# ANALYSIS OF ENERGY CONSUMPTION FOR GROUNDWATER ABSTRACTION TO FULLFIL WATER REQUIREMENT IN IRRIGATED-AGRICULTURAL FIELD CASE STUDY IN SRAGEN, CENTRAL JAVA

**Arranged as one of the requirements to complete the Strata I Study Program at the Civil Engineering Department of the Faculty of Engineering**

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APROVAL SHEET

# ANALYSIS OF ENERGY CONSUMPTION FOR GROUNDWATER ABSTRACTION TO FULLFIL REQUIREMENT IN IRRIGATED-AGRICULTURAL FIELD

**Final Project**

This final project approved as one of requirement to archieve

Civil Engineering Bachelor Degree

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Surakarta , 27 August 2019

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# ANALYSIS OF ENERGY CONSUMPTION FOR GROUNDWATER ABSTRACTION TO FULLFIL WATER REQUIREMENT IN IRRIGATED-AGRICULTURAL FIELD CASE STUDY IN SRAGEN, CENTRAL JAVA


## Abstrak

Setiap tahun populasi manusia semakin meningkat. Hal ini menyebabkan kebutuhan setiap manusia juga semakin meningkat. Air adalah salah satu kebutuhan utama untuk kelangsungan hidup manusia. Air sangatlah penting dalam menentukan kelangsungan hidup manusia, di mana setiap hari manusia membutuhkan air bersih di semua bidang maupun di pertanian seperti irigasi. Seperti diketahui bahwa Indonesia merupakan negara agraris. Hal ini ditunjukkan dengan Indonesia menempati posisi ke enam puluh lima di dunia dan ke lima di ASEAN dalam bidang ketahanan pangan . Tentunya ini merupakan peringkat yang sangat baik jika kita melihat kembali pada peringkat tahun sebelumnya. Ini juga merupakan bukti dari keberhasilan kerja pemerintah. Tidak hanya pemerintah saja, dalam hal ini petani turut berperan dalam meningkatkan produktivitas pangan Indonesia. Namun dibeberapa wilayah terdapat sebagian lahan pertanian yang sering mengalami kekurangan air. Oleh sebab itu sebagian masyarakat mulai menggunakan air tanah untuk memenuhi kebutuhan tersebut. Pada penelitian ini akan diuraikan analysis mengenai banyaknya kebutuhan air yang digunakan, energi yang digunakan untuk menghisap air yang dibutuhkan , serta biaya yang dibutuhkan untuk satu masa tanam.



**Kata Kunci** **:** air, kebutuhan air, energi, biaya



## Abstract

Every year the human population increases. This causes the needs of every human being is also increasing. Water is one of the main needs for human survival. Water is very important in determining human survival, where every day humans need clean water in all fields and in agriculture such as irrigation. As is known that Indonesia is an agricultural country. This is shown by Indonesia occupying the sixty-fifth position in the world and fifth in ASEAN in the field of food security. Surely this is a very good ranking if we look back at the previous year's ranking. This is also evidence of the success of government work. Not only the government, in this case farmers also play a role in increasing Indonesia's food productivity. But in some areas there are some agricultural land that often experience water shortages. Therefore, some people began using groundwater to meet these needs. In this study an analysis of the amount of water needed, the energy used to suck the water needed, and the costs required for one planting period will be explained.



**Keywords** **:** water, waterrequirement, energy, budget


## 1. INTRODUCTION

Water is one of the main needs for human survival. But over time, there has been an increase in the human population resulting in increasing water needs. As a result of the need for water continues to increase, thus encouraging people to find a substitute for clean water sources such as river water which actually has begun to be polluted due to various types of waste. This causes humans to continue to use ground water as their main water source for their daily needs. In addition there are well drilling for the development of industrial activities that are identical to the needs of water needs in carrying out the production process.

Indonesia is an agricultural country. This is evidenced by the large amount of agricultural land in Indonesia, one of which is Sragen Regency in Central Java Province. Geographically, Sragen Regency is on the border between Central Java and East Java. Sragen Regency is located in an area with an average height of 109 M above sea level. Sragen has a tropical climate with a daily temperature of 19º-31º C. The average rainfall is below 3000 mm per year. Sragen has an area of 94,155 ha, with an area of around 40,129 ha of rice fields and an area of dry land of around 54,026 ha.

