ICSI 300 Hydrodynamic

by Surya Hermawan

The utilisation of the numerical hydrodynamic model to face rob floods in coastal areas in the industrial revolution era 4.0 at east java Indonesia

Surya Hermawan[1], Octavius Hans*[1], Christian Gunawan[1], Daniel Tjandra[1], Joko Purnomo[1]

[1]Civil Engineering Department and Planning Petra Christian University
shermawan@petra.ac.id

Abstract. Global warming which occurred has resulted in sea level rise resulting in Rob flooding in coastal areas. The research location is in Rob floods area in Tegalsari Hamlet, Jabon Subdistrict, Sidoarjo that have damaged seaweed cultivation, and estimated losses reached 5 billion rupiahs in early 2018. Therefore, it needs to do research numerical hydrodynamic models to prevent this flood. However, the devices for measurement data are too expensive. The purpose of this research is to utilise economical devices measurement based on the industrial revolution 4.0 with numerical hydrodynamic methods models in the field of civil engineering. This model is an approach to estimate the hydrodynamics of coastal waters such as tides, currents and water levels. To simulate the hydrodynamic model, for nearshore bathymetry data are gained from sonar and offshore bathymetry data from GEBCO. The simulations utilise open-source Delft3D software using the Navier-Stock formula. The outcomes prove that hydrodynamic simulation models can be used to estimate sea-level rise for the next few years in coastal areas. Thus, the determination of the type of construction of civil engineering buildings that are strong and environmentally friendly so that publics do not cause huge losses and make coastal communities resilient to disasters.
Keywords: *rob flood, numerical hydrodynamic model, industrial revolution 4.0*

1. Introduction

The development of technology and science made the industrial revolution has entered the 4th generation were in this era, data/information can be retrieved easily anytime and anywhere with the help of the internet [1]. Industry 4.0 has 3 concepts: Cyber-Physical Systems (CPS), Internet of Things and Internet Service [2]. In this era, the development of computing technology, existing science and the internet can be integrated to help reduce the impact of global warming that is happening, especially in Indonesia.

Global warming is a form of imbalance of ecosystems on earth due to the process of increasing the average temperature of the atmosphere, sea, and land on earth. Global warming is thought to have caused system changes to ecosystems on earth, among others; extreme climate change, melting of ice so that sea level rises, and changes in the amount and pattern of precipitation [3]. Indonesia is the largest archipelago country in the world with a total area of Indonesia's sea area of 5.9 million km2, consisting of 3.2 million km^2 of territorial waters and 2.7 km2 of waters of the Exclusive Economic Zone [4]. The coast and sea areas of the Indonesian archipelago store huge natural resource potential and environmental services, but unfortunately development in the field of maritime affairs and fisheries is still far from expectations so that it cannot be utilised optimally [5].

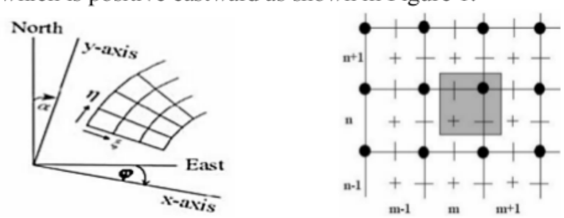
Climate change can have an impact on rising temperatures and rising sea levels. Sea level rise is one of the studies currently being done concerning the issue of global warming [6]. The study of sea-level rise is important considering the impact that will be caused by the fact that in general, the waterfront area plays an important role in the development of a city or country. Sea level rise projections have been carried out until 2010 and it is estimated that there will be a loss of coastal areas and small islands covering an area of 90,260 km^2 due to sea-level rise of up to 1.1 meters in Indonesian territory [7]. Increased seawater temperatures and melting glaciers due to ongoing global climate change are causing sea level rise. Some studies confirm that an increase in seawater temperature causes the increase in air temperature because it absorbs 85% of the excess heat trapped by the atmosphere and is a major driver of rising sea levels globally for 75-100 years after the start of industrialisation [8]. Considering the impact caused by sea-level rise and supported by tools based on the industrial revolution 4.0, research can be conducted to study the hydrodynamic model that is appropriate to find out how the sea level rise occurs in Indonesia, especially in the location of Tanjung Sari, Tegal Hamlet Sari and Kali Alo Hamlet, Jabon District, Sidoarjo Regency, East Java Province.

