# FLOOD DAMAGE AND RISK ASSESSMENT FOR URBAN AREA IN SEGAMAT

**NOOR SURAYA BINTI ROMALI**

**UNIVERSITI TEKNOLOGI MALAYSIA**

We hereby declare that we have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Doctor of Philosophy (Civil Engineering)

Signature : .....

Name of Supervisor I : PROF. DR. ZULKIFLI BIN YUSOP

Date : 9/8/2018

Signature : .....

Name of Supervisor II : DR. ZULHILMI BIN ISMAIL

Date : 9/8/2018

Signature : .....

Name of Supervisor III : DR. MUHAMMAD @ S.A. KHUSHREN BIN SULAIMAN

Date : 9/8/2018

**BAHAGIAN A – Pengesahan Kerjasama***

Adalah disahkan bahawa projek penyelidikan tesis ini telah dilaksanakan melalui kerjasama antara _____ dengan _____

Disahkan oleh:

Tandatangan : …… Tarikh : ……..

Nama : ……....

Jawatan : ……....
(Cop rasmi)

* Jika penyediaan tesis/projek melibatkan kerjasama.

---

**BAHAGIAN B – Untuk Kegunaan Pejabat Sekolah Pengajian Siswazah**

Tesis ini telah diperiksa dan diakui oleh:

Nama dan Alamat Pemeriksa Luar : **Prof. Ir. Dr. Amir Hashim Mohd Kassim**
**Fakulti Kejuruteraan Awam dan Alam Sekitar**
**Universiti Tun Hussein Onn Malaysia**
**86400 Batu Pahat, Johor**

Nama dan Alamat Pemeriksa Dalam : **Prof. Dr. Sobri Harun**
**Sekolah Kejuruteraan Awam**
**Fakulti Kejuruteraan Awam**
**Universiti Teknologi Malaysia**
**81310 Johor Bharu, Johor**

Disahkan oleh Timbalan Pendaftar di SPS:

Tandatangan : …… Tarikh : ……

Nama : ……..

# FLOOD DAMAGE AND RISK ASSESSMENT FOR URBAN AREA IN SEGAMAT

NOOR SURAYA BINTI ROMALI

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

August 2018

I declare that this thesis entitled "*Flood Damage and Risk Assessment for Urban Area in Segamat*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : NOOR SURAYA BINTI ROMALI

Date : 9/8/2018

# DEDICATION

To my beloved parents
Romali Bin Jusoh and Fatimah Binti Mohamad

To my pillar of strength
Aimi Ilmar Bin Ramli

To the love of my life
Muhammad Aiman Bin Aimi Ilmar
Noor Aina Sofia Binti Aimi Ilmar

To me
Thank you for not giving up!

# ACKNOWLEDGEMENT

*In the name of Allah, the most Gracious, the most Merciful,*

First and foremost, I would like to express my sincere appreciation to my supervisor, Prof. Dr. Zulkifli Yusop for his guidance and wisdom. Thank you for the continuous encouragement and support throughout this PhD journey. My endless gratitude also goes to Dr. Zulhilmi Ismail, Dr. Muhammad Sulaiman and Ahmad Zuhdi Ismail for without them, I'd be lost in searching for guidance and ideas.

I would also like to convey my utmost gratitude to the Ministry of Higher Education (MOHE) and Universiti Malaysia Pahang for the scholarship that made it possible for me to sustain my studies. This study has been supported by research grant Q.J130000.2409.00G08, R.J130000.7809.4F208 and Institut Inovasi Strategik Johor (IISJ) Vot 15H00.

Special kind of love and gratitude to all my family members; especially my husband, my children, my parents, my parents in law and my siblings for all the patience and tolerance, for they are the backbones that have supported me throughout this journey and without them, the journey to my PhD won't be possible. To my friends and colleagues, I thank you for all the help and motivation and most importantly being so understanding in these testing years.

Last but not least, to my sweethearts, Aiman and Aina. Thank you for always pushing me to do my best. Please forgive me for all the times I had missed out, for the lack of attention or if I had hurt you both unintentionally for not being there. Do remember that for all that I have done, it is solely for both of you.

# ABSTRACT

In recent years, risk-based flood mitigation approach received more attention compared to conventional or structural approach. However, in developing countries, literatures on flood vulnerability assessment are limited especially on flood damage. In Malaysia, the assessment of flood damages is challenging due to data scarcity. Hence, an attempt has been made to establish a flood damage assessment framework for an urban area of Segamat town, Johor. The concept of flood risk involved the elements of hazard, exposure, and vulnerability. The combination of hydrological characteristics, exposed elements, value of exposed elements, and flood damage function curve was used for estimation of flood damages. The flood depth and areal extend were obtained from flood modeling and mapping using HEC-HMS/RAS and Arc GIS. A site-specific flood depth–damage curve was developed based on land use category, socio-economic status of the flood victims and property characteristics. Due to data scarcity, synthetic method was applied to generate flood damage data based on the 2011 major flood event. Damage percentage was calculated by dividing the replacement cost by the market value of the properties and plotted against the observed flood depth. In addition to flood depth, the flood damage was also influenced by household income and property's price. Therefore, the residential category was further divided into three sub-categories; low price house (LPH), medium price house (MPH) and high price house (HPH). Using $R^2$ of 0.76 for commercial area and from 0.80 to 0.85 for various residential categories, the flood depth-damage curves obtained in this study were good enough and comparable with other studies. The estimated total damages for residential and commercial categories during the 2011 flood were RM456 mil and RM143 mil respectively. The expected annual damage (EAD) for residential areas (50,112 units) and commercial areas (9,318 premises) were RM12.59 million and RM2.96 million respectively. Generalized Pareto (GP) distribution model was used to estimate peak discharge of 10, 25, 50, 100, 200, 500 and 1000 ARI which were subsequently applied for deriving flood maps. Based on the GP distribution, the 2011 flood was equivalent to 42 years average recurrence interval (ARI). Flood hazard map shows that Bandar Seberang area (46,184 properties) was the most affected by flood. The flood damage risk map illustrates similar patterns where the distribution of damages were concentrates at the Bandar Seberang area with some properties suffered damages of more than RM15,000 per unit. Although it is a site-specific study, the framework can be applied to assess the potential future damages and serve as a basis for future studies on flood risk assessment in Malaysia.

