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Galala Bridge Scour Model on Ambon's Way Ruhu River

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***Keywords*— Sccour, Contraction, Pier, Abutment, River**

***Abstract*— *The scouring that occurs on the abutments and pillars of the bridge is total scour, which is a combination of local scour and general scour. It can also be a combination of localized scour, generalized scour and localized scour / constriction scour. Bridge collapses are often the result of scouring. The potential for flooding can increase riverbed degradation, riverbed degradation and local scouring, which adds to the threat of bridge sub-structures. The galala bridge islocated in the lower reaches of the Way Ruhu river with a stretch length of 60 m. Physically, this bridge has been built for a long time so it needs to be evaluated for scour depth by mathematical modeling using the HEC-Ras 6.4.1 application. Scour modeling uses the CSU method and the Froechlich method. Based on the simulation results using three flow conditions against the 10, 25 and 50 year recurrence periods and using physical properties test data (grain size analysis, specific gravity test, and soil content weight test) from the Ambon State Polytechnic Material Test laboratory from soil samples around the Way Ruhu estuary showed that the scouring depth reached the base of the bridge, 2.00 m so that this scouring could affect the stability of the bridge and potentially collapse the bridge based on simulation with flood discharge plan 25 years.*

I. INTRODUCTION

A river is a channel of water that forms naturally on the face of the earth that flows from springs to its flow area according to the conditions of the earth's surface which eventually leads to the lowestarea. Water that flows continuously in the river willresult in the erosion of the bottom soil, continuous scouring forms scouring holes in the river bed. Theexistence of water buildings causes changes in flowcharacteristics such as speed and turbulence, causing changes in sediment transport and scouring. While *scouring* is a natural process that occurs in rivers due to the influence of river morphology, it can be in the form of bends or narrowing parts of river flow and can also be due to water buildings (*hydraulic structures*) such as bridges.

The scouring that occurs on the abutments and pillars of the bridge is total scour, *which is a combination of local* scour *and* general scour. It can also be a combination of localized scour, generalized scour and *localized scour / constriction scour*. Local scouring that occurs around bridge or pillar abutments is caused by a *vortex system* due to disturbances in flow patterns due to obstacles, and localized scouring occurs due to narrowing of the river cross-section by the placement of hydraulic buildings. This scour process can cause erosion and degradation around the *water way opening* of a bridge. This degradation continues continuously until a balance between sediment supply and transport is achieved. If the supply of sediment from upstream is reduced or the amount of sediment transport is greater than the supply of sediment, it can cause a very striking gap betweendegradation and degradation at the base location ofthe bridge waterway.

II. LITERATURE REVIEW

The process of erosion and deposition in rivers generally occurs due to changes in flow patterns, especially in alluvial rivers. Changes in flow patterns can occur because there are obstacles or obstacles in the flow of the river. According to Raudkivi and Ettema (*Rinaldi, 2002*) the types of scour are as follows:

(1) *General scour* in river channels;

(2) Scour is localized in the river channel;

(3) Local scour around the building.

Local scour includes general scouring types and scour that occurs due to narrowing of the flow. Studying the scour process, it cannot be separated from studying the characteristics of existing sediments. The purpose of sediment transport is to determine whether under certain circumstances there will be *equilibrium*, erosion, or depostition and determine the quantity transported in the process. If the structure is placed in a water current, the flow of water around the structure will change, and the *vertical velocity gradient* of the flow will change to a *pressure gradient* at the end of the surface of the structure. This pressure gradient is the result of the underflow hitting the bottom of the channel. At the base of the structure, this lower flow forms a vortex that eventually sweeps around and the bottom of the structure by filling the entire flow. It is called the horseshoe vortex (Miller, 2003). On the surface of the water, the interaction of flow and structure forms a *bow wave* called a *surface roller*. When there is a separation of flow in the inner structure experiencing wake vortices.

