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Controlling Stormwater Runoff Pollution Best Practices of Green Highway Developments

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1- Introduction

Green highway development is a new concept which emerged last decade in developed countries. It steers toward construction and implementation of sustainable highways to minimize and control the environmental impact, while aiming to boost social and economic suitability. Bryce [1] suggested that green highways should embrace more sustainable practices and maximize the highway lifetime than current construction technology and put forth watershed-driven stormwater runoff management. Several attempts have been made in developed countries to set green highway features in order to protect natural water resources [1-4].

Among the objectives stated in Malaysian's 10th Master Plan 2011-2015 [5] reducing water resources pollution and providing quality water to an urban population that is expected to grow over 70% of the total population, is a major concern of the government. Furthermore, develop a long-term strategy for water resource management is a priority in Malaysia where more than 90% of water supply is from rivers and lakes. As a matter of fact, highway/roads have been identified as potential threat sources to water quality, and developed countries are moving forward in curbing highway-related water pollution through the establishment of highway assessment framework. With regard to the growing impetus of sustainable culture along with the Low Impact Development (LID), the study aimed to investigate the Best Management Practices (BMPs) on prevention and control of highway Stormwater runoff pollution.

Highway development Best Management Practices (BMPs) techniques are environmentally sensitive designs which tend to generate less runoff, promoting infiltration and reducing runoff from developed areas. The variety of techniques used, non- structural and structural techniques, are economical and flexible [6]. New Jersey Stormwater Best Management Practices Manual [7] states the impossibility of sole non-structural practices to fulfill Stormwater runoff regulations is. LID is anchored in the concept that Stormwater must not be considered as a waste to quickly be discharged and that opportunities in developed lands must be used to control runoff closed to their sources as possible (US NRDC, 2011).

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2- Structural Best Management Practices

Structural BMPs can be sorted in many ways; Georgia Stormwater Management Manual- GSWMM [8] distinguishes two categories of structural BMPs, namely those of general application and the ones with limited application, while NJ-SWBMP [7] classifies them by functionality. Most of the structural BMPs are determined by the site control requirements and guideline. Hence, in this paper the functional classification is adopted. Stormwater management techniques are:

a. Rain Gardens/Bioretention and Bioswales/Vegetated Swales
b. Vegetated/Grassed Filter Strip: It can effectively aid to remove pollutants from the overland flow
c. Permeable Pavement adapted with infiltration flat
d. Constructed Filter
e. Wet Ponds/Retention Basins
f. Detention Basins
g. Constructed Wetland
h. Buffer Strip

3- Non-Structural Best Management Practices

NJ SWBMP [7] classifies non-structural practices to: time of concentration modifications, minimizing land disturbance, vegetation and landscaping, and impervious area management.

a. Time of Concentration Modifications: NJ SWBMP [7] identifies three factors influencing the time of concentration (Tc) of the runoff, that is, the surface roughness, the slope, and the type of conveyance of the runoff. To increase the Tc and hence minimize peak flow, care must be taken, to reduce surface roughness changes to reduce the sheet flow slope (decrease the slope and increase the flow length using terraces to provide additional travel time and reduced slope channels), and to use vegetated conveyance such as channels and swales, grade stabilization structures [7].

b. Minimization of Land Disturbance: The apportionment of land use is one main factor influencing pollutants load in Stormwater runoff; subdivision of land use can help prevent drinking water contamination and ground water recharge [9]. Identify and assess site constraints such us slope, soil type, drainage area, wetland, floodplain, in order to minimize site clearing,

grading and other land disturbance by fitting the project into the site instead of the reverse case [7].

c. Vegetation and Landscaping: Preservation of Natural Areas; Areas such as forests, riparian corridors, and high groundwater or aquifer recharge capabilities must be preserved and specified measure should be taken to ensure that such areas will remain preserved in the future. Native Ground Cover; The practices here include, the minimization of site disturbance, lawn and grass areas, and r-vegetate disturbed areas using essentially native plants. Vegetative filters and Buffers.

d. Impervious Area Management: According to NJ SWBMP [7] an indicator of stream health in a watershed is cited by several studies as impervious areas. To control Stormwater runoff pollution, the use to the maximum extent possible of pervious materials within parking spaces, driveways, access roadways, sidewalks to disconnect impervious areas from one another is the goal to attain [7].

