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Erosion and Sediment Control Best Management Practices in Agricultural Farms for Effective Reservoir Sedimentation Management at Cameron Highlands

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Abstract: ***For many years, lands in Cameron Highland have been opened and leveled for agricultural farming and intensive crop production. Land-disturbing activities such as agricultural operations that are conducted on regions with steep slopes leads to a high potential of soil erosion, sedimentation and landslide occurrences. As a results, this phenomenon producing large amounts of sediment transported and deposited to the receiving waters or reservoirs. The development of best management practices (BMPs) for agricultural activities is an important step towards minimizing the amount of soil erosion and landslide incidents in Cameron Highlands. Therefore, this Erosion and Sediment Control Guideline for Agricultural Activities in Hilly Area aims to minimize erosion and sedimentation from the agricultural area in Cameron Highlands especially in the scope of reservoir sedimentation management. There numbers of steps taken in order to establish this guidelines. The first step is to define the scope with the purpose of the guideline and conduct a literature review. In order to assess the quality and feasibility of the study to formulate the frameworks, engagement with stakeholders was conducted. Lastly is to undergo review and update based on the recommendations by related stakeholders. Finally, before the establishment of guidelines, all recommendations by related stakeholders are take in account that consists of Best Management Practices components which will be applied in the agricultural area to mitigate issues and problems especially in erosion control and reservoir sedimentation management. The Erosion Control Measures are including agronomic measures, soil management, mechanical methods and Rainwater Harvesting Techniques. Subsequently, these measures are used to apply in open or sheltered farming to control the erosion and sedimentation issues based on the erosion risk level. As a conclusion, this guideline will be useful for the stakeholders especially to local community, dam owners and local authority to mitigate and solve the issues related to erosion and sedimentation in hilly agricultural area.***

Keywords: Agricultural Farming, Erosion and Sedimentation

I. INTRODUCTION

A highland refers to an area located at an elevation greater than 500 m above the mean sea level with slope gradients of more than 25˚ [1]. The highlands have a high potential to cause landslides and soil erosions if not properly managed [2-3]. For many years, lands in Cameron Highland have been opened and leveled for agricultural farming and intensive crop production. With the increasing number of land opening for agricultural purpose, it is considered as a nonpoint source of pollution. Nonpoint sources become difficult to determine due to pollutant movement through surface and subsurface pathway that also depends on many factors such as weather and slope characteristics [4]. The overall agricultural coverage in Cameron Highlands is relatively small and is mostly done on steep slopes. The high usage of fertilizer and pesticides by local farmers, accompanied by the increase in the frequency of major storm events had given rise to high levels of soil erosion and environmental pollution.

There are three major agro-ecosystem Cameron Highland; namely tea, vegetables and floriculture [5]. The agricultural activities surrounding these three ecosystems have an impact on land resource usage and conservation, including the ability to constantly produce hydroelectricity.

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It is widely known that two of the main economic activities in the Cameron Highlands are hydroelectric power generation and agricultural farming. Most of the present agricultural activities led to serious soil erosion that affected by wind or flow or both [6]. Therefore, this phenomenon producing large amount of sediment which finally transported and deposited to the receiving waters or reservoirs [7]. As a result, this phenomenon directly reduced the hydroelectric power generation capacity and shortening the life span of dams or reservoirs. The previous study conducted for Cameron Highlands stated that total storage capacity for Ringlet Reservoir that received water from rivers called Sg. Habu, Sg. Bertam and Sg. Ringlet already 52% taken up by sediments after 35 years being commissioned. This scenario extremely reduce its estimated balance lifespan to only 4 years if no actions prevention is taken to tackle on this issue [8]. Therefore, this Erosion and Sediment Control Guideline for Agricultural Activities in Hilly Area aims to minimize erosion and sedimentation from the agricultural area in Cameron Highlands especially in the scope of reservoir sedimentation management.

Study area

The largest state in Peninsular Malaysia is Pahang which estimated area is 3,594,600 hectares [9]. Cameron Highlands as shown in Figure 1 is located North West of Pahang state which covered 71,218 hectares from the total area and is listed as one of tourist attraction as well as a key agricultural area for vegetables, flowers and tea [10]. Cameron Highlands is located on the Main Range, and the surrounding hilly area consists of steep slopes having gradients of more than 20˚ (approximately 59.7% of the surrounding area).

Fig. 1 Location of Cameron Highlands Districts

According to the Guideline on Agricultural Development on Sloped Areas published by the Department of Agriculture Malaysia in 2013, the following Table 1 shows the Terrain Class in Malaysia.

