SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

UNIVERSITI SAINS MALAYSIA

ESTIMATION AND DESIGN OF FRESHWATER FISH POND USING LOW TEMPERATURE GEOTHERMAL SOURCES AT SUNGAI KLAH HOT SPRINGS

By

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Dissertation submitted in the partial fulfillment

of the requirements for degree of Bachelor of Engineering with Honours

(Mineral Resources Engineering)

Universiti Sains Malaysia

JUNE 2017

DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled **"Estimation and Design Freshwater Fish Pond using Low Temperature Geothermal Source at Sungai Klah Hot Spring''**. I also declare that it has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or university.

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ACKNOWLEDGEMENTS

First of all, praise to ALLAH SWT for His blessing. I am thankful to the ALLAH SWT for the good health and give me strength for me accomplished this project. Honestly, I am thankful to my supervisor, Dr. Teuku Andika Rama Putra, who has guided and supported for accomplished this project. I am very thankful and indebted to him for sharing his opinion and knowledge, and encouragement.

Furthermore, I would like to thank to all officers in Felda Residence Hot Spring Sungai Klah, Perak for giving me permission and a lot of information about Hot Spring Sungai Klah. I would like to express my gratitude to my lovely parents for always cheering me up, and their understanding. I am thankful to all of my friends for their kindness, knowledge and always supporting me. I also thankful to one and all, either directly or indirectly, have been supported and lent their helps for me in completing this project.

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T/ Temp.	Temperature
lbm	Pound mass
Btu	British thermal unit
gpm	Gallon per minute
psia	Pound per square inch
ºC	Degree Celcius
ºF	Farenheit
ft^2	Square feet
mph	Miles per hour

LIST OF EQUATIONS

ANGGARAN DAN REKABENTUK KOLAM IKAN AIR TAWAR DENGAN MENGGUNAKAN SUHU RENDAH SUMBER GEOTERMAL DI AIR PANAS SUNGAI KLAH

ABSTRAK

Kebiasaannya tenaga geotermal digunakan untuk menjana kuasa elektrik tetapi suhu rendah sumber geotermal tidak sesuai digunakan untuk kuasa elektrik. Maka, kegunaan lain untuk suhu rendah sumber geotermal adalah digunakan dalam industri agrikultur, pemanasan daerah atau akuakultur. Di Malaysia pula, kegunaan suhu rendah sumber geotermal sangat terhad. Kebanyakan, sumber geotermal yang bersuhu rendah dijadikan sebagai kawasan tarikan pelancong di Malaysia. Tanpa sedar, sumber geotermal yang bersuhu rendah ini bukan sahaja boleh dijadikan sebagai kawasan pelancongan, tetapi boleh juga digunakan dalam industri perternakan ikan atau agrikultur. Sesungguhnya, tenaga geotermal ini sangat murah, mesra alam dan boleh diperbaharui. Kebolehan sumber geotermal ini dapat meningkatakan pengeluaran dan kualiti ikan air tawar kerana suhu dan kandungan mineral yang terdapat dalam sumber geotermal. Suhu dan kandungan mineral yang terkandung dalam sumber geotermal amat membantu dalam pertumbuhan ikan air tawar. Penternakan ikan atau industri akuakultur dengan menggunakan suhu rendah sumber geotermal boleh menyumbang peningkatan pendapatan seharian usahawan-usahawan kecil di kawasan luar bandar. Projek yang dijalankan ini mengenai anggaran dan rekabentuk kolam ikan air tawar menggunakan suhu rendah sumber geotermal di kawasan air panas Sungai Klah, Sungkai, Perak.

ESTIMATION AND DESIGN FRESHWATER FISH POND BY USING LOW TEMPERATURE OF GEOTHERMAL SOURCES AT SUNGAI KLAH HOT SPRINGS.

ABSTRACT

Geothermal energy is usually used for electricity uses but low temperature geothermal resources are not suitable for electricity. Hence, low temperature of geothermal resources can be used in agriculture, district heating, and aquaculture. In Malaysia, the uses of low temperature geothermal resources are limited. Mostly, geothermal resources in Malaysia are created as recreation center. Besides being recreation center, the geothermal sources can be used in fish farming or agriculture industries since its cheap and environmental friendly and renewable energy sources. The geothermal sources are able to raise the production and quality of fish because of temperature and chemical content of sources. The temperature and chemical content of geothermal sources is most important and aid production of fish growth. Fish farming or agriculture using low temperature geothermal sources can generate income for entrepreneurs. This research is about estimation and design freshwater fishpond using low temperature geothermal source in Sungai Klah Hot Spring, Perak.

CHAPTER 1

INTRODUCTION

1.1 Background

Geothermal energy is natural heat of the earth. The earth's temperature varies widely, and geothermal energy is usable for a wide range of temperatures from room temperature to over 300^{0}C (Boyd and Lund, 2003; Gelegenis et. al., 2006).

