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Feasibility study on "tailor - made" SWMED solutions for the project target areas in Lazio

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1. Analysis and selection of the target areas

1.1 Summary

This document aims to present the feasibility study developed by Regione Lazio, IRIDRA with the support of the local partners (Municipality of Latina, Municipality of Norma and Acqualatina, the water manager of the Latina Province).

1.2 Criteria of Selection of the target area

Lazio Region, in central Italy, is a water rich area, thanks to the good quality of the waters coming from the nearby mountains of Abruzzo (the Region at the eastern border of Lazio). The northwestern part of the region is volcanic and rich of groundwater and lakes, while in the South, on Lepini Mountains feed a good quality acquifer that give life to springs in the alluvial plain of "Agro Pontino".

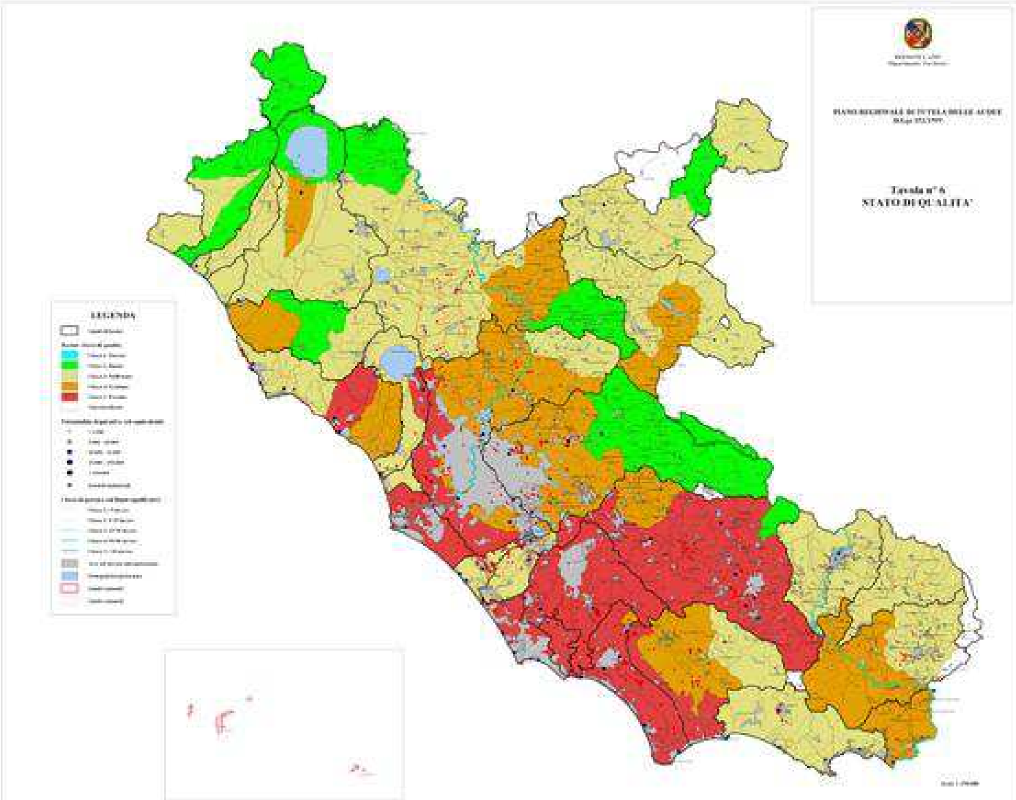
Nearly 600 millions of cubic meters are yearly distributed for urban uses in Lazio, most of them in the Province of Rome (see following table).

Lazio Provinces	Water distributed (thousands of m^3)	% of the Region	Water distributed procapite (l/inhab./day)
Viterbo	27.051	4,5	253,6
Rieti	18.984	3,2	345,4
Roma	440.396	73,9	316,1
Latina	62.449	10,5	335,4
Frosinone	46.987	7,9	260,6
Lazio	**595.867**	**100**	**310,1**
Central Italy	1.118.152	-	275
Italy	5.606.461	-	267,1

Table 1 Water consumption for urban/domestic use in Lazio Region (data from: Regional Environmental Agency, Report on the State of the Environment 2003)

In term of procapite consumption, however, the provinces of Rieti and Latina show higher rates compared to the average of the Region.

Surface water quality in the region is still far from good in most of the river basins, with rivers and canals in worst condition located mainly in the southern part of the Region (Province of Frosinone and Latina).



Picture 1 Surface water quality of Lazio basins: blue (very good), green (good), yellow (moderate), orange (poor), red (bad); major urban areas in grey (Source: Lazio Water Protection Plan 2006)

To select case study areas, the following criteria have been considered:

1. Representativeness of regional water problems (high consumption and surface water quality)
2. Representativeness of regional settlement typology
3. Interest to participate to the project by the representatives of the local communities

Based on the first 2 criteria 3 possible location have been identified:
Latina province, where problems of high consumption and water quality are both relevant, and settlement typologies are quite variable (urban context, small villages, spread urbanization);
Castelli Romani area: near Rome (south/east) characterized by a very spread urbanization and very high water consumption;
Fiano Romano: a medium/village representative of many similar settlement

From the fall 2012, the SWMED project management team of Lazio Region entered in contacts with representatives of these three areas. However the most fruitful contacts were built with the partners of Latina Province, that took part to the 1st water table, held in March 2013, and hosted and organized the II water table in October 2013. During the 2013 summer two pilot sites in Latina area were identified and the possibility of a feasibility study in Fiano Romano explored, trying to acquire data from the ACEA, the local water utility in charge with the water cycle management. After several months, due to the unavailability of basic data on water resources management, the pilot area of Fiano Romano was abandoned.
At the end of the process two pilot area have been identified, both in Latina Province: the Municipality of Norma and the coastal village of Borgo Sabotino, in the Municipality of Latina (see following map).

Picture 2 Location of the 2 case study area of the Lazio Region

1.3 Description of the sites

1.3.1 Norma

Norma is a small village of around 4200 inhabitants located at the top of a steep hill at the foot of Lepini mountains. Its territory is mainly impervious except for a few flat areas located to the south of the hill that hosts the urban centre.

Picture 3 The urban area of Norma

The water distribution system depends on a huge spring located at the very bottom of the hill, that gave life to the original river Nymphaeus. Nowadays most of the water coming from the Ninfa spring is withdrawn for potable use in the area of Latina. A small part of the flow is released locally to in the Ninfa garden, a very popular cultural site managed by the Caetani foundation.
Presently a flow of 18 litres per second coming from the Ninfa spring, is pumped up to the town of Norma to feed the local distribution network.

Picture 4 A picture of the river flowing through the Ninfa Garden (source: Roffredo Caetani foundation)

Considering a population of 4200 inhabitant, a flow of 18 l/s corresponds to 370 litres/inhabitant per day, a quite huge allowance for a such small town, with very few non domestic users. One of the issues to be considered by the present study is, therefore, a more rational water distribution and use. Due to lack of affordable data on water consumption of local households, is not clear if such a large pro-capite water allowance is due to leakages in the distribution network or to excessive water use. According to some interviews made with the representatives of Latina's Municipality both aspects were in need to be improved.

The town of Norma, due to its morphology, is also affected by road flooding, during heavy rains: another issue to be considered by the study is the urban runoff management.

1.3.2 Latina – Borgo Sabotino

Borgo Sabotino is a neighbourhood of the Municipality of Latina located along the sea, south west of the Latina urban center. Originally was one of the several small rural villages built immediately after the reclamation of the "agro pontino" operated by the Italian government in 1929.

Picture 5 location (left) and satellite immane (right) of Borgo Sabotino

Picture 6 Borgo Sabotino: the center

The settlement is formed by a more densely populated center, with buildings that can reach 4 or 5 stores. Tens of other settlements have been built at the end of XX century without an urban plan, sometimes illegally, giving place to a urban sprawl, of building with 1 or 2 stores and a small gardens. The present population of Borgo Sabotino is estimated to reach 15.000 inhabitants during high tourist season, when also vacation homes are inhabited.

The whole neighborhood is served by the public aqueduct while the existing sewage network serves only the main settlements (the center, the more dense coastal settlement and a few other areas). According to the data provided by Acqualatina (the water management body) the average procapite consumption is not very high (around 120 l/inhabitant per day). In Borgo Sabotino, as in most part of the Latina Province, there's a problem of water losses in the distribution network, but is very difficult to study the problem and propose the ad-hoc solutions, due to the lack of reliable data on the difference between input flow in the network and flow delivered for consumption. An affordable map of the distribution network in Borgo Sabotino is also missing. That's why water losses issue will not be considered in the case study analysis of Borgo Sabotino, as it is for the Norma case study.
The other major problem of water management in Borgo Sabotino concerns the wastewater treatment: presently around 5000 inhabitants are not linked to the existing sewage network. Acqualatina plan to enlarge the existing sewage network to collect all the population, however, due to the scattered urbanization, the extension of the sewers it's not neither easy nor cheap.

The SWMED feasibility study, therefore, will focus on alternative solutions for the decentralized wastewater treatment in order to verify if these could allow a more sustainable approach.

2. Draft feasibility evaluations

During the 2013 summer several meetings have been organized by the SWMED project management team of Lazio Region and the IRIDRA technical staff with the representatives of the Municipalities of Norma and Latina and the professionals working in these two local authorities. According to the analysis of data collected and the needs emerged during these meetings some issues appear to be of general interest for the whole Latina area:

- Reduction of water losses in the distribution network
- Reduction of water consumption by the final users (pilot area of Norma, but also other small centres)

Other issues to be addressed (interesting for at least one of the pilot areas) are:

- Collection and reuse of rainwater
- More sustainable urban drainage systems
- Decentralized wastewater system through constructed wetlands

Here below there's a brief list of the possible tools suitable for the Latina area and the related cases studies, with some essential explanation and clarifications in order to understand better the selection of the various tools in the proposed alternatives.

Solutions to reduce water losses: pressure management techniques in the distribution network
A water distribution system is not only infrastructure (pipe, plants, buildings, tanks, valves), but also a set of operational rules. These criteria are needed to supply appropriate quantity (in terms of pressure and flow) of good water (in terms of quality). They are based on the experience of the system manager and on data coming from the monitoring of the distribution system. That is why the installation of automatic Supervisory Control and Data Acquisition systems plays an important role in defining operational rules to decrease water and energy use and to apply leakage reduction strategies.

Technologies of pressure control permits to recover water resources and, consequently, the energy resource, while at the same time, to ensure a satisfactory water service (in terms of quantity and quality). Moreover, by reducing pressure in the distribution system it is possible to decrease the amount of water losses due to the physical defects of the network. If the network doesn't work entirely by gravity, the pressure control must be carried out starting by the water inlet points.
Most common technologies are *variable speed pumps*, *pressure reducing valves* and *turbines*.
Under favourable conditions, *variable speed pumps* (pumps equipped with an inverter able to change the speed of the pump) can provide significant benefits in terms of water and energy savings (Figure 11a).
The typical outline of a pressure controlled distribution network with constant setting, consists of a *Pressure Reducing Valve* (PRV) at the water inlet that transform the variable pressure upstream the valve in a constant pressure downstream (Figure 11b).

Figure 1 Supervisory Control and Data Acquisition systems of HERA S.p.A. (Italy)

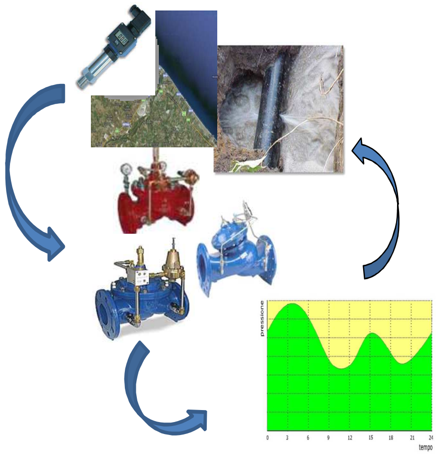
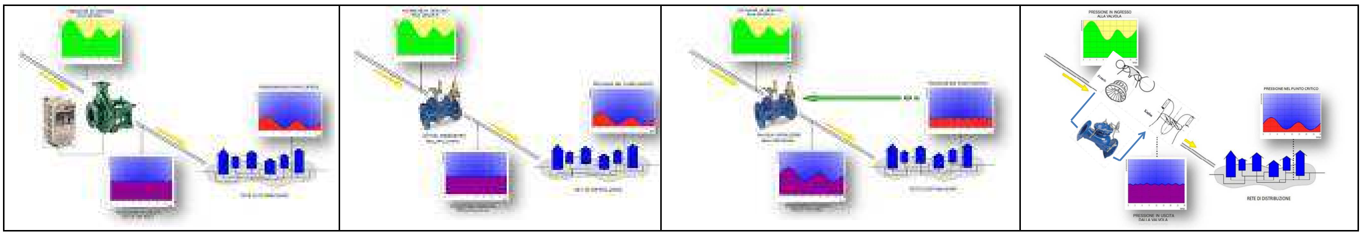


Figure 2 Technologies of pressure control allow to recovery water resources and thus, energy resource

In the case of PRV with remote controller, the point of control of the PRV is different from the point of positioning of the valve and it is precisely the critical point of the network (Figure 11c). This kind of control allows the best performance in terms of water volume savings.



