# Design of Aeration System for the Lake Surrounding An Nur Mosque

by

Asfahani Binti Baharuddin

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

JANUARY 2009

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

## TABLE OF CONTENTS

## LIST OF FIGURES

**LIST OF TABLES**

# CERTIFICATION OF APPROVAL

**Design of Aeration System for the Lake Surrounding An Nur Mosque**

by

Asfahani Binti Baharuddin

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

________________________

(Dr. Azmi Bin Abdul Wahab)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2009

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

________________________________________

ASFAHANI BINTI BAHARUDDIN

# ABSTRACT

The lake surrounding UTP's An Nur Mosque contains murky (or silted) water even though a pumping system is in place to filter the water. It jeopardizes the aesthetical value of the scenic mosque. The purpose of this project is that the lake and its associated water system will be extensively studied to determine the causes of the murky water problem and why the present treatment system failed to solve the problem. The scope for Phase 1 of the project started with the study of the lake's water intake and circulation system, and then followed by water quality testing. Then, the causes of the problem were determined. The solution for this problem is a system to aerate the water and maintain its quality. In the Phase 2 of the project, the detailed engineering design of the suitable solution was executed. Then, cost for the equipment, materials and installation of the aeration system were estimated. The outcome of this project is a complete systems design that would aerate the water and maintain its quality so that the aesthetical value of mosque will be further enhance.

# ACKNOWLEDGEMENTS

The author wishes to take the opportunity to express her utmost gratitude to the individual that have taken the time and effort to assist the author in completing the project. Without the cooperation of these individuals, no doubt the author would have faced some complications throughout the course.

First and foremost the author's utmost gratitude goes to the author's supervisor, Dr. Azmi Bin Abdul Wahab. Without his guidance and patience, the author would not be able to complete the project successfully.

To all the technicians in Waste Water Engineering Lab, thank you for assisting the author in completing her project. Also to the author's parents and colleagues, who have been very supportive, your help and assistance are truly appreciated.

To all individuals that has helped the author in any way, but whose name is not mentioned here, the author thank you all.

# CHAPTER 1
# INTRODUCTION

The title of this Final Year Project is Design of Aeration System for the Lake Surrounding UTP's An Nur Mosque. This chapter will describe the background of study, problem statement, objectives and scope of work of this study.

## 1.1 Background of Project

This project is intended to enhance the water quality of the lake surrounding UTP's An Nur Mosque. The lake's water intake and its circulation system have been studied. The lake's water sample were analysed as per parameters listed in 'Proposed National Water Quality Standards for Malaysia in order to know the present water quality. The elements that were observed are water pH level, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids, Ammonium Nitrate, Color (TCU), Dissolved Oxygen, Turbidity (NTU), Fecal Coliform and its appearance. The causes of the water problem were identified from the water testing result. Consequently, the solution would be found and the treatment system was designed to enhance the purpose of the lake, which acts as habitat for ornamental fishes plus to bring out aesthetic value of the mosque. This water treatment system design can also be adopted in any similar type of lake for future use.

## 1.2 Problem Statement

The lake surrounding UTP's An Nur Mosque contains murky (or silted) water even though a pumping system is in position to filter the water. All lakes should have filtration system to provide good water quality for healthy fish and good appearance. Generally better lake filters mean higher cost, less maintenance, and better water quality. One of the biggest problems for most lakes is leaf debris and a proliferation of algae. If vegetation falls into the lake water and decays, the process of decay uses the oxygen in the water and releases carbon dioxide. This means that if large quantities of plants enter the lake then enough oxygen can be removed to cause the lake's ecological unit to suffocate.

Algae is also caused by decaying vegetation, the reason for this is the nitrogen which is released during the decay process is soluble in the lake water. Nitrogen is a nutrient that is vital for plant growth and if there is abundance of it in the water then this will normally result in algal growth. Apart from all these problems, the chemical contents of the lake water should also be noted. In order to know all the problems associated with it, the lake water samples were tested in laboratory. Plus, the lake's water quality has never been evaluated in laboratory before.

### 1.3 Objectives of Study

The objectives of this study are:

1. To extensively study the lake's water intake and circulation system
2. To determine the causes of the murky water problem
3. To design a system to clean the water and maintain its quality so that ornamental fishes can be kept to enhance the surrounding of the mosque.

### 1.4 Scope of Study

The scope of this project started with a comprehensive study on the lake surrounding UTP's An Nur Mosque's water intake and circulation system. Then the lake water sample is tested based on several parameters as per Water Quality Standard. The probable solutions for this problem were listed and the best solution is being further described. The detail technical on-paper design of the system that is being proposed to solve this problem will be completed. The probable solution to be chosen are by installing the aerator fountain, filtration system, using lake dye or coagulation and flocculation. The outcome of this project will be a complete systems design that would aerate the water and maintain its quality.

# CHAPTER 2
# LITERATURE REVIEW

Review for the study was taken abundantly from interviews, journals, books, reports and the internet. Basically, topics to be highlighted for the study consist of the history of the lake itself, water quality standards for the lake water, the lake ecosystem, filtration and aeration system that is widely used to combat water problems. Here are some notes taken for the study:

## 2.1 Background Study of UTP Lake

The study of the lake's water intake and circulation system has been carried out by the author. A lot of data and information has been gathered from the result on consultation with the project manager of KLCC Projeks Berhad, Mr. Farid and from one of the Engineer in UTP Maintenance Department, Mr. Haji Hazami.

Based on the December 2003 Main Drain Design Report prepared by Angkasa Consulting Services Sdn, Bhd., there are eight lakes of varying sizes in UTP, and the lake surrounding An-Nur Mosque is named as Lake 1. (Refer to Figure 2.1 in Page 4). All the lakes are interconnected and its main purpose serves as flood retention and drainage system. Lake 1 is build for recreational activities and aesthetical value. It is divided into two parts, Pond 'A' and 'B'. The man-made Pond 'A' covers the higher level water area which surrounds the mosque, while Pond 'B' is the lower area of Lake 1. These two ponds are separated by a man-made weir resulting in a waterfall which flows from Pond 'A' to Pond 'B'. There are four pumps (two running, two standby) used to pump water from Pond 'B' to Pond 'A'. Pumps are needed as the water level in Pond 'A' is not sufficient to create the waterfall effect especially during the sunny days. Currently, the lake only has natural water circulation which mix and indirectly clean the water. No mechanical, biological or chemical filtration system was being installed for all the lakes.

Figure 2.1: Previous Approved Drainage Master Plan

## 2.2 Water Quality Standards

The water quality in Malaysia has been monitored by the Malaysian Department of Environment (DOE). The Water Quality Index (WQI) used to appraise the water and act as a tool to summarize and report Ecology's Freshwater Monitoring Unit's routine stream monitoring data (Hallock, D., 2002). Scores are determined for pH level, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids, Ammonium Nitrate, Color (TCU), Dissolved Oxygen, Turbidity (NTU), Fecal Coliform, Total Coliform and its appearance.

Based on the ‘Proposed National Water Quality Standards for Malaysia, the lake water surrounding An-Nur Mosque falls under the category Class IIA/IIB which represents water bodies of good quality *(source www.sabah.gov.my)*. In practice, no body contact activity is allowed in this water for prevention of probable human pathogens. The determination of Class IIB standard is based on criteria for recreational use and protection of sensitive aquatic species. But, in this case, more stringent approach is used, for which the water will be compare to the Class A standard, which is for drinking. It is because Class A gives better clarity of the water, and it is superior to do design that could comply with the most stringent; consequently giving highest result that could be achieved.

## 2.3 Lake Ecology System

Ecology is the scientific study of the distribution and abundance of living organisms and their relations with their environments (Gerry Closs, Barbara Downes, Andrew Boulton, 2004). A lake ecosystem is a delicate balance of fish, plants and other animals. The wrong combination results in dead fish and withering plants. An ecologically balanced environment includes clean, clear water and healthy fauna.

The way to achieve this starts with a good pump and filter. Regularly cleaning the surface of the lake out of leaves and debris will also help keep the lake ecosystem healthy. Other items that will help keep the ecosystem clean include a lake skimmer, lake rake, lake netting, and a lake pump filter.

Pidwirny, M. (2008) states that nitrogen is often a limiting factor for plant growth as plants can absorb nitrogen only in the form of nitrate ($NO_3^-$) or ammonium ($NH_4^+$). Animals obtain their nitrogen by eating organic materials such as plants or other animals that contains nitrogen. Because of this, nitrogen in the form of nitrate is a large proportion of most commercial fertilisers. Unfortunately, excessive amounts if nitrate in agricultural run-off can give harmful effects on aquatic ecology systems. The nitrogen cycle is shown in figure below.

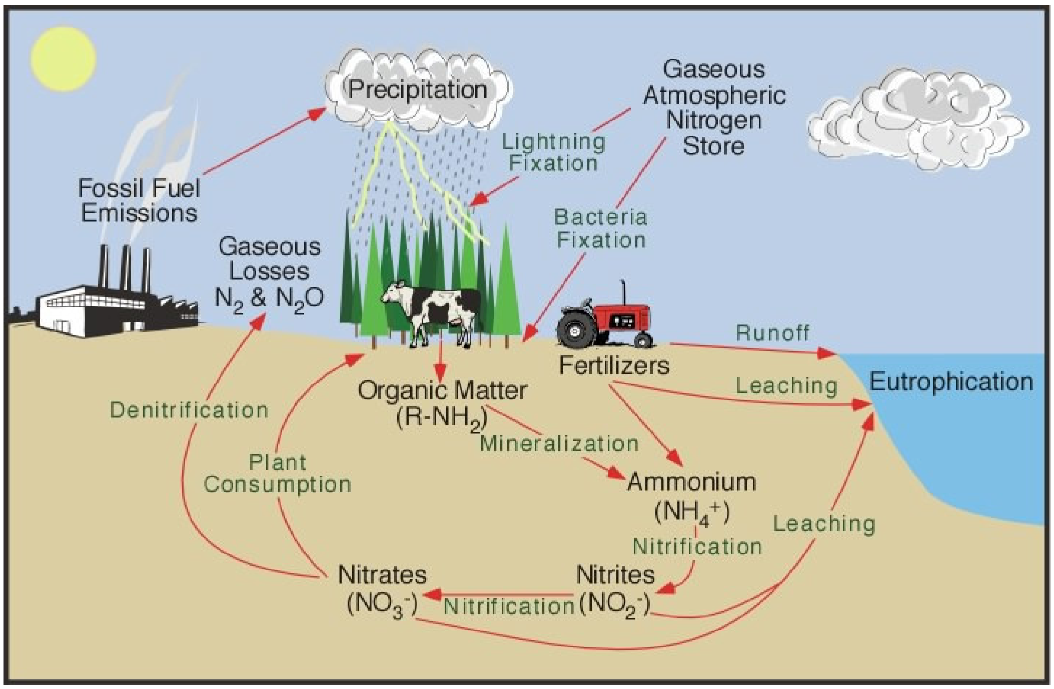



Figure 2.2: Nitrogen Cycle
*(Source Pidwirny, M. (2006) from www.sci.waikato.ac.nz/farm)*

## 2.4 Major Problems with Lakes

Algae are defined as plantlike organisms without roots, vascular tissues and leavy shoots, which constitute a heterogeneous assembly of oxygen-producing, photosynthethic organisms (South and Whittick, 1987).

According to Steve McComas (2003) algal are present in all lakes and are an essential component in the lake's food web. However, when high nutrient concentrations in the water drive the algae to high densities, insufficient control and excessive algae become a nuisance as it can turn a clear lake or lake into a turbid water body capable of producing a pea-green soup appearance. Julie Stauffer (1998) claims this process known as 'eutrophication'. Excessive algae reduce sunlight penetration into the water and limit beneficial aquatic plant distribution. In addition, when algae die, oxygen is consumed in the decomposition process, depriving fish of the oxygen they need to live. In some instances, several blue-green algae species can produce toxic compounds. If such compounds are ingested by animals, they can become sick and even die. Preventing algal blooms in a lake meant fewer toxins could be in the water. Therefore, controlling nuisance algal growth not only improves the aesthetic appearance of a lake, but benefits aquatic plants, fish, and even wildlife.

The lake, which also serves the purpose as a flood retention system, is subjected to several pollutants that results from the water run-off from the main drain and acid rain (Angkasa Consulting Services Sdn Bhd, 2003). Based on a book written by P.K Goel (2001) some pollutants can be formed by way of concentration and transformation of naturally occurring compounds during their domestic, agricultural or industrial use. The generation of sewage and the waste waters containing agrochemicals, certain pesticides, petrochemicals, hydrocarbons and heavy metals are some important examples of pollutants originated in this way. The common sources of water pollution can range from purely natural to several man-made sources like discharge of domestic and industrial waste waters. Agricultural wastes usually originate in the form of run-off from the agricultural fields and animal farms; and also agrochemicals in the form of fertilizers, organic manures, pesticides, nutrient solutions and others. The run-off is considerably rich in nutrients like nitrogen and phosphorus, organic matter and pesticides which will eventually cause the silt at the bottom of the lake, such in Figure 2.3. While nutrients can create the problem of eutrophication, pesticides are responsible for causing toxicities to aquatic life. Algae problem also is due to the unbalanced of chemicals present in the water.

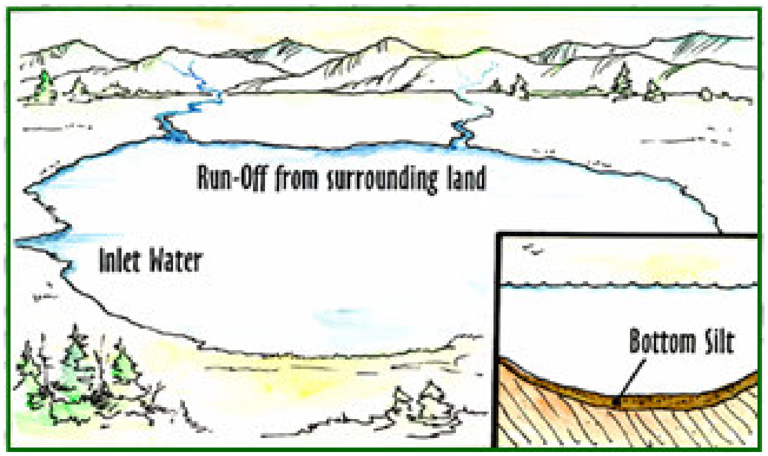



Figure 2.3: Run-offs from Surrounding Land Resulting in Bottom Silt
*(Source www.otterbine.com)*

Julie Stauffer (1998) also conforms to this statement by claiming that the more organic material you throw in a lake, the more oxygen it takes to break it down, and the unhappier the fish in the lake are going to be as there is progressively less oxygen for them to breathe. The biggest impact is immediately downstream from a sewage outfall, where the organic matter starts decomposing, using up oxygen and releasing ammonia. The concentration of organic matter decreases as some of it breaks down into carbon dioxide and nutrients, and the rest of it gets diluted. Ammonia levels are therefore lower and oxygen levels are higher. The further the distance downstream from the outfall, the smaller the effect becomes, as bacteria transform the ammonia to nitrate and oxygen enters the water from the atmosphere.

Stauffer also states that acid rain is a widespread and well publicized problem. It is caused by emissions from a host of sources which contain sulphur dioxide and nitrogen oxide, which are converted to sulphuric and nitric acid in the atmosphere. Acid rain lowers the pH of bodies of water, killing young fishes and other aquatic species, and interfering in the reproduction of surviving adults. It makes metals and other toxic substances dissolve more readily in water, causing further damage to aquatic ecosystems. According to Stauffer based in a 1980 study, it was estimated that 18,000 lakes in Sweden alone are affected by acid rain due to no natural buffering capability. 14,000 Canadian lakes are considered biologically dead, also due to effect of the acid rain.

When a lake is very deep and lacking of any mixing, it means that the water will create two different layers than differs in terms of chemical composition (solutes, dissolved gases, pH, etc.) As a result, the upper layer is usually well-oxygenated while the lower layer becomes hypoxic (low in oxygen). The high soluble 'rotten-egg gas' (hydrogen sulfide, $H_2S$) may build up to extraordinary concentrations. While surface water usually has no odour, water from the depths often stinks because of $H_2S$. Nutrient concentrations may be quite high in the lower layer. When mixing occurs, the nutrient present in this deeper water become temporarily available to the surface producers resulting in algal blooms. The acidity of water usually differs between the layers. Water in the lower layers is usually more acidic than at the surface although acidity can change in response to high rates of photosynthesis. Acidity affects the solubility of most dissolved metals, ions and nutrients, and hence their accessibility to aquatic organisms. (Gerry Closs, Barbara Downes, Andrew Boulton, 2004).

## 2.5 Lake Water Treatment Options

### 2.5.1 **Lake Filtration**

A good filtration system provides many functions including improving water quality, controlling ammonia and nitrite levels, and providing water movement and adding oxygen to the water. Filtration is needed to eliminate particulate and biological wastes from the water. The three basic types of filtrations are Mechanical, Chemical and Biological.