Table. 1 Terrain Class in Malaysia

Terrain Class	Steepness		Type of Terrain
	Degrees (˚)	Percentage (%)	
C1	0 – 2	0 – 4	Flat
C2	2 – 6	4 – 11	Undulated
C3	6 – 12	11 – 21	Wavy
C4	12 – 20	21 – 36	Hilly
C5	20 – 25	36 – 47	Very Hilly
C6	25 – 30	47 – 58	Steep
C7	>30	>58	Very Steep

Source: Department of Agriculture (DOA), 2013

Figure 2 shows the example of cabbage farm planted on terraces at a very steep slope of more than 45° which is under high potential risk to soil erosion and landslides induced by heavy stormwater or runoff generated after irrigation application if without Best Management Practices (BMPs).

Fig. 2 A typical Farm at Cameron Highlands with a slope greater than 45°

II. METHODOLOGY

The creation of this guideline is based on existing procedures for urban development, whereby the approvals for erosion and sediment control plans are usually incorporated as part of the submission of earthwork plans to local authorities for any type of development. Summary of methodology in establishing this guideline is as shown in Figure 3.

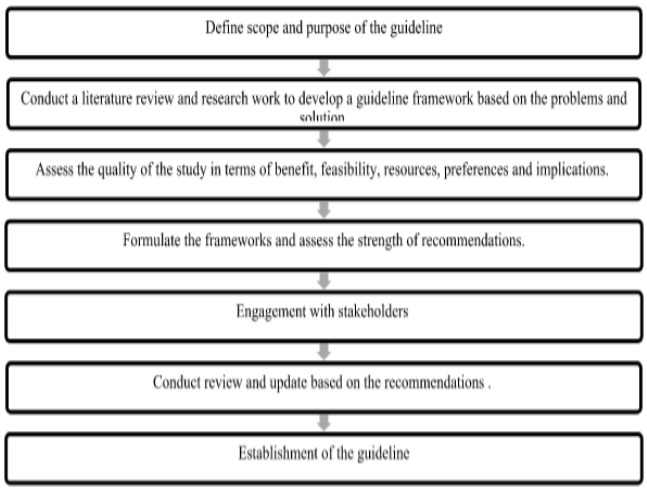

Fig. 3 Overall Methodology for guideline preparation

First steps in developing this guideline are to define scopes as well as conducting a literature review. Some parameters was considered to be included in guideline particularly to control erosion and sedimentation at hilly agricultural area and reservoirs. This section is also to assess the quality of study in terms of benefits, feasibility, resources, preferences and implications.

Next step is to formulate the frameworks for the guidelines by engaging with stakeholders. The stakeholders are mostly from industry such as erosion and sediment expertise, storm water management expertise, dam's owners, local community in Cameron Highlands as well as related government agencies. Finally, the establishment of the guideline was done that consists of Best Management Practices components. The components are later will be applied in the agricultural area to mitigate issues and problems especially in erosion control and reservoir sedimentation management.

III. RESULTS AND DISCUSSIONS

This guideline is to be used by the local authorities, dam owners and farmers in order to conserve soil, protect the natural waterways and the surrounding environments from man-made pollutions. However, it must be highlighted that the best result will be achieved if the adoption of this guideline is used in conjunction with the existing local guidelines. Control at sources is important for the implementation to reduce sedimentation of the reservoir.

Agricultural activities in hilly areas are exposed to the risk of soil erosion. Soil erosion causes the top layer of the fertile soil to be washed away by winds, rainfall or surface runoff which leads to sedimentation in river or rivers [11-13]. This study will be elaborate in details based on four groups of soil conservation techniques/measures as shown in Figure 4.

