



PROCEEDINGS

21st IAHR-APD Congress

International Association for Hydro-Environment
Engineering and Research (IAHR)
Asia Pacific Division (APD)

Multi-perspective Water for Sustainable Development

Volume 2

- o Water Resources
- o Hydroinformatics
- o Water-related Disaster Risk Reduction
- o Special Sessions

Yogyakarta, Indonesia
2-5 September 2018



PROCEEDINGS

21st **IAHR-APD** **Congress**

International Association for Hydro-Environment
Engineering and Research (IAHR)
Asia Pacific Division (APD)

Multi-perspective Water for Sustainable Development

Volume 2

- o Water Resources
- o Hydroinformatics
- o Water-related Disaster Risk Reduction
- o Special Sessions

2 – 5 September 2018
Yogyakarta, Indonesia

ISBN : 978-602-71762-7-0

Edition : First, September 2018

Publisher:

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Faculty of Engineering, Universitas Gadjah Mada
Jl. Grafika No. 2 Kampus UGM, Yogyakarta 55281

Phone & Fax: +62-274-545676

Email: tsipil.ft@ugm.ac.id, jurusan@tsipil.ugm.ac.id

Local Organizing Committee : Radianta Triatmadja (Indonesian EC – IAHRAPD, Indonesia)
 Intan Supraba (Universitas Gadjah Mada, Indonesia)
 Doddi Yudianto (Universitas Parahiyangan, Indonesia)
 Raymond Valiant (Jasatirta I Enterprise, Indonesia)
 Muhammad Amron (Indonesian Water Partnership, Indonesia)

Scientific Advisory Committee : Hyoseop Woo (Chair of IAHR-APD – Gwangju Institute of Science and Technology, Korea)
 Gregory Shahane De Costa (Vice Chair of IAHR-APD, Unitec, Auckland, New Zealand)
 Won Kim (Secretary General of IAHR-APD – Korea Institute of Civil Engineering and Building Technology, Korea)
 Hitoshi Tanaka (Past President IAHR-APD – Tohoku University, Japan)

Editor Team

Chief Editor : Djoko Legono (Indonesia)
 Member Editors : Ani Hairani (Indonesia)
 Benazir (Indonesia)
 Hendy Setiawan (Indonesia)
 Johan Syafri Mahathir Ahmad (Indonesia)
 Karlina (Indonesia)
 Muhammad Ramdhan Olii (Indonesia)
 Roby Hambali (Indonesia)
 Warniyati Warniyati (Indonesia)

Peer Reviewer

: Bambang Agus Kironoto (Indonesia)	Masaharu Fujita (Japan)
Bambang Yulistyanto (Indonesia)	Muhammad Mukhlisin (Indonesia)
Budi Santoso Wignyosukarto (Indonesia)	Nadjadji Anwar (Indonesia)
Daisuke Nohara (Japan)	Nizam Nizam (Indonesia)
Djoko Legono (Indonesia)	Rachmad Jayadi (Indonesia)
Doddi Yudianto (Indonesia)	Radiana Triatmadja (Indonesia)
Endita Prima (Indonesia)	Shie-Yui Liong (Singapore)
Fatchan Nurrochmad (Indonesia)	Shigeru Mizugaki (Japan)
Fatihah Suja' (Malaysia)	Shinichiro Yano (Japan)
Gregory Shahane Decosta (New Zealand)	Sri Harto Br (Indonesia)
Hideo Oshikawa (Japan)	Sri Puji Saraswati (Indonesia)
Hitoshi Tanaka (Japan)	Sunjoto Sunjoto (Indonesia)
Hyoseop Woo (Korea)	Tomoko Kyuka (Japan)
Intan Supraba (Indonesia)	Yasunori Muto (Japan)
Joko Sujono (Indonesia)	Yasuyuki Shimizu (Japan)
Kana Nakatani (Japan)	Yuko Ishida (Japan)
Keiichi Toda (Japan)	Yusuke Yamazaki (Japan)
Makoto Takeda (Japan)	Yutaka Gonda (Japan)



FOREWORDS FROM CHAIRMAN OF THE LOCAL ORGANIZING COMMITTEE

Dear Readers,

Universitas Gadjah Mada was honored to host the 21st Congress of International Association for Hydro-Environment Engineering and Research-Asia Pacific Division (IAHR-APD) on 2-5 September 2018 in Yogyakarta which was co-hosted by PT. Jasa Tirta I (Jasa Tirta I Public Corporation) and Multimodal Sediment Disaster Network (MSD-Network). The Congress brought up the theme “Multi-perspective Water for Sustainable Development”. This phrase was adopted as the main theme of the Congress to maintain awareness of the stakeholders that water should be valued from various viewpoints namely technical, socio-economic, cultural and environmental viewpoints which integrate all efforts on water resources-related development to contribute to people’s welfare.

The 21st Congress of IAHR-APD accommodated the 6th AUN/SEED-Net Regional Conference on Natural Disaster (RCND 2018) which was mostly relevant to water-related natural disasters to be part of the Congress. The joint congress was aimed at introducing the IAHR-APD organization to even wider areas of hydro-environment engineers and scientists as well as strengthening cooperation with similar organizations.

The Congress has successfully encouraged the interactions among researchers, industries, and communities, on the dissemination of water-related research achievements and ideas that paves the way for sustainable water and environment-related development. The local organizing committee especially appreciates all of the staff of the IAHR and IAHR-APD for their endless and excellent support to the congress.

The cooperation and support of Universitas Katolik Parahyangan, Sekolah Tinggi Teknik Nasional Yogyakarta, Universitas Kristen Duta Wacana are also highly appreciated. We would like to thank all of the sponsors and participants for their contributions to make the Congress fruitful and memorable. Our special thanks go to the reviewers of the papers and the editors of the proceedings without whom the publication of such excellent quality proceedings would not have been possible. We hope that this proceedings will furnish the readers with excellent references and stimulate further studies and researches in the related areas.

Thank you very much and God bless you all.

Radiana Triatmadja

21st IAHR-APD 2018 Congress Chair

[This page is intentionally left blank]



FOREWORDS FROM CHAIRMAN OF THE IAHR-APD

It is my great honor and pleasure to say 'Welcome' to all the attendees of the 21st Congress of the International Association for Hydro-Environment Engineering and Research-Asia Pacific Division. The IAHR-APD Congress is the official and most important open forum for all persons, not only the members but also general participants, who are interested in presenting, discussing, and exchanging their knowledge and experiences in hydro-environment areas. Since the first congress was held in Bangkok, Thailand in 1978, this is the 21st, following the previous congress that was held in Colombo, Sri Lanka two years ago with great success in terms of numbers of papers presented and participants. You can see about the past APD congresses at the official website of IAHR-APD <http://www.iahrapd.org/Apd/Congress/webinfo/2014/08/1408074914387664.htm>.

We, the APD members, have tried to delineate as well as generalize the conference characteristics such as by emphasizing specialty sessions dealing with the water-issues which are especially important and sometimes unique in the Asia and Pacific region such as typhoon, monsoon, and tropic-affected water issues, as well as historical water projects and traditional water technologies in the region. For example, we have special sessions of Historical water projects and traditional water technologies in the Asia-Pacific region, Green infrastructure as disaster risk reduction measure, Ecosystem-based disaster risk reduction for floods and tsunamis, Adapting to climate change using green infrastructure and LID measures, Conceptual ideas to solve problems related to hydro-environment engineering, Volcano and multimodal sediment disaster, Simulation and risk mitigation, and Hydrology-geomorphology links in tropical rivers. At this congress, we are also hosting some international panels with recognized high-ranking officials on the water issues that are of mutual interests in the region.

Among many special sessions that are held at this conference, the session of Historical water projects and traditional water technologies in the Asia-Pacific region, would be worthwhile to introduce more in detail. It has the purpose of giving international professional recognition to the works of: 1) past water projects that contributed or are still contributing to the welfare of the people, and 2) past brilliant water technologies that blossomed once and are still useful in the Asia – Pacific region. The first special session was held in Sri Lanka congress in 2016 with seven presentations from different countries in the region. Those are now in the process of being published in the Journal of Hydro-environment Research (JHER), the official journal of IAHR-APD, as a special issue. This type of special session will continue at every APD congress and a few papers presented at the session will be strictly screened and submitted for a possible publication in JHER along with the ones receiving the best-paper award in the congress.

I strongly believe that this conference should be a very useful and effective forum in which we are able to foster interdisciplinary research and collaboration, rapid dissemination of latest findings, and will provide an opportunity for discussing how novel methods and techniques can be used interchangeably in various fields and application areas of hydro-environment engineering and research especially in the Asia and Pacific region.

Last, but not least, I as the IAHR-APD chair express many thanks to the LOC members including Prof. Radianta Triatmadja, the conference chair, for their full devotions to the preparation and proceedings of the conference for the last two years. I strongly believe that this conference will be one of the most successful events ever in the history of the IAHR-APD activities.

Hyoseop Woo

IAHR-APD Chair

[This page is intentionally left blank]



LIST OF CONTENTS

FOREWORDS FROM CHAIRMAN OF THE LOCAL ORGANIZING COMMITTEE	i
FOREWORDS FROM CHAIRMAN OF THE IAHR-APD	iii
LIST OF CONTENT	v
AUTHORS INDEX	xvii
KEYWORDS INDEX	xxv

VOLUME 1

KEYNOTE SPEECH

INTEGRATED WATER RESOURCES MANAGEMENT FOR BATHING AND SHELLFISH WATERS COMPLIANCE <i>Roger Falconer, Guoxian Huang, Binliang Lin</i>	<i>1</i>
EFFECTIVENESS OF A SHORE-PARALLEL CANAL FOR REDUCING TSUNAMI IMPACT <i>Hitoshi Tanaka, Kiyoshi Hashimoto, Nguyen Xuan Tinh</i>	<i>11</i>
MOST COST-EFFECTIVE DEM AND RAINFALL DESIGN CURVES FOR ASSESSING FLOOD HAZARD OF PRESENT AND FUTURE CLIMATES <i>Shie-Yui Liong, Dong Eon Kim, Jiandong Liu, Srivatsan Vijayaraghavan, Ngoc Son Nguyen, Jina Hur</i>	<i>19</i>
URBAN STORMWATER MODELLING <i>James E. Ball</i>	<i>27</i>
THE NECESSITY OF INTEGRATED MONITORING AND SIMULATION IN THE WATER AND SEDIMENT RELATED DISASTER RISK MITIGATION <i>Djoko Legono, Rachmad Jayadi, Adam Pamudji Rahardjo, Roby Hambali, Ani Hairani, Yutaka Gonda, Radiana Triatmadja, Akhyar Musthofa</i>	<i>35</i>

TECHNICAL PAPERS

SUBTHEME 1: RIVER (RIVER HYDRAULICS, RIVER BASIN ENGINEERING AND RIVER BASIN MANAGEMENT)

