

# Study of Hydraulic Models in the Compilation of Alternative Management of Purbaleunyi Toll Road Inundation (+ STA 131)

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## ABSTRACT

Toll roads are currently one of the supporting factors for economic growth. So that if the function is slightly disturbed, obstacles will arise, which will hamper vehicle's journey using the toll road. Many factors hinder this toll road. One of the traffic obstacles is a flood disaster. Floods are also one of the biggest natural disasters in Indonesia. This study aims to calculate and assess the extent of flooding, which will impact toll roads. So that it can determine the impact and how to handle it. Applying the ten years returned rainfall periods, HEC\_RAS simulation shows that the flood inundation area is 176.636,69 m<sup>2</sup>, including toll road areas. The hydraulic simulation also indicates that the flood inundation area can be reduced by adding two 3.5 x 4 meter Box Culvert, while to minimize the traffic disturbance during the construction period, it is recommended to apply microtunneling method.

**Keywords:** Flood, Toll Road, HEC-RAS, Microtunnel.

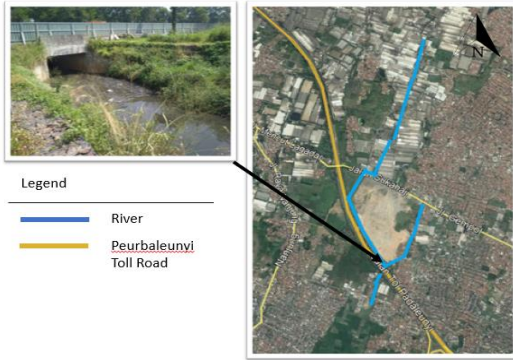
## 1. INTRODUCTION

Transportation is economic support for a region [1]. The road is one of the supports for the smooth operation of land transportation. Many economic activities use land transportation, so that land transportation activities are one of the supports for the sustainability of one area to another. One of the types of land transportation is motorized vehicles. Motorized vehicles that support the economy of an area are vehicles with large carrying capacity [2]. To expedite these activities, the Toll Road is one solution. This is because toll roads have measurable maintenance compared to provincial roads. Toll roads are an instrument for the continuity of goods from one area to another [3]. With the Toll Road, the movement of large vehicles is conditioned to run smoothly and safely.

The smooth operation of the Toll road has many factors, such as traffic jams in the toll booths, roads that are starting to break down, road repairs to floods. Floods that occur on toll roads affect road users' speed, and often traffic congestion occurs because the floods are too high. The extent of the flood that flows through the toll road also affects how far away from the congestion queue that occurs. The driving speed traveled by motorists on flooded toll roads will also

decrease. Meanwhile, floods are also one of the most common natural disasters in Indonesia.

Floods on toll roads also occur frequently in Indonesia [4], one of which is at + STA 131 on the Purbaleunyi toll road section. The Purbaleunyi toll road is a toll road that crosses Karawang Regency, Purwakarta Regency, West Bandung Regency, Cimahi, Bandung City, and Bandung Regency. This toll road also connects Padalarang to Chile. The toll road users are around 35,000 vehicles every day. Around + STA 131 this toll road, there is a river that has been flooded several times. This flood was caused by the confluence of two tributaries, namely the Kalimalang River and the Cilember River [5]. The intersection of these two tributaries is very close to this toll road. After the confluence of these two rivers, there is a box culvert under the Purbaleunyi toll road. The research location is shown in Figure 1.



**Figure 1.** Map of location box culvert, Cilember River, and Kalimalang River

The box culvert that flows under the Peurbaleunyi toll road (+ STA 131) has a combination of two river flows. So the box culvert that is designed around this should also be designed with a qualified flood design. In this case, the 100-year flood calculation must be able to be flowed by water flow. The box culvert design is designed to be able to divert water that will cross the toll road and only pass through the box culvert so that controlled water will flow water across the toll road without passing through the toll road. The water flow design can be designed with a lot of flood simulation software that is HEC-RAS [6][7].

Hec-ras is a free flood simulation software published by the US Army Corps of Engineers Hydrologic Engineering Center. HEC-RAS can simulate water flow, speed, discharge, and flood inundation area with the desired annual rainfall input [8]. With the HEC-RAS software simulation, you can see how much impact the flood plan will have on the toll road [9]. Besides that, the HEC-RAS software can also see after the box culvert that is under the toll road [10][11]. It is hoped that the new box culvert modeling can be a solution for flooding on the Peurbaleunyi toll road.

