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Responsible authors	**Name:**	Fabio Masi Riccardo Bresciani Anacleto Rizzo Giulia Cipolletta	**E-mail:**	fmasi@iridra.com bresciani@iridra.com rizzo@iridra.com g.cipolletta@staff.univpm.it
	Partner:	IRIDRA	**Phone:**	+39 055470729

Brief Description	The aim of the Lesbos pilot site (HYDRO1) is to demonstrate the possibility to treat wastewater produced by a touristic site (high fluctuation in sewage production due to seasonality of touristic activities) and produce an effluent suitable for reuse in irrigation/fertigatioin under strict Greek water quality standards. The treatment chain of the Lesbos pilot include: UASB + constructed wetland + ultrafiltration + UV lamp. The current document summarizes the key aspects related to construction and operation of constructed wetlands (CWs) and the post-treatment units for the treatment of the UASB effluent from the Lesbos full-scale sites and for the pilot systems.
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EXECUTIVE SUMMARY

The aim of the Lesbos pilot site (HYDRO1) is to demonstrate the possibility to treat wastewater produced by a touristic site (high fluctuation in sewage production due to seasonality of touristic activities) and produce an effluent suitable for reuse in irrigation or fertigation under strict Greek water quality standards. The treatment chain of the Lesbos pilot include: UASB + constructed wetland + ultrafiltration + UV lamp.

The current document summarizes the key aspects related to construction and operation of constructed wetlands (CWs) and the post-treatment units for the treatment of the UASB effluent from the Lesbos full-scale site.

The **constructed wetland** stage consists of a full-scale system that provides both secondary and tertiary wastewater treatment, which is designed in order to meet the Greek limits for wastewater reuse in irrigation in terms of TSS, BOD_5, TN as well as contributing in disinfection; moreover four pilot-scale systems have been implemented to test intensified CWs in the same context.

The full-scale system is composed by a hybrid combination of vertical subsurface flow (VF) CWs, that receives the effluent of UASB (not part of the present document) treating a fraction of the influent to Antissa existing WWTP.

The full-scale CW is designed with two stages: 1st stage, saturated downflow VF; 2nd stage unsaturated intermittent load VF CW. The effluent will be directed to a polishing stage constituted by UF and UV disinfection. Recirculation and by-pass chambers allow to test up to 4 different configurations, investigating the best scheme for Greek and also other Mediterranean conditions (e.g. different water quality standards for TN or different N:P ratio for fertigation).

More in details, the CW full scale is composed of:

- General by-pass, C1;
- Bypass manhole towards VF1 SAT, B1;
- 1st stage saturated vertical subsurface downflow CW, VF1 SAT, with a bed of 17.5x14 m (245 m^2);
- Pumping station for VF2 UNSAT, P1;
- 2nd stage unsaturated intermittent load VF CW, VF2 UNSAT, which is divided in 3 beds to fit the local orography; the 3 beds host the 4 VF2 UNSAT lines for batch feeding (lines A, B, C, and D); each line sizes 18x8.5 m, i.e. about 150 m^2; the total net surface of VF2 UNSAT is equal to about 600 m^2.
- Recirculation manhole R2 towards effluent of UASB digester (influent to VF1 SAT).

The pilot CW systems aim to test the possibility to reduce the areal footprint of CWs with innovative solutions. The pilot systems treat 0.5-1 m^3/d each and are composed by a septic tank and four systems in parallel; three bio-electrified CWs and one Aerated CW (AEW).

Post-treatment units include two compact systems; one for the full-scale system and on for the pilot scale systems.

In the Full-scale unit, possible three main flows are identified based on the operational functioning of the full-scale line:

1- Water Line

In this line, two possible system configurations can be applied to test different treatment combination and thus to evaluate the effluent quality:

- Configuration 1a) INLET, UF, UV
- Configuration 1b) INLET, UV

2- Backwash Line

This line is dedicated to the cleaning of the UF membrane for both simple backwash and intensive chemical cleaning. It involves a complete washing of piping, valves, pumps and tanks.

3- Recirculation Line (Concentrate Flow)

This line includes the piping, pump and tank provided to recirculate the backwash discharge to the inlet of HYDRO 1.

The <u>pilot unit</u> operation involves three main flows as follows:

1- Water Line

The configuration of this line includes the treatment of the influent with SF and further with UV Disinfection.

2- Washing Line

This line is dedicated to the cleaning of the filter. It involves complete washing of piping, valves, pumps and tanks.

3- Recirculation Line

This line includes the piping, pump and tank provided to recirculate the backwash discharge to the inlet of HYDRO 1.

The present document is organised in four chapters. Chapter 1 introduces the goal and the structure of the deliverable. Chapter 2 describes the installed system units in terms of secondary (CW) and tertiary (post-treatment) treatment stages, for both full-scale and pilot scale lines; in particular, attention is given to sizes and operation modes, providing also all the P&ID of the installed lines. Chapter 3 reports full details of the installed equipment, e.g. pumps, valves, gauges and any further electro-mechanical equipment; operating manuals are also introduced and annexed to the deliverable. Finally, Chapter 4 describes in details all the construction and start-up phases, including the detailed description of construction and start-up phases accompanied by a photographic documentation of the activities.

