**Modern Environmental Science and Engineering (ISSN 2333-2581)**
**March 2020, Volume 6, No. 3, pp. 324-329**
**Doi: 10.15341/mese(2333-2581)/03.06.2020/003**
**Academic Star Publishing Company, 2020**
**www.academicstar.us**

# Flood Lamination System of Pescara River in Abruzzo Region, Italy

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**Abstract:** The growing urbanization of town of Pescara, as well as of urban centres in its proximity, and frequent and intense extreme rainfall events cause overflow of the Pescara river, with heavy negative effects (hydraulic, hydrogeological and socioeconomic) on the territory and on the people due to flooding. The urban development of the lowland areas often causes the impossibility to build defence works, like river embankments, in the areas subjected to hydraulic risk. Therefore, nowadays, the most common flood prevention measures are retention basins, that temporarily store water volumes during a flood event in order to reduce the flood peak. In this context, this paper shows major mitigation effects (hydraulic and socioeconomic) of an important and complex system of hydraulic works, consisting of retention basins along the Pescara river in Abruzzo Region, Italy.

**Key words:** Pescara River, flood retention basins, hydraulic and socioeconomic effects

## 1. Introduction

The areas adjacent to the town of Pescara (Abruzzo Region, Italy) are often subject of Pescara river flooding, showing territorial criticalities and fragility that induce strong harm and social alarm to the entire concerned community.

The Pescara river (170 km long) is fed by the largest (3.125 km²) river basin of the Abruzzo Region among those flowing into the Adriatic Sea. This river has undergone considerable anthropic pressure that has led to the progressive occupation of the floodplain areas and, therefore, to the reduction of the spaces useful for the defence against the hydraulic and hydrogeological risk of the territory. In fact, the urban development of the lowland areas often makes it difficult to build passive defence works of the areas subject to risk, due to the impossibility of placing protection structures (e.g. river embankments) inside the built-up cores. Therefore, there is a growing number of cases in which active defence works are used, such as retention basins, which allow for the so-called lamination effect of the flood, i.e., the temporary accumulation of the water volumes transiting during a flood event in order to reduce the value of the flood peak [1-3]. As stated in the reference law (called Floods Defence Plan [4]), the flood management strategy of the Governmental Authorities of the Abruzzo Region is oriented to favour active defence works (to reduce the flood peak) instead of passive ones (i.e. to build new river embankments or to rise existing ones) which would further increase the downstream flood peak an so the flood risk.

Therefore, as discussed in previous studies [5-6], the Abruzzo Region has planned the construction of an adequate and complex flood defence scheme, consisting of a system of off line retention basins (designed by BETA Studio Srl and HR Wallingford Ltd), which intercept the flood waves in the final stretch of the Pescara river, at about 25 km from the river mouth (Fig. 1a). In detail, in this Pescara river stretch, near the town of Chieti, the territory occupied

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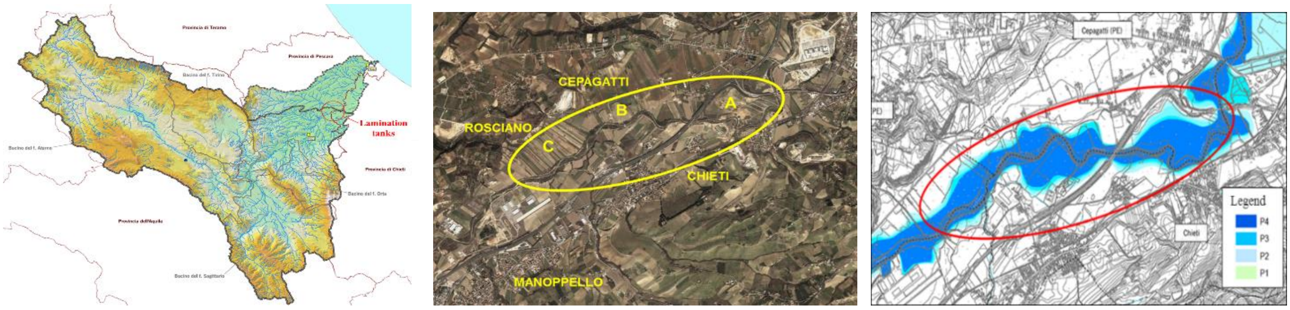
by the works falls entirely within the floodplain (flat agricultural land consisting mainly of alluvial deposits, i.e., gravels, sands and silts) and is crossed by the A25 highway (Fig. 1b). This area is subject to the flooding of the Pescara river, whose hydraulic hazard level (calculated with different flood return times) is highlighted in the mapping of the above mentioned Flood Defence Plan, as shown in Fig. 1c.