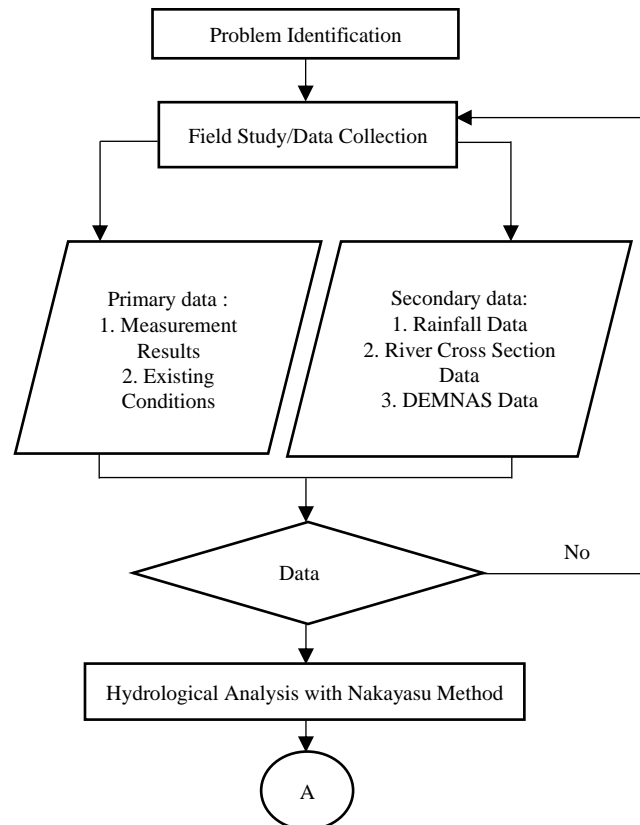
**2. OBJECTIVES**

The purpose of this research is to estimate the discharge that will pass through the Kalimalang and Cilember rivers so that it can predict how much the impact on flooding in the affected areas will affect the Perubaleunyi toll road + STA 131. By knowing the floods that will affect this toll road area, it can be determined what safety measures are will be done on this toll road.

In this case, the prediction of toll road security against flooding will be designed to increase the size of the box culvert. The design box culvert according to water requirements. It is estimated that the increase in the area of water flow that the box culvert can pass through can move the floodwaters to a location that makes the toll road safer against flooding.

**3. METHODOLOGY**

This research method uses river discharge calculations using the Nakayasu method and is continued by using HEC-RAS software. The methodology of this research starts from a literature study looking for information about toll roads that are affected by flooding. Then the primary data collection and secondary data. The premiere data in this study began with direct surveys, then river surveys using flat characteristics. So that finding the contours around the river can be known. Then the secondary data collection is road and channel data. Furthermore, the process of calculating the flood simulation using the Nakayasu method and with the existing HEC-RAS software. The part of the earth's surface that was not surveyed will be filled by the newest DEMNAS. DEMNAS is the result of the integration of various data sources. The results of the evaluation of DEMNAS integration show that the DEM mosaic accuracy test with weight has better accuracy than the weightless DEM mosaic, which is 2,065 meters. DEM is a relief representation of the surface / terrain as well as height information from the earth's surface without any natural or man-made features. After the existing simulation is carried out, then continue the flood simulation with the toll road that has been given an additional box culvert. If there is still flooding passing the Peurbaleunyi toll road, the simulation process is complete. Still, if the flood still flows through the toll road, repeat the simulation process using a better box culvert design. Finally, the verification process for existing floods. Figure 2 shows the flowchart of this research.



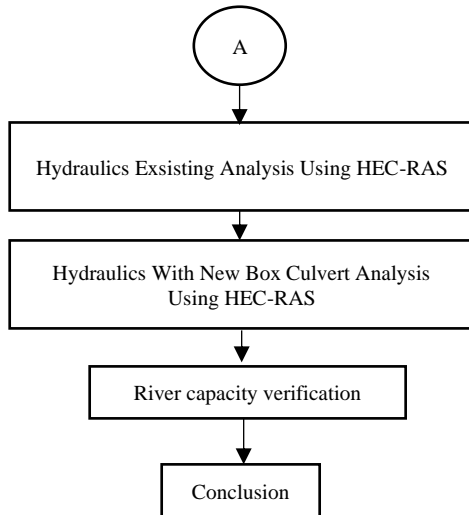


Figure 2. Flow chart methodology

To calculate the flood discharge using the Nakayasu method, use the formula in formula 1 below.