2.1 Scour on the Bridge

Scour is the process of loss of sedimentary materialfrom the bottom and banks of rivers caused by thegrinding power possessed by the flow of water. Themost common cause of bridge failure is a large amount of riverbed material that is eroded andcauses degradation of the riverbed around the bridge foundation. This failure is caused by:

- Lack of knowledge about the scouringphenomenon during bridge construction.
- Lack of data and knowledge regarding floodplans.
- The rate of scour generally depends on:
- Water flow strength, material resistance, andin/out sediment balance (*equilibrium scour*).
- Material piled up due to riprap failure or cliffsaround the river.
- Erosion and failure of dikes with flows formedon two sides of the abutment.

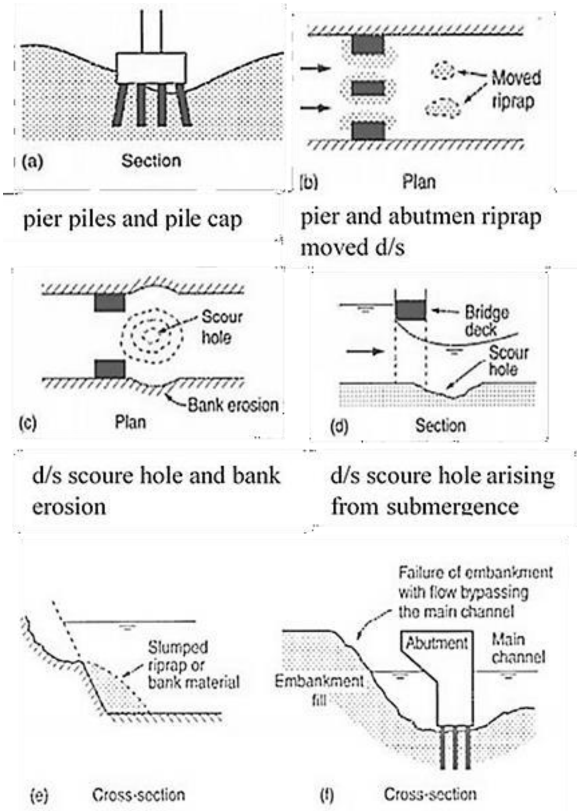

Fig.1 Scour on the Bridge

1. General scouring in river channels, is not related at all to the presence or absence of riverbuildings.
2. Local scouring in the river channel, occurs dueto the narrowing of the river flow to be centralized.
3. Local scouring around buildings, occurs due tolocal flow patterns around river buildings.

Scour of types (2) and (3) can then be divided into scouring with clean water (*clear water scour*) and scouring with sedimentary water (*lived bed scour*). Scour with clean water relates to a situation when the river bed upstream is stationary (no material is transported). While scouring with sediment occurs when flow conditions in the channel cause the base material to move. To determine flow conditions including clear-water or live-bed, the equation given by Neill (1968) below is used, for unobstructed river flow.

$$Vs = 1.58[(Ss-1)gD50]^{\frac{1}{2}}(\frac{y}{D50})^{1/6} \qquad (1)$$

With SS = 2.65 (specific attraction for sediments), g = 9.81 m/s2 , D50 is the mean diameter (m) of sediment grain size 50%, Y = average depth (m) upstream. The above equation becomes.

$$V_S = 6{,}36\ Y^{1/6}\ D_{50}^{1/3} \qquad (2)$$

During one flood period, the average speed will increase or decrease as the outflow of water also increases and decreases, so it is possible for the initial conditions to be clear water *then* live bed *and finally clear water again.*

2.2 Local scour (pillars, abutments)

Local scouring results from increased currents passing under bridges and turbulent flows formed by river banks. Local scour occurs at a flow velocity when the transported sediment is greater than the sediment supplied. Sediment transport increases with increasing sediment shear stress andscouring occurs when flow conditions change causing an increase in base shear stress.