A NEW PERSPECTIVE ON ENERGY LOSS AT VERTICAL DROPS <i>Tsuyoshi Tada, Yoshimisa Miyata</i>	<i>43</i>
MEASURING EFFECT OF GRAVEL AUGMENTATION USING RADIO FREQUENCY IDENTIFICATION (RFID) IN MOUNTAINOUS AREAS OF THE TRINITY RIVER, CALIFORNIA <i>Kanta Kano, David Gaeuman, D. Nathan Bradley</i>	<i>51</i>
TIME OF CONCENTRATION FOR DRAINAGE DESIGN CHARACTERISTICS <i>D Noorvy Khaerudin, Donny Harisuseno, Denik Sri Krisnayanti</i>	<i>59</i>
DOMINATING FACTORS INFLUENCING RAPID CHANNEL MIGRATION DURING FLOODS – A CASE STUDY ON OTOFUKE RIVER <i>Tomoko Kyuka, Yasuyuki Shimizu, Kazunori Okabe, Kho Shinjyo, Satomi Yamaguchi</i>	<i>67</i>
EXPERIMENT ON BANK EROSION AND SEDIMENTATION IN FLUVIAL FUN USING MIXED-SIZE AND COLOR-CODED PLASTIC MEDIA <i>Shigeru Mizugaki, Takuya Inoue, Susumu Yamaguchi.....</i>	<i>73</i>
GEOMORPHIC EFFECTIVENESS OF PEAK FLOWS IN UPPER AND MIDDLE TAPI RIVERS, INDIA <i>Resmi S R, P L Patel, P V Timbadiya</i>	<i>81</i>

THE EFFECTS OF SEDIMENT ACCUMULATION ON THE SEVERE FLOOD DISASTER IN THE PEKEREBETSU RIVER CAUSED BY THE RECORD BREAKING RAINFALL IN HOKKAIDO, 2016 <i>Tomoko Kyuka, Yasuyuki Shimizu, Yoshiaki Ishida</i>	89
FLUME EXPERIMENTS ON LOG ACCUMULATION AT A BRIDGE IN MOUNTAIN RIVER <i>Muhammad Farid Maricar, Muhammad Islamy Rusyda, Haruyuki Hashimoto, Hiroyuki Nagano</i>	97
EFFECTS OF NARROW PASS ON THE NAVIGATIONAL BRAIDED CHANNEL, THE AYEYARWADY RIVER IN MYANMAR <i>Tin Tin Htwe, Yuji Hasegawa, Hiroshi Takebayashi, Masaharu Fujita</i>	105
STUDY TO MINIMIZE THE LOCAL SCOUR DOWNSTREAM OF STILLING BASIN <i>Yiniarti Eka Kumala, Slamet Lestari, James Zulfan</i>	115
HISTORICAL CHANGES OF FLOW AND SEDIMENT BUDGET IN VIETNAMESE MEKONG DELTA DUE TO UPSTREAM DAM DEVELOPMENT <i>Doan Van Binh, Tetsuya Sumi, Sameh Kantoush, Nguyen Phuong Mai</i>	123
SUBWAY INUNDATION BY PLUVIAL FLOODING CONSIDERING WITH A NEWLY PLANNED LINE <i>Mitsuhiro Terada, Taisuke Ishigaki, Taira Ozaki and Keiichi Toda</i>	133
A SENSITIVITY ANALYSIS OF STORM WATER MANAGEMENT MODEL IN A RESIDENTIAL AREA <i>Chang Qing, So Kazama, Yoshiya Touge</i>	139
SCOUR DOWNSTREAM OF CULVERTS <i>Sriparna Paira, Subhasish Dey, Chanchal Kumar Mukherjee</i>	147
EFFECT OF THREE-DIMENSIONAL FLOW STRUCTURE ON GENERATION MECHANISM OF LARGE-SCALE LOCAL SCOURING IN THE KISO RIVER <i>Akihiro Tominaga, Yuji Hara, Yuka Kuno</i>	155
METHODS FOR PREDICTING DISCHARGE OF STRAIGHT ASYMMETRIC COMPOUND CHANNELS <i>Xiaonan Tang</i>	165
SERMO RESERVOIR CAPABILITY TO PERFORM ITS FUNCTION <i>Dyah Ari Wulandari, Suharyanto, Festi Alvi Rahmawati, Intan Savera Damayanti</i>	175
FUNDAMENTAL 3D MODEL TEST AND NUMERICAL ANALYSIS ON RESISTANCE AGAINST PERMEABILITY IN A LINEAR RIVER LEVEE <i>Yoko Machida, Yasuo Nihei, Yuki Kurakami</i>	183
PERFORMANCE IMPROVEMENT OF THE SETTLING BASINS OF KALIGANDAKI A HYDROPOWER PLANT, NEPAL <i>Meg B. Bishwakarma</i>	189
DETERMINING SEDIMENT FLUSHING PERIOD FOR WLINGI RESERVOIR AFTER MT. KELUD ERUPTION IN 2014 <i>Dian Sisingih, Fahmi Hidayat, Sri Wahyuni</i>	199
BEHAVIOR OF DRIFTWOOD IN TERMS OF CONVECTION – DIFFUSION EQUATION <i>Daisuke Harada, Shinji Egashira</i>	209
PREVENTION OF LEVEE CREST OVERTOPPING THROUGH REINFORCEMENT TECHNOLOGY <i>Asataro Shinohara, Yasuo Nihei, Yuki Kurakami, Kengo Suzuki</i>	217
ANALYSIS OF THE RUNOFF COEFFICIENT AT UPPER CITARUM WATERSHED DUE TO CHANGES IN LAND COVER <i>Ana Nurganah Chaidar, Indratmo Soekarno, Agung Wiyono, Joko Nugroho</i>	225
THE EFFECTIVENESS OF U.S.BERAU RECLAMATION'S TYPE 3 STILLING BASIN WITH LOWER TAIL WATER LEVEL ON THE WAY APU SPILLWAY DAM <i>Prasetyorini, Linda, Anwar, Nadjadji, Wardoyo, Wasis</i>	233

CHARACTERISTICS OF PHYSICAL ENVIROMENT RESPONSES IN THE RIVER TRAINING BY SEDIMET SUPPLY CONDITION <i>Xiang Chen, Ryuichi Hirakawa, Terunori Ohmoto</i>	239
SAFETY EVALUATION OF THE WLINGI DAM AFTER SEDIMENT FLUSHING 2017 <i>Teguh Winari, Kamsiyah Windianita, Didik Ardianto, Fahmi Hidayat, Raymond Valiant Ruritan</i>	247
INVESTIGATION ON THE CHANGING OF THE MEANDERING RIVER LENGTH WITHIN ITS MORPHOLOGICAL DEVELOPMENT <i>Agus Maryono, Adhy Kurniawan, Andri P. Nugroho</i>	255
EFFECT OF SUPLLYMENT OF HIGH DO CONCETRATION WATER ON WATER QULITY IMPROVEMENT AND BEHAVIOR OF HAVEY METAL IN DAM RESORVIOR <i>Koji Asai, Tetsuo Ohwaki, Takumi Odamura, Ei-Ichi Hoshiyama, Hajime Shirozu</i>	265
THE SIMPLIFIED OF SUSPENDED SEDIMENT MEASUREMENT METHOD FOR PREDICTING SUSPENDED SEDIMENT DISCHARGE IN NATURAL RIVER (CASE STUDY OF OPAK RIVER, YOGYAKARTA, INDONESIA) <i>Bambang Agus Kironoto, Bambang Yulistiyanto, Bambang Triatmodjo, Mariatul Kaptiah, Rahmat Bangun Giarto, Obed Ebenezer Sitinjak</i>	277
ANALYSIS OF LOCAL SCOUR AT BRIDGE PIER ON COMAL RIVER, CENTRAL JAWA, INDONESIA <i>Muhammad Mukhlisin, Supriyadi, Muhammad Rizal Wicaksono, Sugiarto</i>	289
IMPACTS OF LOW-WATER REVETMENTS ON CHANNEL TRANSITION <i>Yuki Morikawa, Yasunori Muto, Takao Tamura</i>	297
DISCHARGE CHARACTERISTICS FOR TRAPEZOIDAL COMPOUND LABYRINTH WEIRS <i>Anees K. Idrees , Riyadh Al-Ameri , Lloyd Chua , Subrat Das</i>	303
BACKWATER RISE DUE TO BAMBOO DEBRIS ACCUMULATIONS AT A CULVERT BRIDGE DURING A FLOOD <i>Feni Safitri, Slamet Budiyo, Titik Wahyuningsih</i>	313
INVESTIGATION OF FLOW REGIMES AND ENERGY DISSIPATION IN GABION STEPPED WEIRS <i>Mohammed A. Almajeed A. Alabas, Riyadh Al-Ameri, Lloyd Chua, Subrat Das</i>	319
TRANSFORMATION OF BED SURFACE STRUCTURES AFTER DIFFERENT TIME LENGTH OF ANTECEDENT FLOW EXPOSURE <i>Yusron Saadi, Ida Bagus Giri Putra, Agus Suroso</i>	329
RIVER DISCHARGE ANALYSIS BY USING MODIS IMAGE AND CHARACTERISTICS COMPARISON BETWEEN ESTUARY IN THE NORTHERN AND SOUTHERN COAST OF JAVA ISLAND <i>Dwi Agus Kuncoro, Wakhidatik Nurfaida</i>	337
THE EXAMINATION ON URBAN INUNDATION DUE TO HEAVY RAIN BY USING VISUALIZATION FOR TRANSPORT OF RAINWATER <i>Masataka Murase, Makoto Takeda, Naoki Matsuo</i>	343
ESTIMATING SPATIALLY DISTRIBUTED OF SEDIMENT YIELD WITH GIS-RUSLE-SEDD MODEL IN CATCHMENT OF RESERVOIR IN JAVA <i>Muhammad Ramdhan Oliy, Bambang Agus Kironoto, Bambang Yulistiyanto, Sunjoto</i>	351
FIELD OBSERVATION AND NUMERICAL SIMULATIONS ON BRIDGE COLLAPSE CAUSED BY TYPHOONS DURING AUGUST 2016 IN JAPAN <i>Takuya Inoue, Tamaki Sumner, Kazuo Kato, Hiroki Yabe , Yasuyuki Shimizu</i>	359
INVESTIGATING THE EFFECTS OF GEOMETRY ON THE FLOW CHARACTERISTICS AND ENERGY DISSIPATION OF STEPPED WEIR USING TWO-DIMENSIONAL FLOW MODELLING <i>Udai A. Jahad, Riyadh Al-Ameri, Lloyd Chua, Subrat Das</i>	369
ANALYSIS SEDIMENT TRANSPORT BABARSARI-MATARAM IRRIGATION CANAL <i>Agatha Padma Laksitaningtyas, Sumiyati Gunawan</i>	377

