

PART VIII

Case Studies



CHAPTER 239

RIA DE FOZ: WORKS BEHAVIOUR

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INTRODUCTION

When, in the previous Conference, a paper was presented and published (1) aboarding the problems and solutions in a ria of the West End of the Spanish Cantabrian coast, the works of the solution project had just been finished (JUN 1988), so that very few data had been obtained about their behaviour. Additionally, the systematic survey of the dynamics in the ria had been initiated but not finished, not even in the field data collecting, therefore the hydrodynamic and morphodynamic model obtained to implement the project, having explained rather satisfactory all the known coastal and estuary process and changes, only was a qualitative approximation. Nevertheless it was in agreement with a very complete methodology of coastal processes analysis (2) and good enough to justify some singular circumstances: one of them refers to the increasing sandy filling of the ria what, like in all Cantabrian ones and probably like in many other bights -glaciars, like in New England, U.S.A., and Scotland, or structural, like in the rest of the Cantabrian and Bretagne (France),- has been principally filled with littoral materials, without any significant contribution of the respective rivers, whichever its size; other one, to the spit nature and genesis of the barriers of all the Cantabrian rias; they have been generated by the longshore transport through a "negative geometric singularity" (3) more than by onshore-offshore equilibrium and, consequently the migration of the tidal inlets is downdrift, but respect to the local drift, though it could appear to be updrift.

As the rias practically are the only shelter areas in the Spanish Cantabrian coast, the harbours have been initially established in them and even one or more small fishing harbours remain in each of them at present, so that the sandy filling processes, together with the increasing size and draught of the ships has become a meaningful problem in them. In the case of the Foz ria the problem had become even more acute because

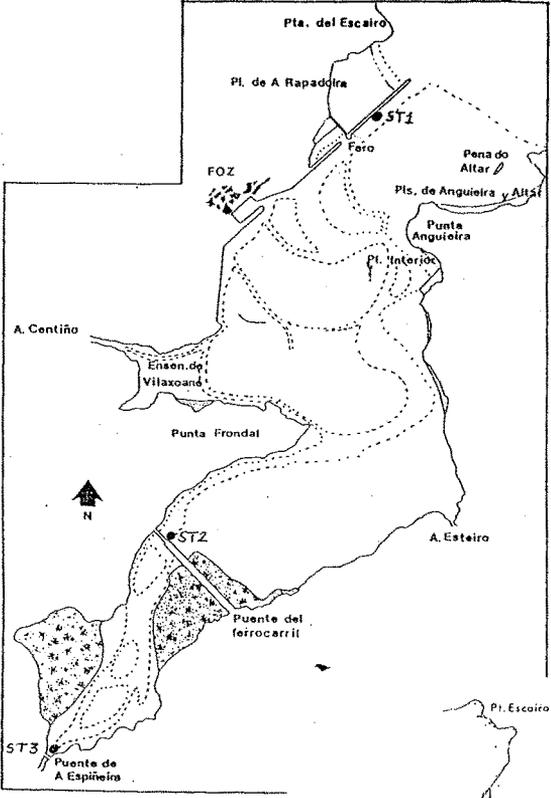
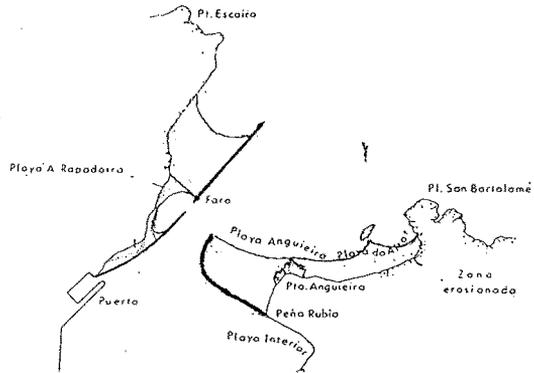


Fig. 1
Location

Fig. 2
designed project



it affected extremely the stability of the channel entrance, so that a jetty had to be constructed, but, being a unique jetty facing the spit end, when it was extended landward at the other side of the gorge, the fast erosion of the spit (just in the winter of 1977-78) was induced, the problem has both extended to the beaches around, which have begun to suffer erosion, and accentuated in the ria, which has increased several times the rate of filling.

The project, described two years ago, tried to be a solution for both aspects of the problem: the regeneration and protection of the beaches and the lessening of the process of filling of the interior of the ria, but subordinating the later to the former.

