PRELIMINARY MODELLING OF BED LEVEL CHANGES IN THE MAHAKAM ESTUARY [1]

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Key words: Mahakam Delta, three-dimensional hydrodynamic and sediment transport model, suspended sediment, erosion, deposition, bed level changes.

Introduction

The Mahakam Delta and its associated estuaries located in Eastern Kalimantan - Indonesia, has many natural resources, which can provide a valuable income for the Indonesian government and its society. However, apart from natural resources, its environment has also been rapidly changing due to the development of its coastal area, such as development of extensive aquaculture or fishing industry (e.g., shrimp pond culture), deforestation at upstream locations, and conversion of mangrove forest. This leads to environmental degradation and hazardous situations such as salinity intrusion, water shortage in dry season, flooding during the rainy season, and catastrophic beach erosion and disrupted navigation because of excessive sedimentation. This situation gets even worse since 1998 when the economic crisis occurred in Indonesia.

The Mahakam Delta provides an ideal case for studying estuarine dynamics and sediment transport. For many centuries sediments have been carried by the Mahakam River and trapped in its estuaries to form the Mahakam Delta. Interaction between fresh water flow and tidal action entering from the Makassar Strait play an important role in forming the delta. The influence of sediments in the estuaries is not only limited to transport and deposition but also to the estuarine ecosystem. Waterways maintenance and a good management of the Mahakam ecosystem resources are required in order to create a sustainable development at the local, regional and national level.

In an estuary, an understanding of relationships between the physical environment and marine ecosystem is required. In general, optimal conditions of temperature, salinity, and circulation will produce abundant fish stocks, whereas unfavorable environmental conditions can lower abundance. Therefore, both for scientific and practical reasons it is desirable to have a better understanding on the management of living marine resources and to have the ability to predict accurately the sediment transport processes in the Mahakam Estuary.

With the development of both computer and numerical methods by means of mathematical equations for solutions of time-dependent flows, numerical simulation has become an economic and effective way to obtain the required flow parameters and to gain insight into sediment transport processes. Mathematical modelling has been extensively applied in sedimentary studies in estuaries. It gives significant contribution for understanding and predicting estuarine problems and allows for developing a rational contingency planning.

In this research, water circulation patterns and suspended cohesive sediment transport in the Mahakam Delta and its estuaries have been simulated by using a fully integrated three-dimensional (3D) hydrodynamic and sediment transport model, ECOMSED, developed by HydroQual, Inc., (2002), USA, by using tides and variation of river discharges as generating forces.

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[1] Paper presented at Open Science Meeting 2007, 'Toward a Sustainable World', Denpasar, Bali, Indonesia, November 19 - 20, 2007.

Results and Discussion

Figure 1 shows the computational domain and bathymetry of the Mahakam Delta. Along the open sea boundary, a real tide is imposed at each node. It is calculated as the sum of 8 tidal components (M_2, S_2, N_2, K_2, K_1, O_1, P_1, and Q_1) published by the Ocean Research Institute, University of Tokyo. Monthly mean discharge of the Mahakam River is introduced at the upstream limit. The river discharge was supplied by the Research Institute for Water Resource Development, the Ministry of Public Works, Indonesia. A mean suspended sediment load of $8x10^6$ m^3/y reported by Allen *et al* (1979) in Davis (1985) is set at the upstream boundary. As a preliminary study, only fine cohesive sediments are dealt with, as they constitute the most part of the suspended matter and extend increasingly on the bottom (Banjarnahor and Suyarso, 2000). The initial condition for the sediment is set as uniform quantity of deposited mud located in the channels, the branches, downstream and upstream of the Mahakam River. After a few tidal cycles, the initial sediment supply is totally resuspended, due to strong currents.

Simulation results of the 3D baroclinic hydrodynamic model show that for flood conditions and highest water, the water flows from the sea (the Makassar Strait) into the delta, whereas during ebb conditions and lowest water, flow is towards the sea. For the whole year, the magnitude of currents at Muara Pegah, Muara Jawa, Muara Kaeli, and Muara Pantuan is stronger (0.4 – 0.6 m/s) than that at Muara Badak, Muara Berau, and Muara Pemankaran (0.1 – 0.2 m/s).

