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EFFECT OF DRAWDOWN ON SUBMERSIBLE PUMP PERFORMANCE

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Abstract: There are 15000 submersible pumps are operating in the Barind area of Bangladesh to supply water for both irrigation and household purposes. During summer, the water level at different locations in this region drops below the optimum range of the pump causing a low discharge as well as poor performance. The total head contains a parameter known as drawdown which is the difference of the static level and the pumping level of water inside the well. Since the pump work against the drawdown, it has decreased pump efficiency. This present work is carried out to observe the drawdown characteristics by varying two parameters: well diameter and filter length, which mainly control the nature of drawdown. The effect of drawdown on pump performance has also been investigated. The maximum drawdown was 1.4 m at a discharge of 228 liter/min for a 0.10 m diameter well with 0.30 m filter and the correspondence pump efficiency was 10%. On the other hand, the maximum pump drawdown for a 0.15 m diameter well was observed 0.18 m for 0.30 m filter length with 9% efficiency. It was also studied that optimum efficiency varies between 36% to 40% and the discharge varies from 95 to 125 liters/min. The reduction of well drawdown could be achieved by increasing well diameter and filter length to obtain better performance of submersible pump.

Keywords: *Submersible pump, Static water level, Drawdown, Energy consumption, Pump efficiency.*

NOMENCLATURE

d_1 = Diameter of the well
d_2 = Diameter of the discharge pipe
P_1 = Suction pressure at datum line
P_2 = Delivery pressure in water distribution line
H_p = Pump head gain
h_{fm} = Major head loss due to friction in the discharge pipe of diameter d_2
h_{ls} = Head loss at pump inlet due to screen
h_{lb} = Head loss at the bend
h_{lf} = Head loss in flange joints
n = number of flange joints
L = Length of the discharge pipe
ρ_w = Density of water

1. INTRODUCTION

In the submersible pump, all stages of the pump end along with the motor are joined and submerged in the water, providing a great advantage of no cavitation over centrifugal pumps. The submersible pump is a multi-stage centrifugal pump where all the impellers are mounted on a single shaft and all rotate at the same speed. Each impeller passes the water to the eye of the next impeller through a diffuser. The diffuser is shaped to slow down the flow of water and convert velocity into pressure. Thus, it can develop more lifting of water without any cavitation. Each time water is pumped from one impeller to the next, its pressure is increased. As the ground water level is declining day by day, it is almost impossible to lift water by low lift pump like centrifugal pump for irrigation, drinking and industrial purposes today. Rajshahi Water Supply and Sewerage Authority (RWASA) have already taken initiatives for supplying ground water by installing submersible pump in the Rajshahi city zone.

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Barind Multipurpose Development Authority (BMDA), Rajshahi is supplying water by using submersible pumps mainly for irrigation in sixteen districts of Northern part of Bangladesh. Total 15000 submersible pumps are supplying water under BMDA among which 14386 pumps are submersible and 614 are turbine pumps up to June 2015 [1]. Rajshahi Water Supply and Sewerage Authority (Rajshahi WASA), uses 87 submersible pumps for supplying of drinking water and household affairs in the Rajshahi City Corporation (RCC) [2]. Besides, large number pumps of smaller capacity are running for supplying water by other organizations and private sectors in the northern part of Bangladesh [3]. The Barind area is comparatively at a higher altitude than the adjacent floodplains. Approximately 41% of the land are medium highland and the rest are lowland. Most of the year agricultural land occupies about 80% of the hill slopes. Agriculture largely depends on the irrigation process during the dry season due to minimum rainfall. Groundwater supplies 75% of water in dry season irrigation and almost all municipal water supplies [4].

Since this region is generally free from floodwater, rainwater is the major source of groundwater [5]. Withdrawal of ground-water during the dry season causes a large drop in ground-water levels in the Barind region. Due to this declining ground water a large number of hand tube wells go out of operation during the dry season [6]. During the summer season the water level goes down, which results in a high static water level. It is generally caused when the ground water heads in an aquifer fall below a critical or threshold level over a certain period of time due to natural or human induced cause and interventions particularly in the northwestern region of the country. For this reason the pump has to work against a high head and providing lower discharge. As a result, the performance of submersible pump drops. The static water level is low during the rainy season since the underground water level increases in this period. The submersible pump provides better performance during rainy season. To obtain the optimum efficiency all the year round, the way of operation should be renovated. It has reported that about 10% to 30% of the energy consumed by submersible pump could be saved through the change of mode of operation and control system [7].

After analyzing the field survey, it was found that drawdown playing vital role responsible for this variation in performance. The factor well drawdown is responsible for shifting the pumping head from the operating range. It depends on both well diameter and filter length. The present work aims to investigate the effect of these two parameters on well drawdown and to observe the variation in pump performance under different well filter configurations.

