Lowland Technology International 2020; Volume 22 (2): 222-227
International Association of Lowland Technology (IALT): ISSN 1344-9656

Research Paper

Debris Analysis in RDNK Site Serpong due to Bridge Blockage Simulations Using HEC-RAS

Yuliastuti [1], T. A. Ryanto[2], E. E.Alhakim[3], H. Susiati[4], E. R. Iswanto.[5], A. B.Wicaksono[6], and H.Suntoko[7]

ARTICLE INFORMATION

Article history:

Received: 03 December, 2019
Received in revised form: 26 May, 2020
Accepted: 04 June, 2020
Publish on: 06 September, 2020

Keywords:

Floating debris
Bridge
HEC-RAS
Pier

ABSTRACT

The objective of this paper is to investigate the debris analysis due to bridge blockage by observing the rising of surface water elevation on the designated bridge based on the HEC-RAS simulation module. Methodology used in this paper covers the preparation of RAS geometry, determination of hydrological parameters, and RAS mapping for the output. Bridge and debris modelling were performed using the floating-pier debris module. Simulation was performed under the unsteady flow simulations. Simulation result showed that there were 3 m of water level increase during the blockage scenario.

1. Introduction

Floating debris such as tree limbs, logs, roots, brush and other material can be caught on the upstream side of a bridge pier, which eventually can cause problems during high flow events. As happened during September 16-19, 2001, typhoon Nari has caused severe overbank flow due to the blockage at Ba-Tu Railway bridge[1]. By using the unsteady flow routing model provided in HEC-RAS, Lee (2006) has managed to make a numerical simulation of bridge blockage during Nari Typhoons. Aside, Zevenbergen (2007) had evaluated the impact of flow contraction due to debris flow to the bridge pier scour[2]. In addition to that, scouring process which explain the sediment and bridge pier interaction had been investigated by Hodi (2009)[3].

National Nuclear Energy Agency of Indonesia has a plan to build a small reactor, here in after referred as Reaktor Daya Non Komersial (RDNK), in the area of PUSPIPTEK Serpong, South Tangerang. The nearest river to the reactor site is a small river called as Salak river.

---

[1] Corresponding author, Researcher, Center for Nuclear Energy System, National Nuclear Energy Agency, Jl. Kuningan Barat, Mampang Prapatan, Jakarta 12710, INDONESIA, yuliastuti@batan.go.id
[2] Researcher, Center for Nuclear Energy System, National Nuclear Energy Agency, Jl. Kuningan Barat, Mampang Prapatan, Jakarta 12710, INDONESIA, theoalvin12@gmail.com
[3] Researcher, Center for Nuclear Energy System, National Nuclear Energy Agency, Jl. Kuningan Barat, Mampang Prapatan, Jakarta 12710, INDONESIA, euisetty@batan.go.id
[4] Researcher, Center for Nuclear Energy System, National Nuclear Energy Agency, Jl. Kuningan Barat, Mampang Prapatan, Jakarta 12710, INDONESIA, heni_susiati@batan.go.id
[5] Researcher, Center for Nuclear Energy System, National Nuclear Energy Agency, Jl. Kuningan Barat, Mampang Prapatan, Jakarta 12710, INDONESIA, ekorudi@batan.go.id
[6] Researcher, Center for Nuclear Energy System, National Nuclear Energy Agency, Jl. Kuningan Barat, Mampang Prapatan, Jakarta 12710, INDONESIA, bondan.wicaksono@batan.go.id
7 Researcher, Center for Nuclear Energy System, National Nuclear Energy Agency, Jl. Kuningan Barat, Mampang Prapatan, Jakarta 12710, INDONESIA, hadi_suntoko@batan.go.id

Note: Discussion on this paper is open until March 2021

Nevertheless, this small river is interconnected with a big river called Cisadane river.

In 2013, Manijo performed flood assessment in the Cisadane river by analyzing the refining land cover and spatial planning along the river. Based on his research, Manijo (2013) stated that peak discharge of Cisadane watershed happened at the downstream section of the watershed[4].