These retention basins, thus, contribute to pursue the Flood Defence Plan goals, aimed at reducing the extent of the areas that are currently subject to an high and very high hydraulic risk level (due to the dense presence of housing and infrastructure systems in conjunction, respectively, with high and very high hydraulic hazard, Fig. 1c). The design and dimension of the retention basins is hence focused on achieving maximum efficiency for flood events return times (RT) equal to 50 (RT 50) and 100 (RT 100) years.




(a) (b) (c)

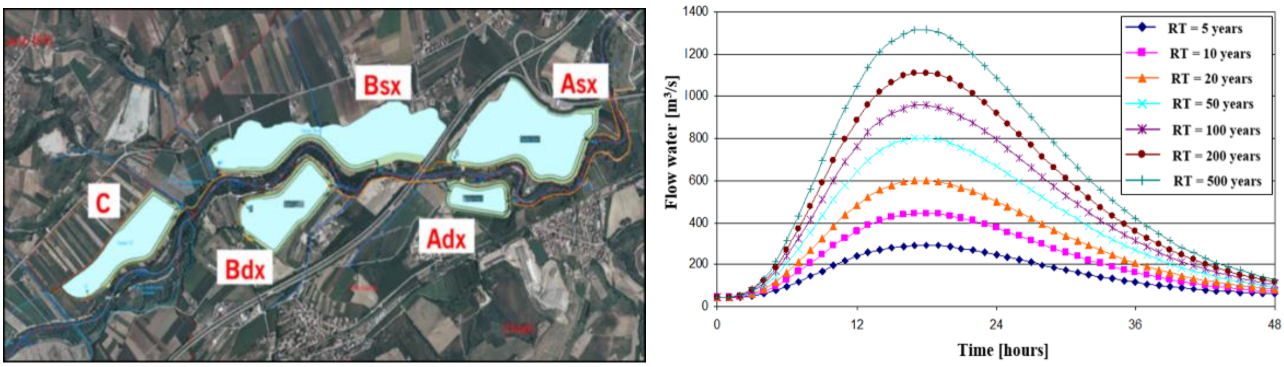
**Fig. 1 Retention basins: (a) localization in Abruzzo Region; (b) Pescara river stretch in which are localized; (c) hydraulic hazard of the Pescara river stretch in which are localized.**

## 2. Retention Basins Characteristics

The flood prevention measure consists of five retention basins, located on both sides of the Pescara river covering several river stretches (Fig. 2a). The retention basins characteristics are shown in Table 1, where the normal regulation level corresponds to that of the overflow spillway height, whereas the river embankment was set at 1.50 m above the maximum storage level reached as a consequence of the passage of a flood event with a 200 year return time (RT 200). The total area occupied by the works system is equal to 136 ha. The retention basins are developed within the territory of three municipalities: Rosciano for 21 ha (15%), Cepagatti for 86 ha (64%) and Chieti for 29 ha (21%). The area affected by the works has variable width comprised from few hundred meters up to 1 km transverse to the Pescara river. In this area the morphology of the river is characterised by meanders and the floodplain is flooded with different frequency, depending on the altimetry of the area. The total length of the retention basins embankments is 12.6 km, with an average height of 5 m and a maximum height of 8 m. The total water volume stored at the maximum regulation level is equal to 5.220.000 m³. Each of the five retention basins will be regulated by means of two hydraulic structures (a hydraulic work for water intake from the river and one for discharge back to the river). Each basin operates independently from the others; in this regard, the construction of a building to be used as a system control centre is planned. The lamination system involves the handling of approximately 1.750.000 m³ of land, part of which will be reused on site. At the end of the construction works, the areas inside the basins will be adjusted to allow the carrying out of the agricultural practice, also restoring and enhancing the existing irrigation system. The construction of the retention basins also includes environmental works on the fluvial area for an extension of 13 ha. In the floodplain area close to these basins, access and transit routes also are planned at the top and at the basis of the embankments, as well as cycle-pedestrian routes for a total length of 9.2 km. The overall construction cost is about €54.800.000.