2. IDENTIFICATION OF GROUND WATER LEVEL

Ground water level shows a seasonal pattern of fluctuation. The ground water level in Barind area rises and falls continuously with the advance of the wet and dry season. Static water level in the different region of Barind area has been collected from the head office of BMDA. The following figures show the monthly fluctuation of ground water level at different regions.

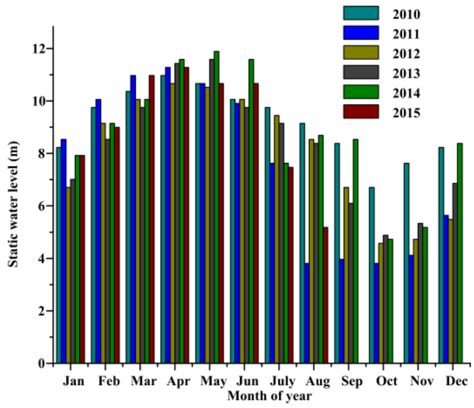

Fig. 1 Monthly fluctuation of ground water level at Shantoshpur, Rajshahi.

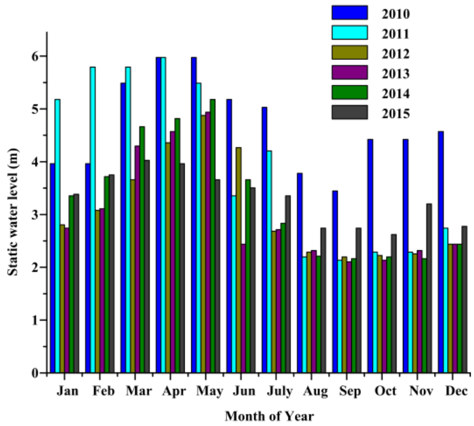

Fig. 2 Monthly fluctuation of ground water level at Rajarhat, Kurigram.

Fig. 1 and Fig. 2 shows the monthly fluctuation of static ground water levels at Paba Upazila, Rajshahi and Rajarhat Upazila, Kurigram respectively for six years. It is observed that the static head of ground water varies from 3.65 m to 12.2 m in Rajshahi region where it varies from 2.12 m to 6.1 m in Kurigram region. Since Rajshahi is situated at higher elevations and except rain water, there is no source of ground water recharge static water level is high in this region compared to Kurigram. It has also investigated that during the summer season (March to June) the static head of the groundwater is quite high and is lower during rainy season (August to November).

3. PERFORMANCE OF SUBMERSIBLE PUMP IN BARIND AREA

For analyzing the submersible pump performance operating in the Barind region, total three pumps from the three different locations were selected and corresponding data of the head and discharge to calculate efficiency were collected for one year. It was found that the efficiency varies with the different month of the year and also with the location. From Fig 3, it was revealed that the pumps provide lower performance from the month March to June since the static water level is high during this period. After this period, higher values of efficiency were obtained between the month September to February because of higher discharge and less electricity consumption.

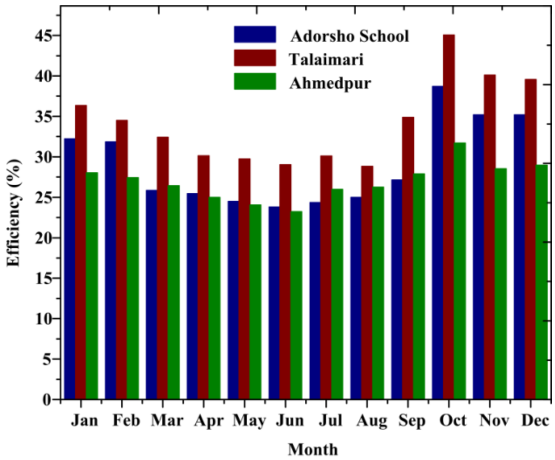

Fig. 3 Efficiency variation of different pumps used in Barind region.

It was found that the efficiency varies with the different month of the year and also with the location. From Fig. 3, it was revealed that the pumps provide lower performance from the month March to June since the static water level is high during this period. After this period, higher values of efficiency were obtained between the month September to February because of higher discharge and less electricity consumption. The maximum efficiency of 45% was found in the month of October at Talaimari location where the minimum efficiency of 23% was found in Ahmedpur location in the month of June. The factor well drawdown is primarily identified for this variation in the submersible pump efficiency since the pump work against this extra head of water.