HEC-RAS are public domain software developed by the Hydrologic Engineering Center of the U.S Army Corps of Engineers. Three hydraulic analysis components were provided in HEC-RAS, namely, steady flow water surface profiles, unsteady flow simulation, and sediment transport/movable boundary computations. Unsteady flow components allows the simulation of 1-D, 2-D and combined one/two dimensional unsteady flow through a full network of open channels, floodplains and alluvial fans. Hydraulic calculations for cross sections, bridges, culverts, weirs, and other hydraulic structures were included in the computations.

Geometric data for hydraulic calculations were prepared using HEC Geo-RAS. HEC Geo-RAS allows the user to enter floating debris information into the HEC-RAS model, so that the effects of floating debris can be analyzed during a flooding event. DEM imagery was used to prepare RAS geometry data such as stream centerline, flow path centerline and cross-section cut lines.

The objective of this paper is to investigate the floating debris analysis due to bridge blockage by observing the water stage rise on the site based on the simulation. Analysis was performed by comparing unsteady flow simulation results with and without debris blockage scenario. The numerical simulation resulted from this study served as an important reference for the RDNK detail design and site development.

2. Methodology

2.1 Area of Study

Cisadane watershed geographically located between 106.48 - 106.93 east and 6.01 - 6.78 south or administratively situated between the Bogor district, Bogor city, Tangerang district and Tangerang city. This watershed covers the area nearly of 151,808 Ha and has the water sources coming from Gede-Pangrango and Salak Mountain in the south. Based on the altitude variations, most of Cisadane watershed area are located at more than 100 meter asl. Higher altitude area which is more than 500 m asl are found for the mountainous area in the south part. Meanwhile, the middle part of the watershed has the altitude range between 100-500 m asl and less than 100 m asl for the north part of the watershed. The study area covered 35216,3 km length of river line. Relatively, the river flow is directed from south to north area. RDNK site area is located roughly 8 km from the lowest river downstream in the study area.

The exposed strata of the studied area are mainly composed of quaternary alluvium and debris flow deposits. Based on Manijo (2013), rainfall records from the past 30 years over the Cisadane watershed showed that upstream of Cisadane reached the highest rainfall rate of 4115 mm/year whereas the middle stream of Cisadane watershed has the peak rainfall rate of 3318 mm/year and about 2243 mm/year for the downstream area. Using spatial and temporal analysis along the Cisadane watershed, Mangapul (2016) concluded that flood prone area were located in the middle and lower reaches[5]. One of the reasons was that the significant changes of the land use on this specific area where the building expansions for the last 10 years was increasing to nearly 300% compare to 2005 data.

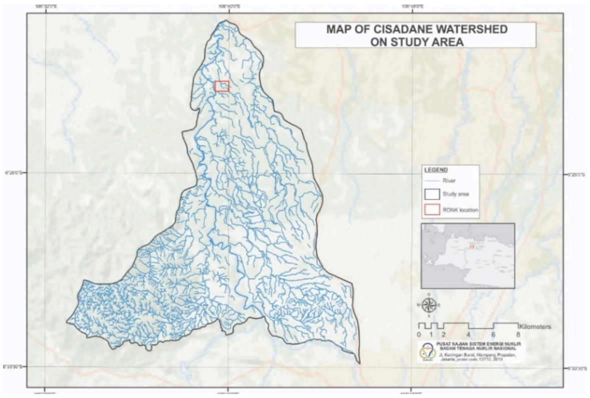

Fig. 1. Area of Study

2.2 Modelling Workflow

In general, data processing workflow was divided into four major steps namely the preparation of RAS geometry, determination of hydrological parameters, Surface Water Elevation Calculation, and RAS mapping for the output. General methods for debris analysis consist of pre-processing, processing and post-processing as shown in Figure 2. Pre-processing data were performed using HEC-GeoRAS as an add-in in ARCGIS©. Digital Elevation Model was required at the pre-processing stage for elevation extraction. For that reason, the simulation used DEMNAS with the spatial resolution of 8 m which readily available for the public provided by the Agency of Geospatial Information.

The pre-processing data or the preparation of river geometry covers the digitation of river or stream centerline, flow path, and banks as shown in Figure 3. Once the studied area has been chosen, stream centerline was established by setting-up the river layer. River digitation was made by using both the satellite imagery and confirmed it with the DEMNAS.