(a) (b) (c) (d)

Figure 3 **Pressure control by means: (a) variable-speed pumps; (b) pressure reducing valve with constant setting; (c) remote control of pressure reducing valve with constant setting at critical point; (d) installation of micro-turbines or Pumps as Turbine**

Where the necessary operational conditions exist, the pressure control can be achieved using *microturbines* or *Pumps operating as Turbine* (PAT) (Figure 11d). In fact, they dissipate the excess hydraulic head, while a turbine\PAT is able to recover part of the available hydraulic pressure energy. The use of microturbines allows the production of renewable energy while reducing pressure, but the complexity of the system increases and it requires a very careful management and maintenance.

Solutions to reduce water losses: innovative technology to fix leaking pipes

LEAKCURE is a project co-funded by the European Union within the CIP Eco-Innovation initiative of the Competitiveness and Innovation Framework. It aims at the market uptake of a trenchless method of repairing small water pipes leakages with trenchless technology and without previous detection. It is run by a company that developed *curapipe* , an innovative Trenchless Automated Leakage Repair (TALR) that repairs leaky holes and cracks in urban water pipes that normally remain undetected by existing detection technologies. With TALR, water utilities can dramatically reduce leakage in urban water distribution networks with minimal disruption. Curapipe's TALR solution is a low-cost alternative to water mains renewal that can be rapidly deployed. This technology does not require leakage detection or location, it self-penetrates the leakage to seal and permanently cure it.

The TARL procedure is as follows:

1. Launch a pig train into an isolated prepped distribution mains from an assembly fixed to an upstream fire hydrant or hot tap.
2. The train contains a "compartment" of special viscous curing substances lodged between the pigs.
3. The substances operating under pressure, penetrate leaky joints, fittings & service connections and plug the leaks.
4. Pig train is extracted through a downstream fire hydrant.
5. Substance hardens and leaks are permanently cured

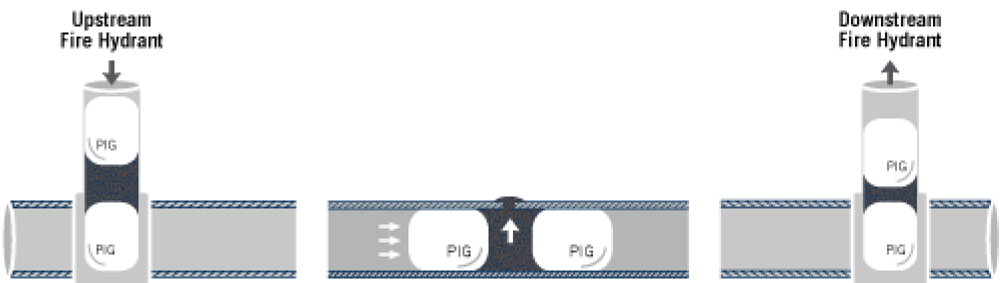


Figure 4 **Representation of the curapipe technology application (picture taken from the Leakcure project www.curapipe.com)**

Water Saving devices

A wide range of fittings and equipment able to reduce water consumption is available on the market. Most effective products are taps aerators and low flow shower-heads. Among the different tap types there are lever taps, taps with timers with electronic shutoff, etc. There are also devices which can be adapted for different tap systems like reduced flow, and Tap aerator. Many models of new taps have these devices already incorporated. In addition, these devices are almost always compatible with each other. You can find mixer taps that have a built-in aerator.

	Savings for supply point
Flow restrictors	30-40%
Tap aerator	30-70%
Water pressure limiter	10-40%
Water saving showers	50%
Mixer taps	30-40%
Automatic taps	30-40%
Electronic taps	40-50%
Thermostatic taps	50%

The flush toilet can be adapted in order to use significantly less water than a full-flush toilet. Low-flush toilets use a special design of the cistern and the siphon in order to allow the removal of faeces and excreta with less water. Most often, they also include a dual flush system, with one flush being designed for urine only, using even less water than the other designed for faeces. Today, there exist many suppliers of different models of low-flush toilets all over the world.

In some case, a low cost intervention, compared to the substitution of the WC cassette, could be considered: the introduction of 1 or 2-litre toilet tank bag in the flushing will ensure the use of a lower volume of water with each flush. These too can be considered as soft measures, which however require the effective engagement of the eventual user to ensure that they are effectively installed in the flushings.

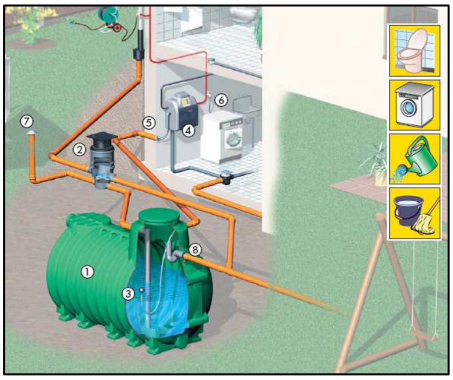
Rainwater Harvesting

Among non conventional resources, the harvesting of rainwater (RWH) is one of the most promising solutions, due to the high quality of rainwater , that allow its safe use for several purposes, and to the positive “side effects” that a diffusion of rainwater harvesting could bring for the overall urban water management. RWH for domestic consumption requires quite simple technologies, it can be done easily, doesn’t cost much and is applicable at small-scale with a minimum of specific expertise or knowledge; or in more sophisticated systems at large-scale (e.g. a whole housing area). Rainwater is collected on the roof and transported with gutters to a storage reservoir, where it is either used for groundwater recharge or provides water at the point of consumption. The rainwater harvesting can supplement water sources when they become scarce or are of low quality like brackish groundwater or polluted surface water in the rainy season. However, rainwater quality may be affected by air pollution, animal or bird droppings, insects, dirt and organic matter. Therefore the regular maintenance (cleaning, repairs, etc.) as well as a filtration treatment before water consumption are very important.

The main components of a system for rainwater harvesting are:

• The collecting surface: only connect suitable roof surfaces if the system does not include a treatment. Take into consideration possible erosion of hazardous matter from the roof. With an appropriate treatment water from pavements can also be used.
• Gutters and downspouts (gullies and rainwater drains)
• Filter – mechanical or natural (as raingarden)
• Tank below ground
• A distribution system for reuse in irrigation or for WC flush

The treatment could be a simple mechanical filter; there are several models on the market, generally they are very simple and permit a basic filtration, due to the presence of mesh grid and/or exploiting forced hydraulic patterns to separate the coarse solids from the water. Generally the models on the market can cover roof surface until 3-400 m^2.

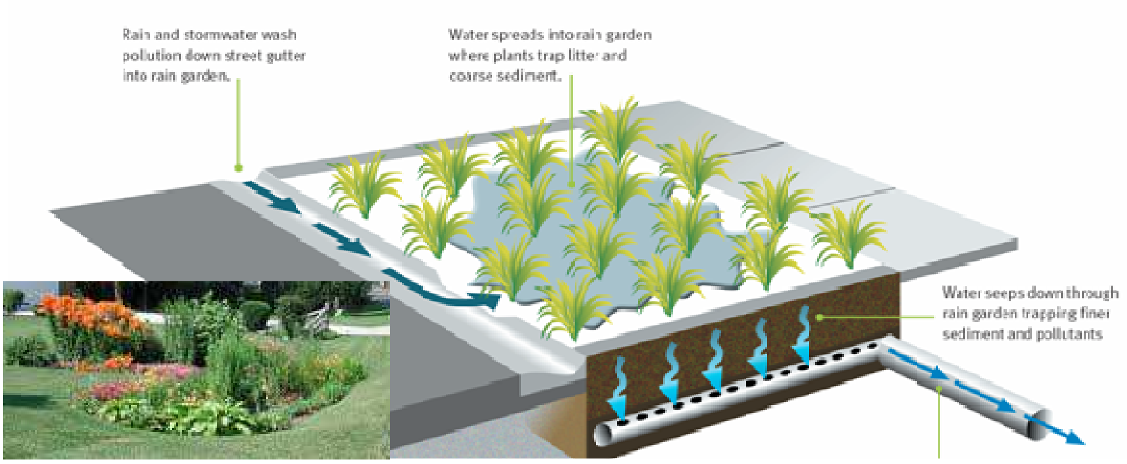


1) tank
2) stormwater mechanical filter
3) suction pipe with floating filter
4) control panel and external pump for reuse
5) dual network for WC
6) emergency connection to potable network in case of empty tank
7) emergency overflow with check valve connected to stormwater network
8) ventilation pipe (optional)

Picture 7 ***Example of rainwater harvesting at household level with mechanical filter.***

If there is available space, the surface of the roof is higher and a higher purification capacity is required, natural treatment systems permit to achieve better results.

Vegetated natural filters (rain gardens) are intended to be landscaped areas that treat stormwater runoff. Homeowners or custodians can treat these gardens, giving them significant attention, or they can blend them into the landscape and make them look "natural." Whatever the context, a rain garden should look like part of the landscape: plants—particularly shrubs and trees—surrounded by mulch. However, the true nature of a rain garden is to treat stormwater. Water is directed into them by pipes, swales, or curb openings. The garden is a depression or bowl that temporarily holds and treats water.



Picture 8 *Example of raingarden used for rainwater harvesting*

The treated stormwater can be collected by a drainage system for the reuse or infiltrated for groundwater recharge.

- Help alleviate problems associated with flooding and drainage.
- Enhance the beauty of individual yards and communities.
- Provide habitat and food for wildlife including birds and butterflies.
- Allow reuse of treated stormwater

Constructed Wetland

Constructed Wetland are nowadays one of the most worldwide diffused technology for the treatment of wastewater; their functioning principles are based on the biological, physical and chemical processes that occur in natural wetland, even if the CWs (especially subsurface types) are engineered systems studied and monitored since the end of ‘70.

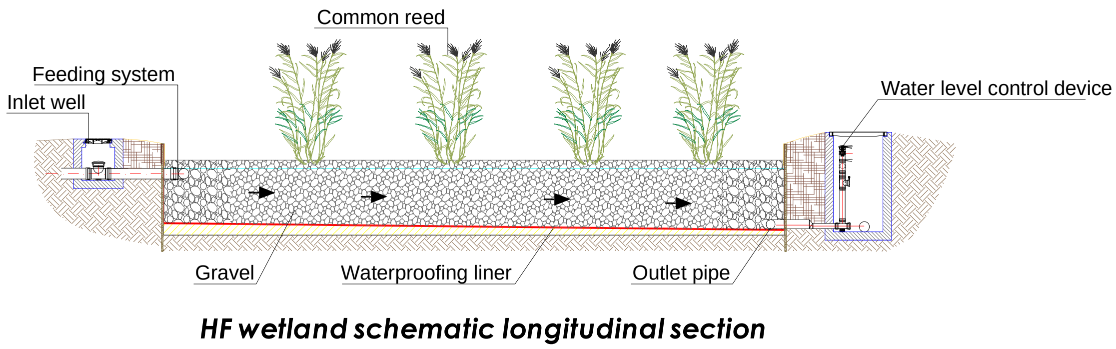
The most diffused are the submerged filters (horizontal and vertical flow type) where the wastewater is filtered by a medium (composed by gravel and/or sand) planted with aquatic macrophyte plants (generally Phragmites Australis or Typha latifolia); these systems require less area than free water systems (more similar to natural wetland) and permit both secondary and tertiary treatment of wastewater (e.g. greywater or blackwater). Because the water is not exposed during the treatment process, the risk associated with human exposure to pathogenic organism is minimized. Generally they require a primary treatment for coarse solids (a manual or automatic grid) and suspended solids removal (a septic tank or imhoff tank). The water is treated by a combination of biological and physical processes. The effluent of a well-functioning constructed wetland can be used for irrigation and aquaculture (in these cases a combination of horizontal flow and vertical flow could be suggested for blackwater and mixed water, considering the low capacity of ammonia reduction of HF) or safely been discharged to receiving water bodies.

