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COMPARISON OF 2D AND 3D MODELS OF SALINITY NUMERICAL SIMULATION

Li Chunhui[a,b],
Pan Xishan[c],
Ke Jie[a,b],
Dong Xiaotian[a,b],
a) Key Laboratory of Coastal Disaster and Defense, Ministry of Education,
Hohai University, Nanjing, China
b) Environment Marine Laboratory, Hohai University, Nanjing, China
c) Tidal Flat Research Center of Jiangsu Province, Nanjing, China

ABSTRACT

For the study of the effect of 2D and 3D mathematical model in salinity simulation, with Liuheng island strong brine discharge of seawater desalination project as an example, using 2D and 3D salinity mathematical models of Liuheng island to simulate coastal hydrodynamic environment and salinity distribution before and after the concentrated brine discharge, and analyzed the results. Finally got the applicable scope of the two models, it has an important significance in the study of similar problems.

Keywords: 2D model, 3D model, salty, strong brine, numerical simulation

INTRODUCTION

Mathematical models and other quantitative methods have been used to research the impact of brine on the water environment and salinity distribution, and this area have made some achievements Domestic and foreign [1-8]. By means of numerical experiments, Luo Feng and Li Ruijie have studied the effect of different hydrologic meteorological environmental factors on saltwater intrusion in the Yangtze river estuary. Anton, Al-Barwani have established mathematical model using 2D convection diffusion equation, and they discussed the influence of Oman discharged coastal brine on tidal oscillation flow. Wang Xiaomeng, Liu Xuehai have set up jiaozhou bay salinity diffusion model, and they handle the planning seawater desalination as input conditions, simulating and calculating salinity distribution and variation of jiaozhou bay, etc. Nowadays, salinity diffusion studies adopt 2D and 3D model simulation mostly. 2D model is simplified by 3D model, with characteristic of fast, convenient processing, furthermore 3D model can draw conclusions of vertical variation of flow and salinity. It is complicated not only because three space coordinates of moving elements should be considered, but some difficulties on equation solving encountered, and cost more simulation time. So, a comparative studies of 2D and 3D simulation can help us to select model effectively, but also is of significance in the study of similar problems.

Based on fully collecting hydrological terrain information in islands nearby, a case study in Liuheng island seawater desalination project has established 3D and 2D salinity mathematical model in connection with tide and salinity simulation near the dischage. In line with actual engineering design and through comparison and analysis, impact on hydrology characteristics and the influence of salinity distribution is calculated, and the salinity increment is analysed.

2. Three-dimensional numerical simulation of flow and salinity in Liuheng sea area

Simulation area is shown in figure 1, mesh dissection is shown in figure 2, 3D simulation of vertical evenly divided into 6 layers, simulation time is from 00:00 on January 11, 2013 to 23:00 on January 19, 2013. Model is verified by the synchronous observations of January 2013, the tide validation is shown in figure 3(‚—' is calculated value, ‚·' for the measured values, the abscissa represents time (h), ordinate represents the water level (m)). Velocity and salinity selection is illustrated by the S1 station on spring tide, the measured values and calculated values of surface, 0.6 layer and the underlying surface velocity is comparied, as shown in figure 4 ~ 6 (figure ‚—' for the calculated value, ‚·' for the measured values, the abscissa represents time (h), ordinate represents the velocity (m/s)/flow direction (°)/ salinity (ppt). By the figure, the tide level calculation values are in good agreement with the measured data, the calculated results of the velocity, flow direction, salinity of each layer is coincided basically with the measured data, the established model can well reflect the tidal current, salinity distribution characteristics of the Liuheng island sea areas nearby.

