

BETTER Water-management for Advancing Resilient-communities in Europe

Action D1 – Monitoring water flows and climate impacts

Third annual monitoring report

Covering the project activities from 01/01/2019 to 30/06/2022

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1 Glossary, Abbreviations, Acronyms

BEWARE	BEtter Water-management for Advancing Resilient-communities in Europe
COMSAN	Municipality of Santorso
COMMAR	Municipality of Marano Vicentino
NWRMs	Natural Water Retention Measures as classified by the Office International de l'Eau (www.nwrm.eu)
SUDS	Sustainable Urban Drainage Systems
TESAF	Dipartimento Territorio e Sistemi Agro-Forestali, Università degli Studi di Padova
Floods	All events in which water inundates lands not normally covered by water (directive 2007/60/EC, 2007) (Salvati et al., 2014)
RG1	Rain gauge number 1, located in Santorso
RG2	Rain gauge number 2, located in Giavenale di Schio

2 Executive summary

Action D1 focuses on the monitoring of the water flows managed by some of the interventions realized in the context of the BEWARE project (Actions C3 and C4).

The action includes two types of monitoring:

- Quantitative monitoring concerns measurements of inflows and outflows from the monitored interventions. The measurements will provide a precise estimation of the effectiveness of the interventions in accumulating and infiltrating water and, consequently, in flood mitigation.
- Qualitative measurements that analyses the improvements in water-quality determined by the realization of the interventions.

The monitored interventions are the following:

- The water retention basin (Action C3, Figure 2.1a) realized on a private agricultural land in Giavenale locality (Municipality of Schio, Vicenza Province) in order to *i)* mitigate the flooding risk of a downstream residential area located in the municipality of Marano Vicentino, *ii)* provide water for irrigation during the dry season to the nearby crops.
- The rain garden (Action C4, Intervention 1, Figure 2.1b) realized in Piazza della Libertà (Santorso Municipality) in order to manage the water runoff produced by the paving of the parking lot of the square.
- The grassed swale and the bioretention area (Action C4, Intervention 2, Figure 2.1c) realized in the Grumo hill (Santorso Municipality) in order to mitigate the flood risk in a down-stream residential area.
- The rain garden (Action C4, Intervention 5, Figure 2.1d) realized in the parking lot of the graveyard located in Via dei Prati (Santorso) in order to manage the water runoff coming from the paved and cultivated upstream areas.



Figure 2.1. Pictures of the interventions monitored by the Action D1 of the BEWARE project: a) water retention basin realized in Giavenale di Schio locality; b) autumn flowering at the intervention of Piazza della Libertà (Santorso); c) the rain garden located in Via dei Prati (Santorso); d) the bioretention area located on the eastern side of the Grumo hill (Santorso).

3 Project BEWARE overview

3.1 Background and justification

The consequences of climate change are exacerbated by land-use changes which affect the control of rainfall-runoff relations, and the impact on flood risk. Effectively, urbanisation is steadily contributing to the increase of impervious areas and reducing the time-to-peak. This actual scenario is fostering the debate on sustainable climate-adaptation strategies in line with the requirements of the EU Strategy on adaptation to climate change, adopted by the European Commission in 04/2013. The pressure that European countries are facing is demonstrated by scientists' modelling disaster scenarios, which evidenced that, in absence of adaptation measures in place, river flooding could affect about 300,000 people per year in the EU by 2050 and 100,000 more by 2080 (doubling the affected people in the period 1961–1990) (Rojas R. et al., 2012). Scientists showed a consistent increase of flood risk in the British Isles, western Europe and northern Italy, mainly due to the population increase.

The Italian Institute for Environmental Protection and Research (ISPRA), in a study published in June 2018, highlighted that 91% of the Italian municipalities is currently under risk of flooding, compared to the 88% in 2015. Nevertheless, in Northern Italy, the consumption of soil is higher than other Italian regions, worsening the already delicate hydrogeological conditions of the country. The effects of soil sealing and climate changes on the flood dynamics, in the Veneto Region (North-Eastern Italy), has been demonstrated in a recent paper published by TESAF (one of the project partners). The paper provides a regional screening of land-use, rainfall regime and flood dynamics in Veneto Region, covering the timeframe 1900–2010. This analysis suggests that both climate and land-use changes contributed (in synergy and individually) to a significant increase in the flood occurrence. Moreover, Sofia et al. (2017) demonstrated that floods are usually of short duration while the number of flooded areas is higher than in the past. In accordance, several flood events occurred in the region during the last decades and the most severe ones had been recorded in 1966, 1982 and in 2010, between October 30th and November 2nd (called the *All Saints* flood). During this last event, heavy rainfalls occurred in the lower mountain belt, between the provinces of Verona and Vicenza simultaneously, favoured by multiple negative atmospheric conditions (e.g. an increase of the temperatures melting the snow and southern winds contrasting the regular water down flow). 140 km of roads were inundated, 130 municipalities and about 500,000 citizens were affected, 3 persons and more than 150,000 animals died. The economic burden reached up to 429 M€. Other moderate events occurred in the same area in 2011, 2012, 2013 and 2014 (the term “water bombs” was used by mass media to describe flood events triggered by intense rainfall events). However, effective disaster management needs an integrated approach to land planning, which promotes sustainable measures to restore the water storage capacity of the soil.

A previous research (Roder, 2019) covering the overall Veneto Region showed that people has a medium-low perception of flood risk, neglecting the future probability of occurrence and undertaking few individual mitigation actions. The lack of knowledge of the inhabitants is the main cause of their lack of preparedness: in fact, they usually delegate the responsibility of their safety to public authorities

in charge. Results justify the need of increasing citizen's awareness and good practices adoption for collective welfare. The study area of the present study is the upper Vicenza province, included in the Bacchiglione–Brenta river system. In this area, and in the rest of Veneto region, green solutions (like the ones promoted by the project) could play a key role in flood mitigation. However, at present time, NWRMs are poorly adopted in the region (and at the National level) and, until now, NWRMs have not been considered/included in the flood risk management plans, drafted by the the *Distretto Idrografico Delle Alpi Orientali* (www.alpiorientali.it). Currently, all the public investments are placed for structural measures without considering neither green solutions nor non-structural measures for people's empowerment. Moreover, Veneto region, with the law n. 3637 of 13/12/2002, asked for a compulsory 'evaluation of hydraulic compatibility' for all the new building regulations. This technical guidance provides methods for hydrologic evaluations but does not suggest NWRMs adoption to preserve the hydraulic invariance.

The individual's adoption of NWRMs is expected to provide positive benefits at the society level: i) under a bottom-down approach (the setting of new water regulations) and ii) under a bottom-up approach (the implementation of transferable measures in a participative context). In this regard, it is remarkable that the Flood Directive recommends a wide involvement of the civil society when defining the management plans: «The Member States shall encourage active involvement of interested parties in the production, review and updating of the flood risk management plans (...)» (Art. 10 p. 2).

3.2 Project BEWARE objectives

The main project objective is the achievement of a global strategy for climate adaptation to flooding risk, increasing water infiltration and storage in urban and rural areas and involving the local communities actively. BEWARE project aims to increase knowledge, benefits and real implementation of NWRMs (Natural Water Retention Measures) both in the territory of COMSAN and COMMAR (Vicenza, Veneto Region, IT) and also in other EU municipalities, thanks to demonstrative interventions fully coordinated with information, communication and education activities. Specific objectives are:

1. To perform six urban NWRMs to reduce flood risk by increasing water infiltration and storage in COMSAN and COMMAR. Such measures are: i) undertrained bioretention, ii) infiltration trenches, iii) detention basin with an internal bioretention pond, iv) rainwater harvesting plus dry wells, v) rain gardens plus grass swales and vi) SUDS treatment train;
2. To perform one agricultural NWRM, in COMMAR, to reduce the flood risk and to partially solve the drought problems of some agricultural firms during the dry periods;
3. To promote a participative approach to implement local initiatives and measures on water-retention actions, facing climate change challenges;
4. To establish a local administrative, financial, and technical context, supporting the diffuse employment of NWRMs;
5. To enhance the link between European policies and local contexts, actively involving citizens and key-stakeholders, on the EU goals on climate change;

6. To demonstrate that small diffused works and the implementation of best practices can guarantee hydraulic safety, facing climate-change consequences effectively;
7. To favour the replication of the proposed actions in other geographic areas of Italy and Europe.

The project is innovative for the Communities because it aims to tackle the flood issue on a new participatory perspective. It promotes a set of low-cost measures that municipalities, farms or citizens can manage efficiently. In fact, although in several European Countries a sustainable water-retention approach is still developing, in Italy and in Veneto Region a substantial delay exists. Similar defective situations have been found in Europe, highlighting the need for modern water-retention techniques (Flood Directive, art.7) to be rapidly translated into practice, inside the EU territory.

The participation is the key to develop a favourable background for effective climate adaptations initiatives. Through active involvement, BEWARE aims to promote a public responsibility for facing hydraulic risks and proposes a set of best practices to be implemented in a wider context. Indeed, the strategy can also be a shortcut to ensure social acceptance of a more sustainable land-use planning. Although the NWRMs are technically mature, they are poorly spread in Veneto Region and other European countries. Therefore the action panel of BEWARE is a virtuous example, voted to trigger a positive trend in NWRMs employment.

In addition to the strong demonstrative character of the project, the involvement of all public and administrative authorities at local level that are considered by the Covenant of Mayor's framework (Mayors Adapt) is a real innovation, if considering such a wide area (the project will involve, in the definition of a common water strategy, all 33 municipalities - *Intesa Programmatica d'Area IPA Altovicentino*).

The project is providing insights for the building code's revision in the two involved municipalities that will include mandatory norms for climate change adaptation improving the resilience of new buildings. Through the network provided by different stakeholders, the code will be proposed as a model; in particular, BEWARE will involve other Italian and European municipalities and local governments. A Permanent Centre for Resilient Communities has been launched by the Consortium and hosted by COMSAN providing:

- training activities for local administrators, civil servants, farmers, technicians;
- educational activities for pupils.

Furthermore, seminars and workshops planned by BEWARE are going to be organized. The knowledge spread with these activities will help the dissemination and replication of such measures. In addition, the transformative impacts of the other actions will strongly contribute to the community awareness to cope with climate problems, taking individual practical actions both in private and public territory (e.g. contrasting the soil sealing).

BEWARE is supported by the Italian Ministry of the Environment and the Protection of the Territory and the Sea (see support letters). A specific agreement will be proposed to involve the Ministry as permanent observant; the agreement will foresee the national dissemination of the project's results.

4 Monitoring methods and devices

4.1 Rainfall measurement

Two rain gauges continuously monitor the rainfall generating the inlet runoff of the interventions. The first rain gauge (RG1) is located on the roof of the secondary school "A. Cipani" in Santorso (Figure 4.1a). This rain gauge allows to measure the rainfall affecting the three monitored interventions located in Santorso (Interventions 1, 2 and 5 of Action C4). The second rain gauge (RG2, Figure 4.1b) is located in Giavenale di Schio locality, on the bank of the water retention basin (Action C3).

RG1 is the model HD2015 produced by Delta Ohm S.r.l. It is a reliable and sturdy bucket rain gauge, entirely constructed of corrosion resistant materials in order to guarantee its durability. The rain gauge is formed by a metal base on which a tipping bucket is set. The rain collector cone, fixed to the aluminum cylinder, channels the water inside the tipping bucket: once the predefined level is reached, the calibrated bucket rotates under the action of its own weight, discharging the water. During the rotation phase, the normally closed reed contact opens for a fraction of a second, sending an impulse to the counter.

The quantity of rainfall measured is based on the count of the number of times the bucket is emptied: the reed contacts, normally closed, open at the moment of the rotation between one bucket's section and the other. The number of impulses is detected and recorded by a data logger HD33-M.GSM provided by a built-in 4G/3G/GPRS modem to set the datalogger and download the recorded data remotely¹.

The second rain gauge (RG2) is located in the proximity of the water retention basin located in Giavenale di Schio locality (Figure 4.1b), in order to characterize the rainfall affecting this intervention (Action C3) located about 5 km south of the other three monitored interventions of Santorso.

