HYDODYNAMICS CHANGE AT REJOSO ESTUARY DUE TO JETTY CONSTRUCTION

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ABSTRACT

Public Works Department of East Java Province, proposed the construction of jetty in Rejoso River to prevent siltation problem in estuary due to sedimentation process. The construction of this jetty is proposed as one solution of this sedimentation problem. It needs to be researched or studied for characteristics of river mouth, sedimentation, current pattern, and water level changes in the vicinity of Rejoso estuary as effect of jetty construction. The objective of this research is to investigate the effects of jetty construction in current pattern, and water level changes using 2D numerical model RMA2 (Resources Management Associates). RMA2 is used to generate water surface elevations and velocities. The simulation has been done in 4 conditions which are in existing, proposed jetty length 1170 m, jetty length 585 m, and jetty length 585 m with constrained condition. From the calibration process, it is used eddy viscosity coefficient and Manning’s value 4000 Pa·sec and 0.03, respectively. The result of calibration shows good agreement between model and observation with R value 0.996, 0.9477, and 0.8143 for water level, current velocity in station 1, and current velocity in station 2, respectively. From 4 jetty scenarios, it provides weakness and advantages. The length of jetty with 556 m can be better than original design.

Keyword: Sedimentation, Jetty, RMA2

1. INTRODUCTION

Rejoso river or commonly known as Kali Rejoso is one of the 4 major rivers in Pasuruan, East Java (see Figure 1). The upstream of Rejoso River located in Tengger Mountain which is one of active volcano in East Java Province and one of sediment sources in Rejoso River. Rejoso river watershed has an area of 357,26 km², with a length of the river 43.23 km. In estuary, Rejoso river also as administrative border between Patugaran village and Jangaran village. Rejoso river has function as flood control, water source for irrigation, and drainage system (PT. Wiratman, 2010)[1]. About 2/3 coastal area in Pasuruan is mild coast with slope less than 3%. According to Eko Kusratmo (2000)[2], coast with slope less than 5% categorized as flat coast. In this mild slope, material dominated by clay and this substrat is good for mangrove vegetation. Therefore, in the past, the width of mangrove forest more than 1 km.

Sedimentation in Rejoso estuary occurred very fast and formed river delta in Rejoso estuary. The high rate of sedimentation in the Rejoso estuary caused by several factors. The first is the abrasion process, this process due to the lack of natural barriers such as mangrove forests and coral reefs. Abrasion process at Rejoso estuary also caused by sharp angle estuary so the waves and the wind can easily eroded. Secondly, is due to the high content of sediment from upstream. The third is the high content of sediment along the coast where due to wind and waves exposure, this sediment increase the area of the
Muryani (2010) [3] studied from 1981-2009, shoreline around Rejoso estuary are progressively move towards the sea. Compared with the condition in 1981, the shoreline change up to 550 meters in 2000, while between 2000 to 2009 the furthest shoreline change reaches 1500 meters towards the sea. This shoreline change because of high rate of sedimentation process and the sediments were deposited there continuously forming new land and increase the land area. Between 1981 to 2000 the area of Rejoso estuary expanded by 146.6 hectares, and between 2000-2009 the area expanded by 148 hectares. From the data can be inferred that the increase rate of land area from 1981 to 2000 was 7.5 hectares per year, while between 2000 to 2009 was 16.4 hectares/year, or twice than previous period. The result of those problem, river bed elevation near esuary become very flat and rise in river mouth. Because of large annual flood discharge and river cross section is reduced due to sedimentation, the downstream area always flooding every year. It was recorded flooding in 9 village in 2 subdistrict every year.

Therefore, Department of Public Works decided to build a jetty to minimalize coastal damage due to sedimentation process. Before Rejoso jetty was built, it needs to be studied whether the construction of the jetty is right solution or even worsen the conditions in the Rejoso estuary. One way to study is using 2-dimensional numerical modeling, because it can be done quickly and cheaply than using physical modeling. In addition, numerical modeling calibration can be easily done by changing the values of the parameters. Numerical model is one of economical choice and getting widely used. Bottin etal. (2002)[4] compared physical model and numerical model to get the wave height in Morro Bay harbor entrance and the result of the numerical model is much more comparable in the Morro harbor entrance. Wu (2010)[5] studied numerical analysis against hydrodynamics parameter in Harbor Port, about 45 mil northern Columbia. The current analysis using CMS-Flow model. The analysis result including the water elevation, velocity and wave height from the model shows good fitness with observation data.
2. METHODOLOGY AND DATA ANALYSIS

Governing equation

RMA 2 numerical model solves the depth integrated equations of fluid mass and momentum conservation in two horizontal directions. Vertical velocity is neglected, so velocity vector has the same value and direction over the entire depth of the water column at any instant of time.