If the design requires expert knowledge, the implementation is very easy because it requires only a basic knowledge of simple hydraulic and civil works (earthmoving, waterproofing, hydraulic connection, small concrete structures); for the littler plants sometimes it is possible also the self-construction. Moreover CWs are relatively inexpensive to build where land is affordable and can be maintained by the local community as no high-tech spare parts, electrical energy or chemicals are required.

Horizontal Flow Constructed Wetland

HF constructed wetlands consist of waterproofed beds planted with hydrofite vegetation tipical of swamps and marshes (generally common reed - Phragmites Australis - is the most used, but to improve aesthetic amenity we could use together also other ornamental essence as Iris pseudacorus) and filled with gravel. The wastewater is fed by a simple inlet device and flows slowly in and around the root and the rhizomes of the plant and through the porous medium under the surface of the bed in a more or less horizontal path until it reaches the outlet zone. The filling material (coarse gravel, fine gravel and coarse sand) has to offer an appropriate hydraulic conductivity but also a large surface for the biofilm growing. Because the water is not exposed during the treatment process, the risk associated with human exposure to pathogenic organism is minimized. Properly designed HF beds do not provide suitable habitat for mosquitoes or other vector organism and permit public access in wetland area.

HF beds are typically comprised of inlet feeding system, a synthetic liner, filter media, emergent vegetation, berms, and outlet piping with water level control.



Picture 9 Horizontal flow constructed wetland

Advantages/Benefits
• High treatment efficiency;
• Excellent environmental integration;
• Low investment cost and low maintenance requirements;
• No Energy consumption;
• The final effluent can be reused;
• High tolerance to seasonal and daily variation of fluxes and dry periods.

Disadvantages/Limitations
• Land requirement;
• High evapotranspiration at high temperatures
• Constrains on geometry (rectangular, ratio between Lenght and Width)

Operation and maintenance
• Management of primary sludge (periodic emptying of primary treatment)

• Annual mowing of emerging macrophytes.

The performance of HF systems are influenced by the wastewater temperature and the hydraulic retention time (HRT): HRT must be minimal 1 day for greywater (3 days for black water) to permit removal performances of organic matter over 60-70%. High temperatures positively influence the natural purification processes.

BOD_5	85-95%
Suspended Solids	70-95%
Total Nitrogen	55-75%
Ammoniacal Nitrogen	50-70%
Phosphorus	50-90%
Pathogen micro-organisms	97-99,999%

Table 2 *Typical removal of a well designed HF system*

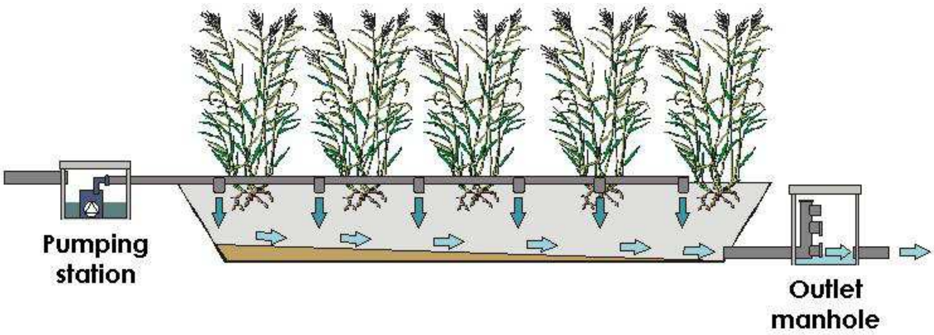
The horizontal flow system is well suitable to treat greywater that contain low content of ammonia and bacteria compared to mixed wastewater and a fast biodegradable organic content; usually 2-3 days of HRT are enough to ensure a safe reuse of greywater.

Picture 10 *HF system fro greywater reuse in Preganziol (TV) for 240 a.e.*

Vertical Flow Constructed Wetland

In the vertical flow systems (VF) the wastewater is applied through a distribution system on the whole surface area and passes the filter in a more or less vertical path. The pre-treated wastewater is dosed on the bed in large batches (intermittent feeding), thus flooding the surface. During the time between the feedings, the pores within the filter media can fill up with air which is trapped by the next dose of liquid. Thus, the oxygen requiring nitrifying bacteria are favored and full nitrification can be achieved, but only a small part of the formed nitrate is denitrified under aerobic conditions. The treated water is collected in a bottom drainage system to be discharged.

The loading of Vfs normally happens intermittently by pumps, or by gravity using special self-priming siphon devices if there is enough difference of level between the primary treatment and the wetland basin.
This kind of CW is particularly efficient in nitrification, carbon and suspended solids removal. Due to its prevalently aerobic conditions, the de-nitrification is poor.



Picture 11 Vertical flow constructed wetland

Advantages/Benefits
• High treatment efficiency;
• Excellent environmental integration;
• Low investment cost and low maintenance requirements;
• Low Energy consumption;
• The final effluent can be reused
• High tolerance to seasonal and daily variation of fluxes and dry periods.

Disadvantages/Limitations
• Land requirement (generally a little bit less than HF);
• Constrains on geometry (to permit uniform distribution on the surface)

Operation and maintenance
• Management of primary sludge
• Annual mowing of emerging macrophytes;
• Periodic inspection of the feeding system (usually centrifugal submerged pumps).

The performance of VF systems are influenced by the Hydraulic Loading Rate (m^3/m^2 per day) and the Organic Loading Rate (grCOD/m^2 per day). The typical removal efficiency are listed below:

BOD_5	85-95%
Suspended Solids	80-95%
Total Nitrogen	55-75%
Ammoniacal Nitrogen	80-90%
Phosphorus	50-90%
Pathogen micro-organisms	2-3 log

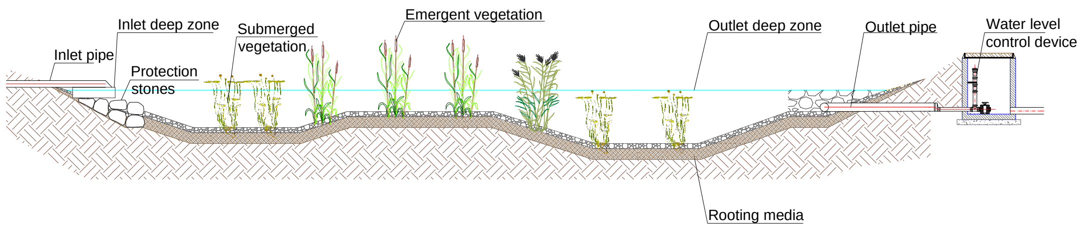
Free Water System (FWS)

Generally the surface flow wetlands are densely vegetated basins that contains open water, floating vegetation and emergent plants. They need soil or another suitable mean to support the emergent vegetation. When the FW systems are applied for the control of diffusion pollution, they don't need of waterproofing with plastic liner, due to the low risk of groundwater contamination.

The main components of a FW wetland are:

- An inlet distribution system, followed by an inlet deep zone to allow the removal of heavier sediments;
- Shallow marsh areas with varying depths (0,4 - 0,6 m) with wetlands vegetation;
- An outlet deep zone to clarify the final effluent;
- An outlet device to control the water level.

The most common application of these systems is the tertiary treatment due to their power of de-nitrification and pathogens removal (due to the high exposure of the wastewater to the UV component of the sunlight). FW systems are also largely used to control diffuse pollutions: these systems are one of better choice for the treatment of agricultural, urban and industrial stormwater, because of their ability to deal with intermittent flows and low concentrations



Picture 12 Free water constructed wetland

Advantages/Benefits
• Environmental restoration;
• Provides aesthetic amenity and increases biodiversity;
• Buffer effect when used as tertiary treatment;
• No energy consumption.

Disadvantages/Limitations
• High land requirements.
• Risk of mosquitoes diffusion.
• High evapotranspiration rates
• not indicated for secondary treatment (large area and bad odor diffusion)

Operation and maintenance
• Examine the functioning of the system;
• Annually mow emergent vegetations.

Integrated monitoring of groundwater status, well functionality and pumping effectiveness: the *smartwell* technology

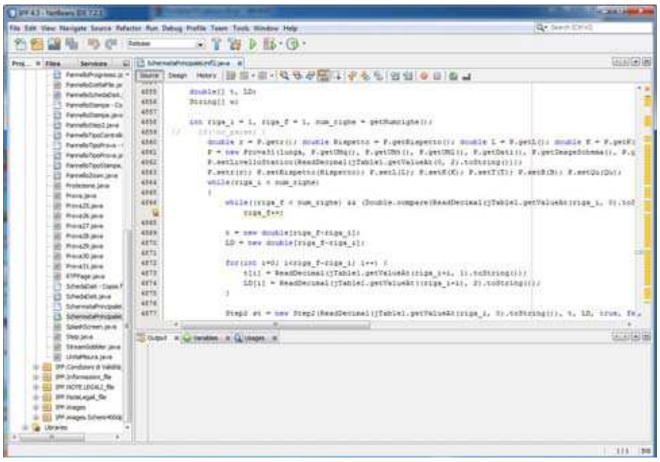
A real time monitoring of water availability (flow for surface water and groundwater level) is more and more important for a correct and rational management of the water resources. Edillio SRL, o SME based in Rome, together with the University of Rome La Sapienza did recently develop a computer based system (SmartWell) applicable to existing wells. SmartWell, integrated with specific sensors, provides a real time flow of information on groundwater quantity (flow, level) and quality (conductivity, pH).

Equipping an existing well with a Smartwell system allows early warning strategies and elaboration of plans to prevent water shortage or sanitary risk due to contamination. In respect of what above, the implementation of a regular monitoring of the work will be the tool for optimal use of pumped water. In particular, the cost of those assets will be amortized by the savings on exercise expenses compared to a situation of failure of the system. Extending the example of the works of uptake in all phases of the management and disposal of water resources, it is possible to obtain an estimate of the potential savings and optimization opportunities that lie ahead with the Integrated System "Smart Water Manager".

The SWM is organized by means of a system consisting of elements that interact on the whole process, each one with its specific peculiarity. In particular, the elements of the SWM system will be:

1. A web-based GIS platform, for collection and management of data.
2. A system for distribution (extraction based on qualitative and quantitative parameters acquired in continuous mode) of the water resource, which is controlled by the Manager in continuous communication with the web-GIS platform.
3. A set of sensors and valves, purposely installed, monitored by the management software, which adjusts the power supply and therefore the operation of the lifting and movement pumps (the system for distribution described in the previous point).
4. A network of counters, installed at the end-users, which will allow you to act on the inefficiencies measured.

To support the SWM system, it is planned that the central platform constantly dialogues with regional or basin-scale monitoring networks, already present in the area, going to integrate information, summarizing the most relevant and avoiding the simple accumulation of data. Finally, it is planned to send digest and periodic warning on activities and significant changes to the entire system operators in the sector, which will verify the operation and significant developments.



Sustainable Urban Drainage Systems

One of the main problems that urban water managers have to face is storm water runoff. As natural areas are developed and turned into parking lots, driveways and houses, more impervious surfaces are created, generating increased amounts of polluted runoff. This increased volume of runoff enters streams at a much faster rate than previously. In a natural setting, rain falls on vegetation and is either captured by plants or infiltrated into the soil. In a developed community, stormwater runoff can cause flooding that is known to scour streambanks and cause erosion. Furthermore, the water that runs over streets and parking lots collects and deposits pollutants such as oil, sediment, fertilizers, trash, debris, and chemicals into nearby waterways. Nonpoint source of pollution resulting from stormwater runoff has been identified as one of the major causes of the deterioration of the quality of receiving waters. Managing stormwater to prevent pollution and flooding is a key aspect of sustainable urban management.

Moreover, in areas served by combined sewing systems (designed to collect and convey domestic, commercial, and industrial wastewater as well as stormwater runoff in the same pipes), during heavy precipitation events, stormwater volume has the potential to exceed a wastewater treatment facility's capacity. When this occurs, wastewater and stormwater are diverted from the facility and discharged directly into designated receiving surface waters. This event is called a combined sewer overflow (CSO). CSOs are a major threat to water quality as they are comprised of both raw sewage and stormwater runoff: several studies[1] show that wastewater discharged by CSOs are presently considered the most important contribution of water polluting load due to point sources .