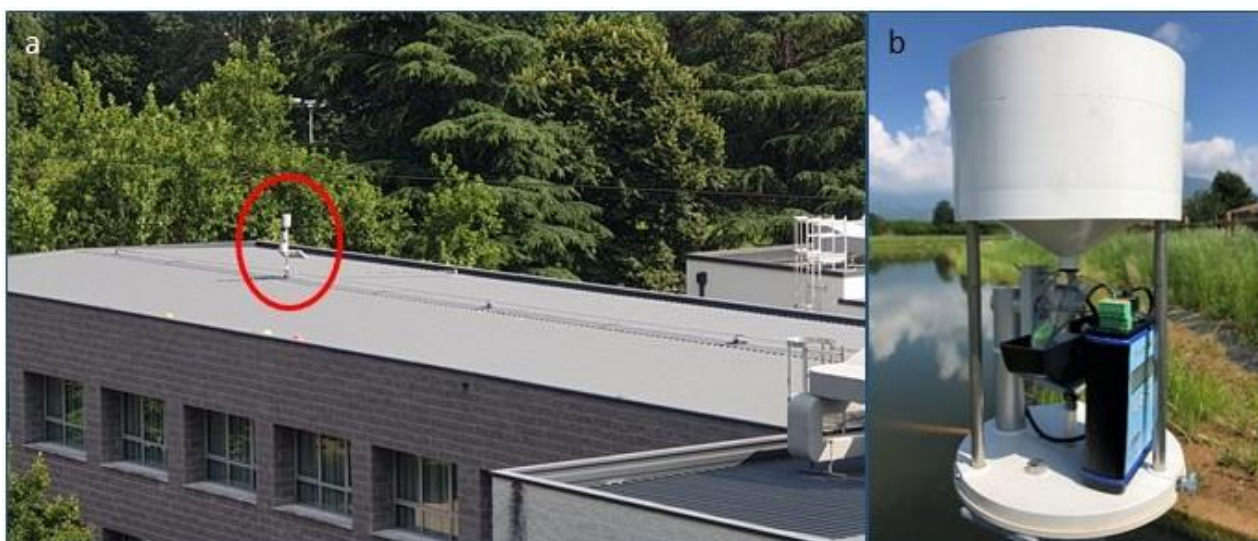


Figure 4.1. Rain gauges installed in Santorso (a), on the roof of the secondary school, and in Giavenale di Schio (b), on the bank of the water retention basin.

¹ Delta Ohm (2020). Operating manual - Tipping bucket rain gauge HD2015.

The RG2 is the model RG50 produced by SEBA Hydrometrie GmbH. The RG 50 is a highly accurate precipitation gauge with a pulse output for data collection systems. It has a one-sided ball-bearing tipping bucket made from plastic with a spirit level and adjusting screw². The rain gauge is provided by a Unilog-Light data logger fully operating with pulse input for measuring rainfall with a current supply of an internal 9V-battery. Measured values and status information can be registered and read out easily on site at the LC-display by means of a 3-buttons display-panel. The 8MB storage (approx. 560,000 measured values) can be programmed, adjusted and read out via RS 232 interface by means of an interface-cable³.

Figure 4.2 reports the location of the rain-gauges respect to the monitored interventions.

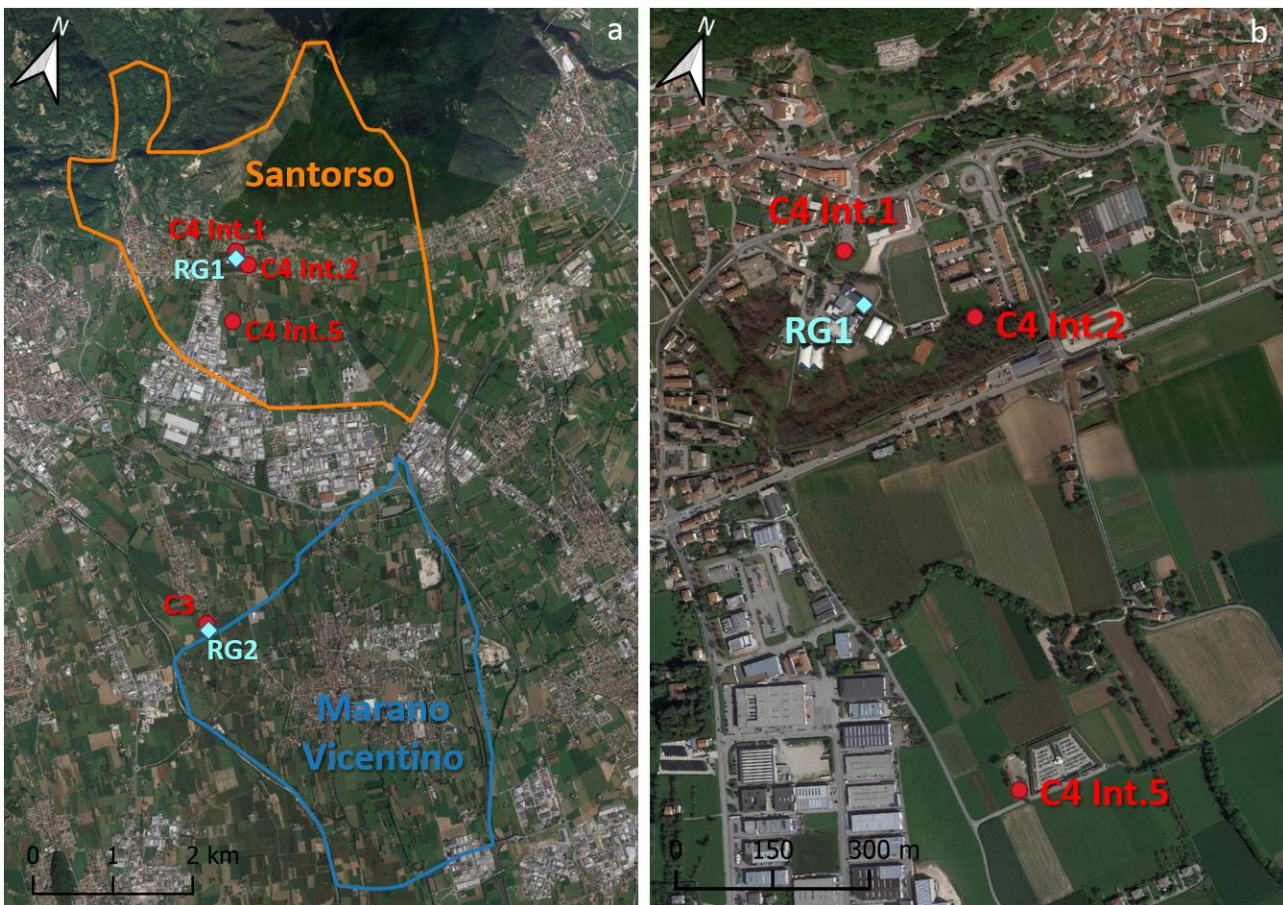


Figure 4.2. Location of the monitored interventions (red dots) and rain gauges (light blue rhombus) respect to the municipalities of Santorso and Marano Vicentino (a); figure b reports a

² SEBA Hydrometrie (2020). RG 50 User Manual Version 2.00.

³ SEBA Hydrometrie (2020). Unilog-Light User Manual Version 1.51.

4.2 Inlet runoff measurement (interventions in urban areas, Action C4)

An *ad hoc* device has been designed and produced in order to monitor the runoff inlet of the three monitored interventions realized in the urban context (Action C4, Interventions 1, 2 and 5, location in Figure 4.2). The device consists of a water collection concrete pit provided by an aluminum sharp-crested weir.

The concrete pit is composed by two chambers: in the first chamber the runoff is intercepted and pre-treated (siphon) in order to remove debris that might clog the second chamber that function as weir pond.

Figure 4.3 explains the general functioning of the inlet runoff measurement using as example the intervention 1 of Action C4.



Figure 4.3. Graphic scheme of the functioning of the inlet runoff measurement, with the positioning of the inlet device that collect the runoff from the drainage area (red polygon) measuring the discharges before it enters the intervention (blue polygon).

The weir installed in the concrete pit is necessary for the discharge measurement and it has been designed considering the range of expecting inlet discharges. This discharge was calculated by using the Rational Method and a Runoff Coefficient selected considering the ground cover of the drainage area. Table 4.1 reports the results of this preliminary analysis. Information about the precipitation analysis and the parameters used in the calculation are reported in the design of the interventions, deliverable of the Action C4 of the project.

Table 4.1. Expected inlet discharges Q for the three monitored interventions realized in the urban context for different rainfall return periods (Tr) and rainfall height (h). Table reports the parameters used in the application of the Rational Method: time of concentration (Tc), drainage surface area (A), and Runoff Coefficient (C).

Intervention	Tc [min]	A [m ²]	C [-]	Q [l/s]				
				$Tr=2$ yr	$Tr=5$ yr	$Tr=10$ yr	$Tr=30$ yr	$Tr=50$ yr
				$h=25.8$ mm	$h=33.8$ mm	$h=39.2$ mm	$h=47.2$ mm	$h=50.9$ mm
1 (Piazza della Libertà)	7.8	783.5	0.9	20.9	26.2	29.7	35.0	37.5
2 (Grumo hill)	25.7	4200	0.2	14.0	18.4	21.3	25.7	27.7
5 (New graveyard)	1.5	700	0.9	41.2	48.5	53.5	61.1	64.6

In order to accurately measure the wide range of expected discharges and limit the head flowing through the notch, a compound rectangular-rectangular sharp-crested weir (CRRSC weir) has been designed. Figure 4.4 reports the dimensions of the weir and a picture of its installation in the field (Intervention 5, Action C4).

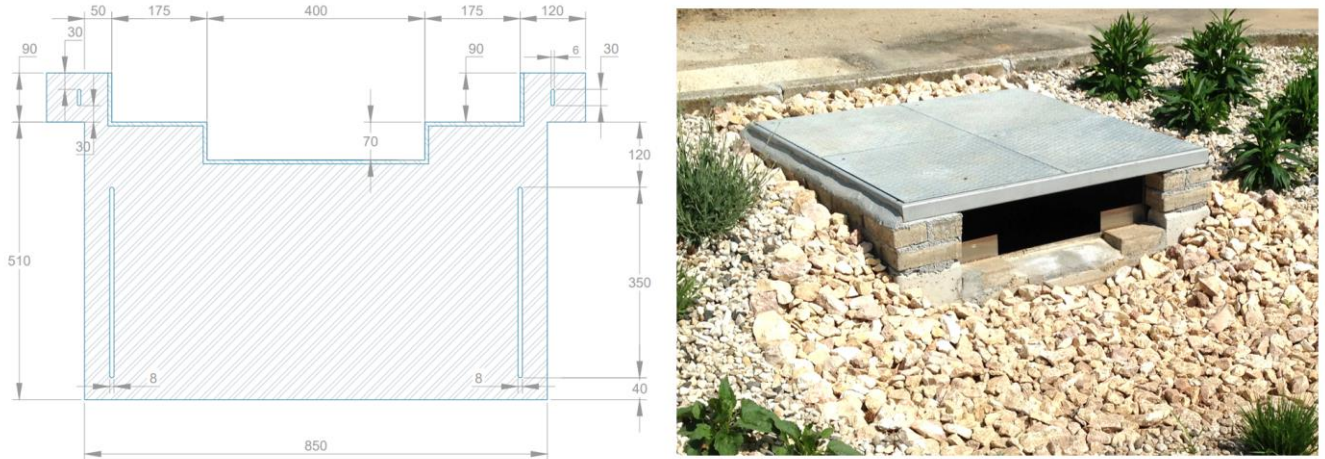


Figure 4.4. Perspective drawing of the weir (on the left, values in millimeters), and picture of its installation into the concrete pit that function as weir pond (on the right).

The CRRSC weir can be considered as a linear combination of two simple rectangular sharp-crested weirs (Jan et al., 2005). Therefore, from the linear combination, the discharge relation for the symmetric CRRSC weir can be written as:

$$Q = C_{d1}\sqrt{2g}(2b_1)h_1^{3/2} + C_{d2}\sqrt{2g}(b_2)h_2^{3/2}$$

Where C_{d1} and C_{d2} are the discharge coefficients and can be set equal to 0.415 if the upstream flow velocity is equal to zero (Ferro, 2011), b_1 is the width of the first left rectangular weir (equal to 175 mm in Figure 4.4, that is equal to the symmetrical right weir), and b_2 is the width of the middle rectangular weir (400 mm in Figure 4.4). An experimental calibration of the weirs has been carried out using a full-scale prototype (Figure 4.5). Experimental data confirmed the validity of the theoretical coefficients, and the final relation adopted to convert flow head values into discharge values is reported in Figure 4.6.



Figure 4.5. Full scale prototype used for the calibration of the CRRSC weir.