Mechanical or physical filtration refers to the removal of particles of debris by means of passing the lake water through various filtration media. Mechanical filters either strain or skim debris such as leaves, stirred up muck, and free-floating algae from the lake. This helps to prevent clogs in other lake equipment as well as reduce the amount of decaying materials from settling on the bottom. Ultra Violet (UV) Filter is one type of mechanical filter that is useful for combating the proliferation of algae. The conventional and still the principal type of filter used for cleaning bulk water is the sand bed with backwashing carried out by a backflow of water, or preferably water backwash combined with air scour. The latter results in better fluidization of the bed and more effective cleansing (Christopher Dickenson, 1997).

Chemical filtration helps to remove organic and inorganic pollutants with specialized media like carbon and resins, usually in a loose, bagged, or pad form. Biological filtration is the process that removes this excess ammonia by using nature's nitrogen cycle to detoxify organic waste products (Drs. Foster & Smith, 2008).

### 2.5.2 **Aeration Fountain**

Lake aeration is defined as adding air to water for the purpose of increasing oxygen levels and improving circulation. Lake aeration ensures the characteristics of a healthy lake, which has sufficient oxygen and adequate mixing of the water to reduce stratification so that the oxygen is uniformly distributed throughout the water column. Fish, vegetation and beneficial microorganisms depend on dissolved oxygen for respiration. The effect of aeration which can increase the lake's oxygen level is shown in Figure 2.4.

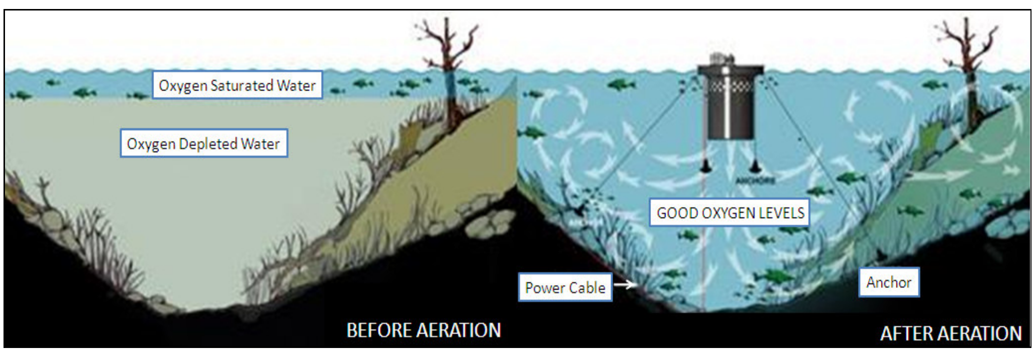



Figure 2.4: The Effect of Aeration to the Lake Water
*(Source http://marcoslawnlandscape.com/RainBird.htm)*

Lake aeration allows the water at all depths the ability to support animal and plant life, control algae growth by limiting its food source and aid decomposition of suspended organic material and muck on the bottom of the lake. Through circulation, the water is able to release harmful gases that build up on the bottom into the atmosphere, thereby further improving water quality, eliminating tastes and unpleasant odors (Vertex Water Features, 2008). Charles R. Cox (1969) also agrees that taste and odour producing substances, such as Hydrogen Sulfide, $H_2S$ or some of the volatile substances liberated by algae growths or incidental to the decomposition of organic matter, are released from water by aeration. Aeration is utilized primarily to provide oxygen from the atmosphere. When oxygen is introduced, the aerobic digestion process is stimulated. In short, aeration is a biological clean up tool which enhances the overall quality of the water and surrounding environment. Independent research shows that surface aeration adds 2 mg/L of dissolved oxygen at 10ft or 3m and is excellent for breaking up algae mats.

A few metal ions like $Fe^{++}$ and $Mn^{++}$ can also be oxidized by aeration. (P. K. Goel, 2001). A lake aeration system improves the aesthetics and overall health of a body of water. Aeration is a holistic, preventative tool which will prolong the useful life of a lake.

There are many types of aerators, such as spray, waterfall, cascade and diffused-air aerators. Possibly the most effective type is spray aerators, as it has large total surface area of the water drop in contact with the atmosphere (Charles R. Cox, 1969). Figure 2.5 shows an example of spray aerator and its main components that consists of a float, nozzle, pump and motor.

Figure 2.5: Spray Aerator and Its Main Component
*(Source http://marcoslawnlandscape.com/RainBird.htm)*

### 2.5.3 **Wetland Treatment**

The philosophy behind aquatic plant treatment systems arises from observations that many natural aquatic systems such as wetlands has the ability to clean the waste water before flowing into the lake. It can be used to remove pollutants, nutrients, reduce the levels of bacteria and suspended solids from waste water by secreting natural antibiotic substances from their roots (Julie Stauffer, 1998). The UTP's Design Team who was in charge in designing the lake has come up with this wetland idea to treat the pesticides that might be flowing from the Rubber Research Institute and other pollutant sources such as the UTP Sewage Treatment Plant but the idea did not turn into reality as the construction and maintenance of a wetland is very costly (Farid, 2008).

### 2.5.4 **Coagulation and Flocculation**

Suspended solids in water range in size from coarse material, which settles readily, to very fine material, which will not settle unless the particles coalesce naturally and precipitate or unless a coagulant is used. The coagulating chemical is applied to the water and this requires rapid agitation or mixing of the water at the point where the coagulant is added. Complex chemical and physiochemical reactions and changes occur, leading to coagulation and the formation of microscopic particles; in other words, the fine particles are flocculated and formed into a larger particles which will then be removed by filtration (Charles R. Cox, 1969). Figure 2.6 shows the basic principle of coagulation and flocculation.

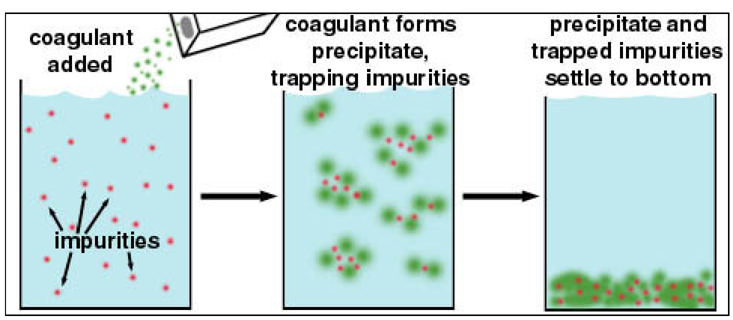



Figure 2.6: Basic Principle of Coagulation and Flocculation
*(Source http://water.me.vccs.edu/courses/env110/Lesson4_print.htm)*

# CHAPTER 3
# METHODOLOGY

There are some procedures to be followed in order to carry out and implement the project. The Flow Chart in Figure 3.1 summarized the overall methodology for this project.

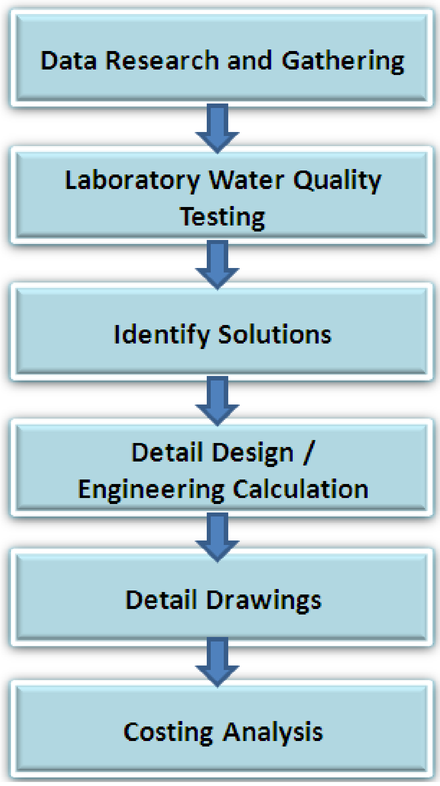



Figure 3.1: Project Flow Chart

## 3.1 Work Done

### 3.1.1 Data Research and Gathering

Elements of projects involved in this stage include the study of the lake's water intake and circulation system. Consultation was made with the project manager of KLCC Projeks Berhad, Mr. Farid who is in the design team during the construction of the An Nur Mosque. He provides a lot of helpful drawings comprising the lake system and its design report. Apart from that, opinions from the Engineer of Maintenance Department, UTP, Mr.Haji Hazami were also gathered. He is the person responsible to maintain all the lakes surrounding UTP.

### 3.1.2 Water Sampling

The lake water has never been tested whether it is within the allowable water quality standard or not. So, as the first step, several lake water samples at different locations were taken on 22nd of August 2008 and 15th September 2008. The water samples were taken to the laboratory for quality testing. In order to take water sample at the middle of the lake, a boat is used.

Figure 3.2: Boat Used to Take Water Sample

Three samples, 1.5 liters each were taken at these locations:

1. Around the perimeter of Pond 'A'
2. Around the perimeter of Pond 'B'
3. Middle of Pond 'B'

Figure 3.3: Pond 'A'

Figure 3.4: Pond 'B'

### 3.1.3 **Laboratory Water Quality Testing**

The lake water samples were taken to the water laboratory for further testing in order measure the water quality. Several parameters based on the 'Proposed National Water Quality Standards for Malaysia, Class II B' as per Water Quality Index (WQI), which are the lake water pH level, BOD, COD, TSS, N, TSU, Dissolved Oxygen, NTU, Fecal Coliform and appearance of the water sample are being analysed. Table 3.1 summarises all the experiments done. Refer to Appendix 1 for detailed laboratory procedure.

Table 3.1: Summary of Laboratory Water Quality Testing

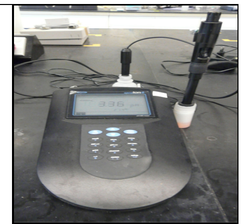
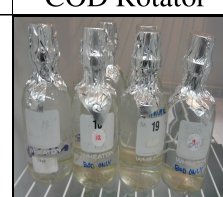
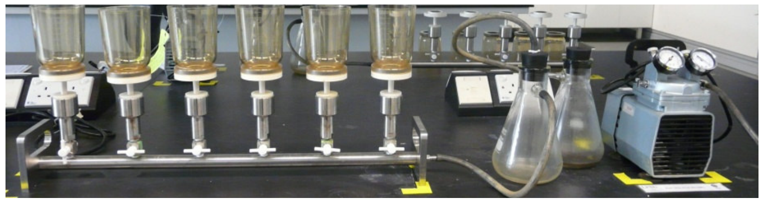
| | |
|---|---|
| 1) <u>pH Measurement</u><br>The lake water pH is measured using a pH meter by placing its electrode in the water sample. The pH value determines the acidity or alkalinity of the lake water. | <br>Figure 3.5: pH Meter |
| 2) <u>Colour Test</u><br>The objective of this experiment is to determine the “apparent” or “true” colour of the water sample. The true colour of the water sample is measured using a spectrophotometer. | <br>Figure 3.6: Spectrophoto meter |
| 3) <u>Turbidity Test</u><br>The turbidity test measures an optical property of the water sample that results from the scattering and absorbing of light by the particulate matter present. The amount of turbidity measured depends on such variables as size, shape and refractive index of the particles. The turbidity of the water sample is measured using a Portable Turbidity Meter by simply placing it inside the meter. | |
| 4) <u>Chemical Oxygen Demand (COD)</u><br>COD test aims to measure the chemical oxygen demand equivalent of the organic material in wastewater than can be oxidized chemically using dichromate in acid solution. | <br>Figure 3.7: COD Rotator |
| 5) <u>Biochemical Oxygen Demand (BOD)</u><br>BOD test aims to determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present thus determining the quality of the lake water. | <br>Figure 3.8: BOD Test Bottles |

Table 3.2: Summary of Laboratory Water Quality Testing *(cont'd)*

| |
|---|
| 1) <u>Total Suspended Solid (TSS)</u><br>The objective of this experiment is to calculate the non-filterable residue in water using gravimetric method.<br><br>Figure 3.9: Apparatus for TSS Experiment |
| 2) <u>Coliform / Bacteriological Examination</u><br>The biological characteristic of water is primarily due to the resident aquatic population of microorganisms. Bacteria in the water make the water unsafe for consumption. This experiment aims to detect the amount of bacteria in 100ml of water sample. |
| 3) <u>Ammonia Test (Nessler Method)</u><br>The objective of this experiment is to determine the present of ammonia nitrate value (it usually indicates domestic pollution) in every hour of water sample using Nessler method. |

### 3.1.4 Determine the Causes of the Problems

The supplementary water report portrays the present water quality of the lake. From the result, the causes of the problems can be determined distinctively. Possible causes of the murky water are clogged debris such as leaves, stirred up muck and free-floating algae from the lake, organic and inorganic pollutants, and high level of ammonia from dissolved organic compounds. Details are discussed in Chapter 4.

### 3.1.5 Identify Solutions

Several options of solutions for the problems causing the water lake to be murky were considered and the most suitable one are selected. The solution chosen to improve the water quality is by installing aerator fountains in Pond 'B' as highlighted below picture. The rationale behind choosing Pond 'B' is because contains the majority of the lake water, and it is the one more polluted than Pond 'A', as the water is deeper. The details are discussed in Chapter 4; Result and Discussion.

Figure 3.10 : Satellite View of Pond 'B'
*(Source: www.wikimapia.com)*

### 3.1.6 **Technical Design of the Water System**

This involves the technical specifications such as the calculation of pump size, capacity and head, nozzle flowrate, electrical cable size and other related specifications.

### 3.1.7 **Estimated Cost of the System**

The estimated project value for the whole system was executed based from the quotation from the local supplier and contractor.

### 3.1.8 **Detail Documentation and Engineering Drawings**

By the end of the project, the schematic drawings of the system were drawn using AutoCAD Software. A 3-D drawing using Rhinoceros Software was also done.

## 3.2 Milestone for First Semester of 2-Semester Final Year Project (FYP1)

Table 3.3: Project Gantt Chart for First Semester

| No. | Detail/ Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Selection of Project Topic | ■ | ■ | | | | | | | | MID SEMESTER BREAK | | | | |
| | | | | | | | | | | | | | | | |
| 2 | Preliminary Research Work | | ■ | ■ | ■ | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 3 | Submission of Preliminary Report | | | | ● | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 4 | Project Work | | | | | ■ | ■ | ■ | ■ | | | | | | |
| | 4.1 Study the lake's water intake and circulation system<br>4.2 Take water samples – send for testing<br>4.3 Analysis on the present water quality | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 5 | Submission of Progress Report | | | | | | | | | ● | | | | | |
| | | | | | | | | | | | | | | | |
| 6 | Seminar (compulsory) | | | | | | | | | ● | | | | | |
| | | | | | | | | | | | | | | | |
| 7 | Project work continues | | | | | | | | | ■ | | ■ | ■ | ■ | ■ |
| | 7.1 Determine the causes of the problem<br>7.2 Identify solutions<br>7.3 Pick best solution for detail design | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 8 | Submission of Interim Report Final Draft | | | | | | | | | | | | | ● | |
| | | | | | | | | | | | | | | | |
| 9 | Oral Presentation | | | | | | | | | | | | | | ● |

■ Process ● Suggested milestone

### 3.3 Milestone for the Final Semester of 2-Semester Final Year Project (FYP2)

Table 3.4: Project Gantt Chart for Second Semester

| No. | Detail/ Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Continuation of Project From FYP1 | ■ | ■ | | | | | | | | MID SEMESTER BREAK | | | | |
| | 1.1 Identify solutions<br>1.2 Pick best solution for detail design | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 2 | Research Work –Detail design (technical) | | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 3 | Submission of Progress Report | | | | ● | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 4 | Project Work | | | | | ■ | ■ | ■ | ■ | ■ | | | | | |
| | 4.4 Costing analysis of the system<br>4.5 Detail documentation /drawing/animation | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 5 | Submission of Progress Report 2 | | | | | | | | ● | | | | | | |
| | | | | | | | | | | | | | | | |
| 6 | Seminar | | | | | | | | | ● | | | | | |
| | | | | | | | | | | | | | | | |
| 7 | Poster Submission | | | | | | | | | | | ● | | | |
| | | | | | | | | | | | | | | | |
| 8 | Submission of Dissertation Draft | | | | | | | | | | | | | | ● |
| | | | | | | | | | | | | | | | |
| 9 | Oral Presentation | | | | | | | | | | | | | | ● |

■ Process ● Suggested milestone

# CHAPTER 4
# RESULTS AND DISCUSSION

## 4.1 Results on Water Quality Assessment

After the laboratory tests conducted, all the results were tabulated according to the tests. The author has done the tests twice to get the averaged value of both results. Some findings were made on the Water Quality. The lake water surrounding An-Nur Mosque falls under the category Class IIA/IIB which represents water bodies of good quality. In practice, no body contact activity is allowed in this water for prevention of probable human pathogens. The determination of Class IIB standard is based on criteria for recreational use and protection of sensitive aquatic species. But, in this case, more stringent approach is used, for which the water will be compare to the Class A standard, which is for drinking. It is because Class A gives better clarity of the water, and it is superior to do design that could comply with the most stringent; consequently giving highest result that could be achieved.

Below are the 10 parameters for water qualities that were analysed based on the 'Proposed National Water Quality Standards for Malaysia, Class A and Class II B'.