According to the "SUDS" approach, a more holistic view of the urban water cycle is advocated and consideration should be given to "source control" techniques rather than a complete reliance on large-scale piped solutions. Source control techniques attempt to deal with rainfall where it lands, or as close to the point of origin as possible. Examples of SUDS techniques include overland flow channels, filter drains, infiltration devices, permeable surfaces, green roofs, detention basins, ponds and wetlands. These generally operate by attenuating the peak stormwater runoff conveyed from the urban catchment to the sewer system or watercourse, thereby reducing the risk of flooding. The rainwater harvesting systems are also a part of the SUDS approach. Runoff arising from impervious surfaces (principally roofs) can be stored in rainwater tanks for subsequent potable and non-potable use. Providing that storage is available at the beginning of a storm event, these systems can act as attenuation devices, reducing both peak flow rates and effective runoff volumes under favorable conditions. Runoff storage in RH systems could also provide significant benefit in terms of pollution control, avoiding or reducing the activation of overflows, in areas served by combined sewing systems.

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[1] Frechen F.B., Schier W., Felmeden J.. 2004. *Plant cover retention soil filter (RSF) – treatment for stormwater overflow from combined sewer systems*. In: Lienard, A., Burnett, H. (Eds.): Proceedings of the 9th IWA Specialized Group Conference on "Wetland systems for Water Pollution Control" – pp537-544. Conte G. 2008. *Nuvole e sciacquoni. Come usare meglio l'acqua in casa e in città*. Edizioni Ambiente. ISBN 978-88-89014-76-9. Conte G., Bolognesi A., Bragalli C., Branchini S., De Carli A., Lenzi C., Masi F., Massarutto A., Pollastri M. and Principi I. 2012. "Innovative Urban Water Management as a Climate Change Adaptation Strategy: Results from the Implementation of the Project "Water Against Climate Change (WATACLIC)" . *Water*, 4(4), 1025-1038; 2012

Tool	Applicability in the region	Diffusion in the region	Remarks/comments
CASE 1 Norma			
Water saving devices	++	+	
Network rehabilitation by Trenchless Automated Leakage Repair	++	-	
Groundwater monitoring (*smartwell*)	++	-	
Rain water collection and reuse	+	-	
Rain water management (SUDS)	++	-	
CASE 2 Latina – Borgo Sabotino			
Water saving devices	++	+	
Constructed wetlands for decentralised wastewater treatment	+	+	

++ applicable without constraints / very diffused
+ applicable with constraints / used in some cases
- not applicable / not used

3. Elaboration of alternative options

3.1 Norma

3.1.1 Water saving devices

The cost of the application of water saving devices can vary depending the type of product and the supplier. In the following table an estimation is provided, based on the experience of SWMED partnership.

Measure Type	Device	Estimated cost per device (Euro)
Water Flow Restrictor	Efficient Shower Head	4.02
	Aerators (see picture below)	1.8-5.2
WC Volume Displacement	Toilet Tank Bag	0.78
WC Volume Displacement	New cassette with double flush	45,00

Some of these facilities have already been installed by the stakeholders in recent years and it is very difficult to estimate where a substitution or an improvement of the water devices is needed. Considering an average cost per household of about 20,00 € and the application to 50% of the household, it can lead to an investment cost of 10.500 €. Considering that these simple measures could permit a water saving of about 20%, and considering a consumption per person of about 185 l/c/d, it means that we could save **28.000 m^3/year**.

3.1.2 Network rehabilitation

Considering the size of the municipality and its activities in comparison to similar villages in the surrounding area, we can assume that the distribution network leakages could reach approximately 50% of the 370 L per inhabitant per day . In fact, the average daily water usage in similar cases is 150-180 liters per inhabitant.

USAGE [m^3/d]	LEAKS [m^3/d]	BALANCE [m^3/d]	BALANCE [m^3/y]
1554	777	777	**283.605**

It is very difficult, basing on existing data, locate leaking points along the network; considering that probably the leakages could be very small and diffused on the whole network, and that it could be very hard to individuate the leakages by a video-inspection survey, the best strategy could be to intervene on all the pipes with a non-invasive approach, or at least on the bigger diameters where the probability of failure could be high as it could be the quantity of leakage.

Two different action strategies have been analyzed and they are both based on Curapipe's TALR technology.

A] Fixing the whole network
B] Fixing only the pipes whose diameter is bigger than 150 mm

The cost of Curapipe Tarl technology is generally 10-12 times less than an open trench approach, and on this basis we have calculated the cost per linear meter.

DIAMETER	TOTAL LENGHT [m]	CURAPIPE FIXING COST [€/m]	TOTAL [€]
DN80	4600	6	€ 27.600,00
DN125	1300	7	€ 9.100,00
DN200	5000	11	€ 55.000,00
			€ 91.700,00

Therefore the cost of the two alternatives are the following:
Alternative A: 91.700,00 €
Alternative B: 55.000,00 €
Estimating to be able to reduce the leakage of 50% in the alternative A and of 25% in the alternative B; it means a **water saving of 283.000 – 141.500 m^3/year**.

3.1.3 Groundwater monitoring

In both alternatives, the main water supply from the wells will be provided with a SmartWell system. The system's core is made up of hardware and data management/control software, which can be customized and expanded progressively with various types of sensors.

The "base + base sensors + advanced sensors" package includes:
- Management and control system
- 1 level sensor (pressure transducer)
- 1 magnetic induction flow meter
- 1 multi-parameter pH and temperature sensor
- 1 multi-parameter conductivity and temperature sensor

The package costs 6.100 € including installation and maintenance.

Presumable cost savings:
- 10% less energy consumption
- 50% increase water pump lifetime
- 70% increase well lifetime

Thus, supposing the current water pump uses 45 kWh for 14,4 hours every day of the year and knowing that 1 kW costs 0,15€, the total energy expenses would amount to 35.478,00 € per year. Installing a SWS could save over 3.547,80 € every year.

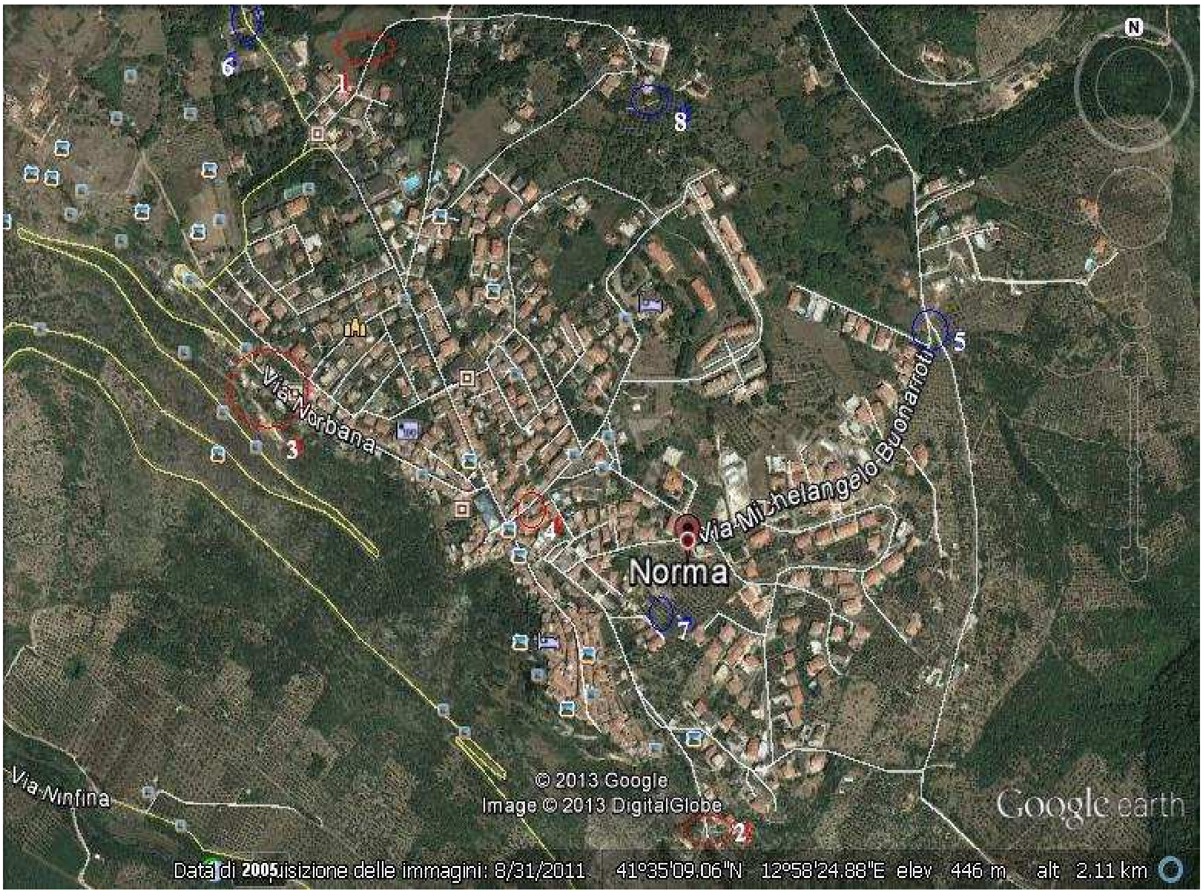
Let us now consider how the hypothesis made in the previous paragraph, which envisage a decrease of water withdrawal to 283.000 m^3/year according to plan A and 425.000 m^3/year according to plan B, would affect this balance.

	PLAN A]	PLAN B]	
WATER USAGE	9,00	13,50	[L/s]
POWER REQUESTED	45,00	45,00	[kWh]
RUNTIME	7,20	10,80	[h/d]
DAYS/YEAR	365,00	365,00	[d/y]
ENERGY CONSUMPTION	118260,00	177390,00	[kW/y]
ENERGY PRICE	0,15	0,15	[€/kW]
TOTAL EXPENSE	17739,00	26608,50	[€/y]
SWS ENERGY SAVING	1773,90	2660,85	[€/y]
PAYBACK TIME	3,44	2,29	[years]

As shown in the table above in both alternative a significant Energy saving is envisaged, with a reasonable payback time.

3.1.4 Rainwater management, collection and reuse

In the following picture are represented the areas where potentially rainwater tanks can be located. The red circles show the tanks to be used for fire prevention and other urban uses, the blue circles shows the tanks to be used for irrigation; sites 7 and 8 could be used for the irrigation of green areas and also for domestic uses. Location has been done according to morphological consideration (natural drainage) and opportunity of water reuse (irrigation).



Picture 13 The urban area of Norma and possible location of rainwater reservoir

Location for urban use:

1. Old municipal treatment plan
2. Bottom of Via delle Svolte (natural drainage area due to morphology:)
3. Area downstream Via Norbana
4. Caio Cestio Place

Location for irrigation:

5. Via Michelangelo Buonarroti crossing Via Capo dell'Acqua
6. Piazza downstream the graveyard

7-8 Areas of urban development, where rainwater could be reused for gardening and for domestic use

The sizing of the storage tanks and open air basins should be done by assessing the catchment area and the quantity of water that can be harvested for each average rainfall event, and at the same time evaluating the real needs for urban use and irrigation. Such assessment requires a deeper knowledge of the potential rainwater users and an hydrology study which goes outside the possibility of the present study. We have therefore made a rough estimation, considering small open air basins of about 100-200 m^2 of surface, capable to store for reuse about 100-300 m^3 each (the bigger ones for irrigation). In case of underground tank, we have instead considered 50 m^3 of storable volume in one case, and 100 m3 in the second case considering that the catchment area is bigger.

The envisaged tanks will be differently made, according to local space availability and local conditions:

1. Open air sealed basin, net available water volume 100 m^3
2. Open air sealed basin, net available water volume 100 m^3
3. Underground concrete tank, net available water volume 50 m^3
4. Underground concrete tank, net available water volume 100 m^3
5. Open air sealed basin net available water volume 200 m^3
6. Open air sealed basin net available water volume 200 m^3
7. Open air sealed basin net available water volume 300 m^3
8. Open air sealed basin net available water volume 300 m^3

Considering a number of about 90 rainfall event per year, capable to reintegrate the reused water, it means that about **75.000 m^3/year** could be available to reuse.

To be reused, the rainwater should be treated, in different ways according to the catchment area typology; considering that the municipality doesn't present any relevant industrial area, and also the roads are not interested by heavy traffic, a very moderate pollution level is expected and an efficient filtration can allows good water quality for non potable uses.

Being the urban area frequently affected by floods, beside rain water harvesting – that could give a significant contribute to reduce urban runoff – other "SUDS" technologies have been envisaged. Infiltration trenches are widely used to reduce runoff peaks, and can also contribute to groundwater aquifer recharge or to rainwater collection, when connected to storage systems. In the following picture, several area suitable for the realization of infiltration trenches are showed: the blue line could be infiltration trenches realized on the borders of the street, with a width of approximately 0.4 m; the blue circle show bioretention areas; all these system are connected to the underground tank n°4).