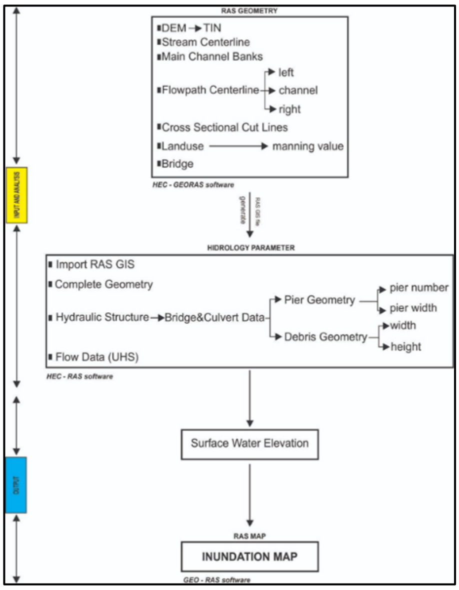

Fig. 2. Data Processing Workflow Diagram

Fig. 3. Stream centerline (left), left and right river bank digitation. (middle and right)

Based on the time variability, the mathematical model of water flow in an open channel could be classified into steady flow and unsteady flow. Steady flow is used when the flow parameters is constant for the whole simulation time. However, if the flow parameters vary throughout the time then unsteady flow should be used. Hydraulic simulation was performed under the unsteady flow analysis provided in HEC-RAS. The unsteady flow numerical calculation was based on open channel Saint-Venant equation which consist of continuity and momentum equation as describe in Eq.1[6][7].

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \qquad [1]$$

$$\frac{\partial Q}{\partial t} + \frac{\partial (\beta Q v)}{\partial x} + gA\,\frac{\partial y}{\partial x} + gAS_f - gAS_0 = 0 \qquad [2]$$

where: A = the cross-sectional area of the section; Q = the discharge rate at the section; x = the position of the section measured from the upstream end; v = the average cross-sectional velocity, y(x,t) = the flow depth; S0 = the longitudinal channel slope; Sf = the friction slope; g = the gravity acceleration; β = correction factor of velocity distribution or momentum correction factor; and t = time.

Numerical solution for those equations were solved by using the finite difference method in accordance to Preissman's scheme using both initial and two boundary condition as stated in Krylova (2017)[7]. Boundary conditions both at the upstream and downstream have to be set up prior to the numerical calculation. For downstream boundary conditions, the options are Rating Curve, Normal Depth, Stage Hydrograph, Stage and Flow Hydrograph. Meanwhile for the boundary conditions at the upstream, the available options are Flow Hydrograph, Stage Hydrograph, Stage and Flow Hydrograph. The selection of the options is highly depend on the data availability.

Flow hydrograph commonly used as an upstream boundary condition using time series of discharge/flow data as an input. This type of upstream hydrograph could be attained from historical discharge data, synthetic flood data, or rainfall-runoff modelling data such as Snyder, SCS or other rainfall-runoff modeling methods. In addition, tage hydrograph acquired from a stream gage or tidal cycle, could also be used as the upstream boundary condition in the form of time versus stage. Fenton (1999) explained in more detail of how to convert stage records data into a corresponding hydrograph[8]. Combination of stage and flow hydrograph is commonly stated as the mixed boundary condition and it could be used simultaneously either as an upstream or downstream condition.

In a condition where a stream gage is available at a sufficient distance downstream the study area, then the rating curve mode could be used as the downstream boundary condition. However, if the stream gage do not exist at an appropriate distance, then normal depth mode could be used as the downstream boundary condition. As explained in Szymkiewicz (2013), the normal depth described a constant flow velocities and cross sectional area[9].

3. Result and Discussion

3.1 *Bridge and debris Modelling*

Modelling scenario for the debris analysis was established prior to the data processing. Subsidence or landslide prone areas near the river were identified using soil classification map. Based on the soil type map there were at least four soil classifications along the Cisadane watershed, namely andosol, podsolik, latosol, and regosol.

