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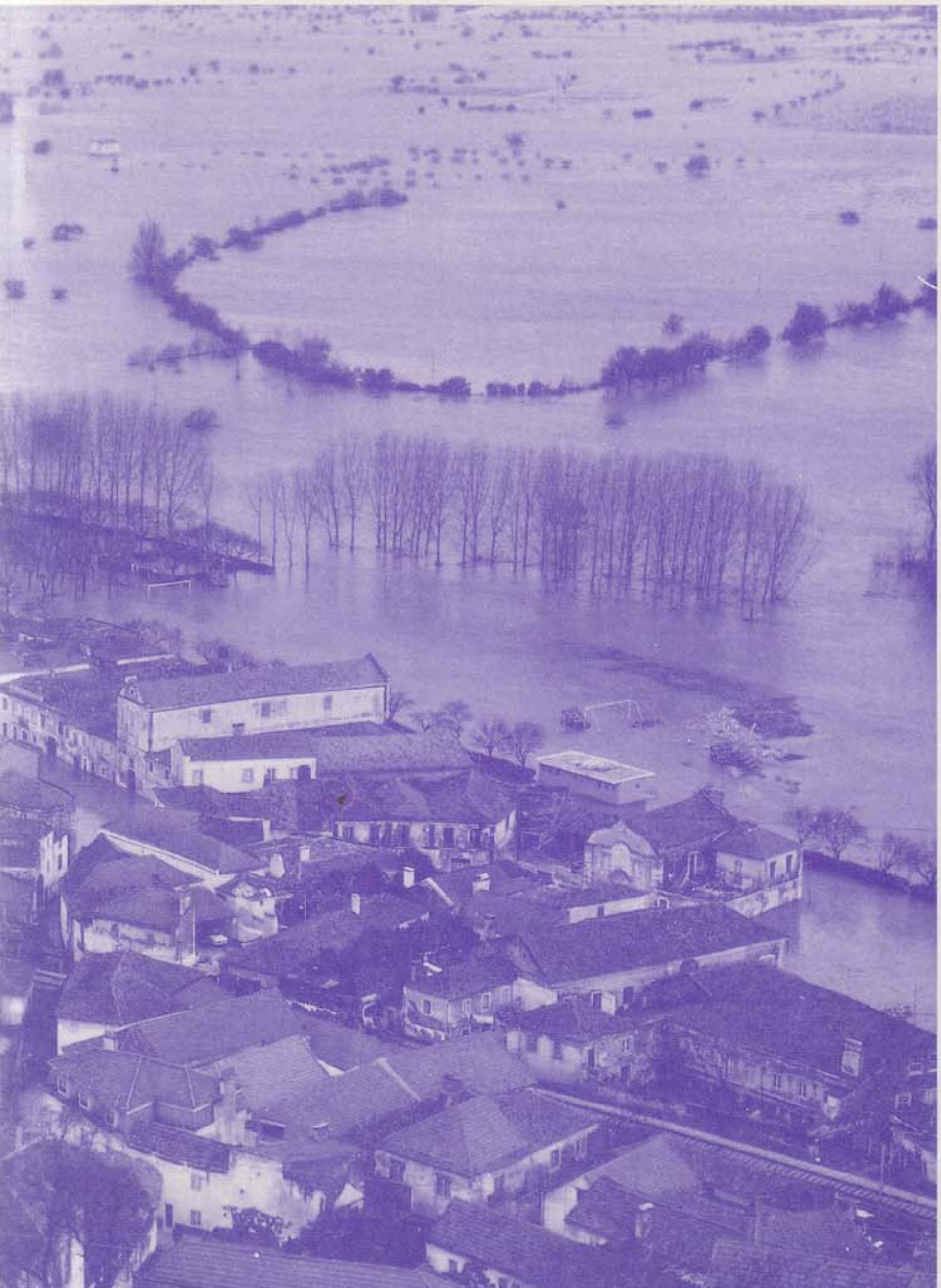

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THE FLOODS OF THE RIVER TAGUS

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Abstract This paper shows the flood frequency of the Tagus river and the impact of its dams in the fluvial regime, as well as in the alluvial plain, stream channel and in the coast southwards of its estuary.

Key words: floods, dams, alluvial plain.

1. FLOOD TYPES OF THE LOW TAGUS REGION

1.1 Flash floods

Floods are one of the most important elements of fluvial regimes; depending on hydrographic basins dimension and shape, rock permeability, slope angle, and man's interference, they may present different behaviours.