In other cases, where more space are available, the filtration facility could be integrated in the design of the pond in the inlet section.

Where instead the spaces are not available, underground filters could be used in order to remove the solids.

The overall system can be considered as an integrated stormwater management system that can improve the flood protection of the area. A quantitative estimation of the stormwater retention effects is impossible without a deeper hydraulic analysis, however the implementation of the proposed plan will certainly improve the flood safety and allow a significant rainwater reuse.

Picture 14 The rainwater management facilities envisaged for Norma

Since the realization of rainwater collection volumes could be quite expensive (specially when groundwater tanks are needed) two alternatives have been considered:

Alternative A: realization of the 8 reservoirs
AlternativeB: realization of 1,2,7 and 8 reservoirs only

In the following table, a rough estimation of the intervention cost is reported.

Rainwater harvesting Storage n°1	**€ 39.000,00**
Open storage pond	€ 18.000,00
solid traps	€ 4.500,00
inlet filtration area	€ 7.500,00
landscaping	€ 6.000,00
hydraulical devices for control	€ 3.000,00
Rainwater harvesting Storage n°2	**€ 39.000,00**
Open storage pond	€ 18.000,00
solid traps	€ 4.500,00
inlet filtration area	€ 7.500,00
landscaping	€ 6.000,00
hydraulical devices for control	€ 3.000,00
Rainwater harvesting Storage n°3	**€ 61.500,00**
Underground tank	€ 45.000,00

undergound sand filter	€ 6.000,00
manual grit and collection chamber	€ 4.500,00
hydraulic connections and pipelines	€ 6.000,00
Rainwater harvesting Storage n°4	**€ 120.900,00**
Underground tank	€ 90.000,00
infiltration trenches	€ 18.000,00
bioretention area	€ 5.400,00
hydraulic connections and pipelines	€ 7.500,00
landscaping	€ 3.000,00
Rainwater harvesting Storage n°5	**€ 60.000,00**
Open storage pond	€ 30.000,00
solid traps	€ 6.000,00
inlet filtration area	€ 13.500,00
landscaping	€ 6.000,00
hydraulical devices for control	€ 4.500,00
Rainwater harvesting Storage n°6	**€ 60.000,00**
Open storage pond	€ 30.000,00
solid traps	€ 6.000,00
inlet filtration area	€ 13.500,00
landscaping	€ 6.000,00
hydraulical devices for control	€ 4.500,00
Rainwater harvesting Storage n°7	**€ 75.000,00**
Open storage pond	€ 36.000,00
solid traps	€ 6.000,00
inlet filtration area	€ 18.000,00
landscaping	€ 9.000,00
hydraulical devices for control	€ 6.000,00
Rainwater harvesting Storage n°8	**€ 75.000,00**
Open storage pond	€ 36.000,00
solid traps	€ 6.000,00
inlet filtration area	€ 18.000,00
landscaping	€ 9.000,00
hydraulical devices for control	€ 6.000,00
Other infiltration trenches and SUDS	**€ 48.000,00**
Total alternative A (1-2-3-4-5-6-7-8)	**€ 578.400,00**
Total Alternative B (1-2-7-8)	**€ 276.000,00**

Table 3 Envisaged costs of the rainwater management system in Norm

3. Summary of the alternatives

Considering the different kind of technologies in the various alternative, it is not easy to find the key to compare them from an economical point of view. In the following tables each alternatives and set of alternatives have been compared, considering investment and maintenance costs and the estimated water volume. A key factor to be compared could be the cost of the investment (including also the cost of maintenance for a period of 20 years) divided by the cubic meter of saved water. It could be underlined that this cost is very low in each alternatives, more than 10 times less of the market price of potable water.

Norma alternatives	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Water saving devices (**WSD)**	NO	YES	YES	YES	YES
Network rehabilitation	NO	partial	100%	partial	100%
Groundwater monitoring (smartwell)	NO	YES	YES	YES	YES
Rain water management (SUDS), collection and reuse		partial	complete	complete	partial

Norma intervention costs (€)	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Water saving devices (**WSD)**	0	10500	10500	10500	10500
Network rehabilitation	0	55000	91700	55000	91700
Groundwater monitoring (smartwell)	0	6100	6100	6100	6100
Rain water management (SUDS), collection and reuse		€ 276.000,00	€ 578.400	€ 578.400	€ 276.000
Total	**0**	**347.600**	**686.700**	**650.000**	**384.300**

Norma maintenance costs (€)	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Water saving devices (**WSD)**	0	0	0	0	0
Network rehabilitation	0	0	0	0	0
Groundwater monitoring (smartwell)	0	-1750	-1750	-2650	-1750
Rain water management (SUDS), collection and reuse	0	6000	10000	10000	6000
Total	**0**	**4250**	**8250**	**7350**	**4250**

Norma m^3/y of water saving	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Water saving devices (**WSD)**	0	28000	28000	28000	28000
Network rehabilitation	0	141500	283000	141500	283000

Groundwater monitoring (smartwell)	-	-	-	-	-
Rain water management (SUDS), collection and reuse	0	45000	75000	75000	45000
Total	0	**214500**	**386000**	**244500**	**356000**

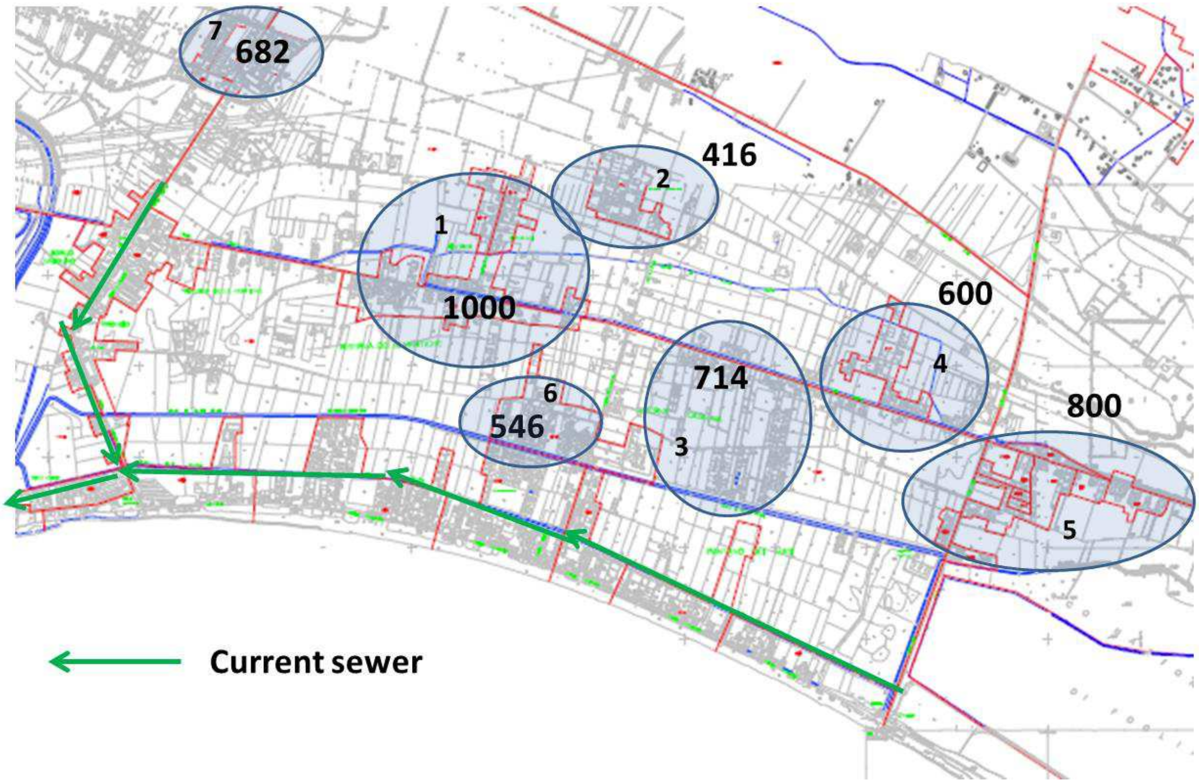
Norma €/m³ of water saving on 20 year	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Water saving devices (**WSD)**	-	0,0188	0,0188	0,0188	0,0188
Network rehabilitation	-	0,0194	0,0162	0,0194	0,0162
Groundwater monitoring (smartwell)	-	-	-	-	-
Rain water management (SUDS), collection and reuse	-	0,4400	0,5189	0,4400	0,5189
Total	-	**0,1008**	**0,1103**	**0,1630**	**0,0659**

3.2 Latina Borgo Sabotino

As previously showed, the areas in the east part of Borgo Sabotino are occupied by several settlements, partially illegally developed in ’60-’70s, not completely served by public sewer networks and not connected to any WWTP. Water use is domestic and no significant industries to be connected to the sewer has been evidenced.

The wastewater coming from those settlements which are not connected to the main sewing system are sometimes equipped with primary treatment and the final disposal in the soil by infiltration trenches. Quite often however group of houses are served by short sewing pipes discharging in local surface water (drainage canals), generating potential sanitary risks.

The present study is focused on possible solution to treat by decentralized systems wastewater generated in existing settlements not connected to the existing Latina Mare wastewater treatment plant (WWTP). In the following picture are represented the 7 settlements object of the study. Population of the settlements range between 550 and 1000 person equivalent (p.e.)



Picture 15 Existing sewer network of Borgo Sabotino and unconnected settlements

There’s lack of reliable data about the population fluctuation due to vacation houses. According to data provided by Acqualatina, the company who manages the Latina Mare WWTP, the Borgo Sabotino sewing network delivers to the WWTP approximately 4.500 p.e. during winter and

10.000 p.e. during summer. Therefore we have considered the same fluctuation for the present study.

Zone 1	999
Riserva e Ciccatelli	299
Riserva delle Vertiche	700
Zone 2	
Consorzio Casilina Nord	416
Zone 3	
Riserva Casilina	714
Zone 4	600
Zone 5	800
Zone 6	546
Zone 7	682
Total P.E.	**4747**

Table 4 Settlements object of the feasibility study and related population

All alternatives developed include the assumption that households will install simple water saving device in order to reduce the water consumption and consequently also the water volume to be treated.

According to data provided by AcquaLatina, the invoiced consumption was in the last year approximately 133 m^3/year per household; considering an average number of 3 inhabitants per household, it mean an average consumption of 120 l/p.e. x day. At the same time, the specific consumption adopted by Acqua Latina in the WWTP upgrading design, is 350 l/p.e. x day with a corrective factor of 0,8 for sewer discharge.

In the study, we have considered a water consumption of 200 l/p.e. as present condition and a water consumption of 140 l/p.e. in all scenarios developed, due to the implementation of Water Saving Devices (WSD). With this assumption the current untreated volume is about 1000 m^3/day.

The WWTP of Latina Mare is object of an upgrading project, to allow the treatment of larger flow originated by the increase of the connections in the catchment area. On the basis of the information contained in the Preliminary Design made by Acqualatina, the current treatment plant is constituted by a primary treatment by Imhoff tank followed by several trickling filters and it receives about 10.000 p.e. during the summer season and about 4500 p.e. during winter; the upgrading design envisages a new configuration, partially developing existing facilities, that will change the treatment technology from trickling filters to activated sludge.

The project envisages a first phase aimed at upgrading the process to the more stringent discharge limits for 15.000 p.e. (this is the current nominal capacity of the plant) and increase the treatment capacity to the sewage flow coming from the new collectors to be realized in the western area of the Moscarello channel. The second phase envisages a further upgrading of the WWTP to 30.000 p.e., in order to receive the flow of the new network expected to convey the sewage of the eastern area of Moscarello Channel (Borgo Sabotino and other settlements).

The cost of the works (not comprehensive of technical costs) to upgrade the current WWTP from 15.000 to 30.000 is about 6.500.000 € (433 €/p.e.); the cost of the new sewer networks (12,5 Km) is 4.375.000 € (350 €/m). The realization of the overall works (phase 1 + phase 2) is expected in 2-3 years.

In the study we didn't consider the costs of the completion and the rehabilitation of the local sewer networks, because this estimation should require an accurate survey and a deeper analysis of the state of the art.

The water quality standard ensured by the project is Tab.1-2 D.Lgs. 152/06 (the area is in a sensitive region and more stringent concentrations for Nitrogen and Phosphorus are required for WWTP higher than 2000 p.e.).

The final configuration of the treatment plant should allow also the reuse of the treated water (a final ultrafiltration and UV disinfection is included in the preliminary design).