4. EXPERIMENTATION

The experiment has been carried out by varying different well filter arrangement to observe the drawdown characteristic of submersible pump in a pump test bed installed at Rajshahi University of Engineering & Technology. During the experiment first, a 3 HP submersible pump was immersed into the reservoir without any well and filter. To observe the operating characteristics of the pump in this condition the pump was run by varying the discharge as well as operating head. The pump was then immersed in 0.10 m diameter well, made pump of UPVC pipe to investigate the variation of pump efficiency with the variation of well diameter and filter length. The filter length was altered by blocking the opening as 0.03 m, 0.60 m, 0.91 m respectively. The electric power delivered to the pump was calculated by multiplying the voltage across the terminal and the current. The whole procedure was repeated for well of 0.15 m diameter. For calculating the pumping level, drawdown and various losses (including friction loss and fittings loss) were considered. A mathematical model has been developed to calculate the pump head gain of submersible pump considering pumping level and losses which are shown in Fig. 4.

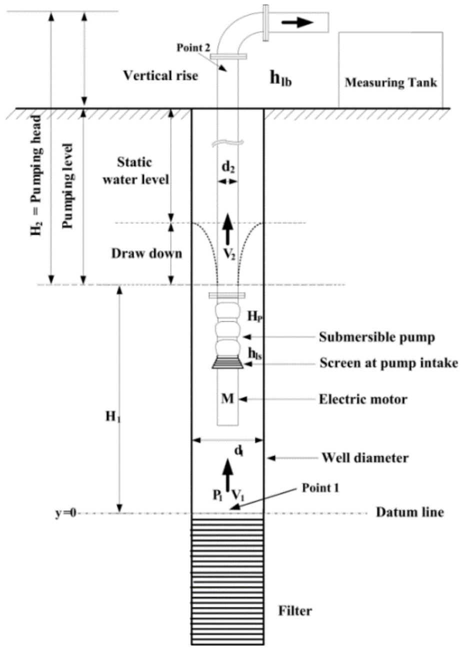

Fig. 4 Experimental set up.

The total head gained by the submersible pump can be obtained by using the following relations-

$$H_p = H_2 + K\frac{V_2^2}{2g} + \frac{P_2}{\rho g} \tag{1}$$

Where, $K = \left\{1 - \left(\frac{d_2}{d_1}\right)^4 + f_{ls} + f_m\frac{L}{d_2} + f_{lb} + n \times f_{lf} + f_{lo}\right\}$

The efficiency of the submersible pump can be calculated by using the Eq. (2)

$$\eta_p = \frac{\rho_w \times g \times Q \times H_p}{P} \tag{2}$$

5. RESULTS AND DISCUSSION

After establishing the experimental setup, the data of discharge and head are measured by varying the boring pipe diameter along with filter length. The maximum pump efficiency found 39 % for a 0.10 m diameter well and the lowest efficiency is calculated as 6% for the configuration with 0.15 m diameter well. The performance of the pump under different operating conditions is presented below:

5.1 Drawdown Characteristics of Submersible Pump

Pump drawdown has a detrimental effect on pump performance since it shifts the operating head of the pump. Also, the pump needs to work against extra head due to this drawdown. An experiment has been conducted to investigate the nature of drawdown by varying the well diameter and filter length. The drawdown reduces with increasing filter length and well diameter. It has observed from Fig. 5 and Fig. 6 that maximum drawdown was 1.4 m and 0.17 m for well diameter of 0.10 m and 0.15 m respectively. It was also observed that with increasing discharge, pump drawdown increases.

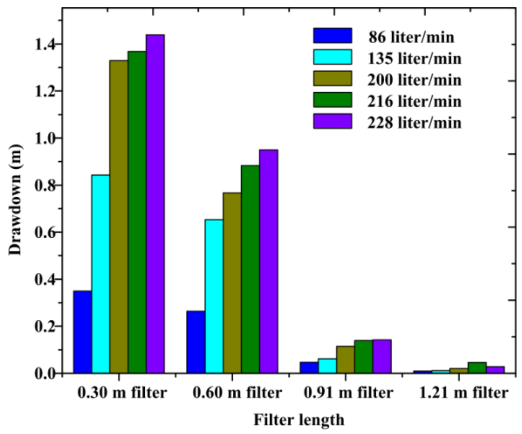

Fig. 5 Variation of pump drawdown in 0.10 m diameter well.

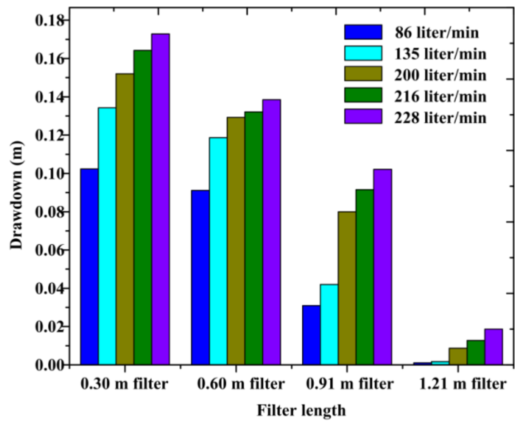

Fig. 6 Variation of pump drawdown in 0.15 m diameter well.

