

Study of Water Quality Changes due to Offshore Dike Development Plan at Semarang Bay

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Abstract. Now, coast of Semarang Gulf is experiencing rapid growth because Semarang as a center economic growth in Central Java. On the other hand, coast of Gulf Semarang also experience a variety of very complex problems, such as tidal flood, land subsidence, as well as coastal damage due to erosion and sedimentation process. To overcome these problems BPPT and other institutions proposed construction of offshore dike. Construction of the offshore dike is a technology intervention to the marine environment that will certainly affect the hydrodynamic balance in coastal water including water quality in the Gulf of Semarang. Therefore, to determine changes in water quality that will happen is necessary to study the water quality modeling. The study was conducted by using a computational modeling software MIKE-21 Eco Lab Module from DHI. Based on this study result knowed that development offshore dike will change water quality in the west and east dam that formed. In west dam the average value of the DO decline 81.56% - 93.32 % and the average value of BOD rise from 22.01 to 31.19% and in the east dam, there is an increase average value DO of 83.19% - 75.80%, while the average value of BOD decrease by 95,04% - 96.01%. To prevent the downward trend in water quality due to the construction of the offshore dike, its necessary precautions at the upstream area before entering the Gulf of Semarang.

1. Introduction

1.1. Background

Coast of Semarang Gulf is area that consist land and water areas along the coast that stretches from the mouth of K. Bodri-Kab. Kendal in the west, the coast of Semarang City up to the estuary of K. Wulan-Kab. Demak in the eastern part. This area has approximately 104 km long coast. Coast of Semarang Gulf is currently experiencing rapid growth. As a consequence of these developments and natural conditions this area, now coast of Semarang Gulf experiencing complex problems.

The first problem that occurred in the Gulf of Semarang city is tidal flood and river flood. Now, if occurrence of high tides, most areas of the Semarang City especially coastal areas ($\pm 3,100$ ha) will be floods [1].

The second problem is the occurrence of land subsidence. Land subsidence occurs in the range of 2008-2009 reached -12.4 cm, then increased in 2009-2010 became -20.4 cm and fell back to 10.5 cm in 2010-2011 [2]. According to the Indonesia Geological Agency, land subsidence speed range of 0-1 cm/yr (in the district. Tugu, West Semarang, Semarang, Central and East of Semarang) and 8-9 cm/yr (North Semarang and Genuk) [1].



The third problem is the occurrence of abrasion along the coastline due to the dynamics of the coast. Between the years 1972 - 1992 in some places along the coast of Semarang back about 500 m, between the years 1992-2001 partially some beach experience abrasion large enough [3].

To overcome these problems has been several concept that proposed to regional governments both to Central Java Government and Semarang City Government. Concepts that are currently the most prominent is the concept of offshore dam and belt/ coastal dike along the shoreline and offshore dike concept proposed by BDP-BPPT. These concepts beside to overcome tidal flood, land subsidence and coastal erosion, also offer solutions of transportation infrastructure development.

Construction of coastal infrastructure such as offshore dikes that proposed by BPPT is a technology intervention to the marine environment that will certainly have an impact on coastal dynamic balance includes the impact on water quality in the Semarang Gulf. Until now the concepts proposed for addressing concerns in the Semarang Gulf has been no systematic study of the impact on existing water in particular the water quality. Therefore this study will be conducted studies on changes in water quality that would occur if the construction of the offshore dike actually built.

1.2. Location and period

The area of this study is along the Semarang Gulf that stretches from the mouth of K. Bodri in Kab. Kendal, the coast of Semarang City until the estuary of K. Wulan in Kab. Demak (figure 1).

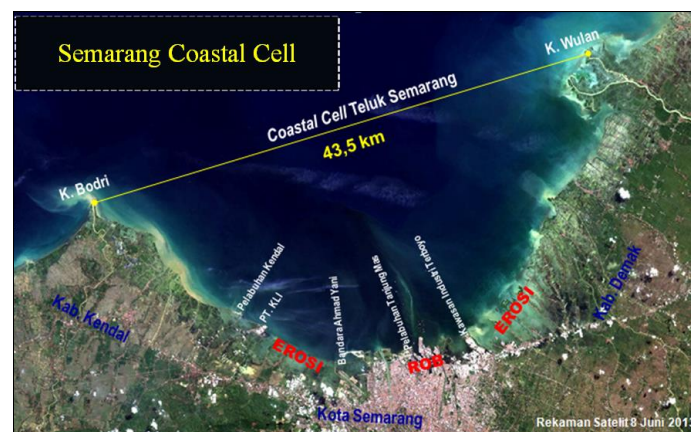


Figure 1. Area of study

The period of this study is the rainy season (January) with consideration the data required for modeling is complete compared to other months.