# ABSTRAK

Kebelakangan ini, pendekatan tebatan banjir berasaskan risiko menerima lebih banyak perhatian berbanding pendekatan konvensional yang menggunakan pendekatan struktur. Walau bagaimanapun, di negara-negara membangun, literatur berkaitan penilaian risiko banjir dari segi kesan kepada masyarakat dan harta benda adalah terhad terutama berkaitan penilaian kerosakan banjir. Di Malaysia, penilaian kerosakan banjir sukar dilakukan kerana kekangan data. Oleh itu, kajian ini bertujuan untuk menghasilkan satu rangka kerja penilaian kerosakan banjir untuk kawasan bandar Segamat, Johor. Konsep risiko banjir merangkumi unsur ancaman, pendedahan dan kerentanan akibat banjir. Gabungan ciri-ciri hidrologi, unsur terdedah, nilai unsur terdedah, nilai anggaran kerosakan disebabkan banjir dan lengkung fungsi kerosakan banjir digunakan bagi menganggarkan kerosakan banjir. Maklumat aras banjir dan kawasan litupan banjir diperolehi daripada permodelan dan pemetaan banjir menggunakan HEC-HMS/RAS dan Arc GIS. Lengkung kedalaman-kerosakan banjir yang khusus untuk kawasan kajian telah dihasilkan berdasarkan kategori guna tanah, status sosio-ekonomi mangsa banjir dan ciri-ciri harta benda. Disebabkan kekurangan data, kaedah sintetik digunakan untuk menghasilkan data kerosakan banjir berdasarkan peristiwa banjir besar 2011. Peratusan kerosakan (dikira dengan membahagikan kos baik pulih dengan nilai pasaran hartanah) di plot melawan kedalaman banjir. Selain daripada kedalaman banjir, tahap kerosakan banjir adalah dipengaruhi oleh pendapatan isi rumah dan harga kediaman. Oleh itu, kerosakan bagi kategori kediaman dibahagikan kepada tiga sub-kategori iaitu rumah harga rendah (LPH), rumah harga sederhana (MPH) dan rumah harga tinggi (HPH). Dengan $R^2$ 0.76 untuk kategori komersil dan 0.80 hingga 0.85 bagi pelbagai kategori penempatan, lengkung kerosakan banjir yang diperolehi adalah baik dan setara dengan kajian-kajian lepas. Anggaran jumlah kerosakan kategori kediaman dan komersil akibat banjir tahun 2011 adalah RM456 juta dan RM143 juta. Jangkaan kerugian tahunan (EAD) untuk kawasan kediaman (50,112 unit) dan kawasan komersil (9,318 premis) adalah RM12.59 juta dan RM2.96 juta. Model taburan Generalized Pareto (GP) telah digunakan untuk menganggar aliran puncak bagi 10, 25, 50, 100, 200, 500 and 1000 ARI, yang seterusnya digunakan bagi menghasilkan peta ancaman banjir. Berdasarkan model taburan GP, banjir 2011 bersamaan dengan 42 tahun purata selang pengulangan (ARI). Peta ancaman banjir menunjukkan bahawa kawasan Bandar Seberang (46,184 harta) adalah yang paling terjejas semasa banjir 2011. Peta risiko kerosakan banjir menggambarkan pola taburan kerosakan yang sama di mana taburan kerosakan tertumpu di Bandar Seberang dengan sebahagian asset mengalami kerosakan lebih daripada RM15,000 per unit. Walaupun fokus kajian ini hanya terhad kepada kawasan kajian, rangka kerja ini dapat digunakan bagi menilai potensi kerugian pada masa akan datang dan boleh dijadikan asas untuk kajian penilaian risiko banjir di Malaysia pada masa-masa akan datang.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| AM | - | Annual Maximum |
| ARI | - | Average Recurrence Interval |
| CBA | - | Cost Benefit Analysis |
| Cum. | - | Cumulative |
| DID | - | Drainage and Irrigation Department |
| DEM | - | Digital Elevation Model |
| DF | - | Damage factor |
| EAD | - | Expected Annual Damage |
| e.g. | - | Example given |
| EM-DAT | - | Emergency Disasters Database |
| FB | - | Food and Beverage |
| FDAP | - | Flood Damage Analysis Package |
| FHAM | - | Flood Hazard Assessment Model |
| GEV | - | Generalized Extreme Value |
| GIS | - | Geographic Information System |
| GOF | - | Goodness of Fit |
| GP | - | Generalized Pareto |
| GS | - | Good and Services |
| GUI | - | Graphical User Interface |
| HEC-HMS | - | Hydrologic Engineering Center's Hydraulic Modeling System |
| HEC-RAS | - | Hydrologic Engineering Center's River Analysis System |
| HPH | - | High Price House |

