Critical Analyzing on Sand, Gravel, and Stone Mining on the Ongka River for Materials which are Not Metalic

S. K. Sahani[1], K. S. Prasad[2*], D. N. Mandal[3], K. Sahani[4]

[1*]Department of Mathematics, M.I.T. Campus, T. U. Nepal
drsks53086@gmail.com

[2*]Department of Mathematics, T.R.M. Campus, T. U., Birgunj, Nepal
kripasinduchaudhary@gmail.com

[3]Department of Mathematics, M. M. C., T. U., Janakpurdham, Nepal
Mandaldevnarayan51@gmail.com

[4]Department of Civil Engineering, Kathmandu University, Dhulikhel, Nepal
kameshwarsahani413@gmail.com

Abstract

Historically, mining rivers for building materials has harmed both the river and the surrounding landscape. To ensure that mining in the river won't cause irreparable damage, we need to conduct in-depth scientific research. They plan to excavate the Osaka Demos River bed for building materials. The researchers employed geodesic mapping to figure out the contours of the river at various points. They examined the river's flow over a distance of 600 metres and over three distinct time spans (25, 50, and 100 years). Sand, gravel, and stones can settle to the river floor as sediment as a river alters its course. For a 100-year return rate flood, the HSS-Snyder technique calculated a flow rate of 1249.1692 cubic metres per second, 1178.8064 cubic metres per second for a 50-year return rate flood, and 1104.2372 cubic metres per second for a 25-year return rate flood. The river is shown to overflow in the simulation when large floods occur at regular intervals of 25, 50, or 100 years. The trapezoid shape will be used in the new technological river design. We use data on river form changes to calculate the volume of dirt that needs to be excavated: 88,347.42 cubic metres.

Keywords: Nonmetallic material, extracting materials, Plan flood discharge, plan to release excess water during a flood, Economic latitude view, the financial aspect, Demos cost, and etc.

INTRODUCTION

Prior to 2014, the government permitted the extraction of nonmetallic material from rivers without considering the potential negative consequences. This resulted in significant damage to rivers, especially the Dumosa Ongka River, where the mining took place before 2014.

The government stopped certain activities because of the damages that happened by creating a law called No. n In 2014, a law was passed stating that the Governor has the power to give permission for non-metal mining or mining in rivers. But we need to do a study to understand how water moves, carries sediment, and shapes rivers.

This research aims to prevent damage in the Ongka Dumosa River caused by sand, gravel, and river stone mining. It also aims to determine the amount of these materials present in the river.

2. Area of Research

The research location is in Totaquin village, Lola sub-district, Bokang Mongongo district. It is located at 0 degrees 46 minutes 48. 33683 seconds latitude and 124 degrees 6 minutes 25. 0785 seconds longitude

This research wants to follow the proper rules for mining materials like sand, gravel, and river stones in rivers. It aims to meet the guidelines for managing river borders, the capacity of cross-sections, and the amount of water flowing in the river. The study is helpful for miners who extract these materials.

3. Method of Data Collection

3.1. Secondary Data

This information can be gathered from groups and people who are linked to the Demos River. It can also be found in books, reports, or notes from researchers and other important people.

The information consists of:

A map that shows the lines and characteristics of a particular place, like a water area or how the land is used, and also points out where a certain building or place is located. A location in Osaka called Demos collects information about the amount of rainfall in the Sulawesi River's first region (BWSS I). The findings from the previous mapping of the land surface.

3.2. Primary Data

We collect the main data by going out into the field and surveying to get accurate information. Identifying and listing is the first step in gathering original data to understand the overall situation at the Research location. We looked at the Dumosa River and talked to people living nearby and the local government to gather information on the river's condition and any harm it has suffered.

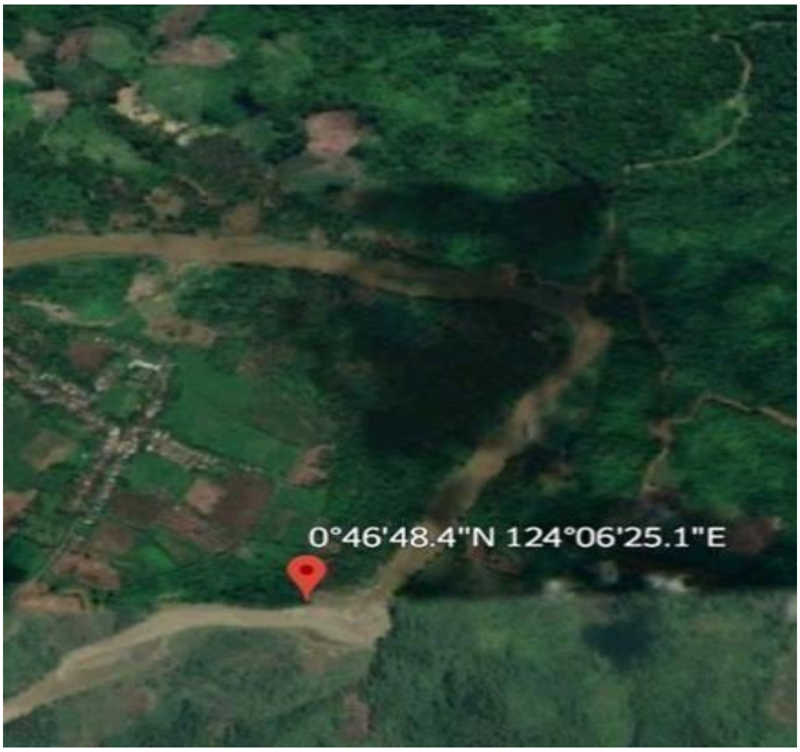

Fig. 1 Map of Ongka River

4. Approach to Data Analysis

The data will be studied to see how often it rains each hour and where the rain is spread out. This will also help calculate how strong the rain is. We used different ways to analyze how water flows during a flood. We will use a software called HEC-RAS to do a hydraulic analysis and figure out the flood water levels. To figure out how much to dig, we calculate the hydraulic profile of the river we will be working on.

4.1. Rainfall Data

We gather data about how much it rained from four nearby weather stations: Tour at Rain, Romanov, Katakana, and Pusan Observation Stations. The information was gathered from BWSS I (Balaji Sung Sulawesi I) in the province of North Sulawesi. The research lasted for ten years, starting in 2008 and ending in 2017.

4.2. Analysis of Data Quality

Before analyzing rainfall data, an outlier data test is done to figure out if extreme rain data is because of mistakes in recording or if it was really extreme conditions. This test checks for data that is very different (outliers) in both high and low values.

4.3. Average Rainfall Analysis Using the Thiessen Polygon Method

Before analyzing rainfall data, an outlier data test is done to figure out if extreme rain data is because of mistakes in recording or if it was really extreme conditions. This test checks for data that is very different (outliers) in both high and low values.

4.4. Rainfall Probability Data Analysis

We use statistical parameters to test the rainfall data and determine what distribution type it follows. The outlier data analysis findings have been utilized to adjust the rainfall data for this analysis. Allocating probabilities may be done in a number of ways, including using the Gumbel, Normal, Normal Log, and Type Person Log III procedures. The following steps are taken in order to determinestatistical values for the observed data:

Central tendency

$$\bar{X} = \frac{\sum \dot{x}}{n} = \frac{956{,}90}{10} = 95{,}69\ mm$$

$$\log\bar{X} = \frac{\sum \log xi}{n} = \frac{19{,}76}{10} = 1{,}975\ \text{mm}$$

Standard deviation source data

$$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(xi - \bar{x})^2}$$

$$= \sqrt{\frac{1}{10-1} . 3566,78} = 19,90$$

$$Slog = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} \log (xi - \bar{x})^2}$$

$$= \sqrt{\frac{1}{10-1} . 0,0760} = 0,0919$$

Variation Coefficient

$$CV = \frac{S}{\bar{X}} = \frac{19,9075}{96,4981} = 0,206$$

$$CVlog = \frac{Slog}{log\bar{X}} = \frac{0,0919}{1,976} = 0,047$$

Skewness coefficient source data

$$Cs = \frac{n \sum (xi - \bar{x})^3}{(n-1)(n-2)S^3}$$
$$= \frac{107315,3223}{568044,6431}$$
$$= 0,19$$

$$Cslog = \frac{n \sum \log (xi - log\bar{x})^3}{(n-1)(n-2)Slog^3}$$
$$= \frac{-0,021592093}{0,055945976}$$
$$= -0,39$$

Kurtosis coefficient source data'

$$Ck = \frac{n^2}{(n-1)(n-2)(n-3)S^4} \sum_{i=1}^{n} (x_i - \bar{x})^4$$

$$Ck = 3.883$$

4.5. Studying the predicted rainfall

The following equation is used to calculate the design rainfall analysis using the Log Pearson type III approach.

$$\log Xtr = \log \bar{X} + Kt \times Slog$$

$$Xtr = 10^{\log Xtr}$$

The following table was used to calculate the design rainfall for the 25th, 50th, and 100th birthdays.

Tr	1/Tr (%)	Kt	Log Xtr	Xtr
25	4	1,699	2,088476	122,596
50	2	1,974	2,118503	131,372
100	1	2,217	2,145038	139,649

4.6. Flood Discharge HSS-Snyder Method Analysis

We studied how much water flowed during a flood using a method called HSS-Snyder. We studied floods that usually occur every 25, 50, and 100 years. Here is what we discovered about the flood flow.

A parameter is a thing that you give to a function or method to make it do what you want or give you what you want.

It provides specific instructions or information for the function to use.

