The Impacts of Quarry Activities on Eco-Hydrological Systems

by

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the requirements for the
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CERTIFICATION OF APPROVAL

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An extended report submitted to the
Civil Engineering Programme
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BACHELOR OF ENGINEERING (Hons)
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Approved by,

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(Dr. Husna Binti Takaijudin)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
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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.

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(MOHAMAD HAFIZI BIN MIOR AZMAN)

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ABSTRACT

Nowadays, the demand for the mineral resources such as limestone is increasing due to the increase of the concrete and other productions. In Malaysia, the mining and quarrying activities contribute a large portion of the nation's economy. In the other hand, the quarry activities also can bring some negative impacts to flora and fauna and environment of its surrounding area. In this study, the scope of the study is to investigate the impacts of quarry activities on eco-hydrological system in the area in which it has focused on the impacts of the activities on the surface water by analysing it in three main parameters such as hydraulic, hydrology and water quality of the natural surface water. The objectives of the study are to measure and examine the identified parameter which are hydraulic, hydrology and water quality if the stream. Then, the data obtained from the study will be used in the analysis part to propose a detention pond to manage the storm water systems in the study area. By performing this study, it can determine the level of impact of the quarry activities on the eco-hydrological system at the area and can propose a suitable mitigation plan to reduce the impact in the future.

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

It estimates about 90% of limestone resources at Kanthan Hill are remains below the ground level and about 10% already utilised. To make the resources is fully utilised, the quarry operator wants to extend the quarry activity to a proposed depth of 80 to 90 meters below the ground level by deep quarrying at the study area. The activities might affect some sensitive features such as flora and fauna and habitat at nearby natural streams due to the disturbance of water systems such as surface and underground water at the area.

STUDY AREA

The location of the study is at Lafarge Kanthan Plant, Chemor, Perak, Malaysia and its coordinates is (4.77.339,101.113057). The quarrying activities have been start since 1964 until now and it can produce about 4.10 million tons of cement annually and the production rate keeps increasing by the year. The age of the limestone hill is about 400 million years and the main resources of the hill is limestone. The limestone hill is divided into 5 parts which are Zone A, Zone B, Zone C, Zone D and Zone E. Currently, the quarry activity is occurring at Zone A, B and E. While, the remaining Zones which are Zone C and D is to be conserved by the authorities (Lafarge Annual Report, 2016). This is because scientist found some new and endangered species in the area which are *Liphistius Kanthan*, *Capricornus Sumatraensis,* and *Paraboea Vulpina*, KIEW et, al (2014). Figure below shows the location of the study area and aerial survey and photogrammetric mapping for limestone quarry and factory of Kanthan works

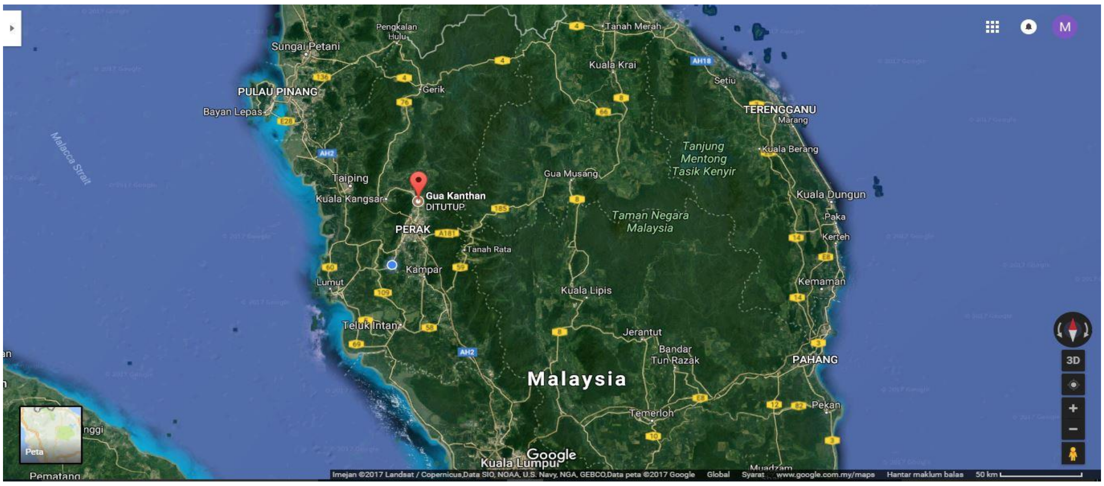


Figure 1: Location of Study

Figure 2: Aerial map of location of study

Figure 3: Paraboea Vulpina

Figure 4: Liphistius Kanthan

1.2 PROBLEM STATEMENT

The quarry activities such as excavating and blasting from the open pit of the quarry can give impact to the natural stream's morphology. The activities can cause the stormwater and water in the natural stream tend to flow to the lowest point of the open pit. Consequently, all the water from stormwater and the natural stream will accumulate at the bottom of the pit. Hence, to ensure that the quarrying operation can run smoothly, the quarry operator need to pump out the water to the natural stream. For the initial hypothesis, the pumped water may pollute by mixing of some minerals from the area such as limestone and others. Hence without any proper study and mitigation plan, the natural stream may also pollute with the pumped water from the pit. Consequently, it will affect the aquatic living in it.

The natural stream also can pollute by the blasting activities. Heavy metal, suspended solids and grease are the pollutants in the water at natural stream. The pollutant are spreading in the air during the blasting activity and mixed with the water in the stream.

1.3 OBJECTIVE

1. To measure Hydraulics and Hydrology parameter of the proposed area
2. To examine water quality parameters of the proposed area
3. To proposed a stormwater control system to cater the discharge from groundwater flow to the existing stream.

1.4 SCOPES OF PROJECT

Generally, in this study, the author has focusses mainly in the surface water area. Some parameters have been identified in this study including hydraulic, hydrology, water quality of the surface water. Below are the specific scopes of the study to obtain the relevant data:

1. To obtain Hydraulic Data (Channel Geometry) and of nearby stream
2. To obtain Hydrology Data of the nearby stream
3. To monitor water quality of nearby stream

1.5 RELEVANCY OF STUDY

The relevancy of the study is it can contribute to conserve and preserve the natural eco-hydrology at the area. These are including to protect some endangered species and to preserve the water sources at study area in which it is the main resources for the ecosystem in the area.

During the site visit, the author has identified that the quarry area is not too far from the residential area. The distance of quarry area and residential area is about 1 kilometer and the residents at the area may be affected form quarry activities. Hence, proposing a mitigation plan can reduce the risk of impact from the quarry activities on the residents. Besides that, it will create self-awareness to the nearby resident about the quarry activities.

1.6 LIMITATION OF STUDY

During the preliminary study, there are some limitations has been identified in the study area. These are during the sampling works, they were doing some excavation works at the surface water and can cause the water stagnant at a point and can't flow to another point of sampling. It also can affect the turbidity reading and total suspended solids in the water in which the reading is not related with the quarry activities. Besides that, the accessibility in the study area limited due to some of the points need to pass through private lots and old temple. This is because the accessibility is controlled by the owner of the lots.

Figure 5: Channel Excavation Works

CHAPTER 2

LITERATURE REVIEW

2.1 Water Cycle

The earth surface is covered with 70% of water and about 97% of the water is comes from the ocean. The 3% percentage remaining is come from glaciers, groundwater, lakes and rivers. Hydrologic cycle or water cycle can be defined as the movement of continuously on, above and below the earth surface through some physical process like evaporation, condensation, precipitation, infiltration, surface runoff and subsurface flow. In the atmosphere, about 10% of the moisture is released by plant through the transpiration process. Plant release it through the underside of their leaves (USGS, 2008). Vegetative cover in the ecosystem also can give an effect of the hydrologic cycle in the area by influences the flow of water and can shape the river channel on the earth surface (L. Zhang et. al., 1999). Below shown an illustration of the process of water cycle which adapted from USGS.

