Determination of Tolerance Limits for Mining of Sedimentation Processed Sirtu Material Using the Cross-Section Method in the Panteu Bahagian Hulu River, Tangse District, Pidie District, Aceh Province, Indonesia

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Abstract. The growth and development of increasingly advanced development have significantly impacted the need for raw materials for sand and stone. To control the utilisation of natural resources and maintain environmental balance, especially in river areas, assessing the tolerance limit for mining sand and stone or sirtu materials is necessary. The method used in this study was a cross-section carried out using Autocad software, bearing in mind that many disasters result from changes in river morphology due to erosion in the upper reaches and their activities. This study aims to determine the amount of deposition volume so that thresholds or tolerances for sirtu mining can be determined which are environmentally friendly and minimise the impact on rivers, which causes further damage. The area calculated in this study is 7 ha hectares. Calculation of the results of the tabulation of calculations with the cross-section method at the study site as many as 19 cross-section incisions with incision intervals of 25-50 meters. This effort is a form of environmental assessment management related to the tolerance limits of the volume of sand and stone or sirtu mining. The calculations found that the mining tolerance limit for sand and rock sedimentation (sirtu) in the study area was 149,989 m^3. These data indicate that the accumulated sedimentation rate is high in the part of the river that is the location of this study. Thus, if the use of natural resources in the form of sand and stone at that location exceeds the tolerance limit from the results of this calculation, it is estimated that it will impact environmental damage and disrupt river conditions in the area.

Keywords: Panteu Watershed; Sirtu Sedimentation; Mining Tolerance Limits.

INTRODUCTION

Sand is a valuable mineral needed by the broader community on a large scale, such as in the construction of modern roads, bridges and dams, as well as in agriculture and other industries [1]. Sand and gravel (cirrh) are natural granular materials of rock and minerals split into fine particles under weathering and abrasion. The accumulation of sand as a layer in the river is a dynamic phenomenon. Sand is essential for the existence of rivers. Riverbeds, streams, channels, and beaches are excellent sources of sand. As a resource, sand is, by definition, 'loose soil, an incoherent mass of mineral matter and a product of natural processes [2].

Sand has become an essential mineral for the world's population because of its many uses. Sand and gravel have long been used as road and building construction aggregates. The demand for these materials is steadily increasing worldwide, especially in emerging developing countries (such as China, India, and Vietnam), due to rapid economic development and the subsequent growth of development activities [3]. In developing areas, the need for sand-concrete construction is higher than usual. In addition,

sand is used industrially as a raw material for making glass. Because of the increased effective demand, sand is over-extracted at different depths, varying from three to forty feet from various streams and basins [2]. Due to the abundant sand and gravel reserves in the upstream areas due to erosion, sedimentation, and easy transportation access, most sand and gravel mining is carried out along the river waters [3].

The river is a medium for material sedimentation in the form of erosion, which can cause silting and changes in river flow patterns. The hydrological theory explains that the higher the discharge value and the lower the water velocity, the higher the sediment load deposited in the downstream area. The action involves the normal processes of erosion, transport and sedimentation along the river [4]. With the intense urbanisation and economic development, the construction industry is fueling the demand for sand and gravel [5]. River sediments usually contain large quantities of high-quality sand that can be used in the construction industry. Thus, commercial sand mining activities have increased along the river banks [6].

River and river ecosystems supply boulders, gravel, and sand for construction activities [7]. According to [8], the process of sand mining hurts lakes and rivers, enormously damaging river morphology using intensive sediment agitation, increasing channel capacity and reducing the elongated slope of river beds, increasing water depth, thus changing chemical, physical and biological properties of the aquatic environment [8]. Environmental problems associated with legal and illegal sand mining in China have been widely reported. Authors [9] proposed that illegal sand dredging significantly alters the balance of sediment inflow rates in Poyang Lake because of the high economic benefits. Meanwhile, Duan et al. (2019) found that illegal sand mining activities were frequent in Hongze Lake, and high concentrations of suspended particles mainly correlated with sand mining activities [10].

