

The floods in Bari: What history should have taught

Les inondations de Bari: ce que l'histoire aurait dû nous apprendre

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ABSTRACT

In this paper, the historic floods in the city of Bari, Italy, are analyzed and compared to the recent flood of October 2005. The objective is to point out the role of anthropogenic action and poor planning in the amplification of territory risks. The studied zone is highly permeable and is characterized by a drainage network which is not always defined. It is constructed of numerous natural incisions which, locally, are called "lame". The main hydraulic characteristics of floods are described evidencing the effect of ungovernable and chaotic anthropogenic impact, that, being united with incorrect planning, result in catastrophic events. A high level of attention must always be given to the protection of the territory in order to avoid high risk situations. Once hydraulic operations are carried out they must be maintained in order to continue their efficiency which cannot be put to risk by poor territorial planning.

RÉSUMÉ

Notre objectif étant de mettre en évidence le rôle que pourrait jouer l'action anthropique ainsi que la mauvaise planification dans l'amplification des risques territoriaux. Nous avons effectué dans le présent travail une analyse des inondations historiques de la région de Bari (Italie) en comparaison avec d'autres, plus récentes, celles d'octobre 2005. La zone étudiée est caractérisée par une très grande perméabilité ainsi qu'un réseau hydrographique qui demeure indéfini et qui est composé de nombreux ravins naturels, localement désignés "lame". Nous décrivons les essentielles caractéristiques hydrologiques de ces inondations soulignant comment l'action anthropique non conforme à la réglementation ainsi que la mauvaise planification sont les origines d'événements catastrophiques. Il est donc question d'éviter des situations à grand risque en accordant une très grande attention à la protection du territoire. Ainsi, il serait nécessaire que la réalisation d'ouvrages hydrauliques soit suivie d'entretiens pour conserver leur efficacité et leur efficience.

Keywords: Hydrology, hydrological risk, floods, rains, anthropogenic action, Bari.

1 Introduction

The distinct honor and opportunity to present this invited paper has special meaning to me. It was Prof. Marcelo Garcia who invited me to write a "forensic" article on the recent floods of Bari, in order to point out essentially the historical and technical aspects and the errors, which have unfortunately, been repeated in the anthropogenic action in the city of Bari, in the Apulia region of Italy, with the main aim of finding solutions to these problems and carrying out warning systems for the future.

The Apulia region, with exception to the northern area of Capitanata in the province of Foggia, is characterized by a landscape devoid of significant high ground (Fig. 1). It has a large presence of limestone as well as outcroppings, and is highly permeable. Such flat and highly permeable surfaces are one of the causes that can form a drainage network which is not always defined. This drainage network is characterized by the absence of significant flows for long periods, even in winter, or, in the rainy seasons. Such grids are formed by numerous natural incisions, at times

characterized by notable transverse sections that do not always flow to the sea, but these grids oftentimes disappear into the ground. These incisions are unique geomorphologic structures that represent, with respect to the surrounding environment, a significant discontinuity and often their presence conserves valuable environmental ecosystems. As pointed out by Alfieri (1927), the topographic configuration of the zone hit by floods is characterized by one terraced rise of the Murge, a plateau that is relatively low in elevation and flat in configuration (Fig. 2a). The geological composition is rather simple. The most elevated area, the Murge, is composed of cretaceous limestone subjected to karst. The less elevated zone, the plateau which lines the Adriatic, is composed of a calcareous platform covered by an anomalous veil of reddish clay, rich in iron peroxide with fragments of limestone. The entire zone is large with mild undulations and lacks a fluvial system. The cretaceous limestone of the Murge is marked by innumerable fractures, that, even though superficial, easily absorb rainwater, leaving only a small amount to flow away in periods of intense rainfall. The limestone is mostly stratified and often characterized

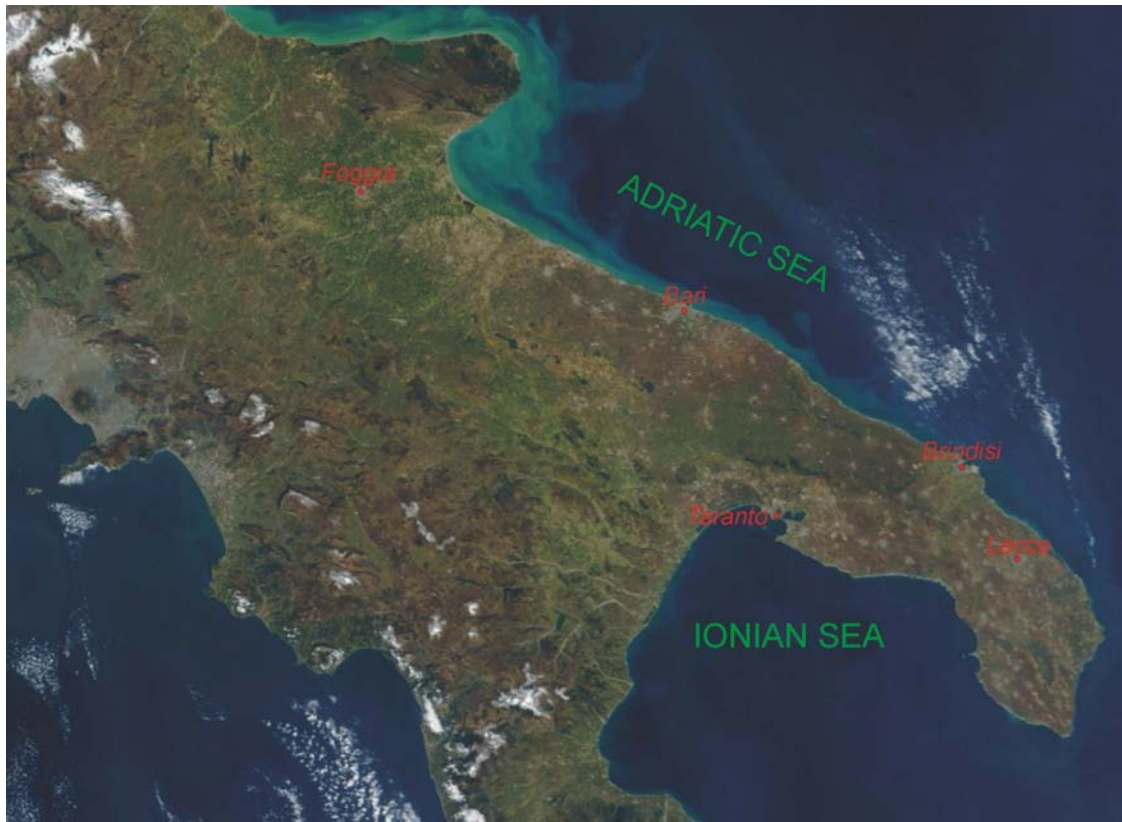


Figure 1 Apulia region (Italy).

