Report on the Spanish pilot deployment of instrumentation and AQDV UD environment

Deliverable DB3.1

Real-time pollution-based control of urban drainage and sanitation systems for protection of receiving waters

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1 Introduction

This deliverable DB3.1 corresponds to the Action B.3 from LIFE RUBIES project called “Spanish Pilot site deployment operation” and specifically to the sub-actions “B.3-1: Deployment of instrumentation” and “B.3-2: Deployment of AQDV UD environment” and its main goal is to describe and prepare the installation of the new sensors required for AQDV UD software and prepare the environment to install and operate AQDV UD software.

The specific objectives for the deliverable are:

- To collect the required data for analyzing the already existing sensors available and validate the current operation in the pilot site.
- To deploy the monitoring equipment necessary in Madrid pilot site to correctly operate AQDV UD
- To deploy the monitoring equipment necessary in the Manzanares river to validate the impact of AQDV UD in the river quality.
- To define the IT architecture necessary to operate AQDV UD in Madrid pilot site
- To define the required input and output data for AQDV UD
- To define a first version of the synoptic views for AQDV UD
- To define the operating principles and goals for the Madrid pilot site.

2 Current sensors and actuators already available in the pilot site

Annex 1 presents the detailed location of the sensors and actuators already available in the pilot site and then explains the historical data collected (1.5 years data from 1/7/2020 until 1/1/2022), and the methodology followed to perform different data analysis with the following objectives:

- To check the data availability and data quality of already existing sensors and actuators.
- To check if the explanation given by the operators for the of actual management strategy of the Manzanares system is consistent with the historical data and, in case of doubts, go back to the operators to ask for more detailed explanations.
- To obtain an initial diagnosis of the current operational strategy followed in the Manzanares System and have some ideas of operational improvements that could be applied within the project. In both cases (diagnosis and operational improvements) will be confirmed at a later stage of the project with the offline tests.

In this chapter a summary of the Annex 1 is presented with a list of the existing network sensors and actuators available in the pilot site and the main conclusions of the data analysis performed.

2.1 Existing network sensors

39 sensor data were collected, and its available data analysed.

Table 1. Current sensors available in the pilot site

CYII Code	Short name	Description
E463PNC059_NCA	By-pass Mercamadrid	Water height for by-pass colector between MD and MI interceptor in Mercamadrid
E463PNC224_NCA	By-pass MD-MI	Water height for by-pass colector between MD and MI interceptor in the pilot site
E463PNC221_NCA	MD aar 1 TBut	Water height in MD interceptor upstream Butarque tank. Sensor 1
E463PNC223_NCA	MD aar 2 TBut	Water height in MD interceptor upstream Butarque tank. Sensor 2
E463PNC220_NCA	DSU AArr TBut	Water height in CSO colector upstream Butarque tank
E463PNC198_NCA	TBut I-1	Water height in Butarque tank compartment I-1
E463PNC199_NCA	TBut I-2	Water height in Butarque tank compartment I-2
E463PNC200_NCA	TBut I-3	Water height in Butarque tank compartment I-3
E463PNC201_NCA	TBut I-4	Water height in Butarque tank compartment I-4
E463PNC202_NCA	TBut II-1	Water height in Butarque tank compartment II-1
E463PNC203_NCA	TBut II-2	Water height in Butarque tank compartment II-2
E463PNC204_NCA	TBut II-3	Water height in Butarque tank compartment II-3

E463PNC205_NCA	TBut II-4	Water height in Butarque tank compartment II-4
E791PND027_NDE	EDARBut ByPCab	Water height in Butarque WWTP upstream by-pass
E791PQT017_QTU	EDARBut Qprim	Flow in Butarque WWTP primary treatment
E791PQT001_QTU	EDARBut Qbiol	Flow in Butarque WWTP biological treatment
E791PQT003_QTU	EDARBut ByPass Qbiol	Flow in Butarque WWTP ByPass before the biological treatment
E463PHV208_NVE	EDAR ButII	Water height in Butarque II colector
E463PHV208_ZVE	DSU ButII	Water height in CSO discharge from Butarque II
E464PNC647_NCA	TBut-colButII	Water height in inlet colector from Butarque II to Butarque tank
E463PQT211_QTU	Bomb Tbut-Prim TP1	Pumped flow from Butarque tank to new primary treatment in Butarque WWTP. Sensor 1
E463PQT212_QTU	Bomb Tbut-Prim TP2	Pumped flow from Butarque tank to new primary treatment in Butarque WWTP. Sensor 2
E463PQT209_QTU	Bomb Tbut-MD1	Pumped flow from Butarque tank to MD. Sensor 1
E463PQT210_QTU	Bomb Tbut-MD2	Pumped flow from Butarque tank to MD. Sensor 2
E778PNC565_NCA	Tabro ColEnt	Water height upstream Abroñigales tank
E778PNC572_NCA	Tabro CamEnt	Water height in Abroñigales tank inlet chamber
E451MED399_ANA	MI aarr WLB3	Water height in MI upstream case study area
E778PNC566_NCA	MI desdob	Water height in MI doubled collector
E778PND575_NDE	TAbro C1	Water height in Abroñigales tank compartment C1
E778PND576_NDE	TAbro C2	Water height in Abroñigales tank compartment C2
E778PND577_NDE	TAbro C3	Water height in Abroñigales tank compartment C3
E778PND578_NDE	TAbro C4	Water height in Abroñigales tank compartment C4
E778PNC574_NCA	TAbro aliv_sal	Water height in Abroñigales tank CSO weir
E778PNC567_NCA	TAbro DSU1	Water height in Abroñigales tank CSO colector 1
E778PNC624_NCA	TAbro DSU2	Water height in Abroñigales tank CSO colector 1
E778PHV569_NVE	MI alivSuR	Water height in MI interceptor at Aliviadero Sur
E778PHV569_ZVE	DSU alivSur	Water height at MI CSO weir at Aliviadero Sur
E794PQT326_QTU	EDARGav QbombMI_m3/h	Pumped flow from MI interceptor to LA Gavia WWTP
E794PQT308_QTU	EDARGav Qbiol_m3/h	Flow in La Gavia WWTP biological treatment
E593PQT035_QTU	EDARGav QByP_biol_m3/h	Flow in La Gavia WWTP by-passing the biological treatment

2.2 Existing actuator data available

20 actuator data were collected, and its available data analysed.

Table 2. Current actuators available in the pilot site

CYII Code	Short name	Description
E463MED274_ANA	C DSU AArr TBut	Gate in CSO colector upstream Butarque tank
E463MED280_ANA	C TBut C52	Butarque tank inlet gate C52
E463MED279_ANA	C TBut C51	Butarque tank inlet gate C51
E463MED278_ANA	C TBut C42	Butarque tank inlet gate C42
E463MED277_ANA	C TBut C41	Butarque tank inlet gate C41
E464MED648_ANA	C TButII	Inlet gate from Butarque II colector to Butarque tank
E778MED640_ANA	C Tabro ByP	Abroñigales tank by-pass gate
E778SDO542	C Tabro Ent2	Abroñigales tank inlet gate 2
E778SDO538	C Tabro Ent3	Abroñigales tank inlet gate 3
E778SDO534	C Tabro Ent4	Abroñigales tank inlet gate 4
E778MED570_ANA	C TAbro DSU1	Abroñigales tank CSO gate to CSO colector 1
E778MED571_ANA	C TAbro DSU2	Abroñigales tank CSO gate to CSO colector 2
E778MED627_ANA	C TAbro salC11	Abroñigales tank outlet gate C11
E778MED628_ANA	C TAbro salC12	Abroñigales tank outlet gate C12
E778MED629_ANA	C TAbro salC13	Abroñigales tank outlet gate C13
E778MED630_ANA	C TAbro salC14	Abroñigales tank outlet gate C14
E778MED631_ANA	C TAbro salC15	Abroñigales tank outlet gate C15
E778MED632_ANA	C TAbro salC16	Abroñigales tank outlet gate C16
E778MED633_ANA	C TAbro salC17	Abroñigales tank outlet gate C17
E778MED634_ANA	C TAbro salC18	Abroñigales tank outlet gate C18

2.3 Data analysis summary for the existing sensors and actuators

Combining the analysis of several sensors and actuators available (as in the example below) conclusions about the data availability and the current operation were obtained.

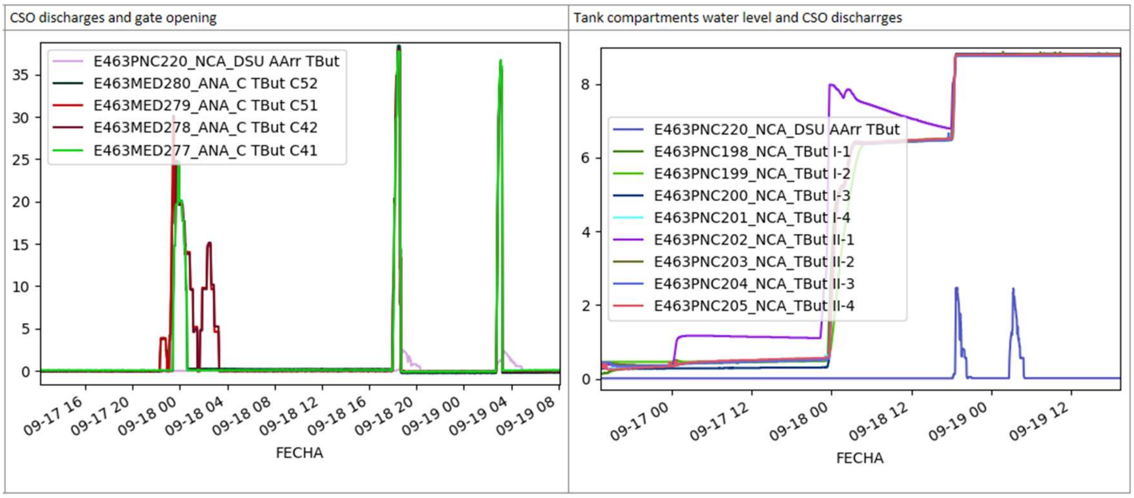

Figure 1. Example of graphs and analysis performed where Butarque tank opening gates are compared with tank filling and CSO, in a first rain peak CSO's are avoided but then a second rain peak occurs filling the tank and causing CSO upstream the tank.

The main conclusions are presented below:

- MD (margen derecho or right margin) interceptor measurements
    - As expected, the two existing water level sensors have same measurements (they are redundant measurements in order to guarantee that there is no data loss)
    - Water levels were smaller in 2020 than in 2021
    - By-pass flow in 2020 only took place during a few hours but in 2021, as there is more flow in MD interceptor, by-pass flows occur during the 24 hours
- CSO upstream the Butarque tank and tank filling operation
    - CSO gate opens at 3.3 m water level in MD which is consistent with CYII explanations
    - Butarque tank inlet gates open when MD water level reaches 2.75 m
    - Inlet gates open in small percentages with PID trying to adjust MD water level at 2.75 m, but very few times they get opened above 20%, but even with these small percentages the tank gets filled very quickly
    - There are several rain episodes in which CSO upstream the tank occurs while the tank is not yet full at 100%
    - Only 3 times in 1.5 years the tank was filled above 300000 m3, most of the times it gets filled up to 250000 m3. Therefore, this operation could be slightly improved although with caution, as there is no security weir in this tank.
- Butarque II collector analysis:

  - The values for sensor E463PHV208_NVE are not being stored.
  - So it cannot be checked the height at which CSO sensor starts to measure.
- Butarque tank emptying operations
  - The pumping station to the new primary treatment is not into operation as CYII stated
  - The tank is emptied using the pumps to MD interceptor but the flow sensors here are not correctly measuring the flow
  - Emptying flows computed by difference of volumes in tank range between 0.84 and 0.94 m3/s
  - It never happens that there is a CSO upstream the tank while it is being emptied which is good operation
  - Usually the pumps start operating when water level in MD interceptor is not 2 m (as described by CYII) but at a lower level (1.7 – 1.6 m)

- Butarque WWTP operation
  - CSO upstream Butarque WWTP can't be analyzed because sensor E791PND027_NDE is always measuring 0 (maintenance required)
  - When the tank is emptied the WWTP tries to operate with flows around 1.5 m3/s although there are some peaks up to 2-2.2 m3/s
  - Biological sensor measurements when the tank is being emptied are around 1.3 m3/s
- Abroñigales tank entrance:
  - Apparently, the tank inlet gates status are not being correctly stored (maintenance needed)
  - By-pass gate position was fixed to 20 % before march 2021 (consistent with CYII description), but from that date onwards, the gate position has increased to 50% opening
  - When flow measurements in entrance collector reach 1.44 m, water exceeds the weir and part of the flow is derived to the tank.
  - Also in 2021 there is DWF in this entrance collector, contrary to what we were told by CYII
  - The effect of the by-pass flow is not visible on the upstream doubled MI (margen izquierdo or left margin) collector
  - Always that the tank is being filled the outlet gates are closed
- CSO at Aliviadero Sur and relation with Abroñigales tank outflow

  - Whenever the sensor in MI interceptor measures above 2.57, then the CSO time serie starts measuring.
  - Often there are CSO and the tank is far from being full maybe CSO can not be avoided but at least it can be reduced closing completely the by-pass gate.
  - Usually two gates are operated at the same time to empty the tank and they are opened in parallel up until 8.7% and the corresponding outflow is ranging between 0.65 m3 /s (when the tank is full) to 0.2 m3/s (when the volumes are below 40000 m3).
- CSO in Abroñigales tank
  - The tank is being 100 % full causing CSO 6 or 7 times in this 1.5 years
  - CSO gates are always closed as described by CYII
  - CSO sensors in the CSO collectors need maintenance because they present often abnormal values
- La Gavia WWTP operation:
  - MI interceptor pumping flows to the WWTP are around 0.67 m3/s in 2021 which is less than the 1.5 m3/s mentioned by CYII
  - In DWF flows range between 1.4 and 0.8 m3/s and all goes through primary and biological treatment.
  - In rain events biological by-pass (around 300-500 m3/h) occurs sometimes but not because it increases the capacity of the primary treatment but because flows in the biological treatment decrease.

3 Additional sensor deployment

Once the available data sensors in the pilot site have been analysed the new additional sensors required to correctly install and operate the AQDV UD are defined. Somehow this is an update of the chapter "3.1 Sensor installation" and chapter "6.5 Scope of the Manzanares river reach and river quality control sections" of deliverable DA1.2 once the previous current sensor and actuators data have been analysed and several visits to the potential installation locations and control points have been performed.

As a conclusion (see Figure 2) the following new network sensors are required:

- 1 water level sensor located in MD interceptor (although in the future 3 other secondary water level sensors might be installed to have better information about the current water levels in those collectors)
- 4 turbidity sensors to obtain correlation with other quality parameters that cannot be measured in real time.
- Temporary water samplers to be installed in the location of the turbidity sensors to perform the quality sensor campaigns to correlate the turbidity real time measurements with other quality parameters such as TSS, COD and BOD, nutrients…
- 1 temporary rain gauge used to compare and calibrate radar rain data and also to calibrate the hydraulic and quality model.

Also 2 control sections with multiparametric sensor will be installed in the Manzanares river, one upstream the pilot area and a second one downstream after all CSO and WWTP effluents have discharged into the river. Also, depending on the results obtained in these control sections, a 3rd control section downstream Butarque WWTP could be installed later on to better understand the quality measurements obtained.

In the next subchapter the description of these new sensors is described.

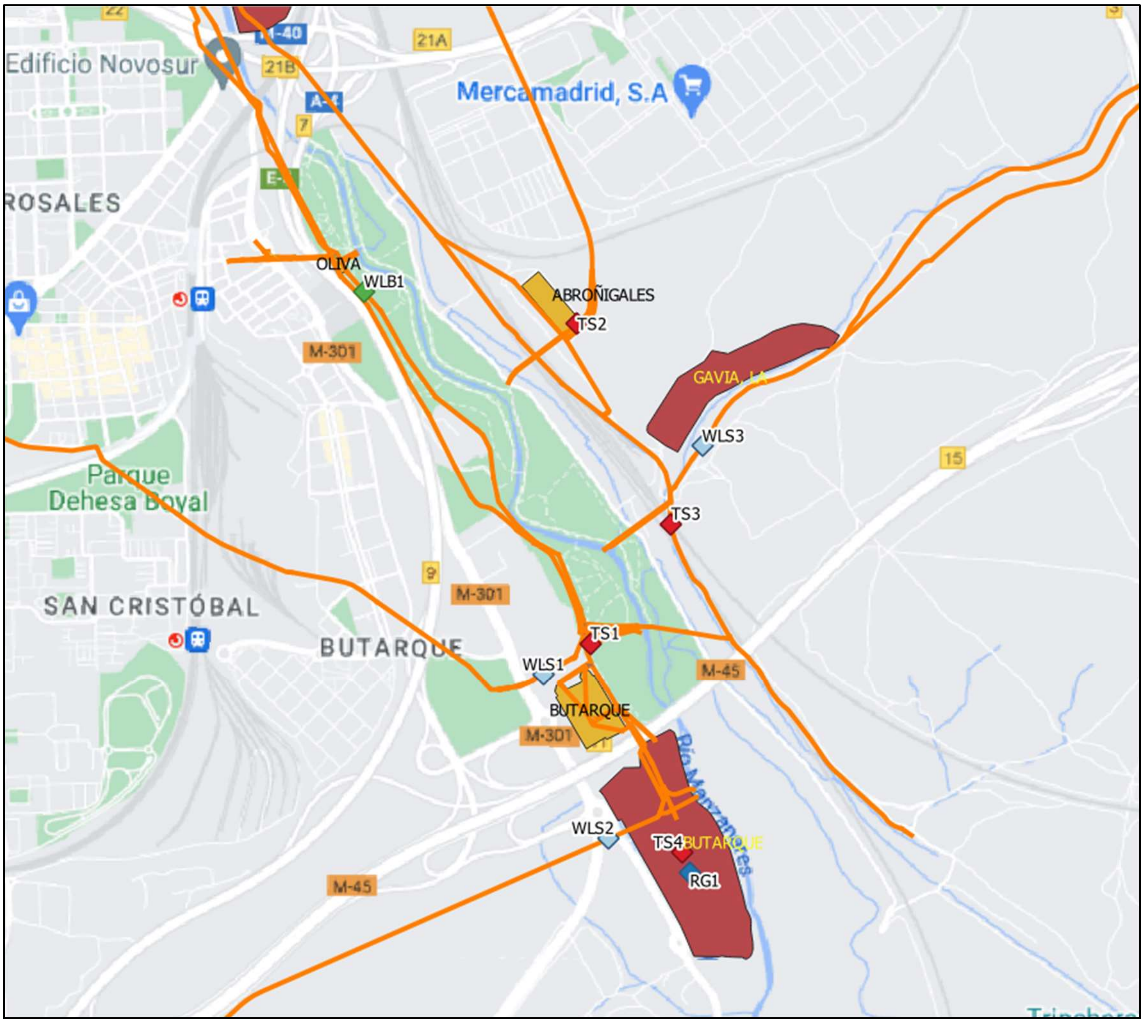

Figure 2. New network sensors required

3.1 Network water level sensors

3.1.1 Required water level sensors

3.1.1.1 MD interceptor water level upstream the pilot area

The most important water level sensor required is one located in MD (right margin) interceptor upstream the pilot area, somewhere between the Oliva tank and the by-pass collector that connects MD interceptor and MI (left margin) interceptor.

The exact location of the sensor has not been defined yet because the interceptor manholes locations are unknown (in the recent years the municipality has built a river park on top of the collector and has buried most of the manholes) so CYII needs to inspect a long stretch of the interceptor in order to find the best location for this sensor counting that it will require energy supply and communications coverage. In addition, civil work will be required in order to execute a new manhole.

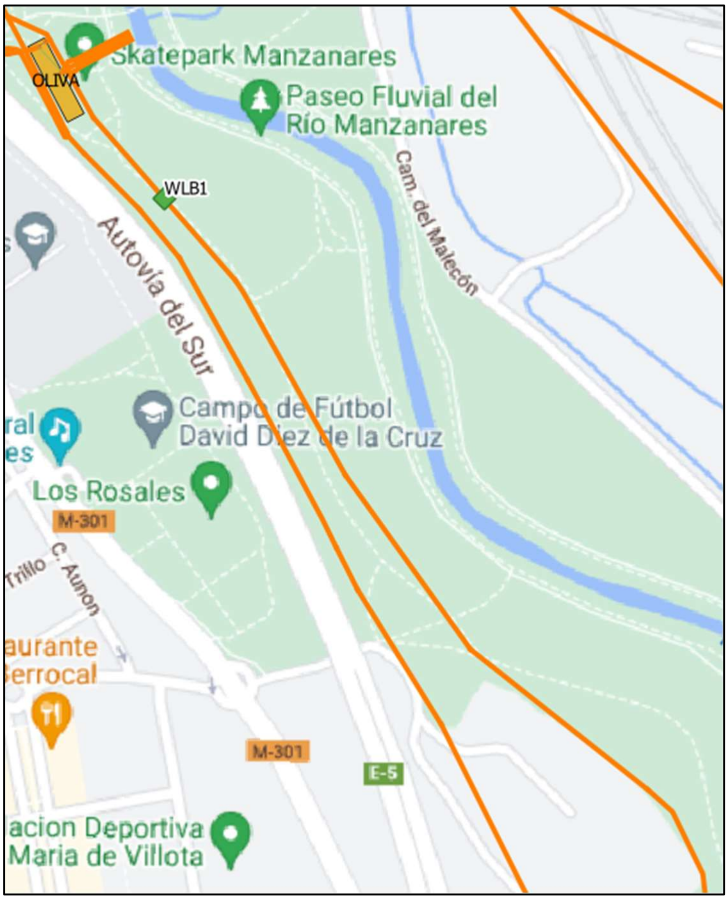

Figure 3. Approx. location of the water level sensor in MD interceptor

3.1.2 Secondary water level sensors

As mentioned previously there are 3 secondary water level sensors that will not be installed in first instance because its information is not critical to operate AQDV UD and also because it is installation is not easy. In the 3 cases the lack of these sensors will be replaced by the data obtained from the online SWMM hydraulic model of the system, then once a first version is operating without these sensors, the need of these sensors will be re-evaluated.