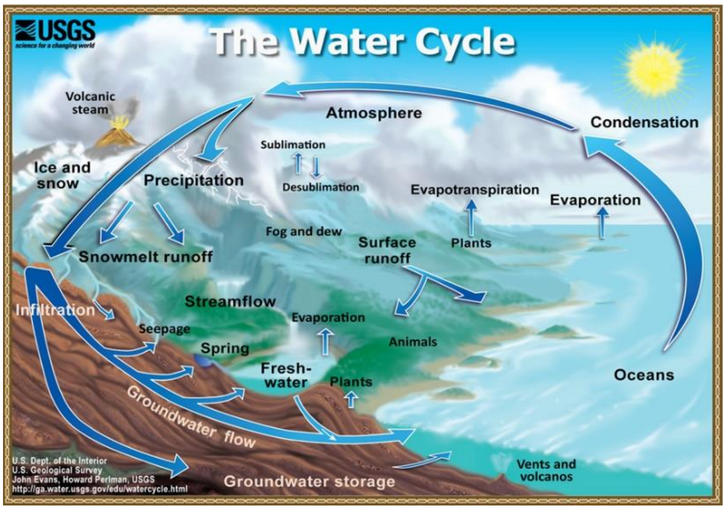


Figure 6: The Water Cycle

2.2 Limestone Quarrying

Nowadays, limestone is widely used in construction industries as it is one of the mixtures in Portland cement, aggregates in concrete and asphalt, and in a various array of other products (USGS, 2008). It is extracted from large pits excavated into the ground using heavy machinery into several hundred feet depth in the ground. In history, limestone was used to build monuments, temple, and pyramids.

The production of limestone is based on the specific needs on an individual project. Heavy automatic drill and horizontal saw are used to cut the limestone blocks in different shape and detach individual blocks from quarry face (USGS, 2008). Due to its characteristics is hard and durable, limestone is suitable to use in construction of tall building.

Even so, the quarrying activities of limestone can give some impacts on environmental and health. Since the activities is mostly at karst area, it can destroy the natural landscape and wild life habitat. Consequently, it will lead to extinction of wild life and using up the limited resources on the earth. Besides that, the activities can contaminate the hydrological system such as underground water and river at the area since some limestone are also aquifers (USGS, 2008). Other than that, vehicles from the site works also can produce air and sound pollution.

2.3 Eco-Hydrological Systems

According to Zalewski, Janauer, and Jolankai (1997), ecohydrology can be define as “the study the functional interrelations between hydrology and biota at catchment scale”. There are two elements are related which are ecosystem and water resources. These are including rivers, lakes, forest, desert and other terrestrial ecosystems. The study area of ecohydrology are including the transpiration and photosynthesis of plant, the effect of vegetation on streamflow, adaption of organism to their water environment and the interaction between ecological process and the hydrological cycle (Jiří Kulhavý et al, 2014)

Generally, the main concept of ecohydrology is the physiology of plant is directly to the water resources. Water stressed condition would occur if there are insufficient of water at some certain area of ecosystem. During the drought season or in semi-arid area, the plant extract the water from the decrease its feedback in photosynthesis and transpiration process by closing their stomata to reduce water loss (I. Yordanov et, al, 2003).

In 2014, several group of scientist found some new plant animal species. The new animal species are including *Charopa Lafargei*, *Liphistius Kanthan*, and *Cyrtodactylus Guakanthanensis*. While, the new plant species are *Vatica Kanthanensis*, *Meiogyne Kanthanensis and Gymnostacchyum Kanthanensis*. The species are found at Zone C and Zone D of Kanthan Hill (KIEW, R. et, al). Hence, Zone C and D need to preserve in order to protect the rare and endangered species from extinct.

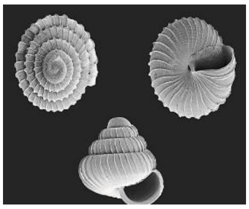


Figure 7: Charopa Lafaraei

Figure 8: Liphistius Kanthan

Figure 9: Cyrtodactylus guakanthanensis

Figure 10: Vatica Kanthanensis

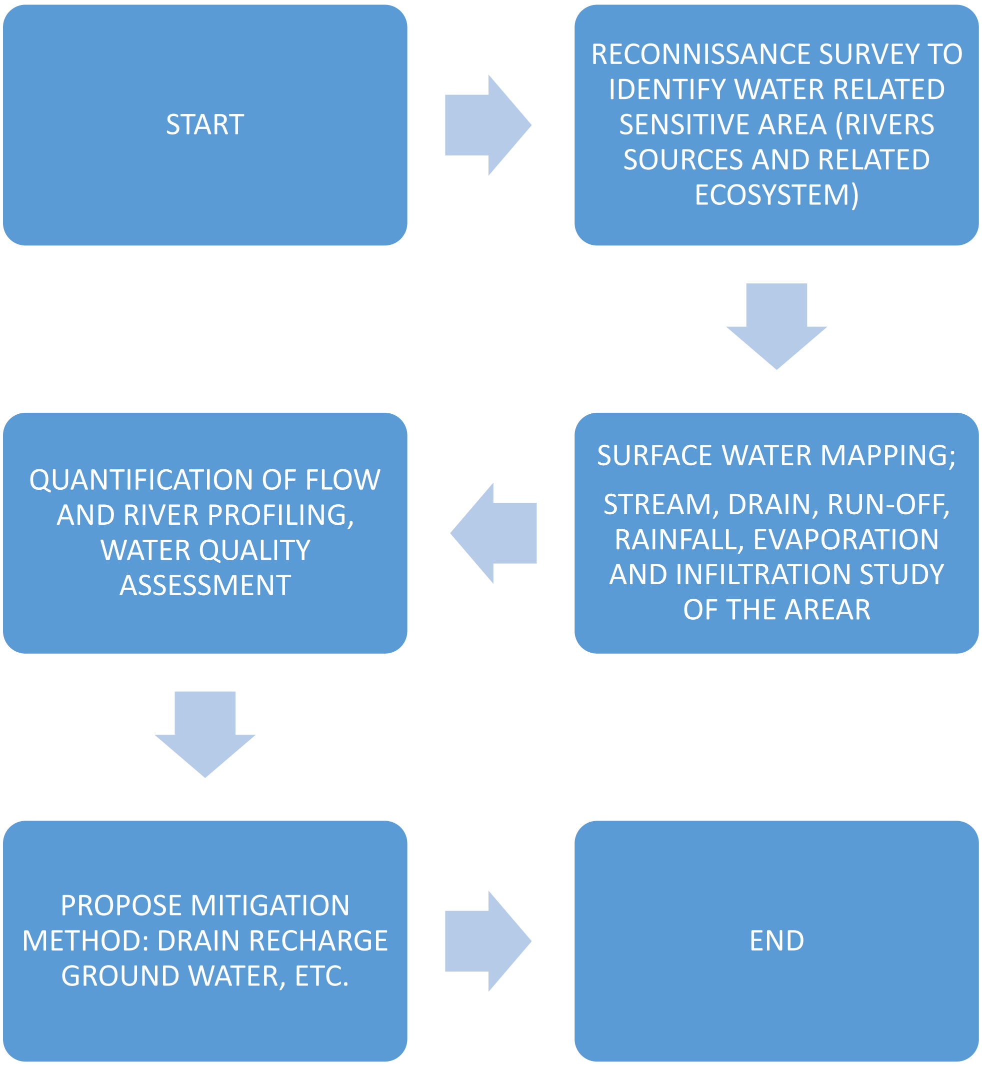
Figure 11: Meiogyne Kanthanensis

Figure 12: Gymnostachyum Kanthanensis

CHAPTER 3

METHODOLOGY

3.1 OVERVIEW



3.2 SURFACE WATER MAPPING AND SURVEY TO IDENTIFY WATER RELATED SENSITIVE AREA

Before all the works started, the project has been briefed by some representatives from quarry operator about the related area which need to study. In the briefing, they also explain about the future works of the quarry operator, direction of surface water and some endangered and newly found species of flora and fauna in the area.

