



**Queensland University of Technology**  
Brisbane Australia

This may be the author's version of a work that was submitted/accepted for publication in the following source:

Pariartha, G., [Goonetilleke, A.](#), [Egodawatta, P.](#), & Mirfenderesk, H. (2020)

The prediction of flood damage in coastal urban areas.

*IOP Conference Series: Earth and Environmental Science*, 419(1), Article number: 012136.

This file was downloaded from: <https://eprints.qut.edu.au/202955/>

© **The Author(s)**

Published under licence by IOP Publishing Ltd

**License:** Creative Commons: Attribution 4.0

**Notice:** *Please note that this document may not be the Version of Record (i.e. published version) of the work. Author manuscript versions (as Submitted for peer review or as Accepted for publication after peer review) can be identified by an absence of publisher branding and/or typeset appearance. If there is any doubt, please refer to the published source.*

<https://doi.org/10.1088/1755-1315/419/1/012136>

PAPER • OPEN ACCESS

## The prediction of flood damage in coastal urban areas

To cite this article: G Pariartha *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **419** 012136

View the [article online](#) for updates and enhancements.

# The prediction of flood damage in coastal urban areas

**G Pariartha<sup>1</sup>, A Goonetilleke<sup>2</sup>, P Egodawatta<sup>2</sup> and H Mirfenderesk<sup>3</sup>**

<sup>1</sup>Engineering Faculty, Udayana University, Bukit Jimbaran, Badung, Bali, Indonesia

<sup>2</sup>Science and Engineering Faculty, Queensland University of Technology (QUT), GPO Box 2434, Brisbane, 4001, Queensland, Australia

<sup>3</sup>Gold Coast Natural Hazards Planning and Environment Division, PO Box 5042 GCMC 9726

E-mail: [gustave\\_sp@unud.ac.id](mailto:gustave_sp@unud.ac.id)

**Abstract.** The increase of impervious surfaces in the urban area triggers a flood. A flood occurs area with a dense population that will result in a lot of damage. The flood simulation itself is not adequate to calculate the flood damage, as it only shows the flood depth and extent. It needs the capability of mapping software to map the vulnerable area. Accordingly, the research study's aim is to propose the methodology to predict the flood damage on the coastal urban area by combining the flood simulation model with GIS mapping software. MIKE FLOOD and ArcGIS were used to represent the flood simulation model and mapping software. The flood depth and inundation area were calculated with MIKE FLOOD; meanwhile, the residential house was mapped using ArcGIS. Both of MIKE FLOOD and ArcGIS were then combined to obtain the flood depth in each residential house. Moreover, to value the flood damage in monetary terms, the depth-damage curve and average house prices were applied. The result shows that the majority of the inundation caused by riverine flood and coastal area is the place where the largest inundation area occurs. As the flood appears in a residential area, the flood damage of the residential building in terms of annual average damage (AAD) was obtained with the amount of \$8,716,227.67 calculated from six AEPs (50%, 20%, 10%, 5%, 2%, and 1%).

## 1. Introduction

One of the common disasters in urban stormwater management is flooding. The increase of urbanization increases the extent of the impervious area which commonly triggers flood in an urban area. The prediction of flood damage is complex as it is influenced by the flood depth, flow velocity, flood duration, contamination, sediment concentration, lead time and flood warning information, building characteristics, and the quality of external responses in a flood situation [1, 2]. Largely, most of the flood damage models use flood depth and the type of asset at risk to simplify flood damage estimation [3-5]. Moreover, to calculate flood damage in monetary terms, it is often based on the unit cost of a particular type of asset [6-8].

There two important components to predict the flood damage in the research study. First, the flood simulation model which can predict the depth and the extent of the flood. Second, the mapping software to map the flood-affected area. The flood simulation models are used to predict the flood depth and extent. Fluid motion is the principle for most of the models. The increase in complexity in real-world problem triggers the use of numerical methods which incorporate a range of assumptions and simplifications [9]. Flood simulation models can come in one-dimensional (1D), two-dimensional (2D), three-dimensional 3D and coupled 1D/2D formats.