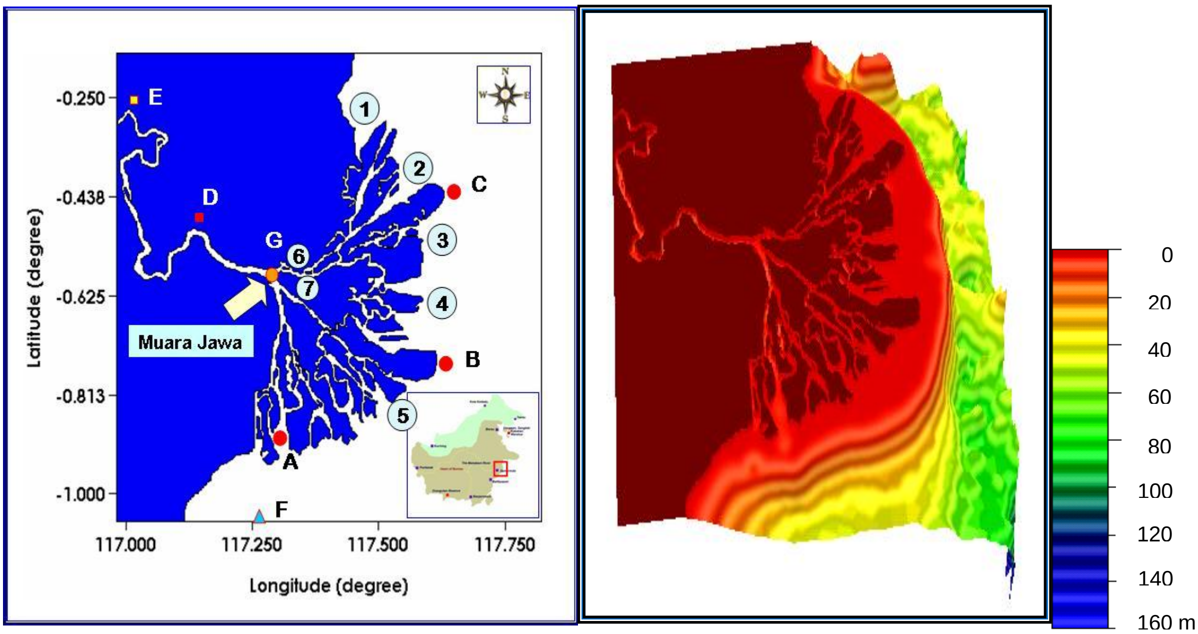

Figure 1. Computational domain and bathymetry of the Mahakam Delta (Source: Dishidros TNI AL, 2003). Legends: A: Muara Pegah; B: Tanjung Bayur; C: Tanjung Ayu; D: Samarinda; E: Sebulu; F: Location at Southern Boundary; G: Muara Jawa (Location of verifications); 1: Muara Badak; 2: Muara Kaeli; 3. Muara Ilu; 4. Muara Pantuan; 5. Muara Pemankaran; 6. Muara Berau; 7. Muara Bayur.

The simulation results of the sediment transport model show that the suspended sediment concentration (SSC) at the Muara Jawa, Muara Pegah, Muara Pantuan, and Muara Kaeli is dominantly influenced by the seasonal variation in river discharges, while at the Tanjung Bayur it is dominantly influenced by tides. Sediments from the Mahakam River are mainly transported towards the Muara Jawa and Muara Pegah compared to the Muara Berau and Muara Bayur. In other words, the simulation of suspended sediment distribution shows that the suspended cohesive sediment is mainly transported southward, namely through the estuaries of Muara Jawa and Muara Pegah. Sediment transport from the Muara Pegah to the sea (the Makassar Strait) seems to spread farthest in February (± 30 km) and reach minimum distance of distribution in October (± 17 km).

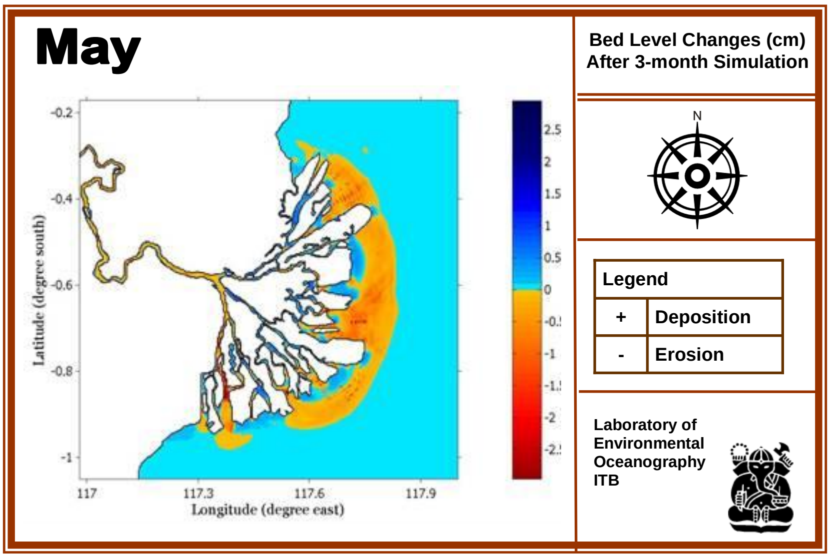

Figure 2. Predicted bed level changes after 3-month simulation.

