For the conservation of Lorenzo Nottolini’s aqueduct in Lucca: survey and representation of historic infrastructure

FOR THE CONSERVATION OF LORENZO NOTTOLINI'S AQUEDUCT IN LUCCA: SURVEY AND REPRESENTATION OF HISTORIC INFRASTRUCTURE

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ABSTRACT

There has been a growing interest for some years about the territory and landscape survey and representation. It is impossible to reduce to geometrical data the elements that make up such multimatters systems because they are complex and changeable. It's necessary to find new parameters both to measure and describe the components of the natural environment - altimetrical variations, water, vegetation - as well as the artificial ones, that is the building environment. This paper illustrates some considerations deriving from the survey and the analysis of a complex system: the aqueduct commissioned to the architect Lorenzo Nottolini by Maria Luisa di Borbone in Lucca. It is a particularly interesting structure because it was built with the attempt not only to supply the necessary water to the town but also in order to decorate and to embellish it. The close relationship and interaction between natural elements and architectonic structures and this particular "territorial" scale of intervention made it necessary to prepare a detailed plan of survey but, above all, to have a new approach to the representation. The relevant area is surveyed in three dimensions; that is manufacturs are located in the three space coordinates and each of them is fixed according to the volume and in its main architectonic details. The result is that the model shows a perspective view, from any point in the space, the whole valley or part of it so that we can realize how complex the space is and be aware of its morphological and dimensional peculiarities. This formulation has a double aim: to represent the Upstream Works having at our disposal the dimensional and geometric information of the site; to create a complete support to the preservation state survey.

1. THE NINETEENTH-CENTURY AQUEDUCT OF LUCCA: PREAMBLE FOR THE CONSERVATION

The construction of the aqueduct of Lucca was realized in the first decades of XIX century (PACINI 1834) and has been checked from a technical and planning point of view since the half of XVIII century. The structure, realized between 1823 and 1832 from a plan by Lorenzo Nottolini, Regal architect, had an immediate critical fortune: in 1829, Tommaso Trenta and in 1843, Antonio Mazzarosa include it in the guides otof Lucca; in 1834, Giovanni Pacini consecrates the work in the *Storia degli Acquedotti lucchesi*, documenting problems and choices of its constructive story.
The nineteenth-century historiography besides makes use of a remarkable list of engravings and prints that visualize the various points of view of the aqueduct in the territory, focusing on perception the mutual relation between the dynamism of the water and the static of the structural conception; a sort of "hydraulic machine" showing a sequence of arcades delimited by circulars little temple which materialize the water's flowing.
In the iconography we can find the linearity of the structure developing along four kilometers, in constant downhill, shaping itself like a monumental screen crossing land divisions and boschive areas marking strongly the territory.
Contemporaries immediately acknowledge not only the useful function of this work, but above all the strong landscaped valence of a work to be promoted and preserved like a "monument" of modernity. And we can immediately realize how complex such work is.
A group of buildings with different connotation standing on an articulated territorial context:
459 round arches (5,17 m diameter), 460 rectangular plant pillars, in mixed masonry of stones and bricks row, 26 of which, with a cruciform plant, with function of buttress (characterize by numeration, in correspondence of the West sides, two circular

Figure 1. Lucca. Aqueduct. Sequence of arcades.

Figure 2. Lucca. Aqueduct. Circulars little temple - cistern.

Figure 3. Lucca. Aqueduct. Upstream works.
The paving depth of the river San Quirico.

Figure 4. Lucca. Aqueduct.
The duct on arcades delimited by two temples.

temple-cistern, entrance buildings to the sources, culverts, "serra vespaiata", embankments, galleries, water mains, stairs, paved way, bridge-canals, vegetation. Going back to the constructive steps, we can notice the dialectics of this plan compared with the naturalistic and monumental preexistence with full cultural awareness. Let's give an example: the interference with the urban walls, in the last strech, where the aqueduct intercepts the edge of the bastion of Saint Colombano and, through the ditch, arrives at the city by means of a forced duct (Cfr. ASLu, *Fondo Stampe*, 1222). Such solution, widly discussed in planning phase, derives from an evaluation that today we would define, "of environmental impact" because of the interference by the arcades with the fortified boundary wall, by now public park, thanks to the plans by Lorenzo Nottolini (GIUSTI, 2005). The comparison with the present state focuses the transformations of the surrounding area, that interact directly and indirectly with the historical structure, denouncing the inability of the contemporaries to manage the complexity of this system. We are talking about new constructions, transfiguration of preexistence, construction of an highway that in 1933 caused the demolition of two arcades and one pillar, interrupting the continuity of the structure, flight from the territory and insertion of new functions, obsolescence of the system, with the consequent interruption of the maintenance works, that guaranteed its survival.