However, several other opinions suggest that sand and stone mining in the river also positively impacts opening up employment opportunities and increasing business opportunities in the surrounding area [11]. It is also a PAD (Regional Original Revenue) source from the non-metal and rock tax revenue sector [1]. Sand and stone mining activities can also economically benefit the

country and society, especially in developing countries [12]. Mining sand and stones in the river is further considered a source of income and livelihood for the various people involved, including the government, in the form of royalties or taxes. Miners, boatmen, drivers, truck owners, brick and block makers, among others, rely on mining activities for the livelihood of many people [13].

The main concern in aggregate (sand and rock) mining is the proper management of mining operations, a significant challenge watersheds face. Appropriate and timely management of mining operations and adequate selection of mine sites contribute significantly to river improvement [14]. In most countries, indiscriminate river sand and gravel mining causes irreparable damage to river ecosystems, including river basins and floodplain areas. Therefore, the healthy and safe operation of the river ecosystem needs to ensure that the surrounding ecological environment is not affected by sand and gravel mining [12].

On the other hand, proper management of aggregate mining from the river contributes to favourable environmental conditions along the river. Flow and discharge patterns strictly affect river mining aggregates. In addition, the mining method (scarping, dredging, or pitting) must be determined based on the hydraulic and morphological conditions of the river. The selection of mining sites is also essential [14].

The Panteu watershed is one of the aggregate sources of sand and stone materials in the Pidie district. Data on the amount of sand and stone aggregates along the river basin of the Panteu watershed needs to be available. However, it is generally known, and monitoring data from the Aceh Provincial Energy Mining Service (Distamben) shows that the Panteu watershed is one of the potential sources of sand and stone material in the Pidie region. Where along the course of the river, especially at the focus point of this research location, which is in Tangse District, there are several potential points of sand and odour material from the river sedimentation process, which has the potential to be mined to supply material for physical development activities that are taking place around the area.

This research provides a middle way and sustainable policies for mining efforts and protecting river environmental conditions by setting a tolerance limit for the amount of material

that can be taken from the river so that physical and ecological development can be sustainable in harmony. This study aims to determine the volume of sedimentation from sand and new so that thresholds or tolerances for mining sand and stone (sirtu) can be determined at the study site. Calculation of the total volume using the Cross Section method,

Predicting the natural equilibrium cross-section of a river has been of interest to many researchers for a long time. This equation is also derived via an extreme hypothesis approach based on maximising (or minimising) some channel functions [15]. Examples in this sense include optimising the capacity of sediment volume calculations (in the form of sand and new at the point of the research location in the upstream Panteu watershed) for determining the tolerance limits for sand and rock mining to minimise the impact of environmental damage due to the uncontrolled use of natural resources.

METHODS

Place and time of research. The research location is Alue Calong Village, Tangse District, Pidie District, Aceh Province. The location of this research is part of the Panteu watershed area, which flows towards the Keumala River. Calculate the sedimentation volume at the study site using spatial data analysis with image map interpretation and field observations. The area calculated in this study is 7 hectares.

Field data collection was carried out from August to September 2022. The primary data collection method in the field used a theodolite measuring instrument to determine the river's morphology and obtain initial data to be used later to calculate sedimentation volume.

Spatial data analysis is used to produce topographic maps using image map data. The volume of sedimentation is calculated using the cross-section method using a theodolite. From the data taken from the field, the total volume of each cross-section will be calculated to obtain the total sedimentation volume at the study site. The research location is shown in Figure 1.