Table 4.1: Ten Parameters of Water Quality and Its Allowable Range Value for Class A and IIB.

| NO. | PARAMETERS | METHOD REF. NO. : APHA- | RANGE VALUE (Class A) | RANGE VALUE (Class IIB) |
|---|---|---|---|---|
| 1 | Ammonium Nitrate, mg/L | 4500$NH_3$ B&F | <0.10 | <0.30 |
| 2 | Biochemical Oxygen Demand @ 20$^oC$ for 5 days, $BOD_5$, mg/L | 5210B & 4500 OG | <1.0 | <3.0 |
| 3 | Chemical Oxygen Demand, COD, mg/L | 5220C | <10.0 | <25.0 |
| 4 | Dissolved Oxygen, mg/L | 4500-O G | >7.00 | 5.00 – 7.00 |
| 5 | pH | 4500 H B | 6.50 – 8.50 | 6.50 – 9.00 |
| 6 | Colour | 2120B | <15 | <150 |

| | | | | |
|---|---|---|---|---|
| 7 | Total Suspended Solid, mg/L | 2540D | <25 | <50 |
| 8 | Turbidity ( NTU ) | 2130B | <0.5 | <50 |
| 9 | Feacal Coliform (MPN/100 ml) | 9221E-1 | <10 | <400 |
| 10 | Appearance | - | - | - |

Several experiments to analyze the parameters above have been done (Refer to Appendix 1). Two different water samples were taken to be analysed. Below is the result of water analysis from samples taken on 22nd August 2008 and 15th September 2008.

Table 4.2 : Results for Current Water Testing

| **NO.** | **PARAMETERS** | **RANGE VALUE** | | **RESULTS (DATE)** | |
|---|---|---|---|---|---|
| | | **Class A** | **Class IIB** | **(22/08/08)** | **(15/09/08)** |
| 1 | Ammonium Nitrate, mg/L | <0.10 | <0.30 | 4.38 | 1.54 |
| 2 | Biochemical Oxygen Demand @ 20$^{o}$C for 5 days, $BOD_5$, mg/L | <1.0 | <3.0 | 10.6 | 20.1 |
| 3 | Chemical Oxygen Demand (COD), mg/L | <10.0 | <25.0 | 40.2 | 53.3 |
| 4 | Dissolved Oxygen (DO), mg/L | <7.0 | <5.0 – 7.0 | 8.18 | 10.91 |
| 5 | pH | 6.5 – 8.5 | 6.5 – 9.0 | 6.2 | 7.4 |
| 6 | Colour | <15 | <150 | 115 | 125 |
| 7 | Total Suspended Solid, mg/L | <25 | <50 | 0.024 | 0.34 |
| 8 | Turbidity ( NTU ) | <0.5 | <50 | 11.9 | 13.9 |
| 9 | Feacal Coliform (MPN/100 ml) | <10 | <400 | 170 | 287 |
| 10 | Appearance | - | - | Light Yellowish Liquid | Light Yellowish Liquid |

## 4.2 Discussion on the Water Test Result

All the parameters tested do not fall between the allowable range set in Class A, except for pH, Dissolved Oxygen and Total Suspended Solids. This result exemplify that the lake water is not suitable for drinking. But, if the results are compared to the Class IIB standard, most of the parameters stay within the allowable range. So, there is still a lot of improvement need to be done to enhance the water quality standard.

The pH value, pH 6.2 is slightly lower than the allowable value, which is pH 6.5. A drop in pH in a lake to below 7 will lead to dramatic changes in fish's health, particularly if they are long term. Exotic fish's colour are likely to fade through the deposition of excess mucus while in extreme cases, fish may even be seen to gasp at the water surface. Acidic lake water is also likely to be corrosive to exposed plastic and metal surfaces, causing the lake water to become a toxic cocktail of contaminants.

According to Hach Company (2006), ammonia is toxic to fish and aquatic organisms, even in very low concentrations. When levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish will begin to die. As levels near 2.0 mg/L, even ammonia-tolerant fish like carp begin to die. Ammonia levels greater than approximately 0.1 mg/L usually indicate polluted waters. The danger ammonia poses for fish depends on the water's temperature and pH, along with the dissolved oxygen and carbon dioxide levels. The higher the pH and the temperature, the more toxic the ammonia content will be.

If water is too warm, there may not be enough oxygen in it. When there are too many bacteria or aquatic animal in the area, they may overpopulate, using Dissolved Oxygen (DO) in great amounts. Oxygen levels also can be reduced through over fertilization of water plants by run-off from fields containing phosphates and nitrates (the ingredients in fertilizers). Under these conditions, the numbers and size of water plants increase a great deal. Then, if the weather becomes cloudy for several days, respiring plants will use much of the available DO. When these plants die, they become food for bacteria, which in turn multiply and use large amounts of oxygen.

Turbidity affects fish and aquatic life by interference with sunlight penetration. Water plants need light for photosynthesis. If suspended particles block out light, photosynthesis and the production of oxygen for fish and aquatic life will be reduced. If light levels get too low, photosynthesis may stop altogether and algae will die. It's important to realize conditions that reduce photosynthesis in plant result in lower oxygen concentrations and large carbon dioxide concentrations. Large amounts of suspended matter may clog the gills of fish and shellfish and kill them directly. Suspended particles may provide a place for harmful microorganisms to lodge. Some suspended particles may provide a breeding ground for bacteria.

The result obtained cannot be considered as precise as the water quality depends on many conditions. For example, if the sample is taken after the rain, the turbidity value will be higher compare to the sample taken on a sunny day. This also happens to some other parameters. So, in order to overcome this, the water testing has to be done several times along the semester of FYP1. Plus, the best way to take the water sample is by using a free-bacteria container that will not affect the amount of bacteria of the water. The water sample were taken at a depth of not more than 1 metre deep due to insufficient tools, thus the quality of water below 1 meter from its surface is undetermined.

Physically, the lake water looks greenish in colour. This can be seen from Figure 4.1. This may be due to algae deposition or sedimentation under the lake's bed.

(a) (b)

Figure 4.1 : Close-up Look of the Lake Water
(a): at the perimeter of Pond B
(b): at the strainer at edge of Pond B

### 4.3 Identify Best Solution

Several options of solutions for the problems causing the water lake to be murky were considered and the most suitable one are selected. Among those of solutions considered to clean and enhance the water lake water quality are by wetland treatment, coagulation and flocculation, filtration system or aeration fountain.

Based on the current water quality, the best solution to treat the water is by aerating it. This solution is well-suited for the purpose, as aeration will eventually give more oxygen in the water that is crucial for fish's growth, and also shorten algae proliferation thus makes the water cleaner. Aerator fountain also add aesthetical value for the lake surrounding as one of the main attraction of UTP.

### 4.4 Aerator System

#### 4.4.1 Water Volume of Pond 'B' Estimation

The method used for estimating lake volume is to determine average lake depth and multiply it by lake area. But, in order to require an exact value, accurate depth contour map and a planimeter is required. Since there is no accurate contour survey has been done, the depth and contour in this calculation is based on the *'2003 Main Drain Design Report'*. Below is the shape and size of the lake traced from Figure 2.1 (refer to Page 4), which is drawn in 1cm:50m scale. The area of the lake is calculated by dividing the area into smaller rectangles for easier calculation.

<u>Pond 'B' Area</u>

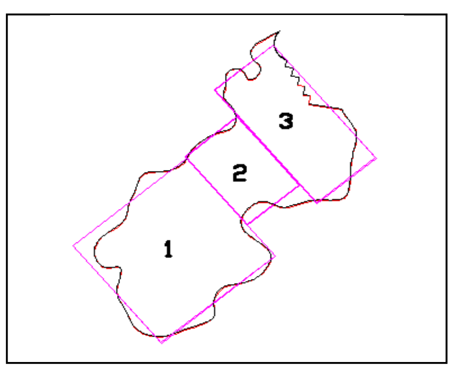



Figure 4.2 : Area of Pond 'B'

**The lake map is drawn on the scale of 1cm : 50m based on the '*2003 Main Drain Design Report*' but the figure above is drawn not to scale.

Area (1) = 9406.25 m²

Area (2) = 5737.5 m²

Area (3) = 15600 m²

Total area = Area (1) + Area (2) + Area (3) = <u>*30734.75 m²*</u>

<u>Pond 'B' Depth</u>

The shape and size of the pond is traced from the drawing titled "Lake Longitudinal Section". (See Appendix 5 for drawing).

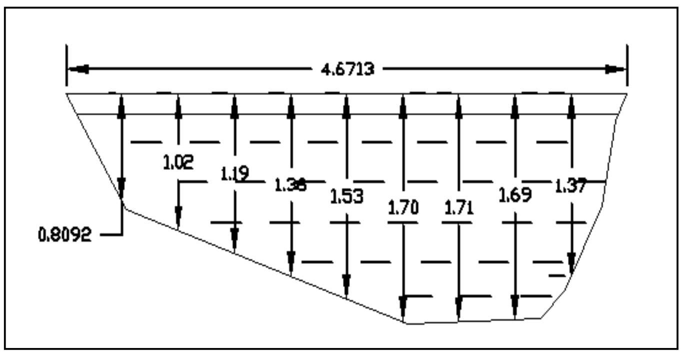



Figure 4.3: Depth of Pond 'B'

Table 4.3 shows the depth reading taken from several locations as marked in the above drawing.

Table 4.3 : Depth Reading from Specified Locations

| Location | Depth (cm) |
|---|---|
| 1 | 0 |
| 2 | 0.81 |
| 3 | 1.02 |
| 4 | 1.19 |
| 5 | 1.36 |
| 6 | 1.53 |

| Location | Depth (cm) |
|---|---|
| 7 | 1.70 |
| 8 | 1.71 |
| 9 | 1.96 |
| 10 | 1.37 |
| 11 | 0 |

- Total Depth = $\Sigma$ (0.81 + 1.02 + 1.19 + 1.36 + 1.53 + 1.7 + 1.71 + 1.96 + 1.37)
  =12.65 cm x (30m/1cm) =379.5m

- Average Depth = 379.5m /11 = <u>*34.5 m*</u>

- Estimated Volume = Total Area x Average Depth
  = 30734.75 $m^2$ x 34.5 m
  = ***<u>1,060,349 $m^3$</u>***

This shows that the water volume of the lake is very large, given the depth and area of it. So, for better effect of water quality management, the quantity of the aeration systems must be large enough to aerate the whole lake.

### 4.4.2 Quantity and Placement of Aeration Systems

The number of aeration system that will be proposed depends on several criteria, such as the size and shape of the pond. Irregular shaped pond should often be treated as two or three separate ponds, such as in illustration below:

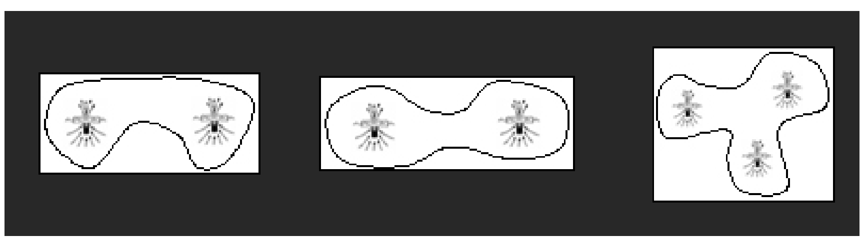


Figure 4.4 : Examples for Placement of Aerator
*(Source: Otterbine Specification Manual)*

Regardless of the type of the system, strategic placement of the aerators or diffusers is critical to insure the success of the aeration system; how quickly and efficiently it will clean the pond. The size and shape of the pond has a direct bearing on the size, number and placement of aerators.

Location of the aerators maybe in some extent is dictated by proximity of the electrical power source. Assuming the power is readily available, the aerators should be strategically placed so that there is uniformed circulation and aeration throughout the entire pond.

This locations and quantity is proposed based on the size and shape of the pond itself. The orientation is design so that the aerator fountain will not overlap one another and the water will not be affect any car or person passing by the aerator during strong wind. The drawing in Figure 4.5 shows the proposed location of the aeration systems.

A total of eight Gemini and one Triad is proposed since the water volume of the lake is very large, which is estimated around 1,060,349 $m^3$. The total flowrate of the water that could be aerated by all these nine aerators are 1498.8 $m^3$/hr. Thus, it will take approximately 30 days to fully aerate the water assuming a 24 hours a day operation. If the number of aerator is increased, it will significantly affect the cost of the system.

## 4.5 Aerator Specification

The aerator system consists of pumps and motor to raise the water, nozzles to spray and reduced the particles of water, pipes as the connecting medium between the nozzles and pump, pontoon or float to hold the pump, motor and nozzles without sinking, and also electrical system such as cables to give power to the motor. Both the designs of aerator, which is Triad and Gemini, will be further justified.

### 4.5.1 Detail Design for Gemini Type Aerator Fountain

The Gemini Type Aerator is a floating, surface spray aerator with a fan-shaped spray pattern. The spray height is 3.5m and the spray diameter 6.9m. The illustration of Gemini is shown in Figure 4.7. The primary pumping rate is 172.6$m^3$/hr and the secondary or induced circulation rate shall be ten times the pumping rate.

Figure 4.5: Proposed Location of Aeration System

Figure 4.6 shows the steps taken to design the Gemini Type Aerator Fountain. First, the aerator's spray height and diameter was determined based on the manufacturer's availability since the whole system comes in one package consisting the pump, nozzle, motor and pontoon. Then, AutoCAD drawings were produced to see the how the system looks like. The pipe size, total head and type of driving motor was further calculated and identified based on some engineering equations and theories. Lastly, the estimated costing was done in accordance with the contractor's quotation.

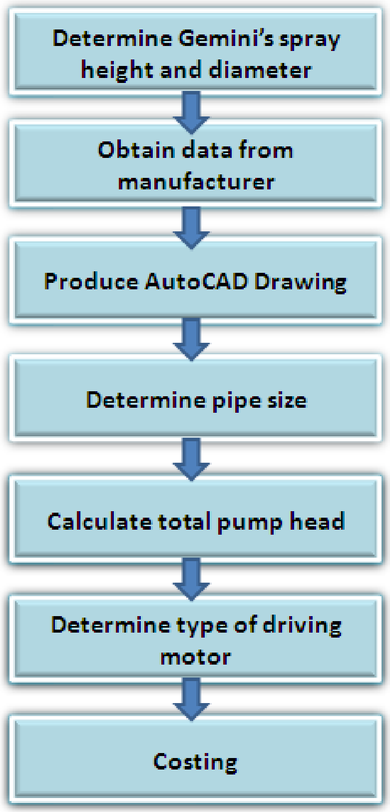



Figure 4.6: Flow Chart to Design Gemini Type Aerator Fountain

The specification of the Surface Spray from the manufacturer, Otterbine Barebo Inc. is as below:

**Type: Gemini Surface Spray**

| | |
|---|---|
| Manufacturer: Otterbine Barebo | Spray Height: 3.5m |
| Pumping Rate: 3HP | Diameter: 6.9m |
| Frequency: 50Hz | Capacity: 172.6m³/hr |

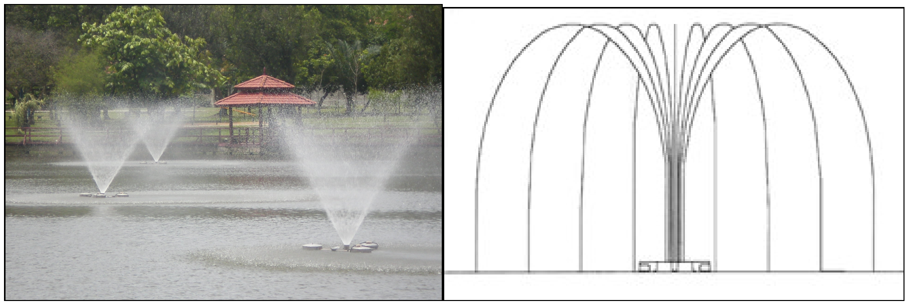


Figure 4.7: Shape and Illustration of Gemini Surface Spray

All supporting data for Gemini is in Appendix 3. The plan and sectional view of the proposed system based on the design from Otterbine Barebo Inc. is drawn using AutoCAD. Refer to the drawing in Figure 4.8 for details.

#### *4.5.1.1 Determine Pipe Size*

Based on the Plastic Pipe and Fittings Association (PPFA), the PVC pipe should be designed for a maximum flow-rate velocity of 5 to 8 feet per second (ft/s) through the pipe. For pipe sizes less than 1" in diameter, the velocity 8ft/s is suitable. But, for the pipe sizes of 1 ¼" or larger, the velocity should be less than 5ft/s. Higher velocities could cause pipe failure and rupture, as it gives larger resistance to flow, which necessitates higher horsepower requirements and higher operating costs. The pipe diameter can be determined using equation below:

$$Velocity, V = \frac{0.4085 \times GPM}{d^2}$$

Where Velocity, $V$ (feet per second) : 5ft/s

Flowrate, $GPM$ (gallons per minute) : 632.78 GPM

Inside diameter of the pipe, $d$ (inches)

$$d^2 = \frac{0.4085 \times GPM}{V} = \frac{0.4085 \times 632.78}{5}$$

$d = 7.2\ inch$ → (Choose 8" pipe)

Figure 4.8: Typical Details of Gemini Type Floating Aeration Fountain

#### 4.5.1.2 *Pump*

The aerator will consist of a nozzle mounted on a circular header with the nozzle tips just protruding above the water level (see Figure 4.9). The pump will be a submersible pump mounted directly below the nozzle distributor in the reservoir. As for the Gemini type, the aerator system manufacturer, Otterbine cannot give the total head of the pump because they do not know where the pump will be located.