\[
\frac{\partial h}{\partial t} + h \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right) = \frac{\partial}{\partial x} \left( h \frac{\partial u}{\partial x} + u \frac{\partial h}{\partial x} + v \frac{\partial h}{\partial y} \right) + \rho \left( \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) + gh \left( \frac{\partial a}{\partial x} + \frac{\partial h}{\partial x} \right) + g \frac{\partial v}{\partial x} + \frac{g \nu n^2}{(1.48h^{1/6})^2} + \left( u^2 + v^2 \right)^{1/2} - \zeta V_a^2 \sin \psi + 2h \nu n \sin \theta = 0
\]

where:
- \( h \) = Depth
- \( u, v \) = Velocities in the Cartesian directions
- \( x, y, t \) = Cartesian coordinates and time
- \( \rho \) = Density of fluid
- \( E \) = Eddy viscosity coefficient,
- for \( xx \) = normal direction on x axis surface
- for \( yy \) = normal direction on y axis surface
- for \( xy \) and \( yx \) = shear direction on each surface
- \( g \) = Acceleration due to gravity
- \( a \) = Elevation of bottom
- \( n \) = Manning's roughness n-value
- 1.486 = Conversion from SI (metric) to non-SI units
- \( \zeta \) = Empirical windshear coefficient
- \( V_a \) = Wind speed
- \( \psi \) = Wind direction
- \( \omega \) = Rate of earth's angular rotation
- \( \phi \) = Local latitude

Model Setup

Model domain for this research is consist of coastal area around Rejoso estuary in Pasuruan Regency, East Java, Indonesia with area ± 127.29 km². At the ocean domain, boundary condition is semi circular with radius ± 9 km (see Figure 2). Boundary condition in land is shoreline with length ± 18 km. Model domain is limited by 4 nodestrings which consist of one ocean boundary, two shoreline, and three sides of Rejoso river (Figure 4.1). The number of elements are 9326 with 9322 triangular elements and 4 quadrilateral elements. The number of nodes are 19320 nodes. The elements size in offshore is larger than near shoreline and the elements density near shoreline is higher than at the offshore.
By several trial of Manning’s value and eddy viscosity coefficient, it can be obtained that Manning’s value is 0.01 and eddy viscosity coefficient is 3000. There are 2 observation points with coordinate 715999.2 E; 9156669.2 S and 715668.2 E; 9156708.8 S. Observation point 1 covers current velocity and water surface elevation measurement, and only velocity measurement for point 2. In calibration process, the input in river boundary condition is river discharge on October 2010, and for offshore boundary condition will be used tidal elevation on October 2010, this condition is done because the calibration data available is in October 2010.

**Modelling scenarios**

Modeling the current before the jetty was built to determine the character of the flow in the existing condition. Boundary condition in the river is the river discharge on May 2010, it is because the discharge on May is maximum discharge in 2010, while the boundary condition at sea is tidal elevation on May 2010. With these boundary conditions, the model is expected to represent the maximum condition in 2010. There are 4 scenario model simulation as follows:

1. No jetty
2. Jetty length 100% (proposed jetty design)
3. Jetty length 50%
4. Jetty length 50% with constrained
In scenario 1 or existing condition, current circulation when spring tide conditions, showing the movement of flow to the southeast. This direction is flow pattern transition from the previous spring tide where dominant water moving toward the river. Sometimes, the change of direction transition causes current velocity relatively small. Current velocity in front of the estuary is around 0.01 to 0.04 m/s and the current velocity inside estuary ranged from 0.02 to 0.05 m/s. In some places it can be found turbulence due to the collision between the current from the river with tidal currents in the opposite direction and it can deposit suspended sediment particles. The small current velocity in the ocean, because the ocean current in the area are not dominated by tidal current, but there is also a wave components, pressure, temperature, etc., which can not be modeled simultaneously in the RMA2 model. The movement of current at neap tide is also identical to current conditions at the spring tide. Because the movement of water surface elevation of sea water, the current flow from river towards the sea, with greater velocity due to accumulated with currents are coming from river. Current velocity in front of the estuary ranged between 0.07 - 0.1 m/s.

In scenario 2 and 3, the global current pattern is similar to the condition prior to jetty construction, the differences is the current pattern around the estuary which is blocked by the jetty. The current flow from the east is blocked by the jetty, resulting in a change in current direction to follow the construction of the jetty. At the end of the jetty the current flows to the west and occurs turbulent on the west side of the jetty. The average
current velocity in the turbulence area for scenario 2 is 0.15 m/s with width dimension 250 x 500 m and 0.15 m/s with width dimension 100 x 100 m for scenario 3. At minimum tide level, currents flowing towards the sea. Current velocity in the inside jetty is around 0.2-0.35 m/s higher than current velocity at the outside jetty which is around 0.1-0.15 m/s

In scenario 4, the length of jetty will be used in model is 50% from proposed design or same with scenario 3, but the mouth of jetty is constrained to be 15 meter. This is done because the jetty will not be used as navigation channel and it is expected to increase the velocity inside jetty that will be useful to push sediment out of jetty.