3.1.2.1 Water level sensor in Butarque I collector

Existing manholes of this collector are located below a private bus parking so it will not be easy to obtain the required permission to install the sensor inside a private installation and also a pole to install the solar panel to supply the energy to the sensor. The only alternative is to execute a new manhole outside the parking limits. Energy and communications cannot be provided at this location, circumstances which hinder the possibility of addressing the installation in the short term.

Figure 4. Butarque I collector general view located under a private property used as bus parking.

3.1.2.2 Water level sensor in Butarque II collector

The collector goes several meters deep from the terrain surface so the required works to build a manhole and install the sensor would be very expensive (see Figure 5). Also, there is already a water level sensor in the grit removal chamber represented in the figure so with the information from the online model and this sensor it has been considered that this water level sensor is not required at this stage of the project.

Figure 5. Butarque II collector reaching the CSO chamber, where it can be observed that it is a very deep collector

Figure 6. Optional future location of the water level sensor in Butarque II collector

3.1.2.3 Water level sensor in La Gavia collector

This sensor goal is to measure the flow flowing from La Gavia Catchment. In dry weather flow (DWF) it is all treated in La Gavia WWTP so this collector is dry and the sensor will measure 0, but in wet weather not all the catchment flow can be treated in the WWTP and when the WWTP capacity is exceeded, some flow by-passes the WWTP and goes through this sensor to the MI interceptor, increasing its flow and increasing the probability of having CSO in the close Aliviadero Sur weir.

Figure 7. Optional future location of the water level sensor in La Gavia collector

3.1.3 Discarded water level sensors

In the previous deliverable "DA1.2 Report for Spanish configuration definition, requirements and preparation", in chapter 3.1.2 a preliminary list of water level sensors required was done. This list has been updated in this deliverable so in this chapter the explanation of the changes is provided:

- **WLB2 in old MD interceptor:** This sensor was thought to be necessary to measure flow getting into the pilot area from the upstream network, but thanks to an inspection, it was noted that there is very few water flowing through this old collector, nowadays most of the water goes through the new MD interceptor where we are installing WLB1 sensor, so this sensor will not be necessary.
- **WLB3 upstream MI interceptor:** Again this sensor goal was to measure flow getting into the pilot area from the MI interceptor upstream network. However, information provided by CYII operating department confirmed the existance of a water level sensor (sensor E451MED399_ANA) some hundred meters upstream for the same purpose. After analysing the historic data available we agreed we could avoid the installation of this sensor (see Figure 8).

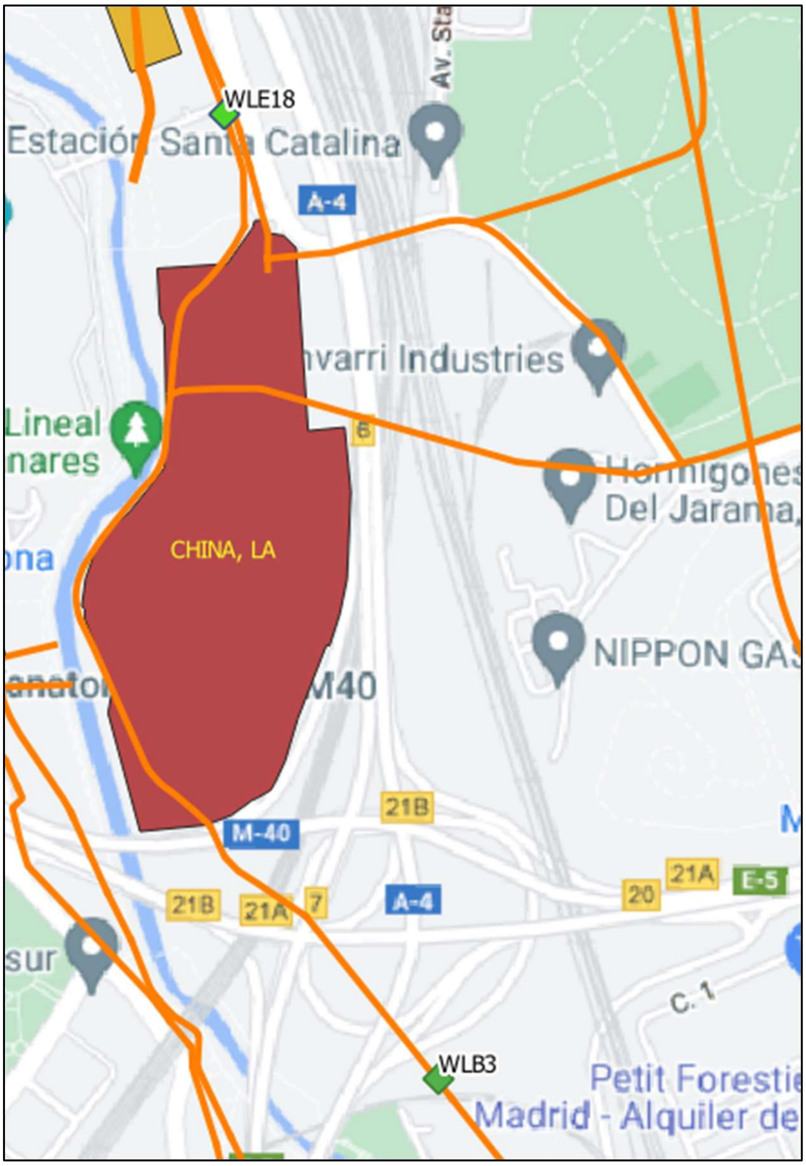

Figure 8.- Existing water level sensor (WLE18 - E451MED399_ANA) upstream so it will not be necessary to install the WLB3.

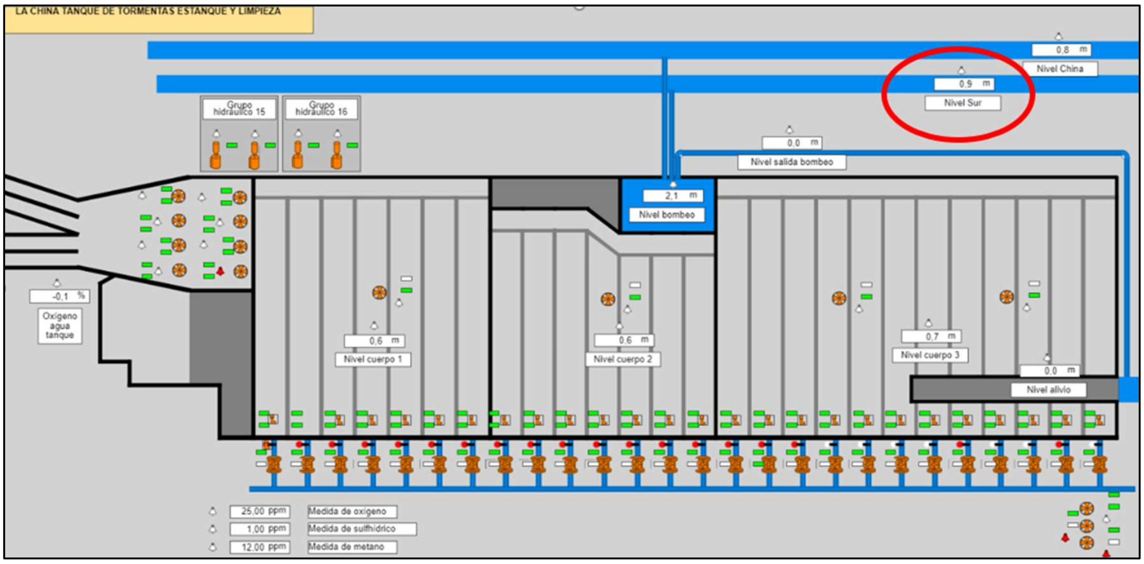

Figure 9.- CYII SCADA's view of the existing water level sensor WLE18 - E451MED399_ANA)

- **WLB4 downstream MI interceptor:** This sensor was required to measure how much water gets out of the pilot area by the left margin interceptor and is driven to the Sur WWTP located downstream. Again CYII explained exactly in the same location there already exists the WL sensor E463PNC064_NCA (see Figure 10).

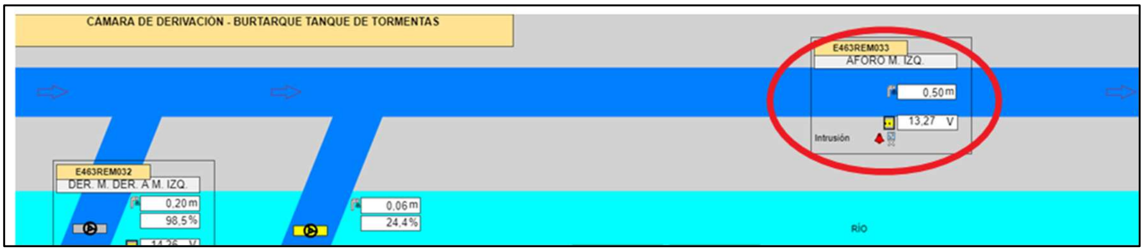

Figure 10. CYII SCADA's view of the existing sensor E463PNC064_NCA located in MI interceptor downstream the pilot area.

- **WLB6 in the by-pass weir upstream Butarque WWTP to the river:** Again in this case, there already exists a sensor in this location (sensor E791PND027 controlled by CYII and also other sensors controlled by the WWTP SCADA used for the same purpose) so this one won't be necessary.

3.2 Network turbidity sensors

The location of the turbidity sensors has also been updated from the DA1.2 after the sewer inspection mainly to improve future maintenance of these sensors. Turbidity sensors are difficult and costly to maintain and if we want to obtain good measurements they should be periodically cleaned. In order to reduce the maintenance the exact location has been moved to avoid permanent contact with wastewater so they will only measure in rain events when the water level in the sewers rises above the maximum daily DWF pattern. This way maintenance will be much more easy and the counterpart is that we will not have DWF measures. However, this is a minor problem as dry weather turbidity can be obtained from the water sample campaigns already available and the ones that are planned in the project. In real time this information can be obtained from the WWTP sensors.

In the next subchapters the location of these sensors is presented.

3.2.1 TS1: In MD interceptor in the CSO collector to the river upstream Butarque tank

In first instance, this sensor was planned to be installed in the right margin interceptor before the by-pass chamber upstream Butarque tank. However, this chamber is not easy to access so maintenance would be difficult. That is the reason why it has been moved to the upstream collector where there already exists a CSO gate.

It will measure the water quality of the MD interceptor during rain events, which will be used to define the quality of water entering Butarque tank, as well as at the WWTP inlet and whenever CSO is measured in this point and in the by-pass upstream the WWTP.

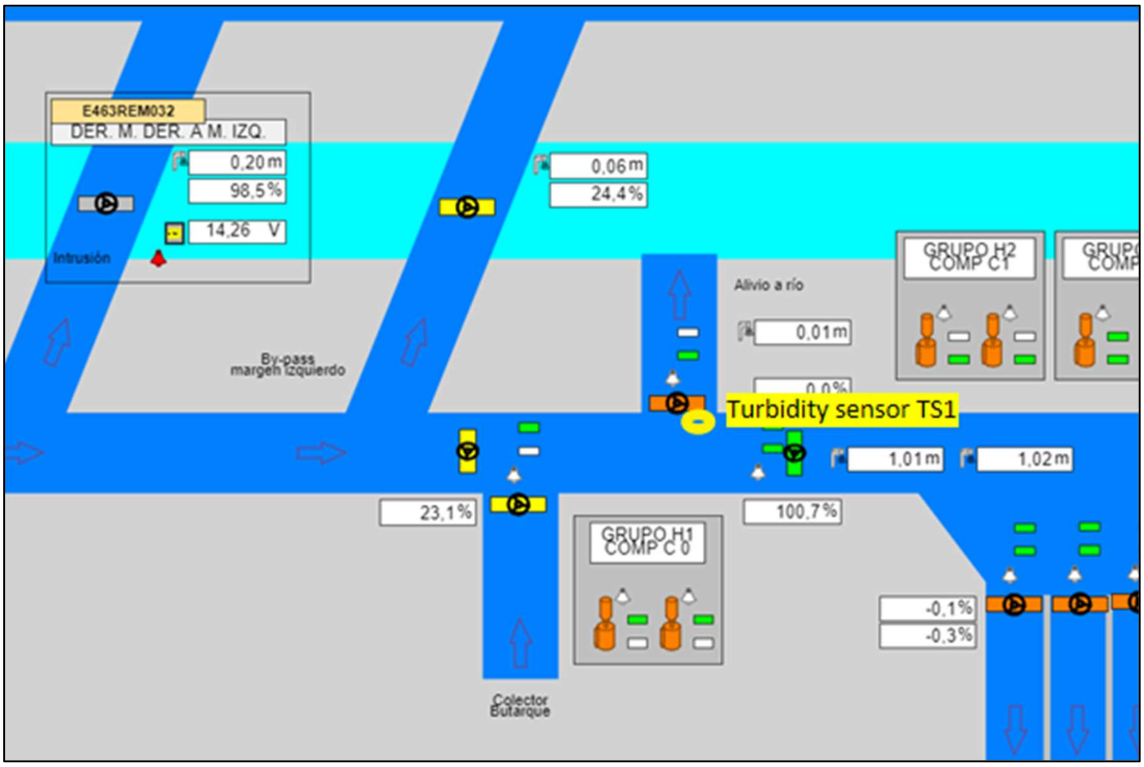

Figure 11. Location of TS1 turbidity sensor.

3.2.2 TS2: In Abroñigales tank entrance channel

This turbidity sensor will be installed in the entrance channel thanks to a small pump connected to a buoy that whenever water is detected will pump water to a bucket where the sensor will be installed in a dry and easy to access location in the tank so sensor maintenance operation will be easy.

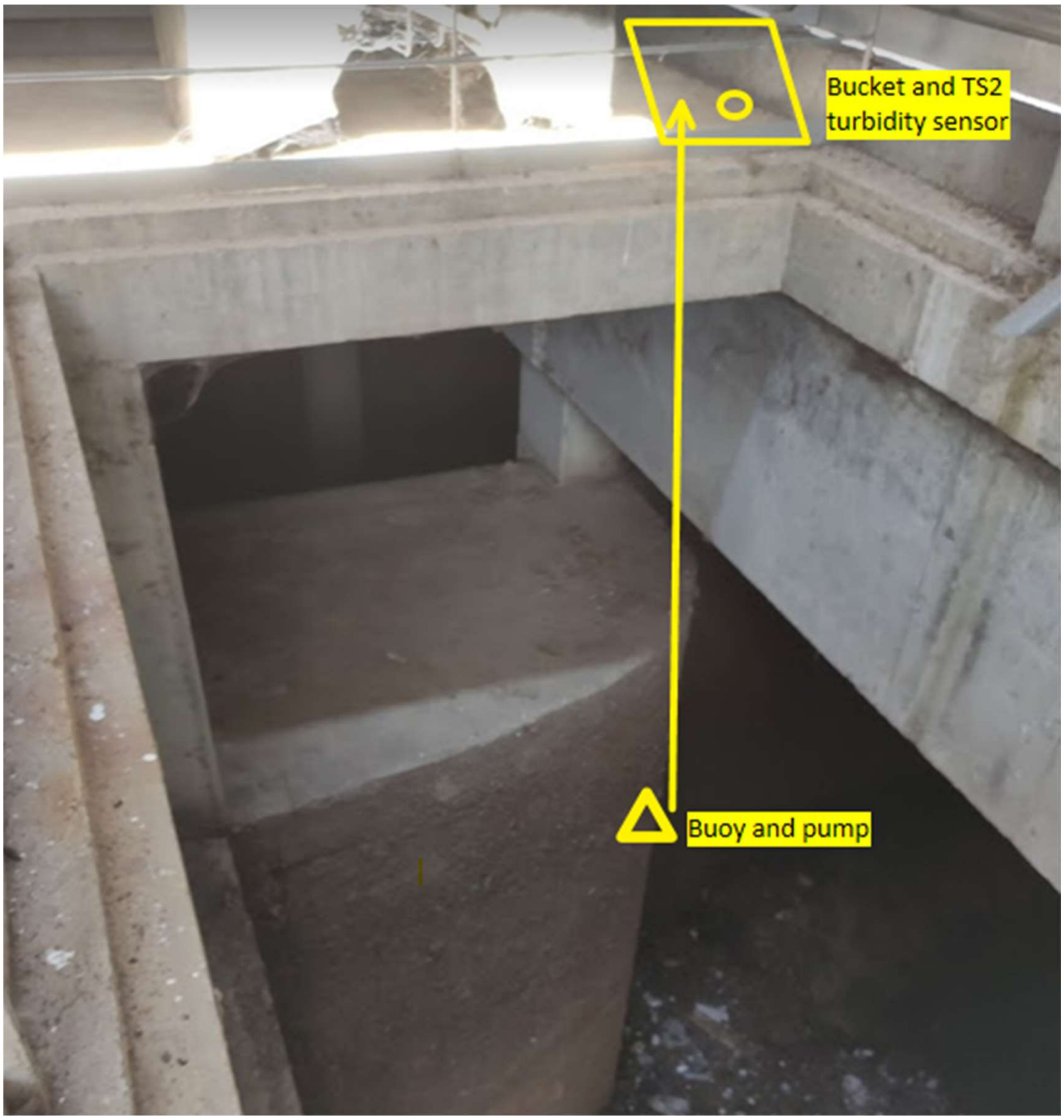

Figure 12. Inspection visit to the location where TS2 will be installed

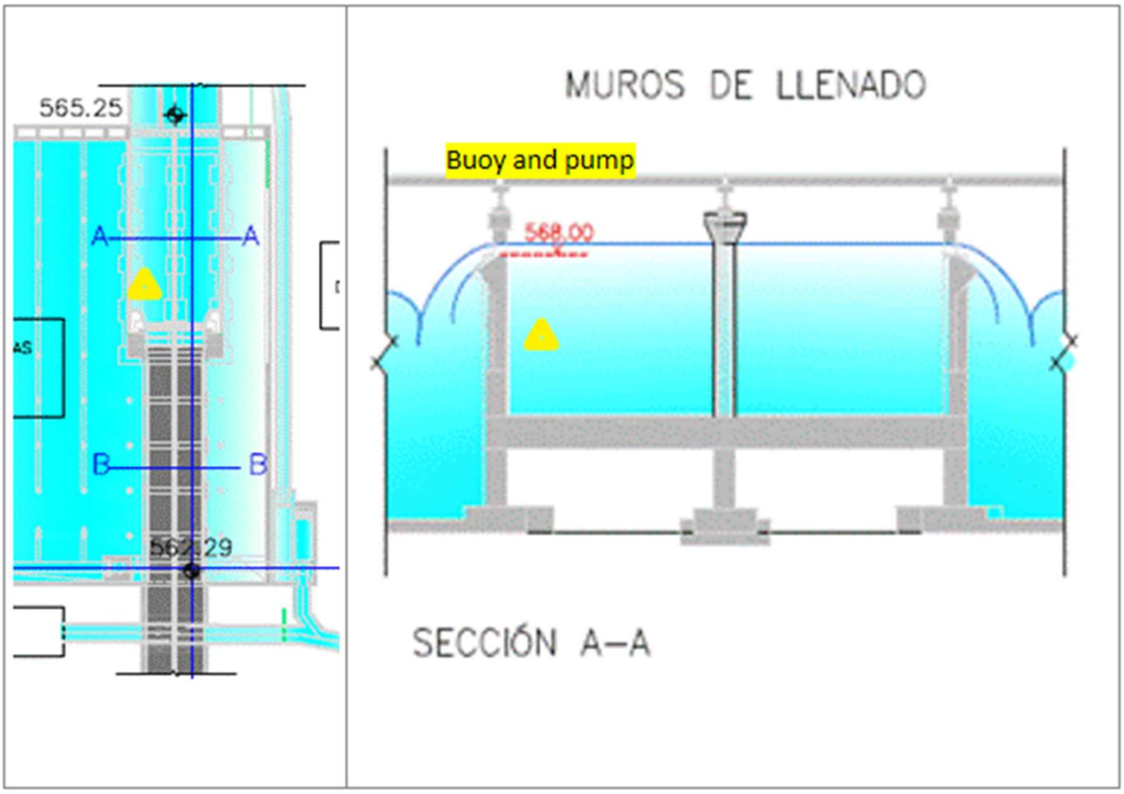

Figure 13. Buoy and pump location in Butarque tank horizontal and cross section plan

This sensor will be used to define water quality getting into the tank, and also whenever a CSO is happening from the tank it will measure the quality of CSO.