There are several types of geothermal resources as shown in Table 1.1, classified after White and Williams (1975) with the range of ambient temperature from 20^{0}C to over 300^{0}C. Normally, resources with temperature above 150^{0}C are used in electric power generation while resources with temperature below 150^{0}C used in direct-used projects such as heating and cooling. The ambient temperatures is between 5-30^{0}C can be used with geothermal heat pumps which supply both heating and cooling (World Energy Council, 2013).

Table 1.1: Geothermal resources types (Source: White and Williams, 1975)

Resource Type	Temperature Range (^{0}C)
Connective hydrothermal resources	
Vapor dominated	≈ 240
Hot-water dominated	20-350
Other hydrothermal resources	
Sedimentary basin	20-150
Geo-pressured	90-200
Radiogenic	30-150
Hot rock resources	
Solidified (hot dry rock)	90-650
Part still molten (magma)	>600

Direct utilization of geothermal energy consists of various forms for heating and cooling instead of converting the energy for electric power generation. The major areas of direct utilization of geothermal energy are swimming, bathing and balneology, space heating, agriculture applications, aquaculture applications, industrial processes and heat pumps. (Lund et. al., 2005, 2011; Lund, 1997).

Direct supply of low temperature of geothermal sources into the fish pond usually for heating the water and to flush organic matter from the pond and contributes the water quality in ponds (Lucas and Southgate, 2012,2013).

Freshwater fish pond using low temperature geothermal sources have been used in developed country such as Unite States of America, Italy, Japan, and China. The use of low temperature geothermal sources is to accelerate the production of fish by maintaining the temperature. The benefit when using geothermal energy in fish farming able to heat water at very low cost compared to use electricity or gas. It is also able to produce the products in a short time if geothermal energy is used. When the water temperature is fall, the fishes are not capable to feed themselves because of body metabolism is affected (Johnson, 1997). The main species in fish farming using geothermal energy are catfish, tilapia, prawn, and abalone. In Snake River, Southern Idaho, there are fish farmers using geothermal energy in fish breeding. As example, Ray, owner of Fish Breeders of Idaho, is using eight geothermal wells with temperatures between 90 to 95^{0}F to raise warm-water fish, such as catfish and tilapia.

In Peninsular Malaysia, there are more than sixty hot springs that have been discovered. Some of it, have been commercial as bathing and recreational center and hot spring at the urban area have been developed with hotels, hot spas and swimming pools. Besides being recreational center, geothermal sources in Malaysia have possibilities renewable and cheap energy sources which can develop fish farming industries and agriculture industries. The products from both industries can be stock for local community in that area. Furthermore, it can be export industries to another state. Table 1.2 shows the summary of hot spring in West Malaysia with a list and location of the analyzed hot springs of this study.

Table 1.2: Summary of hot springs in West Malaysia as well as list and location of the analyzed hot spring of this study (Baioumy et al, 2015).

State	No. of Hot Spring	Surface Temperature ^{0}C	Analyzed Sprigs in this study	Longitude	Latitude
Johor	5	46	Labis	2^{0} 28’ 08.74”	103^{0} 03’ 01.46”
Kedah	4	30-35	Ulu Legong Ayer Hangat	5^{0} 49’ 01.44” 6^{0} 25’ 21.48”	100^{0} 56’ 05.36” 99^{0} 48’ 50.01”
Kelantan	3	27-52	-	-	-
Melaka	3	46-59	Bemban	2^{0} 17’ 32.87”	102^{0} 22’ 36.27”
Negeri Sembilan	2	46-58	Kampong Lada	2^{0} 32’ 58.73”	102^{0} 07’ 49.64”
Pahang	3	41-45	Loging	4^{0} 42’ 36.09”	101^{0} 34’ 08.88”
Perlis	1	27	-	-	-
Perak	21	29-99	Pengkalan Hulu Sungkai Klah Ulu Slim	5^{0} 43’ 26.46” 3^{0} 59’ 42.91” 3^{0} 54’ 06.13”	101^{0} 00’ 54.84” 101^{0} 23’ 35.74” 101^{0} 29’ 59.09”
Selangor and Kuala Lumpur	10	45-77	Beranang Semenyih Sungkai Serai Kepong Selayang	2^{0} 50’ 55.8” 3^{0} 02’ 32.52” 3^{0} 05’ 26.91” 3^{0} 15’ 31.37” 3^{0} 33’ 49.47”	101^{0} 53’ 08.1” 101^{0} 52’ 20.2” 101^{0} 47’ 40.65” 101^{0} 38’ 45.19” 101^{0} 38’ 51.86”

			Taman Arif		
Terengganu	3	30-5-	-	-	-
Total	55	27-99	15	-	-

1.2 Problem Statements

Population in Malaysia is increasing day by day hence the food supply is decreasing. The decreasing of fish production due to over-fishing in the sea and ecological growth is affected by pollutant. There are several solutions or way to overcome this problem. Therefore, the best solution for increasing the food supply in shorter time is using geothermal energy in aquaculture industries.

