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Integration of hydraulic model (HEC-RAS) with Geographical Information System (GIS) in developing flood evacuation center along Sembrong River

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Abstract. Flood event create a continuing threat to lives, environment and infrastructure throughout the world. Recently, there is an increasing use of computer models in identifying flood prone area. Identification of flood prone area will assist in determining flood evacuation center in needs of protecting flood victims. The objective of this research is to develop flood evacuation center along Sembrong river of Batu Pahat using Hydraulic Model HEC-RAS integrated with Geographical Information System (GIS). HEC-RAS was used to produce an output of two-dimensional unsteady flow analysis to determine flood prone area. Integration of both softwares will determine the suitability of the existing flood evacuation center. By using GIS technology, 14 new locations of evacuation center with suitable criteria such as route network and capacity were proposed for rescuing and evacuating flood victims. The developed flood evacuation center can be a very useful information for flood evacuation planning.

1. Introduction

Natural disasters are said to be cataclysmic or in other words a violent natural event that could give either a direct or indirect impact towards the public health and wellbeing [1]. Flood is one of the major concerns in natural disaster since it happened in many places all around the world. The impact of flood has caused considerable damage to high-ways, settlement, agriculture and livelihood [2].

Floods are usually local short-lived events that can happen suddenly and sometimes with no warning. They are usually caused by intense storms that produce more runoff for an area to store or a stream to sustain within its normal channel. A theoretical explanation state that flooding usually caused either by the continuous rain that causes greater quantity than usual or overflow of river water to the river bank or both happen at once [3]. Low land area that does not able to accommodate the overflow of river water will have high probability of flooding due to the rising of sea level.

The issue of flood involving the emergency response solution can be approached from the aspect of flood evacuation center’s suitability and that require multiple solutions especially in using HEC-RAS and GIS software. Assistance measures such as planning routes for evacuation people and the location of temporary facilities are important in disaster measurement [4]. Flooded in an area can be analyses by using HEC-RAS hydraulic model since it can provide an overview of a situation similar to the situation that exists in the real world. HEC-RAS is a software package that is well-suited for
developing flood inundation maps for a variety of applications [5]. HEC-RAS also can be used for the simulation of one-dimension or two-dimensions of the flood evolution which could have a stable or an unstable flow rate, sediment transport, change of the river bed and others [6]. While, GIS is one of the technological developments that began to develop and start to be used in Malaysia recently. There are various definitions and purposes of GIS application, but based on this research’s field, GIS is said to be a tool that helps in handling and integrate various spatial and non-spatial datasets, automates the development of the flood models, facilitate risk analyses and efficient generation of inundation maps and statistics that can be used as bases in various stages of flood disaster management [7].

Generally, this research presents two dimensional HEC-RAS hydraulic model of Sembrong River and the location of flood evacuation center. The results will be discussed at the end of this paper in order to determine floodprone area along Sembrong river area and location of the proposed flood evacuation center. This research also permits that combination of HEC-RAS and GIS as an effective data source in the floodprone management, addressing public awareness and also in flood evacuation planning.

2. Evacuation center
Evacuation is a risk management strategy that may be used to mitigate the effects of an emergency on a community where it involves the movement of people to a safer location and their return [8]. While, evacuation centre means a shelter for people who are directly affected by an emergency situation such as flood event and not have anywhere else. For example, they have been evacuated from their homes or cannot access their homes because of the incident.

Thus, planning for an evacuation centre needs to address many public health concerns that may include the physical amenities and space required for well-being, minimizing of the risk of communicable disease outbreaks, and the need to promote the health of evacuees to prevent the acute exacerbation of chronic disease [9]. There is a certain criteria that need to be accomplished as an evacuation centre. In disaster-prone developing countries, evacuation centers should be safely located. Since evacuation center usually established in schools and community centres, they should be designated and built to serve as an evacuation centres; and also be stocked with essential supplies such as food and equipped with good facilities.

