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Identification of Dam Site Based on Inundated Area of Forest Ecosystem in Bengoh Catchment

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ABSTRACT

The proposed Bengoh Dam which is located at Bungoh catchment with the latitude between 1.184° to 1.296° N and in longitude between 110.106° to 110.242° E . The dam is designed to operate as a water reservoir dam for meeting the long-term water supply need of Kuching City and its vicinities. The catchment of the proposed Bengoh Dam is approximately 127km^2. The construction of this dam is expected to inundate an area of approximately 8.77 km^2. The entirely Bengoh Catchment is constitutes of primary forest, old secondary forest, young secondary forest and agroforestry. Using the application of GIS, the vegetation within the dam layout was delineated leading to the determining of the area cover by the respective vegetation cover such as primary forest, young secondary forest, old secondary forest and agroforestry. In this study the inundated area was quantified by taken into consideration the contour that marks the reservoir maximum level which is 80 meters above sea level. Five alternative of Dam site are being proposed. Alternative 1 exhibits the highest percentage of submerge area which is 59.962% followed by alternative 3 (36.080%). Alternative 2 causes 33.921% inundated area while alternative 5 contributes 30.592%. Alternative 4 indicate 28.188% area being submerged which is the least among all the five alternatives. The least area being submerged is considered to be the most appropriate site for the dam.

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I. INTRODUCTION

Dams are built for multiple purposes which include providing water for irrigated agriculture, domestic and industrial consumption as well as providing alternative for meeting energy needs and supporting economic development. Statistic from the Department of Water Supply Malaysia (2012) shows that 80 dams being built throughout Malaysia and majority of the hydropower dams are located in State of Sarawak. Despite the importance of dams in promoting the betterment of human kind the existing of dams posed adverse impact to terrestrial ecosystems and biodiversity. The inundated of the reservoir cause direct impact in terms of ecosystem loss, ecosystem fragmentation and land degradation. However, the ecosystem loss and the ecosystem fragmentation can be reduced if the appropriate site is being identified prior to the construction of dams.

The proposed Bengoh Dam is designed to operate as a water reservoir dam for meeting the long-term water supply need of Kuching City and its vicinities. The catchment of the proposed Bengoh Dam is approximately 127 km2 or one quarter the size of the entire Sg. Sarawak Kiri catchments. The construction of this dam is expected to inundate an area of approximately 8.77 km². A large part of the basin is covered by secondary or regenerated forest or barren ground and secondary forests are mainly the fallows of shifting cultivation. The hill slopes are cultivated with hill paddy, fruit trees and permanent cash crops such as rubber and cocoa.

This study proposes to address all the ecosystems living within the boundary of the study area. Four types of forest ecosystem are considered in this study. These include the primary forest, old secondary forest, young secondary and agroforestry. Geneletti (2002) states that the most common method for mapping ecosystems consist of mapping the vegetation types. This indicates that vegetation communities are considered a representative for delimiting the boundaries of ecosystem units. This assumption is justified by the fact that vegetation communities typically show a strong relationship with both their physical environment and the organisms they act upon. Moreover, vegetation mapping represents a feasible alternative to carry out a truly complete biodiversity survey. As a result, it is widely held that vegetation cover types can be used as surrogate for the ecosystems in which they participate and represent typical stating point of ecological evaluation.

In this study the inundated area was quantified by taken into consideration the contour that marks the reservoir maximum level which is 80 meters above sea level. Five alternative of Dam site are being proposed. The least area being submerged is considered to be the most appropriate site for the dam.

ISSN No:-2456-2165

II. MATERIALS AND METHOD

A. Study area

The study was carried out at the Bengoh catchment which is a segment of Sarawak Kiri River catchment areas and upstream of Bengoh Dam. It is located in latitude between 1.184° to 1.296° N and in longitude between 110.106° to 110.242° E and 60 km from Kuching, the capital of Sarawak (Figure 1). The catchment covers an area of approximately 127 square kilometres. The altitude ranges from 20m to 1300 m a.s.l. There are Bidayuh villages within the Bengoh catchment, namely Kampung Pain Bujung, KampungSemban, KampungTabaSait and Kampung Rejoi. The four villages have a total of 190 heads of households (Table 1). A nearby village, KampungBengoh is located outside the catchment area. Kpg. TabaSait and Kpg. Pain Bojong are situated below 60 m.a.s.l. and 70 m.a.s.l respectively. Both villages will be inundated when the dam is flooded up to 80m based on the Full Supply Level (EIA report 2008). Kpg. Rejoi is located between 80 m.a.s.l and 90 m a.s.l and usually inundated during major flood events.

