Determining the Effectiveness of Harapan Lake as Flood Retention Pond in Flood Mitigation Effort

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Abstract. Malaysia is one of developing countries that undergo urbanization rapidly. Human activities that have increased the construction of paved areas resulted in the increase of the surface runoff and lead to the flash flood events as what has happened in USM Main Campus area. In order to mitigate the flash flood problems in USM Main Campus area, Harapan Lake as one of flood retention ponds has been constructed inside the campus. Unfortunately, the flash flood problems still occur and thus, the effectiveness of the Harapan Lake in reducing flood problems is questionable. This study tried to investigate the effectiveness of Harapan Lake in reducing the flood problems by comparing the flood behaviors of several conditions using mathematical model simulation. The study evaluation has been done at downstream part of Gambir River reach connected to Harapan Lake through a channel as inlet and outlet. WinTR-55 model based on SCS curve number has been applied to generate the runoff hydrographs as boundary condition of model simulation. GIS tool has been used to provide required geometric input data. The runoff hydrographs and data obtained from GIS were inputted into the HEC-RAS hydraulic model to simulate the flood behaviors. The result shows that Harapan Lake in the current river system is able to reduce the flood levels approximately 19.5 % for 2 years ARI and 18.4 % for 10 years ARI. By adding an outlet channel that connects Harapan Lake to Gambir River reach at RS 134 in the current river system, Harapan Lake can reduce flood levels approximately 43% and thus, can reduce the flood problems at USM Main Campus area more effectively.

Keywords: flash flood, GIS, HEC-RAS, retention ponds, urbanization, WinTR-55

1. Introduction

Malaysia is one of the developing countries that undergo urbanization rapidly. Urbanization activities that have altered rural area to become urban area resulted in the increase of paved area constructions and subsequently increase surface runoff and lead to the flash flood events as what has happened at USM Main Campus area [1-7].

The flash flood problems have become a main issue in USM Main Campus area [8]. Based on study carried out by Teh et al., [9] through comparison of peak flows before and after USM Main Campus development, it can be suspected that flood problems here are triggered by the heavy rainfall and the increased of surface runoff induced by urbanization and expansion of USM main campus from an army barrack to a modern campus. However, Harapan Lake as one of flood retention ponds has been constructed inside USM Main Campus in order to mitigate flood problems inside campus. This pond is connected to the middle part of the Gambir River by one channel as inlet and outlet. Unfortunately, the flash flood problems still occur [8] and thus, the effectiveness of Harapan Lake in reducing flood problems is questionable. This study tried to investigate the effectiveness of Harapan Lake as a flood retention pond in reducing flood
problems. It carried out by comparing the simulation of flood behaviors for several conditions by using HEC-RAS hydraulic model.

HEC-RAS model is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels [10]. This model considers the impact of any hydraulic structures such as bridges, culverts, weirs, spillway and etc at flood plain. It is an excellent model applied for analyzing flood profile and extent of flooding [7, 10, 11]. In addition, a hydrological model and Geographic Information System (GIS) tool also have been applied in this study in order to provide the required input data.

2. Description of Study Area

This study has been carried out at Gambir River reach within USM Main Campus. The study reach of Gambir River is 666 m length. The river is connected to Harapan Lake at the middle, and culverts at the end. The Harapan lake has an area of about 1.05 ha, storage volume of about 30000 m³ and 1 channel as inlet and outlet manually controlled by gate (1m x 1m).

The water flows that enter into the study area are conveyed from several part of inside campus area and several part of outside campus area. They flow throught the existing natural channels and constructed channels that have been set to be connected and directed to the study area through five major inlets. The description of the study area is shown in Figure 1.

