

REVIEW OF ALTERNATIVES FOR JAKARTA NCICD PROJECT USING NUMERICAL MODELING

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ABSTRACT

A numerical simulation was conducted to compute changes in hydrodynamic characteristics that result from the installation of the outer sea dike in Jakarta Bay for NCICD Project. The tidal difference did not exceed 1.3m and the tidal current velocity did not exceed 0.5m/s. The tidal current consists of the flood current flowing from west to east and the ebb current flowing from east to west, with the flood current slightly stronger than the ebb current. The velocity of the tidal residual current was close to 0m/s in the planned area for the outer sea dike. The water mass near the coast moves slowly from west to east but cannot move out of the area near Jakarta Bay for a long time. Therefore, to implement for outer sea dike installation, it needs to take attentions in these simulation results of circulation and dilution of the water in the Jakarta Bay. In simulations to which reclamation of artificial islands and alternative routes for the outer sea dike were applied, it was confirmed that active flood response is possible with the exception of Alternative 1 and the preferred alternative (Phase 1). Alternative 4 and the preferred alternative can be good alternatives that block incoming waves and allow ocean circulation if accompanied by the reinforcement of coastal and river embankments. Alternative 1 allows flood control but its water quality problem should not be neglected. Alternative 2 allows flood control but an eddy occurs in front of the first sluice gate in the northwest area. Alternative 3 and the preferred alternative – Phase 2 allow active and elaborate flood control but an optimal operation method needs to be developed.

Keywords: NCICD, Numerical Simulation, Hydrodynamic Modeling, Sea Dike, Water Circulation.

1. INTRODUCTION

The Jakarta National Capital Integrated Coastal Development (NCICD) Project is a strategic project initiated by the Indonesian government in an effort to safeguard the northern Jakarta area from coastal and river flooding. For this project, three nations, Indonesia, South Korea and the Netherlands, entered into an MoU for the NCICD project. The key task for the South Korean side is carrying out a feasibility study on the said project to support the Indonesian government make an official decision on its investment in an outerseadike(OSD).

1.1 Objectives

The objectives and expected contributions of this work are as follows:

- To determine the topological and hydrodynamic characteristics of Jakarta Bay, the target area, and utilize the findings as preliminary data to examine sea dike routes;
- To examine changes in hydrodynamic characteristics, resulting from the installation of new coastal structures (sea dikes) and hydraulic structures and

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utilize the findings as preliminary data to examine hydraulic phenomena that are adverse to their design and construction and provide possible solutions;

- To provide hydrodynamic background data for related numerical simulations (sediment transportation, dispersion of thermal discharge, change in water quality, etc.).

1.2 Scope

The work scope of hydrodynamic modeling can be summarized as follows:

- To perform a study on the target sea area and collect data that can be used for model set-up and then process the data to use it with models;
- To operate models as two types: regional and local models;
- To set up hydrodynamic models that reflect current conditions before the sea dike is installed as well as alternatives presented in conceptual design of the work in order to simulate the phenomenon;
- To examine the characteristics of tides (water level, current velocity) at proposed points for sea dike installation;
- To examine characteristics and applicability of alternatives presented in conceptual design of the work.

2. USED DATA

2.1 Coastline

Digitizing was performed after projecting an electronic nautical chart on a coordinate system. The electronic nautical chart (ID400086, 2015) in the geographic tagged image file format was issued by the Hydro-Oceanographic Center of Indonesia Navy. The planned boundary lines of 17 artificial islands were drawn by using the GIS shapefile and the digitizing for some artificial islands (C, D, G, N), completely reclaimed, was performed using satellite images from Google Maps (as of Sep. 1, 2017).

2.2 Bathymetry

A depth contour chart was drawn using the echo sounding raw data provided by Indonesia Ministry of Public Works and Housing (PUPR) to eliminate noise and merging the echo sounding raw data with the data for unmeasured zones in GEBCO_2014, which was provided by the International Hydrographic Organization (IHO). Where the two overlapped, the echo sounding raw data superseded the GEBCO_2014 data. The completed chart of coastline and bathymetry is shown in Figure 1.