| | | |
|---|---|---|
| ICPR | - | International Commission for the Protection of the River Rhine |
| IPF | - | Iterative Proportional Fitting |
| ISFAR | - | Interferometric Synthetic Aperture Radar |
| K-S | - | Kolmogorov-Smirnov |
| KTA | - | Kumarasivam, Tan & Ariffin |
| LOOCV | - | Leave-One-Out Cross-Validation |
| LPH | - | Low Price House |
| MAE | - | Mean Absolute Error |
| MAR | | Missing at Random |
| MBE | - | Mean Bias Error |
| MCAR | - | Missing Completely at Random |
| ME | - | Model Efficiency |
| Mil. | - | Million |
| MNAR | - | Missing Not at Random |
| MPH | - | Medium Price House |
| MRE | - | Minimum relative error |
| MURL | - | Ministerium für Umwelt, Raumordnung und Landwirtschaft des Landes Nordrhein-Westfalen |
| NAHRIM | - | National Hydraulic Research Institute of Malaysia |
| OFAT | - | One Factor at a Time |
| PD | - | Partial Duration |
| POT | - | Peaks Over Threshold |
| RM | - | Ringgit Malaysia |
| RMSE | - | Root Mean Square Error |
| Sg. | - | Sungai (river) |
| TIN | - | Triangular Model Network |
| TS | - | Time Series |
| USACE | - | The United States Army Corps of Engineers |

# LIST OF SYMBOLS

| | |
|---|---|
| $\sum$ | Summation of |
| % | Percentages |
| $X_T$ | T-year quantile |
| $k$ | Shape parameters |
| $\alpha$ | Shape parameters |
| $\sigma$ | Continuous scale parameters |
| $\beta$ | Continuous scale parameters |
| $\mu$ | Continuous location parameters |
| $\gamma$ | Continuous location parameters |
| $Q$ | Flow |
| $R^2$ | Coefficient of determination |
| $<$ | Less than |
| $\geq$ | Greater than or equal to |
| $>$ | Greater than |
| $m^3/s$ | Cubic metres per second |
| mm/hr | Millimetre per hour |
| hr | Hour |
| m | Metre |

# LIST OF APPENDIX

## References


Ahamad, M. S., Ali, R., Zakaria, N. A., Ab. Ghani, A., and Chang, C. K. (2011). Flood Loss Asssessment of the 2003 Muda River Flood. *3rd International Conference on Managing Rivers in the 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity.* 6-9 December. Penang, Malaysia, pp.601–606.

Ahmad, I., Fawad, M., Akbar, M., Abbas, A., and Zafar, H. (2016). Regional Frequency Analysis of Annual Peak Flows in Pakistan Using Linear Combination of Order Statistics. *Polish Journal of Environmental Studies*, 25 (6), pp.2255-2264.

Anbarci, N., Escaleras, M., and Register, C.A. (2005). Earthquake Fatalities: The Interaction of Nature and Political Economy. *Journal of Public Economics*, 89, pp.1907–1933.

Andrews, T., Billen, G., Kim, H., Lui, A., Pollack, C., Simpson, L., Smith, D., Underhill, S., and Whittle, D. (2008). The Insurance of Flood Risks. *Institute of Australia 16th General Insurance Seminar.* 9-12 November. Coolum, Australia.

Apel, H., Merz, B., and Thieken, A. H. (2008). Quantification of Uncertainties in Food Risk Assessments. *International Journal of River Basin Management*, *6*(2), pp.149–162.

Apel, H., Thieken, A. H., Merz, B., and Blöschl, G. (2006). A Probabilistic Modelling System for Assessing Flood Risks. *Natural Hazards*, *38*(1–2), pp.79–100.

Apel, H., Thieken, A. H., Merz, B., and Blöschl, G. (2004). Flood Risk Assessment and Associated Uncertainty. *Natural Hazards and Earth System Science*, *4*(2), pp.295–308.

Appelbaum, S. J. (1985). Determination of Urban Flood Damages. *Water Resources Planning Management*, 111, pp.269–283.

Asian Reduction Disaster Centre. (2011). *Country Report of Malaysia*. Retrieved from http://www.adrc.asia/countryreport/MYS/2011/FY2011A_MYS_CR.pdf

Browne, B. (2011). *Sysnthetic Data Generation Based on Monte Carlo Simulation.* Master Thesis, The University of Manchester.

Budiyono, Y., Aerts, J. C. J. H., and Ward, P. J. (2015). Flood Risk Assessment for Delta Mega-Cities : A Case Study Of Jakarta. *Natural Hazards*, 75, pp.389-413.

Camarasa-Belmonte, A. M., and Butrón, D. (2015). Estimation of Flood Risk Thresholds in Mediterranean Areas using Rainfall Indicators: Case Study of Valencian Region (Spain). *Natural Hazards*, doi: 10.1007/s11069-015-1769-8.

Chan, N. W. (2012). Impacts of Disasters and Disasters Risk Management in Malaysia: The Case of Floods. In Sawada, Y. and S. Oum (eds.), *Economic and Welfare Impacts of Disasters in East Asia and Policy Responses. ERIA Research Project Report 2011-8.* (pp.503-551). Jakarta: ERIA.