1.3 Significance of Works

This project was designed to know the suitable function of low temperature geothermal resources. The study on fish farming by using low temperature of geothermal water is investigated and thus the proper proposal of aquaculture industries using geothermal water can be developed. In this research, there are three pond with different temperature accordingly are investigated to ensure which types of fish is suitable for raise in different temperature. Besides, the design of pond also is a main part to make the fish alive.

1.4 Objectives

1. To estimate and design of freshwater fish pond using low temperature in Felda Residence Hot Spring Sungai Klah, Sungkai, Perak to be used in aquaculture industries based on geochemical content in the hot spring and the suitable or maintain temperature for raising freshwater fish.
2. To discuss the implication of freshwater fish pond using low temperature geothermal resources.

1.5 Benefits

The geothermal energy is considered as reliable sources of energy and continuous supply. It is available in any weather condition since it is formed from the earth's crust. Furthermore, it does not require any device storage to keep it hot always. The most important is less pollutant. Thus, environmental issues at least as no natural gas, propane or oil were used to generate energy which defines no fossil fuels exhaust or greenhouse gases are being emitted into the atmosphere. Moreover, by using geothermal energy can lower operating and life cycle costs because geothermal energy is drawing free energy from the earth.

With all the benefits listed, farmers and entrepreneurs of fish farming in Malaysia will not have to face the problems due to high cost and lack of harvest. This study will make freshwater fish pond using low temperature geothermal sources will increase the number of harvest and increase the quality of the fish pond. The temperature and mineral content in the hot springs really help in growing the fish in the shorter period of time.

CHAPTER 2

LITERATURE REVIEW

2.1 Geological, Geophysical and Geochemical of Sungai Klah Hot Spring.

Low temperature geothermal energy is defined as energy resources derived from the earth's shallow subsurface, i.e., at temperature less than 150^{0}C (300^{0}F). The energy resources commonly applied in greenhouses, fisheries, mineral recovery and more.

Figure 2.1: Geothermal hot spots around the world by Hanania et al, undated.

Geothermal energy is the heat generated internally in the Earth, mainly by decay of radioactive elements in the rock, is continually conducted slowly to the surface along a geothermal gradient which is normally 15 to 30^{0}C/km. superimposed over this natural heat flow in localized areas are high temperatures associated with volcanic activity. This occurs where two tectonic plates move apart (divergent boundary), such as mid ocean ridges; collide (convergent boundary), such as New Zealand, where one plate is subducted beneath another, or in hot spot under mid ocean volcanic island such as Hawaii, Iceland or Samoa (Thain, 2006).

A geothermal resource is a volume of rock where heat can be economically harnessed for conversion to electricity or direct heat utilization. Heat is mined from liquid and vapor circulating in pores and fractures in the rock or directly from the rock. Heat stored in the fluids is more easily to extract. The amount of the fluid in a rock is determined by its porosity. In volcanic rocks the porosity may be as high as 40% near to the surface, decreasing <5% at a depth of several kilometers (Thain, 2006).

In sedimentary rocks, such as sandstones and mudstones, the porosity may be up to 20%. For a given temperature the higher the amount of fluid stored in porous rocks the higher the amount of extractable heat. Permeability, in the form of rock fractures and faults, magnify extraction efficiency (Thain, 2006).

In Malaysia, the utilization of geothermal energy is totally none for this moment. The potential of using geothermal resources in Malaysia as a source has not been investigated yet. Luckily, in Poring Ranau and Semporna areas in Sabah, East Malaysia has been investigated to assess their potential (Chow et al, 2010).

Sungai Klah Hot Spring is located at near Sungkai town, where is known as the hottest hot springs found in Malaysia which the temperature can be reach till 98^{0}C. Sungai Klah is located at Sungkai which Trolak formation was formed. It is calcerous series (Roe, 1951). The strike formation is from the northwest to southwest. The bed dipping is moderate to steeply west and away from main range granite (Gan, 1992).

The formation is comprises argillaceous, arenaceous, and calcerous rocks which feature vertical and lateral changes. Argillaceous rock is predominant facies which consist of quartz-mica schist, graphitic schist and graphitic phyllite with quartz-biotite hornfels. Arenaceous rock is metaquarzite and quartz-schist which inter-bedded with argillaceous rocks.the calcerous rock is metamorphosed limestone or marble and perhaps of dolomite (Gan, 1992).

Sungai Klah Hot Spring has over 10 natural springs with sulfur content is 0.005 ppm (Fauziah Che Leh et al, 2011). The geological setting of Sungai Klah is probably located along the major fault and shear zones between granite and sedimentary rocks. The hot spring is happened because of magmatic activities near to the springs. The Sungai Klah hot spring is high in degree of total organic content because of plant litter.

The temperature of hot springs in West Malaysia is from 41 to 99^0C. Table 2 shows that Sungai Klah hot spring is recorded as the highest surface temperature at 95 to 99^0C then followed by Ulu Slim hot spring at temperature 92^0C. Both hot springs is located at the North-South trend while the lowest temperature of hot spring is discovered at Ayer Hangat hot spring with the temperature at 41^0C which located at West-East trend. The pH value for all the hot springs in West Malaysia is vary at 5.5 to 9. The lowest pH is 5.5 which located at Taman Arif hot spring and the highest pH is discovered at Beranang with pH 9 (Baioumy et. al, 2015).