Areas that have regosol soil type were classified as prone area that have the possibility of landslide and eventually creating debris flow to the river. In addition to that, hillside slope data were also used as the criteria to determine prone areas by overlaying soil type and hillside slope data. Based on slope classification by the Ministry of Forestry (1986), slope with more than 15% were considered as a prone area. Afterward, land use of each of the prone areas were investigated.

Based on the soil classification, hillside slope and land use data, it was concluded that the potential debris sources were the tree limbs, logs, roots, and bushes. This potential debris was then considered as the significant debris that should be taken into account for the analysis. Some areas along the river were identified vulnerable to landslide.

The chosen bridge for floating debris analysis in this study are the bridges located in the downstream of RDNK site. The targeted bridge distance to the site area is less than 1 km and categorized as an A bridge class according to the national regulation published by the Ministry of General Works. Although, there exists a bridge near the site area, but to use it as the targeted bridge regards as an illogical approach.

Bridge geometry as shown in Figure 5 has been slightly modified from the actual geometry by adjusting to the extracted topographic profile of the river bank. The assigned bridge has four piers with the pier width of 1 m.

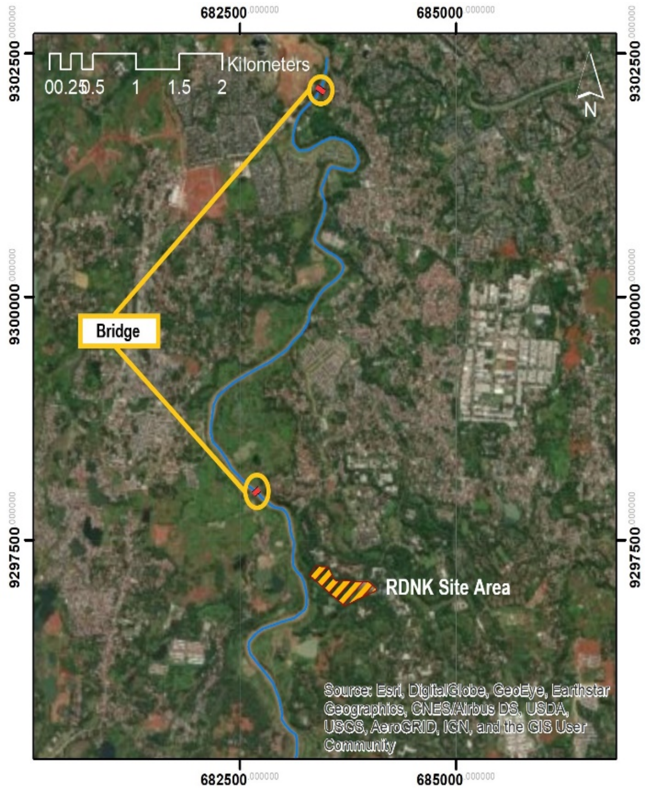

Fig. 4. Bridge Location

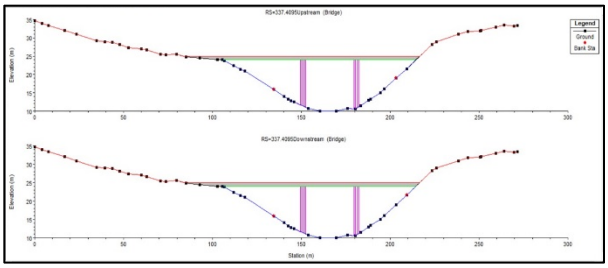

Fig. 5. Upstream and downstream of bridge cross-section lines.

The scenario for blockage simulation was determined by considering the entry angle, discharge ratio to the mainstream and debris volume[10]. HEC-RAS required input debris size for simulating the floating pier debris. Intense rainfall could somehow induce the debris flow where loose materials rushed into the river together with the debris flow. Since there has been no blockage data along the Cisadane river, then the debris size determination is estimated by some assumptions. The default assumptions used in HEC-RAS were that the debris height was 2.5 times the pier width and the debris width was 5 times the pier width.

The blockage scenario was developed somehow that the debris flowing through the river was big enough to blockage the river flow. Thus, by considering the targeted bridge geometry, the floating debris size was 30 m in width and 20 m in height.

