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Laboratory Investigations on Estuary Salinity Mixing: Preliminary Analysis

F. H. Nuryazmeen[a]*, T. Wardah[b]

[a,b]Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM),

40450 Shah Alam, Selangor, Malaysia

[a]Email: neemzay@yahoo.com

[b]Email: wardah_tahir@yahoo.com

Abstract

Estuaries are bodies of water along the coasts that are formed when fresh water from rivers flows into and mixes with salt water from the ocean. The estuaries serve as a habitat to some aquatic lives, including mangroves. Human-induced activities such as dredging of shipping lanes along the bottom estuarine, the disposal of industrial wastes into the water system and shoreline development influence estuarine dynamics which include mixing process. These activities might contribute to salinity changes and further adversely affect the estuarine ecosystem. In order to study at the characteristics of the mixing between salt water (estuary) and freshwater (river), a preliminary investigation had been done in the laboratory. Fresh water was released from one end of the flume and overflowing at weir at the other end. Meanwhile, salt water was represented by the red dye tracer released through a weir and intruded upstream as a gravity current. The isohalines are plotted to see the salinity patterns. Besides, to examine the spatial and temporal salinity profiles along the laboratory investigations, the plotted graphs have been made. The results show that the changes in salinity level along the flume due to mixing between fresh water and salt water. This showed typical salt-wedge estuary characteristics.

Keywords: mixing; salinity; estuary; laboratory investigation

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* Corresponding author. Tel.: +6-019-9748352
E-mail address: neemzay@yahoo.com

1. Introduction

Estuaries are semi-enclosed coastal bodies of water where fresh water and salt water meet and mixed [1, 2]. Based on mixing characteristics, estuaries can be classified as vertically-mixed, slightly-stratified, highly-stratified or saline-wedge [3]. The fresh water from river lighter than salt water, so it had a tendency to remain on top of the salt water. If the estuary was deep enough, the salt water from the sea will travelled up the estuary by passing under the fresh water while the fresh water going down the river will stay above the salt water layer and enter the sea. This was called a salt-wedge estuary.

Estuaries act as habitats for many species of plants and animals. Besides, they perform as filters for terrestrial pollutants and provide protection from flooding [4]. Various human activities have been done along the estuary such as dredging and coastal development affects the dynamics of the estuary, including the mixing of saltwater and freshwater [5, 6, 7]. The dredging work might contribute to salinity changes and further adversely affect the estuarine ecosystem. The presence of resisting structures in the estuary or along its banks might also affect the salinity patterns.

This paper presents the preliminary laboratory investigation to visualize the estuary salinity mixing pattern. The objective of this study was to obtain a better understanding on estuary salinity mixing process and salt-wedge estuary characteristics along the flume.

2. Experimental Setup

Preliminary laboratory investigations were conducted using a flume channel model with an effective length of 500 cm, 30 cm wide and 50 cm deep. Fresh water with total ambient flow depth of 0.175 m runs from one end of the flume overflowing a weir at the other end. Salt water is represented by the red dye tracer was discharged at the bottom of the weir in the opposite direction of fresh water flow.

Table 1: Location of the sampling stations

Station	Distance from movable weir, x (cm)
1	103
2	207
3	323
4	428

During the laboratory experiments, four sampling stations were established along the flume channel (in x-direction). Meanwhile, for each sampling stations, three samples were collected in order to measure the salinity level. The salinity level at each station was then measured using conductivity meter, for a total duration of 120 seconds with a 40 seconds interval. The locations of the sampling station are given in Table 1. The constant fresh water and salt water flow rates used were 3.33 l/s and 2.5 l/s, respectively. Fig. 1 illustrates the experimental setup. x, y and z represent longitudinal, transverse and vertical directions, respectively.