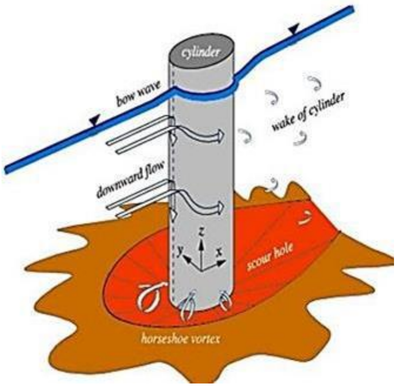

Fig.2 Local scour mechanism

The depth of scour on the pillars, the intensity depends on the flow, bottom sediments, and geometric disturbances of the bridge pillars. Scouraround the pillars begins to occur when the base material begins to move. Particles undergo erosionfollowing the direction of flow starting from the upstream to downstream of the pillar. The base material will continue to be eroded, and if the flowspeed increases, the size and depth of scour also increase.

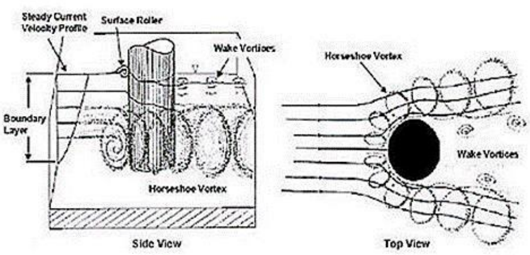

Fig.3 Scour Mechanism due to water Flow Pattern around Pillars

2.3 Rainfall frequency analysis

Rainfall analysis needs to be done to determine the maximum height of river water discharge so that the maximum flood height can be determined. Themaximum flood height is used to find the height ofthe bridge from the maximum flood water table, abutment height, and bridge span length.

The data used in the plan's precipitation analysis isthe average daily maximum rainfall intensity taking into account the dispersion of hydrological variables located or equal to their mean values, butthere may be values greater or smaller than their mean values. In flood estimation, it is necessary toestimate rain in advance which is called plan rain and flood estimation is also called plan flood. In flood estimation, the required parameters are Catchment Area area, rain plan height and flow coefficient.

2.4 Flow Coefficient

This drainage coefficient depends on the land use in the flow area. In this study the runoff coefficient must be adjusted to the development of the city, forthat the planned land use will be used in accordance with the applicable spatial plan land use directives.Each type of land use has a drainage coefficient (C)which is based on the allotment function and building density.

$$C = \frac{Runoff\ (mm)}{Curah\ Hujan\ (mm)} \qquad (3)$$

III. METHODOLOGY

To determine the natural phenomena that occur due to erosion of water flow at the base and cliffs of alluvial channels. So a mathematical model simulation was made using the HEC-RAS 6.4.1 device to find out the scouring that occurred. This application also provides the results of the process of decreasing piers and abutments to the riverbed below the natural surface elevation (*datum*) due to the interaction between the flow and the riverbed material.

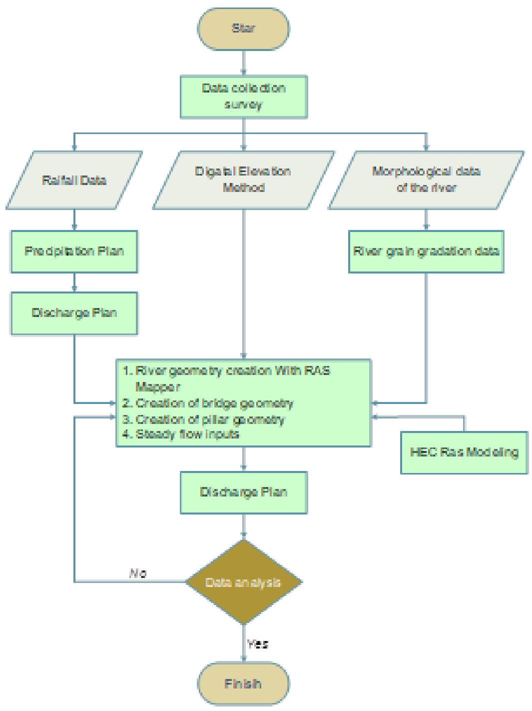

Fig.4 Research flow chart

Fig.5 Study location

IV. RESULTS AND DISCUSSION

4.1 General State of Location

Way Ruhu watershed is located in the Great Watershed of Way Batu Merah with the area of Way Ruhu watershed is 1,629 Ha and is located in Sirimau District of Ambon City which is located in 4 villages namely Batu Merah, Galala, Hative Kecil and Halong.