The aim of this paper is to analyze the data obtained since then to check the initial hypothesis and the behaviour of the works.

2. DESCRIPTION OF THE WORKS

The construction of the project defined two different kind of works: one of them, the basic one, was the artificial nourishment of the eroded beaches and spit up to about 275.000 m³, the minimum volume was supposed to guarantee the posterior stability of the system; the other, the construction of a jetty to support the spit-sand and to lead the interior channel, this jetty might, likely have not been necessary if the nourishment had been developed during the summer and accomplished in a short term; nevertheless this last condition would have been very unlikely to happen.

The sands for the designed nourishment had to be obtained exclusively from the interior of the ria, from a delimited area, which was supposed to have been overfilled since the erosion of the spit-barrier and whose sands were not only compatible but equal to the remaining sands of the beaches; our previous sedimentological surveys show the identity not only in the grain-size distribution but in the minerals content too. and it had been projected to be laid down adequately distributed along all the eroded area to obtain the best effect, taking into account the direction of the local transport (westward) and trying to minimize it. The bulk of sand was determined from the designed final form of the beaches and barrier so that the sand had to be laid rather homogeneously down, half about along the beaches (Altar and Anquieira) to partially replenish them, and half about in the spit, to regenerate it.

The jetty was designed shorter than the supposed necessary one to keep the channel clean, trying more to behave like a hook-groin than to constitute a real jetty, and being only the initial stretch of the final

likely necessary complet jetty, whose seaward stretch was not considered at that moment nor was designed. A mere arc of circle, ending the designed jetty was considered enough to behave like a suport-groin. The first strait section was designed aproximately parallel to the longshore transport from the Angueira point towards the channel; and it was short designed too, leaving so a wider than the adequate gorge for the channel. Two kind of reasons have imposed this design: the first and principal one was that no sufficient previous research had been developed to accurately determine the most convenient width for the channel (distance between jetties). The second one was derived from the different but convergent responsibilities of several administrative authorities; Coastal authorities (central) has the responsibility of shore protection, had assumed the regeneration of the beaches and financed the project and other studies in the ria; harbour (authonomic) authority has the responsibility of the harbour facilities; and township (local) authority was afraid that the project could affect the opposite beach of the "Rapadoira". Being urgent the regeneration of the beaches, this solution was assumed to guarantee none administrative delay was going to be produced. And, at the same time, it compatibilized its efficiency with a minor foreseeable destruction when the posterior extention and adaptation of the jetty ought to be decided, once the most adequate width between jetties could be defined for the outlet.

During constructions (September 86-June 88), coastal authorities decided to enlarge the hook stretch of the jetty 30 meters aproximately and to increase the volume of nourishment up to 350.000 m³; some differences between the project bathymetry (Aug. 1985) and the one for planning work (Nov 86) seemed to justify the last decission, supposing mistake in the former.

Nearly all the sands obtained from the interior of the ria have been pumped down by the jetty and, later, distributed on land by means of dumpers, bulldozers, etc. The accretion of the upper part of the beaches seemed to be minor than the theoretically pumped sand; so the constructor decided to take the sands of the tidal plane (fig 3). They supposed that part of the pumped sand was moved by water. The authors of this paper claimed against this practice without any possitive result.

3. SURVEYS AND MONITORING.

A complete series of compaigns of observation has been developed since August-86 to Spring-89 as surveying the dynamics of the ria, but the analysis of

some of the data has not been completed yet.

On other hand, a monitoring program of cross profiles has been developed during and after the construction of the works. Related to the first program, the maritim weather of this area permits to stablish four annual seasons but the storms are randomly distributed along winter and springtime, in such a way that spring equinox happens at the end of the stormy period and the fall-equinox happens before it begins; therefore the two annual survey compaigns have been developed around equinoccial terms, just before and during the spring and fall tides, which happen here in the later relative maxima immediately anterior to every equinoccial date; just before every maximum, a minimum of the astronomical tide happens, so that the largest and the smallest annual tides have been surveyed with this schedule. The data obtained in every campaign have been the following:

- a. Flood and ebb currents (maximum and minimum) have been measured in different cross-sections of the interior channels and in the gorge, and in several pints of each cross-sections.
- b. Tide levels have been continuously registred in two meaningfull points of the inner part of the ria and in a third one close to the gorge of the inlet (formerly in the closest basin of the harbour and lately by the Rapadoira jetty); the two former points are respectively around the middle and the end of the ria and coincident with two narrowness caused by embankments and bridges built for railway and the highway crossing the ria.
- c. the bathymetries of both the inner and outer (here not always extended under low tide) areas of the ria and the long cross-profiles in front of the beaches, have been as accurately surveyed as possible every season and compared to the previous references.
- d. Sedimentological analysis including organic material containt, percentage of carbonats and grain size distribution have been surveyed in all the shoals and beaches.

