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Water is Not Flowing Wireless, Even in Smart Tunnels: Addressing Critical Issues for the New Stormwater and Wastewater Network in L'Aquila (Italy)

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Abstract. As a consequence of the earthquake that struck L'Aquila (central Italy) on April 2009, the city is undergoing a complex process of reconstruction, not only aimed at the physical rehabilitation of the buildings, but also at the modernization and improvement of the utilities for an enhanced resilience and sustainability, towards the creation of a Smart City. The design of the *Smart Tunnel*, extending over the historical center of L'Aquila, has translated this new vision into reality. The basic idea behind the project is to collect and integrate the critical services in an underground concrete tunnel, in order to protect them from external threats and make them easily accessible and repairable, in case of disasters and/or for ordinary maintenance. This paper discusses critical hydraulic issues in the original project of the *Smart Tunnel*, highlighting that, for stormwater and wastewater networks, the adoption of a local design approach, without an appropriate consideration of external boundary conditions, could lead to ineffective solutions, because “water is not flowing wireless” even in *Smart Tunnels*.

1. Introduction: Post-earthquake Reconstruction in L'Aquila and the New *Smart Tunnel*

On April 6, 2009 a magnitude 6.3 earthquake struck the medieval city of L'Aquila and the Aterno Valley (central Italy), causing 308 deaths and 1500 injuries, leaving about 67500 people homeless [1]. More than 60000 buildings were damaged, including churches and historical structures. The whole historic city center was evacuated and isolated, with restricted access to registered individuals and groups escorted by firefighters.

The required post-event reconstruction transformed the entire city center into a single large construction site, thus laying the foundation for an unprecedented opportunity of innovation, consisting in the conversion of L'Aquila into a Smart City [2-4]. Besides specific opportunities for technological development, such as the implementation of pre-commercial experiments on the 5G network and the INCIPICT project, for the development of solutions oriented to a living laboratory for smart city applications [5,6], the reconstruction phase involved the creation of a new *Smart Tunnel*, which is aimed at optimizing and improving the management of the underground utilities of the city. The work, which is the largest public intervention of the post-earthquake reconstruction of L'Aquila, with a total expenditure of 80 Million EUR, was funded by Decree of the Special Commissioner for Reconstruction (n. 24/24.10.2010) and CIPE (Italian Committee for Economic Programming) resolution n. 43/2012, with Gran Sasso Acqua S.p.A. as implementing entity.

The *Smart Tunnel* is an underground 2.10 m high and 1.50 m wide concrete walkable box, extending over 23.5 km of road network, suitable to accommodate the main services of the city, including: water



supply, sewerage, electricity, communication services as well as remote control systems (Figure 1). The gas distribution and the urban drainage system are not installed inside the box, due to obvious safety reasons for the first and to space constraints for the second. Concerning the drainage system, a concrete culvert (0.35 m wide and 0.38 m high, with semi-circular bottom) on the top of the tunnel collects the rainwater from the streets and then conveys it into main pipes if bigger cross-sections are required. The utilities are located in specific spaces inside the tunnel, with compartments allowing users' connection to the different systems. The realization of such a complex technological project in an established urban environment requires the cooperation of many different managing bodies, since it involves the solution of numerous critical issues, like, for instance, the modification of the routes of existing networks into a single one or the implementation of temporary by-passes during the construction phases to guarantee the service continuity in the sections affected by the passage of the tunnel. It is clear that this system, compared to the traditional one, can guarantee an easier maintenance and therefore the reduction of related management costs, with almost no impact on vehicular traffic, since no excavations are needed in case of breakdowns or maintenance of the networks.