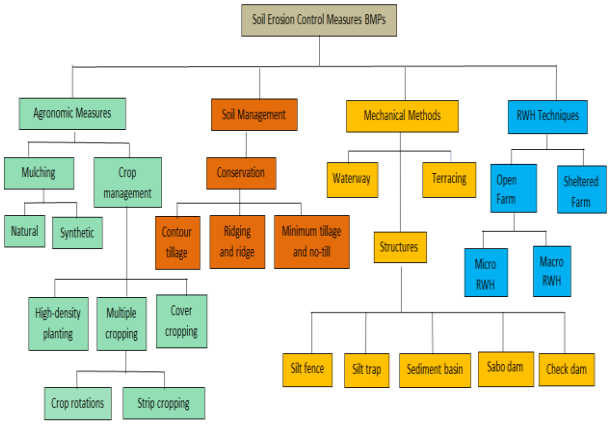

Fig. 4 Soil Erosion Control Measures (BMPs) for agricultural farming

IV. AGRONOMIC MEASURES

According to figure 4 shown earlier, the first component (highlighted in Green Color) is the agronomic measure which employs the role of vegetation to minimize soil erosion [10][14]. This measure offers protection to the soil by covering soil surface, increasing surface roughness, increasing surface depression storage and increasing soil infiltration capacity [15]. For BMPs control measures in unsheltered farms, the agronomic activities should be done in such a way that the minimum soil disturbance is achieved with least soil erosion. In order to achieve that, there are two important approaches, which are called as Natural (straw) Mulch and Synthetic Mulch. Meanwhile, cropping management system refers to a sequence of crops growing on a given area over a period of time [16]. According to ASABE standards 2011, the cropping is regarded as to achieve BMPs control measures if it conforms to the following standards; maintain soil fertility, protect the soil from erosion and making the best use of available soil moisture. Cropping systems includes: Strip cropping, Crop rotation, Intercropping/mixed cropping.

V. SOIL MANAGEMENT MEASURES

The second component as shown in Figure 4 (Highlighted in Orange Color) is the soil management measures. This measure provides ways in preparing the soil to promote dense vegetative growth and improve the soil structure. This is to ensure that it can offer more resistant to erosion as referred to ASABE standard, 2011. It helps not only to control soil erosion but helps to harness rainwater and conserve soil moisture. These measures aimed at increasing the resistance of the soil to erosion which includes tillage practices.

Tillage operation refers to mechanical manipulation of soil to provide a suitable environment for crop growth, maintenance of infiltration capacity, aeration and weed control [17]. Nowadays, a number of modified tillage operations are available with the objective of providing improved soil-water-plant relations, reduce soil erosion and runoff, helping in moisture conservation and reducing the time and cost of tillage operation [15]. The term minimum tillage describes the preparation of the seed-bed with minimum soil disturbance [18]. The tillage practices for BMPs erosion control are strip or zone tillage and Mulch Tillage.

VI. MECHANICAL MEASURES

Drainage BMPs

The drainage system in open farms is a very important consideration in preventing soil erosion. The purpose of a drain in a conservation system is to convey runoff at non-erosive velocity to a suitable disposal point. Its dimensions must have sufficient capacity to carry the peak runoff from a storm of about 10-year return period [19]. There are three types of drains according to ASABE (2011) as; Diversion channels, Terrace channels and Grass-covered drain. The design of the grass-covered drain is more complex than the design of the irrigation channel. The basic aim is to control runoff which can result to channel or gully formation. Therefore, the focus is for the reduction of peak flow rate by full utilization of field protection practices and provision of a stable channel that can handle the flow discharge.

VII. RAIN WATER HARVESTING SYSTEM IN AGRICULTURAL AREAS

Rainwater harvesting is one major key to meeting the global millennium goal on water issues. The water collected can be concentrated in the soil profile or in artificial reservoirs such as pond, basin, or tank and used for various purposes, ranging from crop production to water supply for domestic, animals and other productive uses. Rainwater Harvesting technique is, therefore, a collection and concentration of direct rainfall or surface runoff for productive purposes, instead of runoff being left to cause soil erosion, on-farm direct use of rainwater in rain-fed agriculture and irrigation through practices which enhance soil water use efficiency. Rainwater-harvesting system can be classified into the following basic categories which area; (a) Rooftop rainwater harvesting technique: used to harvest water for domestic and animal water needs, (b) Micro-catchment techniques: In-situ water harvesting for crop production (Simple RWHS) and (c) Macro-catchment techniques: can be used to harvest water for animal and agricultural use (Complex RWHS).

VIII. RECOMMENDED BMPS BASED ON TYPE OF FARMING & EROSION RISK LEVEL

Erosion Risk Classification

Weight of soil loss per hectare accounted for one year is a unit for soil loss. Table 2 shows that it can be classified into 5 levels where Very low level is the loss of less than 1 t ha^{-1} $year^{-1}$. Low level is between 1 to 5 t ha^{-1} $year^{-1}$ and Medium level is between 5-15 t ha^{-1} $year^{-1}$. The most severe level is when the soil loss is more than 15 t ha^{-1} $year^{-1}$ and can be categorized as High level.