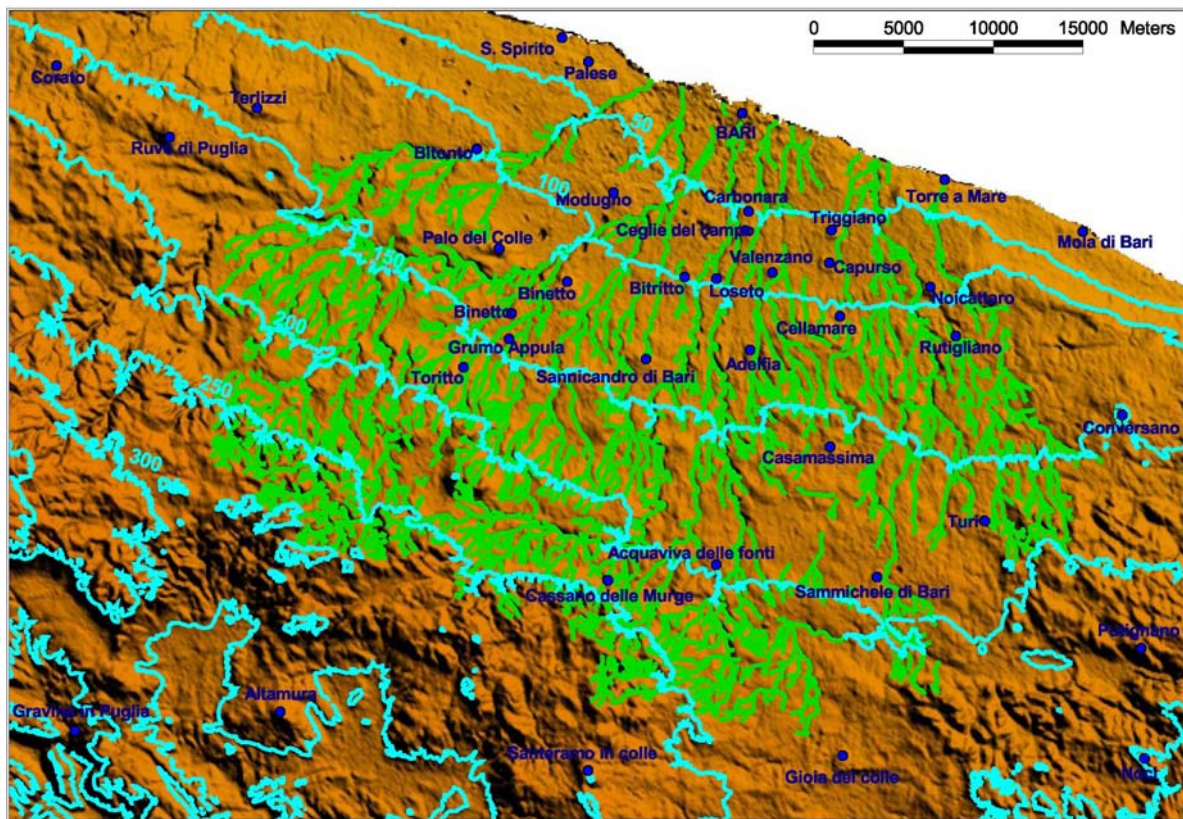


Figure 2a Digital Terrain Model of the province of Bari with contour lines, streams and main towns.

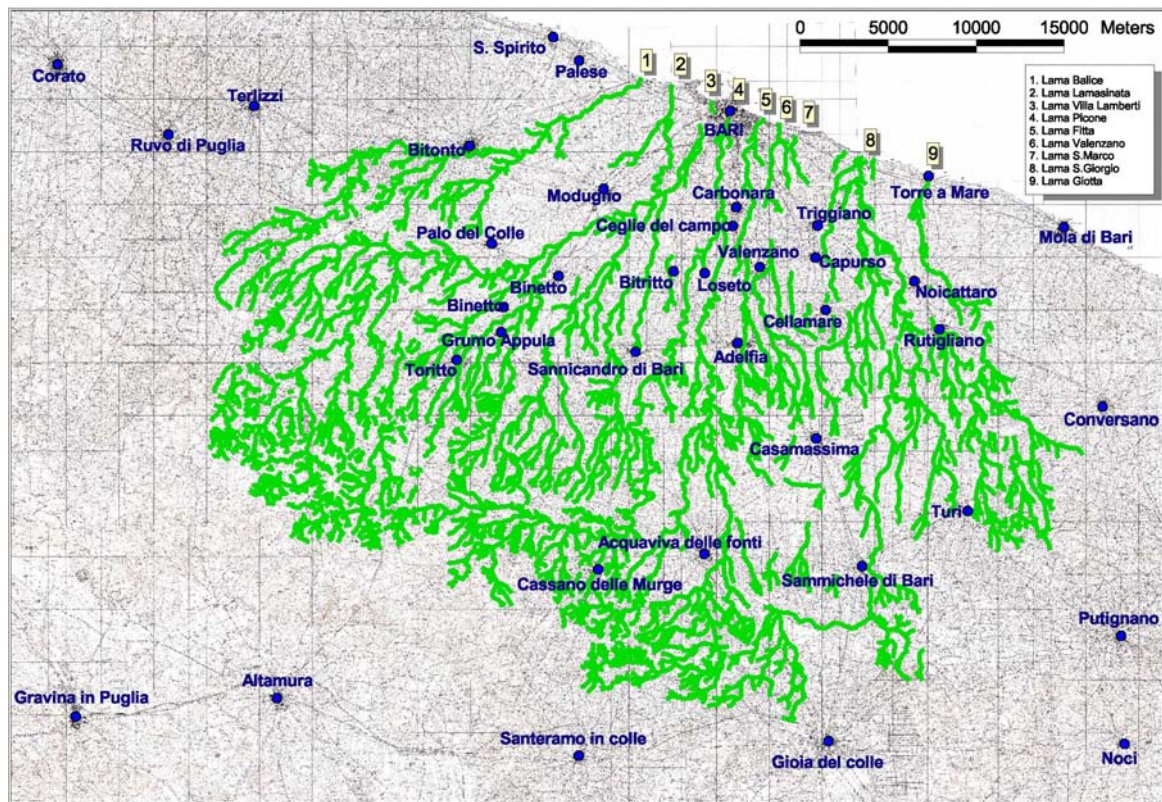


Figure 2b The streams (“lame”) of Bari, Italy.

by natural grooves or notches that are eroded into the calcareous mass. The surface runoff reaches the sea only when the precipitation is so voluminous that it is not able to be drained by the above mentioned cavities. On the other hand, the clay veil that covers the flat land can assure a certain impermeability. If the rains are light they are easily absorbed and conveyed to the underlying fissured limestone. If the rains are intense and long, after having transformed the ground into an almost impermeable mixture, they partly flow into karstic basins. These basins are widespread and characterized by a sinkhole in their lowest point. Part of the water remains stagnant because of the flat nature of the land and the vegetation that covers it. The other part of the water, favoured by the slope of the land is collected in ephemeral streams and brought to the sea. For these reasons, a hydrographic network is not well defined. There are no out and out water flows, but the depressions, in times of intense and prolonged rains, collect water from surrounding lands. Such depressions form local streams called “lame” (*lah-may*) (Fig. 2a and 2b). Figure 3 shows the satellite map of city of Bari with some points of reference that will be referred to afterwards. The main “lame” are listed below:

- (i) The Balice Lama (no. 1, Fig. 2a and 2b) is the continuation of the Tifis Lama passing through Bitonto, descending to the sea affecting the zone near the Palese.
- (ii) The Lamasinata Lama (no. 2, Fig. 2a and 2b) is among one of the most important streams. It descends between Palo del Colle and Bitetto, therefore affecting the land between Modugno and Bitritto, then continues its path towards Bari’s industrial zone. It more or less flows near the S. Francesco—S. Cataldo beach where a channel, made

at the beginning of the 20th century to carry flood waters, is still visible. Numerous ancient structures carved out of the stone are visible on the edge of the Lamasinata Lama. One of its derivations is the Gambetta Lama, which, from Modugno is reunited to the Lamasinata Lama in the industrial zone. The Lamasinata Lama has a catch basin of 370 Km².

- (iii) The Villa Lamberti Lama (no. 3, Fig. 2a and 2b) is relatively small and takes the name of an 18th century villa. It originates just west of Bitritto and continues on until the zone called Marisabella (Fig. 3), where the new Port of Bari currently arises.
- (iv) The Picone Lama (no. 4, Fig. 2a and 2b) together with the Lamasinata Lama is the most important water flow that splits Bari. It passes through Adelfia, Loseto, Valenzano, and Ceglie (here the stream is called Baronale Lama) and merges with a second stream that, from Sannicandro, descends between Loseto, Bitritto and Ceglie, forming one stream, called Picone Lama. It continues towards Parco Domingo and Poggiofranco (see Fig. 3), where important ancient structures carved out of the stone are still visible. It then flows into the Marisabella zone together with the Lamberti Lama. Therefore, the Picone Lama, which is of more direct interest to the city of Bari, is made up of two principal branches that rejoin each other near the locality of Carbonara and has a catch basin until the sea of 292 Km².
- (v) The Fitta Lama (no. 5, Fig. 3) is on the east side of a valley and the Picone Lama is on the west side, with the towns of Loseto and Ceglie between these streams. It descends towards the sea, adjacent to Corso Alcide De Gasperi and Via Fanelli streets (Fig. 3), ending at the “Pane



Figure 3 Satellite map of city of Bari with some points of reference.

and Pomodoro” beach (Fig. 3). Important ancient structures carved out of the stone have been found along its course.

- (vi) The Valenzano Lama (no. 6, Fig. 2a and 2b) originates in Valenzano and descends along today’s modern Via Fanelli (Fig. 3) and reaches the area of Mungivacca (Fig. 3). It flows to the sea along the channel that still exists in the Japigia zone (Fig. 3). The Valenzano Lama has a catch basin of 140 Km².
- (vii) The S. Marco Lama (no. 7, Fig. 2a and 2b) is a small stream that originates near the Carbone Masseria (farmhouse), which is now the S. Marco Church (in Japigia zone, see Fig. 3). It descends along a small stretch that leads to the sea.
- (viii) The S. Giorgio Lama (no. 8, Fig. 2a and 2b) from Noicattaro wets the surrounding countryside until it flows into the sea at the S. Giorgio cove zone, where a camping site of the same name currently exists.

