Verhagen

ADMINISTRAÇÃO-GERAL DO PORTO DE LISBOA

Hydro-morphological study Tagus Estuary

Memorandum on the salinity on the inner estuary

August 1983 / P642

PORT AND WATERWAY ENGINEERS

hydronamic bv
sliedrecht holland

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INTRODUCTION

This memorandum has been prepared on request of mr. Castro and mr. Perestrello; the aim of this memorandum is to give a more general interpretation to the findings of the previous studies of the Tagus estuary as performed by Hydronamic in the past, especially in relation to salinity problems.

In one of the most recent studies for AGPL, Hydronamic studied the influence of works in the outer bar on the salinity-distribution in the upstream section of the estuary. The main conclusion from this study was that current-patterns, tidal prism, etc. in the inner estuary are fully determined by the geometry of the Corredor, and that consequently the influence of civil engineering works west of Belem on the salinity distribution are negligible.

Although it was not studied, it became obvious that works east of the Ponte de 25 Abril may have an impact on on the salinity distribution. This impact may be considerable.

In this memorandum some general aspects of impacts on the salinity distribution are discussed, as well as those aspects which should be studied by AGPL before and after permission is given to construct important works in the area.

THE EFFECT OF SALINITY AND SALINITY DIFFERENCES

Both for the physical as for the biological balances in the estuary salinity is an important item. Because the biological aspects are beyond the scope of this memorandum, they will not be discussed here. From a physical point of view two aspects of salt water are very important:

- salt water is heavier than fresh water
- chloride ions cause an increase in coagulation of clay particles.

Because of the second aspect this process can strongly influence the siltation pattern in the estuary. Suspended clay in fresh water consists of flat or needle-shaped particles, having a maximum dimension less than a few micrometers. Because of their form, large surface area and the crystal structure of the clay minerals, these particles are negatively charged on the surface. Since the particles are so small, the electrostatic forces rather than the gravity control data behaviour of the clay particles and work to keep the particles seperated and in suspension.
As the salinity of the water increase the positive ions (Na^{+}, Mg^{++}, Ca^{++}, etc.) present tend to neutralise the electrostatic forces, thus allowing the clay particles to flocculate, and settle. A salinity of about 3 o/oo is critical in this process. The physical chemical influences are only important for salinity variations below this value. This means that this effect is important for upper section of the estuary, more than 35 km upstream of Paço d'Arcos.

The flocculation caused by an increase in water salinity is at least partially reversable. When, later in the tide cycle, the salinity decreases, the flocs of clay particles exposed to the fresh water can "explode" dispersing the individual particles once again in suspension. This process can provide disturbing on suspended sediment measurements in area's where low, variable salt concentrations can be found. This implies that sediment transport measurements upstream the 35 km limit have to cover longer intervals than the intervals applied in the downstream area.

Because saline water is heavier than freshwater it will flow over the bottom, forming a so-called salt wedge. Such a salt-wedge can be calculated quite accurately with the method of Schijf & Schönfeld (1953) for a prismatic, horizontal rectangular channel discharging into an infinite, non-tidal sea. In fact, this is quite theoretical. Because of the tides mixing will occur, making a so-called partially mixed estuary. An import value in such an estuary is the rate of stratification , as defined by Harleman and Abraham (1966).

For sedimentation the density currents due to this stratification might be of considerable importance. Sediment transport is mainly determined by the current near to the bottom (both direction and magnitude). Due to the density induced currents, the sediment transport may devide from the transport determined from the depth-averaged current value only.

From the above follows that the stratification of an estuary is important for the determination if detailed research in the field of sediment transport deviations due to density differences is required. If the estuary is well mixed, such a detailed investigation is not required.

For big estuaries as the Tagus inner estuary the degree of stratification may differ considerably for various locations, and may also differ for various seasons, for the type of the tide (spring-tide, neap-tide).

PRACTICAL ELABORATION

The only trustworthy way to determine the rate of stratification is to do measurements. As will be discussed lateron, such measurements be done quite easily.

