

One-Way Flow System Water Quality Modelling of Terantang Reclamation Channel

Abstract. The implementation of reclamation process in wetland has encountered some obstacles, such as the occurrence of pyrite oxidation, sedimentation, and accumulation of toxic materials, especially the concentration of Fe (iron) in the channel. The condition of the reclamation channel which is influenced by tidal events and environmental factors causes the dynamics of Fe concentration to be strongly influenced by hydrodynamic aspects and its interaction with dissolved and suspended particulates. An accurate model will be useful as a tool to evaluate alternative management of water systems to overcome the problem of Fe concentration accumulation in the tidal wetland reclamation channel. Fe fate and transport were modeled using a numerical model of hydrodynamics and water quality EFDC (Environmental Fluid Dynamic Code). The partition process separates the metal fraction into two phases (dissolved and solid), which is related to the value of the partition coefficient (K_p). The application of the partition process is considered to have a significant influence on the accuracy of the estimated Fe concentration. The simulation results of the model with the partition coefficient approach have better accuracy than the conventional model which tends to be over-predicted compared to the observation data. Simulation of one-way flow system shows a decrease of Fe concentration in the channel by an average of 52.9% compared to two-ways flow system.

Keywords: one-way flow, Terantang unit, Fe, EFDC

[Is it possible that this 1-way simulation can be applied to the tidal area on a large scale, because the tidal area is naturally two directions per day?](#)

1. Introduction

The reclamation process gradually begins with building an open gravity system drainage followed by the application of water management systems, namely comb systems and fork or tidal pool systems. This system generally uses a two-ways flow pattern, in which the flow of water in and out occurs in the same channel. This system still requires further review of its effectiveness compared to one-way flow systems [1]. In its development, the implementation of reclamation experienced obstacles, such as pyrite oxidation, sedimentation, and toxic materials accumulation in segments of secondary channel [2]. Toxic materials accumulation is dominated by iron (Fe), aluminum (Al), and Sulfate (SO_4) occurs in the end segments of secondary channels and tidal pools [3]. This situation also occurred at the research location, Terantang reclamation channel, South Kalimantan.

Methods of estimating the distribution of toxic material concentrations in reclamation channels at research sites generally still use an advective-dispersive physical process approach and have not noticed the reactive properties of those materials. One-dimensional unsteady flow models with pollutant transport models based on physical processes (advection-dispersion) are still commonly applied to model the movement of pollutants in channels. Ball's research [4] showed that Fe (iron) and Al (aluminum) are constituents that not only undergo physical processes (advection-dispersion), but also

experience interactions with sediments. Then Caruso [5] stated that modeling of metal interactions with sediments through the process of resuspension-deposition is needed in the analysis of water quality. Sediment resuspension and mixing events due to tidal currents in bodies of water also affect water quality conditions in water affected by tidal forces [6]. Riduan's research [7] also showed that modeling the fate and transport of toxic materials in reclamation channels in acid sulfate soils requires a non-conventional approach with not only physical processes but reactive processes of pollutants. For example, the application of partitioning processes on water quality modeling in reclamation channels will be able to improve the accuracy of modeling [8] and [9].

Based on these conditions, research is needed to evaluate the partition process approach on the accuracy of modeling the movement of toxic materials in reclamation channels, accompanied by the availability of representative models and modeling parameters on tidal wetland reclamation channels. The application of partitioning processes on the modeling of Fe (iron) fate and transport in this reclamation channel is expected to better represent the processes that occur in the channel. The model is also expected to help planners and managers of wetland reclamation units to be able to evaluate problems in the infrastructure supporting tidal wetland reclamation efforts.

2. Materials and Methods

2.1. Research Location

The location of reclamation channel is in Terantang Village, Barito Kuala Regency, South Kalimantan. The reclamation channel is located within coordinates 3°07'33" S and 114°35'43" E to 3°09'52" S and 114°40'11" E. Terantang wetland reclamation channel has a total length of ± 9 km consisting of around 2 km primary channel and around 7 km of secondary channel.

2.2. Research Method

The research method is divided into three steps: (1) hydrodynamic and water quality conditions identification, (2) hydrodynamic and water quality model development using EFDC software, and (3) flow patterns and iron concentration simulation for one-way (Figure 1) and existing two-ways system.