- (ix) The Giotta Lama (no. 9, Fig. 2a and 2b) also starts near Noicattaro and descends, widening towards the town of Torre a Mare where it flows into the sea.

The flood currents that threaten Bari are those caused by Lamasinata, Picone, and Valenzano Streams (lame). The analysis of rainfall data shows that average annual precipitation in the zone is about 600–700 mm. Examination of the annual distribution of rainfall shows that the minimum monthly precipitation typically occurs in July and the maximum during the period of October to January.

2 Historic aspects

Numerous floods have hit the city of Bari. Scattered stone tablets on city streets testify of more recent events, specifically those of 23 February–3 March 1905, 3 September 1915 and 5–6 November 1926. Figure 4 shows the photos of two of the previously



(a) Via Murat – Via Trevisani crossroad.



(b) Via Trevisani – Via Garruba crossroad.

Figure 4 Two of the stone tablets of Bari remembering the floods of 1905, 1915, and 1926.

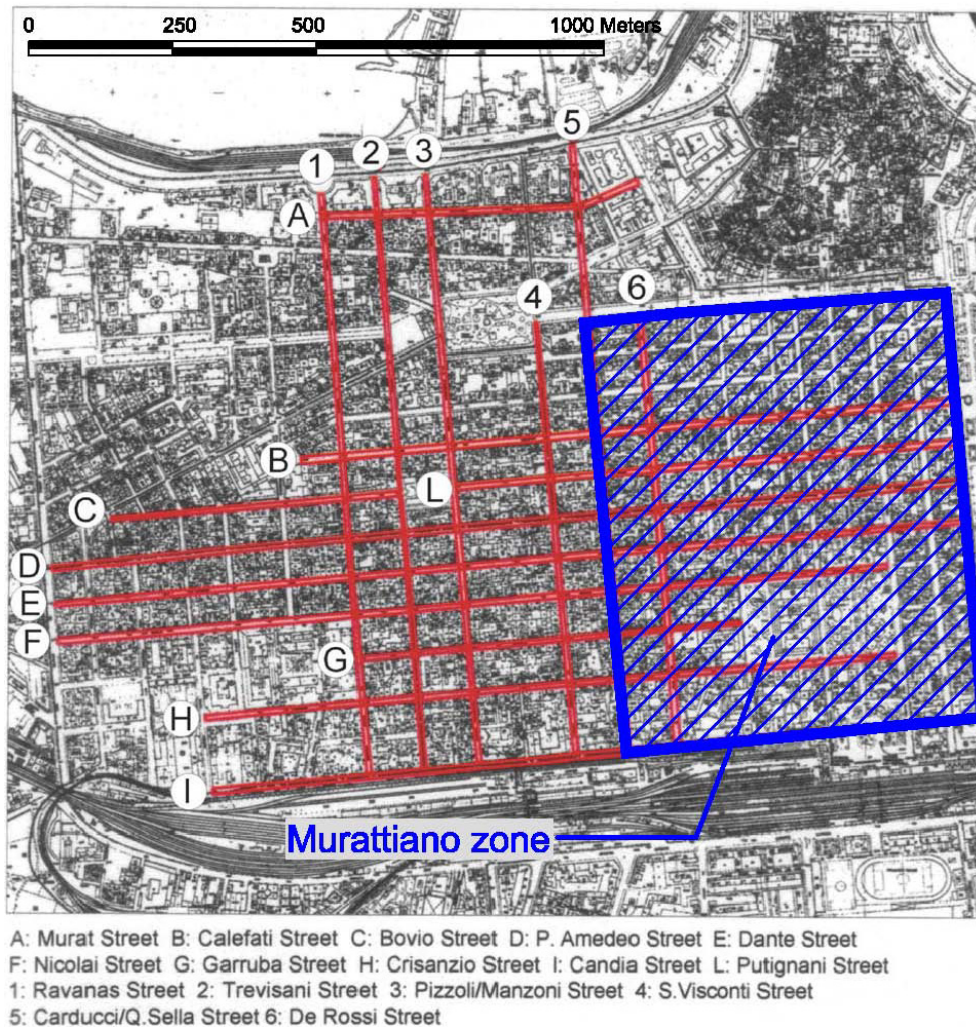


Figure 5 Main streets of Bari's Murattiano zone and neighbourhood.

Table 1 Water heights in some streets of Bari during the historical floods as reported by the stone tablets

Stone tablets	Water heights (m)		
	23 February–3 March 1905	9 March 1915	5–6 November 1926
1 Via Murat—Via Trevisani crossroad	0.60	0.65	1.20
2 Via Pizzoli—Via Murat crossroad	0.40	0.50	1.00
3 Via Carducci—Via Murat crossroad	0.20	0.30	0.80
4 Via Calefati—Via Ravanasi crossroad	—	—	0.65
5 Via Garruba—Via Ravanasi crossroad	0.70	0.70	0.90
6 Via Trevisani—Via Garruba crossroad	0.40	0.52	1.00
7 Via Quintino Sella—Via Crisanzio crossroad	0.35	0.40	0.53
8 Via G. Bovio—Via Trevisani crossroad	—	0.50	0.70

mentioned stone tablets and Fig. 5 shows the principal roads in Bari's Murattiano zone and neighbourhood. Table 1 shows the values of water heights observed on the streets in Fig. 5, as indicated from the stone tablets in Fig. 4.

2.1 Floods previous to 1905

There is evidence (Perotti, 1907) that in the early 1550's the Duchess Isabella Sforza of Aragon initiated the construction of a

navigable canal outside of the city wall at a good distance from the populated area in order to divert flood waters from the Picone Lama. In occasions of intense precipitation these floodwaters threatened the urban area of that time (currently the area of San Nicola). This canal, which was not completed at that time, was not able to contain the flood waters of October 2, 1567. Historian Antonio Beatillo hands down the report of an inundation that occurred on October 2, 1567, which is perhaps the oldest record found. The 1567 flood surged over Bari, bringing among other



(a) Railway Bari-Barletta.



(b) Via Crisanzio.

Figure 6 Photos of the flood in 1905 (courtesy of Melchiorre, 1982).

things the destruction of a bridge which united today's Libertà zone with the Ponente Riviera (Melchiorre, 1982). As reported by Moretti (2005), a devastating flood in the middle of the 1500's (possibly the 1567 flood) destroyed all of the construction carried out by the Duchess Isabella Sforza, making the mouth of the Picone Lama even swampier and more disease ridden. The swamp, therefore, became larger insalubrious and it was given the name Marisabella to remember the unsuccessful attempts of Duchess Isabella Sforza to divert the Picone Lama.

In 1815, Gioacchino Murat initiated a new expansion plan for the city of Bari that made provision for streets to be aligned in a grid pattern with cross intersections. This condition is an urban characteristic of Bari which did not consider the topography of the area. To construct the new expansion, the city planners filled the erosive grooved stretches found in the city and this caused blockage of water flow to the sea, (i.e., the Picone Lama and the locality of Marisabella, Fig. 3).

On the night of 27 September 1827, as recounted by Melchiorre (1982), a tremendous flood smashed down on Bari—not an unusual occurrence. Regarding the 1827 disaster, one can read an unedited detailed manuscript of a song written by Rocco Luigi Pietrocola of Valenzano, which was dedicated to the Royal Judge of the Canneto district describing his eyewitness account. The flood began with a torrential rain that flowed towards Loseto and Bitritto and then in the direction of Bari, with the water falling on the high grounds of Altamura, Cassano delle Murge, Santeramo and surrounding areas (Fig. 2a and 2b), uprooting trees, demolishing homes, devastating fields, sweeping away livestock and claiming human lives.