2.3 Tide

The tidal observation data of the Indonesian coast are managed by the Indonesia Geospatial Information Agency (BIG), and there are three tidal stations in Special Capital Region (DKI) of Jakarta. PUPR performed the observation of tidal current velocity at three points and provided tidal data. The website of BIG offers downloads of tidal datum calculated through numerical simulations; amplitude of harmonic constituents and phase distribution; and the raw data of tidal level time series (1 hour interval) for each coordinate.

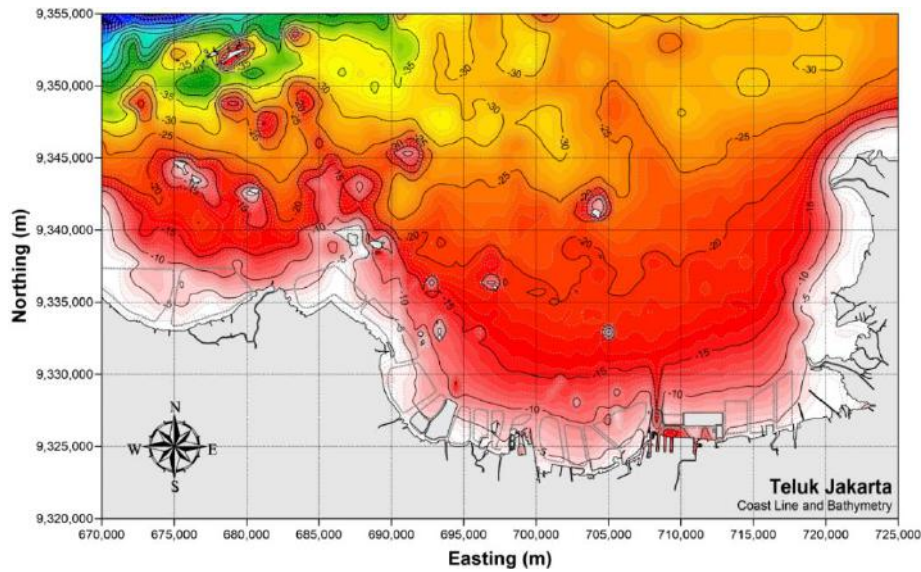


Figure 1. Completed Chart of Coastline and Depth Contours

2.4 Discharge

The long-term discharge flowing into Jakarta Bay was calculated by computing the discharge from all river basins in Jakarta Bay, using the TANK model (four layer) of Masami Sugawara, based on the average daily rainfall data provided by PUPR. The flood discharge was calculated using rainfall-runoff analysis based on the average daily rainfall data provided by PUPR, and the unit hydrograph method was adopted due to several circumstances.

3. MODEL SET-UP

3.1 Overview

The hydrodynamic modeling was operated in two separate models: Regional LautJawa Utara Model and Local TelukJakarata Model. The software used in this work was the Delft3D-FLOW module.

3.2 Regional Model

The applied computational grid was a two-dimensional grid that considered only one layer of depth average in the vertical direction, in accordance with the nature and usage of the model. The horizontal computational grid was an orthogonal grid laid down in a due north direction, and it was also a rectangular grid composed of cells having vertical and horizontal lines representing 200 m. The total number of cells in this computational grid was 44,874 (277 × 162).

3.3 Local Model

The applied computational grid was a two-dimensional grid that considered depth-average in the vertical direction, as with the regional model. The horizontal computational grid was composed of 5,539 (191×29) cells in the north and 88,764 (569×156) cells in the south. One side of a grid cell in the north represents 120-200m, while one side of a grid cell in the south 40-60m. The resolution of the computational grid is three times higher in the south section than in the north section.