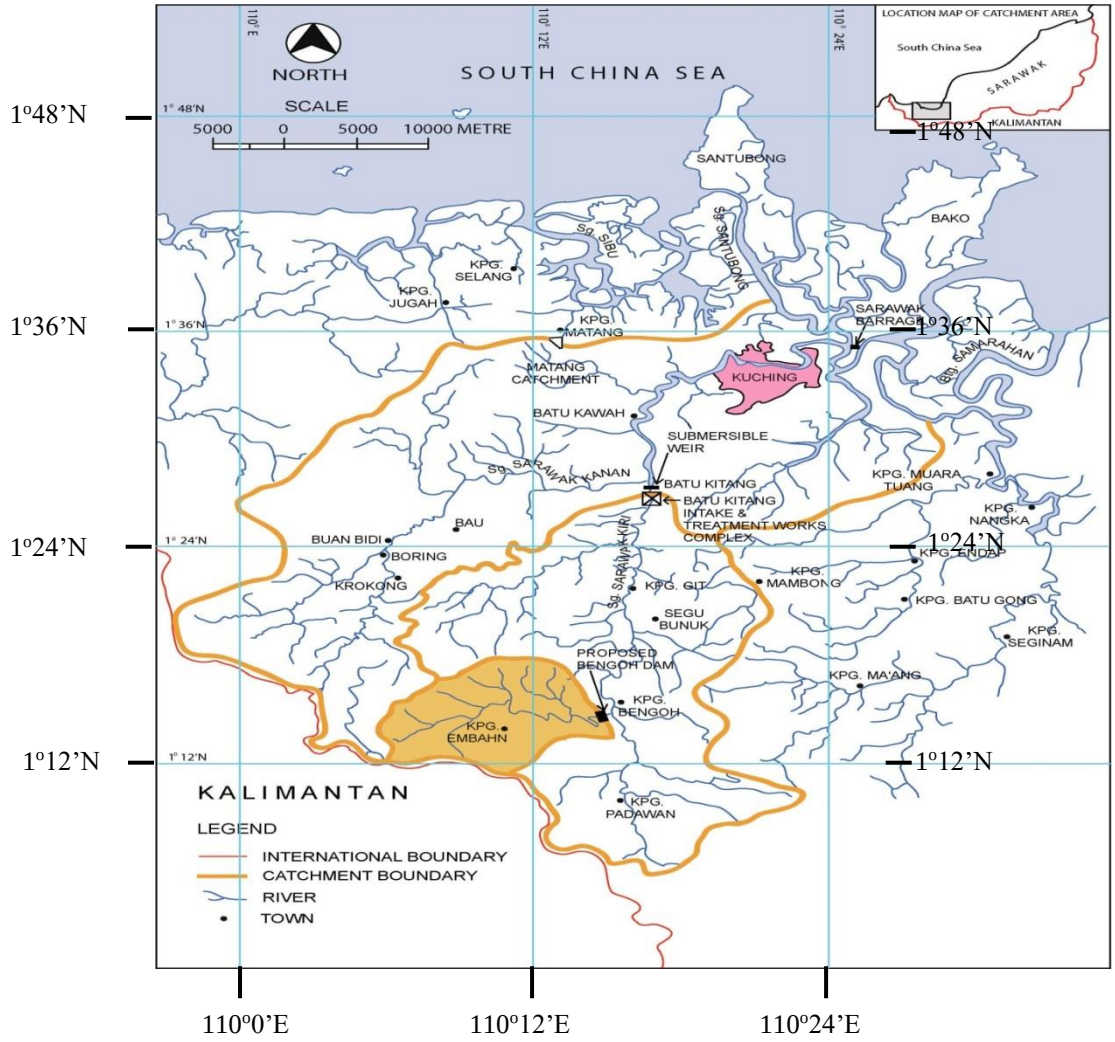


Fig 1:- Locality of Bengoh Catchment area

ISSN No:-2456-2165

The proposed alternatives dam site are located on the Bengoh river. The catchment area of Bengohriver is 127 km^2 which represent only approximately 8 % of the total catchment of the Sarawak Kiri river at Kuching. (Table 1).

Name of River	Catchment area(km^2)
Sg. Bengoh	127 km^2
Sg. Semadang	28 km^2
Sg. Sarawak Kiri	440 km^2

Table 1. Catchment area for the major rivers

The upper river basin of Bengoh river is steep while the lower basin is relatively flat. Bengoh River has three tributaries namely the Toen River, Teka River and EmbahnRiver. The tributaries meet just downstream of Bengoh River. Onwards from the convergence of the tributaries, Bengoh River meanders through a flood plain before joining Semandang River to form Sarawak Kiri River (Figure 2.). The Bengoh tributary rises from the Bengoh range. There are various manmade structures spanning across and along the Bengoh River serving various purposes. These structures have altered the natural river flow and consequently the morphological development as well.

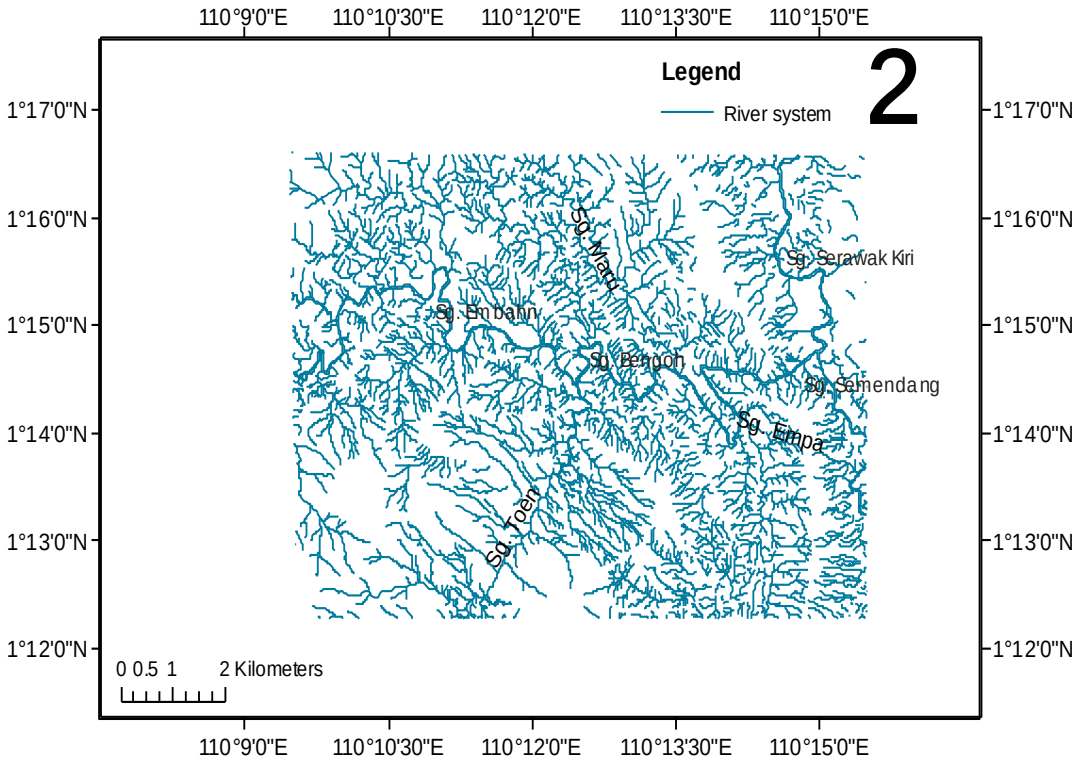


Fig 2:- River system of Bengoh catchment

The forest ecosystem constitutes of primary forest, old secondary forest, young secondary forest and agroforestry.Nakagawa et al (2006) and Kishimoto et al (2011) have classified forest type based on characteristics of spatial structure such as canopy openness, tree basal area, tree density, tree species richness and distance to primary forest. According to Nakagawa et al (2006) and Kishimoto et al (2011), old secondary forest (>20 years) did not exhibit any obvious differences in spatial structure whereas the young secondary forest exhibit high canopy openness. The climate is equatorial type with warm and humid weather throughout the year; and annual rainforest of the area is approximately 3.990 mm/year with a high proportion falling during the North West monsoon season from November to February. The driest period

ISSN No:-2456-2165

occurs from June to August. The mean temperature is approximately 26.6°C and means relative humidity is around 85.3%. The wind pattern in this area generally shows relatively calm condition with 33.9% of the time with wind blowing and light breezes recorded for 42% of the time.

B. Field sampling and measurement of biodiversity

A survey was carried out by the single plot method in all the four major forest ecosystem of Bengoh catchment. The same plot design and a systematic line sampling was employed in this study. A total of 14 sampling plots were establish The main plot was designed to be (20 m x 20 m) which included four subplots (10 m x 10 m) inside the main plot (Figure 3). The single plot method 20 × 20 m (400 m^2) plots have emerged as the standard plot size and is currently the most widely applied of all vegetation plot methodologies (Hurst and Allen 2007, Almendinger 2013). In using this method, three assumptions are being considered. Those assumptions include all individuals within the plots and seedling subplots are observable and counted, the precise area (m^2) being measured remains constant between surveys and the plot is representative of the vegetation community of interest (Hurst and Allen 2007).

The first field survey was conducted on the 1 February 2011 and 2 February 2011. The second field survey was conducted on the 27 April 2011 until 29 April 2011. The third field survey was conducted from the 7 August 2011 to 8 August 2011.