The best way to start is to determine the water stratification for the estuary from the rate which are already available. One of the most important sets is of course the set of data from 1974/1975, consisting of 56 measurements in 21 different locations. The data from these measurements are fully worked out, and in fact the rate of stratification for each point is known for one springtide and for one neap tide. Effects of river discharge etc, can only be studied for two points (Montana and Jusante) which were measured during more days.

More field data are available within AGPL, however these data are not worked out, and cannot be used at this moment.
It is therefore advisable to start with the elaboration of these data.

After having worked out these data one can see which areas of the estuary were not yet covered by measurements. Also one can see from which other groups of environmental situations (like season, tide, river-discharge) data are missing.
Knowing which data are missing one can make plans for additional measuring campaigns.

Especially in areas where larger infrastructural works may be expected in the near future (e.g. Siderurgia area, Canal do Cabo Ruivo; Cala do Norte) should be covered by these measurements.

Having done salinity measurements in these areas one may decide on facts if a more detailed study is required, or not before giving permission to proceed with the works.

PERFORMANCE OF MEASUREMENTS

The best way to do these measurements is to measure during 13 hours the velocity and salinity-profile at several locations. The disadvantage of this method is that it is a very expensive method, because no more than 5 station/week can be measured, if one boat is available. And because it takes also time to go to the station, such a week is a week at approx. 75 working hours.

But in order to get a good impression of the salinity, it is not necessary the measure also the velocities. Provided that a fast, electronic salinometer is used (like the salimometer of Yellow Springs Instruments, type nr. 33) a salinity profile can be measured in only one or two minutes. With such a fast salinometer a dynamic measuring campaign can be set-up.

As measuring vessel a small speed-boat with an outboard engine can be used (the meter does not need a power supply, and is not sensitive to motions of the ship). If one uses a scheme of 4 minutes sailing and 2 minutes measuring, 5 stations can be measured, if one measures the profiles every half hour. The distance between the stations can be approx one kilometer.
So if 20 stations are required, all these stations can be measured in four days. (For practical reasons it is advisable to work in two shifts)

For comparison:

normal way	15 hours/day	
	4 man	
	20 days	1200hours
dynamic way	15 hours/day	
	2 x 3 man	
	4 days	360 hours

A second advantage of the dynamic way of measuring is that groups of 5 stations have the same environmental conditions, (especially same tidal condition), while with the static way, each station has different environmental conditions, because the measurements are made on different days.

'SALINE ENGINEERING'

It might be advantageous to keep the salt water as far as possible to an upstreem location, especially in areas where channels are dredged, and a stratification occurs.
In such points one can improve the situation by increasing the fresh-water flow through that channel.

As an example, one may increase the fresh-water flow through the Cala do Norte by closing the gaps between the islands in the estuary, and forcing all the fresh-water of the Tagus through the Cala do Norte.

Doing this one may guarantee that water intakes northwest of Povoa have always fresh-water.

However, before making such an important change in the hydraulic system of the estuary, a thourough study of salinity in that area has to be made.

Of course such a change should also be tested in the mathematical model of the Inner Estuary.

CONCLUSIONS

From our experiences from studies of the Tagus estuary follows that changes west of Belem are not affecting the inner estuary, but that changes east of Belem may have an influence on the hydraulics and the density distribution of the inner estuary.

It is expected that only in the transition zone (i.e. between Poço do Bispo and Alcochete) the effects are considerable but it is not possible to say on beforehand that changes elsewhere are negligible.

Therefore it is advisable to get a general idea of the importance of salinity-changes by determining the rate of stratification for a number of stations in the estuary, if possible all as a function of the environmental conditions (tide, seasons, river discharge).

First of all the measurements already done should be worked out and analysed, with the results of this analysis missing data can be determined and an additional measuring program can be set-up.

Additional measurements can be done fast and relatively cheap, applying modern, electronic salinometers. These meters are available in Portugal through specialised hydro-survey companies.

After the total analysis at all data a general impression of the salinity distribution of the whole estuary can be given. With the data than available one can determine for which projects additional salinity-studies are required, and also for with project salinity effects are of no importance at all.