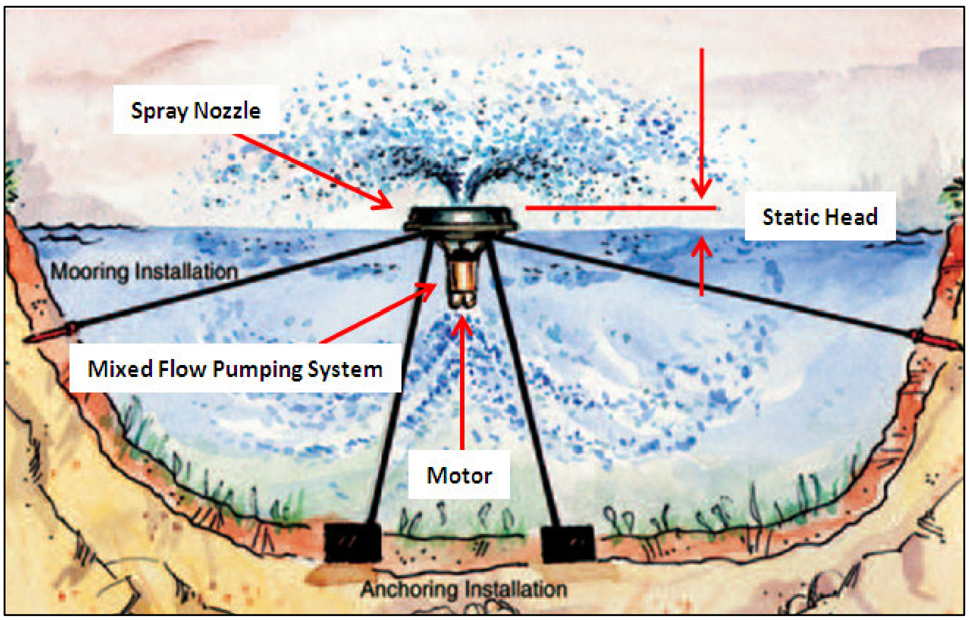



Figure 4.9 : Static Head
*(Source www.otterbine.com)*

The total head of the pump $H_P$ will be the sum of the static head $H_S$, the pipe friction head $H_F$ and the nozzle head $H_N$.

$$H_P = H_S + H_F + H_N$$

In this case, the static head is zero or is so small that it is close enough to zero. The static head is the difference in height between the fluid particles located at the inlet of the system (the tank fluid surface) and the outlet (the business end of the nozzle). The friction head will depend on the flow and the size of the main distributor (below the nozzle) and its length.

#### *4.5.1.3 Mean Pump Head Required*

The mean pump head for the Gemini type aerator cannot be calculated since the nozzle performance data is not provided by the manufacturer. However, the estimated total pump head can be calculated from the pump rating given.

$$3HP = \frac{633\ GPM\ \times H\ (ft)}{3300\ \times 0.7\ \times 0.85}$$

$$H = 9.3\ ft = 2.9\ meter\ head$$

#### *4.5.1.4 Friction Loss of Head*

This friction loss consists of the pipe friction. An 8 inch pipe will be installed from the pump discharge. The tubing size running from the pump is determined by the maximum flow rate of the pump selected, which is 633 GPM. Assume the pump will lie in the middle of the water level so that the pipe length will be 35 feet.

- Total length of PVC pipe to be installed = 35 feet
- Refer to the Friction Loss Chart at Appendix 2 for PVC pipe of 8 inch diameter at flowrate of 633 gallon per minit;
- The corresponding value of head loss = 1.02 ft. per 100 ft. length.

For 35 feet length,

$$Loss\ of\ friction\ head = \frac{friction\ loss\ per\ 100\ ft\ of\ pipe\ \times total\ equiv. pipe\ length}{100}$$

$$= \frac{35\ \times 1.02}{100}$$

$$= 0.357\ ft$$

The value from Friction Loss Chart (Refer to Appendix 2) is constructed using the Hazen – Williams Equation;

$$Pump\ head = \frac{104.4}{C^{1.852}} \times \frac{GPM^{1.852}}{d^{4.8655}}$$

#### *4.5.1.5 Minor Pipeline Losses*

These losses occurred at entry, exit and intermediate at bends, branches, change of section, valves and other fittings.

Table 4.4 : Minor Pipeline Losses

| **Type of fitting** | **K (losses)** | **Total K** |
|---|---|---|
| Entry Losses | 1 x 2.50 | 2.50 |
| Check Valve | 1 x 3.50 | 3.50 |
| Exit losses | 1 x1.00 | 1.00 |
| **TOTAL** | | **7.00** |

From empirical formula,

$$H = \frac{KV^2}{2g}$$

Where,

*H* : loss of head in feet

*V* : mean velocity in ft/sec, 5 ft/sec

*g* : acceleration due to gravity, 32.2 ft/sec².

Therefore,

$$H = 2.717\ ft$$

#### *4.5.1.6 Total Dynamic Head*

$$Total\ dynamic\ head = friction\ loss + minor\ loss = 0.357 + 2.717$$
$$= 3.074\ ft = \ 0.94\ meter\ head \rightarrow \ lower\ than\ 2.9\ meter\ head$$

So, the value of total head calculated above is lower that the head calculated from the power rating given by the manufacturer. In actual practice, the dynamic head is increased further by about 20% to overcome any circumstantial losses and worn out that might occur later. The pump capacity of 3HP provided by the aerator manufacturer, Otterbine is considerable as it already caters for other contingency.

#### *4.5.1.7 Driving Motor*

Submersible pumps which will be used for this aeration system come with an integrated motor so that there is no need to calculate the motor horsepower required. If the pump can handle the flow and total head that has being calculated then there is no doubt that the motor installed will be adequate. A 2785@50Hz custom built motor will be used for this purpose.

### 4.5.2 **Detail Design for Triad Type Aerator Fountain**

The Triad Type Aerator is a floating, three-tier aerator pattern. The spray height is 11m (in), 5.8m (mid) and 3m (out) respectively with the primary pumping rate of 118m³/hr. The nozzle performance is based on its manufacturer's data, Oase while the pump is manufactured by Grundfos. All specification regarding Triad is in Appendix 4.

Figure 4.10 shows the steps taken to design the Triad Type Aerator Fountain. First, the aerator's spray height and diameter was determined based on the nozzles manufacturer's (Oase) datasheet.Then, AutoCAD and 3D drawings were produced to see the how the system looks like from all views. The pipe size, pump head and the total weight of system was further calculated and identified based on some engineering equations and theories. Triad design differs slightly from Gemini as the pontoon (float) is fabricated using stainless steel plates while Gemini's float comes together with its pump, motor and nozzle in a complete set. So, the buoyancy effect of the pontoon has to be calculated also. Then, the power cables were chosen based on the manufacturer's specifications. Lastly, the estimated costing was done in accordance with the contractor's quotation.

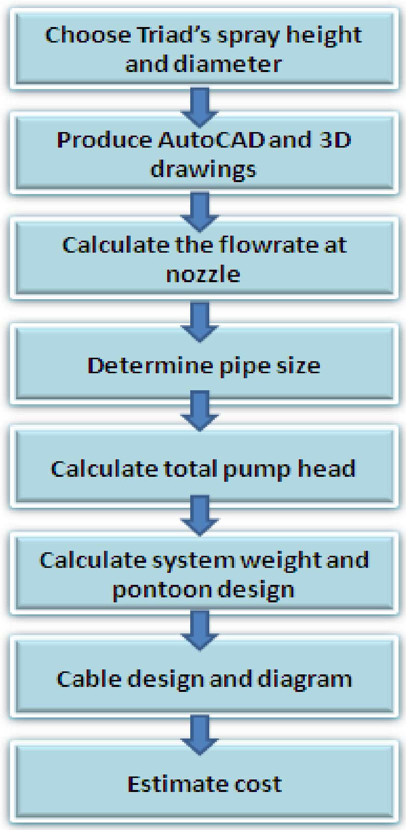



Figure 4.10: Flow Chart to Design Triad Type Aerator Fountain

Below is the specification of 1 no. of a giant fountain as proposed to be in the middle of Pond 'B':

**Type: Triad**

Frequency: 50Hz

Nozzle Manufacturer: Oase — Capacity: 118m³/hr

Pump Manufacturer: Grundfos — Pumping Rate: 15HP

Spray Height: 11m (in), 5.8m (mid), 3m (out)

Spray Diameter: 15cm (in), 10.7m (mid), 10.7m (out)

The plan and sectional view of the proposed system is drawn. Refer to the AutoCAD drawing Figure 4.11 for details.

Figure 4.11: Typical Details of Triad Type Floating Aeration Fountain

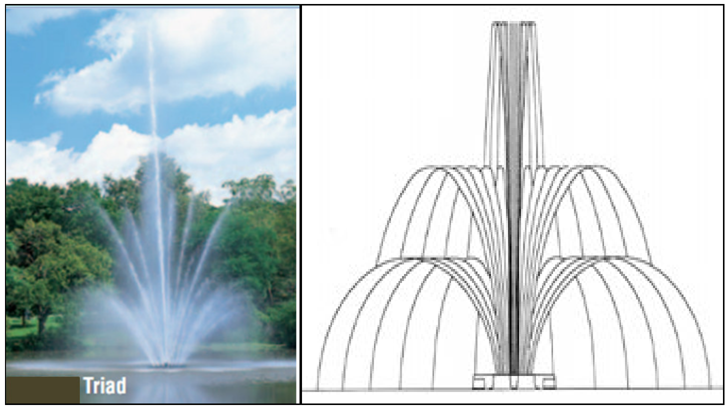



Figure 4.12: Shape and Illustration of Triad Type Fountain

#### *4.5.2.1 Flowrate at Nozzle*

- Velocity, $v$ = 7 ft/s = 2.135 m/s
- Flowrate, $Q$ = 1968 L/min = $0.0328 m^3/s$
- Flowrate, $Q = vA$

$$A = \frac{0.0328\ m^3/s}{2.135\ s} = 0.0154\ m^2$$

<u>Nozzle Data</u>

1) Type A : 1 no. x 17 mm diameter to shoot 11 meter height
   - Oase Comet 15-17T
   - $Q$ = 204 L/min
   - $P$ = 1.18 bar

2) Type B & C: 18 nos. x 12 mm diameter to shoot 8 meter height
   - Oase Comet 10-12T
   - $Q$ = 98 L/min
   - $P$ = 1 bar

$$Q_{total} = \frac{204\ L}{min} + \frac{98\ L}{min} = \frac{1968\ L}{min} = \frac{118\ m^3}{hr}$$

$$Pressure\ (from\ nozzle\ data) = 1.18\ bar \times 10.3$$
$$= 12.15\ meter\ head + losses$$

Now, determine the losses in order to select the pump.

#### *4.5.2.2 Determine Pipe Size*

The pipe diameter can be determined using equation below:

$$Velocity, V = \frac{0.4085 \times GPM}{d^2}$$

In our case, the velocity is taken to be 5ft/s with flow rate of 433 GPM.

$$d^2 = \frac{0.4085 \times GPM}{V} = \frac{0.4085 \times 433}{5}$$

$d = 5.94\ inch$ → Choose 6 inch pipe

#### *4.5.2.3 Friction Loss of Head*

This friction loss consists of the pipe friction. A 6 inch pipe will be installed from the pump discharge. The tubing size running from the pump is determined by the maximum flow rate of the pump selected, which is 533 GPM. Assume the pump will lie in the middle of the water level so that the pipe length will be 35 feet.

Total length of PVC pipe to be installed = 35 feet
Refer to the Friction Loss Chart at Appendix 2 for PVC pipe of 6 inch diameter at flowrate of 533 gallon per minit;
The corresponding value of head loss = 1.66 ft. per 100 ft. length.

For 35 feet length,

$Loss\ of\ friction\ head$

$$= \frac{friction\ loss\ per\ 100\ ft\ of\ pipe\ \times total\ equiv. pipe\ length}{100} = \frac{35 \times 1.66}{100}$$

$= 0.581\ ft = 0.18\ meter$

The value from Friction Loss Chart is constructed using the Hazen – Williams Equation;

$$Pump\ head = \frac{104.4}{C^{1.852}} \times \frac{GPM^{1.852}}{d^{4.8655}}$$

$$Pressure\ (from\ nozzle\ data) = 1.18\ bar \times 10.3$$

$$= 12.15\ meter\ head + losses$$

Therefore, round-up to higher value of 15 meter head. From the Grundfos catalogue, the appropriate pump for 118m³/hr flowrate is SP 125-1 Pump with 11kw capacity.

#### *4.5.2.4 Pontoon Design*

The pontoon is designed based on Archimedes principle which states that the buoyant force acting on an object immersed or floating in a fluid equals the weight of the fluid displaced. The buoyant force is the upward force on an object immersed in or floating on a fluid. If the object weighs less than the buoyant force, it will float on top of the fluid. If it weighs more, it will sink. Because the buoyant force equals the weight of the fluid displaced, an object must displace a greater weight of fluid than its own weight in order to float. That means that to float an object must have a density (mass divided by volume) less than the density of the fluid. If the object's density is greater than that of the fluid, it will sink. (Paul A. Heckert, 2008).

The fluid displaced has a weight $W = mg$. The mass can now be expressed in terms of the density and its volume, $m = pV$. Hence, $W = pVg$.

The volume of pontoon must be calculated so that it could sustain the weight of the whole system without totally submerging the nozzle into the water. Only ¾ of the pontoon must be submerged into the water. In order to obtain this, the Archimedes Law is applied. Refer to Appendix 4 for the overall weight of the system.

Weight of the fluid displaced = weight of the system

- Total mass, $m$ = 210.009 kg
- Vvolume of pontoon, $V$ = 0.28209 m³
- Weight of pontoon, $m = \rho V$ = 1000kg/m³ x 0.28209m³ = 282.09 kg

$$\frac{weight\ of\ system}{weight\ of\ pontoon} = \frac{210.009\ kg}{282.093\ kg} \approx \frac{3}{4}$$

#### *4.5.2.5 Fabrication*

The pontoon is fabricated using stainless steel plate, with standard size of 4'x8'x3mm thick. Three numbers of pontoons is chosen to stabilize the nozzle, underwater lights, cables and also the pump.

### 4.5.3 **Electrical System**

Calculation of the electrical system for the Triad Aerator Fountain is as below:

#### *4.5.3.1 Motor*

The 3phase x230V submersible motor is chosen for the SP125-1, 11kW pump. At duty point, flow rate, $Q$ is 118m3/hr, the pump requires 9kW, thus a motor load of 81.8% (9kW/11kW) and a power reserve of 18.2%.

From the table of motor efficiency can be read as:

82.5% at the load of 75% (η75%)

82.5% at the load of 100% (η 100%)

#### *4.5.3.2 Cable sizing*

- <u>Calculation of the Cross-section of the Cable</u>

For calculation of the cross-section of the submersible drop cable for direct-on-line (DOL) starting method, use the following formula:

$$q = \frac{I \times 1.73 \times 100 \times L \times \rho \times cos\varphi}{U \times \Delta U - (I \times 1.73 \times 100 \times L \times X_L \times sin\varphi)}$$

Where,

$U$ : Rated voltage ($V$): 230$V$

$\Delta U$ : Voltage drop (%): 3%

$I$ : Rated current of the motor ($A$): 45$A$

$q$ : Cross-section of submersible drop cable ($mm^2$)

$X_L$ : Inductive resistance: 0.078 x $10^{-3}$ ($\Omega/m$)

$cos\ \varphi$ : Power factor: 0.79

$sin\ \varphi$ : $\sqrt{(1-cos^2\ \varphi)}$: 0.613

$\rho$ : Specific resistance: 0.02 ($\Omega mm^2/m$)

$L$ : Length of cable ($m$): 150$m$

Sample calculation:

$$q = \frac{I \times 1.73 \times 100 \times L \times \rho \times cos\varphi}{U \times \Delta U - (I \times 1.73 \times 100 \times L \times X_L \times sin\varphi)} = 29.09\ mm$$

Therefore, the size of that might be chosen is 3Core x30mm$^2$. This size is compared with the 3Core x35 mm$^2$ cables in term of annual saving. The cable with lower annual savings will be chosen.

- <u>Calculation for Power Loss</u>

The power loss is calculated to see the difference between the 3Cx30 mm$^2$ and 3Cx35 mm$^2$ cables. From here, the annual saving can be determined.

$$\Delta p = \frac{3 \times L \times p \times I^2 \times \cos\varphi}{q}$$

Where,

Motor size : 11kW, MS 6000

Rated current : 45A

Voltage : 3x230V, 50Hz

Starting method : Direct-on-line (DOL)

Required cable length : 150$m$

Power factor : 0.79

Cable selection : Choice A: 3x30 $mm^2$

: Choice B: 3x35 $mm^2$

Choice A:

$$\Delta p = \frac{3 \times L \times p \times I^2 \times \cos\varphi}{q} = 480\ W$$

Choice B:

$$\Delta p = \frac{3 \times L \times p \times I^2 \times \cos\varphi}{q} = 411\ W$$

By choosing the cable size 3x35$mm^2$ instead of 3x30$mm^2$, power savings of 69W is achieved.