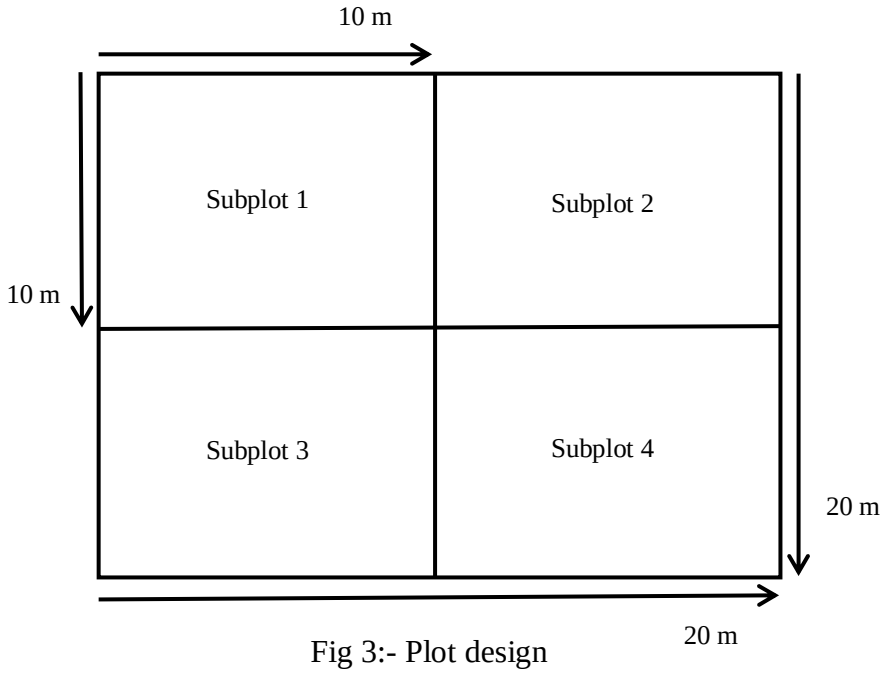


Fig 3:- Plot design

For the purpose of this study, the equipments and meterials such as nylon ribbons, diameter tape, Suunto clinometer, measuring tape, data recording sheets, and Global Positioning System (GPS) device were applied for the data collection. The forest area under study is first delimited precisely by using the Landsat TM image, topographic and aerial photos of the area. During the field work, the main plot was established by tying a nylon ribbon to trees above breast height to mark the four conners of the main plot. Consequently the coordinates for each plot was established using the Geographical Positioning System (GPS) as shown in Table 2.

ISSN No:-2456-2165

Forest ecosystem type	Sampling site	Location	
		Latitude	Longitude
YSF	1	110°13'58.08"E	1°14'23.99"N
YSF	2	110°14'02.39"E	1°14'27.06"N
AF	3	110°14'05.99"E	1°14'28.49"N
YSF	4	110°12'32.03"E	1°14'32.39"N
OSF	5	110°12'29.52"E	1°14'29.78"N
OSF	6	110°12'26.64"E	1°14'13.99"N
OSF	7	110°12'25.92"E	1°13'39.39"N
AF	8	110°11'41.99"E	1°14'45.59"N
YSF	9	110°11'20.39"E	1°14'56.04"N
OSF	10	110°11'34.79"E	1°15'02.00"N
AF	11	110°12'38.15"E	1°14'39.09"N
OSF	12	110°10'45.84"E	1°15'39.99"N
PF	13	110°13'40.79"E	1°15'39.99"N
OSF	14	110°11'45.59"E	1°14'49.99"N

Table 2. Plots location and forest types

Figure 4 indicates the sampling locations where the floristic data for the forest ecosystem of Bengoh catchment being collected.

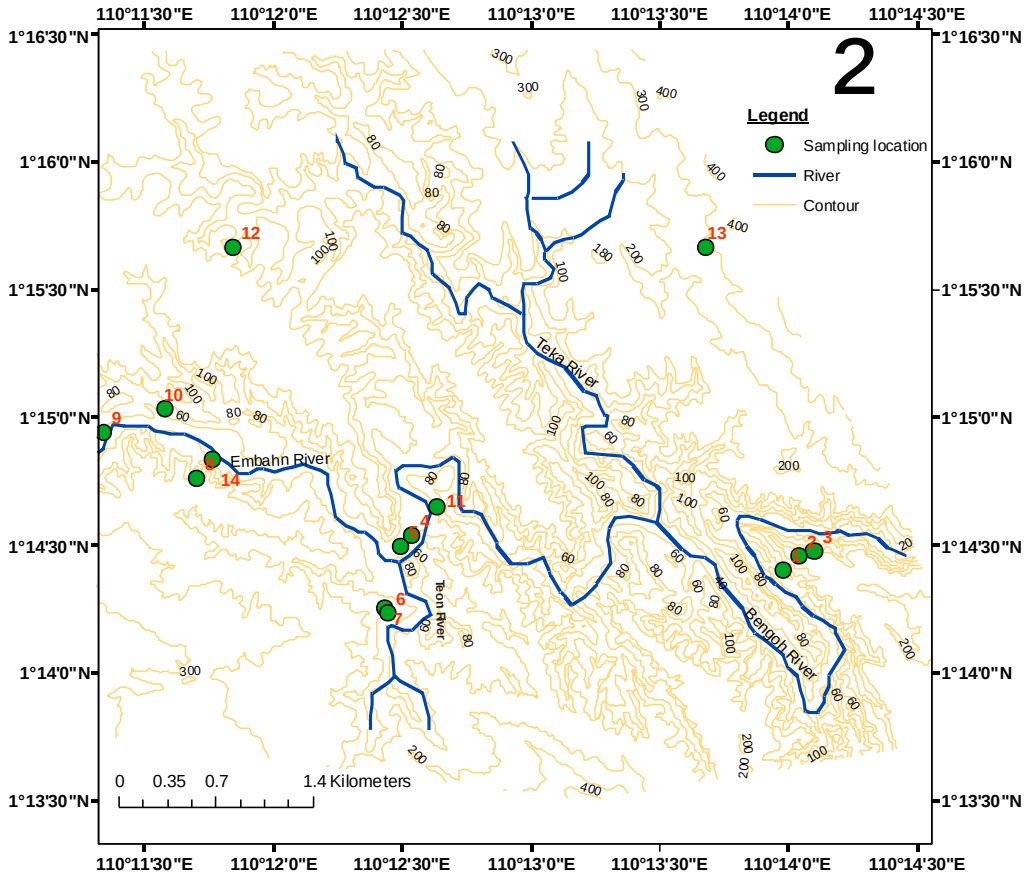


Fig 4:- Sampling Locations

ISSN No:-2456-2165

In each quadrate, the parameters recorded during the vegetation survey included circumference (diameter at breast height, DBH ≥5 cm), trees height, type of forests ecosystem and plant species. In this study the DBH of a trees which had a minimum diameter of 4 cm or, equivalently, a minimum circumference of 12.5 cm was measured (Mitchell 2010). Brokaw and Thompson (2000) state that it is important to use the same height to measure the diameter or circumference.All terrestrial plant species encountered during field survey were identified and when it was impossible to do so, the voucher specimens were collected and identified in the herbarium and a list of plant species that occurred within the study boundary were compiled.

C. Proposed alternatives dam site

There is no alternatives dam site has been officially proposed prior to this research. However, for the purpose of this research, five dam alternatives were constructed. All the five alternatives share the main characteristics such as high, storage capacity, saddle dams, embankment zone, cofferdams and diversion channels, spillway and its control structures, outlet and intake towers, and the ancillary structures. However, there is no structural design of dam has been defined. The preparation of site and the construction of dam post the most potential destructive to the environment due to the fact that it involves a complete conversion of land use from a highly cover with vegetation to a bare area. During the site clearing and earthwork, the vegetation were removed and posed adverse impact on biodiversity. The bare soil not only expose soil to excessive weathering but also cause severe soil erosion as the ridges on both side of the river being cleared. As a result, the selection of the proposed five alternative dam sites take into consideration the existing vegetation cover of the land used.