Table 2.1: pH, Surface Temperature, and Concentrations of Cations and Anions (ppm) in the volcanic hot springs in West Malaysia (Baioumy et. al, 2015).

Hot Springs	pH	T ^{0}C	SiO_2	Ca	Mg	K	Na	Fe	HCO_3	SO_4	Cl	F	CO_3
Ayer Hangat	7.0	41.0	42.0	418.0	1360.0	277.0	8500.0	43.0	282.0	1550.0	16800.0	3.3	-
Semenyih	7.5	41.0	73.0	15.4	0.1	2.8	44.8	<0.1	98.0	1.0	3.0	5.3	-
Beranang	9.0	57.0	83.0	26.3	0.2	2.4	46.8	0.2	108.0	0.9	1.8	4.0	-
Kampong Lada	7.5	49.0	52.0	8.8	0.6	2.7	45.4	0.1	60.0	2.0	3.6	4.1	-
Labis	7.3	49.0	80.0	1.8	0.3	1.9	41.3	0.1	63.0	4.0	9.0	4.6	-
Selayang	7.5	54.0	80.0	16.9	0.2	2.5	44.1	<0.1	73.0	0.9	1.9	4.2	-
Taman Arif	5.5	41.0	76.0	9.7	1.0	1.9	32.7	<0.1	78.0	0.9	2.0	6.9	-
Bemban	-	-	98.0	4.3	0.3	2.8	60.8	<0.1	88.0	6.0	6.9	9.9	-
Sungkai Serai	7.5	45.0	74.0	13.5	0.2	1.9	40.8	0.2	78.0	0.9	3.0	6.4	-

Ulu Slim	7.8	92.0	93.0	2.0	0.3	1.7	35.2	<0.1	58.0	4.0	5.3	7.6	-
Kepong	-	-	88.0	4.2	0.2	3.1	57.5	<0.1	91.0	10.0	4.4	5.1	-
Pengkalan Hulu	7.3	44.0	65.0	147.0	1.1	2.1	37.7	1.1	193.0	7.0	1.3	0.8	-
Sungai Klah (P1)	7.5	95.0	111.0	0.5	0.1	2.8	55.0	<0.1	55.0	2.0	1.7	4.9	16.0
Sungai Klah(P2)	7.5	99.0	92.0	0.9	0.1	2.6	48.9	<0.1	54.0	2.0	1.1	4.3	15.0
Lojing (HS6)	7.5	63.0	125.0	1.6	0.1	2.3	51.0	<0.1	57.0	20.0	2.0	5.0	21.0
Lojing (HS7)	7.5	60.0	75.0	1.9	0.1	1.9	47.0	<0.1	100.0	14.0	2.0	3.1	2.0
Lojing (HS8)	7.5	70.0	79.0	2.3	0.1	1.5	44.0	<0.1	92.0	12.0	1.9	2.5	4.0
Lojing (HS10)	7.5	72.0	134.0	1.5	0.1	2.5	53.0	<0.1	66.0	20.0	3.0	5.4	23.0
Lojing(HS13)	7.5	68.0	63.0	2.2	0.2	1.5	54.0	<0.1	68.0	22.0	2.0	5.4	16.0
Lojing (HS16)	7.5	57.0	76.0	2.0	0.1	2.1	48.0	<0.1	100/0	15.0	2.0	3.6	3.0

Ulu Legong	7.8	55.0	-	2.7	0.4	1.9	34.7	<0.1	10.0	15.3	15.9	12.0	8.0
Ulu Legong	7.8	53.0	-	3.0	0.3	2.1	32.5	<0.1	12.0	9.9	13.2	9.8	10.0

The cation content that obtained from the analyzed water samples specify that Lojing hot springs contain the highest SiO2 (134ppm) while the lowest is Ayer Hangat with the SiO2 content is 42ppm. However, Ayer Hangat contains the highest concentration of Ca (418ppm), Mg (1360ppm), K (277ppm), Na (8500ppm), and Fe (43ppm). Moreover, Ayer Hangat hot spring have the highest anion concentrations such as HCO3 (282ppm), SO4 (1550ppm), and Cl (16,800ppm). The other hot springs in average value of anion content which are 76, 8, and 4 ppm for HCO3, SO4 and Cl accordingly.

Type of geothermal water is a major role to select geothermal plant in application. The analysis of Cl-HCO_3-SO_4 contents in the geothermal water is then classify by plotting the Cl-, SO_4, and HCO_3 values on the Cl-SO_4-HCO_3 ternary diagram as shown in Figure 2.2. In the Cl-SO_4-HCO_3 ternary diagram, if the content of HCO_3 is higher, it shows the mixing of thermal spring waters with cold groundwater and might be because of the presence carbonate rocks within or surrounding the area. The higher chloride contents, it indicates the water is mature (Javino, 2016).