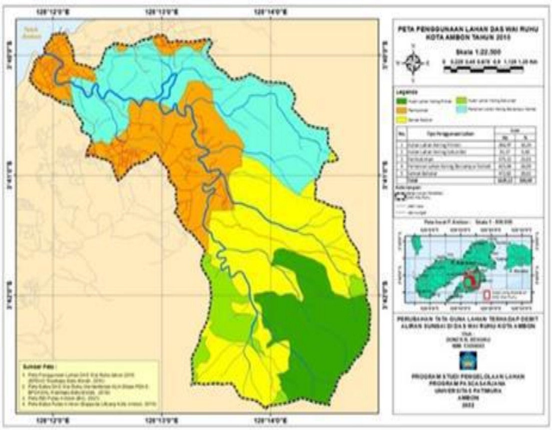

Fig.6 Map of Way Ruhu Watershed AmbonCity

4.2 Land Use

The factor of vegetation land cover is quite significant in reducing or increasing surface flow. Dense forests have a high level of land cover, so if rain falls on the rain area, this land cover factor slows down the surface flow speed, and can even occur near zero speed. The area of the Way Ruhu watershed is greater than 2000 Ha, based on research plans for land use in 2023 as shown in the table below.

Table 1 Land cover in 2023

Land Cover	2023			
	Area (Ha)	(%)	(C)	A x C
Primary Dryland Forest	264.97	16.26	0.3	79.49
Secondary Dryland Forest	187.33	11.50	0.35	65.57
Residential	393.89	24.18	0.25	98.47
Dryland Farming Mixed with Shrubs	379.07	23.27	0.7	265.35
Shrubbery	372.65	22.87	0.3	111.80
Savanna/Grassland/Empty Land	31.31	1.92	0.1	3.13
Total	1629.22	100.00		0.38

4.3 Discharge Frequency Analysis

Analysis of the frequency of discharge is carried out to determine the amount of discharge that occurs in a certain repeat period. Discharge frequency analysis includes determining the type of discharge distribution, then calculating the amountof discharge based on the repeat period using an equation corresponding to the type of distribution.The type of discharge distribution depends on the value of statistical parameters, namely the mean (*X*), standard deviation (*Sd*), coefficient of astonishment (*Cs*), coefficient of variation (*Cv*) and coefficient of curtosis (*Ck*).

Table 2. Distribution Selection Requirements

No	Distribution Type	Available	Calculations	Summary
1	Normal	CS ≤ 0 CS =	2.207	Not compliant
		CK = 3 CK =	-1.43	Not compliant
2	Log Normal	CS = 1.137 CS =	2.207	Not compliant
		CV = 5.383 CK =	2.21	Not compliant
3	Log Pearson III	CS ≠ 0 CS =	2.207	Not compliant
		CV = 0.3 CV =	0.64	***Meet***
4	Gumbel	CS ≤ 1.139 CS =	2.207	Not compliant
		CK ≤ 5.402 CK =	-1.428	Not compliant

From the distribution selection requirements, there are qualified Pearson III logs so that the results of calculating the maximum rainfall re-period with the Pearson III log method for 10, 25 and 50 year re-periods can be seen in the following table.

Table 3. Log Pearson III Maximum Rainfall

RRP	KTr	LogXTr	XTr(mm)
10	1.337	3.009	1021.122
25	2.128	3.085	1216.392
50	2.703	3.140	1381.225

4.4 Plan Flood Discharge Calculation

A commonly used peak flow rate analysis is the rational method of USSCS (1973). The rational method was developed based on the assumption that the rain that occurs has a uniform intensity andevenly distributed throughout the DPS as long as itis at least equal to the time of DPS concentration. After obtaining the flow coefficient (*C*), rainfall intensity (*I*), and drainage area (*A*) then calculated the peak discharge from the sub-watershed with a rational method.