3.2 *Numerical Simulation Parameters*

Boundary and initial condition for the unsteady simulation should be defined prior to the simulation. For the simulation purpose, the hydrograph flow, in this case regarded as the flood discharge, was based on the Snyder model that has been developed using 10 years historical rainfall data across the Cisadane watershed as shown in Figure 6. This hydrograph shown to be in a good agreement with the records coming from automatic water level recorder located at the upstream of the study area.

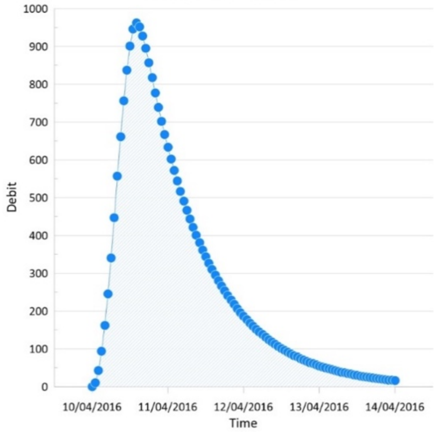

Fig. 6. Snyder flow discharge hydrograph for runoff simulation

For the boundary condition at the upstream, flow hydrograph was set while for the downstream location the normal depth was used with the friction slope of 0.0025. The friction slope was estimated using the water surface slope throughout the river system. In addition to the boundary condition, initial condition was assumed to be constant throughout the river system and represent the stable flow condition prior to the flooding period. Different initial flow conditions will affect the water surface elevation at the initial stage of flood simulation as shown in Figure 6. Two discharge rate levels were used to analyze the effect of initial conditions namely 300 m3/s to represent one-third of maximum flood discharge and 90 m3/s to represent the 10% of maximum flood discharge. The green line (mark with red arrow) shows the water surface elevation of the initial simulation stage. It shows that the initial conditions did not affect the water surface elevation at the peak flood discharge.

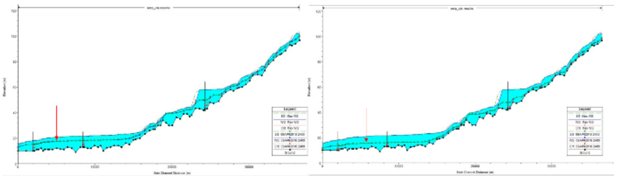

Fig. 7. Water elevation profile comparison for 300 m^3/s (left) and 90 m^3/s (right) initial condition

3.3 *Water Elevation Profile*

Water elevation profile as shown in Figure 7 and 8 were generated using maximum water flood discharge of 962 m^3/s with the base flow of 100 m^3/s. The water surface elevation at the targeted bridge was about 18 masl when using the maximum discharge. Adding debris to the simulation caused a rising water surface to the elevation of 21 masl or an additional water height of 3 m.

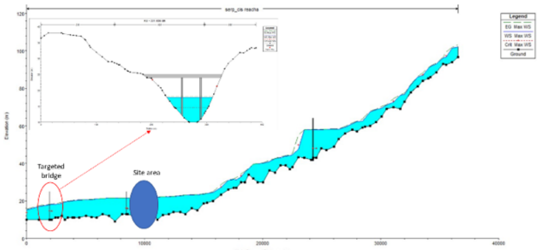

Fig. 8. Water elevation profile with debris

3.4 *Flood Inundation*

Figure 9 below illustrates the Cisadane river flood inundation map produced from modeling using the HECRAS software. Inundation areas are identified in bright blue while the maximum flood level is shown in lighter blue. The left figure shows the inundation map without considering the debris blockage at the targeted bridge. The cross section profiles shows the topography profile and water surface elevation on maximum flood condition in the site area.

Water level rising has caused a wider area of inundation especially at the nearest location to RDNK site area. The inundation areas as shown in Figure 9 was increasing from 13640 m^2 to 46138 m^2 when considering the blockage scenario. However, based on the simulation performed, the RDNK site area was relatively safe from inundation due to the fact that RDNK site is located at the minimum elevation level of 30 masl.