Aiming to plan government instruments, suitable to guarantee the conservation of the system aqueduct-landscape, we can prefigure a subdivision in different areas, functional to the relations that the aqueduct is going to establish with various landscape typologies: orography of the mount, with forests, water paths, ways, the cultivated land with the rural built up and the industrial urbanization, the fortified town-walls of the city. Such subdivision is meant to locate homogenous ensembles, finalized to an analytical deepening of the components, both natural and artificial, and to locate the characters determining various levels of criticality of the structure and its surrounding landscape.

More precisely:

1. the works of water (Upstream Works);
2. the duct on arcades delimited by two temples;
3. the forced culvert with the city fontanas.

The cognitive picture of all the components of the mainly aqueduct system and of their preservation state, presents a differentiated phenomenology of decay in correspondence of the extreme poles, with prevailing anthropic damages towards the city, deriving from the railway and the road network and from the process of urban migration that involved the loss of the landscape identity of the structure; while Upstream works show a widespread decay caused by the obsolescence, neglect, lack of maintenance of the architectonic and naturalistic elements.

The result was the processing of analytics cards of each building, whose computerization enables to enrich the information, including variables about the single areas. Such survey must be led back to an organic vision of the questions, open and updating, able to interconnect the single questions with the unit of the system. The various survey steps, in the same way, as we'll see later, were meant to visualize dynamics of the infrastructural of the course, in a syntagmatic restitution, that gets the functional-perspective consequentiality of the various elements.

1.1 Upstream Works

The first step of the search focused on the complexity of the Upstream Works, the functional apex of the aqueduct concentrated in the area of the sources, named "Parole d'oro" (from the commemorative registration in bronze, set on the parapet of the bridge), where are situated the works of collecting, purification and optimization of the regime of the rainwaters coming from the mount. The area is characterized by a series of architectonic and naturalistic elements: the winding sign of the San Quirico river in the furrow of a tightened valley delimited by the forest, the culvert of inspection and of settling, along the course, the buildings that characterize the 18 sources, some of which subsequently connected (the source n.8, in 1852; n. the 18, to the beginning of the past century), the "Serra vespaiata", situated at the confluence of the two paved brooks, to filter and canalize the "luxury waters" that had to feed the city monumental Fontanas.

Each work is meant to get a wide and constant fruition of the water (the same water of the river surface, destined to feeding the Fontanas, was canalized in underground and submitted to filtering, in order to prevent the contamination with meteoric waters, rendering it drinkable under necessity).

To the same purpose also the depth of the river is covered by paving like a street and contained within containments covered with the same local stone (of Guamo), that receiving by side the steps where there are level gabs.

The concave conformation towards valley of the various level plans carries out more functions: it optimizes the control of the push of the land, it increases the settling ability, it takes advantage of the interstices of the wall in order to insert access stairs to the river bed.

Figure 5. Lucca. Aqueduct.
3D model of the Upstream Works.