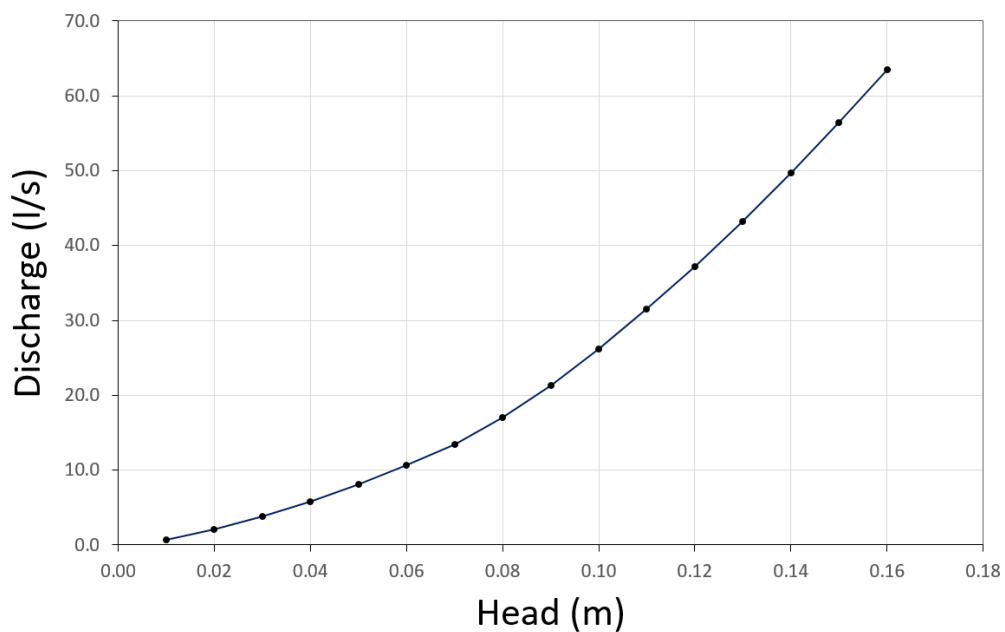


Figure 4.6. Graph of head vs discharge for the compound rectangular-rectangular sharp-crested weir used to monitor the inlet discharge to the monitored urban interventions of Action C.4.

In order to constantly measure the flow head over the crest weir and consequently know the flow discharge inlet of the interventions, a pressure transducer has been installed inside the concrete pits hosting the weirs. The adopted device is a Datalogger Dipper PT produced by SEBA HYDROMETRIE GmbH equipped with an external battery compartment (Power-pack module: Power supply with 4 x 1.5 V replaceable C-type batteries alkali-manganese), Figure 4.6. The SEBA Data Loggers type Dipper-PT are used for digital data recording of water level in ground water and surface water. The Dipper-PT/PTEC has a RS485 interface for configuring and calibrating the probe, retrieving measurement values and

reading data storage. All these functions can be executed with software SEBAConfig. The robust ceramics pressure measuring cell makes it possible to measure the water level above the probe (hydrostatic pressure). The combination of the referential pressure sensor and the special measuring cable with integrated air pressure compensation capillary compensates air pressure fluctuations⁴.



Figure 4.7. The pressure transducer SEBA Dipper-PT used to monitor the flow head over the weir crest (on the left), and a picture of its installation in the Intervention 2 of Action C4 (Grumo hill, Santorso).

⁴ SEBA Hydrometrie (2020). Dipper-PT User manual Version 2.84.

4.3 Outlet runoff measurement (interventions in urban areas, Action C4)

In case the intervention stops to retain runoff waters (this means that its storage and infiltration capacities are exhausted), an overflow pipe collects the excess water to a second concrete pit that measure the outlet volumes before they reach the urban drainage system (Figure 4.8). Knowing the pit dimensions (1m² of planimetric section), the outlet volumes are measured through the monitoring of the flow level inside the pit.

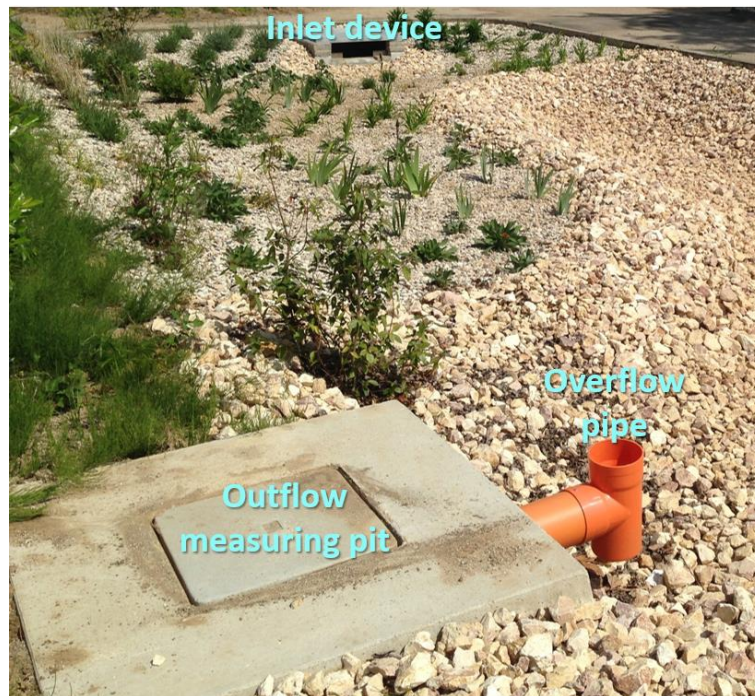


Figure 4.8. Picture of the Intervention 5 of Action C4 showing the position of the outlet measuring devices.

The flow level inside the pit is measured using the same device used in the inlet pit: the pressure transducer SEBA Data Loggers type Dipper-PT. In this case, the Dipper-PT is not provided by an external battery pack as in the inlet measuring device because the recording rate (30 min) does not require the installation of an external power supply.

Differently from Interventions 1 and 5 (Piazza della Libertà and Via dei Prati), in the intervention 2 (Grumo hill) the outlet runoff is monitored through the installation of a piezometer in the downstream bioretention area: the intervention consists of two bioretention areas organized in a cascade (details in the intervention design, Action C4 deliverable). The pressure transducer installed in this PVC pipe allows to detect the activation of the second bioretention area (i.e. define when the water accumulation and infiltration of the first bioretention area was not able to manage the inlet runoff), and to provide evidences in its functioning, included the documentation of the outflow.

4.4 Monitoring the water volumes managed by the retention basin (intervention in an agricultural area, Action C3)

In the agricultural area of Giavenale di Schio locality (Vicenza Province), a retention basin has been built with a double aim: reduce the flooding risk of a residential area in the municipality of Marano Vicentino, and guarantee, even in times of drought, the water resource to the agricultural activities of the area.

As a consequence, during the summer period the basin is maintained full of water in order to provide water for irrigation, while during the winter season the basin is empty in order to receive and accumulate the water runoff generated by prolonged rainfall.

The basin effect in reducing the flooding risk is measured in terms of volume of water retained during rainfall events that may result in potential flooding.

In order to accurately measure the water volume retained by the basin, a UAV flight has been carried out the 8th October 2019, after the conclusion of the construction works, using a DJI Phantom 4 Pro (Figure 4.9), a consumer-grade quadcopter with a 20 Megapixel camera. The flight provided high resolution imagery and a high-resolution topographic reconstruction of the basin based on Structure-from-Motion (SfM) photogrammetry. Twelve ground targets were used to georeference the UAV SfM data. The easting, northing, and elevation of each target was recorded using two Topcon HiPer V differential GPS (Rover and base receivers, Figure 4.9) with a centimetric accuracy. Agisoft™ Metashape PC software was then used to create a orthophoto mosaic and a digital terrain model (DTM) with a resolution of 10 cm (Figure 4.10) from the 92 photos taken during the flight.



Figure 4.9. Devices used for the high-resolution topographic survey of the empty retention basin (on the background): the DJI Phantom 4 Pro and the Topcon HiPerV differential GPS (used as base station in the picture).



Figure 4.10. Orthophoto mosaic (on the left) and the digital terrain model (hillshade view on the right) obtained by the UAV survey of the empty water retention basin (Action C3).

The geoprocessing toolbox of ESRI ArcGIS has been used to analyze of the digital terrain model. The Surface Volume algorithm, available on of the 3D Analyst extension of the toolbox, calculates the area and volume of the region between a surface and a reference plane. Using the DTM of the basin as reference plane, the tool has been used to calculate the volumes of water retained by the basin for different elevations of the water level inside the basin. The data obtained by this analysis is reported in Figure 4.11. The linear interpolation between the points of the graph in Figure 4.11 has been used to obtain a value of volume retained for each possible water level measured inside the basin.

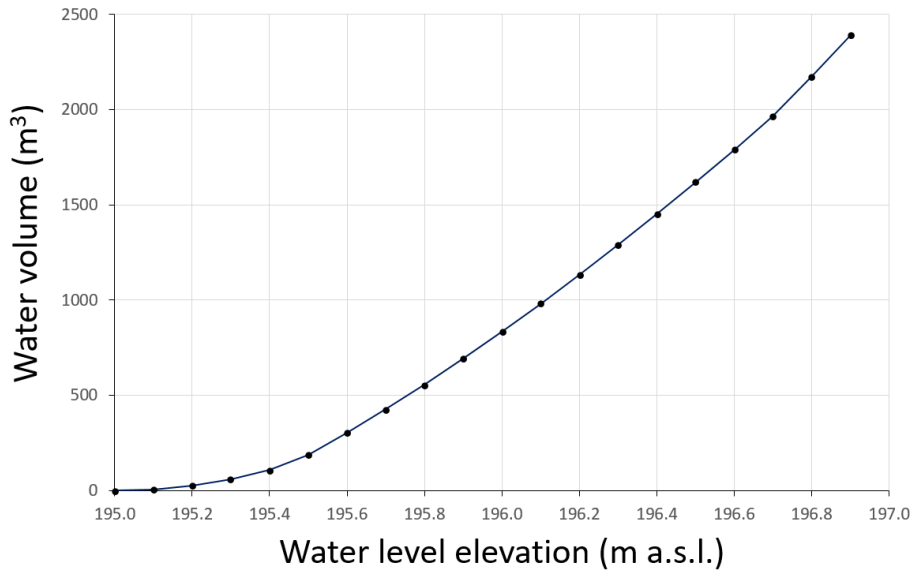


Figure 4.11. Water volume retained by the retention basin (Action C3) Vs. elevation of the water level inside the basin.

The water level is constantly monitored by a pressure transducer SEBA Dipper-PT (description of the device in the previous section; picture of the installation site in Figure 4.12). The application of the identified relationship of Figure 4.11 to the measured water levels allows to know the volume retained by the basin through time. Consequently, the adopted methods allow to measure the water retained by the basin after potentially flooding rainfall events.



Figure 4.12. The perforated PVC pipe installed on bank of the basin that host the pressure transducer in order to measure the water level.

4.5 Monitoring the water quality managed by the interventions

For the four interventions, the quality of the water has been investigated through laboratory analysis. The samples has been collected during some rainfall events in 2021 (Figure 4.13). The compounds investigated in the urban interventions involve the analysis of Biochemical Oxygen Demand (BOD₅), oils, hydrocarbons and suspended solids. For the retention basin (agricultural area) a larger number of compounds has been investigated, including metals, bacteria, volatile organic compounds and aromatic hydrocarbons. The analysis has been carried out in the laboratory of VIACQUA S.p.A., while volatile organic compounds and aromatic hydrocarbons has been sent to Veritas S.p.A. laboratory.



Figure 4.13: samples for monitoring the water quality of the interventions just collected from the Intervention 5 of Action C4

5 Monitoring results

5.1 Rainfall

Table 5.1 reports the monthly rainfall recorded during the year 2020 by the two rain gauges (description of the devices in Section 4.1) installed in Santorso (RG1) and Giavenale di Schio locality (RG2). The pattern of the precipitation over the year is similar in the two locations, and the annual cumulative rainfalls differs by about 150 mm.

Figure 5.1 reports the graph of the daily rainfall recorded by the rain gauges.