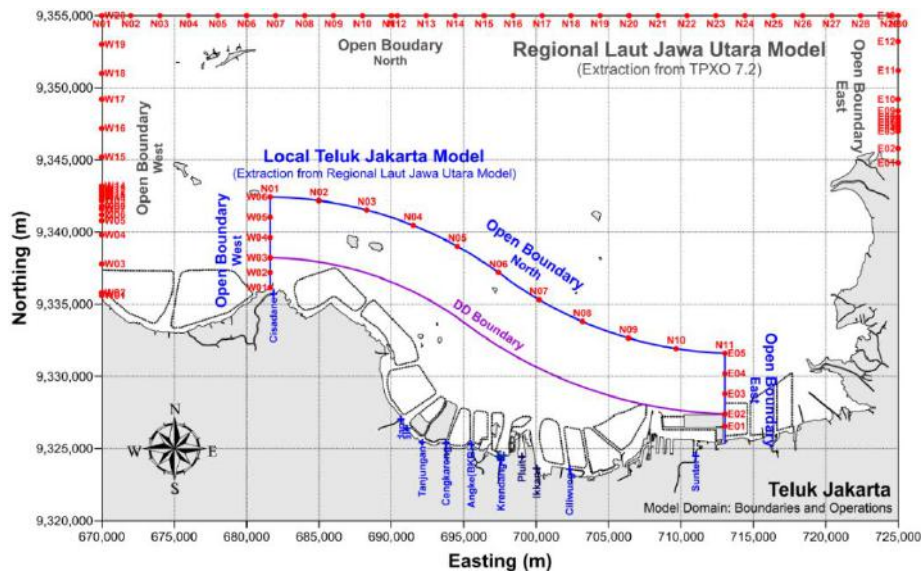


Figure 2. Model Area and Boundary Condition Application Points

The boundary condition of rivers was divided into two cases. One case is when long-term normal discharge was applied, and the other case is when the hydrograph (100-year frequency), obtained through the calculation of flood discharge, was applied. Long-term normal discharge was used to simulate the current condition when there is no sea dike, while the hydrograph was used to examine a flood discharge pattern of each sea dike alternative. When the hydrograph was applied, all rivers had different delivery time and peak flood time from one another. Therefore, for a conservative approach, the occurrence time of peak flood and peak rainfall was fitted to the highest high tide time at spring tide/high water level at spring tide.

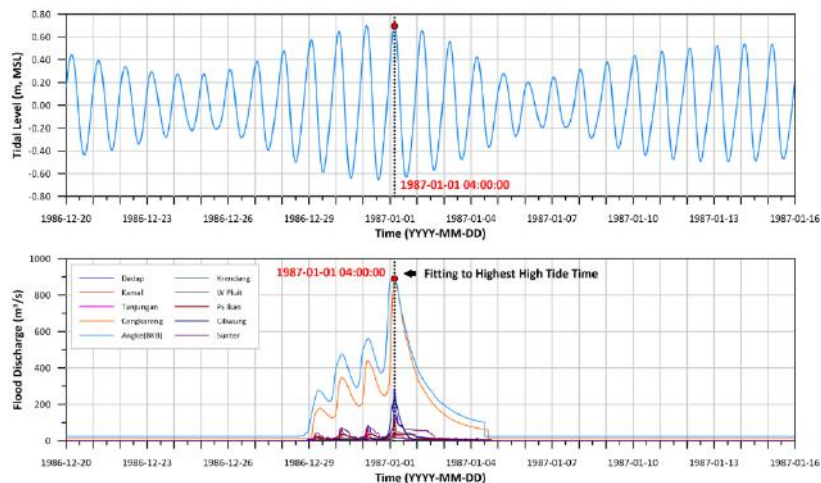


Figure 3. Hydrograph with the Occurrence Time of Peak Flood and Peak Rain Fitted to Highest High Tide Time

4. CONCEPTS OF ALTERNATIVES

In Alternative 1, the extension of the outer sea dike totals 19.1km and a 5,900-ha retention lakes are formed by closing the bay. It is assumed that the reclamation of artificial islands is 75% completed. Two 100m wide drainage gates are installed, one on the east extension and the other on the west extension. And two drainage pumping

stations are installed, one with a capacity of 190m³/s on the west extension and the other with a capacity of 350m³/s on the east extension. Flood water is discharged from the sea dike only through these two structures. The water level of the retention lakes is always maintained at LWS₂₀₁₂(-) 1.4m.