The one-dimensional model only can estimate flow in one direction, which will often be the longitudinal direction of a waterway. Due to its simplicity, such models are still used in a range of modeling applications. Two-dimensional models are usually used to model floodplains, coastal and marine systems. It calculates the flow depth and velocity over grids or a mesh. The three-dimensional has been developed to eliminate all the limitations of 1D and 2D models. Consequentially, three-dimensional models require significantly high computation times. Therefore, based on the limitation of all flood simulation models, the 1D and 2D coupled model is commonly selected in a compromise between the accuracy and the computing time [10, 11].

However, the flood simulation model only shows the characteristics of flood that comprises the flood depth and inundation area. To calculate the flood damage in an urban area, it needs to map the flood-affected infrastructure in the studied area. Mapping software based on geographic information system is crucial to locate the infrastructures, and by combining both tools, the damage caused by flood in each infrastructure can be obtained.

Accordingly, the research is aimed to generate the methodology to predict the flood damage in the coastal urban area by investigating and combining the flood simulation model and GIS mapping software. The urban area infrastructure investigated in the research study was limited to the residential area as this type of area were commonly vulnerable to flooding.

## **2. Material and method**

### *2.1. Study area*

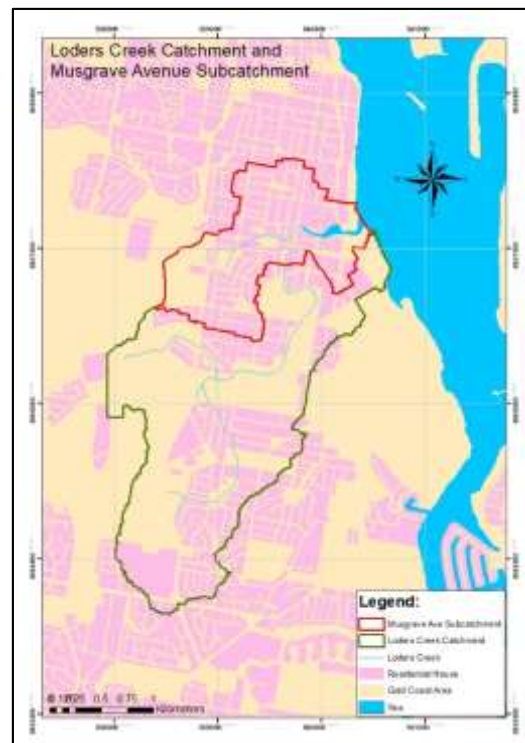
The research study was undertaken in Musgrave Avenue sub-catchment in Gold Coast, Australia. The Musgrave Avenue sub-catchment is a part of the Loders Creek Catchment. The Musgrave Avenue sub-catchment consists of highly dense, urban residential areas. This sub-catchment has an area of about 1.82 km<sup>2</sup> with a fairly flat landscape, especially at the downstream. Therefore, downstream of the sub-catchment is a flood-prone area. Furthermore, the flooding in the area is also influenced by tidal inflow as it is close to the coast. This condition is in accordance with the scope of the research study, which focused on flood damage to residential buildings in a coastal area. Figure 1 shows the Musgrave Avenue sub-catchment.

### *2.2. The selection of flood simulation model*

A model with the capability to simulate flooding in a catchment and estimate the inundated area and flood depth was required for this research study. The following criteria were important to be considered for the selection of an appropriate flood simulation model. First, the flood simulation model has to have the ability to accurately simulate hydrologic and hydraulic processes inherent to the selected urban catchment. Second, such a model needs to have the ability to simulate flooding with discrete rainfall events as flooding and conveyance ability of the stormwater network was considered to be based on discrete rainfall events. Third, the model can utilize a range of different file formats such as Microsoft Excel, Geographic Information System (GIS), and Google Earth. Last, the capability to simulate flood in 2 dimensions is essential.

