AAPG Annual Convention
Salt Lake City, Utah
May 11-14, 2003

Influence of the Finer Material Portion in Physical Simulation of Density Currents

RICHARD EDUARD DUCKER, IPH Instituto de Pesquisas Hidráulicas UFRGS, Porto Alegre, RS, Brasil;MARCELO DEVENUTTE AVILA IPH Instituto de Pesquisas Hidráulicas UFRGS, Porto Alegre, RS, Brasil; ROGÉRIO DORNELLES MAESTRI IPH Instituto de Pesquisas Hidráulicas UFRGS, Porto Alegre, RS, Brasil; ANA LUIZA DE OLIVEIRA BORGES IPH Instituto de Pesquisas Hidráulicas UFRGS, Porto Alegre, RS, Brasil.

ABSTRACT
The study of deep water sedimentation shows that density currents are the main mechanism on the formation of most turbidity systems. In order to understand the flow parameters and specially its depositional patterns, many researches have been developed in many laboratories around the world. The use of small scale physical modeling in this field is a powerful tool in the creation of an analogue system, once it can reproduce the natural environment.

Real density currents usually carry a wide grain size range on its sediment load. The finer material, that doesn't settle down during the current development, plays an important role in the transportation capacity of the flow. The present work aims to evaluate the use of salt to simulate this portion of the material.

The simulations were conduced in a bidimensional variable slope channel (300 x 12.5 x 20cm). The currents were composed by a mixture of water, salt and mineral coal. This mixture density and volume were kept constant, while the amount of salt and coal was changed.

The results show that with sediment load increasing: the currents desacelerate with an increase magnitude and their geometry dimensions (head and body height) enhance. However, the depositional patterns didn't show any significant difference for the mixtures simulated.

INTRODUCTION
In the field of density currents, several studies have been developed in order to comprehend the flow parameters and specially its depositional patterns. This knowledge is very useful in the understanding of the formation processes of turbity systems, which have great economic interest for being excellent hydrocarbon reservoirs.

The present study is primarily concerned about evaluating the use of salt to represent the finer material portion in density currents physical modeling. Secondly, the interest was to replace the salt by very fine material to evaluate the variations in transportation capacity. In nature this finer material doesn't settle down during the current development, although it plays an important role in its transportation capacity.

APPARATUS AND METHODOLOGY
The simulation took place in a bidimensional small scale channel (300 x 12.5 x 20cm) shown in figure 1. The methodology of the experiments consisted in the variation of the components proportion present in the mixture. Thus the experiments were divided in two stages (table 1). In the first one, the mixture was composed by mineral coal (density 1365kg/m^3 grain size ranging between 0.053 and 0.210mm) and salt. In the second stage the salt was replaced by very fine sediment (smaller than 0.053mm). For each experiment configuration three runs were performed. Each experiment configuration used a different amount of mineral coal as follows: 0g (only saline solution), 52g, 104g, 156g e 208g (only sediment suspension). In both stages the mixtures had a similar density (1010kg/m^3), adding up to a 41 volume and flow rate around 6.851/min.

Table 1 – Mixtures characteristics

	Coarse Portion (0.053 - 0.210mm)	Finer Portion	Density (kg/m3)
1st Stage	none	salt	1010
	52g	salt	
	104g	salt	
	156g	salt	
	208g	none	
2nd Stage	52g	coal (< 0.053mm)	1010
	104g	coal (< 0.053mm)	
	156g	coal (< 0.053mm)	

In the first stage experiments, the coal was first added to the water followed by the required amount of salt to reach the desired density of 1010kg/m^3. The mixture was stored in a small reservoir and then injected into the channel. The ambient fluid was composed by fresh water.

A pair of digital cameras and a portable ultrasound scanner registered the experiments enabling dynamic and geometry features observations. The first camera focused the current head for velocity and acceleration analysis, while the second followed the body for geometry feature analysis. The ultra sonic images were used to analyze the internal structures behavior.

To the analysis of the current dynamics, the channel was divided in 5cm intervals. The elapsed time was measured, using electronic devices, as the current passed through each interval. This data was used to velocity determination through spreadsheet calculations.