Table. 2 BMPs Component for Open Farm Condition

Very Low (VL)	0-1
Low (L)	1-5
Medium (M)	5-15
High (H)	>15

(Source: Singh (1989)*)*

BMPs at Open Farm

For the farm types, open farm and rain sheltered farm may have different approach to control soil erosion and sedimentation and somehow it should be emphasized on the management of run-off water at the on-farm level because soil erosion is basically caused by run-off water. Figure 5 shows an example of open farming practices for tea plantation in the Cameron Highlands.

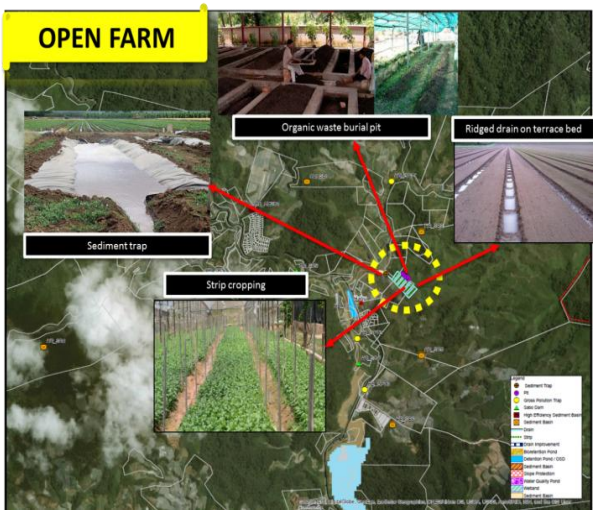

Fig. 5 Example of open farming practices (tea plantation) in Cameron Highland

[redacted]

Table. 3 BMPs Component for Open Farm Condition

No	Item	Descriptions	Erosion Risk Level
1	Terrace	At 35^0 slopes, the terrace bed should be constructed with a length of about 1.2m. During the construction of the terrace, the erosion control measures should be applied such as silt fence and sediment trap Avoid any earthworks during monsoon season	L, M, H
2	Drain	Ridged drain on the terrace bed is important to increase infiltration rate and collect the run off to the side drain. It also serves as a micro rainwater harvesting system. The side drain is necessary to allow the stormwater to flow into an engineered waterway. If the slope of the side drain is too high, it is suggested to construct several steps to reduce the runoff velocity and water energy. Drain collector and diversion drain are important to allow the stormwater to the nearest river. A proper size of these waterways should be rational to the size of the planting area. The bank of earthen waterways should be protected by vegetative measures. Setting up of a group that shares the same drainage system should be encouraged for better management.	M, H

3	Mulching	Synthetic mulching on the terrace platform should be applied all the time during planting season. This synthetic mulch has several benefits to soil erosion and sediment control and it also provides advantages to the plant such as weed control, moisture conservation and temperature control. Natural mulching on the side slope of the terrace is encouraged such as the planting of crop cover or synthetic mulching for temporary protection of soil erosion and sedimentation.	M, H
4	Cropping	In a sustainable manner, strip cropping or conservative cropping at every 5 terrace interval should be practiced to use as a sediment trap zone. Moreover, vertiver grass or other similar characteristic crops should be used as a slope control measure.	L, M, H
5	Waste Management	Waste management center should be comprised of a burial pit for organic waste and inorganic waste center. Burial pit is a dumping site for organic waste such as rotten vegetables and the size of this burial pit depends on the amount of organic waste produced by a farm. An inorganic waste center should be constructed at every farm to collect plastic bottles after 3 times rinsed. This center at the farm is just a temporary collection before sending to the main collection center. Composting center should be constructed by farmers to return the organic waste into compost and it can be used for their farming to replenish the nutrients. The use of compost gives many benefits to farmers such as reduction in the use of nutrient inputs, reduction in chemical fertilizers, provides many micronutrients, etc. The main purpose of stormwater management is that organic waste should be properly managed in order for it does not flow into a stream or river, which eventually will block the river flow.	VL, L, M, H
6	Basin and Pond	Sediment basin and irrigation pond should be placed at the right location within a farm. More benefits could be gained if both can serve to reduce sedimentation and runoff.	M, H
7	Others	Workers house should be located at a good place within the farm boundary where its drain should be proper sizing and diverted the drain water into the adjacent river. Some other aspect of open farm BMPs can be referred to a guideline for Erosion and Sediment Control Plan (ESCP) preparation stage. Incorporate with other farms as Water User Group (WUG) to work together in maintaining the pipes for irrigation water supply that run from a long distance of the upstream water source. Do not allow to have any bare soil areas in the farm especially during monsoon season. Mulching by natural or synthetic means should be applied to protect soil erosion and sedimentation.	VL, L, M, H

Note: VL = very low, L = low, M = medium, H = high

BMPS at Sheltered Farm

Sheltered farming activities are quite different and have more control over unsheltered farming described earlier [19]. In this case, rainfall is not in contact with both soils, crop and intercepted by roofing as shown in Figure 6. More the interception of the rainwater the larger volume of runoff is collected in the drains. In order to achieve best practice, an entire cropping area should be covered with a roof tilting towards particular drainage outlet.