Then, the author and his team had been brought to the study area to survey the identified flora and fauna near the Kanthan hill.

Figure 13: Briefing Session with Quarry Operator

Figure 14: Site Visit at Identified Study Area

Figure 15: Identifying Sampling Points

Initially, the author has identified 20 points for sampling works and river profiling. But due to some accessibility issue, he able to reach at 10 points of sampling for river profiling and water quality assessment.

During the surveying work, some of element of ecosystem were identified and documented in a map as shown below. The map also displays the water related area such as natural stream, artificial stream and water catchment area which are within the scope of study.

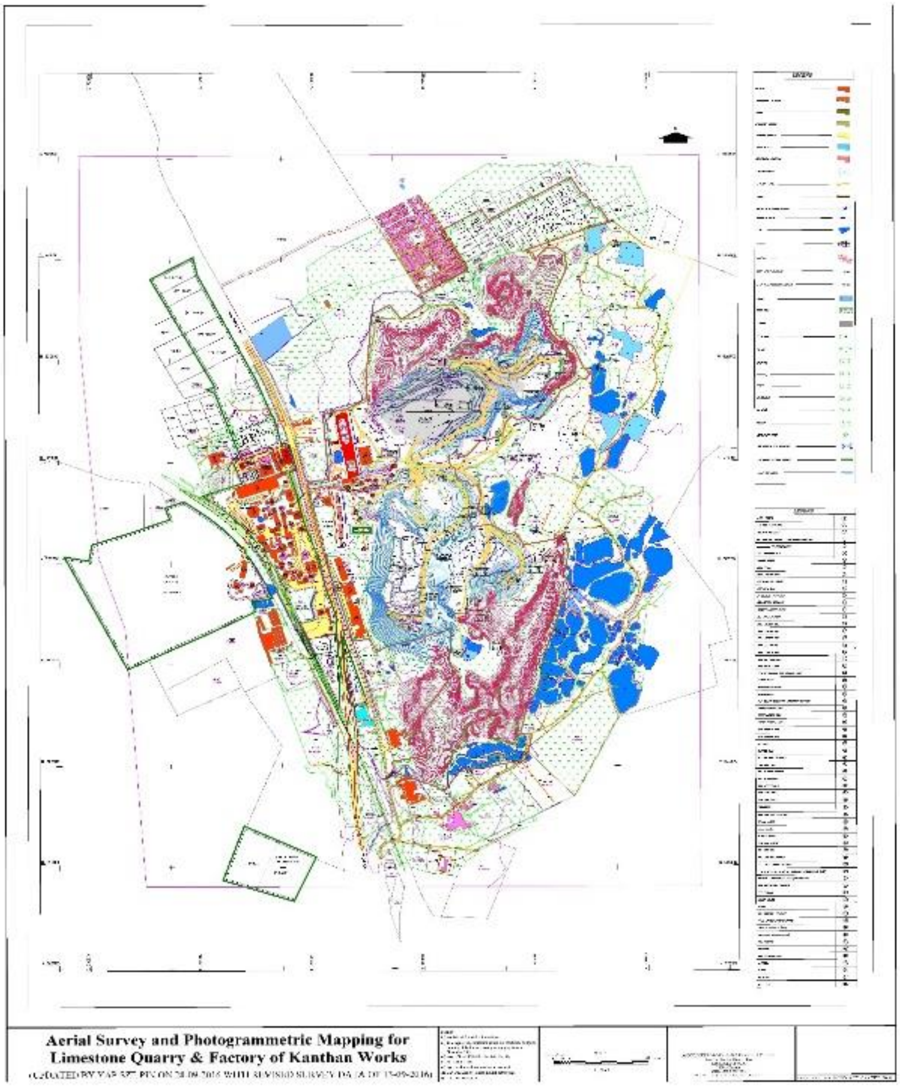
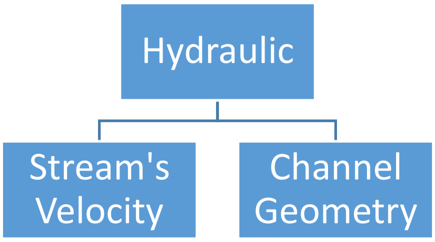


Figure 16: Aeriel Survey and Photogrammetric Mapping for Limestone Quarry & Factory of Kanthan Works

3.4 QUANTIFICATION OF FLOW AND RIVER PROFILING

Stream's Velocity



Objective: To estimate the optimum discharge of water in the stream

Apparatus: Velocity meter

Procedure: Record the velocity of the stream by using velocity meter at 10 different points and different level of water.

Channel Geometry

Objective: To determine the channel geometry of the stream

Apparatus: Measuring Tape, Staff, Desto Meter

Procedure: Measure the width and the depth of the channel at 10 different points

Figure 17: River Profiling Work

Manning's Equations

In this study, the hydraulics modellig for surface water can be obtained from Manning's Equation. The Manning's Equation is shown as below:

$V = (k_n / n) R_h^{2/3} S^{1/2}$

Where,

- *v = cross-sectional mean velocity (ft/s, m/s)*
- *k_n =1.0 for SI units*
- *n = Manning coefficient of roughness*
- *R_h = hydraulics radius (ft, m)*
- *S = slope of river (ft/ft, m/m)*

Hydraulic radius can be expressed as:

$R_h = A / P_w$

Where,

- *A = cross sectional area of flow (m)*
- *P_w = wetted perimeter (m)*

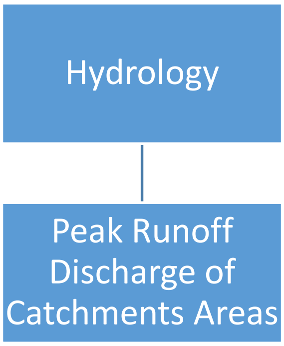
Hence, based on the manning's equation, the surface water discharge equation can be expressed as:

$Q = (k_n / n) AR_h^{2/3} S^{1/2}$

Besides that, the roughness coefficient can be assumed as 0.035. The assumption of the value is based on the streambed characteristic which is winding natural stream with weeds. Below is the roughness coefficient table as mentioned:

Table 1: Roughness Coefficient

Streambed Characteristics	Roughness Coefficient
Mountain streams with rocky beds	0.04-0.05
Winding natural streams with weeds	0.035
Natural streams with little vegetation	0.025
Straight, unlined earth canals	0.020
Smoothed concrete	0.012



Rational Method

In this study, the peak runoff discharge of catchment areas were obtained by using rational method. The equation for this method is shown as below:

$Q=CiA/360$

Where,

- Q – Peak flow (cfs or m^3/s).
- C – Dimensionless runoff coefficient.
- i – Rainfall intensity (in/hour, mm/hour).
- A – Catchment area (acres, ha).

Estimation of Catchment Areas, Runoff Coefficient Value and Rainfall intensity.

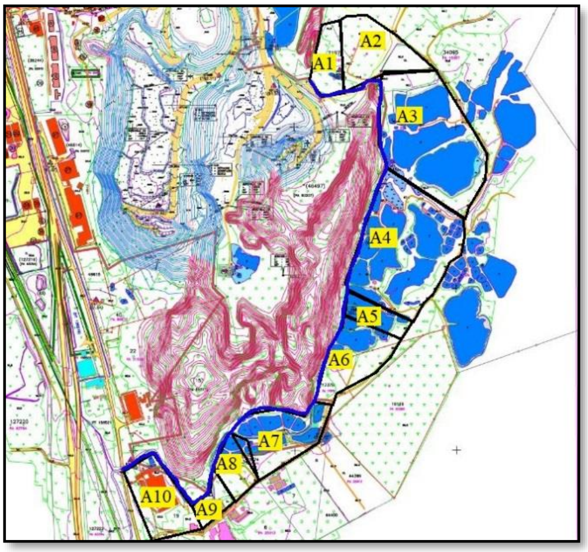


Figure 18: Division of Catchment Area

The catchment area has been divided into 10 areas. The division of the area is to identify the runoff coefficient based on the land surface of nearby surface water. The estimation of catchment areas is done by using Auto-Cad Software. The based on the surveying works, it has estimate that the runoff coefficient is 0.6 for pond and 0.3 for agricultural land.

