The feasibility study of bridge construction plan in Digoel River Province of Papua

N R Setiati
Institute Road of Engineering, Research and Development Agency, The Ministry of Public Works and Public Housing, Indonesia
E-mail: retno.setiati@pusjatan.pu.go.id

Abstract. The planning of the bridge construction in Digoel river that connects the western part with the eastern part of Boven Digoel in Papua Province is part of the development program as stipulated in PP No 78 Tahun 2014 about “Acceleration of development in underdeveloped regions”. The land, river, and air transport systems that connect between regions in Boven Digoel are very difficult to be reached, also to extreme weather and climate conditions make the transportation cost expensive. One of the efforts to overcome these problems is to build road and bridge infrastructure. To support the implementation of infrastructure development in the district of Boven Digoel, a feasibility study of road and bridge planning is required. It refers to the guidelines PdT-19-2005-B (Studi Kelayakan Proyek Jalan dan Jembatan). A feasibility study was undertaken to analyze in more detail some of the proposed road trace alternatives. Based on the feasibility study results, two alternatives of road trails connecting the western and eastern part of Boven Digoel of Papua Province are chosen. The bridge plans were made across the Digoel river. Bridge construction on alternative road trails connecting Kampung Ampera with Tanah Merah is considered to be more effective and efficient because it is safer from river scouring hazard. The bridge length is made longer than the width of the Digoel river, considering the rapid changes of the channel size. From the results of field measurement analysis, the average speed of the movement of the horizontal river flow direction is \((80-180) \times 10^{-4}\) meters/day so that in the 50-year period, the movement speed of the horizontal river flow path becomes \((160 - 3200)\) meters. Based on Kun Qarshov method, the movement of the river flow for 50 years at the location of the bridge connecting Tanah Merah through Ampera Village is 311.64 meters so that the optimum bridge length at the location is designed 600 meters.

1. Introduction
Boven Digoel Regency located on 4° 98 ‘- 7° 10’ South Latitude and 139° 90 ‘- 141° East Longitude is one of the districts in Papua Province. Before the issuance of the Law of the Republic of Indonesia No. 26 in 2002, the area is part of Merauke Regency. Based on geographical location, Boven Digoel Regency is adjacent to the North - Yahukimo District and Pegunungan Bintang Regency; South - Merauke Regency; West - Mappi District; East - The State of Papua New Guinea [1] The geographical condition of Boven Digoel Regency are shown in figure 1.
Figure 1. Road conditions in Boven Digoel Regency of Papua Province [2]

Based on figure 1, regarding geography, 61% of Boven Digoel Regency consists of flat and wavy terrain. The Digoe River separates the Boven Digoel Regency into the western and eastern regions. The limited transportation facilities in Papua Province, especially Boven Digoel Regency, cause the price of necessities in the area is very high compared to other regions in some provinces. Development in the western and eastern part of Boven Digoel Regency has not been realized. The economic growth rate of the population in the western part is lower than the population in the east. To reach the Capital of Boven Digoel Regency, from Kampung Ampera it takes travel time between (2-3) days by road, with very poor road condition as shown in figure 2.

Figure 2. Road conditions in Boven Digoel Regency of Papua Province [2]

The length of travel time between the Capital (Tanah Merah) with some other areas causing the development equity gap in the District. To anticipate the occurrence of this need to be built road and bridge transport system that connects the western region with the eastern part. The construction of a bridge across the Digoel River is essential for the economic growth and prosperity of the people to be realized. The construction of the bridge in the Digoel river is in line with Boven Digoel Regency Regulation no. 4 in 2012, Article 7 point (3) regarding land transportation network system of Ampera bridge construction in Mandobo District. With the new bridge connecting the western region with the eastern part of Boven Digoel Regency is expected to reduce travel time so that economic growth can grow rapidly. In connection with this, it is necessary to conduct some feasibility studies related to the planning of roads and bridges connecting the western and eastern regions of Boven Digoel Regency. This study aims to obtain an appropriate analysis results in determining the road and bridge trails that connect the western part with the eastern part of Boven Digoel Regency, looking for solutions related to bridge types that are appropriate or applicable to the Digoel river location, as well as analyze the
impacts that occur if the bridge can be built. The method used in this assessment refers to the guidance of Pd T-19-2005-B (Feasibility Study of Roads and Bridges Project). The determination of the road trace determined refers to several aspects reviewed in the feasibility study of bridge planning in Digoel river (topography, geographical, geological, geotechnical, and hydrological aspects). Primary data and secondary data are required in the analysis of traffic load determination, road class, and bridge type that are suitable to be applied at Digoel river location. The properties and the characteristics of the Digoel river greatly affect the type of bridge to be built at the site. Based on the results of pre-feasibility studies conducted in 2012, there are two alternative road trails determined to connect the western region with the eastern region of Boven Digoel Regency, namely: Trace the road that connects the existing path of Tanah Merah to Fofi District and Trace the road that connects the existing road Tanah Merah to Kampung Ampera.

