# Analysis of Salt Water Intrusion Based on Observation and Numerical Simulation

LIU Haisheng*, Natsuki YOSHIKAWA**, Shin-ichi MISAWA**, Kouhei WATANABE**

## 1. Introduction

The seawater intrusion renders the quality of river water unsuitable for agricultural use. The phenomenon called "saltwater wedge", in which upper layer of freshwater and underlying layer of saltwater are highly stratified, is likely to occur near the estuaries of rivers draining into the Sea of Japan due to its small tidal range.

Agricultural area irrigated using the water from Shinkawa River in Niigata city (Fig.1) has been suffering from the presence of saltwater wedge. The saltwater intake by 9 pumps equipped along the river has influenced rice quality. In fact, the first class rice harvested in the year 2010 remained only 10% of the total rice production of this area.

An attempt to avoid saltwater mixture to the irrigation water has been implemented by closing the sluice gate at the river mouth when the wedge is expected to ascend up to the height of pumps' intake opening. However, this method incurs a cost to operate drainage pumps, and more decisively the effect is limited due to the mixture of saltwater and freshwater by stirring and breaking the layer structure of saltwater wedge by the pump operation. As a countermeasure, therefore, a selective intake of freshwater may be a better option in terms of the cost and effect.

For the implementation of selective intake, on the other hand, salt wedge geometry and extension must be predicted since the saltwater wedge is invisible and the actual phenomenon occurring under the water has been unknown.

The study attempts to visualize the saltwater wedge by integrating field observations and numerical calculations of the Shinkawa River estuary.

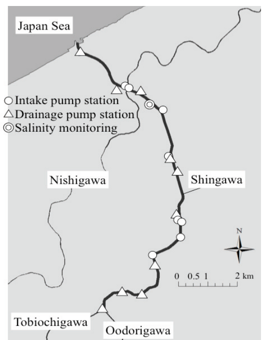



Figure 1 Research area

## 2. Materials and Methods

### 2.1 Field observation

The longitudinal profile of the saltwater wedge was surveyed by an echo-sounding profiling system (SC-3) as shown in Fig.2, and vertical density distribution by EC meters. With respect to the longitudinal profile survey, a survey boat on which the SC-3 and GPS installed was used, and cruised from river mouth towards the upstream direction. This survey was conducted to observe the extreme events of high water of spring tide (July 15, 2011 13:29) and low water of neap tide (August 23, 2011 16:21).

Simultaneously with the longitudinal profile survey, the water density survey using the EC meters was conducted at each bridge crossing Shinkawa River, and vertical density distribution data with the interval of 5cm at each site were obtained. This survey was conducted periodically every two weeks, not only along with the longitudinal profile survey.

### 2.2 Numerical simulation

The numerical simulations adopted in this study is a one-dimensional two-layer unsteady flow model comprised of the following six governing equations; volume conservation equations for the upper (freshwater) and the lower (salt water) layer, a mass conservation equation for the lower layer, a diffusion

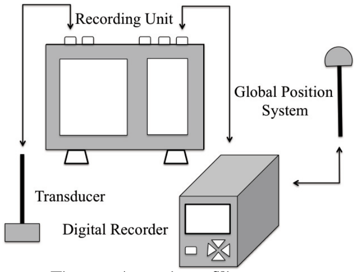



Figure 2 Acoustic profiling system

*Graduate School of Science and Technology, Niigata University
** Institute of Science and Technology, Niigata University
Key word: Salt Water Intrusion, Acoustic Profiling System, Numerical Simulation

equation, and momentum equation for the upper and the lower layers. Since the primary governing factors to determine the extent and the shape of the saltwater wedge are considered to be river discharge volume supplied from upstream and tidal stages at the river mouth, these factors are applied as upstream and downstream boundary conditions. These equations are solved by an implicit-finite difference method.

## 3. Results and Discussion

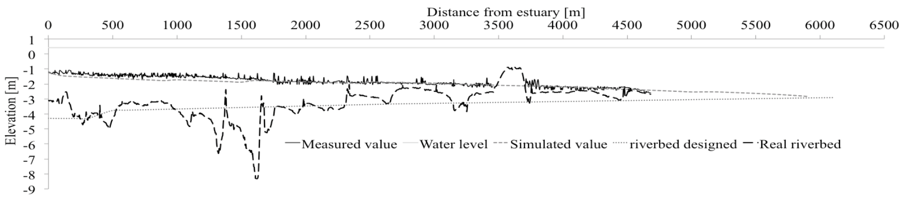
The result of the echo-sounding profiling in the case of the high water of spring tide and the low water of neap tide shown in Fig. 3 (a) and (b) suggests that the longitudinal profile of saltwater layer extended towards upstream in the form of wedge under the freshwater. The extension of saltwater wedge was approximately 4.7 km and 2.2 km respectively. These profiles are well reproduced by the numerical calculations with an error of approximately 1 km in longitudinal extension, and, thus, provide strong confirmation of the model's predictive ability (depicted by a gray dashed line in Fig. 3 (a) and (b)). Fig.3 (c) is the vertical distribution of electric conductivity observed by the EC meters at 7 sites. The results present an existence of an interface between freshwater and saltwater with thin halocline zone of approximately 10cm. This suggests that a rigid saltwater wedge is formed in Shinkawa River.

## 4. Influence of saltwater wedge on irrigation water intake

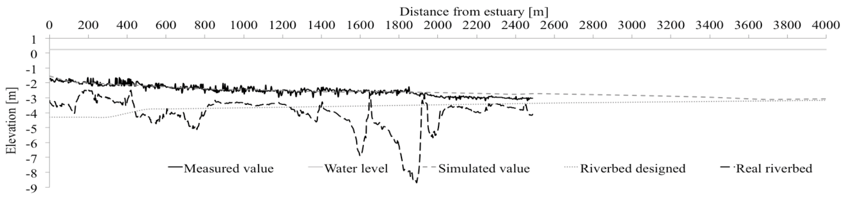
The model was applied to simulate the vertical position of the halocline zone for the whole irrigation period using actual boundary conditions. The calculated vertical position of the halocline zone is compared with the conductivity value measured by an EC meter installed at one of the pumps. As a result reaches the EC value reaches 1500μS/cm, at which the irrigation pump operation stops, when the vertical distance between the pump opening and halocline zone becomes less than 1.2m. This condition is estimated to occur about 23.0% of the total irrigation period.

## 4. Conclusion

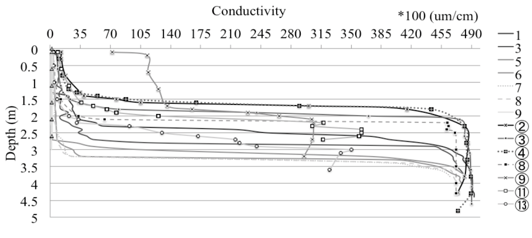
In this study, the saltwedge in Shinkawa River was successfully visualized by field observations and numerical calculations. Based on the analysis of this study, we will proceed to make proposals for some practical and inexpensive countermeasure.




(a) The observed and simulated salt water wedge for a spring tide




(b) The observed and simulated salt water wedge for a neap tide




(c) The conductivity on July 15th, 2011 (“ 1 ”) and on August 23rd, 2011 (“ ② ”)

Figure 3 The results of observation and numerical simulation