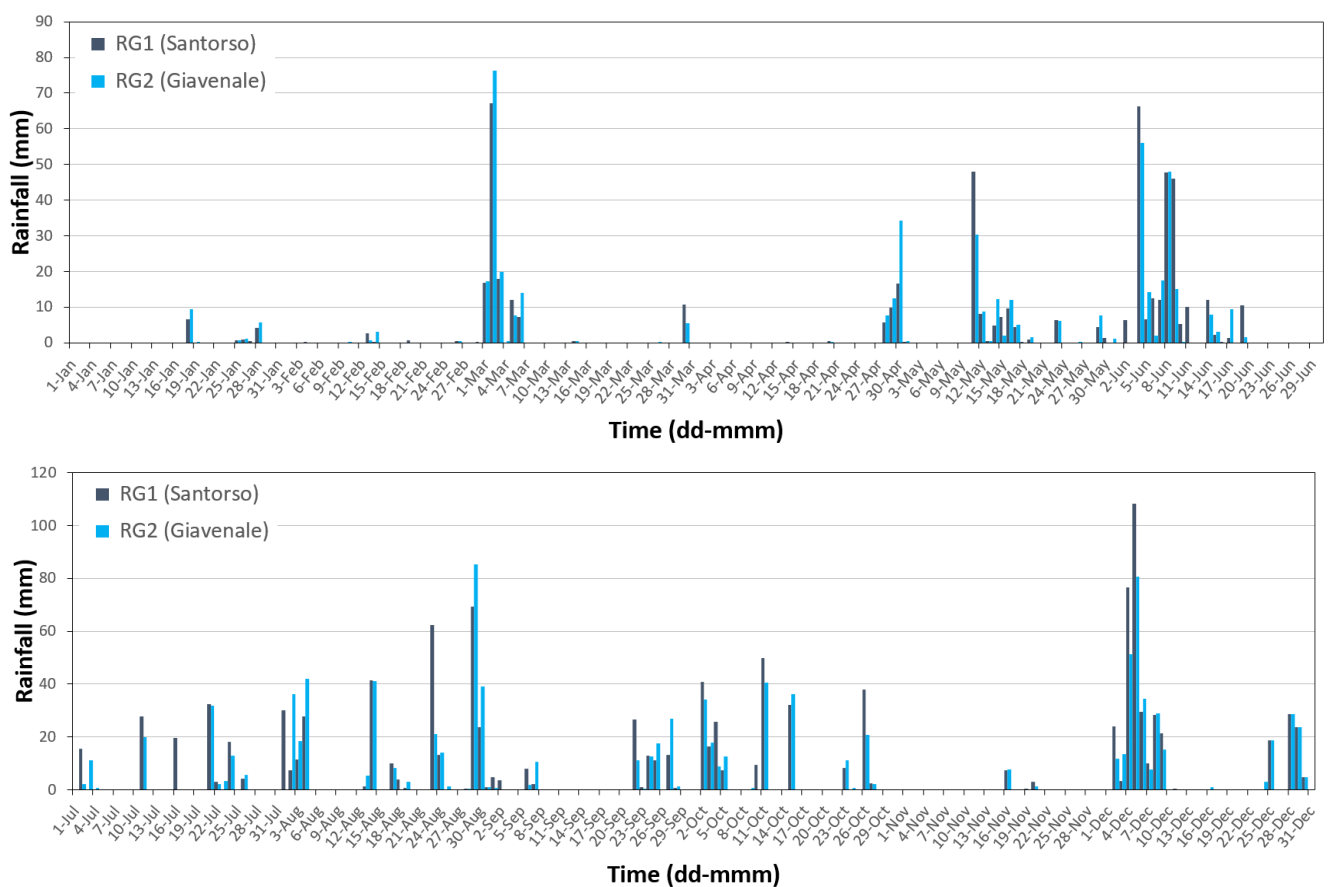


Figure 5.1. Bar charts showing daily rainfall recorded by the two raingauges in 2020.

Table 5.1. Monthly rainfall collected by the two installed Rain Gauges in 2020.

Month	RG1 (mm)	RG2 (mm)
Jan	12.9	17.4
Feb	4.4	4.4
Mar	132.3	141.2
Apr	33.0	54.4
May	95.9	88.0
Jun	239.6	174.8
Jul	122.2	90.3
Ago	305.5	317.7
Sep	85.2	83.8
Oct	231.2	186.9
Nov	11.1	9.4
Dec	378.1	324.2
Annual Rainfall	1651.5	1492.5

Table 5.2 shows the monthly rainfall for the year 2021. The raingauge located in Santorso recorded a cumulative annual rainfall equal to 1518 mm, while RG2 (located in Giavenale) measured 1236 mm. The difference in precipitation recorded for the year 2021 between the two raingauges is equal to 282 mm in favour to RG1. This value is greater than the previous year, while the cumulative annual rainfall recorded in 2021 resulted lower than in 2020 of about 130 mm considering RG1 and 250 mm considering RG2. Figure 5.2 reports the daily rainfall recorded by the two raingauges.

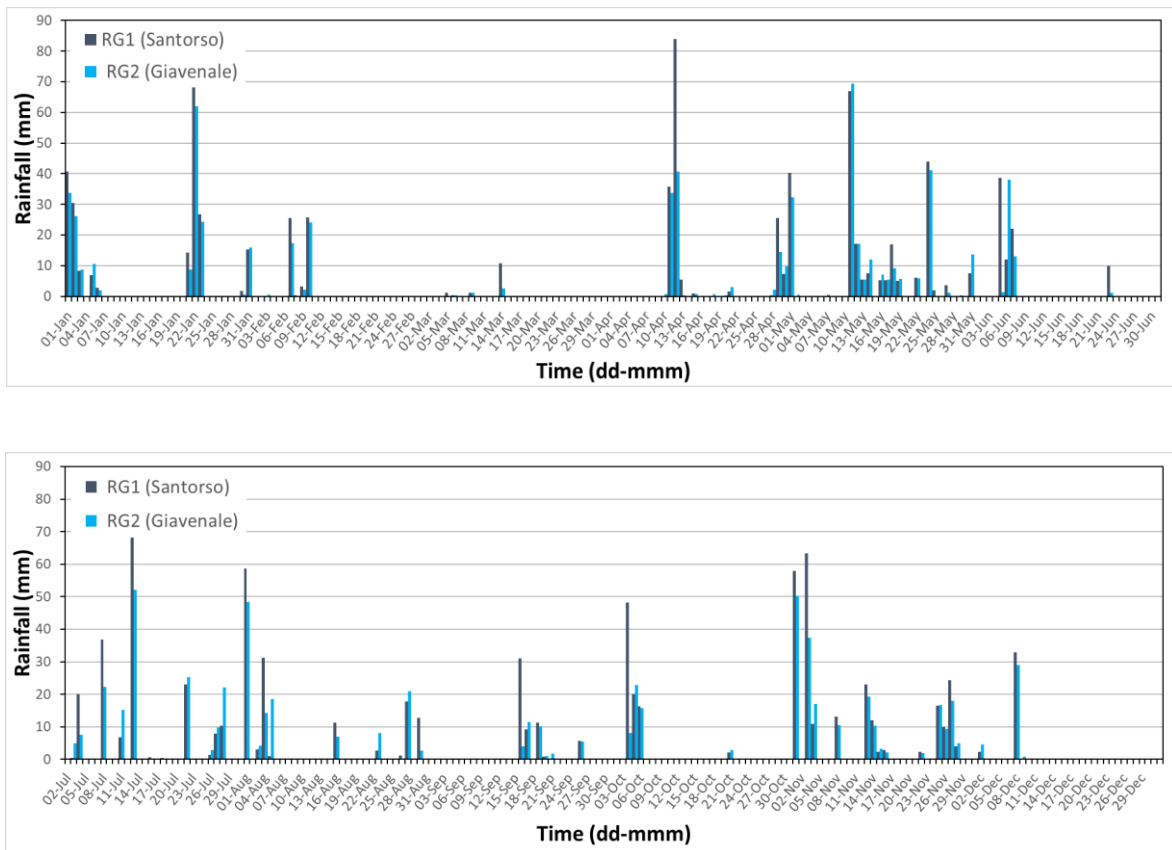


Figure 5.2. Bar charts showing daily rainfall recorded by the two raingauges during in 2021.

Table 5.2. Monthly rainfall collected by the two installed raingauges in 2021.

Month	RG1 (mm)	RG2 (mm)
Jan	219.3	192.9
Feb	54.9	44.5
Mar	13.9	4.2
Apr	162.0	106.9
May	233.6	226.7
Jun	82.8	53.7
Jul	187.9	163.0
Ago	139.9	124.1
Sep	57.9	33.8
Oct	87.0	49.9
Nov	243.2	201.4
Dec	35.8	35.0
Annual Rainfall	1518.7	1236.1

Table 5.3 reports the monthly rainfall recorded during the first six months of 2022 by the two rain gauges installed in Santorso (RG1) and Giavenale di Schio locality (RG2); the description of the devices is reported in Section 4.1).

The pattern of the precipitation over the recorded period is similar in the two locations, except for the rainfall event of the 5th January (RG1 recorded two times the precipitation height of RG1), and the cumulative rainfalls differs by about 80 mm. The total rainfall height resulted very low if compared to the mean value of the period, equal to 679 mm (meteorological station located in Monte Summano, managed by ARPAV – Regional Agency for the environmental Protection and Prevention of the Veneto). Indeed, the whole north-east of Italy has been affected by a prolonged dry period for the first half of the 2022. Figure 5.3 reports the graph of the daily rainfall recorded by the rain gauges.

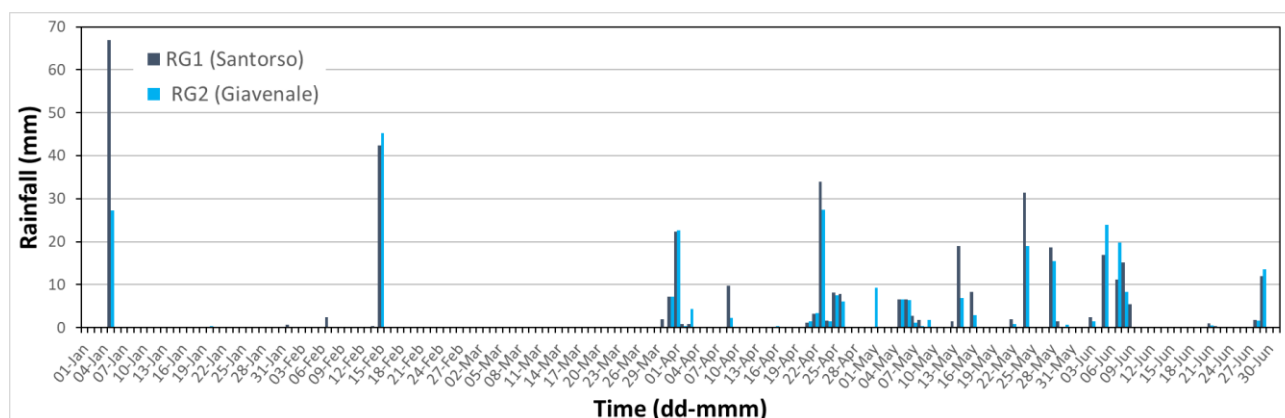


Figure 5.3: Bar charts showing daily rainfall recorded by the two raingauges in the period January – June 2022.

Table 5.3: Monthly rainfall collected by the two installed raingauges in the period January – June 2022.

Month	RG1 (mm)	RG2 (mm)
Jan	66.9	28.0
Feb	46.4	45.5
Mar	9.2	7.2
Apr	89.7	77.3
May	100.3	71.3
Jun	66.0	69.4
Annual Rainfall	378.5	298.7

5.2 Interventions in urban area (Action C4)

The methods described in Section 4 are providing data in order to monitor the functioning and the efficiency of the rain garden realized in Piazza della Libertà (Santorso Municipality, Action C4, Intervention 1), of the grassed swale and the bioretention area realized in the Grumo hill (Santorso Municipality, Action C4, Intervention 2), and of the rain garden realized in the parking lot of the graveyard located in Via dei Prati (Santorso Municipality, Action C4, Intervention 5).

For each monitored rainfall event, the fielded actions provided the data graphically displayed in the graphs of Figure 5.4: the rainfall affecting the drainage area managed by the intervention, the inlet discharge and volume, and the cumulative outlet water volume after each rainfall event.

This is for each of the monitored interventions except for the intervention of the Grumo hill where, as described in the Section 4, the probe at the outlet does not provide information about the outlet volume, but give information about the functioning of the bioretention system, i.e. the outlet activation from the first and from the second bioretention areas.

