APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN WATER QUALITY STUDY ON A ROAD CONSTRUCTION PROJECT

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To my beloveds

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ABSTACT

According to the Malaysian Department of Environment's (DOE) Water Quality Index for 2005, 52 river basins were polluted. Non point source pollution is a major pollution that has been affecting the quality of these river basins. It has been considered as the major pollution for river as the source can come from anywhere. But one of the most significantly of nonpoint sources is from the combined effects of land disturbances to construct new developments during construction activity. A study is conducted on a road construction project in Labis, Segamat to assess the non-point source pollution level through GIS. This study is done by generating the river network for the area in order to estimate the pollution loads. Rainfall and runoff are the components that are able to transport the pollution from one place to another. As the non-point source pollution is a diffused matter transported from land to river, the determining factors include the land use and soil type. A GIS software, ArcGIS 9.2 was used to produce the Digital Elevation Model (DEM) to generate a river network. With the aid of the 3D extension, visualization for the terrain produced was enhanced. The generated river was overlaid with the land use and geological map and interpolates with the WQI data from the sampling to estimate the loads of pollution. Expected Mean Concentration (EMC), which is associated with the land use, were used in this study to produce the pollutant load. Based on the final Pollutant Accumulated Loading Map, the total annual loading through the outlet of the river are 1940, 471, 595 and 1396 kg/year for total BOD, total TSS and NH^3N, respectively. This project also demonstrates that Geographical Information System (GIS) fits in the role with its analytical operations of spatial and non-spatial information to identify and solve the pollutant loading in this construction area.

ABSTRAK

Merujuk kepada data Jabatan Alam Sekitar, bagi Indeks Kualiti Air tahun 2005, terdapat 52 lembangan sungai di Malaysia yang telah tercemar . Pencemaran bukan poin (rawak) adalah punca pencemaran utama yang telah menjejaskan kualiti lembangan sungai di Malaysia. Ia dianggap sebagai punca pencemaran yang utama kerana sumbernya berasal dari pelbagai tempat dan aspek. Tetapi salah satu sumber utama bagi pencemaran bukan titik (rawak) berpunca dari kesan kerosakan muka bumi yang terjadi semasa aktiviti pembinaan dijalankan di tapak pembinaan. Kajian ini dijalankan di sebuah projek pembinaan jalan raya di Labis, Segamat untuk mentafsir tahap pencemaran bukan poin (rawak) menggunakan aplikasi Geographic Information System (GIS). Kajian ini dilakukan dengan menghasilkan rangkaian sungai secara digital menggunakan perisian ArcGIS 9.2. Hujan dan aliran permukaan adalah komponen utama yang membawa bahan pencemaran dari satu lokasi ke lokasi yang lain. Oleh kerana pencemaran bukan titik(rawak) adalah bahan rawak yang dibawa dari tanah ke sungai, maka faktor yang perlu diambil kira adalah jenis guna tanah. Model permukaan digital (DEM) dihasilkan dan seterusnya menghasilkan rangkaian sungai secara digital . Rangkaian sungai kemudiannya ditindihkan bersama dengan peta guna tanah dan disisipkan dengan data Indeks Kualiti Air yang diperolehi dari tapak projek untuk menganggarkan jumlah kuantitaif pencemaran. Konsentrasi Purata Anggaran (EMC) dimana ia berkaitan dengan jenis guna tanah, digunakan untuk menghasilkan jumlah kuantitatif pencemaran. Berdasarkan hasil akhir kajian ini, jumlah kuantitatif pencemaran bagi kawasan kajian ialah 1940, 471 595 dan 1396 kg/tahun bagi BOD, TSS dan NH^3N, masing-masing. Kajian ini dapat menbuktikan kemampuan GIS bagi memenuhi fungsi dalam menganalisis maklumat spatial dan bukan spatial untuk mengenalpasti maklumat kuantitatif pencemaran bagi kawasan pembinaan ini.