Besides: 1. Once and for all a more complete sedimentological survey, including mineralogical analysis has been done afecting to the ria and the rest of the shore between the rias of Vivero and Ribadeo. 2. An ecological survey, completed with a more ambitious research (4) have been developed before the construction (1984-1986), but no posterior observation could be done because of the lack of financial support. 3. And a very frequent survey of the beaches and spit cross-profiles has been developed by the coastal authorities as a monitoring work during the priod of construction (1986-88) though unfortunately these profiles were short, not having been extented farer

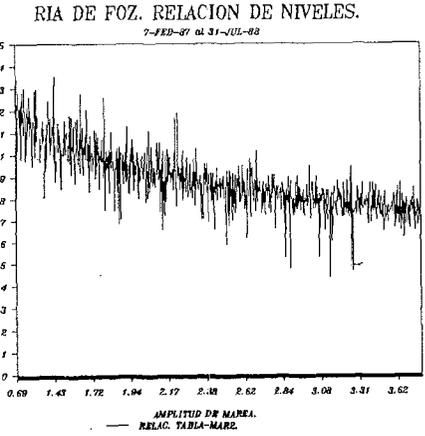
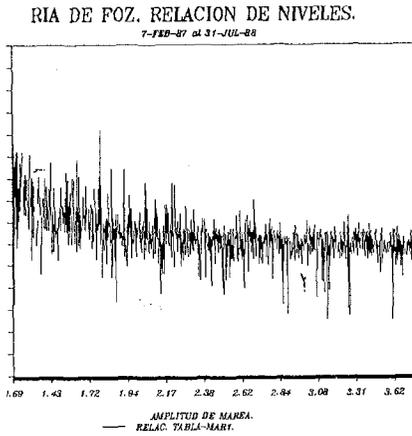
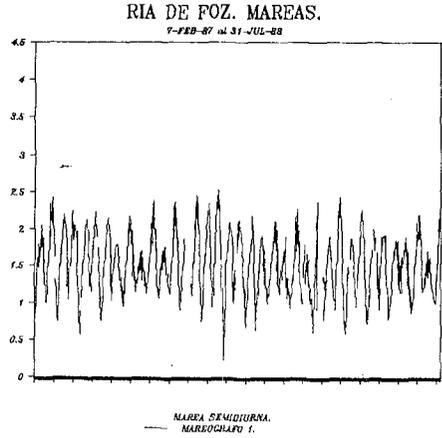
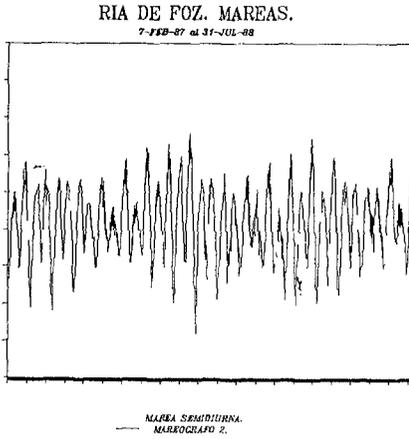
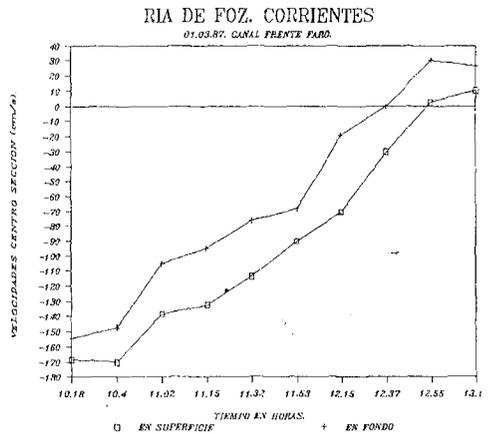


Fig. 3, 4, 5, 6 y 7
Tides and currents



than the low see level.