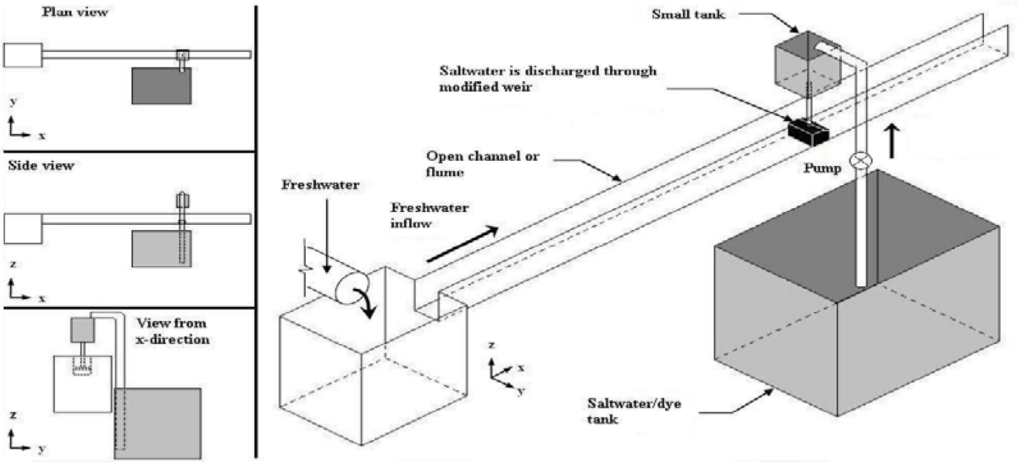

Fig. 1. Experimental setup from plan view, side view and view from *x*-direction

3. Estuarine Salinity Profiles

Initially, the saltwater flow enters the bottom of the open channel as a typical gravity current. As it moved into the channel, the salt water that mixed vertically across the interface was pushed back to the downstream by the fresh water flow, thus creating a mixing layer between the salt water and fresh water. The rest of the salt water travelled upstream and mixed at the bottom of the flume. It took approximately 120 seconds for the salt water to reach the most upstream, station 4. Three important features studied in this experiment are cross-sectional salinity patterns, longitudinal salinity profile and temporal salinity profile in the channel.

3.1 Cross-sectional Salinity Pattern

The cross-sectional salinity pattern was observed through isohalines at different locations. Fig. 2 shows the salinity patterns at the most downstream station 1, located 1.03 m from the weir. From the figure, DS represents for salinity changes. This station is the most downstream of the channel and receives the highest volume of salt water. Salt water intrusion occurs at the bottom of the channel because it is denser than fresh water. The salt water then further dispersed and diluted as it flows to the upstream of the channel as shown in Fig. 3, 4 and 5. Fig. 3, 4 and 5 indicate the observed salinity profiles, where the distance from the weir are 2.07 m, 3.23 m, and 4.28 m, respectively. The salinity profile was uniformly distributed across the channel.