In the Tagus tributaries small-size drainage-basins, the very intense rainfall that sometimes occur in the Mediterranean climate, may give way to flash floods, particularly serious in the urban and suburban Lisbon areas.

There, the urban growth (responsible for the impermeabilization of the soils with resulting increase in the surface runoff), has taken place, and still does, in a chaotic way, with a stress on the lack of planning or its faulty application. The illegal construction boom, since the 60's, due to the population migration towards Lisbon in search of better work conditions, intensified this phenomenon.

The uncontrolled urbanization invaded not only the floodplains, but also some small valleys that remain dry for several years, inducing the allochthon populations to unknow or to "forget" the existance and regime of the small rivers.

The lack of environmental education, both of the official entities that should promote the regular cleaning of the stream channels, and of part of the population, that uses streams to throw away their garbage are the main causes of blockages during flood events. Likewise, the building of hydraulic infrastructures and other state-of-the-art constructions show, sometimes, serious shortages, namely in the restraining of the channels, in the defective size of the rainwater ducts, or even in the absolute lack of drainage structures.

If we add to these problems the effect caused by tides, due to the littoral position of Lisbon and nearby towns and villages, we will understand why the pernicious effects of this kind of floods may be rather problematic whenever a high tide occurs.

In rural areas the situation is different, not only because of the non-existance of an uncontrolled urbanization, but also because of the knowledge that local populations have gathered, through several generations, on the behaviour of the streams. Households are built on fluvial terraces, not reached by floods, or on higher places, so that the floodplains are saved for agriculture or animal and plant-farming.

1.2 Progressive floods

This second kind of floods (progressive floods) occur after a rather long rain period, which saturate the soil and fill up the reservoirs. These floods are connected either to a westerly zonal circulation, or to low blocking situations, particularly active and stationary. Thus, these floods affect all the kinds of drainage basins.

In Portugal, the River Tagus is affected only by progressive floods. The ones with greater

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magnitude (the big Tagus floods) occur during the former meteorological situation, in which several fronts sweep, continuously and progressively, the whole or the major part, of the hydrographic basin of the longest Peninsular river (1,100 km).

The large flooding events of the Tagus depend, today, on dam discharges, especially of the Spanish Alcântara dam, located near the Portuguese border (Fig.1), whose reservoir has a storage capacity of 1/4 of the total water stored in the 141 dams of the hydrographic basin (*Daveau*, 1995).

When the Tagus invades its alluvial plain, hundreds of square kilometres of agricultural land are flooded, interrupting roads and isolating human settlements. There is no way to avoid them. Local populations face floods as an usual phenomena without being so dramatic as town people. They consider them beneficial, because they wash up the fields of the chemical pollutants, recharge the aquifers and leave back the "muds" (silts and clays), which fertilize farming lands. When the water approaches their houses, they move the furniture to the upper floor, put the cattle and the agricultural implements in safer places (sometimes they fail to do it) and use a boat, in a sort of amphibious life.

2. THE REGIME OF THE RIVER TAGUS

In Portugal the Tagus valley is divided in two distinct sections: in the first one, in the Hercynian Massif, the river flows ENE to WSW, as far as a little downstream of the river gauging-station of Almourol (Fig.1). In this first and steeper section, the valley narrows when crossing quartzitic ridges or more resistant granites and broadens when crossing small tectonic depressions.

In the second section, the valley broadens remarkably, since the river enters the wide Cenozoic Sedimentary Basin, flowing from NE to SW as far as Lisbon. This section is known as the Lower Tagus and it is there that it acquires its plain river nature. It is here that the most spectacular floods in the Portuguese territory take place, owing to the lenght of the flooded area (over 800 km^2).

The study of the Tagus discharges becomes difficult because hydrometric statins active since the last century were recently closed (like Vila Velha de Rodão, next to the border, in 1973, due to the construction of Alcântara and Cedillo dams - Fig.1).