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ABBREVIATIONS

AEW	**Aerated wetland (intensified constructed wetlands)**
BOD	**Biochemical Oxygen Demand**
CEB	**Chemical Enriched Backwashing**
CW	**Constructed wetland**
F	**flow meter**
HDPE	**High-Density Polyethylene**
HV	**Hand Valve**
IBC	**Intermediate Bulk Container**
IP	**Ingress protection**
LS	**level sensors**
LSH	**level switch high**
LSHH	**level switch highest**
LSL	**level switch low**
LSLL	**level switch lowest**
MF	**microfiltration**
MFC	**Microbial Fuel Cell**
ND	**Nominal Diameter**
O&M	**Operation and maintenance**
P	**Pump**
P&ID	**Piping and Instrumentation Diagram**
PI	**pressure gauge**
PLC	**Programmable Logic Controller**
PT	**pressure transmitter**
PVC	**Polyvinyl Chloride**
SAT	**Saturated**
SF	**Sand Filtration**
SMC	**Sheet moulding compound**
SP	**sampling point**
SSF	**Subsurface flow (wetlands)**
TK	**Tank**
TMP	**TransMembrane Pressure**
TN	**Total Nitrogen**
TS	**Technical Specification**
TSS	**Total Suspended Solids**
UASB	**Upflow anaerobic sludge blanket**
UF	**Ultrafiltration (Membrane)**
UNIVPM	**Università Politecnica delle Marche**
UNSAT	**Unsaturated**
UV	**Ultraviolet**
VF	**Vertical flow (subsurface flow constructed wetland)**
WWTP	**Wastewater treatment plant**

1. INTRODUCTION

The objective of this report is to describe the construction and start-up works of the Constructed wetland (CW) and post-treatment full scale system and the pilot units, which are designed aiming to meet, combined with tertiary treatment, the Greek limits for wastewater reuse in irrigation in terms of TSS, BOD_5, TN as well as contributing in disinfection.

The full-scale system is composed by a hybrid combination of vertical subsurface flow (VF) CWs, that receives the effluent of UASB (not part of the present Technical Specification - TS) treating a fraction of the influent to Antissa existing WWTP; the CW is designed with two stages: 1st stage, saturated downflow VF; 2nd stage unsaturated intermitted load VF CW. The effluent will be directed to a polishing stage constituted by membrane ultrafiltration system and UV disinfection.

The pilot systems treat up to 1 m^3/d each and it is composed of a septic tank and four systems in parallel; three bio-electrified constructed wetlands and one aerated constructed wetland.

This document provides a detailed technical description of the full-scale system, including electro-mechanical equipment. The installation and construction processes of the work are described, with the description of the start-up of the entire plant including the Hydraulic & safety tests.

The document is structured as follow:

- System description: the chapter describes briefly the different treatment units, defining for each component the final dimensions and technical features. The way of use of each component is also introduced, with schemes and P&ID of each sections;
- Equipment: this section shows the main characteristics of all the electro-mechanical equipment provided for the installation of each unit; specific operating manuals for each component, attached to O&M plans in Annexes 2 and 3, complete the section;
- Construction and start-up: the phases of construction and installation works are described for each part of the treatment plant and pilot systems, accompanied with pictures of the most relevant activities. For each stage, the chapter gives also indications about start-up activities and the main requirement for operation and maintenance, that are described in details in the manuals included in Annexes 2 and 3.

2. SYSTEM DESCRIPTION

2.1 Constructed wetlands

2.1.1. Full-scale

The full-scale system is composed of a hybrid combination of vertical subsurface flow (VF) CWs and treats from 10 to 100 m^3/d. The full-scale system is designed with two stages: 1st stage, saturated downflow VF (VF1 SAT); 2nd stage unsaturated intermitted load VF CW (VF2 UNSAT). Different recirculation options allow to test up to 5 different configurations, investigating the best scheme for Greek and other Mediterranean conditions (e.g. different water quality standards for TN).

The CW full scale line receives the effluent of UASB digester and is composed of:

- Bypass manhole, B1;
- 1st stage saturated vertical subsurface downflow CW, VF1 SAT, with a bed of 17.5x14 m (245 m^2);
- Pumping station for VF2 UNSAT, P1;
- 2nd stage unsaturated intermitted load VF CW, VF2 UNSAT, which is divided in 3 beds to accommodate the local orography; the 3 beds host the 4 VF2 UNSAT lines for batch feeding (lines A, B, C, and D); each line sizes 18x8.5 m, i.e. about 150 m^2; the total net surface of VF2 UNSAT is equal to about 600 m^2.
- Recirculation manhole and pumping system towards effluent of UASB digester (influent to VF1 SAT), R2

2.1.1.1. VF1 SAT unit

The VF1 SAT unit (Figure 2.1) consists of the following characteristics shown in Table 2.1

Table 2.1. VF1 SAT unit construction characteristics

Flow	m^3/d	10-100
Bottom surface area	m^2	250
Size and depth of filter media (starting from bottom) 30 – 50 mm round washed gravel 10-20 mm round, washed gravel 5-10 mm round, washed gravel	m	0.80 0.10 0.10
Total Depth of filter media	m	1.00
Free board	m	0.30
Total Depth	m	1.30
Type of plants	-	*Phragmites australis*
Material of construction	-	Excavated in the soil, soil embankments, waterproofed with HDPE liner 1.5 mm