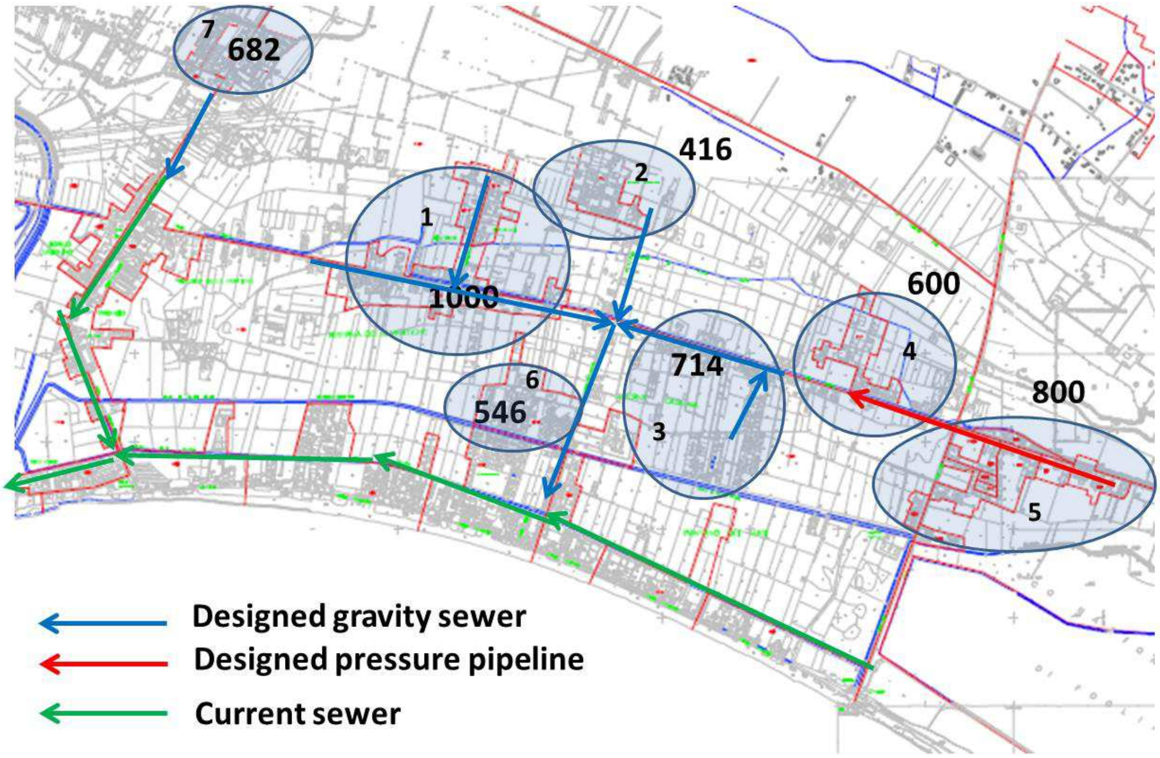
LATINA MARE WWTP – BASIC DATA	
Present population (P.E. including fluctuants)	15000
Expected population (P.E.)	30000
Population already served by WWTP or expected to be served in the next future	25000
Population resident in peripheral area not expected to be linked to WWTP	5000
Flow pro capite (l/person/day)	350

The scenario "zero" consider the current situation (no connection to the WWTP and no upgrading). In the remaining options, we have compared the centralized approach of the preliminary design made by Acqualatina, with other alternatives envisaging the realization of decentralized natural systems for the eastern area of Borgo Sabotino (about 5000 p.e.)

In all the scenarios, we have considered the realization of a separate network, in order to contain the pipe diameters and the overall costs. The rehabilitation of the local network should take in account also the separation of the rainwater that could be collected diffusively in the open canal drainage network of the area or managed by SUDS systems (see Norma case study).

3.2.1 Alt.1 Sewer connection to Latina Mare WWTP

In the following figure, a hypothesis on a new network to connect all the settlements to the WWTP is showed, taking into account natural slopes and the morphology of the area and following the indications of the Technical Office of Latina Municipality and of the Preliminary design of the WWTP developed by AcquaLatina. It has to be noted that the new sewers are provided by the municipal restoration plan, but it is considered as a long-term realization.



The total extension of this sewer network is approximately 6700 m. The connection of the eastern settlements requires most likely a pumping station, being located at a level that doesn't allow collection by gravity. Generally all the area is very flat and depressed, and an interference of the sewer with the underground water table has to be considered.

Scenario n° 1		
sewer network	2.375.000,00	€
Upgrading of WWTP of 5000 p.e.	2.165.000,00	€
Technical services	285.000,00	€
Total costs	4.825.000,00	€
Operational costs	185.154,80	€/year
cost of treated water (investment payback time 20 years)	1,23	€/m^3

The cost of the sewer has been estimated using the cost included in the preliminary design of the new WWTP (350 €/m), as for the cost of the upgrading (433 €/p.e.). Technical services has been considered in the fix percentage of 12% in all the scenarios. Operational cost has been estimated as 0.3 €/p.e. for the treatment, considering the presence of all the p.e. for 3 months per year and the presence of the half in the rest of the year; sewer maintenance cost has been estimated as 2 €/m per year.

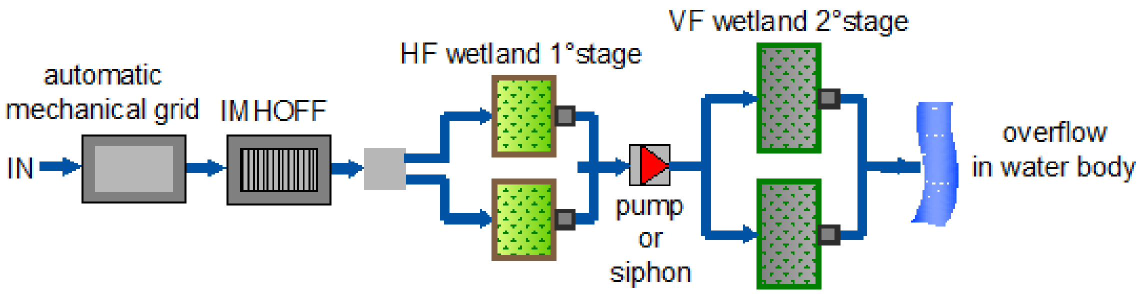
3.2.2 Alt.2 Decentralized approach Constructed Wetland

In this second alternative, we consider to realize decentralized treatments with natural constructed wetland technology, in order to reduce upgrading and collection costs. Only the settlements 6 and 7, that are near to existing networks, are connected to the WWTP.

Alternative B include different "sub-scenarios" (alt B1, B2, B3), envisaging progressively more decentralized treatment systems (2, 4 and 6 treatment facilities).

The proposed treatment technology is constructed wetlands; it is well known that for a population less than 5000 p.e. a natural treatment is better feasible and more flexible to seasonal hydraulic and organic fluctuation typical of coastal and touristic areas.

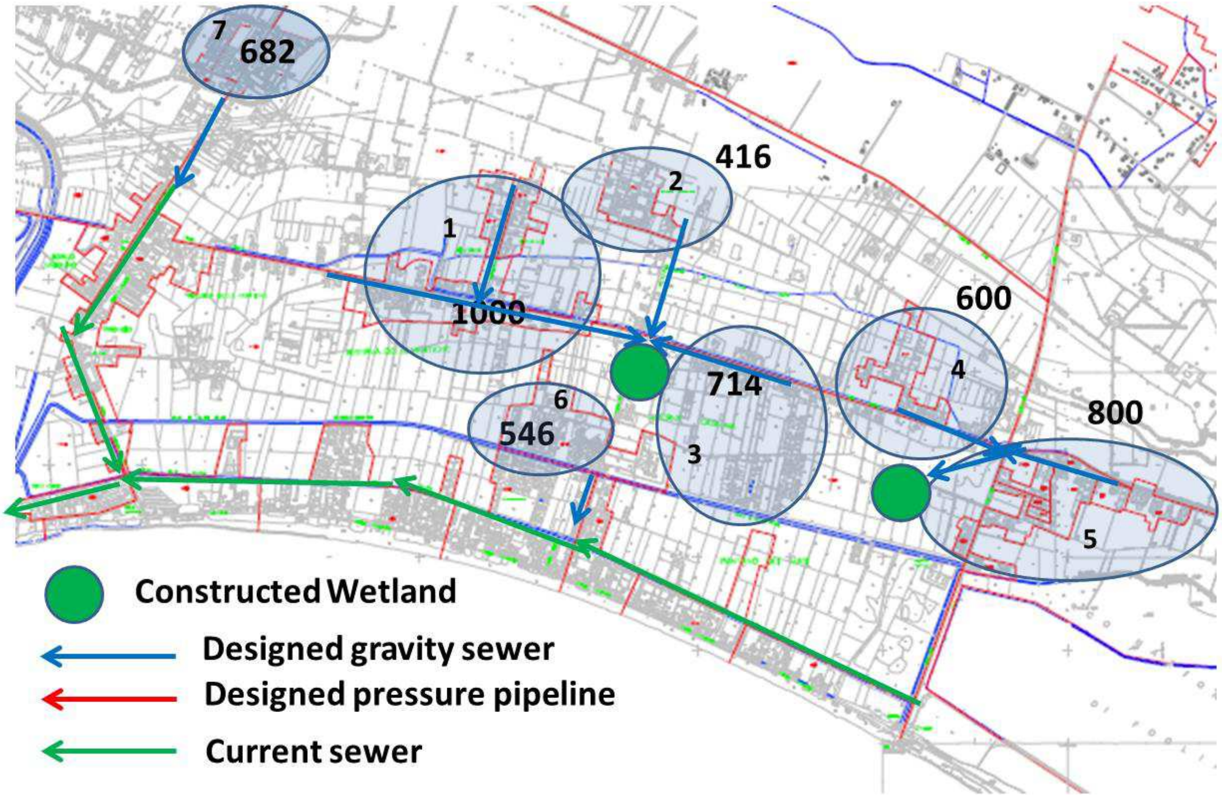
To minimize the required space and enhance the overall efficiency of the system during the peak season, each of the treatment wetland has the configuration of a multi-stage hybrid system that combines horizontal and vertical flow type. The CWs are sized to reach the limits for final discharge in a water body, using the mathematic models recognized by scientific literature for process calculation of constructed wetland. The system can guarantee during peak season a good removal of organics, suspended solids and bacteria, with outlet value respectively below 40 mg/l for BOD, 30 mg/l for SST and 10^4 UFC/100 ml. The presence of the Vertical flow stage permits also a good removal ammonia, maintaining it under 15 mg/l. Being small treatment plants (treating less than 2000 p.e.) they are not required to respect Tab.2 of D.Lgs. 152/06 with its very stringent discharging limits for nitrogen and phosphorus.