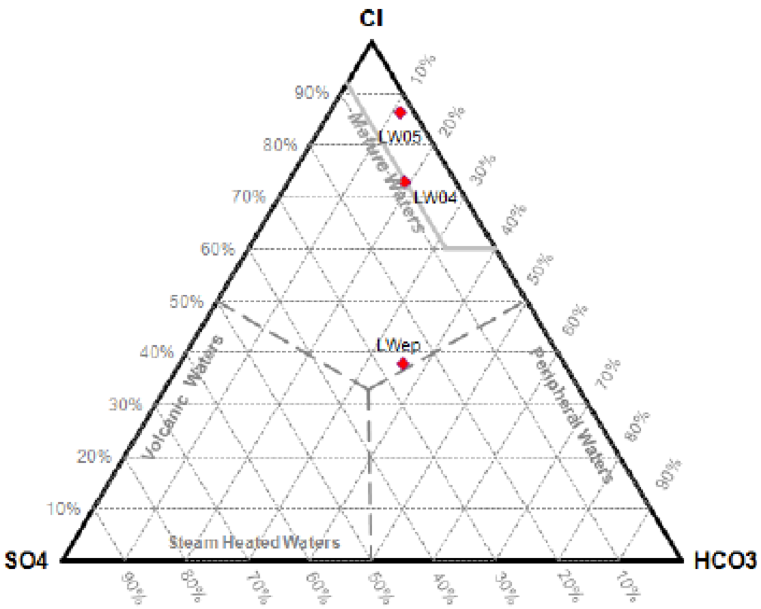

Figure 2.2: Ternary diagram for Cl-SO_4-HCO_3

2.2 Uses of Hot Spring in Malaysia

Most of the hot springs in West Malaysia is designed as recreational places. The most popular hot springs such as the Kampung Air Panas in Ulu Slim and Tambun have up to a thousand of visitors each on weekends. The hot waters are collected and channeling in swimming pools and spas. Out of 45 hot springs in Malaysia, there are twelve hot springs are well developed, three are fairly developed, thirteen are still underdeveloped, and the remaining of hot springs still undeveloped (Chow et. al, 2010).

At the moment, none of the discovered hot springs in the Peninsular Malaysia has been utilized for use as a source of geothermal energy. The full potential of these geothermal resources is yet to be investigated. However, investigations are now on going in the Poring Ranau and Semporna areas in Sabah, East Malaysia, to assess their potential (Chow et. al, 2010).

The rapidly growing population in the world, drinking water is becoming scarce and efforts have been made to tap river waters, groundwater and spring waters. In recent years, even polluted river waters or sea waters have been treated and converted to drinking water. The World Health Organization (WHO) had proposed standards for drinking water since 1958 and the standards had been revised every 10 to 12 years.in year 2002, the Pan American Health Organization (PAHO) also established a guideline for drinking water to aid developing countries (Chow et. al, 2010).

The aim of geothermal aquaculture is to heat water to the optimum temperature for aquatic species. This involves the raising of freshwater or marine organisms in a controlled environment to magnify production rates. The geothermal water is commonly used to heat water in raceways, pond and tanks. The water temperature depends on the species involved, ranging from 13 to 30^{o}C. by controlling the rearing temperature the growth rate of the fish can be increased by 50 to 100%, thus increasing the number of harvests (Arni Ragnarson, 2014).

2.3 Benefits of Chemical in Geothermal Water.

Geothermal hot spring comes from the geochemical environment in the deep reservoir. Under high pressure and temperature condition, hot water is rich in dissolved minerals, such as metasilicate, metaboric acid, hydrogen sulfide, radon, radium, and fluoride (Zheng et al, 2010).

Usually it constitutes medical mineral water and features precious medical value. This is one of most reason for medical care and bath with hot spring water for thousand years in around the world. Medical care and bath are the most common use of low temperature geothermal water. Basically, old folks visit the traditional hot springs for bath. Nevertheless, more activities are physical therapy under supervise of doctors in the hot spring sanatorium and rehabilitation center, including dipping bath, sports bath, jet bath, mud therapy, hydrotherapy, hydroelectrotherapy, drinking therapy and so on (Zheng et al, 2010).

Sulfur is naturally occurring mineral in hot springs. Sulfur can be recognized by distinct smell which is caused by sulfur dioxide gas is released to the air. Sulfur is part of chemical structure of three different amino acids, namely as cysteine, cysteine, and methionine. Sulfur works with vitamin B1, B5, and H (biotin) to promote metabolism and communication between nerve cells. Therefore, hot springs bath is popular because sulfur rich in hot springs. Hot spring bath can make the body absorbs trace amount of minerals such as carbon dioxide, sulfur, calcium, magnesium, and lithium. Those minerals aid provide healing effects to different organs and systems in body. There are more benefits of minerals and chemicals in hot springs. Such as boron which helps in build muscle mass, increase brain activity, and strengthen bones. Magnesium helps in maintaining heart rhythms, assist in reducing high blood pressure and eliminating body toxins. It also converts blood sugar to energy.