If Ct is 2. 1 and Cp is 0. 9, then

Find out how long it takes from when it starts raining heavily until the water flow reaches its highest point.

$$tp = Ct \times (Lc \times L)^3$$

$tp = 2{,}1 \times (48{,}95 \times 145{,}22)^3 = 30{,}044\ jam$

Duration of effective rain (tr ')

$$tr' = \frac{tp}{5{,}5} = \frac{30{,}044}{5{,}5} = 5{,}462$$

Because tr '<tr assumption then:

$$Tp = tp + \frac{tr}{2} = 30{,}044 + \frac{7}{2} = 33{,}544\ jam$$

Determine peak hydrograph peak units (qp)

$$qp = Cp \times \frac{275}{Tp} = 0.9 \times \frac{275}{33{,}544} = 7{,}378\ m^3/detik/km^2$$

Determine peak discharge (Qp)

$$Qp = \frac{qp \times A}{1000} = \frac{7{,}378 \times 1158{,}0164}{1000} = 8{,}544\ m^3/detik$$

$$Qb = 0{,}4751 \times A^{0{,}6444} \times D^{0{,}9430}$$

$$Qb = 0{,}4751 \times 1158{,}016^{0{,}6444} \times 1{,}42571^{0{,}9430} = 62{,}55\ m^3/detik$$

The analysis of flood discharge was carried out employing the HSS-Snyder technique, considering return periods spanning 25, 50, and 100 years. These are the water measurements from the flood.

Return Time	flooding outflow
25 Year	1104,2372 m^3/s
50 Year	1178,8064 m^3/s
100 Year	1249,1336 m^3/s

4.7. Discharge Measurement Calibration

Calibration is performed to determine the accuracy of the parameters utilized in the flood discharge study.

4.7.1. Regional Debit Analysis

Because measured discharge data is not accessible in the field, The measured flow from the closest river is found using regional discharge analysis. The Ongka Plumbagin River is the river for which the debit data was gathered in 2011, and it was done so by:

$$Q_2 = \frac{Q_1}{A_1} \times A_2$$

Q2 = Ongka Dumosa’s discharge

A2 = Ongka Dumosa catchment area

A1 = Ongka Dumosa’s catchment area

Q1 = Ongka Dumosa’s measured discharge

4.7.2. HSS-Snyder parameter calibration

The coefficient of determination test is used during calibration to assess the degree of similarity between estimated and observed discharge results. It is considered that the test result of the coefficient of determination, which exceeds 0.6, satisfies the requirements for the level of similarity.

The coefficient of determination test serves as a crucial tool in the calibration process, facilitating an in-depth evaluation of the concordance between estimated and observed discharge outcomes. Within this pivotal phase, the coefficient of determination test plays a pivotal role in quantifying the alignment between the modeled and actual discharge data. A pivotal benchmark in this assessment is the threshold set for the coefficient of determination, a numeric indicator that signifies the strength of the relationship between the estimated and observed discharge results. A coefficient of determination surpassing the threshold of 0.6 stands as a decisive marker of meeting the stipulated criteria for similarity. This threshold underscores the significance of achieving a substantial level of agreement between the estimated and observed discharge outcomes, thereby validating the accuracy and reliability of the calibration process. In essence, the coefficient of determination test emerges as a pivotal gauge, shedding light on the extent to which the modeled discharge aligns with real-world observations. This meticulous assessment, coupled with the benchmark threshold, serves as a robust mechanism for ensuring that the calibration endeavor attains a level of fidelity that meets the requisite standards of similarity between predicted and actual discharge results.

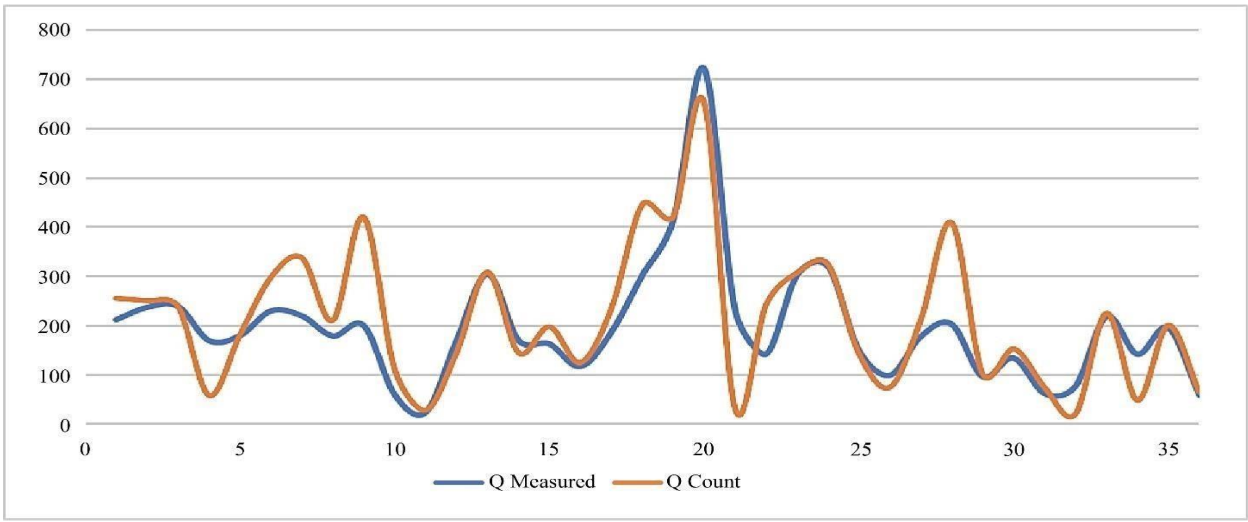

Fig. 2 Rating curve for discharge

Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 43 No. 4 (2022)

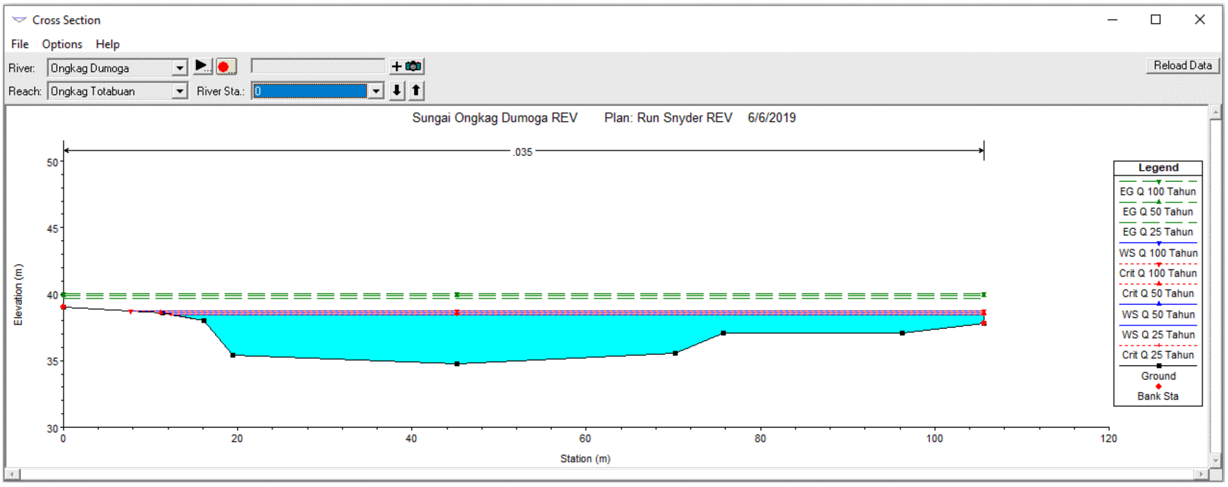

Fig. 3 High water mark at STA 0

A test value of zero is noted while measuring the coefficient of determination (r2).86, indicating a fair degree of agreement between the measured discharge values. We can estimate the amount of water that will be discharged during a flood thanks to the HSS-Snyder parameter.

4.8. Hydraulic Analysis of Current River Cross Sections

In order to predict future flood conditions, the state of rivers is assessed to collect data on water levels, surface area, channel slope, and other related information. A research was conducted to understand how a river is doing at present. It examines factors like water level, water surface area, river slope, and other details related to flooding.

The Snyder HSS flood discharge method was used to simulate crossing the river at different time intervals (25, 50, and 100 years) using the HEC-RAS software. You can see the outcomes of the simulation in the picture provided.

The Snyder HSS flood discharge approach is utilized for establishing the means of river crossing. This method considers different return times, such as 25, 50, and 100 years. The HEC-RAS software is used to make these calculations. You can see the simulation results in the picture below.

In the pursuit of accurately predicting future flood conditions, a meticulous evaluation of river states is conducted, encompassing a comprehensive dataset encompassing water levels, surface area, channel slope, and other pertinent variables. This data forms the foundation for insightful analysis. To gain a thorough grasp of the river's present state, a comprehensive research endeavor was undertaken. This investigation delved into pivotal factors including water levels, water surface area, river slope, and other intricacies that play a pivotal role in flood dynamics. A pivotal facet of this research involved the application of the Snyder HSS flood discharge methodology. This method proved invaluable in replicating the act of traversing the river across varied temporal intervals—spanning 25, 50, and 100 years—through the proficient utilization of the HEC-RAS software. The simulation outcomes, portrayed in the accompanying visual representation, underscore the efficacy of this approach. Central to the establishment of a reliable means of river traversal is the deployment of the Snyder HSS flood discharge approach. This strategy is notably versatile as it factors in diverse return intervals—namely 25, 50, and 100 years—augmenting its applicability to a broad spectrum of scenarios. The intricate calculations required for this endeavor are facilitated by the adept utilization of the HEC-RAS software, a tool renowned for its precision in hydraulic analysis. The synthesis of these elements culminates in the visual representation that follows, offering a lucid portrayal of the simulation results. In essence, this integrated approach to river state assessment and flood prediction stands as a testament to the strides made in harnessing advanced methodologies and cutting-edge software, thereby furnishing a more profound comprehension of flood dynamics and aiding in the formulation of robust mitigation strategies.