Picture 16 treatment scheme of proposed Constructed Wetlands

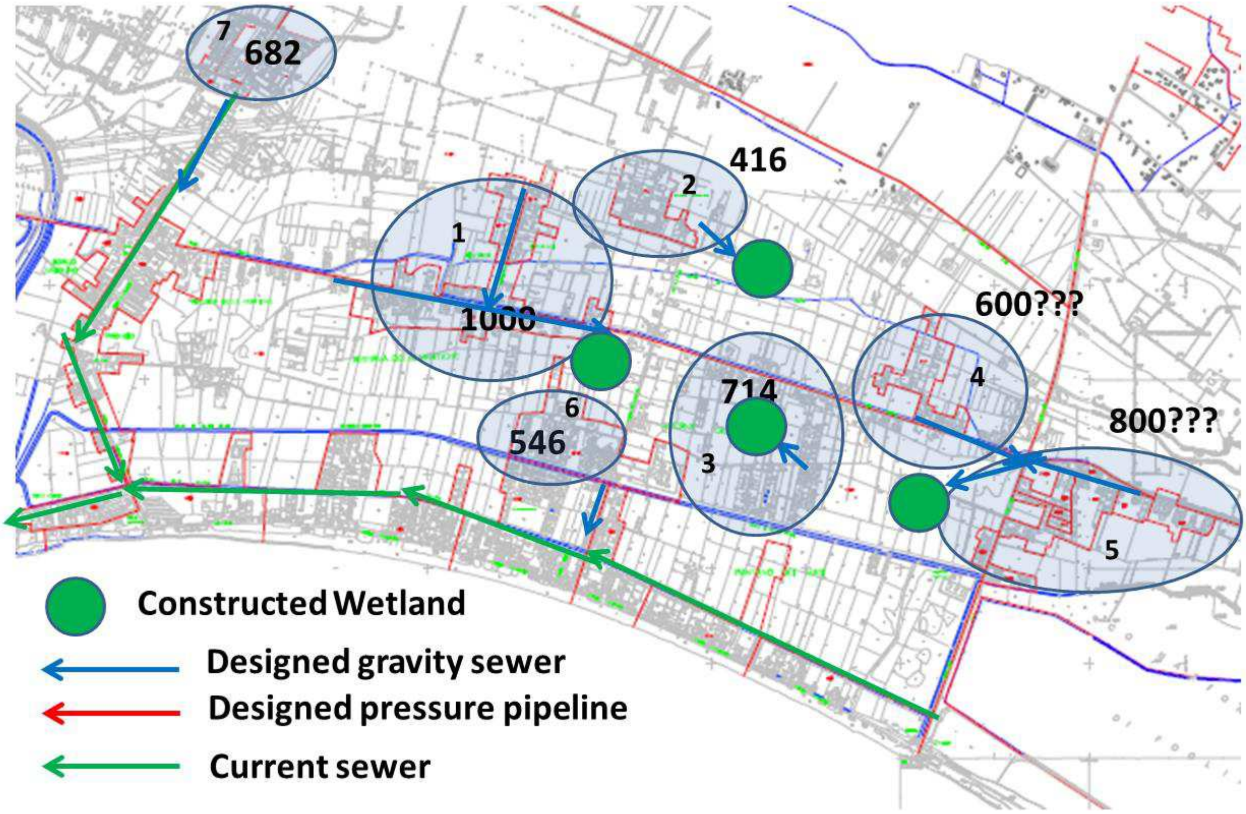
The cost of Constructed Wetland are calculated using parametric costs deduced by the official price list issued by Lazio Region and by quotation of local companies for the not included materials. Maintenance costs are very low and limited to the yearly emptying of the Imhoff tank and to the cut of the aquatic plants and the grass in the treatment area. The cost to buy the land has been estimated in 10 €/m2.

Scenario 2a



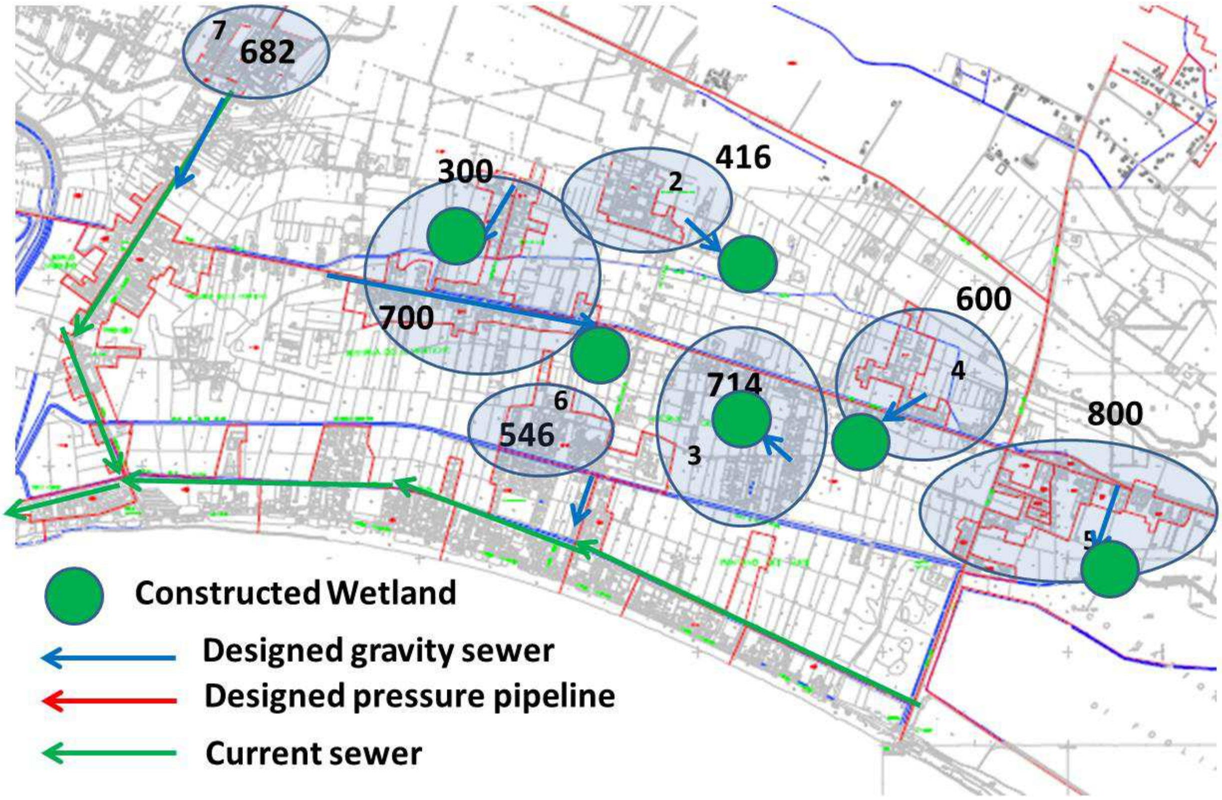
Scenario 2a		
sewer network	1.750.000,00	€
Upgrading of WWTP of 1300 p.e.	562.900,00	€
CW 2100 a.e.	798.000,00	€
CW 1400 a.e.	560.000,00	€
Technical services	440.508,00	€
Total costs	4.111.408,00	€
Operational costs	97.290,00	€/year
cost of treated water (investment payback time 20 years)	0,87	€/m^3

Scenario 2b



Scenario 2b		
sewer network	1.225.000,00	€
Upgrading of WWTP of 1300 p.e.	562.900,00	€
CW 1000 a.e.	410.000,00	€
CW 400 a.e.	168.000,00	€
CW 700 a.e.	294.000,00	€
CW 1400 a.e.	560.000,00	€
Technical services	386.388,00	€
Total costs	3.606.288,00	€
Operational costs	97.990,00	€/year
cost of treated water (investment payback time 20 years)	0,80	€/m^3

Scenario 2c



Scenario 2c		
sewer network	700.000,00	€
Upgrading of WWTP of 1300 p.e.	562.900,00	€
CW 700 a.e.	294.000,00	€
CW 300 a.e.	135.000,00	€
CW 450 a.e.	189.000,00	€
CW 750 a.e.	315.000,00	€
CW 600 a.e.	252.000,00	€
CW 800 a.e.	252.000,00	€
Technical services	323.988,00	€
Total costs	3.023.888,00	€
Operational costs	98.690,00	€/year
cost of treated water (investment payback time 20 years)	0,72	€/m^3

3. Summary of the alternatives

Borgo Sabotino	**ALT 0**	**ALT 1**	**ALT 2a**	**ALT 2b**	**ALT 2c**
Water saving devices (**WSD)**	NO	YES	YES	YES	YES
Sewer connection to Latina Mare WWTP **(Sewer)**	NO	YES	partial	partial	partial
Decentralized Constructed Wetland for CW treatment (**CW)**	NO	NO	YES	YES	YES
COSTS (€/m3 on 20 years)	/	1,23	0,87	0,8	0,72

4. Definition of sustainability criteria for evaluation

NORMA

Health issues		weight (1-5)
Don't causes any risk of	additional mosquitoes (or other insects) growth	3
	illness	-
Reduced exposure to pathogens	of users	-
	of waste workers	-
	of resource recoverers /reusers	-
	of "downstream" population	-
Impact to environment / nature		
use of natural resources	Minimize water use	4
	Low land requirements	2
	Low energy requirements	3
	Uses mostly local Construction material	2
low emissions and impact to the environment	Surface water	1
	Ground water	4
	soil/ land	1
	Air	1
	Noise and vibration	1
	aesthetic	1
	odours	1
good possibilities for nutrients recovering resources	energy	-
	Organic matter	-
	Water	5
	Landscape integration	2
Technical issues		
allows simple construction		3
low level of technical skills required for construction		3
High level of efficiency (wastewater input/depurated/timing)		-
Purification capacity (wastewater depurated/soil used by the plant)		-
has high robustness and long lifetime/high durability		3
enables simple and low operational procedures		3
Low maintenance and low skills required		3
not reliant on a continuous supply of a resource (such as water or energy)		-
adaptable to unexpected future changes (adaptability)		1
Good quality of effluent (according to the receiving environment)		-
Amount and quality of generated sludge		-
reduction of the imbalance water at the basin level		-
Economical and financial issues		
Provides benefits to the local economy (business opportunities, local employment, etc.)		3
provides benefits or income generation from reuse		1
Social, cultural and gender		
Improves quality of life		3
requires low level of awareness and information to assure success of technology		2
requires low operation & maintenance and little involvement by the user/workers		4

high level of satisfaction of the local people regarding the implemented technology	3
requires low policy reforms at local, regional or national level.	3
educational impacts	2
Costs	
Investment cost (euro)	5
Maintenance cost (euro/year)	5

Weight definition: number from 1 to 5, 5 is the max score, 1 is the minimum score

LATINA – BORGO SABOTINO

Health issues		weight (1-5)
Don't causes any risk of	additional mosquitoes (or other insects) growth	4
	illness	5
Reduced exposure to pathogens	of users	5
	of waste workers	3
	of resource recoverers /reusers	5
	of "downstream" population	2
Impact to environment / nature		weight (1-5)
use of natural resources	Minimize water use	5
	Low land requirements	5
	Low energy requirements	4
	Uses mostly local Construction material	4
low emissions and impact to the environment	Surface water	4
	Ground water	4
	soil/ land	4
	Air	2
	Noise and vibration	2
	aesthetic	3
	odours	4
good possibilities for nutrients recovering resources	energy	3
	Organic matter	3
	Water	5
	Landscape integration	3
Technical issues		weight (1-5)
allows simple construction		1
low level of technical skills required for construction		3
High level of efficiency (wastewater input/depurated/timing)		-
Purification capacity (wastewater depurated/soil used by the plant)		-
has high robustness and long lifetime/high durability		3
enables simple and low operational procedures		3
Low maintenance and low skills required		4
not reliant on a continuous supply of a resource (such as water or energy)		-
adaptable to unexpected future changes (adaptability)		1
Good quality of effluent (according to the receiving environment)		4
Amount and quality of generated sludge		2
reduction of the imbalance water at the basin level		-
Economical and financial issues		

Provides benefits to the local economy (business opportunities, local employment, etc.)	3
provides benefits or income generation from reuse	1
Social, cultural and gender	weight (1-5)
Improves quality of life	0
requires low level of awareness and information to assure success of technology	1
requires low operation & maintenance and little involvement by the users	3
high level of satisfaction of the local people regarding the implemented technology	3
requires low policy reforms at local, regional or national level	4
educational impacts	2
Costs	weight (1-5)
Investment cost (USD)	5
Maintenance cost (USD/year)	5

The “weights” will be multiplied for the specific indicator “measures” in order to obtain a final value that will contribute to the calculation of an aggregated and normalised index for each macro-indicator.

5. Evaluation of the proposed scenarios based on a multi-criteria analysis

The kind of procedure to be applied is essentially the same used for a cost-benefit analysis and an environmental risks assessment (like in a EIA), considering not only the direct effects but also the most important indirect effects; the effects/impacts can be both material or immaterial, and so some of them can be measured while some others will need to be quantified by indicators. At the end of every evaluation of possible alternatives, simple and objective indicators should be the results of the multi-criteria analyses, so to provide the stakeholders with proper and "easy to understand" instruments for choosing the most appropriate alternative considering all the environmental, economical and social contexts for every case.

The economic evaluations will have to include the O&M costs for all the lifespan of the realizations and some recommendations in each feasibility study about the locally available fund raising options could be highly welcome from the stakeholders and considered as a very important contribution for the future application in real scale of the proposed solutions.