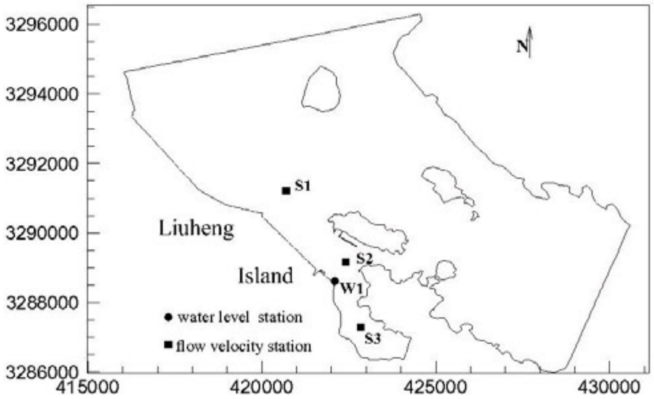

Fig. 1. The small scale calculation area and the field stations distribution

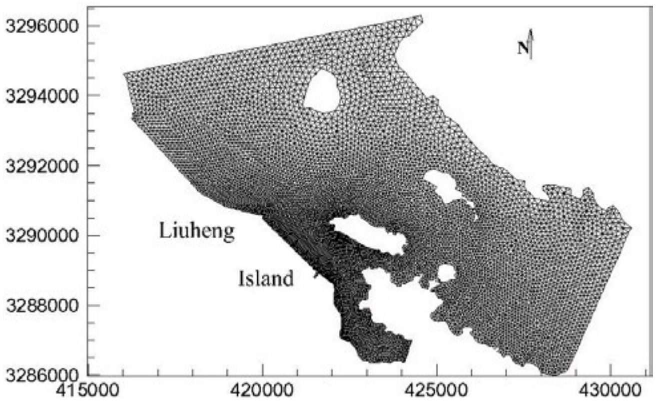

Fig. 2. The grid of the calculation area

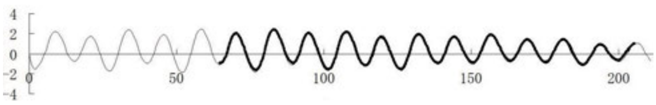

Fig. 3. Comparison of water level from field data with the calculation values

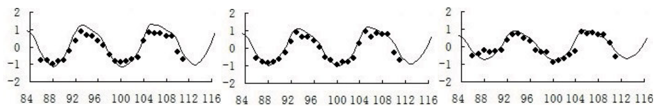

Fig. 4. Comparison of flow velocity from field data with the calculation values (surface, middle and bottom layers)

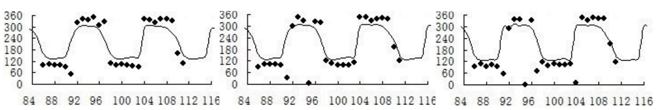

Fig. 5. Comparison of flow direction from field data with the calculation values (surface, middle and bottom layers)

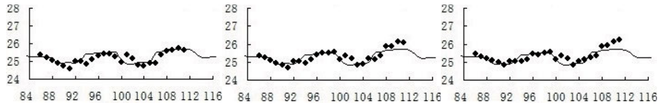

Fig. 6. Comparison of salinity from field data with the calculation values (surface, middle and bottom layers)

TWO-DIMENSIONAL TIDAL CURRENT AND SALINITY NUMERICAL SIMULATION

2D simulation area and the parameters is adopted from 3D numerical simulation, the tidal level verification is shown in figure 7. Flow velocity, direction and salinity selection is illustrated with S1 station during the spring tide. By the figure 8, the tide level calculation values are in good agreement with the measured data, the calculated results of velocity, direction and salinity of each layer is coincided basically with the measured data, the established model can well reflect the Liuheng island tidal current, salinity distribution characteristics.

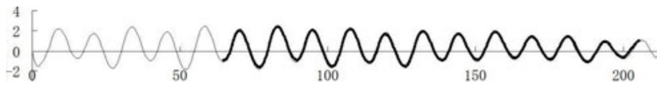

Fig. 7. Comparison of water level from field data with the calculation values

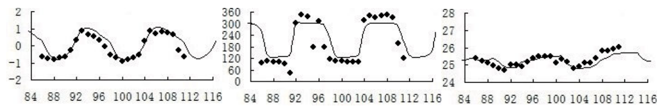

Fig. 8. Comparison of flow velocity, flow direction, salinity from field data with the calculation values

4. COMPARISON OF 2D AND 3D CALCULATED RESULT BEFORE BRINE DISPOSAL

The comparison of average vertical salinity values of 2D and 3D at the stations of S1, S2, S3 are given in the Fig.9(‚—' is 2D value, ‚·' is 3D values, the abscissa represents time (h), ordinate represents the salinity (ppt)). Table 1 presents the difference between the 2D simulated values and 3D average vertical values(3D minus 2D). As can be seen from the figure and table, the difference of the two salinity values from different method is very small, and values are basically the same.

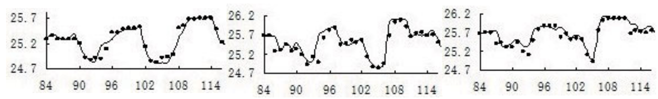

Fig. 9. Comparison of 2D simulated values and 3D average vertical values

Tab. 1. Difference between the 2D simulated values and 3D average vertical values(ppt)

S1	S2	S3
0.009261	-0.07604	-0.07767

COMPARISON OF 2D AND 3D CALCULATED RESULT AFTER BRINE DISPOSAL

Water withdrawal and displacement as shown in Table 2, Water intake and outfall location shown in Figure 10. After verification the 2D and 3D salinity mathematical model with the measured data, set the water intake and outfall as the source and sink in model to predict the impact of brine disposal on the surrounding environment and the salinity distribution.