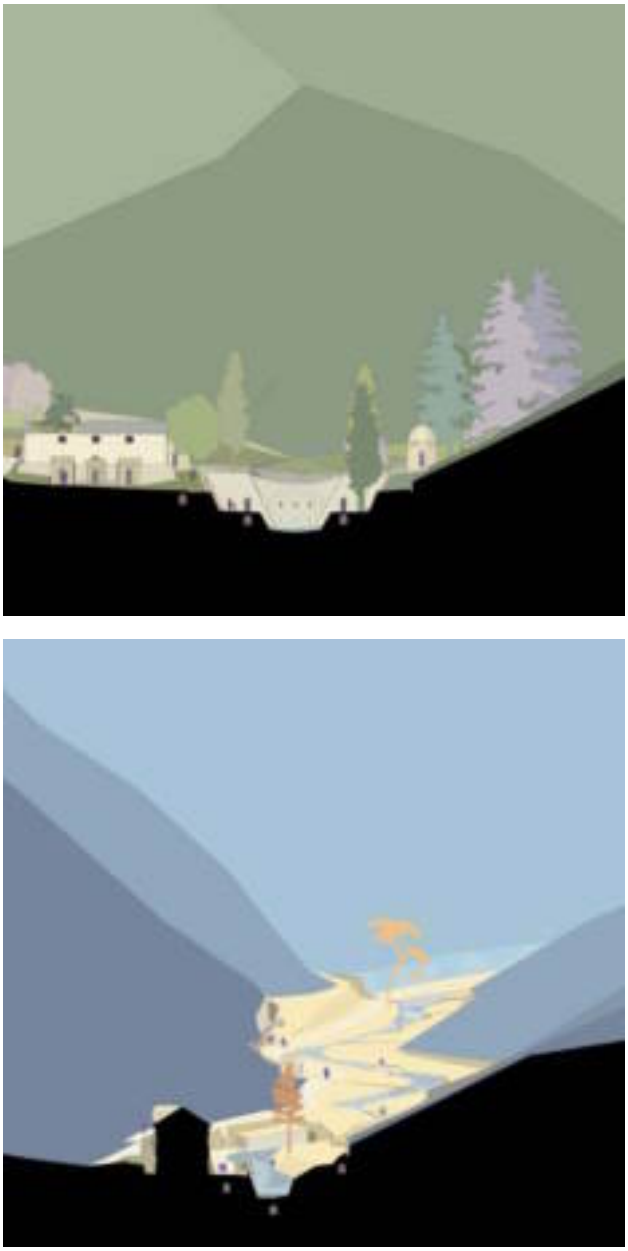

Figure 6, 7. Lucca. Aqueduct. Cross-sections of the 3D model: near the "Serra Vespaiata (top) and near the "Casa del Fontaniere" (bottom).

On both sides, a series of small neo-gothic buildings characterize and protect the access to the sources.
Therefore A "machine" planned according to the details of the complex gear, made of different materials, whose conservation is made by direct intervention on the structures (restoration of the buildings, improvement of the collection works and treatment of waters, arboreal integrations in order to complete perspective lines and to reorder the points of view) and on the landscape, characterized by the hill mostly covered by mixed forest, terracings planted with olives and vines, courses of lanes.
Their preservation is fundamental to maintain the idro-geologic equilibrium (the vegetation as floating stock for the meteoric waters and protection from upheaval and erosive phenomena), ecological (powder absorption), structural and aesthetic of the entire system, and is guaranteed by a constant and aware maintenance, that can be managed thanks to the interactive flexibility of the instruments of knowledge.

2. REPRESENTATION OF COMPLEX SYSTEMS

It is impossible to reduce to geometrical data the elements that make up such multimatters systems because they are complex and changeable. It's necessary to find new parameters both to measure and describe the components of the natural environment - altimetrical variations, water, vegetation - as well as the artificial ones, that is the building environment. Gibson, in his *The Ecological Approch to Visual Perception* (Boston 1979), expressed his theory about the importance of finding out and use of parameters typical of a natual view, which is not only instant, but environmental too - looking around in a scenary - and wandering - walking through the country. It's an attempt to go beyond the mere search of data - which nowadays is widely supported by topographic instruments - and to be able again to convey the sensation related to the fragrance of a specific environment's perceptive experience. All that according to an

Figure 8. Lucca. Aqueduct.
Cross-section of the 3D model near the area of the sources.