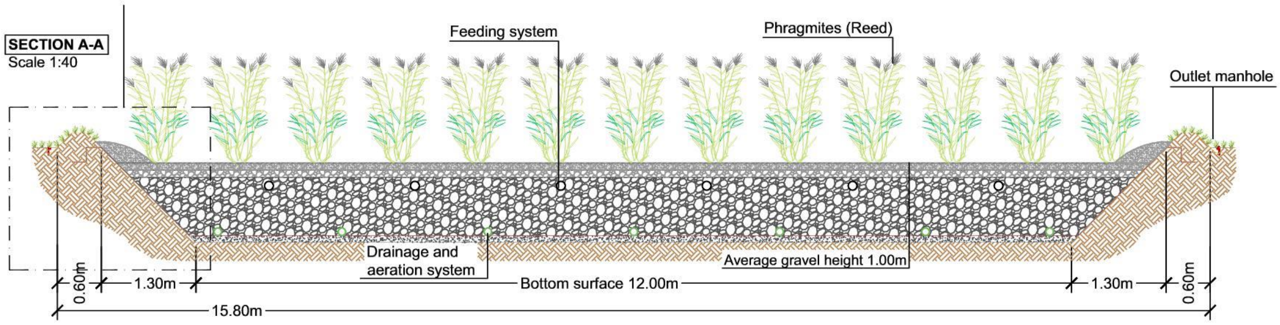
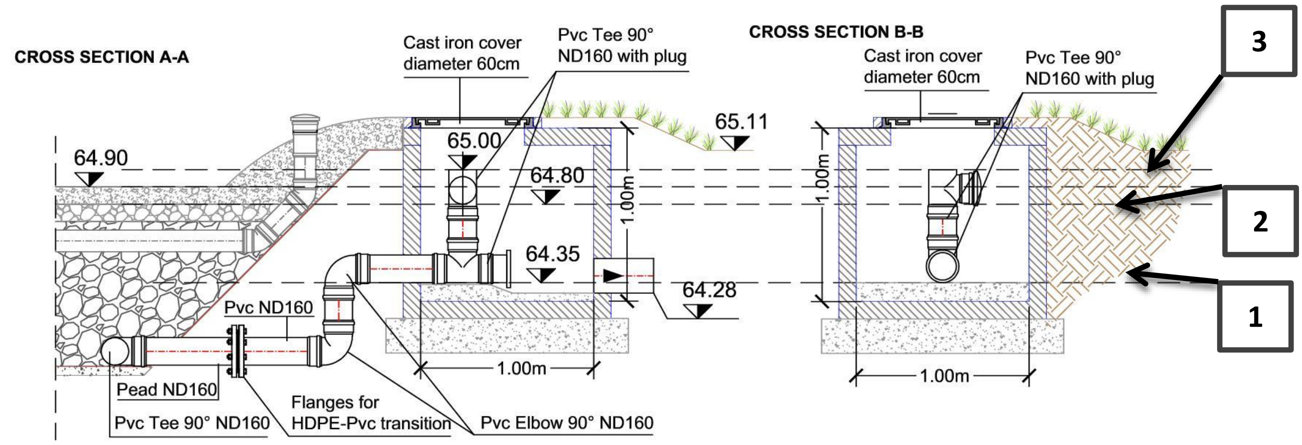


Figure 2.1. Section of VF1 SAT

The **feeding system** of the VF1 SAT bed is constituted by several PVC pipes ND125 connected to a main distribution PVC pipe ND200 by PVC reducer Tee 90° ND200-125. The branches are closed at the end through caps for allowing regular washings.

The **drainage water pipe** of the VF1 SAT bed is constituted by several slotted drainage PVC pipes DN110 connected to a main collecting slotted PVC pipe ND160 by PVC reducer Tee 90° ND160-110. The drainage collecting pipe is connected on two PVC pipes ND160 that pass through the liner and are connected to two manholes.

- Outlet manhole: a circular manhole with internal diameter of 1.0 m, total height 1 m; the manhole receives a PVC ND160 pipe from the VF SAT1 drainage system; before entering into the manhole, the pipe has two elbows 90° ND160, which permit to regulate the water level within the bed; the entering pipe is installed in a water level control device. The water level device is composed of two PVC Tee 90° with plug, allowing 3 settings (see Figure 2.2)
    - *Operational and maintenance mode*: about + 55 cm from the bottom of the VF1 SAT bed, permitting to decrease the water level in the bed to provide maintenance of the feeding system, which result uncovered by the water level in this functioning mode (**(1)** Figure 2.2)
    - *Standard mode*: about +100 cm from the bottom of the VF1 SAT bed, maintain saturated condition within the bed in standard conditions and covering the buried feeding system with the water level (**(2)** Figure 2.2)
    - *Start-up and flooding maintenance mode*: about +110 cm from the bottom of the VF1 SAT bed, flooding the bed with +10 cm above the gravel bed surface to control the weed during the planting phase of the start-up or for weed maintenance in general (**(3)** Figure 2.2)
- Emergency emptying manhole: a circular manhole with internal diameter of 1.0 m, total height 1.5 m; the manhole receives a Pead ND125 pipe from the VF SAT1 drainage system; inside the manhole is installed a gate valve ND125, which permit to empty the VF1 SAT bed in case of emergency maintenance activity (see Figure 2.3).