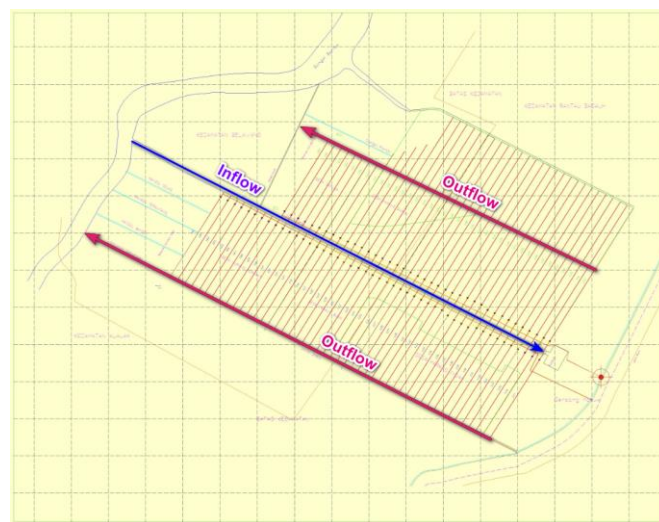


Figure 1. One-Way Flow System

Measurements of water level on the channel were taken for two days at 4-hour and 2-hours intervals at three locations on the reclamation channel. The first location (point 1) is located near the tidal pool, second location (point 2) is at the middle of secondary channel, and third location (point 3) is at the first segment of the secondary channel.

Not enough information about position and No location map ?

The construction of the model is carried out in several stages. The initial stage that must be done is the preparation of the network (grid) model, the determination of the initial condition and boundary condition of the model (boundary condition), and the identification of modeling parameters. The next stage is the data entry and model execution step, followed by the model calibration, model validation, and model simulation.

2.3. Data Analysis

Channel geometry was obtained through echo-sounding surveys, tidal and channel water level were measured in the field, and water quality data were obtained from laboratory analysis. The data and model simulation results were analyzed using error analysis (relative-error and average-error) to determine the accuracy of partition process and water quality condition improvement of the one-way flow system.

3. Result and Discussion

3.1. Model Boundary Condition

The input for boundary condition of terantang channel is an existed tidal pattern which is categorized as mixed pattern but tends to be a semi-diurnal pattern. The pattern consists of two peaks of high tide in one-day tidal cycle [10]. Tidal pattern and water level on tertiary channel were used as inlet boundary conditions, on 5x5 m model grid. The channel model boundary condition scheme is in Figure 2 below.

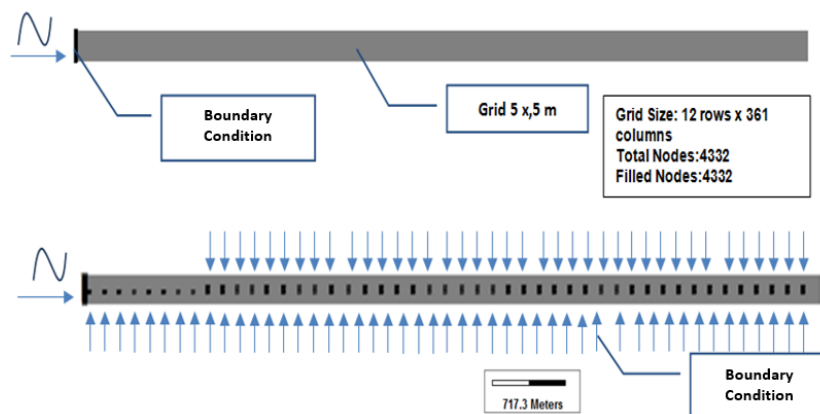


Figure 2. Grid and Boundary Condition

3.2. Water Quality

Water quality measurement was carried out to determine the TDS, TSS pH and Fe concentration in Terantang reclamation channel. Water quality laboratory test results are in Table 1.