3. Materials and methods
3.1 Study area
Sembrong dam is situated 10 km from Air Hitam town in the state of Johor. The dam provides downstream flood protection up to 100-years return period with a maximum release of 42 cumecs. Sembrong River flows through south-eastern part of Johor and afterward flows into Bekok River and Simpang Kanan River. It has a drainage length of 22.3 km that covers an area of 273 km².

In this research, Sembrong River is subdivided into sixty five (65) cross-sections according to cross-section data availability from Department of Irrigation and Drainage Batu Pahat in the form of drawing plan as shown in Figure 1. That drawing plan was obtained in the year of 1988 after the alignment of Sembrong River was made and still been used until now for the process of upgrading the river system. The cross-section is started from the downstream of river (Station 1) to the upstream of river (Station 65). Each of the cross-sections had an interval of approximately 344 meter. The land usage activities along this river inclusive of industrial areas, residential areas and agriculture activities, such as palm oil mill and paddy fields [6].
3.2 Approach and methodology

The approach and methodology in creating database for the integration process of HEC-RAS and GIS is illustrated as in Figure 2, whereby it covers the following steps:

- Data collections for HEC-RAS and GIS,
- Analysis of flood prone area using HEC-RAS software,
- Integration data process from HEC-RAS to GIS,
- Analysis of existing evacuation center and its access route,
- Proposing new evacuation center using GIS software.

Figure 1. Sembrong river [10].
4. HEC-RAS analysis

4.1 Data collection

HEC-RAS analysis requires several parameters such as the left and right bank location, contraction and expansion coefficient, Manning’s coefficient, segment length between two adjacent cross-sections and DEM of Batu Pahat for the process of hydraulic model and flood prone area analysis. Manning’s coefficient, $\eta$ of 0.03 for each cross-section is taken from the Urban Storm Water Management Manual for Malaysia, MSMA by Department of Irrigation and Drainage Malaysia [11]. Those parameters were used to obtain a series of cross-sections along the stream.

4.2 Cross-section of Sembrong River

Result from the geometry and flow data show the physical state of the available cross-section in each station. The physical state of each cross section is different from each other depending on the depth and width of the river’s station. Figure 3 shows example of HEC-RAS cross-section plot in Station 8. In the figure legend, EG stands for energy grade line and WS refers to the water surface. In order to determine when the river water will overflow to the flood prone area, left and right cliffs coordinate were plotted.

Table 1 tabulated the result of water overflow in all 65 stations. From the table, it can be concluded that the highest level of water overflow is 2.5 meter and the lowest level is 0.4 meter. The overflow of water for each station is different and not consistent depending on its cross section itself and the land elevation.
Figure 3. HEC-RAS cross-section plot.

Table 1. Water overflow in Sembrong River’s station.

| Station | Water overflow (m) | Station | Water overflow (m) | Station | Water overflow (m) | Station | Water overflow (m) | Station | Water overflow (m) |
|---------|--------------------|---------|--------------------|---------|--------------------|---------|--------------------|---------|--------------------|
| 1       | -                  | 15      | 0.4                | 29      | 0.6                | 43      | 1.4                | 57      | 2.0                |
| 2       | -                  | 16      | 1.0                | 30      | 0.4                | 44      | 2.5                | 58      | 2.0                |
| 3       | -                  | 17      | 0.8                | 31      | 0.4                | 45      | 1.2                | 59      | 2.0                |
| 4       | 0.4                | 18      | 0.8                | 32      | 2.5                | 46      | 1.2                | 60      | 2.0                |
| 5       | 0.4                | 19      | 0.4                | 33      | 2.5                | 47      | 2.4                | 61      | 2.0                |
| 6       | 0.4                | 20      | 0.4                | 34      | 2.5                | 48      | 0.6                | 62      | 2.0                |
| 7       | 0.4                | 21      | 0.4                | 35      | 2.5                | 49      | 2.0                | 63      | 1.6                |
| 8       | 0.4                | 22      | 0.4                | 36      | 2.5                | 50      | 1.6                | 64      | 1.5                |
| 9       | 0.4                | 23      | 0.4                | 37      | 2.5                | 51      | 1.4                | 65      | 0.6                |
| 10      | 0.6                | 24      | 0.4                | 38      | 2.5                | 52      | 1.2                |         |                    |
| 11      | 0.4                | 25      | 0.4                | 39      | 2.5                | 53      | 2.0                |         |                    |
| 12      | 0.4                | 26      | 0.4                | 40      | 2.5                | 54      | 1.0                |         |                    |
| 13      | 0.4                | 27      | 0.4                | 41      | 2.5                | 55      | 2.0                |         |                    |
| 14      | 0.4                | 28      | 0.4                | 42      | 2.0                | 56      | 2.0                |         |                    |