The Digoel River that separates the western part of the eastern part of Boven Digoel Regency comes from the southern part of the Sterren mountains and is one of the largest rivers in the province of Papua. This river empties into the Arafura Sea. Digoel River is a river meander type with river flow that tends always to move [3]. To know the geographic and geological condition of the location area around the bridge to be built in Boven Digoel Regency made several measurements, such as with the DEM (Digital Elevation Model), SPOT Satellite Image Map, and Geological Map.

2. Methods
Some of the field tests conducted are topography, geology, geotechnical, and bathymetry. To know the type and some properties of local materials laboratory testing, such as coarse aggregate testing, fine aggregate, and acidity level of river water Digoel. Laboratory tests were conducted to determine the type of local material that can be used in the construction of bridges in the Digoel river. Road trace measurements were made using the Digital Elevation Model, SPOT Satellite Image Map and Geological Map. Measurement with DEM Map (Digital Elevation Model) aims to determine the condition of geomorphology and topography of the region [4]. Measurements with SPOT Image Map aim to know the condition of the land cover area [5]. While the measurement with the Geological Map is intended to determine the geological or rock formations and the location of faults. Soil testing is done by sonar test. This method is then known by various names such as static penetration test or quasi-static penetration test, dutch cone test, and briefly called sounding course which means estimation. In Indonesia then called soldier taken from the Dutch [6]. Tidal observations were made on the area or survey location bathymetry. The tidal observation aims to determine the depth reference plane (mean water level).

3. Discussion
The measurement results of SPOT Satellite Image Map on the road trace connecting the existing Tanah Merah road to Fofi District are shown in figure 3.

![Figure 3](image-url)
Based on figure 3 (a) on the road trace, the total length of the road should be built 7.5 km with a 323-meter river span. The determination of the road trace through Kampung Ampera as shown in Figure 3 (b) is intended to avoid potential scouring if the bridge is built in such a location. When compared with the previous road trace, the length of the road passes through Kampung Ampera is 10.2 Km. In this trace, the travel time is longer than the previous road trace. In this trace, the travel time is longer than the previous road trace. After traveling through Kampung Ampera directly to Fofi District, and the width of the river stretch where the bridge is built is 228 meters. The stretch of the river is shorter than the stretch of the river on the previous road trace (i.e., 323 meters). Most of the eastern region is a vast floodplain area with tropical forests. The location of the plain is located at the height of less than 1 meter. The density level of vegetation is very tight. While in the western region is a corrugated area with a high difference up to 19 meters. The area is used as residential areas, fields, and gardens. On the road, the trace is also done with measurement with DEM Map (Digital Elevation Model). The measurement results are shown in figure 4.

![Figure 4. The result of road trace measurement that connects existing road of Tanah Merah to Fofi District with DEM (Digital Elevation Model) [7]](image)

From figure 5, the height of the eastern region is less than 25 meters on average from the sea level, while the western average is in the range (25-50) meters from the sea surface. To determine the geological formations (rocks) and geological hazards of the road trace, there were also measurements with the Geological Map as shown in figure 5.

![Figure 5. The result of road trace measurement that connects Tanah Merah's existing road to Fofi District with Geological Map [8]](image)
Based on figure 5, the road trace connecting the western region to the east of Boven Digoel Regency is in the sediment of a young river. Based on the results of visual surveys and field testing in general the condition of the road trace that connects the existing road of Tanah Merah to Fofi District is as follows: the condition of the land is the sediment of the young river, the road trace location is not adjacent to the fault area, so it is quite safe from the danger of the earthquake, the length of the built bridge must be greater than the stretch of the river (> 323 meters), the bridge that is built is located in the bend area of the river so that the impact of the risk of a higher scour. However, the potential of scouring hazard can be anticipated by minimizing the flow of river flow so that scouring becomes smaller. The change of discharge is very influential on the scour depth that occurs if the debit increased then scour it happens will be deeper. It can be concluded that the pillar shape and the change of debit greatly affect the value of scour depth. The best pillar used for bridges is rounded, compared to square and parallelogram columns [9]. For the road trace through Kampung Ampera it appears that the road trace area is in the sediment of the young river. The length of the built bridge must be greater than the stretch of the river (> 228 meters), the planned bridges are not located in the bend area of the river to avoid the scouring hazard. Soil data test in the form of sondir and CBR is done to find out the soil data on the road trace connecting Tanah Merah to Fofi District. Testing Sondir conducted to a depth of land 10 meters. Sondir test results are shown in figure 6.

**Figure 6.** Sondir test results on road trails connecting Tanah Merah to Fofi District [8]

Based on figure 6, the amount of soil bearing capacity at four points sondir at a depth of 10 meters from ground level of 375 kN/m², 431 kN/m², 509 kN/m² and 777 kN/m². The carrying capacity of soil from sondir test result on road trace connecting Tanah Merah through Ampera Village at four points of sondir location is 403 kN/m², 507 kN/m², 575 kN/m² and 616 kN/m². The soil conditions around the Digoel River belong to the category of unstable soils. The arrangement of ground stratigraphy in the area of road and bridge trace planning is dominated by sand, mud, and gravel. The tidal conditions of the Digoel river for bridge planning are shown in figure 7.