2. Method

The main step in this study is field surveys and computational modeling.

2.1. Steps of Study

The stages of the activities to be undertaken are as follows:

- Literature and secondary data collection; field surveys, including bathymetric surveys, sampling and basic sediment drift, currents measurements and tidal measurements
- Analysis of secondary, primary data and preparation of scenario computational modeling
- Computational modeling and analysis the modeling results

2.2. Water Quality Modeling

Numerical advection-dispersion modeling was conducted to determine the distribution of water quality parameters that wants to be reviewed, based on hydrodynamic conditions of local waters. The

modeling is done by using modeling software MIKE 21 Modules Eco Lab with WQ Simple Template MIKE 21/3. Based on this template is the main parameter DO (Dissolved Oxygen), BOD (Biological Oxygen Demand) and salinity [4].

Builder equation for water quality modeling based on the advection dispersion process. Dynamism of a substance to be modeled in the advection process can be expressed by the equation of its transport, which for non-conservative form can be written as follows [4]:

$$\frac{\partial c}{\partial t} + u \frac{\partial c}{\partial x} + v \frac{\partial c}{\partial y} + w \frac{\partial c}{\partial z} = D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} + D_z \frac{\partial^2 c}{\partial z^2} + |S_c + P_c \quad (1)$$

where :

- c : Concentration of ECO Lab variabel
- u, v, w : Current velocity component
- Dx, Dy, Dz : Coefficient of dispersion
- Sc : Sources and sinks
- Pc : Eco Lab processes

2.3. Equipments and Data

Equipments used in this study are : echo sounding SB CEEDUCER for measure bathymetry; sediment grabber for sampling basement sediment; Nansen Bottle or sampling water, software MIKE-21 FM : hydrodynamics and ECO-Lab modul, software Global Mapper 13. The data that used in this study :

- Hydrodynamic data at *boundary*, such as salinity, temperature and tidal level, etc.
- Source : river debit (river at Semarang area [5]; Kendal area [6]; Demak area [7])
- Water quality data at boundary, concentration of BOD and DO that will simulated ((river at Semarang area [8]; Kendal area [9]; Demak area [10])
- ECO Lab forcing and ECO Lab constanta
- ECO Lab Load : temperature, concentration at source (BOD, DO and TSS)

3. Result and Discussion

Discussion of the results of water quality modeling is done per-scenario to try to compare the existing condition and ultimate. Existing condition is a condition that exists today (in the absence of giant dike and islands reclaimed) and the condition after the construction of the offshore dike proposed by BPPT.

3.1. Modeling Scenarios

Generally, scenarios is divided into three major parts of the existing condition and the condition after the construction of the offshore dike according Concept of BPPT 1 and BPPT 2 (see figure 2).

Due to limited data and time available, simulating is only done for the west season (represented by the month of January 2014), because the existing data for the month of January 2014 is more complete compared with the data in September 2014 so expect the resulting condition can approach the actual conditions. Simulation chosen dates 1 to 11 January 2014, with the consideration that this happens timescales low tide and high tide.

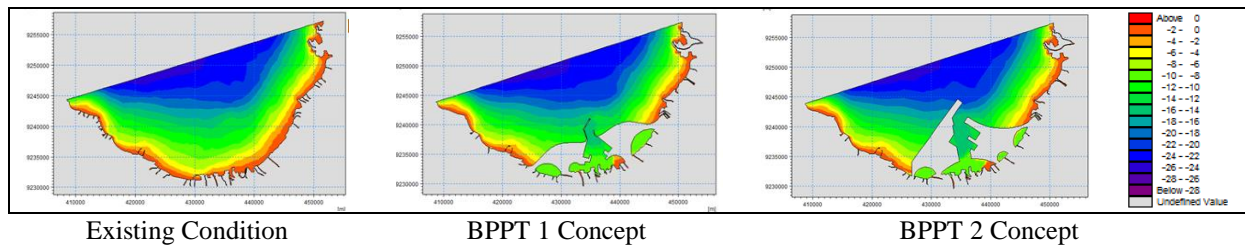


Figure 2. Bathymetry of Semarang Gulf as domain model : existing condition, after construction offshore dike BPPT 1 and BPPT 2 concepts

3.2. Discussion

Based on the results of water quality modeling, the folders are formed and on the waters of the Port of Tanjung Emas shipping lanes are located between the dike changes offshore water quality significantly. The figure to show the changes in water quality over time until the end of the simulation shown in the figure 3 below.