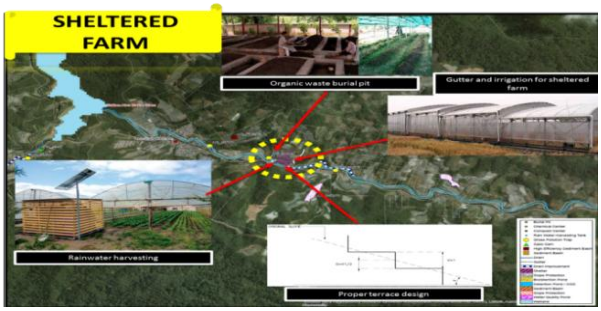

Fig. 6 Example of sheltered farm equipped with rain gutter in Cameron Highlands

The following components in Table 4 should emphasize for sheltered farm practices:

Table. 4 BMPs Component for Sheltered Farm Condition

No	Item	Descriptions	Erosion Risk Level
1	Gutter and irrigation system	The proper gutter should be installed at rain-sheltered farm. A typical rain shelter size is 20x50m and under high rainfall intensity region of about 100 mm/hr, 4-inch pipes should be installed as gutter surrounding the roof to reduce the direct impact of a raindrop on the ground which later will erode the soil Waterspout with a typical size of about 6 inches should be installed at the corners of the shelter to guard the rainwater against the gutter to the down part. Observation and maintenance of the join between the water spout and gutter should be conducted frequently. Without circumstances, the join is broken and the leakages can create high water energy from about 3 m height to the ground and will erode the soil Sediment basin and irrigation pond should be placed at the right location within a farm. More beneficial could be gained if both can serve to reduce sedimentation and runoff Incorporate with other farms as Water User Group (WUG) to work together in maintaining the pipes for irrigation water supply that run from a long distance of the upstream water source	VL, L, M, H
2	Shelter	With a typical size of the 20x50m shelter, 10 shelters can be fitted in 1 ha farm. Large volume and flow rate of rainwater can cause soil erosion and sedimentation. A proper system of engineered waterways should be constructed according to the ratio of farm size as contribution catchment area and the size of waterways. For a 1-ha farm, perimeter drain could be sized up to 0.7 x 0.7 m and should be properly channeled to the diversion drain and to the river	VL, L, M, H
3	Rainwater Harvesting	Rainwater harvesting storage should be installed to utilize them for irrigation purpose. With proper storage size, the flow of stormwater could be reduced before entering the downstream. The size of the storage should be proportional to the farm size	VL, L, M, H
4	Management of Earthworks	During earthwork (cut and fill), the erosion control measures should be applied such as silt fence, sediment trap and sediment basin Avoid earthwork during monsoon season Do not allow to have any bare soil areas in the farm especially during monsoon season. Mulching by natural or synthetic means should be applied to protect soil erosion and sedimentation	M, H
5	Waste Management	Waste management center should be comprised of a burial pit for organic waste and inorganic waste center. Burial pit is a dumping site for organic waste such as rotten vegetables and the size of this burial pit depends on the amount of organic waste produced by a farm. An inorganic waste center should be constructed at every farm to collect plastic bottles after 3 times rinsed of water for cleaning purpose. Handling of used shelter sheet should in good conduct such as chopping off the sheet into a small size of about 2 inches and put them in a proper container. Temporary place them at this collection center and transfer them to the main collection center	VL, L, M, H