- <u>Maximum Cable Length</u>

In order to obtain an economical duty of the pump, the voltage drop should be low. The calculation of the cable length is based on a maximum voltage drop 3% of the nominal voltage and water temperature of maximum 30ºC.

Maximum cable length of a three-phase submersible pump:

$$L = \frac{U \times \Delta U}{I \times 1.73 \times 100 \times \left(\cos\varphi \times \left({}^{\rho}/_{q}\right) + sin\varphi \times X_L\right)}$$

Where,

$U$ : Rated voltage (V): 230V

$\Delta U$ : Voltage drop (%): 3%

$I$ : Rated current of the motor (A): 45A

$Q$ : Cross-section of submersible drop cable ($mm^2$):30 $mm^2$

$X_L$ : Inductive resistance: 0.078 x $10^{-3}$ (Ω/m)

$cos\ \varphi$ : Power factor: 0.79

$sin\ \varphi$ : $\sqrt{(1-cos^2\ \varphi)}$: 0.613

$\rho$ : Specific resistance: 0.02 (Ω$mm^2$/m)

$q$ : Cross-section of submersible drop cable ($mm^2$): 35$mm^2$

Sample calculation for motor size 11kW (MS 6000):

$$L = \frac{U \times \Delta U}{I \times 1.73 \times 100 \times \left(\cos\varphi \times \left({}^{\rho}/_{q}\right) + sin\varphi \times X_L\right)} = 177.53\ m$$

The maximum cable length of $35mm^2$ submersible cable that could withstand the 3% voltage drop is 177.53 meter. The single-line diagram for the overall electrical system is shown in Figure 4.13.

### 4.5.4 3-Dimensional Drawing of Triad Using Rhinoceros Software

Triad aerator does not come in one package from the manufacturer so it has to be further fabricated by the contractor. Figure 4.13 shows the various views of Triad from four different angles; from the top, front, end and the perspective. The 3-D drawing was drawn using Rhinoceros Software.

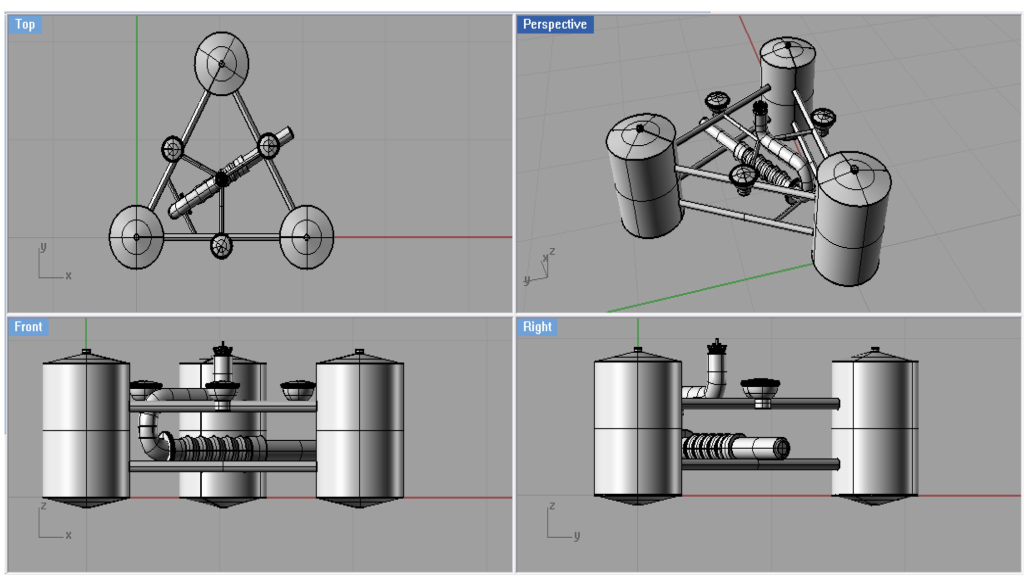



Figure 4.13: Various Views of Triad

Figure 4.14: Electrical Single Line Diagram

## 4.6 Estimated Cost of the Systems

Cost for the equipment, materials and installation of the aeration system are based upon the quotation from a local aerator design & build company, A. S. Engineering Sdn. Bhd. who has been a professional in the designing of lake aerators for more than 20 years. A. S. Engineering has design and builds many aeration systems for ponds and lakes around Malaysia, such as in Tasik Titiwangsa, Tasik Manjalara, Taman Jaya, etc. The costing is shown in tables below:

Table 4.5: Triad Type Aeration Fountain System Estimated Cost

| No. | Description | Cost |
|---|---|---|
| 1. | Supply, install, tools, accessories and positioning of floating aeration fountain and each comprising:-<br><br>Type of Nozzle : Triad<br>Nozzle Manufacturer : Oase<br>Pump Manufacturer : Grundfos or equiv.<br>Pump Hp rating : 15 Hp<br>Power supply : 230V, 3 phase<br>Speed : 2870 rpm at 50Hz<br>Running Amp. : 45 Amps (motor cable)<br>Spray height : Min. 10meter Ht | RM 50,756.20 |
| 2. | Supply and install 1 set anchoring system with tensioner using stainless steel wire rope, stainless steel shackles etc. and concrete blocks. | RM 18,345.60 |
| 3. | All necessary 3C x 35mm$^2$ neoprene waterproof cables for the single-phase aeration pumpsets c/w waterproof jointing. | RM 17,466.00 |
| 4. | All necessary, stainless steel frames, if required and bracket for mounting underwater light. | RM 11,466.00 |
| 5. | One lot of OASE or equiv. underwater light 120watts, 240 volts, 50Hz, 6 nos. | RM 5,503.60 |
| 6. | One lot of 2C x 4 mm$^2$ neoprene submersible cable for the underwater light system, one length for each aeration pumpset system c/w necessary waterproof jointing. | RM 5,466.00 |
| 7. | One lot of safety floats with 300mm spacing similar to swimming pool racing lane at the aeration pump perimeter c/w stainless steel rod and stainless steel wire rope. | RM 1,834.50 |
| | *Total Cost* | *RM110,838.00* |

Table 4.6: Estimated Cost for 8nos. of Gemini Spray Aeration System

| No. | Description | Cost |
|---|---|---|
| 1. | Supply, install, tools, accessories and positioning of 8 nos. of Gemini spray fountain and each comprising:-<br><br>No. of nozzle : 8 nos.<br>Type of Nozzle : Gemini<br>Spray height : Vertical ht. = 3.5 m<br>Horizontal w = 6.9m<br>Manufacturer : Otterbine or equiv.<br>Hp rating : 3 Hp<br>Power supply : 230V, 1 phase<br>Speed : 2875 rpm at 50Hz | RM145,517.90 |
| 2. | Supply and install 1 set pontoon c/w anchoring system with tensioner using stainless steel wire rope, stainless steel shackles etc. and concrete blocks. | RM 52,596.80 |
| 3. | All necessary 3C x 35mm$^2$ neoprene waterproof cables for the single-phase aeration pumpsets c/w waterproof jointing | RM 40,872.90 |
| 4. | All necessary, stainless steel frames, if required and bracket for mounting underwater light. | RM 32,872.90 |
| 5. | One lot of OASE or equiv. underwater light 120watts, 240 volts, 50Hz, 3 Nos for each of fountain jets. | RM 15,779.00 |
| 6. | One lot of 2C x 4 mm$^2$ Neoprene submersible cable for the underwater light system, one length for each aeration pumpset system c/w necessary waterproof jointing. | RM 24,872.90 |
| 7. | One lot of safety floats with 300mm spacing similar to swimming pool racing lane at the aeration pump perimeter c/w stainless steel rod and stainless steel wire rope. | RM 5,259.60 |
| | *Total Cost* | *RM317,772.00* |

Table 4.7: Weatherproof Type Control Panel Estimated Cost

| No. | Description | Cost |
|---|---|---|
| 1. | One no 60Amps 3 phase Weatherproof type control panel c/w :-<br>- 1 no. 60A MCCB<br>- 1 no. 0-100 Ampmeter<br>- 1 no. 1-500 Voltmeter3 nos. RYB Indicating light<br>- Fuse<br>- Star-Delta starter for all pumps<br>- Auto-Trans starter for Floating Fountain<br>- DOL starter for Metering Pump<br>- All necessary cablings for pool circulation. | RM 42,390 |
| | *Total Cost* | *RM 42,390.00* |

Estimated Total Cost of Project:

RM 110,838.00 + RM 317,772.00 + RM 42,390.00 = ***<u>RM 471,000.00</u>***

# CHAPTER 5
# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

The aerator fountain system has been selected as the best solution to treat the lake water. This selection is based on the current water quality for which the parameters tested do not fall between the allowable range set in Class A, except for pH, Dissolved Oxygen (DO) and Total Suspended Solids (TSS). The DO reading is believed to not be representative of the entire volume of water as the water samples were taken at the surface of lake. Thus, the DO reading at the deeper level is presumed to be less than the allowable range since more oxygen will be consumed by fishes, algae, and decaying matter. Therefore, aeration will eventually add more oxygen in the water that is crucial for fish's growth and shorten algae proliferation which makes the water cleaner. Aerator fountains also add aesthetical value for the lake surroundings, which would be one of the main attractions in UTP. A total of eight Gemini Type Spray Aerators and a Triad Aerator Fountain are proposed to be installed. The Gemini Type Aerator is floating, surface spray aerators with a fan-shaped spray pattern. The spray height shall be 3.5m with a diameter of 6.9m. Its primary pumping rate is 172.6m$^3$/hr with 3HP pumping capacity. The Triad Type Aerator is a floating, three-tier aerator pattern. The spray height shall be respectively 11m, 5.8m and 3m for inside, middle and outer spray. The primary pumping rate is 118m$^3$/hr with pumping capacity of 15HP. The nozzle performance is based on its manufacturer's data, Oase while the pump is manufactured by Grundfos. Triad design differs slightly from Gemini as the pontoon (float) is fabricated using stainless steel plates while Gesmini's float comes together with its pump, motor and nozzle in a complete set. The overall estimated cost to install the whole system is RM 471,000.00.

### 5.2 Recommendations

There are some recommendations or suggested future work for expansion and continuation. Among the suggested works are:

1) The water quality testing need to be done several times to obtain more precise result. Plus, proper procedure such as using the anti-bacteria bottle to take the water sample, need to be further enhanced to get better results.

2) The information about the lake is not precise, since it is based on the 2003 main drain report. So, the lake topography must be slightly changed since then. Therefore, proper site surveys need to be done in future.

# REFERENCES


Hallock, D. (2002). Publication Summary. *A Water Quality Index for Ecology's Stream Monitoring Program*. Retrieved August 5th, 2008, from http://www.ecy.wa.gov/biblio/0203052.html

Drs. Foster & Smith, Inc. Veterinary & Aquatic Services Department. *Pond filtration.* Retrieved August 5th, 2008, from http://www.peteducation.com/article.cfm?articleid=2262

Vertex Water Features. *Pond aeration system*. Retrieved 10th August, 2008, from http://www.vertexwaterfeatures.com/pond_aeration_system.php

Charles R. Cox. (1969). World Health Organization Geneva. *Operation and control of water treatment processes,* pp. 24-26.

*Proposed National Water Quality Standards for Malaysia.* Retrieved September 3rd, 2008, from http://www.sabah.gov.my.

P.K. Goel. Department of Pollution Studies, Y.C. College of Science, Vidyanagar, Karad. (2001). *Water pollution: causes, effects and control.* New Age International (P) Limited.

Angkasa Consulting Services Sdn. Bhd. (2003). *Main Drain Design Report - Cadangan Pembangunan Universiti Teknologi Petronas di Daerah Perak Tengah di Negeri Perak Darul Ridzuan.*

Gerry Closs, Barbara Downes, Andrew Boulton (2004). *A scientific introduction - freshwater ecology.* Blackwell Science Publishing Ltd.

Julie Stauffer. (1998). *The water crisis: constructing solutions to freshwater pollution.* Earthscan Publications Limited, London.

Steve McComas. (2003). *Lake and pond management guidebook.* Lewis Publishers.

Christopher Dickenson, FBIM. (1997). *Filters and filtration handbook.* 3rd edition. Elsevier Science Publishers Ltd.

Farid. (September 2008). *Private conversation.* Engineer of KLCC Projeks Berhad.

Hach Company. (2006). *Important water quality factors.* Retrieved 10th November 2008, from http://www.h2ou.com

Taube, Clarence M. (2000). *Instructions for winter lake mapping*. Chapter 12 in Schneider, James C. (ed.) 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Paul A. Heckert. (2008). Retrieved 30 March 2009, *Archimedes' Principle Archimedes, Buoyant Force, Floating Objects, and a Gold Crown*, from http://physics.suite101.com/article.cfm/archimedess_principle

Marco's Lawn and Landscape, Co., Rainbird, Hunter. (2006). Retrieved 1st May 2009, *Rainbird,* from http://marcoslawnlandscape.com/RainBird.htm

Dunn's Fish Farms. (2002-2007). Retrieved 30th April 2009, *Saving all your pond and lake needs for over 30 years,* from http://www.dunnsfishfarm.com/kasco_pond_aerators_61_ctg.htm

Kerri, K.D. (2002). Water Treatment Plant Operation. California State University, Sacramento. Retrieved 30th April 2009, *Water Works Operator Manual*, from http://water.me.vccs.edu/courses/env110/Lesson4_print.htm

Otterbine Barebo, Inc. (2006). *Otterbine Specification Manual.* pp. 4, 6, 10, 19, 20.

G. K. Sahu. (2000). *Pumps.* New Age International (P) Limited.

Pidwirny, M. (2006). "The Nitrogen Cycle". *Fundamentals of Physical Geography, 2nd Edition*. Retrieved 5th March 2009, from http://sci.waikato.ac.nz/farm

**APPENDIX 1: Laboratory Water Quality Testing**

- **Experiment 1 – pH Measurement**

PH is technically defined as the negative base 10 logarithm of the effective hydrogen ion concentration in gram equivalents per liter. A broad range of these characteristics has been divided into the two categories, acid and base. If a substance has one acid component for each base component, it is said to be neutral and has a pH value of 7. pH greater than 7 to 14 are alkaline and less than 7 is acidic. The lake water pH is measured using a pH meter by placing its electrode in the water sample.

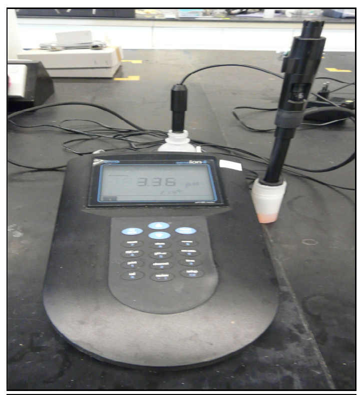


Figure 0.1: pH Meter with Electrode

- **Experiment 2 – Colour Testing**

The objective of this experiment is to determine the “apparent” or “true” colour of the water sample. Colour may be expressed as “apparent” or “true”. The apparent colour includes that from dissolved materials plus that from suspended matter. By filtering or centrifuging out the suspended materials, the true colour can be determined. The true colour of the water sample is measured using a spectrophotometer.

A spectrophotometer is a photometer (a device for measuring light intensity) that can measure intensity as a function of the color, or more specifically, the wavelength of light.

- **Experiment 3 – Turbidity Test**

Turbidity occurs in most surface waters as a result of suspended clay, silts, finely divided organic and inorganic matter, plankton and other microorganisms. The turbidity test measures an optical property of the water sample that results from the scattering and absorbing of light by the particulate matter present. The amount of turbidity measured depends on such variables as size, shape and refractive index of the particles. The turbidity of the water sample is measured using a Portable Turbidity Meter by simply placing it inside the meter.

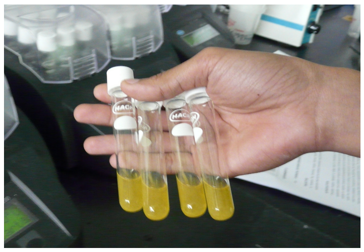

Figure 0.2: Portable Turbidity Meter

- **Experiment 4 – Chemical Oxygen Demand (COD)**

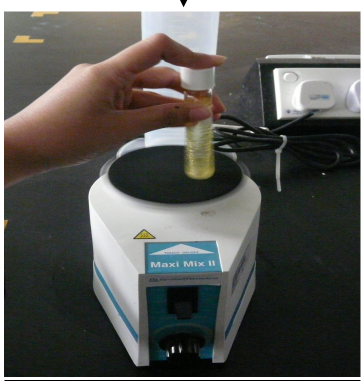
This experiment aims to measure the chemical oxygen demand equivalent of the organic material in wastewater than can be oxidized chemically using dichromate in acid solution.

Chemical oxygen demand is widely used to characterize the organic strength of wastewater and pollution of natural waters. It is the amount of oxygen that is required to oxidize an organic compound (biodegradable and non-biodegradable) to

$CO_2$ and water under the influence of a strong oxidant ($K_2Cr_2O_7$) in an acid environment (silver nitrate used as a catalyst). Compared to the BOD test, the major advantage of this test is that it requires a shorter time which is approximately 3 hours. Figure 6.3 shows the pictorial methodology of this experiment:



1. Each 2ml of water sample (3 samples + 1 blank) is put into atest tube containing Potassium Dichromate solution.




2. Shake all the test tubes.


3. Put the test tubes into a Rotator for two hours.
4. Then, take the COD readings, and the average of the readings is calculated.