4.3 Creating 2D flow area

DEM data of Batu Pahat in float (.flt) format was used to generate the terrain data in HEC-RAS. RAS Mapper extension in HEC-RAS will convert the float file to GeoTIFF (.tif) file so that smaller storage capacity, faster computational speed and a dynamic map can be produced. Computation points were generated and its spacing point is set before computing the 2D flow area. Figure 4 shows 2D model of Sembrong river flow produced due to water spills out into the overbank areas.

4.4 Integration process between HEC-RAS and GIS

Floodprone area data obtained from HEC-RAS analysis was exported to GIS. Figure 5 shows the uses of RAS Mapper in exporting the layer of geometric region so that the polygon shapefile can be created. While, Figure 6 represents the result when the layer is being added to Arc Map window.
Figure 4. 2D model flow of Sembrong River.

Figure 5. Exporting layer from RAS Mapper.

Figure 6. Arc Map displaying result from HEC-RAS.
5. GIS analysis

5.1 Data collection
Data were collected through field and computerized work. Global Positioning System (GPS) was used to locate the coordinate of existing flood evacuation center as tabulated in Table 2. Route of Batu Pahat was digitized in this research by using Google Earth. Other data such as Digital Elevation Model (DEM), contour line, land use, and population data also needed for the GIS analysis.

| No. | Name of evacuation center          | Coordinate  | Location |
|-----|-----------------------------------|-------------|----------|
|     |                                    | Latitude    | Longitude|          |
| 1   | Sekolah Kebangsaan Seri Bandan    | 1.93568     | 103.12547| Ayer Hitam|
| 2   | Sekolah Kebangsaan Bukit Kuari    | 1.91528     | 103.17799| Parit Raja|
| 3   | Sekolah Kebangsaan Kota Dalam     | 1.90020     | 103.16360| Ayer Hitam|

5.2 Flood map analysis
Flood map was produced by the process of raster calculating selected contour and elevation value of DEM data. Flood level of 3.0 meter high was selected as a reference level in this research. In this analysis, flood level map of 3.0 meter high was overlapped with the result of 2D Sembong river flow. Figure 7 illustrates map of flood prone area produced when all the results were overlapped with each other. The area coverage for floodprone with 3.0 meter high is 104.114 km² areas out of 1872.56 km² of Batu Pahat area.

5.3 Flood evacuation center’s suitability
This analysis is to determines the suitability of each evacuation center and its access route that affected by the flood area. Figure 8 illustrated the existing location of flood evacuation center in the research area. According to Department of Public Welfare, location of building and its access route that is safe from flood affected area are the criteria of good evacuation center.