2.2 Flood of 1905

As a consequence of Murat's expansion plan for the city of Bari, the flood of February 23, 1905 could not follow the path of the Picone Lama nor could it be contained in locally abandoned quarries, so it flowed over onto streets and nearby structures causing extensive damage. In particular, as told by Melchiorre (2002), on the morning of February 23, 1905 after two days of continuous rain, Bari's streets were transformed into immense lakes of mud, but there were a few weak rays of sun shining through the clouds, giving hope for a respite from the bad weather. However, around one o'clock in the afternoon, a dark and loud gurgling from a torrential flood coming from the area of Picone entered

the area of Via Manzoni (Fig. 5) along the southwest slopes of the city, making an unstoppable course towards the sea, sweeping away, with unprecedented violence, all that was in its path. The flood waters poured over parallel streets of Via Sagarriga Visconti, Via Quintino Sella, Via De Rossi and also onto the sidestreets of Via Crisanzio, Via Garruba, Via Dante, Via Putignano, and Via Calefati (see Fig. 5), submerging a large surface under mud and debris. On March 3, heavy rains produced a new flood, smashing down on the city affecting the same zone. Fortunately, even greater disaster was avoided by opening a temporary canal to divert the flood's path and erecting a levee at the mouth of the Picone basin in the direction of Via Manzoni. The photos in Fig. 6 (by Melchiorre, 1982) show the effects of the 1905 flood.

2.3 Flood of 1915

To remedy the disastrous events of 1905, the construction of a flow canal along the outskirts of the populated areas (the canal path roughly followed Via Crisanzio and Via Trevisani, Fig. 5) was initiated. However, after ten years it had not been completed and was not effective against the flood that hit the city in 1915. As reported by Melchiorre (2002), on the evening of September 3, 1915 two violent floods, one originating in Cassano Murge from the Picone Lama and the other coming from Noci and Putignano (Fig. 2a and 2b) poured over Bari, inundating populated areas, assailing structures, causing 23 deaths and more than 50 injuries. Just a few days later, the same events repeated themselves, but without causing additional damage. Above all, the flood from the Valenzano Lama caused the major damage. The streets of Principe Amedeo, Dante, Nicolai, Trevisani, Sagarriga Visconti, Garruba, Manzoni, Crisanzio and Candia (today's Corso Italia; see Fig. 5) remained flooded. Many buildings collapsed in these streets and there was damage to the existing factories along the Picone route. In the successive days, the streets that had been invaded by the mud were cleaned up and a complete cleaning of the canal was carried out along the path of Via Pizzoli, leading to the sea.

2.4 Flood of 1926

Following the 1915 flood, a levee was erected at the Picone Lama near the locality of Carbonara in order to deviate the waters into

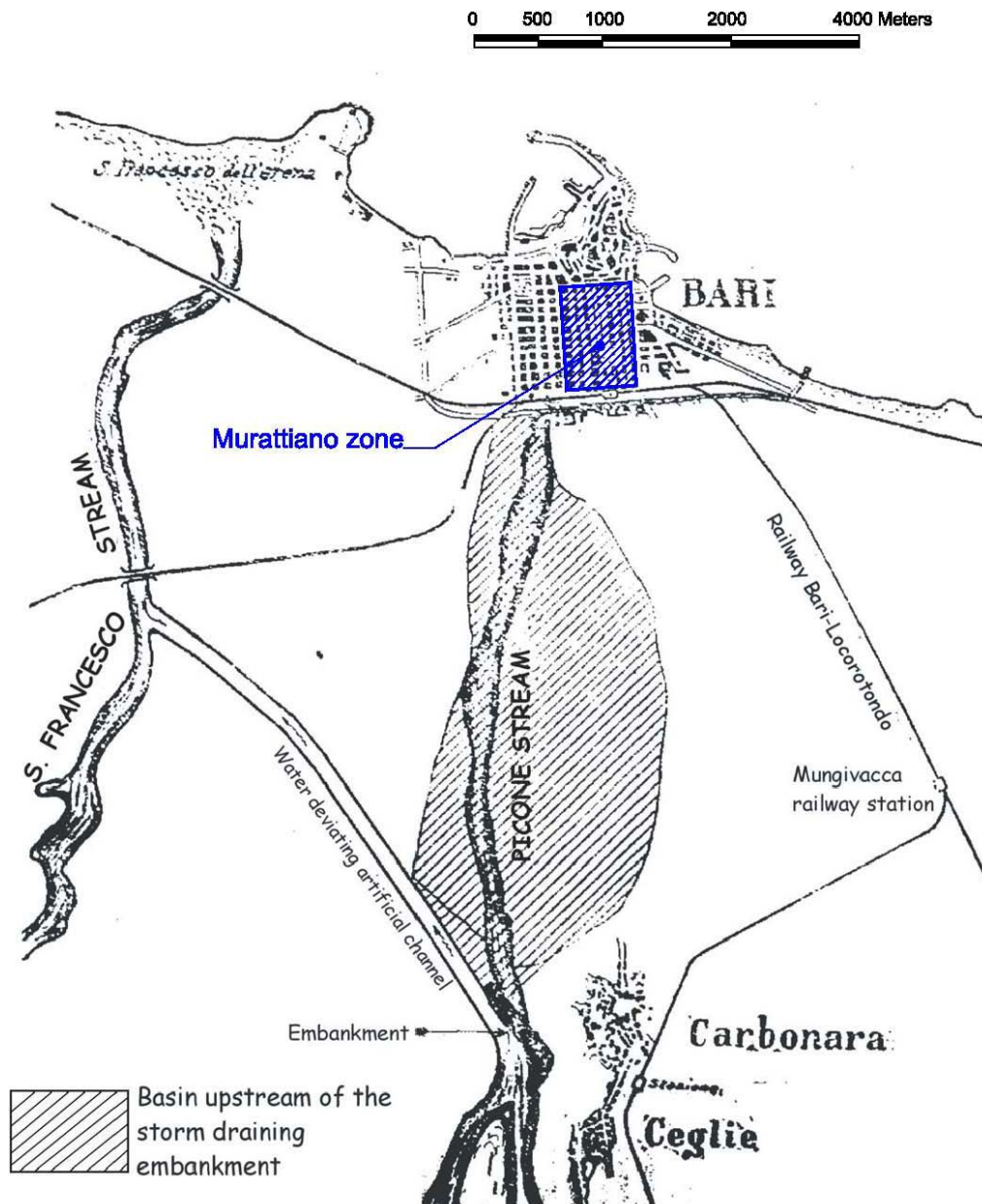


Figure 7 Flooded zone for the overflow of the Picone Lama levee (from La Gazzetta di Puglia, 1926).

an artificial canal (Lamasinata Deviating Canal, see Figs 3 and 7) which led straight to the sea near S. Francesco all'Arena. In spite of this construction, the violence and force of the November 5–6 floods in 1926 were too strong for the above mentioned levee and it collapsed. Figures 7 and 8 (from La Gazzetta di Puglia newspaper, 1926) outline the area flooded in black. As Melchiorre (2002) recounts, it rained for two entire days straight and muddy water covered every street in the city rising almost to the height of the sidewalks, but these events could not predict the approaching disaster, even taking into account the engineering defense structures of the Picone levee that had been built after the 1915 catastrophe. At approximately 2:00 a.m. the flood assailed populated areas with unparalleled violence wiping out 70 m of the levee's barrier which was constructed of 10 m^3 masses of stone. A wave of about 5 m penetrated and broke open the mighty wall advancing through the breach, destroying buildings, uprooting trees and electrical poles and eviscerating whole groups of houses. In fact,

as one reads in the annals of La Gazzetta di Puglia newspaper, following the disaster of February 23, 1905, in order to defend Bari from the Murge catch basin's overflow, a levee was built in 1915 in nearby Carbonara. (The Murge catch basin has an expanse of about 2750 hectares and a flood discharge of approximately $250\text{ m}^3\text{ s}^{-1}$). The levee is a masonry barrier embankment that conducts the said waters into a specific artificial canal dug out of the rock. With such a canal, as seen in Fig. 7, these floodwaters are deviated to the riverbed channel of S. Francesco (which is called the terminal stretch of the Lamasinata Lama; Figs 2 and 3). The S. Francesco channel flows almost parallel to that of the Picone Lama with its terminal part forming a swamp near the sea.