1. **Operational and maintenance mode**
2. **Standard mode**
3. **Start-up and flooding maintenance mode**

Figure 2.2. Outlet manhole of VF1 SAT bed

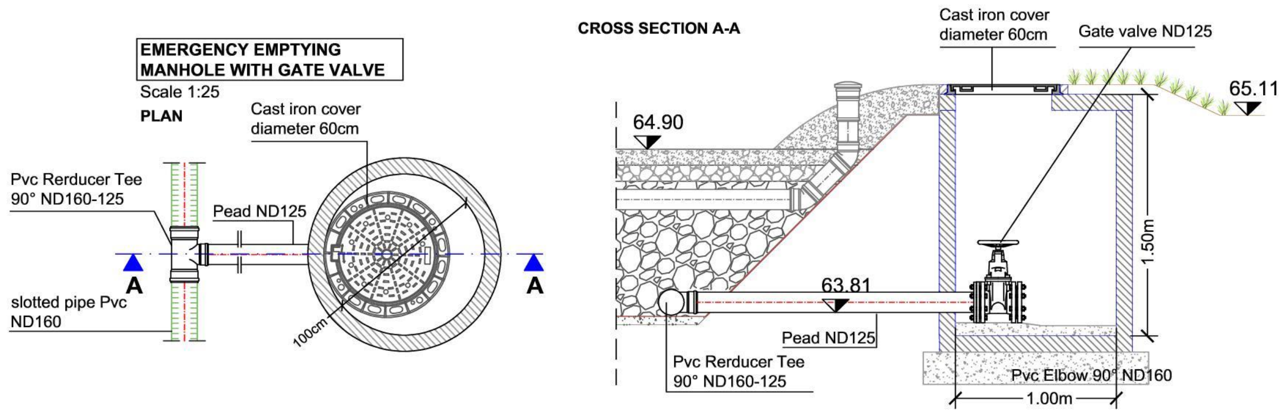


Figure 2.3. Emergency emptying manhole of VF1 SAT bed

2.1.1.2. *VF2 UNSAT unit*

The VF2 UNSAT is divided in 3 beds to fit the local orography; the 3 beds host the 4 VF2 UNSAT lines for batch feeding (lines A, B, C, and D); each line sizes 18x8.5 m, i.e. about 150 m^2; the total net surface of VF2 UNSAT is equal to about 600 m^2 (Figure 2.4).

In order to allow ordinary (feeding system washing) and extra-ordinary management, the 4 different lines of the VF2 UNSAT stage 2 are served by two valve manholes (M1 and M2). The manholes are made of reinforced concrete with 1.30 x 1.30 m (internal dimensions); and internal height of 0.9 m. The entering pipe from the pumping station have installed n°2 PVC Tee90° with a reduction from ND160 to ND125, on which are installed n°2 gate valves ND125, respectively. The entering pipe end with a blind flange.

The pipes **inlet** to the manhole are:

- N° 1 Pead Pn10 ND160 from the pumping station

The pipes **outlet** to the manhole are:

- N°2 Pead Pn10 ND125 towards manhole the two hydraulically separated lines of the VF2 UNSAT stage

To test the potential also in terms of biodiversity increase, the 3 beds are filled with different aquatic species:

- Line A: *Iris Pseudacorus*
- Line B: *Scirpus Lacustris*
- Line C-D: *Juncus Effusus*, *Carex Acuta*

The VF2 UNSAT unit consists of the following characteristics shown in Table 2.2:

Table 2.2 VF2 UNSAT unit construction characteristics

Flow	m^3/d	10-100
Bottom surface area	m^2	600
Size and depth of filter media (starting from bottom) 20 – 40 mm round washed gravel 5-10 mm round, washed gravel sand 0.2-5 mm 5-10 mm round, washed gravel	m	 0.20 0.20 0.40 0.20
Total Depth of filter media	m	1.00
Free board	m	0.30
Total Depth	m	1.30
Type of plants	-	*Typha latifolia, Iris pseudacorus, Carex spp, Scirpus lacustris*
Material of construction	-	Excavated in the soil, soil embankments, waterproofed with HDPE liner 1.5 mm

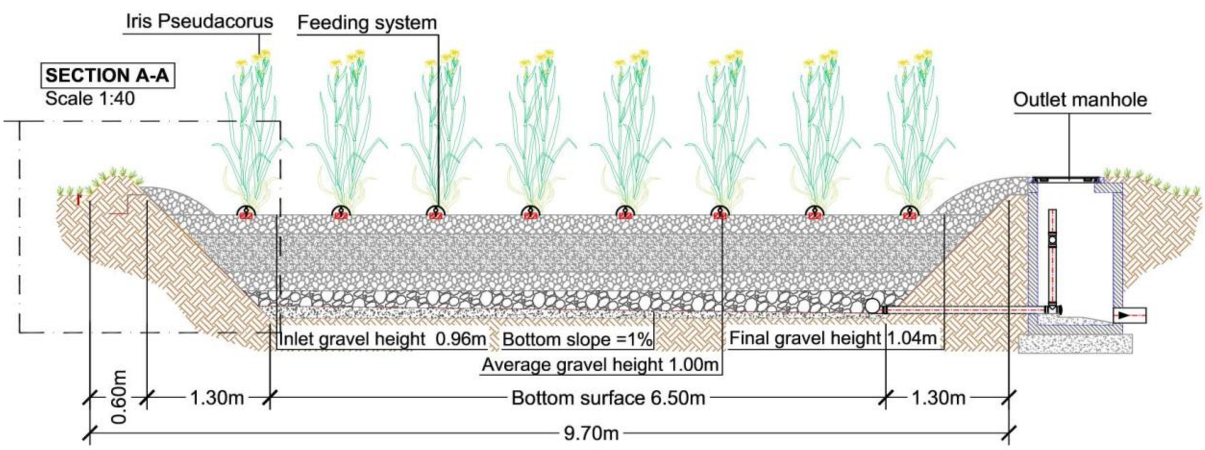


Figure 2.4. Section of VF2 UNSAT – Line A

The **feeding system** of the VF bed is constituted by several small pipelines with hole every 1 m connected to a main distribution pipe. The branches are closed at the end through plags for allowing regular washings. A line can be stopped by simply closing the corresponding gate valve in the valve manhole