From the data, we know that part of the area is an agricultural area, which of course every day requires water as the main energy in agriculture. To meet these water needs, the Sragen Regency government has developed water resources infrastructure such as reservoirs, dams, reservoirs and irrigation networks. Sragen Regency has 7 reservoirs with inundation area 131.01 Ha and a capacity of 4,482 $m^3$, 76 dams scattered in 20 sub-districts capable of serving an irrigation area of 26,907 Ha, 19 retention reservoirs to hold water during the rainy season, secondary irrigation networks along 383,140 Km.

The large number of population and the extent of this agricultural land has led to an increase in water consumption as the main energy. So there is often a shortage of clean water sources. In addition, cropping patterns also affect the use of water as the main energy in agriculture. In the past we knew the cropping pattern according to the season. This of course causes increased water consumption. So that the community can use ground water to meet their daily needs. So that this study aims to determine the amount of groundwater requirements used for agricultural land and also the costs incurred when using groundwater.

## 2. METHOD

The initial stage that must be done is by studying the literature and collecting the necessary data such as rainfall data and climatology data. Data as material used to analyze in this study.The second stage in this research is analyzing the data that has been obtained. The first is by analyzing the water requirements for irrigation using rainfall and climatology data obtained from the Surakarta PUSDATARU. The second analyzes the energy requirements for irrigation based on the results of previous analyzes.The third stage of this research is to draw conclusions from what has been analyzed.

## 3. RESULT AND DISCUSSIONS

### 3.1 Consistency test

In analyzing water requirements for irrigation, rainfall data processing is needed. However, before analyzing water requirements it is necessary to carry out a consistency test whose purpose is to assess the stability of the variance value and average rainfall. The following table along with a graph of the results of the rainwater consistency test. Described in table 1 Cumulative Data Sta. Tested and Sta. Index of Batu Jamus station.

Table 1.Cumulative Data Sta. Tested and Sta. Index of Batu Jamus station

| Year | Sta.Batu Jamus (mm) | Sta.Index (B) | Cumulative | |
|---|---|---|---|---|
| | | | (A) | (B) |
| 2004 | 2106 | 1770.33 | 2106 | 1770.33 |
| 2005 | 2039 | 1624.67 | 4145 | 3395.00 |
| 2006 | 1701 | 1684.00 | 5846 | 5079.00 |
| 2007 | 4397 | 2598.00 | 10243 | 7677.00 |
| 2008 | 3898 | 1805.33 | 14141 | 9482.33 |
| 2009 | 4204 | 2228.67 | 18345 | 11711.00 |
| 2010 | 6066 | 2865.00 | 24411 | 14576.00 |
| 2011 | 4112 | 2295.00 | 28523 | 16871.00 |
| 2012 | 3866 | 1957.00 | 32389 | 18828.00 |
| 2013 | 5728 | 2281.33 | 38117 | 21109.33 |
| 2014 | 3839 | 1549.00 | 41956 | 22658.33 |
| 2015 | 4718 | 1680.33 | 46674 | 24338.67 |
| 2016 | 4104 | 3094.33 | 50778 | 27433.00 |
| 2017 | 2528 | 2440.00 | 53306 | 29873.00 |
| 2018 | 2045 | 1744.00 | 55351 | 31617.00 |