Table 1. Water Quality Condition in Terantang Channel

Parameters	Unit	Location Location map?		
		1	2	3
Total Dissolved Solids (TDS)	mg/L	426	28	5,2
Total Suspended Solids (TSS)	mg/L	<2.5 *	24	201
pH	-	2,6	4,7	5,2
Dissolved Iron	mg/L	2.39	<0.3	<0.3

Toxic substances accumulation on the channel occurred mostly at some locations near the tidal pool. This situation is also indicated by the higher TDS (Total Dissolved Solid) and iron concentration than the other sampling locations at the channel.

3.3. Model Development

Modeling was conducted to simulate the one-way and two ways flow system scenario. Development of hydrodynamic and water quality model using EFDC (Environmental Fluid Dynamic Code) must undergo verification, calibration, and validation process [11].

Model verification was carried out to ensure that EFDC software can be applied for this simulation. A theoretical example of hydrodynamic and water quality problem was compiled using EFDC software. The flow pattern obtained from the verification results had satisfactory result according to previous research [12]. The calibration process was carried out as an adjustment to the modeling parameters. The adjusted parameters were roughness coefficient (value between 0.02-0.05), and partition coefficient (0.796 and 0.246 for cohesive and non-cohesive sediment). These coefficient values were obtained based on water level and dissolved iron concentration. This calibration value for partition and roughness coefficient is in accordance with previous research [7].

explanation of model development is not easy to understand. Information how to validate?

3.4. Simulation Result

Channel performance was analyzed based on the flow pattern in the secondary channels that had a significant effect on the accumulation of toxic materials. Simulations were carried out in 2 stages: (1) Simulation of hydrodynamic aspects and water quality based on partition and non-partition models; and (2) Simulation of the one-way flow compared to two-ways flow system.

The simulation results showed that not only do the hydrodynamic aspects have a role in the accumulation of Fe concentrations in the channel, but other factors such as the partitioning process and the movement of pollutant transport. Based on the results, the difference between models that use partition coefficients and data has an average of 0.28 mg/L. The difference between models without using partition coefficients with data has an average of 4.7 mg/L. So that the average increase in accuracy between the partition coefficient model against non-partitions is 5.1 mg/L. The comparison of Fe modeling without partition coefficient and with partition coefficient for water level elevation can be seen in Figure 3.

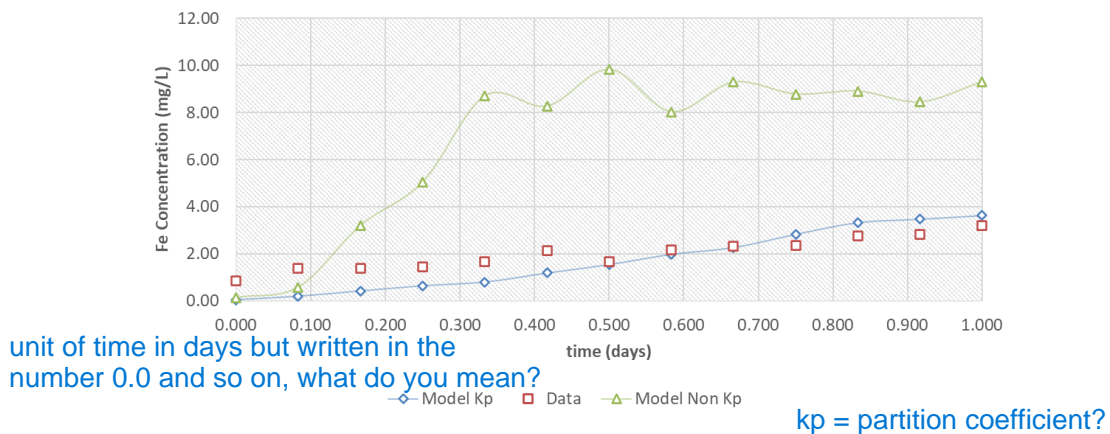
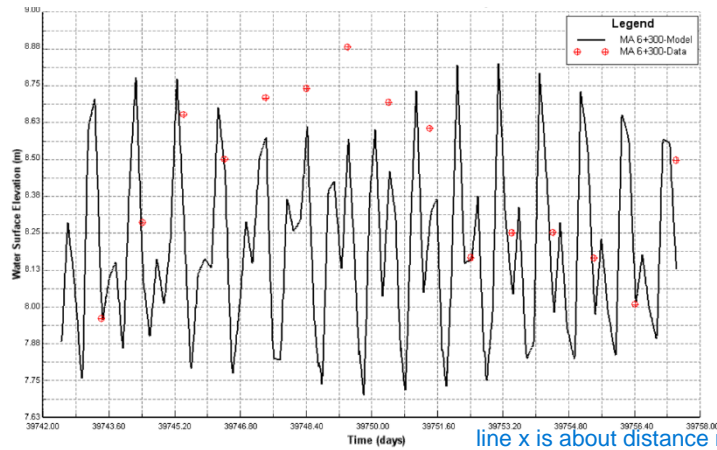