3.2.3 TS3: In MI interceptor

The first idea was to install this turbidity sensor in Aliviadero Sur, but after an inspection to this point it was discarded because there was no energy available but mainly because it is a very difficult and dangaerous location to access with high flows so maintenance would have been dangerous.

Instead the sensor will be installed downstrean this point where it already exists a water level sensor so the energy supply is guaranteed and the maintenance is much more easy

Figure 14. CYII SCADA's view of the existing sensor E463PNC064_NCA located in MI interceptor downstream the pilot area. Same location is foreseen for TS3 turbidity sensor

This sensor will be used to measure quality of the water getting out of the pilot area towards SUR WWTP. Also whenever there is CSO from this collector in the Sur CSO discharge point this sensor will define the quality of the discharge.

In DA1.2 it was also planned a turbidity sensor located in La Gavia collector that could measure the the quality of the effluent WWTP but also during rain events it could measure the quality of the mixture waters (effluent and by-pass WWTP waters) discharging to the river from this point. After CYII inspections at this point and talking with the operation department of CYII it was concluded that Gavia collector is not discharging directly to the river, instead it connects to MI interceptor upstream Aliviadero Sur CSO point, so this turbidity sensor won't be necessary because the TS2 will provide the general quality of the waters being discharged by Aliviadero Sur and it is not needed the deatailed quality of La Gavia waters.

3.2.4 TS4: In Butarque WWTP after primary treatment

This turbidity sensor will be located between the primary and the secondary treatment and it will measure the quality of the effluent from the primary treatment that can not be treated in the secondary because it has not enough capacity and so it by-passes it discharging directly to the river (see Figure 15 and Figure 16).

Figure 15. Water channel driving the waters from the primary to the secondary treatment. At the left waters are driven to the secondary while whenever the biological capacity is surpassed the waters are driven right to the river.

Figure 16. By-pass channel from the primary treatment to the river

3.3 Temporary water samplers

In each of the locations where the turbidity sensors will be installed, we will also install temporary water samplers in order to correlate the turbidity real time measures provided by the sensors with other quality parameters at each point where these sensors are located. These values will be used to calibrate the models but also as inputs for AQUD real time operation.

The parameters to be analyzed at each campaign are:

- TSS
- Turbidity
- Conductivity
- BOD5
- COD Total
- N-Total
- N-NH4+

Two types of quality campaigns are planned:

- Dry weather flow campaigns: In the locations where these campaigns are planned, 2 campaigns will be done one for weekday and another one for weekend taking and analyzing 6 samples per day (one sample for each 4 hours).
- Wet weather flow campaigns: In the locations where these campaigns are planned, 3 rain events campaigns will be done taking and analyzing an average of 6 samples per

rain event with shorter sampling time at the starting of the event (15 minutes) and longer one at the end (30 minutes or even 1 hour)

According to the location of the turbidity sensors the following table summarizes the quality campaigns that are planned:

Table 3.- Quality campaigns planned

Location	Description	DWF	WWF
TS1	**MD (Right margin) interceptor**	**X**	**X**
TS2	**Abroñigales tank inlet and CSO**		**X**
TS3	**MI (Left margin) interceptor**	**X**	**X**
TS4	**WWTP primary treatment effluent**		**X**
Total		2	4

3.4 Rain gauges

Two rain gauges have been installed in each of the WWTP in the pilot site. One in Butarque WWTP is operative since end July 2022 and the second one in La Gavia WWTP installed November 2022.

Figure 17. Rain gauge installation and leveling

Figure 18. Rain gauge installed in Butarque WWTP parking garden

The second one was installed in November 2022 in La Gavia WWTP

Figure 19. Rain gauge installed in La Gavia WWTP

3.5 Natural environment sensors

Two visits to the river reach have been done, one in July 2022 to define the reference quality control points and a second one in November 2022 to better define the downstream point.

Two main points have been identified to assess the improvements that would be observed in the river reach as a result of the operation and management of effluents from WWTPs and CSO tanks, and also to have enough quality data to do and calibrate the river model. One upstream the pilot site and the second one downstream.

3.5.1 River quality control section upstream

This section is located near Oliva tank where it already exists a river structure for an old monitoring station with an old monitoring stand. (see Figure 21 and Figure 22).

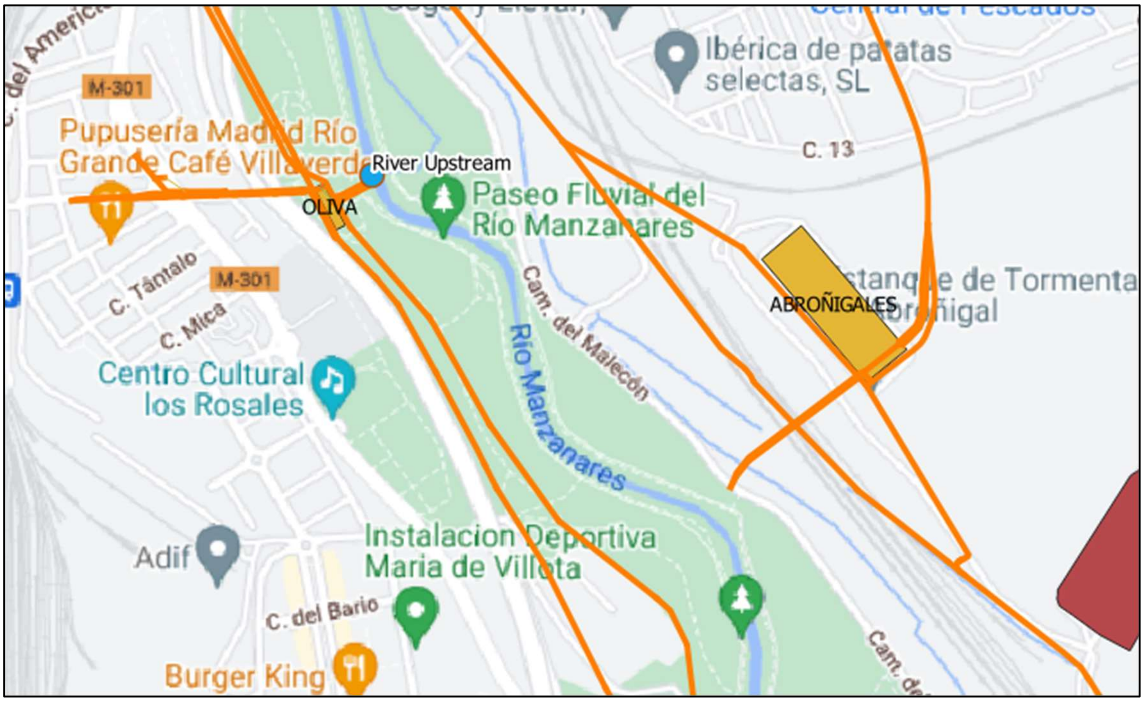

Figure 20. Location of the upstream quality control section

Figure 21. Old monitoring station structure that will be used to install the upstream quality control section

Figure 22. General view of the monitoring point with the Oliva tank CSO discharges and the monitoring stand in blue.

The installation of the monitoring station can have two options:

1. The best option would be to channel the water from the river to an offline bucket located in the stand, in which the different sensors would be immersed (see Figure 23 as an example). The existing stand has an anti-vandalism system and it is very close to the intake point, but permission from the municipality is needed to use it.

2. In case we can’t use the stand, the second option would be install the bucket inside Oliva tank (maybe in the CSO interceptors that are already protected by bars avoiding vandalic actions.

Figure 23. Example of the configuration planned where river water is pumped to a bucket where the sensors are located.

In both cases a small pump is needed to pump water from the riverbed in the metal structure to the bucket.

The sensors to be installed here measure ammonium, dissolved oxygen, turbidity/SS, EC (conductivity), temperature and pH. and they will be rented from Universidad de la Coruña who has calibrated them and they are ready to be installed (see Figure 25) .

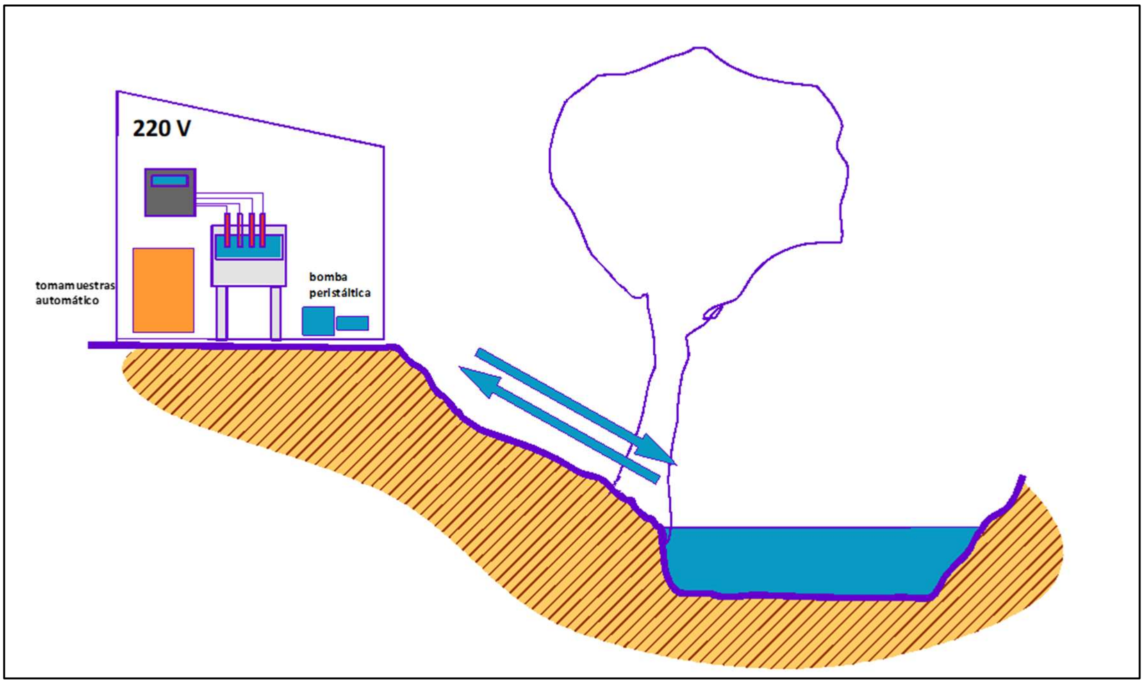

Figure 24. Scheme of the monitoring station structure with the peristaltic pump pumping the river water to the bucket where the sensors are located.

Figure 25. HAC sensors being calibrated in Universidad de la Coruña laboratory

During the visit done the 27th July 2022 some quality measurements were obtained and they are compared with the quality goals for the good ecological potential in Manzanares river (River type T-15):

- In situ measurements:

- DO[1]: 8.3 mg/l (quality goal ≥ 5 mg/l)
- Conductivity: 687 µS/cm
- Dissolved Oxygen Saturation: 105 % (quality goal 60 ≤ %OD ≤ 120))
- Temperature: 24.2 ºC

➢ Laboratory analysis:

- pH: 7.36 (quality goal 6 ≤ pH ≤ 9)
- Turbidity: 7.14 UFT
- Alcalinity: 47 mg/L $CaCO_3$
- $CDBO_5$[2]: 1.1 mg/L
- $CDBO_{20}$[3]: 3.1 mg/L
- DQO: 19 mg/L
- NH_4^+: 0.12 mg/L (quality goal ≤ 0,6)
- NO_2^-: <2 mg/L
- NO_3^-: 26.5 mg/L (quality goal ≤ 25)
- NT[4]: 7.87 mg/L
- PO_4^{-3}: <0.15 mg/L (quality goal ≤ 0,5)

Except for the nitrate concentration, the measured values confirm the visual perception obtained during the visit of the good quality of the water in this section of the river, surprisingly good for the time of year when most of the river flow it has to come from the effluents of the WWTPs located upstream (La China and Viveros). The nitrate value itself measured at this point in the river (26.5 ppm) is only slightly higher than the established limit (25 ppm).

3.5.2 River quality control section downstream

For the downstream quality control section in the July visit we identified two location options, both very close to the Sur WWTP:

a) This would be the best option because it would be located upstream the by-pass of the Sur WWTP and so the quality sensors would not be affected by these discharges.

b) The second option is about 0.5 km downstream from point a) and in this case the quality station would be affected by the by-pass discharges of the WWTP.

[1] DO : Dissolved oxygen
[2] CDBO5: carbonaceous DBO5, assay with inhibition of nitrification
[3] CDBO20: carbonaceous DBO20, assay with inhibition of nitrification
[4] NT: total nitrogen


River Downsrteam Option A
River Downstream option B

Figure 26. Installation point A upstream Sur WWTP by-pass

Figure 27. Installation point B 500 m downstream point A

We did a second visit in November 2022 mainly to confirm location point A was a good choice and to define with Canal Isabel II and the Sur WWTP operators the necessary works to install the sensors.

During this second visit we observed the impact of the WWTP by-pass in the river (see Figure 28) with many toilet wipes some meters above the current river water level, which means that whenever the discharge weir is in operation, the impact to the river quality spreads several meters upstream the discharging point. This impression was confirmed by the WWTP operator manager when he said that through this weir about 30 m3/s are discharged during rain events.

Figure 28. point A upstream Sur WWTP by-pass where it can be seen on the opposite bank of the river toilet wipes a few meters above the current river water level.

This means that installing the river quality sensors in any of these points would be highly affected by this discharge, so we agreed a new location is needed for this river downstream section.

Several options have been identified but a third field visit to the river must be done in the coming to confirm the better location.

Figure 29. Several optional river control sections have been identified all of them located between Butarque WWTP and Sur WWTP.

In this case a multiparametric sensor (Aquatroll 600) will be rented from Universidad de la Coruña measuring ammonium, dissolved oxygen, turbidity/SS, EC (conductivity), nitrates, temperature, and pH.

Two installation options are planned here depending if we can have energy (which would be the best option) then we would pump water to a bucket (same solution as in the upstream control point). In case we can't have energy supply, the second option is to place a stainless steel tube with perforations, semi-submerged, fixed to one of the riverbank trees, inside it the sensor would be submerged in "abandonment" and would operate thanks to a battery. In this second option the maintenance is somewhat more complex.

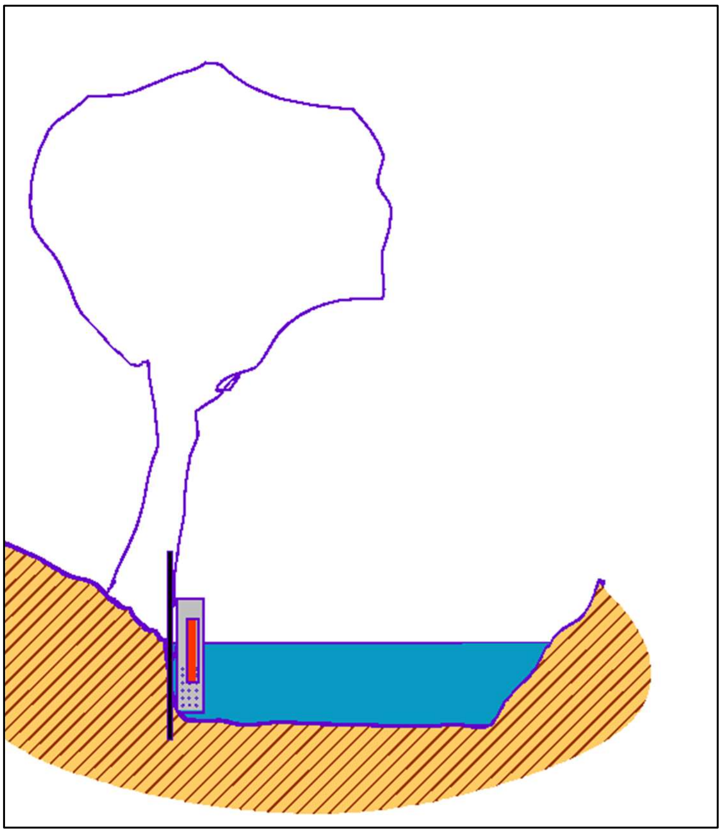

Figure 30. Scheme for the installation of the multiparametric sensor in "abandonment" mode, and example of stainless steel tube with perforations from Universidad de la Coruña.

Here as well, during the visit done the 27th July 2022 some quality measurements were obtained and they are compared with the quality goals for the good ecological potential in Manzanares river (River type T-15):

- In situ measurements:
  - DO[5]: 5.4 mg/l (quality goal ≥ 5 mg/l)
  - Conductivity: 823 µS/cm
  - Dissolved Oxygen Saturation: 70.2 % (quality goal 60 ≤ %OD ≤ 120))
  - Temperature: 24.8 ºC
- Laboratory analysis:
  - pH: 7.35 (quality goal 6 ≤ pH ≤ 9)
  - Turbidity: 1.6 UFT
  - Alcalinity: 76 mg/L $CaCO_3$
  - $CDBO_5$[6]: 3.9 mg/L
  - $CDBO_{20}$[7]: 7.9 mg/L
  - DQO: 40 mg/L
  - NH_4^+: 5.1 mg/L (quality goal ≤ 0,6)
  - NO_2^-: 3.48 mg/L
  - NO_3^-: 23.8 mg/L (quality goal ≤ 25)
  - NT[8]: 12.1 mg/L
  - PO_4^{-3}: <0.15 mg/L (quality goal ≤ 0,5)

Comparing these results with those of the point located upstream, a clear worsening of the quality of the water is observed, especially in terms of dissolved oxygen. This drop in quality must be caused mainly by the effluents from the La Gavia and Butarque WWTPs located between the two control points. However, it improves the quality in terms of nitrate concentration, which, as stated before, is also in accordance with the quality goal.

---

[5] DO : Dissolved oxygen
[6] CDBO5: carbonaceous DBO5, assay with inhibition of nitrification
[7] CDBO20: carbonaceous DBO20, assay with inhibition of nitrification
[8] NT: total nitrogen

4 AQDV UD deployment

4.1 Introduction

AQUADVANCED® Urban Drainage (AQDV UD), is the platform developed by the SUEZ group for global sewage management, from real-time data management, to the prediction of events that may affect the proper functioning of the drainage network, through supervision of the operations being carried out.

AQUADVANCED® Urban Drainage is an advanced real-time drainage management system that has 3 modules: monitoring, early warning and advanced control. Thanks to these three pieces, a global control of the drainage systems is achieved that allows to avoid urban flooding and contamination of the receiving environment of the waters of the sewage network that are not assumable neither by the interceptors nor by the treatment plants.

The monitoring module allows you to monitor the status of the entire drainage system in terms of hydraulic behavior, water quality, operations in progress in the network or performance, all in real time. In addition, the monitoring module incorporates both confirmed meteorological information: weather stations, rain gauges and radar images, as well as predicted through short-term rain forecast data: radar nowcasting.

Regarding the early warning module, the system models and predicts the impacts on the receiving environment and on the sewage systems to prevent and manage the risks of flooding in urban areas, or pollution in rivers and coastal waters. To do this, it simultaneously runs hydraulic and hydrological models in real time, as well as marine pollution models. The early warning module also performs calculations to forecast the hydraulic behavior of the drainage network, the river environment and the sea in order to be able to take measures in advance and reduce the impact.

Finally, the advanced control module calculates optimized operating strategies in real time and automatically controls system actuators. It also makes it possible to coordinate wastewater management with treatment plants. With this, an optimized and real-time operation of the drainage systems is achieved.

This advanced control module already existing in AQDV UD, is the one that will be improved in this project with the Pollution-based Model Predictive Controller (see chapter 4.6)

4.2 IT architecture

Two main configurations are planned for AQDV UD:

- Cloud server installation and ftp communication with CYII SCADA data
- CYII network installation and OPC connection with SCADA data

In the next subchapters the two configurations are explained.

4.2.1 Cloud server and ftp communication with CYII SCADA data

During a first phase of the project, and meanwhile several offline tests are being performed to compare the current operation strategy with the new quality based control strategy developed in Rubies project, AQDV UD will be installed in a cloud server and the communication will only go in one direction from CYII SCADA to AQDV UD via ftp (see Figure 31).