The geometry analysis was performed through photographic images taken as the current passed by determined sections of the channel. Vertical and horizontal scales fixed in the channel were used as references for dimensions. This procedure allowed the evaluation of mixture effects in the current geometry.

Twelve hours after the experiment was performed, when most of the material was already settled down, the channel was slowly drained to avoid sediment remobilization. The deposits were described by grain size analysis of samples collected in 50cm intervals, adding up to 6 distinct samples.

CURRENT GEOMETRY

Figure 2 shows a first stage image sequence obtained during the currents development across determined sections for each experiment configuration. It shows geometry changes occasioned by mixture sediment amount variations. The conservative currents present a clearly delimited head and body. As the coal portion increases in the mixture, this delimitation becomes less sharp, current dimensions enlarge and vortex shedding gets more numerous. These facts indicate behavior differences among currents composed by different amounts of salt and sediment.

The second stage currents and first stage currents composed only by sediment present similar shapes and dimensions. Second stage currents presented a more intense vortex shedding though.

CURRENT VELOCITY

During the current development its concentration is diluted by incorporation of ambient fluid. As a consequence the current density decrease, as well as its velocity, which is directly density dependent. In figure 3, a tendency line indicates the velocity gradient caused by this mixture. A stronger deceleration is observed as the amount of coarser suspended material increases. In this case, the mixture density also decreases faster as the sediment is deposited. The first and second stages currents showed the same behavior.

The strong velocity variations observed in the beginning of the channel are due to its transition and stabilization features caused by mixture admission. Velocity analysis also showed small accelerations and decelerations, which are probably related to vortex shedding processes.

GRAIN SIZE DISTRIBUTION OF THE DEPOSITS

Second stage currents, which were composed by coal very fine sediment instead of salt, presented an increased transportation capacity, carrying the coarser grains to the distal portions of the channel (figure 4). The finest fractions of the material were deposited homogeneously across the whole channel adding a bimodality character to the grain size distribution histograms. This fact indicates that these particles remain in suspension after the current is gone and are only settled down after some hours.

The obtained deposits presented a tendency of thickness and grain size decreasing towards the distal portions. First stage currents (sediment and salt mixtures) didn't present significant variations on its depositional patterns. This fact is relevant because the mixture different sediment amounts introduced great variations in the current dynamics.

DISCUSSION

The salt/sediment current expressive dynamic variations observed didn't cause depositional patterns modifications. This indicates that somehow the increasing in the particle settling velocity resulting from the density variations is compensated by some unknown factor. It turns out that the use of salt to simulate the finer material portion in density currents physically simulated should be better studied.

The experiments have showed that the current transportation capacity is mainly affected by grain size distribution instead of its density, altering its rheology behavior.