For this paper not all these data were equally outstanding and, unfortunately, not all the relevant ones could be completely analysed. On the other hand study of littoral dynamics developed for the project and described in (1) has been assumed in the following discussion as related to the winds, wind-waves and littoral transport. But some few considerations must be done:

a) Wave regimes estimated from the visual observations seem to be only roughly accurate and has some unacceptable distribution of the calms. b) Hindcasting wave regimes seem to be much more accurate but their use in estimating the littoral transport appears very problematic here because of the extreme high power of the storms (at least using the C.E.R.C. formule). It has been realized that above a certain value of the wave energy (or height) the estimated longshore transport rate became roughly high, as under a certain value they are too low. c). In any case, the littoral drift is much less than the potential littoral transport because of the lack of materials and the steepness of the platform. d) Whatever the estimation method the net littoral transport and drift are eastward seaside in front of the mouth headlands (Escairo and San Bartolome points), but both of them are westward in front of the Altar and Angueira beaches, landside between the points, over all with high tide levels of the sea. And the mouth is extremely short and narrow to permit an accurate reflection-refraction-diffraction model.

3.1 Tides

Between March and July 1987 a mareograph was located in the harbour of Foz. Continuous data was registered in this point, being the most relevant results these that follow: The maximum amplitude registered was 3.9 m. faced to 3.67 m. in the same date, calculated by the Tables of Tides published by the "Centro Hidrografico Nacional" related to Gijon harbour and corrected to Foz.

The maxima negative differences (bigger in the mareograph than in the Tables) and positive are shown in the next table:

	MAX. DAILY DIFFERENCE		MAX. MONTHLY AMPLITUDE
	+ DIF	-DIF GAUGE	TABLE GIJON
March	0.33	-0.42 3.9	3.83
April	0.26	-0.44 3.65	3.64
May	0.14	-0.43 3.5	3.58
June	0.18	-0.42 3.5	3.47
July	0.09	-0.31 3.7	3.62

An estadistical analysis of the data shows that the probability of a tide-amplitude differing of the one calculated by the Tables in less than 10 cm. is about 65 %, between 10 and 20 cm. 21 % and more than 20 cm. 14 % being the difference bigger than 30 cm only in 4 % of the tides. Considering a posible measuring error of about 10 cm. (the mareograph is graphic), the correlation between the meassures and the Table calculations can be defined as good. The observed differences can be attributed to the meteorological tide and the interferences principally caused by the flow of the river Masma. A maximum of about 50-60 cm. has been estimated for the meteorological tide. The two other mareographs mentioned in a paragraph above were located in two sections in the inner part of the ria (in the railway and the highway bridges), both were registrering tide-levels between February 1987 and July 1988. figs 3,4

The relationships between tide amplitudes in gauges 1 and 2 are very stable when the amplitude in the mouth of the ria is higher than 1.75 m. and do not vary too much with minor amplitudes, this relationship is not bigger than 1 in any case. However, between the gauge 2 and 3 (or the tables) the mentioned relationship is higher than 1 for amplitudes minor than 1.75 m. in the exterior, that means that there is a noticeable steepness of the tide in some special cases (Mehta, Mc. Manus). The tidal prism is in these circunstances bigger than the one calculated without any level-gradient along the ria. The opposite occurs when the amplitudes are bigger; so the tidal prism is more delimited than the prism calculated in previous phases of the study, (aproximately 15 % bigger for little amplitudes and 10 % minor for the higher ones).

3.2 Currents

Since 1986 some campaigns has been made; currents has been measured in several points of the ria, especially in the gorge cross-section, in the railway and highway bridges, and in the main ebb-channel. The velocities in the gorge have had a maximum of about 170 cm/s in ebb equinoctial tide and a minimum of 75 cm/s in neap tide. After the construction of the jetty the velocities have increased in about 30 cm/s for the maxima and 10 cm/s for the minima. The other sections have practically maintained the maxima and minima after the contructions (60 cm/s and 30 cm/s respectively for the highway and, 50 cm/s 30 for the railway).

3.3 Several bathymetries of the ria were used: 1967, March 1985, September 1986, March 1987, September 1987, September 1988 (partial) and September 1989 (partial).