For each group X of indicators X_i, a normalized indicator $I_k(X)$ from 1 to 5 has been calculated for each alternative with the following procedure:

- For each indicator a weight W (X_i) in the range 1-5 has been assigned; the max score indicates that the indicator is very important for the case study, instead the minimum one indicates that is not so relevant in that particular case study; if the weight is 0, the indicator is instead not suitable in that case study and it will not participate to the determination of the final indicator.
- Then, for each alternative a0-ak in the case study (where 0 is the no intervention alternative) a point from 1 to 5 has been assigned for each indicator X_i in each group X
  - 5 the criterion is very fulfilled by this alternative
  - 4 the criterion is fulfilled by this alternative
  - 3 the criterion is neutral to this alternative
  - 2 the criterion does not fulfilled well by this alternative
  - 1 the criterion does not at all fulfilled by this alternative
- For each alternative a0-ak in the case study (where 0 is the no intervention alternative) a point from 1 to 5 has been assigned for each indicator X_i in each group X
- $I_k(X) = \sum W(Xi)*a_k / \sum W(Xi)$

The final score of each alternative S_k, is given by:

$$S_k(X) = \sum I_k(X)$$

For the cost indicators (investment cost and maintenance cost), a point from 3 to 5 has been assigned considering the max score for the cheapest alternative and the minimum score for the more costly one; in alternative zero, the minimal score has been considered. In fact in the several alternatives of the case studies there is not a strong difference between the costs, and assigning 1 to the more expensive alternative could generate a strongest impact of cost items on the overall evaluation.

The max score is 30; in this way we consider that each group X has the same importance (or "weight") and the max score should be the winner alternative. However in the final evaluation each group of indicator should be evaluated also separately, trying to assess for example that an alternative is better from an "health issue" point of view, but it create greater impact on nature/environment compared to another; often things are not completely black or white.

NORMA

Health issues		weight (1-5)	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Don't causes any risk of	additional mosquitoes (or other insects) growth	3	3	2,5	2	2	2,5
	illness	0	3	3	3	3	3
Reduced exposure to pathogens	of users	0	3	3	3	3	3
	of waste workers	0	3	3	3	3	3
	of resource recoverers /reusers	0	3	3	3	3	3
	of "downstream" population	0	3	3	3	3	3
Impact to environment / nature			ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
use of natural resources	Minimize water supply use	4	1	3,5	5	4	4,5
	Low land requirements	3	3	2,5	2	2	2,5
	Low energy requirements	3	3	3,5	5	4	4,5
	Uses mostly local Construction material	0	3	3	3	3	3
low emissions and impact to the environment	Surface water	2	3	3,5	4	4	3,5
	Ground water	0	3	3	3	3	3
	soil/ land	0	3	3	3	3	3
	Air	0	3	3	3	3	3
	Noise and vibration	0	3	3	3	3	3
	aesthetic	1	3	5	5	5	5
	odours	0	3	3	3	3	3
good possibilities for nutrients	energy	0	3	3	3	3	3
	Organic matter	0	3	3	3	3	3

recovering resources	Water	4	3	4	5	5	4
	Landscape integration	3	3	4	5	5	4
Technical issues			ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
allows simple construction		0	3	3	3	3	3
low level of technical skills required for construction		0	3	3	3	3	3
High level of efficiency (wastewater input/depurated/timing)		0	3	3	3	3	3
Purification capcity (wastewater depurated/soil used by the plant)		0	3	3	3	3	3
has high robustness and long lifetime/high durability		0	3	3	3	3	3
enables simple and low operational procedures		0	3	3	3	3	3
Low maintenance and low skills required		1	3	2	2	2	2
not reliant on a continuous supply of a resource (such as water or energy)		0	3	3	3	3	3
adaptable to unexpected future changes (adaptability)		0	3	3	3	3	3
Good quality of effluent (according to the receiving environment)		0	3	3	3	3	3
Amount and quality of generated sludge		0	3	3	3	3	3
reduction of the imbalance water at the basin level		0	3	3	3	3	3
Economical and financial issues			ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Provides benefits to the local economy (business opportunities, local employment, etc.)		3	3	4	5	5	4
provides benefits or income generation from reuse		0	3	3	3	3	3
Social, cultural and gender			ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Improves quality of life		1	3	3,5	4	4	3,5
requires low level of awareness and information to assure success of technology		0	3	3	3	3	3
requires low operation & maintenance and little involvement by the user/worker		1	3	2,5	2	2	2,5
high level of satisfaction of the local people regarding the implemented technology		0	3	3	3	3	3

requires low policy reforms at local, regional or national level.	1	3	2,5	2,5	2,5	2,5
educational impacts	2	3	5	5	5	5
Costs		ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Investment cost	5	0	€ 347.600,00	€ 686.700,00	€ 650.000,00	€ 384.300,00
Maintanance cost	5	0	€ 4.250,00	€ 8.250,00	€ 7.350,00	€ 4.250,00

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Health issues		weight (1-5)	ALT 0	ALT 1	ALT 2a	ALT 2b	ALT 2c
Don’t causes any risk of	additional mosquitoes (or other insects) growth	5	3	3	2,5	2,5	2,5
	illness	0	3	3	3	3	3
Reduced exposure to pathogens	of users	0	3	3	3	3	3
	of waste workers	0	3	3	3	3	3
	of resource recoverers /reusers	0	3	3	3	3	3
	of “downstream” population	0	3	3	3	3	3
Impact to environment / nature		weight (1-5)	ALT 0	ALT 1	ALT 2a	ALT 2b	ALT 2c
use of natural resources	Minimize water supply use	5	3	3	3	3	3
	Low land requirements	2	3	2,5	2	1,5	1,5
	Low energy requirements	1	3	1	2,5	2,5	2,5
	Uses mostly local Construction material	0	3	3	3	3	3
low emissions and impact	Surface water	4	1	5	5	5	5

to the environment	Ground water	0	3	3	3	3	3
	soil/ land	0	3	3	3	3	3
	Air	0	3	3	3	3	3
	Noise and vibration	0	3	3	3	3	3
	aesthetic	2	3	2	4	4	4
	odours	2	3	3	3	3	3
good possibilities for	energy	0	3	3	3	3	3
nutrients	Organic matter	0	3	3	3	3	3
recovering resources	Water	3	1	5	4	4	4
	Landscape integration	3	3	1	5	5	5
Technical issues		weight (1-5)	ALT 0	ALT 1	ALT 2a	ALT 2b	ALT 2c
allows simple construction		1	5	2	4	4	4
low level of technical skills required for construction		1	5	1	4	4	4
High level of efficiency (wastewater input/depurated/timing)		1	1	3	3	3	3
Purification capcity (wastewater depurated/soil used by the plant)		1	3	5	2	2	2
has high robustness and long lifetime/high durability		0	3	3	3	3	3
enables simple and low operational procedures		1	3	1	2	2	2
Low maintenance and low skills required		1	3	2	4	4	4
not reliant on a continuous supply of a resource (such as water or energy)		1	3	1	2	2	2
adaptable to unexpected future changes (adaptability)		0	3	3	3	3	3
Good quality of effluent (according to the receiving environment)		5	1	4	4	4	4
Amount and quality of generated sludge		3	3	2	3	3	3
reduction of the imbalance water at the basin level		0	3	3	3	3	3

Economical and financial issues	weight (1-5)	ALT 0	ALT 1	ALT 2a	ALT 2b	ALT 2c
Provides benefits to the local economy (business opportunities, local employment, etc.)	1	3	4	4	4	4
provides benefits or income generation from reuse	0	3	3	3	3	3
Social, cultural and gender	weight (1-5)	ALT 0	ALT 1	ALT 2a	ALT 2b	ALT 2c
Improves quality of life	0	3	3	3	3	3
requires low level of awareness and information to assure success of technology	0	3	3	3	3	3
requires low operation & maintenance and little involvement by the user/worker	0	3	3	3	3	3
high level of satisfaction of the local people regarding the implemented technology	0	3	3	3	3	3
requires low policy reforms at local, regional or national level.	0	3	3	3	3	3
educational impacts	2	3	3	4	4	4
Costs	weight (1-5)	ALT 0	ALT 1	ALT 2a	ALT 2b	ALT 2c
Investment cost	5	0	€ 4.825.000,00	€ 4.111.408,00	€ 3.606.288,00	€ 3.023.888,00
Maintanance cost	5	0	€ 185.154,80	€ 97.290,00	€ 97.990,00	€ 98.690,00

Alternative 0 = no intervention
++ or 5 the criterion is very fulfilled by this alternative
+ or 4 the criterion is fulfilled by this alternative
0 or 3 the criterion is neutral to this alternative
- or 2 the criterion does not fulfilled well by this alternative
-- or 1 the criterion does not at all fulfilled by this alternative

(the + and – can be substituted by numbers in the range 1-5 as specified above)

6. Conclusions

In the following section, for each case study, the results of the analysis is reported together with a few technical comments.

6.1 Definition of the optimal “tailormade” alternative

Legenda

5	the criterion is very fulfilled by this alternative
4	the criterion is fulfilled by this alternative
3	the criterion is neutral to this alternative
2	the criterion does not fulfilled well by this alternative
1	the criterion does not at all fulfilled by this alternative

NORMA

		ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Health issues		3,0	2,5	2,0	2,0	2,5
Impact to environment / nature		2,6	3,6	4,5	4,1	4,0
Technical issues		3,0	2,0	2,0	2,0	2,0
Economical and financial issues		3,0	4,0	5,0	5,0	4,0
Social, cultural and gender		3,0	3,7	3,7	3,7	3,7
Investment cost (€)		0	€ 347.600	€ 686.700	€ 650.000	€ 384.300
Maintanance cost (€/year)		0	€ 4.250	€ 8.250	€ 7.350	€ 4.250
	WEIGHT	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Investment cost	2	3,0	2,5	1,0	1,5	2,0
Maintanance cost	4	3,0	2,5	2,0	2,0	2,5
COST		3,0	2,5	1,7	1,8	2,3
TOTAL SUM		**17,6**	**18,3**	**18,8**	**18,6**	**18,5**

The 4 project alternatives appear to perform quite similarly. All of them have a better performance compared to alternative 0, even though, obviously, alternative 0 is the less expensive. The best performing alternatives are the ones that envisage the most complete action on rainwater management (altetrnatives 2 and 3). They have higher scores for the environmental impact, due to the positive effects in terms of water consumption (due to the availability of rainwater for non potable uses), of runoff management and on landscaping. They also have good performance on economic/financial indicators, due to the capacity to support the local economy: in fact design and implementation of innovative solution for rainwater management rely mainly on local enterprises.

Alternative 4, that envisage 100% of pipeline rehabilitation and only partial intervention on runoff management, also have a very good performance: it reaches good scores in environmental protection and local economy, but, being less expensive, its final total score is slightly less than alternative 3.

The four alternative are very similar for what concern health, technical and social issues: solutions envisaged in fact doesn't impact significantly such issues, and their performance is very similar to the 0 alternative.

The optimal alternative, according to the analysis done, is alternative 2, that envisage the complete rehabilitation of distribution pipelines and the most extended action of rainwater management and reuse. The environmental benefit that the proposed solutions could reached are very important, compared to the costs.

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		ALT 0	ALT 1	ALT 2a	ALT 2b	ALT 2c
Health issues		3,0	3,0	2,5	2,5	2,5
Impact to environment / nature		2,4	3,1	3,8	3,7	3,7
Technical issues		2,5	2,7	3,3	3,3	3,3
Economical and financial issues		3,0	4,0	4,0	4,0	4,0
Social, cultural and gender		3,0	3,0	4,0	4,0	4,0
Cost (€/m3 x 20 years)		0	1,23	0,87	0,8	0,72
	WEIGHT	ALT 0	ALT 1	ALT 2a	ALT 2b	ALT 2c
Cost (€/m3 x 20 years)	5	3,0	1,0	1,5	2,0	2,5
Maintanance cost (€/year)	5	3,0	1,0	2,5	2,5	2,5
COST		3,0	1,0	2,0	2,3	2,5
TOTAL SUM		**16,8**	**16,9**	**19,6**	**19,8**	**20,0**

The comparison among different alternatives in the case study of Borgo Sabotino shows a very clear framework. Alternative 1, that envisages the construction of a new network of sewers to connect untreated settlements to the existing treatment plant is by far the less performing alternative. It scores slightly better than Alternative 0. In fact its performance is significantly better than alternative 0 for environmental and economic indicators (due to its effects in reducing water pollution and promoting local economy), but its high costs compared to the "do nothing" alternative reduce the difference between the two alternatives.

Decentralized alternatives have the best performances on the environmental indicators, adding the creation of new habitat to the capacity to treat wastewater. They also show good performance – as alternative 1 – on economic indicators, due to the positive effect on local economy of the construction works and of the improvement on water quality.

The higher performance of alternatives 2a,2b and 2c on social indicators are due to the opportunity to use constructed wetland for educational purposes: in fact in many cases such systems are equipped with informative notices and visited by schools and NGOs for environmental education (see Picture 17).

Picture 17 Example of picture used for educational purposes in a constructed wetland realized in Isola Polvese (PG)

Among the three decentralized alternatives, alternative 2c – the most decentralized that envisages the construction of 6 different wetlands and the minimum length of sewers – is the best performing, being the less expensive.