There are many types of flood simulation modeling software that were commonly used. Some of them namely, URBS [12], EPA SWMM [13], INFOSWMM [14] and MIKE FLOOD [15]. These models were reviewed in-depth to identify the most appropriate model. URBS and EPA SWMM models are limited in several ways. These models cannot import GIS data files automatically and can only simulate floods in one-dimensional arrangements. Also, URBS and EPA SWMM models cannot handle the prerequisite data types, which is an essential requirement for this research study. On the other hand, INFOSWMM was developed based on SWMM with some modifications to improve its capability to handle GIS and other data formats. However, it can simulate floods only in a one-dimensional arrangement. Among the flood simulation models considered, MIKE FLOOD has all the criteria needed for the research study. Therefore, MIKE FLOOD was used as the primary flood simulation model in the research study.

MIKE FLOOD is a combination of three different models, namely, MIKE URBAN, MIKE 11, and MIKE 21. Such a model used the combination of 1 dimension and two dimensions (1D/2D) to simulate the flood. The 1D analysis is undergone by using MIKE URBAN which is primarily used for simulating urban stormwater networks and MIKE 11 which is a popular tool that is commonly used for simulating streamflow in channels and rivers. The 2D analysis was undertaken with MIKE 21 which is a runoff simulation model that is used for hydrodynamic simulations.



**Figure 1.** The Musgrave Avenue Subcatchment.

### 2.3. The GIS tool

GIS is the term that is used to discuss spatial data and the tools to manage, compile, and analyze the data [16]. The research study used ArcGIS as a GIS tool. Such a mapping tool is commonly used to analyze spatial data, and it integrates perfectly with MIKE FLOOD. In the research study, ArcGIS was used to map the residential area to support the estimation of flood damage. As the flood depth and inundation areas were the outcomes from MIKE FLOOD modeling, ArcGIS was applied to combine these results with the land use map to obtain flood damage in relation to each land use. Moreover, ArcGIS was also important to create various thematic maps used in the research study. To support MIKE FLOOD modeling, the geoprocessing feature in ArcGIS was frequently used

### 2.4. The assessment of flood damage

Hazard and vulnerability are the two factors essential to assess the flood damage. Hazard is the frequency and severity of the flood event. Meanwhile, vulnerability is the assets and people affected by the flood [17].

In order to assess the degree of hazard, the research study was applied to three crucial components. The first component is the determination of the design rainfall. The design rainfall applied is the Annual Exceedance Probability (AEP). AEP is the probability that a given total rainfall accumulated over a given duration will be exceeded in any one year [18]. The second component is urbanization. Such component was depicted by modifying the infiltration rate in MIKE FLOOD based on current study

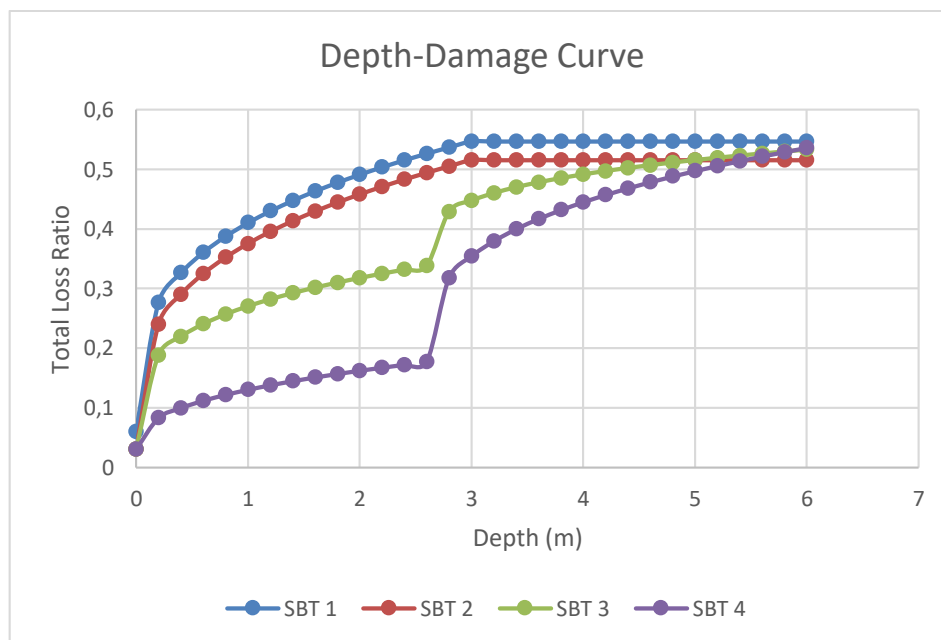
area land use. The last component is the sea level rise. This component was applied by modifying the outflow boundary.