2. Material and Method

2.1 Simulation of Numerical Hydrodynamics Model with Delft 3D Open Source

The numerical hydrodynamic model is an approach to predict the hydrodynamic movement of water over time in a particular region [5]. In the past various numerical models were applied to investigate the fields of water flow and mass transportation. However, the 2D model used does not include the vertical variability of the parameters being investigated. Then, starting from 1994, the 2D model consists of several different modules: hydrodynamics, water quality, and eutrophication used for modelling the hydrobiological and hydrochemical processes [9]. At this time 3D hydrodynamic models have been applied to simulate hydrodynamic models based on the Delft3D modelling system [10]. Delft3D software is an open-source software developed by Deltares and is an encouragement for experts from all over the world to further develop modelling. Approaches and calculations in coastal areas such as rivers and estuaries can be done through flow simulations, sediment transport, waves, water quality, morphological development, and ecology using Delft3D. Delft 3D is a multi-dimensional hydrodynamic simulation or modelling program that has functions for calculating waves, river flow, sediment, water quality, and ecological analysis in coastal areas [11].

The Flow module in Delft3D is a multi-dimensional 2D and 3D hydrodynamic that simulates a program for calculating dynamic flow phenomena due to tides and meteorologists on linear curves, thus requiring a grid. The equations are solved numerically using the orthogonal horizontal coordinate arch system which provides a good grid installation with the shape of the area being modelled [12]. Grid or assist lines are part of Delft3D stimulation [5]. Grid is a coordinate line of vertical and horizontal direction to determine the area of the simulated area or set the boundary area consisting of two systems, namely rectangular coordinate cartesian and spherical coordinate. The coordinate cartesian system is rigid and only has parameters namely the vertical direction (η) and horizontal direction (ξ), while the spherical coordinate system follows the contour line of the earth's surface which has two parameters namely direction and height, with latitude (α) having positive values to the north and longitude (φ) which is positive eastward as shown in Figure 1.



(a) (b)

Figure 1. Spherical coordinate system (a) and cartesian coordinate system (b) [10]

A finite-difference grid equation can also solve the determinant diffraction equation in the appropriate combination of initial arrangements. To complete the modelling of currents and tides. The Delft3D system uses the Navier-Stokes equation in its calculations. According to Navier Stokes's formula [13] is:

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\rho x} + \frac{\partial(\rho v)}{\rho y} + \frac{\partial(\rho w)}{\rho z} = 0 \qquad (1)$$

2.2. Tidal Harmonic Components

In each group, these components have members as in Table 2.1.

Table 2.1. Tidal Constituents that driven the model on Delft 3D

Symbol	Amplitude (m)	Phase (deg)	Symbol	Amplitude (m)	Phase (deg)	Symbol	Amplitude (m)	Phase (deg)
M2	1.51	55.84	K1	0.55	312.03	MM	0.01	13.67
S2	0.67	122.79	O1	0.11	288.40	MF	0.01	21.53
N2	0.33	15.21	S1	0.20	276.24	M4	0.06	313.15
2N2	0.25	121.05	P1	0.01	185.42	MN4	0.05	260.52
K2	0.55	312.03	Q1	0.01	13.67	MS4	0.05	44.37

Each constituent represents a periodic change or variation in the relative position of the earth, moon and sun. Constituents vary with the position at which tides are observed. In this representation, general formulas for astronomical waves can be used:

$$H(t) = A_0 + \sum A_i F_i \cos(\omega_i t + (V_0 + u)_i - tt_i) \qquad (2)$$

Fi and (V0 + u) i are time-dependent factors, together with ω, can be easily calculated and generally arranged in various tidal yearbooks. V0 is a phase correction factor that links the observational timeframe with the internationally agreed-upon celestial timeframe [10].

Methodology

Before carrying out the numerical hydrodynamic modelling, field survey conducted as answering to figure out Rob flood occurrence at research location. As can be seen in Figure 2, the previous river retaining wall constructed by government and people was damaged. Primary data collection in the form of the nearshore bathymetry of the river around the flood site Rob. The primary data collection carried out by deploying the sonar (Figure 3) on a boat that is running a maximum of 5 km/hour. The advantage of this Sonar, the researcher can show data in realtime through software from smartphones. On the other hand, the data that has been retrieved cannot be directly used, because it must first be uploaded to the cloud using an account. After uploading, the data can only be downloaded through the maps.deepersonar.com website [14]. The further step is carried out by the simulation with Delft 3D. After getting river bathymetry data around the study site, it can be continued by entering the data into Delft 3D. The first step is to prepare a land boundary. Land Boundary is taken by making a line on Google Earth Pro and will be assisted by Global Mapper and ArcGis software to change the file format so that Delft 3D can read it. After creating a land boundary, the next step is preparing a grid on Delft 3D as shown in Figure 4. The grid used in this model has an average size of 450 meters, along with the number of grid 249,804 cells. If the grid is ready, bathymetry data is ready to be included in Delft 3D. For nearshore bathymetry data are gained from data measurement with sonar smart pro which will be downloaded from the website in the form of excel, y, z files.