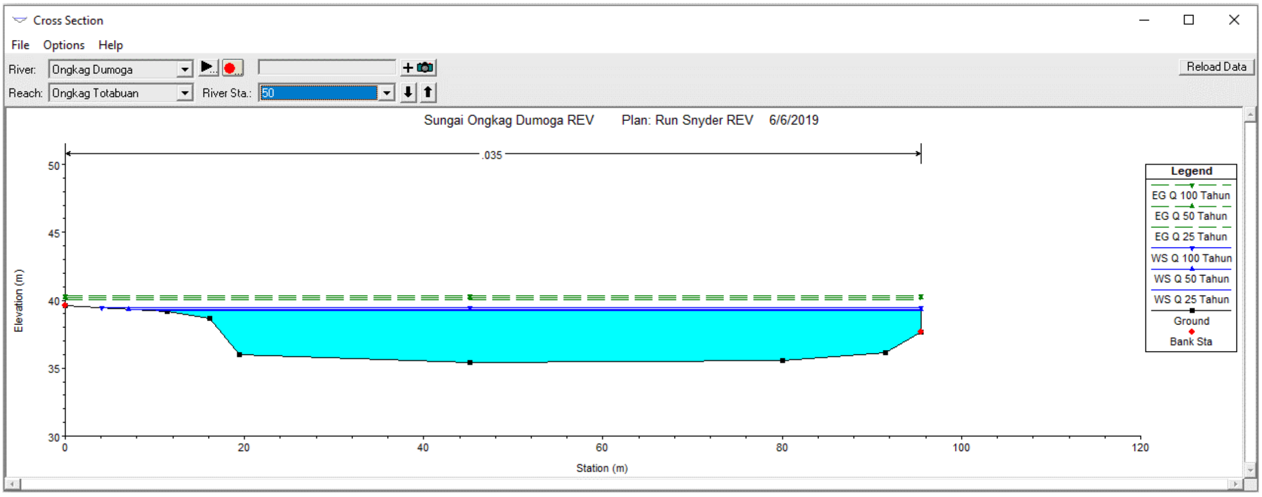

Fig. 4 High water mark at STA 50

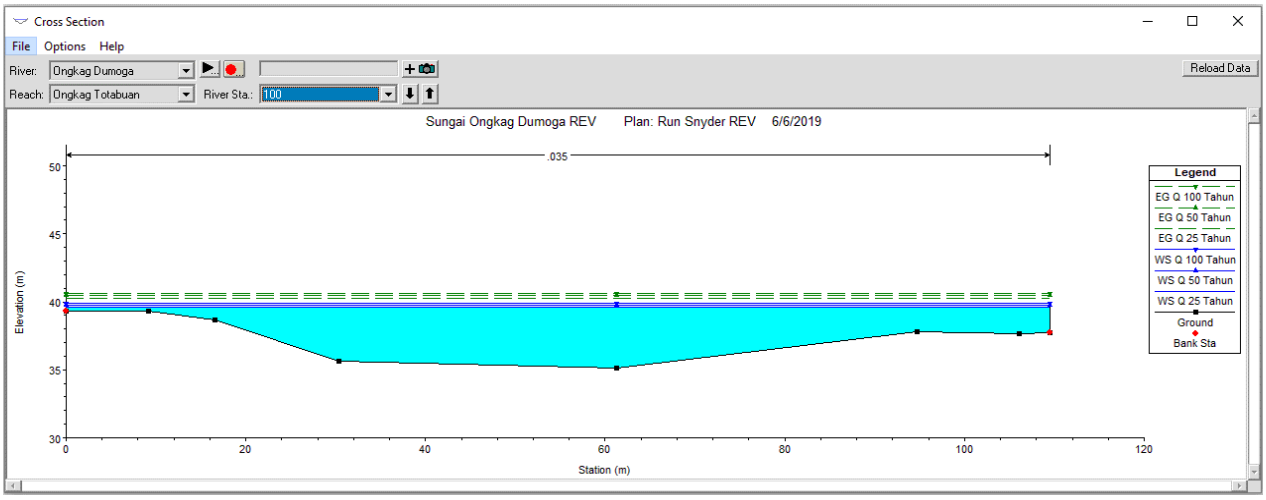

Fig. 5 High water mark at STA 100

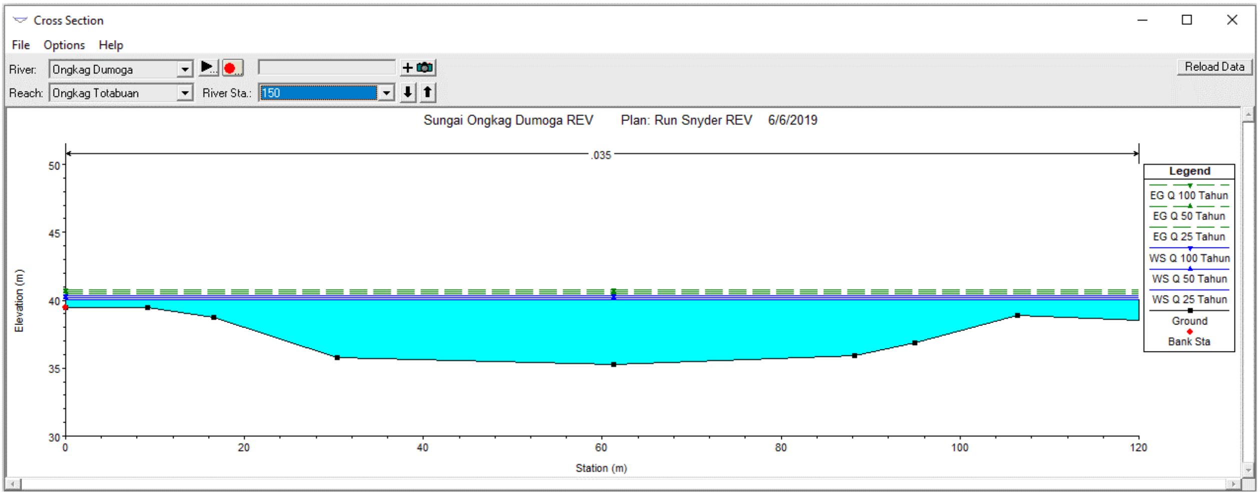

Fig. 6 High water mark at STA 150

Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 43 No. 4 (2022)