Chang, L., Lin, C., and Su, M. (2008). Application of geographic weighted regression to establish flood-damage functions reflecting spatial variation. *Water SA*, *34*(2), pp.209–216.

Chen, A. S., Hammond, M. J., Djordjevic, S., Butler, D., Khan, D. M., and Veerbeek, W. (2016). From Hazard to Impact : Flood Damage Assessment Tools for Mega Cities. Natural Hazards, 82, pp. 857-890, doi.org/10.1007/s11069-016-2223-2.

Chow, V. T. (1964). *Handbook of Applied Hydrology.* McGraw-Hill.

Cressman, D. R., Fortin, M. H. P., Hensel, M. J., Brubacher, P. H., and McBride, R. A. (1988). Estimation of Cropland Damages Caused by Overland Flooding, Two Case Studies. *Canadian Water Resources Journal*, *13*(3), pp. 15–25.

De Bruijn, K. M. (2006). Bepalen van schade ten gevolge van overstro- mingen voor verschillende scenario's en bij verschillende belei-dsopties, WL. Delft Hydraulics, Delft, The Netherlands (in Dutch).

De Moel, H., van Alphen, J., and Aerts, J. C. J. H. (2009). Flood Maps in Europe - Methods, Availability and Use. *Natural Hazards and Earth System Science*, *9*(2), pp.289–301, doi.org/10.5194/nhess-9-289-2009.

De Moel, H. and Aerts, J. C. J. H. (2011). Effect of Uncertainty in Land Use, Damage Models and Inundation Depth on Flood Damage Estimates. *Natural Hazards*, *58*(1), pp.407–425, doi.org/10.1007/s11069-010-9675-6.

De Moel, H., Asselman, N. E. M., and Aerts, J. C. J. H. (2012). Uncertainty and Sensitivity Analysis of Coastal Flood Damage Estimates in the West of the Netherlands. *Natural Hazards and Earth System Science*, *12*(4), pp.1045–1058, doi.org/10.5194/nhess-12-1045-2012

De Moel, H., Bouwer, L. M., and Aerts, J. C. J. H. (2014). Uncertainty and Sensitivity of Flood Risk Calculations for a Dike Ring in the South of the Netherlands. *Science of the Total Environment*, *473–474*, pp.224–234, doi.org/10.1016/j.scitotenv.2013.12.015

Debo, T. N. (1982). Urban Flood Damage Estimating Curves. *Journal of the Hydraulic Division, Proceedings of the ASCE,* 108 (HY10), pp.1059–1069.

Diakakis, M., Deligiannakis, G., Katsetsiadou, K., Antoniadis, Z., and Melaki, M. (2017). Mapping and Classification of Direct Flood Impacts in the Complex Conditions of an Urban Environment. The Case Study of the 2014 Flood in Athens, Greece. *Urban*

*Water Journal, 14(10),* pp.1065-1074.

Dutta, D., Herath, S., and Musiake, K. (2000). Flood Inundation Simulation in a River Basin Using a Physically Based Distributed Hydrologic Model, *Hydrological Process,* 14, pp.497-519.

Dutta, D., Herath, S., and Musiake, K. (2003). A Mathematical Model for Flood Loss Estimation. *Journal of Hydrology*, 277(2003), pp.24–49.

Eekhout, I. (2014). *Don't Miss Out! Incomplete Data Can Contain Valuable Information*. Doctor Philosophy, VU University, Amsterdam.

Egorova, R., van Noortwijk, J. M., and Holterman, S. R. (2008). Uncertainty in Flood Damage Estimation. *International Journal of River Basin Management*, 6(2), pp.139–148, doi.org/10.1080/15715124.2008.9635343.

Eleuterio, J. (2012). *Flood Risk Analysis : Impact of Uncertainty in Hazard Modelling nd Vulnerability Assessments*. Doctor Philosophy, University of Strasbourg, France.

Elias, Z., Hamin, Z., and Othman, M. B. (2013). Sustainable Management of Flood Risks in Malaysia: Some Lessons from the Legislation in England and Wales. *Procedia - Social and Behavioral Sciences*, 105, pp.491–497.

EM-DAT (2016). *The International Disaster Database.* Centre for Research on the Epidemiology of Disasters (CRED). Retrieved from http://www.emdat.be

Frick and Axhausen (2004). Generating Synthetic Populations using IPF and Monte Carlo Techniques: Some New Results. *4th Swiss Transport Research Conference.* 25-26 March. Monte Varita/Ascona.

Gain, A. K., Mojtahed, V., Biscaro, C., Balbi, S., and Giupponi, C. (2015). An Integrated Approach of Flood Risk Assessment in the Eastern Part of Dhaka City. *Natural Hazards*, 79(3), pp.1499–1530, doi.org/10.1007/s11069-015-1911-7.

Gasim, M. B., Surif, S., Mokhtar, M., Toriman, M. E. H., Rahim, S. A., and Bee, C. H. (2010). Analisis Banjir Disember 2006: Tumpuan di Kawasan Bandar Segamat, Johor. *Sains Malaysiana*, 39(3), pp.353–361.

Graham, P., Young, J., and Penny, R. (2008). *Preface: Methods for Creating Synthetic Data.* Official Statistics Research Series, Vol 3, The Official Statistics System, Wellington.