**Table 1 Characteristics of the retention basins.**

| Retention basin | Normal regulation level [m a.s.l.] | Embankment level [m a.s.l.] | Internal surface [$m^2$] | Volume [$m^3$] |
|---|---|---|---|---|
| Asx | 40,10 | 41,60 | 228.000 | 1.370.000 |
| Adx | 40,10 | 41,60 | 46.000 | 300.000 |
| Bsx | 44,50 | 46,00 | 304.000 | 2.080.000 |
| Bdx | 44,20 | 45,70 | 149.000 | 800.000 |
| C | 48,10 | 49,60 | 153.000 | 670.000 |
| Total | | | | 5.220.000 |




(a) (b)

**Fig. 2 (a) Retention basins localization; (b) Flood hydrograms at the river section S. Teresa (area of the river basin equal to 2.865 $km^2$) for different return times (RT) varying between 50 and 500 years.**

## 3. Hydraulic Modelling

The flood hydrographs used in the hydraulic models simulating the different flooding scenarios of the Pescara river (Fig. 2b) are those defined in the Flood Defence Plan. The hydrometric behaviour (i.e., the flooding scenarios) of the Pescara river from the designed basins to the town of Pescara at the river mouth was initially analysed using the mathematical model HEC-RAS, under steady state hydraulic condition. 61 topographic sections of the river were surveyed for the whole river reach (34 km). Subsequently an unsteady state model has been implemented to check the correct operation of the lamination works system. This was done using the 1D-2D finite elements hydraulic model Infoworks ICM. The topographic data of a detailed LIDAR (Laser Imaging Detection and Ranging) survey has been used generating a 1 m size DTM (Digital Terrain Model) of the studying area.

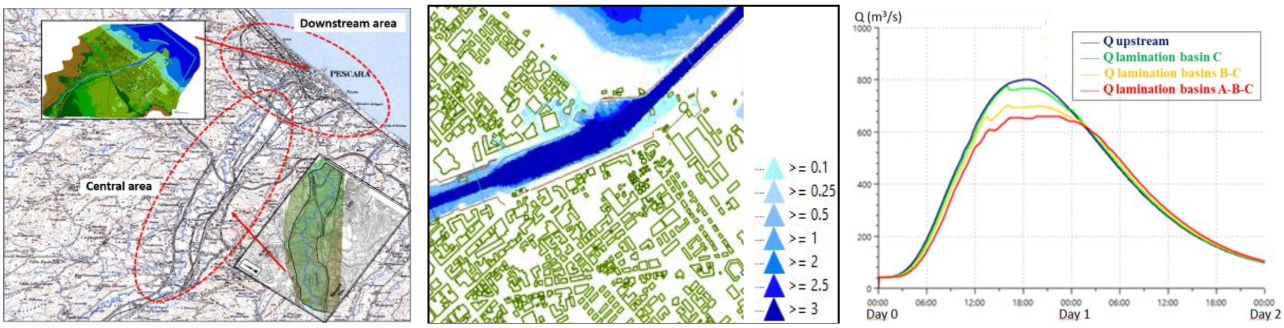
The 2D model was also used to assess the downstream effects of the retention basins, in order to evaluate and compare the flooding effects on the territory, before (present state) and after (design state) the construction of the retention basins. More in detail, the overall extension of the 2D-modelled river stretch was 25 km (i.e., from downstream the basins to the river mouth, see Fig. 3a), covering a flood prone area of 3.430 ha; the simulations included flooding scenarios and effects related to return time of 50, 100 and 200 years. It is important to highlight that the 2D hydraulic model was calibrated using the December 2013 flood event (Fig. 3b). The design and hydraulic validation of the retention basins and the ancillary hydraulic works were carried out using the same 2D hydraulic model.

## 4. Results and Discussions

*4.1 Hydraulic Effects of the Retention Basins*

The 2D hydraulic model Infoworks ICM allowed to evaluate the hydraulic performance of the retention basins guiding the design of their main characteristics: volumes, dimensions of the intakes and outlets, level of the spillways, etc. Moreover, the model was used to calculate the flood hydrograms downstream the basins thus evaluating the efficiency of the flood prevention measure (Fig. 3c, Table 2).

The comparison between the flood hydrograms of present and design state at a reference river section called S. Teresa (upstream of Pescara town) has showed a flood peak ($Q_p$) reduction equal to 15%, both for RT50 and for RT100 (Fig. 4a). The hydraulic model results showed a decrease of the extent of the high and very high hydraulic hazard areas for the whole territory affected by hydraulic risk at present state (Fig. 5a, 5b). The most significant results in terms of decrease of hydraulic hazard (and so of the flooding areas) occurred into the town of Pescara, a long way downstream of the retention basins (Fig. 4b, Table 3).




