The 1997 floods in the province of Badajoz and subsequent measures taken by the water management authorities

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A huge storm in November 1997 caused severe floods in the cities of Badajoz and Mérida and the town of Valverde de Leganés, and in the lowland region of Vegas Bajas del Guadiana. This article describes the damage caused by the floods and the steps taken by the water management authorities to repair the damage and to try to prevent this situation from repeating while at the same time taking the opportunity this presented to improve the urban areas surrounding the channels of the streams that had overflowed.

The november 1997 floods

The month of November 1997 in southwest Spain kicked off with heavy rainfall. The rainfall saturated the ground, greatly increasing the runoff coefficient[1]. Then, on 4-6 November a small subtropical storm that had begun south of the Azores underwent explosive cyclogenesis[2] as it was poised to pass over the Iberian Peninsula, making landfall at Cape San Vicente.

The basis for action was to resize the channels so that they would be able to contain the maximum discharge volumes in the historical record, namely, the November 1997 flooding, so that if a similar flood situation recurred, it would cause no damage.

In the case of Mérida and Badajoz, the opportunity provided by the works was also used to transform the environmentally neglected margins of the streams in question into green areas (parks and walking paths), land uses that were apt for areas potentially subject to flooding. This would help integrate the river channels into the urban setting while at the same time creating recreational areas for public use.

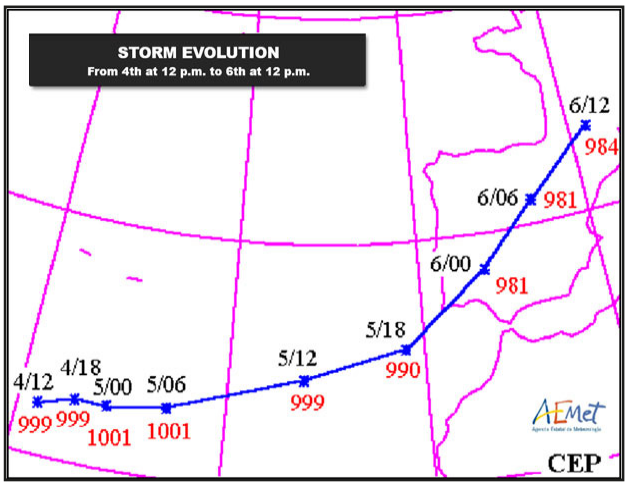

Figure 1.

[1] The runoff coefficient is the ratio of rainfall to the amount of water that ends up flowing down the river channels. The higher the level of ground saturation, the closer the value of the coefficient approaches one.

[2] Cyclogenesis is a weather phenomenon that occurs when a storm grows in size while deepening the low pressure area as it moves along. When this happens very rapidly, it is termed "explosive".

The storm produced very high levels of precipitation along its track, with 100 to 150 mm of rain falling in just a few hours, more than double the precipitation rate for an average month of November (usually the wettest month in the watershed area concerned). The return period[3] for an event of this type is somewhere between 500 and 1,000 years. The upshot was that the rivers in the area overflowed their banks, resulting in numerous personal losses and substantial property damage. The storm also had heavy winds that gusted at speeds of up to 130 km/h, augmenting the destruction it wreaked.

Those river channels that were regulated by dams obviously benefited from the dams' significant flood abatement[4] potential, but the many river channels that were not experienced enormous freshets, resulting in discharge volumes much higher than was normal for those channels.

The flooding caused property damage over a wide area, but the impact was particularly severe in the cities of Badajoz and Mérida, the town of Valverde de Leganés, and the irrigated agricultural lands in the lowland region of Vegas Bajas del Guadiana between Mérida and Badajoz on both sides of the Guadiana River.

Damage in Badajoz

Most of the damage in the city of Badajoz was produced by the Rivillas Stream, a left-bank tributary of the Guadiana River, and by its tributary the Calamón Stream, which joins the Rivillas Stream within the city limits of Badajoz. It is estimated that the discharge volume in the final section of the Rivillas Stream after the junction of the two streams rose to around 700 m^3/s (a level with a return period of roughly 500 years), while the capacity of the river channel is just 180 m^3/s. The river flow peaked at around 2:30 AM on the night of 6 November.

The result was 22 dead and massive material damage, with a large number of buildings heavily damaged or completely destroyed. An important factor that contributed to the amount of damage was that the properties concerned were in many cases poorly built traditional dwellings. Most of the damage occurred along the banks of the Calamón Stream and where the two streams converged, an area called "El Cerro de Reyes".

In the following days very high peak discharge volumes of around 4,000 m^3/s were recorded for the Guadiana River in Badajoz, but the damage this caused was limited, first because the waters did not rise as suddenly as they had in the tributaries, and second because the area in the immediate vicinity of the river was much less built-up.

[3] The Return Period (commonly abbreviated "T") is the inverse of the average probability of occurrence, in this case for rainfall. In point of fact, it is a dimensionless variable, but for reasons outside the scope of this article it is usually expressed in years, which can give rise to misunderstandings.