The rainfall intensity was obtained from MSMA. The identified rainfall station is at Politeknik Ungku Omar, Ipoh.

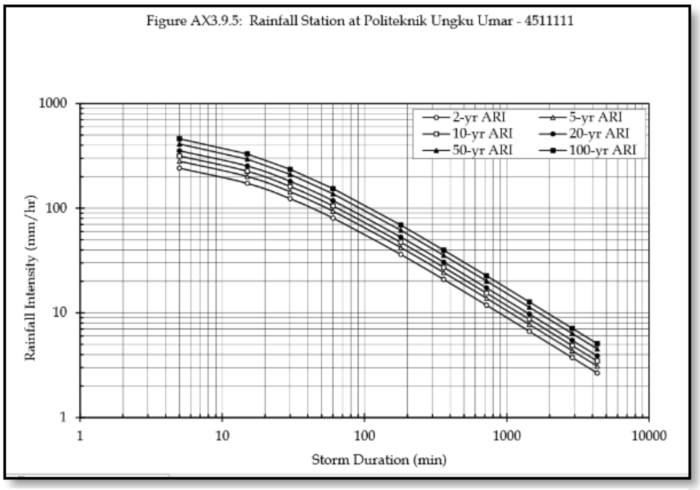
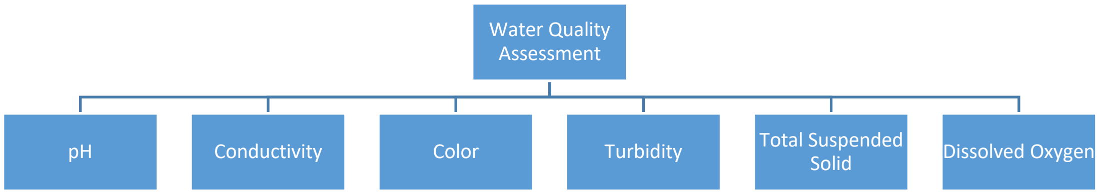


Figure 19: IDF Curve for Rainfall Station at Politeknik Ungku Omar



Water Quality Index

Water quality data were used to determine the water quality status weather in clean, slightly polluted or polluted category and to classify the rivers in Class I, II, III, IV or V based on Water Quality Index (WQI) and Interim National Water Quality Standards for Malaysia (INWQS) every year. Water Quality Index (WQI) is computed based on 3 parameters:-

- pH
- Dissolved Oxygen (DO)
- Total Suspended Solids (TSS)

	Unit	Class				
		I	II	III	IV	V
Dissolved Oxygen	Mg/l	>7	5-7	3-5	1-3	<1
Ph	-	>7	6-7	5-6	<5	>5
Total Suspended Solid	Mg/l	<25	25-50	50-150	150-300	>300
Water Quality Index	-	<92.7	76.5-92.7	51.9-76.5	31.0-51.9	<31.0

Class	**Uses**
Class I	**Conservation of natural environment Water Supply I – Practically no treatment necessary Fishery – Very sensitive aquatic species**
Class IIA Class IIB	**Water Supply II – Conventional treatment Fishery – Sensitive aquatic species Recreational use body contact**
Class III	**Water supply III – Extensive treatment required Fishery III – Common of economic value and tolerant species; livestock drinking**

Class IV	**Irrigation**
Class V	**None of the above**

SAMPLING POINTS

During the surveying works, 10 potential points were identified to measure water quality, flow of the stream and river profiling at the study area. There are three parameters were obtained from the sampling in the points which are water quality assessment, river profiling and measuring the surface water flow.

For river profiling, the water depths were taken in the left, middle and right at each of the points and in measuring the velocity of surface water, the measurement were taken at upstream and downstream for each of the points

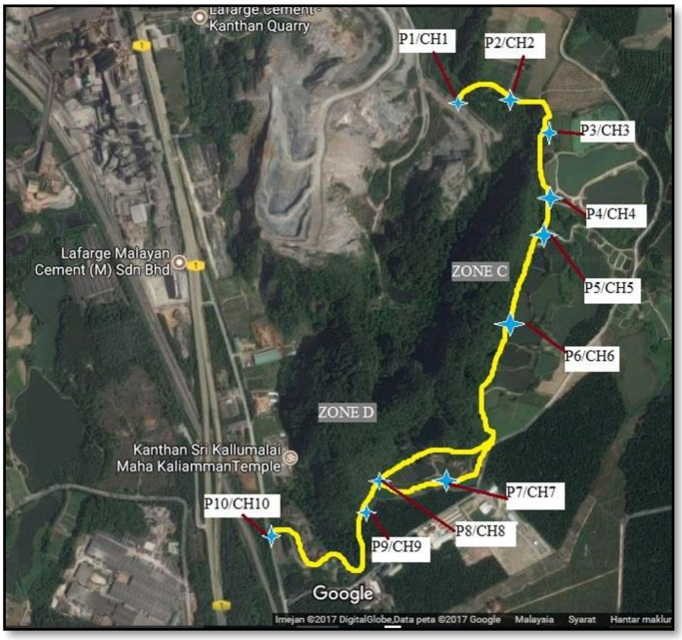


Figure 20: Sampling Points Map

The figures below show the view for each sampling point at the study area.


Figure 21: Point 1


Figure 22: Point 2


Figure 23: Point 3


Figure 24: Point 4


Figure25: Point 5


Figure 26: Point 6


Figure 27: Point 7


Figure 28: Point 8


Figure 29: Point 9


Figure 30: Point 10

IN-SITU WATER QUALITY MONITORING

Parameters of monitoring: pH Value, Conductivity, Dissolved Oxygen,

Apparatus: Water quality Sonde

Figure 31: Multiparameter Water Quality Sonde

Figure 32: A complete set of multiparameter water quality sonde

Figure 33: During the setting up the sonde

Figure 34: During the monitoring process

LABORATORY WATER QUALITY TESTING

Total Suspended Solids

Objective: To determine the Total Suspended Solid in water sample of stream at different points

Apparatus: Measuring Cylinder, Filter Membrane, Vacuum Pump, Distilled Water, Forceps, Aluminum Dish, Drying Oven, Dessicator, Wahttman Filter Paper,

Procedure:

1. Use a Sharpie permanent marker, sequentially number outside edge of each pad with a unique label.
2. After pads have been labelled, place in a Pyrex dish and dry overnight in a 105° C oven.
3. When ready to weigh, remove pads from oven and place into a desiccator to cool to room temperature.
4. Turn on analytical balance and computer.
5. After pads have come to room temperature, weigh pads individually on balance and enter data into respective spread sheets and store in their labelled boxes for future use.
6. When ready to sample, place pad numbered side down onto filtering apparatus.
7. Filter a known volume of sample through the filter pad.
8. Rinse pad very well with deionized water to rinse down filter tower and remove any salts from the pad.
9. Fold pad in half, sample side in and place pad into a labelled foil pouch and place in labelled storage bag and store in -20° C freezer. Place replicate pads side by side in pouch and not on top of each other.
10. When ready to analyse, place opened pouch with sample in 105° C drying oven about 2 hours.
11. Calculate TSS value by using formula below:

$$TSS\ (\frac{mg}{L}) = \frac{(final\ weight\ of\ sample - initial\ weight\ of\ sample)\left(1000\frac{mg}{L}\right)}{Sample\ Volume\ in\ L}$$

Colour Test

Objective: To determine the “apparent” or “true” color of water sample in the stream at different points

Apparatus: Sample Cells, 10 ml, Spectrophotometer, Filter Apparatus; Membrane Filter, Filter Holder, Filter Flask and Aspirator

Procedure:

1. Assemble the filtering apparatus.
2. Rinse the filter by pouring about 50ml of distilled water through the filter. Discard the rinse water.
3. Pour another 50ml of distilled water through the filter.
4. Blank preparation: Fill a sample cell with 10ml of distilled water.
5. Prepared sample: Fill a second sample cell with 10ml of sample.
6. Wipe the blank sample cell and insert it into the cell holder with the fill line facing right.
7. Press ZERO. The display will show: 0 units PtCo.
8. Wipe the prepared sample cell and insert it into cell holder with the fill line facing right. Press READ. Result are in mg/L PtCo. This gives “apparent colour” value.
9. Filtered sample: Fill the sample cell into 10ml of filtered sample.
10. Wipe the filtered sample cell and insert it into the cell holder with the fill line facing right. Press READ. Result are in mg/L PtCo. This gives “true colour” value.