Table 4 Rational Plan Flood Discharge

Tr	C	A	I	Q
10	0.37	1629.2	25.20	41.89
25	0.37	1629.2	63.00	104.71
50	0.37	1629.2	125.99	209.43

4.5 Gradation Relationship and Grain Uniformity

The analysis carried out is a sieve analysis that aims to determine the percentage of sediment for each specific grain size. From the results of sieve analysis, it can be known the characteristics of the sediment reviewed in the form of grain size distribution graphs. The sieve analysis results for sediment samples taken in Way Ruhu River, while for the table of the percentage of granules that escaped for each sieve can be seen in the following figure.

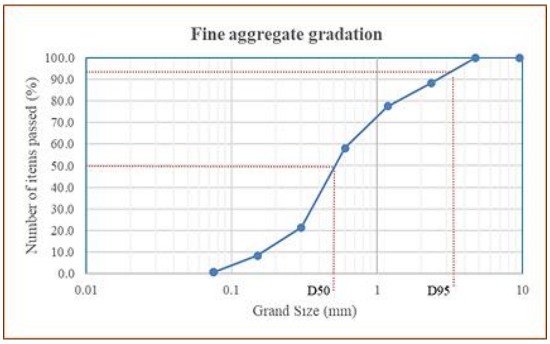

Fig.7. Graph Sediment Sieve Analysis

4.6 Simulated Local Scour on Bridges

Simulating local scour that occurs on the pillars ofthe Way Ruhu Bridge in Galala village using the unsteady flow option contained in the HEC-RAS

6.4.1 program and knowing in local scouring that occurs using hydraulic design after running with HEC-RAS. To run the simulation, the data that has been analyzed previously will be included as imputdata in the HEC-RAS 6.4.1 program. In general, the required data input is:

1) Cross-sectional geometry of the channel.
2) Bridge geometry.
3) Discharge data that will pass at the bottom of the bridge.
4) Sedimentary grain sizes d50 and d95.

After all the geometric data of the bridge is enteredin the HEC-RAS program, it must then be run usingsteady flow simulation.

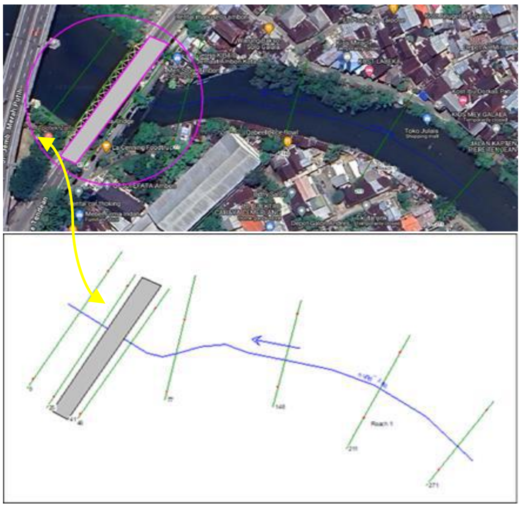

Fig.8 Geometrics of the Way Ruhu River

After all data is inputted based on criteria and river characteristics, from the results of flow simulation in three different flow discharge conditions, the maximum water level difference is obtained in the downstream flow conditions of the bridge and the flow conditions upstream of the bridge as shown below.