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µg	-	micro gram
AN	-	Ammoniacal-nitrogen
BMP		Best Management Practice
BOD	-	Biochemical Oxygen Demand
C		Runoff Coefficient
CAD		Computer-aided Design
COD	-	Chemical Oxygen Demand
CN		Curve Number
DEM		Digital Elevation Model
DFX		AutoCAD Exchange Format
DO	-	Dissolved Oxygen
DOE	-	Department of Environment
EMC		Expected Mean Concentration
ESRI		Environmental System Research Institute
g	-	gram
GIS	-	Geographic Coordinate System
GPS	-	Global Positioning System
GRASS		Geographical Analysis Support System
ha	-	Hectares
IDW		Inverse Distance Weighted
JKR		Jabatan Kerja Raya
JUPEM	-	Jabatan Ukur dan Pemetaan Malaysia
m	-	meter

mg	-	milligram
NPS		Non-Point Source
ppm	-	part per million
RSO	-	Rectified Skew Orthomorphic
TIN		Triangulated Irrigular Network
USGS	-	United State Geological Survey
USLE		Universal Soil Loss Equation
UV		Ultraviolet
WQI	-	Water Quality Index
3D		Three Dimension

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CHAPTER 1

INTRODUCTION

1.0 Introduction

River play an important role as the natural drainage arteries of a country, meeting the needs of an expanding population and supporting agricultural, industrial and socio-economic development besides being the most important freshwater resource for man. Social, economic and political development has, in the past, been largely related to the availability and distribution of fresh waters contained in reverie system.

As development intensifies, the natural river systems are subjected to increasing stresses resulting in a host of problems, among which include natural runoff, dissolved chemicals in water that percolates through the soil and human sources, such as agriculture, mining, construction, industry, homes and businesses (Prabhakar, V.K. 2000). The introduction of pollutants from human activity has seriously degraded water quality even to the extent of turning pristine trout streams into foul open sewers with few life forms and less beneficial use (Hill, K.M. 2004). Actually there are many sources where pollutants can enter the water body. In general the sources of pollutions divided into two categories know as point sources and non point sources.

River basin is an intricate natural resource which demands varied practices, complex management decisions and manifold research efforts in order to ensure its

efficient utilization. In Malaysia, there are about 150 river basins, which are made up of more than 1800 rivers (DOE, 2005). Hence, one of the greatest challenges in river basin management is achieving an appropriate balance between the developments of natural resources and maintaining an optimal natural environment. For example, since nonpoint source pollution control cannot begin until the location and severity are identified. Geographical Information System (GIS) and nonpoint source pollution models are becoming an integral part of national and state efforts to control the degradation of water bodies. The emergence of GIS will provide database management, tools, visualization, simulation and assessment models that supply open and unclouded information that generate dependence and a common purpose between all parties involved in river basin management.

1.1 Definition of Nonpoint Source Pollution

Nonpoint source pollution (NPS) is the introduction of impurities into a surface-water body, usually through a non-direct route and from sources that are diffuse in nature. Discharge from nonpoint sources are usually intermittent, associated with a rainfall runoff event and occur less frequently and for shorter periods of time than do point source discharges. Nonpoint source of pollution are often difficult to identify, isolate and control. In many cases, nonpoint source pollution such as runoff from agriculture land, runoff from construction site, urban storm water and strip mining are becoming major water quality problem (Alexander 1976). According to United States Environmental Protection Agency (EPA), nonpoint source pollution is the nation's largest water quality problem. NPS pollution is caused by rainfall moving over and through the ground. As the runoff moves, it picks up and carries away natural and human made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters and even or groundwater resources (United States Environmental Protection Agency 1997). These pollutants include:

- Excess fertilizer, herbicides and insecticides from agricultural lands and residential areas;
- Sediment from improperly managed construction sites, crop and forest lands and eroding stream banks;
- Oil, grease and toxic chemicals from urban runoff and energy production;
- Salt from irrigation practices and acid drainage from abandoned mines;
- Bacteria and nutrients from livestock, pet wastes and faulty septic systems.

1.2 Definition of Geographic Information System (GIS)

According to Taher (1989), GIS is a computer-based system that supports functions for managing, analyzing and displaying geographical data. Another definition states that GIS allows users to effectively organize, update and query mapped data (Berry 1993). Although many definitions of GIS have been discussed, they all have a common feature, namely GIS systems deal with geographic information (Maguire 1991). This technology has developed so rapidly over the past two decades that it is now accepted as essential tools for the effective use of geographic information.

GIS is sometime considered a subset of other information systems like computer-aided design (CAD), computer carthography, database management and remote sensing. Many feel that GIS is simply a catch-all for almost any type of automated geographic data processing. These systems all predate GIS which, because they have evolved from them, have many features in common. GIS, however, has a number of other features not available in other system. The major characteristic of GIS is the emphasis placed on analytical operation, thus distinguishes GIS from systems whose primary objective is map production.

However, GIS is not an entity that stands by itself solely. It covers and embraces disciplines that deal with the concept of space like geography, practical tools that gather and utilize spatial data like remote sensing, land surveying, geodetic science, theory and concept that make GIS functional like computer science, statistics, software, engineering, artificial intelligence, with countless application of a GIS in forestry, urban and infrastructure planning and engineering.