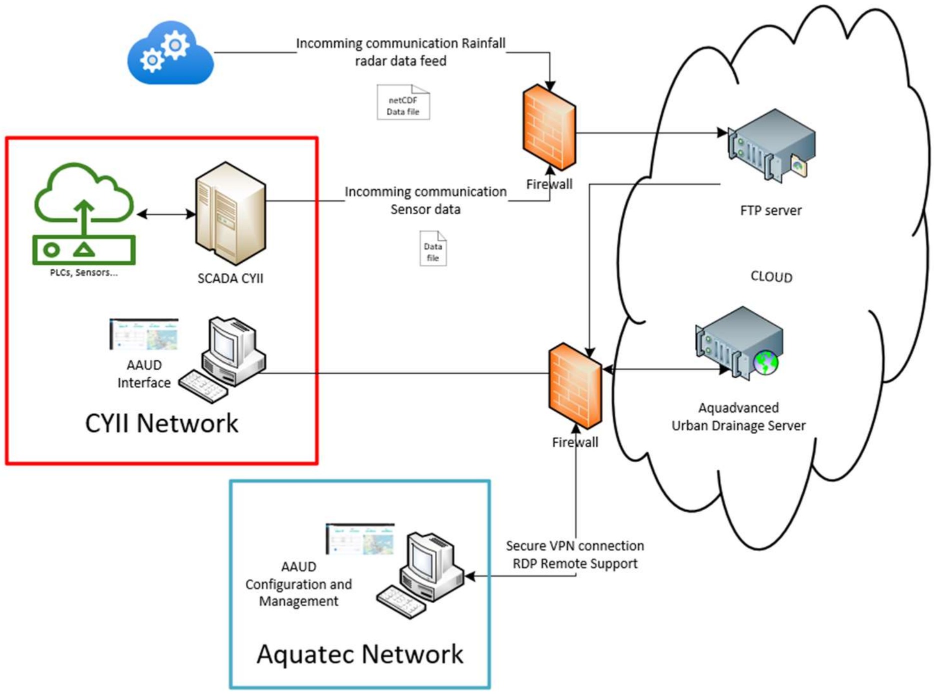

Figure 31. IT architecture to connect with AQDV UD with CYII systems via ftp

The communication with CYII data is done via standard txt files which at regular times (for example every 5 minutes) will be created exporting time series values from CYII SCADA, creating a unique file with a time stamp in its name. This file will be send to a specific FTP server - in the cloud and AQDV UD will have configured and scheduled procedure to connect to the FTP server and acquire this file to and specific folder, and then the data contained in the file will be processed and saved at AQDV UD database and used in the application.

In the figure below an example of txt files is shown. It is a very basic configuration with three main columns for each file:

- A time stamp with date and time
- An identificator for each sensor or actuator required for AQDV UD. This identificator is the one used by CYII.
- A value

```
"FECHA";"EQUIPO";"MEDIA"
01/08/2020 00:01:59;"E463PNC220_NCA";0,016022857278585434
01/08/2020 00:01:59;"E463PNC221_NCA";1,3515625
01/08/2020 00:01:59;"E463PNC222_NCA";1,335416555404663l
01/08/2020 00:01:59;"E463PNC223_NCA";1,3601562976837158
01/08/2020 00:01:59;"E463PNC224_NCA";0,19386574625968933
01/08/2020 00:03:59;"E463PNC220_NCA";0,016022857278585434
01/08/2020 00:03:59;"E463PNC221_NCA";1,3515625
01/08/2020 00:03:59;"E463PNC222_NCA";1,3354165554046631
01/08/2020 00:03:59;"E463PNC223_NCA";1,3601562976837158
01/08/2020 00:03:59;"E463PNC224_NCA";0,19386574625968933
01/08/2020 00:05:59;"E463PNC220_NCA";0,016022857278585434
01/08/2020 00:05:59;"E463PNC221_NCA";1,3414062261581421
01/08/2020 00:05:59;"E463PNC222_NCA";1,3354165554046631
01/08/2020 00:05:59;"E463PNC223_NCA";1,3492187261581421
01/08/2020 00:05:59;"E463PNC224_NCA";0,19386574625968933
01/08/2020 00:07:59;"E463PNC220_NCA";0,016022857278585434
01/08/2020 00:07:59;"E463PNC221_NCA";1,3414062261581421
01/08/2020 00:07:59;"E463PNC222_NCA";1,3354165554046631
01/08/2020 00:07:59;"E463PNC223_NCA";1,3492187261581421
01/08/2020 00:07:59;"E463PNC224_NCA";0,19386574625968933
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01/08/2020 00:09:59;"E463PNC222_NCA";1,3354165554046631
01/08/2020 00:09:59;"E463PNC223_NCA";1,3492187261581421
```

Figure 32. Example of txt file to import CYII time series values from their SCADA or DB to AQDV UD.

The intelligence to know the correspondence between the identificator and the units and meaning of the values is done during the AQDV UD configuration process and this correspondence is given in chapter 4.4

At this first phase of the project AQDV UD will be operated to monitor the operation of the Manzanares system and how it behaves, being able to provide simple information to the operator about the current state of the system, send some warnings and alerts (for example when there are CSO discharging to the river) or provide some regular KPI.

4.2.2 CYII network and OPC connection with SCADA data

Once the offline tests have been performed and CYII operators are convinced about the utility and improvements of the new control strategy applied with the Rubies project controller, AQDV UD will be installed in a server inside CYII network. Then the communication with SCADA will be bidirectional that means that data from sensors and actuators will come from SCADA to ADDV UD software and also setpoints for the actuators will be sent from AQDV UD to the SCADA. In this case the communication will be done via OPC.

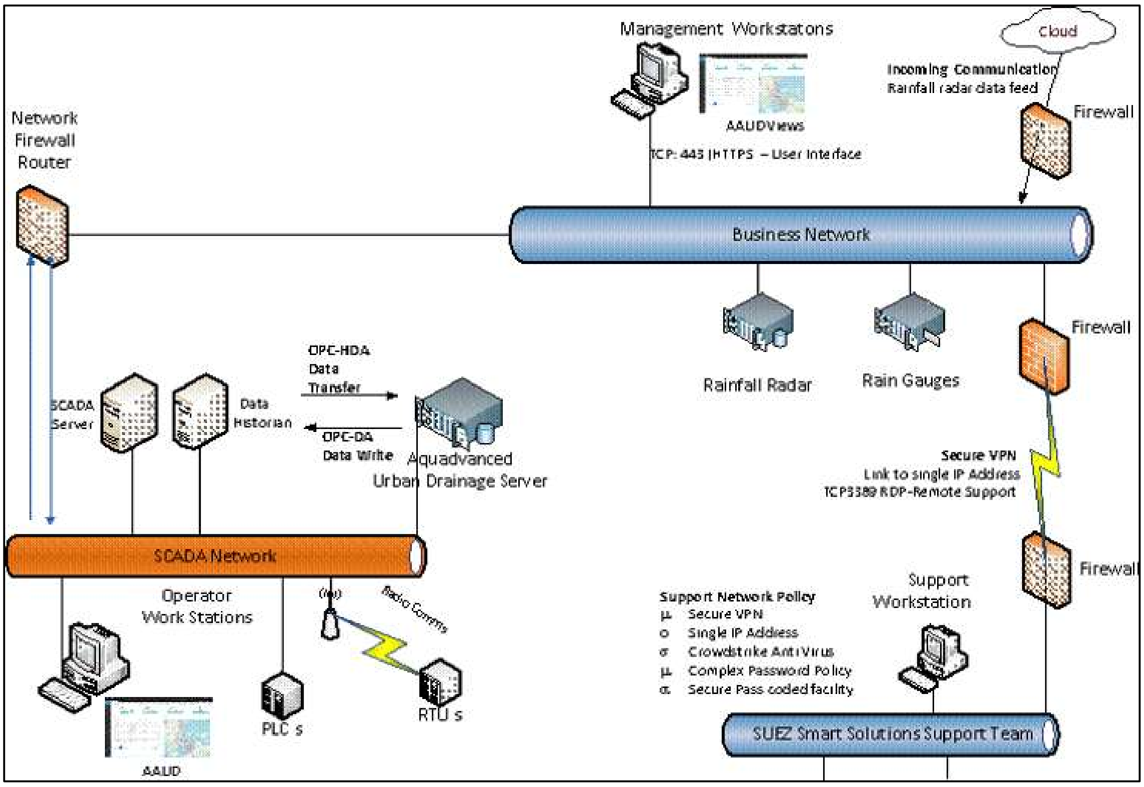

Figure 33. IT architecture where AQDV UD is installed in CYII network and the communication with the SCADA is bidirectional via OPC.

4.3 Weather data connection

Weather data will come from two main sources:

- Radar rain data observed and forecasted from an external service provided by HYDS company.
- Rain Gauges from CYII.

These two weather sources will be displayed in AQDV UD weather view and some KPI indicators as well as warnings by intense or heavy rainfalls will be shown there.

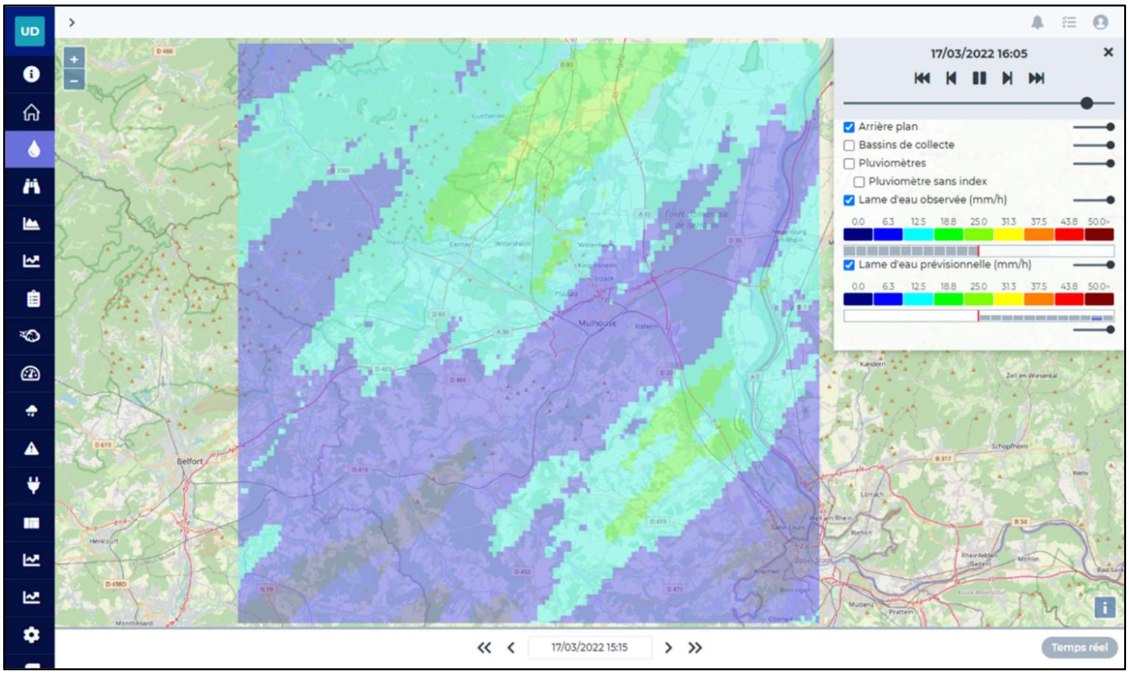

Figure 34.- Example of AQDV UD weather view where the weather data will be displayed.

There is still a 3rd raingauge data source from the temporary ones installed in Butarque and La GAvia WWTPs, but this information will be used for offline calibration of the hydraulic model and for the offline radar data adjustment if necessary, but these sensors are not connected online so their data won't be used for the online operation of AQDV UD.

4.3.1 Radar rain data observed and forecasted

The service provides 1 hour observed radar rainfall from Spanish National Meteorological Agency (AEMET) and 1 hour of forecast data from a nowcasting service on 400km² around Manzanares river with a matrix of 1km² (1km x 1km). The service provides a netCDF file for each 10 minutes via ftp and the AQDV UD will process and import it into its platform.

The observation and study of rainfall-type data, where data is collected geographically over periods of time, generating data with a matrix structure, adds complexity to the data collected. For the management of this data, some formats such as NetCDF appear.

In the figure below an example of netCDF files is shown. It is a very basic configuration with three main columns for each file:

- A time stamp UNIX type (seconds since 1970-01-01 00:00:00 UTC)
- Coordinate longitude (Using WGS84 coordinate reference system)
- Coordinate latitude (Using WGS84 coordinate reference system)
- 10-minute rainfall accumulation value in mm

```
time =
  {1.6644528E9, 1.6644534E9, 1.664454E9, 1.6644546E9, 1.6644552E9, 1.6644558E9, 1.6644564E9, 1.664457E9, 1.6644576E9, 1.6644582E9, 1.6644588E9, 1.6644594E9, 1.66446E9}
longitude =
  {-3.870000123977661, -3.8500001430511475, -3.830000162124634, -3.81000018119812, -3.7900002002716064, -3.7700002193450928, -3.750000238418579, -3.7300002574920654, -3.7100002765655518, -3.690000295639038, -3.6700003
47125244, -3.6500000953674316, -3.630000114440918, -3.6100001335144043, -3.5900001525878906}
latitude =
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rain =
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    },
```


Figure 35. Example of netCDF file for the radar data

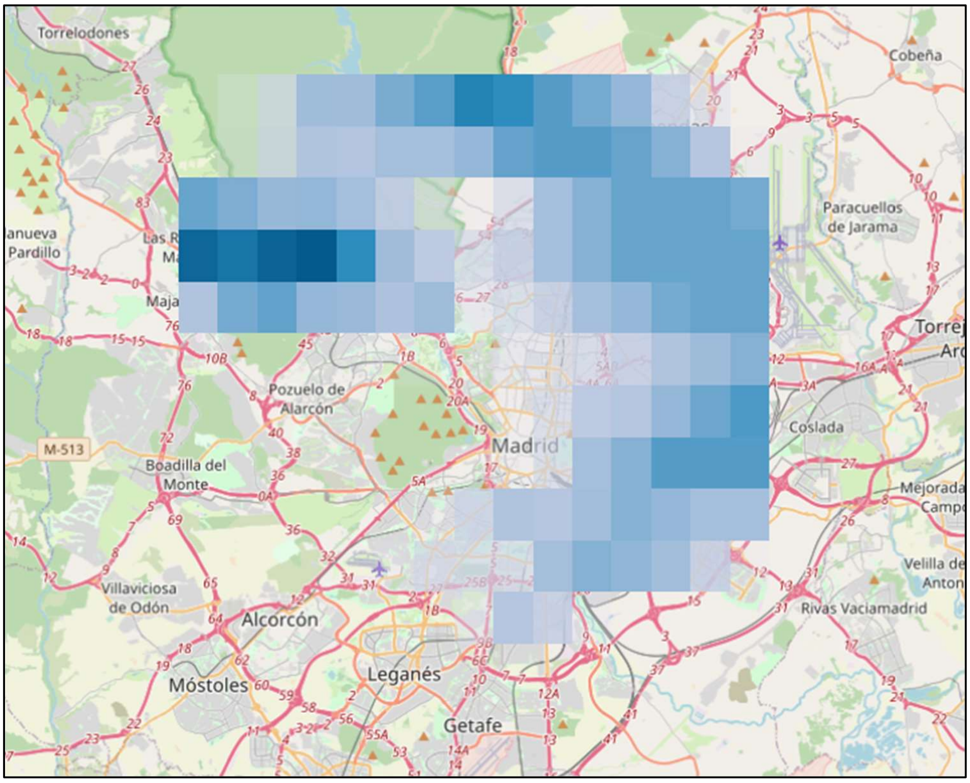

Figure 36.- Radar image for Madrid pilot site.

4.3.2 Rain gauges from CYII

This information will be introduced in AQDV UD the same way as any other time serie sensor described in the previous chapter, in a first step using txt files via ftp, and at a later stage via OPC connection to the SCADA. This rain gauge data will be used to validate and if necessary correct the radar rainfall data by comparing the values provided by the radar and the ones provided by the rain gauge.

4.4 Sensor and actuators data connection

As mentioned in chapter 4.1 several sensor and actuator data must be transferred to AQDV UD software to be able to visualize this data and compute warnings about the pilot site operation and provide KPI about the pilot site management as well as setpoints for the defined actuators to reduce pollution discharged to the Manzanares river and thus improve its quality.

In order to correctly transmit all the information from the sensors to AQDV UD, we must link each sensor and its data variable to an object in AQDV UD. To do so, an exchange tables system is used and presented in subchapter 4.4.1 which will be used to configure later AQDV UD.

Also, from this data measured by the sensors, some secondary variables will be directly computed by AQDV UD. Subchapter 4.4.2 presents some of these variables.

4.4.1 Data transmission to AQDV UD

In order to correctly transmit all the information from the sensors to AQDV UD, we must link each sensor and its data variable to an object in AQDV UD. To do so, an exchange tables system is used which are presented below in the following subchapters ordered by:

- Network sensors from current CYII SCADA.
- Networks actuators from current CYII SCADA
- Butarque WWTP sensors from current Butarque WWTP SCADA
- La Gavia WWTP sensors from current Butarque WWTP SCADA

4.4.1.1 Network sensors from current CYII SCADA

The table below shows the current sensor variables that have been identified in CYII SCADA that are necessary to be imported in real time into AQDV UD to fulfil the project objectives.

Table 4.- Exchange table to transmit and connect the required information from the available sensors to AQDV UD

CYII SCADA Code	AQDVUD name	Variable	Units	Description
E463PNC224_NCA	By-pass MD-MI	Water height	m	Water height for by-pass colector between MD and MI interceptor in the pilot site

CYII SCADA Code	AQDVUD name	Variable	Units	Description
E463PNC221_NCA	MD aar 1 TBut	Water height	m	Water height in MD interceptor upstream Butarque tank. Sensor 1
E463PNC223_NCA	MD aar 2 TBut	Water height	m	Water height in MD interceptor upstream Butarque tank. Sensor 2
E463PNC220_NCA	DSU AArr TBut	Water height	m	Water height in CSO colector upstream Butarque tank
E463PNC198_NCA	TBut I-1	Water height	m	Water height in Butarque tank compartment I-1
E463PNC199_NCA	TBut I-2	Water height	m	Water height in Butarque tank compartment I-2
E463PNC200_NCA	TBut I-3	Water height	m	Water height in Butarque tank compartment I-3
E463PNC201_NCA	TBut I-4	Water height	m	Water height in Butarque tank compartment I-4
E463PNC202_NCA	TBut II-1	Water height	m	Water height in Butarque tank compartment II-1
E463PNC203_NCA	TBut II-2	Water height	m	Water height in Butarque tank compartment II-2
E463PNC204_NCA	TBut II-3	Water height	m	Water height in Butarque tank compartment II-3
E463PNC205_NCA	TBut II-4	Water height	m	Water height in Butarque tank compartment II-4
E791PND027_NDE	EDARBut By-pass	Water height	m	Water height in Butarque WWTP upstream by-pass
E791PQT017_QTU	EDARBut Qprim	Flow	m3/h	Flow in Butarque WWTP primary treatment
E791PQT003_QTU	EDARBut Qbiol	Flow	m3/h	Flow in Butarque WWTP biological treatment
E463PHV208_NVE	EDAR ButII	Water height	m	Water height in Butarque II colector
E463PHV208_ZVE	DSU ButII	Water height	m	Water height in CSO discharge from Butarque II
E464PNC647_NCA	TBut-colButII	Water height	m	Water height in inlet colector from Butarque II to Butarque tank
E463PQT211_QTU	Bomb Tbut-Prim TP1	Flow	m3/h	Pumped flow from Butarque tank to new primary treatment in Butarque WWTP. Sensor 1
E463PQT212_QTU	Bomb Tbut-Prim TP2	Flow	m3/h	Pumped flow from Butarque tank to new primary treatment in Butarque WWTP. Sensor 2
E463PQT209_QTU	Bomb Tbut-MD1	Flow	m3/h	Pumped flow from Butarque tank to MD. Sensor 1
E463PQT210_QTU	Bomb Tbut-MD2	Flow	m3/h	Pumped flow from Butarque tank to MD. Sensor 2

CYII SCADA Code	AQDVUD name	Variable	Units	Description
E778PNC565_NCA	Tabro ColEnt	Water height	m	Water height upstream Abroñigales tank
E778PNC572_NCA	Tabro CamEnt	Water height	m	Water height in Abroñigales tank inlet chamber
E451MED399_ANA	MI aarr	Water height	m	Water height in MI upstream case study area
E778PNC566_NCA	MI desdob	Water height	m	Water height in MI doubled collector
E778PND575_NDE	TAbro C1	Water height	m	Water height in Abroñigales tank compartment C1
E778PND576_NDE	TAbro C2	Water height	m	Water height in Abroñigales tank compartment C2
E778PND577_NDE	TAbro C3	Water height	m	Water height in Abroñigales tank compartment C3
E778PND578_NDE	TAbro C4	Water height	m	Water height in Abroñigales tank compartment C4
E778PNC574_NCA	TAbro aliv_sal	Water height	m	Water height in Abroñigales tank CSO weir
E778PNC567_NCA	TAbro DSU1	Water height	m	Water height in Abroñigales tank CSO colector 1
E778PNC624_NCA	TAbro DSU2	Water height	m	Water height in Abroñigales tank CSO colector 1
E778PHV569_NVE	MI alivSuR	Water height	m	Water height in MI interceptor at Aliviadero Sur
E778PHV569_ZVE	DSU alivSur	Water height	m	Water height at MI CSO weir at Aliviadero Sur
E794PQT326_QTU	EDARGav QbombMI_m3/h	Flow	m3/h	Pumped flow from MI interceptor to LA Gavia WWTP
E794PQT308_QTU	EDARGav Qbiol_m3/h	Flow	m3/h	Flow in La Gavia WWTP biological treatment
E593PQT035_QTU	EDARGav QByP_biol_m3/h	Flow	m3/h	Flow in La Gavia WWTP by-passing the biological treatment
E025CPL080_PLU	Raingauge	Rain volume	mm	Hourly rain volume in Bravo Murillo rain gauge

As seen in the table most of the sensors are water level sensors and the values are stored in meters. There are also a few flow meters (with values stored in m3/h) and a rain gauge.