2.4 Direct Use of Geothermal Water.

Aquaculture involves the raising of freshwater or marine organisms in a controlled environment to builds up production rates. The principal species raised are aquatic animals, such as catfish, bass, tilapia, sturgeon, shrimp, and tropical fish. The application temperature in fish farming depends on the species involved, range between 13^0C to 30^0C, and the geothermal water can be used in raceways, ponds, and tanks. The benefit of a controlled rearing temperature in aquaculture operations is to increase the rate of growth by 50% to 100% (Lund, 2011).

Aquaculture is an important direct utilization of low temperature geothermal fluids, and is commonly the last stage in a cascading scheme before the fluids are re-injected or disposed of on the surface. Based on data presented at the last World Geothermal Congress of 2005, aquaculture pond and raceway heating represents about 4.2% of the total geothermal energy used in non-electric applications, consuming 10,970 TJ/year. According to the same review, at least 17 countries have geothermally-heated aquaculture installations, with the largest in USA, China, Iceland, and Italy. Although the most common fish raised are tilapia, salmon and trout, some unusual species are also farmed, such as tropical fish, lobster, shrimp, prawns, and even alligators (J. Gelegenis et al., 2006).

Fish farming has been slowly growing sector in Iceland for a number of years. After a rapid growth from 2002, the total production reached about 10,000 ton in 2006, mainly salmon. The dominating species are now salmon and arctic char followed by trout. There are 70 fish farms in Iceland and the total production was 7,000 tons in 2013. Initially, Iceland’s fish farming was mainly in shore-based plants. Geothermal water commonly 20 to 50^{o}C, is used to heat fresh water in heat exchangers, typically from 5 to 12^{o}C (Ragnarsson, 2013).

For United States of America, the geothermal aquaculture producers usually located in the Northen California, Oregon, and Idaho where the cool climate takes place. During nighttime, the temperature of surrounding is decreased to 14^{o}F regularly in between December until February. The lowest temperature that can be achieved is -4^{o}F for every winter. Therefore, all of the outdoor farms must have small ponds, concrete raceways or circular tanks. The highest production of fish is depends on the ability to heat tanks, raceways, or pond sufficiently during the coldest months. (USAID, 2013).

2.5 Optimum Temperature for Fish Growth.

Optimum temperature is commonly important for aquatic species compare to land animals, which suggests that the potential of geothermal energy in aquaculture may be greater than in animal husbandry, such as pig and chicken rearing shows the growth trends for a few land and aquatic species. Land animal grow best at wide range temperature, from 10^{o}C up to 20^{o}C. Aquatic species such as shrimp and catfish have a narrow range of optimum temperature production at a high temperature nearly to 30^{o}C. However, trout and salmon have a lower optimum temperature, it is not greater than 15^{o}C (Dickson and Fanelli, 2005).