The proposed site is preferable where the area are dominated by young secondary forest and existing disturbances such as shifting cultivation plots as well as selective logging activities to reduce the significant conversion or degradation of critical natural habitats and hence reduce the significance loss of biodiversity. In order to select the proposed alternative dam site, the land take of the dam layout is selected approximately 0.1983 km^2. The land take for the dam layout includes the main dam, saddle dam, embankment zone, cofferdams and diversion channels, spillway and its control structures, outlet and intake towers, and the ancillary structures. The land take for the dam layout was being limited to approximately 0.1983 km^2 to minimize the environmental disturbances. Using the application of GIS, the vegetation within the dam layout was delineated leading to the determining of the area cover by the respective vegetation cover such as primary forest, young secondary forest, old secondary forest and agroforestry. Subsequently the percentage of the respective vegetation cover was than calculated using the following equation.

$$Vc = \frac{Ai}{\sum Aj}$$

Where
Vc = percentage of vegetation cover
Ai = area occupy by respective vegetation
Aj = total land take of the dam layout

Another factor that is considered in the selection of the proposed dam sites is that the project must be sited at the area where there is no archaeological or historical and cultural site.This is to avoid the destruction of the historical sites that could cause sensitivity issues among the indigenous communities. Furthermore the destruction not only posed impacts on the immediate living alongside these monuments, but of entire generations. Table 3. indicates the characteristic of the proposed alternative dam sites.

ISSN No:-2456-2165

Alternative dam site	Location		Disturbances	Historical site
	Layout	Vegetation types		
A1	Situated across Bengoh River which is approximately 1.5 km upstream from the confluence of Sarawak Kiri River and Semadang River	Majority of the area cover by old secondary forest and scatter primary forest.	Selective logging	No
A2	Situated across Bengoh River which is approximately 2.6 km upstream from the confluence of Sarawak Kiri River and Semadang River	Cover with old secondary forest, young secondary forest, agroforestry and scatter primary forest.	No latest anthropogenic disturbances	No
A3	Situated across Bengoh River which is approximately 3.6 km upstream from the confluence of Sarawak Kiri River and Semadang River	Cover with young secondary forest and agroforestry.	No latest anthropogenic disturbances	No
A4	Situated across Bengoh River which is approximately 4.8 km upstream from the confluence of Sarawak Kiri River and Semadang River	Cover with old secondary forest and young secondary forest	Dominated by shifting cultivation plots.	No
A5	Situated across Bengoh River which is approximately 4.5 km upstream from the confluence of Sarawak Kiri River and Semadang River	Cover with old secondary forest, young secondary forest and agroforestry	Shifting cultivation plots	No

Table 3. Criteria for the proposed alternative dam site

D. Flooded area

Topographic map and contour map were needed in this study. First the contour map was converted into a triangulated irregular network (TIN) using the application of analyst tools in GIS. The contour that marks the reservoir maximum level was than selected which is 80 meters above sea level. In order to compute the flooded area, all the contour that is not linked to the actual dam surface must be closed. At this point, the selected contours were converted into polygon using Arc Toolbox in GIS. As the volume of the dam was not need in this study, only the inundated areas are being quantified and an inundated map was produced.

ISSN No:-2456-2165

III. RESULTS AND DISCUSSIONS

A. Alternative dam site in Bengoh catchment

Table 4. shows the location of the alternative dam site at Bengoh River. The alternatives dams site that are created are situated in the upper region of a Bengoh river basin where the terrain and narrow valley provide significant reservoir storage and surface area with sufficient volume upstream for a relatively small dam. The propose alternatives were based on the criteria stated on Table 5. Figure 5. illustrate the location and the dam layout as well as the contour lines.

Proposed dam site	Location	
	Latitude	Longitude
Dam Alternative 1	110°14’20.095” E	1°14’31.656”N
Dam Alternative 2	110°13’46.470”E	1°14’37.951”N
Dam Alternative 3	110°13’13.236”E	1°14’18.669”N
Dam Alternative 4	110°12’34.528”E	1°14’28.899”N
Dam Alternative 5	110°12’45.476”E	1°14’37.950”N

Table 4. Alternatives location of the dam

Alternative 1,the land take is approximately 0.1983 km^2. The dam layout is situated across Bengoh River which is approximately 1.5 km upstream from the confluence of Sarawak Kiri River and Semadang River and majority of the area covered by old secondary forest which constitutes 83.26%. and scatter primary forest(16.74%).

Aletrnative 2, the land take is approximately 0.1983 km^2. The dam layout is situated across Bengoh River which is approximately 2.6 km upstream from the confluence of Sarawak Kiri River and Semadang River and majority of the area cover with old secondary forest (63.94%). Other vegetation cover found in the area includes young secondary forest (31.11%), agroforestry (4.14%) and scatter primary forest (0.81%).

Alternative 3, the land take of the dam layout is approximately 0.1983 km^2. The dam layout is situated across Bengoh River which is approximately 3.6 km upstream from the confluence of Sarawak Kiri River and Semadang River. The area is densely covered by old secondary forest (83.81%) and scattered young secondary forest (10.19) are also found in this area. Agroforestry (6.00%) are found mainly at the river bank.

Alternative 4, the land take of the dam layout is approximately 0.1983 km^2. The dam layout is situated across Bengoh River which is approximately 4.8 km upstream from the confluence of Sarawak Kiri River and Semadang River and densely covered with young secondary forest (64.04%). The remaining area is covered by old secondary forest which constitutes 35.96%.

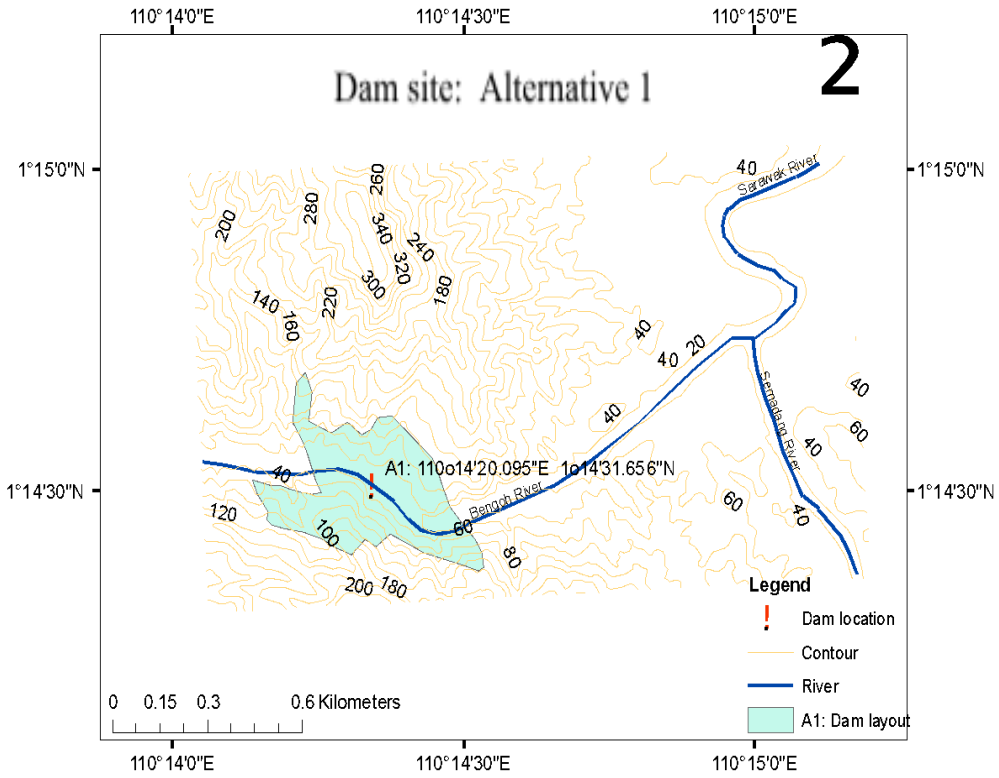
Alternative 5, the land take of the dam layout is approximately 0.1983 km^2. The dam layout is situated across Bengoh River which is approximately 4.5 km upstream from the confluence of Sarawak Kiri River and Semadang River and the area is mostly covered with old secondary forest (82.30%). Young secondary forest (3.58%) and agroforestry(14.12%) cover the riverine area.