The catch basin of Picone Lama between Carbonara and Bari has an expanse of about 575 hectares and flood discharge of $23\text{ m}^3\text{ s}^{-1}$. During the 1926 storm, water from this catch basin was carried to the Picone storm drain (Fig. 7) rather than the

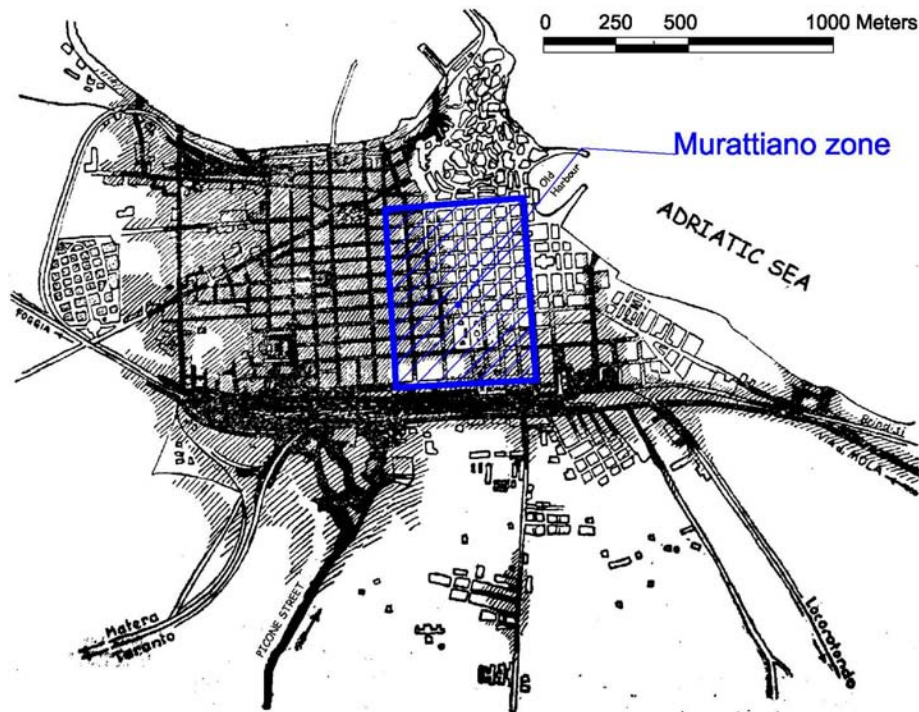


Figure 8 Black outline indicating the zone of Bari flooded in 1926 (from *La Gazzetta di Puglia*, 1926).

S. Francesco Stream. This storm drain was designed for a flood discharge of about $40 \text{ m}^3 \text{ s}^{-1}$. When the levee in Carbonara broke, the water (which in the opinion of the technicians of that period was characterized by a discharge of $500 \text{ m}^3 \text{ s}^{-1}$), rather than flowing through the deviator canal of the riverbed channel of the S. Francesco Stream, went into the old riverbed channel spilling into Bari. So, the Picone storm drain was designed to collect only the flood waters downstream of the levee along the Picone Stream which led to the city. Because of the levee break this collector gathered a big mass of water with a depth of more than 2 m and rather than a free surface channel, it functioned as a pipeline with a flood discharge greater than $50 \text{ m}^3 \text{ s}^{-1}$. All the same, the Picone collector functioned in appreciably diminishing the disaster. Other registered annals of that period reported that the city drains and sewers also functioned well rendering the disaster less serious.

In conclusion, the origin of this disaster can be imputed exclusively to the collapse of the barrier levee, whereas the Picone collector and the sewers helped in diminishing even more damage. However, the collapse of the barrier was not the only consequence of the disaster. The number of victims and damage was also due to the common dwellings which were built on the ground floor facing the street, and, in violation of the regulations. The morning of Sunday, November 7th, the final account of victims was made, a total of 20 dead. The event resonated so loudly in all of Italy that many cities, including Rome, Naples, Milan, Florence, immediately sent their fire departments to help. Figure 9 shows some photos of the 1926 flood. The Italian government sent the Minister of Public Works to evaluate the essential nature of damage and to implement the most urgent measures to be taken. Amongst other things, enlarging the width of the Picone Stream by 34 m, moving the last trunk of the Lamasinata Lama towards

the west as well as deviating the Montrone Lama (which is the stream flowing through Adelfia, Fig. 2a and 2b) in Valenzano Lama (Fig. 11), and reconstructing the outlet of the Valenzano Lama at the sea were considered. In addition, a forestation of a large area upstream of the Picone catch basin, corresponding to the current Mercandante forest (in Cassano delle Murge, Fig. 2a and 2b) was planned. Figure 10 shows the Picone Lama levee after the 1926 flood and after reconstruction (for the location of this levee see Figs 3 and 7). The photos in Fig. 11 show different phases of the said protective operations carried out in Bari after the 1926 flood.

2.5 Flood of 2005

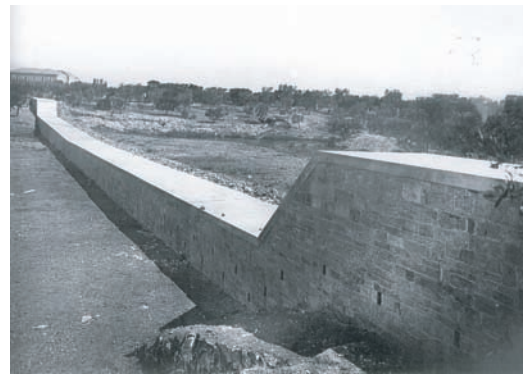
Bari was recently hit again by a flood caused by heavy rainfall on the night between October 22–23, 2005. The events of this flood caused 6 deaths and many injuries (Fig. 12). Five people were killed in an embankment collapse on the road between Cassano delle Murge and Bitetto (Fig. 12i). The other victim was swept away in his car in the S. Giorgio Lama flood. The bad weather also incited two railway accidents: the first occurring in Cassano delle Murge, where train carriages derailed and turned on their sides (14 injuries), while the other train accident occurred between Acquaviva delle Fonti and Sannicandro di Bari where the Taranto–Milan Eurostar derailed (Fig. 12a–12c). It was carrying 60 passengers, 22 of which were injured. As pointed out by Moretti (2005), material damage resulted in major road collapses, damage to agricultural crops, and to the electrical networks. The images in Fig. 12 need no other words for they prove the severity of the facts and the repeated engineering errors in spite of the preceding tragic events that should have taught us well.



Figure 9 Photos of the flood in 1926 (Fotostampa Ficarelli, Bari).



(a) The Picone levee (see Fig. 7) after the 1926 flood (from La Gazzetta di Puglia, 1926).



(b) The reconstruction of the Picone Levee after the flood of 1926 (courtesy of Melchiorre, 2000).

Figure 10 The Picone levee damaged after the flood of 1926 and subsequently reconstructed. See Figs 3 and 7 for the Lamasinata deviating canal and the Picone levee.



Figure 11 Reconstruction work after the 1926 flood. Deviation of Montrone Lama in Valenzano Lama (courtesy of Melchiorre, 2000).



(a) Derailed Eurostar train.



(b) Derailed Eurostar train. It is evident the undersized culvert.



(c) Derailed Eurostar train.



(d) Area of S. Rita di Bari.



(e) Area of S. Rita di Bari. Bus warehouse.



(f) Area of S. Rita di Bari. Channel underflooding.

Figure 12 The effects of the flood of October, 2005 (the location of these zones are described in the text and see Fig. 3).



(g) Area of S. Rita di Bari. Ex-quarry DiMaso.



(h) Area of S. Rita di Bari. Road destroyed by flood.



(i) Area of S. Rita di Bari.



(j) Collapse of a road embankment between Cassano delle Murge and Bitetto.

Figure 12 (Continued)

3 Hydrological analysis of precipitation during historical Bari floods

As read in the Annals of Hydrology, the rains of November 5–6, 1926 caused a flow in the basins of the Lamasinata, Picone, Montrone and Valenzano Streams of $1.8 \text{ m}^3 (\text{sKm}^2)^{-1}$. In Bari there was a 24 h precipitation of 103.0 mm (5 November 1926) and a 48 h precipitation of 160.0 mm (5–6 November 1926), which represented the maximum values seen then. The average hourly rainfall intensity was measured at 21.7 mm h^{-1} . Figure 13 shows the data of daily rainfall at different weather stations (Fig. 2a and 2b) involved in this meteorological event. It is observed that the peak daily rainfall measuring 151 mm, occurred in Grumo Appula on 6 November 1926.

The diagrams in Fig. 14 shows, for the weather stations in which historic data exists, the ratios between monthly rainfall and the number of days of rainfall during that month with the same data averaged up to 2000. From the above mentioned analysis, it is observed that the average to above-average rain was concentrated into fewer days in 1926. It is important to see that values are all larger than average. Alfieri (1927) gauged that the water volume overflowing the Picone levee, inundating Bari, was approximately $4 \times 10^6 \text{ m}^3$. The flood was also noted for its substantial movement of sediments. After the flood waters passed,

the total mud volume deposited in the city was estimated to be about $200\,000 \text{ m}^3$ (Borri *et al.*, 2002a,b).