The river gauging stations working today are very recent (1970's). Almourol and Ómnias are the more downstream ones (Fig.1). The later has

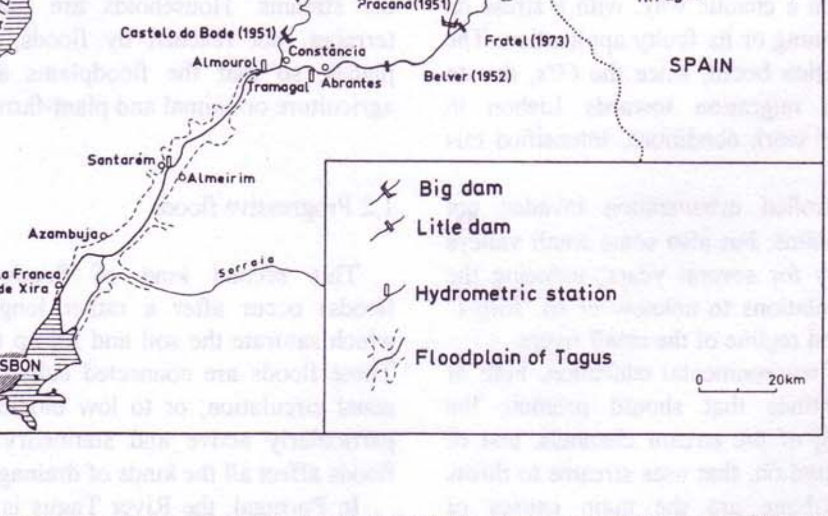

Fig.1 - The Portuguese Tagus and its more important dams (adapted from *Daveau*, 1995, p.66).

Table 1 - Tagus river in Almourol

Annual discharge	329.0m³/s
Annual specific discharge	4.91/s/km²
Semipermanent flow	192.6m³/s
Characteristic minimum discharge	50.7m³/s
Characteristic maximum discharge	3,886.2m³/s
Minimum flood discharge	2,200m³/s
Instantaneous maximum discharge	13,855.2m³/s
Coefficient of fluctuation (Qmax/Qmin)	12

functionning problems when big floods occur, because it is located on the alluvial plain. We will use some data from the Almourol station (1978-1979 to 1989-1990). At this station measured discharges correspond to 84% of the area of the hydrographic basin (Table 1).

In spite of being short, this observations period covers 1978-1979 (in which the biggest flood of the century took place), and 1980-1981, one of the dryest of the century, reason why it is representative of the big fluctuations that occur in the river discharges. In 1978-1979, the average annual discharge reached 890.3m³/s and, only 2 years later, in 1980-1981 72.8 m³/s, that is, 12 times lower.

Despite the influence of the dams, the Tagus still is a very irregular river. Its regime in Portugal is clearly pluvial, of the subtropical type (Mediterranean), with 4 months of high flow (November-February) and with an annual peak, in February, 2.5 times the average annual discharge (Fig.2).

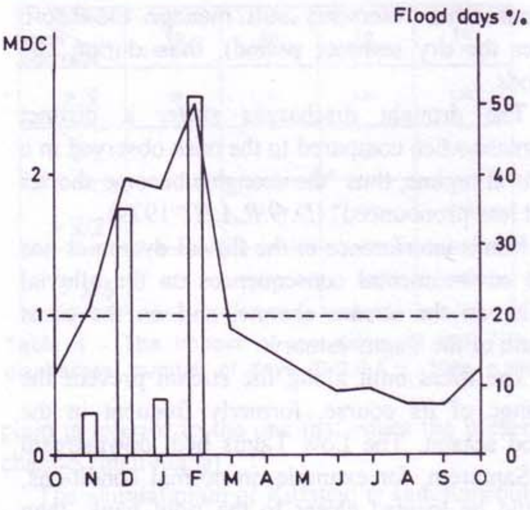

Fig.2 - Monthly discharge coefficients and flood days of Tagus river in Almourol (1978-79 to 1989-90).

The drought influences especially the months of August and September (Fig.2).

During this period, floods occur between November 20th and February 18th. February with 51% of the flood days (Fig.2 and Table 2) was the most affected month, followed by December with 35%.

The biggest flood of the century occured between February 2nd and 17th of 1979, flooding 871 km². On the 11th, the river reached a instantaneous maximum discharge of 13,855.2 m³/s corresponding to a return period of 222 years. This peak flow represents 72 times the semipermanent flow and 273 times the characteristic drought flow.

When the flood period ends, the alluvial plain stays submerse due to its low altitude and gradient. During that period (100 days in 1979), one million tones of sediments were dragged into the Tagus estuary, the equivalent to 85% of the total annual amount (*Vale*, 1981).