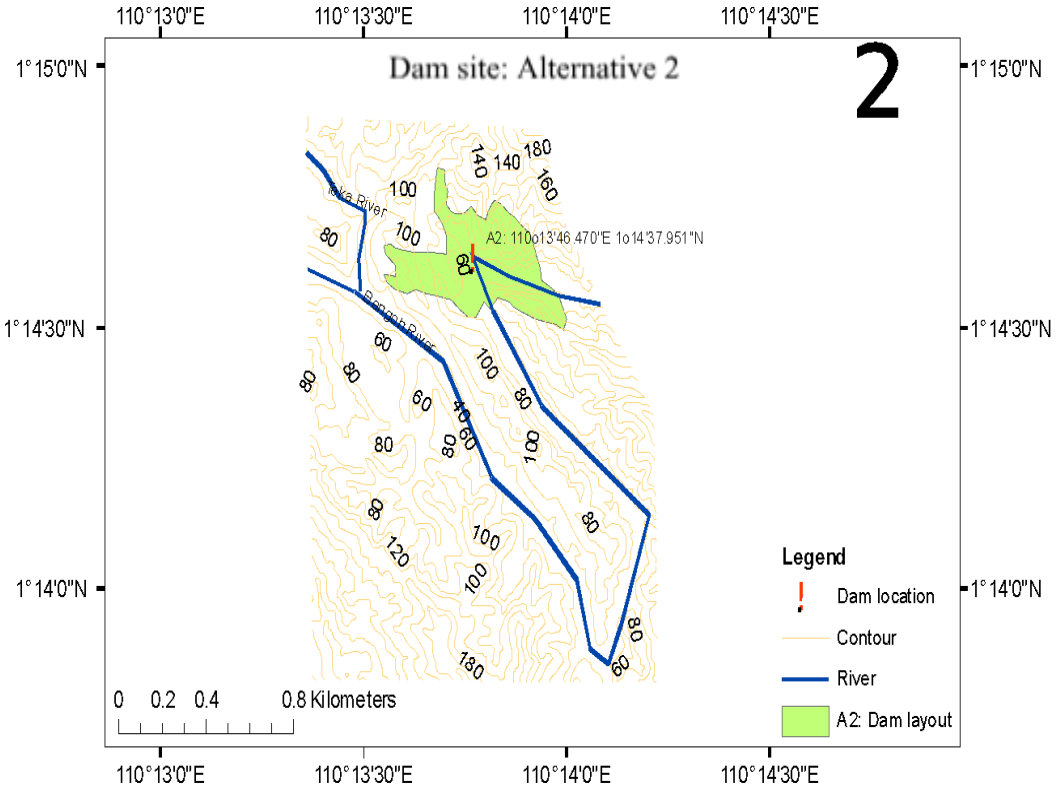
ISSN No:-2456-2165

Alternative dam site	Location		Disturbances	Historical site	Vegetation cover (%)			
	Layout	Vegetation types			PF	OSF	YSF	AF
A1	Situated across Bengoh River which is approximately 1.5 km upstream from the confluence of Sarawak Kiri River and Semadang River	Majority of the area cover by old secondary forest and scatter primary forest.	Selective logging	No	16.74	83.26	0.00	0.00
A2	Situated across Bengoh River which is approximately 2.6 km upstream from the confluence of Sarawak Kiri River and Semadang River	Cover with old secondary forest, young secondary forest, agroforestry and scatter primary forest.	No latest anthropogenic disturbances	No	0.81	63.94	31.11	4.14
A3	Situated across Bengoh River which is approximately 3.6 km upstream from the confluence of Sarawak Kiri River and Semadang River	Cover with old secondary forest, young secondary forest and agroforestry.	No latest anthropogenic disturbances	No	0.00	83.81	10.19	6.00
A4	Situated across Bengoh River which is approximately 4.8 km upstream from the confluence of Sarawak Kiri River and Semadang River	Cover with old secondary forest and young secondary forest	Dominated by shifting cultivation plots.	No	0.00	35.96	64.04	0.00
A5	Situated across Bengoh River which is approximately 4.5 km upstream from the confluence of Sarawak Kiri River and Semadang River	Cover with old secondary forest, young secondary forest and agroforestry	Shifting cultivation plots	No	0.00	82.30	3.58	14.12

Table 5. Criteria for the alternative dam site

ISSN No:-2456-2165





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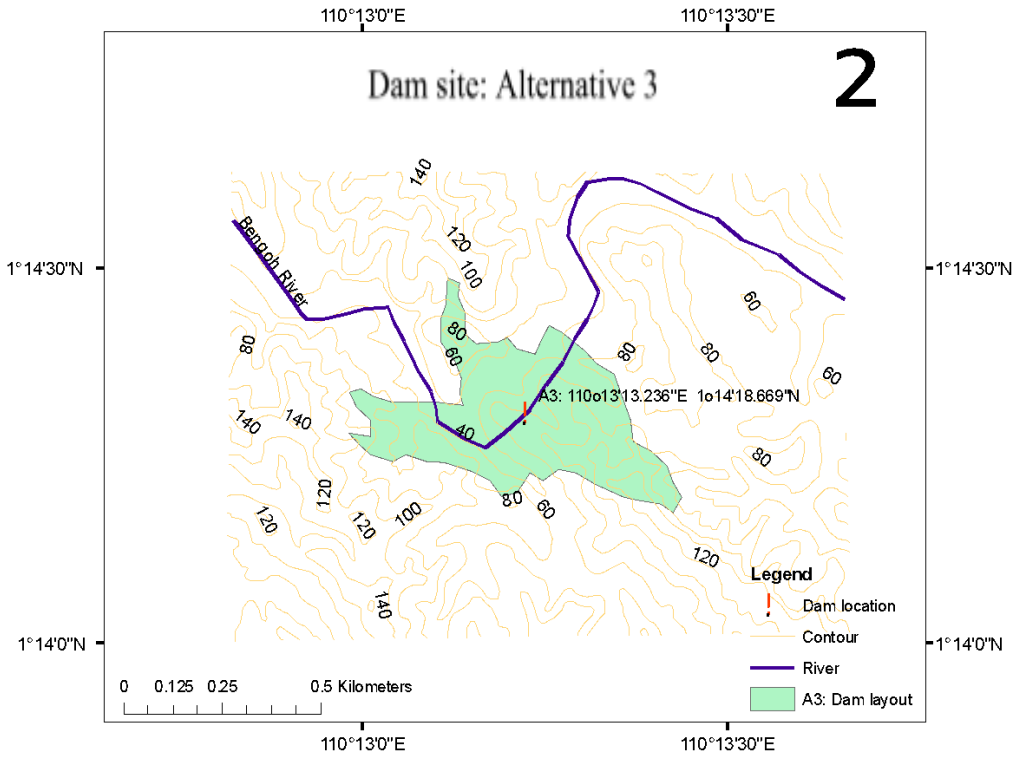