Figure 3. Model Comparison

Based on the above results, the partition approach will be used for the next simulation to model the difference in water level and Fe concentration between a one-way flow system and a two-way flow system. The simulation results for the water level at point-1 show a lower water level for a one-way flow system, and the pattern of water level shifts closer to the tidal pattern (Figure 4).

An explanation of figure 3 needs to be added. Explain more about the picture above



pay attention to the alignment of the legend with the image title

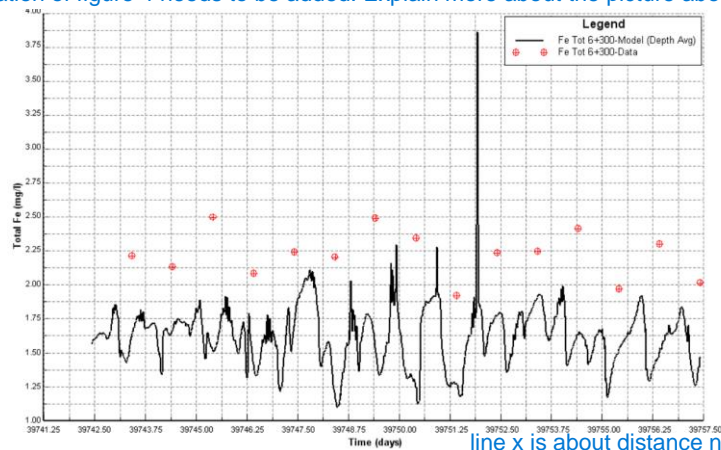
line x is about distance not time(days)?

Figure 4. Water Level Difference of One-Way and Two-Ways Flow on Point-1

Figure 4 seems to be about is it about actual and model water level conditions in the tidal area? please check it again!

Simulation result for Fe concentration on point-1 location indicates that one-way flow system gives lower Fe concentration compared to the two-ways flow system (Figure 5).

An explanation of figure 4 needs to be added. Explain more about the picture above

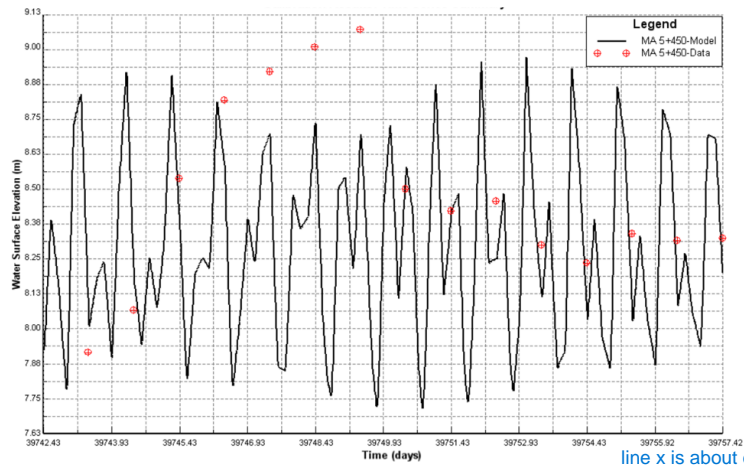


line x is about distance not time(days)?

Figure 5. Fe Concentration Difference of One-Way and Two-Ways Flow on Point-1

does figure 5 provide information on the total Fe data and the modeling results? If yes, please correct the title of picture 3..

The same results were also obtained for the water level and Fe concentration at point 2. In a one-way flow system, the water level also has a shift in tidal patterns and tends to have a lower maximum water level than the two-way flow system. Water level comparison between measurement data for existing two-ways flow system and water level model for one-way flow system on sampling location point-2 can be seen in Figure 6.