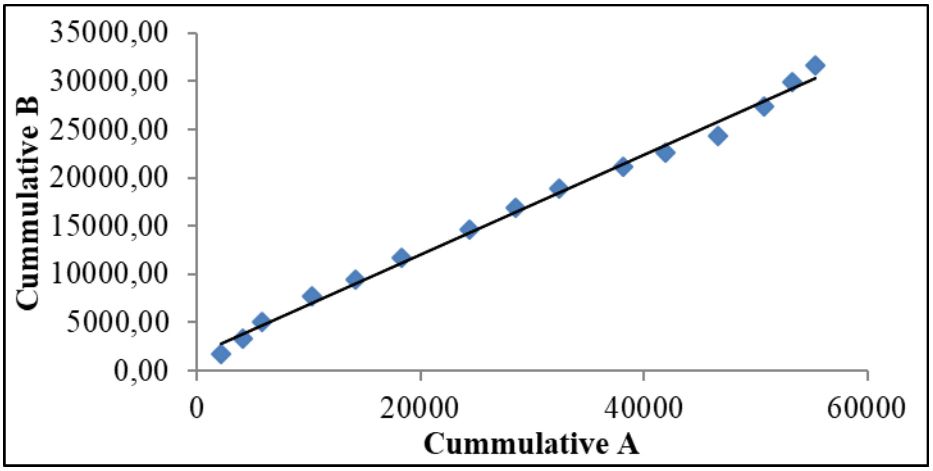


Figure 1. Graph of Double Mass Curve Batu Jamus Station

Table 2 Testing Data Consistency with RAPS of Batu Jamus Station

| n | Year | P(mm) | $(P-\bar{P})$ mm | $S_k^*$ | $D_y^2$ | $S_k^{**}$ |
|---|---|---|---|---|---|---|
| 1 | 2004 | 2106 | -1584.067 | -1584.07 | 167284 | -1.2194 |
| 2 | 2005 | 2039 | -1651.067 | -3235.13 | 181735 | -2.4904 |
| 3 | 2006 | 1701 | -1989.067 | -5224.20 | 263759 | -4.0216 |
| 4 | 2007 | 4397 | 706.933 | -4517.27 | 33317 | -3.4774 |
| 5 | 2008 | 3898 | 207.933 | -4309.33 | 2882.42 | -3.3173 |
| 6 | 2009 | 4204 | 513.933 | -3795.40 | 17608.50 | -2.9217 |
| 7 | 2010 | 6066 | 2375.933 | -1419.47 | 376337 | -1.0927 |
| 8 | 2011 | 4112 | 421.933 | -997.53 | 11868.50 | -0.7679 |
| 9 | 2012 | 3866 | 175.933 | -821.60 | 2063.50 | -0.6325 |
| 10 | 2013 | 5728 | 2037.933 | 1216.33 | 276878 | 0.9363 |
| 11 | 2014 | 3839 | 148.933 | 1365.27 | 1478.74 | 1.0509 |
| 12 | 2015 | 4718 | 1027.933 | 2393.20 | 70443.10 | 1.8422 |
| 13 | 2016 | 4104 | 413.933 | 2807.13 | 11422.70 | 2.1609 |
| 14 | 2017 | 2528 | -1162.067 | 1645.07 | 90026.60 | 1.2663 |
| 15 | 2018 | 2045 | -1645.067 | 0 | 180416 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total = | 55351 | Total $D_y^2$ = | 1687521 | | | |
| Average $(\overline{P})$ = | 3690.07 | $D_y$ = | 1299.05 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Qmax = 4.022 | $Q/\sqrt{n}$ = | 1.038373 | < | 1.075 | 90% | ok |
| R = 4.022 | $R/\sqrt{n}$ = | 1.038373 | < | 1.275 | 90% | ok |
| n^0,5 = 3.873 | | | | | | |

**3.2 Analysis of Water Requirement**

Analysis of water requirements is an analysis that aims to determine the amount of water needed to meet the needs of plants, through rainfall data and climatological data available. In this analysis using the penman modification method and several stages in the calculation. But in analyzing water requirements for irrigation several steps are needed, including:

1) Determine Monthly Rainfall with 80% Probability ($R_{80}$)

   $R_{80}$ is a value that shows the amount of rainfall by 80%, which comes from rainfall data which has been sorted from the largest value to the smallest value. So that the $R_{80}$ value obtained in the fourth year is 2016.

2) Determine The Evapotranspiration Value

   Evapotranspiration is the amount of water that comes from the surface of the ground, water, and vegetation is evaporated back into the atmosphere by several factors such as climate and also the physiology of vegetation. This calculation uses the Pennman Method, with the following formula:

$$Eto = \frac{\delta}{\delta + c}.\left[\frac{1}{58}(1-r).R\right] - \frac{\delta}{\delta + c}.\left[\frac{1}{58}.117.10^{-9}.(t(a)+273)^4 \times (0.56 -\right.$$

$$0.092.\sqrt{e(a)}\Big)\times\left(0.1+0.9\frac{n}{N_{\max}}\right)\Bigg]+\frac{c}{\delta+c}.\Bigg[\ 0.35\times(1+0.54.V)$$

$$(e(s)-e(a))\ \Bigg]$$

$$Eto = 0.745\ x\left[\frac{1}{58}x\ (1-0.25)x485.16\right]-0.75$$

$$\left[\frac{1}{58}\ x\ (117x10^{-9})x(26.2+273)^4x\big(0.56-0.092x\sqrt{22.54}\big)x(0.1+0.9x0.586)\right]$$
$$+0.25x[0.35\ x\ (1+0.54\ x0.309)x(25.61-22.54]=4.06$$

Using the above equation, we can see the evapotranspiration value of Batu Jamus station as shown in table 3.