3. DISCUSSION

From the four scenarios that has been done, then compared changes in current velocity in the river mouth before jetty is constructed and inside the jetty construction. The result can be seen in the Figure 4 below. The current velocity in existing scenario is lower than 100% jetty length and 50% jetty length scenario. This is because in existing condition, the river mouth is directly connected with the sea, so the effect of tidal will directly influenced the river flow and decrease the flow velocity.

![Figure 4. Scalar velocity at the river in every scenario](image)

From the figure 5 above, the velocity along the river is not much different in every scenario. The big differences occur starting at distance 1000 meter, in scenario 4 the river flow velocity is significantly increased because of the width of jetty width is
constrained by 15 meter at the jetty mouth and it caused the increasing of velocity inside the jetty. This condition is very important to flush the sediment out from jetty. And for scenario 2 and 3 the velocity smoothly decreased because the width of jetty is following the river width, therefore the behaviour of velocity will follow natural processes in the river where the velocity is decreased because of tidal effect. The changes of water surface elevation in maximum tide condition is not quite large, the differences between scenario 1, 2, and 3 is approximately 0.001 m, in scenario 4 the large differences with the other scenario is caused by constrained jetty width, but the differences with the other scenario is maximum 0.004 meter and it still can be accepted corresponding the capacity of the river. Basically, the water surface elevation before jetty construction is lower than after jetty construction.

Figure 6. Flow velocity and water surface elevation along river channel and jetty in minimum tide condition (144 hours time steps)

Similar with phenomenon in figure 5, from figure 6 above the velocity along the river is not much different in every scenario. The big differences occurs starting at distance 1000 meter, in scenario 4 the river flow velocity is significantly increased because of the width of jetty width is constrained by 15 meter at the jetty mouth and it caused the increasing of velocity inside the jetty. This condition is very important to flush the sediment out from jetty. And for scenario 2 and 3 the velocity smoothly decreased because the width of jetty is following the river width, therefore the behaviour of velocity will follow natural processes in the river where the velocity is decreased because of tidal effect. The changes of water surface elevation in minimum tide condition is not quite large, the differences between scenarios is approximately 0.002 m. In minimum tide condition, the water surface elevation in scenario 4 is higher than the other scenario, it is possibly happened because the tide level at the end of jetty is still great enough to give backwater effect to the water surface elevation inside river and jetty. The water surface elevation in scenario 1 also occurred great decreasing starting from distance 700 m, it is because the river branches into two channel, the shorthest branch to the sea has increased the flow velocity.

Overall, after the jetty construction becomes a shortcut, it makes the river flow more smoothly so the velocity that occurs becomes larger. The flow of current at maximum tide conditions is blocked by jetty construction, it also triggers turbulence at the west side of the jetty. This allows the possibility of sediment in the surrounding area turbulence. The current velocity at the end of the jetty ranged from 0.05 to 0.25 m/s.

By using 25 year return period discharge as boundary condition in the river, it is obtained result that with jetty length 50% with constrained from proposed design the
water surface elevation will increase maximum 0.123 m from existing condition, and for jetty length 50% and 100% are 0.019 m and 0.082 m respectively. From that result, it can be concluded that even constrained jetty is good in providing high flow velocity which is useful for flushing the sediment, but the effect of increasing water surface elevation in the upstream area needs to be noticed.

4. CONCLUSIONS

The result in every scenario provides weakness and advantages. If using jetty length 1170 m, it will good in moving sediment deposition from estuary to the offshore, but the length of jetty is no need that long because Rejoso estuary is river dominated, and also the longshore sediment transport is difficult to move bypass the jetty. If using jetty length 50% with unconstrained, the velocity and the water surface elevation changes in the river is not much different with jetty length 100%, it is showed that with jetty length 50% from proposed design is enough to maintain condition in the river. If using jetty length 50% with constrained, the velocity in the river is higher up to twice than the other simulations, but the changes of water surface elevation in the river is need to be noticed.

The length of jetty with 556 m or 50% from original design can be better than original design. From sedimentation rate inside the jetty, it can be concluded that the high velocity inside the jetty can successfully pushed the sediment out of jetty.

5. RECOMMENDATIONS

It needs longer time series sediment concentration data to represent the process sedimentation more representatively with actual condition.

Wave current simulation is needed to make more representative model for nearshore sediment transport

It needs to run the model in longer time more than 30 days.

6. REFERENCES