4 Hydrological analysis of precipitation during 2005 Bari flood

Regarding the flood of October 2005, Fig. 15 shows 30 min. measurements of rainfall between October 22–23, 2005, while Fig. 16 shows daily rainfall in October 2005. From the analysis of both figures, it is observed that the maximum quantity of rainfall was registered at the Mercadante (Cassano delle Murge) and Santeramo in Colle weather stations the night between 22 and 23 October, 2005 with maximum 30 min. measurement values of 43.2 and 34.4 mm, respectively, and maximum daily values of 149.4 and 53.8 mm respectively. Figure 17 report the depth-duration-frequency curves together with maximum precipitation intensity of November 5, 1926 and of October 22–23, 2005 and the historical maxima measured until the year 2000 at the weather stations that possess the records. The depth duration frequency curves with return time of 30, 200 and 500 years are obtained starting from a minimum observation of 30 years and a maximum of 48 years. It is hypothesized that the observations were described by Gumbel's probability distribution function.

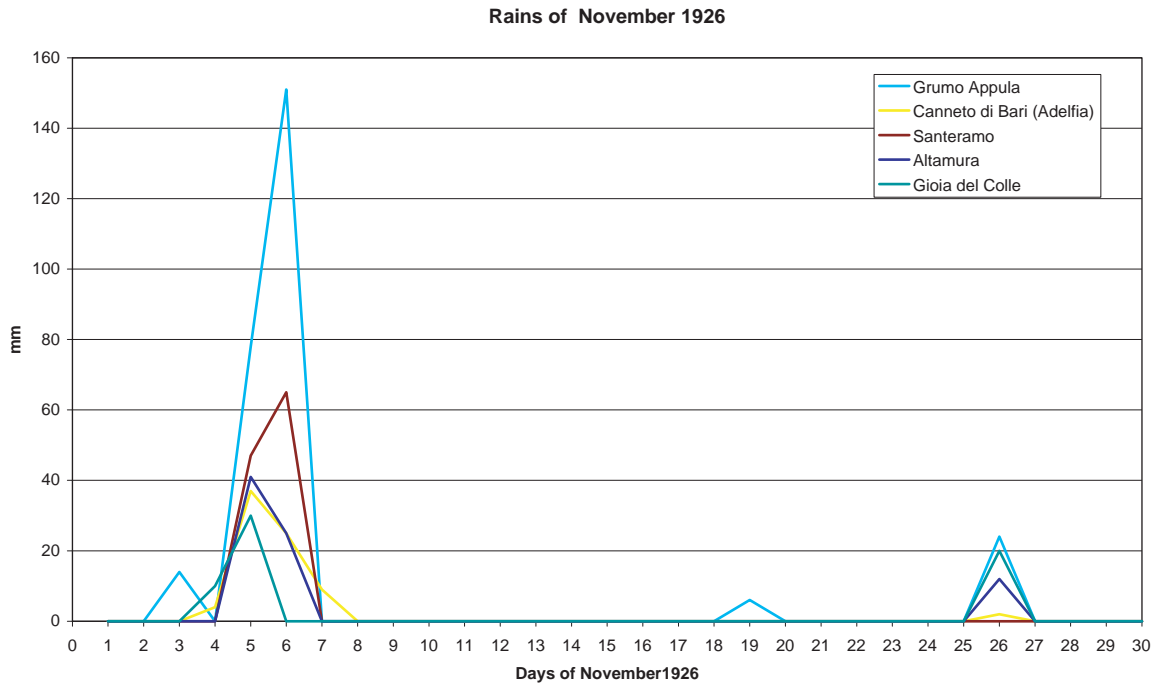


Figure 13 Daily rains of Novembre 1926.

The test of significance of χ^2 indicates that Gumbel's theoretical distribution hypothesis can be utilized to describe the data in a very reliable manner, since the χ^2 parameter is always less than 0.40, which is below the value of $\chi_{0,95}^2 = 5.99$.

One considerable observation is that the 103 mm of rain which fell on Bari on November 5, 1926 between the hours of 19:00 and 23:45 was extremely unusual, having a return time of more than 200 years. Regarding the flood of 2005, this rare behavior was evidenced at the weather stations in Santeramo in Colle and, above all, at Mercadante (Cassano delle Murge), while at other stations the rainfall was characterized by a return time less than 30 years and in many times, even shorter.

5 Conclusions and observations on the Bari floods

After the 1905 disaster and the construction of the Picone Lama levee, Bari was sure that it could not be hit again by another inundation of floodwaters. On the contrary, another flood, even though much less severe, hit the city again. At that time, it was said that the engineering operations were not completed but eventually the operations were taken up again and finished. Ministerial inspectors and other officials from the Public Works Department came to Bari. All agreed and believed that the completed works were sufficient to confront the danger. Above all, new housing construction was authorized near the zones that had been flooded in 1905 and 1915. They were so assured of the safety that homes were actually constructed in the streams' beds. To have a complete picture of the situation, one needs to assume that prior to 1905, Bari did not have particularly dangerous floods. In fact, the old city (currently the S. Nicola area) was constructed with expertise. The water, that in periods of rainfall flowed towards the sea from Murgia of Gioia and Cassano, flowed normally in the streams and

ended quite far away from the old wall in Marisabella. However, in the 1800's the expansion of residential buildings and railways changed the appearance of the city, without considering its hydrological and hydraulic aspects. The engineering works carried out after the flood of 1915, unfortunately, were not enough to protect the city. The annals from that period remark that certain officials from that period, above all the expert technical officials, who did not initiate engineering projects that would have protected the city from inundation, should be blamed.

Engineer Valente (La Gazzetta di Puglia, 1926), as Director of the Provincial Technical Office, after the Valenzano Lama 1915 flood studied the flood waters' course suggesting the necessary measures for the populated zones and adjoining countryside. It seemed evident from Eng. Valente's reports that the Picone Lama was not Bari's only danger. The annals of that period (La Gazzetta di Puglia, 1926) indicated that the Valenzano Lama was another enemy. In fact, the dangerous flood of 1914 and, above all, the historical floods of 1915 and 1926 were due to the Valenzano Lama, which flooded the countryside east of Bari and destroyed very important structures. In 1926 Bari was between the Picone Lama and the Valenzano Lama, namely between two permanent high risk currents. But, it is to be pointed out that the two streams would not have been dangerous if their age old riverbeds had been left alone. In Fig. 7 the work that was carried out on the riverbed around the Picone Lama is observed. Another regrettable chapter in Bari's urbanization is the Valenzano Lama, whose riverbed in some points reaches a width of 145 m and a depth of 6.5 m. This stream had three obstacles created by the Bari–Locorotondo railway, namely one in proximity to Adelfia, the other near Valenzano and the third in proximity to Carbonara (Fig. 3). The Bari–Locorotondo railway company, rather than building a bridge to pass over the Valenzano Lama riverbed, as it should have, constructed an embankment of considerable length,