THE IMPACT OF FLOOD-DETENTION BASIN ON FLOOD PROPAGATION IN THE HUAIHE RIVER <i>Bangyi Yu, Liemin Lv, Jin Ni, Jueyi Sui, Peng Wu</i>	385
FUNDAMENTAL EXPERIMENT USING STEEL STAKES TO CAPTURE DRIFTWOOD ON AN IMPERMEABLE TYPE SABO DAM <i>Norio Harada, Yoshifumi Satofuka, Takahisa Mizuyama</i>	393
STUDY ON CAUSE AND MECHANISM OF HYDRAULIC STRUCTURES FAILURE IN BANGLADESH <i>Kazumitsu Muraoka, Koji Asai, Yosuke Usui, Tatsuya Mochizuki</i>	399
SUBTHEME 2: PORT, HARBORS, COASTAL ENGINEERING AND MANAGEMENT	
THE ANALYSIS ABOUT LONG TERM VARIATION IN DENSITY STRATIFICATION OF ARIAKE BAY BASED ON THE MONTHLY-OBSERVED WATER ENVIRONMENT DATA <i>Akira Tai, Yosuke Morimoto</i>	409
IMPACTS OF SEDIMENT TRANSPORT DUE TO THE KUMAMOTO EARTHQUAKES ON AN INTERTIDAL FLAT AT THE MOUTH OF THE SHIRAKAWA RIVER, JAPAN <i>Akira Tai, Keitaro Hattori, Yoshihisa Akamatsu, Koichi Yamamoto, Tomohiro Komorida, Ryutei Inui, Yasuo Nihei</i>	417
SALINITY TRANSPORT PREDICTION IN RIVERS DURING A TSUNAMI ATTACK: A STUDY OF THE YODO RIVER IN JAPAN <i>Hiroshi Nagashima, Nozomu Yoneyama</i>	425
ANALYZING HARBOR LOCATION AND ORIENTATION BASED ON WAVES CONDITIONS: A CASE STUDY AT WEST OF BORNEO <i>Alamsyah Kurniawan, Bayu Mujahidin, Krisnaldi Idris</i>	435
CURTAIN WALL BREAKWATER ANALYSIS USING DUALSPHYSICS (CASE STUDY: PORT OF KUALA TANJUNG, NORTH SUMATRA) <i>Tedjo Kusumo Yohanes Adi, Nizam, Kuswandi</i>	443
SEDIMENT TRANSPORT AND MORPHOLOGICAL MODELLING IN SINGAPORE STRAIT <i>Serene Hui Xin Tay, Seng Keat Ooi, Vladan Babovic</i>	451
COASTAL FLOODING AND SEDIMENT TRANSPORT DURING EXTREME STORMS IN THE NORTHEASTERN USA IN A CHANGING CLIMATE <i>Qingping Zou, Dongmei Xie</i>	457
CONSIDERING ECOSYSTEM VALUATION FOR COASTAL ZONE MANAGEMENT BY USING ECONOMIC VALUATION AND VISITOR PREFERENCES ON TOURISM ASPECT <i>Iwan Nursyirwan, Biota Fitrah, Betania Caesariratih L., Cecilia Ratna P S</i>	465
APPLYING LOW-CRESTED BREAKWATERS IN RESTORING ERODING MUDDY COASTS OF DEMAK, CENTRAL JAVA <i>D.M.Sulaiman, B. Yungga, B.Wiryawan, M.R. Nugraha</i>	473
PRELIMINARY STUDIES OF DIKE PROFILES FOR JAKARTA OUTER SEA DIKE: PHYSICAL MODEL TEST RESULTS <i>Agustia A. Larasari, Semeidi Husrin, Leo E. Sembiring, Huda Bachtiar</i>	483
SUBTHEME 3: ENVIRONMENTAL HYDRAULICS AND HYDROLOGY	
EFFECTS OF RAIN DROPLETS AND SEA SPRAY ON THE MOMENTUM AND LATENT HEAT FLUXES <i>Hiroki Okachi Tomohito J. Yamada, Yasunori Watanabe</i>	493
IMPACTS OF CASCADE HYDROPOWER DEVELOPMENT ON SALINITY INTRUSIONS INTO THE VIETNAMESE MEKONG DELTA <i>Nguyen Phuong Mai, Sameh Kantoush, Tangduc thang, Tetsuya Sumi</i>	503
APPLICATION OF TRMM FOR PREDICTIONS IN UNGAUGED BASIN, CASE STUDY: NANJUNG CATCHMENT <i>Wanny Kristyanti Adidarma, Bambang Adi Riyanto, Doddi Yudianto, Anri Noor Annisa Ramadan</i>	513

SIMULATION OF LARGE FRESH WATER BEHAVIOR IN HAKATA BAY DUE TO TORRENTIAL RAIN USING NESTED TWO-DIMENSIONAL MODEL <i>Akihiro Fukuda, Toshinori Tabata, Yuri Honda, Kazuaki Hiramatsu, Masayoshi Harada</i>	521
INVESTIGATION OF THE EFFECTS OF HUMAN ACTIVITIES USING MULTI-BOX ECOSYSTEM MODEL IN THE AIRAKE SEA, JAPAN <i>Toshinori Tabata, Kodai Nakashima, Kazuaki Hiramatsu and Masayoshi Harada</i>	531
DEVELOPMENT OF A MESH-BASED DISTRIBUTED RUNOFF MODEL INCORPORATED WITH TANK MODELS OF SEVERAL LAND UTILIZATIONS IN A SOUTHEAST ASIAN WATERSHED <i>Asari Takada, Kazuaki Hiramatsu, Trieu Anh Ngoc, Masayoshi Harada, Toshinori Tabata</i>	539
EFFECT OF CLIMATE CHANGE VARIABLES ON THE COASTAL WIND PREDICTION <i>Heri Sulistiyono, Eko Pradjoko, Syamsidik</i>	549
ESTIMATION OF SEDIMENT YIELD AND BENEFIT IN NORTHERN PART OF THAILAND USING REMOTE SENSING DATA <i>Prem Rangsiwanichpong, So Kazama</i>	559
METHODS FOR PREDICTING VERTICAL VELOCITY DISTRIBUTIONS IN OPEN CHANNEL FLOWS WITH SUBMERGED RIGID VEGETATION <i>Xiaonan Tang</i>	567
FLOW RESISTANCE AND TURBULENT STRUCTURE IN OPEN CHANNEL WITH SUBMERGED PERMEABLE AND IMPERMEABLE SIDE-CAVITIES <i>Takayuki Tanaka, Terunori Ohmoto, Kota Sawa</i>	577
ASSESSMENT OF POTENTIAL BRACKISH WATER FOR AGRICULTURAL USE IN THE UTILIZED AQUIFERS IN KUWAIT <i>Amjad Aliewi, Hana'a Burezq</i>	583
EVALUATION OF CIBULAKAN SPRING FLOW DISCHARGE FOR THE DEVELOPMENT OF BANDUNG DISTRICT DRINKING WATER SUPPLY SYSTEM <i>Mariana Marselina, Arwin Sabar</i>	591
CANOPY SATURATION AND TROUGHFALL FOR ACACIELLA ANGUSTISSIMA, ARTOCARPUS HETEROPHYLLUS, PINUS MERKUSII AND ANTHOCEPHALUS CADAMBA RELATED TO RAINFALL INTENSITY <i>Ahmad Reza Kasury, Joko Sujono, Rachmad Jayadi</i>	599
ESTIMATION OF HIGH TEMPORAL RESOLUTION RIVER DISCHARGES INTO SINGAPORE COASTAL WATERS FOR OPERATIONAL FORECAST <i>Serene Hui Xin Tay, Mengyu Wang, Vladan Babovic, Seng Keat Ooi</i>	609
ESTIMATION OF ENVIRONMENTAL FLOWS USING PHYSICAL HABITAT SIMULATIONS <i>Seung Ki Kim, Sung-Uk Choi</i>	617
WATER QUANTITY AND QUALITY MATHEMATICAL MODEL OF RIVER NETWORK IN THE MIDDLE REACH OF HUAIHE RIVER <i>Jin Ni, Bangyi Yu</i>	625
ASSESSMENT OF RAINWATER HARVESTING AS AN ALTERNATIVE WATER SOURCE FOR RURAL INDONESIA <i>Raden Ajeng Koesoemo Roekmi, Lloyd Hc Chua, Kanagaratnam Baskaran</i>	629
APPLICABILITY OF NONLINEAR FILTERING TO WATER-LEVEL FORECASTING OF SMALL- AND MEDIUM-SIZED RIVERS <i>Kohji Tanaka, Masayuki Sugiura, Hiroki Tsujikura</i>	639
SUBTHEME 4: IRRIGATION, WATER SUPPLY AND SANITATION	
SHAPE FACTORS AND INSITU FIELD PERMEABILITY FOR ARTIFICIAL RECHARGE <i>Azizah Rachmawati, Suhardjono, Ussy Andawayanti, Pitojo Tri Juwono</i>	651

ON SEDIMENTATION CHARACTERISTICS OF POWDERED ACTIVATED CARBON POROUS PARTICLES IN STILL WATER <i>Shehua Huang, Kun Chen, Yang Tian, Tianyu Sui</i>	659
HYDROLOGICAL DROUGHT INTENSITY AND STRESS IN THE PEMALI-COMAL RIVER BASIN <i>Waluyo Hatmoko, Roberus Wahyudi Triweko, Iwan Kridasantausa Hadihardaja</i>	667
IMPROVING THE PERFORMANCE OF TIDAL IRRIGATION THROUGH THE WATER MANAGEMENT, (STUDY CASE GANDUS PALEMBANG, SOUTH SUMATRA) <i>Haryo Istianto, Ronny Bernard, F.X. Suryadi</i>	677
STUDY ON SUSTAINABLE METHODOLOGY FOR WASTEWATER TREATMENT IN MAINLINE-DISCONNECTED GER AREAS OF ULAANBAATAR CITY <i>Ariuntuya Byambadorj, Han Soo Lee</i>	687
EVALUATION AND DEVELOPMENT OF THE DISTRIBUTION NETWORK ON PIPED DRINKING WATER OF LENDAH SYSTEM AT PDAM (REGIONAL WATER SUPPLY COMPANY) OF KULONPROGO REGENCY <i>Angga Budi Kusuma, Radiana Triatmadja, Intan Supraba</i>	695
CALIBRATION OF IRRIGATION GATES IN PUNGGUR UTARA IRRIGATION AREA <i>Dyah Indriana Kusumastuti, Dwi Jokowinarno</i>	703
DESIGN OF A WATER SUPPLY TREATMENT DEVICE FOR RURAL COMMUNITIES <i>Sarah Andrew, Shea Patten-Wise, Dr Gregory De Costa</i>	711
WATER AVAILABILITY IN THE PRIMARY CANAL OF TERANTANG TIDAL IRRIGATION UNITS, BARITO KUALA SOUTH KALIMANTAN PROVINCE <i>Maya Amalia Achyadi, Koichiro Ohgushi, Atika Wulandari</i>	719

VOLUME 2

SUBTHEME 5: WATER RESOURCES

DO SAG-CURVE MODELING USING HEC-RAS V.4.1.0: CASE STUDY SURABAYA RIVER <i>Christian Alfonsus Liguori, Doddi Yudianto, and Guan Yiqing</i>	727
GENERATING A PLAUSIBLE FUTURE OF SALINITY INTRUSION DUE TO MORA-LIKE CYCLONE ALONG THE COAST OF BANGLADESH <i>Tansir Zaman Asik, A.S.M. Alauddin Al Azad, Rabeya Akter, Mohiuddin Sakib, Anisul Haque, Munsur Rahman</i>	737
THE ANALYSIS OF WATER BALANCE FOR SEMIARID REGION IN SABU RAIJUA – EAST NUSA TENGGARA <i>Denik Sri Krisnayanti, I Made Udiana, Oliver Kevin Ndoen</i>	747
IMPACT ASSESSMENT OF CLIMATE CHANGE ON OPERATION OF RESERVOIR SYSTEMS FOR WATER USE IN JAPAN <i>Daisuke Nohara, Shunsuke Suzuki, Tomoharu Hori, Yoshinobu Sato</i>	755
THE EFFECT OF THE LENGTH OF RAINFALL DATA TO IDF CURVE <i>Dwi Jokowinarno, Dyah Indriana Kusumastuti</i>	765
ESTIMATION OF SOIL INFILTRATION AND GROUNDWATER RECHARGE IN SUKHUMA DISTRICT OF SOUTHERN LAOS <i>Sinxay Vongphachanh, William Milne-Home, James E Ball, Ashim Das Gupta, Paul Pavelic</i>	773
BIOCHEMICAL CHARACTERISTICS OF WATER QUALITY DYNAMICS NEAR THE BOTTOM SEDIMENT UNDER ANAEROBIC STATE IN THE ORGANICALLY POLLUTED RESERVOIR <i>Masayoshi Harada, Tran Tuan Thach, Kazuaki Hiramatsu, Toshinori Tabata</i>	783
LINKING CLIMATE CHANGE TO URBAN STORM DRAINAGE SYSTEMS DESIGN: RECENT ADVANCES IN MODELING OF EXTREME RAINFALL PROCESSES <i>Van-Thanh-Van Nguyen, Truong-Huy Nguyen</i>	793