$$Q_p = \frac{C \cdot A \cdot R_0}{3,6(0,3 T_p + T_{0,3})} \quad (1)$$

Where

- Qp = flood peak discharge (m<sup>3</sup>/s)
- C = flow coefficient
- R0 = rain unit (mm)
- A = watershed area (km<sup>2</sup>)
- Tp = the grace period from the beginning of the rain to the peak of flood (hour)
- T0,3 = time required by the decrease of discharge, from peak discharge to 30% of peak discharge

According to research conducted by Sihotang in 2015, a flood prediction plan is to carry out a flood simulation plan for 2 years, 5 years, 10 years, up to 25 years which represents a flood planning for an area [12]. The results of the calculation of the Nakayasu method are shown in the table below.

Table 1. Nakayasu method flood discharge

Time [hour]	Qt [m <sup>3</sup> /s]	Q2	Q5	Q10	Q25
0	0	6.359	6.359	6.359	6.359
1	0.178	7.905	8.327	8.576	8.866
2	0.941	41.346	43.575	56.531	63.087
2.08	1.036	52.551	57.098	72.599	81.254
3	0.678	39.393	43.134	53.730	59.920
4	0.427	28.467	31.179	38.062	42.205
4.68	0.311	22.461	24.436	29.450	32.467
5	0.282	20.960	22.750	27.297	30.033
6	0.207	17.077	18.391	21.728	23.736
7	0.152	14.229	15.194	17.644	19.119
8	0.112	12.158	12.869	14.675	15.761
8.58	0.093	11.174	11.765	13.264	14.166
9	0.085	10.760	11.300	12.670	13.495
10	0.067	9.828	10.253	11.333	11.983
11	0.053	9.103	9.440	10.294	10.808
12	0.042	8.533	8.800	9.477	9.885
13	0.034	8.119	8.335	8.883	9.213
14	0.027	7.757	7.928	8.364	8.626
15	0.021	7.446	7.580	7.918	8.122
16	0.017	7.239	7.347	7.621	7.786
17	0.013	7.032	7.115	7.324	7.450
18	0.011	6.928	6.998	7.176	7.282
19	0.008	6.773	6.824	6.953	7.030
20	0.007	6.721	6.766	6.879	6.947
21	0.005	6.618	6.650	6.730	6.779
22	0.004	6.566	6.591	6.656	6.695
23	0.003	6.514	6.533	6.582	6.611
24	0.003	6.514	6.533	6.582	6.611

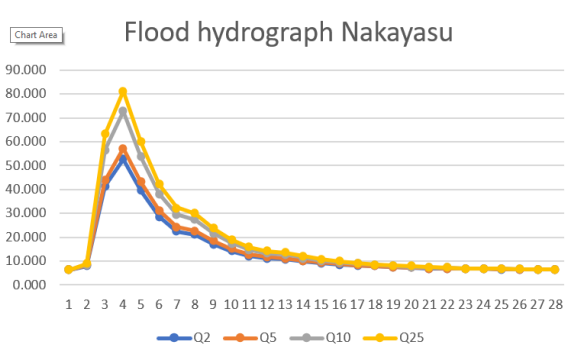


Figure 3 Graph flood hydrograph Nakayasu

Figure 3 above shows a graph of the magnitude of the flood that the flood will go through. there it can be seen that the discharge with a 25-year plan flood is the largest.

The shape of some of the existing cross sections of the Cilember river which is adjacent to the Peurbaleunyi toll road is as shown in Figure 4

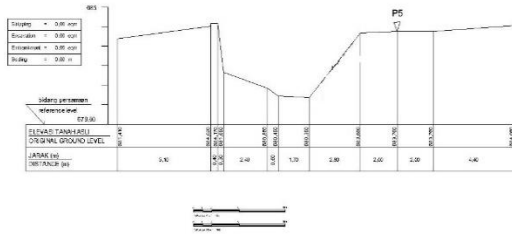


Figure 4 The existing cross sections

#### 4. RESULTS

The results of the simulation using the existing channel HEC-RAS software are shown in Figure 5, Figure 6, figure 7 ,and figure 8 below.