To determine the changes in more detail that caused by infrastructure development like BPPT 1 concept and BPPT 2 concept, it needed extraction at 4 locations, namely : outside the west dam; inside the west dam; in the navigation channel Tanjung Mas; outside the east dam (see figure 4). And to know changes in the value of the DO and BOD during the simulation process (time series) then made extraction at several points for observation (see figure 5).

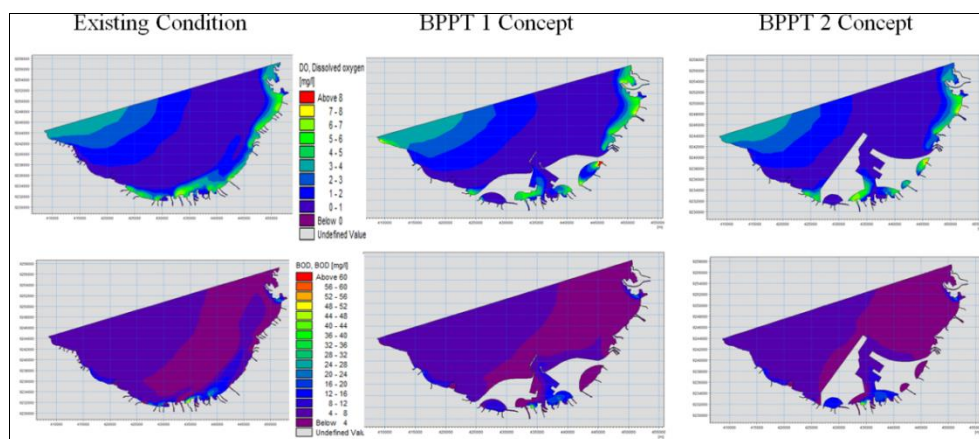


Figure 3. Comparison modeling result between existing condition, BPPT 1 Concept and BPPT 2 Concept at 240 hours simulation (DO : above; BOD : below)

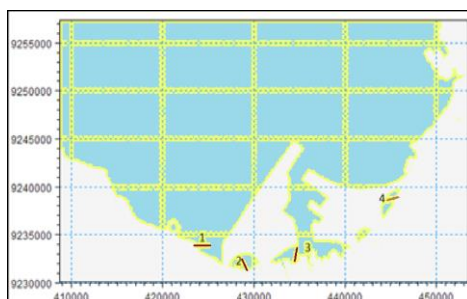


Figure 4. Extraction line to observe water quality changes

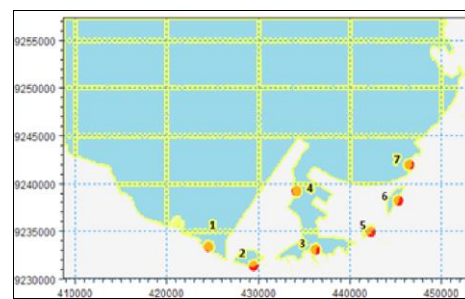


Figure 5. Extraction point to know the water quality changes as a function of time

Based on modeling results in this scenario, generally at the end of the simulation (day 10th) in the west, especially the outside dam with the concept of BPPT 1 and 2 will raise the value of the DO

particularly at positions 1 km of the coastline (see figure 6.a). This is probably occur caused of the movement of water due to the lack of infrastructure that can improve the aeration process at locations in the west infrastructure.

The sea waters at the west, that according to the concept of BPPT 1 and 2 will be formed dam, a decline in the average value of DO is significant and bit an increase in the average value of BOD (see figure 6.b). The decreasing DO value occurs because the presence of dam cause the waters became calm because it is not affected by tidal and wave from the offshore waters so the aeration process is much reduced resulting in dissolved oxygen is also reduced. While the BOD value will raise because with the dam organic substances polutant will be concentrated in the dam and can't spread to the open waters). The magnitude of decrease in the average value of the DO in the dam west this amounted to 81.56% (due to the BPPT 1 Concept) and 93.32% (due to BPPT 2 Concept) of the average DO value of the existing condition of 4.42 mg/l. As for the average BOD value increased by 31.19% (due to the BPPT 1 Concept) and amounted to 22.01% (due to the concept of BPPT 2) of the average value of BOD existing condition of 10.45 mg/l.