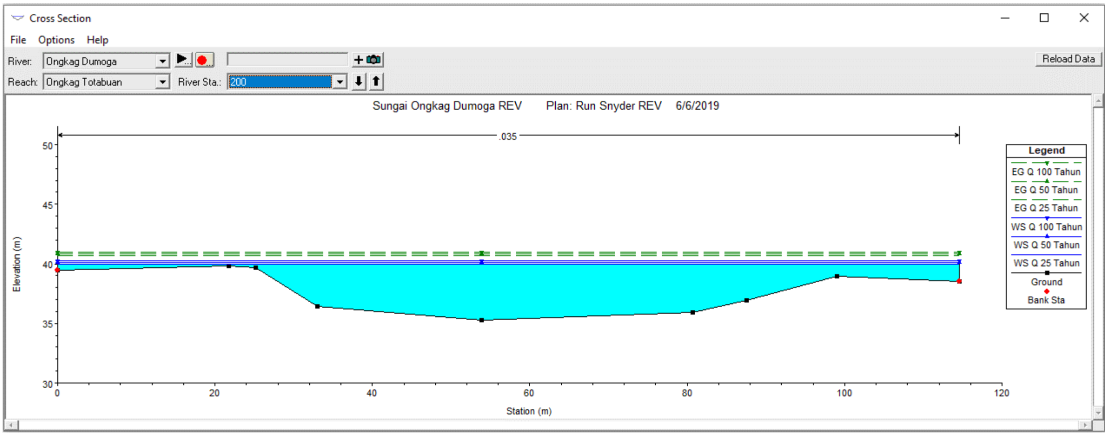

Fig. 7 High water mark at STA 200

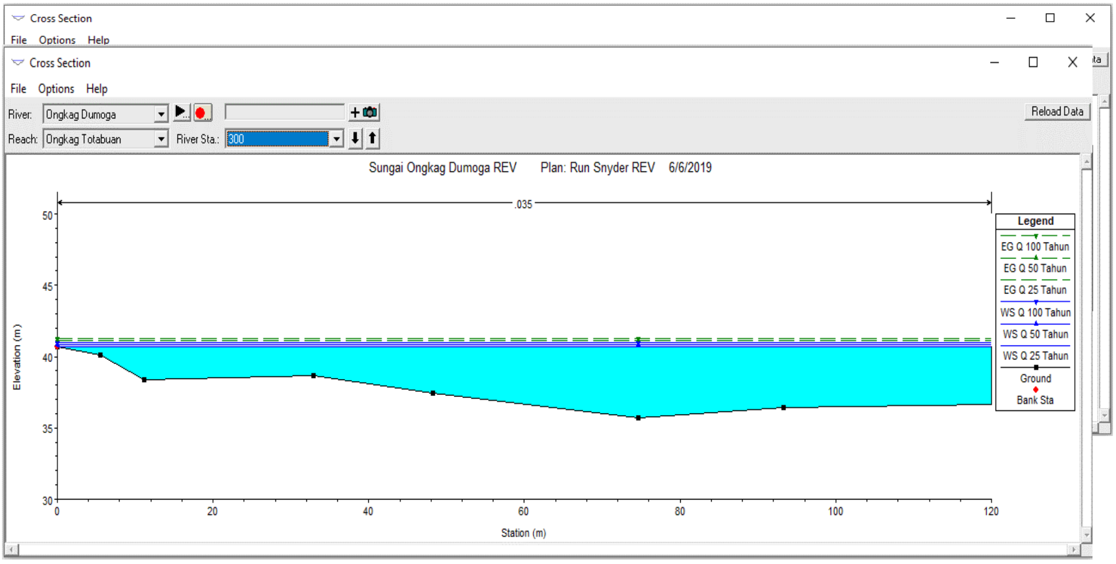

Fig. 8 High water mark at STA 250

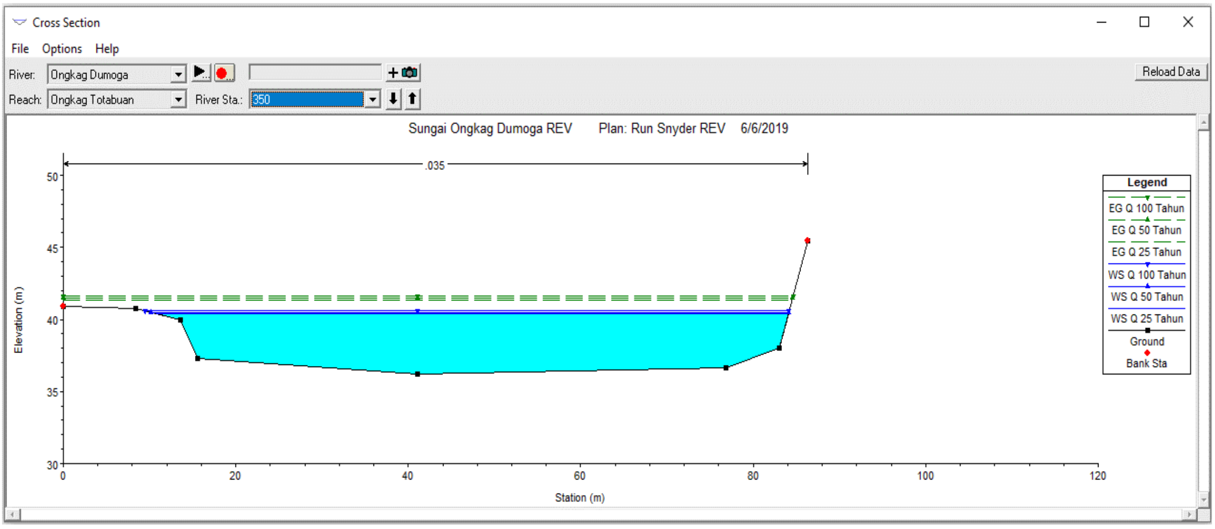

Fig. 9 High water mark at STA 300

Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 43 No. 4 (2022)