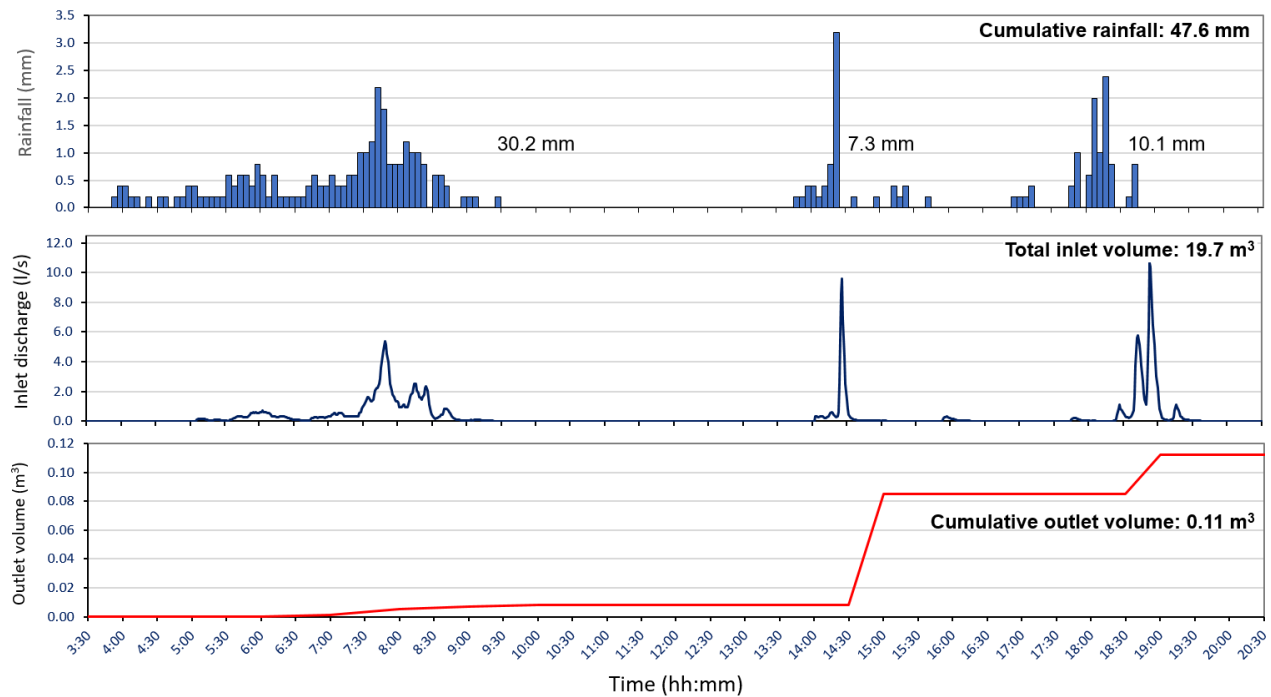


Figure 5.4. Rainfall affecting the urban area of Santorso Municipality the 11th of May 2020 (first graph), and the consequently measured inlet and outlet runoff from the Intervention 1 of Action C4 (rain garden located in Piazza della Libertà).

The following tables summarize the data showed in the graph of Figure 5.2 for each rainfall event able to generate inlet runoff in the monitored interventions in 2020. Respect to the interventions of Piazza della Libertà and via dei Prati, fewer events are documented for the Grumo hill (Table 5.4). This is because of the drainage area that in the Grumo hill is constituted mainly by a forest that intercept and infiltrate most of the precipitation (low or no inlet runoff occurs).

Data recorded during the first year of monitoring highlight that all the monitored interventions were able to manage almost all the rainfall events occurred in 2020. The fraction of the rainfall runoff that reached the outflow (overflow pit; see e.g. Figure 4.8) was always less than 2%; in addition, for the intervention of the Grumo hill, outflow runoff has never been observed, and only during one rainfall event, the second bioretention area has been activated (for all the other events, the first bioretention area was able to accumulate and infiltrate all the inlet water volume).

Table 5.4. Inlet and outlet volume measured in the intervention of Piazza della Libertà in 2020.

Date	Daily rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m ³)	Outlet volume (m ³)	Fraction of the inlet volume managed by the intervention (%)
11/05/2020	47.6	3.2	19.7	0.110	99.4
15/05/2020	7.2	1.8	0.9	0.000	100.0
16/05/2020	9.6	0.6	0.1	0.000	100.0
23/05/2020	6.4	0.8	3.5	0.000	100.0
02/06/2020	6.4	2.4	5.6	0.000	100.0
04/06/2020	66.3	2.2	38.2	0.000	100.0
05/06/2020	6.6	0.6	12.1	0.000	100.0
08/06/2020	47.4	4.4	30.7	0.380	98.8
09/06/2020	46.0	9.8	26.0	0.349	98.7
10/06/2020	5.4	1.0	0.3	0.000	100.0
11/06/2020	10.1	3.0	0.3	0.000	100.0
14/06/2020	12.1	4.0	13.6	0.000	100.0
19/06/2020	10.5	3.2	1.9	0.000	100.0
03/07/2020	0.2	0.2	1.0	0.000	100.0
11/07/2020	27.7	2.4	11.3	0.000	100.0
16/07/2020	19.5	4.8	35.2	0.360	99.0
24/07/2020	18.3	2.2	12.3	0.000	100.0
26/07/2020	4.4	2.6	0.7	0.000	100.0
03/08/2020	11.1	0.8	5.6	0.000	100.0
04/08/2020	27.7	2.2	26.3	0.000	100.0
14/08/2020	41.4	11.7	52.0	0.030	99.9
19/08/2020	0.2	0.6	0.6	0.000	100.0
23/08/2020	62.5	10.1	44.2	0.034	99.9
29/08/2020	69.3	4.6	52.6	0.268	99.5
30/08/2020	23.7	3.0	10.5	0.000	100.0
22/09/2020	26.7	7.2	1.7	0.000	100.0
24/09/2020	12.9	1.0	4.5	0.000	100.0
25/09/2020	11.1	2.8	14.0	0.000	100.0
27/09/2020	13.1	0.8	5.5	0.000	100.0
02/10/2020	41.0	1.6	28.7	0.000	100.0
03/10/2020	16.5	1.8	6.6	0.000	100.0
04/10/2020	25.7	1.2	2.2	0.000	100.0
05/10/2020	7.4	1.0	12.5	0.000	100.0
11/10/2020	49.9	1.0	34.7	0.081	99.8
15/10/2020	32.2	0.8	12.7	0.000	100.0
23/10/2020	8.4	0.4	0.3	0.000	100.0
26/10/2020	38.0	1.8	22.1	0.000	100.0
27/10/2020	2.6	1.0	0.8	0.000	100.0
04/12/2020	76.6	2.0	21.6	0.000	100.0
05/12/2020	108.3	2.0	39.4	0.035	99.9
06/12/2020	29.5	1.2	10.9	0.018	99.8
07/12/2020	10.0	0.6	1.9	0.000	100.0
08/12/2020	28.5	0.6	2.9	0.000	100.0
09/12/2020	21.3	0.4	1.3	0.010	99.3
25/12/2020	16.2	0.2	24.9	0.000	100.0
28/12/2020	27.7	0.2	3.8	0.000	100.0
29/12/2020	23.8	0.2	10.3	0.000	100.0

Table 5.5. Inlet and outlet volume measured in the intervention of via dei Prati in 2020.

Date	Daily rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m ³)	Outlet volume (m ³)	Fraction of the inlet volume managed by the intervention (%)
11/05/2020	48.0	3.2	2.7	0.000	100.0
15/05/2020	7.2	1.8	0.5	0.000	100.0
17/05/2020	4.0	0.4	0.0	0.000	100.0
23/05/2020	6.4	0.8	3.3	0.000	100.0
24/05/2020	6.4	0.8	0.1	0.000	100.0
29/05/2020	4.4	1.0	1.1	0.000	100.0
02/06/2020	6.4	2.4	3.5	0.000	100.0
04-10/06/2020	196.2	3.2	217.6	0.690	99.7
14/06/2020	12.1	4.0	0.9	0.000	100.0
19/06/2020	10.5	3.2	2.8	0.000	100.0
02/07/2020	15.7	4.4	1.4	0.000	100.0
03/07/2020	0.2	0.2	2.4	0.000	100.0
11/07/2020	27.7	2.4	29.0	0.000	100.0
16/07/2020	19.5	4.8	46.8	0.000	100.0
21/07/2020	32.4	8.2	2.0	0.000	100.0
22/07/2020	3.2	0.8	2.9	0.000	100.0
23/07/2020	3.2	0.8	1.7	0.000	100.0
24/07/2020	18.3	2.2	15.0	0.000	100.0
25/07/2020	0.2	0.2	0.4	0.000	100.0
26/07/2020	4.4	2.6	3.2	0.000	100.0
02/08/2020	7.6	0.8	1.7	0.000	100.0
03/08/2020	11.1	0.8	12.9	0.000	100.0
04/08/2020	27.7	2.2	31.3	0.092	99.7
13/08/2020	1.4	0.8	0.2	0.000	100.0
14/08/2020	41.4	11.7	35.9	0.049	99.9
17/08/2020	10.1	5.2	1.4	0.000	100.0
19/08/2020	0.2	0.6	3.4	0.000	100.0
23-25/08/2020	75.8	10.1	60.2	0.059	99.9
29/08/2020-02/09/2020	102.9	4.6	80.1	0.414	99.5
06/09/2020	8.2	1.8	1.9	0.000	100.0
07/09/2020	2.2	0.4	1.6	0.000	100.0
22-25/09/2020	51.9	7.2	66.7	0.018	100.0
27/09/2020	13.1	0.8	17.2	0.000	100.0
02-05/10/2020	90.5	1.8	111.5	0.296	99.7
11/10/2020	49.9	1.0	72.2	0.011	100.0
15/10/2020	32.2	0.8	58.7	0.014	100.0
23-27/10/2020	57.3	1.8	49.3	0.023	100.0
16/11/2020	7.6	0.4	8.8	0	100.0
20/11/2020	3.0	0.4	9.1	0	100.0
02-05/12/2020	212.1	2.0	446.8	0.34	99.9
06/12/2020	29.5	1.2	86.9	0.05	99.9
07/12/2020	10.0	0.6	17.6	0	100.0
08/12/2020	28.5	0.6	41.1	0.05	99.9
09/12/2020	21.3	0.4	26.2	0.03	99.9
25/12/2020	16.2	0.2	38.9	0	100.0
28/12/2020	27.7	0.2	35.6	0	100.0
29/12/2020	23.8	0.2	72.4	0.152	99.8
30/12/2020	23.8	0.2	6.4	0	100.0

Table 5.6. Inlet volume measured for the intervention of the Grumo hill and activation of the second retention basin in 2020.

Date	Daily rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m ³)	Activation of the second bioretention (yes/no)
01-04/08/2020	77.0	11.3	4.2	no
12-14/08/2020	43.0	11.7	11.6	no
23/08/2020	62.5	10.1	26.0	yes
28-30/08/2020	93.5	4.6	30.9	no
22-27/09/2020	65.1	7.2	0.2	no
02-05/10/2020	90.5	1.8	16.1	no
10-11/10/2020	59.5	3.4	7.9	no
15/10/2020	32.2	0.8	2.7	no
26/10/2020	38.0	1.8	2.0	no
02-09/12/2020	301.3	2.0	268.7	no
25/12/2020	16.2	0.2	3.2	no

Regarding the year 2021, results of the monitoring activity in urban areas are reported in Table 5.7, Table 5.8 and Table 5.9. Similarly, to the first monitoring year, looking at the fraction of the inlet volume managed by the intervention, it is possible to observe a great capacity of the interventions in managing the input volume generated by surface runoff. The fraction that reached the outflow was always lower than 1% respect the input volume. Only in two cases, this value was greater than 1, corresponding to two really intense and short rainfall events. The first occurred in 23rd of June for the intervention located in Piazza della Libertà and the second in 16th August for the intervention in via dei Prati.

Table 5.7. Inlet and outlet volume measured in the intervention of Piazza della Libertà in 2021.