Moreover, the vulnerability was estimated by considering the direct tangible losses as indirect and intangible losses are difficult to estimate in monetary terms [19, 20]. The tangible losses were based on the number of assets that are exposed to flooding in the study area. The assets used in the research study are the residential house. Thus, in order to value the flood damage in monetary terms, the property average price was used. To simplify, similar types of residential houses were grouped together based on the Simplified Building Type (SBT) classification. The SBT classification is taken from the Geoscience Australia (GA) classification. In this classification, there are four generic building classifications, as presented in table 1. However, to estimate the flood damage in monetary terms, both hazard and vulnerability assessment need the support of the depth-damage curve.

**Table 1.** Simplified Building Type (SBT) attributes [21].

SBT	Attributes
1	Single story, raised the floor, weatherboard cladding (Queenslander style)
2	Single story, brickwork cladding (notionally slab on ground)
3	Two stories all wall types (this type includes elevated and built under Queenslanders)
4	Type 3 but with the lower story partially built under or used as a garage

The depth-damage curve is commonly used for economic estimation of the tangible flood damage [22-24]. The depth-damage curve is a fraction of the total value in a vulnerable area or element at risk [25]. Accordingly, the depth-damage curve provides an estimation of the damage to a building with an increase in the flood height. The depth-damage curve used in the research study is a simplified version of Geoscience Australia (GA) figure 2.



**Figure 2.** Depth-damage curve.

The Average Annual Damage (AAD) is used to represent the flood damage in the research study. AAD provides the estimation of flood damages for the full range of flood events and an understanding of the financial benefits and limitations of stormwater management. To estimate AAD, several AEPs were selected, namely, 50%, 20%, 10%, 5%, 2%, and 1%. This selection was undertaken to cover the range of design floods, from frequent to rare flood events based on ARR 2016. The general equation for AAD is as equation 1.

$$AAD = \sum_n^1 \left[ \frac{d_{n-1} + d_n}{2} (p_n - p_{n+1}) \right] \quad (1)$$

Where:

$AAD$  = Average Annual Damage  
 $d, n-1, \dots, n$  = flood damage (\$)  
 $p, n, \dots, n+1$  = the probability of AEP occurrence

### 3. Result and discussion

#### 3.1. MIKE FLOOD setup

The basic model MIKE FLOOD model for Loders Creek and Musgrave Avenue as its sub-catchment was supplied by Gold Coast Natural Hazards Planning and Environment Division (GCNHPED). However, several setups need to undertake to run the basic model in the research study prior to simulating the flood events. The setups are described as follows.

##### 3.1.1. MIKE 21 setup

MIKE 21 is the two-dimensional model used to estimate runoff by using hydrodynamic equations. The MIKE 21 setup by GCNHPED comprised of topography, surface roughness, initial surface elevation, boundary condition, and rainfall intensity. However, this setup of MIKE 21 still does not depict the urban expansion rate. Hence, the research study depicted the urbanization rate by changing the infiltration rate. The size of the grid in MIKE 21 used in the research study is 2 x 2 m with the elevation of the area located beyond the Loders Creek catchment was given a value of 38 m above mean sea level to ensure all the runoff flows into Loders Creek

The surface roughness in MIKE 21 was based on Manning's roughness value. Manning's roughness is typically used in the form of  $n$  or  $M$  where  $M$  is equal to  $1/n$ . In MIKE 21, Manning's roughness in the form of  $M$  is used where, the higher the value of  $M$ , the smoother the surfaces. A range of Manning's roughness values for different land cover types, namely, road pavement, community facilities, high density residential, low density residential, medium-density residential, neighbourhood centre, sport and recreation, open spaces (thick with trees), and open spaces (fewer trees), are available in the MIKE FLOOD model

Meanwhile, the initial surface elevation, which is the initial value of the water level in Loders Creek was consistent with the topography values. However, to model the initial water depth in the creek, the GCNHPED used the value "0".