		Composting center should be constructed by farmers to return the organic waste into compost and it can be used for their farming to replenish the nutrients. The use of compost gives many benefits to farmers such as reduction in the use of nutrient inputs, reduction in chemical fertilizers, provides many micronutrients, etc. The main purpose of waste handling in stormwater management is that the organic waste should be properly managed in order for it does not flow into a stream or river which eventually will block the river flow	
6	Slope Protection	Slope protection – For cut and fill, maximum slope height for every terrace should not exceed 10m. Natural mulching such as vertiver grass to strengthen the slope should be applied. At the slope toe, slope protection such as gabion should be installed	M, H
7	Others	Workers house should be located at a good place within the farm boundary where its drain should be proper sizing and diverted the drain water into the adjacent river Workers house should be located at a good place within the farm boundary where its drain should be proper sizing and diverted the drain water into the adjacent river Do not allow to have any bare soil areas in the farm especially during monsoon season. Mulching by natural or synthetic means should be applied to protect soil erosion and sedimentation. Do not allow to have any bare soil areas in the farm especially during monsoon season. Mulching by natural or synthetic means should be applied to protect soil erosion and sedimentation. Some other aspect of open farm BMPs can be referred to a guideline for Erosion and Sediment Control Plan (ESCP) preparation stage	VL, L, M, H

IX. ESCP FOR AGRICULTURE ACTIVITIES SUBMISSION PROCEDURE

The Erosion and Sediment Control Plan (ESCP) must be prepared for land clearing, planting season and fallow period phases for open, rain-shelter and terraced plot (Figure 7).

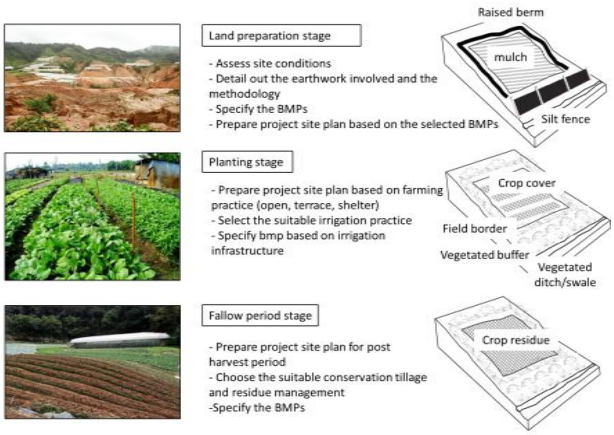

Fig. 7 ESCP Preparation Stages

A standard submission procedure for Erosion and Sediment Control Plan (ESCP) was developed in line with the procedure for land development and other ESCP submission procedures previously practiced by the Department of Irrigation & Drainage (DID) and other related agencies. This standard submission procedure is part of the strategy of DID in getting all parties involved such as consultant, planners, farmers and the local authorities to improve their understanding and practices and to achieve the required erosion and sediment control objectives. This procedure covers the basic authority requirements for ESCP submission as mentioned in the previous guidelines published by DID. The following Figure 8 describes the submission procedures:

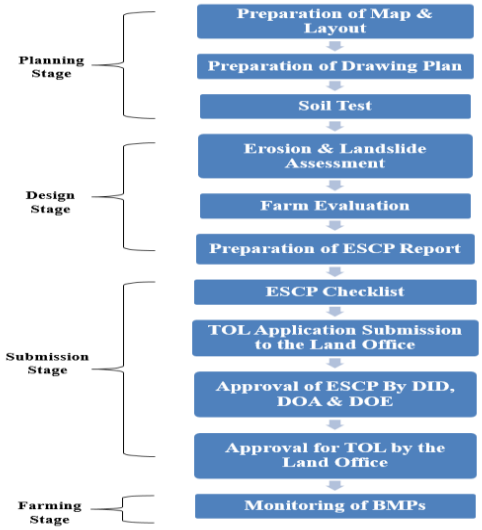

Fig. 8 ESCP Submission Procedures

X. CONCLUSION

As a conclusion, this guideline will be useful for the stakeholders especially to local community, dam owners and local authority to mitigate and solve the issues related to erosion and sedimentation in hilly agricultural area. In lieu of recent environmental issues pertaining to the effects of agricultural activities to the surrounding water bodies in Cameron Highland (such as sedimentation), there is an urgent need to focus on erosion and sediment control practices implemented at agricultural farms in hilly areas. In order to convey irrigation water, besides having a proper drainage facilities, there is also other measures that can be considered from this guidelines by implementation of Rainwater Harvesting system at farming area.

All four measures proposed in this guidelines are suitable for open and sheltered farming to prevent significant effect which increased the potential for soil erosion and landslide occurrences for agricultural farming operation at hilly areas in Cameron Highland. However, it must be highlighted that the best result will be achieved if the adoption of this guideline is used in conjunction with the existing local guidelines.

Control at sources is important for the implementation to reduce sedimentation of the reservoir.

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