Date	Event rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m ³)	Outlet volume (m ³)	Fraction of the inlet volume managed by the intervention (%)
1-6/01/2021	89.4	0.8	134.2	0.0	100.0
21-23/01/2021	112.6	1.6	172.9	0.1	100.0
31/01/2021	15.3	0.6	28.0	0.0	100.0
07-08/02/2021	25.9	1.6	31.1	0.0	100.0
10/02/2021	25.7	0.6	45.2	0.0	100.0
14/03/2021	10.7	1.6	3.5	0.0	99.9
11-13/04/2021	125.4	2.2	127.7	0.0	100.0
29-30/04-01/05/2021	73.0	4.0	79.5	0.3	99.6
11-14/05/2021	97.1	2.8	112.1	0.0	100.0
16-19/05/2021	32.6	2.2	31.3	0.0	100.0
22/05/2021	6.2	0.8	8.7	0.0	100.0
24-25/05/2021	46.0	1.0	62.2	0.0	100.0
06-07/06/2021	34.0	3.8	37.9	0.3	99.2
23/06/2021	9.9	4.2	1.7	0.1	94.5
04/07/2021	20.1	4.0	27.7	0.1	99.5
08/07/2021	36.8	11.5	23.7	0.0	100.0
11/07/2021	6.8	4.8	9.9	0.0	99.9
13-14/07/2021	79.4	11.7	239.8	0.0	100.0
22/07/2021	23.1	5.2	6.1	0.0	99.9
27-28/07/2021	18.3	2.8	15.2	0.0	99.9
01/08/2021	58.7	5.0	71.4	0.1	99.9
04-05/08/2021	32.2	6.2	48.6	0.0	99.9
16/08/2021	11.3	4.0	16.8	0.0	99.8
28/08/2021	17.7	3.0	18.2	0.0	99.9
30/08/2021	12.7	3.4	6.9	0.0	99.9
16-17/09/2021	40.2	7.6	18.7	0.0	99.9
19/09/2021	11.3	2.2	10.5	0.0	100.0
04-06/10/2021	84.6	19.1	121.8	0.0	100.0
01/11/2021	57.9	1.4	66.3	0.0	100.0
03-04/11/2021	74.2	3.8	156.1	0.0	100.0
08/11/2021	13.1	0.6	6.7	0.0	100.0
13-14/11/2021	35.0	0.8	37.2	0.0	100.0
25/11/2021	16.5	0.4	1.6	0.0	99.9
27-28/11/2021	28.3	1.6	27.9	0.0	100.0

Table 5.8. Inlet and outlet volume measured in the intervention of via dei Prati in 2021.

Date	Event rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m ³)	Outlet volume (m ³)	Fraction of the inlet volume managed by the intervention (%)
1-6/01/2021	89.4	0.8	212.9	0.1	99.9
21-23/01/2021	112.6	1.6	290.4	0.2	99.9
31/01/2021	15.3	0.6	24.6	0.0	100.0
07/02/2021	25.5	1.6	15.4	0.0	99.9
10/02/2021	25.7	0.6	27.1	0.0	99.9
14/03/2021	10.7	1.6	2.9	0.0	99.9
11-13/04/2021	125.4	2.2	120.8	0.3	99.8
29-30/04/2021	32.8	2.2	32.0	0.0	100.0
01-02/05/2021	40.2	4.0	44.6	0.1	99.8
11-14/05/2021	97.1	2.8	134.4	0.1	99.9
16-19/05/2021	32.6	2.2	48.8	0.0	100.0
22/05/2021	6.2	0.8	9.4	0.0	100.0
24/05/2021	44.0	1.0	67.6	0.0	100.0
06-07/06/2021	34.0	3.8	65.2	0.1	99.8
23/06/2021	9.9	4.2	1.5	0.0	99.5
04/07/2021	20.1	4.0	13.3	0.0	99.9
08/07/2021	36.8	11.5	21.5	0.0	99.9
11/07/2021	6.8	4.8	8.9	0.0	100.0
13/07/2021	79.4	11.7	103.9	0.1	99.9
22/07/2021	23.1	5.2	5.4	0.0	99.8
27-28/07/2021	18.3	2.8	4.7	0.0	99.8
01/08/2021	58.7	5.0	70.7	0.0	100.0
04-05/08/2021	32.2	6.2	33.8	0.0	100.0
16/08/2021	11.3	4.0	0.1	0.0	96.8
28/08/2021	17.7	3.0	10.4	0.0	99.9
30/08/2021	12.7	3.4	11.9	0.0	99.9
16-19/09/2021	51.5	7.6	28.4	0.0	99.9
04-06/10/2021	84.6	11.7	77.0	0.0	99.9
01-04/11/2021	132.1	3.8	154.2	0.2	99.9
08/11/2021	13.1	0.6	15.5	0.0	100.0
13-15/11/2021	37.4	0.8	76.2	0.0	100.0

Table 5.9. Inlet volume measured for the intervention of the Grumo hill and activation of the second retention basin in 2021.

Date	Event rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m ³)	Activation of the second bioretention (yes/no)
01-03/01/2021	79.6	0.8	42.5	no
22-23/01/2021	98.3	1.6	93.0	no
12/04/2021	84.0	2.2	0.1	no
01/05/2021	40.2	4.0	6.1	no
11-12/05/2021	84.0	2.8	3.7	no
18/05/2021	16.9	2.2	0.1	no
24/05/2021	44.0	1.0	0.7	no
06-07/06/2021	34.0	3.8	8.9	no
01/08/2021	58.7	5.0	13.4	no
05/08/2021	1.0	0.4	4.0	no
01/11/2021	57.9	1.4	2.8	no
03-04/11/2021	74.2	3.8	13.7	yes

In Figure 5.5 the analysis of the recorded rainfall (from RG1) and the inlet volume for the intervention of Piazza della Libertà has been reported as example of monitoring action. The event was short but intense, characterized by two peaks in precipitation. The first reached a maximum intensity of 7.2 mm/5min between 16:55 and 17:00 (UTC time) while the second of 11.5 mm/5min between 18:05 and 18:10. The return period of the second peak has been assessed in 3.6 years, analysing the annual maximum rainfall of the weather station located in Monte Summano. The generated runoff of the parking area was completely managed by the intervention, since the outlet sensor was not activated by the event. The total volume of water flowing in the raingarden was assessed in 23.7 m³. The total event volume of water calculated with the runoff coefficient (equal to 0.9) was assessed in 26.0 m³.

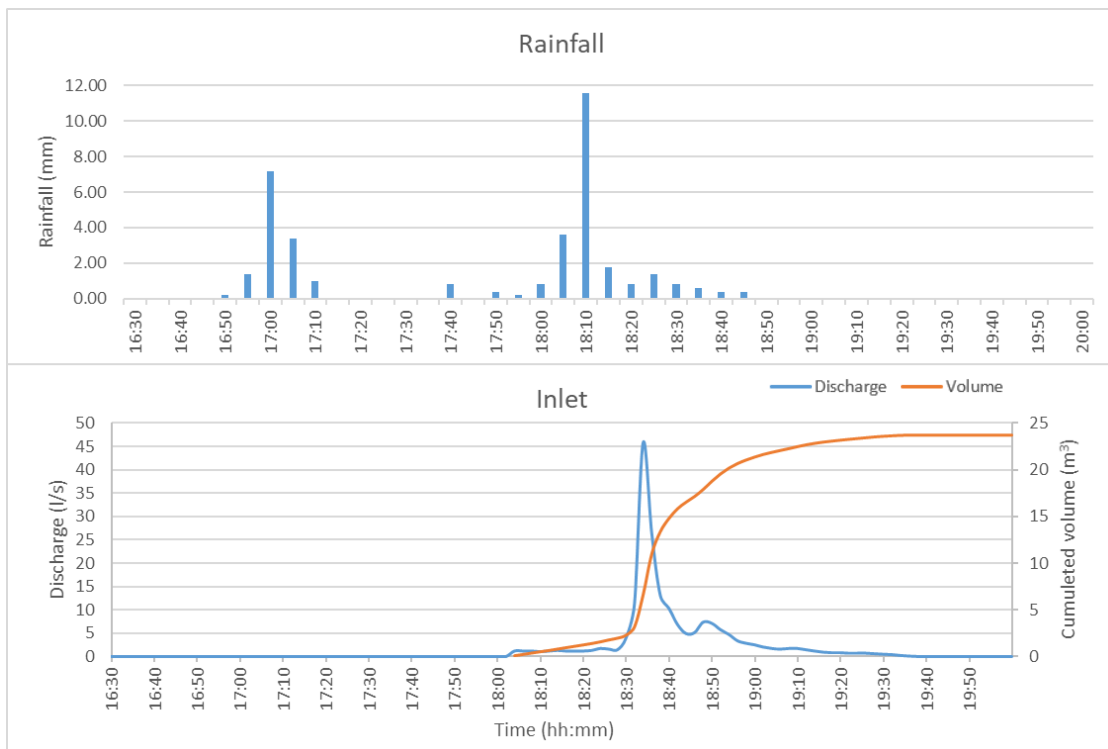


Figure 5.5: Analysis of the rainfall pattern and inlet volume over time of the Piazza della Libertà intervention for the event occurred in 8th July 2021

Regarding the year 2022, results of the monitoring activity in urban areas are shown in

Table 5.10 and Table 5.11 for the interventions located in Piazza della Libertà and in via dei Prati respectively. Instead the intervention of the Grumo hill did not produce any inlet volume in the first half of the 2022. Also the frequency of activation of the other interventions was substantially low if compared to the previous two years of monitoring. This result is the consequence of the extremely low amount of precipitation (as reported in the description of the data acquired by the raingauges) in combination with the dry conditions of the soil before the rainfall events. Looking at the data reported in

Table 5.10 and Table 5.11 we can observe a good capacity of the interventions in managing the surface runoff, similarly to the previous two years of monitoring. Indeed, fraction of water volume that reached the outflow was always lower than 1% respect the input volume. Only for the event occurred on the 23rd-25th April 2022 recorded in the Piazza della Libertà, this value resulted greater than 1, corresponding to an intense and short rainfall event.

Table 5.10 Inlet and outlet volume measured in the intervention of Piazza della Libertà in the period January June 2022.

Date	Event rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m ³)	Outlet volume (m ³)	Fraction of the inlet volume managed by the intervention (%)
04-05/01/2022	66.9	2.0	29.2	0.024	99.9
23-25/04/2022	43.8	2.2	2.1	0.026	98.8

Table 5.11 Inlet and outlet volume measured in the intervention of Via dei Prati in the period January June 2022.

Date	Event rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m ³)	Outlet volume (m ³)	Fraction of the inlet volume managed by the intervention (%)
15/02/2022	42.4	0.8	29.2	0.040	99.9
01/04/2022	22.3	1.6	2.1	0.014	99.3
09/04/2022	9.8	1.2	0.7	0.004	99.4
23/04/2022	34.0	1.6	9.5	0.021	99.8
25-26/04/2022	15.9	2.2	4.8	0.013	99.7
05/05/2022	6.6	0.4	0.4	0.007	98.2
14/05/2022	18.9	3.8	10.9	0.011	99.9
24/05/2022	31.4	9.4	1.9	0.014	99.2
28-29/05/2022	20.1	1.0	18.1	0.012	99.9
05/06/2022	23.9	5.8	3.7	0.011	99.7
07/06/2022	19.7	1.2	5.9	0.023	99.6
08-09/06/2022	8.4	0.6	7.9	0.013	99.8

Regarding the quality of the water managed by the three interventions located in the urban areas, a total of eight surveys have been performed (five in 2021 and three in 2022). The results of the water analysis for the respective investigated compound are reported in Table 5.12, Table 5.13 and Table 5.14.

For the raingarden located in Piazza della Libertà the samples have been collected for the water entering the intervention. Generally, the water sampled of the eight surveys showed a good water quality, considering that the runoff is generated by the parking slot. Exception is the survey of the 27th April 2021, for which the values of the compounds resulted higher than the other surveys.

Table 5.12: Analysis of the water quality entering in the raingarden of Piazza della Libertà.

Compound	Unit	27/04/2021	12/05/2021	15/07/2021	05/10/2021	16/11/2021	15/02/2022	31/03/2022	09/06/2022
Biochemical Oxygen Demand (BOD₅)	mg/L	90,0	< 5,0	10	< 5,0	45	< 5,0	20	< 5,0
Animal and vegetable fats and oils	mg/L	2,2	< 1,0	< 1,0	1,0	1,6	< 1,0	< 1,0	< 1,0
Total hydrocarbons	mg/L	2,1	< 1,0	< 1,0	< 1,0	1,5	< 1,0	< 1,0	< 1,0
Total oils	mg/L	4,3	< 1,0	< 1,0	1,0	3,1	14	< 1,0	< 1,0
Total suspended solids	mg/L	146	< 5	7	< 5	36	12	18	< 5,0

For the raingarden located in via dei Prati 10 samples (8 entering and 5 leaving the intervention) have been collected for the water quality assessment. Generally, the water samples entering in the raingarden showed a good water quality, considering that the runoff is generated by the parking slot and by the upward fields. Exception is the survey of the 27th April 2021, for which the values of the compounds resulted higher than the other dates. Also the survey of the 15th February 2022 showed a higher value of suspended solids respect to the other dates, probably because of the antecedent dry conditions that allowed the accumulation of particles on the parking slot, successively transported by the water runoff. Looking at the values leaving the raingarden we can notice a decrease respect the entering ones, highlighting the positive effect of the intervention in increasing the quality of the water.