With high discharge, the pump needs to supply more water that causes corresponding high drawdown. On the other hand, with a larger well diameter more waters are available for discharge which consequently results reduced drawdown. The increases filter length also provides more water that corresponds reducing drawdown and vice versa.

5.2 Operating Characteristic Curves

In open pond, the maximum efficiency of the pump was 31% where the operating discharge ranges between 95 to 125 liter/min and pumping head ranging from 34.3 m to 29.6 m as shown in Fig. 7. Since, the well diameter and filter length has an effect on pump performance; an attempt has been made to investigate the pump behavior under various condition of operation. Fig. 8 and Fig. 9 shows the characteristic of a submersible pump with variable operating conditions. With the increasing value of discharge, pump head drops as well as the efficiency. Optimum efficiency of the pump was found as 40 % for 0.10m well diameter for which operating head and discharge are 57 m and 87 liter/min, respectively. The maximum efficiency for 0.15 m well diameter is 38 % when the operating head and discharge are 54 m and 83 litre/min, respectively. But in open pond submersible pump provides poor performance. The pump efficiency, increased up to 20% for 0.10 m well diameter and 10.85% for 0.15 m well diameter.

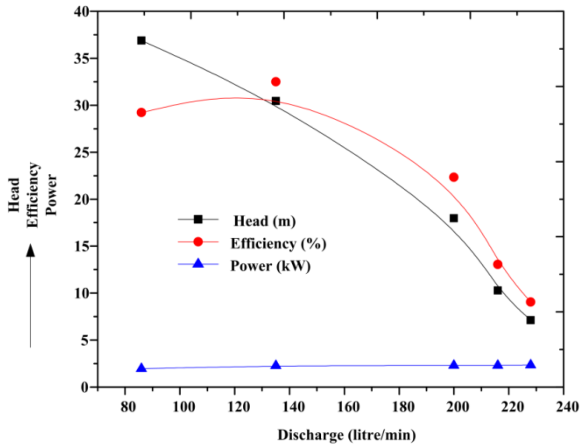

Fig. 7 Optimum performance curve of the pump in open pond.

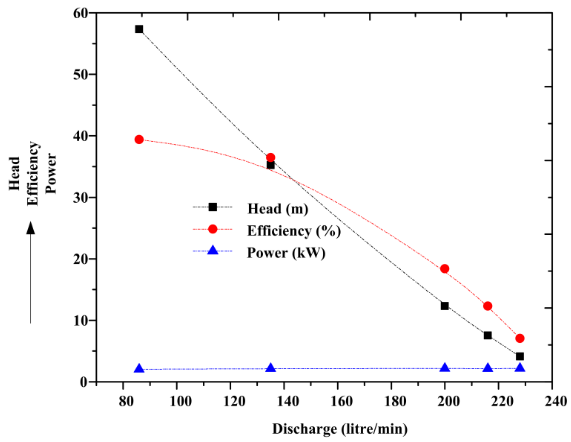

Fig. 8 Optimum performance curve for 0.10 m diameter well.

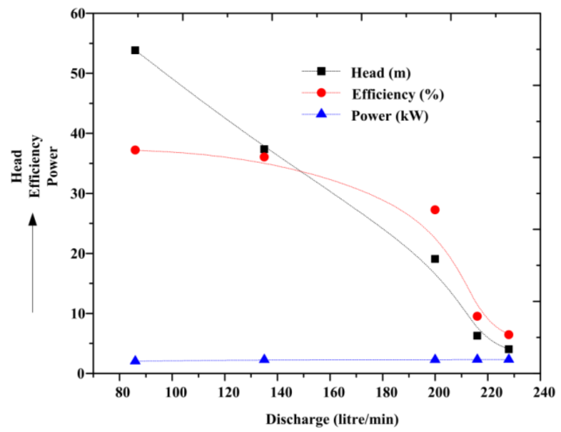

Fig. 9 Optimum performance curve for 0.15 m diameter well.

4. CONCLUSIONS

In the Barind region of Bangladesh, submersible pump provides variable performance around the year. The efficiency is maximum during rainy season because of the low static water level. Along with this, pump drawdown is also responsible for this variation in performance since the pump work against it. Characteristic of a submersible pump under different operating conditions has been studied. The parameter drawdown depends on both well diameter and filter length. It was found that the well diameter and filter length has a subsequent effect on pump performance. For a large well, drawdown decreases. Also, pump discharge maintains a linear relationship with pump drawdown. Higher discharge of pump results in high drawdown. Higher drawdown causes poor performance. Further research works are suggested to carry on submersible pump to improve its performance in Barind area of Bangladesh.

5. ACKNOWLEDGMENTS

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