In common, most of flood simulation model needs boundary condition to bound the calculation. In MIKE 21, The boundary of Loders Creek consists of an upstream boundary and downstream boundary. The upstream boundary is the water level of Loders Creek Dam and the downstream boundary is the water level at the Broadwater. Moreover, the rainfall intensities were the primary input to MIKE 21.

For the infiltration, the research utilized the Initial Loss (IL)-Continuing Loss (CL) to model the infiltration rate. The initial assumption of IL and CL was inspired by design loss value from the Australian Rainfall and Runoff (ARR) 2016 data hub [26]. Hence, the road pavement was assumed to have no infiltration, while for open spaces the IL was initially taken as 42 mm and the CL as 3.9 mm/hour. For the community facilities, high-density residential, low-density residential, medium-density residential, neighborhood center, special purpose, and sport and recreation, the IL and CL were initially assumed to be 12.6 mm and 1.17 mm/hr, which is 30% of the IL and CL values for open spaces.

### 3.1.2. MIKE URBAN

MIKE URBAN is a one-dimensional modeling tool, which has the capability to simulate stormwater drainage systems, water distribution systems, and sewer systems [27]. MIKE URBAN was used to simulate the stormwater drainage system at Loders Creek catchment. The setup of MIKE URBAN for calibration focused on the current stormwater drainage system in Loders Creek catchment. The drainage pipes consist of circular and rectangular shaped concrete conduits. The Manning's roughness coefficient was taken as 75 for the concrete stormwater drainage based on the value determined by GCNHPED.

### 3.1.3. MIKE 11

MIKE 11 is a 1D model that can simulate flow and flood depth in rivers, canals, reservoirs, and other inland water bodies. In the research study, MIKE 11 was applied to model the streamflow in open channels below the bridges. In Loders Creek catchment, there are two bridges that needed to be modeled. The first bridge spans Loders Creek at Musgrave Avenue. The second bridge spans Loders Creek at Gold Coast Highway. To model the streamflow under these bridges, two cross-sections for each bridge were established. One cross-section was located upstream of the bridge and the other at the downstream of the bridge.

## 3.2. MIKE FLOOD calibration

Two flood events were used for the MIKE FLOOD calibration. These events were historical flood events obtained from Gold Coast Natural Hazards Planning and Environment Division (GCNHPED). The first was the flood event on 28 June 2005. It was recorded as the heaviest June daily rainfall since 1967 [28]. The Loders Creek flood gauge recorded the flood peak of this event, reaching 4.82 m at 10.15 AM. The second event was the flood on 2 January 2008. The recorded flood peak was 1.33 m at 11.00 PM [29].

