CHAPTER 5

Conclusion and Suggestions

The conclusions from this dissertation were described in four parts according to the objectives. The first part was the laboratory testing of the pumping system which were Hydraulic Ram Pump (H.R.P.) and Water Wheel Pump (W.W.P.). The second part was the design and construction of prototype natural water sources as waterfall and stream integrating with H.R.P., W.W.P and Hybrid Water Pump (H.W.P.). The third part was the study of variables, appropriate technology, and performance of the three water pumping systems with the prototype natural water sources. The final part was the economic analysis for the investment and payback period as well as the overall suggestions.

The characteristic of hydraulic ram pump and water wheel pump were evaluated for the discharge volume and delivery head performance in the laboratory. The two systems provided the range for maximum discharge range at 8-19 L/min and delivery head range at 4-10 m. For the hydraulic ram, the higher supply head of the waterfall provided more force from water hammer principle and therefore provided higher delivery head. However, with the higher delivery head, the discharge decreased. The amount of usable discharge water was only within 5-10% depending on the supply head. The hydraulic pump with 25.4 mm inlet size had D’aubuisson’s, Rankine and Mechanical Efficiency as 18.33%, 14.43% and 14.0%, respectively. The natural water pump efficiency was significantly lower than the conventional electric
pump which was about 60-80%. If high flowrate of water loss that occurred during hydraulic ram pumping could be reused, the efficiency of the natural pump system would improve.

Contrary to hydraulic pump, the evaluation of W.W.P. in the laboratory provided higher discharge but with lower delivery head. The water wheel pump was tested in a laboratory at water velocity of 0.5 m/s, 0.8 m/s, and 1.0 m/s with the discharge range of approximately 3-12 L/min and delivery head range of 4-10 m. The result of the mechanical efficiency of the water velocity of 0.5 m/s and 1.0 m/s were 34-37% and 8-19%, respectively. The result suggested that water velocity clearly affected the discharge and delivery head. It was found that the relationship profile between the water velocity and the mechanical performance tend to decrease, when the water velocity increased. The increased velocity reduced the time for water wheel pump to gather water. Therefore, low volume of discharge lower mechanical efficiency was observed. Opposite characteristics of hydraulic ram and water wheel pump were noted for the performance of head and discharge volume. However, the goal of the research was to provide the water pumping system with high head and high discharge. Integrating both pump as hybrid system could be the technology to deliver the high head and high discharge volume.

The resulted from the laboratory was used in the design and construction of the prototype water sources and operational testing of H.R.P., W.W.P and H.W.P. to determine the optimal condition for highest delivery head and discharge. The prototype water fall was constructed with 5 tiers at the height (h) of 1-5 m, with the flowrate (q) of 100, 150, and 200 L/min. The water was circulated in the prototype stream with 1 m width, 1 m depth, and 10 m length. The surface water velocity was
controlled at 0.5, 1.0 and 1.5 m/s. After the construction of the prototype sources, the
3 types of water pumping system were installed. H.R.P. with inlet diameter of 25.4
mm were connected in series with the W.W.P. with the diameter of 2 m, width of 40
cm and paddle 30 cm beneath the water surface. The water storage tank was installed
up to 15 m.

H.R.P., W.W.P, and H.W.P performance with prototype water sources were
evaluated to determine the optimal operating condition. During the experiment,
H.R.P. with 25.4 mm inlet were tested with the waterfall of 4 tiers at 2, 3, 4, and 5 m
with the inlet water flowrate of 100, 150 and 200 L/min. The evaluations were
conducted with 10 replications for each condition with the total of 120 experiments.
The overall performance of H.R.P. was discharge at 5 to 12 L/min and delivery at the
range of 5 to 14 m. However, increasing the inlet water flowrate from 100 to 200
L/min did not affect the amount of discharge and delivery head. Large amount of
water was significantly loss and were not fully utilized as the discharge flowrate with
the increase of inlet flowrate. At inlet of 100 L/min, the maximum height of the
pumped water was 5 m which provided mechanical efficiency of 13.16%. The
mechanical performance decreased with higher inlet flowrate because the water trays
had the maximum capacity for only 100 L/min. The water would overflow the tray
and mechanical performance decreased. Therefore, for the system to start working,
the inlet flowrate must be at least 100 L/min. Similar result trends were observed
with the evaluation of Rankine and D’aubuisson’s Efficiency. Mechanical efficiency
calculated the overall efficiency of water inlet and outlet. D’aubuisson’s efficiency
calculated the kinetic energy, potential and impact energy. In addition, Rankine
calculated only the impact energy, therefore the value was lower than D’aubuisson
efficiency. This result was similar to the result of the experiment conducted in a laboratory.