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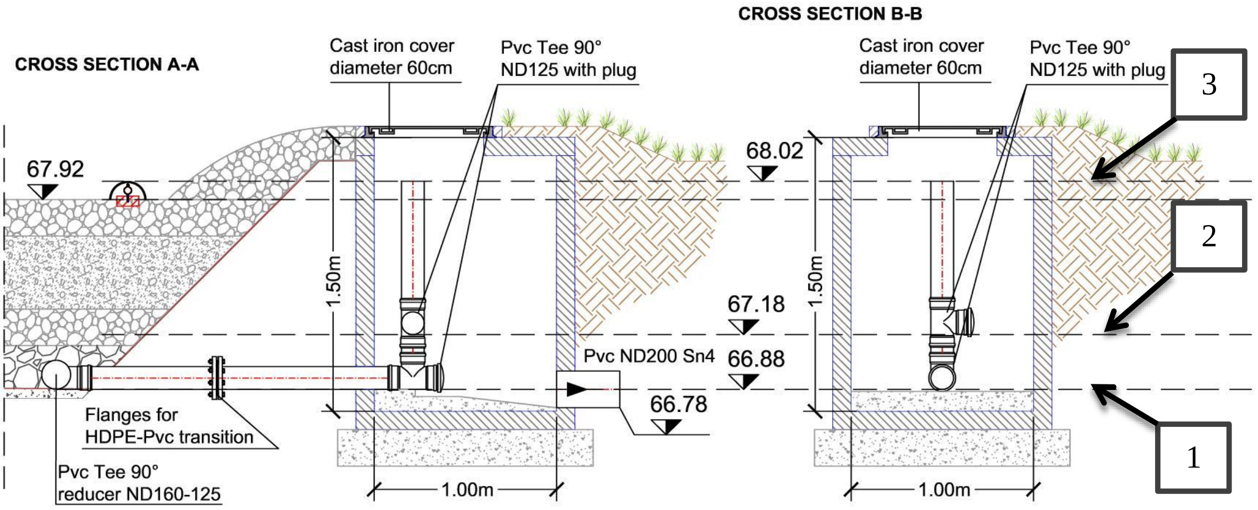
- Valve manhole M1 for line A and B
- Valve manhole M2 for line C and D

The **drainage water pipe** of the VF bed is made by several slotted HDPE pipes connected on one side to a main pipe, linked to the outlet manhole; on the other side the slotted pipes reach the bed surface providing aeration on the lower part of the filter bed through a chimney. Downstream of the bed <u>a water level control and sampling manhole</u> is placed: inside the manhole a level control device achieved by segments of PVC pipe is located. The outlet pipe has three lateral openings, which can be individually blocked, for flooding, denitrification mode and emptying standard condition (from top to bottom). The water level device allows thus 3 settings:

- *Emptying bed. Standard condition*: set to maintain unsaturated the whole VF2 UNSAT bed and to empty the bed in case of denitrifcation mode or after the start-up starting flooded phase (**(1)** Figure 2.5);
- *Denitrification mode:* about + 30 cm from the bottom of of the VF2 UNSAT bed, it permits to develop partially saturated condition in the VF2 UNSAT and to sustain denitrification also at this stage (**(2)** Figure 2.5);
- *Start-up and flooding maintenance mode*: about +110 cm from the bottom of the VF2 UNSAT bed, flooding the bed with +10 cm above the gravel bed surface to control the weed during the planting phase of the start-up or for weed maintenance in general (**(3)** Figure 2.5**)**



1. **Standard mode**
2. **Denitrification mode**
3. **Start-up and flooding maintenance mode**

Figure 2.5. Outlet manhole of VF2 UNSAT bed – Line A

2.1.1.3. *Operational modes*

The CW stage consists of a full-scale system and two pilot systems, which are designed aiming to guarantee the Greek limits for wastewater reuse in irrigation in terms of TSS, BOD_5, TN as well as contributing in disinfection.

The full-scale system is designed with two stages: 1st stage, saturated downflow VF (VF1 SAT); 2nd stage unsaturated intermitted load VF CW (VF2 UNSAT). Recirculation and by-pass chambers allow to test up to 4

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different configurations, investigating the best scheme for Greek and also other Mediterranean conditions (e.g. different water quality standards for TN or different N:P ratio for fertigation).

Comparing to the design of the deliverable D3.2, the final design decided to limit the number of possibilities in terms of operational modes. This because the significant monitoring periods would be short, that is only the summer touristic peak seasons. Since we expect two summers as peak monitoring phases, the possibilities to test different configurations are limited. To this aim, the final design removed the option to recirculate towards the UASB, maintaining only the recirculation towards the VF1 SAT as denitrification stage.