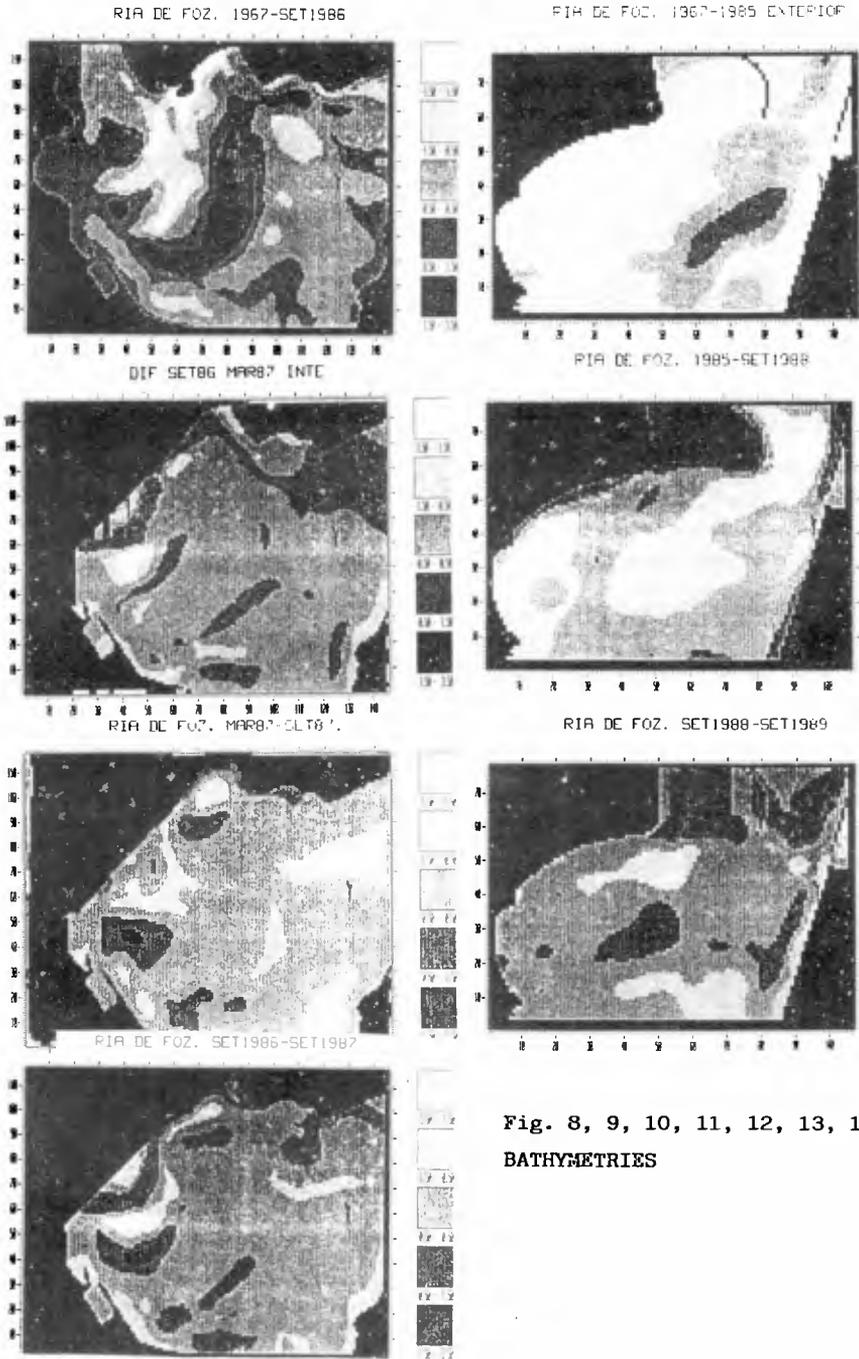


Fig. 8, 9, 10, 11, 12, 13, 14 BATHYMETRIES

in the inner part of the ria and: 1967, August 1985, September 1988 and September 1989. From 1985 to 1989 in the outer part, 22 cross profiles has been taken 17 times.