TREND IN WATER USE AND ITS ANTICIPATION ALONG THE WOLOWONA RIVER <i>Bernadetha Tea, Susilawati, Triweko</i>	803
URBAN WATER SUPPLY MANAGEMENT INDEX : CASE STUDY PONTIANAK CITY <i>R. Wahyudi Triweko, Doddi Yudianto</i>	811
ANALYSIS OF WATER RESOURCE DEVELOPMENT STRATEGIES TO MEET WATER DEMAND IN DON ALEIXO SUB-DISTRICT, DILI-TIMOR LESTE <i>Aderita Mariana Takeleb, Joko Sujono, Rachmad Jayadi</i>	819
CURRENT STATUS AND NECESSARY FUTURE ANTICIPATION AGAINST SEDIMENTATION PROBLEM ON FIVE RESERVOIRS IN CENTRAL JAVA <i>Angga Widyo Pramono, Didik Ardianto, Fahmi Hidayat, Raymond Valiant Ruritan, Djoko Legono</i>	829
WATER CYCLE ANALYSIS OF THE BORYEONG-DAM WATERSHED, SOUTH KOREA, USING CAT MODEL <i>Sanghyun Park, Hyeonjun Kim, Cheolhee Jang, Dereje Birhanu</i>	835
POTENTIAL SALT WATER INTRUSION STUDY AT KYEEMYINDAING TOWNSHIP, YANGON REGION, MYANMAR <i>Thinzar Aye, Maung Maung</i>	843
URBAN DESIGN STORM CURVES USING HIGH SPATIAL AND TEMPORAL RESOLUTION RAINFALL DATA <i>Jiandong Liu, Ngoc Son Nguyen, Srivtsan V. Raghavan, Jina Hur, Shie-Yui Liong</i>	849
ESTIMATION OF FLOOD FLOW RATE HYDROGRAPH APPLYING SATELLITE RAINFALL DATA TO RUNOFF MODEL WITH H-Q FORMULA <i>Fuma Tanaka, Takao Tamura, Yasunori Muto</i>	859
CHALLENGES OF INTEGRATED WATER RESOURCES MANAGEMENT IN KAPUAS RIVER BASIN <i>Stefanus B. Soerryamassoeka, R.W. Triweko, D. Yudianto, Kartini</i>	867
HOW INDONESIAN WATER RESOURCES INSTITUTION SHOULD BE ADAPTED TO SOCIAL, ECONOMIC AND ENVIRONMENTAL CONSTRAINTS <i>Budi Santoso Wignyosukarto, Fatchan Nurrochmad, Lely Masthura</i>	873
GROUNDWATER AQUIFER PARAMETERS EVALUATION USING ARTIFICIAL DYE TRACERS <i>Harish Bhandary, Asim Al-Khalid</i>	881
ANALYSIS ON RAINFALL MEASUREMENT USING A MULTIPLE PIT-GAUGE <i>Chanjoo Lee, Donggu Kim, Bongju Jang, Won Kim</i>	889
SUBTHEME 6: HYDROINFORMATICS	
CONSOLIDATION AND DISCLOSING NATIONAL INSTRUMENTS FOR WATER RESOURCE MANAGEMENT <i>Arnejan van Loenen, Mirwan Rofiq</i>	895
RAINFALL ESTIMATION USING A REAL-TIME COMBINATION OF WEATHER RADAR AND TELEMETRIC RAIN GAUGE DATA IN THAILAND <i>Narongrit Luangdilok, Watin Thanathanphon, Piyamarn Sisomphon, Siriluk Chumchean, Sudajai Lowanichchai</i>	905
DROUGHT ASSESSMENT USING SATELLITE-BASED DATA FROM FDMT WEB PORTAL TOOLS: CASE STUDY OF CHAO PHRAYA RIVER BASIN <i>Watin Thanathanphon</i>	911
MODEL INTEGRATION FOR DECISION SUPPORT AND WATER MANAGEMENT <i>Watin Thanathanphon, Sathit Chantip, Apimook Mooktaree, Theerapol Charoensuk, Narongrit Luangdilok, Ticha Lolupiman, Piyamarn Sisomphon</i>	921
MODELLING STAGE-DISCHARGE RELATIONSHIP USING ARTIFICIAL NEURAL NETWORK <i>Shreenivas Londhe, Kirti Sonawane</i>	931

MODELLING EVAPOTRANSPIRATION USING ARTIFICIAL NEURAL NETWORK <i>Shreenivas Londhe, Madhura Kulkarni</i>	939
AUTOMATIC AND CONTINUOUS DISCHARGE MONITORING WITH SPACE-TIME IMAGE VELOCIMETRY (STIV) AND DYNAMIC INTERPOLATION AND EXTRAPOLATION (DIEX) METHOD <i>Yuya Suzuki, Jin Kashiwada, Yasuo Nihei, Tomohito Fujii, Kenji Taira, Eiji Ueda, Junya Kaji, Ichiro Fujita</i>	949
DEVELOPING BAYESIAN PROBABILISTIC FLASH FLOOD GUIDANCE FOR KONTA RIVER BASIN, EAST JAVA, INDONESIA <i>Astria Nugrahany</i>	959
COMPARATIVE ASSESSMENT OF CAT AND GR4H MODEL FOR FLOOD EVENT SIMULATION IN THREE KOREAN WATERSHED <i>Dereje Birhanu, Hyeonjun Kim, Cheolhee Jang, Sanghyun Park</i>	971
SUBTHEME 7: WATER-RELATED DISASTER RISK REDUCTION	
RISK TO A VEHICLE IN A FLOOD IN CONSIDERATION OF FLOW DIRECTION <i>Hideo Oshikawa, Takashi Oshima, Akihiro Hashimoto, Koichiro Ohgushi, Toshimitsu Komatsu</i>	981
OPEN SOURCE TSUNAMI SIMULATION MODELS: A SYSTEMATIC REVIEW <i>Retno Utami Agung Wiyono</i>	991
RELATIONSHIP OF THREE HOURS OF CUMULATIVE RAINFALL DURING CONCENTRATION TIME OF SLOPE AND COLLAPSED AREA OF LAND SLIDE <i>Toshiyuki Moriyama, Muneo Hirano</i>	999
A STUDY ON THE 2016 AUGUST FLOOD AND LEVEE BREACHES IN THE SORACHI RIVER, HOKKAIDO, JAPAN <i>Jun Okuda, Yasuyuki Shimizu, Tomoko Kyuka, Toshiki Iwasaki, Yoshiaki Ishida</i>	1007
EFFECT OF THE COMBINATION OF FOREST AND THE FRONT-SIDE MOAT ALONG A RIVER WHERE A TSUNAMI RUNS UP <i>Norio Tanaka</i>	1015
PHYSICAL-BASED HYDROLOGICAL MODELLING: RELIABLE METHOD OR EXCESSIVE ESCAPE ROUTE <i>Steven Reinaldo Rusli, Randy Rivaldi Trisnojoyo, Malvin Samuel Marlim, Doddi Yudianto, Wanny Kristiyanti Adidarma</i>	1023
FLOOD CONTROL ADAPTATION FOR MASSIVELY RESIDENTIAL LAND DEVELOPMENT IN BANDUNG CITY <i>Doddi Yudianto, Randy Rivaldi Trisnojoyo, Malvin Marlim</i>	1033
EVACUATION ANALYSIS IN INUNDATION AT MULTI-LAYER UNDERGROUND SPACE <i>Keiichi Toda, Toshiyuki Nishikori, Taisuke Ishigaki</i>	1043
EXPERIMENTAL STUDY ABOUT THE INFLUENCE THAT DEBRIS FLOW AND MUD FLOW GIVE TO A STRUCTURE <i>Yu Inami, Takeshi Fujinami, Hiroki Yabe, Takaaki Abe</i>	1051
STUDY ON DESIGN METHOD FOR MOUND TYPE TSUNAMI EVACUATION FACILITY “INOCHIYAMA” <i>Kenji Harada</i>	1059
FLOOD RISK ASSESSMENT USING GIS-BASED MULTI-CRITERIA ANALYSIS: A CASE STUDY IN DAVAO ORIENTAL, PHILIPPINES <i>Jonathan S. Cabrera, Han Soo Lee</i>	1069
COUPLED STORM SURGE AND WAVE SIMULATIONS FOR THE COAST OF TAIWAN <i>Wen-Cheng Liu, Wei-Cher Huang</i>	1079

DEVELOPMENT OF FLOOD INUNDATION MAP USING UAV-BASED DEM ON RESIDENTIAL AREA <i>Sarino, Helmi Haki, Reini S. Ilmiaty</i>	1089
A METHOD TO SPECIFY CRITICAL RAINFALL CONDITIONS FOR SEDIMENT DISASTERS AND THEIR REGIONALITY <i>Yusuke Yamazaki, Shinji Egashira</i>	1097
A NEW FLOOD PREDICTION METHOD WITH DATA ASSIMILATION FOR WATER-LEVEL DATA <i>Jin Kashiwada, Yasuo Nihei</i>	1105
THE EFFECTIVENESS OF DETENTION POND FOR REDUCING PROPERTIES FLOOD DAMAGE <i>Agus Suharyanto, Diah Susilowati</i>	1113
EVALUATION OF FLOOD HAZARD AREAS IN LAOS BY USING ANALYTICAL HIERARCHY PROCESS <i>Phrakonkham Sengphrachanh, So Kazama, Daisuke Komori</i>	1121
CLIMATE CHANGE ADAPTATION STRATEGY- TAIPEI'S WENSHAN FLOOD PREVENTION AND DRAINAGE PLAN AS A CASE STUDY <i>Cheng-Sheng Pong, Shih-Bin Lin, Yung-Chia Hsu</i>	1129
SPATIALLY DISTRIBUTED EVALUATION OF INITIATION OF MASS EROSION <i>Ani Hairani, Adam Pamudji Rahardjo, Djoko Legono, Istiarto, Shusuke Miyata</i>	1139
SUBTHEME 8: SPECIAL SESSION	
8.1 HISTORICAL WATER PROJECTS AND TRADITIONAL WATER TECHNOLOGIES IN THE ASIA-PACIFIC REGION	
CHANGES OF A ROUTE AND AN UPSTREAM WELL FOR AN INVERTED SIPHON OF TATSUMI CANAL IN THE CITY OF KANAZAWA <i>Nobuyuki Tamai, Haruhiko Todo, Toshikazu Ikemoto</i>	1145
EFFECT OF OPEN DYKE FOR FLOOD DISASTER MITIGATION IN KYOTO <i>Taisuke Ishigaki, Ryuji Kawanaka, Michiko Hayashi</i>	1153
TECHNOGRAPHICAL REVIEW OF LEVEE PLANTING FOR FLOOD – RISK REDUCTION FOCUSED ON RIPARIAN FOREST STRIPS IN KOREA <i>Hyoseop Woo, Woon Ji</i>	1161
ANALYSIS OF EXTREME FLOODS IN CHEONGYEcheon URBAN RIVER BASED ON CHUGUGI RAINFALL DATA AND HISTORICAL DOCUMENTS DURING 19TH CENTURY IN SEOUL, KOREA <i>Hyeonjun Kim</i>	1167
CHARACTERISTICS OF CHIKUGO RIVER'S OLD MEANDERING WITH ITS INFLOWING TRIBUTARIES <i>Koichiro Ohgushi, Wataru Kawahara, Toshihiro Morita, Maya Amalia Achyadi</i>	1173
VAN DER WIJCK IRRIGATION CHANNEL, A SUCCESS STORY AND ITS IMPLICATION <i>Radiana Triatmadja, Djoko Legono, Budi Santoso Wignyosukarto, Fatchan Nurrochmad, Sujoto Sunjoto</i>	1181
WATER RESOURCE REGULATE AND CONTROL SYSTEM IN ANCIENT TUOSHAN WEIR ENGINEERING <i>H.B. Gu, Qianli Guo, P. Lin, Y. Zhang</i>	1187
THE MEETING PROJECT BETWEEN THE GRAND CANAL AND THE YELLOW RIVER AND THE HUAIHE RIVER DURING THE INVASION OF THE YELLOW RIVER INTO THE HUAIHE RIVER (1128-1855) <i>Wang Yinghua</i>	1197