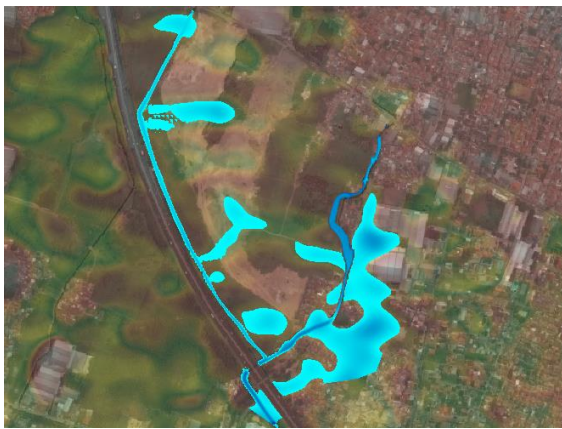


Figure 5. Flood discharge return period of the existing 2 years

Figure 5 shows the extent of the existing flood inundation that occurs around the Peurbaleunyi toll sta 131 with a 2-year planned return flood period. the area of the inundation is 67.175 m<sup>2</sup>.

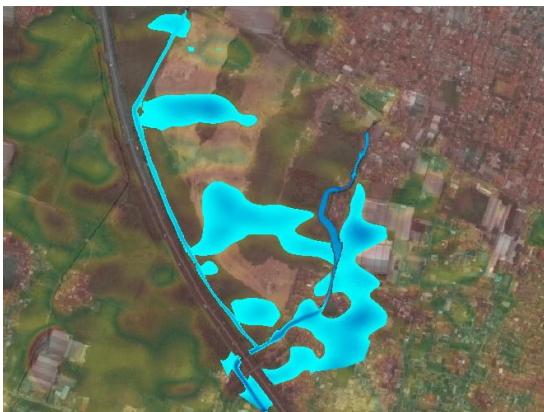


Figure 6. Flood discharge return period of the existing 5 years

Figure 6 shows the extent of the existing flood inundation that occurred around the Peurbaleunyi toll sta 131 with a 5-year planned return flood period. The area of the inundation is 107.245,4 m<sup>2</sup>.

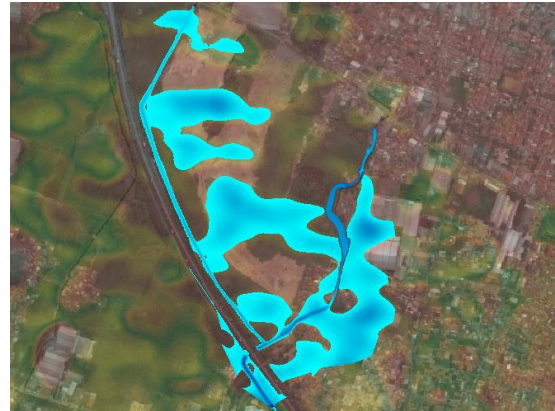


Figure 7. Flood discharge return period of the existing 10 years

Figure 7 shows the extent of the existing flood inundation that occurs around the Peurbaleunyi toll sta 131 with a 10-year planned return flood period. the area of the inundation is 148.272,77 m<sup>2</sup>. From this picture, it can be seen that the inundation area has entered the toll road.

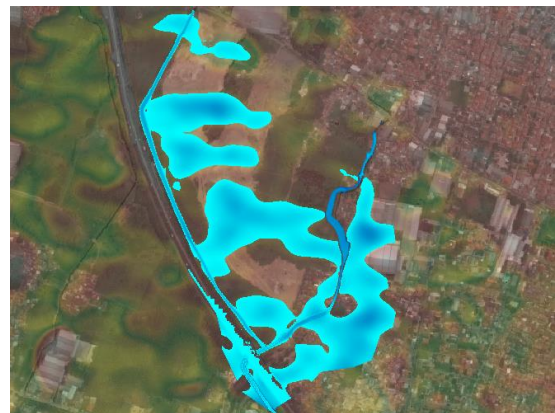


Figure 8. Flood discharge return period of the existing 25 years

Figure 8 shows the extent of the existing flood inundation that occurred around the Peurbaleunyi toll sta 131 with a 25 year planned return flood period. the area of the inundation is 176.636,69 m<sup>2</sup>.