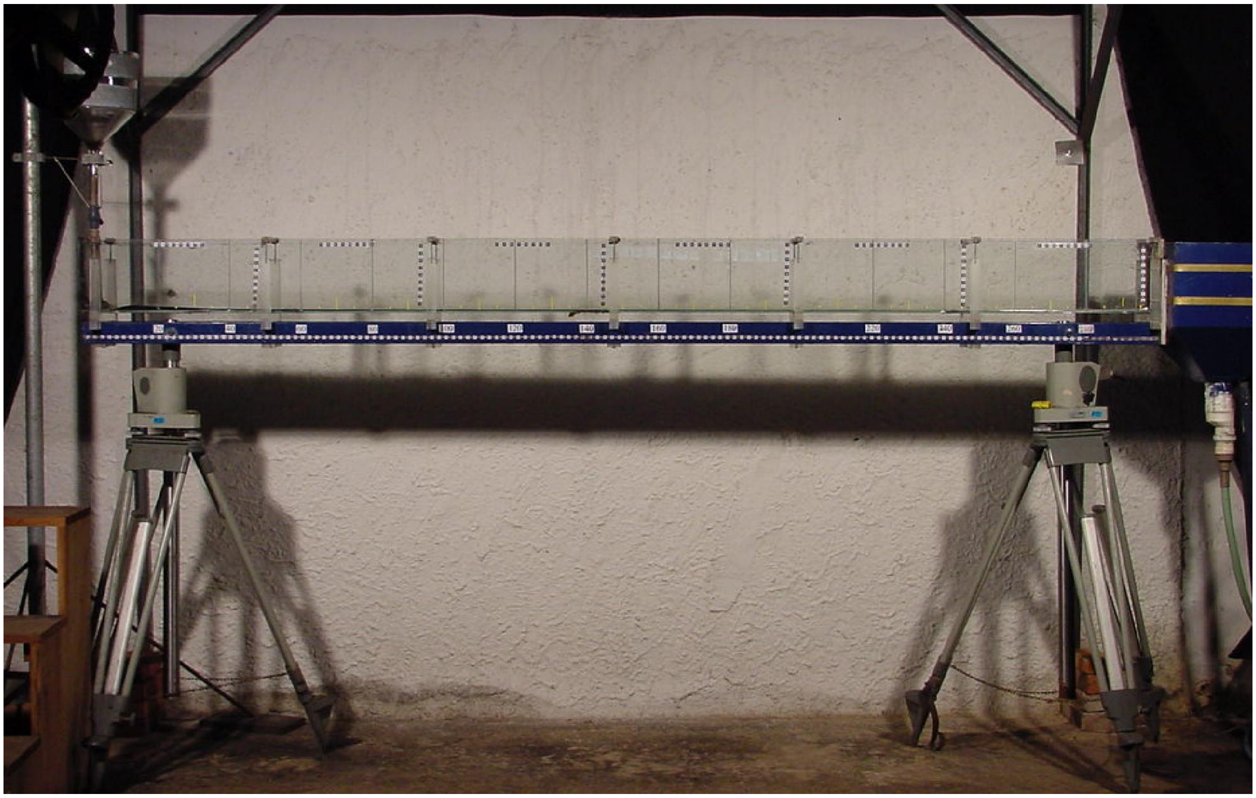

Fig. 1 – Channel where the experiments were performed

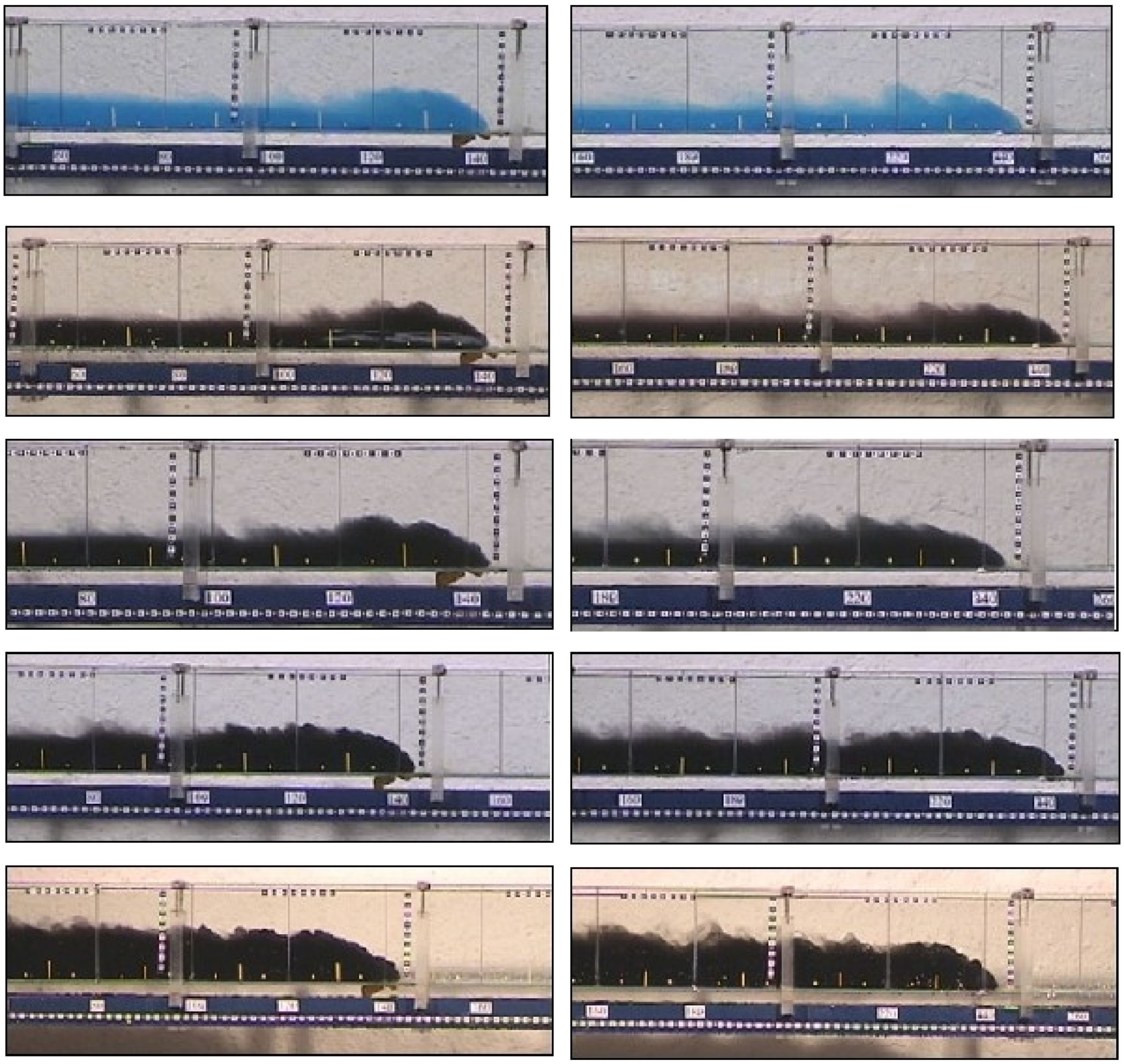

Fig. 2 – Pictures of the currents of the first stage experiments. On the left the current with 140cm from source and in the right with 240cm. The current on top is composed only by salt, and in the bottom is the current composed only with coal (0,053 - ,210mm).