approach aiming to revalue the original valencies of a "pre-scientific" graphic representation and therefore able to direct the attention towards the multidimensional sensations conveyed by the territory. The main problem doesn't consist in fact in the most suitable topographic accuracy, but on the possibility of finding out a kind of representation responding to precision demands as well as to convey the sensations you feel while gazing round or walking in order to express the multidisciplinar peculiarity of one another.
The focus on the sight perception, with variables not easy to be quantified, gave a strong helping - hand to go beyond the rigid systems of the cartographical representation.
The landscape representation of spatial continuity of the research object (that is the third dimension too) has been a clear will ever since. In this concern let's take into consideration the following items: subsidiary projection plans to enlarge the point of view and to increase communication; the co-existence of vertical, horizontal and perspective projections in the Renaissance cartography; the creation of a new method turning over the horizontal representation of Egyptian gardens to summarize in only one pseudo-planimetric diagram also the information concerning the front-view. Joining the geometric accuracy of the cartographic description to the semantic wealth of the perspective views we arrived, step by step, to different solutions.
The time variable is another element contributing to the characterization of the landscape as a complex system both natural and build. The structure and the vegetation have different time scale: the first is mostly subject to very slow variations, while the second one changes according to season and climate variations showing ever new pictures. The fourth dimension is fundamental both as regards the status and the updating, monitoring and check operations of the changes impact. The landscape analysis involves therefore a wide range of aspects pointing out a critical system focused on the landscape qualities. Therefore we realized we need thematic representations for each information standard by reading transformations and permanences; from the basic standard, resulting from the geometric topographic rationalization, to the most elusive perceptive aspects (colour, texture, light). The means at our disposal nowadays to survey the environment and the territory bring the foundation of description closer and closer to those of perception. The survey disciplines (topography, photogrammetry, laser scanning, remote sensing...) must take into consideration images (now digital and coming from different sensors) that already used in the past to test perceptive valencies, make possible nowadays to go beyond the limits of the cartographic representation. A multisensor acquired knowledge is followed now by a multiresolution representation.

3. SURVEY AND REPRESENTATION OF A MASTER LANDSCAPE

The surveyed area is the whole share of the Upstream Works including the paved river from the Pioppino springs up to the Parole d'Oro bridge. It consists of about two hectares relevant to S. Quirico river in the flow distance where there is the function

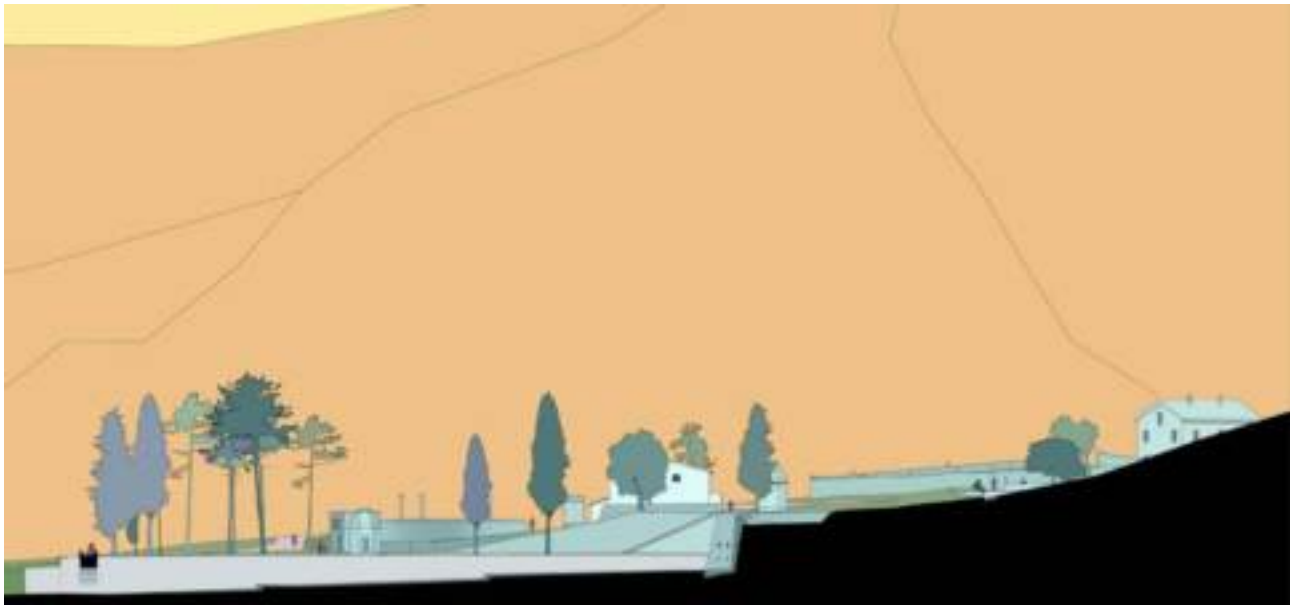

Figure 9. Lucca. Aqueduct. The Upstream Works. Longitudinal section of the 3D model.

and monumental heart of the intake, ducting and filtering of the water: a development of 650 meters. That space acquires the meaning thanks to the interaction of architectural interventions and spontaneus flora. The knowledge of the Upstream Works enables to establish the reference system from which derives the information meaning and the location which can bring out the limited size of the manufactures. It's therefore very important to reproduce also the environment where the works are, in order to represent both the physical aspect of architecture and its worth compared with the surrounding area.
The metric survey of the whole complex, planned on the scale of 1:200 is accompanied by an indexing of each manufacture carefully analysed from the point of view of its preservation.