[4] Flood abatement is an effect produced by dams that consists of reducing and delaying spikes in discharge volumes by temporarily holding the water back in reservoirs beyond maximum capacity until the water is released. This is clearly a very beneficial effect.

Figure 2.

Damage in Valverde de Leganés

The La Nave Stream runs through the village of Valverde de Leganés through an underground culvert with a discharge capacity rated at no more than 20 m^3/s. However, on the night of 5-6 November, the peak discharge volume was estimated at about 80 m^3/s, an event with a return period of around 1,000 years. The result was flooded streets and homes, leaving 3 dead and severe property damage in the flood's wake.

Figure 3.

Damage in Mérida

In Mérida, the Region's capital city, the damage was caused by the Albarregas Stream, a right-bank tributary of the Guadiana River whose last 3 km run through the city centre. The discharge capacity of the river's channel was 75 m^3/s, and according to estimates the rate of flow reached around 200 m^3/s, an event with a return period of 500 years.

There was serious flood damage, though not as bad as in Badajoz, and fortunately there was no loss of human life. This outcome was largely ascribable to the fact that the buildings affected were of better quality than in Badajoz.

The peak discharge volume of the Guadiana River freshet as it passed Mérida was subsequently recorded at some 2,000 m^3/s, but the damage caused was minor, for the same reasons as in Badajoz.

Damage in the irrigated lands in the lowland region of Vegas Bajas del Guadiana

As already mentioned above, the Vegas Bajas del Guadiana lowland region was also hard hit. Besides substantial damage to the region's towns (again, fortunately, with no loss of life), damage to the irrigation infrastructure in the irrigated farmlands around Montijo and Lobón was extremely heavy.

These irrigated lands, covering a surface area of some 42,000 ha, have an extensive network of irrigation infrastructure, canals (the Montijo canal along the right bank of the Guadiana River and the Lobón canal along the left bank), irrigation ditches, pumping stations, pipelines, drainage channels, and service roads.

To mention just a few figures that give some idea of the size of these infrastructure networks, the main canals total 110 km in length, and there are 430 km of irrigation ditches, 45 km of pipelines, 265 km of drainage channels, and 524 km of service roads.

The entire system suffered heavy flood damage, and the enormous socioeconomic impact of the irrigated farmlands in the region made it essential to repair the network before the next irrigation season (usually starting in April of each year).

Measures taken by the water management authorities in the aftermath

This event posed an enormous challenge for all the authorities, which had to respond quickly (something that tends not to be easy for administrative bodies) in view of the enormity of the damage. A little more than a month after the floods, Spain's national government issued the Spanish Royal Decree 24/1997, of 12 December, on urgent measures to repair the damage caused by the flood and wind event on 5-6 November 1997, enacting a wide range of measures to help the victims.

The river basin authority for the region, the Confederación Hidrográfica del Guadiana, an independent agency of the then Ministry of the Environment (now the Ministry for the Ecological Transition and the Demographic Challenge) was directly involved.

The Guadiana River Basin Authority's most urgent initial priority was to repair the irrigation infrastructure in the Montijo and Lobón districts in the Vegas Bajas region. This was critical, because, as already mentioned, irrigated agriculture is of basic socioeconomic importance to the region, and given the condition in which the infrastructure had been left irrigation would have been impossible.

After that, less urgently, further measures were taken to overhaul the river channels in Badajoz, Valverde de Leganés, and Mérida, where most of the damage had occurred. The Hydrographic Studies Centre of *CEDEX*[5] , provided invaluable support for the first stage of this process in the form of comprehensive studies on the flooding. The second stage was drawing up and finalising project proposals, and the third and last stage was executing the work.

The basis for action was to resize the channels so that they would be able to contain the maximum discharge volumes in the historical record, namely, the November 1997 flooding, so that if a similar flood situation recurred, it would cause no damage.

In the case of Mérida and Badajoz, the opportunity provided by the works was also used to transform the environmentally neglected margins of the streams in question into green areas (parks and walking paths), land uses that were apt for areas potentially subject to flooding. This would help integrate the river channels into the urban setting while at the same time creating recreational areas for public use.

Irrigation infrastructure repair in the Vegas Bajas region

The aforementioned *Spanish Royal Decree 24/1997* provided a management framework for urgent repair of the damage to basic infrastructure, including the irrigation systems in the Vegas Bajas region (the irrigated farmlands around Montijo and Lobón).

The emergency work was divided into three parts, one for each of the two irrigation areas and a smaller, third section involving repairs to nearby dams, which had made a critical contribution to flood abatement but had been damaged in the process. The total cost came to 1,165 million pesetas, around 7 million euros (12.7 million today adjusted for inflation).

The three parts of the work were parcelled out under 30 different contracts awarded to 24 participating companies with a view to expediting execution of the repairs as much as possible. The work was mostly done in the first four months of 1998, with a total workforce of around 300 workers at any one time.