On the other hand, the offshore bathymetry data was taken from the General Bathymetric Chart of the Oceans (GEBCO) [15]. Then combine all of the information of the land boundary, grid and bathymetry of the river and sea. The final step in this simulation is Delft 3D-Flow for one-year simulation and 2 weeks of extreme condition. The most important thing in this step is to include 15 tidal constituents that make this model run from BWGeoHydromatics. It can also include data on wind, viscosity, roughness.

Figure 2. Damaged Retaining Wall

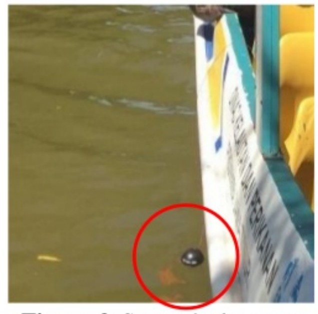


Figure 3. Sonar deployment

Validation is needed to ensure that the model has similarities with actual occurrence. Therefore, in this research, tidal primary data will be taken with a direct measurement for several days to ensure that the outcomes meet the agreement with the field data. Thus, this model can estimate the extreme tides that have occurred and will occur in the next few years.

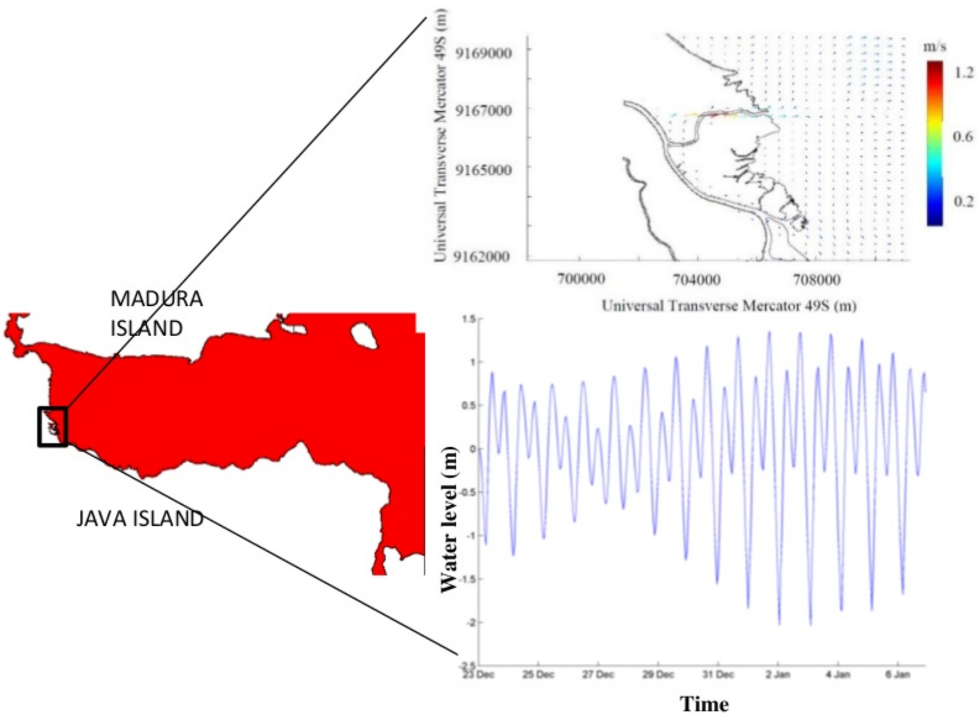


Figure 4. 3D Delft Model Results in Tidal Forms and Water Depth Velocity

3. Result

The *outcomes* of this research project can be seen in Figure 4. Regarding the numerical hydrodynamic model, the maximum depth average current velocity in the vicinity of the research location which triggered the retaining wall damaged is 1,2 m/s during the ebb flood. Then, for the estimation of the Rob flood occurrence, as can be seen in Figure 4, the water level during the flood was 2,10 m or higher 10 cm than the existing retaining wall. This numerical hydrodynamic model deliver some hydrodynamic condition at the research location.