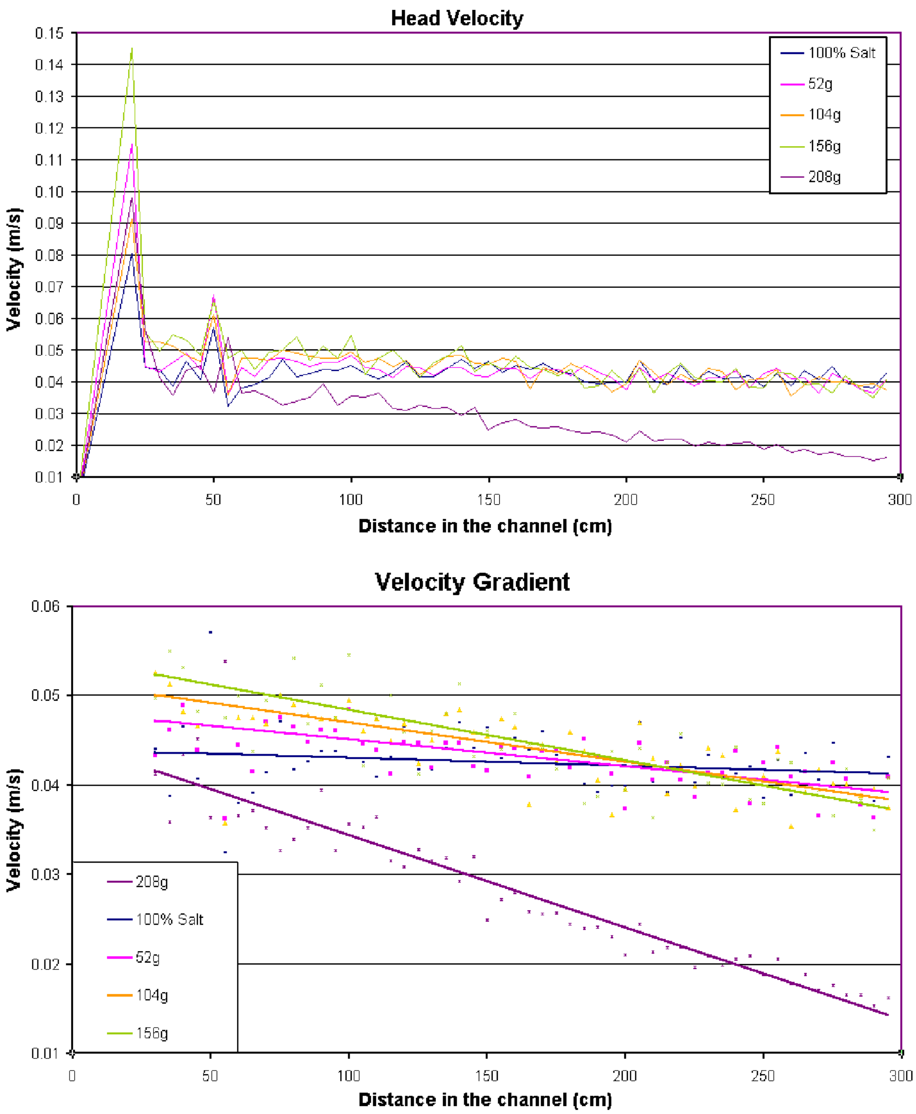

Fig. 3 – On top: Velocities of the first stage currents. Above: The gradient of velocities.