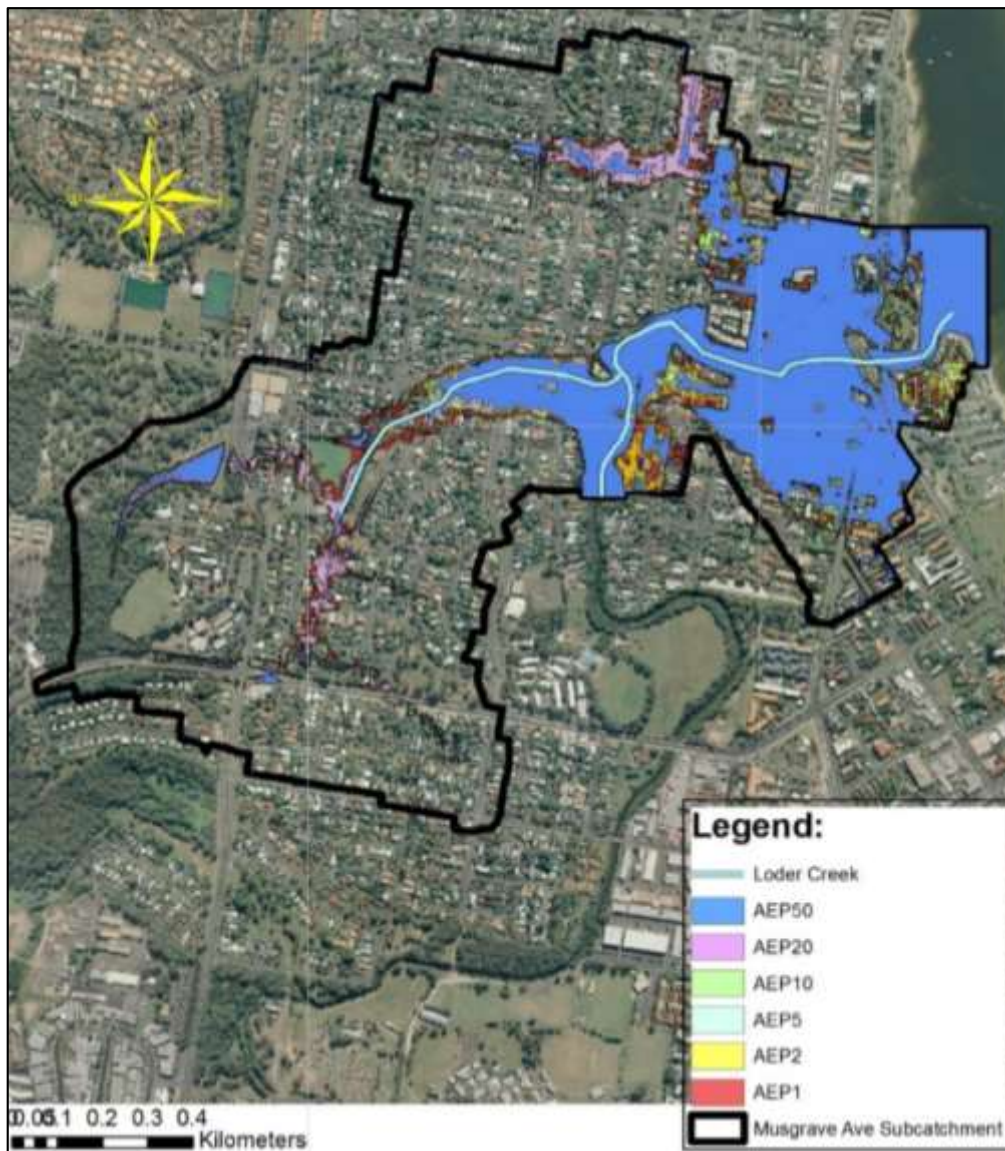
The recalibration process underwent only the parameters in MIKE URBAN and MIKE 21. The parameter in MIKE 11 was not calibrated as it only aimed to discharge the flow to the receiving water without any disruption (it only modeled the flow below the bridges). The calibration processes compared the simulated water level obtained from MIKE FLOOD and observed water level recorded by the streamflow gauge. The recalibration was undertaken for the infiltration rate and roughness coefficient for land uses in MIKE 21. Meanwhile, the pipe roughness coefficient also needs to recalibrate in MIKE URBAN.

The recalibration procedures yield that the roughness coefficient for a drainage pipe is similar to what was determined by GCNHPED. Also, the roughness coefficient for land uses followed Manning's value determined by GCNHPED. Moreover, the recalibration for the infiltration rate in various land uses was found 21 mm/hour for initial loss (IL) and 1.95 mm/hour for continuous loss (CL). However, the infiltration rate for the road pavements and open space remained the same as before the recalibration.

## 3.3. Flood damage assessment

The initial procedure is to simulate the flood in MIKE FLOOD to generate the flood depth and area. The flood simulation generated the flood based on six annual exceedance probabilities (AEPs). The 6 AEPs comprise of AEP50, AEP20, AEP10, AEP5, AEP2, and AEP1. These AEPs were used as the AAD needs a range of flood damage from various flood events probability. The rainfall intensity for each AEP as a crucial input to the MIKE FLOOD was obtained from Australia Rainfall and Runoff (ARR) datahub. Meanwhile, the rainfall critical duration and the temporal pattern was determined based on ARR 2016 guidelines. Accordingly, the result of MIKE FLOOD is illustrated in figure 3.