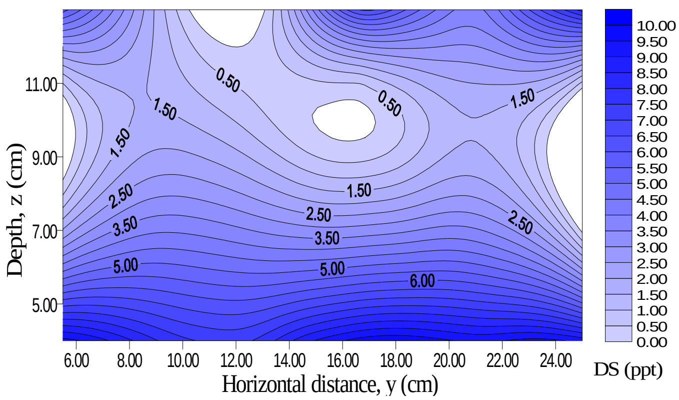

Fig. 2. Isohalines of saltwater intrusion at station 1, x = 1.03 m

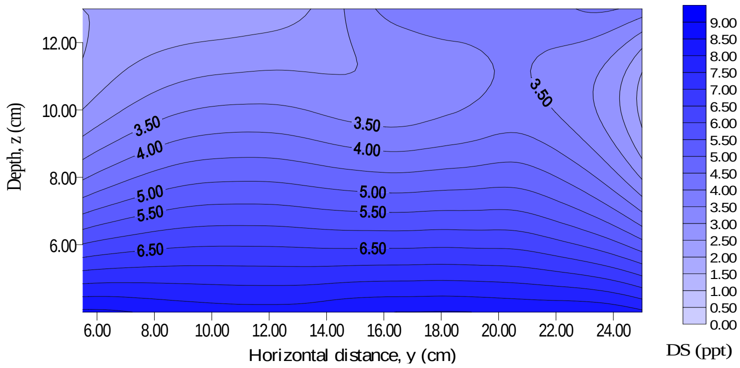

Figure 3: Isohalines of saltwater intrusion at station 2, x = 2.07 m

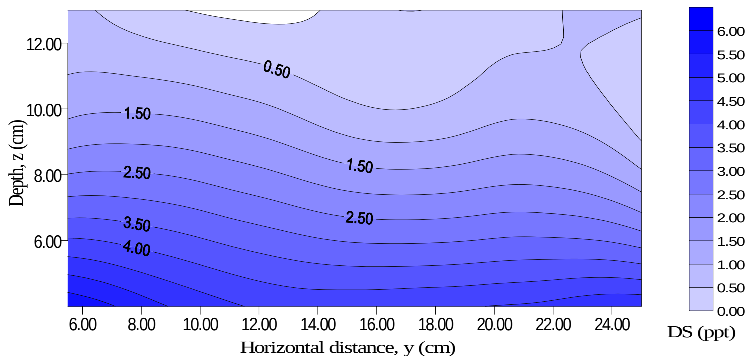

Fig. 4. Isohalines of saltwater intrusion at station 3, x = 3.23 m

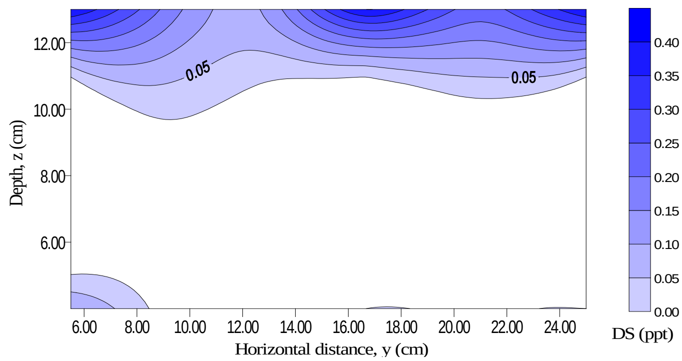

Fig. 5. Isohalines of saltwater intrusion at station 4, x = 4.28 m

Fig. 5 illustrates the isohalines pattern at station 4 located most upstream, near to the fresh water tank. The high volume of fresh water and vertical mixing process that occurs in the channel has contributed to the dilution of salt water. It can be seen that, the salinity gradient is small. Generally, as the salt water flows to the upstream, mixing occurs and salt water diluted by the fresh water.

3.2 Longitudinal Salinity Profile

Fig. 6 presents the salinity profiles along the channel length, observed at different depths. In general the graphs show that salinity at the bottom of the channel is higher than at water surface, due to the high density of salt water.

As expected, fresh water lies on top flow layer due to of its lower density while the salt water accumulate at the bottom of the flume. This represents the formation of the salt-wedge in the channel. Downstream part of the channel experience higher salinity compared to the upstream part. Such phenomenon occurs as a result of high salt water volume at the downstream end, and high fresh water volume at the upstream end. It is also possibly caused by the vertical and longitudinal mixing processes.

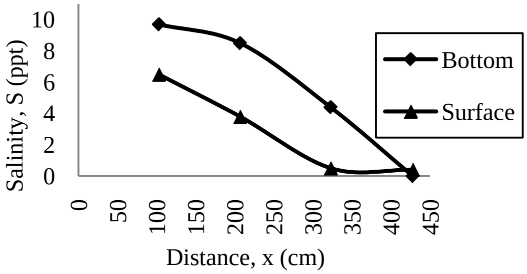

Fig. 6. Salinity profiles along the channel length

3.3 Temporal Salinity Profile

The experiments were carried out for a total duration of 120 seconds. Salinity levels were measured at 40 (t_1), 80 (t_2) and 120 (t_3) seconds after saline water is introduced. As shown in Fig. 7, the salinity at the upstream increases from t_1 to t_3. This provides evidence for the occurrence of salinity intrusion in the channel.