Gujarati, D.N. (1988). *Basic Econometrics*. (2nd ed.). McGraw Hill International Edition.

Guru, N. and Jha, R. (2015). Flood Frequency Analysis of Tel Basin of Mahanadi River System, India using Annual Maximum and POT Flood Data. *Aquatic Procedia 4*, pp.427–434. https://doi.org/10.1016/j.aqpro.2015.02.057

Heidari, A. (2009). Structural Master Plan of Flood Mitigation Measures. *Natural Hazards and Earth System Science*, 9, pp.61–75.

Hudson, P., Botzen, W. J. W., Kreibich, H., Bubeck, P., and Aerts, J. C. J. H. (2014). Evaluating the Effectiveness of Flood Damage Mitigation Measures by the Application of Propensity Score Matching. *Natural Hazards and Earth System Sciences Discussions*, 2, pp.1731–1747.

Ismail, A. Z., Yusop, Z., and Yusof, Z. (2015). Comparison of Flood Distribution Models for Johor River basin. *Jurnal Teknologi (Science and Engineering)*, 72:1, pp.1–6.

Ismail, A. Z. (2015). *Effect of Tide on Flood Modelling and Mapping in Kota Tinggi.* Master Thesis, Universiti Teknologi Malaysia.

Japan International Cooperation Agency (JICA) (1995). *Comprehensive Management Plan of Muda River Basin*. Final Report. Drainage and Irrigation Department, Malaysia.

Jonge, T. D. E., Kok, M., and Hogeweg, M. (1996). Modelling Floods and Damage Assessment using GIS. *HydroGIS 96: Application of Georaphic Information Systems in Hydrology and Water Resources Management(Proceedings of the Vienna Conference, IAHS Publication.* 235, pp.299–306.

Jonkman, S. N., Brinkhuis-Jak, M., & Kok, M. (2004). Cost Benefit Analysis and Flood Damage Mitigation in the Netherlands. *HERON*, *49*(1), pp.95–111.

Jonkman, S. N., Bo, M., Kok, M., and Bernardini, P. (2008). Integrated Hydrodynamic and Economic Modelling of Flood Damage in the Netherlands, *Ecological Economics,* 66, pp77-90.

Jung, Y., Shin, Y., Hwa, C., and Donghyuk, J. (2014). Estimation of Flood Risk Index Considering the Regional Flood Characteristics : A Case of South Korea, *Paddy Water Environment (2014)*, 12 (Supp. 1), pp.S41-S49.

Kanchanarat, S. (1989). *Estimation of Flood Damage Function for Bangkok and Vicinity*. Master Thesis. Asian Institute of Technology, Bangkok, Thailand.

Kazama, S., Sato, A., & Kawagoe, S. (2009). Evaluating the Cost of flood Damage Based on Changes in Extreme Rainfall in Japan. *Sustainable Science (2009)*, 4, pp.61-69.

Kefi, M., Mishra, B. K., & Kumar, P. (2018). Assessment of Tangible Direct Flood Damage Using a Spatial Analysis Approach under the Effects of Climate Change : Case Study in an Urban Watershed in Hanoi , Vietnam. *International Journal of Geo-Information*, 7(29), pp.1-18.

Kellenberg, D. K., and Mobarak, A. M. (2008). Does Rising Income Increase or Decrease Damage Risk from Natural Disasters? *Journal of Urban Economics*, *63*(3), pp.788–

802.

Kim, S. H., Lee, B. S., Chung, C. H., & Hak, J. (2014). 피해설문조사 기반의 도시지역의 침수심별 피해 추정함수 개발 Development of Depth-Damage Function by Investigating Flooded Area with Focusing on Building Damage. *J. Korea Water Resources Association*, *47*(8), pp.717–728.

Kourgialas, N. N. and Karatzas, G. P. (2013). A hydro-economic modelling framework for flood damage estimation and the role of riparian vegetation. *Hydrological Processes*, 27, pp.515–531.

Kreibich, H., Seifert, I., Merz, B., and Thieken, A. H. (2010). Development of Flemocs – A New Model for the Estimation of Flood Losses in the Commercial Sector. *Hydrological Sciences Journal*, *55*(8), pp.1302–1314, doi.10.1080/02626667.2010.529815

KTA Tenaga Sdn. Bhd. (2003). *Flood Damage Assessment of 26 April 2001 Flooding Affecting the Klang Valley and the Preparation of Generalised Procedures and Guidelines for Assessment of Flood Damages (Final Report)*. Drainage and Irrigation Department, Malaysia.

Kuiper, E. (1971). *Water Resources Project Economics*. Butterworth, London, UK.

Lee, W., & Mohamad, I. N. (2013). Flood Economy Appraisal : An Overview of the Malaysian Scenario. *Proceeding of the International Civil and Infrastructure Engineering Conference.* 22-24 September. Kuching, Malaysia.

Lekuthai, A. and Vongvisessomjai, S. (2001). Intangible Flood Damage Quantification. *Water Resources Management*, 15, pp343–362.

Li, Q., Zhou, J., Liu, D., & Jiang, X. (2012). Research on Flood Risk Analysis and Evaluation Method Based on Variable Fuzzy Sets and Information Diffusion. *Safety Science*, 50(5), pp.1275–1283.

Li, Z., Wang, Y., Zhao, W., Xu, Z., and Li, Z. (2016). Frequency Analysis of High Flow Extremes in the Yingluoxia Watershed in Northwest China. *Water 2016*, 8, 215, pp.1–15.