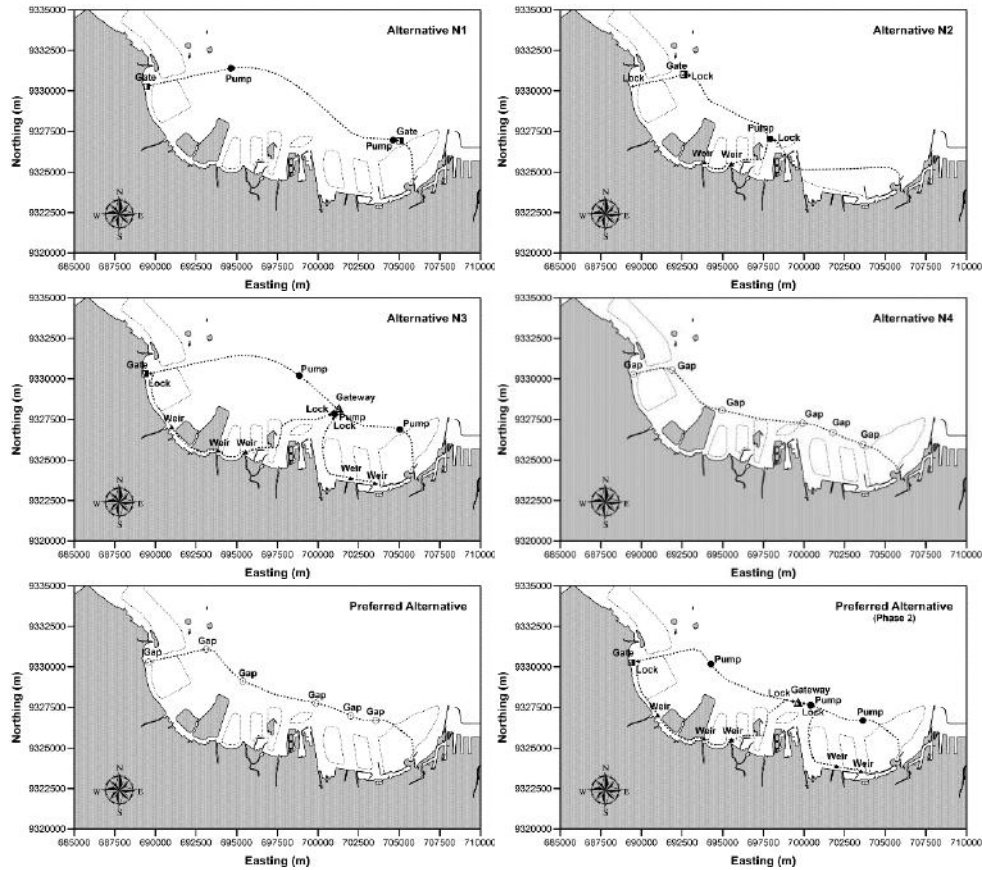


Figure 4. Layout of Alternatives

In Alternative 2, the west and central sides of Jakarta Bay are closed and the east side is open. The extension of the outer sea dike totals 9.2km. A 2,000-ha retention lake and a 500-ha retention lake are formed against the west and central sides of Jakarta Bay, both of which are closed. It is assumed that the reclamation of artificial islands is 75% completed. And a drainage pumping station with a capacity of 8,100m³/s is installed in the center of the bay for flood discharge. A 100m wide drainage gate is installed on the west extension, and the controlled water level of the retention lake is LWS₂₀₁₂(-) 1.4m. Two 100m wide movable weirs are installed along the inner dike.

In Alternative 3, the outer sea dike is basically in the same form as the one in Alternative 1. But an inner dike is added to divide the retention lake into east and west parts, and hydraulic structures are manipulated for management. There are three retention lakes. The east and west retention lakes are 4,300ha and the central site is 1,600ha, with the central site serving as both a retention lake and a diversion channel. The extension of the outer sea dike totals 19.1km as in Alternative 1, and it is assumed that the reclamation of artificial islands is 75% completed. Each retention lake has a drainage pumping station for flood discharge. The drainage pumping stations have a capacity of 80m³/s (west), 420m³/s (central) and 30m³/s (east), respectively. A 200m wide drainage gate is installed for the west retention lake, and a 160m wide gateway for the central retention lake. And 100m wide movable weirs are installed along the inner dike; three movable weirs on the west side and two on the east side. The controlled water level of

the retention lakes is $LWS_{2012(-)}$ 1.4 m, and overflow is blocked through weirs for up to one hour after flood has occurred in order to prevent the deterioration of water quality in the retention lakes.