As tabulated in Table 3, SK Seri Bandan does not pass the criteria since it was located at flood affected area and its access route has been submerged by flood of 3.0 meter high. While, SK Bukit Kuari and SK Kota Dalam still can be used as an evacuation center since they were not located at flood affected area and their access route can be used in transferring flood victims from residential area to evacuation center and vice versa. This analysis had determined that more evacuation center should be open in the research area for the next flood event preparation.

| No. | Flood evacuation center       | Address                  | Capacity | Route Condition               |
|-----|--------------------------------|--------------------------|----------|-------------------------------|
| 1   | SK Bukit Kuari                | Parit Raja               | 300      | Not affected                  |
| 2   | SK Seri Bandan               | Batu 3, Jalan Yong Peng  | 300      | Access route submerged by flood|
| 3   | SK Kota Dalam                | Taman UPC, Ayer Hitam    | 300      | Not affected                  |
Figure 7. Floodprone area of Sembrong River.
5.4 Propose new location of flood evacuation center

This analysis was carried out to determine new locations of evacuation center. Several criteria such as elevation value more than 3 meter from mean sea level, enough capacity to accommodate the population in that area and the availability of access route were used in determining the new location. Table 4 tabulated the details of 14 proposed evacuation center including its latitude and longitude value. Location of proposed flood evacuation centers in flood and its access route were shown in Figure 9.

Table 4. Details of proposed evacuation center.

| No. | Proposed Evacuation Center | Northing (N) | Easting (E) | Contour/Elevation (m) | Capacity (People) | Access Route |
|-----|-----------------------------|--------------|-------------|----------------------|-------------------|--------------|
| 1   | SK Seri Bulan               | 1.97579      | 103.10955   | 28                   | 300               | ✓            |
| 2   | SK Ayer Hitam               | 1.91922      | 103.18170   | 24                   | 300               | ✓            |
| 3   | SJK (C) Malayan             | 1.91513      | 103.18055   | 8                    | 300               | ✓            |
| 4   | SMK Datuk Menteri           | 1.91523      | 103.17841   | 6                    | 400               | ✓            |
| 5   | SMK Suria Perdana           | 1.88260      | 103.15170   | 32                   | 600               | ✓            |
| 6   | SK Seri Paya                | 1.87181      | 103.14478   | 24                   | 220               | ✓            |
| 7   | SK Parit Bingan             | 1.86277      | 103.10350   | 6                    | 300               | ✓            |
| No. | School Name                  | Latitude  | Longitude | Population | Status |
|-----|-----------------------------|-----------|-----------|------------|--------|
| 8   | SK Seri Sabak Uni           | 1.87093   | 103.12956 | 8          | 300    | √      |
| 9   | SK Tanjung Sembrong         | 1.87650   | 103.06308 | 14         | 300    | √      |
| 10  | SMK Tun Ismail              | 1.86785   | 103.11280 | 18         | 600    | √      |
| 11  | SK Parit Raja               | 1.85573   | 103.11549 | 20         | 400    | √      |
| 12  | SK Pintas Puding            | 1.85701   | 103.10062 | 24         | 300    | √      |
| 13  | SK Parit Jelutong           | 1.84599   | 103.08646 | 14         | 300    | √      |
| 14  | SK Pintas Raya              | 1.84790   | 103.07320 | 12         | 300    | √      |

**Figure 9.** Location of proposed flood evacuation center.
6. Conclusion
Through this research, flood-prone areas along Sembrong River were identified. It is important for the future in determining the flood-prone area especially once river overflow occurs. While, by using GIS technology, suitability of evacuation center was determined. In the other hand, this research helps Social Welfare Department in identifying the suitable location of evacuation center based on certain flood stage. It is important that the evacuation center is located in a suitable location that is near to residential area, on higher ground, can accommodate enough capacity of people and have a proper route network for the rescuing process.

The results of the analysis are very helpful during flood event since both the HEC-RAS and GIS are basically used for flood evacuation management, analysis and decision making purpose. Other than informing people about the flood occurrence, organizations such Fire and Rescue Department, National Security Council, Social Welfare and Malaysia Civil Defence Department will be able to have a better plan in providing shelter and medical facility to probable vulnerable area in the future.

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