(a)

**Fig. 3 Pescara river: (a) study area with indication of the river reach modelled; (b) flooding event of December 2013: results of the hydraulic model (maximum hydraulic levels) at the river mouth; (c) hydrograms for RT50 in different sections of the Pescara river: upstream the basins (blue), downstream the basin C (green), downstream the basins Bsx and Bdx (yellow) and downstream the basins Adx and Asx (red).**

**Table 2 Peak value of water flow ($Q_p$):present vs. design state and lamination efficiency.**

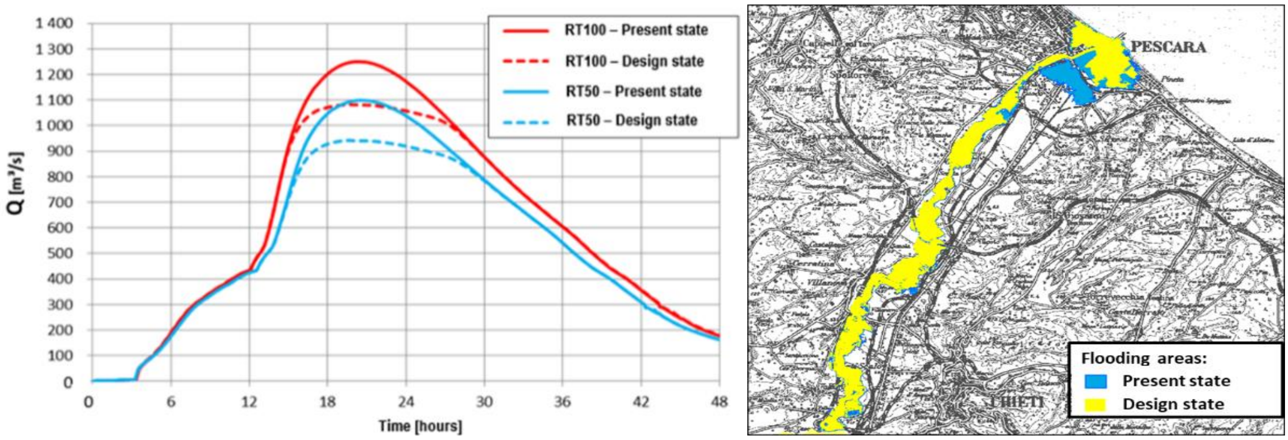
| Return time RT [years] | Peak discharge $Q_p$ [m$^3$/s] | | Efficiency [%] |
|---|---|---|---|
| | Present state | Design state | |
| 50 | 804 | 636 | 21 |
| 100 | 958 | 779 | 19 |
| 200 | 1112 | 923 | 17 |

**Table 3 Flooding areas extent for various RT at the two study areas shown in Fig 3a.**

| | Central and downstream areas | | | Downstream areas (Pescara town) | | |
|---|---|---|---|---|---|---|
| | RT50 | RT100 | RT200 | RT50 | RT 100 | RT 200 |
| **Present state [ha]** | 1353 | 1422 | 1502 | 494 | 527 | 578 |
| **Design state [ha]** | 1107 | 1227 | 1314 | 295 | 363 | 416 |
| **Difference [ha]** | 247 | 195 | 188 | 199 | 165 | 162 |
| **Difference [%]** | 18 | 14 | 13 | 40 | 31 | 18 |