In Alternative 4, the 17.2km long extension of the sea dike does not form a continuous boundary. The sea dike is an open-type dike with gaps in some sections. It is assumed that the reclamation of artificial islands is 75% completed. The open sections allow tide to freely come and go, solving problems related to water quality and the preservation of mangrove forests. Ships can pass through the open sections, which can reduce conflict with stakeholders.

In the preferred alternative, the outer sea dike is located further towards the sea than in Alternative 4. The sea dike is an open-type dike with gaps in some sections, as in alternative 4, and its extension totals 17.9km. The open type is not intended to last permanently and the open sections can be closed if ground subsidence continues. This alternative leaves room for active response in the future. It is assumed that the reclamation of artificial islands is 75% completed.

The preferred alternative – phase 2 is based on the preferred alternative and supposes the closure of the existing open sections if ground subsidence continues until 2050. It is a compromise between the existing preferred alternative and Alternative 3. And 2,700-ha retention lakes are formed through the installation of the outer sea dike, and it is assumed that the reclamation of artificial islands is 75% completed. Drainage pumping stations with a capacity of $70m^3/s$ (west), $620m^3/s$ (central) and $30m^3/s$ (east) are installed for flood discharge. A 200m wide drainage gate is installed for the west retention lake. The controlled water level of the retention lakes is $LWS_{2012(-)}$ 1.4m. As in Alternative 3, a total of five movable weirs are installed among Islands B through F and Islands I through L to block overflow for up to one hour after flood has occurred.

5. SIMULATION RESULT

5.1 Regional Model

The tidal characteristics computed using the prepared model have the characteristics of a diurnal tide, which has only one high and low tide each day, and among different tidal constituents, K_1 was found to have the most dominant effect. In the inner side of Jakarta Bay, the tidal level was below $LWS_{2012 (+)}$ 1.3m and the current velocity did not exceed 0.5m/s. The flood current was formed to flow from west to east and the ebb current from east to west, with the flood current slightly stronger than the ebb current.

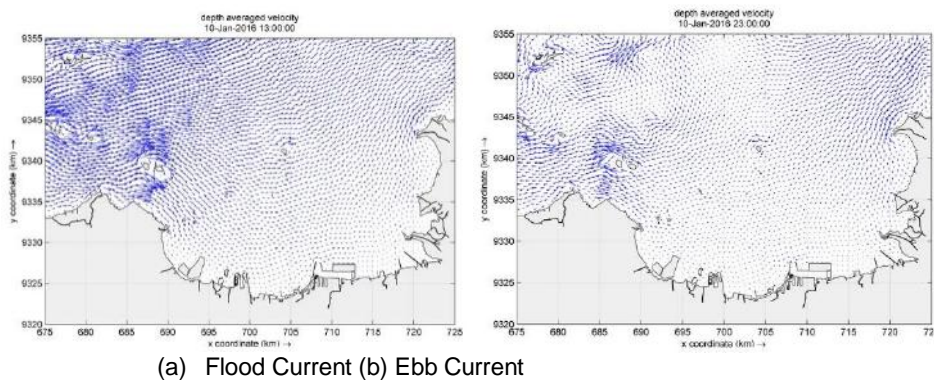


Figure 5. Tidal Current at Spring Tide

The tidal residual current, computed quarterly in the domain of the prepared model. In Jakarta Bay, the velocity of the tidal residual current is close to 0m/s with the exception of the seas near northwest islands and the protruding coastline, because there is one high and low tide each day and the difference between high tide and low tide is not large.

The drogues generally showed a tendency to move from west to east because in the target area, the flood current moving from west to east is stronger than the ebb current moving from east to west. Drogues, floated in coastal seas, moved to the east but did not move out of the seas near Jakarta Bay for a long period, due to low current velocity. In contrast, drogues, floated at the location about 5 km off the coast and close to the east side, were found to move toward the east and then toward the north out of the seas near Jakarta Bay, which is notable considering the water circulation and flushing in Jakarta Bay.