**Figure 3.** The Result of MIKE FLOOD simulation result for Musgrave Avenue Subcatchment for all AEPs.

Figure 3 shows that most of the inundation occurs at the downstream of Musgrave Avenue subcatchment which dominate by the flat slope. Furthermore, the inundation also appears along the Loders Creek. This condition indicates that the inundation mostly caused by riverine flood as the inundation comes from the creek channel to its vicinity. This step yields the flood depth in each 2 x 2 m grids. The next part is to calculate the flood-related damage in a residential area by combining the MIKE FLOOD result with SBT mapping in ArcGIS.

The area of each SBT was obtained using ArcGIS, Google Street View, and field survey. The Google Street View provides a panoramic view from the street. Additionally, a field survey was undertaken to confirm the current condition of the residential buildings. Accordingly, Google Street View and field surveys were used to categorize the residential buildings based on SBT classification. SBT mapping is illustrated in figure 4.



**Figure 4.** Classification of residential houses at Musgrave Avenue Subcatchment Based on SBT.

Figure 4 shows that the majority of the residential houses in Musgrave Avenue is a single-story house with brick or weatherboard cladding. However, some of the single-story buildings have their floor raised (Old Queenslander style) with most of the two-story houses (SBT3 and SBT4) that are found to be built near the coastal area. Moreover, the SBT map and the flood map were combined using ArcGIS. With this combination, the flood depth in each residential building was obtained. To simplify, the calculation of flood damage for each SBT was not based on a number of residential houses but it used the area of each SBT.

Thus, the depth-damage curve used to calculate the damage in each SBT by multiplying the fraction of the total loss ratio in each grid with the average price of the residential house. The average price of each SBT type of residential house had been calculated with the price for SBT 1 is \$1026.59 /m<sup>2</sup>, SBT2 is \$1842,39 /m<sup>2</sup>, SBT3 is \$1544.49 /m<sup>2</sup>, and SBT4 is \$1767.78 /m<sup>2</sup>. The total flood damage of each AEP and the AAD value is shown in table 2.

**Table 2.** The flood damage for each AEP and AAD.

AEP	Damage	AAD
50	\$9,588,877.01	
20	\$19,767,673.16	
10	\$20,481,236.64	\$8,716,227.67
5	\$26,166,746.75	
2	\$27,537,578.95	
1	\$38,169,456.70	

Table 2 shows that the flood damage is increasing while the AEP value decreases. This is because AEP shows the probability of occurrence for the flood events. The AEP 1 means the occurrence probability for flood is only 1%. Meanwhile, AEP50 means the flood has a 50% probability to occur in each year. The AAD value obtained is \$8,716,227.67.

#### 4. Conclusions

Based on the flood model simulation, the largest inundation occurs around the coastal area of the Musgrave Avenue sub-catchment as the slope is relatively flat. Moreover, the model also shows that most of the inundation in Musgrave Avenue sub-catchment was caused by a riverine flood. Hence, by combining the flood simulation model result with the SBT map in ArcGIS, the flood depth in each residential house was obtained. In order to determine the flood damage in monetary terms, the depth-damage curve was applied. By summarising all the flood damage for each residential house based on their SBT type, the total flood damage in each AEP was obtained. In conclusion, the proposed methodology by combining the 2D flood simulation model (MIKE FLOOD) and GIS (ArcGIS) shows a satisfying result as it can calculate the flood damage by considering the detail flood depth in each residential house.