Lim, Y. H. and Lye, L.M. (2003). Regional Flood Estimation for Ungauged Basins in Sarawak, Malaysia. *Hydrological Sciences J*., 48 (1), pp. 79–94.

Little, R. J. A. (1993). Statistical Analysis of Masked Data. *Journal of Official Statistics*, 9, pp.407-426.

Luino, F., Cirio, C. G., Biddoccu, M., Agangi, A., Giulietto, W., Godone, F., and Nigrelli, G. (2009). Application of a Model to the Evaluation of Flood Damage.

*GeoInformatica*, 13, pp.339–353, doi.org/10.1007/s10707-008-0070-3

Mann, C. (2003). Observational Research Methods. Research Design II: Cohort, Cross sectional, and Case-control Studies. *Emergency Medicine Journal*, 20, pp.54–60.

matewave (2015). Retrieved April 16, 2015, from http://www.mathwave.com/downloads.html

Mcbean, B. E. A., Gorrie, J., Fortin, M., Ding, J., and Mouiton, R. (1989). Flood Depth-Damage Curves by Interview Survey. *Journal of Water Resources Planning and Management*, *114*(6), pp.613–634.

McGrath, H., Stefanakis, E., and Nastev, M. (2015). Sensitivity Analysis of Flood Damage Estimates: A Case Study in Fredericton, New Brunswick. *International Journal of Disaster Risk Reduction*, 14, pp.1–9.

Mehrannia, H. and Pakgohar, A. (2014). Using Easy Fit Software for Goodness-Of-Fit Test and Data Generation. International Journal of Mathematical Archive, 5(1), pp.118–124.

Merz, B., Kreibich, H., & Apel, H. (2008). Flood Risk Analysis : Uncertainties and Validation. *Oesterreichische Wasser und Abfallwirtschaft*, 5-6, pp.89-94.

Merz, B., Kreibich, H., Schwarze, R., and Thieken, A. (2010). Review Article "Assessment of Economic Flood Damage." *Natural Hazards and Earth System Science*, 10(8), pp.1697–1724, doi.org/10.5194/nhess-10-1697-2010.

Merz, B. and Thieken, A. H. (2009). Flood Risk Curves and Uncertainty Bounds. *Natural Hazards*, 51(3), pp.437–458, doi.org/10.1007/s11069-009-9452-6.

Messner, F., Penning-Rowsell, E., Green, C., Tunstall, S. and van der Veen, A. (2007). *Evaluating Flood Damages : Guidance and Recommendations on Principles and Methods*. FLOODsite-Report T09-06-01.

Meyer, V. and Messner, F. (2005). *National Flood Damage Evaluation Methods - A Review of Applied Methods in England, the Netherlands, the Czech Republic and Germany*. UFZ Discussion Papers, UFZ-Discussion Papers, Leipzig.

MOC. (1996). *Flood Damage Statistics in Japan*. Technical Report, River Engineering Bureau, Ministry of Construction, Japan, in Japanese.

Mohd Daud, Z., Mohd Kassim, A. H., Mohd Desa, M. N., & Nguyen, V. (2002). Statistical Analysis of At-Site Extreme Rainfall Processes in Peninsular Malaysia. *FRIEND 2002-Regional Hydrology: Bridging the Gap between Research and Practice, AHS Publication No. 274*, (274), pp.61–68.

Mohsen, S., Yusop, Z., Yusof, F., Shahid, S., and Jajarmizadeh, M. (2013). Flood

Frequency Analysis based on t-copula for Johor River, Malaysia. *Journal of Applied Science*, *13*(7), pp.1021–1028.

Muhadi, N. A. and Abdullah, A. F. (2015). Flood Damage Assessment in Agricultural Area in Selangor River Basin. *Jurnal Teknologi (Science and Engineering)*, *15*, pp.111–117.

NAHRIM (2012). *A Research Study on Flood Modelling for Segamat River*. National Hydraulic Research Institute of Malaysia, Malaysia.

Nash, J. E. and Sutcliffe J. V. (1970). River Flow Forecasting through Conceptual Models Part 1 - A Discussion of Principles. Journal of Hydrology, 10 (3), pp.282 -290.

Notaro, V., De Marchis, M., Fontanazza, C. M., La Loggia, G., Puleo, V., and Freni, G. (2014). The Effect of Damage Functions on Urban Flood Damage Appraisal. *Procedia Engineering*, 70, pp.1251–1260.

Okamoto, K., Yamakawa, S., and Kawashima, H. (1998). Estimation of Flood Damage to Rice Production in North Korea in 1995. *International Journal of Remote Sensing*, 19(2), pp.365–371.

Okazawa, Y., Yeh, P. J., Kanae, S., and Oki, T. (2011). Development of a Global Flood Risk Index Based on Natural and Socio-Economic Factors Socio-Economic Factors. *Hydrological Sciences Journal*, 56:5, pp.789-804.

Okazumi, T. (2014). *Uncertainty Estimation and Reduction Measures in the Process of Flood Risk Assessment with Limited Information*. Master Thesis, Kyoto University, Japan.

Oliveri, E. and Santoro, M. (2000). Estimation of Urban Structural Flood Damages : The Case Study of Palermo. *Urban Water 2*, *2*(2000), pp.223–234.

Penning-Rowsell and Chatterton. (1979). *The Benefits of Flood Alleviation: A Manual of Assessment Techniques*. Gower Technical Press, UK.