Fig. 10 High water mark at STA 350

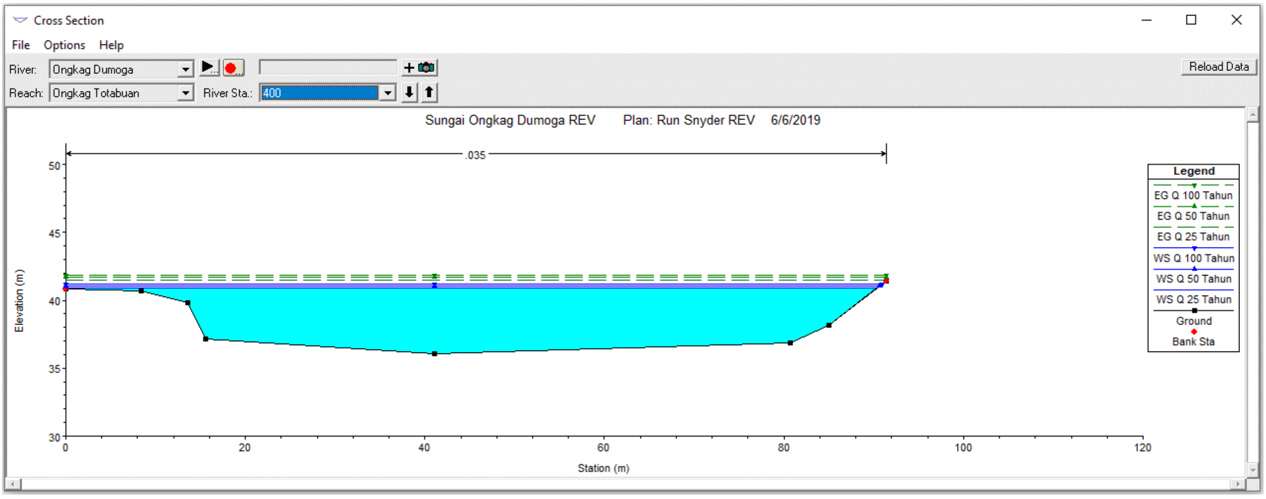

Fig. 11 High water mark at STA 400

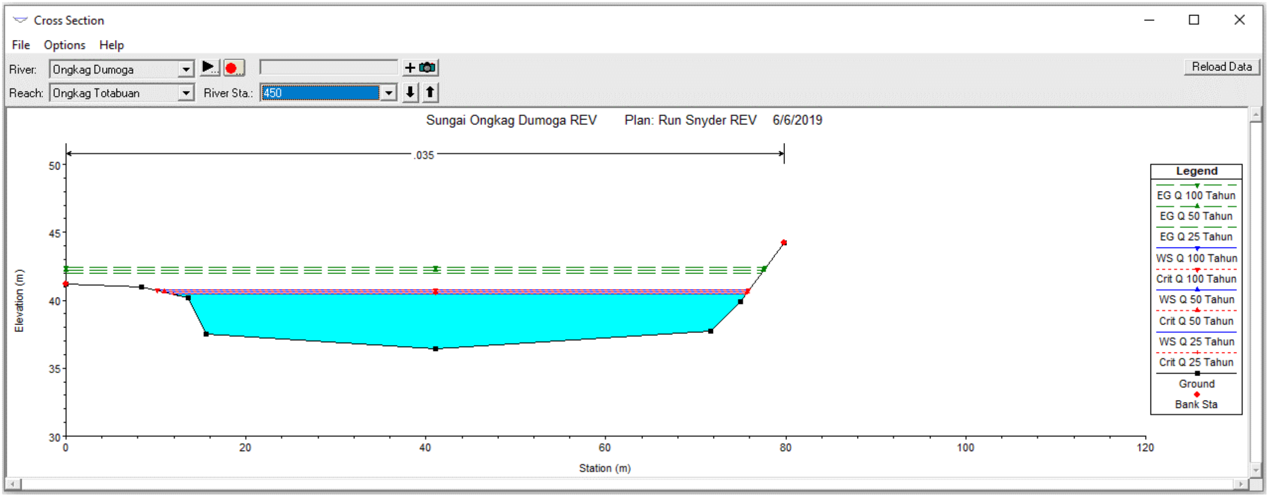

Fig. 12 High water mark at STA 450

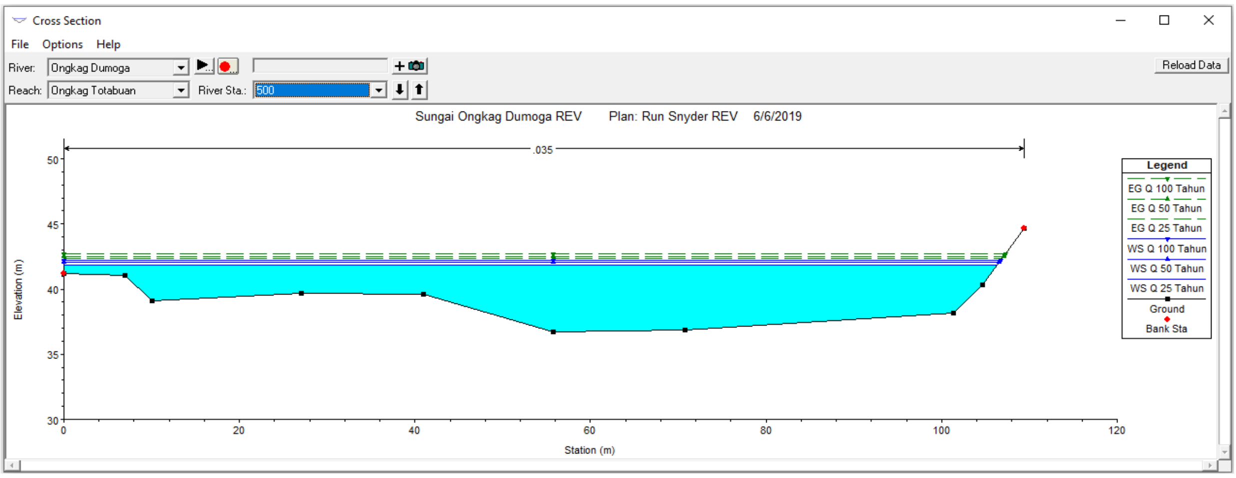

Fig. 13 High water level at STA 500

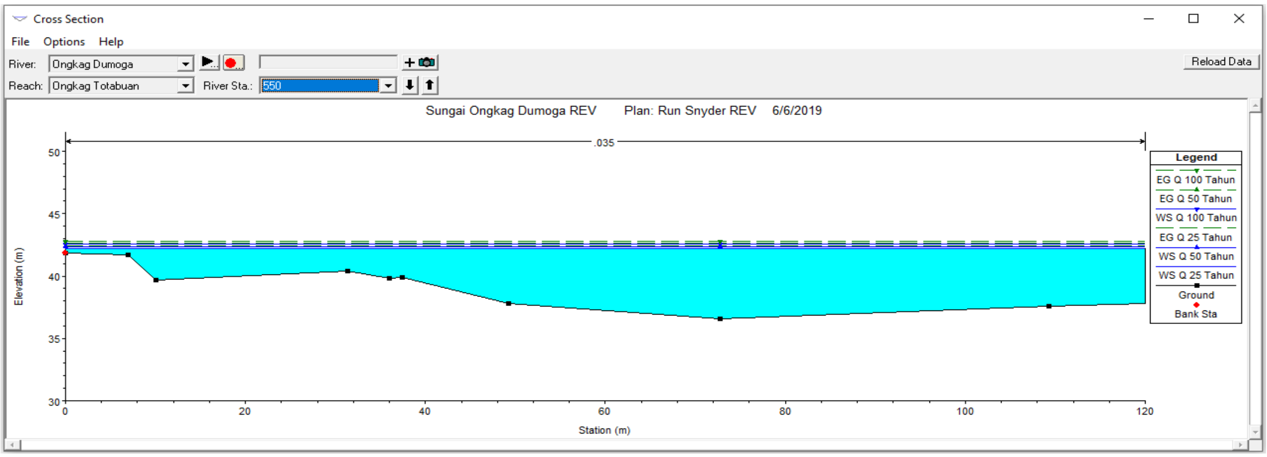

Fig. 14 High water mark at STA 550

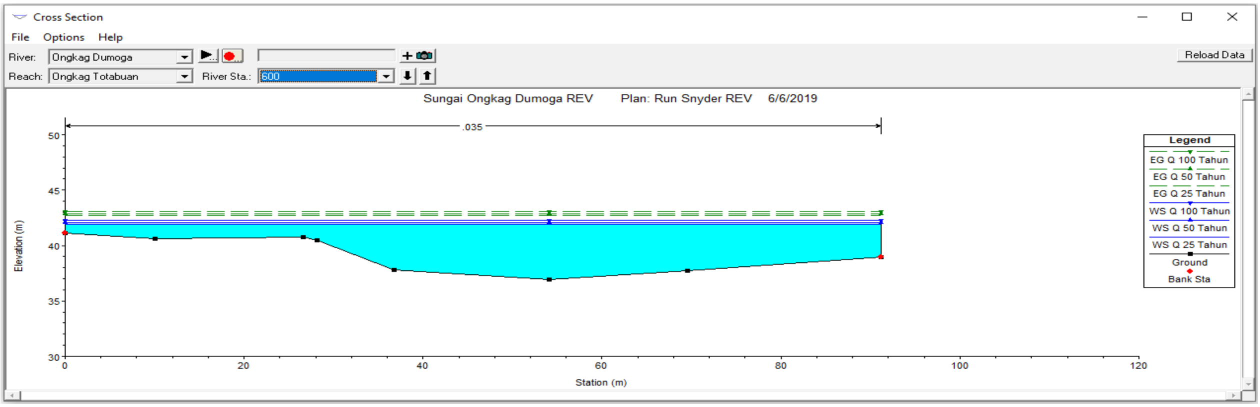

Fig. 15 High water level at STA 600

4.9. Hydraulic Post-Mining River Cross-Section Technical Analysis

After mining, we examine a river's form to determine the optimal new shape for the economy while preserving the slope of the original river bed. We'll examine the river's form at various locations to see whether it can withstand a massive flood that only occurs once every hundred years. The new river's appearance has to be changed. In the field of river analysis, a wealth of vital information is at our fingertips, including the typical width of the current riverbed, its gentle slope, the coefficient of velocity based on the state of its walls, the depth containing the potential for sand, gravel, and river stone excavations, and a host of other crucial details. This priceless information will be a crucial component of the practical cross-section method used to analyse the trapezoidal cross-section of our river. We will perform a thorough investigation of the height and width of the surface water in the technical cross section of the post-mining river as we delve deeper into the complexities of our study. The HEC-RAS programmed will then be used to assess how well the new river cross-sectional capacity handles flood flows that span a century.

Following the extraction phase, our focus turns to a comprehensive analysis of the river's morphology, a pivotal step in orchestrating a sustainable economic transformation while preserving the natural gradient of the riverbed. The intricate examination encompasses distinct segments of the river, gauging their resilience against the rare centennial deluge. Our imperative lies in reshaping the river's visage, a process imbued with multifaceted considerations. Within the realm of river scrutiny, a treasure trove of indispensable data comes to the fore. Metrics of utmost significance encompass the riverbed's breadth, its incline, the velocity of the coursing waters as dictated by the embankments, the river's profundity, and the gamut of substances that find haven within its aquatic embrace. A plethora of supplementary particulars further enriches this tapestry of knowledge. This invaluable compendium of insights forms the bedrock of our pragmatic methodology for delving into the trapezoidal contours of our riverine landscape. Our meticulous investigation entails a profound assessment of the post-mining river's elevations and expanses, concurrently delving into a panoply of ancillary intricacies that bestow lucidity upon our inquiry. The efficacy of the rejuvenated river's capacity to contend with centennial inundations will be subjected to rigorous evaluation through the discerning lens of the HEC-RAS program, an indispensable instrument for hydraulic analysis.

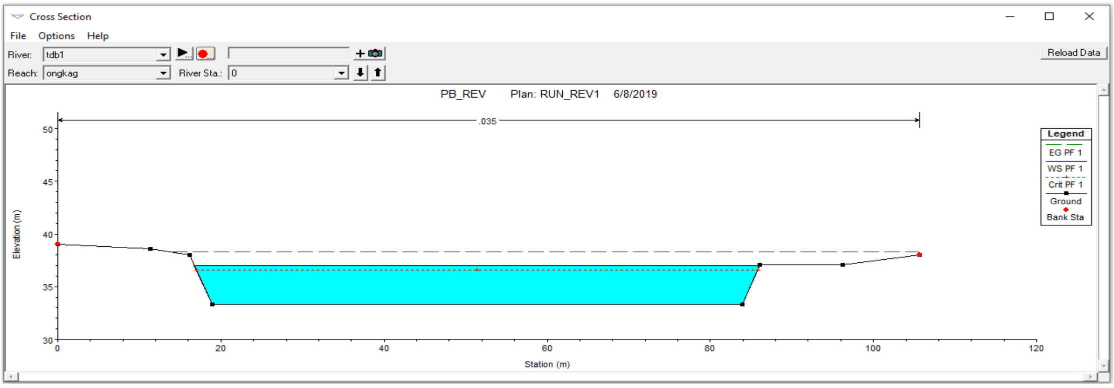

Fig. 16 High water mark at STA 0

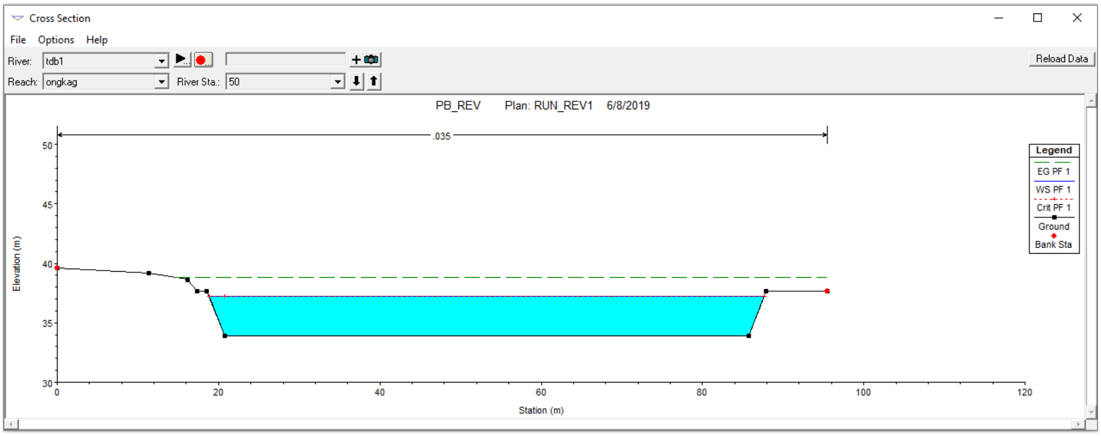

Fig. 17 High water mark at STA 50

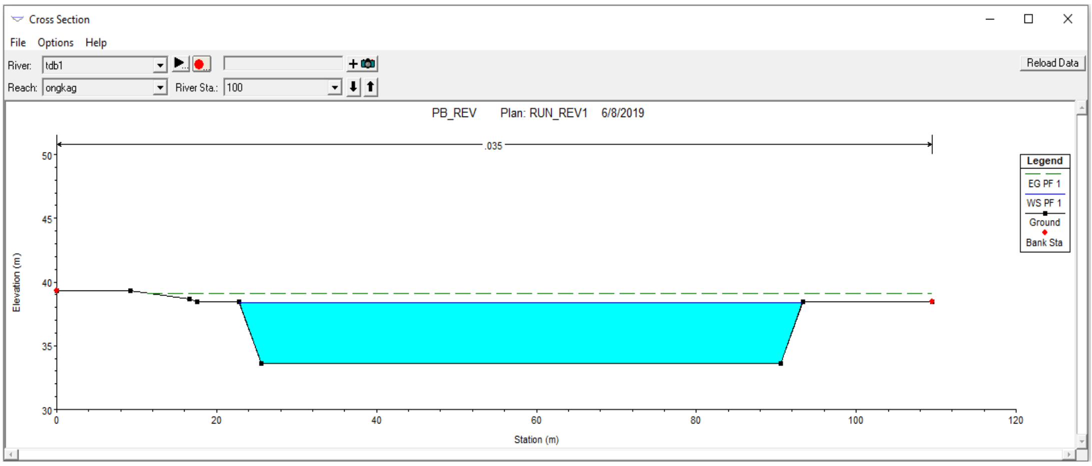

Fig. 18 High water mark at STA 100

Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 43 No. 4 (2022)