Tab. 2. The design discharge of the water intake and outfall

	Location	Discharge (kt/h)	salinity (ppt)	Location (From the bottom) (m)
intake	29°42'48.50"N, 122°11'39.59"E	56	—	1
outfall	**29°43'0.45"N, 122°11'22.77"E**	**30**	**48**	**0.3**

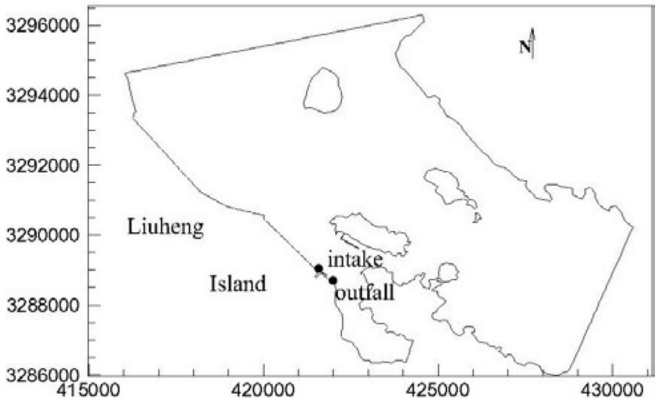

Fig. 10. The location of the water intake and outfall

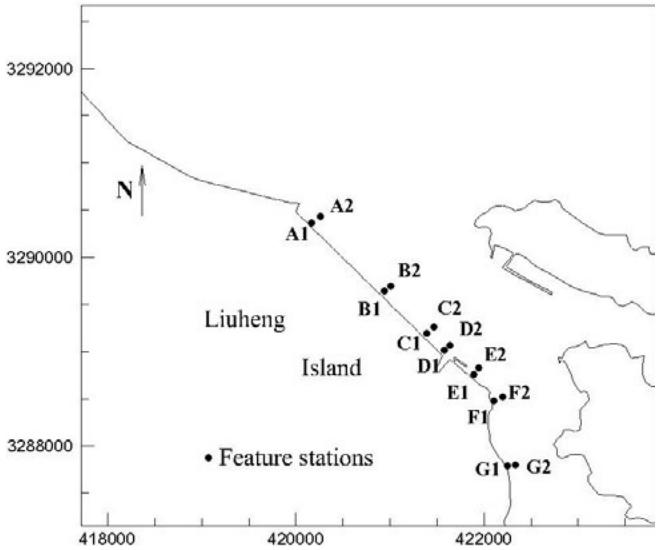

Fig. 11. The location of feature stations

As can be seen from Figure 12, salinity has significant incremental vertical stratification after the brine disposal, the largest increment at the bottom, and the least at the surface. These are because the outfall located at the bottom, the density of brine disposal is larger than the sea water, the higher concentration of salt water outward diffusion in the bottom, resulted that the increment of the salinity in the bottom is greater than the upper.

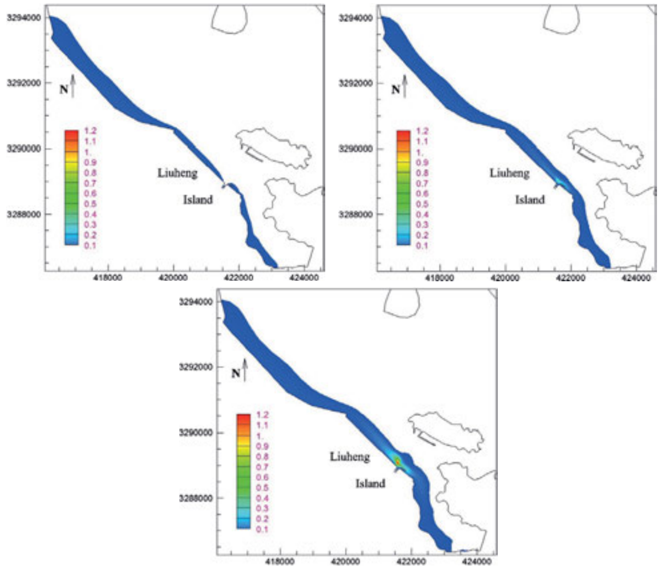

Fig. 12. The incremental displacements of the spring tide(surface, middle and bottom layers)