The waters in the shipping channel Tanjung Mas Port decline in the average value of the DO and the average value of BOD (see figure 6.c). A decrease in the average value of DO is due to the limited contact with the waters of the open sea so will reduce aeration process.. The magnitude of decrease in the average value of the DO in the waters around Tanjung Mas about to 35.79% (due to the BPPT 1 Concept) and 46.51% (due to the concept of BPPT 2) from the existing condition of 5:16 DO mg/l. As for the average value of BOD decrease about to 48.25% (due to the BPPT 1 Concept) and about to 19.79% (due to the concept of BPPT 2) from the existing condition of 23.27 mg/l.

The waters at the east, which according to the concept of BPPT 1 and 2 will be formed dam, an increase in the average value of the DO as well as a decrease in the average value of BOD significantly (see figure 6.d). Increasing DO value in the dam is caused by the high value of the DO of river water into the dam east though the process airation as tidal and wave did not happen because isolated by dikes. While the decline in value caused by the low BOD value of river water into the dam is compared to the value of the initial BOD sea waters before. The magnitude of the increase in the average value of the DO in deep waters east dam is at 83.19% (due to the BPPT 1 Concept) and 75.80% (concept of BPPT 2) of the average DO value of the existing condition of 3.17 mg/l. As for the average BOD value dropped by 95.04% (due to the BPPT 1 Concept) and about to 96.01% (due to the concept of BPPT 2) of the average value of BOD existing condition of 6.25 mg/l.

An example of extraction results at some observation point such as outside the dam (point 1) and inside the dam (point 2) as a function of time will be discuss at below.

At the observation point outside the west dam is seen that the pattern of changes in the value of the DO was not significant (see figure 7.a). At the end of simulation, DO value changes less than 1%. It is caused at this location is still directly connect with the open sea as the existing condition. Slight changes seen in the BOD value (about 1.37%) due to the concept of BPPT 1 because of the shifting of the flow K. Siangker.

At the observation point in the west dam is seen that the pattern of changes are very significant (see figure 7.b). This is probably due to the existing condition is very dynamic beside the influence of the incoming river flow is also due to the tides, waves and wind. So with the concept of BPPT changes in the value of the DO and BOD become more stable does not fluctuate like when it is open to the ocean. At the end of the simulation, DO value decreasing about 97%. While the BOD values fell between 49.4% (due to BPPT 1 concept) and 65.67% (BPPT 2 concept).

At the observation point no. 3 in the shipping channel of Tanjung Mas Port, shows that the pattern of changes in the value of the DO and BOD as a result of infrastructure development is significant (see figure 7.c). This is probably due to that the existing condition upheaval of sea waters at this location is large enough, the opposite occurs when it is already built infrastructure, at this location although it still can be in direct contact with the waters of the open sea, but the condition is relatively quiet because shielded from waves. At the end of the simulation decreasing DO value approximately 53.56% (due to

the BPPT 1 Concept) and 79.39% (due to BPPT 2 Concept). While the BOD values fell between 63.69% (due to the BPPT 1 Concept) and 68.03% (due to the concept of BPPT 2).

At the observation point no. 4 in the shipping channel of Tanjung Mas Port, shows that the pattern of changes in the value of the DO and BOD as a result of infrastructure development was not significant (see figure 7.d). This is probably due to that the existing condition and has built the infrastructure can still be in direct contact with the open sea waters despite all effect is not large. Thus the fluctuations of DO and BOD values change as a result of this infrastructure is relatively uniform.

At the end of the simulation impaired DO approximately 1.92%. While the BOD values fell between 19.78% (BPPT 1 Concept) and 33.66% (BPPT 2 Concept).