The possible operational modes of the final design are:

- MODE 1: UASB + VF2 UNSAT + UV (no recirculation, nitrification, no denitrification):
- MODE 2: UASB + VF1 SAT + VF2 UNSAT +UV (no recirculation, nitrification, no denitrification, enhanced BOD_5 and TSS removal)
- MODE 3: UASB + VF1 SAT + VF2 UNSAT +UV plus recirculation to VF1 SAT (recirculation, nitrification, partial denitrification)
- MODE 4: UASB + UF + UV (no recirculation, nitrification, no nitrogen removal)

Operation MODE 1: UASB + VF2 UNSAT + UV

Operation MODE 1 (Figure 2.6) can be selected in case only the nitrification would be required. To this aim, no recirculation is provided, not using the VF1 SAT denitrification stage. The anaerobically treated wastewater flows by gravity towards by-pass manholes C1 and B1. The wastewater by-passes the VF1 SAT stage and is diverted from B1 towards the pumping system serving VF2 UNSAT stage, where the wastewater is uniformly distributed on the whole surface by a feeding system constituted by pressure pipes developed along the entire VF2 UNSAT surface. The feeding of VF2 UNSAT is in batch, feeding alternatively the four lines (either A, B, C, or D) according with the set batches and resting. Wastewater drains under the unsaturated bed and is collected at the bottom of the bed by the VF2 UNSAT drainage system, which delivers the wastewater towards the next stages. The wastewater by-passes the recirculation towards VF1 SAT R2 and is conveyed by gravity to a treated wastewater pumping system (not included in this detailed design). Finally, the wastewater is sent by pressure to the final UV stage (not included in this detailed design) for disinfection before to be used in HYDRO 2 system.

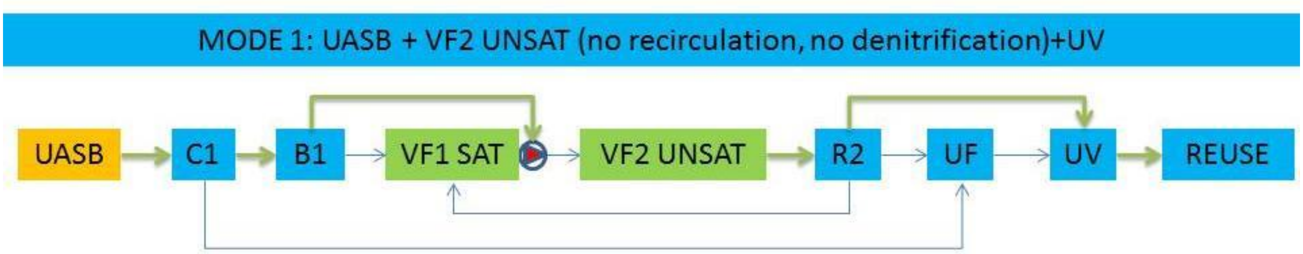

Figure 2.6. Schematization of MODE 1 operation modes of full scale Lesbos system: green arrows represent the functioning treatment chain, while the blue arrows the turned off options within the operational mode.

Operation MODE 2: UASB + VF1 SAT + VF2 UNSAT +UV

Operation MODE 2 (Figure 2.7) can be selected in case the TSS and BOD5 removal would be enhanced exploiting also the VF1 SAT first stage, but without recirculation (i.e. without denitrification). In other words, VF1 SAT functions also as “safety” stage before the VF2 UNSAT stage, which is filled by sand and is more sensitive to potential sludge escaping from UASB reactor. The anaerobically treated wastewater flows by gravity towards by-pass manholes C1 and B1. The wastewater is conveyed by gravity from B1 to the VF1 SAT stage, where the wastewater is uniformly distributed on the whole surface by a feeding system constituted by gravity pipes developed along the entire VF1 surface. The feeding of VF1 SAT is continuous. Wastewater drains with a downward plug functioning under saturated conditions and is collected at the bottom of the bed by the VF2 UNSAT drainage system, which delivers the wastewater towards the pumping system serving VF2 UNSAT stage. The wastewater is taken from the VF2 UNSAT pumping station and is uniformly distributed on the whole surface by a feeding system constituted by pressure pipes developed along all the VF2 UNSAT surface. The feeding of VF2 UNSAT is in batch, feeding alternatively the four lines (either A, B, C, or D) according with the set batches and resting periods defined in Operational and Maintenance manual. The wastewater drains under the unsaturated bed and is collected at the bottom of the bed by the VF2 UNSAT drainage system, which delivers the wastewater towards the next stages. The wastewater by passes the recirculation to VF1 SAT stage (R2) and is conveyed by gravity to a treated wastewater pumping system (not included in this detailed design). Finally, the wastewater is sent by pressure to the final UV stage (not included in this detailed design) for disinfection before to be used in HYDRO 2 system.

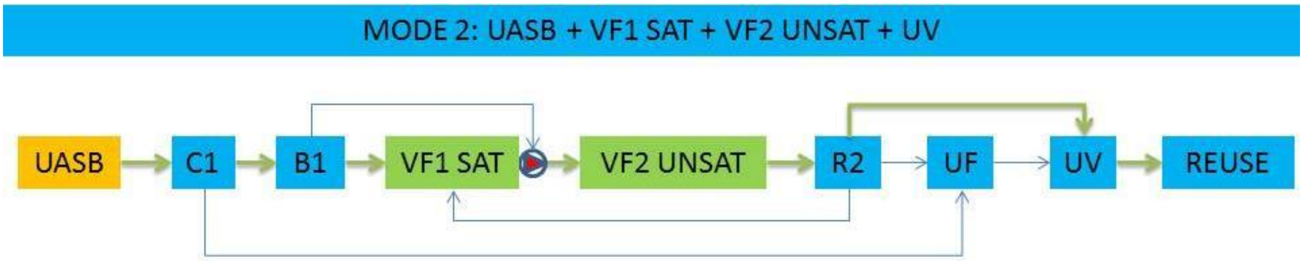

Figure 2.7. Schematization of MODE 2 operation modes of full scale Lesbos system: green arrows represent the functioning treatment chain, while the blue arrows the turned off options within the operational mode.