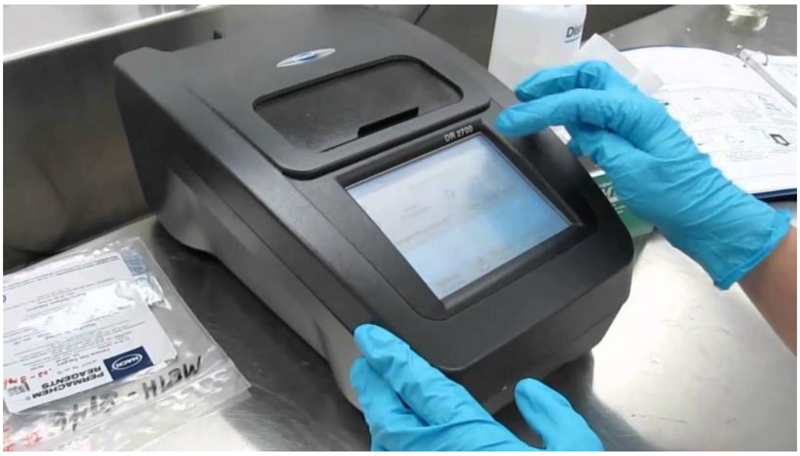


Figure 35: Spectrophotometer

Turbidity Test

Objective: To determine the turbidity of water sample at different points

Apparatus: Sample Cells with Cap, Portable Turbidity Meter, Water Sample

Procedure:

1. Collect the representative sample in a clean container.
2. Fill a sample cell to the line (about 15ml), taking care to handle the sample cell by the top. Cap the cell.
3. Wipe the cell with a soft, lint-free cloth to remove water spots and fingerprints.
4. Place the sample cell in the turbidity meter and take the turbidity reading.

Figure 36: Turbidity Meter

CHAPTER 4
RESULTS & DISCUSSIONS

Table 2: Water Quality Results

4.1 Water Quality Result

Water Quality Parameters	Sampling Points										Mean	Class
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10		
pH	6.9	7	6.9	7.4	7.6	7.6	7.4	6.9	7.3	7.4	7.22	I
DO Concentration (mg/l)	5.66	7.08	4.59	6.19	4.96	7.05	6.00	8.03	7.32	7.62	6	II
TSS (mg/l)	59	42	41	23	26	31	30	43	34	41	37	II
Conductivity(µS/m)	490	484	377	500	310	258	163	341	341	343	361	-
DO Saturation (%)	71	60	58	78	62	92	77	107	96	99	80	-
Colour	64	62	87	106	123	154	83	61	83	103	92	-
Turbidity (NTU)	1.62	3.94	9.05	13.47	9.93	12.35	7.58	6.72	8.16	11.55	8	-

Based on the table above, it shows that the water quality results are obtained in 7 parameters which are pH, Dissolved Oxygen Concentration. Total Suspended Solid, Conductivity, Dissolved Oxygen Saturation, Colour and Turbidity. While, ppH, DO

Concentration and TSS has been classified based on water quality index. PpH value can be classify in class I which is practically no treatment necessary. While for DO Concentration and TSS, can be classify in class II which is need only conventional treatment if required.

4.2 Hydraulics Modelling

Parameters		Sampling Points									Mean
		P1	P2	P3	P4	P5	P6	P7	P8	P9	
Depth	Left	0.23	0.33	1.30	0.58	0.30	0.34	0.31	0.20	0.56	
	Middle	0.27	0.43	1.25	0.62	0.33	0.35	0.34	0.20	0.53	
	Right	0.20	0.36	1.05	0.58	0.29	0.32	0.27	0.19	0.51	
Sectional Area (m^2)		0.116	ND	0.558	ND	0.114	0.776	0.708	0.812	ND	0.514
Wetted Perimeter (m)		1.7	ND	0.97	ND	1.07	1.03	5	11.17	ND	3.378
Discharge (m^3/s)		0.055	ND	0.780	ND	0.518	1.298	0.389	0.277	ND	0.296

Table 3: Hydraulics Modelling Results

Based on the depth and channel width data measured from the surface water, the estimation of sectional area and surface water discharge can be made by using Microsoft Excel.

Due to limitation of study, there are only 6 points were able to reach and measured during the sampling works.

The mean for surface water discharge is 0.296 m^3/s and it can be control value in the hydrology analysis and detention pond proposal parts.

4.2.1 Surface Water Cross Sectional

The figures below show the estimated cross-sectional area and wetted perimeter for 6 sampling points which is done by using Microsoft Excel.