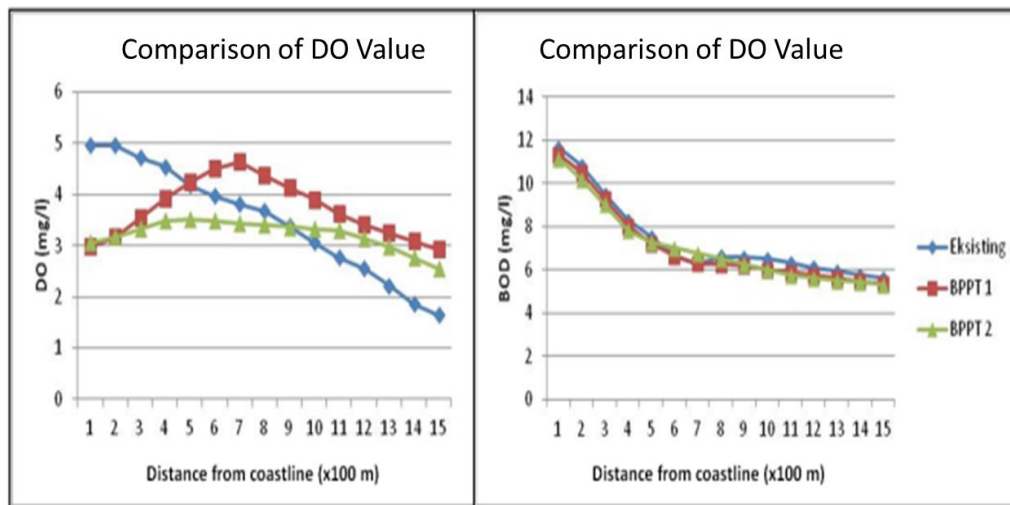


Figure 6. Comparison DO and BOD in January at 10th simulation day (In outside west infrastructure, location 1)

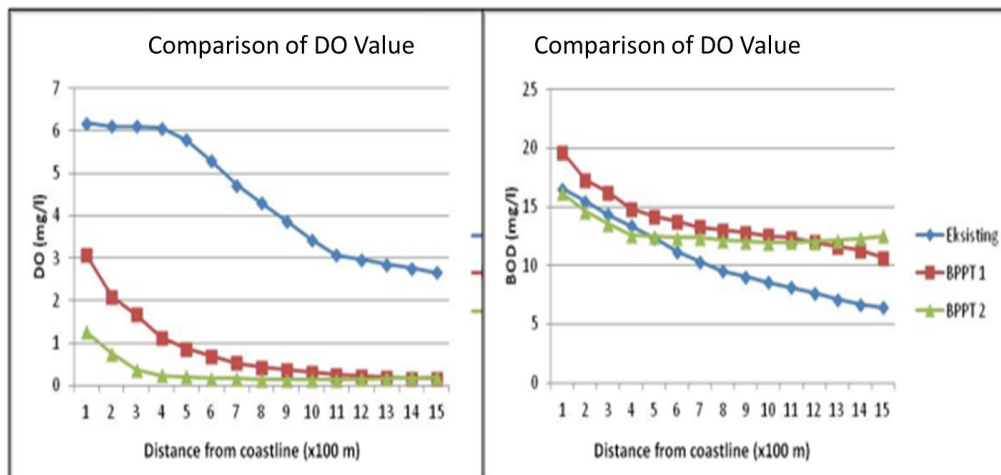


Figure 7. Comparison DO and BOD in January at 10th simulation day (Inside west dam, location 2)

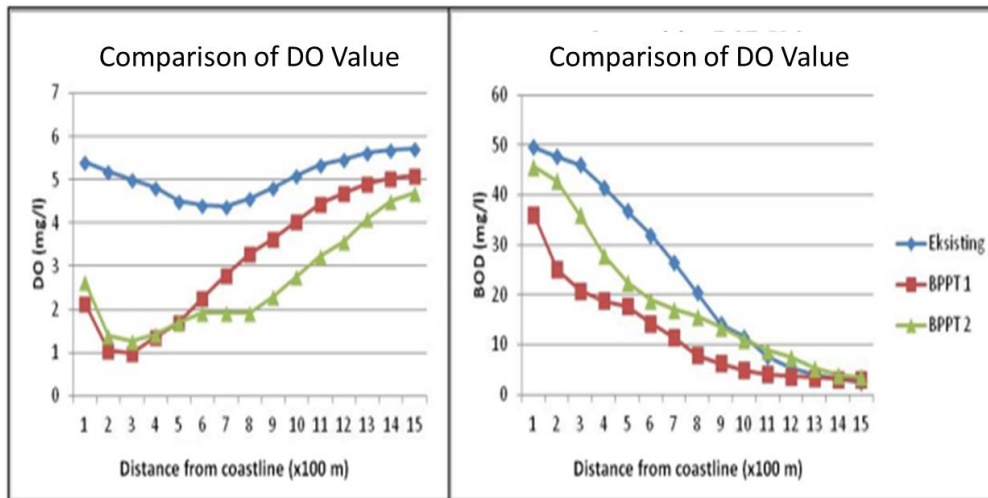


Figure 8. Comparison DO and BOD in January at 10th simulation day (In the shipping channel Tanjung Mas Port, location 3).