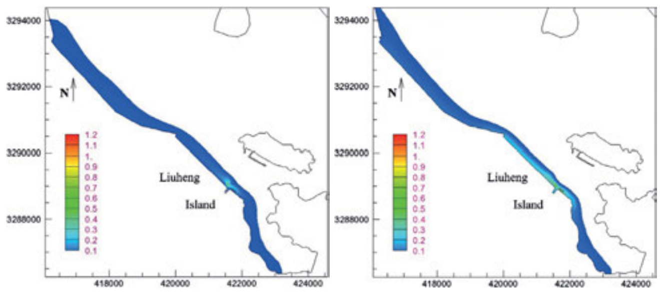

Fig. 13. The incremental displacements of the spring tide (3D average vertical and 2D)

As can be seen from Fig 13, the brine disposal range of the 3D and 2D calculated results are basically the same, and the difference is that, the greater increment in 3D model is concentrated in the outfall, and the increment scope of 2D is larger than 3D model. These are because in the 3D model, the brine diffusion with the bottom water, but the velocity in the bottom is less than the average velocity (2D model results), so that the increment of 3D model is more concentrated than 2D model.

In order to better reflect the difference between the2D and 3D calculated results after the brine disposal project, 14 feature points are set around the outfall to analysis the salinity calculation results, points distribution in figure 11. Table 3 presents the difference at the feature points between the 2D simulated values and 3D average vertical values(3D minus 2D).

Tab. 3. Difference between the 2D simulated values and 3D average vertical values(ppt)

feature station	difference	feature station	difference
A1	-0.263283	A2	-0.154693
B1	-0.28877	B2	-0.147945
C1	-0.378092	C2	-0.101155
D1	-0.399361	D2	-0.078855
E1	-0.297576	E2	-0.116532
F1	-0.238772	F2	-0.136838
G1	-0.161838	G2	-0.134843

As can be seen from Tab 3, the results at A1-G1 points near the shore have a larger difference, the values of 2D are obviously greater than 3D results. And the point closer outfall, the difference is greater. The points far away from the shore, the difference of calculated results at A2-D2 points is small, further evidence that brine diffusion at the 3D simulation is more slowly than 2D, reflected that the influence of the vertical velocity variation on the simulation of brine diffusion.

CONCLUSION

For the study of the effect of 2D and 3D mathematical model in salinity simulation, with Liuheng island strong brine discharge of seawater desalination project as an example, using 2D and 3D salinity mathematical models of Liuheng island to simulate coastal hydrodynamic environment and salinity distribution before and after the concentrated brine discharge. Results show that before the concentrated brine discharge (natural conditions), the simulation results of the two models are almost the same. For the 2D model is simple to set up and has the characteristics of short calculation time, it is recommended to use 2D model to simulate the natural waters salinity; After concentrated brine discharge, 2D and 3D simulation results appeared larger differences, this is mainly due to the strong brine has the characteristics of large density, concentrated in the underlying diffusion, for this kind of apparent salinity stratification is need to use 3D model for research. From the spread of the concentrated brine discharge after scale, 2D and 3D results have not much difference. If only need to study the influence area of strong brine, using 2D model for research is also desirable.

REFERENCE

1. AL-BARWANI H H, ANTON Purnama. Re-assessing the impact of desalination plants brine discharges on eroding beaches.Desalination, 2007(204):94-101.

2. Anton Purama, AL-Barwani H H, AL-Lawatia M. Modeling dispersion of brine waste discharges from a coastal desalination plant. Desalination, 2003(155):41-47.

3. Anton Purnama, H.H.Al-Barwani. Spreading of brine waste discharges into the Gulf of Oman.Desalination. 2006(195):26-31.

4. Luo Feng, Li Ruijie. Influence of hydrometeorological variation on saltwater intrusion in Changjiang River Estuary. Journal of Marine Sciences, 2011,3(29):9-17.

5. MALFEITO J J, DIAZ-CANEJA J. Brine discharge from the Javea desalination plant. Desalination, 2005(185):87-94.

6. Rachel Einav, Fredi Lokiec. Environmental aspects of a desalination plant in Ashkelon.Desalination. 2003(156):79-85.

7. TSIOURTIS N X, Desalination and the environment. Desalination, 2001(141): 223-235.

8. Wang Xiaomeng, Liu Xuehai. The effect of brine discharged from desalination plant on the distribution of the salinity in the Jiaozhou Bay .Acta Oceanologica Sinica, 2009,1(31):44-51.

CONTACT WITH AUTHOR

Li Chunhui
lichunhui35@126.com

Ke Jie
kj36170909@163.com

Dong Xiaotian
do.ng.xt@163.com

Key Laboratory of Coastal Disaster and Defense\
Ministry of Education
Hohai University
Nanjing 210098
China

Environment Marine Laboratory, Hohai University
Nanjing
China

tel: 18512547902, fax: 025-83786997

Pan Xishan
xspan@nhri.cn

Tidal Flat Research Center of Jiangsu Province
Nanjing
China