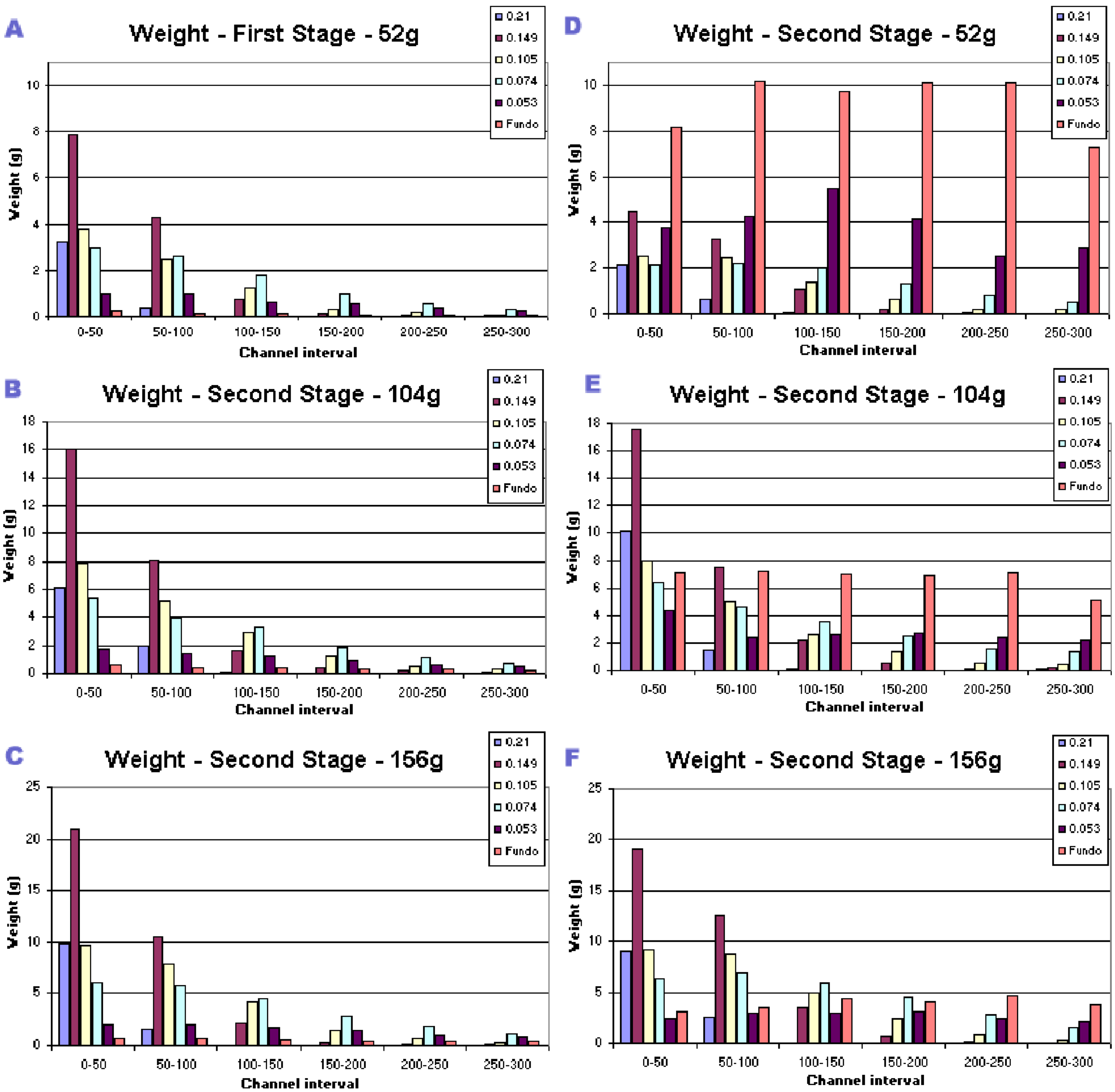

Fig. 4 – Total mass deposited in experiments 52g, 104g and 156g of both stages in each channel interval

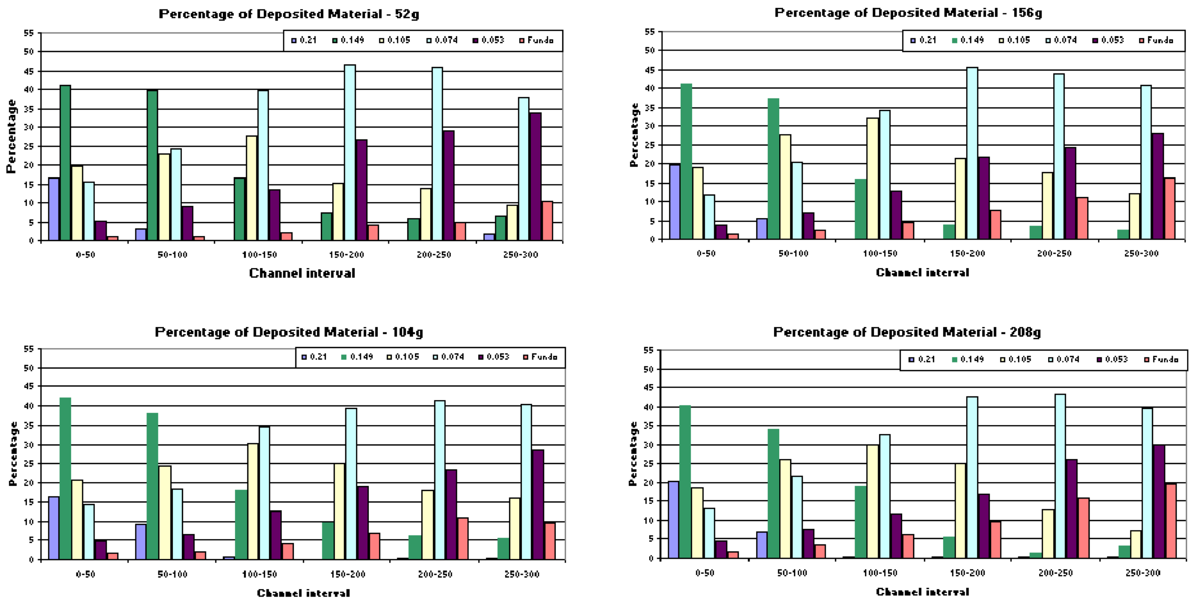

Fig. 5 – Percentage of deposited material of the first stage experiments. These graphics show the similar depositional patterns of the currents composed by sediment and salt.