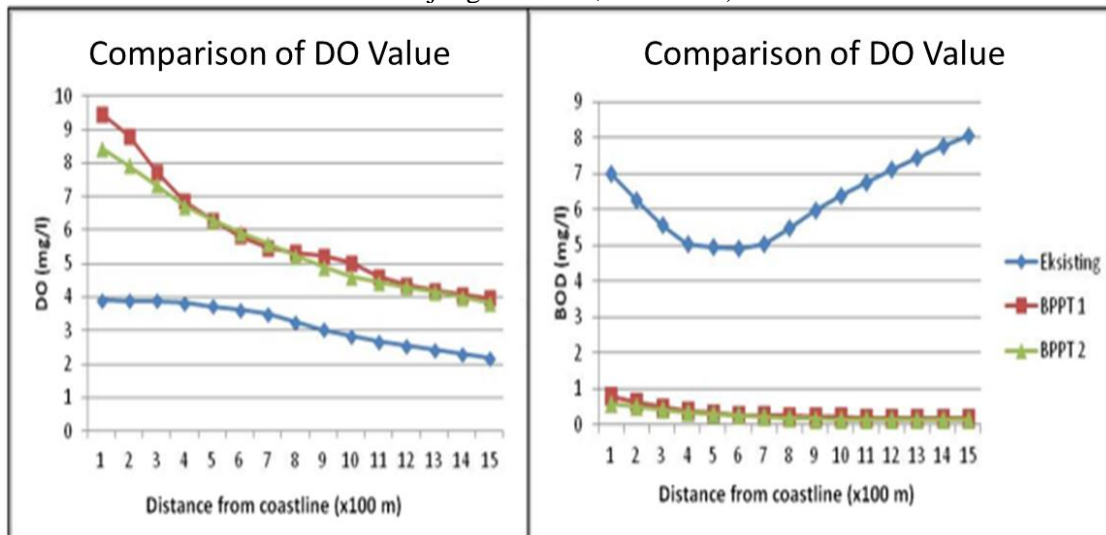


Figure 9. Comparison DO and BOD in January at 10th simulation day (Inside east dam, location 4)

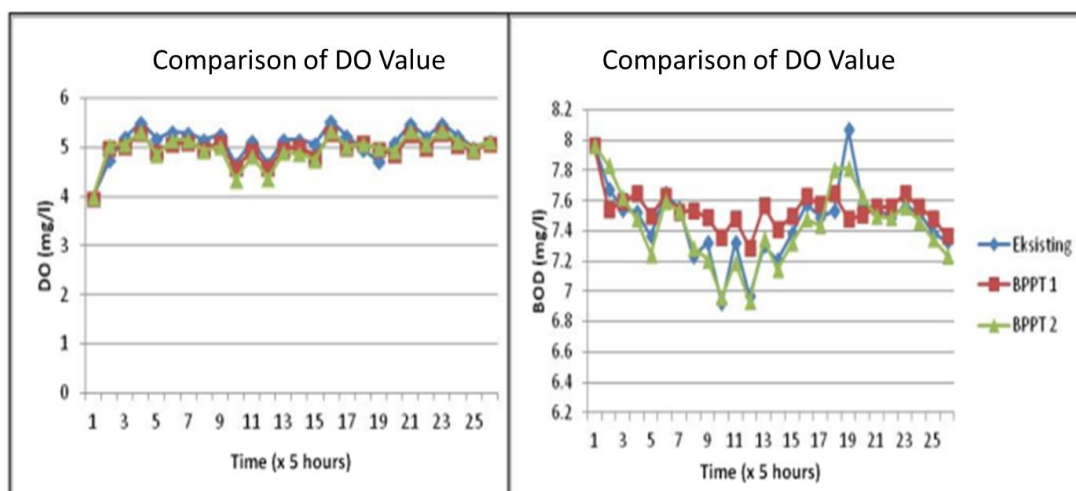


Figure 10. Water quality changes as a function of time at observation point 1 (outside west dam)