Figure 2 shows an example of simulation results of predicted bed level changes. In general, the simulation results show that depositional processes occur continuously at the Muara Bayur area, and erosion exists continuously at the Muara Jawa and Muara Pegah. Meanwhile, at other areas such as the Muara Badak, Muara Pemangkaran and Tanjung Bayur depositional processes exist at the entrance point near the mouth of the Mahakam River and erosion occurs in seaward located areas (the Makassar Strait).

The simulation results of free surface elevation, zonal velocity component at depth of about 4 m, and suspended sediment concentration (at depth of about 4 m) have been verified with those of the measured data of IMAU (Institute for Marine and Atmospheric Research Utrecht) at Muara Jawa (pilot campaign EKP project June 30 - July 8, 2003). The model predicts the free surface elevation quite well, mainly for the tidal phases, but the amplitude is smaller (in the order of less than 0.3 m). Mean relative error for the free surface elevation is 22.9 %. The simulated zonal velocity component shows a good agreement with the measured one, mainly for the tidal current phases. However, the magnitude of the predicted results is smaller, with a mean error of about 28.1 %. Meanwhile, the agreement between the simulated and the measured sediment concentration is reasonable, especially in relation to the general trend of the measured data, with a mean relative error of 38.7 %. Another comparison of predicted and measured suspended sediment concentration of Budhiman (2004) has been carried out at several stations in the period 3 - 5 July 2003 (with the mean relative error of 19.1 %). The difference between the model results and the field data is probably due to a combination of: inaccurate definition of the sediment source from the Mahakam River, inaccurate discharge rate of the suspended sediment from the river, assumption of homogenous cohesive sediment in the computational domain. In addition, inaccurate discharge rates from surrounding rivers may also contribute to the error of prediction.

Conclusions

Simulations of hydrodynamics, suspended sediment, and bed level changes in the Mahakam Delta have been carried out by means of a coupled 3D hydrodynamics and sediment transport model. The simulation of suspended sediment distribution shows that the suspended cohesive sediment is mainly transported southward, namely through the Muara Jawa and the Muara Pegah and seems to spread farthest in February, whereas the minimum distance of sediment distribution occurs in October. An 11-month simulation of bed level changes (March 2005 – January 2006) generated by tides and river discharge variability shows qualitatively that most deposition appears around Muara Badak, Muara Berau, and Muara Bayur, whereas erosion occurs mainly around Muara Jawa, Muara Pegah, Muara Kaeli, Muara Pemankaran, and Tanjung Bayur. Meanwhile, alternating zones of deposition and erosion exist around Muara Ilu and Muara Pantuan.

By performing further study and simulation, the works carried out in this study hopefully can be used as a valuable tool for designing proper management of investment policies in dealing with human impact in the Mahakam delta system so that catastrophic beach erosion and disrupted navigation because of changes in the natural ecosystem will be reduced while the stocks of shrimp products will be kept at a sustainable level.

References

Banjarnahor, J., and Suyarso, 2000, *Profil Sumberdaya Kelautan Kawasan Pengembangan dan Pengelolaan Laut (Kappel) Kalimantan Timur*, Proyek Pengembangan dan Penerapan Iptek Kelautan, Pusat Penelitian dan Pengembangan Oseanologi - LIPI. (in Indonesian).

Budhiman, S., 2004, *Mapping TSM Concentrations from Multisensor Satellite Images in Turbid Tropical Coastal Waters of Mahakam Delta, Indonesia*, Master of Science Thesis, ITC, Enschede, The Netherlands.

Davis, R. A., (eds.), 1985), *Coastal Sedimentary Environments*, Springer-Verlag New York Inc.

HydroQual, Inc., 2002, *A primer for ECOMSED*, Users Manual, Mahwah, N. J. 07430, USA.

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Research support from:

We gratefully acknowledge support from the Ministry of Research and Technology of Republic of Indonesia for funding this research under grants of RUT-XI.