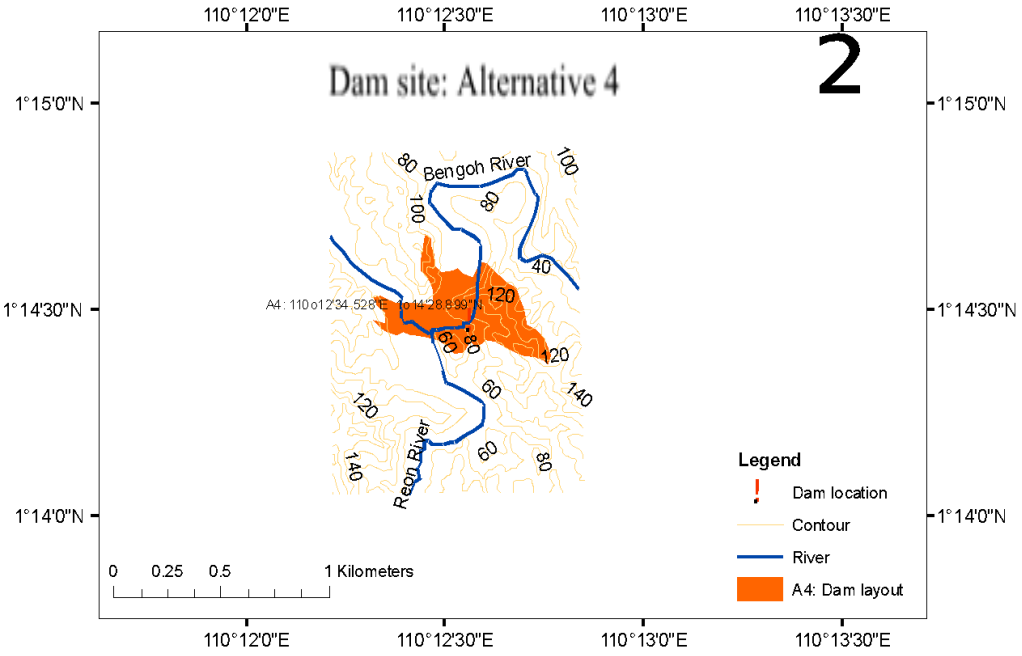

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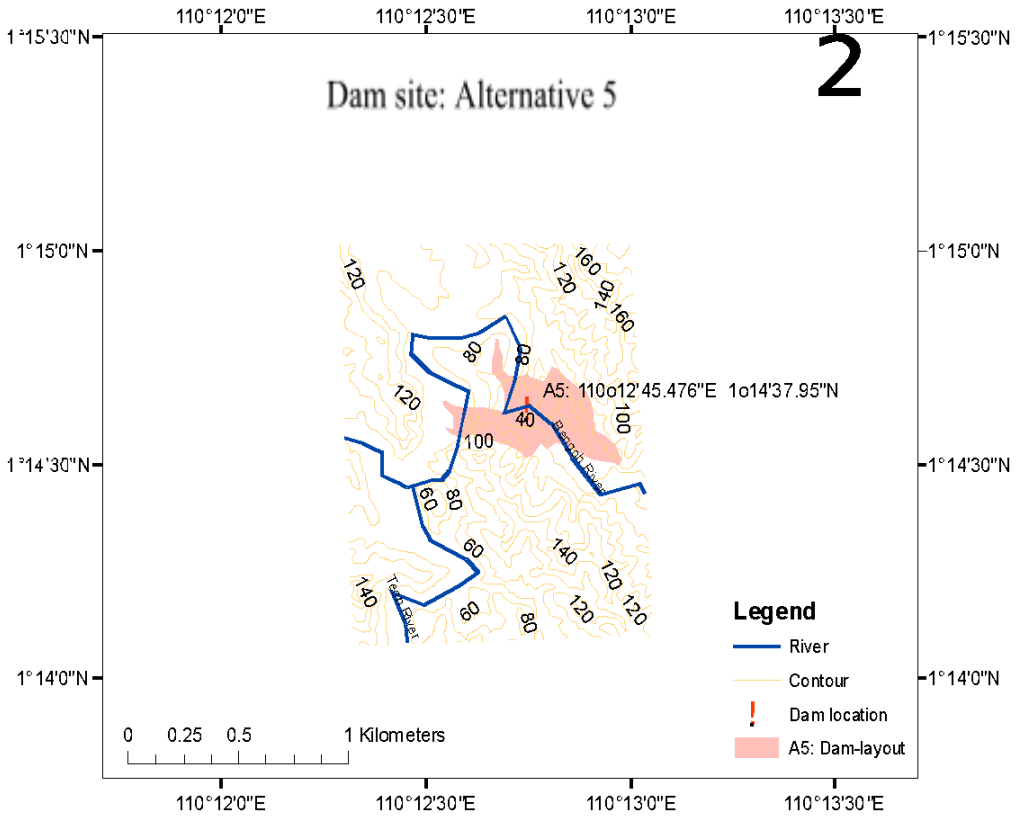


Fig 5:- Alternative dam site and the river system

B. Identification of the potential dam site

Many planning decision carried out in infrastructure and other development issues cause the fragmentation of natural habitats which results in both habitat loss and isolation, as well as habitat degradation (Opdam and Wein 2002; Gontier et al. 2006; Monavari et al. 2010). The report of the World Commission on Dams (2000) have stated that to date, over 400,000 km^2 of the earth have been flooded due to damming and the direct impacts include habitat loss, elimination of flora and fauna and, in many cases land degradation. It also states that an estimated 60% of the world's large river basins are highly or moderately fragmented by dams.

C. Inundated area of alternatives dam site

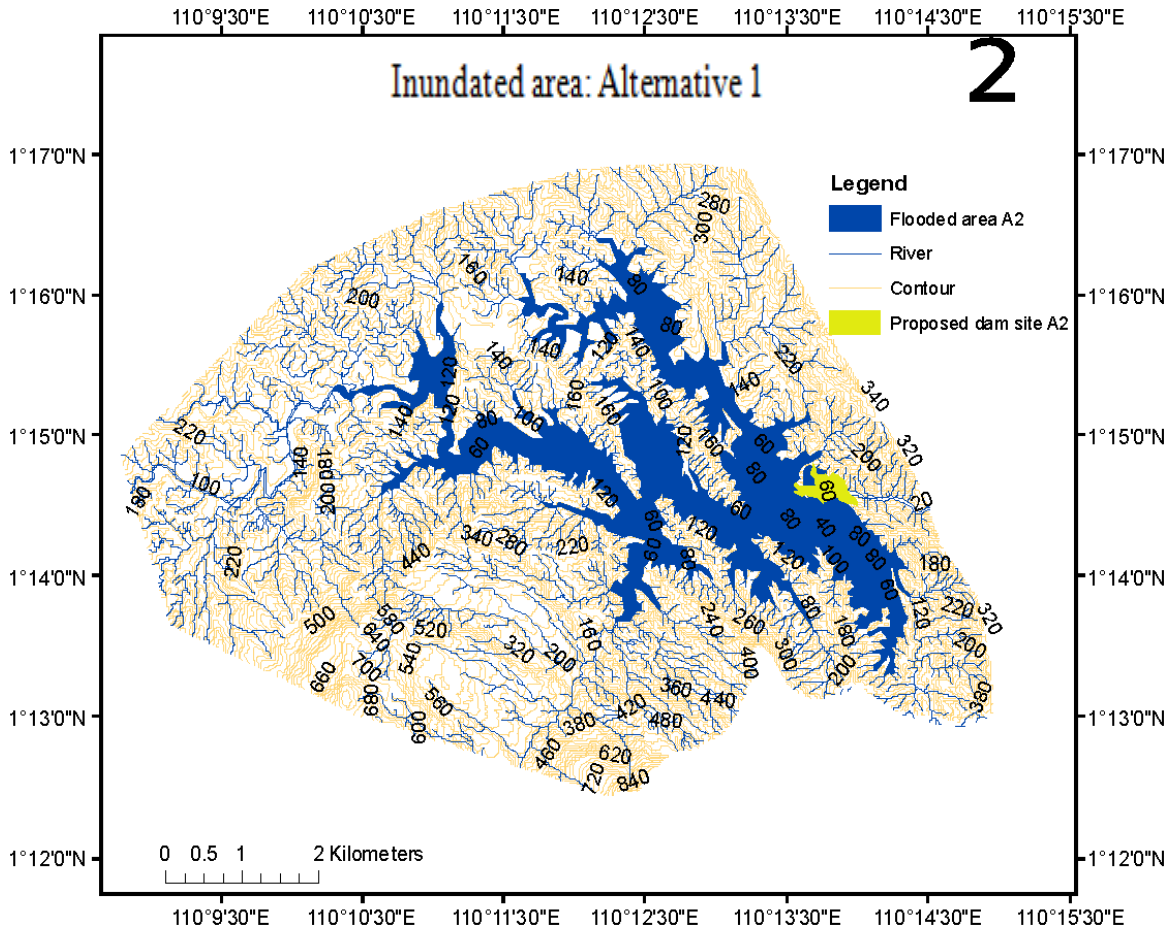
The inundated area was quantified by taken into consideration the contour that marks the reservoir maximum level which is 80 meters above sea level. Based on Table 6., Alternative 1 exhibits the highest percentage of submerge area which is 59.962% followed by alternative 3 (36.080%). Alternative 2 causes 33.921% inundated area while alternative 5 contributes 30.592%. Alternative 4 indicate 28.188% area being submerged which is the least among all the five alternatives.