The implementation of the project has been essentially divided into two main working areas (Figure 2): (i) the first, covering the so-called "Asse Centrale", is currently almost completed; (ii) the second, including the areas of San Pietro, San Marciano, Villa Comunale, Via Strinella, Via della Croce Rossa, has not been entirely designed yet. The works are concentrated almost entirely inside the ancient walls of L'Aquila (i.e. covering only a small portion of the total networks of the city) and then, as for other aspects of the reconstruction process [2, 7], the *Smart Tunnel* seems to have been conceived as an independent and isolated item. In the present paper, based on the consideration that "water is not flowing wireless", we critically discuss ignored issues in the design of the new stormwater and wastewater networks in L'Aquila, in order to highlight how a myopic design could lead to ineffective solutions: can a project of a complex system, based on such a local approach, be considered a wise decision?

2. The Existing Stormwater and Sewerage System in L'Aquila and Compatibility Issues with the *Smart Tunnel*

The very first sewerage network of L'Aquila dates back to the XIV century and consisted of a single outfall. Over the years, and especially in the post-World War II period, the city, bounded to the south by the Aterno river, experienced a significant urban growth in its northern areas, from east to west, with the construction of new districts up to the edge of the mountains [8].



Figure 1. The Smart Tunnel under construction (left); view from inside the tunnel, with installed wastewater and water supply pipes (center); the top channel for the collection of rainwater (right).

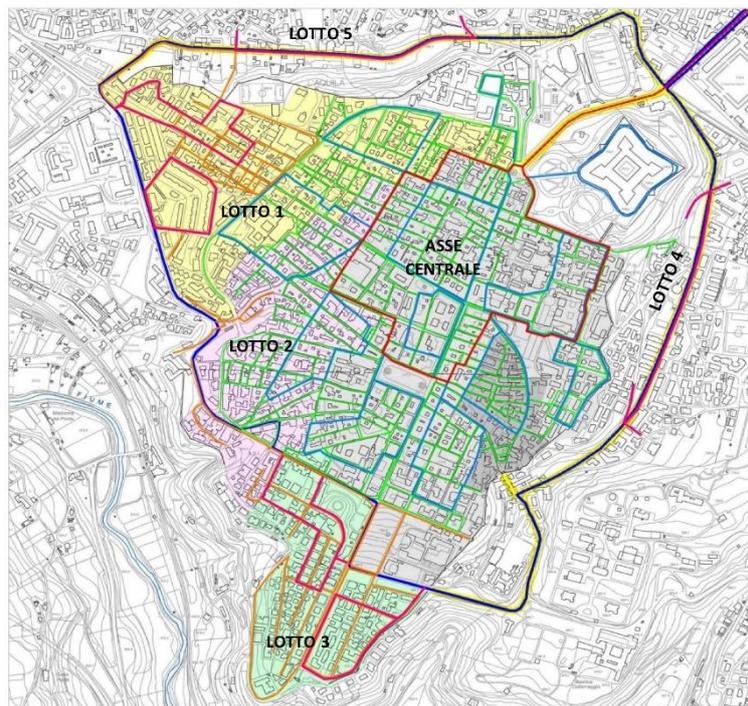


Figure 2. Identification of the main areas for the *Smart Tunnel* project: San Pietro (Lotto 1), San Marciano (Lotto 2), Villa Comunale (Lotto 3), Via Strinella (Lotto 4), Via della Croce Rossa (Lotto 5).

In the 1970s the drainage system of the city was adapted to the new developed urban asset, by implementing a combined sewer system with two main outlets, located on the east and west sides of the city; a wastewater channel conveys collected sewage from six overflow devices to two treatments plants. Figure 3 (left) shows the drainage areas contributing to the runoff to the Aterno river, with indication of the two main outlets; the different basins can be distinguished in “urban” (in black, within the historic city center; a zoom on this area is provided on the right panel of Figure 3), “sub-urban” (in red, including the more recently developed urban areas) and “mountain” basins. In detail, sub-basin A drains to the east outlet, while part of urban basins (E_3 and E_4 , Figure 3), mountain and the other two sub-urban basins (E_2 and E_1) drain to the west outlet.