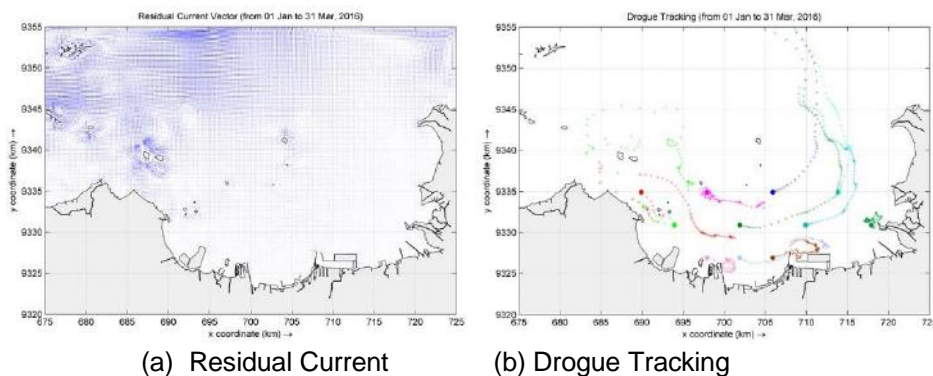


Figure 6. Tidal Characteristics

5.2 Local Model

5.2.1 Alternative 1

In terms of the distribution of high tidal current velocities, the highest current velocities were found at the west flood canal, Cengkareng Drain and Dadap in descending order. These high tidal currents affected Channels D through E and Channels E through F. The highest current velocity was 1.870m/s in Channels D through E and 1.600m/s in Channels E through F. The water level of the retention lake is as low as LWS₂₀₁₂(-) 1.4m, and there is no effect of tides. Naturally, the current velocity is higher than when there is no outer sea dike.

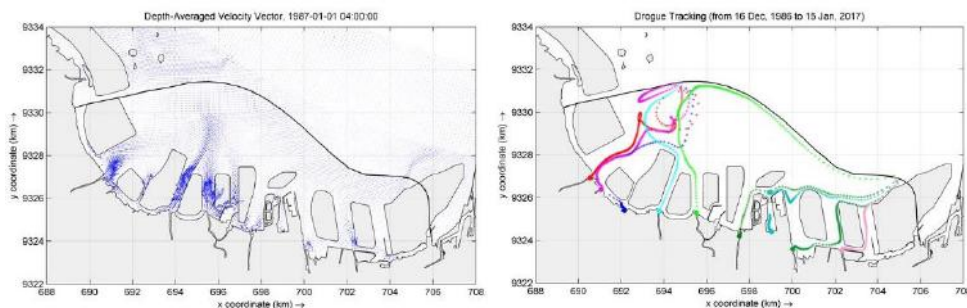


Figure 7. Velocity Vector and Drogue Tracking (ALT-1)

5.2.2 Alternative 2

In terms of the distribution of high tidal current velocities, the highest current velocities were found at the west flood canal, Cengkareng Drain and Dadap in descending order. The discharged water overflows movable weirs, installed in the inner dike, and flows into the west retention lake. And an eddy occurs due to tidal effect and an island located in front of the first drainage gate in the northwest area. This problem needs improvement by changing the location of the drainage gate.

The highest current velocity was found to be 0.140m/s in Channels D through E and 0.163m/s in Channels E through F. The water level adjustment is performed well in the diversion channel that is formed between the coast and the inner dike, and the discharged water from Krendang, located east of the west flood canal, flows into the ocean through Channels G through H.

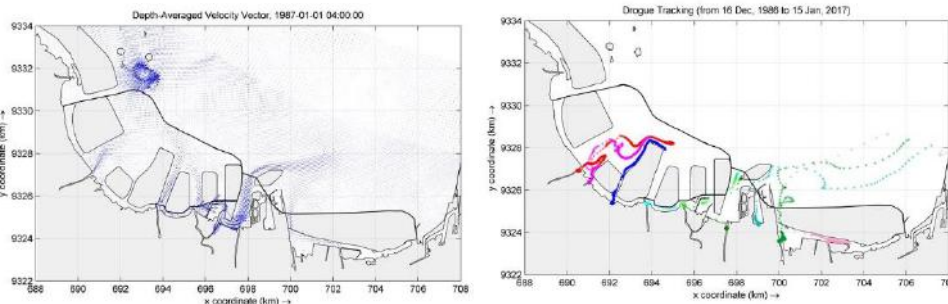


Figure 8. Velocity Vector and Drogue Tracking (ALT-2)

5.2.3 Alternative 3

In terms of the distribution of high tidal current velocities, the highest current velocities were found at the west flood canal, Cengkareng Drain and Dadap in descending order. The discharged water overflows movable weirs, installed in the inner dike, and flows into the west flood control site. The highest current velocity was found to be 0.616m/s in Channels D through E and 0.275m/s in Channels E through F. The water level adjustment is performed well in the diversion channel that is formed between the coast and the inner dike, and the discharged water from Krendang, located east of the west flood canal, flows into the ocean through Channels G through H.