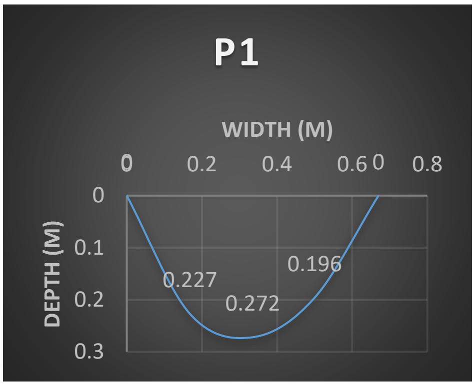


Figure 37: Surface Water Cross Sectional area at point 1

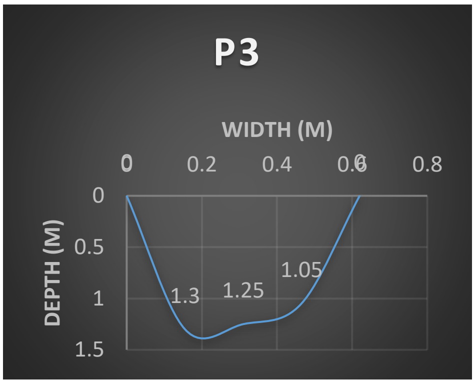


Figure 38: Surface Water Cross Sectional Area at Point 3

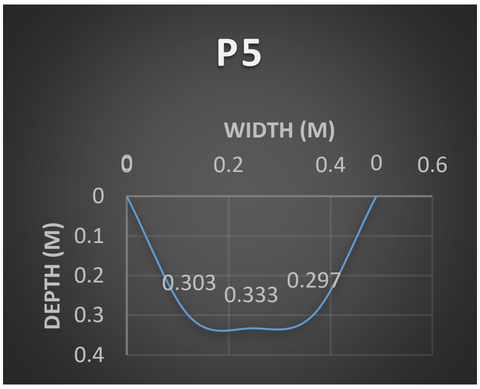


Figure 39: Surface Water Cross Sectonal Area at Point 5

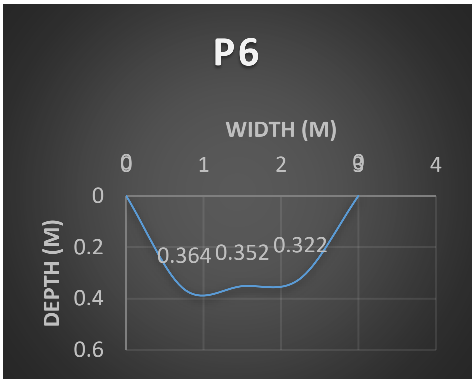


Figure 40: Surface Water Cross Sectional Area at Point 6

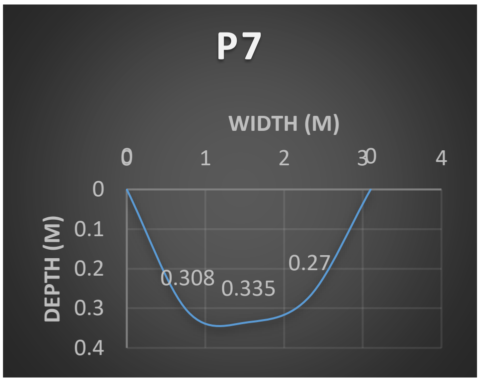


Figure 41: Surface Water Cross Sectional Area at Point 7

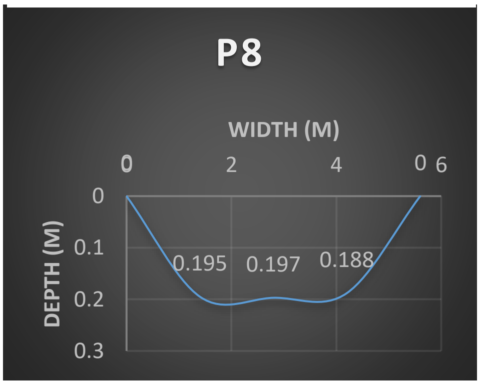


Figure 42: Surface Water Cross Sectional Area at Point 8

4.3 Hydrology Modelling

Parameters	Catchments Areas									
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Estimated Area (m)	226	416	697	519	127	274	124	117	97	231
Runoff Coefficient ©	0.4	0.4	0.95	0.95	0.95	0.95	0.95	0.95	0.4	0.4
Peak Discharge (m^3/s)	0.00269	0.00495	0.01968	0.01465	0.00359	0.00774	0.0035	0.0033	0.00115	0.00275
Mean Peak Discharge (m^3/s)	0.0588									

Table 4: Hydrology Modelling Results

Based on the hydrology results, it shows that the estimated catchment areas were obtained by using Auto-Cad software and the runoff coefficient for each catchment areas and rainfall intensity were estimated and obtained based on MSMA. The rainfall intensity for the study area is adopts from nearby station which is at Politeknik Ungku Omar and the rainfall value is 106.99 mm/hour.

The peak runoff discharge calculated based on rational method and the calculation is based on 50 years ARI. The equation is shown as below;

$$Q=CiA/360$$

Besides that, the mean for peak runoff discharge obtained is 0.0588 and it is lower than the maximum discharge of the surface water which is 0.296 m^3/s and it can cater the water from runoff for at least 50 years.

4.4 PROPOSE MITIGATION METHOD: DETENTION POND.

From the storm water control proposal, it has proposed that to build a detention pond to mitigate the pumped water form open pit of the quarry to the surface water. It is because the pond can be used as treatment plant and to control the discharge pumped water.

The treatment required in the detention pond is depends on the level of pollutant from underground water. Initially, it is believed that the underground water has mixed with limestone minerals and can cause increasing of water hardness. Hence, the designed detention pond should have a proper treatment process to reduce the water pollution.

Based on the analysis, the outflow of the detention pond must less than 0.296 m^3/s and its inflow is based on the size of the pond. The determination of detention pond size can be done in the future based on the underground water analysis. Below is the summary of detentions pond's characteristics in the area.

Table 5: Characteristics of detention pond

Characteristics	Value
Water Discharge Inflow	Depends on pond's size
Water Discharge Outflow	$<0.296\ m^3/s$

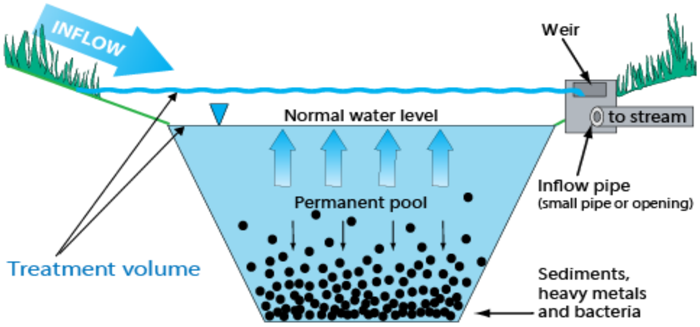


Figure 43: The Illustration of Detention Pond

CONCLUSIONS

It shows that the quarry activity does not give a significant impact to the water quality of surface water based on the analysis. Three parameters of water quality index such as Total Suspended Solid, Dissolved Oxygen Concentration and pH Value has been classified in class I and II which is the water can be used and only need minor treatment if required.

Besides that, the current analysis of Hydraulics and Hydrology parameters show that the surface water can cater the flow from runoff discharge for 50 years ARI.

In the future, the project will continue to analyse water quality and flow of underground water at the study area. The continuation of the study will have adequate data in designing detention pond.

Based on the detention pond proposal, it suggest that the quarry operator need to control inflow and outflow of the detention pond to make sure that the surface water not overflow to the nearby area.

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APPENDICES

Water Quality Assessment's Results

Total Suspended Solid (mg/l)

Table 1: Total Suspended Solids (mg/l)

Points of Samples	Date of Trips								Mean	Class
	24.5.17	3.6.17	10.6.17	8.7.17	18.7.17	8.8.17	15.8.17	24.8.17		
P1	48	24	83	18	35	58	89	117	59	II
P2	39	23	34	23	7	45	60	104	42	
P3	20	17	27	13	15	46	60	90	36	
P4	29	15	21	11	ND	36	ND	ND	22	
P5	15	47	13	19	ND	37	ND	ND	26	
P6	19	21	8	16	7	42	54	78	31	
P7	25	13	15	12	ND	28	43	58	28	
P8	ND	64	19	15	15	87	46	50	42	
P9	ND	33	11	7	22	62	52	51	34	
P10	ND	24	21	14	32	78	46	62	40	

Turbidity (NTU)

Table 2: Turbidity Reading (NTU)

Points of Samples	Date of Trips								Mean
	24.5.17	3.6.17	10.6.17	8.7.17	18.7.17	8.8.17	15.8.17	24.8.17	
P1	1.06	3.41	ND	1.99	1.71	2.25	2.8	18.9	4.58
P2	1	12.01	ND	2.69	8.56	26.4	6.9	11.8	9.9
P3	35.6	18.2	ND	2.6	9.49	21.9	5.2	1.4	13.48
P4	53.8	5.34	ND	5.28	ND	8	ND	ND	18.11
P5	21.3	16.22	ND	6.16	ND	2.5	ND	ND	11.55
P6	20	15.03	ND	9.42	7.55	14.57	11.95	36.5	16.43
P7	6.5	8.56	ND	6.41	ND	2.2	6.45	ND	6.02
P8	ND	5.63	ND	9.5	25	36.5	17.7	15.2	18.26
P9	ND	9.83	ND	10.4	12.2	47.4	40.2	12.3	22.05
P10	ND	22.53	ND	14.53	34.35	21.95	33.65	42.3	28.39