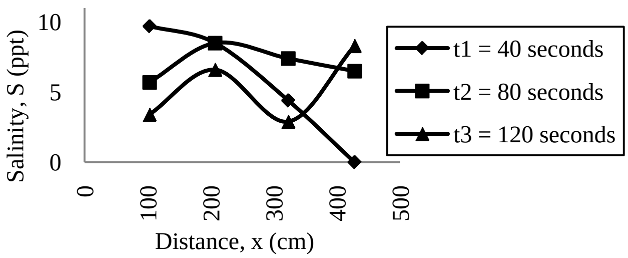

Fig. 7. Temporal salinity profiles along the channel length

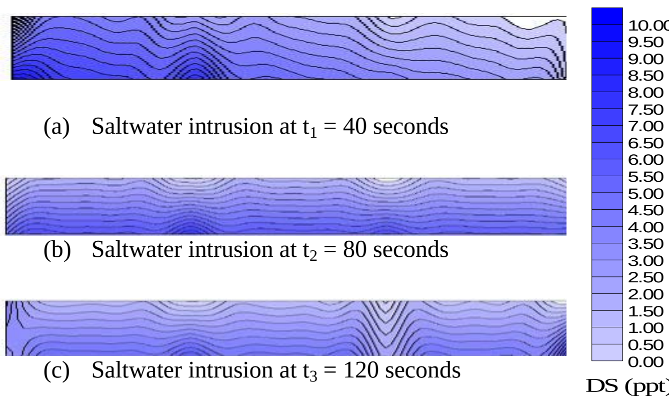

Fig. 8. Temporal isohalines pattern along the channel length

Meanwhile, at the downstream section, salinity decreases with time. This is due to the turbulent condition which leads to circulation and mixing process. Fig. 9 shows the temporal isohalines pattern along the channel. It can be seen that the salt water tends to accumulate at the bottom of the channel and mixing takes place as it moves to the upstream section of the channel.

4. Conclusion

This preliminary laboratory investigations aim at understanding the possible behavior of salt-wedge estuary. Stratification occurrence in the channel is obvious. The salinity profiles show the bottom salinity was higher than the water surface. It indicates a typical salt-wedge estuary. As the salt water current flows upstream, the mixing and dilution occurs. Salinity is high at downstream (near to the sea) and decreasing gradually towards upstream (river flow).

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References

[1] R. H. Weisberg and L. Zheng, "How estuaries work: A Charlotte Harbor example," *Journal of Marine Research*, vol. 61, pp. 635–657, 2003.

[2] J. Cao, R. Li, and Y. Zhu, "Study on Saltwater Intrusion in the Yangtze River Estuary by 3D Numerical Model," in *Education Technology and Training, 2008. and 2008 International Workshop on Geoscience and Remote Sensing. ETT and GRS 2008. International Workshop on*, 2008, vol. 2, pp. 81–84.

[3] H. B. Fischer, E. J. List, R. C. Y. Koh, J. Imberger, and N. A. Brooks, *Mixing in inland and coastal waters*. Academic Press, Inc., New York, 1979.

[4] Q. Liang, G. Du, J. W. Hall, and A. G. L. Borthwick, "Flood inundation modeling with an adaptive quadtree grid shallow water equation solver," *Journal of Hydraulic Engineering*, vol. 134, no. 11, pp. 1603–1610, 2008.

[5] Y. H. Kim and G. Voulgaris, "Lateral circulation and suspended sediment transport in a curved estuarine channel: Winyah Bay, SC, USA," *Journal of Geophysical Research*, vol. 113, no. C9, pp. 1–15, Sep. 2008.

[6] L. C. Rijn, "Analytical and numerical analysis of tides and salinities in estuaries; part I: tidal wave propagation in convergent estuaries," *Ocean Dynamics*, vol. 61, no. 11, pp. 1719–1741, Jul. 2011.

[7] K. Kuijper and L. C. V. Rijn, "Analytical and numerical analysis of tides and salinities in estuaries; part II: salinity distributions in prismatic and convergent tidal channels," *Ocean Dynamics*, vol. 61, pp. 1743–1765, Jul. 2011.