4. Conclusions

After carrying out this research project by direct measurement data on the field along with numerical hydrodynamic model simulation can be concluded that

1. Bathymetry data of the river at the nearshore area in the vicinity of the research location can be taken with deeper smart sonar. Industrial revolution 4.0 features support this device technology. This data can also be used as input parameters for creating numerical hydrodynamic models using Delft 3D.
2. The outcomes prove that hydrodynamic simulation models can be used to estimate sea-level rise for the next few years in coastal areas. Thus, the determination of the type of construction of civil engineering buildings that are strong and environmentally friendly so that publics do not cause huge losses and make coastal communities resilient to disasters.

5. Referrences

[1] Rosyadi, Slamet 2018 *Revolusi Industri 4.0: Peluang dan Tantangan bagi Alumni Universitas Terbuka*.

[2] Pikkarainen, Pekkarinen, Koivumäki and Huhtala 2018 *Data As A Driver For Shaping The Practices Of A Preventive Healthcare Service Delivery Network*. JIM 6, **1** (2018) *55-79*

[3] Utina, Ramli 2009 *Pemanasan Global: Dampak Dan Upaya Meminimalisasinya*.

[4] United Nations, *United Nations Convention on The Law of The Sea*

[5] Putra, Niko 2019 *Pemanfaatan Unmanned Aerial Vehicle (Uav)/ Drone Dan Sonar Dalam Upaya Menghadapi Banjir Rob Pada Desain Konstruksi Teknik Sipil*.

[6] Suprijanto, Iwan 2003 *Kerentanan Kawasan Tepi Air Terhadap Kenaikan Permukaan Air Laut: Kasus Kawasan Tepi Air Kota Surabaya* **Vol. 31** (No. 1), 28-37

[7] Susandi, A., Herlianti, I., Tamamadin, M. and Nurlela 2008 *Dampak Perubahan Iklim Terhadap Ketinggian Muka laut di Wilayah Banjarmasin* **Vol. 12** (No.2)

[8] Asuncion, R. C. and Lee, M. 2017 *Impacts of Sea Level Rise on Economic Growth in Developing Asia* No.507

[9] Ołdakowski, B., & Kwiatkowski, J 1995 *Forecast model of water quality of Vistula Lagoon* **6**, 258-66

[10] Delft3D-Flow 2014 *Simulation of multi-dimensional hydrodynamic flows and transport phenomena, including sediments*

[11] Hafli, T. M. 2014 *Simulasi Numerik Perubahan Morfologi Pantai Akibat Konstruksi Jetty Pada Muara Lambada Lhok Aceh Besar Menggunakan Software Delft3D*.

[12] Bielecka, M., & Kazmierski, J. (2003). *A 3D mathematical model of Vistula Lagoon hydrodynamics-general assumptions and results of preliminary calculations* **80** 2-4

[13] Girault, V., & Raviart, P. A. (1979). *Finite element approximation of the Navier-Stokes equations* 749

[14] Lakebook 2019 https://maps.deepersonar.com/ Accessed September 29, 2019.

[15] General Bathymetric Chart of the Oceans 2003 Liverpool http://www/gebco.net/data and products/gebco digital atlas/ Accessed September 29, 2019.

ACKNOWLEDGEMENT

The authors would like to express appreciation for the support of the sponsors of Petra Christian University project number: **01/HBK-Penelitian/LPPM-UKP/IV/2019** and Directorate General of Higher Education Indonesia and Kopertis VIII, project number: **002/SP2H/LT/K7/KM2017**.

ICSI 300 Hydrodynamic

ORIGINALITY REPORT

15%	%	15%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Surya Hermawan, Joko Purnomo, Daniel Tjandra. "The Benefit of Wind Distribution Analysis for Coastal Construction Design in East Java Province", MATEC Web of Conferences, 2018 Publication	2%
2	Advances in Water Resources and Hydraulic Engineering, 2009. Publication	1%
3	Atiek Suprapti, Edward E. Pandelaki, Indriastjario, Agung Budi Sardjono, Yosidha Tomohiko, Yagi Masao, Adriana P. Higashino. "Towards a harmonious development between nature and culture on Walisanga religious site, Indonesia – learning from the best practices in Japan", IOP Conference Series: Earth and Environmental Science, 2017 Publication	1%
4	E Malihah, S W Tanshzil. "Scholars Remote Teaching Service: Indonesia's Geopolitical Strategy", IOP Conference Series: Earth and	1%