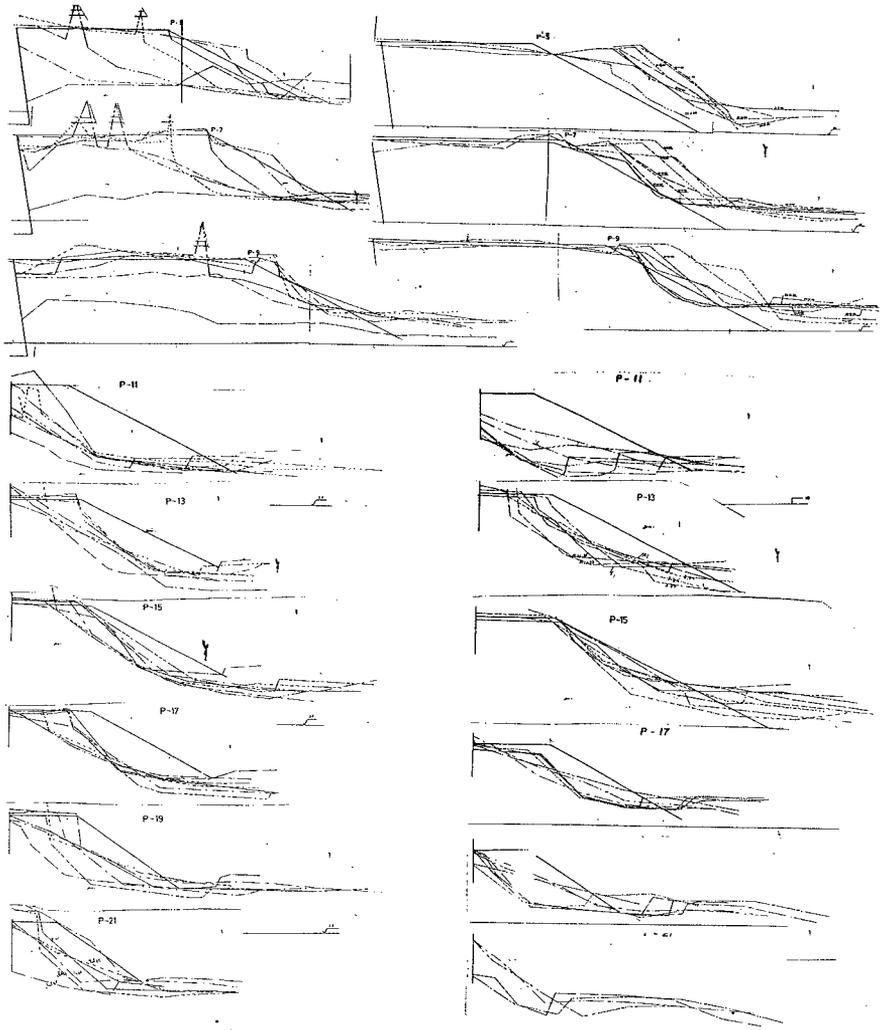
Comparing the inner bathymetries (figs 8-11) it may be noticed that the rate of filling of this area has increased after the erosion of the old natural spit (barrier); during the construction a local reduction of sand is noticeable, undoubtedly related to the sand dredged for nourishment. After the construction of the artificial barrier the rate of filling is unnoticeable from the bathymetries and may be estimated in about 12.000 m³/year, locally by the end of the jetty, part of the filling seems to have passed in front of the end of the jetty and the rest through it because its impermeability has not been appropriately got. Comparative analysis as a calcul permit estimate in about 10.000 m³/yr and in about 80.000 m³/yr the rates of filling respetively before and after the destruction of the natural barrier in March 1978.

Comparing quantitatively outer bathymetries (figs 12-14) it may be shown: 1. A strong erosion has been produced from 1967 to 1985 (it has been visually observed that the process began after 1978), of at least 420.000 m³. 2. The bathimetrie of the project (Aug. 1985) was allright, the difference of 75.000 m³ mentionedd before likely being product of the erosion. 3. The rate of erosion after desapearing the natural barrier was about 67.000 m³/year, consistent to the anterior datum; and before 1978 the rate of accretion of the outer part of the ria was of about 37.000 m³/yr.

During the period of erosion not less than 135.000 m³ have been dredged from the inner part of the ria, in agreement with all the bathymetries, but the bathymetry of March 1985 (5).

The analysis of the profiles fig (15-16) shows that a permanent, or quasi-permanent, tranport of sand from the eastbound westward nas been happening along all period of monitoring. A continuous erosion was detected from August 1985 to May 1987, when the jetty began to behave as a barrier, and a continuous accretion may be noticed later.