![Description of study area at USM Main Campus, Pulau Pinang, Malaysia](image)

Fig. 1: Description of study area at USM Main Campus, Pulau Pinang, Malaysia

3. Methodology

3.1. Data Collection

The data required in this study consist of spatial data and non-spatial data. The spatial data includes topographic data, landuse data and Hydrologic Soil Group (HSG) data and the non-spatial data includes rainfall intensity data, Manning data and hydraulic structure parameters. The topographic data and landuse data in AutoCAD drawing format were obtained from Development Department of USM Main Campus while Hydrologic Soil Group (HSG) data in shapefile format was obtained from Department of Agriculture.
The topographic data in AutoCAD drawing format were then converted to the Arview-GIS compatible format in order to provide required geometric input data by HEC-RAS model. The landuse map and the HSG map together with rainfall data and hydraulic structure parameters were used in order to produce flow rate hydrographs as boundary condition of HEC-RAS model.

Since no rain gage around the study area, the rainfall design method based on Urban Stormwater Management Manual for Malaysia (MSMA) (DID, 2000) have been applied here to determine amounts of the rainfall intensity. Observation and measurement in the field have been carried out to obtain the Manning values and hydraulic structure parameters. The Manning values then were determined by using Manning Equation.

### 3.2. Developing Geometric Data Using Arcview-GIS

Arcview-GIS software has been used to develop the geometric data files required by HEC-RAS model. It has been done through creating themes such as stream theme and cross section theme using preRAS menu came out from HEC-GeoRAS extension. All themes then were inputted into theme set up for generating the geometric data import files. Description of those themes and theme set up is shown in Figure 2.

![Themes and theme set up used to generate the geometric data import file](image)

### 3.3. Generating Inflow Hydrographs Using Win-TR55 Hydrologic Model

Win-TR55 model has been used to generate inflow hydrographs required as boundary condition by HEC-RAS model. In order to run WinTR-55 model, the total runoffs area was divided into 5 major subareas and 15 sub-subareas based on topographic condition and runoff flow direction. A subarea can consist of single sub-subarea or several sub-subareas. The runoff from a sub-subarea then was conveyed to another sub-subarea in a subarea through the existing natural channels and constructed channels that have been set to be connected and directed to the study area through a major outlet. This model generated hydrographs for each sub-subarea, and each outlet based on SCS method by inputting amount of rainfall intensity, the landuse distribution, HSG type and hydraulic structure parameters in each sub-subarea. This study used rainfall intensity for 2 and 10 years Average Recurrence Interval (ARI). The description of sub-subareas distribution and runoff flow direction is shown in Figure 3 and the hydrographs of each outlets resulted for 2 and 10 years ARI are shown in Figure 4.
3.4. Performing and running the model using HEC-RAS Hydraulic Model

HEC-RAS hydraulic model has been applied in this study to simulate the water surface profiles for condition with and without Harapan Lake in the model as shown in Figure 5. This model also has been used to simulate three additional conditions that are:

- Condition with the increase of Harapan Lake storage capacity by 20% in the model,
- Condition with the increase of Harapan Lake storage capacity by 50% in the model,
- Condition with an additional channel as outlet of Harapan Lake to be connected to Gambir River reach at RS 134.

3.5. Flood Profiles Simulation
Primarily, water surface profile simulations for condition with and without Harapan Lake were carried out for 2 years ARI and 10 years ARI. The maximum water surface elevations for three selected river stations (RS 408, RS 304 and RS 110) from each condition was taken out as shown in Figure 6 and summarized in Table 1 and compared in order to investigate the effectiveness of Harapan Lake in reducing the flood levels for 2 years ARI and 10 years ARI. Furthermore, three additional simulations as mentioned in section 3.4 also were carried out for 2 years ARI. The simulation of maximum water surface elevations inside Gambir River reach for RS 408, RS 304 and RS 110 from those conditions then were compared to condition without Harapan Lake for 2 years ARI as shown in Figure 7 and summarized in Table 2. Subsequently those results are analyzed in order to present the effect of improvement of the current Harapan Lake storage capacity and river system on flood behavior for 2 years ARI.