Reduce runoff and associated pollutants to adjacent Reduce thermal impacts in reducing the quantities of pollutants in typical water resources by allowing infiltration of surface highway runoff that are discharged into adjacent water resources. The water, filtration of pollutants, or other methods to treat pollutants include sediment, oil and grease, chemicals such as deicing salts stormwater runoff, and pesticides, litter and trash, and metals. In this regards, Table 1 identifies the Synopsis of BMPs, their function, potential applications and efficiency in pollutants removal.

A structured fixed format self-reporting questionnaire form was designed based on 5-point likert scale (1: strongly disagree, to, 5: strongly agree) to obtain the agreement level of respondents from 22 companies and 109 consultants in highway engineering. The research has applied the Average Index method (developed by Abd Majid and McCaffer [10]) which provides means of validation of a criterion. The Average or the Mean Index of a criterion is evaluated using the following Equation:

$$\text{Average/Mean Index} = \frac{\sum a_i X_i}{\sum X_i}$$

Where, a = constant, weighing factor for i, {i = 1, 2, 3.....n}, Xi = frequency of respondent. The analysis result shows that respondents have agreed to the combination of both nonstructural and structural BMPs to control SWRQ as each of them scores higher than 3.5 average indexes. Specifically, the non-structured scores 3.78 while the structured is agreed at 3.77 level. According to Table 1, most significant elements are vegetation and landscaping, Runoff Quality/Peak Rate BMPs, and minimize land disturbance which score respectively (3.88; 3.85; and 3.83). On the other hand, the less significant elements are identified as impervious area management, restoration BMPs, and time of concentration modifications which have the same average index of 3.71.

Table 1: Average Index value analysis result of Best Management Practices

BMPs	Average Index value
Vegetation and Landscaping (use native Ground Cover, Vegetative filters and Buffers)	3.88
Runoff Quality Rate	3.85
Minimize Land Disturbance (minimize site clearing and grading by fitting the project into the site)	3.83
Volume or peak reduction through filtration (Bio retention Trench, Vegetated Swale, Vegetated Filter Strip, Constructed Filter, etc.)	3.75
Impervious Area Management (reduce impervious surfaces and disconnect them from one another)	3.71
Restoration	3.71
Time of concentration modifications	3.71

The runoff quality/peak rate BMPs is the only structural BMPs to figure within the significant BMPs capable of controlling runoff quality while two of the non-structural BMPs are found significant for it. It is therefore important during highway planning stage to properly locate those structural BMPs which are runoff quality/peak rate discharge structure so that they efficiently fulfill the purpose of their existence. Their efficiency depends on their capability to remove pollutants from the runoff. Consequently they need to be monitored and maintained to preserve their acceptable level of functionality. This result is very significant and consistent with the green highway criterion, instrumentation and monitoring of storm water runoff which is found significant. This result infers that instead of directly discharging SWR into sanitary sewer systems, it must be retained and treated using appropriate BMPs to remove pollutants from it.

Regarding the significant non-structural BMPs identified the non-structural practices will restrict the hydromodification effect of highway on the SWRQ. BMPs that can enable better control of SWRQ are identified as a combination of non-structural and structural BMPs which are equally important and include from the most significant to the less significant:

a. Vegetation and Landscaping (use native Ground Cover, Vegetative filters and Buffers);
b. Minimize Land Disturbance

The outcome of this study will provide, respective of Malaysian environment, requirements against which highway performance can be measured and consequently provide means to construct highway development toward more sustainable practices. According to mentioned issues and problems, the current study aimed to identify Best Management Practices (BMPs) that can achieve a better quality of Stormwater runoff.

The following made for future studies:

- Determine the specific needs from water resources of various watershed in Malaysia in order to design appropriate stormwater plan for various zones;
- Include a stormwater management plan as a priority into the development of all areas since the primary development stage in order to efficiently management the post development;
- Non-point source pollution discharge which has been neglected over century by statutorily regulations should be considered for better control of storm pollution;
- Monitoring and instrumentation of runoff is primordial to achieve better control.

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