Tools and materials. Several tools are needed to calculate the total sedimentation volume in this research. Some of the equipment used is: Topographic Map Scale 1: 10,000; Garmin Montana 650 GPS; Topcon theodolite DT-200

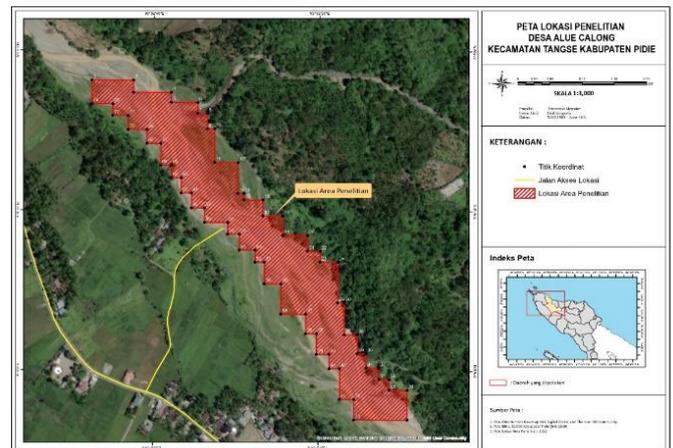series; Stationery; Computer/Laptop devices; Autocad Land Desktop software2009.

Figure 1 – Research Location in Alue Calong Village, Tangse District, Pidie Regency

Data collection. Field primary data collection begins with taking the coordinates of the tie points as a reference in making measurements, using a Garmin Montana 650 series handheld GPS handheld, followed by topographic mapping activities with the help of the Theodolite Topcon DT-200. The sedimentation volume calculation method used is the cross-section method. After the field data has been completed, it is continued with data processing using the AutoCAD Land Desktop 2009 software.

In addition to primary data, this research is also assisted by secondary data obtained from the Sumatra 1 River Region Office, which uses Pidie data in the 2021 version.

Sedimentation Volume Analysis. Sedimentation volume analysis was obtained from field data measurements, which were then overlaid with the Google Earth Pro image map to obtain data on the volume of sirtu material deposition in the study location (Figure 2).
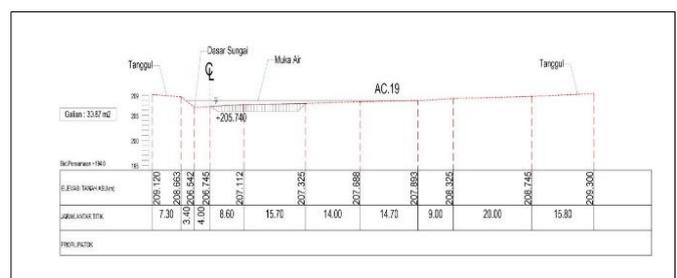

Figure 2 – Cross Section Method Pattern

RESULTS AND DISCUSSION

Overview of Research Locations. The Panteu Watershed in Tangse District, Pidie Regency, has a fluctuating discharge every year. Even though the flow of the Panteu River decreases during the dry season, the discharge increases sharply during the rainy season. It sometimes overflows to the boundaries of the villages it crosses. Coupled with the presence of sediment deposits, especially in coastal areas, thus increasing the river floor's height, there has been silting due to sedimentation. This indirectly reduces the capacity of the river to accommodate the peak load of water discharge.

The morphology of the Panteu River has widened in several places and narrowed at other points, showing that it is affected by structural processes. In some parts of this river, abundant reserves of sand and stone (sirtu) originate from the sedimentation process.