In this study, Geography Information System (GIS) will be implemented to monitor water quality changes within a water body in the road construction area and calculate loads to a surface water body. A load is the product of flow and concentration, and it refers to how much mass of a contaminant or chemical enters a system in a specified amount of time.

The GIS software that will be used in this study is ArcGIS Version 9.2. ArcGIS provides a scalable framework for implementing GIS for varieties of environmental application. The hydrologic modeling function in ArcGIS provides methods for describing the hydrologic characteristic of a surface. For example in this study, by using an elevation raster data set as a input, it is possible to model where water will flow, create watersheds and stream networks and at last, by using map algebra function which is one of the common analysis language in ArcGIS, the accumulated loading of the pollutants can be determine.

Undoubtedly, the term GIS is always associated with computer hardware and software. Together these will provide the means for data input, storage, manipulation, analysis and output. The use of GIS for water quality study also can be useful for creating digital visual interpretation of water quality characteristic. Therefore, GIS can be described as best tools to address environmental problems.

1.3 Background of the study

The Malaysian Government intends to make a new 22 km-road with bridges linking an existing one from Felda Maokil in Segamat to Bukit Kepong in Muar, Johor Darul Takzim. The purpose of this new road and bridge project is to shorten the trip from Chaah to Bukit Kepong by a distance of 24 km. It will pass through the existing Felda Maokil oil palm estates along with open fields, forest and farms. There are settlements at both ends of the roads, namely Felda Maokil 1 in the east, and Kg. Raja and Bukit Kepong in the west. The rest of the road is mainly of plantations and part of forested areas (Maokil Forest Reserve) in the east of Kg. Raja.

Earthworks will involve the cutting of existing slopes and hills to fill low lying areas to minimize the importation of outside soils. Imported soils, if involved will be taken from a nearby hill. Thus, minimal truck movements will occur outside the project area and therefore reducing the safety and health impacts on nearby residents and plantation workers. All roadside drain along the proposed road will be earth drains. The water from the drains will be channelled to the existing rivers and swamps.

1.4 Statement of Problem

There is a concern that deficiencies in the project development may adversely effect the long-term health of the existing environment especially water quality. The potential problems regarding water quality include transport of potential pollutants into water bodies, standing water and flooding of nearby estates, unregulated storm water runoff surges and accumulation of sediment. The runoff from the construction site will flow to Sungai Gatom which located downstream of the area. Sungai Gatom is tributaries of Sungai Muar. Downstream, there are water intakes, including the Gresik intake point, from which Malacca buys water from Johor. Therefore the runoff from the upstream to the water supply in downstream of Sungai Muar area is such a big concern.

The road construction sites can result in the release of significant amounts of pollutants into the storm drain system, Sungai Gatom without proper management. Construction work involves the removal of vegetation and the excavation of soils causing erosion and the subsequent discharge of sediment. Activities conducted at the construction sites can also result in the release of other pollutants to Sungai Gatom. Therefore, GIS is applied in this study as it has been used in the area of environmental modeling, by providing ease and accuracy in surface terrain representation, watershed delineation, precipitation, data compilation, non-point source pollutant loading calculation and other concepts related to environmental processes.

The national government is fully aware of the need to protect and enhance the environment. And, the Government is committed to take the appropriate action to ensure that the development is sustainable and balanced. Towards this end, environment and conservations considerations will increasingly be integrated with development planning. In line with the Government's interest in protecting and enhancing the environment, focus on the potentially significant adverse impacts that its projects could have on the environment should be emphasized especially on water quality monitoring.

Mostly all research and studies that been conducted on the Malaysian context had been on point source pollution as this pollution is giving acute impacts on the ecosystem. Controlling of point source pollution is also much easier. As for non point source pollution, this area is still new in term of number of study that been conducted and due to much difficulty in acquiring information regarding the pollution as this kind of impacts is long term. With its characteristic such as diffuse, arise over an extensive area of land and are in transit over land before entering the navigable waters, technology such as Geographic Information System (GIS) can be applicable in this area.

Furthermore, managing data by using conventional method is laborious task. In the conventional methods, technicians are confronted with restrictions and limitation when there are too much water quality data. There is no systematic system that helps to reduce their work loads as well as updating the data. Therefore, applying GIS in water

quality management may improve the traditional method in the preparation of geographical information.