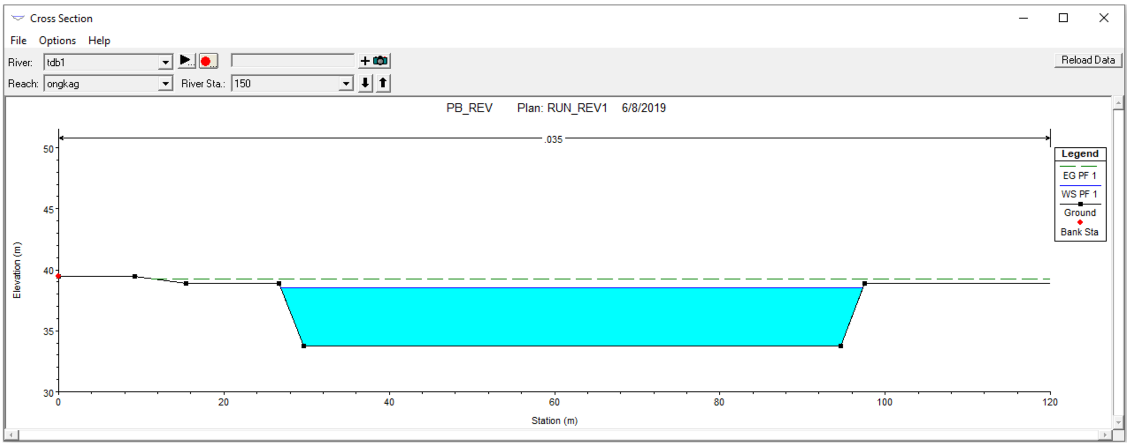

Fig. 19 High water mark at STA 150

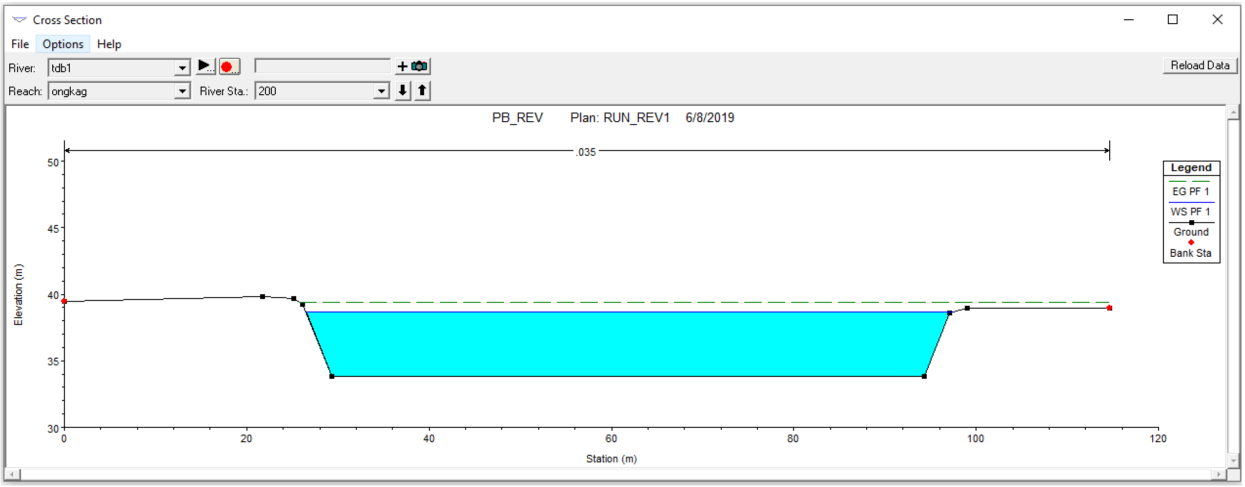

Fig. 20 Water level high at STA 200

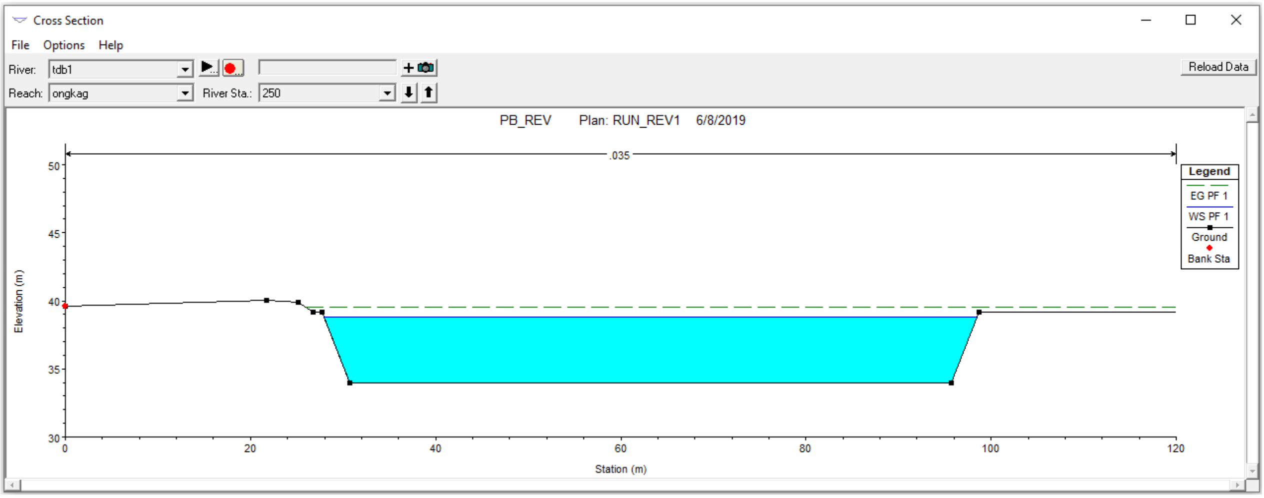

Fig. 21 High water mark at STA 250

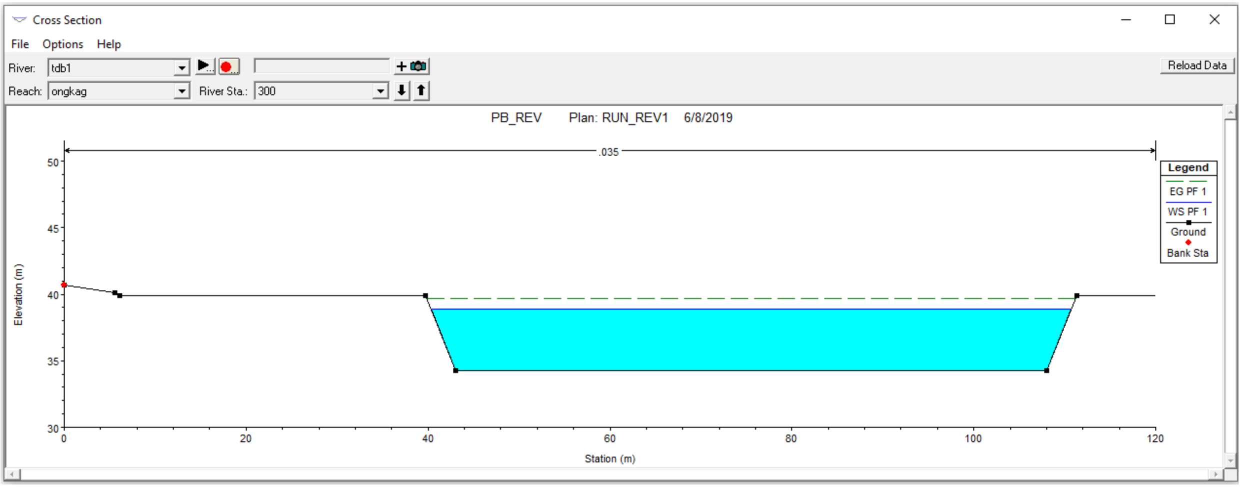

Fig. 22 High water mark at STA 300

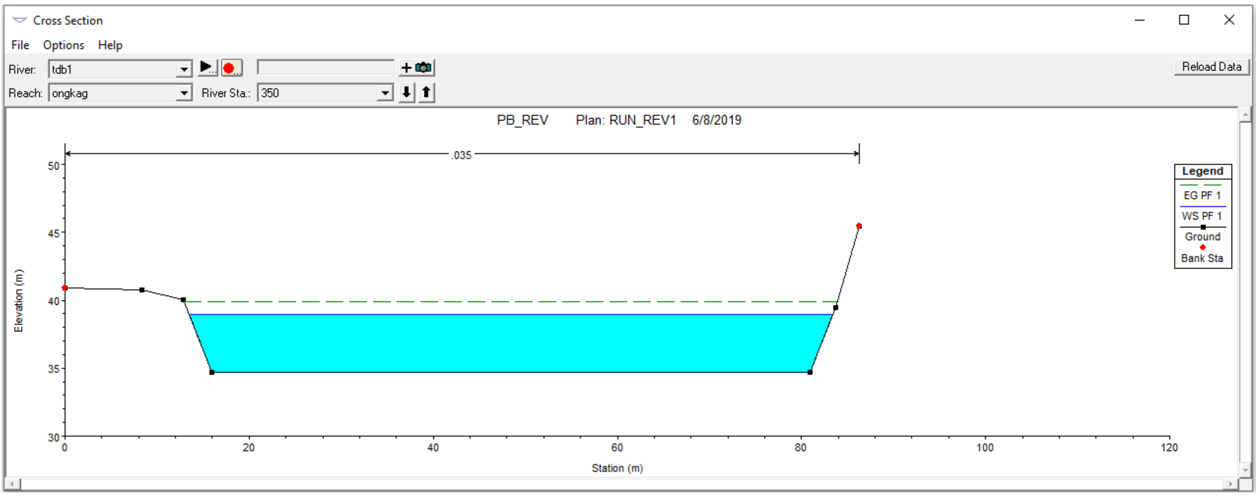

Fig. 23 High water mark at STA 350

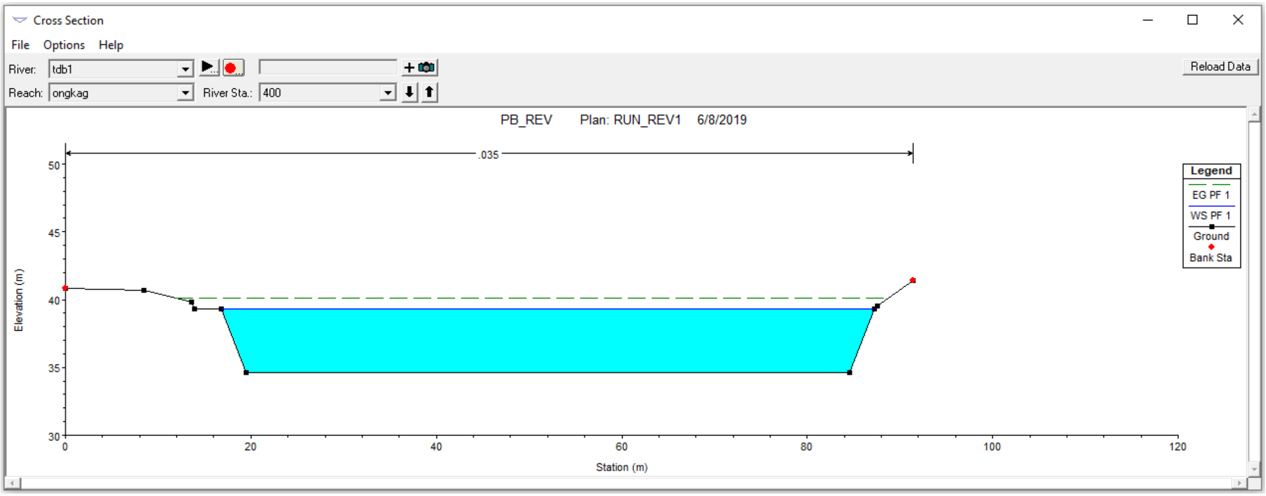

Fig. 24 High water mark at STA 400

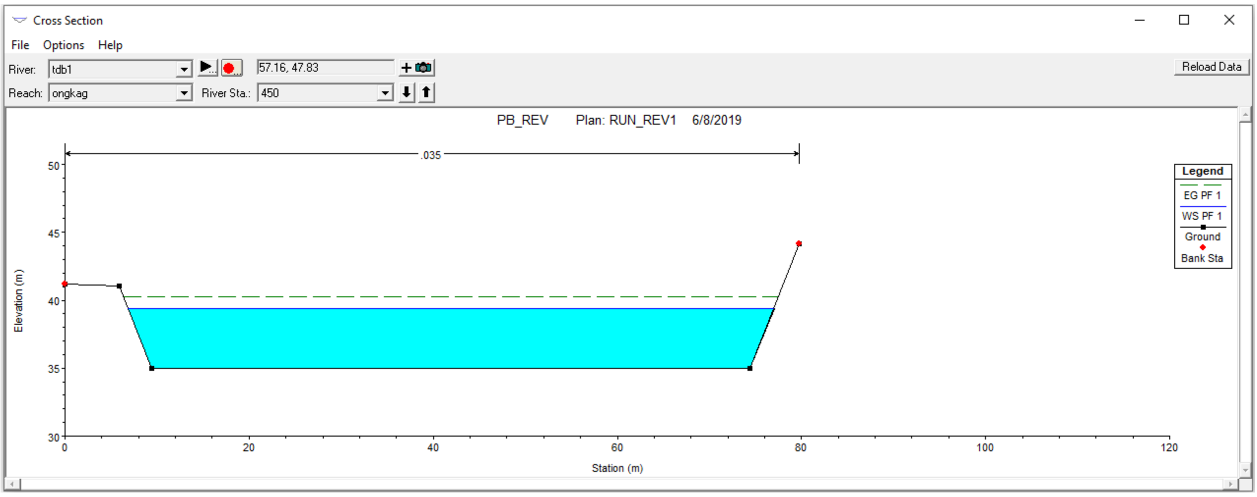

Fig. 25 Water level high at STA 450

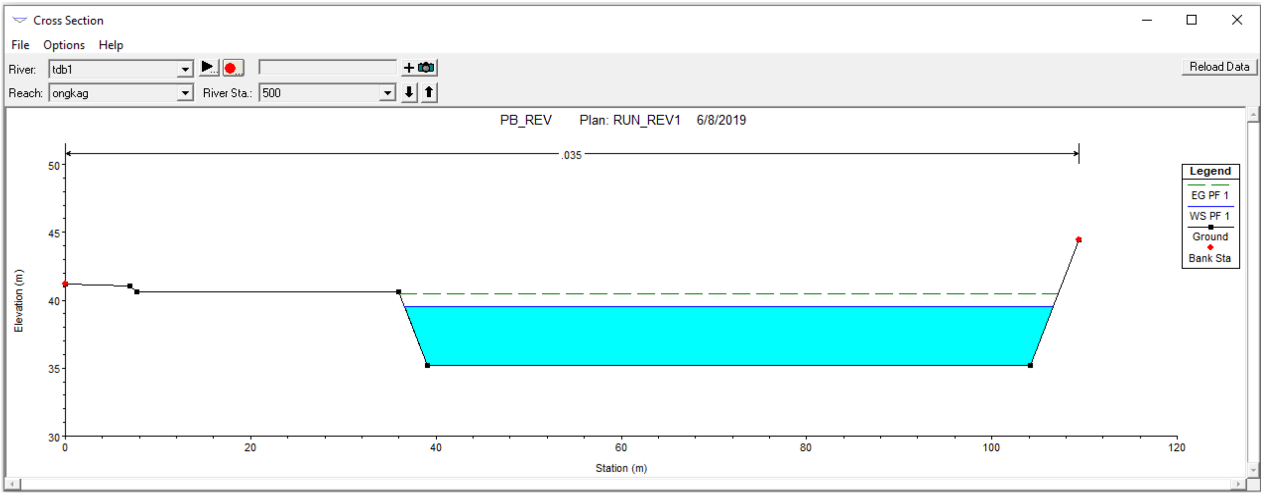

Fig. 26 Water level high at STA 500

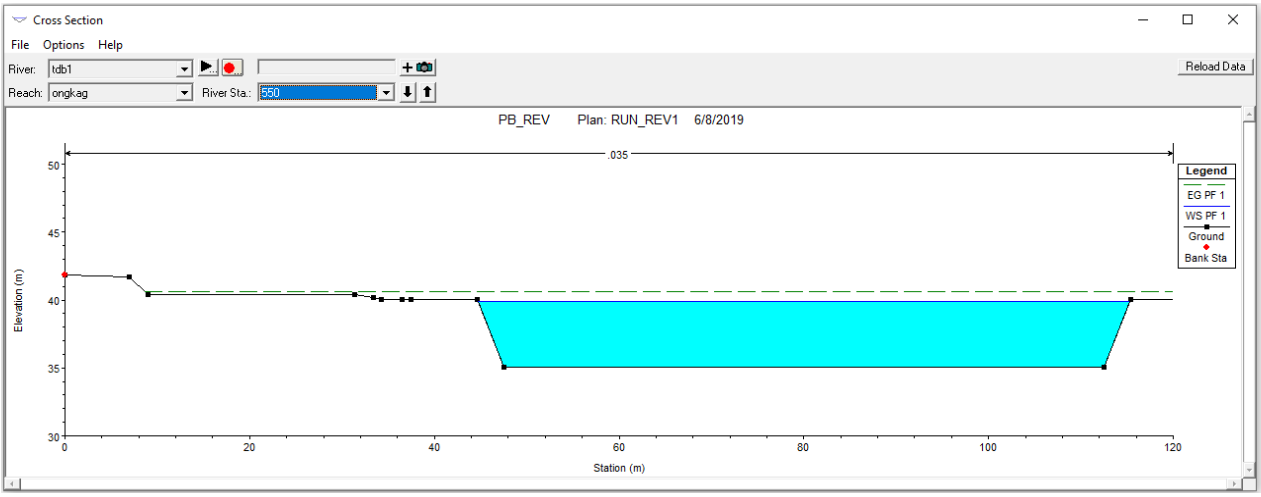

Fig. 27 Water level high at STA 550