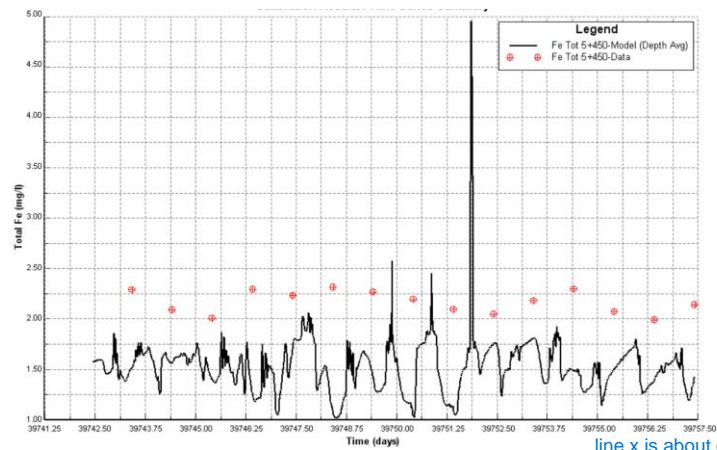


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data model and data actual

line x is about distance not time(days)?

Figure 6. Water Level Difference of One-Way and Two-Ways Flow on Point-2

Fe concentration comparison between measurement data for existing two-ways flow system and water quality model for one-way flow system on location point-2 is as follows.

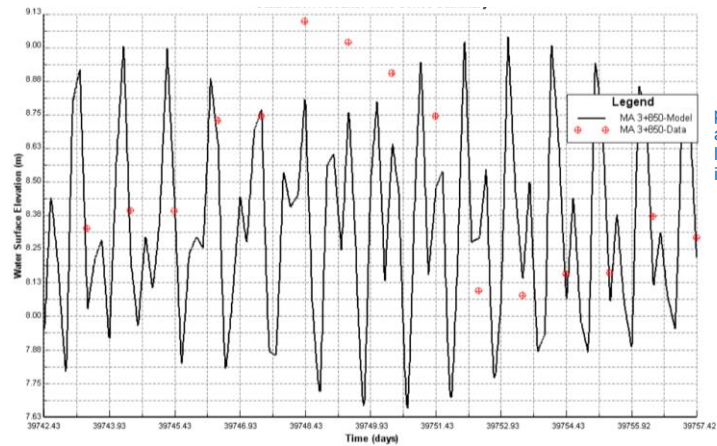


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line x is about distance not time(days)?

Figure 7. Fe Concentration Difference of One-Way and Two-Ways Flow on Point-2

The next comparison for water level and Fe concentration at point 3, has the same result as the previous result. Water levels for one-way flow systems tend to shift their pattern compared to two-ways flow system (Figure 8). The maximum and minimum level for one-way flow also shifted down compared to the two-ways flow system.



pay attention to the alignment of the legend with the image title

Figure 8. Water Level Difference of One-Way and Two-Ways Flow on Point-3

Fe concentration comparison between measurement data for existing two-ways flow system and water quality model for one-way flow system on location point-3 is as Figure 9 below. The Fe concentration tends to be lower for one-way flow system compared to two-ways flow system.