ISSN No:-2456-2165

Alternative	% inundated area based on ecosystem					Ranking
	PF	OSF	YSF	AF	Total	
A1	0.000	14.662	22.452	22.848	59.962	5
A2	0.000	18.196	7.744	7.981	33.921	3
A3	0.000	7.918	20.024	8.137	36.080	4
A4	0.000	4.870	17.459	5.859	28.188	1
A5	0.000	6.422	18.311	5.859	30.592	2

Table 6. Percentage of inundated area based on ecosystem

Inundated map was prepared by considering all the alternative dam site as shown in Figure 6.



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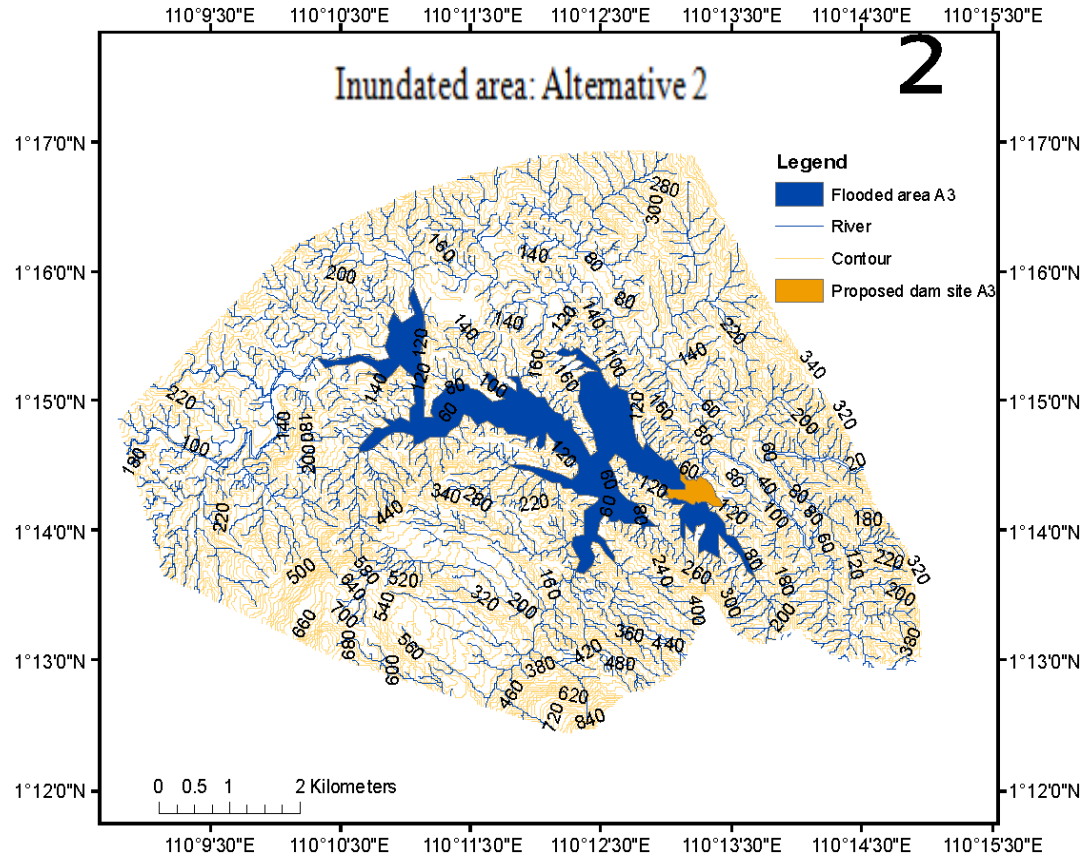