Colour

Table 3: Colour Reading

Points of Samples	Date of Trips								Mean
	24.5.17	3.6.17	10.6.17	8.7.17	18.7.17	8.8.17	15.8.17	24.8.17	
P1	51	59.5	ND	73.5	64.5	87.5	54.5	47.5	62.57
P2	42.6	63.5	ND	71	80	76.5	57.5	19	58.59
P3	287.3	71	ND	74	80	44	55	11	88.9
P4	229	87	ND	93.5	ND	36	ND	ND	111.3
P5	172.5	151	ND	77.5	ND	62.5	ND	ND	115.9
P6	186.5	220	ND	96	ND	300	47.5	5	142.5
P7	175.5	66	ND	73.5	ND	132.5	56.5	7	85.2
P8	ND	31.5	ND	90	ND	129	73.5	10.5	66.9
P9	ND	71	ND	97.5	ND	179.5	66	10.5	84.9
P10	ND	141.5	ND	103	ND	151	75.5	3	94.8

pH Reading

Table 4: pH Reading

Points of Samples	Date of Trips								Mean	Class
	24.5.17	3.6.17	10.6.17	8.7.17	18.7.17	8.8.17	15.8.17	24.8.17		
P1	ND	ND	6.83	7.09	7.29	6.66	6.85	7.06	6.96	I
P2	ND	ND	6.83	7.2	6.98	7.14	7.03	7.23	7.07	
P3	ND	ND	6.88	7.17	6.72	7.22	7.55	7.56	7.18	
P4	ND	ND	7.31	7.51	ND	7.54	ND	ND	7.45	
P5	ND	ND	7.64	7.6	ND	7.29	ND	ND	7.51	
P6	ND	ND	7.28	7.51	7.29	7.91	7.69	7.41	7.52	
P7	ND	ND	6.88	7.05	ND	7.17	7.52	ND	7.16	
P8	ND	ND	7.38	7.35	7.4	7.16	7.39	7.27	7.33	
P9	ND	ND	7.42	7.31	7.46	7.3	7.45	7.9	7.47	
P10	ND	ND	7.22	7.3	7.32	7.62	7.14	7.59	7.37	

Conductivity (µS/m)

Table 5: Conductivity (µS/m)

Points of Samples	Date of Trips								Mean
	24.5.17	3.6.17	10.6.17	8.7.17	18.7.17	8.8.17	15.8.17	24.8.17	
P1	ND	ND	521	446	503	295	510	536	469
P2	ND	ND	498	367	587	659	507	540	526
P3	ND	ND	494	114	524	558	517	533	457
P4	ND	ND	500	ND	ND	550	ND	ND	525
P5	ND	ND	475	145	ND	559	ND	ND	393
P6	ND	ND	298	140	336	362	374	529	339
P7	ND	ND	184	142	ND	485	363	ND	293
P8	ND	ND	144	ND	537	429	388	585	416
P9	ND	ND	ND	141	541	361	388	530	392
P10	ND	ND	ND	142	542	362	396	560	400

Dissolved Oxygen Saturation (%)

Table 6: Dissolved Oxygen Saturation (%)

Points of Samples	Date of Trips								Mean
	24.5.17	3.6.17	10.6.17	8.7.17	18.7.17	8.8.17	15.8.17	24.8.17	
P1	ND	ND	98.9	5.7	109.4	ND	14.7	91.4	64.02
P2	ND	ND	46.05	39.75	94.7	ND	11.65	41.8	46.79
P3	ND	ND	51.9	60.3	60.9	ND	7.1	ND	45.05
P4	ND	ND	82.6	73.8	ND	ND	ND	ND	78.2
P5	ND	ND	83.4	41.4	ND	ND	ND	ND	62.4
P6	ND	ND	72.1	61.65	141.6	ND	16.6	34.7	65.33
P7	ND	ND	83.2	71.15	ND	ND	11.15	ND	55.17
P8	ND	ND	85.2	74.3	161.2	ND	11.1	41.7	74.7
P9	ND	ND	106.2	75.15	107.45	ND	11.8	36.6	67.44
P10	ND	ND	77.35	88.75	131.65	ND	12.9	41.4	70.41

Dissolved Oxygen Concentration (mg/l)

Table 7: Dissolved Oxygen Concentration (mg/l)

Points of Samples	Date of Trips								Mean	Class
	24.5.17	3.6.17	10.6.17	8.7.17	18.7.17	8.8.17	15.8.17	24.8.17		
P1	ND	ND	7.85	ND	8.66	1.65	1.19	7.26	5.32	II
P2	ND	ND	3.67	ND	7.31	4.48	0.95	3.32	3.95	
P3	ND	ND	4.14	ND	4.83	3.05	0.58	ND	3.15	
P4	ND	ND	6.53	ND	ND	2.74	ND	ND	4.64	
P5	ND	ND	6.66	ND	ND	2.86	ND	ND	4.76	
P6	ND	ND	5.58	ND	10.87	3.28	1.32	2.74	4.76	
P7	ND	ND	6.49	ND	ND	3.24	0.87	ND	3.53	
P8	ND	ND	6.67	ND	11.74	2.69	0.86	3.24	5.04	
P9	ND	ND	8.36	ND	7.85	3.08	0.93	2.85	4.61	
P10	ND	ND	6.11	ND	9.9	3.84	1.01	3.26	4.82	

Stream Profiling Results

Table 8: Stream Profiling on 24/5/17 and 3/6/17

Points	**Depth**			**Width**
	Left	**Middle**	**Right**	
P1a	0.29	0.315	0.21	0.67
P1b	0.25	0.38	0.265	
P2a	0.38	0.45	0.47	
P3a	1.3	1.25	1.05	0.715
P3b	0.51	0.5	0.49	0.52
P4a	0.175	0.23	0.245	
P4b	0.48	0.47	0.25	
P5a	0.06	0.25	0.07	
P5b	0.2	0.24	0.2	0.49
P6a	0.25	0.25	0.25	3
P6b	0.32	0.29	0.3	
P7a	0.25	0.21	0.32	3.1
P7b	0.5	0.75	0.62	
P8a	0.2	0.2	0.2	5.6
P8b	0.2	0.2	0.2	

Points	**Depth**		
	Left	**Middle**	**Right**
P1a		0.2	
P2a	0.28	0.4	0.31
P2b		0.29	
P4a	0.66	0.88	0.99
P5a	0.55	0.6	0.55
P6a	0.2	0.28	0.15
P6b	0.15	0.17	0.16
P7a	0.1	0.11	0.11
P7b	0.3	0.25	0.18
P8a	0.25	0.2	0.2
P8b	0.28	0.28	0.25
P9a	0.25	0.3	0.32
P9b	0.65	0.65	0.6

Table 9: Stream Profiling on 8/7/17 and 18/7/17

Points	Depth		
	Left	**Middle**	**Right**
P1a	0.04	0.08	0.07
P2a	0.35	0.4	0.35
P4a	0.6	0.5	0.5
P5a	0.16	0.16	0.14
P6a	0.35	0.4	0.3
P6b	0.64	0.56	0.48
P7a	0.018	0.25	0.025
P7b	0.19	0.03	0.03
P8a	0.02	0.02	0.02
P8b	0.025	0.025	0.02
P9a	0.07	0.08	0.1
P9b	0.22	0.21	0.19

Points	Depth		
	Left	**Middle**	**Right**
P6a	0.29	0.4	0.35
P6b	0.48	0.48	0.46
P8a	0.2	0.2	0.2
P8b	0.25	0.25	0.25
P9a	0.3	0.2	0.15
P9b	0.65	0.6	0.65

Table 10: Stream Profiling on 15/8/17

Points	**Depth**		
	Left	**Middle**	**Right**
P1a	0.34	0.38	0.23
P1b	0.37	0.46	0.28
P2a	0.46	0.5	0.5
P2b	0.3	0.5	0.3
P6a	1.18	1.41	1.41
P6b	0.2	0.2	0.21
P7a	0.38	0.4	0.35
P7b	0.24	0.31	0.25
P8a	0.24	0.34	0.19
P8b	0.22	0.23	0.22
P9a	0.2	0.21	0.29
P9b	0.71	0.68	0.59