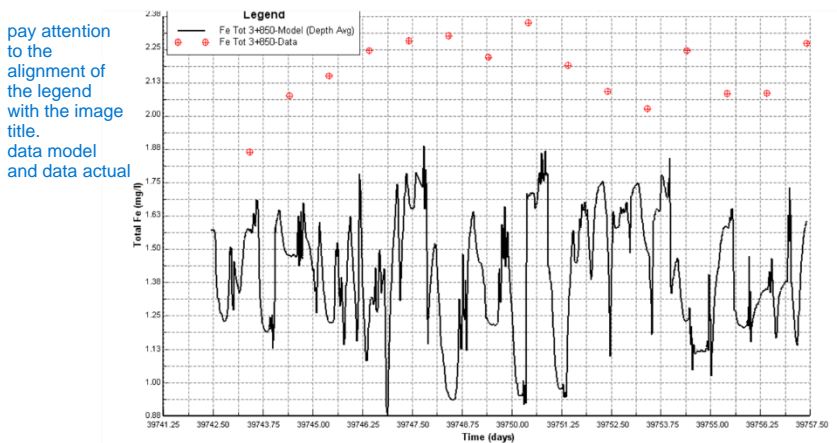


Figure 9. Fe Concentration Difference of One-Way and Two-Ways Flow on Point-3

Explain the important things in Figure 9? do not directly to Table 2

The results of error analysis for the parameters of Fe concentration on one-way and two-way flow system conditions are in the following Table 2. Based on these results, the one-way flow system can reduce up to 55.66% Fe concentration in the channel. With an average reduction of Fe concentration of 52.9%, it can be concluded that the one-way flow system is an alternative solution of macro water system that can be applied for toxic materials accumulation problem in the reclamation channel.

there are 2 words "and" in the table title, please correct again.

Table 2. Comparison Between One-Way Flow and Two-Ways Measurement Data and Model

Point	Fe Concentration Comparison	Average Error	Relative Error	Absolute Error
1	Measurement Data	0.36	47.42	0.36
	Two-Ways Model	0.36	45.00	0.36
2	Measurement Data	0.40	52.88	0.40
	Two-Ways Model	0.41	52.00	0.42
3	Measurement Data	0.42	55.66	0.42
	Two-Ways Model	0.39	53.00	0.39

4. Conclusion

The existing flow pattern and distribution of Fe concentration in Terantang units tend to accumulate in certain segments in the channel. The simulation results using the partition coefficient approach have better accuracy than conventional models which tend to be over-predicted compared to observation data. Simulation of the one-way flow system shows a decrease in Fe concentration in the channel by an average of 52.9% compared to the two-way flow system.

5. Acknowledgment

This work was supported by the Institute of Research and Community Service (LPPM) Lambung Mangkurat University (Grant No: 009.18/UN8.2/PL/2021)

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Author's Responses to Reviewer's Comments:

Comment 1:

Is it possible that this 1-way simulation can be applied to the tidal area on a large scale because the tidal area is naturally two directions per day?

Author Response:

We thank the reviewer for this comment. We add some explanation about technical application of 1-way flow system on the abstract, and hopefully we can continue this research to a more detailed engineering design.

Comment 2:

Not enough information about position and no location map ?

Author Response:

We thank the reviewer for this correction. Location map is added in research location (chapter 2).

Comment 3:

Sampling location?

Author Response:

We thank the reviewer for this correction. Location map is added in section 3 (figure 4) to support measurement result from Table 1.

Comment 4:

Explanation of model development is not easy to understand. Information how to validate?

Author Response:

Value for partition and roughness coefficient is validated using data from previous research (Riduan R and Utomo B 2016 Compilation of Numerical Models for the Movement of Toxic Materials in the Unrestricted Reclamation Channel *J. Env. Eng.* **2** 51-61). The explanation from subsection 3.3 is corrected using this reference.

Comment 5:

Unit of time in days but written in the number 0.0 and so on, what do you mean?

Author Response:

We thank the reviewer for this comment. The measurement data unit is actually in hours, but to simplify the graphical display and in order to standardize the data with other x-axis graphs, we used days as the x-axis unit.

Comment 6:

An explanation of figure 3 needs to be added. Explain more about the picture above

Author Response:

We thank the reviewer for this comment. The explanation of this graph is presented in subsection 3.4 Simulation Result.

Comment 7:

Figure 4 seems to be about is it about actual and model water level conditions in the tidal area?
please check it again! line x is about distance not time(days)?

Author Response:

We agree with the reviewer on this comment. The graph is the difference of water level on existing condition (one-way flow) and the model (two ways flow). The x-axis is in time unit, as the representation of water level change in one point of measurement as the result of tidal force. This explanation can also be applied to subsequent comments regarding figure 5 to 8.

Comment 8:

there are 2 words "and" in the table title, please correct again.

Author Response:

We thank the reviewer for this correction. The table title is corrected to "Comparison Between One-Way System (Measurement) and Two-Ways Model".

will give a more precise and more visible definition of what we called misfits (which will now be called discrepancies following the reviewer's suggestion below) and signature as early as possible in the revised manuscript