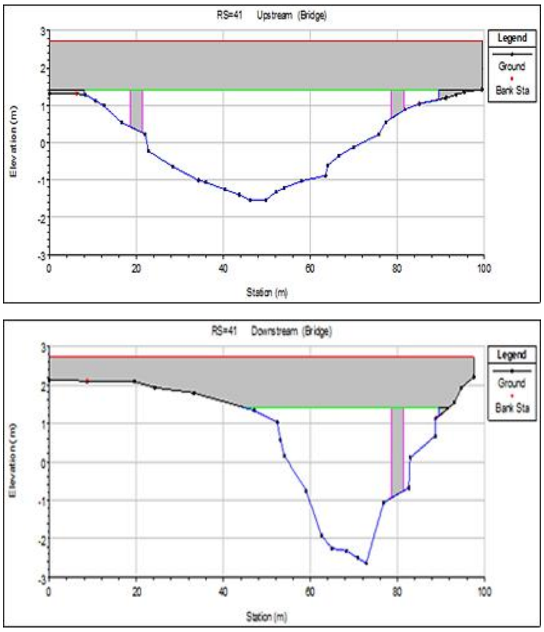

Fig.9 Condition of Existing Model of Bridge

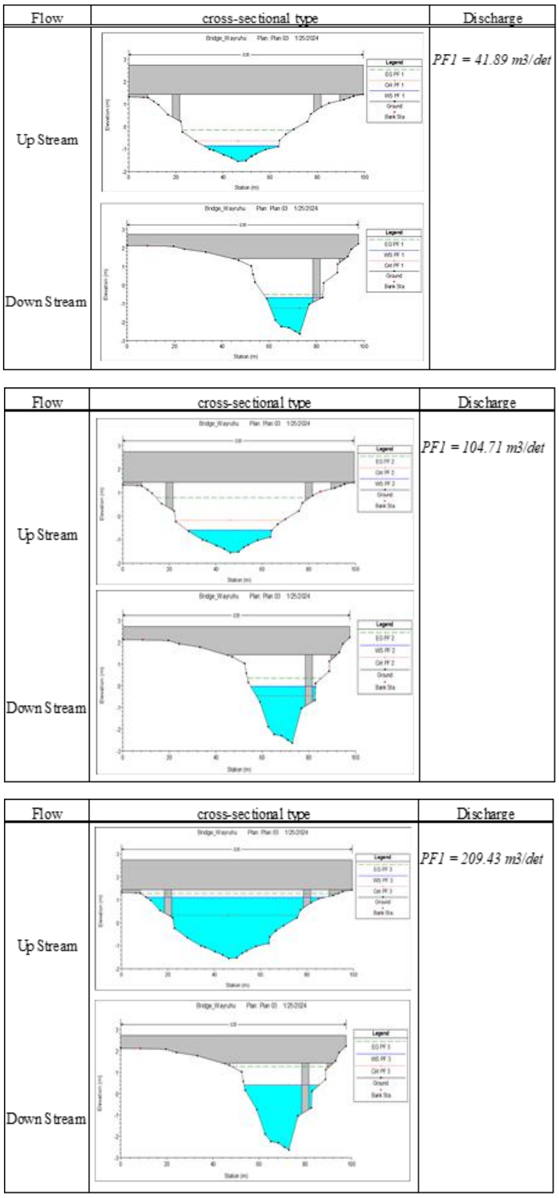

Fig.10 Simulated flow against a bridge

4.7 Analysis of local scour that occurs on the bridge

After running steady flow to determine the amount of local scouring that occurs due to discharge passing through the Way Ruhu, using the analysis in the HEC-RAS program on the perform hydraulic design computation menu. In hydraulic design there are three kinds of scour analysis that can occur. Contraction,pierand abutment.In ontraction scour, almost all data needed to calculate contraction scouring have been automatically taken by the HEC-RAS program from the output of flow calculation results in the selected cross section, namely in the upstream and approach flow. The data that must be inputted is d50 in millimeters and the coefficient K1 as can be seen in. In this study, the diameter of the d50 sediment was 0.20 mm and the d95 was 2.3 mm. The HEC-RAS program calculates the pier scour with the CSU (*California State University*) or Froehlic equation. There are 4 types of data needed, namely the shape and dimensions of the pillars, the angle of incidence of flow to the pillar (*angle*), the shape of the river bed (K3) and the diameter of the sediment (d95). From the results of the HEC-RAS analysis above, the depth of local scour that occurs at the bottom of the bridge is obtained based on the cross-section of the sudetan plan and also the flow discharge that has been entered using a flow hydrograph.