4.4.1.2 Network actuators from current CYII SCADA

In a similar way the table below shows the exchange table of the current CYII SCADA actuators that need to be imported in AQDV UD.

These actuators are gates and in most of the cases the variable stored is gate opening as a percentage meaning that 0 % is closed and 100 % is fully opened

A few cases the information stored is a gate status with a code number that is stored every time there is a status change. The code meaning is:

- 0: Data transmission problem. No data available
- 1: Closed
- 2: Opened
- 3: Half opened

Table 5. Exchange table to transmit and connect the required information from the available actuators to AQDV UD

SCADA Code	AQDVUD name	Variable	Units	Description
E463MED274_ANA	C DSU AArr TBut	Gate opening	%	Gate in CSO colector upstream Butarque tank
E463MED280_ANA	C TBut C52	Gate opening	%	Butarque tank inlet gate C52
E463MED279_ANA	C TBut C51	Gate opening	%	Butarque tank inlet gate C51
E463MED278_ANA	C TBut C42	Gate opening	%	Butarque tank inlet gate C42
E463MED277_ANA	C TBut C41	Gate opening	%	Butarque tank inlet gate C41
E464MED648_ANA	C TButII	Gate opening	%	Inlet gate from Butarque II colector to Butarque tank
E778MED640_ANA	C Tabro ByP	Gate opening	%	Abroñigales tank by-pass gate
E778SDO542_SDO	C Tabro Ent2	Gate status	Position code	Abroñigales tank inlet gate 2
E778SDO538_SDO	C Tabro Ent3	Gate status	Position code	Abroñigales tank inlet gate 3
E778SDO534_SDO	C Tabro Ent4	Gate status	Position code	Abroñigales tank inlet gate 4
E778MED570_ANA	C TAbro DSU1	Gate opening	%	Abroñigales tank CSO gate to CSO colector 1
E778MED571_ANA	C TAbro DSU2	Gate opening	%	Abroñigales tank CSO gate to CSO colector 2
E778MED627_ANA	C TAbro salC11	Gate opening	%	Abroñigales tank outlet gate C11
E778MED628_ANA	C TAbro salC12	Gate opening	%	Abroñigales tank outlet gate C12
E778MED629_ANA	C TAbro salC13	Gate opening	%	Abroñigales tank outlet gate C13
E778MED630_ANA	C TAbro salC14	Gate opening	%	Abroñigales tank outlet gate C14
E778MED631_ANA	C TAbro salC15	Gate opening	%	Abroñigales tank outlet gate C15
E778MED632_ANA	C TAbro salC16	Gate opening	%	Abroñigales tank outlet gate C16
E778MED633_ANA	C TAbro salC17	Gate opening	%	Abroñigales tank outlet gate C17
E778MED634_ANA	C TAbro salC18	Gate opening	%	Abroñigales tank outlet gate C18

4.4.1.3 Quality sensors from current CYII SCADA

CYII has several online quality sensors to control effluent quality of the WWTP. These quality stations are called MINERVA and the information of these stations for the Butarque WWTP and La Gavia WWTP in the pilot site will also be imported according to the following exchange table.

Table 6. Exchange table to transmit and connect the required information from the available Butarque WWTP quality sensors to AQDV UD

SCADA Code	AQDVUD name	Variable	Units	Description
E791PPH051_PHD	Qual_pH EDARBut	pH	pH	Quality in effluent Butarque WWTP: pH
E791PCD052_CND	Qual_Cond EDARBut	Conductivity	microS/cm	Quality in effluent Butarque WWTP: Conductivity
E791PAM053_NH3	Qual_NH3 EDARBut	NH3	mg/l	Quality in effluent Butarque WWTP: NH3
E791PTB050_TBA	Qual_Turb EDARBut	Turbidity	NTU	Quality in effluent Butarque WWTP: Turbidity
E791PNT054_NTR	Qual_Nitrat EDARBut	Nitrates	mg/l	Quality in effluent Butarque WWTP: Nitrates
E791PNT055_NTR	Qual_Nitrit EDARBut	Nitrites	mg/l	Quality in effluent Butarque WWTP: Nitrites
E791PCL056_CLL	Qual_DQO EDARBut	COD	mg/l	Quality in effluent Butarque WWTP: COD
E791MED057_ANA	Qual_SS EDARBut	Suspended solids	mg/l	Quality in effluent Butarque WWTP: SS
E791MED058_ANA	Qual_Fosf EDARBut	phosphates	mg/l	Quality in effluent Butarque WWTP: Phosphates
E593PPH192_PHD	Qual_pH EDARGav	pH	pH	Quality in effluent La Gavia WWTP: pH
E593PCD193_CND	Qual_Cond EDARGav	Conductivity	microS/cm	Quality in effluent La Gavia WWTP: Conductivity
E593PAM194_NH3	Qual_NH3 EDARGav	NH3	mg/l	Quality in effluent La Gavia WWTP: NH3
E593PTB191_TBA	Qual_Turb EDARGav	Turbidity	NTU	Quality in effluent La Gavia WWTP: Turbidity
E593PNT195_NTR	Qual_Nitrat EDARGav	Nitrates	mg/l	Quality in effluent La Gavia WWTP: Nitrates
E593PNT196_NTR	Qual_Nitrit EDARGav	Nitrites	mg/l	Quality in effluent La Gavia WWTP: Nitrites
E593PCL197_CLL	Qual_DQO EDARGav	COD	mg/l	Quality in effluent La Gavia WWTP: COD
E593MED198_ANA	Qual_SS EDARBut	Suspended solids	mg/l	Quality in effluent Butarque WWTP: SS

SCADA Code	AQDVUD name	Variable	Units	Description
E593MED199_ANA	Qual_Fosf EDARBut	phosphates	mg/l	Quality in effluent Butarque WWTP: Phosphates
E794PNT609_NTR	Qual_Nitrat EDARGav 2arysett	Nitrates	mg/l	Quality in La Gavia WWTP before secondary settling: Nitrates
E794PAM063_NH3	Qual_NH3 EDARGav 2arysett	NH3	mg/l	Quality in La Gavia WWTP before secondary settling:: NH3
E794MED520_ANA	Qual_Fosf EDARBut 2arysett	phosphates	mg/l	Quality in La Gavia WWTP before secondary settling: Phosphates

4.4.1.4 Butarque WWTP sensors local SCADA data

Butarque WWTP has its own SCADA which receives several sensor data. We have selected the most important ones for AQDV UD operation. In a first stage this sensor data will be transferred via ftp files, and in the future this sensor data will communicate with CYII SCADA and from there will be imported via OPC connection to AQDV UD.

Theses sensors are:

- Flow data from the upstream WWTP by-pass (point A in Figure 37) divided in 3 sensors / measurements: Flow discharged before the pumping station, flow discharged before the degritting and flow after the degritting .
- Flow data discharged from Butarque II weir (point C in Figure 37).
- Flow data before the primary treatment (point F in Figure 37).
- Flow discharged after the primary treatment (point D in Figure 37).
- Flow data after the biological treatment (point G in Figure 37).
- Quality data from the ATENEA monitoring station at the WWTP effluent (point E in Figure 37).

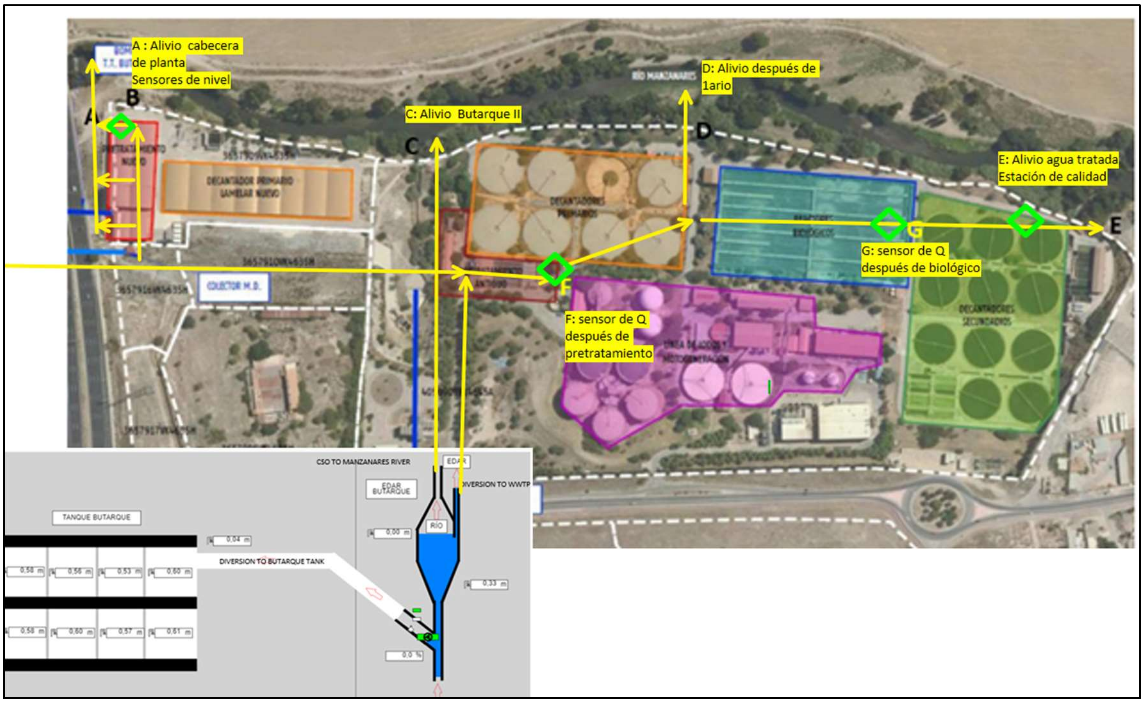

Figure 37. Butarque WWTP scheme with the sensors data to be imported to AQDV UD

Table 7. Exchange table to transmit and connect the required information from the Butarque WWTP SCADA to AQDV UD

SCADA Code	AQDVUD name	Variable	Units	Description
QAlivio antes bombeo	EDARBut QByP MD1	Flow	m3/s	Flow from MD interceptor by passing Butarque WWTP to the river before the pumping station
Qalivio previo desarenadores	EDARBut QByP MD2	Flow	m3/s	Flow from MD interceptor by passing Butarque WWTP to the river before degritting
Qalivio despues desarenadores	EDARBut QByP MD3	Flow	m3/s	Flow from MD interceptor by passing Butarque WWTP to the river after degritting
Qalivio Butarque II	EDARBut QByP_ButII	Flow	m3/s	Flow from Butarque II collector by passing Butarque WWTP to the river
QEntrada primaios Parshal	EDARBut Qprim	Flow	m3/s	Flow in Butarque WWTP primary treatment

Qalivio antes biologico	EDARBut QByP_biol	Flow	m3/s	Flow in Butarque WWTP by passing the biological treatment
Qagua tratada	EDARBut Qbiol	Flow	m3/s	Flow in Butarque WWTP biological treatment
pH atenea	EDARBut AT_pH	pH	pH	Butarque WWT effluent pH
Temperatura atenea	EDARBut AT_Ta	Temperature	ºC	Butarque WWT effluent temperature
Nitratos atenea	EDARBut AT_Nitrat	Nitrates	mg/l	Butarque WWT effluent nitrates
Turbidez atenea	EDARBut AT_Turb	Turbidity	FNU	Butarque WWT effluent turbidity
Materia organica atenea	EDARBut AT_MO	Organic matter	m-1 SAK	Butarque WWT effluent organic matter
Condutividad atenea	EDARBut AT_Cond	Conductivity	microS/cm	Butarque WWT effluent conductivity
Fosforo Atenea	EDARBut AT_P	Phosphorus	mg/l	Butarque WWT effluent Phosphorus
Orto fosfatos Atenea	EDARBut AT_OrtoP	Ortophosphate	mg/l	Butarque WWT effluent Ortophosphate

4.4.2 Computed secondary variables to be created in AQDV UD

From the time series measured by the sensors and described in the previous chapters and imported in real time into AQDV UD, the application is able to compute secondary variables in real time that are useful to launch warnings to operators, improve the operation of the system or compute important KPI's.

Some of the most relevant secondary variables to be computed are:

- Tank volumes obtained from the water level sensors in each tank compartment and tank filling percentage.
- Tank inflow and outflow
- Flows in collectors from water level sensors
- Pollution concentrations from turbidity sensors
- Pollution mass from pollution concentration and flows

4.4.2.1 Tank volumes and tank filling percentage

From the measurements of the water level sensors in each compartment of the tank, and knowing the average area of each compartment a unique time series of the water volume will be computed in real time for each tank:

- Abroñigales tank:

- Volume = 4513.5* WLC1+5729 * WLC2 +5729 * WLC3+5729 * WLC4

  Being WLC1, 2, 3 and 4 the water level measurements in each of the 4 tank compartments.

- Butarque tank:
  - Volume = WLCI1*3874.732+ WLCI2*3874.732+ WLCI3*3444.193+ WLCI4*6449.272+ WLCII1*3874.732+ WLCII2*3874.732+H WLCII3*3444.193+ WLCII4*6449.272

    Being WLCI1,2,3,4 and WLCII1,2,3,4 the water levels in each of the 8 tank compartments

Even more useful and quick to understand for an operator is the tank filling percentage.

4.4.2.2 Tank inflow / outflow

With the known volume computed in the previous chapter it can be also computed the flows getting in or getting out of the tank for each time difference:

- $\text{Flow}_t = (\text{Tank volume}_t - \text{Tank volume}_{t-1}) / \Delta t$

4.4.2.3 Collector flows

From the water level sensor data and thanks to a correlation from water levels to flows, it can be computed the flow through a sewer where there is a water level sensor.

The correlation from water levels to flows can be more easy or more difficult to obtain depending on the sewer cross section and slope, but in general and than (¿?)

4.4.2.4 Pollution concentrations

Two ways to obtain pollution can be applied depending if there is a turbidity sensor installed or not:

- **With a turbidity sensor**: and thanks to the sampling campaigns a correlation will be obtained from the real time turbidity data measured and the different pollutants concentrations
- **Without turbidity sensor:** In this case a more simple correlation is done applying an average pollution concentration value depending of the “type” of water in the sewer. Again this average pollution concentration is obtained from the sampling campaigns in the same sewer or in sewers with the same type of water. XX types of water have been defined in the pilot site:
  - Average dry weather flow data
  - Average unitary flow in the pilot site in rain event
  - Average primary treatment outflows from the WWTPs by-pass in rain event
  - Average effluent treatment outflows from the WWTP in rain event

4.4.2.5 Pollution mass

Multiplying pollution concentration by flows pollution mass is obtained. This is an important KPI to compute total pollution mass discharged to the river by the CSO structures in rain events for example.

4.5 Detailed Hydraulic model connection

In AQDV UD two hydraulic models will be configured to run online each one with a specific objective:

- The detailed model is configured to run on-line with real and forecasted rain data measurements in order to provide time series data to correctly run the Pollution-based MPC Controller (PBMPC) which integrates the simplified model as a constraint of the optimization problem solved by the PBMPC at every time instant. The time series provided by the detailed model is required at:
    - Sensor locations: At some points where it already exists a real time sensor, the model will provide a forecast of the future data that is expected to be measured. Those locations corresponding to the inlets of the pilot are the most relevant in order to run the PBMPC requiring flow and TSS forecasts for the prediction horizon considered by the controller.
    - Virtual sensor locations: At some points where there is no sensor but flow and TSS measurement estimations and forecasts could benefit the controller performance in order to reduce pollution mass released to the environment. an estimation of the past and forecast values is required (water levels or flows)
- The simplified model integrated as constraints of the optimization problem solved at every time instant by the PBMPC (see Chapter 4.6). This model represents a simplification of the detailed dynamics represented by detail model. This allows to solve fastly the PBMPC optimization problem at every time instant computing actuator setpoints in order to optimize the pilot site operation according to the operating principles (avoiding or reducing pollution mass discharged to the river in rain events while protecting floods).

4.5.1 Detailed model work

Chapter 2.4 of deliverable DA1.2 presented the existing model in Manzanares system which was done in Infoworks ICM. That model has been updated with the latest GIS, inspection and operational data available confirming and updating some of the assumptions done when in was first developed several years ago.

Also during these first project months the model has been transferred from Infoworks ICM to SWMM for two main reasons:

- Compatibility with AQDV UD software: Although the AQDV UD apparently can integrate both softwares, SWMM and Infoworks ICM, as a matter-of-fact SWMM integration has been tested much more and therefore its integration is more robust and we will avoid several operation problems that would happen if we worked with Infoworks ICM
- Also using SWMM, being an open-source software will facilitate that several teams can work in parallel at the same time. This would not be possible with Infoworks ICM because being a commercial software it requires a license to run, and we would only have only one license available (the license costs are too high for more than one license).