Figure 0.3: Flow Chart of the Chemical Oxygen Demand (COD) Experiment

- **Experiment 5 – Total Suspended Solid (TSS)**

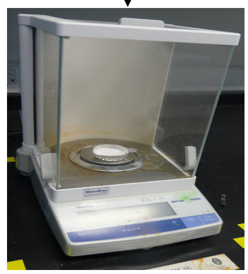
The objective of this experiment is to calculate the non-filterable residue in water using gravimetric method. The most important physical characteristic of water is its total solids content, which is composed of floating matter, matter in suspension, colloidal matter, and matter in solution.

Analytically, the total solids content of water is defined as all the matter that remains as residue upon evaporation at 103ºC to 105ºC. Matter that has a significant vapor pressure at this temperature is lost during evaporation, and is not defined as a solid. Total solids, or residue upon evaporation, can be classified as either suspended solids or filterable solids by passing a known volume of liquid through a filter. The filter is commonly chosen so that the minimum diameter of the suspended solids is about 1micron. The suspended solids fraction includes the settleable solids that will settle to the bottom of a cone-shaped container in a 60 minute period. Settleable solids are an approximate measure of the quantity of sludge that will be removed by sedimentation. The filterable solid fractions consist of colloidal and dissolved solids. The colloidal fraction consists of the particulate matter with an approximately diameter range of from 1 milimicron (1mμ) to 1μ. The dissolved solid consists of both organic and inorganic molecules and irons that are present in true solution in water. The colloidal fraction cannot be removed by settling. Generally, biological oxidation or coagulation, followed by sedimentation, is required to remove these particles from suspension.

Figure 6.4 shows the flow chart summarizing the processes of this experiment.

1. Six nos. of 47mm filter disc is placed in the filter holder.

↓

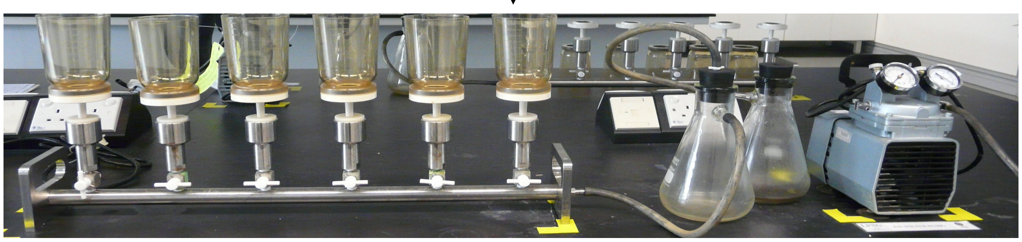


2. The initial weight of each of the filter disc with holder is measured.

↓

3. The entire discs are put inside the drying oven for at least one hour to get rid of moisture.

↓



4. Two nos. 100 ml of the water sample at each lake location is filtered through the filter disc by applying vacuum to the flask. The suspended solids can be seen physically when removing the filter discs.

↓

5. The filter discs with suspended solids were put inside the drying oven for at least two hours. Then, carefully place it in a desiccator. Allow it to cool to room temperature. The weight of the filter discs with suspended solids is remeasured.

Figure 0.4: Flow Chart of Total Suspended Solids Experiment

- **Experiment 6 – Biochemical Oxygen Demand (BOD)**

Biochemical oxygen demand, BOD is an indirect indicator of the amount of the organic matter present in waste. In simple words, BOD is the amount of oxygen used by bacteria to degrade the organic matter that present in the lake water. When bacteria are placed in contact with organic matter, it will utilize it as a food source. The organic matter will eventually be oxidized to stable end products such as carbon dioxide and water.

The most widely used parameter of organic pollution applied to both wastewater and surface water is the 5-day BOD (BOD5). This determination involves the measurement of the dissolved oxygen used by the microorganisms in the biochemical oxidation of organic matter. The results from the BOD test are now used:

1. To determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present.
2. To determine the quality of the lake water.

Nitrates and Phosphates are plant nutrients that can lead to higher BOD levels. When BOD levels are high, dissolved oxygen (DO) levels will decrease and it will cause fishes and other aquatic life to die. Natural sources of organic matter include plant decay and leaf fall. However, plant growth and decay may be unnaturally accelerated when nutrients and sunlight are overly abundant due to human influence. Urban runoff carries pet wastes from streets and sidewalks; nutrients from lawn fertilizers; leaves, grass clippings and paper from residential areas, which increase oxygen demand. Oxygen consumed in the decomposition process robs other aquatic organisms of the oxygen they need to live. Organisms that are more tolerant of lower dissolved oxygen levels may replace a diversity of more sensitive organisms.

The presence of BOD in water can be removed by two methods, which is oxidation reaction and synthesis in the activated sludge or aeration tank.

Oxidation:

COHNS + $O_2$ + bacteria $\rightarrow$ $CO_2$ + $H_20$ + $NH_3$ + other end products + energy

Synthesis:

COHNS + $O_2$ + bacteria + energy $\rightarrow$ $C_5H_7NO_2$

The activated sludge process of water treatment is based on providing intimate contact between the water and biological active sludge. Such sludge is developed initially by extend under conditions which favor the growth of organisms with special ability to oxidize organic matter.

The actual BOD test involves placing a sample of waste in a test bottle that includes bacteria (seed), nutrients and dissolved oxygen. The test bottle is incubated for 5 days at a constant temperature of 20ºC. The amount of dissolved oxygen used under these conditions is known as the 5 day biochemical oxygen demand.

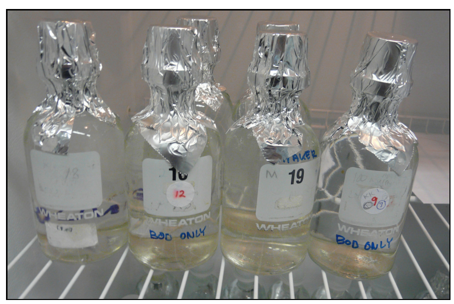



Figure 0.5: The BOD test bottles

- **Experiment 7 – Coliform / Bacteriological Examination**

The biological characteristic of water is primarily due to the resident aquatic population of microorganisms. Bacterial in the water makes the water unsafe for consumption. This experiment aims to detect the amount of bacteria in 100ml of water sample.

The equipment used is called 'Quanti-Tray'/2000. It is a device designed to count the amount of bacteria in 100ml samples using IDEXX-d Substrate reagent product. The sample is added with reagent in Quanti-Tray/2000. Then, it is sealed in a Quanti-Tray Sealer and incubates to develop the population for 24 hours. After 24 hours, number of positive large and small wells is counted and the MPN table attached is used to determine the Most Probable Number (MPN).

Below is the step-by-step procedure using the Colilert Test Kit:

1. Carefully separate one Snap Pack from the strip taking care not to accidentally open the adjacent pack.
2. Tap the Snap Pack to ensure that all of the Colilert powder is in the bottom part of the pack.
3. Open one pack by snapping back the top at the shoreline as shown.
4. Add the reagent to the water sample in a sterile, transparent, non-fluorescent vessel (100ml for WP020 and WP200, 50ml for WO050 and W050B).
5. Aseptically cap and seal the vessel.
6. Shake until dissolved
7. Pour the sample reagent mixture from step 6 above directly into the tray avoiding contact with the foil tab and then seal the tray according to Quanti-Tray instruction.
8. Incubate for 24 hours at 35º + 0.5ºC.
9. Follow the same interpretation directions from step 8 above to count the number of positive wells. Refer to the MPN table provided with the Quanti-Tray to determine the Most Probable Number (MPN) of coliforms (yellow wells) and E-coli (fluorescent wells) in your sample. The color and fluorescent intensity of positive wells may vary.
10. Read the result at 24 hours. Compare each results against the comparator dispensed into identical vessel.

After incubation for 24 hours, the sample is examined under the fluorescent light. The population is count using small comparator and large comparator. Then, the MPN is found from the MPN table

- **Experiment 8: Ammonia Test (Nessler Method)**

The objective of this experiment is to determine the present of ammonia nitrate (it usually indicates domestic pollution) value in every hour of sample using Nessler method.

Ammonia results from the metabolism of nitrogenous (nitrogen containing) compounds, mainly protein. Ammonia is also formed from the bacterial degradation of nitrogen containing organic materials such as decaying plant and animal matter. It is present in solutions as both ionized (nontoxic $NH_4^+$) and unionized (toxic $NH_3$) species; the proportion of these two forms is pH and temperature dependent.

Low-level ammonia nitrogen may be naturally present in water as a result of the biological decay of plant and animal matter. Higher concentrations in surface waters can indicate contamination from waste treatment facilities, raw sewage, industrial effluents (particularly from petroleum refineries), or fertilizer runoff. Excessive ammonia concentrations are toxic to aquatic life.

In an established biological filter, nitrifying bacteria will utilize ammonia and convert it to nitrite; however this conversion is dependent upon environmental conditions including pH, oxygen content and temperature of the water. If conditions inhibit nitrification (conversion of ammonia to nitrite) or if the bacteria in the filter have not been established, the ammonia can reach dangerous levels in a very short period of time. As little as 0.6 mg/L total ammonia can be toxic to fish. Although the proportion of total ammonia that is in the more toxic (un-ionized) form is pH and temperature dependent, it is necessary to accurately monitor the total ammonia present so that the actual concentration of the more toxic form can be determined.

Apparatus:

- Cylinder
- Beaker
- Spectrophotometer
- Erlenmeyer
- Pipette

Reagents:

- Sample water
- Mineral stabilizer
- Polyvinyl alcohol
- Nessler reagent

Procedure:

1. 25ml of sample is prepared as diluted sample.
2. The prepared sample is filled into the Erlenmeyer.
3. 3 drops of mineral stabilizer is added into the sample in the Erlenmeyer.
4. 3 drops of polyvinyl alcohol is added into the sample in the Erlenmeyer.
5. 1ml of Nessler reagent is pipette into it.
6. The sample is leave for one-minute reaction to begin.
7. 10ml of the sample is poured into the vial.
8. The reading value is taken at the spectrometer.

**APPENDIX 2: Friction Loss Chart**

| GPM | GPH | 1" | 1 1/4" | 1 1/2" | 2" | 3" | 4" | 6" | 8" |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 1200 | 25.07 | 6.39 | 2.94 | .86 | .13 | | | |
| 30 | 1800 | | 16.32 | 6.26 | 1.81 | .26 | | | |
| 40 | 2400 | | 23.55 | 10.7 | 3.11 | .44 | .12 | | |
| 50 | 3000 | | | 16.45 | 4.67 | .66 | .17 | | |
| 60 | 3600 | | | 23.48 | 6.60 | .93 | .25 | | |
| 70 | 4200 | | | | 8.83 | 1.24 | .33 | | |
| 80 | 4800 | | | | 11.43 | 1.58 | .41 | | |
| 90 | 5400 | | | | 14.26 | 1.98 | .52 | | |
| 100 | 6000 | | | | | 2.42 | .63 | .08 | |
| 125 | 7500 | | | | | 3.80 | .95 | .13 | |
| 150 | 9000 | | | | | 5.15 | 1.33 | .18 | |
| 175 | 10500 | | | | | 6.90 | 1.78 | .23 | |
| 200 | 12000 | | | | | 8.90 | 2.27 | .30 | |
| 250 | 15000 | | | | | | 3.36 | .45 | .12 |
| 300 | 18000 | | | | | | 4.85 | .63 | .17 |
| 350 | 21000 | | | | | | 6.53 | .84 | .22 |
| 400 | 24000 | | | | | | | 1.08 | .28 |
| 500 | 30000 | | | | | | | 1.66 | .42 |
| 600 | 36000 | | | | | | | 2.35 | .59 |
| 700 | 42000 | | | | | | | 3.65 | .79 |
| 800 | 48000 | | | | | | | | 1.02 |
| 900 | 54000 | | | | | | | | 1.27 |
| 1000 | 60000 | | | | | | | | 2.15 |

** Loss is based on 100 ft length of pipe.

## APPENDIX 3: Gemini Data

*(Refer to Otterbine Specification Manual enclosed in CD)*

## APPENDIX 4: Triad Data

*(Refer to System Weight & Volume, Oase Comet Nozzle Data and ASE Quotation enclosed in CD)*

## Type key

Example SP 95 - 5 - A B N

- Type range (SP A, SP) — SP
- Nominal flow rate in m³/h — 95
- Number of impellers — 5
- First impeller with reduced diameter (A, B or C) — A
- Second impeller with reduced diameter (A, B or C) — B
- Stainless steel parts of material — N
  = DIN W.-Nr. 1.4301
  N = DIN W.-Nr. 1.4401
  R = DIN W.-Nr. 1.4539

## Pumped liquids

Clean, thin, non-aggressive liquids without solid particles or fibres.

The special SP A-N and SP-N versions made of stainless steel to DIN W.-Nr. 1.4401 and SP A-R and SP-R versions made of stainless steel to DIN W.-Nr. 1.4539 are available for applications involving aggressive liquids.

## Operating conditions

Flow rate, Q: 0.1-280 m³/h.
Head, H: Maximum 660 m.

Maximum liquid temperature:

| Motor | Installation | | |
|---|---|---|---|
| | Flow velocity past motor | Vertical | Horizontal |
| Grundfos MS 4" and 6" | Free convection 0 m/s | 20°C | Flow sleeve-recommended |
| Grundfos MS 4" and 6" | 0.15 m/s | 40°C | 40°C |
| Grundfos MS industry versions 4" and 6" | 0.15 m/s | 60°C | 60°C |
| Grundfos MMS 6" to 12" rewindable | Free convection 0 m/s | 20°C | 20°C |
| | 0.15 m/s | 25°C | 25°C |
| | 0.50 m/s | 30°C | 30°C |

**Note:** For MMS 6000, 37 kW, MMS 8000, 110 kW, and MMS 10000, 170 kW, the maximum liquid temperature is 5°C lower than the values stated in the table above. For MMS 10000, 190 kW the temperature is 10°C lower.

Operating pressure:

| Motor | Maximum operating pressure |
|---|---|
| Grundfos MS 4" and 6" | 6 MPa (60 bar) |
| Grundfos MMS 6" to 12" rewindable | 2.5 MPa (25 bar) |

## Curve conditions

The conditions below apply to the curves shown on the following pages:

### General

- Curve tolerances according to ISO 9906, Annex A.
- The performance curves show pump performance at actual speed cf. standard motor range.

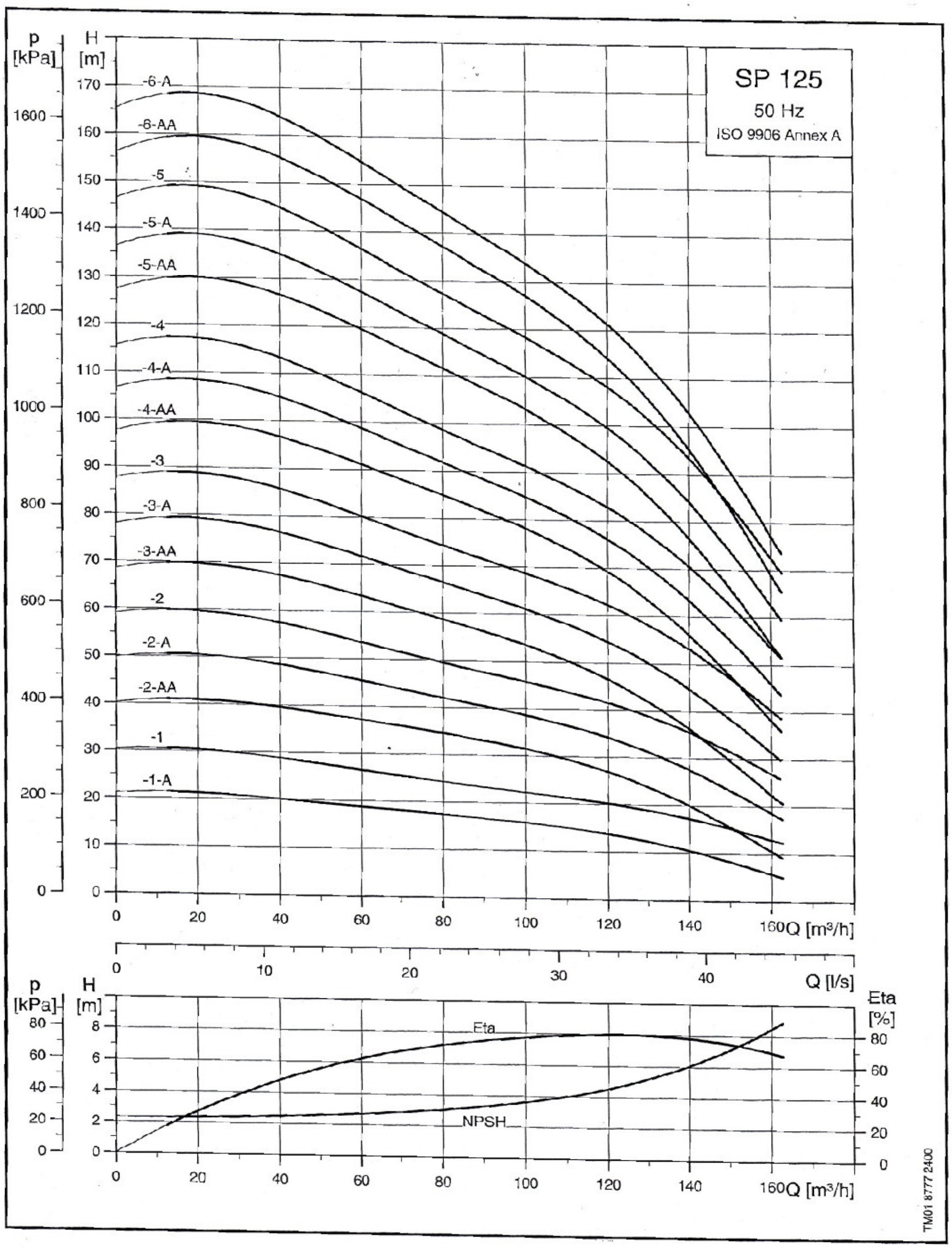
  The speed of the motors is approximately:
  4" motors : $n = 2870$ min$^{-1}$
  6" motors : $n = 2870$ min$^{-1}$
  8" to 12" motors : $n = 2900$ min$^{-1}$
- The measurements were made with airless water at a temperature of 20°C. The curves apply to a kinematic viscosity of 1 mm²/s (1cSt). When pumping liquids with a density higher than that of water, motors with correspondingly higher outputs must be used.
- The bold curves indicate the recommended performance range.
- The performance curves are inclusive of possible losses such as non-return valve loss.

