	920	58.0	119.12
13:06	13.10	40	12.1	22.08	3586	947	59.8	117.78
13:08	13.13	45	13.7	26.99	2934	775	48.9	108.67
13:10	13.17	45	13.7	27.96	2832	748	47.2	96.10
13:12	13.20	50	15.2	28.21	2807	742	46.8	93.98
13:14	13.23	55	16.7	30.3	2613	690	43.6	90.33
13:16	13.27	60	18.2	32.27	2454	648	40.9	84.45
13:18	13.30	75	22.8	32.35	2448	647	40.8	81.70
13:23	13.38	160	48.7	37.61	2105	556	35.1	189.71
13:28	13.47	200	60.9	43.82	1807	477	30.1	163.00
13:33	13.55	205	62.4	49.84	1589	420	26.5	141.50
13:38	13.63	220	67	60	1320	349	22.0	121.21
13:43	13.72	240	73.1	64.34	1230	325	20.5	106.25
13:48	13.80	250	76	68.22	1160	306	19.3	99.58
					2482.125	656	41.4	**1735.85**

Figure 10: Pump Test Discharge and Water Level Data with Completely Open Valve

Time hour:minutes	Time decimal hours	Water level FOOT	Water level METER	Time sec to pump 22 Liter	YIELD LITERS PER HOUR	YIELD GAL PER HOUR	LPM	liters
17:00	17.00	45	13.7	40.72	1944	514	32.4	
17:05	17.08	50	15.2	44.66	1773	468	29.6	148.68
17:10	17.17	55	16.7	47.5	1667	440	27.8	148.95
17:15	17.25	60	18.2	48.21	1642	434	27.4	137.99
17:20	17.33	65	19.8	48.5	1632	431	27.2	135.87
17:25	17.42	70	21.3	49.51	1599	422	26.7	140.55
17:30	17.50	75	22.8	50.41	1571	415	26.2	126.80
17:35	17.58	90	27.4	52.26	1515	400	25.3	123.44
17:40	17.67	115	35	52.86	1498	396	25.0	129.56
17:45	17.75	125	38	56.19	1409	372	23.5	122.09
17:55	17.92	140	42.6	56.07	1412	373	23.5	239.79
18:05	18.08	155	47.2	56.12	1411	373	23.5	225.84
18:15	18.25	160	48.7	93.9	843	223	14.1	191.59
18:25	18.42	160	48.7	97.33	813	215	13.6	140.76
18:35	18.58	160	48.7	98.43	804	212	13.4	129.36
18:45	18.75	160	48.8	98.7	802	212	13.4	136.51
19:05	19.08	165	50.2	111.94	707	187	11.8	248.98
19:15	19.25	165	50.2	112.09	706	187	11.8	120.11
19:25	19.42	165	50.2	113.07	700	185	11.7	119.51
					1286.7368			**2766.37**

Figure 11: Pump Test Discharge and Water Level Data with Partially Closed Valve

Time hour:minutes	Time decimal minutes	Water level feet	Water level meter
13:50	13.83	250	76.1
13:52	13.87	240	73.1
13:54	13.90	230	70.1
13:56	13.93	220	67
13:58	13.97	210	64
14:00	14.00	210	64
14:02	14.03	205	62.4
14:04	14.07	200	60.9
14:06	14.10	195	59.4
14:08	14.13	190	57.9
14:13	14.22	185	56.3
14:18	14.30	180	54.8
14:23	14.38	180	54.8
14:28	14.47	180	54.8
14:33	14.55	175	53.3
14:38	14.63	170	51.8
14:43	14.72	165	50.2
14:48	14.80	165	50.2
14:53	14.88	165	50.2
14:58	14.97	160	48.7
15:03	15.05	155	47.2
15:08	15.13	140	42.6
15:18	15.30	130	39.6
15:28	15.47	115	35
15:38	15.63	100	30.4
15:48	15.80	95	28.9
15:58	15.97	85	25.9
16:08	16.13	75	22.8
16:18	16.30	75	16.8
16:28	16.47	65	16.7
16:38	16.63	55	15.2
16:48	16.80	50	13.7
16:58	16.97	45	13.7

Figure 12: Pump Test Recovery Data

7.4 Pump Data

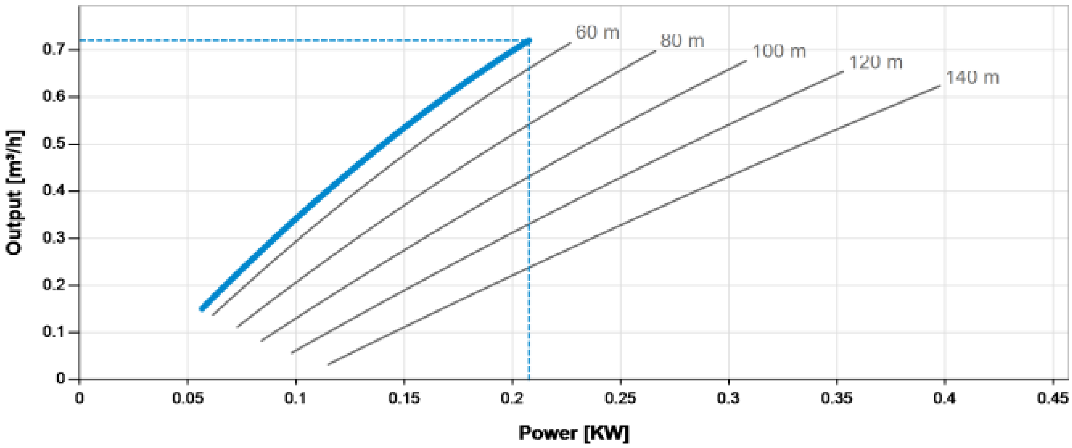


Figure 13: Pump Curve for Lorentz PS600 HR-04 submersible 1 horsepower pump