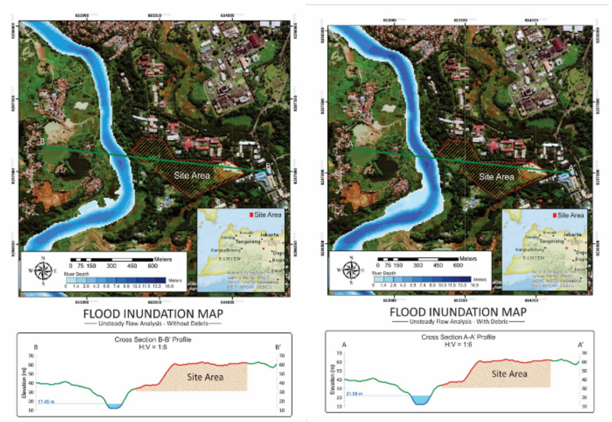

Fig. 9. Flood inundation map

The flood inundation map in Figure 9 can be used as a basis for anticipating possible flooding towards the RDE site. Flood-prone areas are based on their distribution area so that an appropriate flood anticipation effort can be determined in the area. Flood vulnerability maps can be used as a basis for flood disaster mitigation, in the preparedness, reconstruction and construction of embankments or weirs for handling / reducing the threat of flooding[11].

4. Conclusion

HEC-RAS model was used to simulate the rise of water elevation surface due to the bridge blockage in the middle section of Cisadane river. Simulation of bridge blockage resulting from an accumulated potential debris along the river was performed using the floating-pier-debris module. The simulation results showed that the water level surge due to the debris blockage scenario was 4.53 m. Inundation area increasing almost 240% when the debris blockage scenario was running.

The flood risk map produced in this study shows areas that have the possibility of flooding. No mapped flooded areas are in the RDE site. On the RDE site, the risk of flooding mainly from the Salak river is possible. However, further evaluation is needed on the impact of the Salak river flooding not far from the RDE site.

Acknowledgements

Funding for this research was provided by the Ministry of Research, Technology and Higher Education under the grant of Insentif Riset Sistem Inovasi Nasional number 06/INS-1/PPK/E4/2019 on February 18th, 2019. This support is gratefully acknowledged.

References

A. I. Krylova, E. A. Antipova, and D. V Perevozkin, “The derivation of the Saint – Venant equations,” *Bull.Nov.Comp.Center, Numer. Model Atmos.*, vol. 16, pp. 21–35, 2017.

B. Hodi and B. S. Hodi, “Scholarship at UWindsor Effect of Blockage and Densimetric Froude Number on Circular Bridge Pier Local Scour,” University of Windsor, 2009.

E. Retsinis, E. Daskalaki, and P. Papanicolaou, “Hydraulic and Hydrologic Analysis of Unsteady Flow in Prismatic Open Channel,” in *Proceedings*, 2018, vol. 2, no. 11, p. 571.

J. D. Fenton, “Calculating hydrographs from stage records,” in *Proc. 28th IAHR Congress*, 1999, no. August, pp. 22–27.

K. T. Lee, Y.-H. Ho, and Y.-J. Chyan, “Bridge Blockage and Overbank Flow Simulations Using HEC–RAS in the Keelung River during the 2001 Nari Typhoon,” *J. Hydraul. Eng.*, vol. 132, no. 3, pp. 319–323, 2006

L. Wang, M. Chang, X. Dou, G. Ma, and C. Yang, “Analysis of River Blocking Induced by a Debris Flow,” *Geofluids*, vol. 2017, pp. 1–8, 2017.

M. P.Tambunan, T. Giok Pin, B. Permana, A. Zikrullah, and A. Maulana, “Spatial and Temporal Pattern of Flood Area in Cisadane Watershed, Banten Province,” in *1st International Conference on Geography and Education (ICGE 2016)*, 2016, vol. 79, no. October 2017, pp. 70–75.

Manijo, “Evaluasi Risiko Banjir dan Pola Ruang di Daerah Aliran Sungai Cisadane,” Insitut Pertanian Bogor, 2013.

P. F. Lagasse, L. W. Zevenbergen, and P. E. Clopper, “Impacts of debris on bridge pier scour,” in *Geotechnical Special Publication*, 2010, no. 210 GSP, pp. 854–863.

R. Szymkiewicz, *Numerical Modeling in Open Channel Hydraulics*, vol. 83, no. 9. 2013.