Velocity of Surface Water Results

Table 11: Velocity of Surface Water on 24/5/17

Points	Flow Meter Reading			V (cm/s)			V (m/s)			Average Velocity (m/s)
	Left	Middle	Right	Left	Middle	Right	Left	Middle	Right	
P1a	4	9	0	0.0231812	0.0335678	0.0152676	0.00023181	0.000335678	0.000152676	0.000240055
P1b	4	33	10	0.0231812	0.0825332	0.0355462	0.00023181	0.000825332	0.000355462	0.000470869
P2a	5	7	4	0.0256542	0.0293637	0.0231812	0.00025654	0.000293637	0.000231812	0.000260664
P2b	0	33	0	0.0152676	0.0825332	0.0152676	0.00015268	0.000825332	0.000152676	0.000376895
P3a	0	7	0	0.0152676	0.0293637	0.0152676	0.00015268	0.000293637	0.000152676	0.000199663
P4a	47	36	31	0.1107254	0.0887157	0.0783291	0.00110725	0.000887157	0.000783291	0.000925901
P4b	16	20	17	0.0476639	0.0563194	0.0501369	0.00047664	0.000563194	0.000501369	0.000513734
P5a	51	77	29	0.1193809	0.1642608	0.0746196	0.00119381	0.001642608	0.000746196	0.001194204
P5b	49	33	15	0.1149295	0.0825332	0.0459328	0.0011493	0.000825332	0.000459328	0.000811318
P6a	27	55	12	0.0704155	0.1154688	0.0397503	0.00070416	0.001154688	0.000397503	0.000752115
P6b	0	40	24	0.0152676	0.0966293	0.064233	0.00015268	0.000966293	0.00064233	0.0005871
P7a	49	50	32	0.1149295	0.1174025	0.0808021	0.0011493	0.001174025	0.000808021	0.00104378
P7b	56	36	15	0.1180368	0.0887157	0.0459328	0.00118037	0.000887157	0.000459328	0.000842284

Table 12: Velocity of Surface Water on 3/6/17

Points	Flow Meter Reading			V (cm/s)			V (m/s)			Average Velocity (m/s)
	Left	Middle	Right	Left	Middle	Right	Left	Middle	Right	
P1a	2	5	5	0.0189771	0.0256542	0.0256542	0.00018977	0.000256542	0.000256542	0.000234285
P1b	0	13	13	0.0152676	0.0417287	0.0417287	0.00015268	0.000417287	0.000417287	0.000329083
P2a	9	4	10	0.0335678	0.0231812	0.0355462	0.00033568	0.000231812	0.000355462	0.000307651
P2b	0	27	0	0.0152676	0.0704155	0.0152676	0.00015268	0.000704155	0.000152676	0.000336502
P6a	27	17	17	0.0704155	0.0501369	0.0501369	0.00070416	0.000501369	0.000501369	0.000568964
P6b	5	17	25	0.0256542	0.0501369	0.0662114	0.00025654	0.000501369	0.000662114	0.000473342
P7a	49	50	32	0.1149295	0.1174025	0.0808021	0.0011493	0.001174025	0.000808021	0.00104378
P7b	56	36	15	0.1180368	0.0887157	0.0459328	0.00118037	0.000887157	0.000459328	0.000842284
P8a	29	56	47	0.0746196	0.1180368	0.1114673	0.0007462	0.001180368	0.001114673	0.001013746
P8b	29	56	47	0.0746196	0.1180368	0.1114673	0.0007462	0.001180368	0.001114673	0.001013746
P9a	21	25	16	0.0580505	0.0662114	0.0476639	0.00058051	0.000662114	0.000476639	0.000573086
P9b	7	29	7	0.0293637	0.0746196	0.0293637	0.00029364	0.000746196	0.000293637	0.00044449

Table 13: Velocity of Surface Water on 18/7/17

Poi nts	Flow Meter Value			V (cm/s)			V (m/s)			Average Velocity (m/s)
	Le ft	**Mid dle**	**Rig ht**	**Left8**	**Middl e**	**Right**	**Left**	**Middle**	**Right**	
P4b		10		0.035 546	0.0355 462	0.0152 676	0.0003 555	0.00035 5462	0.00015 2676	0.000287867
P8a	33	37	0	0.082 533	0.0904 468	0.0152 676	0.0008 253	0.00090 4468	0.00015 2676	0.000627492
P8b	30	20	0	0.076 598	0.0563 194	0.0152 676	0.0007 66	0.00056 3194	0.00015 2676	0.00049395
P9a	14	19	13	0.044 202	0.0538 464	0.0417 287	0.0004 42	0.00053 8464	0.00041 7287	0.000465923
P9b	30	28	30	0.076 598	0.0721 466	0.0765 98	0.0007 66	0.00072 1466	0.00076 598	0.000751142

Table 14: Velocity of Surface Water on 8/8/17

Points	Flow Meter Value			V (cm/s)			V (m/s)			Average Velocity (m/s)
	Left	Middle	Right	Left	Middle	Right	Left	Middle	Right	
P1a	0	5	0	0.0152676	0.0256542	0.0152676	0.000152676	0.000256542	0.000152676	0.000187298
P1b	0	7	0	0.0152676	0.0293637	0.0152676	0.000152676	0.000293637	0.000152676	0.000199663
P2a	3	8	14	0.0214501	0.0318367	0.0442017	0.000214501	0.000318367	0.000442017	0.000324962
P6a	15	24	25	0.0459328	0.064233	0.0662114	0.000459328	0.00064233	0.000662114	0.000587924
P6b	3	4	3	0.0214501	0.0231812	0.0214501	0.000214501	0.000231812	0.000214501	0.000220271
P7a	36	31	14	0.0887157	0.0783291	0.0442017	0.000887157	0.000783291	0.000442017	0.000704155
P7b	19	35	33	0.0538464	0.0869846	0.0825332	0.000538464	0.000869846	0.000825332	0.000744547
P8a	33	38	0	0.0825332	0.0929198	0.0152676	0.000825332	0.000929198	0.000152676	0.000635735
P8b	38	28	0	0.0929198	0.0721466	0.0152676	0.000929198	0.000721466	0.000152676	0.000601113
P9a	23	24	20	0.0625019	0.064233	0.0563194	0.000625019	0.00064233	0.000563194	0.000610181
P9b	21	22	23	0.0580505	0.0600289	0.0625019	0.000580505	0.000600289	0.000625019	0.000601938

Table 15: Velocity of Surface Water on 15/8/17

Points	Flow Meter Value			V (cm/s)			V (cm/s)			Average Velocity (m/s)
	Left	Middle	Right	Left	Middle	Right	Left	Middle	Right	
P1b	21	30	23	0.058051	0.076598	0.062502	0.000581	0.000766	0.000625	0.000657
P2a	16	23	9	0.047664	0.062502	0.033568	0.000477	0.000625	0.000336	0.000479
P2b	9	99	9	0.033568	0.476	0.033568	0.000336	0.00476	0.000336	0.00181
P6a	15	21	10	0.045933	0.058051	0.035546	0.000459	0.000581	0.000355	0.000465
P6b	10	15	30	0.035546	0.045933	0.076598	0.000355	0.000459	0.000766	0.000527
P7a	64	23	15	0.476	0.062502	0.045933	0.00476	0.000625	0.000459	0.001948
P7b	64	25	12	0.146584	0.066211	0.03975	0.001466	0.000662	0.000398	0.000842
P8a	40	45	24	0.094898	0.107016	0.064233	0.000949	0.00107	0.000642	0.000887
P8b	30	44	15	0.076598	0.105285	0.045933	0.000766	0.001053	0.000459	0.000759
P9a	35	41	38	0.086985	0.099102	0.09292	0.00087	0.000991	0.000929	0.00093
P9b	15	21	25	0.045933	0.058051	0.066211	0.000459	0.000581	0.000662	0.000567