Supporting Information for

Effect of Anisotropy on Saline Groundwater Pumping Efficiency for Seawater Intrusion Control

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Introduction

This supplementary material aims to provide a detailed sensitivity analysis for our study on the impact of hydraulic conductivity anisotropy on seawater intrusion management in coastal aquifers. By evaluating the effects of variations in key parameters such as hydraulic conductivity, dispersivity, and porosity on model outcomes, we further validate the reliability and robustness of our model. The analysis reveals that hydraulic conductivity and porosity are critical factors influencing the reduction rate of the saltwater wedge and the total salt removal rate, findings that are consistent with previous research and further demonstrate the applicability of our model.

Through a comprehensive presentation of the sensitivity analysis process and results, this supplementary material enhances the transparency and replicability of our research, offering the scientific community a detailed account of the analytical procedures and outcomes. We believe that these analyses not only support the conclusions drawn in the main manuscript but also provide valuable insights for the management of coastal aquifers.

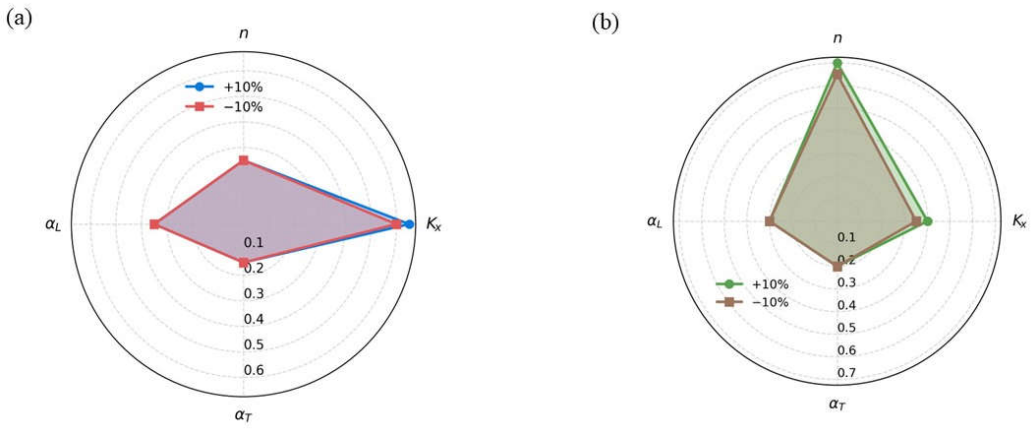


Figure S1. Radar diagrams showing the sensitivity of indicators to parameters: (a) the reduction rate of the saltwater wedge in the inland aquifer behind the pumping wells (L^*) and (b) the total salt removal rate (M^*) with respect to hydraulic conductivity ($\mathbf{K_x}$), longitudinal dispersivity (α_L), transverse dispersivity (α_T), and porosity (n).

Table S1 Parameter settings for sensitivity analysis: baseline values and ±10% variation ranges for hydraulic conductivity ($\mathbf{K_x}$), longitudinal dispersivity (α_L), transverse dispersivity (α_T), and porosity (n) used to evaluate their influence on the reduction rate of the saltwater wedge in the inland aquifer behind the pumping wells (L^*) and (b) the total salt removal rate (M^*) in the coastal aquifer model.

Parameter	***Baseline***	***X* (-10%)**	***X* (+10%)**
$\mathbf{K_x}$	1	0.9	1.1
α_L	200	180	220
α_T	18	16.2	19.8
n	100	90	110

Text S1 Sensitivity Analysis

To comprehensively evaluate the reliability of our model results and the impact of parameters, we conducted a sensitivity analysis on key parameters. Specifically, we selected four parameters: hydraulic conductivity ($\mathbf{K_x}$), longitudinal dispersivity (α_L), transverse dispersivity (α_T), and porosity (n). We varied each parameter by ±10% from their baseline values to assess their impact on two key output indicators: the inland aquifer behind the pumping wells (L^*) and (b) the total salt removal rate (M^*).

The sensitivity analysis was performed by independently varying each parameter by ±10% from their baseline values. Sensitivity coefficients were calculated using the following formula:

$$S = \frac{\frac{\mathrm{Y}' - \mathrm{Y}}{Y}}{\frac{\mathrm{X}' - \mathrm{X}}{X}} \tag{S1}$$

where Y represents the output variable (L^* or M^*) at baseline conditions, and Y′ represents the output after parameter adjustment; X and X′ represent the baseline and adjusted parameter values, respectively. Radar diagrams were used to visually compare the sensitivity of parameters, with longer radial extents from the center indicating greater parameter influence. The baseline values and ±10% variation ranges for the four parameters are listed in Table S1.

The sensitivity analysis results for L^* and M^* are presented in Figures S1, respectively. Radar diagrams provide a multidimensional visualization of the parameter impacts. For L^*, the highest sensitivity was observed for $\mathbf{K_x}$, with coefficients of 0.65 for a 10% increase and 0.60 for a 10% decrease. This indicates that changes in **K** significantly impact the reduction rate of the saltwater wedge. α_L and n showed moderate sensitivity, with coefficients of 0.35 and 0.25, respectively. α_T had the lowest sensitivity, with a coefficient of 0.15. For M^*, n exhibited the highest sensitivity, with coefficients of 0.70 for a 10% increase and 0.65 for a 10% decrease. This suggests that changes in porosity significantly affect the total salt removal rate. $\mathbf{K_x}$ and α_L showed moderate sensitivity, with coefficients of 0.40 and 0.30, respectively. α_T again had the lowest sensitivity, with a coefficient of 0.20.

These findings are consistent with previous studies, such as Stein et al. (2019), who found that their model was most sensitive to hydraulic conductivity and recharge rate when studying the impact of saline groundwater pumping on saltwater intrusion dynamics. Similar results were reported in studies from China (Zeng et al., 2018) and Italy (Filippis et al., 2016). These studies collectively highlight that hydraulic conductivity and recharge rate are key parameters influencing saltwater intrusion dynamics. Our study also identified hydraulic conductivity as a significant factor affecting both L^* and M^*, aligning with the conclusions of Stein et al. (2019). Additionally, the

notable impact of porosity on M^* further validates the reliability and applicability of our model. Specifically, the high sensitivity of M^* to changes in n underscores the importance of accurately representing this parameter in our model. This result is consistent with the physical understanding that porosity directly influences the storage capacity of the aquifer, thereby affecting the efficiency of salt removal processes. By demonstrating that our model captures this relationship, we provide additional evidence of its robustness and suitability for predicting the effectiveness of saltwater intrusion management strategies.

References

1. Stein, S., Yechieli, Y., Shalev, E., Kasher, R., Sivan, O., (2019). The effect of pumping saline groundwater for desalination on the fresh-saline water interface dynamics. Water Research, 156, 46–57. https://doi.org/10.1016/j.watres.2019.03.003.
2. Zeng, X., Dong, J., Wang, D., Wu, J., Zhu, X., Xu, S., Zheng, X., Xin, J., (2018). Identifying key factors of the seawater intrusion model of Dagu river basin , Jiaozhou Bay. Environmental Research, 165, 425e430. https://doi.org/10.1016/j.envres.2017.10.039.
3. Filippis, G. De, Giudici, M., Margiotta, S., (2016). Conceptualization and characterization of a coastal multi-layered aquifer system in the Taranto Gulf (southern Italy). Environmental Earth Sciences, 75, 1e17. https://doi.org/10.1007/s12665-016-5507-7.