Table 1: The maximum water surface elevations of three selected river station for condition with and without Harapan Lake (2 years ARI and 10 years ARI)

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>The Maximum water surface profiles for selected river station (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 years ARI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RS. 408</td>
</tr>
<tr>
<td>1</td>
<td>With Harapan Lake</td>
<td>4.84</td>
</tr>
<tr>
<td>2</td>
<td>Without Harapan Lake</td>
<td>5.11</td>
</tr>
<tr>
<td>*</td>
<td>Bank Elevation</td>
<td>4.4</td>
</tr>
</tbody>
</table>

* Bank Elevation

Fig. 6: Comparison of maximum water surface elevations for conditions with and without Harapan Lake (2 years ARI and 10 years ARI)

Table 2: The maximum water surface elevations of three selected river station for all conditions (2 years ARI)

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>The Maximum water surface profiles for selected river station (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 years ARI</td>
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<tr>
<td></td>
<td></td>
<td>RS. 408</td>
</tr>
<tr>
<td>1</td>
<td>Without Harapan Lake</td>
<td>5.11</td>
</tr>
<tr>
<td>2</td>
<td>With Harapan Lake</td>
<td>4.84</td>
</tr>
<tr>
<td>3</td>
<td>Addition of Harapan Lake storage capacity by 20%</td>
<td>4.84</td>
</tr>
<tr>
<td>4</td>
<td>Addition of Harapan Lake storage capacity by 50%</td>
<td>4.84</td>
</tr>
<tr>
<td>5</td>
<td>Addition of an outlet channel at RS 134</td>
<td>4.56</td>
</tr>
<tr>
<td>*</td>
<td>Bank Elevation</td>
<td>4.4</td>
</tr>
</tbody>
</table>

* Bank Elevation
4. Result and Discussion

Based on Figure 6 and Table 1, the simulation results for both 2 years ARI and 10 years ARI shows that condition without Harapan Lake produce higher flood levels than the condition with Harapan Lake constructed in the river system. The result also shows that the current storage capacity of Harapan Lake for current river system is able to reduce the flood levels at RS 110 approximately 19.5 % (25 cm) for 2 years ARI and 18.4 % (60 cm) for 10 years ARI.

Furthermore, Figure 7 and Table 2 show that the increasing by 20% or 50% of the current storage capacity of Harapan Lake produce the same flood levels with condition before its improvement while addition of an outlet channel that connects Harapan Lake to Gambir River reach at RS 134 give reduction of the flood level at RS 110 by 73 cm (43%). It demonstrates that the current storage capacity of Harapan Lake in the current river system is effective in reducing the flood levels at USM Main Campus area. However, increasing the current storage capacity by 20% or 50% of Harapan Lake does not give effect on hydrologic performance of Harapan Lake and adding an outlet channel that connect Harapan Lake to Gambir River reach at RS 134 will reduce the flood levels more effectively.

5. Conclusion

USM Main Campus has experienced the flash flood problems since its development. Harapan Lake as one of flood mitigation structures has been constructed inside USM Main Campus in order to reduce the flood problems inside the campus area. Unfortunately, the flash flood problems still occur and thus, effectiveness of Harapan Lake in reducing the flood problems is questionable. Based on comparison of flood behaviors from conditions with and without Harapan Lake for 2 and 10 years ARI and others conditions for 2 years ARI, it can be concluded that the current storage capacity of Harapan Lake in the current river system can reduce the flood levels approximately 19.5 % (25 cm) for 2 years ARI and 18.4 % (60 cm) for 10 years ARI. The increasing of the current storage capacity of Harapan Lake by 20% or 50% does not influence the hydrologic performance of the Harapan Lake and by adding an outlet channel that connect Harapan Lake to Gambir River reach at RS 134 in the current river system, the Harapan Lake can reduce the flood levels approximately 43% and thus, can reduce the flood problem at study area more effectively.

6. Acknowledgement

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7. References