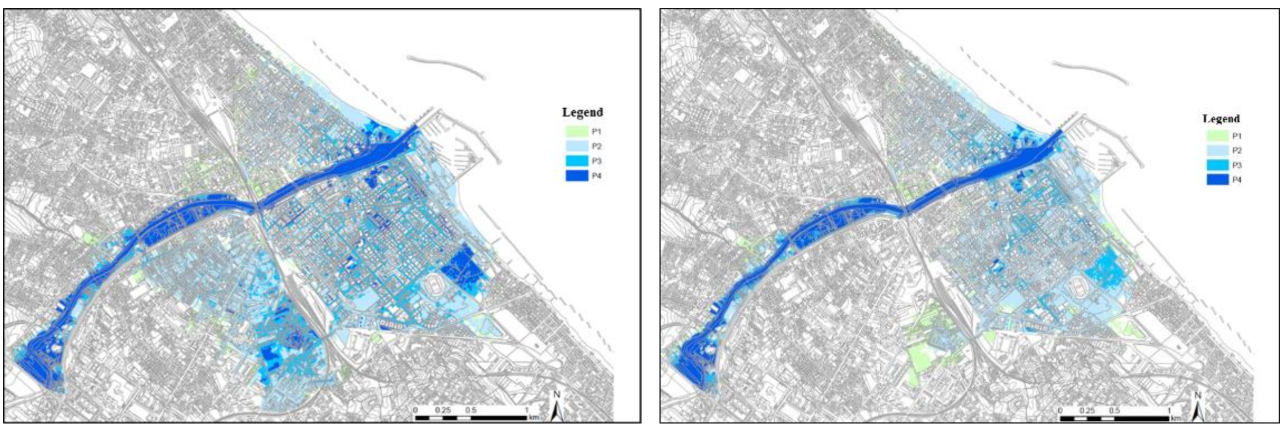
### *4.1 Socioeconomic Effects of the Retention Basins*

Several methods and parameters exist for flood damage assessment [7-9]. In this case the potential damage for the flood prone areas downstream the retention basins was carried out by analysing the risk level of the territory via the frequency of the expected floods, the potential damage (e.g., economic value) and the vulnerability of the assets for a specific flooding. The potential damage distribution is derived from land use. To each class of potential damage an economic value is assigned. The expected damage for a specific RT is obtained multiplying the potential damage for a coefficient (varying from 0 to 1) function of water height in the flooding areas. For the study areas the expected damage for RT200 is about €490.000.000 and about €279.000.000 at present and design state respectively, therefore with a reduction of 57%. In order to assess the retention basins benefit, the mean annual benefit is evaluated as the difference between present and design state mean annual damage. The mean annual damage is calculated as the area below the damage-probability curve (Fig. 6). The mean annual damage at present state is about €15.200.000, whereas at design state is about €7.100.000 (with a reduction of 53%), and the mean annual benefit is about €8.100.000. Other benefits (socio-economic) for the design state are evaluated through the estimate of other significant assets affected by flood through the following indicators: residents number (-36%), main infrastructure network length (-30%), urbanised areas (-34%), industrial and business areas (-12%), strategic buildings (-27%), historical and cultural assets (-46%).




(a) (b)

**Fig. 4 (a) Comparison between the flood hydrograms for RT50 and RT100 at river section S. Teresa; (b) flooding areas along Pescara river at present scenario (in blue) and at design scenario (in yellow, on top of the present flooding area).**




(a) (b)

**Fig. 5 Hydraulic hazard classes along the Pescara river stretch near the mouth (town of Pescara): (a) present state; (b) design state.**

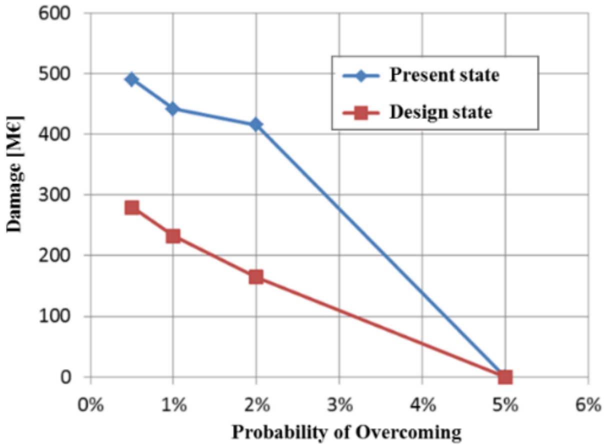



**Fig. 6 Cost-benefit analysis: damage-probability curves at present and design state.**

## 5. Conclusions

The paper at hand aims to present the complex hydraulic system of the retention basins of the Pescara river (Italy) being designed to reduce the existing flood risk in particular at the town of Pescara.

This system is composed by five retention basins with a total stored water volume equal to 5.220.000 $m^3$, located about 25 km upstream the town of Pescara.

The benefits of this lamination system are very important for the town of Pescara. In fact, with the designed retention basins, there is a reduction of the flooding areas up to 25% compare to present state, with a reduction of the mean annual damage of 53%.

The importance and necessity of these retention basins for the whole territory and community of Pescara town are proven by the significant amount of the overall cost of about €54.800.000, at which the Italian Central Government also contributes, in order to build this flood prevention measure.

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