From the results of the scour simulation at the footof the bridge, the condition at PF 3 (*50-year plan discharge*) did not occur contraction and change inthe abutment due to the planned flood discharge water table being at the foot of the abutment whichcaused the bridge structure not to contract becauseno pressure occurred. From the results of the HEC-RAS simulation of the Way Ruhu bridge, the depthof local scour that occurs at the bottom of thebridge is as follows:

Table 5 Scour simulation results

Debit (m3/det)	Section	Contraction (m)	Pier (m)	Abutmen (m)	Total (m)
PF1 = 41.89	Left	0.21	0.96	1.17	1.38
	Channel	0.21	0.96	-	1.17
	Right	0.21	0.96	1.17	1.38
PF1 = 104.71	Left	0.43	1.13	1.57	2.00
	Channel	0.43	1.13	-	1.56
	Right	0.43	1.13	1.57	2.00
PF1 = 209.43	Left	0	1.26	0	1.26
	Channel	0	1.26	-	1.26
	Right	0	1.26	0	1.26

From the results of maximal scour modeling in the Way Ruhu River with three discharge model conditions for the 10, 25 and 50 Year re-periods as shown in table 5 shows that the scouring depth in PF2 conditions (25-year plan discharge) in pillar 1 and pillar 2 is the same, because the shape and size of pillar 1 and pillar 2 are the same. Similarly, the depth of scour in both the left abutment and the right abutment is the same, because the shape and size of the left abutment and right abutment are the same. Where in this condition there is a maximum scouring depth around the pillars.

4.8 Protection against scour on the bridge

Based on the results of modeling with HEC RAS, the scouring that occurred on the left and right piers and abutments as deep as 2.00 meters with a 25- year plan discharge simulation, it is necessary to carry out Operation and Maintenance actions on scouring protection on the Galala Bridge. From these results, there is a need for protection to anticipate structural failure due to continuous scouring. There are several kinds of scour control methods, including:

1. With the installation of a rip-rap floor around the pillars.

2. Creation of foundation blocks around pillars in the river bed.
3. Placement of pseudo-pillars in font (*upstream*) of the real pillars.
4. Placement of pillars in the direction of the flow.
5. Changes in the shape of pillars that can reduce flow resistance.

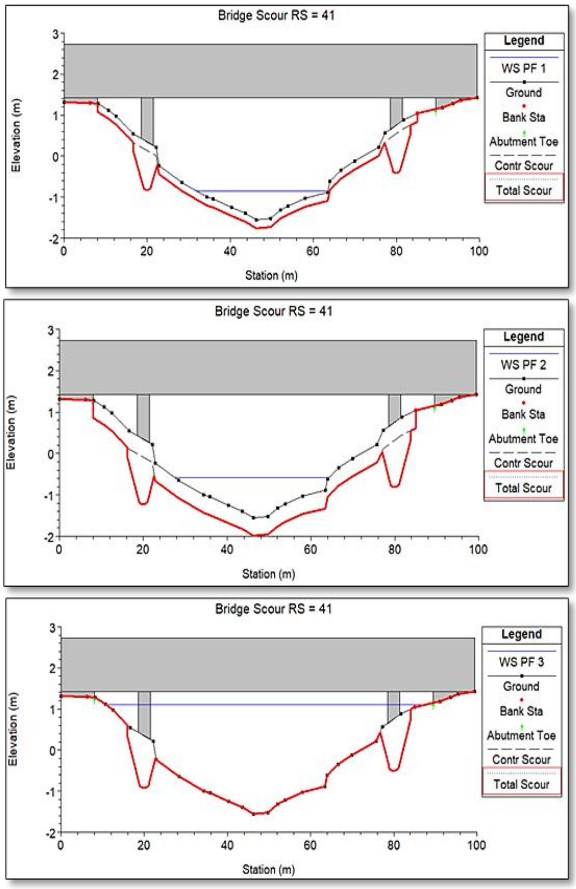

Fig.11 Simulated scour on a bridge

V. CONCLUSION

1) The scouring that occurs on the bridge is caused by a layer of soil with small grains. From the results of HECRAS simulations show that the scouring depth reaches the base of the bridge, 2.00 m. This scouring can affect the stability of the bridge and potentially collapse the bridge.
2) One way to evaluate bridge damage due to scouring is to conduct regular visual inspections.
3) In addition, analysis of weather data and water flow around the bridge can also be carried out to understand the potential for scouring that occurs. By conducting periodic evaluations, it can help in determining the necessary corrective actions to prevent further damage to the bridge due to scouring.

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