The biggest flood ever registered, occured in December 7th, 1876. The river Tagus rised about 25m in the narrow gorge of the quartzitic ridge of Vila Velha de Rodão, and 8m in Santarém, already on the alluvial plain. The spreading through the vast Ribatejo's alluvial plain (the floodplain reaches 10km wide in front of Vila Franca de Xira), prevents Lisbon from suffering its consequences. There, "the rise of the river level becomes insignificant compared to the normal variation and to the usual tie levels" (*Daveau*, 1995).

The big Tagus floods take place when the waters surpass 7m high in Santarém (*Almeida D'Eça* in *Sobrinho*, 1980). By using this point of view, we can see that, between 1852 and 1996, there occurred fifty large floods in the Low Tagus.

Table 2 - River Tagus in Almourol. Monthly distribution of the number of flood days

Months	NOV	DEC	JAN	FEB	Total
1978-79			2	16	18
1979-80					
1980-81					
1981-82		1			1
1982-83					
1983-84	2				2
1984-85			2	10	12
1985-86					
1986-87					
1987-88					
1988-89					
1989-90	1	17			18
Total	3	18	4	26	51

One of the consequences of frequent Low Tagus valley flooding events, was the rather quick raising of its alluvial plain and the silting up of its stream channel. 200 years ago (1783) the three big islands that form the interior delta of Tagus, nowadays completely occupied by farming lands, were then, small sand banks that only emerged in the low tide.

3. THE IMPACT OF THE DAMS

The great irregularity of the river and the frequent flooding lead to man's interference in the Low Tagus valley floodplain, at least, since 8 centuries ago, during the Muslim occupation of the Iberian Peninsula (*Alexandre & Borralho*, 1982). Those measures were mostly protection dikes and ditches for a better water drainage.

The dams construction policy started by Portugal and Spain since the 50's (Fig.3), aimed to regularize the Tagus and to solve the water supply and irrigation problems, mainly during dry years (which occured frequently in the South and centre of the Iberian Peninsula). Hydroelectrical power was also an objective.

Today, the river Tagus, of all the rivers that cross Portuguese territory, is the one whose ability to store water from the dams, reaches a higher percentage (95%) of its average annual streamflow estimated in the estuary (Table 3).

The flooding decrease in the years after the dam construction boom (Fig.3), seems to confirm that the large Peninsular river was controled. Nevertheless, that state of euphoria vanished along with the catastrophical floods in 1978 and 1979, and with the big December floods of 1989, whose flood peaks were worsened by the continuous dam discharges, not always co-ordinated between the Spanish and the Portuguese authorities. This situation lead to the burst of several protection dikes, that should protect fields and population from the floods. The study made by the D.G.R.A.H. in 1986, on the impact of dams in the Tagus discharges, using the curve method of classified daily average discharges (Table 4 and Fig.4), shows clearly that there is a tendency to reduce the floods frequency, which is more noticeable during early floods (that reservoirs still manage to absorb after the dry summer period), than during late floods.

The drought discharges suffer a distinct increase when compared to the ones observed in a natural regime, thus "the droughts become shorter and less pronounced" (*D.G.R.A.H.*, 1979).

Man's interference in the fluvial dynamics has had environmental consequences on the alluvial plain, on the stream channel and on the coast South of the Tagus estuary.

The dikes built along the stream prevent the change of its course, formerly frequent in the flood season. The Low Tagus bed, downstream of Santarém, for example, in normal conditions, would be located closer to the right bank, than today, because there, the altitude of the alluvial