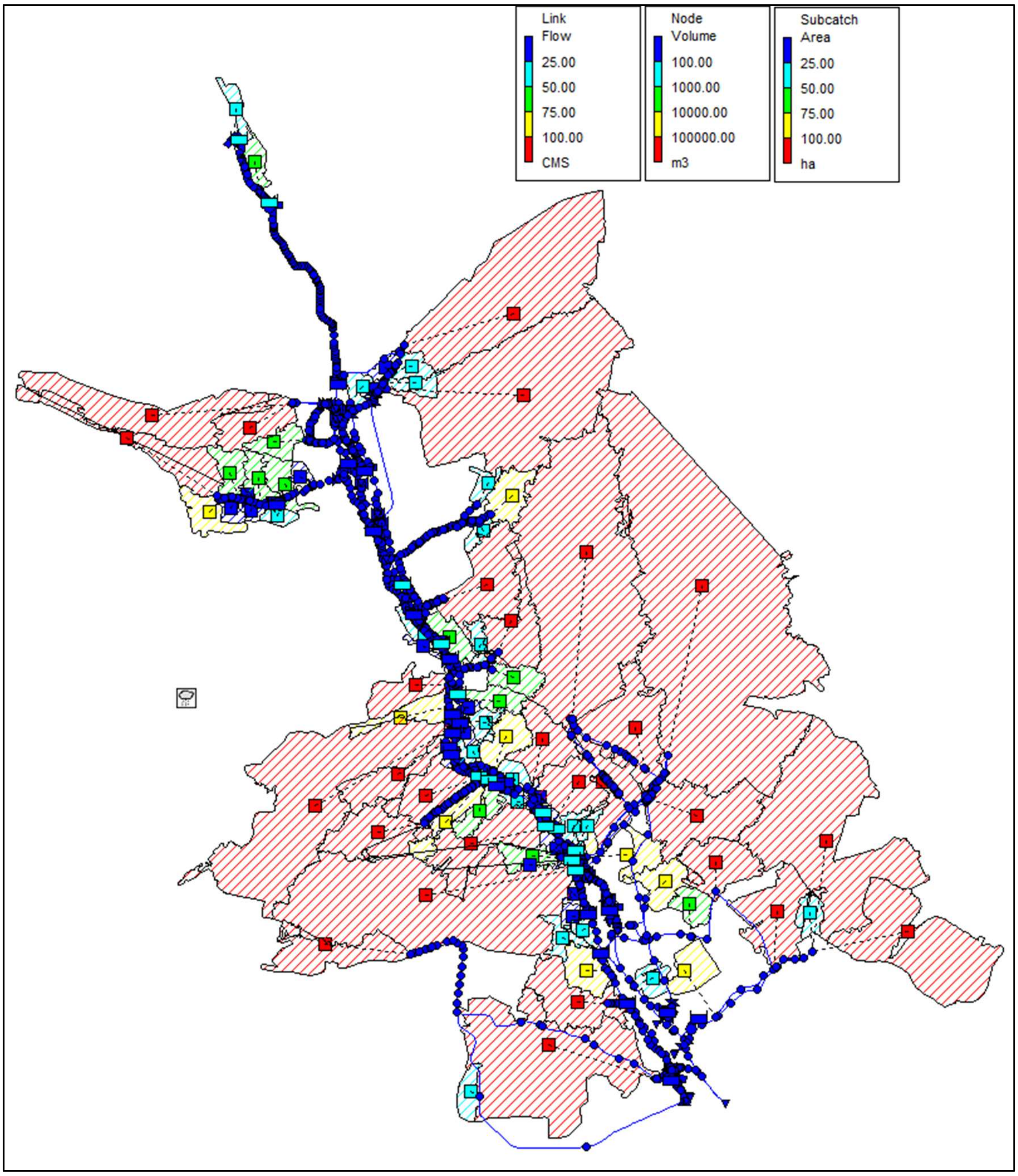

Figure 38. General view of the SWMM model for all the Manzanares system

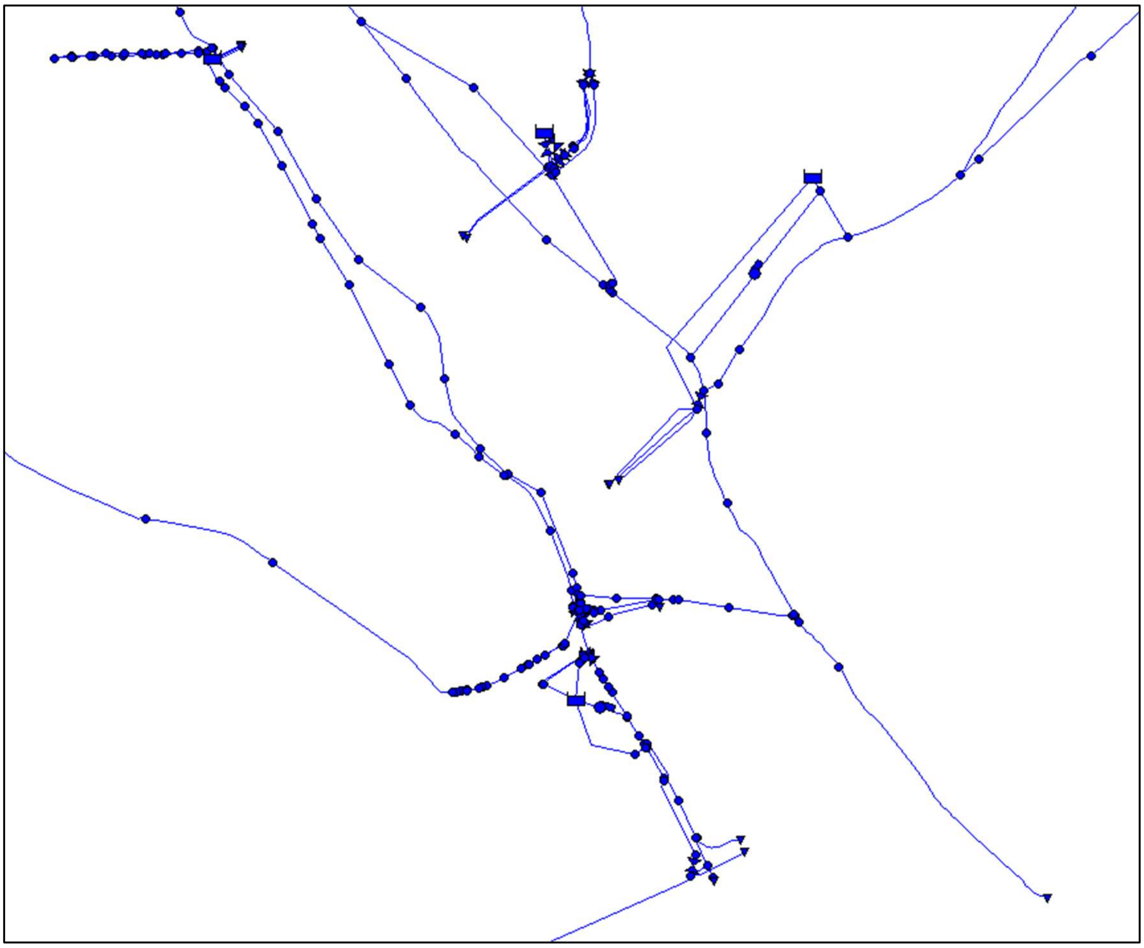

Figure 39. Detailed view of the SWMM model in the pilot area in the south of the Manzanares system

Next task related with the detailed model will be to calibrate it selecting between 3 and 5 rain events from the rain gauges and radar data available described in chapters 3.4 and 4.3 respectively.

4.5.2 Detailed model run configuration

SWMM model will run periodically (how often is a configuration parameter in AQDV UD but it must be configured to run between 5 and 10 minutes maximum) with the goal to provide time series values (water levels, or flows) at some strategic points which will be called virtual points or virtual sensors (these are defined in the next chapter).

To have it correctly configured there are 3 configuration parameters so that AQDV UD can launch SWMM as an operational model:

- Spin up or coldstart time: It is a time interval along which a model starting from a simplified initial condition (e.g. no movement, no water or dry weather condition) reaches a realistic dynamic equilibrium, so that after this coldstart time the model results can be analyzed and compared with real field data. This coldstart time is only applied the first model run, in the next model runs hindcast time is applied.

- Hindcast time: It is a time interval of the model run period that is past relative to the current launching time of the model. The goal of the hindcast period is to do a simulation with the best boundary conditions available. These boundary conditions can be defined based on measured data (for example flow, water level, or rain data measurements) or previous model runs.
- Forecast time: It is a time interval of the model run period that is the future relative to the current launching time of the model. In the forecast period the boundary conditions are only based in forecasts (rain forecast, flows, or actuators future setpoints)
- SWMM launch frequency: It defines the period between SWMM runs or how often the SWMM model is launched.

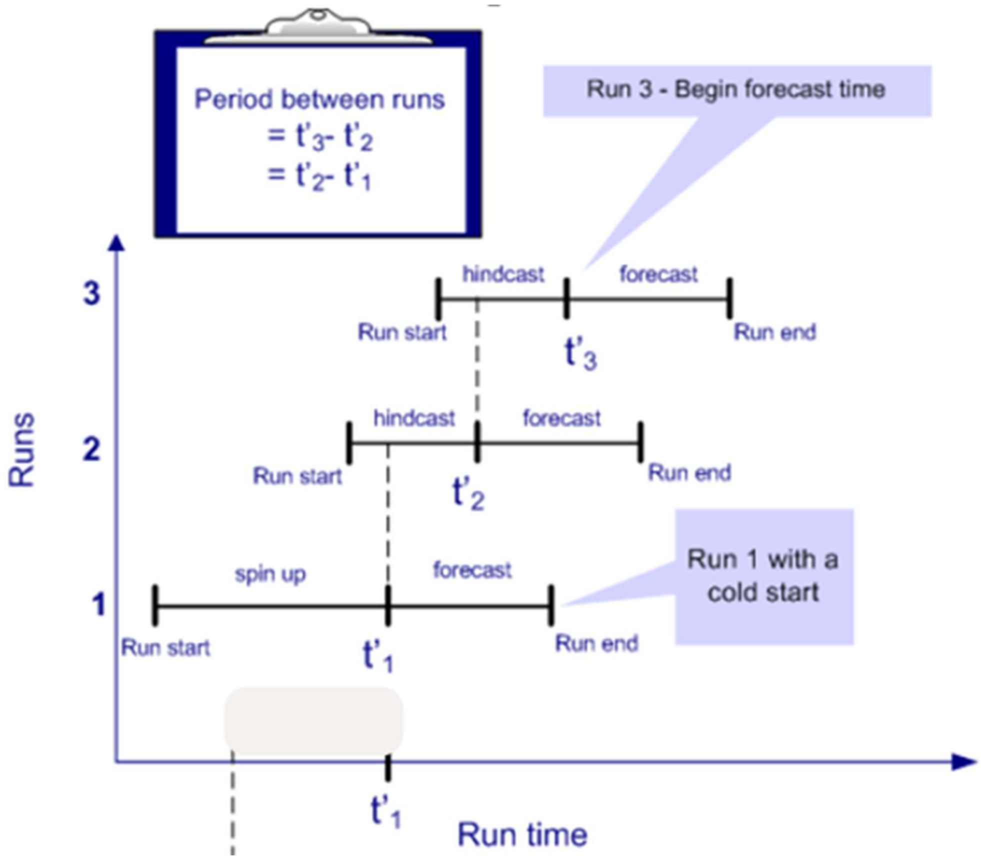

Figure 40. Diagram with a schematic representation of the time variables configuration for the SWMM operationalization in AQDV UD for each model ru

SWMM run period for the first model run is the sum of the spin up or hindcast time plus the forecast time. For all the other subsequent runs it is the sum of the hindcast and the forecast times.

Some typical configuration of these variables will be:

- Spin up or coldstart time: 4 hours
- Hindcast time: 0.25 hour
- Forecast time: 1 hour

- SWMM launch frequency: Minimum 5 minutes and maximum 10 minutes

These values are initial estimations that will be confirmed or better defined first during the offline tests and later on during the initial online tests.

4.5.3 Detailed model time series configuration

4.5.3.1 Model inputs

In order to correctly run the SWMM model, some input data must be configured. This is defined and explained below.

For the whole SWMM run period (coldstart or hindcast depending if it is the first model run,and the forecast time) must be provided for these variables:

- Rain data time series: must be provided by AQDV UD to the SWMM model and this is done based on:
    - For the coldstart or hindcast time: Rain measurements time series from rain gauges or the radar data available.
    - For the forecast time: Rain forecast data available in the same format as radar data.
- Actuators planned to be monitored in the pilot site. In this case the time series must be created based on:
    - For the coldstart or hindcast time: Real actuator position time series based on the SCADA values will be done
    - For the forecast time the actuators position will be computed based on the current operation strategy for instance based on a water level sensor of the model or a similar approach.
- Actuators planned to be controlled in the pilot site. In this case the time series are created based on:
    - For the coldstart or hindcast time: Real actuator position time series based on the SCADA values will be done (similar to the previous one)
    - For the forecast time the actuators position time series will be provided based on the setpoints given by the optimization control module.

Apart of these time series values initial conditions for water level (or water volume) tanks at the beginning of the model run must be imported based on the water tank sensor measurements.

4.5.3.2 Model outputs

SWMM model is able to provide several time series variables at different model locations (for example link flows, node or tank volumes, etc.). Most of this information is not important for the project but some must be imported in the AQDV UD database and these ones are called **virtual sensors.**

These virtual sensors have 3 main objectives:

- To run the PBMPC Controller.
    - These are mainly locations where flows or water levels sensors do not exist or they exist but the PBMPC controller needs forecasted values that, of course, they are not supplied by the real sensors. Usually, they are linked with inflows to the pilot site as seen in Figure 41.
- To compute important KPI for the project. These ones are mainly related with system discharges to the river, either CSO or WWTP effluent (see Figure 42).
- To get an idea of the accuracy of the operational model by comparing model results with real sensor measurements. There could be configured as many virtual sensors as existing sensors but the most important ones are given in Figure 43 which are:
    - Water level virtual sensors: located in the places where there are measurements for water inlet to the pilot site or in the interceptor collectors (MD or MI)
    - Flow virtual sensors related with the WWTP treatment flows in Butarque and La Gavia
    - Tank volume virtual sensors related to the 2 tanks in the pilot site (Butarque and Abroñigales).

The figures below show a first version of virtual sensors configuration according to the 3 main objectives, and of course some virtual sensor configured could be used for two or more of these objectives.

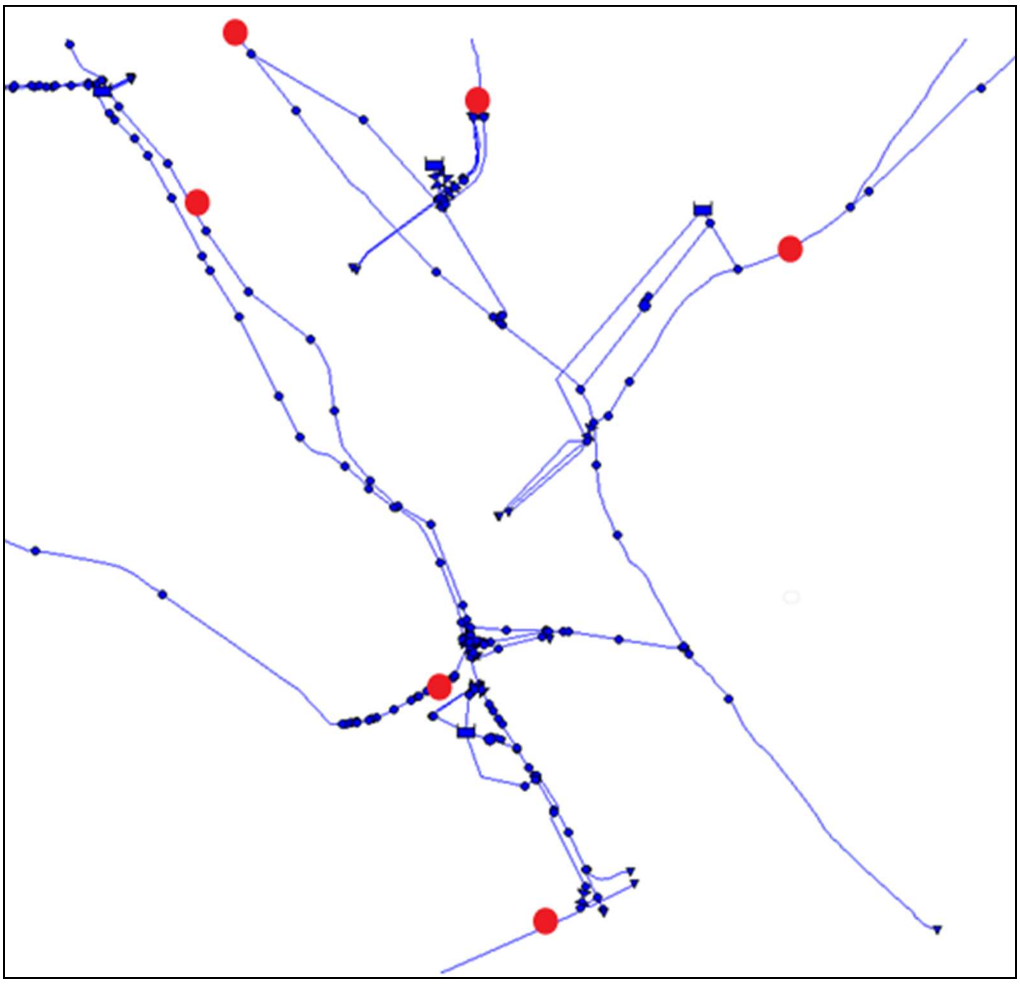

Figure 41. Flow virtual sensors configured to provide input data to launch the PBMPC module

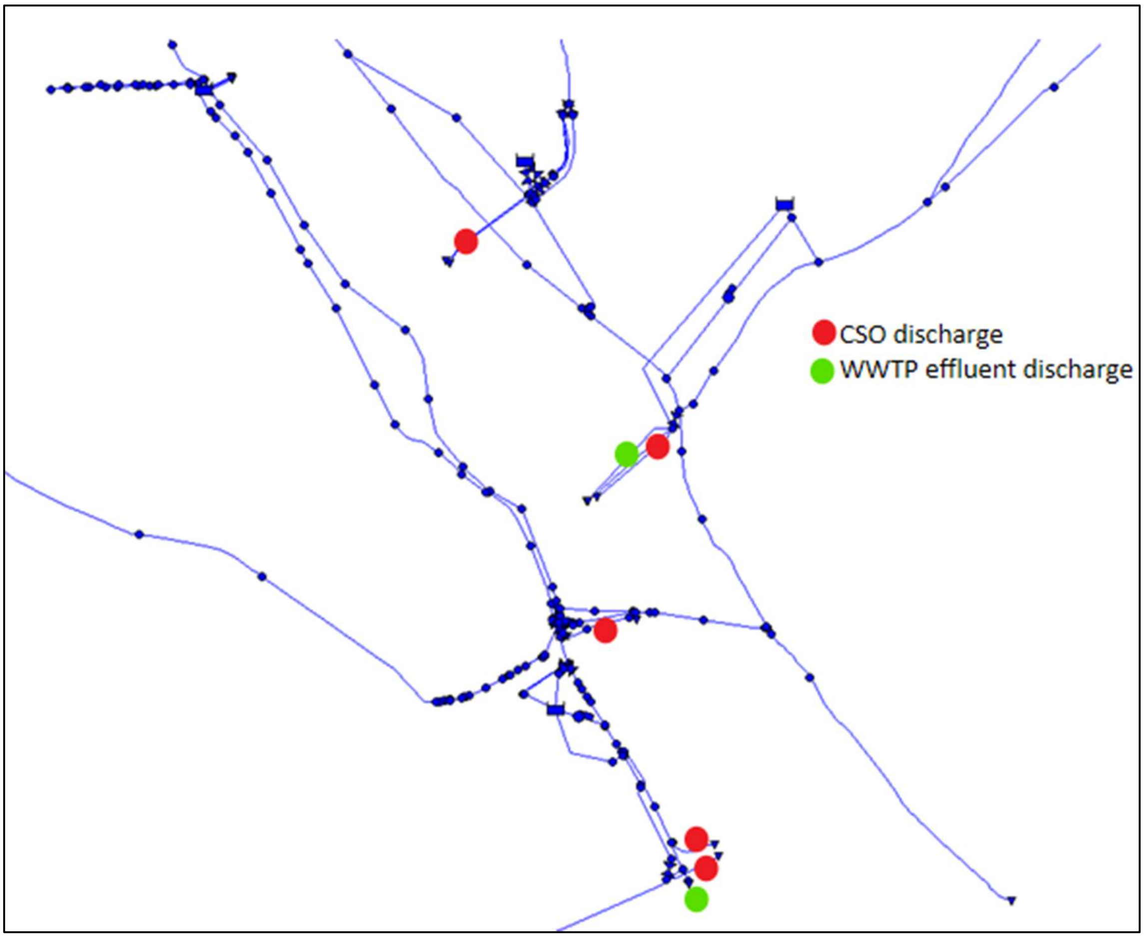

Figure 42. Flow virtual sensors configured to provide important project KPI related with system discharges to the Manzanares river

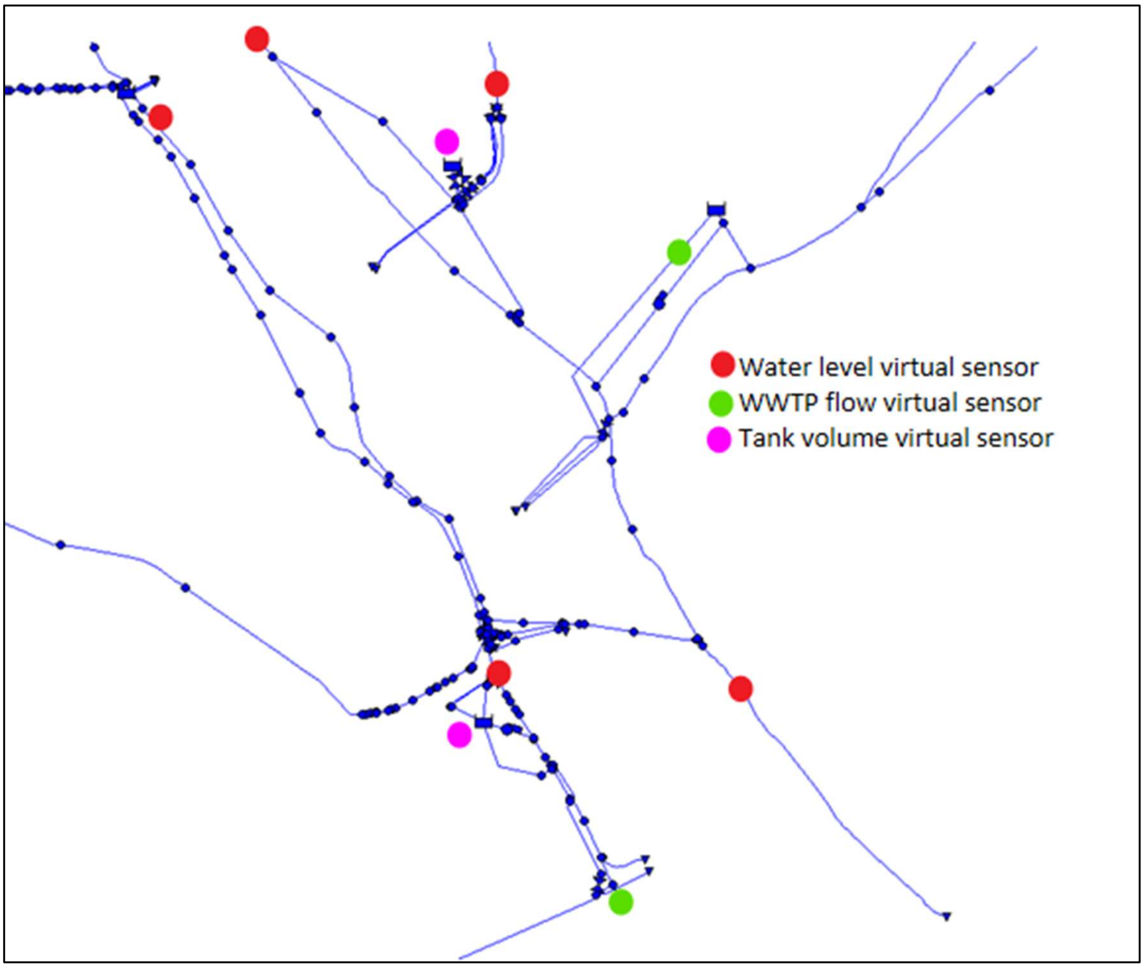

Figure 43. Virtual sensors to be configured to know the accuracy of the detailed operational model.