Since the *Smart Tunnel* has been primarily designed to serve the historic center of L'Aquila, the new stormwater and wastewater networks are almost entirely confined within the ancient city walls, with only the two portions of Via Strinella and Via Della Croce Rossa outside of them (Figure 2). However, as pointed out in the Introduction, these kinds of systems cannot be designed as isolated objects, without taking into account actual boundary conditions and external constraints. Unfortunately, the original project of the *Smart Tunnel* is just an example of an unwise design. Indeed, as from project documentation, only the networks inside the city walls have been designed and verified, whilst the original sizes of the drainage pipes (as calculated in the project of the existing network, dated back to the 1970s) in Via Strinella and Via Della Croce Rossa have been, obscurely, considered to be sufficient to convey the 30-year return period design flows. However, as shown in a study by the Authors [9,10], the growing urbanization occurred over the last 50 years in suburban basins (E_2 , E_1 and A (Figure 3), drained to Via Strinella and Via Della Croce Rossa) has led to a substantial increase in the percentage of impervious areas, with a consequent impact on the hydrological response of the catchments to rainfall events, producing larger peak flow rates. While this increase in runoff coefficients does not affect the efficiency of the actual eastern outlet (Via Strinella), with the most critical hydraulic section able to discharge up to a 100-year return period flood, in the case of Via della Croce Rossa, the current size of the main drainage pipe is not adequate to convey the increased design flow [10].

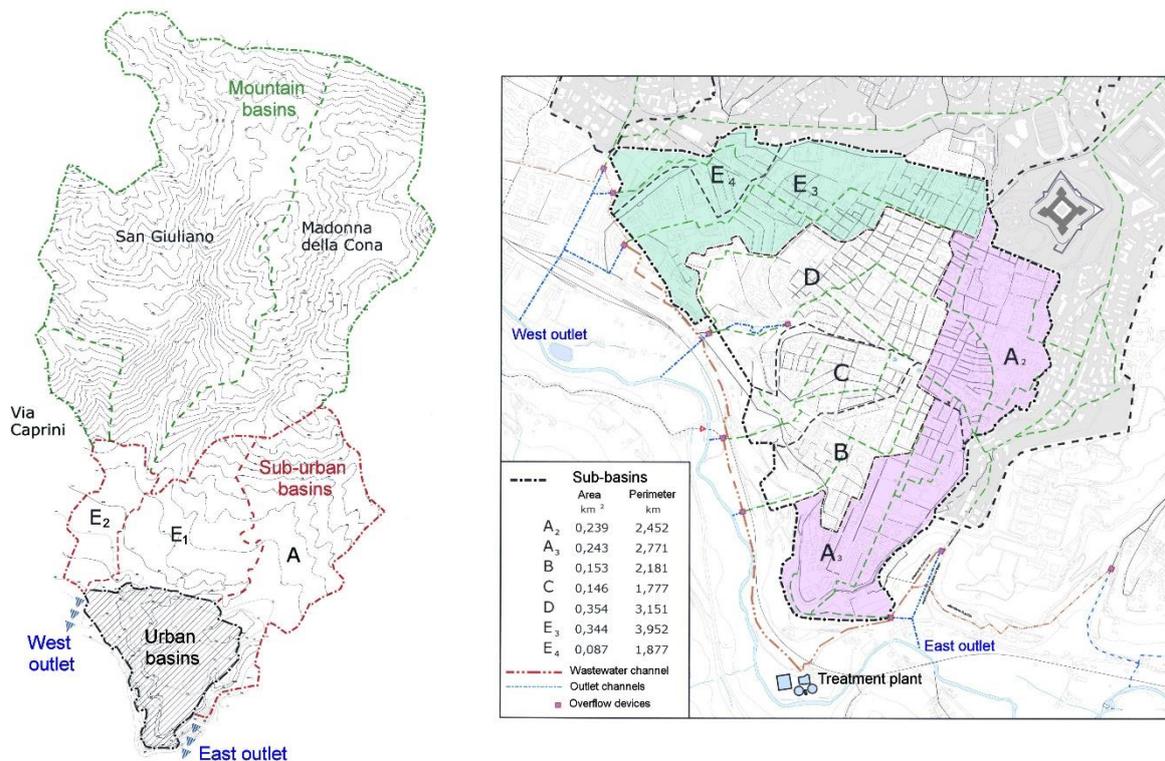


Figure 3. Identification of the main sub-basins in L'Aquila (left), with a zoom an urban ones (right).