Pistrika, A., Tsakiris, G., and Nalbantis, I. (2014). Flood Depth-Damage Functions for Built Environment, *Environmental Processes* (2014) 1, pp.553–572,doi.org/10.1007/s40710-014-0038-2.

Poussin, J. K., Botzen, W. J. W., and Aerts, J. C. J. H. (2014). Factors of Influence on Flood Damage Mitigation Behaviour by Households. *Environmental Science and Policy*, *40*, pp.69–77.

Qi, H., & Altinakar, M. S. (2011). Simulation-Based Decision Support System for Flood Sensing and Census Block Information. *Natural Hazards*, 59, pp.1125–1143, doi.org/10.1007/s11069-011-9822-8.

Rao, A. R. and Hamed, K. H. (2000). *Flood Frequency analysis*. Florida, U.S.: CRC Press.

Rahman, A. S., Rahman, A., Zaman, M. A., Haddad, K., Ahsan, A., and Imteaz, M. (2013). A Study on Selection of Probability Distributions for At-Site Flood Frequency Analysis in Australia. *Natural Hazards*, 69(3), pp.1803–1813, doi.org/10.1007/s11069-013-0775-y

Ren, M., Wang, B., Liang, Q., and Fu, G. (2010). Classified Real-Time Flood Forecasting by Coupling Fuzzy Clustering and Neural Network. *International Journal of Sediment Research*, 25(2), pp.134–148.

Rubin, D. B. (1993). Discussion: Statistical Disclosure Limitation. *Journal of Official Statistics*, 9, pp. 462-468.

Salleh, N., Yusof, F., and Yusop, Z. (2016). Bivariate Copulas Functions for Flood Frequency Analysis. *AIP Conference Proceedings*, 1750, 0*60007 (2016)*, doi.org/10.1063/1.4954612.

Seifert, I., Kreibich, H., Merz, B., and Thieken, A. H. (2010). Application and Validation of Flemocs – A Flood-Loss Estimation Model for The Commercial Sector. *Hydrological Sciences Journal*, 55(8), pp.1315–1324.

Segamat (town). (2017). Retrieved January 31, 2017, from Wikipedia: https://en.wikipedia.org/wiki/Segamat_(town)

Selaman, O.S., Said, S and Putuhena F. J. (2007). Flood Frequency analysis for Sarawak using Weibull, Gringorten and L-Moments Formula. in *The Intitutions of Engineers, Malaysia*, 68 (1), pp. 43–52.

Shaw, D. G., Huang, H., and Ho, M. (2005). Modeling Flood Loss and Risk Perception: The Case of Typhoon Nari in Taipei. *Proceeding of 5$^{th}$ Annual IIASA-DPRI Forum on Integrated Disaster Risk Management: Innovations in Science and Policy*, 14-18 September, Ministry of Civil Affairs of China, China.

Shrubsole, D., Kreutzwiser, R., Mitchell, B., Dickinson, T., and Joy, D. (1993). The History of Flood Damages in Ontario. *Canadian Water Resources Journal*, 18(2), pp.133–143, doi.org/10.4296/cwrj1802133.

Sindhu, K. and Durga Rao, K. H. V. (2016). Hydrological and Hydrodynamic Modeling for Flood Damage Mitigation in Brahmani–Baitarani River Basin, India. *Geocarto International*, doi.org/10.1080/10106049.2016.1178818.

Singo, L. R., Kundu, P. M., Odiyo, J. O., Mathivha, F. I., and Nkuna, T. R. (2012). Flood Frequency Analysis of Annual Maximum Stream Flows for Luvuvhu River Catchment, Limpopo Province, South Africa. *16th SANCIAHS Hydrology Symposium*. 1-3 October, University of Pretoria, South Africa.

Smith, D. (1981). Assessment of Urban Flood Damage. *Proceedings of Flood Plain Management Conference.* Australian Water Council, Canberra, Australia, pp. 145–180.

Smith, D. (1994). Flood Damage Estimation-A Review of Urban Stage-Damage Curves and Loss Functions. *Water SA 20*, pp. 231–238.

Spachinger, K., Dorner, W., Metzka, R., Serrhini, K., and Fuchs, S. (2008). Flood Risk and Flood Hazard Maps – Visualisation of Hydrological Risks. *IOP Conference Series: Earth and Environmental Science*, 4, 12043, doi.org/10.1088/1755-1307/4/1/012043.

Suriya, S., Mudgal, B. V., and Nelliyat, P. (2012). Flood Damage Assessment of An Urban Area in Chennai, India, Part I: Methodology. *Natural Hazards*, 62(2), pp.149–167.

Tam, T. H., Ibrahim, A. L., Rahman, M. Z. A, and Mazura, Z. (2014). Flood Loss Assessment in the Kota Tinggi. *IOP Conference Series: Earth and Environmental Science*, 18, 12120, doi.org/10.1088/1755-1315/18/1/012120.

Tang, J. C. S., Vongvisessomjai, S., and Sahasakmontri, K. (1992). Estimation of Flood Damage Cost for Bangkok. *Water Resources Management*, *6*(1), pp.47–56.

Tezuka, S., Takiguchi, H., Kazama, S., Sato, A., Kawagoe, S., and Sarukkalige, R. (2014). Estimation of the Effects of Climate Change on Food-triggered Economic Losses in Japan. *International Journal of Disaster Risk Reduction*, 9 (2014), pp.58-67.