4.6 Pollution-based Model Predictive Controller (PBMPC)

As described in deliverable DA1.2, PBMPC methodology/controller applied to Madrid pilot follows an optimization approach which uses the dynamic model of the system and forecasts of external variables to derive future optimal control strategies. In this approach, the dynamic model of the urban drainage system and the performance indexes were built considering both the quantity and quality dynamics of flows in the urban drainage network and the effluents to the receiving environment. The approach uses the total suspended solids concentration (TSS) as a key quality parameter given that TSS is generally correlated with turbidity, which can be measured continuously online. The hydraulics and TSS dynamics were represented by simplified mathematical equations (Simplified Model; SM), included in the optimization procedure.

In this context, simplified models (SMs) are required to simulate large amounts of scenarios and control strategies and to evaluate the corresponding performance to choose the best one. In order to allow the optimizer system to work fast enough, it has to be taken into account during the development of the SMs of the sewer and of the WWTPs that it is more desirable to use simple equations in the SMs.

In this sense, in the Madrid pilot, the deployment of the PBMPC controller requires the identification and calibration of the simplified models of the UDN and WWTP associated with the considered pilot perimeter.

4.6.1 PBMPC integration and configuration in AQDV

In order to enable real-testing of the PBMPC methodology, the controller will be integrated following the scheme shown in **Erreur ! Source du renvoi introuvable.**. The controller will be connected to the reality through AQDV platform. AQDV platform is the system able to connect to the SCADA system which registers in real time measurements coming from the existing instrumentation and send computed control actions to the existing local controllers (i.e. PLCs). In this sense, at every time instant (or closed-loop iteration), AQDV retrieve measurements coming from the instrumentation and estimations generated by the virtual reality (detailed model) which are sent to the Controller. Then, the Controller solve the optimization problem corresponding to the current time instant computing control actions which are retrieved by AQDV platform in order to be sent to the SCADA system. In the following, the workflow associated with this iterative process is detailed highlighting information exchanged among the different components (blue numbers in **Erreur ! Source du renvoi introuvable.**). A 5-minutal closed-loop between AQDV and the controller considering a 30-minutal horizon prediction (H) is considered. Then, every time instant (5 minutes):

1. *(Time instant k) AQDV proceeds to:*
    1. *Read sensor measurements from the reality corresponding to the time window [k-h, k]*
    2. *Read 5 – minutal estimations of pre-defined (from a static list) hydraulic / quality variables computed in the last (h+H) – minutal simulation of SWMM (time instant k-1; from k-h-1 to k-1+H time instant). Critical variables are those ones associated to inlets of the pilot perimeter (*Figure 41*;* Figure 43*)*
    3. *[Optional: Run validation / re - construction of sensor measurements; data assimilation strategy for the detailed model (re – calibration), check deviations between sensor measurements and Virtual Reality measurements]*
    4. *Send to the controller real rain measurement corresponding to the time window [k-h, k]*
    5. *Send to the controller 5 - minutal rain forecast corresponding to the time window [k, k+H]*
    6. *Send to the Controller validated sensor measurements corresponding to the time window [k-h, k]*
    7. *Send to the Controller available actuators, their operational constraints and their current stats (i.e. gate positions)*
    8. *Send to the Controller 5 – minutal estimations of pre-defined (from a static list) hydraulic / quality variables computed in the last (h+H) – minutal simulation of*

*SWMM (time instant k-1; from k-h-1 to k-1+H time instant) (*Figure 41*;* Figure 43*) .*

9. *Run Controller*

2. <u>*(Time instant k) Controller*</u>

    1. *Update Flow / TSS input files associated to the inlets of the pilot perimeter using measurements and forecasts coming form AQDV*
    2. *Update initial states using measurements and / or forecasted values coming from AQDV*
    3. *Run WWTP capacity estimation calculator computing 5-min treatment capacity of the WWTP for the period [k, k+H]*
    4. *Update file associated with the actuator constraints using the notified availability of the actuators.*
    5. *Solve optimization problem*
    6. *Update files associated to the actuator set-points (per actuator, 5-min set-points corresponding to the time interval [k, k+H])*
    7. *Transform computed set-points to new ones that could be applied to the Virtual Reality and the Reality*
    8. *Send adapted actuator set-points to AQDV (per actuator, 5-min set-points corresponding to the time interval [k, k+H]) (**Erreur ! Source du renvoi introuvable.**)*

3. <u>*(Time instant k) AQDV:*</u>

    1. *Send actuator set-points associated to the time window [k, k+H] to the SCADA*
    2. *Run 5 – minutal simulation of the virtual reality (SWMM; one step ahead simulation from time instant k-h to k-h+1) using suitable hotstart coming from last 5 – minutal simulation (time instant k-1-h to k-h), rain inputs (1 measure per rain gauge; time instant k-h) and control actions (1 value per actuator ; time instant k-h) provided by the controller run corresponding to time instant k-h*
    3. *Run (h+H) – minutal simulation of SWMM (from time instant k-h to k + H) using suitable hotstart coming from last 5 – minutal simulation (time instant k – 1-h to k-h) and rain inputs (measurements corresponding to [k-h, k] time interval and forecasted 5-min values per rain gauge corresponding to the time interval [k, k+H]) and control actions (values applied to the Reality corresponding to [k-h, k] time interval and estimated 5-min set-points corresponding to the time interval (k, k+H]) provided by the controller in the last run (time instant k)*

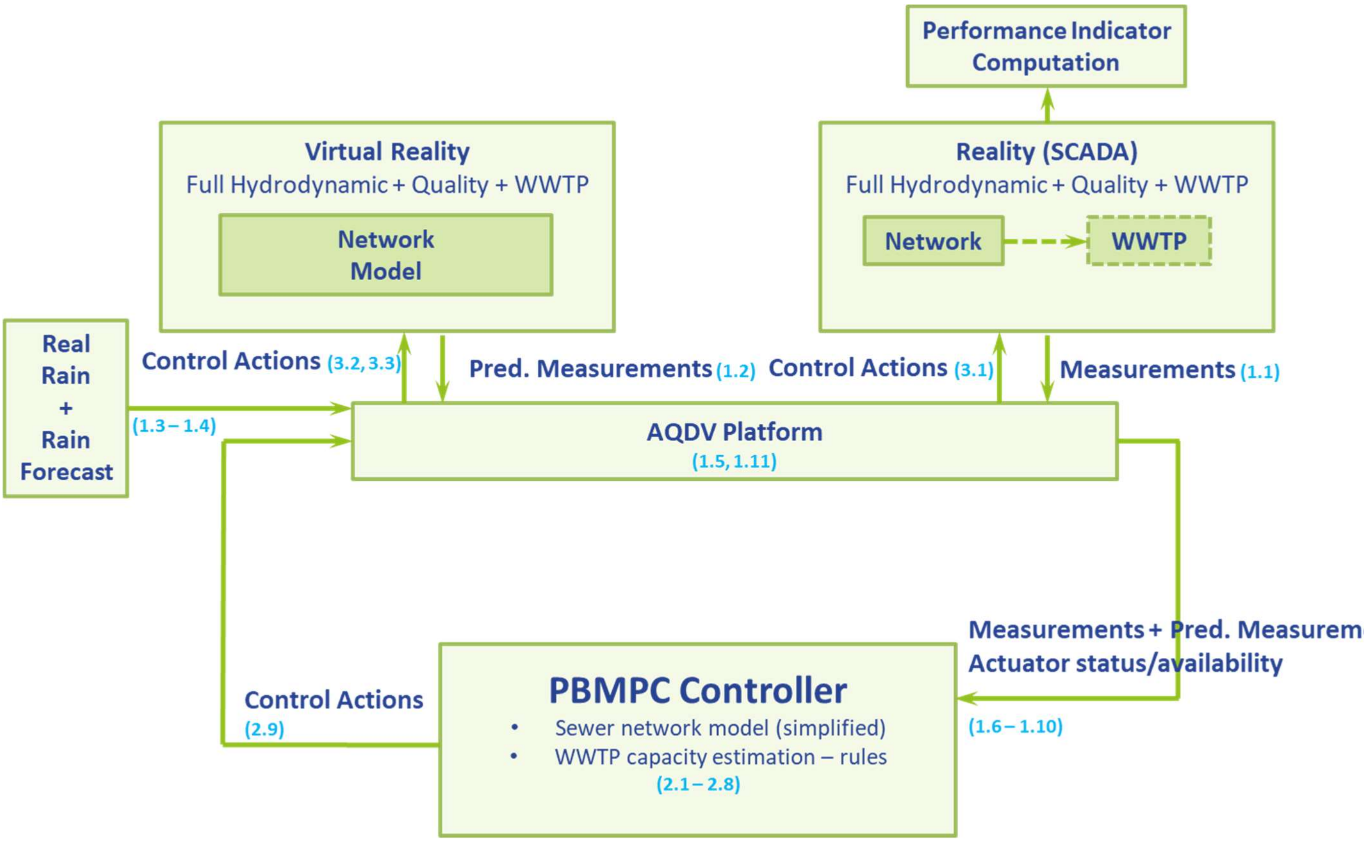

Figure 44. Integration of PBMPC Controller with AQDV platform in order to enable interaction with the pilot system (Reality / actuators and sensors)

4.6.2 Simplified Model

The identification and calibration of the SM is a crucial step in order to apply the PBMPC methodology to the Madrid pilot. At the moment, this is an on-going task whose main output will be presented in DB3.2 focused on the virtual testing of the PBMPC methodology considering historical rain scenarios. At the current stage, the SM version just covers the detailed hydraulic model being in a second step when the water quality dynamics will be considered deriving a new version of the SM.

The approach to identify the SM considers the following steps:

1. Segmentation of the pilot area hydraulic model in the main parts / stations.
2. Characterization of dynamics of every part / station of the hydraulic model running simulations considering a large set of historical rain events and all potential configurations of the existing actuators.
3. Assessment of simple expressions which allow compute outputs (i.e. CSO flows, tank emptying flows, WWTP inflows) in terms of the inputs (i.e. inflows, flows associated with the actuators) considering those operational constraints that actuators must satisfy (i.e. maxim flow that could be sent to the tank). The main idea is trying to neglect complex dynamics (i.e. volume accumulation in sewer pipes) and test whether simple mass balance equations allows to estimate accurately outputs in terms of the inputs.

According to the resulting errors comparing SM and detailed model estimations, more complex equations are considered or not.

Mainly, the detailed model of the pilot has been segmented in the following parts

a. Entrance to Butarque WWTP / Butarque tank entrance from Butarque II sewer / CSO point

b. Main entrance to Butarque tank / CSO point / transfer between MD and MI

c. Butarque I sewer connection with MD / transfer between MD and MI

d. Abroñigales tank and connection with the MI

e. Las Gavia connection with MI and associated CSO structure.

At the moment, assessments in parts a) and b) have been completed deriving corresponding SM equations and constratins; parts c) and d) are still on-going. Finally, a complete SM will be obtained being a conceptual representation of the detailed hydraulic model as the example shown in **Erreur ! Source du renvoi introuvable.** corresponding to the LIFE EFFIDRAIN Mediterranean pilot.

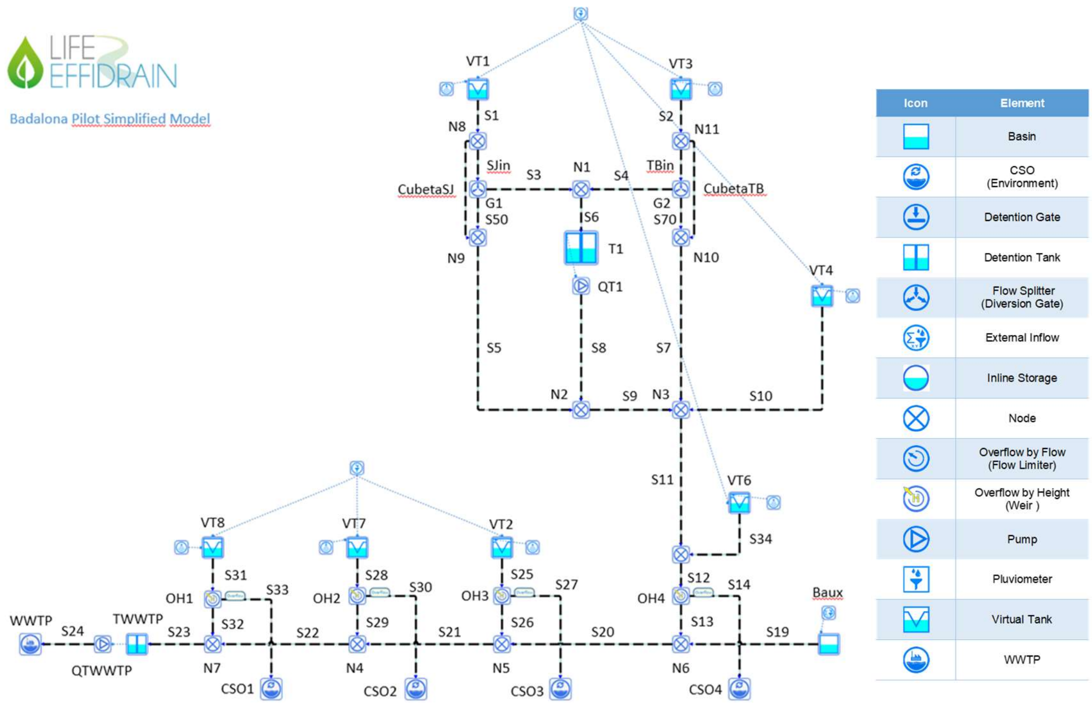

Figure 45. SM corresponding to the LIFE EFFIDRAIN Mediterranean pilot (Badalona, Spain).

4.6.3 PBMCPC time series configuration

4.6.3.1 Model inputs

In order to correctly run the PBMPC controller the data inputs that must be configured are the ones defined and explained below:

- Inflows to the pilot site for the hindcast period and forecast period.The location of these inflows is presented in Figure 41.
    - For the hindcast period, these values come from real sensors measurements and in case there is no sensor the values are obtained from the detailed model virtual sensors.
    - For the forecast period these values are obtained from the detailed model virtual sensors.
- Tank water levels / volumes measured for the hindcast period. In the pilot site these are the one for Butarque and Abroñigales tanks.
- Actuators planned to be monitored in the pilot site. In this case the time series must be created based on real actuator position time series obtained from the SCADA values for the hindcast period, and for the forecast period the time series can be obtained from the detailed model values or directly based on the current operation strategy.
- Actuators planned to be controlled in the pilot site will require the real actuators position time series obtained from the SCADA values for the hindcast period.

Also the module will need information about the status of the actuators that need to be controlled that is to know if they are active and can receive setpoints from AQDV UD or not.

4.6.3.2 Model outputs

the model outputs are the setpoints time series for all the actuators planned to be controlled in the pilot site.

Figure 46 shows these actuators location in the SWMM model that the model will provide setpoints. They are listed below:

- Butarque tank by pass gate in MD interceptor
- Butarque tank entrance gates (4 gates) from the MD interceptor
- Butarque tank entrance gate from Butarque II collector
- Butarque tank pumping station to MD interceptor to empty the tank
- Abroñigales tank by pass gate.
- Abroñigales tank outlet gate to empty the tank

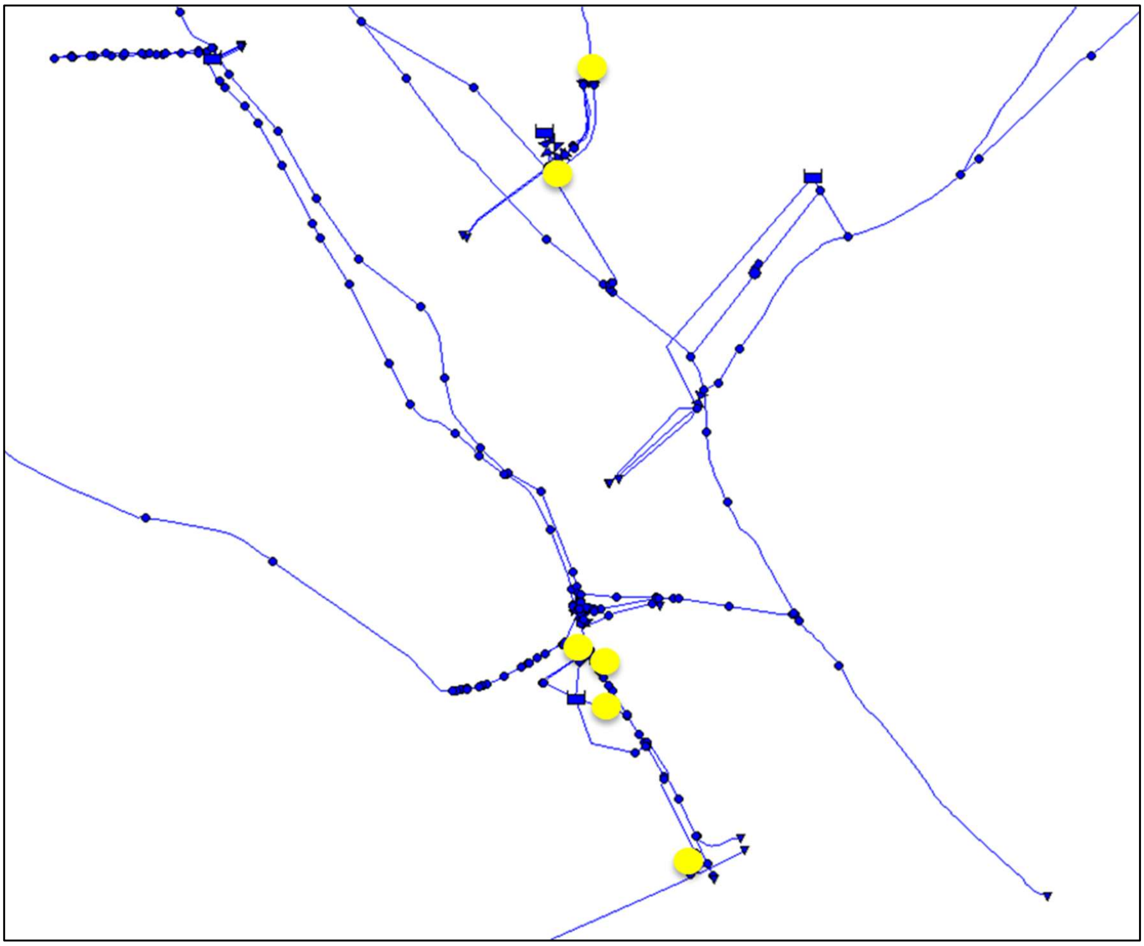

Figure 46. Locations of the actuators controlled by PBMPC controller.

4.7 Quality connection

On a first phase, AQDV UD will be operated based on hydraulic parameters with the goal to minimize the non-treated CSO discharges to the Manzanares river, so the quality connection will not be necessary.

It will be on a second phase, where AQDV UD will be operated based on quality parameters with the goal to minimize pollution mass discharged to the river, and for that quality data is required in AQDV UD.

For that quality connection, two approaches can be done:

- Use the turbidity sensor data and the correlations obtained from turbidity with the quality parameters to estimate the flow quality concentration at the most relevant pilot site locations such as CSOs discharging points, WWTP influents, and effluents, and main pilot site sewers.

- Implement the quality equations available in the SWMM software and calibrate the model according to the turbidity sensors data and the quality campaigns values available.

The first approach will be implemented for sure, and then according to the results obtained, the second approach can be tested to check if it can improve the operation strategy.

4.8 Synoptic

According to the planned tasks for the deployment of AQDV UD environment described in deliverable DA1.2 three different versions are planned to be installed:

- AQDVUD_v1 (monitoring): where AQDV_UD works to show the current operation status of the pilot site but it does not provide actuators setpoints. For this all communications with sensors (existing ones and new sensors to be installed), actuators, radar data and rain forecast must be configured.
- AQDVUD_v2 (hydraulic operation): In this case communication with SCADA must be bidirectional so AQDV UD must receive sensors and actuators data (same as in the monitoring) but it also must send actuator setpoints or actuators position recommendations.
- AQDVUD_v3 (quality operation): Finally, the third version will require the same input and output configuration as in version 2 but in this case the actuator setpoints or recommendations will be computed based on quality data.

In any case the synoptic views for the 3 versions will be very similar with very small differences among them:

- Monitoring (version 1): will allow to easily see how the system behaves according to the sensor data available
- Hydraulic operation (version 2): It will have the same information as the monitoring one plus:
  - Information from the virtual sensors (detailed model results time series) to compute important project KPIs and check model accuracy.
  - Information about the suggested actuator setpoints for the coming minutes
- Quality operation (version 3): It will have the same information as the hidraulic operation version plus:
  - Quality and mass pollution information to compute important project KPIs.

In the coming subchapters some preliminar synoptic screens have been developed and in the coming months these will be improved and adapted to AQDV UD software requirements.