Table 3 Evapotranspiration Value

| Months | a | b | $R_{top}$ | R | $E_{to}$ |
|---|---|---|---|---|---|
| | | | (kg/d) | (kg) | (mm/d) |
| Januari | 0.250 | 0.480 | 912.90 | 485.16 | 4.06 |
| Februari | 0.250 | 0.480 | 916.40 | 499.13 | 4.21 |
| Maret | 0.250 | 0.480 | 892.20 | 441.22 | 3.88 |
| April | 0.250 | 0.480 | 833.30 | 475.87 | 4.06 |
| Mei | 0.250 | 0.480 | 762.80 | 426.12 | 3.59 |
| Juni | 0.250 | 0.480 | 722.30 | 478.59 | 3.72 |
| Juli | 0.250 | 0.480 | 737.20 | 494.49 | 3.77 |
| Agustus | 0.250 | 0.480 | 794.40 | 480.82 | 3.89 |
| September | 0.250 | 0.480 | 860.10 | 443.63 | 4.06 |

| | | | | | |
|---|---|---|---|---|---|
| Oktober | 0.250 | 0.480 | 900.40 | 514.64 | 4.69 |
| November | 0.250 | 0.480 | 904.50 | 487.67 | 4.27 |
| Desember | 0.250 | 0.480 | 906.20 | 417.63 | 3.70 |

3) Determine The Average Daily Rainfall in X Year

Average rainfall is the average of the amount of water falling on the surface of the ground during a certain time measured by a rainfall gauge and expressed in units of mm. Below is a formula that determines the average rainfall:

$R_{80} = m/(n+1)$

$= m/(15+1)$

$m = 12.8 = 13$

With the formula above we can determine the value of the average rainfall as shown in table 4.

Table 4 The Average Daily Rainfall in 2016

| Months | Total days 1 months | R (mm/d) | | R (mm/d) | R (mm/m) | | R (mm/m) |
|---|---|---|---|---|---|---|---|
| | | I | II | | I | II | |
| January | 31 | 5.80 | 8.73 | 7.27 | 179.80 | 270.63 | 225.22 |
| February | 28 | 5.07 | 9.13 | 7.10 | 141.88 | 255.64 | 198.76 |
| March | 31 | 9.13 | 9.06 | 9.10 | 283.12 | 280.95 | 282.04 |
| April | 30 | 4.67 | 2.40 | 3.53 | 140.01 | 72.00 | 106.01 |
| May | 31 | 1.67 | 0.38 | 1.02 | 51.68 | 11.63 | 31.65 |
| June | 30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| July | 31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| August | 31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| September | 30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| October | 31 | 0.00 | 1.88 | 0.94 | 0.00 | 58.13 | 29.06 |
| November | 30 | 2.20 | 7.47 | 4.83 | 66.00 | 224.01 | 145.01 |
| December | 31 | 2.70 | 4.90 | 3.80 | 83.70 | 151.90 | 117.80 |

4) Determine The Effective Rainfall for Rice field and Palawija

Effective rainfall is the amount of rain falling to the ground during the period of plant growth which functions to meet the water needs of plants during the planting period. Below is a formula that can be used to determine the effective value of rainfall. Where the value of $R_{80}$ is based on previous analysis data.

a. Effective Rainfall Formula of Rice Field

$$Re = 0.7 \times \frac{1}{15} \times R_{80}$$

$$R_e = 0.7 \times \frac{1}{15} \times 0.94 = 0.04\ mm/day$$

b. Effective Rainfall Formula of Crops

Re = R x 1.02

= 23.080$\times$ 1.02 = 23.54 mm/month

= 23.54/30 = 0.78 mm/day

5) Determine of Water Requirement

Plant water needs are a water requirement used for plants during the planting period. From the start of the land preparation process until the harvest period. Below is an example of an analysis of water requirements for rice and secondary crops.