Figure 4.

[5] CEDEX stands for Centro de Estudios y Experimentación de Obras Públicas [Public Works Research Centre], an independent agency attached to what was formerly the Ministry of Development, now the Ministries for Transport, Mobility, and Urban Agenda, and for the Ecological Transition and the Demographic Challenge.

All the work was in a suitable stage of completion in time for the start of the 1998 irrigation season, which got under way in mid-April with everything working smoothly.

Flood defences along the Rivillas and Calamón Streams in Badajoz

The work on the Rivillas and Calamón Streams in Badajoz was carried out in two stages, a first stage consisting of civil construction work to increase river channel discharge capacity to 700 m^3/s (T = 500 years), the estimated volume of the flood. And a second stage of appropriately remodelling the urban and environmental features of the river margins.

The civil works were not restricted to river channel enlargement to increase the channel cross-section. The unavoidable increase in channel size, both in plan and elevation, had serious implications for all sorts of urban infrastructure, especially structures like bridges and walkways spanning the rivers, many of which had to be replaced by others that were longer in length or raised up to higher elevations, and sewage systems, which were often located right next to the river channels and had to be moved away from the modified channels.

As already mentioned, work to integrate the margins into the urban and environmental setting consisted mainly of transforming the margins into parks and walking paths equipped with playgrounds for children and facilities for engaging in sporting activities.

The total cost of both stages of the work came to around 28.5 million euros, and the work was carried out from 2002 to 2009 (the civil work in 2002-2007 and the urban and environmental remodelling work in 2006-2009). The main features of the combined work appear below:

- Modifying 4.19 km of the river channels in urban areas (2.45 km for the Rivillas Stream and 1.74 for the Calamón Stream) to have a discharge capacity of 700 m^3/s (T = 500 years).
- 9 new bridges.
- 4 new walkways.
- Relocation of 1.7 km of sewers.
- 25 ha of green areas.
- 9 facilities for recreational and sporting activities.

Figure 5.

Flood defences along the La Nave Stream in Valverde de Leganés

For urban development reasons the channel of the La Nave Stream in Valverde de Leganés could not be enlarged within the limits of the town, where, it will be recalled, the stream passes through an underground culvert, so the solution chosen was to divert the stream upstream of the town. The stream was diverted to the Piedra Aguda reservoir on the Olivenza River (the original stream discharges into that same river but downstream from the dam).

The work took place between 2000 and 2002 and cost 2.44 million euros (3.66 million in adjusted for inflation), and the main features included:

- A 2.5 km-long diversion of the stream upstream of the urban area limits.
- Diversion discharge capacity: 80 m^3/s (T = 1,000 years).
- A flow divider to allow a small volume of water (8 m^3/s, subsequently reduced to 2 m^3/s) to flow through the original course through the underground culvert.

Figure 6.

Flood defences along the Albarregas Stream in Mérida

Work on the flood defences along the Albarregas Stream in Mérida consisted of a combination of enlarging the river channel discharge capacity and remodelling the urban and environmental setting of the margins. The same observations made concerning the civil works in Badajoz also apply here: it was necessary to renovate a series of service elements that were affected, namely, structures spanning the river and sewage systems.

Mérida had an added problem, namely, the presence of monuments of great artistic and historic value (and hence subject to statutory protection measures that prevented them from being altered), such as the San Lázaro and Los Milagros aqueducts and the Roman bridge across the Albarregas Stream. Some of these imposed constraints on channel discharge capacity. All these aspects had to be addressed without affecting those monuments. Indeed, the works needed to be particularly respectful of their surroundings to accentuate their monumental nature and enhance them as places of interest for sightseeing.

Instead of establishing a single standard cross-section for the length of the channel, different cross-sections were selected in an effort to remodel the channel as naturally as possible, restricting concrete walls and channel bottoms to areas where they were absolutely necessary having in mind the closeness of buildings, streets, and other urban structures.

These works cost 22.9 million euros at the time (35.7 million adjusted for inflation). They were carried out between 2001 and 2004. The main features of the works include:

- A 3.5 km-long section of channel with a capacity of 200 m3/s (T = 500 years).
- 6 new bridges.
- 5 new walkways.
- Relocation of 5 km of sewers.
- 22 ha of green areas.
- 6 facilities for recreational and sporting activities.

Figura 7.

It should be emphasised that there have been some freshets of a certain size (though not as strong as in November 1997) since these works were completed and that the remodelled channels have given no further trouble. At the same time, the green areas next to the rivers (in Mérida and Badajoz) have become very popular parks and urban walking paths in these cities.

In summary, the river basin authority made a suitable response to the problems that were faced after the 1997 floods within a reasonable time period and further took the opportunity to integrate the channels of the Rivillas and Calamón Streams in Badajoz and the Albarregas Stream in Mérida into the urban setting.