8.2. GREEN INFRASTRUCTURE AS DISASTER RISK REDUCTION MEASURE

RETARDING CAPACITY CHANGE OF WETLAND PADY FIELDS DUE TO HOUSE LAND DEVELOPMENT -TOWARD WISE LAND USE AGAINST FLOOD UTILISING PADDY FIELDS AS GREEN INFRASTRUCTURE

Muto, Y., Kotani, S., Miyoshi, M., Kamada, M., Tamura, T. 1209

INFLUENCE OF VEGETATION PROPAGATION CONDITION ON FLOOD FLOW

Junya Yamamoto 1219

STUDY ON FLOOD CONTROL METHODS AND HABITAT CREATION IN THE YODO RIVER BASIN UTILIZING A RETARDING BASIN

Yuko Ishida, Misaki Kitamura, Kento Okunishi, Kenji Sawai, Masanori Sera, Yoshiya Ogawa, Masato Maegawa, Ryo Hirako, Yukisada Kitamura 1229

FLUME EXPERIMENTS ON THE EFFECTIVE SHAPE OF A HISTORICAL FLOOD GUARD MOAT, KAMAEBORI, AROUND A PROTECTIVE MOUND AND STRUCTURE, MIZUKA, IN FREQUENT FLOOD OCCURRENCE AREA

Norio Tanaka, Yu Hasemi 1239

8.3. CONCEPTUAL IDEA TO SOLVE PROBLEMS RELATED TO HYDRO-ENVIRONMENT AND ENGINEERING

THE EFFORT OF WES CURVE PERMEABLE SPUR DIKE ON HYDRO-ENVIRONMENT IN YANGTZE RIVER

Hu Jielong, Wang Meili, Zhang Jie, Li Jian, Wang Pingyi 1247

MORPHODYNAMIC AND HYDROLOGICAL ASPECTS OF WATERWAYS ON LARGE TROPICAL RIVERS: THE TOCANTINS-ARAGUAIA SYSTEM

Adriano Coutinho de Lima 1255

THE BENEFIT OF HYDRODYNAMIC MODEL AS AN ASSESSMENT OF THE HYDRO-ENVIRONMENT ENGINEERING IN DECISION SUPPORT SYSTEM FOR THE SUSTAINABLE MARICULTURE DEVELOPMENT IN INDONESIA

Surya Hermawan 1263

ARTIFICIAL RECHARGE TO PREVENT WATER SCARCITY AT YOGYAKARTA CITY

Intan Supraba, Deendarlianto, Adhika Widyaparaga 1272

8.4. VOLCANO AND MULTIMODAL SEDIMENT DISASTER: SIMULATION AND RISK MITIGATION

TEMPORAL CHANGES OF RAINFALL-RUNOFF RELATIONSHIP AFTER THE 1984 ERUPTION OF MT. MERAPI

Yutaka Gonda, Shusuke Miyata, Masaharu Fujita, Djoko Legono, Daizo Tsutsumi 1277

EFFECTS OF SPATIO-TEMPORAL VARIATIONS OF GAUGES AND RADAR RAINFALL OBSERVATIONS ON RAINFALL-RUNOFF SIMULATION

Ratih Indri Hapsari, Satoru Oishi, Magfira Syarifuddin, Dandung Novianto, Fahmi Hidayat 1285

EVENT CHAINS SIMULATION OF PYROCLASTIC FLOW AND LAHAR FOR QUASI- REAL TIME HAZARD MAPPING

Makoto Shimomura, Kuniaki Miyamoto 1295

A METHOD FOR PREDICTING DEBRIS FLOW OCCURRENCE IN VOLCANIC ASH DEPOSITION AREAS

Masaharu Fujita, Kazuki Yamanoi, Shusuke Miyata, Ani Hariani, Djoko Legono 1303

MERAPI'S LAHAR EARLY WARNING SYSTEM 2011-2012 PERIOD

I Gusti Made Agung Nandaka, Nurudin, Anton Sulistio 1311

STATISTICAL PROPERTIES OF SHORT-TERM RAINFALL TIME SERIES AS OBSERVED BY XMP RADAR; CASE OF MT. MERAPI AREA <i>Roby Hambali, Djoko Legono, Rachmad Jayadi, Satoru Oishi</i>	1317
DEBRIS FLOW SIMULATIONS OCCURRING FROM LANDSLIDE DAM OUTBURST AT MT.SINABUNG <i>Kana Nakatani, Yoshifumi Satofuka, Yutaka Gonda, Kuniaki Miyamoto</i>	1325
8.5 MISCELLANEOUS	
SOIL HYDRAULIC PROPERTIES IN THE NEAR-SURFACE SOIL PROFILE OF BANARAN LANDSLIDE CROWN AREA <i>Hatma Suryatmojo, Nia Amalia Septiani, Danang Sri Hadmoko, Ngadisih</i>	1333
ASYMMETRIC SPATIAL DEPENDENCE OF PRECIPITATION AMOUNTS OVER SINGAPORE USING NON-GAUSSIAN COPULAS <i>Suroso Suroso, András Bárdossy</i>	1341
ADVANCED PANDANDURI RESERVOIR RULE CURVE <i>M. Yura Kafiansyah, Anang M. Farriansyah</i>	1353
AN ANALYTICAL MODEL OF THE SALT ELUTION METHOD <i>Qihan Qiu, Hiroaki Terasaki, Teruyuki Fukuhara, Ximan Liu</i>	1363
THE INUNDATION ANALYSIS DUE TO TSUNAMI IN CONSIDERATION OF WATER BEHAVIOR OF SUBWAY <i>Makoto Takeda, Masataka Murase, Yusuke Nakajima, Naoki Matsuo</i>	1371
EFFECTIVENESS OF ECODRAINAGE APPLICATION BY USING INFILTRATION WELLS <i>Bambang Sulistiono, Khalis Fatmawati</i>	1377
ATMOSPHERIC BOUNDARY LAYER ANALYSIS USING LARGE EDDY SIMULATION <i>Fanny Kristianti, Tomohito Yamada</i>	1385
STUDI ON WATER DEMAND FOR SEDIMENT TRANSPORT IN THE YELLOW RIVER, CHINA <i>Chen Jianguo , Wang Chonghao</i>	1393
EVALUATION OF AGING PROCESS OF ECOLOGICAL SWALE SYSTEM IN ENGINEERING CAMPUS, UNIVERSITI SAINS MALAYSIA <i>Puay How Tion, Siti Rohaya Jokefli, Nor Azazi Zakaria</i>	1401
DEVELOPMENT OF A NUMERICAL MODEL FOR THE SIMULATION OF SUPERCRITICAL FLOW AT ABRUPT EXPANSION STRUCTURE <i>Lim Jia Jun, Puay How Tion, Nor Azazi Zakaria</i>	1408
NUTRIENT ELEMENTS' PATTERN RECOGNITION IN COMPOSITE BIORETENTION SYSTEM USING PRINCIPAL COMPONENT ANALYSIS (PCA) STUDIES <i>Hui Weng Goh, Nor Azazi Zakaria</i>	1419
APPLICATION OF LIMESTONE IN GROUNDWATER TREATMENT <i>Muhammad Fitri Mohd Akhir, Noor Aida Saad, Nor Azazi Zakaria</i>	1425
OPTIMIZATION OF NICKEL REMOVAL IN WASTEWATER CONTAINING HIGH CONCENTRATION OF NICKEL <i>Siti Fairuz Juiani, Mohd Ariffin Abu Hassan, Nor Azazi Zakaria, Nazlina Ya'aini, Noor Sabrina Ahmad Mutamim , Khairul Rahmah Ayub, Siti Fadilla Md Noor</i>	1433
APPLYING A SYSTEM THINKING APPROACH TO EXPLORE ROOT CAUSES OF RIVER POLLUTION: A PRELIMINARY STUDY OF PINANG RIVER IN PENANG STATE, MALAYSIA <i>Chee Hui Lai, David T. Tan, Ngai Weng Chan, Nor Azazi Zakaria</i>	1441
INTENSIVE GREEN ROOF PERFORMANCE IN EL-NINO AND HIGH INTENSITY RAINFALL <i>Khairul Rahmah Ayub, Aminuddin Ab Ghani, Nor Azazi Zakaria</i>	1449

WAN MAT SAMAN CANAL - LINKING WATER RESOURCES AND CROP PRODUCTION IN MALAYSIA

Fouzi Ali, Nasiruddin Abdullah, Mukhlis Zainol Abidin, Nor Azazi Zakaria, Chun Kiat Chang1455

SUSTAINABLE SOLUTIONS TO RIVER IMPROVEMENT WORKS USING BIO-ENGINEERING TECHNIQUE

Chun Kiat Chang, Nor Azazi Zakaria, Muhamad Nurfasya Alias, Haslina Abu Hashim, See Hean Gan1461

INCREASING WATER PRODUCTIVITY IN RICE PRODUCTION THROUGH ORGANIC AMENDMENTS UNDER WATER SAVING IRRIGATION

Endita Prima Ari Pratiwi, Fatchan Nurrochmad, Robi Arianta Sembiring, Sarra Rahmadani, Joko Sujono
.....1469



DEVELOPMENT OF FLOOD INUNDATION MAP USING UAV-BASED DEM ON RESIDENTIAL AREA

MUHAMMAD B. AL AMIN

Universitas Sriwijaya, Civil Engineering Department, Ogan Ilir – South Sumatra, Indonesia, baitullah@unsri.ac.id

SARINO

Universitas Sriwijaya, Civil Engineering Department, Ogan Ilir – South Sumatra, Indonesia, sarinopl95@gmail.com

HELMI HAKI

Universitas Sriwijaya, Civil Engineering Department, Ogan Ilir – South Sumatra, Indonesia, helmi_haki@yahoo.com

REINI S. ILMIATY

Universitas Sriwijaya, Civil Engineering Department, Ogan Ilir – South Sumatra, Indonesia, reini_mahyuddin@yahoo.co.id

AYU MARLINA

Universitas Tridianti, Civil Engineering Department, Palembang – South Sumatra, Indonesia, ayumarlina.utp@gmail.com

ABSTRACT

This paper presents the hydraulic modeling and simulation to develop flood inundation map in residential areas using high-resolution digital elevation model (DEM) generated by Unmanned Aerial Vehicle (UAV) survey. The research was done at Bukit Sejahtera and Tanjung Rawa residential areas located in Palembang City, South Sumatra Province, Indonesia with total area about 200 ha. The new HEC-RAS 5.0 was used as a hydrodynamic model to simulate the combined one and two-dimensional flow routing based on 5-year return period of flood hydrographs for upstream boundary conditions and the highest tide level for downstream boundary condition. The results show that the UAV survey can produce a high-resolution DEM. The grid size of UAV-based DEM was generated in this study is 0.1x0.1m, so it can be said to have a high spatial resolution. The simulated flood depths compared with measured data show a good trend and corresponding values. However, a more detailed calibration cannot be performed because of the limitation of measurable data. Nevertheless, the results of this study have demonstrated the enormous potential use of UAV in the future to acquire high-resolution elevation data for generating a detailed and accurate flood inundation map. The authors believe that the utilization of UAVs will be more extensive for flood control and management strategies, especially in Indonesia due to its flexibility, reliability and affordable cost. The characteristic of flood depths in the study area is also discussed in this paper.