Environmental Science, 2018

Publication

5	Marek Kruk, Ewa Paturej. "Indices of trophic and competitive relations in a planktonic network of a shallow, temperate lagoon. A graph and structural equation modeling approach", Ecological Indicators, 2020 Publication	1 %
6	H. Elmilady, M. Wegen, D. Roelvink, B. E. Jaffe. "INTERTIDAL AREA DISAPPEARS UNDER SEA LEVEL RISE: 250 YEARS OF MORPHODYNAMIC MODELING IN SAN PABLO BAY, CALIFORNIA", Journal of Geophysical Research: Earth Surface, 2018 Publication	1 %
7	Iwan Rudiarto, Wiwandari Handayani, Holi B. Wijaya, Tia D. Insani. "Rural Livelihood Resilience: An Assessment of Social, Economic, Environment, and Physical Dimensions", MATEC Web of Conferences, 2019 Publication	1 %
8	"Thermal Analisys of the Increase in Ambient Temperature Due to Motor Vehicle Activities", International Journal of Engineering and Advanced Technology, 2019 Publication	1 %
9	Hao Shao. "Sun glitter imaging of submarine	

sand waves on the Taiwan Banks: Determination of the relaxation rate of short waves", Journal of Geophysical Research, 06/28/2011
Publication

1%

10 Khaled A. Mohamed. "Long-Term Tidal Water Level Measurements in Abu Dhabi Emirate", Volume 4: Ocean Engineering; Offshore Renewable Energy, 2008
Publication

1%

11 Ezra Dessers, Bernard J Mohr. "An ecosystem perspective on care coordination: Lessons from the field", International Journal of Care Coordination, 2019
Publication

1%

12 T. Bouhennache, J. Sahbani. " CONJUGATE OPERATORS FROM DISPERSION CURVES FOR PERTURBATIONS OF FIBERED SYSTEMS IN CYLINDERS ", Communications in Partial Differential Equations, 2001
Publication

1%

13 Hans F. Burcharth, Stephen J. Hawkins, Barbara Zanuttigh, Alberto Lamberti. "Design tools related to engineering", Elsevier BV, 2007
Publication

1%

14 Guo, L., M. van der Wegen, J. A. Roelvink, and Q. He. "The role of river flow and tidal

1%

asymmetry on 1-D estuarine morphodynamics : Estuarine Morphodynamics", Journal of Geophysical Research Earth Surface, 2014.
Publication

15 A. Staskiewicz, M. Bielecka, A. Lewandowski. "Prediction of hydrodynamic parameters for the Vistula Lagoon", 2004 USA-Baltic Internation Symposium, 2004 1%
Publication

16 Liu, W.C.. "Using a three-dimensional particle-tracking model to estimate the residence time and age of water in a tidal estuary", Computers and Geosciences, 201108 1%
Publication

17 Dina Sugiyanti, Purnama Darmadji, Sri Anggrahini, Chairil Anwar, Umar Santoso. "Preparation and Characterization of Chitosan from Indonesian Tambak Lorok Shrimp Shell Waste and Crab Shell Waste", Pakistan Journal of Nutrition, 2018 1%
Publication

18 Zuratih, Y Widiawati. "Estimation of Greenhouse Gas (GHG) Emission from Livestock Sector by Using ALU Tool: West Java Case Study", IOP Conference Series: Earth and Environmental Science, 2019 1%
Publication

19	Michał Szydłowski, Tomasz Kolerski, Piotr Zima. "Impact of the Artificial Strait in the Vistula Spit on the Hydrodynamics of the Vistula Lagoon (Baltic Sea)", Water, 2019 Publication	1 %
20	Francisco Javier Murillo, Pablo Durán Muñoz, Javier Cristobo, Pilar Ríos et al. "Deep-sea sponge grounds of the Flemish Cap, Flemish Pass and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): Distribution and species composition", Marine Biology Research, 2012 Publication	<1 %
21	Shane Elipot, Chris Hughes, Sofia Olhede, John Toole. "Coherence of Western Boundary Pressure at the RAPID WAVE Array: Boundary Wave Adjustments or Deep Western Boundary Current Advection?", Journal of Physical Oceanography, 2013 Publication	<1 %
22	"Climate Action", Springer Science and Business Media LLC, 2020 Publication	<1 %

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		