3.4 The mineralogical analysis of the samples of the banks from the interior of the ria are completely similar to the samples of the beaches around the ria. Only the samples from the beaches westward of the Fazouro ria show a meaning difference. It means a general littoral transport eastward, some kind of sink in front of Fazouro mouth and a unique origine for all sands of the beaches and the ria banks. In its turn the ecological study shows: a) The maritime origin of all the materials (sands) of the banks and its recent



- 21 JULIO 1967
- 31 JULIO 1967
- 7 AGOSTO 1967
- 30 SEPTIEMBRE 1967
- 31 OCTUBRE 1967
- 29 JUNIO 1988
- 1 AGOSTO 1988
- 28 SEPTIEMBRE 1988
- 23 NOVIEMBRE 1988
- 23 NOVIEMBRE 1988
- 10 FEBRERO 1989
- 7 ABRIL 1989
- 19 JULIO 1989

Fig. 15 y 16
Profiles.

increasing. b) The reduction of the land materials at the marshes of the inner ends of the different lobes of the ria.

4. DISCUSSION AND CONCLUSIONS

Tides in the ria of Foz have an acceptable correlation with the tides of Gijon harbour, but some differences are very noticeable, over all by the effect of the storm surges (frequently up to 50 cm) and by the steepness in the interior basin of the ria (weaker the tides, more meanings the local differences the water level). These discord may explain the disagreement of some bathymetry (5) analyzed above.

Inlet currents have increased a little bit after the construction of the jetty because of the small increasing of the tidal prism and mostly because the better estabilization of the channel. Nevertheless, currents still are less than admisible what, together with the sediments laid backside by the jetty end, show that the aim of designing a short barrier was got, but that the cleaning capability of the currents has improved also.

As it has previously said, nearly all the sands obtained from the interior of the ria have been pumped by the jetty and later distributed by land means. But the periodic visual observations of the works permit to question the accuracy of the nourishment operations: an overview to the bulk of the materials accumulated in front of the jetty supports that the real nourished volume was rather minor than the bulk theoretically pumped; and the way in which sand was fetched up to the berm (upper part) of the Angueira and, over all, Altar beaches to get the designed profiles, that nearly all of sand was obtained from the tidal plain in frot of both beaches; so it would be happening that very few sand from outside of the beach system was actually being used in the regeneration of the berms and that most of it was merely transported from the lower to the upper part of the emerged profile during low tide (that is to say, from the emerged tidal plain towards the permanent berm), it would be like trying to accelerate the natural process of nourishment of these beaches, which had been foreseen in the project to happen when the jetty had been finished and the spit rebuilt. Nevertheless the rate of fetching up sand was undoubtely excesive because an immediate strong and very noticeable steepness of the berm profile was produced after every high tide; the sand so applied obviously formed already part of the beach and, consequently, it was put immediately back in the tidal platform by the onshore-offshore dynamics. Some of the
in this paper in

observations described and analysed in this paper in the previous items permit to support this explanation which is particularly consistent with the different bathymetries of the ria: March 87, Sept 87 and Sept 88 in the inner part, showing the effects of the extraction and Aug 85, Sept 88 (showing the effects of the dragging from the tidal plain) and Sept 89 (showing the deferred consequences) of the outer part of it.

The immediate answer of the system shows an insufficient volume of nourishment: the tombolo and most of berm in Altar and Anguleira beaches, just where the sand was brought from the tidal plain vanished. The slow recovery up to the natural rebuilt of the tombolo was favoured by the delay of the storms in the 1988-1989 winter. Nevertheless, the insufficiency of sands permitted the new disappearance of the tombolo (Feb-Mar 89). As a consequence, in both occasions part of the mobilized sand has been transported westward, and it has passed to the backside of the jetty, laying aside just by it, approximately in a volume of 12.000 m³/yr, and, in both occasions it happened in a very short time (Mar-May) following the disappearance of the tombolo; in May the new natural accretion from the seaside permitted the regeneration of the tombolo and the restabilization of the system.

All these processes could be continuously followed by visual observations, besides the monitoring here shown. And they are consistent with the continuous westward potential transport and with the necessity of a certain minimum threshold of sand to set firmly the tombolo; also with the hypotheses of the project that this is necessary to estabilize the system and to reduce at a minimum the sand entering and filling the ria.

The winter 1989-1990 was anomalously quite in storms and the natural nourishment permitted the tombolo to remain all the year: it was enough to permit a beautiful recovery of all the beaches (fig 19) in the summer of 1990. What shows that, in any case, the natural nourishment exceeds the volume entering into the ria, and it is consistent with the rough calculs from bathimetries. As a consequence the volume of sand overpassing and laying aside by the jetty in this year (1990) was unnoticeable (less than 5000 m³/yr roughly).