<u>Operation MODE 3: UASB + VF1 SAT + VF2 UNSAT +UV plus recirculation to VF1 SAT</u>

Operation MODE 3 (Figure 2.8) can be selected in case both nitrification and denitrification would be required. To this aim, recirculation towards the VF1 SAT is activated. Therefore, this option exploits the VF1 SAT both as denitrification stage and as an additionally saturated bed for TSS and COD removal (as detailed in MODE 2 description). The anaerobically treated wastewater flows by gravity towards by-pass manholes C1 and B1. The wastewater is conveyed by gravity from B1 to the VF1 SAT stage, where the wastewater is uniformly distributed on the whole surface by a feeding system constituted by gravity pipes developed along the entire VF1 surface. The feeding of VF1 SAT is continuous. Wastewater drains with a downward plug functioning under saturated conditions and is collected at the bottom of the bed by the VF2 UNSAT drainage system, which delivers the wastewater towards the pumping system serving VF2 UNSAT stage. The wastewater is taken from the VF2 UNSAT pumping station and is uniformly distributed on the whole surface by a feeding system constituted by pressure pipes developed along all the VF2 UNSAT surface. The feeding of VF2 UNSAT is in batch, feeding alternatively the four lines (either A, B, C, or D) according with the set batches and resting periods defined in Operational and Maintenance manual. The wastewater drains under the unsaturated bed and is collected at the bottom of the bed by the VF2 UNSAT drainage system, which delivers the wastewater towards the next stages. The wastewater is sent to the recirculation to VF1 SAT stage (R2). Therefore, part of the VF2 UNSAT effluent is recirculated by gravity to VF1 SAT and another portion is conveyed by gravity to a treated wastewater pumping system (not included in this detailed design). Finally, the wastewater is sent by pressure to the final UV stage (not included in this detailed design) for disinfection before to be used in HYDRO 2 system.

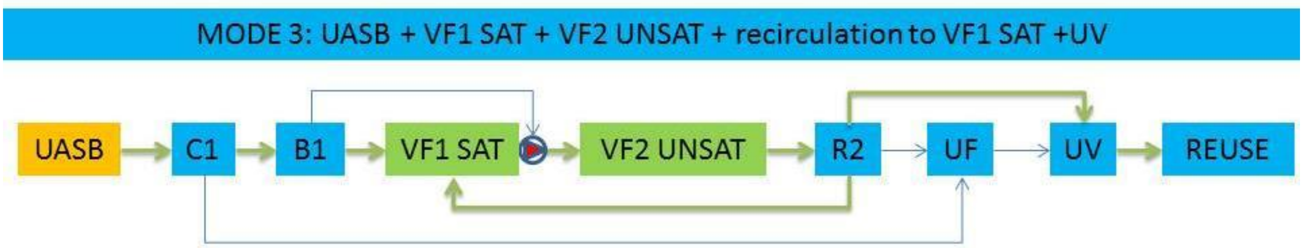

Figure 2.8. Schematization of MODE 3 operation modes of full scale Lesbos system: green arrows represent the functioning treatment chain, while the blue arrows the turned off options within the operational mode.

<u>Operation MODE 4: UASB + UF + UV</u>

Operation MODE 4 (Figure 2.9) can be selected to test the possibility to have neither nitrification nor denitrification, and to reuse anaerobically treated wastewater after only an ultrafiltration (UF) and a disinfection (UV) stages. To this aim, no recirculation is provided, not using the denitrification stage into VF1 SAT. Moreover, all the CW stages are by-passed. The anaerobically treated wastewater flows by gravity towards the general by-pass manhole C1. The wastewater by-passes both the VF1 SAT and VF2 UNSAT stages and is diverted from C1 by gravity to a treated wastewater pumping system (not included in this detailed design). Finally, the wastewater is sent by pressure to the UF and final UV stage for disinfection before to be used in HYDRO 2 system.

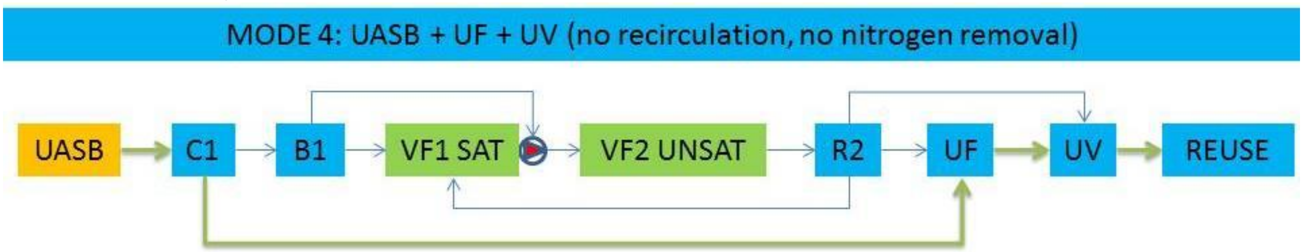

Figure 2.9. Schematization of MODE 4 operation modes of full scale Lesbos system: green arrows represent the functioning treatment chain, while the blue arrows the turned off options within the operational mode.