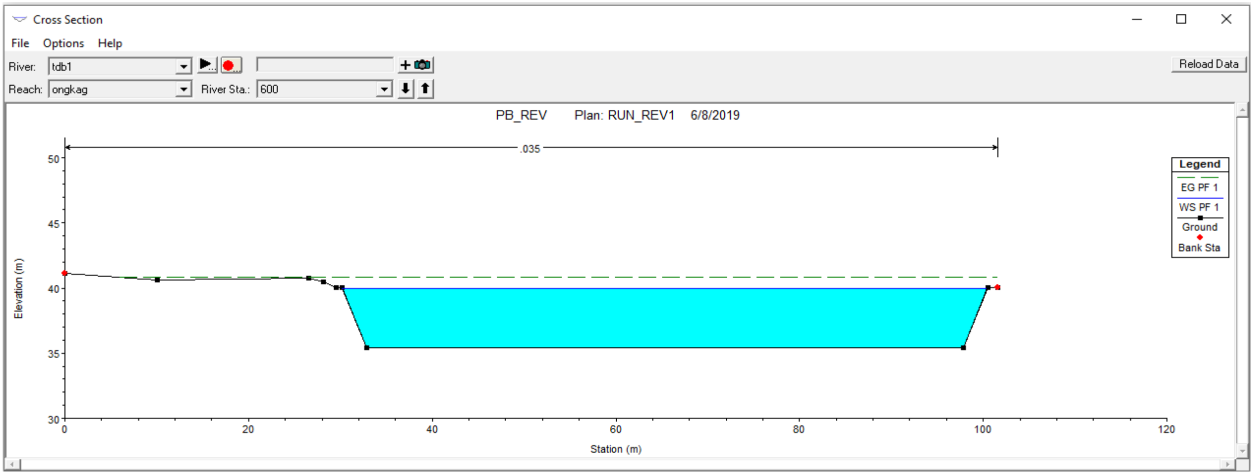

Fig. 28 Water level high at STA 600

5. Result and Discussion

We use hydraulic analysis to figure out how high and wide the flood water level will be by examining the shape of the river. During the computer simulation of water flowing out, the study found flooding in five different areas: STA 0, STA 50, STA 100, STA 150, and STA 200.

other statistics courses are available at our institution.

STA 600 only overflows in the area where STA 350 and STA 450 intersect. We need to make a new river shape to make the river hold more water. - The trapezoidal economic cross-section is employed to devise the design for the new river cross-section, utilizing a more specialized approach.