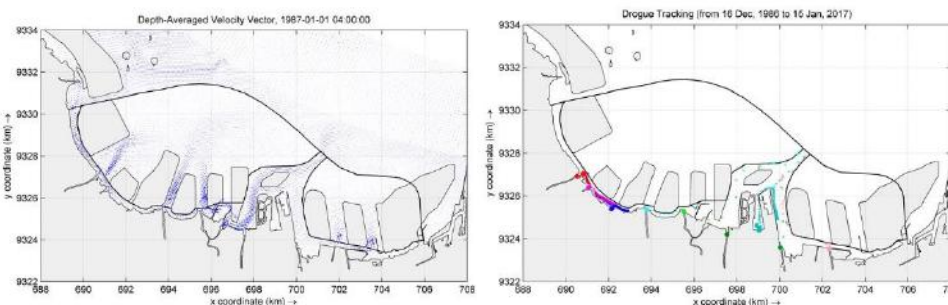


Figure 9. Velocity Vector and Drogue Tracking (ALT-3)

5.2.4 Alternative 4

In terms of the distribution of high tidal current velocities, the highest current velocities were found at the west flood canal, Cengkareng Drain and Dadap in descending order. The discharged water flows into the sea outside the dike through the third open section (Gap 3) from the west. The current velocity is relatively low in the sea inside the dike

because tide can come and go freely. The highest current velocity was found to be 0.163m/s in Channels D through E and 0.357m/s in Channels E through F. The highest current velocities of the six open sections were compared, and the third open section (Gap 3) recorded the highest (1.360m/s) and the fifth open section (Gap 5) recorded the lowest (0.198m/s). Gap 3 recorded the highest because the water cannot flow well in the narrow space between the front side of Island D and the outer sea dike and all the discharged water from Cengkareng Drain affects the water flow in Gap 3.

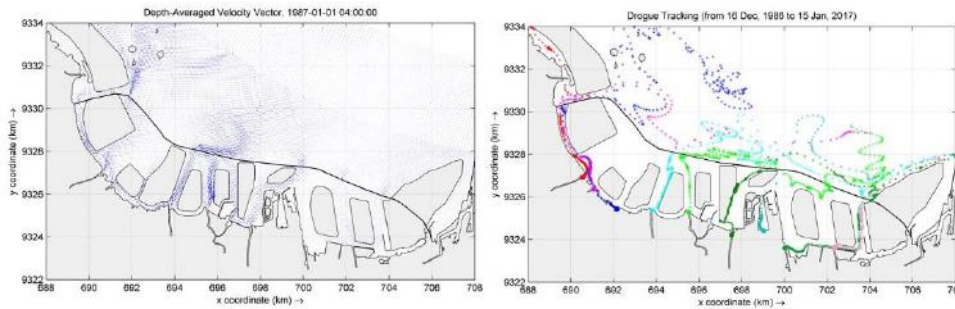


Figure 10. Velocity Vector and Drogué Tracking (ALT-4)

5.2.5 Preferred Alternative

In terms of the distribution of high tidal current velocities, the highest current velocities were found at the west flood canal, Cengkareng Drain and Dadap in descending order. The discharged water flows into the sea outside the dike through the third open section (Gap 3) and the fourth (Gap 4) from the west. The tide can come and go freely even in the sea inside the dike, and the water flow is relatively stable because the outer sea dike is located further towards the sea than in Alternative 4. The highest current velocity was found to be 0.233m/s in Channels D through E and 0.364m/s in Channels E through F. The current velocity in Channels D through E is found to be higher in the preferred alternative than in Alternative 4. The reason is that in the preferred alternative, the outer sea dike is located further towards the sea to secure a larger space for water flow. The highest current velocities of the six open sections were compared, and the second open section (Gap 2) recorded the highest (0.526m/s) and the first open section (Gap 1) recorded the lowest (0.109m/s).