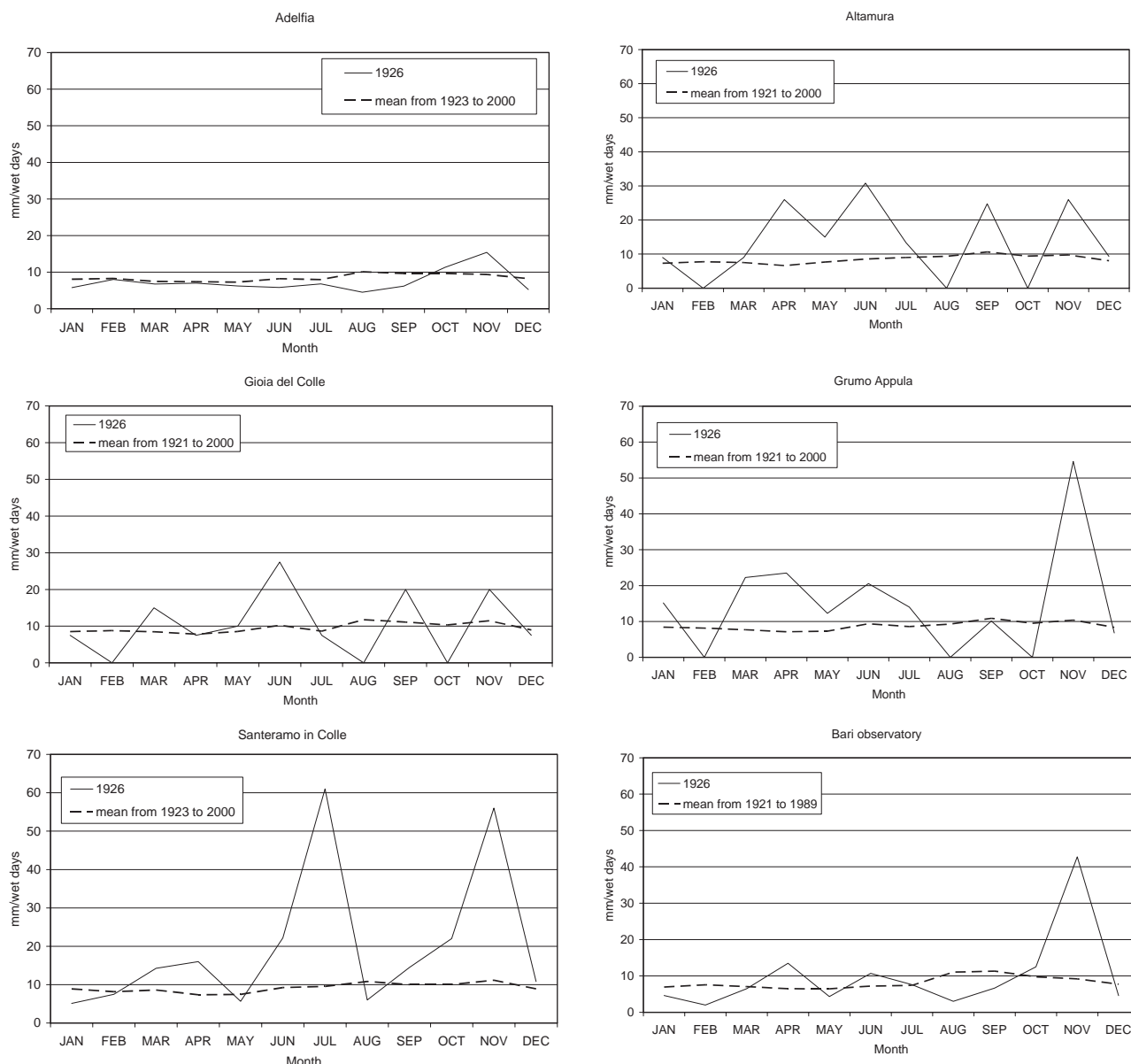


Figure 14 Ratios between monthly rainfall and the number of days of rainfall during that month of year 1926 with the same averaged data.

more than 140 and 6.50m in height, leaving in the middle a culvert of only 1 m width and 2 m height. As was easily foreseen, the Valenzano Lama flood of 1914 completely washed away the embankment causing manifold damage. In 1915, while there was still a pending legal case against the railway’s administration for payment of damages derived from the flood because of the aforementioned works, and when an expert judgment report had proved the responsibility of the railway administration, the embankment was rebuilt, again obstructing the stream’s riverbed! This time the embankment was constructed with more solid rocks, but in September of 1915 the floods came again, in an even more disastrous manner. After 1915, the railway administration made 5 culverts instead of spending money on constructing a bridge. With the flood of 1926 an enormous mass of water slammed against the railway embankment, engulfing and invading the surrounding countryside. Even though the embankment was not damaged, the flood waters filled the culverts and reached the Picone Lama

pouring into Bari, penetrating the lands and the eastern area of the city. Baldassarre and Francescangeli (1987) observed that numerous linking factors were the causes that shaped the flood of November 6, 1926 and that inundated the populated areas of Bari. These causes can be attributed to extreme and intense precipitation, geological, morphological, and hydro-geological conditions of the ground upstream of the inhabited areas, and the presence of erosive grooves (“lame”) that converge towards the city. But above all, it was the urban expansion of the city that was not well suited to the local physical conditions of the areas of interest. The aforementioned facts highlight poor planning and poor maintenance of civil engineering operations. Errors were made due to the lack of understanding the geomorphology during the development of the city which, in the last two centuries has extended to areas outside the historic center. Highly dramatic is the case of the last flood in 2005. In fact, as already evidenced in this paper, notwithstanding the historical testimonies, of which

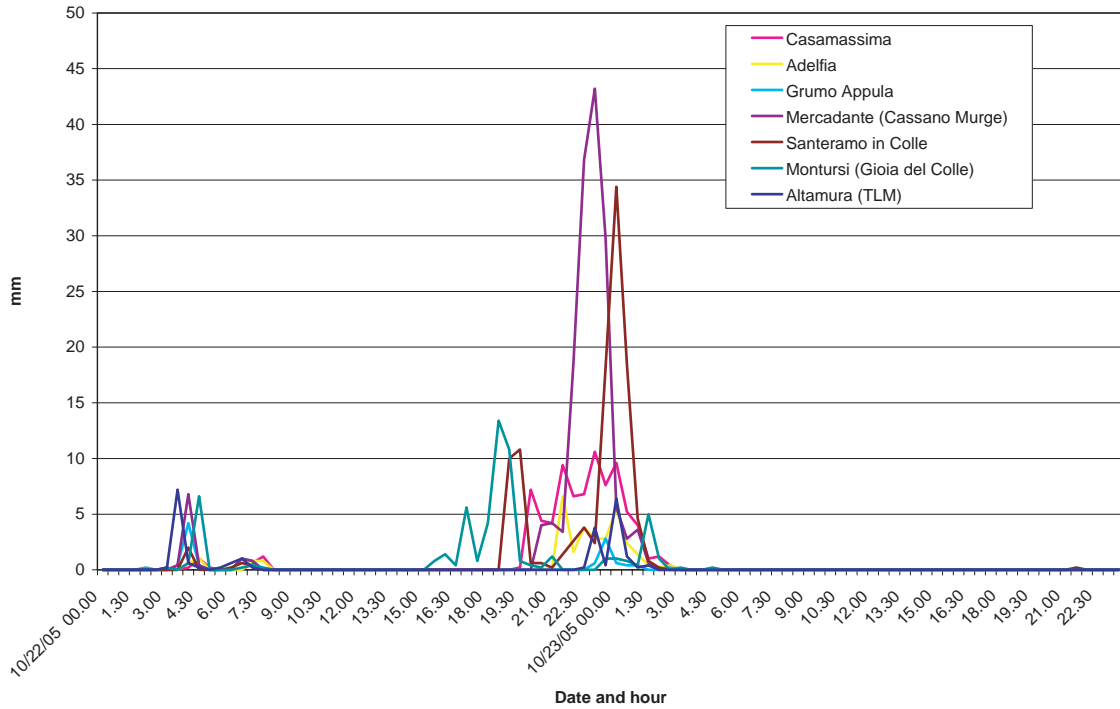


Figure 15 Thirty minute measurements of rainfall between October 22–23, 2005.

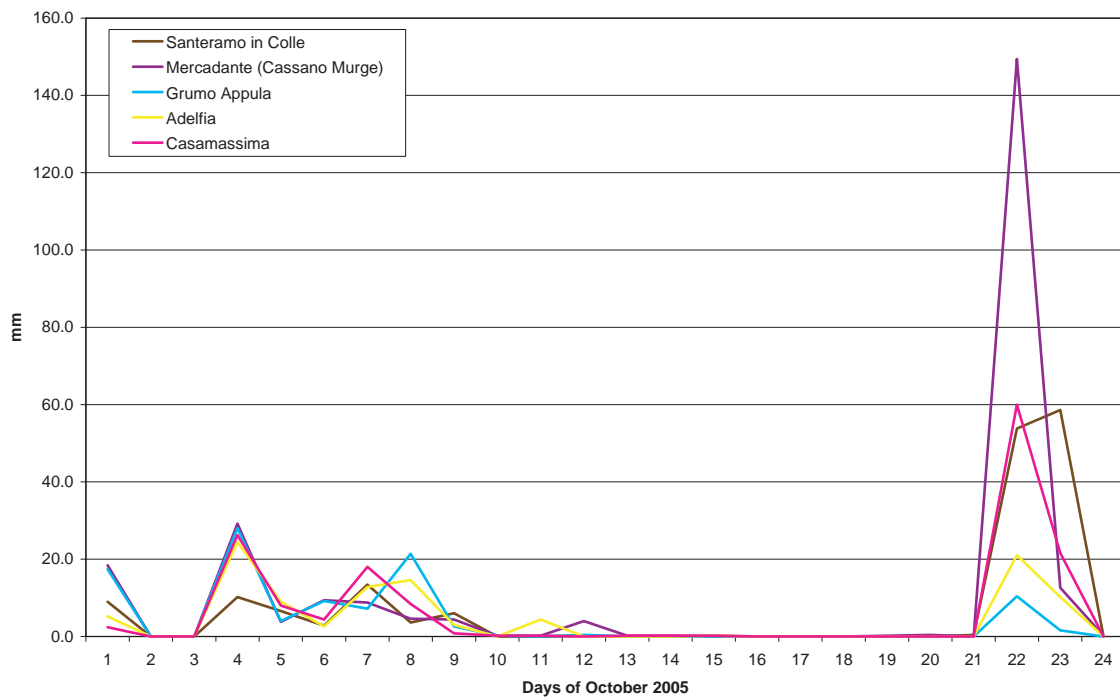
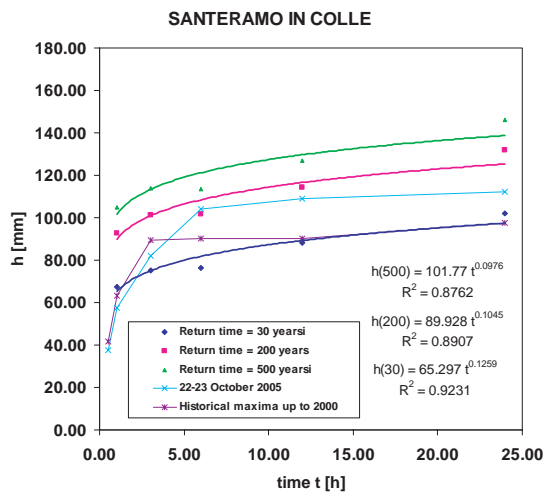