Thieken, A., Ackermann, V., Elmer, F., Kreibich, H., Kuhlmann, B., Kunert, U., Maiward, H., Merz, B., Muller, M., Piroth, K., Schwarz, J., Swarze, R., Seifert, I., and Seifert, J. (2008). Methods for the Evaluation of Direct and Indirect Flood Losses. *4th International Symposium on Flood Defence: Managing Flood Risk, Reliability and Vulnerability.* 6-8 May, Toronto, Ontaria, Canada.

Thieken, A. H., Müller, M., Kreibich, H., and Merz, B. (2005). Flood Damage and Influencing Factors: New Insights from the August 2002 Flood in Germany. *Water Resources Research*, 41(12), pp.1–16.

Toyo, H. and Skidmore, M. (2007). Economic Development and the Impacts from Natural Disasters. *Economics Letter*, 94 (1), pp.20–25

Ullah, S., Farooq, M., Sarwar, T., Tareen, M. J., and Wahid, M. A. (2016). Flood Modeling and Simulations using Hydrodynamic Model and ASTER DEM - A Case Study of Kalpani River. *Arabian Journal of Geosciences*, 9, pp.439.

UNSW. (1981). *Evaluation Methodology of Flood Damage in Australia.* Technical Project Report. University of New South Wales, Australia.

USACE (1980). Hydrologic Engineering Center. Interactive Nonstructural Analysis

Package, User's Manual.

USACE (1982). Hydrologic Engineering Center. Structure Inventory For Damage Analysis, User's Manual.

USACE (2015). Hydrologic Engineering Center. Retrieved from http://www.hec.usace.army.mil/software/hec-hms/downloads.aspx

UN-SPIDER Knowledge Portal (2014). Step by Step: Flood Hazard Mapping. Advisory support. Retrieved from http://www.un-spider.org/advisory-support/recommended-practices/recommended-practice-flood-hazard-mapping/step-by-step.

van der Sande, C. J., de Jong, S. M., and de Roo, A. P. J. (2003). A Segmentation and Classification Approach of IKONOS-2 Imagery for Land Cover Mapping to Assist Flood Risk and Flood Damage Assessment. *International Journal of Applied Earth Observation and Geoinformation*, 4, pp.217–229.

Velasco, M., Cabello, À., and Russo, B. (2015). Flood Damage Assessment in Urban Areas . Application to the Raval District of Barcelona using Synthetic Depth Damage Curves. *Urban Water Journal*, doi: 10.1080/1573062X.2014.994005

Vozinaki, A. E. K., Karatzas, G. P., Sibetheros, I. A., and Varouchakis, E. A. (2015). An Agricultural Flash Flood Loss Estimation Methodology: The Case Study of The Koiliaris Basin (Greece), February 2003 Flood. *Natural Hazards*, doi:10.1007/s11069-015-1882-8

Wagenaar, D. J., de Bruijn, K. M., Bouwer, L. M., and De Moel, H. (2015). Uncertainty in flood Damage Estimates and Its Potential Effect On Investment Decisions. *Natural Hazards and Earth System Sciences Discussions*, *3*, pp.607–640, doi:10.5194/nhessd-3-607-2015

Wan Zin, W. Z., Jemain, A. A., and Ibrahim, K. (2009). The Best Fitting Distribution of Annual Maximum Rainfall in Peninsular Malaysia Based on Methods Of L-Moment And LQ-Moment. *Theoretical and Applied Climatology*, 96, pp.337–344, doi:org/10.1007/s00704-008-0044-2.

Ward, P. J., Marfai, M. A., Yulianto, F., Hizbaron, D. R., and Aerts, J. C. J. H. (2011a). Coastal Inundation and Damage Exposure Estimation : A Case Study for Jakarta. Natural Hazards, 56, pp.899–916, doi: 10.1007/s11069-010-9599-1.

Ward, P. J., De Moel, H. and Aerts, J. C. J. H. (2011b). How Are Flood Risk Estimates Affected by The Choice of Return-Periods? *Natural Hazards and Earth System Sciences*, 11, pp.3181–3195.

White, G. F. (1964). *Choice of Adjustment to Floods.* Research Paper No. 93, University of Chicago, Dept. of Geography.

Wind, H. G., Nieron, T. M., De Blois, C. J., and De Kok, J. L (1999). Analysis of flood

damages from the 1993 and 1995 Meuse floods. *Water Resour. Res.*, 35, pp. 3459–3465.

Yi, C., Lee, J., and Shim, M. (2010). GIS-based Distributed Technique for Assessing Economic Loss from Flood Damage : Pre-Feasibility Study for the Anyang Stream Basin in Korea, 55, pp.251–272, doi: 10.1007/s11069-010-9524-7

Yu, J. J., Qin, X. S., and Larsen, O. (2013). Joint Monte Carlo and Possibilistic Simulation for Food Damage Assessment. *Stochastic Environmental Research and Risk Assessment*, 27, pp. 725-735.

Zhang, Z. (2016). Missing Data Imputation: Focusing On Single Imputation. *Annals of Translational Medicine, 4*(1), 9.

Zhou, C. R., Chen, Y. F., Huang, Q., and Gu, S. H. (2017). Higher Moments Method For Generalized Pareto Distribution In Flood Frequency Analysis. *IOP Conference Series: Earth and Environmental Science*, 82, 012031.