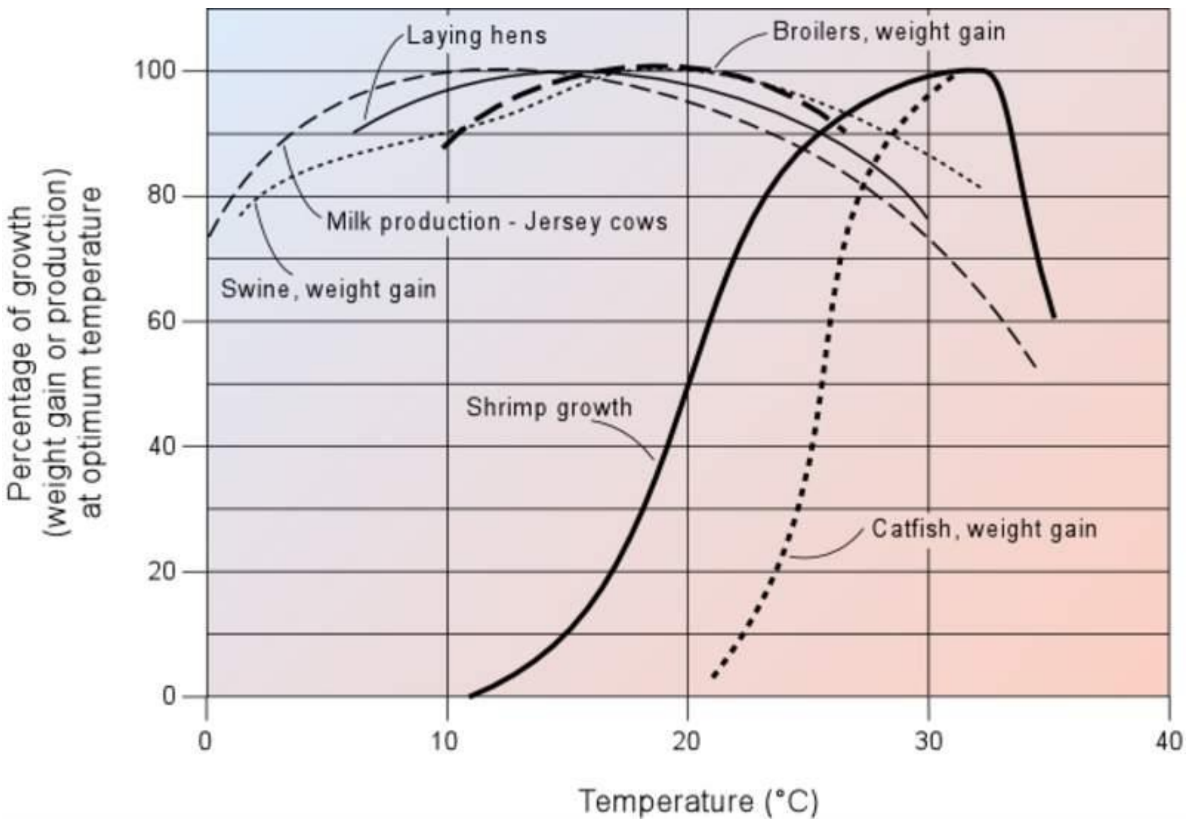

Figure 2.3: Effect of temperature on growth or production of food animals. (From Beall and Samuels, 1971).

It has been showed that more fish can be produced in a shorter period of time if geothermal energy is used for aquaculture pond and raceway heating rather than water dependent upon the sun for its heat. When the water temperature fall below the optimal values, the fish loss their abilities to feed because of their basic body metabolism is affected (Boyd and Lund, 2003).

Table 2.2: Aquaculture Crops by Lund, 1985.

Species	Growth Period (months)	Water Temperature ºF	ºC
Tropical Fish	2-3	74-90	23-27
Catfish	4-6	65-75	18-24
Trout	4-6	55-65	13-18

Prawns	6-9	81-86	27-30

Pond require geothermal water of 100 to 150ºF (38-66ºC) and a peak flow of 300 gpm for one acre of uncovered surface area in colder climates.

2.6 Required Mineral for Fish Growth.

The nutrition of fish has been fairly investigated and some of the achievements have been highlighted in reviews by Watanabe et al. (1988) Hilton (1989) Lal l (19890 and Steffens (1989). The present article collates information on several trace elements in nutrition of fish, excluding shellfish, with emphasis on zinc and manganese (Watanabe et al., 1997).

Table 2.3: Trace mineral requirement ranges for fish (Watanabe et al., 1997)

Mineral	Requirement
Iron	30-170
Copper	1-5
Manganese	2-20
Zinc	15-40
Cobalt	0.05-1.0
Selenium	0.15-0.5
Iodine	1-4

(Expressed as mg mineral per kg dry diet)

Besides mineral requirement for growing fish, water quality factor for fish culture should be considered too. The water quality factor is important to ensure the survival of the fish. The water quality is included temperature, dissolved oxygen, nitrogenous wastes, pH, alkalinity, hardness, carbon dioxide salinity, chlorine, and hydrogen sulfide. Table 2.4 shows the summary of water quality factors and preferred ranges (Boyd, undated).

Table 2.4: Water quality factor and preferred ranges for fish culture (Boyd,undated).

Water Quality Factor	Preferred Ranges for Fish Culture
Temperature	Species dependent
Dissolved Oxygen	>4-5 ppm for most species
Ammonia –Nitrogen (ionized and un-ionized)	NH_3<0.02
Nitrite	<1ppm; 0.1ppm in soft water
pH	6-8
Alkalinity	50-300 ppm calcium carbonate
Hardness	>50ppm, preferably >100ppm calcium carbonate
Carbon Dioxide	<10ppm
Salinity	Species dependent typically <0.5-1.0 ppt (for freshwater fish)
Chlorine	<0.02 ppm
Hydrogen Sulfide	No detectable level

2.7 Utilization of Geothermal Sources

Nowadays, the worldwide is using direct utilization for low temperature of geothermal resources. As examples, domestic heat pumps, bathing, space heating, greenhouse heating, aquaculture, industrial processing and many more. Most of the processes are requiring the input of the heat can completely use low temperature geothermal resources compare to electricity, fuel oil, or natural gas.

The aquaculture use of geothermal sources has been increase annually. The main country using geothermal energy in aquaculture is USA, China, Iceland, and Italy. The following Table 2.5 is shown the countries which practicing fish farming using geothermal resources.

Table 2.5: Summary of utilization of geothermal water resources by Lund and Boyd, 2015