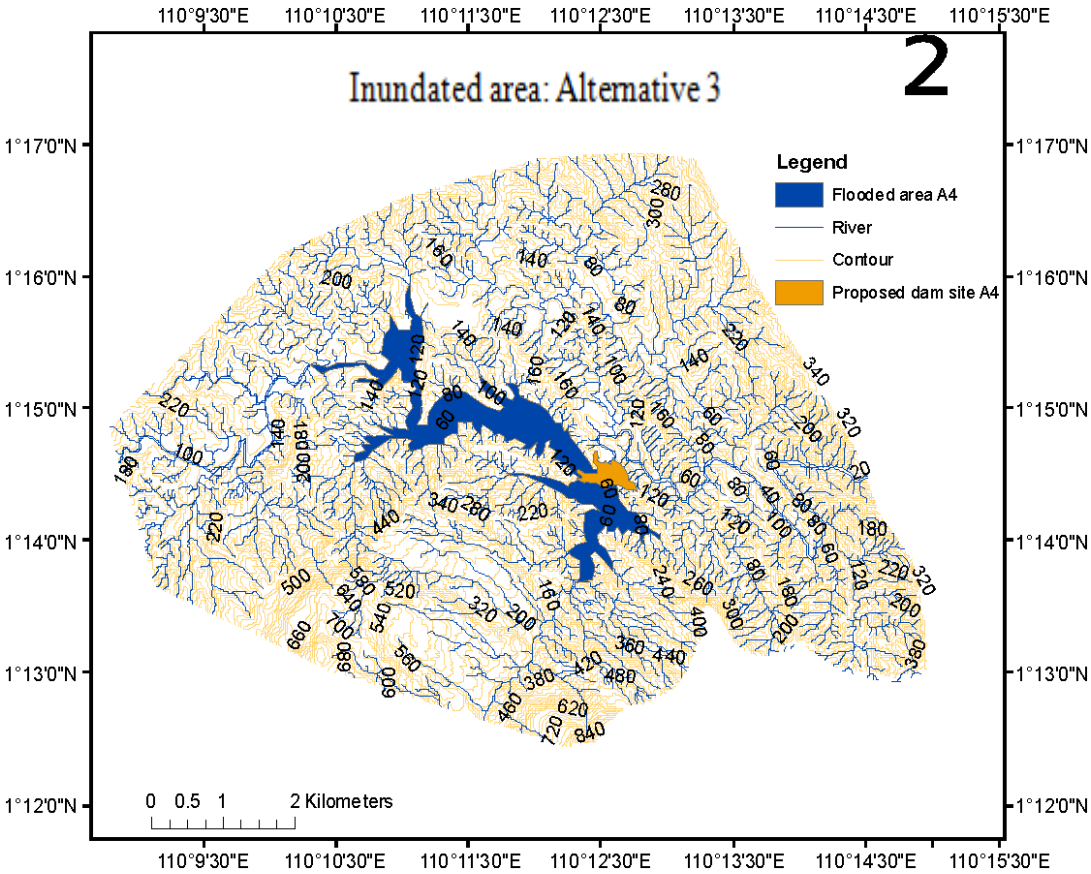

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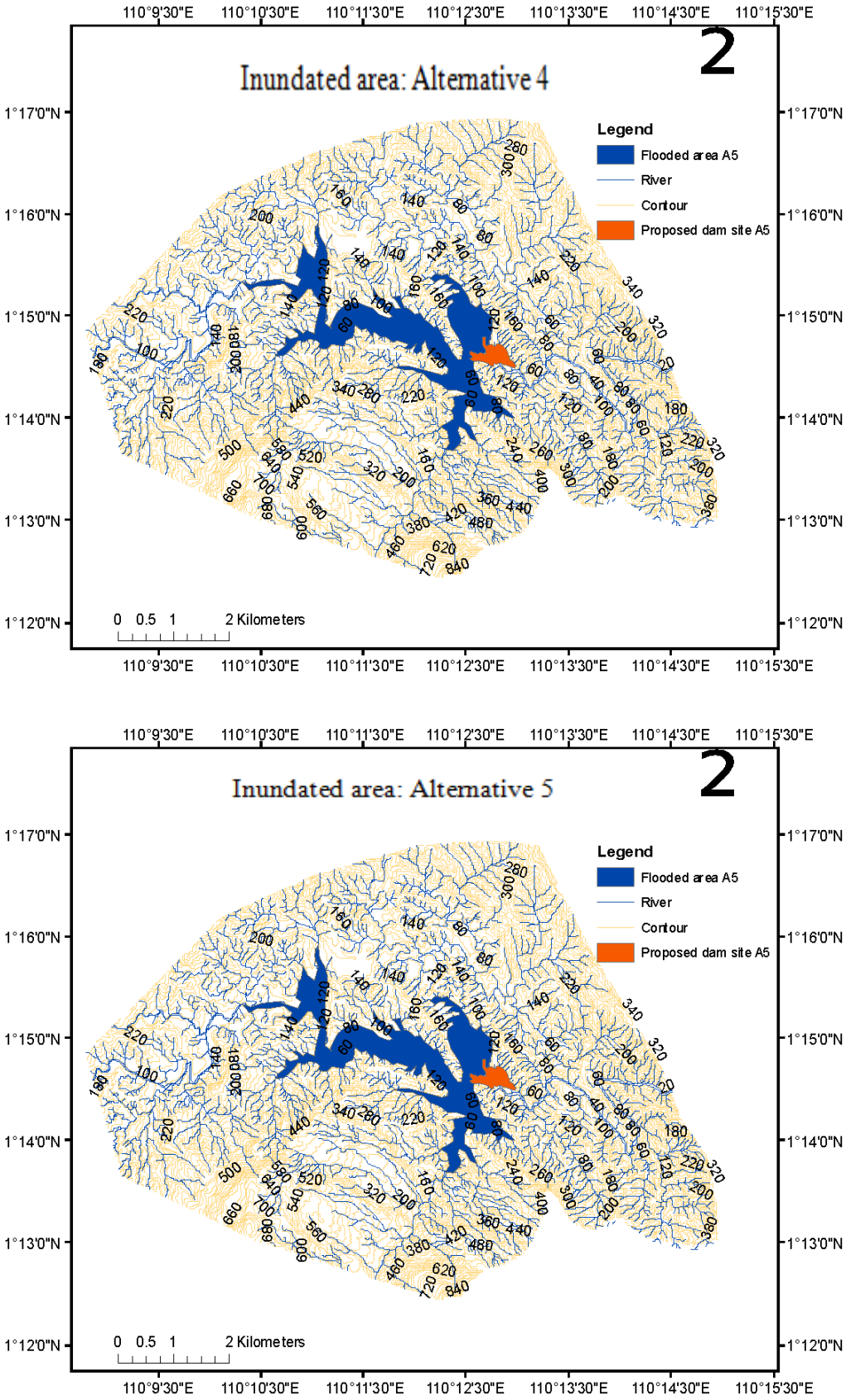

Fig 6:- Inundated area of the proposed alternative dam site

ISSN No:-2456-2165

IV. CONCLUSION

The proposed alternative dam site in this study were covered by the four major forest ecosystem namely the primary forest the old secondary forest, young secondary forest and agroforestry except alternative 4 which cover only with young secondary forest (64.04%) and old secondary forest which constitutes 35.96%. Upon commissioning of the dam, it is estimated that alternative 1 exhibits the highest percentage of submerge area which is 59.962% followed by alternative 3 (36.080%). Alternative 2 causes 33.921% inundated area while alternative 5 contributes 30.592%. Alternative 4 indicate 28.188% area being submerged which is the least among all the five alternatives. Thus the study conclude that the alternative 4 is the most appropriate site for the dam.

REFERENCES

[1]. Department of Water Supply,(2012). Dams distribution in Malaysia, Resource Centre, Minister of Energy, Green Technology and Water, Putrajaya,Government of Malaysia.
[2]. EIA (Environmental Impact Assessment) report (2008). Proposed development of Bengoh Dam across sungai Sarawak Kiri, Kuching, Sarawak. Centre for Technolgy Transfer and Consultancy University Malaysia Sarawak.
[3]. Almendinger. (2013). A handbook for collecting vegetation plot data in Minnesota The releve method. 2nd ed. Minnesota Biological Survey, Minnesota Natural Heritage and Nongame Research Program. Biological Report 92. St. Paul : Minessota Department of Natural Resources.
[4]. Brokaw, N., Thompson, J.(2000). The H For DBH. Forest Ecology and Management. 129(1-3): 89-91.
[5]. Geneletti, D. (2000 a), Using classification and spatial index techniques on remotely sensed data for environmental impact assessment. Proceedings of the 28th international symposium on remote sensing of the environment, Cape Town.
[6]. Hurst, J.M., Allen.R.B.(2007). A permanent plot method for monitoring indigenous forest-field protocals. Landcare research, Lincoln, NZ.
[7]. Kishimoto, Y.K., Itioka, T., Nakagawa, M., Momos, K.,and Nakashizuka, T.(2011). Phytophagous scavabaeid diversity in Swidden Cultivation Landscapes in Sarawak Malaysia. The raffles bulletin of zoology 59(2) : 285-293.
[8]. Mitchell, K.(2010). Quantitve analysis by the Point-Centred Quarter Method. Hobert and William Smith Colloge. Geneva NY.
[9]. Nakagawa, M., Miguchi, H., Nakashizuka, T.(2006). The effects of various forest use on small mammal communities in Sarawak, Malaysia. Forest Ecology and Management, 231 (1-3) : 55-62.