From the ecological point of view, the fishing had vanished from the ria since the erosion of the natural barrier in 1978. Though many opinions supposed this phenomenon to be caused by washing aggregates of a next quarry, in the memorandum of the project was assumed to be caused by the biotopic changes so suddently produced, in such a way that regenerating the barrier, a recuperation of the catch could be expected. In fact fishing has been recovered in the inner part of the ria since 1989, and specially since 1990, when the



Fig. 17
1.978



Fig. 18
1.985

Fig. 19 1.990



the ria since 1989, and specially since 1990, when the movements of sands in the outer part of the ria have begun to be reduced.

Consequently with all these analysis and discussion several conclusions may be established.

1. The natural barrier had been generated as a spit, that is to say, as a consequence of a longshore littoral drift, instead as a bar, consequence of the onshore-offshore equilibrium. The question was not obvious because the general net littoral transport in all Spanish Cantabrian coast is eastward, but it is in agreement with the remake of the project about the permanent westward local littoral drift in the outer basin of the ria. And the conclusion is not trivial because most of the barriers of the Cantabrian rias and other analogous estuaries and bights behave in the same way; also because it shows that many tidal inlets, if not all of them, described as "updrift" migrating inlets, really migrate "downdrift", taking into account the local nearshore drift and not the direction of the net littoral transport along a more general and extensive coastal stretch. In this case, the headlands of Escalero and St. Bartolome and the bathymetry of the Gulf of Masma may justify, as it was exposed in the project (1) this local change on the transport direction. But in many inlets, their ebb-shoals may be cause enough to produce an analogous change. In the ria of Foz, the role of the shoals at both sides of the Rapadoira jetty may explain the unsuitability of some numerical models to explain the actual permanent westward transport along the Altar and Angueira beaches; that is likely right because this area was not taken into account in the refraction model.

2. Nevertheless the littoral transport off-shore of both the Peña do Altar, and the Rapadoira jetty is dominantly eastward, justifying the submerged spit starting in the end of the Rapadoira beach eastward; this spit is noticeable in the bathymetry of Sept 88, when the channel was very dangerous at strong low tides, but it nearly disappeared in Sept 89. It may be explained by the process of recovery of the tidal plain after the undue (wrongful) extraction to nourish the berm; and may be noticed comparing both bathymetries each other and with the design's (figs 13-14).

3. Also the real volume of sand obtained from the inner part of the ria likely was less than projected having been substituted by the sand previously accumulated on the tidal plain of the outer part of the ria, but not accrued from the pumped sands. That explain the immediate erosion of Altar and Angueira beaches just after the construction of the designed profiles, and the differed partial recovery of the profiles once the tidal plain was reacrued from both the berm and the

submerged spit.

4. The behaviours of the artificial barrier has been successful in spite of the defects of construction: it has permitted the natural renourishment of the beaches and, secondary improved the conditions of the harbour channel. Nevertheless this improving situation must be considered only transitory because an increasing of the outer ebb-shoals must be expected. Therefore the complementary actions foreseen in the project must be put forward.

4.bis. It has also been successful decreasing the filling rate of the inner basin of the ria, from about 70.000 m³/yr to about 12.000 m³/yr as a maximum (or transitory) and likely to less than 5.000 m³/yr. But the present situation of the ria corresponds to a very high degree of filling.

5. The behaviour of the ria as a sink of sands has been checked, so that the beaches seaward of it obviously suffer now a deficit of material. Therefore dredging the ria to nourish this beaches and to increase its tidal prism up to at least the bulk of filling since 1978 seems to be previous to the construction of the eastern jetty of the inlet.

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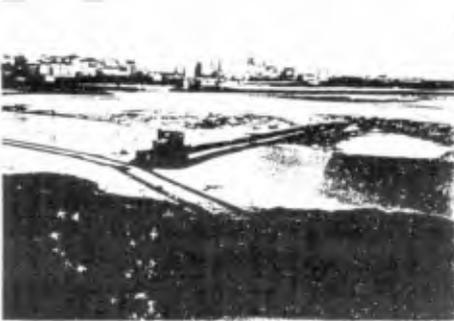


Fig. 20

Taking sand from the tidal plane.

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