1.5 Objective of Study

A set of objectives has been drawn up to archieve the purpose of this study:

i. To analyze the effect of the Segamat road project to the water quality;
ii. To integrate GIS (ArcGIS) in the analysis of water quality and estimation of loading for the site;
iii. To illustrate the proficiency of GIS technology as an application tool on data management, analysis and visualization of nonpoint source pollution models

1.6 Significant of Study

Generally, Water Quality Index (WQI) and INWQS are used to determine the classification and pollutant status of particular water bodies. Since the road construction will cause several adverse effects to the environment, therefore the water quality of the water body within the project area should be study to level of construction impact towards the environment with focus to quality of the water bodies. Therefore this study is conducted to determine the existing quality of the water bodies within the project area. The importance of monitoring the water quality from the road construction site is to ensure the quality and sanitation of the water supply sources as the runoff from the site will flow to Sungai Gatom which is the of Sungai Muar. More over, downstream of Sungai Muar are water intakes, including the Gresik intake point, from which Malacca buys water from Johor.

It is also important to ensure that water quality management during the construction phase be closely related to management of soil erosion and sedimentation,

as excessive erosion and siltation will contribute to water quality deterioration. Other related aspects of water quality management include management of waste disposal from site clearing works, solid waste and sewage as well as potential pollution of oil and grease from waste oils, fuels and lubricants from machinery.

The integration of Geographical Information System to monitor the water quality of the construction area will give the better information access regarding to the quality of the water bodies. GIS helps identify and map critical areas of land use and reveal trends that affect water quality during the construction period. ArcGIS 3D Analyst can map multiple contamination layers at multiple depths.

1.7 Scope of the study

The scope of this study cover the modeling of nonpoint source pollution for the selected study area by determining and utilizes appropriate spatial analysis data classification
technique in ArcGIS and its extention, ArcGIS Spatial Analyst and 3D Analyst.

1.7.1 Site Description

The study area is situated in Daerah Labis, about 4 km from Chaah in the east. The proposed road will connect the existing State Road J32 from Bukit Kepong to Felda Maokil and continue to the State Road. It will pass through the existing Felda Maokil oil palm estates along with open fields, forest and farms. Figure 1.0 show the land use of the sampling point location. Some of the land uses surrounding the project site include:

Table 1.1: Landuse Area of the Project Site

Land use	Area Covered
Residential Areas	Bukit Kepong, Kg. Raja, Kg Jawa, Kg. Sg. Muda Luar, Kg. Lenga, Felda Maokil, Kg. Jawa Baru, Kg.Batu Tanum, Kg.Baharu, Tmn. Chaah Baru, Kg. Kuala Sabar, Kg.Btg. Merbau
Commercial Areas	Pekan Bukit Keopng, Chaah
Institutions	Primary School (S.K. Bukit Kepong), Sk. Felda Maokil 2, Labis, Segamat 85300 Labis
Plantations/Orchards	Felda Maokil Satu, Felda Maokil Dua, Ladang Song near Kg. Raja, Ladang Lim Sim Eng

The boundary of this study is from the upstream of the construction area (2^0 17' 06.6") until the downstream of the water bodies at (2^0 18' 15"). Figure 1.0 and 1.1 shows the sampling point location. Detailed description of the location will be discussed in Chapter III.

Figure 1.0 (a) (b)

Figure 1.0(a): Oil Palm Plantation North-west (b) Reserved forest at West of the Proposed Road