### SP A curves

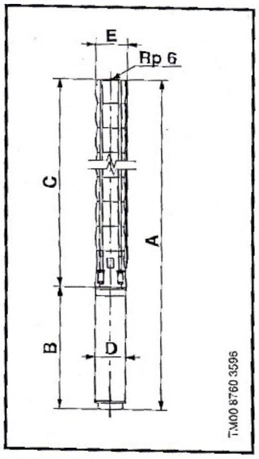
- **Q/H:** The curves are inclusive of valve and inlet losses at the actual speed.
- **Power curve:** $P_2$ shows pump power input at the actual speed for each individual pump size.
- **Efficiency curve:** Eta shows pump stage efficiency.

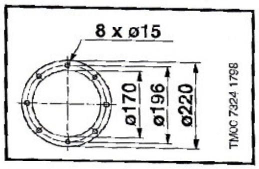
### SP curves

- **Q/H:** The curves are inclusive of valve and inlet losses at the actual speed.
  Operation without non-return valve will increase the actual head at nominal performance by 0.5 to 1.0 m.
- **NPSH:** The curve is inclusive of suction interconnector and shows required inlet pressure.
- **Power curve:** $P_2$ shows pump power input at the actual speed for each individual pump size.
- **Efficiency curve:** Eta shows pump stage efficiency.


SP 125
50 Hz
ISO 9906 Annex A
p [kPa]
H [m]
-6-A
-6-AA
-5
-5-A
-5-AA
-4
-4-A
-4-AA
-3
-3-A
-3-AA
-2
-2-A
-2-AA
-1
-1-A
Q [m³/h]
Q [l/s]
Eta [%]
Eta
NPSH
TM01 8777 2400

## Dimensions and weights



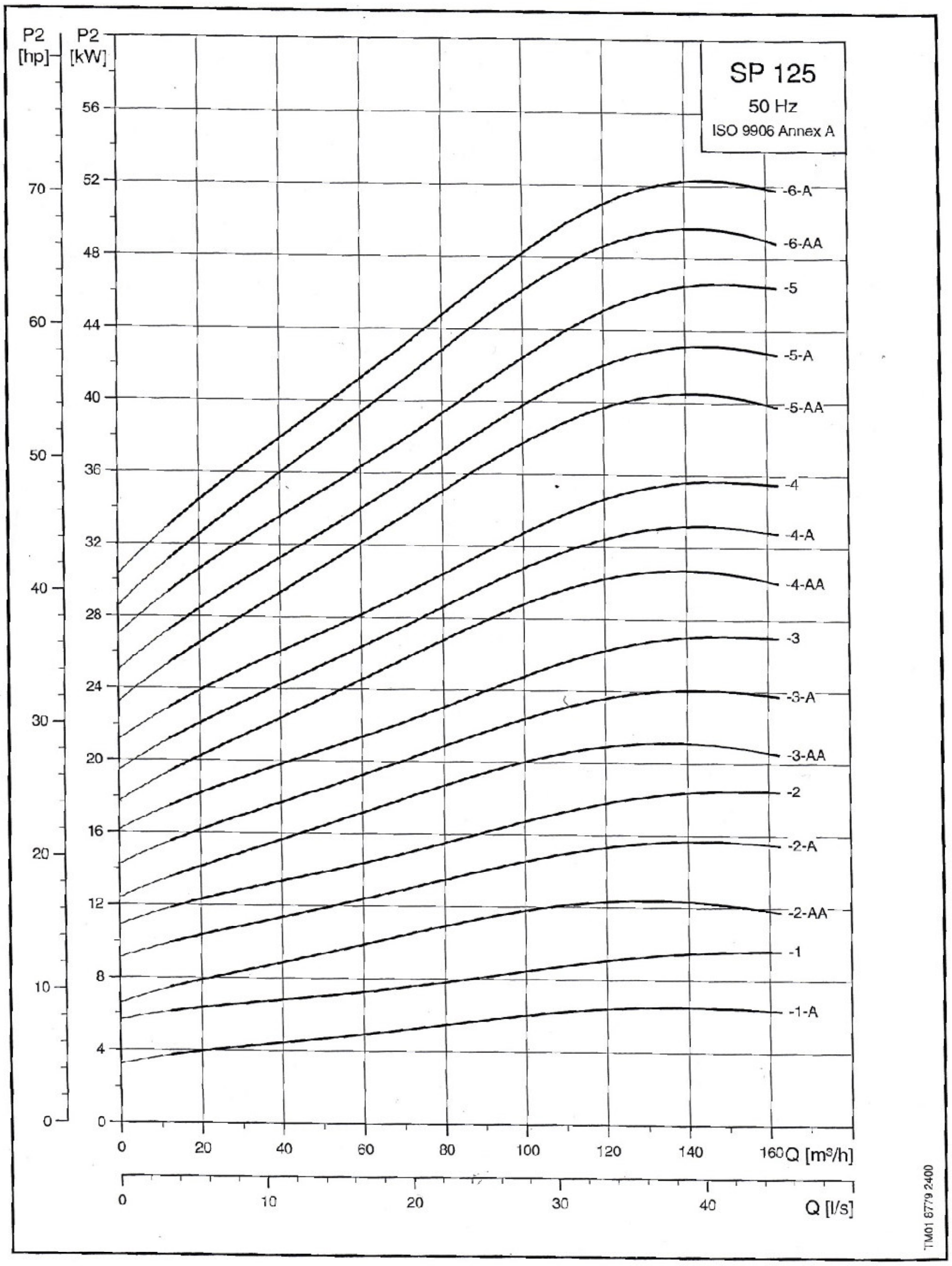

| Pump type | Motor | | Dimensions [mm] | | | | | | | | | | Net weight [kg] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Type | Power [kW] | Rp 6 connection | | | | 6" Grundfos flange | | | | B | D | |
| | | | A | C | E* | E** | A | C | E* | E** | | | |
| SP 125-1-A | MS 6000 | 7.5 | 1225 | 651 | 211 | 218 | 1225 | 651 | 222 | 226 | 574 | 138 | 70 |
| SP 125-1 | MS 6000 | 11 | 1285 | 651 | 211 | 218 | 1285 | 651 | 222 | 226 | 634 | 138 | 79 |
| SP 125-2-AA | MS 6000 | 13 | 1471 | 807 | 211 | 218 | 1471 | 807 | 222 | 226 | 664 | 138 | 88 |
| SP 125-2-A | MS 6000 | 18.5 | 1561 | 807 | 211 | 218 | 1561 | 807 | 222 | 226 | 754 | 138 | 97 |
| SP 125-2 | MS 6000 | 22 | 1621 | 807 | 211 | 218 | 1621 | 807 | 222 | 226 | 814 | 138 | 103 |
| SP 125-3-AA | MS 6000 | 22 | 1777 | 963 | 211 | 218 | 1777 | 963 | 222 | 226 | 814 | 138 | 109 |
| SP 125-3-A | MS 6000 | 26 | 1837 | 963 | 211 | 218 | 1837 | 963 | 222 | 226 | 874 | 138 | 115 |
| SP 125-3 | MS 6000 | 30 | 1907 | 963 | 211 | 218 | 1907 | 963 | 222 | 226 | 944 | 138 | 123 |
| SP 125-4-AA | MMS 6000 | 37 | 2544 | 1119 | 211 | 218 | 2544 | 1119 | 222 | 226 | 1425 | 144 | 176 |
| SP 125-4-A | MMS 6000 | 37 | 2544 | 1119 | 211 | 218 | 2544 | 1119 | 222 | 226 | 1425 | 144 | 176 |
| SP 125-4 | MMS 6000 | 37 | 2544 | 1119 | 211 | 218 | 2544 | 1119 | 222 | 226 | 1425 | 144 | 176 |
| SP 125-5-AA | MMS 8000 | 45 | 2545 | 1275 | 213 | 218 | 2545 | 1275 | 223 | 226 | 1270 | 192 | 236 |
| SP 125-5-A | MMS 8000 | 45 | 2545 | 1275 | 213 | 218 | 2545 | 1275 | 223 | 226 | 1270 | 192 | 236 |
| SP 125-5 | MMS 8000 | 55 | 2595 | 1275 | 213 | 218 | 2595 | 1245 | 223 | 226 | 1350 | 192 | 251 |
| SP 125-6-AA | MMS 8000 | 55 | 2781 | 1431 | 213 | 218 | 2781 | 1431 | 223 | 226 | 1350 | 192 | 257 |
| SP 125-6-A | MMS 8000 | 55 | 2781 | 1431 | 213 | 218 | 2781 | 1431 | 223 | 226 | 1350 | 192 | 257 |
| SP 125-6 | MMS 8000 | 63 | 2921 | 1431 | 218 | 227 | 2921 | 1431 | 229 | 232 | 1490 | 192 | 283 |
| SP 125-7-AA | MMS 8000 | 63 | 3077 | 1587 | 218 | 227 | 3077 | 1587 | 229 | 232 | 1490 | 192 | 289 |
| SP 125-7-A | MMS 8000 | 63 | 3077 | 1587 | 218 | 227 | 3077 | 1587 | 229 | 232 | 1490 | 192 | 289 |
| SP 125-7 | MMS 8000 | 75 | 3177 | 1587 | 218 | 227 | 3177 | 1587 | 229 | 232 | 1590 | 192 | 308 |
| SP 125-8-AA | MMS 8000 | 75 | 3333 | 1743 | 218 | 227 | | | | | 1590 | 192 | 314 |
| SP 125-8-A | MMS 8000 | 75 | 3333 | 1743 | 218 | 227 | | | | | 1590 | 192 | 314 |
| SP 125-8 | MMS 8000 | 75 | 3333 | 1743 | 218 | 227 | | | | | 1590 | 192 | 314 |
| SP 125-9-AA | MMS 8000 | 92 | 3729 | 1899 | 218 | 227 | | | | | 1830 | 192 | 366 |
| SP 125-9-A | MMS 8000 | 92 | 3729 | 1899 | 218 | 227 | | | | | 1830 | 196 | 366 |
| SP 125-9 | MMS 8000 | 92 | 3729 | 1899 | 218 | 227 | | | | | 1830 | 196 | 366 |
| SP 125-10-AA | MMS 8000 | 92 | 3885 | 2055 | 218 | 227 | | | | | 1830 | 196 | 372 |
| SP 125-10-A | MMS 8000 | 92 | 3885 | 2055 | 218 | 227 | | | | | 1830 | 196 | 372 |
| SP 125-10 | MMS 8000 | 92 | 3885 | 2055 | 218 | 227 | | | | | 1830 | 196 | 372 |

* Maximum diameter of pump with one motor cable.

** Maximum diameter of pump with two motor cables.

All pumps are also available in N version with motors up to 30 kW in R version.
From 37 kW and up the motors are in N version.
Dimensions as above.

Other types of connection are possible by means of connecting pieces, see page 85.


P2 [hp]
P2 [kW]
SP 125
50 Hz
ISO 9906 Annex A
-6-A
-6-AA
-5
-5-A
-5-AA
-4
-4-A
-4-AA
-3
-3-A
-3-AA
-2
-2-A
-2-AA
-1
-1-A
Q [m³/h]
Q [l/s]
TM01 6779 2400

## 1 x 230 V, submersible motors

| Motor | | | Electrical data | | | | | | | | | | Dimensions | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | Size | Power [kW] | Full load current $I_n$ [A] | Motor efficiency [%] $\eta_{50\%}$ | $\eta_{75\%}$ | $\eta_{100\%}$ | Power factor Cos φ 50% | Cos φ 75% | Cos φ 100% | $\frac{I_{st}}{I_n}$ | Control box for 3-wire motors | Capacitor for PSC motors | Length [mm] | Weight [kg] |
| MS 402 | 4" | 0.37 | 3.95 | 48.0 | 54.0 | 57.0 | 0.58 | 0.68 | 0.77 | 3.4* | SA-SPM2 | 16μF, 400V, 50Hz | 256 | 6.8 |
| MS 402 | 4" | 0.55 | 5.80 | 49.5 | 56.5 | 59.5 | 0.52 | 0.65 | 0.74 | 3.5* | SA-SPM2 | 20μF, 400V, 50Hz | 291 | 8.2 |
| MS 402 | 4" | 0.75 | 7.45 | 52.0 | 58.0 | 60.0 | 0.57 | 0.69 | 0.79 | 3.6* | SA-SPM2 | 30μF, 400V, 50Hz | 306 | 8.9 |
| MS 402 | 4" | 1.1 | 7.30 | 62.0 | 69.5 | 72.5 | 0.99 | 0.99 | 0.99 | 4.3* | SA-SPM3 | 40μF, 400V, 50Hz | 346 | 10.5 |
| MS 402 | 4" | 1.5 | 10.2 | 56.5 | 66.5 | 71.0 | 0.91 | 0.96 | 0.98 | 3.9 | SA-SPM3 | | 346 | 11.0 |
| MS 4000 (R) | 4" | 2.2 | 14.0 | 67.0 | 73.0 | 75.0 | 0.91 | 0.94 | 0.96 | 4.4 | SA-SPM3 | | 576 | 21.0 |

* Applies to 3-wire motors.
MS 402 2-wire motors incorporate motor protection and can therefore be connected directly to the mains.

## 3 x 230 V, submersible motors

| Motor | | | Electrical data | | | | | | | | Dimensions | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | Size | Power [kW] | Full load current $I_n$ [A] | Motor efficiency [%] $\eta_{50\%}$ | $\eta_{75\%}$ | $\eta_{100\%}$ | Power factor Cos φ 50% | Cos φ 75% | Cos φ 100% | $\frac{I_{st}}{I_n}$ | Length [mm] | Weight [kg] |
| MS 402 | 4" | 0.37 | 2.55 | 51.0 | 59.5 | 64.0 | 0.44 | 0.55 | 0.64 | 3.7 | 226 | 5.5 |
| MS 402 | 4" | 0.55 | 4.00 | 48.5 | 57.0 | 64.0 | 0.42 | 0.52 | 0.64 | 3.5 | 241 | 6.3 |
| MS 402 | 4" | 0.75 | 4.20 | 64.0 | 69.5 | 73.0 | 0.50 | 0.62 | 0.72 | 4.6 | 276 | 7.7 |
| MS 4000 (R) | 4" | 0.75 | 3.35 | 66.8 | 71.1 | 72.9 | 0.66 | 0.76 | 0.82 | 5.1 | 401 | 13.0 |
| MS 402 | 4" | 1.1 | 6.20 | 62.5 | 69.0 | 73.0 | 0.47 | 0.59 | 0.72 | 4.6 | 306 | 8.9 |
| MS 4000 (R) | 4" | 1.1 | 5.00 | 69.1 | 73.2 | 75.0 | 0.57 | 0.70 | 0.78 | 5.2 | 416 | 14.0 |
| MS 402 | 4" | 1.5 | 7.65 | 68.0 | 73.0 | 75.0 | 0.50 | 0.64 | 0.75 | 5.0 | 346 | 10.5 |
| MS 4000 (R) | 4" | 1.5 | 7.40 | 66.6 | 71.4 | 72.9 | 0.53 | 0.66 | 0.74 | 4.5 | 416 | 14.0 |
| MS 402 | 4" | 2.2 | 10.0 | 72.5 | 75.5 | 76.0 | 0.56 | 0.71 | 0.82 | 4.7 | 346 | 11.9 |
| MS 4000 (R) | 4" | 2.2 | 11.6 | 64.5 | 70.8 | 73.3 | 0.44 | 0.58 | 0.69 | 4.2 | 456 | 16.0 |
| MS 4000 (R) | 4" | 3.0 | 14.6 | 67.5 | 72.8 | 74.6 | 0.48 | 0.62 | 0.73 | 4.4 | 496 | 17.0 |
| MS 4000 (R) | 4" | 4.0 | 17.6 | 73.9 | 77.4 | 77.9 | 0.52 | 0.67 | 0.77 | 4.9 | 576 | 21.0 |
| MS 4000 (R) | 4" | 5.5 | 24.2 | 76.0 | 78.8 | 79.6 | 0.51 | 0.66 | 0.76 | 4.9 | 676 | 26.0 |
| MS 6000 (R) | 6" | 5.5 | 24.8 | 77.0 | 79.0 | 80.0 | 0.61 | 0.64 | 0.73 | 4.5 | 544 | 35.5 |
| MS 6000 (R) | 6" | 7.5 | 32.0 | 79.0 | 82.0 | 82.0 | 0.55 | 0.68 | 0.77 | 4.6 | 574 | 37.0 |
| MS 6000 (R) | 6" | 9.2 | 39.5 | 77.0 | 80.0 | 80.0 | 0.56 | 0.70 | 0.78 | 4.8 | 604 | 42.5 |
| MS 6000 (R) | 6" | 11 | 45.0 | 81.0 | 82.5 | 82.5 | 0.60 | 0.72 | 0.79 | 4.8 | 634 | 45.5 |
| MS 6000 (R) | 6" | 13 | 54.5 | 81.0 | 82.5 | 82.5 | 0.58 | 0.71 | 0.78 | 4.8 | 664 | 48.5 |
| MS 6000 (R) | 6" | 15 | 62.0 | 82.0 | 83.5 | 83.5 | 0.59 | 0.71 | 0.78 | 5.2 | 699 | 52.5 |
| MS 6000 (R) | 6" | 18.5 | 76.5 | 82.5 | 84.5 | 84.0 | 0.56 | 0.69 | 0.77 | 5.3 | 754 | 58.0 |
| MS 6000 (R) | 6" | 22 | 87.5 | 84.5 | 85.0 | 84.0 | 0.61 | 0.74 | 0.81 | 5.2 | 814 | 64.0 |
| MS 6000 (R) | 6" | 26 | 104 | 83.5 | 84.0 | 83.5 | 0.61 | 0.73 | 0.81 | 5.0 | 874 | 69.5 |
| MS 6000 (R) | 6" | 30 | 120 | 83.0 | 84.0 | 83.0 | 0.59 | 0.72 | 0.80 | 5.0 | 944 | 77.5 |

MS 402 : Data apply to 3 x 220 V.