Therefore, after these evaluations, it was suggested to reject the initial solution proposed in the preliminary draft of the project and amend it according to the current characteristics of the catchments.

But the most critical aspect of the entire project of the *Smart Tunnel* is probably related to the terminal reach of Via della Croce Rossa, which drains to the western outlet after receiving also the rainwater from San Pietro and (partly) San Marciano areas. The terminal section of the western outlet, draining an urban basin of about 220 hectares, has a current discharging capacity of about 6.7 m³/s, significantly lower than the estimated design flow of 13.8 m³/s. Therefore, given that “water is not flowing wireless”, the effectiveness of the planned stormwater system of the *Smart Tunnel* would be highly compromised without an adaptation of the existing external network.

On this point, an additional issue that has never been analyzed in previous projects of extension of the sewerage network in the 1970s, as well as in the original design of the *Smart Tunnel*, is the contribution of the “mountain” basins (Figure 3) to the drainage efficiency of the west outlet. Indeed, these basins, although being characterized by longer times of concentration and more permeable surfaces, could be potentially dangerous for the western outfall in case of intense rainfall events. In particular, the Authors [9] have proposed alternative interventions for the collection of the incoming stormwater, which can be achieved with an appropriate and shared municipal planning. A first solution consists in a cross section enlargement in the terminal reach of the western outfall; the actual feasibility is currently under investigation, after a detailed topographic survey of the *status quo* and an administrative check for solving bureaucratic issues. In case of a negative (administrative and/or technical) outcome, an alternative hypothesis is to lengthen the terminal reach until a new outlet point to the Aterno River, located slightly upstream from the original one.

Finally, we conclude with a comment on the adopted sewerage type in the project of the *Smart Tunnel*. This new sewerage network has been conceived as a separate system, differently from the combined system characterizing the whole historical network of L'Aquila. In general, from a technical point of view, there is no reason to prefer one system over another and then it would have been wiser for the designers to adopt also for the *Smart Tunnel* the combined type. Unfortunately this did not happen and

the conversion of the entire sewerage system would be now very expensive, even in sub-urban areas draining to Via Strinella and Via Della Croce Rossa, which will maintain a combined sewerage, while partly collecting the contribution of separate systems. For this reason, the construction of specific waste water separation devices was necessary at the confluence of the two different systems.

3. Conclusions

After the 2009 earthquake the city of L'Aquila has experienced extensive transformations, often unplanned, unassessed and produced through isolated and incoherent planning sessions [2, 7]. In this paper, we showed that the *Smart Tunnel* is not an exception to this "fragmented" approach for the reconstruction of the city, with a critical point represented by the stormwater and wastewater networks, which have been designed adopting a local focus, without taking into proper consideration the existing conditions outside of the area of intervention. For most of the utilities (e.g. water supply, electricity, communication services), this approach does not represent a major limitation, given that usually the operator and the users determine the network load, with the users being the end points of the path. Instead, as far as sewerage and stormwater systems are concerned, the user is an entry point in the network and receptors (treatment plants and final receiving water bodies) the end points. Therefore, for this kind of systems, boundary conditions and external constraints should have been carefully considered since the early design stages, in order to avoid the implementation of ineffective solutions and consequent waste of public money. In this study, we have then summarized the main criticalities and required additional project interventions outside of the main construction area in order to make the new *Smart Tunnel* in L'Aquila really effective.

Acknowledgments

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