Table 5.13: Analysis of the water quality entering (IN) and leaving (OUT) the raingarden of via dei Prati.

Compound	Unit	27/04/2021 IN	27/04/2021 OUT	12/05/2021 IN	12/05/2021 OUT	15/07/2021 IN	15/07/2021 OUT	05/10/2021 IN	05/10/2021 OUT	16/11/2021 IN	16/11/2021 OUT	15/02/2022 IN	31/03/2022 IN	09/06/2022 IN
Biochemical Oxygen Demand (BOD₅)	mg/L	70,0	<5,0	<5,0	<5,0	7	5	5	<5,0	8	6	< 5,0	8,0	< 5,0
Animal and vegetable fats and oils	mg/L	1,2	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total hydrocarbons	mg/L	1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total oils	mg/L	2,2	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total suspended solids	mg/L	210	< 5	< 5	6	11	42	11	< 5	12	34	60	13	5

For the intervention located in the Grumo hill nine samples of water has been collected, of which eight entering and one leaving the intervention. Overall, the quality of the water resulted good, showing low values of BOD₅, oils and hydrocarbons. Indeed, the runoff entering the intervention derive from the hill that is not urbanized. Differently from the previous intervention, the suspended solids resulted slightly higher, with values in the range of 50 – 12 mg/L.

Table 5.14: Analysis of the water quality entering (IN) and leaving (OUT) the intervention of the Grumo hill.

Compound	Unit	27/04/2021 IN	12/05/2021 IN	12/05/2021 OUT	15/07/2021 IN	05/10/2021 IN	16/11/2021 IN	15/02/2022 IN	31/03/2022 IN	09/06/2022 IN
Biochemical Oxygen Demand (BOD₅)	mg/L	10,0	8,0	12,0	<5,0	<5,0	6	< 5,0	< 5,0	11
Animal and vegetable fats and oils	mg/L	< 1,0	< 1,0	< 1,0	1,2	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total hydrocarbons	mg/L	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total oils	mg/L	< 1,0	< 1,0	< 1,0	1,2	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total suspended solids	mg/L	51	31	16	17	24	12	7	10	16

5.3 Interventions in agricultural area (Action C3)

As described in Section 4.4, the retention basin acts as flood mitigation measure, especially during the winter time when the basin is emptied to receive and accumulate the water runoff generated by prolonged rainfall. During the summer period the basin is maintained partially full of water to provide water for irrigation. To this reason, the following data analysis has been carried out in the two seasons separately.

Figure 5.6 reports the rainfall recorded by RG2 and the water level measured in the basin during the 2020 summer period. The flow level shows a daily fluctuation due to irrigation. Effectively, the “Consorzio di bonifica Alta Pianura Veneta” (CB-APV, project partner) constantly provides water for irrigation that every day partially fills the basin. At the same time, farms take water from the basin for the irrigation. The operations of irrigation are usually carried out during the morning as the decreasing sections of the flow level are generally reported from 8.00 AM to 12.00 AM. As a consequence, in the summer period is not possible to exactly define the contribution of the basin in the flood risk mitigation. Nevertheless, Figure 5.6 shows that for most of the rainfall events, the complete filling of the basin has almost never been reached. An exception is reported in the late summer when maximum water level in the basin was reached because of a reduction in the irrigation withdrawals.

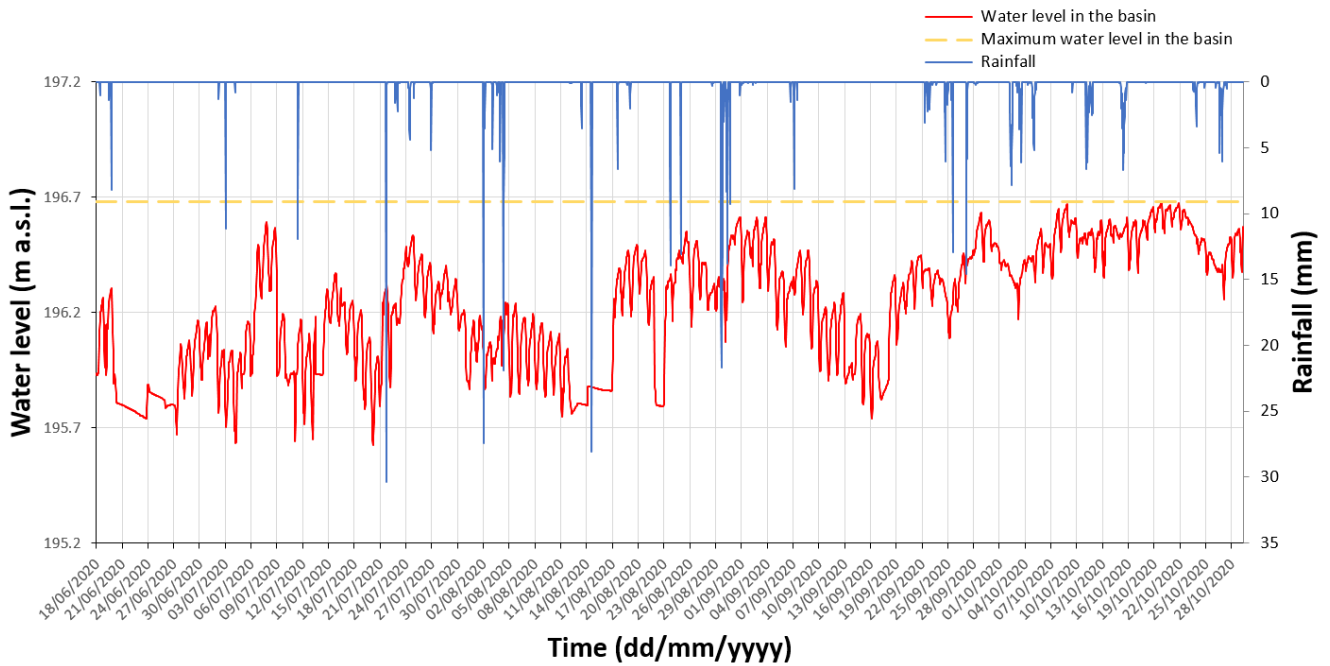


Figure 5.6. Rainfall affecting the Giavenale di Schio area and water level in the basin during the 2020 summer period.

Figure 5.7 reports the rainfall recorded by RG2 and the water level measured in the basin during the 2020 winter period. Differently from the summer period, in the winter period the water inlet is only provided by the flood discharges generated by the rainfall events. As a consequence, the contribution of the basin in flood risk mitigation can be precisely assessed in terms of volume of water stored by the basin. First of all, the graph shows that the basin was able to manage all the flood events occurred in the analysed period, because the maximum level has never been reached (as reported in Figure 5.7). Three rainfall events occurred during the analysed period that produced discharge able to partially fill the basin. For each event, a rainfall characterization and the volume of water stored in the basin are reported in Table 5.15.

Thanks to these results, we can conclude a correct functioning of this intervention, which could certainly manage more severe events (e.g. stronger rainstorm events and/or period of more water scarcity) with respect to those observed up to now.

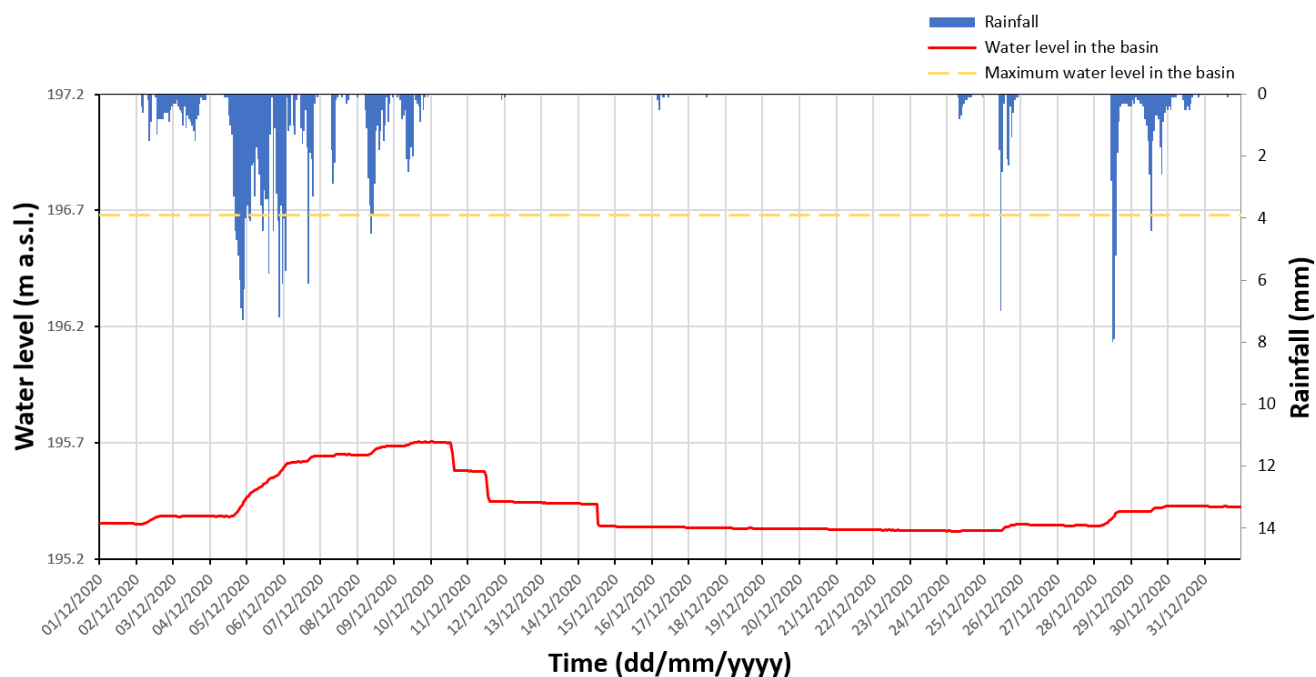


Figure 5.7. Rainfall affecting the Giavenale di Schio area and water level in the basin during the 2020 winter period.

Table 5.15. Rainfall events occurred in the 2020 winter period and corresponding water volume stored in the basin.

Date (dd/mm)	Duration of the rainfall event (days)	Cumulative rainfall (mm)	Maximum rainfall intensity in 5 min (mm/h)	Volume stored in the basin (m ³)
02/12 - 09/12	7.9	243.6	22.8	349.9
24/12 - 25/12	1.6	21.9	10.8	9.7
28/12 - 30/12	2.4	57.2	9.6	50.3

Figure 5.8 shows the rainfall pattern measured by the raingauge located in Giavenale (RG2) and the water level in the basin in the summer period (02/03/2021 to 18/11/2021). The summer period refers to the period for which irrigation is active as identifiable from the chart of Figure 5.8 (fluctuation in the water level). As stated for the previous year, in the summer period is not possible to correlate the rainfall precipitation with the water level due to irrigation operations. However, the maximum level reached by the basin in 2021 was equal to 196.1 m a.s.l. while the projected maximum value is 196.7 m a.s.l. (Figure 5.8).

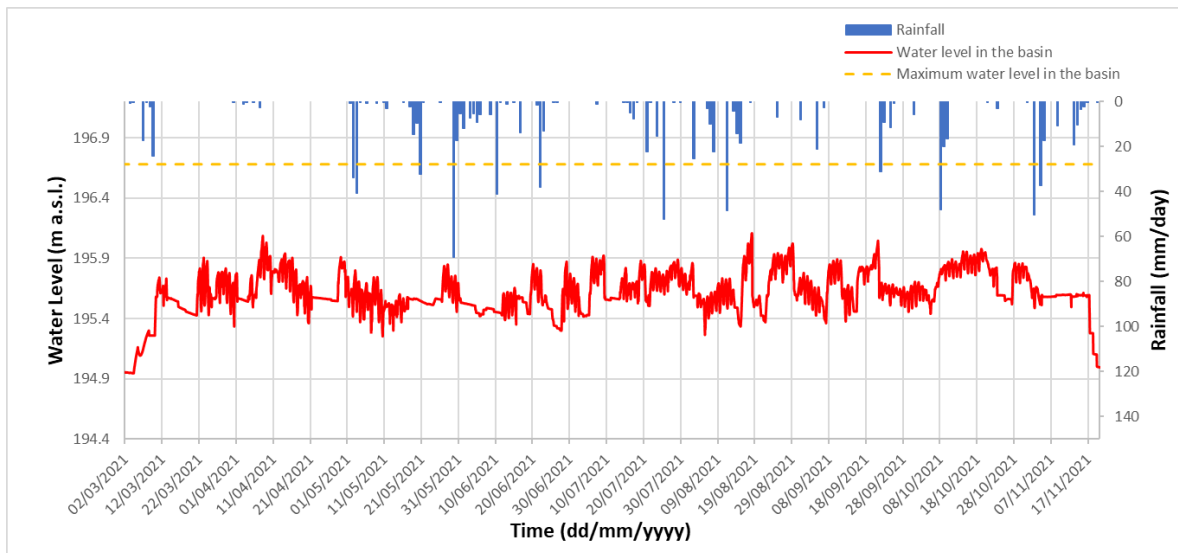


Figure 5.8. Rainfall affecting the Giavenale di Schio area and water level in the basin during the 2021 summer period.