Keywords: Flood mapping, hydrodynamic model, GIS, UAV

1. INTRODUCTION

Flood is natural phenomenon may frequently occur especially in urban areas. The flood inundation could happen due to heavy rainfall and spring tides in lowland areas, i.e., areas that the surface elevation is lower than tide level. Both structural and nonstructural approaches are taken to obtain the optimal solution for the planning of flood control and mitigation. For such purposes, a series of hydrologic and hydraulic analyzes combined with GIS are required to obtain potential flood inundation map that may occur in an area.

The accuracy of flood inundation is highly dependent on the level of accuracy of elevation data used (Haile & Rientjes, 2005; Marks & Bates, 2000). The elevation data, known as digital elevation model (DEM) is a model to represent the appearance of surface topography in three-dimensional format (Ruzgiene et al., 2014). The spatial resolution value can show the accuracy level of DEM. The higher the resolution of DEM, the better accuracy in term of elevation can be achieved and vice versa. The DEM is said to have a high spatial resolution if the grid size is less than 1 m, and high accuracy if the height error is less than 0.05 m (Pichon et al., 2016). Several previous studies have shown that the higher the DEM resolution used, the better the accuracy of the resulting flood map. As an example of a study conducted by Hsu, et al. comparing simulation results of flood inundation within Sanyei drainage area located in southern Tainan City, Taiwan by using light detection and ranging (LiDAR)-based DEM with five different grid sizes, i.e., 1x1m, 5x5m, 10x10m, 20x20m, and 40x40m. The results showed that the coarser of the grid size used, the area of inundation becomes larger where the accuracy of the simulation is reduced. It can be due to the coarser DEM simplifying the topographic information thus affecting the hydraulic characteristics of the simulated area (Hsu et al., 2016). The same results are also

explained in (Brandt & Lim, 2016) and (Haile & Rientjes, 2005) which the inundation area generated by the coarser DEM tends to be overestimated compared to the finer DEM. Furthermore, Hsu et al. (2016) also explained that flood inundation map is the most essential information in the estimation of economic losses so that high-resolution DEM is required to obtain better simulation results. A sufficient number of ground control points (GCPs) is necessary to produce an accurate DEM. Coveney & Roberts (2017) have simulated flood inundation of DEM with varying amounts of GCPs, i.e., 5, 10, 15, 30, 45, and 61 sets. The simulation results showed that the more the number of GCPs, the smaller the elevation error of generated DEM, so the inundation area becomes closer to the observed one. It indicates that a sufficient GCPs number can provide better accuracy for the resulting inundation map (Coveney & Roberts, 2017). However, the high-resolution DEM is usually generated only by technologies such as Interferometric Synthetic Aperture Radar (IFSAR) and LiDAR at prohibitive cost (Coveney & Roberts, 2017; Hashim et al., 2016). It becomes an obstacle especially for developing countries that still rarely or not commonly use LiDAR technology and with limited budgets for flood control studies also (Wedajo, 2017). Therefore, it is necessary to have technology that can produce DEM with high spatial resolution but affordable cost so that it can be applied widely for flood control and mitigation works.

The unmanned aerial vehicle (UAV) is a device commonly used for purposes such as photography, monitoring, and remote sensing. Recently, the UAV has been extensively researched for photogrammetry surveys so that it can generate DEM with high spatial resolution and level of accuracy. De Silva et al. (2016) mentioned that spatial resolution of DEM created by UAV survey could be less than 1 m. Pichon et al. (2016) explained that UAV-based DEM could have a high level of accuracy with elevation error less than 0.01 m. The same is also mentioned in (Entwistle & Heritage, 2017). This value is smaller than the height error generated by conventional photogrammetry survey, which is 0.35 m (Hudec, 2011). Even the accuracy of UAV-DEM may have more average minor mistake compared to LiDAR, thus indicating the UAV survey can be more effective than LiDAR (Entwistle & Heritage, 2017). However, the maximum height error of UAV-DEM may go up to 0.55 m (Ruzgiene et al., 2014). The degree of error is highly dependent on flying height, camera characteristics, and the number and accuracy of GCPs (Küng et al., 2011; Ruzgiene et al., 2014; Santise et al., 2014). Jeong et al. (2016) have investigated the level of DEM resolution may be generated from UAV survey. The results showed that UAV survey could produce DEM with high-level spatial resolution up to 0.05 m. Also, the costs incurred for DEM data acquisition using UAV are still affordable compared to other photogrammetry technologies and terrestrial surveys (Madawalagama et al., 2016). It suggests that UAV technology should be used widely for mapping purposes especially in flood inundation mapping (Sze et al., 2015).

This paper deals with the mapping of potential flood inundation through hydrodynamic modeling by using DEM generated by UAV survey. The object of this research are residential areas constitute of lowland influenced by the river tides so often being flooded. This research is expected to contribute in the application of UAV technology widely for the making of flood control strategies and plans, especially in developing countries such as Indonesia, where the technology of LiDAR survey is relatively expensive and still very rarely used.

2. METHOD

The two residential areas as the object of this research are Bukit Sejahtera and Tanjung Rawa residence with total area about 200 ha located in Palembang City, South Sumatra Province, Indonesia (Figure 1). In general, some regions in Palembang are lowland so that the areas may be flooded during spring tides (Putra et al., 2011). The study area has similar characteristic to such regions with a relatively low and flat topography affected the Lambidaro River tides, which is a drainage subsystem that is flowing into Musi River, the largest river in South Sumatra Province. During the rainy season, which is accompanied by spring tides from the river, the residential areas are often flooded. Some previous studies on flooding in Palembang City have been conducted by Al Amin et al. (2017) and Farid et al. (2017) indicating that the residential areas on which this study was located have a moderate level of flood hazard.

In this study, DEM data were collected from photogrammetry survey using commercial UAV type quadcopter, namely DJI Phantom 3 Advanced with flying height set to 100 m from the surface. This flying height is sufficient to produce high-resolution DEM maps (Jeong et al., 2016). This UAV was equipped with 12.4 MP resolution camera, GPS, and altitude sensor. Figure 2 shows the UAV and supporting devices used in this study as well as the process of acquisition data. The control points employed as many as five GCPs connected to GPS RTK. The flight time for single flight mission was about 15 – 20 minutes. The resulting data were in the form of photo mosaics, which were then merged to become a unified orthophoto. The DEM map was generated using an extracted of the dense point cloud. This paper does not focus on the process of data acquisition and processing method from UAV survey. The complete explanations on the UAV types, specifications, the process of acquisition and data processing can be found in excellent detailed in (Madawalagama et al., 2016) and (Ajayi et al., 2017).

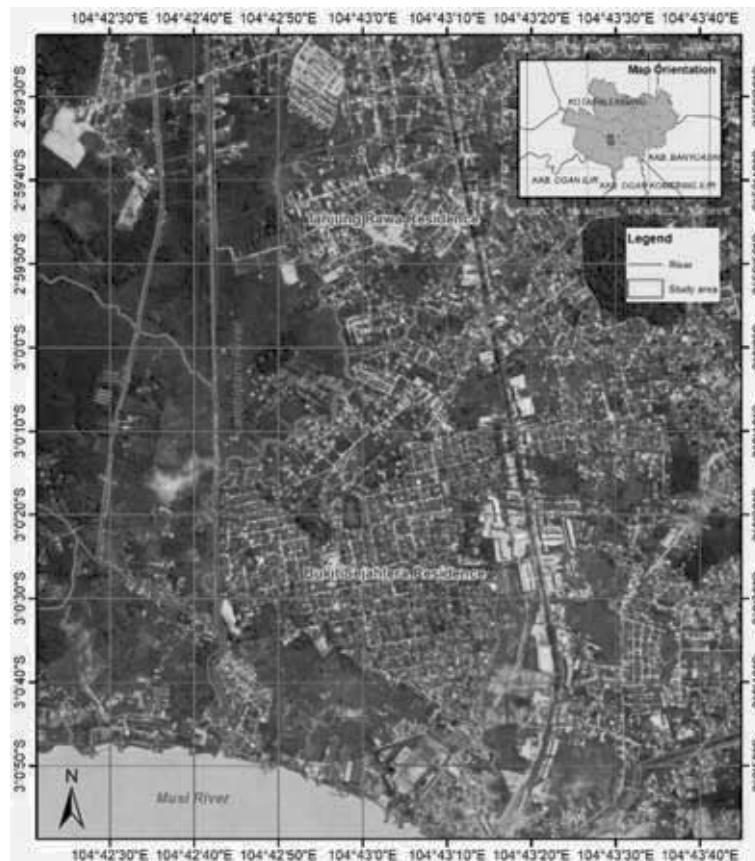


Figure 1. Area of study



Figure 2. The UAV, marker point (GCP) and GPS RTK used in the study and the illustration of the process of acquisition and data processing

The stages of analysis conducted in this study are a hydrologic and hydraulic simulation and flood mapping respectively. The HEC-HMS software was used for hydrologic simulation, which produces flow hydrographs in the Lambidaro subsystem based on the Soil Conservation Service (SCS) rainfall-runoff model. The completed

explanations about the process and results of this simulation can be found in (Al Amin et al., 2015). The flow hydrographs were then set as upstream boundary conditions in the hydraulic simulation. The HEC-RAS 5 was used as for hydraulic flood simulation based on a combination of 1-dimensional and 2-dimensional (1D/2D) flow that completely solved using the Saint-Venant 2D equation (Patel et al., 2017). The downstream boundary condition was the highest tide elevation resulting from tidal forecasting based on measurable data on the Musi River. The simulation results were then integrated with the GIS software so that a flood inundation map was obtained for the study area. Although HEC-RAS 5 is new software, several previous studies as in (Patel et al., 2017) and (Quiroga et al., 2016) have shown that the HEC-RAS 5 successfully simulates flood inundation accurately. It suggests that HEC-RAS 5 can be widely applied, especially in strategies for better flood management and control.

3. RESULTS

3.1 Digital Elevation Model (DEM)

The DEM map generated from the UAV survey for the study area is given in Figure 3. In the figure, the surface elevation shown in the center of the residential area is higher than the surface elevation near the river. It is due to the former landfill for the construction of housing in the residential area. Based on generated DEM from the Figure 3a, when the cross-section is made in detail (Figure 3b), a surface elevation profile is obtained which very clearly illustrates the shape of a building. It shows that the DEM produced by UAV has excellent quality. The resolution of the DEM generated by the UAV for the study area is 0.1 x 0.1 m so it can be said to have a high resolution.