Countries	Uses of Geothermal
Algeria	There are more than 240 thermal springs over the country. The highest temperatures were recorded at 68ºC for the western area, 80ºC at central country and 98ºC at the eastern area. The main uses of geothermal waters in Algeria are balneology, space heating and greenhouse heating. But, nowadays Algeria is established new project for fish farming and agriculture. As example, Tilapia fish farming projects started in Ghardaia and Ouargla prefectures. The individual uses of geothermal energy are 9.02 MWt and 279.1 TJ/year for fish farming.
Indonesia	Nowadays, the direct use of geothermal energy in Indonesia is developed for agriculture and aquaculture. Agriculture such as copra drying in Lahenong, Mataloko, and Wan Rai Lapung,

	mushroom cultivation in Pengalengan, and tea drying and pasteurization in Pengalengan. A cocoa drying also have been developed near to copra drying operations as state above. For aquaculture, in Lampung, there is catfish farming using geothermal water. The farmers at this area reported that fish grow better in the geothermal fluid and freshwater mixture (Lund and Freeston, 2011).
Iceland	The use of geothermal energy is major role in the energy supply for Iceland in many years. The primary energy supply for the Iceland is about 68%, the uses of geothermal water for house heating and other direct-uses started early in twentieth century. Almost 90% geothermal energy used for house heating. Other direct-uses are for swimming pools, snow melting, industrial applications, greenhouse heating and fish farming. The largest industrial use of geothermal heat is the seaweed drying plant Thorverk, located in West Iceland. Fish farming produces about 7,000 tons annually on 70 fish farms, mainly arctic and salmon (Ragnarsson, 2015).
Jordan	Usually the geothermal water is used for spas at several hotels in Jordan. But, there are several farms producing tilapia in Jordan too. For example, the Arab Fish Company farm consists of some 40 basins. It produces between 20 and 55 tonnes of tilapia per year. During winter season, the temperature cannot be maintained at sufficient level to ensure the survival of the

	fingerlings and allow for the growth of the fish. In the future, Jordan is planning to use geothermal waters for greenhouse heating and refrigerating.
Switzerland	Direct use of geothermal energy has had a long tradition in the country and is very successful. The popular thermal spas still can be found in the alpine region and midlands. Water with temperature up to 50^{o}C can be utilized for space heating, greenhouses, balneology, fish farming etc. The geothermal applications in term of installed capacity and annual energy use are estimated 2.00 MWt and 7.2 TJ/year for fish farming and 1.60 MWt and 8.64 TJ/year for district heating.
United States of America (USA)	The direct utilization use of geothermal energy includes the heating of pools and spas, greenhouses and aquaculture facilities, space and district heating, snow melting, agricultural drying, industrial applications and ground-source heat pumps. The second largest uses of geothermal energy are fish farming and swimming pool heating. The distribution of annual energy use in fish farming is 34% and 3% for agricultural drying. The current installed capacity and annual energy uses for fish farming is estimated 141.95 MWt and 3,074.0 TJ/year while agricultural drying is 22.41 MWt and 292.0 TJ/year. As example in Hagerman, Idaho, the catfish and tilapia are being breed in tanks using 32^{o}C of water from eight geothermal wells with depth at 300m. Other example is in Klamath Falls, Oregon where more than hundreds varieties of high-value tropical fish are raised in ponds which the ponds are heated to 27^{o}C by geothermal water from 50m deep well.

New Zealand	At Wairakei,Taupo there are nine ponds built in the area between 0.2 to 0.35 hectare to farm Malaysian Freshwater Prawns also known as *macrobrachium rosenbergii*. A temperature probe controls the rate of flow water into the ponds and aerator is used to mix well the water to ensure a constant temperature through the depth of each pond. Water for the pond comes from two sources. First, from the a plate heat exchanger with temperature is 55ºC that takes wastewater from the Wairakei Geothermal Power Plant and Waikato River Water with temperature at 10ºC. Besides that, water is recirculated from pond system which is from storage and settling pond with temperature is maintained at 21ºC.

2.8 Formulation, Design Calculation, and Requirement for Ponds

a. Evaporative loss (qEV)

Evaporation is the main component of the sum heat loss from the pond. Normally, loss of volume more considered compare to the loss of heat. The amount of heat required to evaporate one pound of water varies with temperature and pressure but in atmospheric conditions with the value about 1,000 British thermal units (Btu). When water is evaporated to the atmosphere from the surface of the pond, the heat is taken from the remaining water. As a result, as each pound of water evaporates from the surface, about 1,000 Btu are lost with escaping vapor (Rafferty, 1995).

The rate at which evaporation occurs is a function of air velocity and the pressure difference between the pond water and water vapor in the air, also known as vapor pressure difference. As the temperature of the water pond is rise or the humidity of the air is dropped relatively, therefore, evaporation rate is increase. The equation that explains the evaporation rate is (ASHRAE, 1995)

Evaporation rate, Wp (lbm/h) = (0.097 + 0.038v)•(Pw-Pa)•A………………………….(2.1)

Where A = surface area of pond (ft2)

v = air velocity (mph)

Pw = saturation vapor pressure of the pond water (psia)

Pa = saturation pressure at the air dew point (psia)

For closed pond or indoor pools, this equation can be reduced to (ASHRAE, 1995).

Wp = 0.204•A•(Pw-Pa)…………………………………………………………………….(2.2)

Where A = pond area (ft2)

Pw = saturation pressure of the pond water (psia)

Pa = saturation pressure at air dew point (psia)

Following are the common values for Pw and Pa:

For Pw:

Temperature of water (^oF)	Pw value (psia)
60	0.256
70	0.363
80	0.507
90	0.698
100	0.9493