4.8.1 General pilot site view

This will be the main screen where a general view of the pilot site will be showed and an operator at a quick glance will be able to know the current state of the system. The idea is that there is no values or at least very few values in this screen and everything works with icons that thanks to some colours or animations show:

- Water tank filling percentage
- Water level sensors if they operate in DWF range of values or they are above these values
- CSO discharges: if there are any or not
- Actuator current position (opened, closed or half way)

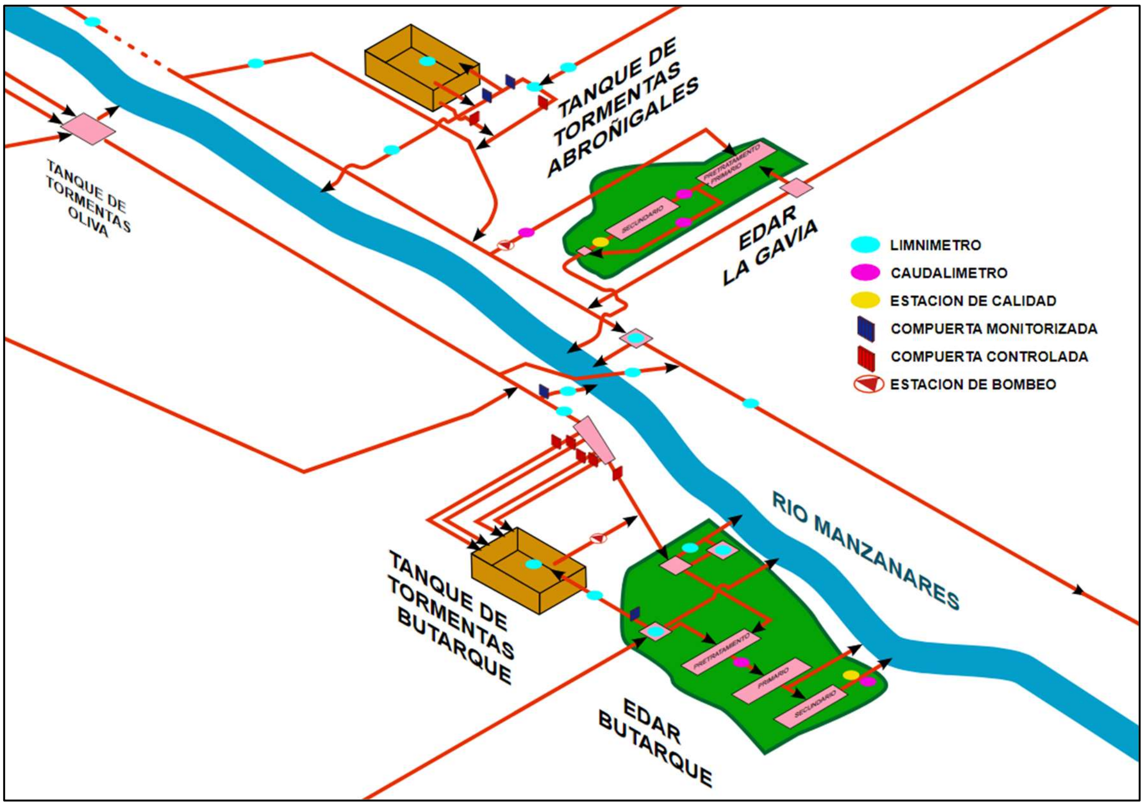

Figure 47. Synoptic general pilot site view

4.8.2 Detailed views

In the detailed views is where the values for sensors and actuators will be shown.

4 main detailed views are planned at this stage one for each of the most important infrastructures in the pilot site, but maybe in the future some more detailed views are needed depending of how much information and values we want to show in each screen.

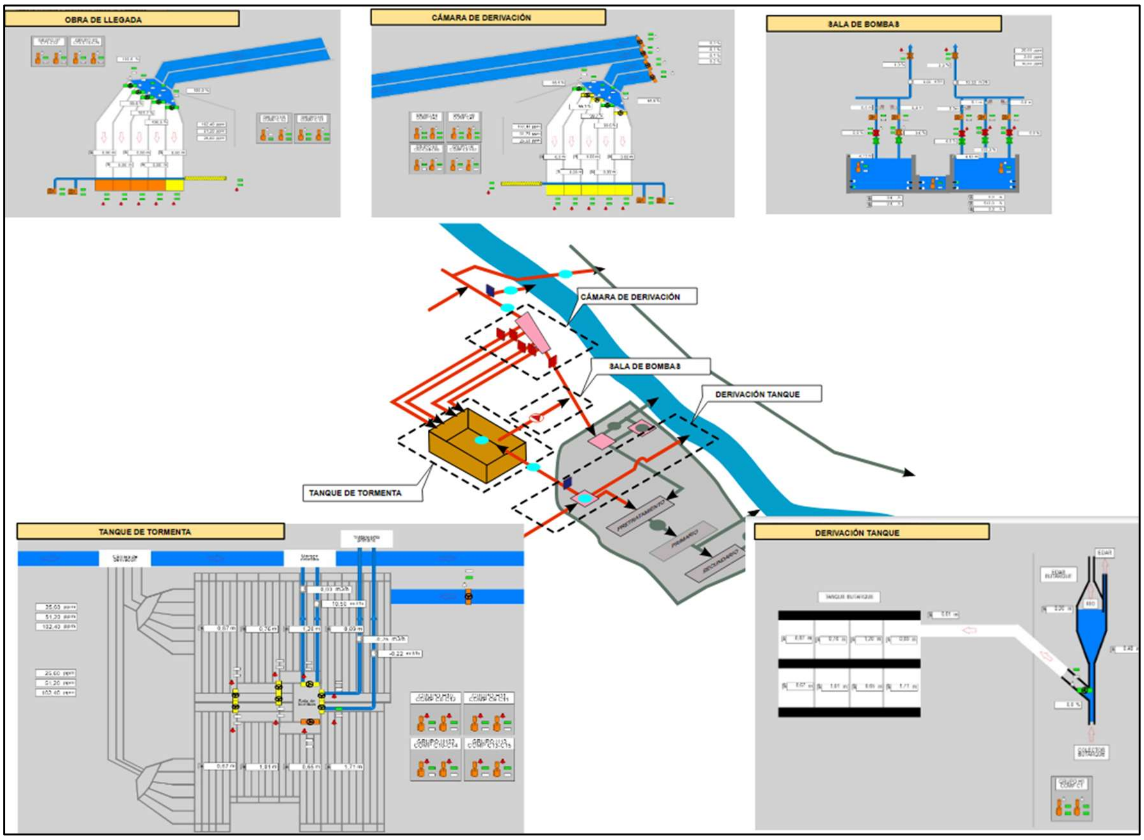

Figure 48. Synoptic for Butarque tank

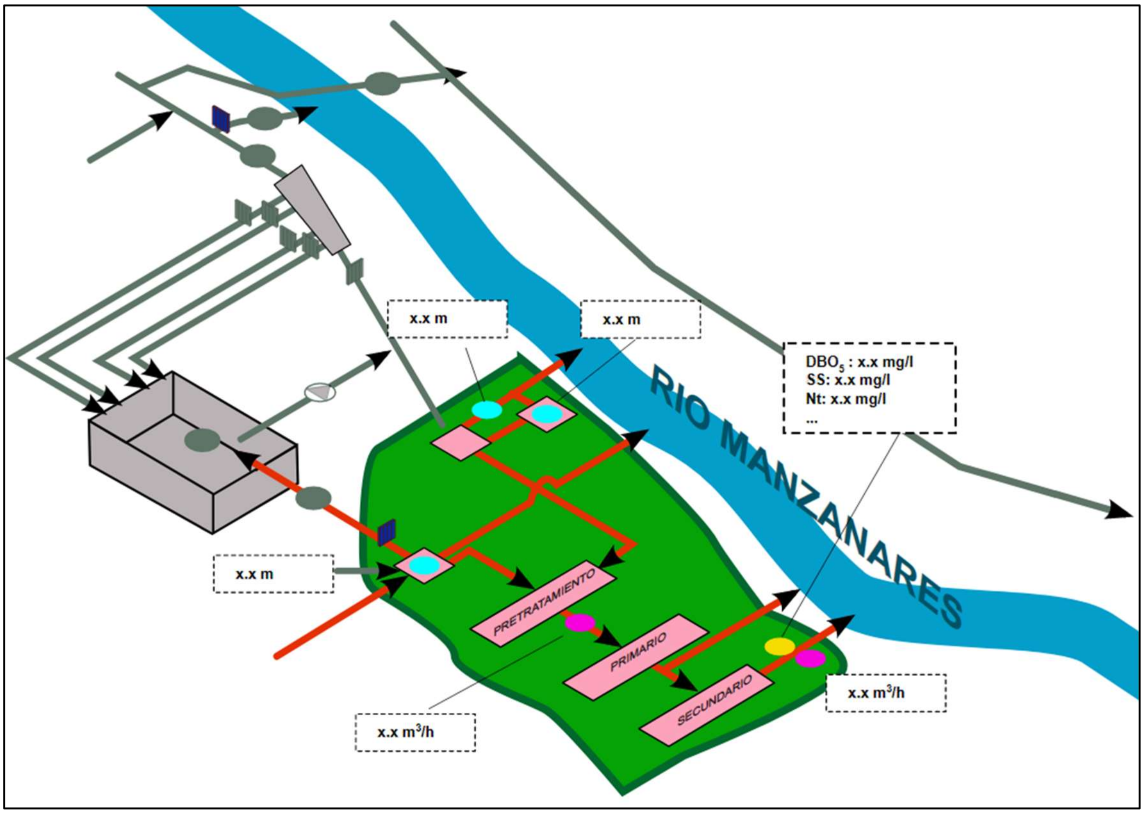

Figure 49. Synoptic for Butarque WWTP

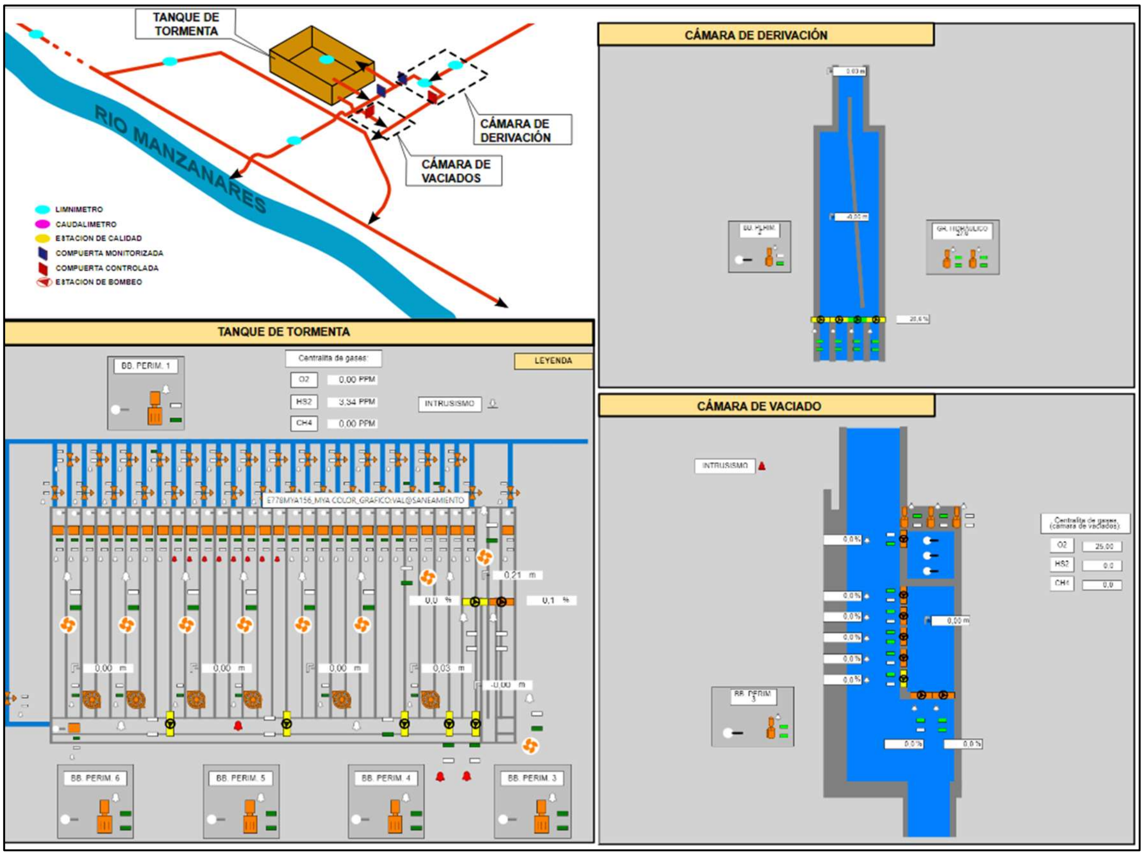

Figure 50. Synoptic for Abroñigales tank

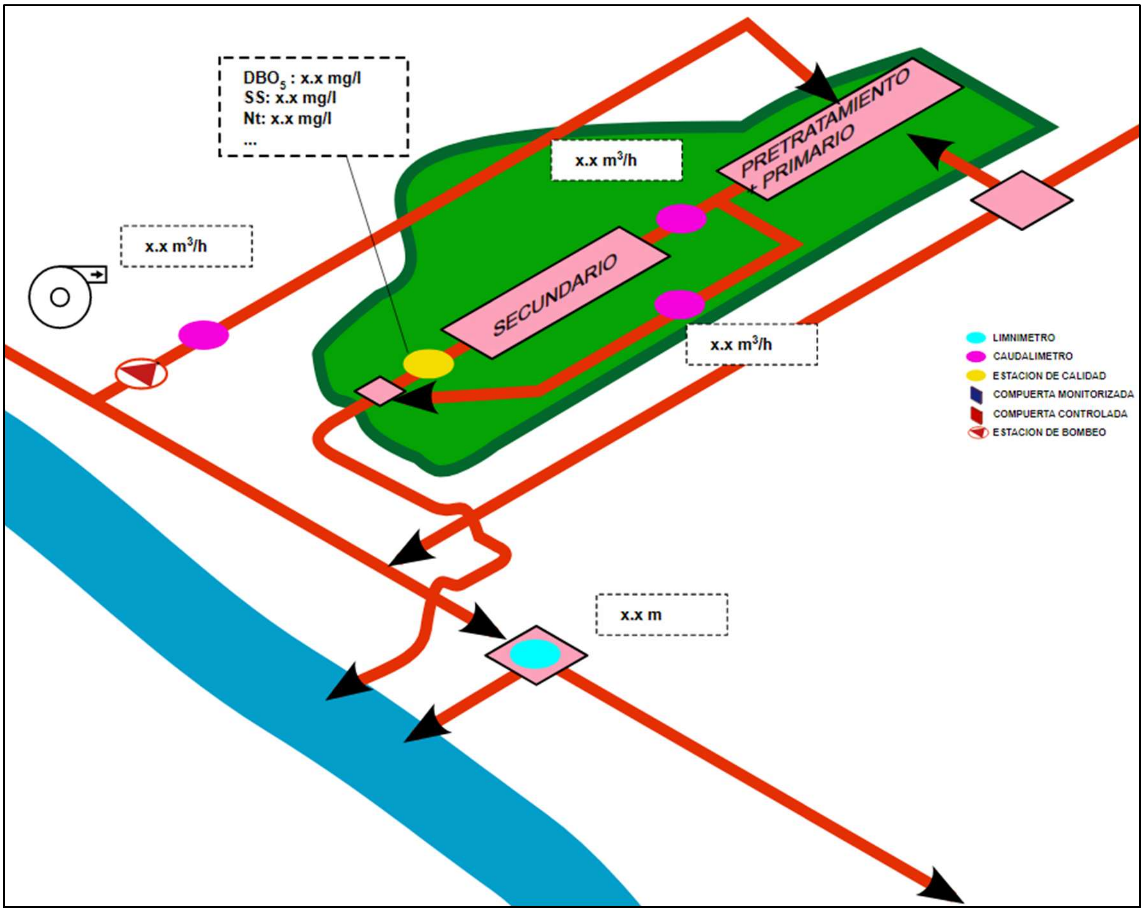

Figure 51. Synoptic for La Gavia WWTP

4.9 Operating principles for the pilot site

4.9.1 Goals for the operation strategies

The operation strategies have been defined in order to meet the following 2 major objectives:

- Protection of the aquatic environment by avoiding (or reducing spills) during rain events by optimizing the filling of the storage tanks and the treatment capacity of the WWTPs
- Protection of properties and people by avoiding floodings and by securing the structures during heavy rainfalls.

In order to reach these goals, 4 strategies have been defined and are presented in the next chapter. These strategies can be increased or improved during the whole execution of the project and specially in the following months where tests using a virtual reality will be performed, so we will be able to better understand the system behaviour and improve the strategies to reach the defined goals.

4.9.2 Definition of strategies and their objective

In order to reach these objectives, the following strategies have been defined:

- Dry weather
- Normal rain event
- Heavy rain event
- Post – rain event

Table below defines the strategies, its meteorological and hydraulic conditions and the objectives of each one.

Table 7. Definition of operation strategies, its conditions and objectives

Strategy	Conditions	Objective
1.- Dry weather	Dry weather conditions with no rain	No spills and no water storage in the tanks
2.- Normal rain event	Rainy weather conditions	Reduce CSO discharges (volume and polluted mass) and maximize treatment capacity of the WWTPs
3.- Heavy rain event	Heavy rain event causing that storage tanks are at their maximum water capacity	Protection of properties and people against floods and structures (tanks and WWTPs)
4.- Post – rain event	No rain but the storage tanks are not empty and WWTPs do not operate yet in normal dry weather conditions	Empty the tanks maximizing the WWTPs capacity without causing CSO discharges

4.9.3 Tree decision for the main strategies and main indicators

The indicators are used to define the most appropriate strategy according to the current state of the Manzanares system given by the sensors installed in the pilot site. These indicators are continuously computed by AQDV UD according to the last data received.

The indicators are listed in the next table.

Table 8. Indicators used to choose the strategy

Indicator	ID	Sensor / Data	Objective
Weather context	WC	Rainfall radar data • WC=0 no rain • WC=1 rain in the catchment	To evaluate the meteorological situation

Tank filling	TF	Butarque and Abroñigales tank filling • TF= 0 both tanks are empty • TF=1 one tank has some water • TF = 2 one of the two tanks is filled above 90%	To know the percentage of water filling in each tank
		•	

According to the indicators listed above, the strategy is chosen based on the decision tree presented in Figure 52. This decision tree is computed each 5 minutes. AQDV UD optimal operation algorithm will be mostly used in strategies 2 (normal rain event) and 4 (post rain event). Current operation done by CYII in dry weather is good enough to guarantee that there are no CSO spills and that the tanks keep empty, while in heavy rain once the tanks are filled the security positions for the actuators are defined and there again the current operation is good to guarantee there are no floods and that the installations (tanks and WWTPs) are secured.

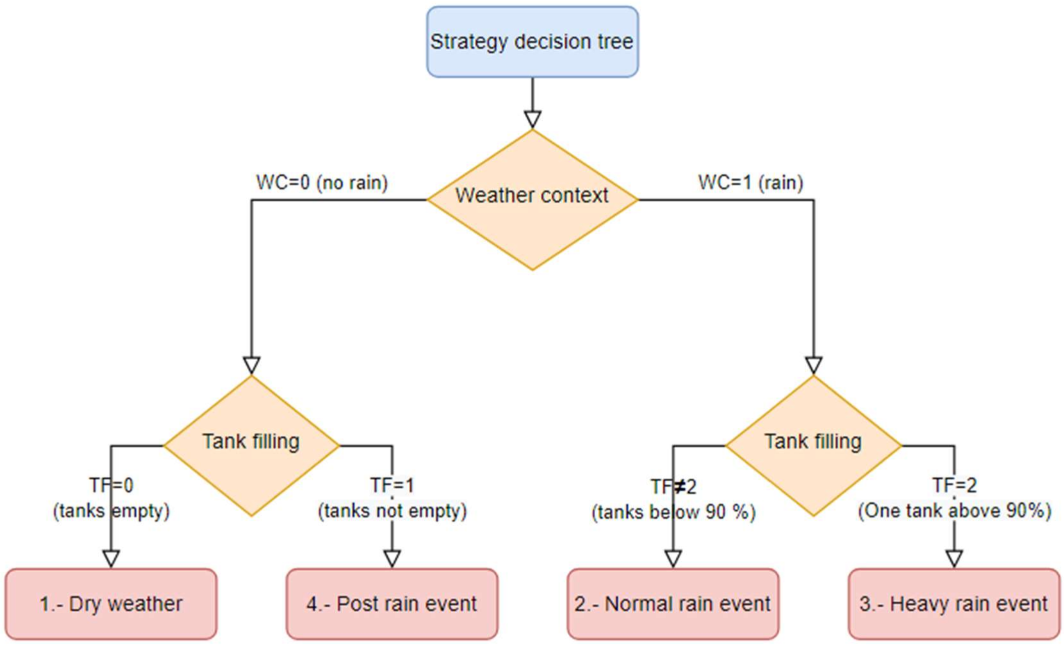

Figure 52. Strategy decision tree