## 3 x 230 V, submersible rewindable motors

| Motor | | | Electrical data | | | | | | | | Dimensions | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | Size | Power [kW] | Full-load current $I_n$ [A] | Motor efficiency [%] $\eta_{50\%}$ | $\eta_{75\%}$ | $\eta_{100\%}$ | Power factor Cos φ 50% | Cos φ 75% | Cos φ 100% | $\frac{I_{st}}{I_n}$ | Length [mm] | Weight [kg] |
| MMS 6000 (N) | 6" | 3.7 | 17.2 | 67.3 | 70.5 | 70.0 | 0.64 | 0.75 | 0.82 | 4.7 | 630 | 45 |
| MMS 6000 (N) | 6" | 5.5 | 24.2 | 75.0 | 76.2 | 74.2 | 0.63 | 0.75 | 0.81 | 4.2 | 660 | 48 |
| MMS 6000 (N) | 6" | 7.5 | 32.0 | 77.6 | 78.8 | 77.1 | 0.61 | 0.74 | 0.80 | 4.3 | 690 | 50 |
| MMS 6000 (N) | 6" | 9.2 | 38.5 | 76.9 | 78.2 | 76.7 | 0.64 | 0.76 | 0.82 | 4.6 | 720 | 55 |
| MMS 6000 (N) | 6" | 11 | 45.5 | 78.1 | 79.2 | 77.5 | 0.66 | 0.77 | 0.83 | 4.4 | 780 | 60 |
| MMS 6000 (N) | 6" | 13 | 52.5 | 80.8 | 81.5 | 79.8 | 0.65 | 0.77 | 0.82 | 4.8 | 915 | 72 |
| MMS 6000 (N) | 6" | 15 | 58.5 | 82.0 | 82.8 | 81.3 | 0.66 | 0.78 | 0.83 | 5.0 | 975 | 78 |
| MMS 6000 (N) | 6" | 18.5 | 67.0 | 84.8 | 85.0 | 83.3 | 0.76 | 0.85 | 0.88 | 5.7 | 1065 | 90 |
| MMS 6000 (N) | 6" | 22 | 79.5 | 85.0 | 85.3 | 83.8 | 0.75 | 0.84 | 0.87 | 5.8 | 1195 | 100 |
| MMS 6000 (N) | 6" | 26 | 100 | 84.3 | 85.0 | 83.6 | 0.63 | 0.76 | 0.83 | 5.3 | 1315 | 115 |
| MMS 6000 (N) | 6" | 30 | 112 | 85.0 | 85.4 | 84.0 | 0.66 | 0.78 | 0.84 | 5.5 | 1425 | 125 |
| MMS 6000 (N) | 6" | 37 | 146 | 84.7 | 85.5 | 84.4 | 0.59 | 0.73 | 0.80 | 5.9 | 1425 | 125 |
| MMS 8000 (N) | 8" | 22 | 82.5 | 80.4 | 83.5 | 84.1 | 0.71 | 0.80 | 0.84 | 5.4 | 1010 | 126 |
| MMS 8000 (N) | 8" | 26 | 95.5 | 80.6 | 83.5 | 83.9 | 0.76 | 0.83 | 0.86 | 5.1 | 1050 | 134 |
| MMS 8000 (N) | 8" | 30 | 110 | 82.5 | 85.2 | 85.6 | 0.71 | 0.80 | 0.84 | 5.9 | 1110 | 146 |
| MMS 8000 (N) | 8" | 37 | 134 | 83.2 | 85.7 | 86.0 | 0.73 | 0.82 | 0.85 | 5.8 | 1160 | 156 |
| MMS 8000 (N) | 8" | 45 | 168 | 84.3 | 87.1 | 87.8 | 0.62 | 0.74 | 0.81 | 6.3 | 1270 | 177 |
| MMS 8000 (N) | 8" | 55 | 214 | 83.7 | 86.7 | 87.6 | 0.57 | 0.70 | 0.77 | 6.2 | 1350 | 192 |
| MMS 8000 (N) | 8" | 63 | 210 | 87.2 | 88.7 | 88.5 | 0.81 | 0.87 | 0.90 | 7.0 | 1490 | 218 |
| MMS 10000 (N) | 10" | 75 | 270 | 83.4 | 85.7 | 85.9 | 0.72 | 0.81 | 0.85 | 5.2 | 1500 | 330 |
| MMS 10000 (N) | 10" | 92 | 345 | 82.9 | 85.4 | 85.7 | 0.65 | 0.77 | 0.82 | 5.2 | 1690 | 385 |
| MMS 10000 (N) | 10" | 110 | 385 | 84.7 | 86.2 | 85.7 | 0.80 | 0.86 | 0.88 | 5.5 | 1870 | 435 |

## Energy consumption of submersible pumps

The percentage distribution of service life costs occurring with a submersible pump for water supply is:

5% initial costs (pump)
85% operating costs / energy costs
10% maintenance costs.

It is obvious that the highest savings can be achieved within energy consumption!

The annual energy consumption, E, of a submersible pump can be calculated as follows:

$E = c \times h \times P_1$ (EURO)
c = specific energy price (EURO/kWh)
h = operating hours/year (hours)
$P_1$ = power input of the submersible pump (kW).

**Example:** Calculation of the annual energy consumption of the submersible pump, type SP 125-3.

SP 125-3 with MS 6000, 30 kW, 3 x 400 V, 50 Hz.

Duty point:

Flow rate Q = 120 $m^3/h$
Total head H = 63 m
Specific energy price c = EURO 0.1/kWh (consisting of day and night rate)
Operating hours/year h = 3200.

$$P_1 = \frac{Q \times H \times \rho}{367 \times \eta_{pump} \times \eta_{motor}} \text{ in kW}$$

Q = $m^3/h$
H = m
Density $\rho$ = $kg/dm^3$ (assumed 1)
367 = conversion factor
$\eta_{motor}$ = (example 84.5%, in equation 0.845)
$\eta_{pump}$ = (not to be confused with the stage efficiency curve).

By showing the $P_2/Q$ curve we make it easier for you to calculate the energy consumption.

$$P_1 = \frac{P_2}{\eta_{motor}}$$

$P_2$ = 26 kW (power requirement of SP 125-3 pump at 120 $m^3/h$, from curve $P_2$ / Q on 56).

### Calculation of motor efficiency at duty point

As standard the SP 125-3 is equipped with a 30 kW MS 6000 motor.

At duty point (Q = 120 $m^3/h$) the pump requires 26 kW, thus:

a motor load of 87% (26 kW/30 kW) and a power reserve of 13%.

From the table on 72 the motor efficiency can be read as:

85% at a load of 75%. ($\eta_{75\%}$)
84% at a load of 100%.($\eta_{100\%}$)
The interpolated value in this example is
$\eta_{motor}$ = 84.5%, $\eta_{motor}$ = 0.845.

$$P_1 = \frac{26}{0.845} = 30.77 \text{ kW}$$

E = 0.1 EURO/kWh x 3200 h x 30.77 kW.
The annual energy costs account to EURO 9846.

If we compare the energy costs of this energy-efficient Grundfos submersible pump with a submersible pump, type SP 120-4, from 1995, (Q = 110 to 120 $m^3/h$; H = 63 to 58 m; $\eta_{motor}$ = 82%), we see that at the same annual total flow of 384,000 $m^3$ and the same current price of 0.1 EURO/kWh, the annual energy consumption of the old pump amounts to EURO 12777.

**Wear and deposits on the motor and the pump were not taken into account.**

The pay-off time, A, (months) is calculated as follows:

$$A = \frac{\text{Purchase price of energy-efficient pump}}{\text{Energy savings/year}} \times 12$$

The purchase price of the energy-efficient pump is EURO 4090.

$$A = \frac{4090}{(12777 - 9846)} \times 12 = 16.7 \text{ months}$$

The pay-off time is 16.7 months.

**Note:** The complete system should be sized for energy efficiency (cable/discharge pipes).

**Cable sizing:**

In order to obtain an economical duty of the pump the voltage drop should be low.

Today large water works already size cables for a maximum voltage drop of 1%).

The hydraulic resistance in the discharge pipe should be as low as possible.

## Cables

Grundfos offers submersible drop cables for all applications: 3-core cable, 4-core cable, single leads.

Cables for Grundfos 4" submersible motors are available with or without plugs. The submersible drop cable is chosen according to application and type of installation.

| | |
|---|---|
| Standard version: | Max. liquid temperature +60°C. |
| Hot water version: | Max. liquid temperature +70°C, for short periods up to +90°C (For MS only). |

### Tables indicating cable dimension in borehole

The tables indicate the maximum length of drop cables in metres from motor starter to pump at direct-on-line starting at different cable dimensions.

If star/delta starting is used the current will be reduced by $\sqrt{3}$ (I x 0.58), meaning that the cable length may be $\sqrt{3}$ longer (L x 1.73) than indicated in the tables.

If for example the operating current is 10% lower than the full-load current, the cable must be 10% longer than indicated in the tables.

The calculation of the cable length is based on a maximum voltage drop of 1% and 3% of the nominal voltage and a water temperature of maximum 30°C.

In order to minimize operating losses the cable cross section may be increased compared to what is indicated in the tables. This is economical only if the borehole provides the necessary space, and if the operational time of the pump is long, especially if the operating voltage is below the rated voltage.

The table values are calculated on the basis of the formula:

Max. cable length of a single-phase submersible pump:

$$L = \frac{U \times \Delta U}{I \times 2 \times 100 \times \left(\cos\varphi \times \frac{\rho}{q} + \sin\varphi \times X_L\right)} [m]$$

Max. cable length of a three-phase submersible pump:

$$L = \frac{U \times \Delta U}{I \times 1.73 \times 100 \times \left(\cos\varphi \times \frac{\rho}{q} + \sin\varphi \times X_L\right)} [m]$$

where

$U$ = Rated voltage [V]

$\Delta U$ = Voltage drop [%]

$I$ = Rated current of the motor [A]

$q$ = Cross-section of submersible drop cable [mm²]

$X_L$ = Inductive resistance: 0.078 x $10^{-3}$ [Ω/m]

$\cos\varphi$ = Power factor

$\sin\varphi$ = $\sqrt{1 - \cos^2\varphi}$

$\rho$ = Specific resistance: 0.02 [Ω mm²/m]

**Example:**

| | |
|---|---|
| Motor size: | 30 kW, MMS 8000 |
| Rated current: | 64.0 A |
| Rated voltage: | 3 x 400 V, 50 Hz |
| Starting method: | Direct-on-line |
| Power factor: | $\cos\varphi = 0.85$ |
| Voltage drop: | 3% |
| Cross-section: | 25 mm² |
| $\sin\varphi$: | 0.54 |

$$L = \frac{400 \cdot 3}{64.0 \cdot 1.73 \cdot 100 \cdot \left(0.85 \cdot \frac{0.02}{25} + 0.54 \cdot 0.078 \times 10^{-3}\right)}$$

L = 150 m

### Cable dimensions at 1 x 230 V, 50 Hz

| Motor | kW | $I_n$ [A] | 1.5 mm² | 2.5 mm² | 4 mm² | 6 mm² | 10 mm² |
|---|---|---|---|---|---|---|---|
| 4" | 0.37 | 4.0 | 111 | 185 | 295 | 440 | 723 |
| | 0.55 | 5.8 | 80 | 133 | 211 | 315 | 518 |
| | 0.75 | 7.5 | 58 | 96 | 153 | 229 | 377 |
| | 1.1 | 7.3 | 48 | 79 | 127 | 190 | 316 |
| | 1.5 | 10.2 | 34 | 57 | 92 | 137 | 228 |
| | 2.2 | 14 | | 43 | 68 | 102 | 169 |

Maximum cable length in metres from motor starter to pump.

## Dimensioning of cable

### Calculation of the cross-section of the cable

**Formula designations**

U = Rated voltage [V]
ΔU = Voltage drop [%]
I = Rated current of the motor [A]
q = Cross-section [mm²]
$X_L$ = Inductive resistance $0.078 \times 10^{-3}$ [Ω/m]
cosφ = Power factor
sinφ = $\sqrt{1-\cos^2\varphi}$
L = Length of cable [m]
Δp = Power loss [W]
ρ = $1/\chi$
Materials of cable:
Cubber: $\chi = 52$ m/Ω x mm²
Aluminium: $\chi = 35$ m/Ω x mm²

For calculation of the cross-section of the submersible drop cable, use the following formula:

**DOL**

$$q = \frac{I \cdot 1.73 \cdot 100 \cdot L \cdot \rho \cdot \cos\varphi}{U \cdot \Delta U - (I \cdot 1.73 \cdot 100 \cdot L \cdot X_L \cdot \sin\varphi)}$$

**Star-delta**

$$q = \frac{I \cdot 100 \cdot L \cdot \rho \cdot \cos\varphi}{U \cdot \Delta U - (I \cdot 1.73 \cdot 100 \cdot L \cdot X_L \cdot \sin\varphi)}$$

The values of the rated current (I) and the power factor (cosφ) can be read in the tables on the pages 71- 74.

### Calculation of the power loss

For calculation of the power loss in the submersible drop cable, use the following formula:

$$\Delta p = \frac{3 \cdot L \cdot \rho \cdot I^2 \cdot \cos\varphi}{q}$$

**Example:**

| | |
|---|---|
| Motor size: | 45 kW, MMS 8000 |
| Rated current: | $I_n = 96.5$ A |
| Voltage: | 3 x 400 V, 50 Hz |
| Starting method: | Direct-on-line |
| Required cable length: | 200 m |
| Power factor: | Cos $\varphi_{100\%} = 0.82$ |
| Water temperature: | 30°C |

| | |
|---|---|
| Cable selection: | |
| Choice A: | **3 x 150 mm²** |
| Choice B: | **3 x 185 mm²** |

**Calculation of power loss**

**Choice A:**

$$\Delta p_A = \frac{3 \cdot L \cdot \rho \cdot I^2 \cdot \cos\varphi}{q}$$

$$\Delta p_A = \frac{3 \cdot 200 \cdot 0.02 \cdot 96.5^2 \cdot 0.82}{150}$$

$$\Delta p_A = \mathbf{611\ W}$$

**Choice B:**

$$\Delta p_B = \frac{3 \cdot 200 \cdot 0.02 \cdot 96.5^2 \cdot 0.82}{185}$$

$$\Delta p_B = \mathbf{495\ W}$$

**Savings**

Operating hours/year: h = 4000.

Annual saving (A):

$A = (\Delta p_A - \Delta p_B) \cdot h = (611\ W - 495\ W) \cdot 4000 = 464000 Wh = 464 kWh$

By choosing the cable size 3 x 185 mm² instead of 3 x 150 mm², an annual saving of 464 kWh is achieved.

Operating time: 10 years

Saving after 10 years ($A_{10}$):

$$A_{10} = A \cdot 10 = 464 \cdot 10 = \mathbf{4640\ kWh}$$

The saving in amount must be calculated in the local currency.

**APPENDIX 5: Lake Longitudinal Section**