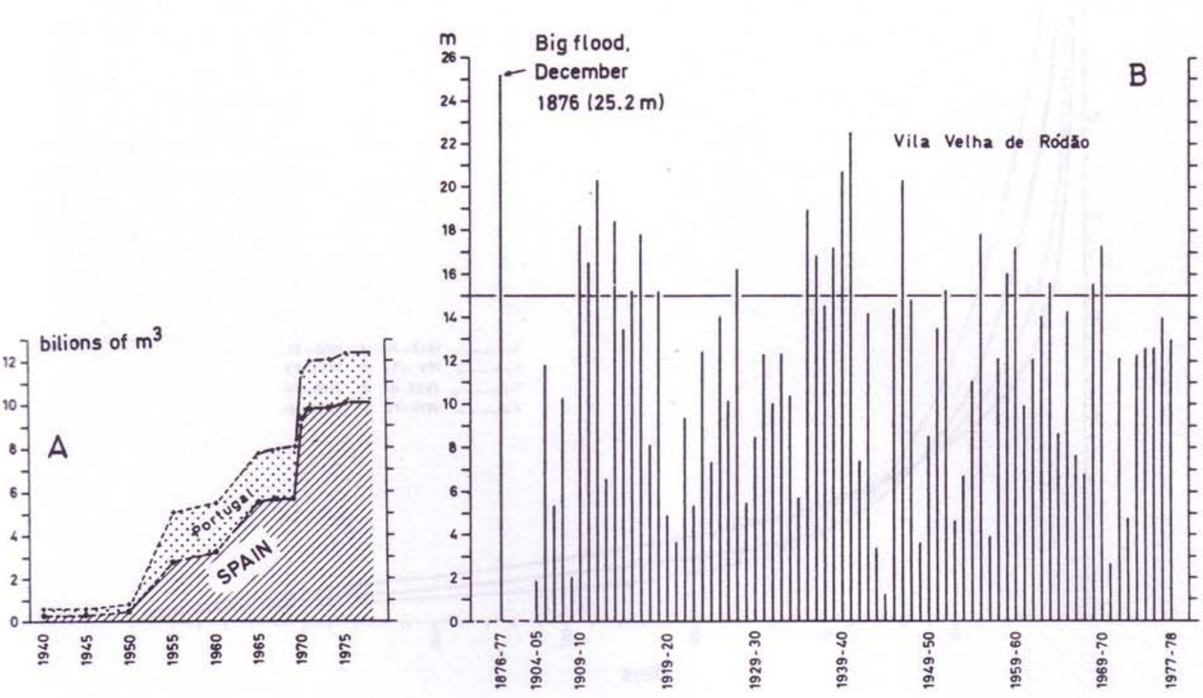

Fig.3 - Dams´ capacity of the Tagus´ hydrographic basin upstream Santarém (A) and flood levels (B); (*Daveau*, 1995, p.67).

Table 3 - Hydrographic basin of the river Tagus

Country	Portugal	Spain	Total
Basin area (km²)	24,860 (31%)	55,769 (69%)	80,629
Number of dams	22 (16%)	119 (84%)	141
Stored volume (10^6 m³)	2,700 (20%)	10,600 (80%)	13,300

D.G.R.A.H. (1986)

Days

Periods / Mean discharge	1943-44 to 1950-51	1951-52 to 1962-63	1963-64 to 1969-70	1970-71 to 1983-84
$> \bar{x}$	90	90	120	120
$> 3\bar{x}$	45	33	20	15
$> \bar{x}/2$	140	180	240	240
$> \bar{x}/5$	270	300	340	340

Table 4 - The impact of the dams in the Tagus discharges: number of days (D.G.R.A.H., 1986, p.326).

plain is inferior to the one that edges the present channel (man-made).

The alluvial plain of Ribatejo is simultaneouly the best aquifer area in Portugal (with bigger productivity) and with better farming lands (along with Mondego fields). Because of the occupied area, it is undoubtedly, as *Gaspar* (1993) points out "the biggest natural patrimony of the Portuguese agriculture", and it has a major strategical importance in a country with poor soils and that imports more than a half of what its food necessities.

Nevertheless, the nitrate surplus of some cultures, namely mellon and tomato, keep contaminating soils and aquifers.

Along with the decrease in the floods frequency, came the decrease in the "nateiros" (suspended sediments) deposit. The "nateiros" fertilize the alluvial plain soils. There is also a decrease in the "cleaning" of lands and in the aquifers renewal.