Sediment deposition at the bottom of the river can be used for mining sand and stone or sirtu. There are several potential locations for sirtu mining, one of which is the location of this study, which is in the village of Alue Calong, Kec. Tangse. The area to be calculated in this study is 7 ha, as shown in Figure 1. From the overlay with the Regency Spatial Planning, the research location, which is a potential source of sand and stone mining, is in the APL (Other Use Area), meaning that this location is in an area where it is possible to obtain a mining permit because it is not in a conservation area or protected forest. Further research locations after being overlaid with the RTRW Map of Pidie Regency 2012–2032 can be seen in Figure 3.
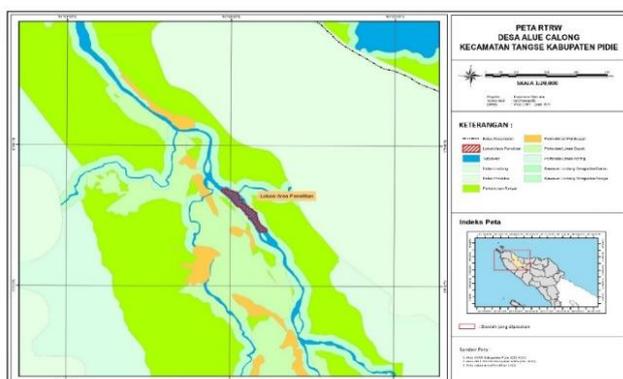

Figure 3 – Directional Map of Area Functions Based on RTRW of Pidie Regency 2012–2032

Based on Minister of Energy and Mineral Resources Decree No. 1827.K/30/MEM/2018 Appendix II Guidelines for Mining Technical management Point C Item 3, Mineral and Coal Reserves are part of the Indicated and/or measured confidence degree Resources that have been evaluated economically, technically, environmentally and legally declared mine worthy. Cross-section calculation results are shown in Table 1.

Table 1 – Tabulation of Method Calculation Results Cross Section at the Research Location

NO	PATOK	X.Y	LUAS	LUAS RATA-RATA (M2)	JARAK (M')	VOLUME (M3)
1	AC.1	0+000	33,85			
				68,79	30	2063,66
2	AC.2	0+030	103,72			
				95,87	50	4793,35
3	AC.3	0+080	88,01			
				109,16	50	5457,80
4	AC.4	0+130	130,30			
				169,95	50	8497,56
5	AC.5	0+180	209,60			
				198,45	50	9922,50
6	AC.6	0+230	187,30			
				191,87	50	9593,34
7	AC.7	0+280	196,43			
				152,37	50	7618,28
8	AC.8	0+330	108,30			
				172,87	50	8643,46
9	AC.9	0+380	237,44			
				175,03	50	8751,66
10	AC.10	0+430	112,63			
				183,03	50	9151,37
11	AC.11	0+480	253,43			
				276,54	50	13827,19
12	AC.12	0+530	299,66			
				294,53	50	14726,71
13	AC.13	0+580	289,41			
				263,46	50	13172,90
14	AC.14	0+630	237,51			
				206,88	50	10344,21
15	AC.15	0+680	176,26			
				157,66	50	7882,81
16	AC.16	0+730	139,05			
				136,22	50	6810,98
17	AC.17	0+780	133,39			
				133,51	50	6675,27
18	AC.18	0+830	133,62			
				82,25	25	2056,14
19	AC.19	0+855	30,87			
			SUB TOTAL		855	149989,199
		SUB TOTAL GALIAN SIRTU			855	149989,199