a. Rice-plant (*Padi*)

(1) Duration for land processing

NHR = Ir – Re

= 10.90-0.23 = 10.67

(2) Duration for the growth

NFR = Etc - Re + WLR + P

= 4.699-0.93+1.7+2

= 7.47 mm/day

b. Crops (*Palawija*)

1) Duration for land processing

NFR = Etc + Re

= 1.941+0.23 = 2.171

2) Duration for the growth

NFR = Etc + P – Re -WLR

= 1.941+2-0.23+1.7

= 5.64 mm/day

Based on the results of the calculation , it can be determined the volume of water per month as outlined in the form of a chart as below:

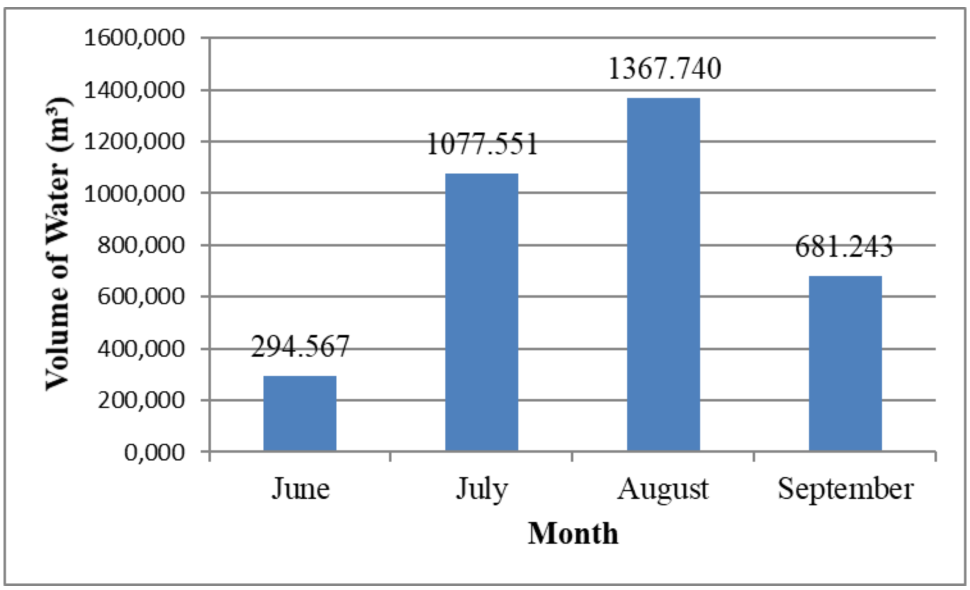


Figure 2 Chart of Volume for Water Requirement

The values in the chart above are taken from water demand data (NFR) from june until september. Where in the month occurs dry season. This is based on data on avergae rainfall in 2016. In order to obtain the highest volume in august, with a volume of 1367.740 $m^3$

### 3.3 Analysis of Energy Requirement

In general, energy is defined as the ability to do work or business. In this study the energy meant is the amount of capacity of the pump to make an effort to lift water with a certain discharge to meet the needs of plants. In analyzing the amount of energy produced to meet plant needs several steps are needed as follows:

1) Determine pumping discharge every month

Known :

V = 1367.740 m³ (From chart previous)

T = Pump operation time (assumed 2.5 hour per day)

$$Q = \frac{Volume}{Time}$$

$$Q = \frac{1367.740\ m^3}{\frac{2.5 hour}{day} \times 30 day} = 18.232\ m^3/hour$$

2) Calculate the number of pump needs.

From the previous pump discharge capacity calculation, it is known that the pump capacity for each month is 18,232 m³ / hour. In this case, we can use a HONDA WL20XN pump with a capacity of 670 liters / minute. So it can be concluded that, to meet this capacity we only need to use one pump. Or if it is set forth in the calculation as below

$$Np = \frac{Q}{q_p} = \frac{18.232\ m^3/hour}{40.2\ m^3/hour}$$

$$= 0.45 = 1 \text{ unit}$$

3) Calculate the time to use the pump every day

$$T = \frac{Volume}{Qpump}$$

$T_{June}$ $= \frac{294.567\ m^3}{40.2\ m^3/hour}$ = 7.32 hour $= \frac{7}{30}$ hour = 0.23 hour

So we assumed So it is assumed that the pumping time for each day is 1 hour.