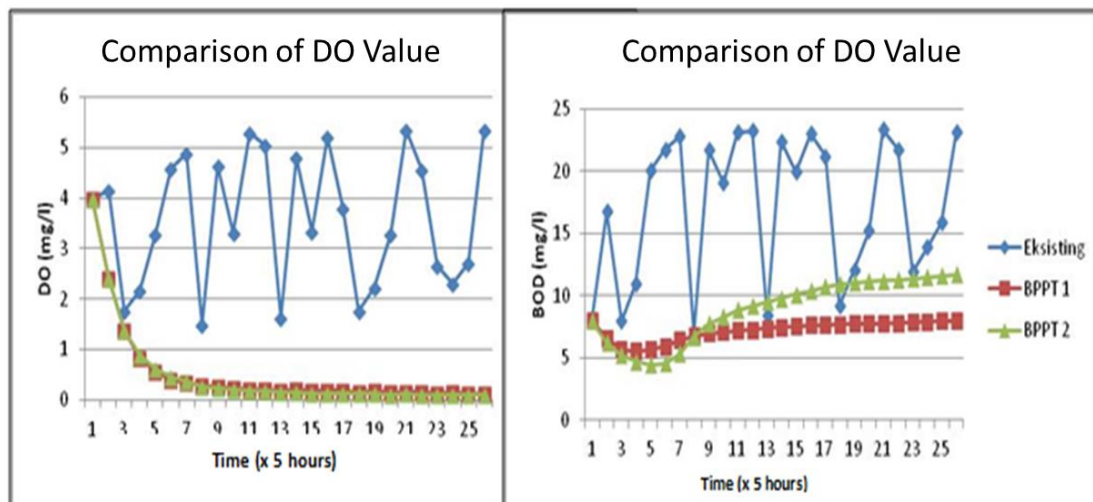


Figure 11. Water quality changes as a function of time at observation point 2 (inside west dam)

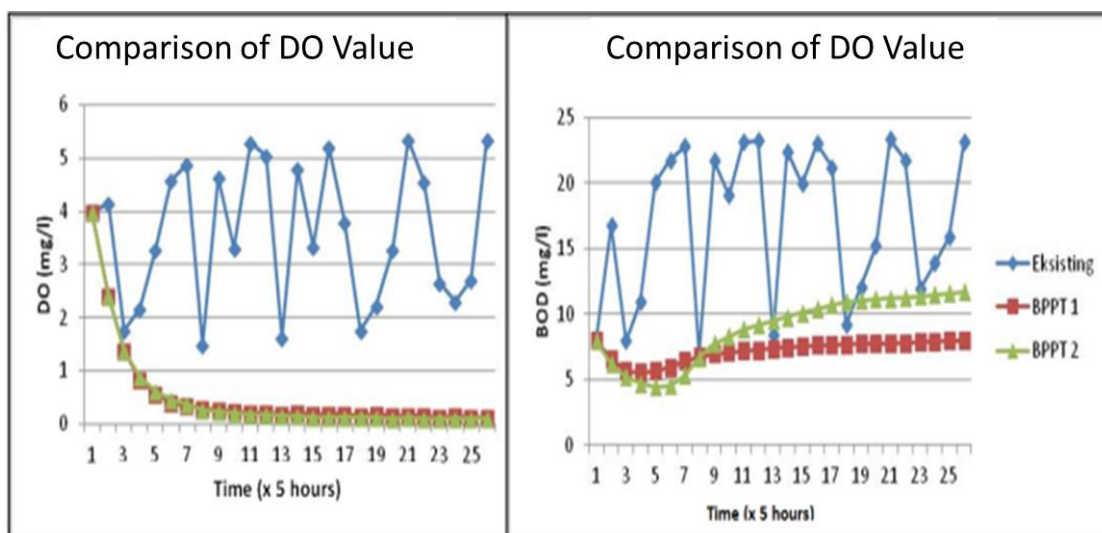


Figure 12. Water quality changes as a function of time at observation point 3 (Tanjung Mas shipping channel)