**Figure 7.** Sondir test results on road trails connecting Tanah Merah to Fofi District [8]
Based on figure 6, the water level is 561 cm. The high-water level of the highest water level reached high tide in a tidal cycle is 515 cm. The low water level is the lowest water level achieved at low tide in one tidal cycle is 5 cm. Mean sea level (MSL) is 290 cm. The analysis of river flow shift done by using Kun Qarshov program. The Kun Qarshov Method [11] was conducted to estimate the movement of river meanders. The use of Kun Qarshov method aims to obtain the rate of grinding and precipitation of the river flow at points at the relative angle of the river meander. River water levels occur periodically. Water from the sea will enter the river at high tide and will flow back into the sea at low tide (ebb tide). Part of this tidal river will have a water discharge that varies according to the prevailing season and depending on the water discharge on the upper reaches of the river [10]. The result of river flow shift analysis at the location of the bridge plan is shown in table 1.

### Table 1. The velocity of the Digoel river flow

| No. | The velocity of movement of river flow | At the location of Tanah Merah-District Fofi | At the location of Tanah Merah-Kampung Ampera-District Fofi | Period (years) |
|-----|--------------------------------------|--------------------------------------------|----------------------------------------------------------|----------------|
| 1.  | Average velocity of vertical direction of the river flow | 1.171×10^{-4} m/day | 9.733×10^{-4} m/day | - |
|     | The velocity of movement of the vertical river direction | 0.04 meters | 0.06 meters | 1 |
| 2.  | 1.07 meters | 1.58 meters | 25 |
|     | 2.14 meters | 3.16 meters | 50 |
|     | 4.27 meters | 6.33 meters | 100 |
| 3.  | Average velocity of movement of the river in the horizontal direction | 89.863×10^{-4} m/day | 170.761×10^{-4} m/day | - |
|     | The velocity of movement of the horizontal river direction | 3.28 meters | 6.23 meters | 1 |
| 4.  | 82.00 meters | 155.82 meters | 25 |
|     | 164.00 meters | 311.64 meters | 50 |
|     | 328.00 meters | 623.28 meters | 100 |

Based on table 1 the horizontal direction of the river flow movement during the 50 year period on the location of the bridge connecting Tanah Merah to Fofi District is 164.00 meters. While the movement of river flow horizontal direction through Kampung Ampera is 311.64 meters (horizontal movement al two times longer). The difference in direction and flow velocity at each point at the relative angle of the meander arch is the main parameter affecting the precipitation and scouring, in addition to other complex parameters [12]. Based on the result of horizontal river flow analysis with Kun Qarshov method, the map of river flow changes as shown in figure 8.

![The movement of the Digoel river flow in the horizontal direction](image)

**Figure 8.** Map of potential changes to the Digoel river channel for the next 50 years [8]
Based on figure 8, the occurrence of changes in river flow for 50 years to come potentially occur at the location of the bridge connecting Tanah Merah through Ampera village with a length of 311.64 meters. The road trails connecting Tanah Merah through Ampera Village to Fofi District are the paths determined in the results of this study. The technical consideration taken is that the bridge built at the location does not lie in the bend area of the river so that bridge damage due to scour can be avoided. The pattern of movement of the river in the horizontal direction during the 50-year period is very significant, so the length of the bridge needs to be designed along 600 meters (long span bridge). For long-span bridge, types can use a suspension bridge, cable-stayed bridge or arch bridge. The main bridge type uses an arch bridge (200 meters). As for the type of bridge approach using a steel frame type with a variation of 40 meters and 60 meters span. The width of the bridge is 12 meters, and the height of the bridge clearance from the floodwater level is greater than 15 meters. For the type of arch, because the length of the span is greater than 150 meters, it is included in the long span bridge category where the reference of planning, implementation, supervision and bridge maintenance must meet the criteria of long spans bridge planning.

4. Conclusion
The construction of the bridge in Digoel River depends on geographical, geological, and environmental conditions. In planning various possible aspects must be considered. Based on some test results in the field with the condition of the soil which is generally a young river sediment and will occur a horizontal shift in the river flow in the 50-year period along 311.64 meters, the total length of the bridge built is greater than 539.65 m (taken the total length of the bridge 600 meters). Based on SE No. 07/SE/M/2015 on the General Requirements for Bridge Planning, the type of suspension bridge is the most economical for the span between (200 - 3000) meters. However, due to some considerations, such as suspension bridge type is suitable for stable soil condition, the type of bridge is not suitable to be applied in Digoel river location due to unstable soil condition, switching river channel, and maintenance of suspension bridge is more complex than a steel frame and an arch bridge. For that purpose, we choose the type of steel frame and arch bridge for all of the total length of 600 meters.

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