$T_{July}$ $= \frac{1077.551\ m^3}{40.2\ m^3/hour}$ = 26.80 hour $= \frac{27}{30}$ hour = 0.9 hour

So we assumed So it is assumed that the pumping time for each day is 2 hour.

$T_{August}$ $= \frac{1367.740\ m^3}{40.2\ m^3/hour}$ = 34.02 hour $= \frac{34}{30}$ hour = 1.13 hour

So we assumed So it is assumed that the pumping time for each day is 2.5 hour.

$T_{september}$ $= \frac{681.243\ m^3}{40.2\ m^3/hour}$ = 16.94 hour $= \frac{17}{30}$ hour = 0.56 hour

So we assumed So it is assumed that the pumping time for each day is 1.5 hour.

4) Calculation of fuel requirements.

Known :

Sfc : Specific fuel consumption (0.24 kg/kwh for diesel fuel)

ρ : Fuel type mass (0.87 kg/l for diesel fuel)

P : Engine power (HONDA WL20XN 5.5 HP)

5.5 HP = 41.013 KW

$$K_{bb} = \left(\frac{Q}{qp}\right) \times \left(\frac{sfc}{\rho}\right) \times P$$

$$= \left(\frac{18.232\ m^3/hour}{40.2\ m^3/hour}\right) \times \left(\frac{0.24\ kg/kwh}{0.87\ kg/litre}\right) \times 41.013\ kw$$

= 5.131 liters = 5 liters

In this case the fuel needs are assumed to be the same every month. So that the fuel needs obtained in one month is 5 liters.

5) Calculation of Energy

Known :

P : Engine power (HONDA WL20XN 5.5 HP=41.013 KW)

t : Time (2.5 hour/day)

E = P x t

= 41.013 x 2.5 hour

= 102.532 KW.H

= 203.202 x ($3.6 \times 10^6$)

= 7369117000 Joule

Using the above equation, we can see the evapotranspiration value of Batu Jamus station as shown in table 3.

### 3.4 Budget Plan Analysis

Based on pump specifications and analysis, we can determine the budget for irrigation water. This is explained in the table below:

| No | Job description | Total requirement | Unit price | Total price |
|---|---|---|---|---|
| 1. | Procurement of pump machines | 1 units | 3,500.000 | 3,500.000 |
| 2. | Pipe 2’’ | 20 meters | 35,800 | 716,000 |
| 3. | Diesel fuel | 20 liters | 9,800 | 196,000 |
| Total | | | | 4,412.000 |

# 4. ClOSING

## 4.1 Conclusions

Based on the analysis in the previous chapter, it can be concluded that:

1) The calculation of the amount of irrigation water needs begins in October,namely when preparing land. So that MTI starts in November. Whereas MTII began in March AND MTIII in July. This follows the cropping pattern that was attached to the previous chapter. So that the total MTI NFR is 65.22 mm / day, NFR MTII is 31.64 mm / day, and NFR MTIII is 32.13 mm / day. While the total NFR of MTI, MTII and MTIII is 128.99 mm / day.

2) Based on the irrigation area of 92 Ha, then from the calculation we get the highest volume of water requirement as 1367.720 $m^3$ ,this is occurs on august . To get water requirements, the required discharge is as much 18.232 m3 / month. In order for the fulfillment of water needs 1 pump units with 5.5 HP power and a maximum discharge of 670 liters / minute are needed with as much energy 7369117000 Joule.

3) From the previous calculation known that on the irrigation we need 1 pump with total price 3,500.000 . Besides it is also needed pipe with diameter 2 inch with total price 716,000 , and also needed diesel fuel as much 5 liters with total price 196000. So the total price of all requirement irrigation is 4,412.000.

### 4.2 Suggestion

1) Based on the results of research on water and energy requirements for irrigation, the authors have suggestions to be able to compare again with previous research. This aims to determine whether there are changes in the pattern of water consumption for irrigated land. if there is a change with the previous one, this research becomes a source of information for alertness if there is an increase in water requirements. Because we know there are some impacts caused by excessive use of ground water. So we can use underground water use and find other alternatives to meet irrigation water needs.

2) The pump operating time is calculated and assumed to vary each month. This aims to reduce cost when using pumps. While in the selection of pumps, choose a pump that suits the required discharge needs. So that spending more efficient.

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