The Water Wheel Pump experiments were evaluated with the prototype stream. The water velocities were varied from 0.5 to 1.5 m/s and the testing were conducted with 10 replications for each condition with the total of 30 experiments. The discharge was 2-16 L/min and the delivery head was about 3-13 m. However, with increasing velocity to 2 m/s, the discharge did not increase prominently. It was observed that with high velocity stream, the paddle moved quickly thus provided less time to bail the larger quantity of water. So, the optimal water velocity is at 1.0 m/s. Higher velocity could not provide more discharge and resulted in higher quantity of water loss. Mechanical efficiencies of the W.W.P. was at 8-23%. This is because the mechanism inside the spiral tube of the wheel which employs the principle of air contraction and the movement of air mass and water mass.

The Hybrid Water Pump (H.W.P.) system was installed with the prototype waterfall and stream. The goal of the hybrid system was to effectively utilize the natural water source with minimal loss water. For the testing of 360 experiments, the water flowrates were varied at 100, 150 and 200 L/min and dispensed from the prototype waterfall tier of 2, 3, 4, and 5 m. In addition, the velocities of the prototype stream were varied as 0.5, 1.0 and 1.5 m/s. The results also clearly indicated that the optimal condition with maximum mechanical efficiency was flowrate at 150 L/min and velocity at 1.0 m/s for all the supply head variation. This was because the flowrate of 150 L/min was the maximum flowrate for the H.R.P. inlet diameter of 25.4 mm. The higher flowrate at 200 L/min would create excess water instead of higher usable discharge. In addition, the velocity at 1.0 m/s was optimal for the
W.W.P. at diameter 2 meter with 30 cm depth into the stream. With higher velocity, the paddle could not uptake more water and resulted in more unused water.

For the relationship between supply head and delivery head, the most influential parameter was the water velocity. At velocity of 1.5 m/s, provide the most stable maximum delivery head irrespective of the supply head. The mechanism of W.W.P. took over the hybrid system with higher velocity. For the water inlet condition at low water velocity and low supply head, H.R.P. mechanism would dominate the H.W.P. system with performance varying according to the supply head level. Therefore, the condition of the natural waterfall would be very important in the design and size of the hybrid pump.

For H.W.P., the mechanical efficiency remained quite stable around 14-16% even with the increased in discharge volume unlike H.R.P. and W.W.P. For the performance of delivery head and discharge, reverse characteristic was found with H.R.P. and W.W.P. For H.R.P., higher delivery head reduced the mechanical efficiency, while the opposite was found for W.W.P. In addition, for the H.W.P., the mechanical efficiency was stable in the high delivery head range of 7-11 m. This was the water storage height range that was suitable for farming to achieve pressure of 1 bar. Therefore, it was proven that when combined the reverse efficiency characteristic of H.R.P. and W.W.P. into the hybrid system, the combined water pumping system achieved the stable efficiency and performance.

The result of the economic analysis of 3 natural water pump and electric power pump system (1 hp). The investment, operation, and maintenance costs and payback period were compared with the pumps’ operating lifetime of 10 years. The payback periods for the natural water pump systems’ investment costs were calculated
with reference to the annual electricity operating cost from the centrifugal electric pump. The calculation of the payback period was performed based on the assumption of electric pump system was replaced with the natural water pump systems. The natural pumps did not require electricity and therefore this operation cost would be saved as compared to the investment cost. The investment cost of H.R.P., W.W.P., H.W.P., and Electric pump were 4,600 baht, 7,810 baht, 12,410 baht, and 4,614 baht, respectively. The H.R.P. had the lowest annual operating cost of 720 baht per year because it had the least parts and the maintenance was not complicated. However, the H.R.P. could only be operated at the waterfall. For W.W.P., the annual cost was 1,220 baht per year. The higher cost was also due to the more parts in the W.W.P. and with higher efficiency more maintenance was needed. Similarly, the annual cost for H.W.P. was combined between H.R.P. and W.W.P. at 1,942 baht per year. The electric pump annual operating cost was based on the electricity price for operation of 8 hour per day for 365 days for the total of 8,917.80 baht per year. The payback periods of the investment cost for the 3 natural water pump systems were calculated based on the savings of electricity from electric pump. So, the payback periods were 0.5, 0.75 and 1.5 years for H.R.P., W.W.P., and H.W.P., respectively. The short payback period clearly indicated the economic benefit of using natural water pump systems for farming. The other advantage of the natural water pump systems compared to electric pump was that they could be used in the remote area without electricity access. The natural water pumps could be operated for 24 hours per day unlike the electric pump which could not be operated continuously. If the electric pump operated continuously, the motor could get hot and damaged. Typically, in agriculture, the water pumping for storage could be performed at any time without the
rush as long as there was sufficient water storage for farm use. Therefore, the water did not need to be pump at the fast speed with the high efficient electric pump. The efficiency of the H.W.P. could provide sufficient operability for the farm needs. Not only H.W.P. used clean energy from nature, the natural pump system could be used in other applications such as maintaining the watershed, creating moisture in the forest, preventing forest fire, and treating air and waste water, etc.