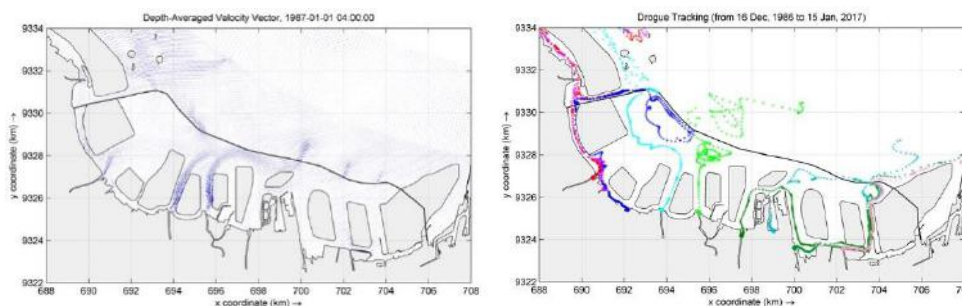


Figure 11. Velocity Vector and Drogué Tracking (ALT-PA)

5.2.6 Preferred Alternative – Phase 2

In terms of the distribution of high tidal current velocities, the highest current velocities were found at the west flood canal, Cengkareng Drain and Dadap in descending order. The discharged water overflows movable weirs, installed inside the inner dike, and flows into the west control site. The highest current velocity was found to be 1.300m/s in Channels D through E and 0.230m/s in Channels E through F. The water level adjustment is performed well in the diversion channel that is formed between the coast

and the inner dike, and the discharged water from Krendang, located east of the west flood canal, flows into the ocean through Channels G through H.

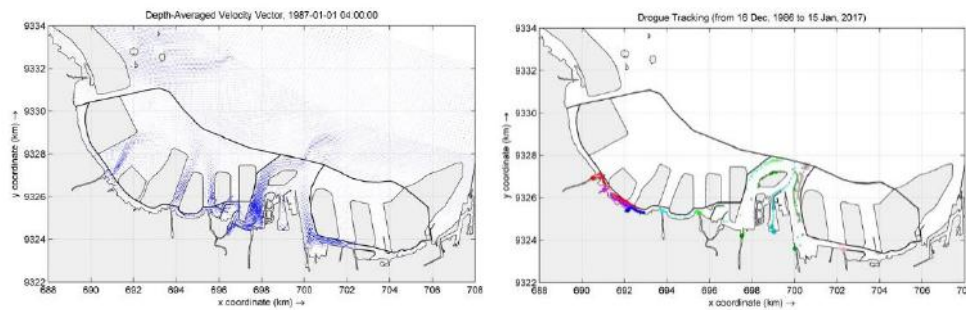


Figure 12. Velocity Vector and Drogué Tracking (ALT-PA-P2)

6. CONCLUSION

The hydrodynamic phenomenon in North Java Sea and Jakarta Bay was simulated using Delft3D-FLOW in two separate models: Regional LautJawa Utara Model and Local Teluk Jakarta Model. As for tidal characteristics in Jakarta Bay, the tide has characteristics of a diurnal tide, which has only one high and low tide each day; the tidal difference does not exceed 1.3m; and the tidal current velocity does not exceed 0.5m/s.

The tidal current consists of the flood current flowing from west to east and the ebb current flowing from east to west, with the flood current slightly stronger than the ebb current. The velocity of the tidal residual current is close to 0m/s in the planned area for the outer sea dike because there is one high and low tide each day and the difference between high tide and low tide is not large. The water mass near the coast moves slowly from west to east but cannot move out of the area near Jakarta Bay for a long time.

In simulations to which reclamation of artificial islands and alternative routes for the outer sea dike were applied, it was confirmed that active flood response is possible with the exception of Alternative 1 and the preferred alternative (Phase 1). Alternative 4 and the preferred alternative can be good alternatives that block incoming waves and allow ocean circulation if accompanied by the reinforcement of coastal and river embankments. Alternative 1 allows flood control but its water quality problem should not be neglected. Alternative 2 allows flood control but an eddy occurs in front of the first sluice gate in the northwest area. Alternative 3 and the preferred alternative – Phase 2 allow active and elaborate flood control but an optimal operation method need to be developed.

ACKNOWLEDGMENT

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