Figure 5.9 reports the water level of the Giavenale basin for the winter period of 2021, identified as the period without irrigation operations (note the absence of daily fluctuation in the water level). The winter period considered the time between 01/01 to 02/03 and 19/11 to 31/12. In winter, the assessment of the basin efficiency in mitigating the flood hazard can be precise. In Table 5.16, the rainfall events are reported together with the volume of water stored in the basin. The volume of water stored in the basin as consequence of rainfall was not large, because the events occurred in the winter period of 2021 were moderate. The water level and consequently the volume did not drastically increase. In 2020, the winter rainfall events resulted decisively more intense.

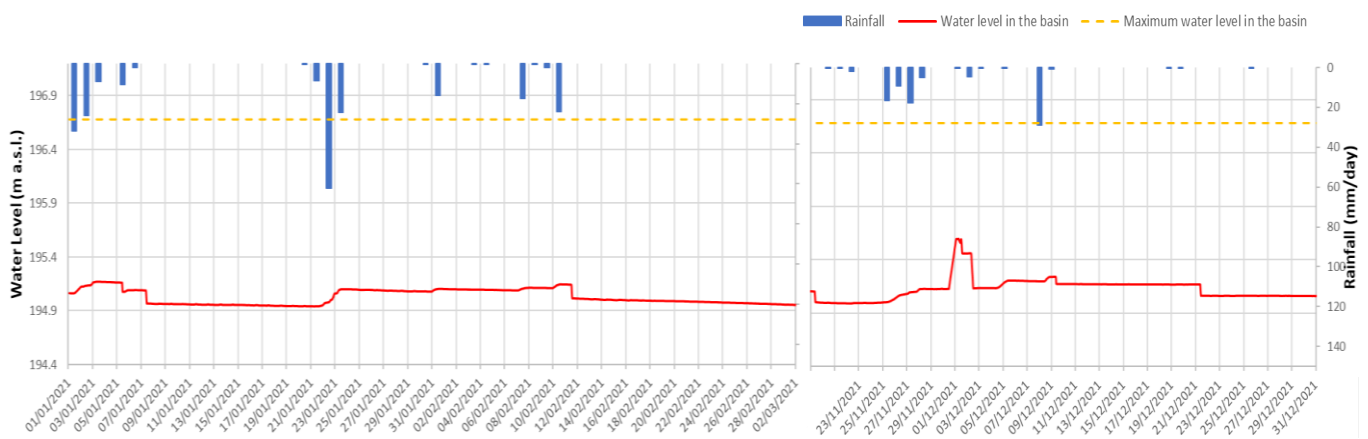


Figure 5.9. Rainfall affecting the Giavenale di Schio area and water level in the basin during the 2021 winter period.

Table 5.16: rainfall events occurred during the winter period in 2021, reporting the water volume stored in the basin.

Date (dd/mm)	Duration of the rainfall event (days)	Cumulative rainfall (mm)	Maximum rainfall intensity in 5 min (mm/h)	Volume stored in the basin (m ³)
01/01 - 06/01	5.0	81.2	0.8	19.52
21-23/01	2.5	95.1	1.4	6.43
07-10/02	3.4	43.8	1.4	14.97
25-28/11	2.7	48.7	1.6	11.18
08-09/12	0.9	29.7	0.6	38.64

Figure 5.10 shows the water level of the Giavenale basin for the period January – June 2022. Regarding the winter period characterized by the low level of the water, it is possible to observe the mitigation effect of the infrastructure for the rainfall event occurred on the 15th of February. On that day and in the following one the basin collected a total volume of 54 m³. The summer period starting from the 24th of March is characterized by the fluctuations of the water level as consequence of the irrigation process. Interruptions of the water uptake can be noticed in the weeks where rainfall events occurred. For the year 2022, characterized by a noticeable lower amount of precipitation, the basin represented an important resource for the agricultural area to contrast the exceptional dry conditions.

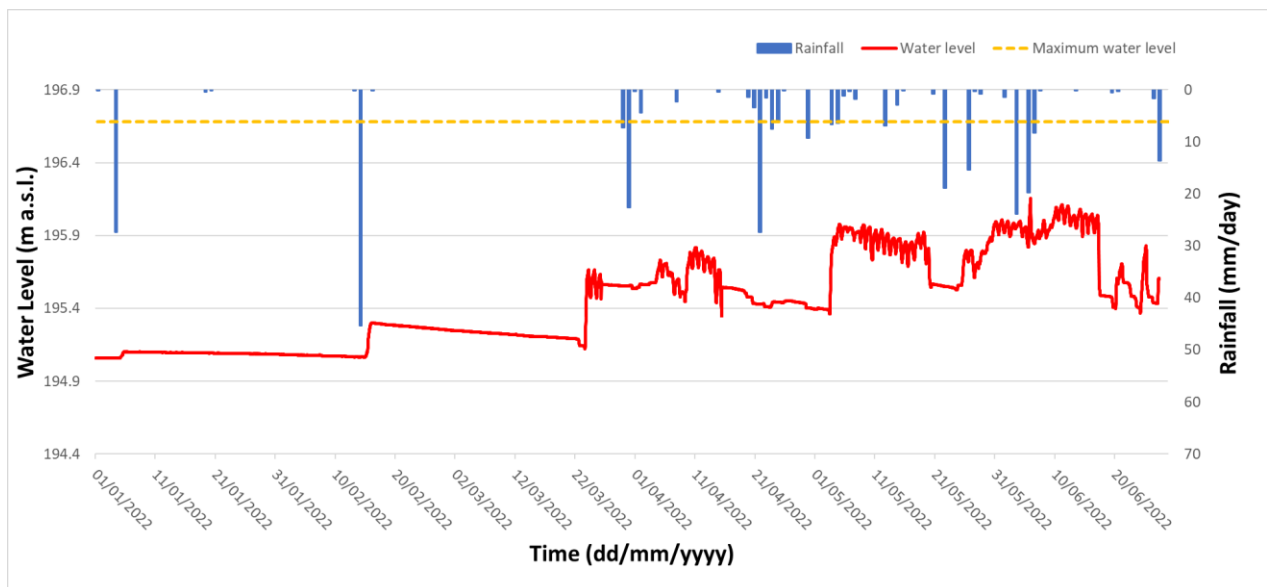


Figure 5.10: Rainfall affecting the Giavenale di Schio area and water level in the basin in the period January – June 2022

Regarding the quality of the water, eight analysis have been carried out during the monitoring period, five in 2021 and three in 2022. The results of the compounds surveyed in the retention basin are reported in Table 5.16 and Table 5.17. The results of the qualitative analysis showed an overall good quality of the water retained in the basin. Most of the compounds resulted below the threshold for being identifiable, especially looking at the halogenated volatile organic compounds, aromatic

hydrocarbons and metal components. Looking at the values of enterococci, Escherichia coli and coliform bacteria it is possible to notice a trend that followed the temperature of the water. The higher concentration is observed in the survey of 15th July 2021.

Table 5.17: Results of the compounds investigated in the retention basin in 2021 and 2022.

Compound	Unit	27/04/2021	12/05/2021	15/07/2021	05/10/2021	16/11/2021	15/02/2022	31/03/2022	09/06/2022
Aluminium	mg/L	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	0,10	< 0,05	< 0,05
Ammonia	mg/L	< 0,5	< 0,5	< 0,5	0,7	< 0,5	< 0,5	< 0,5	< 0,5
Arsenic	mg/L	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Nitrate nitrogen	mg/L	0,11	< 0,1	< 0,10	0,67	1,1	1,3	0,22	1,2
Nitrous nitrogen	mg/L	< 0,03	< 0,03	< 0,03	< 0,03	< 0,03	0,05	< 0,03	< 0,03
Barium	mg/L	0,04	0,04	0,05	0,05	0,04	0,05	0,05	0,05
Beryllium	mg/L	< 0,002	< 0,002	< 0,002	< 0,002	< 0,002	4640,0	5910,0	57940
Boron	mg/L	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,002	< 0,002	< 0,002
Cadmium	mg/L	< 0,002	< 0,002	< 0,002	< 0,002	< 0,002	< 0,05	< 0,05	< 0,05
Calcium	mg/L	37	27	31	62	49	< 0,002	< 0,002	< 0,002
Chlorides	mg/L	4,4	32	5,0	11	12	35	56	48
Conductivity at 20°C	µS/cm	300	260	315	485	382	14	8,8	5,8
Total Chromium	mg/L	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	286	542	382
Enterococci	MPN/100 mL	5,2	129,8	144,5	406,0	< 1	< 0,02	< 0,02	< 0,02
Escherichia coli	MPN/100 mL	3	43	8820	1090	1	< 100	1730,0	8600
Coliform bacteria	MPN/100 mL	139,6	1732,9	111990,0	36450,0	8,7	200	100	3450
Iron	mg/L	0,18	0,09	0,15	0,08	0,07	0,30	0,08	< 0,05
Fluorides	mg/L	< 0,2	< 0,2	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20
Magnesium	mg/L	18	16	17	22	16	13,6	21	17
Manganese	mg/L	0,05	0,02	0,10	< 0,02	0,02	0,03	< 0,02	< 0,02
Nickel	mg/L	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
pH	-	8,5	9,0	8,1	8,4	8,6	7,6	8,8	8,0
Lead	mg/L	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Potassium	mg/L	0,3	0,3	1,3	1,4	2,1	2,9	1,0	2,6
Copper	mg/L	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Fixed residue at 180°C	mg/L	231	200	242	347	273	220	388	273
Sodium	mg/L	4,8	4,3	6,7	9,0	8,4	6,2	10,5	8,2
Sulphates	mg/L	59	43	69	126	74	37	105	68
Tin	mg/L	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05
Vanadium	mg/L	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02
Zinc	mg/L	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02

Table 5.18: Results of the analysis relatively to the halogenated volatile organic compounds and aromatic hydrocarbons in 2021 and 2022.

Compound	Unit	27/04/2021	12/05/2021	15/07/2021	05/10/2021	16/11/2021	15/02/2022	31/03/2022	09/06/2022
Acetonitrile	mg/l	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Acrylonitrile	mg/l	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Organic nitrogen solvents	mg/l	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
1,1,1,2-tetrachloroethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1,1-trichloroethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1,2,2-tetrachloroethane	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
1,1,2-trichloroethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1,2-trifluorotrichloroethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1-dichloroethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1-dichloroethylene	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
1,1-dichloropropene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2,3-trichloropropane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2-dibromo-3-chloropropane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2-dichlorobenzene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2-dichloropropane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,3-dichlorobenzene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,3-dichloropropane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,4-dichlorobenzene	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
2,2-dichloropropane	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
2-chlorotoluene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
4-chlorotoluene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bromochloromethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dichlorobromomethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-dichloroethylene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,3-dichloropropene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chlorobenzene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chloroethane	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chloromethane	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dibromochloromethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dichlorodifluoromethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dichloromethane	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
trans-1,2-dichloroethylene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,3-dichloropropene	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Trichlorofluoromethane	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chlorinated organic compounds (total)	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
1,2,3,4-tetrachlorobenzene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
1,2,3,5-tetrachlorobenzene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
1,2,3-trichlorobenzene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
1,2,4,5-tetrachlorobenzene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
1,2,4-trichlorobenzene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichloroethane	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
1,3,5-trichlorobenzene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Chloroform	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Hexachlorobutadiene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Tetrachloroethylene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Tetrachloromethane	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Trichloroethylene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Halogenated Organic Solvents (total)	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Benzene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
m+p-xylene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
o-xylene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Xylene	µg/l	<1	<1	<1	<1	<1	<1	<1	<1
Aromatic Organic Solvents (total)	µg/l	<1	<1	<1	<1	<1	<1	<1	<1

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