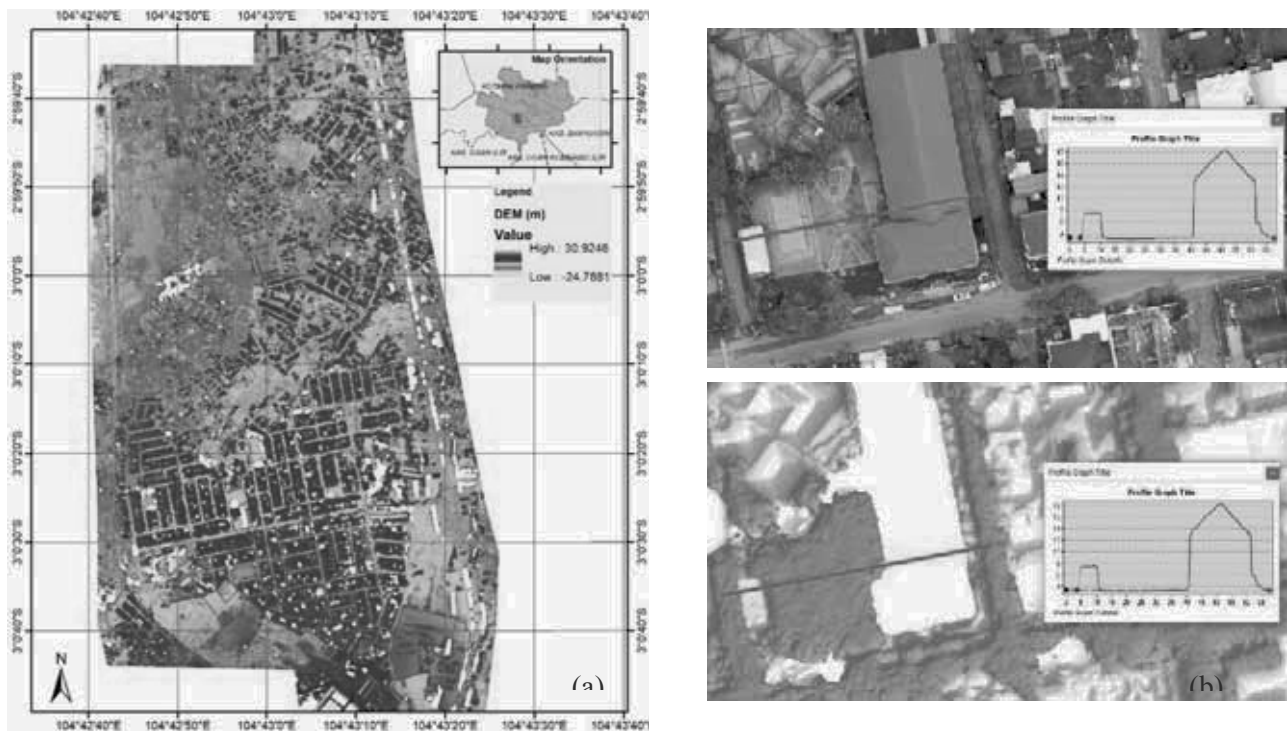


Figure 3. The DEM map of the study area (a), an example of the detailed cross-section to illustrate the shape of the building (b)

3.2 Hydraulic simulation

In this study, the new HEC-RAS 5 was used as a hydrodynamic model to simulate flood inundation with the principle of a combination of 1-dimensional and 2-dimensional flow. The scheme of the geometric model applied to the study area is given in Figure 4a. In the figure, the 1-D domain is represented by stream flows as a function of depth along the channels, whereas the 2-D domain is described by the overland flow of the floodplain surface as a function of depth in the 2D areas. The 1-D flow domain is associated with a 2-D flow domain using lateral structures. The upstream boundary conditions of the channels were the flow hydrographs of a 5-years return period with a peak discharge of 34.4 m³/s (RS 1890.761), and 22.2 m³/s (RS 2729.567) resulted from hydrologic simulations using HEC-HMS. For the downstream at RS 204.551, the boundary condition was the highest tide with a level of 3.46 m resulting from tidal forecasting. In the 2D Area geometry model, the surface roughness values for the study area were determined based on the land use that affected overland flow.

Based on the result of hydraulic simulation given in Figure 4b, it is seen that most of the inundated areas with high flood depth are located near the river, whereas the lower depth occurs for the area further. It is because the surface elevation of the areas near the river is lower than the surface elevation at the center of the residential area. Flood depth map in more detail is given in Figure 5. The picture shows that the depth of inundation in Bukit Sejahtera residence ranges from 0 to 1.5 m, whereas in Tanjung Rawa residence ranges from 0 - 4.25 m. It suggests that the area of Tanjung Rawa residence has the potential to experience higher flood risk compared to Bukit Sejahtera residence. Based on the picture can also be seen that the areas that are very vulnerable to be flooded are directly adjacent to the Lambidaro River.

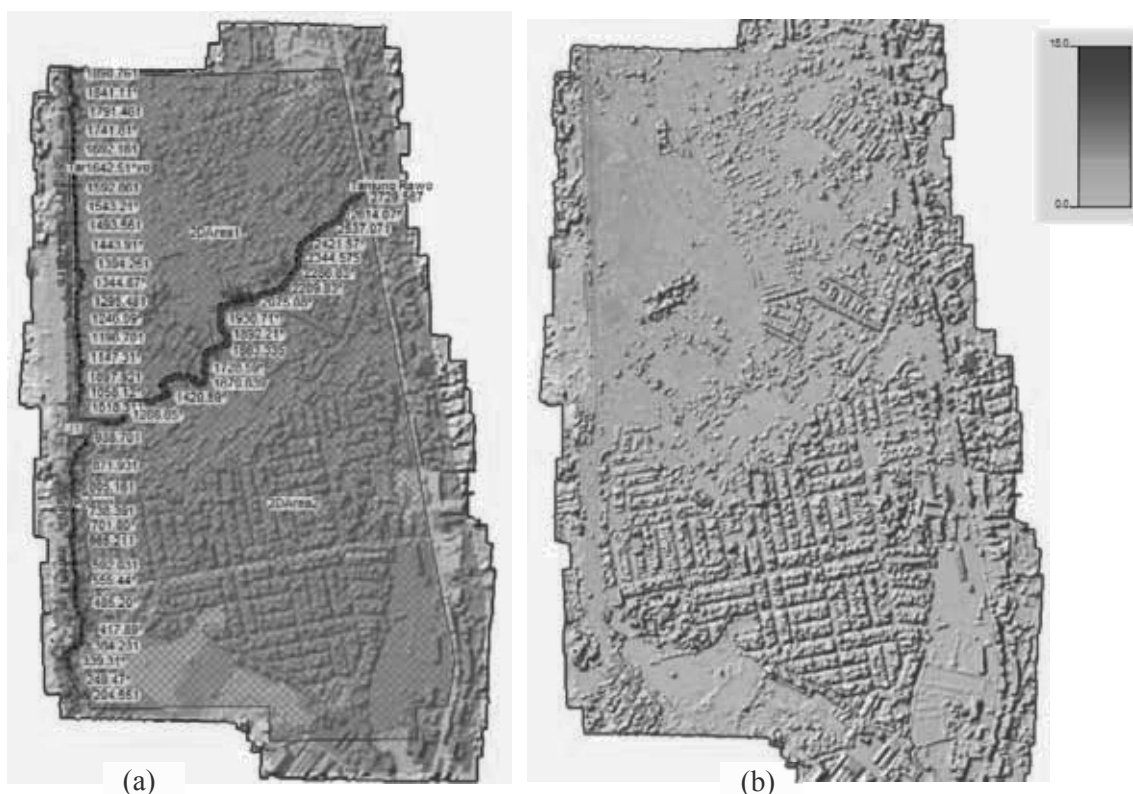


Figure 4. The geometry model for stream channels (1-D domain) and floodplain (2-D domain) in HEC-RAS (a), the simulation result shows flood inundation visualized in RAS Mapper (b)

The calibration of flood simulation result was conducted by comparing the flood depth to the observed data at 41 observed points as shown in Figure 5. Since in the study area the water level recorder was not available, the observed flood depths were taken by interviewing the residents and observing the ex-flood marks on the walls, fences and so on. Although this method does not provide accurate data of the real flood conditions in the study area, the simulation and observation results show that the flood depths and its trend are corresponding each other as given in Figure 6 though with reasonably high errors. It suggests that the simulation result of the flood inundation can be accounted for with satisfactory result.

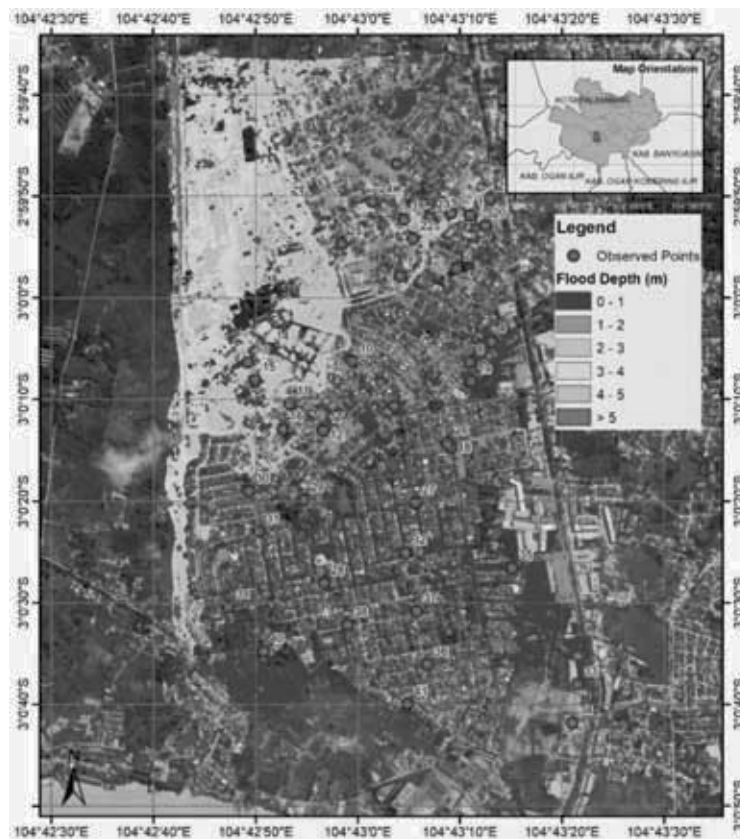


Figure 5. Flood inundation map for the study area, along with 41 observed points

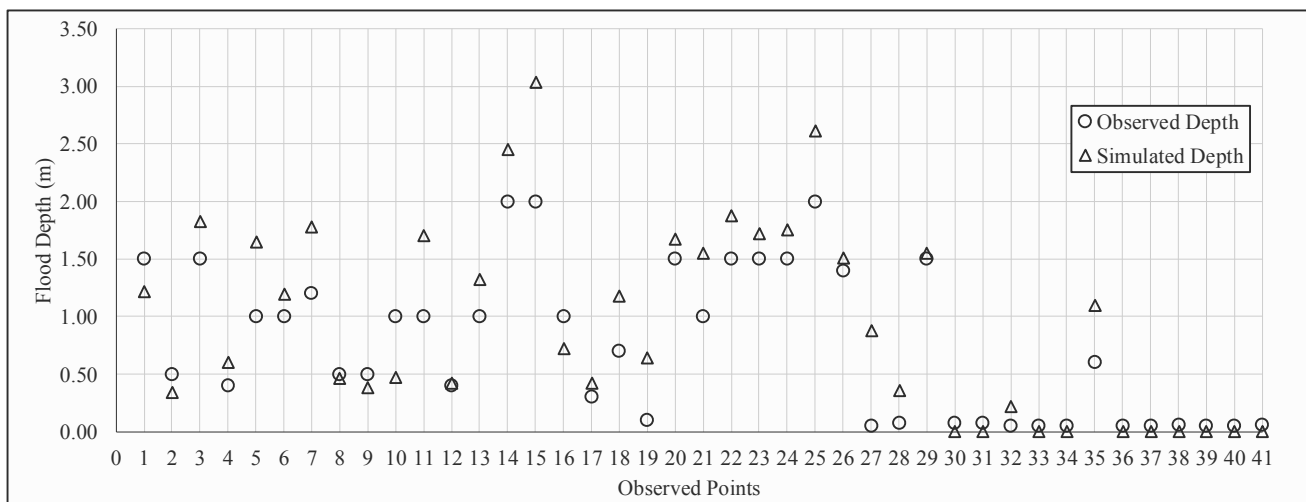


Figure 6. The comparison of simulated and observed flood depths in the study area