#### References

- [1] Merz B, et al 2010 Review article "Assessment of economic flood damage" *Natural Hazards and Earth System Sciences* **10**(8) 1697-1724.
- [2] Chinh D, et al 2016 Multi-Variate Analyses of Flood Loss in Can Tho City, Mekong Delta *Water* **8**(1) 6.
- [3] Wind H, et al 1999 Analysis of flood damages from the 1993 and 1995 Meuse floods *Water resources research* **35**(11) 3459-3465.
- [4] Merz B, A Thielen, and M Gocht 2007 Flood risk mapping at the local scale: concepts and challenges, in *Flood risk management in Europe Springer* 231-251.
- [5] Pistrika A K and S N Jonkman 2010 Damage to residential buildings due to flooding of New Orleans after hurricane Katrina *Natural Hazards* **54**(2) 413-434.
- [6] Apel H, et al 2004 Flood risk assessment and associated uncertainty *Natural Hazards and Earth System Science* **4**(2) 295-308.
- [7] Ballesteros-Cánovas J, et al 2013 An integrated approach to flood risk management: a case study of Navaluenga (Central Spain) *Water resources management* **27**(8) 3051-3069.
- [8] Zhou Q, et al 2013 Adaption to extreme rainfall with open urban drainage system: An integrated hydrological cost-benefit analysis *Environmental management* **51**(3) 586-601.
- [9] Toombes L and H Chanson 2011 Numerical Limitations of Hydraulic Models *Engineers Australia* 2322-2329.
- [10] Anees MT, et al 2016 Numerical modeling techniques for flood analysis *Journal of African Earth Sciences* **124** 478-486.
- [11] Dimitriadis P, et al 2016 Comparative evaluation of 1D and quasi-2D hydraulic models based on benchmark and real-world applications for uncertainty assessment in flood mapping *Journal of Hydrology* **534** 478-492.
- [12] Carrol D G 2007 *A Rainfall-Runoff Runoff Routing Model for Flood Forecasting and Design*. (Australia: Queensland)
- [13] Gironás J, et al 2010 A new applications manual for the Storm Water Management Model (SWMM) *Environmental Modelling & Software* **25**(6) 813-814.
- [14] MWH 2005 *InfoSWMM user manual* (Pasadena, CA: MWH Soft Inc)
- [15] DHI 2016 *MIKE 21 Flow Model Hydrodynamic User Guide*
- [16] Childs C 2004 Interpolating surfaces in ArcGIS spatial analyst *ArcUser* **3235** 569.
- [17] Haynes H, R Haynes and G Pender 2008 Integrating socio-economic analysis into a decision-support methodology for flood risk management at the development scale (Scotland)

- Water and Environment Journal* **22**(2) 117-124.
- [18] Ball J, et al 2016 Australian Rainfall and Runoff: A Guide to Flood Estimation *Commonwealth of Australia*
- [19] Kreibich H, et al 2010 Development of FLEMOcs—a new model for the estimation of flood losses in the commercial sector *Hydrological Sciences Journal—Journal des Sciences Hydrologiques* **55**(8) 1302-1314.
- [20] Eleuterio J 2012 *Flood Risk Analysis: Impact of Uncertainty in Hazard modeling and Vulnerability Assesment in Damage Estimations in National School of Water and Environmental Engineering of Strasbourg, France* (France: University of Strasbourg)
- [21] Mason M, et al 2012 *Analysis of damage to buildings following the 2010–11 Eastern Australia floods* (Gold Coast: National Climate Change Adaptation Research Facility) p 95
- [22] Smith D 1994 Flood damage estimation- A review of urban stage-damage curves and loss functions *Water S A* **20**(3) 231-238
- [23] Freni G, G La Loggia and V Notaro 2010 Uncertainty in urban flood damage assessment due to urban drainage modeling and depth-damage curve estimation *Water Science and Technology* **61**(12) 2979-2993.
- [24] Pistrika A, G Tsakiris and I Nalbantis 2014 Flood Depth-Damage Functions for Built Environment *Environmental Processes* **1**(4) 553-572.
- [25] de Moel H and J C J H Aerts 2011 Effect of uncertainty in land use, damage models and inundation depth on flood damage estimates *Natural Hazards* **58**(1) 407-425.
- [26] Babister M, et al 2016 *The Australian Rainfall & Runoff Datahub*
- [27] DHI 2016 *Mike Urban User Manual* (Danish Hydraulic Institute)
- [28] BoM 2007 *Heavy Rainfall Gold Coast, 30<sup>th</sup> June 2005* (Australia: Bureau of Meteorology, Australian Government)
- [29] BoM 2008 *South East Queensland Flood, January 2008* (Australia)