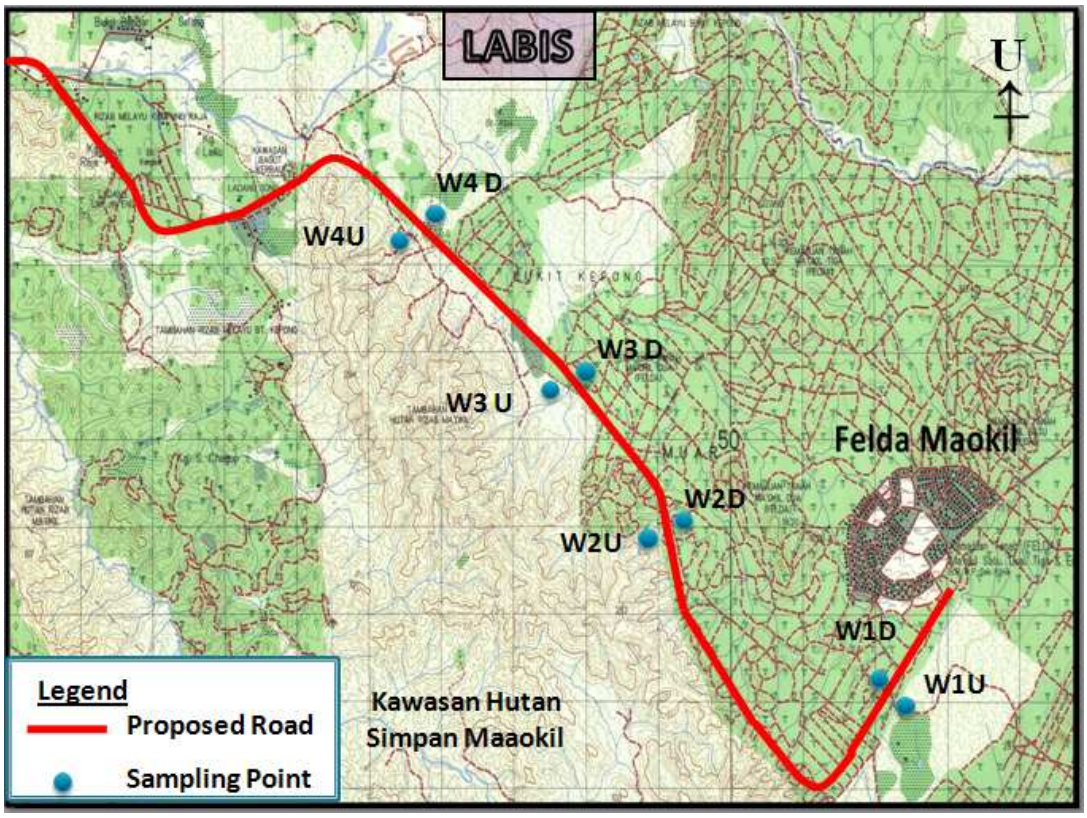

Figure 1.1: Sampling Points

1.7.2 Catchment area

They are 12 small catchment areas along the proposed locations ranging from 0.3 to 4.5 km^2. The biggest catchment is located south of the Felda Maokil Dua. The sampling points represent the major catchment area in the proposed location. The area of coverage for the major water catchments are described in table 1.2 and illustrated in figure 1.2:

Table 1.2: The Area of Coverage for the Water Catchment

Water Catchment	Area of coverage
Water Catchment NO 4	3.15 km2
Water Catchment NO 6	2.4 km2
Water Catchment NO 10	3.1 km2
Water Catchment NO 12	4.5 km2

Source : Pengiraan Hydrologi dan kapasiti hidraulik, Ogos 2007 with reference to Urban Stormwater Management Manual For Malaysia (MASMA)-Volume 4: Design Foundamentals

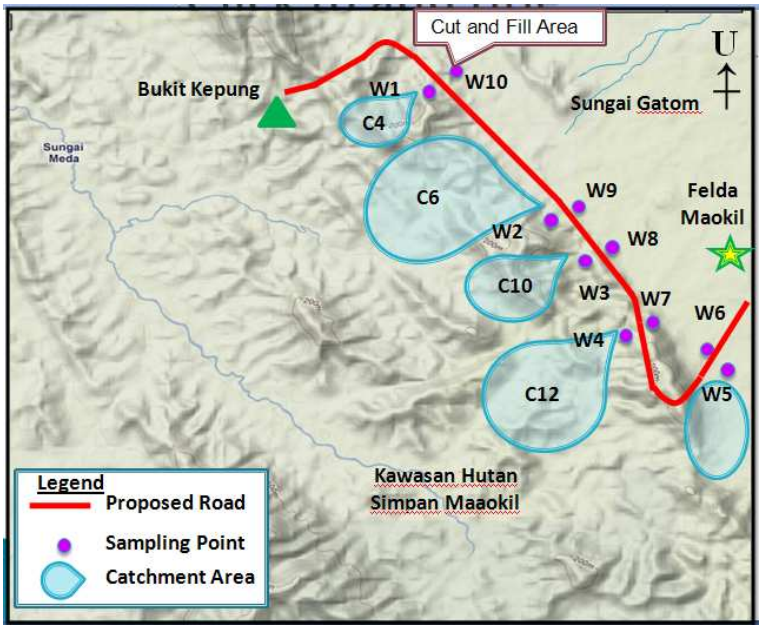

Figure 1.2: The Catchment of the Study Area

1.7.3 Frequency and Parameters of Sampling

The sampling frequency of water quality is taken at eight stations with three times of frequency for during both dry and rainy days. Two samples will be taken for each major catchment area. There are two types of parameters considered in order to determine the water quality which are physical parameters and chemical parameters.

Water quality is determined by assessing three classes of attributes: physical, chemical, and biological. The detail of the parameter will be discussed in Chapter 2.