We studied the height and width of the flood water level and found that the new river can handle the amount of water that would occur during a simulated flood. The potential amount of material that can be taken out of a river quarry is measured by comparing the shape of the river before and after mining. We can observe differences in the height of the river bed and the amount of water between where people used to mine in the river and the way the river looks after mining.

5.1. Calculating the volume of leftover materials after mining, specifically sand and gravel.

We calculate how much sand, gravel, and river stones can be taken out of the Dumoga Ongkag River section after mining. We will calculate the size of each segment's hole and then compare the sizes of two segments' holes multiplied by the distance between them to find the volume of soil we need to dig.

After the mining process, we determine the quantity of sand, gravel, and river stone that can be extracted from the Dumoga Ongkag River portion. The size of the digging area in each segment will be determined by multiplying the segment's area by the distance between segments. We employ a meticulous methodology to ascertain the extractable reserves of sand, gravel, and river stones within the Dumoga Ongkag River section following mining activities. Our approach involves a precise assessment of the dimensions of individual excavation zones within each segment. By subsequently juxtaposing the magnitudes of these segmental excavations and multiplying them by the intersegmental span, we arrive at an accurate determination of the total soil volume necessitating excavation. Upon the conclusion of the mining endeavor, a comprehensive evaluation is conducted to delineate the quantum of sand, gravel, and river stones amenable to extraction from the designated tract of the Dumoga Ongkag River. This evaluation encompasses a systematic computation of the excavatable expanse within each distinct segment. This computation is achieved by the multiplication of the segment's surface area with the spatial gap between adjoining segments. The synergy of these parameters culminates in an exhaustive estimation of the material reservoir awaiting extraction.

6. Conclusion

The study of flood water flow calculates Snyder HSS flood water flow, which is used to determine how much water should be released during a controlled flood.

The measurements of how tall and wide the flooded water is can tell us how high the water is and how much it spills over the river. This information is collected for different parts of the river and is based on calculations for time periods of 25, 50, and 100 years.

Technical research is done to study the characteristics of a new river after mining. This research studies how high and wide the water level gets during a flood that happens once in a hundred years. The results of the research show that the water does not overflow in any part of the river.

The size of the river changes depending on the current conditions. We calculated that there is a possibility of finding sand, gravel, and stones that can be dug up. We found that there are 88,347. 42 cubic meters of materials in a 600-meter section of the river that can be extracted. Additionally, 13,89385 cubic meters of material are used to make the river wider and deeper.

When mining sand, gravel, and river stone, it is important to consider the technical studies that have been done in order to reduce any harm to the river.

To make the river wider, we should use the dirt we dig up from the river. The material scraps from Dumoga Ongkag mining should be sediment that did not originally come from the river. By delving into the dimensions of the inundated water body, one can discern not only its water level but also the extent of its spillover onto the surrounding terrain. This critical data is meticulously collected across various sections of the river, and its formulation is grounded in calculations spanning 25, 50, and 100-year intervals.

The realm of technical inquiry thrives as it examines the post-mining metamorphosis of rivers. This rigorous research scrutinizes the behavior of riverine entities during centennial floods, elucidating the upper limits of water level and width. The findings gleaned from these studies manifest in the assurance that no breach of riverbanks occurs even during extreme events.

A central tenet governing river morphology lies in its propensity for change contingent upon prevailing conditions. Rigorous computation has revealed a tantalizing prospect: the potential discovery of valuable sand, gravel, and stones nestled within its bed. Precise calculations unveil a substantial endowment of 88,347.42 cubic meters of extractable materials within a 600-meter span of the river. Further, an additional 13,893.85 cubic meters of material contribute to the augmentation of river breadth and depth. In the pursuit of sand, gravel, and river stone extraction, a paramount consideration is the harmonization with the findings of comprehensive technical analyses. This symbiotic approach underpins the preservation of the river's ecological integrity. The strategy to expand the river's width finds its foundation in a pragmatic resource: the soil unearthed during excavation. This organic integration of extracted material ensures a sustainable and functional expansion. Intrinsically tied to the ethical imperative is the requirement that remnants from Dumoga Ongkag mining constitute sediment that remains extraneous to the river's original composition. This conscientious delineation ensures the preservation of the river's intrinsic characteristics and resilience.

References

[1] Bambang Triadmodjo, Hidrologi Terapan, Yogyakarta: Beta Offset, 2008.

[2] Bambang Triadmodjo, Hidraulika II, Yogyakarta: Betta Offset, 1996. [Google Scholar]

[3] Chow Ven Te, “Hidrolika Saluran Terbuka (Open Channel Hydraulic),” Erlangga, Jakarta. 13, BMG Klas,1992. [Google Scholar]

[4] Chow Ven Te, Applied Hydrology, McGraw- Hill, 1988. [Google Scholar] [Publisher Link]

[5] Sri Harto Br, Analisis Hidrologi, Jakarta: Gramedia Pustaka, 1993. [Publisher Link]

[6] Kamase Malinda, Liany Amelia Hendratta, and Jeffry S. F. Sumarauw, "Analisis Debit dan Tinggi Muka Air Sungai Tondano di Jembatan Desa Kuwil Kecamatan Kalawat," Journal of Civil Statics, vol. 5, no. 4, pp. 175-185, 2017. [Google Scholar] [Publisher Link]

[7] Isri Ronald Mangangka, and Eveline Maria Wuisan, "Studi Pemanfaatan 'Constructed Wetland' (Rawa Buatan) Sebagai Komponen Eko- Drainase Sesuai Sifat-Sifat Hujan Di Wilayah Manado," Jurnal Sipil Statik, vol. 6, no. 1, pp. 35-46, 2018. [Google Scholar] [Publisher Link]

[8] Muhammad Erwin, "Police College Library (STIK)," Environmental Law: In the Environmental Development Policy System, 2008. [Google Scholar] [Publisher Link]

[9] Mahlon Marvin Kida et al., "Neural Network Based Performance Evaluation of a Waterflooded Oil Reservoir," International Journal of Recent Engineering Science, vol. 8, no. 3, pp. 1-6, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[10] Rahim F, Sistem dan Alat Tambang, Akademi Teknik Pertambangan Nasional Banjarbaru, Jakarta, 1995.

[11] Snyder F. F., SyntheticUnitgraph. Trans Am Geophis Union. Report Paper in Hidrolog, USA, 1938.

[12] C.D. Soemarto, Hidrologi Teknik Edisi Kedua, Jakarta: Erlangga, 1987.

[13] S. Soewarno, Hidrologi Aplikasi Metode Statistik Untuk Analisa Data, Nova Bandung, 1995. [Google Scholar]

[14] Victor Mockus, Section 4: Hydrology In National Engineering Handbook, Soil Conservation Service, 1972. [Google Scholar] [Publisher Link]

[15] Sudjarwadi, Dewan Riset Nasional,Kebutuhan Riset dan Koordinasi Pengelolahan Sumberdaya Air di Indonesia, Jakarta, 1990.

[16] Sukarno, Koefisien Limpasan DAS Simpang Lima Kota Semarang, Yogyakarta: Universitas Gajah Mada, 2000.

[17] Istiarto, Modul Pelatihan, "Simulasi Aliran 1 Dimensi dengan Bantuan Paket Program Hidrodinamika HEC-RAS," Universitas Gadjah Mada, Yogyakarta, 2014. [Google Scholar]

[18] Feri Fadlin et al., "Spatial Modeling for Flood Risk Reduction in Wanggu Watershed, Kendari," International Journal of Engineering Trends and Technology, vol. 70, no. 12, pp. 219-226, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[19] Kairupan C. Reynaldo, Tiny Mananoma, and Jeffry S. F. Sumarauw, "Pola Distribusi Hujan Jam-jaman Wilayah Bolaang Mongondow,"Jurnal Tekno, vol. 15, no. 68, pp. 109-111, 2017. [Google Scholar] [Publisher Link]

[20] Welliang Aditya Hadipradana, Jeffry S. F. Sumarauw, and Tiny Mananoma, "Analisis Debit Banjir Dan Tinggi Muka Air Sungai Lombagin Kabupaten Bolaang Mongondow," Jurnal Tekno, vol. 17, no. 71, pp. 100-109, 2019. [Google Scholar] [Publisher Link]

[21] N. Shaina Beegam, G Prince ArulRaj, and J Brema, "Effect of LULC on Ordinates of Unit Hydrograph of Muvattupuzha Sub Basin,"International Journal of Engineering Trends and Technology, vol. 69, no. 4, pp. 94-99, 2021. [CrossRef] [Publisher Link]

[22] E.M. Wilson, Hidrologi Teknik, Penerbit ITB, Bandung, 1993.

[23] R.L. Brass, Hydrology: An Introduction to Hydrologic Science, Addison-Wesley Publishing Company, 1990. [Google Scholar]

[24] R.K. Linsley, M.A. Kohler, and J.LH. Paulhus, Hidrologi untuk Insinyur, Jakarta: Erlangga, 1989. [Google Scholar]

[25] Hydrologic Engineering Center, HEC-RAS River Analysis System 5.0.7 Reference Manual, U.S Army Corps of Engineers, USA, 2019. [Publisher Link]

[26] Hydrologic Engineering Center, HEC-HMS V4.7 Technical Reference Manual, U.S Army Corps of Engineers, USA, 2020. [Publisher Link]

[27] Victor Miguel Ponce, Engineering Hydrology, Principle and Practices, vol. 640, Englewood Cliffs, Prentice Hall, 1989. [Google Scholar]

[28] Jeffry S. F. Sumarauw, Sisca V. Pandey, and Hanny Tangkudung, “Analysis of Water Level of Binjeita River for Several Return Periods of Flood,” SSRG International Journal of Civil Engineering, vol. 9, no. 11, pp. 33-42, 2022. [CrossRef] [Publisher Link]