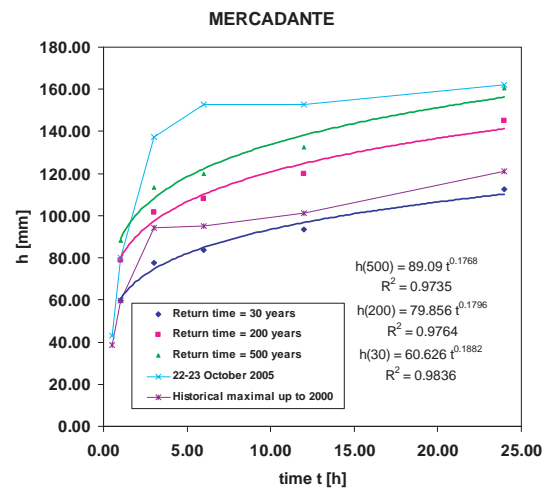
Figure 16 Daily rainfall in October 2005.

are many, the development of the city, instead of respecting the geomorphological territory, has been built contrary to its nature. The result is that one finds vineyards and olive groves, or worse, homes constructed against building codes right in the stream beds. Other examples are large buildings constructed in proximity to the streams or very close to quarries. A grave example is that of the Cassano delle Murge road embankment which was swept away by a river created in just a couple of minutes that apparently

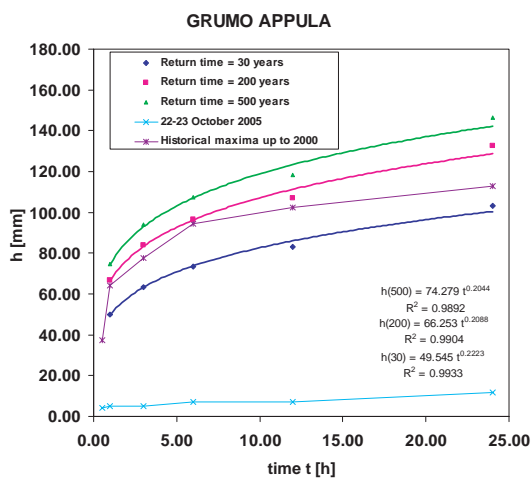
came from nowhere (Fig. 12l). All this came about from rains recorded only at Mercadante (in Cassano delle Murge) and Santeramo in Colle. The consequences would have been worse if the rains were heavier in other nearby areas. The images in Fig. 12 speak very clearly about the errors committed. The derailed train can be employed as an image representative of the recent disaster (Fig. 12a–12c), above all if one remembers the occurrences of the Bari-Locorotondo railway in 1915. It would seem that



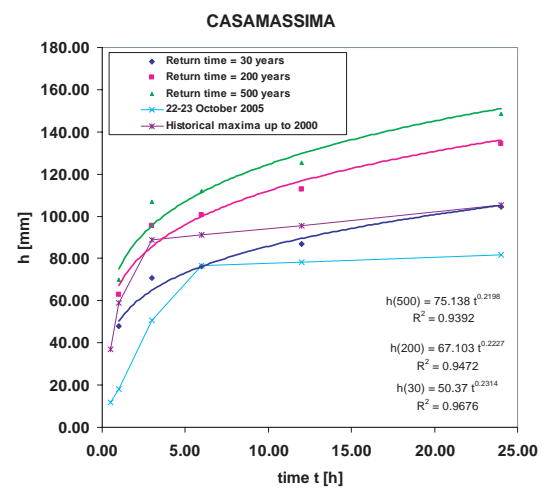
(a) Santeramo in Colle.



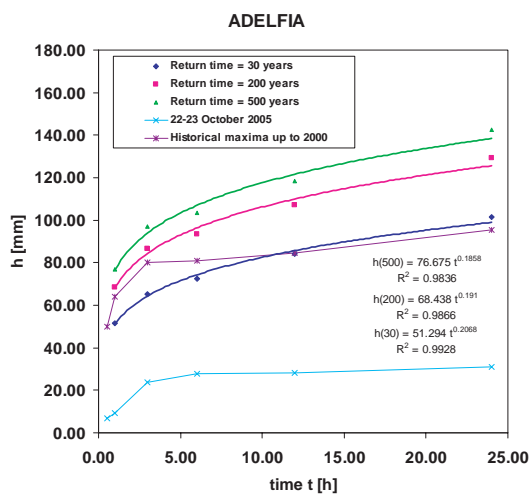
(b) Mercadante (in Cassano delle Murge).



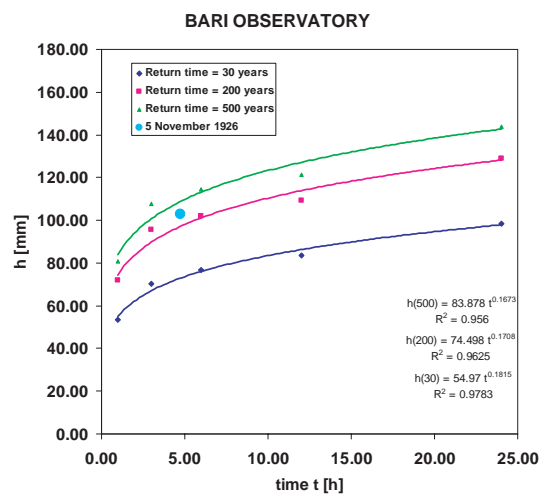
(c) Grumo Appula.



(d) Casamassima.



(e) Adelfia



(f) Bari observatory.

Figure 17 Depth duration frequency curves together with maximum precipitation intensity of November 5, 1926 and of October 22–23, 2005 and the historical maxima measured until the year 2000.

this story has not taught us anything. These muddy rivers, the homes built on the canal beds (Fig. 12d), this panorama of floating debris (Fig. 12h–12i), of horrors scattered among cement cubes is the result of man, who disobeys the hydraulic nature of

the territory. The torrential rain is enough to split an embankment in two, tear up illegally constructed streets, to destroy a public park built inside a quarry in Carbonara (Fig. 12g), to drown many small residential towns created in the last years,

and to sweep away cottages and crops in the middle of the channel, a channel constructed in order to collect rainwater and to bring it to the sea. In spite of these abuses, the channels drained off the floodwaters in a few hours, as evidence that the engineering operations conducted after the flood of 1926 were well conceived, well planned, and well carried out. The errors are present in recent projects which did not consider the hydraulic and geomorphological structures of the territory. Many unanswered questions remain, but, as pointed out in this paper, it is certainly not possible to ignore the historical data. On the contrary, this data has been well evidenced as a warning for future engineering projects.

Acknowledgments

I would like to thank Prof. Marcelo Garcia for having asked me to prepare an invited article for the *Journal of Hydraulic Research* about the recent floods in Bari, which occurred in October, 2005. He did not exactly want a technical article but rather one more oriented towards “forensic” engineering and the lesson learned from these floods. I hope that I have accomplished this goal through historic investigation. Thanks also to Prof. Hubert Chanson who also invited me to write this article on this theme in light of the recent floods in Bari, testifying of his particular interest to environmental problems. Additional thanks to Eng. Vincenzo Pizzo for his help in the cartographical work and to Eng. Valeria Greco, Eng. Andrea Pollio e Ms. Chrissie Oppedisano for their help with this paper.

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