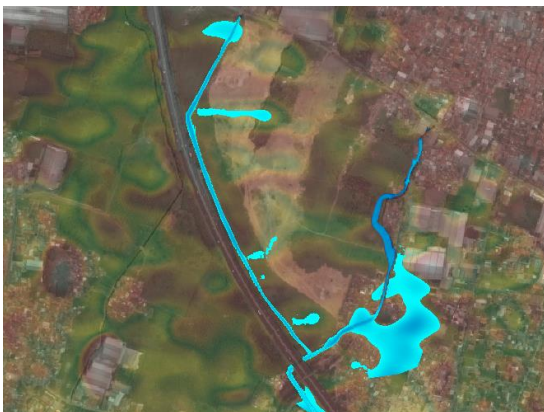
The picture shows the area of the flood that will occur in the 2 year return period, 5 year return period, 10 year return period, and 25 year return period. It can be seen that during the 10-year flood return period the puddle has touched a part of the toll road. the area of inundation area of the flood area is 2.6 km<sup>2</sup>.

The results of the simulation using two box culverts measuring 3.4 m x 4 m using the existing channel HEC-RAS software are shown in Figure 9, Figure 10, Figure 11, and 12 below.



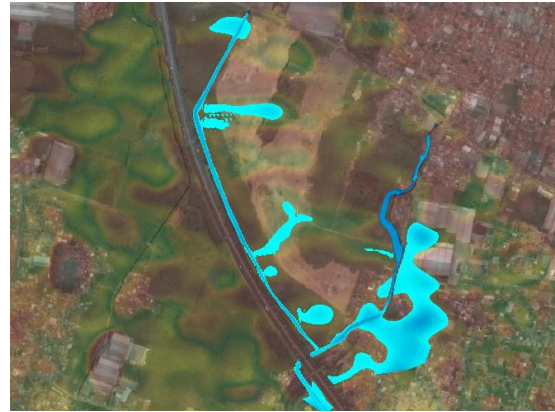
**Figure 9.** The return period of flood discharge is 2 years after having 2 box culverts

Figure 9 shows the extent of inundation after adding a new box culvert with a 2-year return flood period. The inundation area is 32.871,75 m<sup>2</sup>.



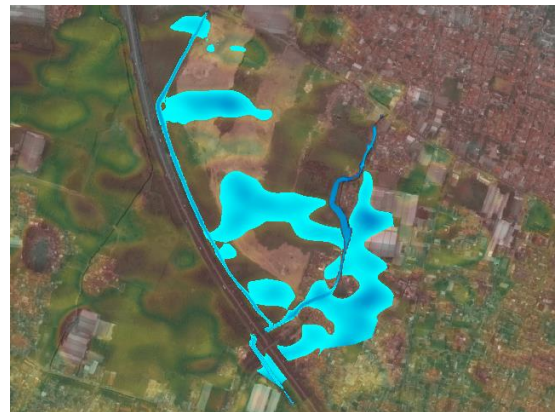
**Figure 10.** The return period of flood discharge is 5 years after having 2 box culverts

In Figure 10 showing the area of the flood inundation after adding a new box culvert with a 5-year return flood period. The inundation area is 40.115,79 m<sup>2</sup>.



**Figure 11.** The return period of flood discharge is 10 years after having 2 box culverts

In Figure 11 shows the area of flood inundation after adding a new box culvert with a 10-year return flood period. The inundation area is 54.744,02 m<sup>2</sup>.

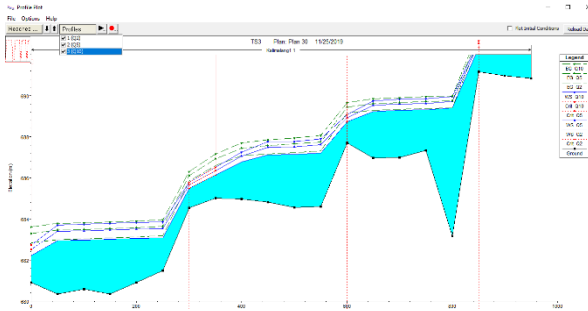


**Figure 12.** The return period of flood discharge is 25 years after having 2 box culverts

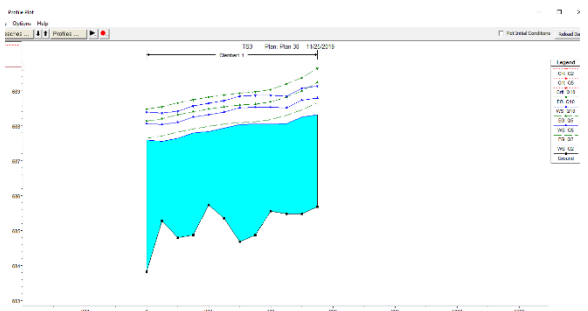
In Figure 12 showing the area of flood inundation after adding a new box culvert with a 25-year planned return flood period. the area of the inundation was 114.057,93 m<sup>2</sup>.