3.1 A multiresolution approach

As regards the scale to be used in such analysis it ranges from the territorial to the architectonic one. That's why we must answer the different detail question as well the metric accuracy when representing the various components. As you know each cartography responds to a tolerance related to the nominal scale; therefore it's necessary to weigh carefully the work scale. When we gather the cartographic datus we cannot leave aside the scale, while we aren't so tightly bond to it when we manage the elements. As a consequence it's possible to separate the acquired knowledge accuracy from the representation scale involving information out of scale, too. The modern GIS problems lead to take into consideration elements with a geometrical valency more and more out of scale, that is determined by a metric reliable level independent of the nominal scale typical of the numerical basic cartography. If we use a scale as metric reference for every following operation based on it, we can make a more detailed analysis where we can better read even the functional model of buildings. The survey of this complex was planned according to a scale of 1:200; later we zoomed the architectonic structures also on a higher scale in order to study the preservation status and the main decay factors.

3.2 Three-dimensional representation

The topographic net made according to classical methodology presents 9 vertices, so that they can reach every architectonic structure allowing the survey of the paved river and 1649 points measured with a celerimetric method. In order to check the celerimetric measures some points have been taken by different vertices. In the meantime direct measures (distances) with triangulation method were carried out. According to that we were able to fix the architectonic volumes and the emergencies of the whole system. The relevant area is surveyed in three dimensions; that is manufacturs are located in the three space coordinates and each of them is fixed according to the volume and in its main architectonic details. The result is that the model shows a perspective view, from any point in the space, the whole valley or part of it so that we can realize how complex the space is and be aware of its morphological and dimensional peculiarities. This formulation has a double aim:
- to represent the Upstream Works having at our disposal the dimensional and geometric information of the site;
- to create a complete support to the preservation state survey.
In fact the primacy of geometry and of the measure does not complete the whole praxis of the survey. There are other measurable components: materials, patologies, colors, phisical and chimical phenomena in general, that need to be represented on the geometric base. To satisfy this second demand on a double level - landscape and architecture - we carried out the representation of the whole complex taking into consideration the over mentioned perspective rules and moreover we drew up analysis cards on a larger scale for each structure.

3.2 Some remarks about the landscape representation techniques

We obtained a three-dimensional landscape scale simplified model. But as everybody knows to simplify is typical of the operations using symbols and languages to describe different abstraction levels. If we develop fashionable but simplified models of reality in a formalized system, we are able to concentrate information to a swayed reading. There is a hierarchy of the information: the hills, simplified, are the background of this linear complex and are the reference system for the whole complex, while the single buildings and the whole infrastructure are emphasized by a higher detail level. Neither shadows nor shaded colours at all. It's neither a mimetic realistic model nor a symbolic one. Even the section used to represent the clearer passage towards the symbolic representation does never leave aside the perception of the spatial continuity. Beyond the section line you can constantly read the whole complex, while you keep feeling the surrounding masses evoking the location, even if represented by simple paintings without details. And the relation between the background and the black painting of the section, thanks to this sole system of graphic reference points out the different section portions recovering in a certain way the peculiarity of the natural view – immediate, environmental and walking. The vegetation represented as far as long-trunked trees near the surveyed structures are concerned and its only shown by silhouette (painting out the various species) with painting of the same kind, whose intensity decreases according to the distance of the observer's point of view.
The colour palettes are always full painting of the same kind suggesting the changing of season and of the light intensity during the day. In this way we can also perceive the time going by.
"Eastern people- Chines, Japanes and Persians - have studied and used such relations for centuries: in the gardens, in painting, in wall decorations, in the carpets (drawing and colours). We must admit our civilisation has still a lot to learn from those people, at least as far as aesthetic harmony is concerned (…). I think it would be good for us if we learnt and took their concepts". (Pietro Porcinai).