4. DISCUSSION

4.1 Findings

The flood as a natural phenomenon that often occurs should be estimated early using a flood inundation map generated from high-resolution DEM. Although LiDAR is currently the best technology to produce such DEM maps, its utilization in developing countries is still insufficient, especially in Indonesia. Also, the costs required for the airborne-LiDAR survey are still prohibitive. It led to the more extensive use of UAVs to produce high-resolution elevation data through photogrammetry surveys. This research has succeeded to create DEM map with high spatial resolution, that is 0.1×0.1 m for Bukit Sejahtera and Tanjung Rawa residential area with total area about 200 ha. The DEM map can be used in hydraulic simulation using the combined 1D/2D flow of HEC-RAS 5 model to obtain a description of the flood inundation for the area. The simulated flood depths compared with measured data show a somewhat similar trend and corresponding values. However, a more detailed calibration cannot be performed because of the limitation of measurable data. Indeed, in the study area, there is no any water level recorder and or flood gauge. Nevertheless, the results of this study have demonstrated the enormous potential use of UAV in the future to acquire high-resolution elevation data for generating a detailed



and accurate flood inundation map. The authors believe that the utilization of UAVs will be more extensive for flood control and management strategies, especially in Indonesia due to its flexibility, reliability and affordable cost.

4.2 Future works

To obtain a more detailed description about the accuracy of the flood inundation map, in the next study, it is necessary to compare the results of the flood simulation generated by UAV-DEM and UAV-LiDAR with different DEM resolutions or grid sizes. Also, it is essential to test the model of flood inundation in the area with a steeper topography to obtain a complete description of how the effectiveness of DEM-UAV on the simulation results of flood inundation. This study only deals with flood depths, while other parameters such as flow velocities, propagation time, and time of flooding are not discussed. Therefore, further research that addresses these parameters is also necessary to do.

5. CONCLUSIONS

Based on the results obtained above, it can be concluded that high-resolution DEM map can be efficiently generated using UAV survey. The flood simulation using UAV-based DEM can provide a clear picture of potential flooding in the study area. It is demonstrated by the comparison between the simulation results and the corresponding field observations. Therefore, its application in flood management and control strategy needs to be widely developed. Based on the simulation result, the flood depth at the study area varies between 0 - 1.5 m for Bukit Sejahtera residence, and 0 - 4.25 m for Tanjung Rawa residence. The areas closed to the Lambidaro River have higher floods depth and risks than other areas further from the river. Therefore, in term of flood control in the study area, for the structural approaches, it is recommended to build a dike or flood wall along the river to avoid overflowing water especially during high tides and heavy rainfall. For further research, it is advisable to compare the flood simulation generated by DEM-UAV and DEM-LiDAR. Also, the calibration using measured data with a sufficient number of flood gauges needs to be done for the study area to obtain a more accurate description of the potential flood.

ACKNOWLEDGMENTS

The authors would like to thank Universitas Sriwijaya for funding this research. The authors also extend their gratitude to the undergraduate students of Civil Engineering Department of Universitas Sriwijaya, which are supervised by the authors who have assisted in surveying and collecting data.

REFERENCES

- Ajayi, O. G., Salubi, A. A., Angbas, A. F., & Odigure, M. G. (2017). Generation of accurate digital elevation models from UAV acquired low percentage overlapping images. *International Journal of Remote Sensing*, 38(8–10), 3113–3134. <https://doi.org/10.1080/01431161.2017.1285085>
- Al Amin, M. B., Sarino, & Haki, H. (2017). Floodplain Simulation for Musi River Using Integrated 1D / 2D Hydrodynamic Model. In *MATEC Web of Conferences. SICEST 2016* (Vol. 5023, pp. 1–5). Bangka, Indonesia. Retrieved from https://www.matec-conferences.org/articles/mateconf/pdf/2017/15/mateconf_sicest2017_05023.pdf
- Al Amin, M. B., Sarino, & Sari, N. K. (2015). Visualisasi Potensi Genangan Banjir di Sungai Lambidaro Melalui Penelusuran Aliran Menggunakan HEC-RAS (Studi Pendahuluan Pengendalian Banjir Berwawasan Lingkungan). In *Prosiding Seminar Nasional Teknik Sipil I (SeNaTS I)* (Vol. 1, pp. 123–132). Bali, Indonesia.
- Brandt, S. A., & Lim, N. J. (2016). Visualising DEM-related flood-map uncertainties using a disparity-distance equation algorithm. In *Proceedings of the International Association of Hydrological Sciences* (Vol. 373, pp. 153–159). <https://doi.org/10.5194/piahs-373-153-2016>
- Coveney, S., & Roberts, K. (2017). Lightweight UAV digital elevation models and orthoimagery for environmental applications : data accuracy evaluation and potential for river flood risk modelling. *International Journal of Remote Sensing*, 0(0), 1–22. <https://doi.org/10.1080/01431161.2017.1292074>
- De Silva, T., Kahandagamage, R., Sanjeewa, I., Kulasinghe, C., & Ariyaratne, R. (2016). Generating more accurate digital elevation models incorporating off the shelf GIS software by using drone imagery. In *37th Asian Conference on Remote Sensing, ACRS*. Colombo.

- Entwistle, N., & Heritage, G. (2017). An evaluation DEM accuracy acquired using a small Unmanned Aerial Vehicle across a riverine environment. *International Journal of New Technology and Research (IJNTR)*, 3(7), 43–48.
- Farid, M., Marlina, A., & Kusuma, M. S. B. (2017). Flood hazard mapping of Palembang City by using 2D model. In *AIP Conference Proceedings* (Vol. 100009, pp. 1–11). American Institute of Physics Articles. <https://doi.org/10.1063/1.5011619>
- Haile, A., & Rientjes, T. (2005). Effects of LiDAR DEM resolution in flood modelling: a model sensitivity study for the city of Tegucigalpa, Honduras. In *Isprs Wg Iii/3, Iii/4* (pp. 168–173). Retrieved from <http://www.isprs.org/proceedings/XXXVI/3-W19/papers/168.pdf>
- Hashim, S., Mohd, W., Wan, N., & Adnan, N. A. (2016). Evaluation of Vertical Accuracy of Airborne IFSAR and Open-Source Digital Elevation Models (DEMs) for Flood Inundation Mapping. In *Regional Conference on Science, Technology and Social Sciences (RCSTSS 2014)*. <https://doi.org/10.1007/978-981-10-1458-1>
- Hsu, Y. C., Prinsen, G., Bouaziz, L., Lin, Y. J., & Dahm, R. (2016). An Investigation of DEM Resolution Influence on Flood Inundation Simulation. *Procedia Engineering*, 154, 826–834. <https://doi.org/10.1016/j.proeng.2016.07.435>
- Hudec, P. (2011). Analysis of Accuracy of Digital Elevation Models Created From Captured Data By Digital. *Slovak Journal of Civil Engineering*, XIX(4), 28–36.
- Jeong, H. H., Park, J. W., Kim, J. S., & Choi, C. U. (2016). Assessing the accuracy of ortho-image using photogrammetric unmanned aerial system. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* (Vol. XLI-B1, pp. 867–872). Prague, Czech Republic. <https://doi.org/10.5194/isprsarchives-XLI-B1-867-2016>
- Küng, O., Strecha, C., Beyeler, A., Zufferey, J.-C., Floreano, D., Fua, P., & Gervais, F. (2011). The Accuracy of Automatic Photogrammetric Techniques on Ultra-Light UAV Imagery. In *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* (Vol. XXXVIII-1/, pp. 125–130). <https://doi.org/10.5194/isprsarchives-XXXVIII-1-C22-125-2011>
- Madawalagama, S. L., Munasinghe, N., Dampegama, S., & Samarakoon, L. (2016). Low Cost Aerial Mapping With Consumer-Grade Drones. In *37th Asian Conference on Remote Sensing*. Colombo.
- Marks, K., & Bates, P. (2000). Integration of high-resolution topographic data with floodplain flow models. *Hydrological Processes*, 14(11–12), 2109–2122. [https://doi.org/10.1002/1099-1085\(20000815/30\)14:11/12<2109::AID-HYP58>3.0.CO;2-1](https://doi.org/10.1002/1099-1085(20000815/30)14:11/12<2109::AID-HYP58>3.0.CO;2-1)
- Patel, D. P., Ramirez, J. A., Srivastava, P. K., Bray, M., & Han, D. (2017). Assessment of flood inundation mapping of Surat city by coupled 1D/2D hydrodynamic modeling: a case application of the new HEC-RAS 5. *Natural Hazards*, 89(1), 93–130. <https://doi.org/10.1007/s11069-017-2956-6>
- Pichon, L., Ducanhez, A., Fonta, H., & Tisseyre, B. (2016). Quality of Digital Elevation Models obtained from Unmanned Aerial Vehicles for Precision Viticulture. *OENO One*, 50(3), 101–111. <https://doi.org/10.20870/oeno-one.2016.50.4.1177>
- Putra, E. S., Suryadi, F. X., Tarigan, K., Bastari, A., & Sylvia, M. (2011). Strategy of Drainage and Flood Control in Palembang City.
- Quiroga, V. M., Kure, S., Udo, K., & Mano, A. (2016). Application of 2D numerical simulation for the analysis of the February 2014 Bolivian Amazonia flood: Application of the new HEC-RAS version 5. *RIBAGUA - Revista Iberoamericana Del Agu*, 3(1), 25–33. <https://doi.org/10.1016/j.riba.2015.12.001>
- Ruzgiene, B., Berteska, T., Gecyte, S., & Jakubauskiene, E. (2014). Photogrammetric Processing of UAV Imagery : Checking DTM. In *The 9th International Conference “Environmental Engineering”* (pp. 1–6). Vilnius, Lithuania. Retrieved from <http://enviro.vgtu.lt>
- Santise, M., Fornari, M., Forlani, G., & Roncella, R. (2014). Evaluation of dem generation accuracy from UAS imagery. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* (Vol. 40, pp. 529–536). Riva del Garda, Italy. <https://doi.org/10.5194/isprsarchives-XL-5-529-2014>
- Sze, L. T., Cheaw, W. G., Ahmad, Z. A., Ling, C. A., Chet, K. V., Lateh, H., & Bayuaji, L. (2015). High resolution DEM generation using small drone for interferometry SAR. In *International Conference on Space Science and Communication, IconSpace* (pp. 366–369). Langkawi, Malaysia. <https://doi.org/10.1109/IconSpace.2015.7283801>
- Wedajo, G. K. (2017). LiDAR DEM Data for Flood Mapping and Assessment ; Opportunities and Challenges : A Review. *Journal of Remote Sensing & GIS*, 6(4), 2015–2018. <https://doi.org/10.4172/2469-4134.100021>