Sedimentation Volume. This method assembles incision lines that cut the topography of a specific boundary and follow the direction of propagation of rock and sand deposits, then arranges them on a topographic map and obtains a floor plan drawing of the sand and rock deposit cross-sectional model and the topographical shape. The surface area of each part of the sandstone deposit model is calculated, and finally, the volume is found by multiplying the distance between the sections. In constructing these sections, straight lines are drawn from predetermined separation points, following the direction of distribution of the sandstone-rock deposits. The results of calculating the cross-sectional method for the study area are shown in Figure 4.
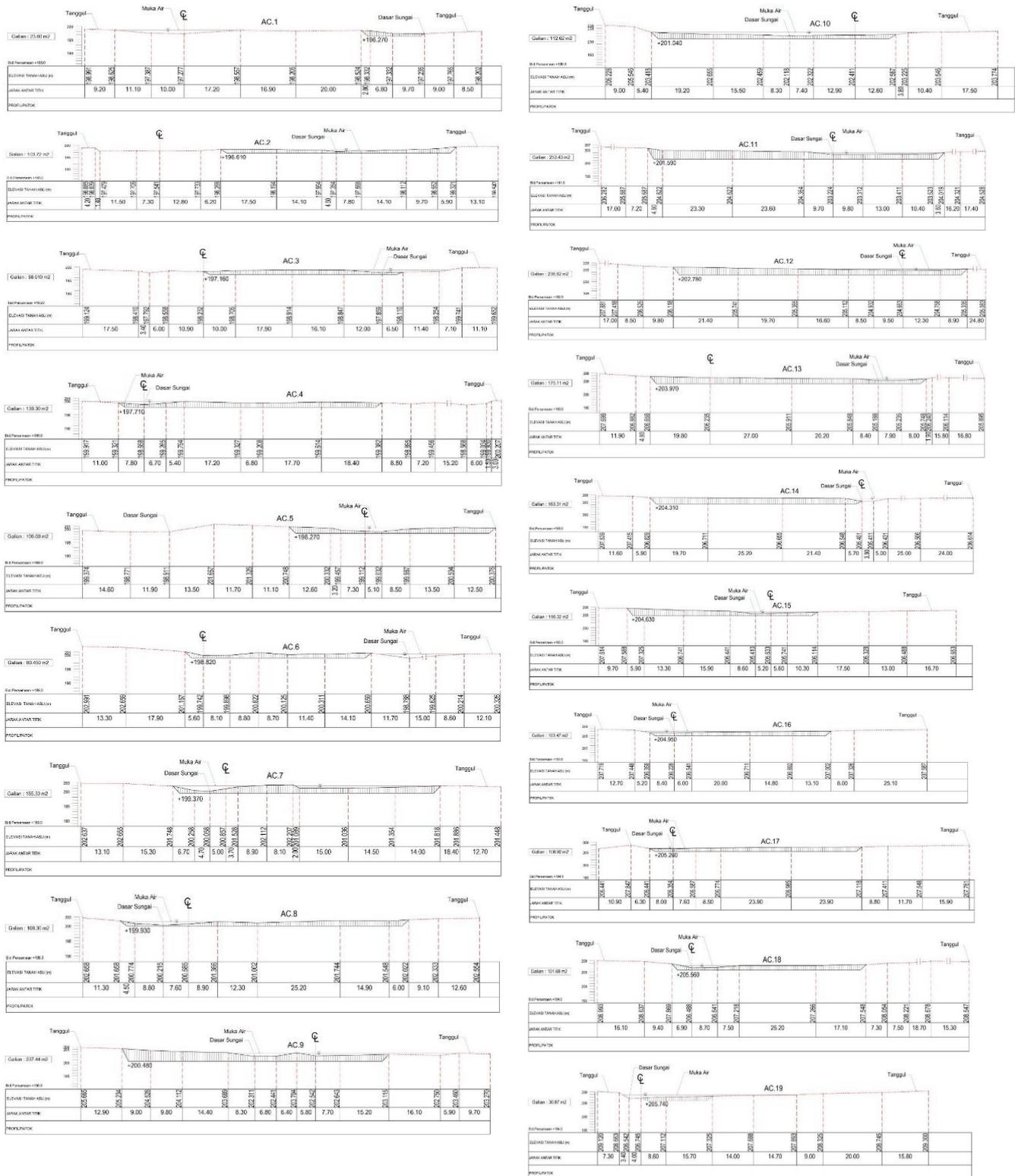
Figure 4 – Results Sketch Location of Results Incision in Auctocad

At least 19 cross-section sections have been previously measured in the field. Then, the results of calculating the incisions were carried out using Autocad software in the shaded research area. The results of each shading area's calculation show a difference in the amount of rock sand reserves (stone). The total results from the

tabulation of the results of each section can be seen in Figure 5 and Table 1.