Figure 10. Lucca. Aqueduct.
Cross-section of the 3D model near the "Serra Vespaiata".

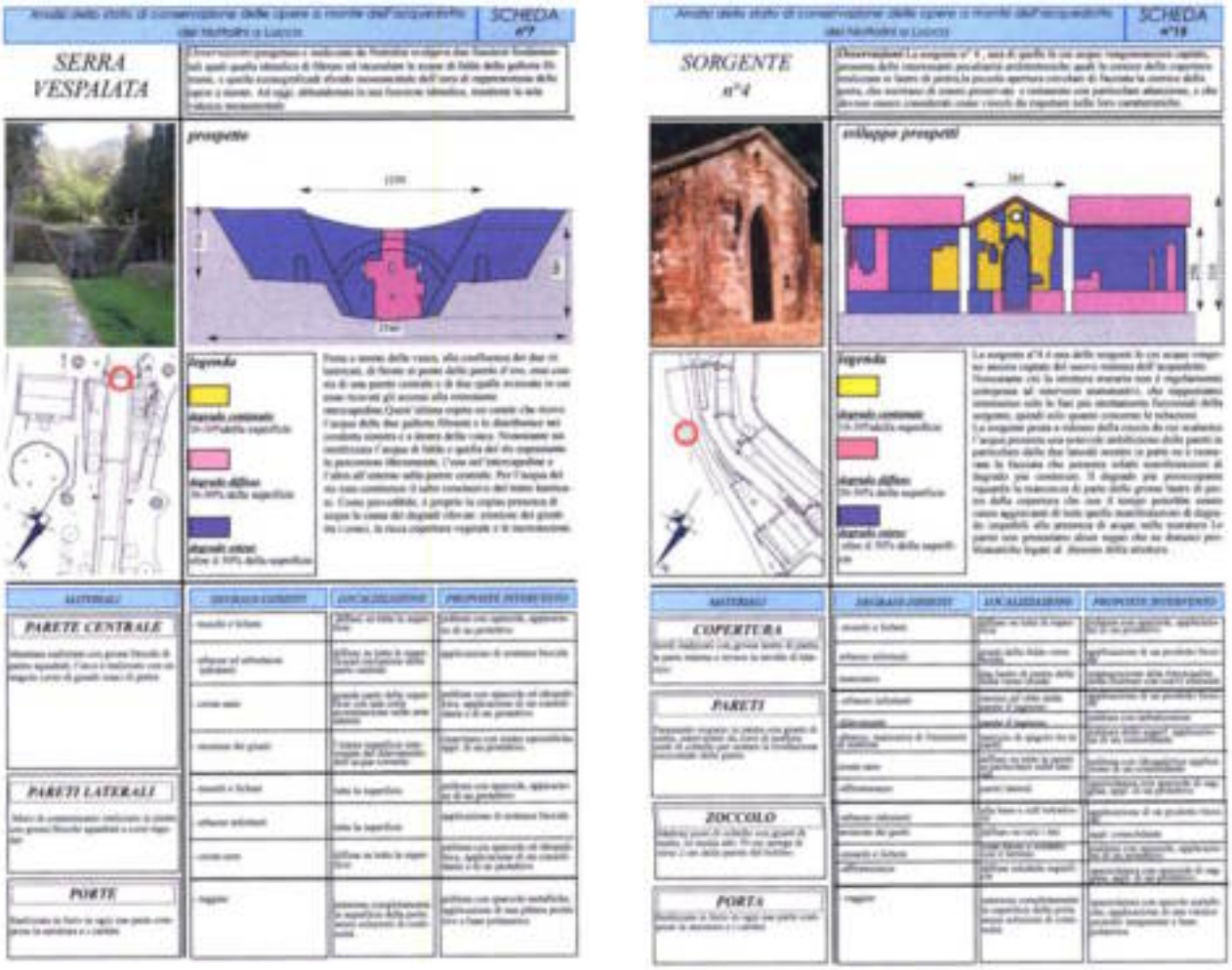

Figure 11. Lucca. Aqueduct. Upstream Works. Analysis of the buildings preservation state.

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* The published survey is taken from degree thesis mentioned in bibliography.