The figure 9, figure 10, figure 11 and figure 12 shows the area of the flood with two box culverts under the toll road which will occur in the 2 year return period, 5 year return period, 10 year return period, and 25 year return period. There were no visible floods entering the toll road.

While the water level of the Cilember River that can be maintained from this hecras software is as in Figure 13, and the results of the water level in the Kalimalang River are in Figure 14.



**Figure 13.** The the water level of the Cilember River



**Figure 14.** The the water level of the Kalimalang River

**Box Culvert Installation Applications**

The boxculvert installation in the toll road area will be divided into two stages. The first step is to close one lane of the toll road and carry out excavation work on the toll road and make the work area. After the installation is complete and the land has been filled again and the road is asphalt as before, then the work area is moved to the next part where no installation has been carried out. box culvert. The steps for installing the box culvert are as follows.

**1. Traffic diversion and restriction of work areas**

In this implementation, traffic diversion is carried out so that vehicles only pass through the intricate lanes of the northern part of the toll road. Then on the opposite lane begin to install the work guardrail and take measurements according to the new box culvert installation path.

**2. Excavating the work area**

After the work area is safe from external disturbances, the excavation process of the road and soil is continued using an excavator in accordance with the new box culvert installation path. The depth must follow the minimum depth required by the precast concrete manufacturer. While the width of the trench must pay attention to the width of the box culvert and the tool when placing it. Unnecessary excavated areas should be closed and compacted immediately. For filling the slope of the drains must be considered

according to the plan. Perform dewatering work if needed.

**3. Soil Laying**

After the trench is formed, the second process is laying the lining for the box culvert. Coating material as required. The base does not need rough material, as it will damage the box culvert. Grounding is needed so that the box when installed does not shift downward. The height of the base is not less than 75mm, if the area consists of hard soil and rocks then the lining is at least 150mm high. It should be noted that both the site manager, the foreman and the workers who handle this air channel installation project must be experts in their fields, and really understand how to install box culverts.

**4. Box culvert installation**

Next is the box culvert installation process. The first step is to create a row of boxes, where the first placement of the box will determine the alignment of the next box placement. It must be placed in accordance with the height and slope required in the plan. The placement of the box is by placing the spigot or tongue downstream while the socke is upstream. Otherwise pushing the box with the machine is avoided because it can damage the box or move the box from the trench that has been prepared.

**5.Connection between box culverts**

Connection between box culverts Sealant is needed to avoid soil and water migration to the box culvert. One of the basic materials for sealants that is suitable for use is bitumen (asphalt). Sealant can be applied to the top and inside of walls with a thickness of approximately 300 mm. The culvert box that has been laid out as the beginning of the line must be connected to the fill box. There should be workers who can direct the crane. And before placing the box, the trench must be checked first whether the height and condition of the trench are as planned. Between boxes must be attached to the rail or by means of a crane. This chain must be tightened gradually until the boxes are attached, after which the crane can remove the box. Please note that the joints between the boxes do not change when the crane is lifted.

**6. Backfilling the work area**

Backfilling the work area After the box culvert is installed properly, then backfilling is carried out. The landfill must be free of organic matter and must be compacted immediately. The compaction should not damage the box culvert or change its position.

## 5 . CONCLUSION

Based on the results that have been obtained using the HEC-RAS flood simulation software, the 10-year return period flooding that occurs around the Perubaleunyi toll road has shown that the area of flood inundation is 107,245.4 m<sup>2</sup> and has entered the tol area as shown in Figure 7. which caused the Peurbaleunyi toll road around + STA 131 to be flooded.

After adding two culvert boxes at the bottom of the toll road, the floods that inundated the toll road area have disappeared and the resulting flood inundation area is 54,744.02 m<sup>2</sup>. The box culvert design of this plan can also accommodate the capacity of a 25 year return period. With the design of two box culverts at the bottom of the toll road, it can have an impact on the absence of flooding entering the toll road area.

The most efficient application of the box culvert installation under the toll road has 6 stages, namely; (1) Traffic diversion and restriction of work areas; (2) Excavating the work area; (3) Soil Laying; (4) Box culvert installation; (5) Connection between box culverts; (6) Backfilling the work area.

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