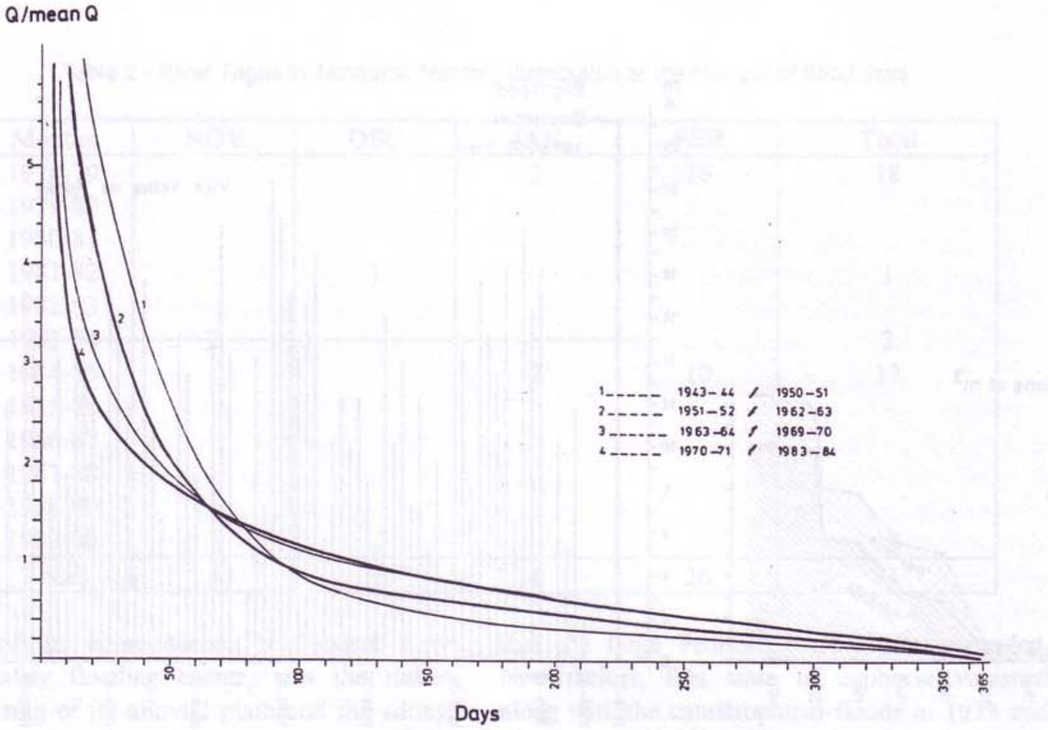

Fig.4 - River Tagus in Santarém: classified daily average discharges (*D.G.R.A.H.*, 1986, p.326)

The bedload transport has also suffered a drastic decrease, as shown in the studies of *Quintela et al.* (1982). Considering the bedload transport in a natural regime (between 1899 and 1953) and after the first dam construvtion boom (1956 to 1966), these authors got certain that it suffered a 50% decrease (from 1,200,000 m^3/year to 530,000 m^3/year.

As a consequence of the sediments retention in dam reservoirs, the beaches located South of the Tagus estuary, which are feed mainly from alluvial sand deposits, have suffered an accentuated erosion. 40 years ago, there were several hundreds of meters wide sand Beaches (Costa da Caparica, near the estuary). Today, we can only see few meters wide narrow beaches, that vanish during high tide. Because of this, swimmers perch upon huge boulders, which are part of the artificial rocks gathering of longitudinal dikes and of waterbreakers that protect the coastline from marine erosion.

References

ALEXANDRE L. M. & BORRALHO M. E. (1982) - *Defesa contra as cheias na Lezíria Grande de Vila Franca de Xira.* Simpósio sobre a Bacia Hidrográfica Portuguesa do Tejo, vol. I, A. P. R. H., Lisboa.

DAVEAU S. (1995) - *Portugal Geográfico.* Ed. João Sá da Costa, Lisboa, 223 pp.

DIRECÇÃO-GERAL DE RECURSOS E APROVEITAMENTOS HIDRÁULICOS (1979) - *Regularização do Rio Tejo. Plano Geral.* Volume Síntese, Hidrotécnica Portuguesa, Lisboa.

DIRECÇÃO-GERAL DE RECURSOS E APROVEITAMENTOS HIDRÁULICOS (1986) - *Monografias hidrológicas dos principais cursos de água existentes em Portugal continental.* M.P.A.T., Lisboa, 569 pp.

GASPAR J. (1993) - *As regiões portuguesas. Direcção-Geral de Desenvolvimento Regional*, Lisboa, 118-125.

QUINTELA A. C. and Others (1982) - *Avaliação da evolução do transporte sólido no Rio Tejo e sua influência no leito.* Simpósio sobre a bacia hidrográfica portuguesa do Rio Tejo, A. P. R. H., vol. I, Lisboa, 20 pp.

RAMOS C. (1994) - *Condições geomorfológicas e climáticas das cheias da Ribeira de Tera e do Rio Maior (Bacia Hidrográfica do Tejo).* Dissertação de doutoramento, F.L.U.L., Lisboa, 520 pp.

SOBRINHO A. S. (1980) - *Os temporais de Fevereiro de 1979 no Ribatejo e região de Lisboa.* Finisterra, XV, 29, Lisboa, 85-93.

VALE C. (1981) - *Entrada de matéria em suspensão no estuário do Tejo durante as cheias de Fevereiro de 1979.* Recursos Hídricos, 2, 1, Lisboa, 37-45.