The distance between the sections is 25 to 50 meters, and several sections are made from the determined boundary point to the potential area following the direction of gravel deposit propagation. Once the sections are completed, the total cross-sectional area can be calculated using

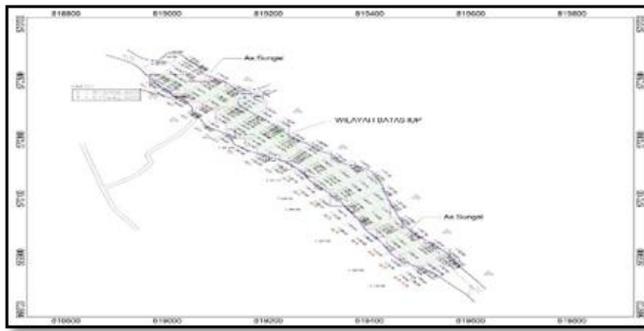Autocad software to determine the volume and tonnage of rock sand.

Figure 5 − Combined Cut Results from Calculations Cross Section Method

Estimating rocky sand reserves using the cross-sectional method involves calculating the area of each cross-section perpendicular to the river contour. This calculation relies on a particular sandstone cross's thickness, length, density, and distance between cross-sections. The results of assessing rock sand reserves using the cross-sectional method using the gradual change rule guidelines are presented in Table 1.

Determination of Mining Tolerance Limits. Sand and gravel (collectively called aggregate) are the materials most needed by the world's population [16]. This material is the main foundation of our economy and is integral to sectors such as construction, infrastructure, electronics and others [17]. The increasing need to protect the world's coasts to help mitigate climate change [18] also added to the pressure on the world's sand resources. With increasing consumption, we are rapidly approaching the point where natural sand and gravel demand will exceed natural levels [19].

Based on the tabulated calculation results with the cross-section method at the research location, the volume of the calculation of sedimentation reserves for sand and stone (sirtu) is 149,989 m³. These data indicate the accumulated sedimentation rate in the river section, which is the location of this study.

Based on the river patterns in this study, a matrix method is proposed to evaluate the aggregate mining potential and determine the most appropriate method for mining operations. Determining the right location for mining, efficient mining methods, and the right season

and time for mining operations are the main challenges that must be overcome to reduce the negative impact of mining on rivers [14].

The results of this calculation provide an overview of the tolerance limits that can be mined at the research location. This can reference the tolerance limit for the amount of sand and rock resources that can be mined within controlled limits to utilise natural resources and suppress the potential impact of further environmental damage. This tolerance determination limit helps maintain ecological balance so that the river flow is in place and damage does not damage the left and right natural dikes.

Suppose the utilisation of natural resources in the form of sand and stone at that location exceeds the tolerance limit from the results of this calculation. In that case, it is estimated that it will impact environmental damage and disrupt the condition of the river in that area.

CONCLUSIONS

The results of volume calculations on the details utilising the cross-section method at the research location found 149,989 m3 of rock sand reserves. In these river systems, eroding (mining) the exposed land in the active floodplain is advisable. Suppose enough gravel is not available in the active floodplain. In that case, gravel extraction activities at this location should be done by open pit mining or scrapping methods according to the required aggregate.

Some factors affecting rock sand reserve estimation are accuracy, incision placement, and error rate. Sedimentation that occurred on the Panteu River in Alue Calong village in Tangse District has silted up the river; sedimentation results can be used for development activities by following the tolerance limits generated through research activity so that environmental balance control, especially in rivers, can be maintained.

The use of Autocad software requires a high computer processor capability. It is recommended that data processing be carried out on a computer with better capabilities. Another area for improvement of the cross-sectional design is that it cannot explain the processes in the items/variables studied and their correlations. At the same time, the benefits are realised relatively quickly. Researchers can collect all the variables at once. Several results can be

examined at once. Prevalence for all factors can be measured. Those interested in Cross Section can study it through guidebooks and tutorials already widely available in libraries, especially engineering faculties, and various online document sources.

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