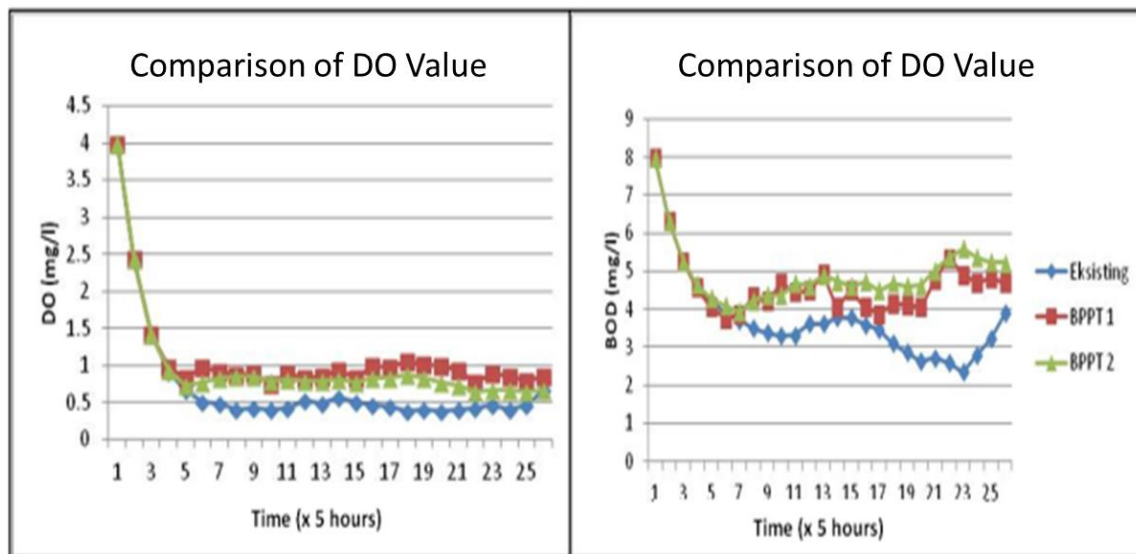


Figure 13. Water quality changes as a function of time at observation point 4 (Tanjung Mas shipping channel)

4. Conclusion

Based on the result of this study, can be concluded as follows :

- In general, the concept of BPPT I and BPPT II will form the dam that isolated from open waters, the input of water from river discharge will affect the quality of water in the dam formed.
- As a result of the construction of the offshore dike according concept of BPPT 1 or BPPT 2, in the dam formed in the west part decline in the average value of the DO 81.56% - 93.32% and the average value of BOD increasing by 22.01 to 31 , 19%.
- In the navigation channel of Tanjung Mas Port, decrease the average DO value of 35.79% - 46.51%, while the average BOD value dropped by 19.79 - 48.25%.
- In the dam to be formed to the east of an increase in the average DO value of 83.19% - 75.80%, while the average BOD value dropped by 95.04% - 96.01%.

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References

- [1] KOICA-BAPPENAS 2012 *Disaster Survei and Thematic Map Building in Semarang Area*, (Jakarta: Koica-Bappenas) p 21
- [2] Saraswati S A 2012 *Study of Land Subsidence in Semarang* (Denpasar: Thesis at Environmental Science Faculty, Post Graduate Program, Udayana University) not published p ix
- [3] Marfai M A 2011 *GIS Modelling of River and Tidal Flood Hazards in a Waterfront City – Case Study : Semarang City* (Netherlands: International Institutie for Geo-Infomation Science and Earth Observation Enschede) p 59

- [4] DHI 2004 *Marine MIKE 2/3 Ecological Modelling- Mike 21/3 Eco Lab FM Short Discreption*, (Horsholm Denmark: DHI) p 4
- [5] BLH Semarang City 2013 *Buku Data Status Lingkungan Hidup Daerah Kota Semarang Tahun* (Semarang: Pemerintah Kota Semarang) p 12
- [6] BLH Kabupaten Kendal 2013, *Laporan Status Lingkungan Hidup Daerah, Kabupaten Kendal* (Kendal: Pemerintah Kabupaten Kendal) p I-10
- [7] Direktorat Jenderal Sumberdaya Air-Departemen Pekerjaan Umum 2010 *Profil Balai Besar Wilayah Sungai Pemali Juana* (Semarang: BBWS Pemali Juana) p 25
- [8] BLH Kota Semarang 2014 *Hasil Pemantauan Kualitas Perairan 2013* (Semarang: Pemerintah Kota Semarang)
- [9] BLH Kabupaten Kendal 2014 *Hasil Pemantauan Kualitas Perairan 2013* (Kendal: Pemerintah Kabupaten Kendal)
- [10] BLH Kabupaten Demak,, 2013, *Buku Laporan Pemantauan Kualitas Air Sungai Kabupaten Demak Tahun 2013* (Demak: Pemerintah Kab. Demak) p I-8