2.1.2. Pilot scale

Four pilot systems are included and are designed to evaluate the possibility to reduce the areal footprint of CWs and in the bio-electrified CWs investigate the potential of energy production through wastewater treatment with intensified innovative solutions:

- an aerated CW, AEW (aerated wetland);
- three bio-electrified CW, MFC (microbial fuel cell);

Each pilot unit receives a maximum flow rate of **1 m^3/d**. The influent is derived by a pump from the wastewater entering the main WWTP, after the preliminary treatments, and it is pre-treated in a septic tank. A small pumping station consent to load the four pilot systems in parallel.

2.1.2.1. Aerated constructed wetland pilot

The aerated pilot bed will be constituted by a 1000 liters IBC tank, filled with gravel and maintained under saturated condition, i.e. in sub-surface flow mode. An aeration system has be placed under the gravel substrate at the bottom of the bed using the Forced Bed Aeration™ technology. The air is supplied to the aeration system by a small membrane blower.

2.1.2.2. *Bio-electrified constructed wetland pilots*

The iMETland technology will be tested, which consists of CW bed working in sub-surface flow conditions and filled with electrically conductive material of selected sizes. The electrically conductive material allows to grow particular bacteria community, able to generate electricity from the wastewater treatment as well as to treat the wastewater in much more efficient way.
Each of the three bio-electrified CWs is designed in order to operate independently of the other two MFC units. Nevertheless, the three pilot units could also run in parallel. Unit 1 is a vertical down flow aerobic wetland, Unit 2 will operate as a flooded anoxic CW, while Unit 3 provide a hybrid operation mode combining both vertical down flow and flooded operation.
Each modular MFC unit consists of a 1 m^3 tank, hosting a biofilter bed made of carbon electro-conductive material, inoculated with a colony of electro-active Geobacter bacteria. The bio-filter is open-top in order to provide sufficient area for plantation of compatible plants like Typhas, Phragmites etc.
The concept of the pilot-scale CWs, includes the load of the untreated wastewater to a septic tank and then to the pilot CWs, where the AEW unit will be combined with the MFC units operation.
The implemented process can achieve high BOD and COD removal capacity while at the same time electricity will be produced by the cultivated bacteria. The MFC CWs will be monitored on real time by biosensors able to convert BOD into electrical current.

2.2. Post Treatments units

Post Treatments units, provided by UNIVPM in the context of the HYDROUSA Project, involves filtration and disinfection of the effluents obtained from CW or UASB reactor.
Specifically, two compact skids have been supplied for the two treatment lines implemented at the Antissa.
In the Full-scale line (100 m^3/d), a combined system of membrane Ultrafiltration (UF) and UV disinfection (UV) is supplied; while for the pilot line (1m^3/d), a sand filtration (SF) and UV disinfection are provided.
Technical details of each unit are reported below.

2.2.1. Full-scale line (100 m^3/d): Membrane Ultrafiltration (UF) and UV Disinfection (UV)

Post-treatment units include two compact systems for the different lines.
In the Full-scale unit, possible three main flows are identified based on the operational functioning of the full-scale line:

1- Water Line

In this line, two possible system configurations can be applied to test different treatment combination and thus to evaluate the effluent quality:

- Configuration 1a) INLET, UF, UV
- Configuration 1b) INLET, UV

2- Backwash Line

This line is dedicated to the cleaning of the UF membrane for both simple backwash and intensive chemical cleaning. It involves a complete washing of piping, valves, pumps and tanks.

3- Recirculation Line (Concentrate Flow)

This line includes the piping, pump and tank provided to recirculate the backwash discharge to the inlet of HYDRO 1.

Detailed functional description of the lines is reported as follows:

Water Line

The water line is provided by inlet pipes from storage tanks (one for UASB and one for CW) and controlled by manual valves (HV1 and HV2) to introduce the influent wastewater into the water line. The valves located downstream of each influent storage tank allow to supply the units (UF Membranes + UV Disinfection) with the UASB effluent or with the CW effluent depending on the valves to be chosen manually. In each tank, a submerged "Dreno DNA 50-2/220 T" pump is provided (P1 and P2) to feed the FULL-SCALE unit based on the level variation (minimum and maximum) registered by the level switch (LS1 and LS2). The flow can also be adjusted by a valve (HV3), which is operated as a by-pass that can be manually adjusted (open / closed) to regulate the flowrate of the pump P1 or P2 and recirculate a part of it in the storage tank of the influent. Specifically, main settings are reported for valves (Tables 2.3-2.4):

Table 2.3. UASB FEEDING

VALVE	STATUS
HV1	Open
HV2	Closed
HV3	Open 1/4
HV5	Closed
HV8	Closed
HV11	Closed
HV12	Open 1/4

Table 2.4. CW FEEDING

VALVE	STATUS
HV1	Closed
HV2	Open
HV3	Open 1/4
HV5	Closed
HV8	Closed
HV11	Closed
HV12	Open 1/4

After starting the system, adjust the HV3 and HV12 valves until the following pressure and flow values are obtained:
PI1 = 1 bar,
PI2 = 1 bar,
PI3 = 0.8 bar,
FI1 = 80 l/min.
The full-scale line can be operated in two different configurations namely 1a and 1b. To set a specific configuration, manual of automatic modes can be selected in the main PLC (see Figure 2.10). Specifically, to work in configuration 1a) automatic mode should be selected for all components (e.g. pumps and valves), whereas in configuration 1b) firstly valves on the water line should be manually selected and switched on, then pumps and UV lamps should be activated.

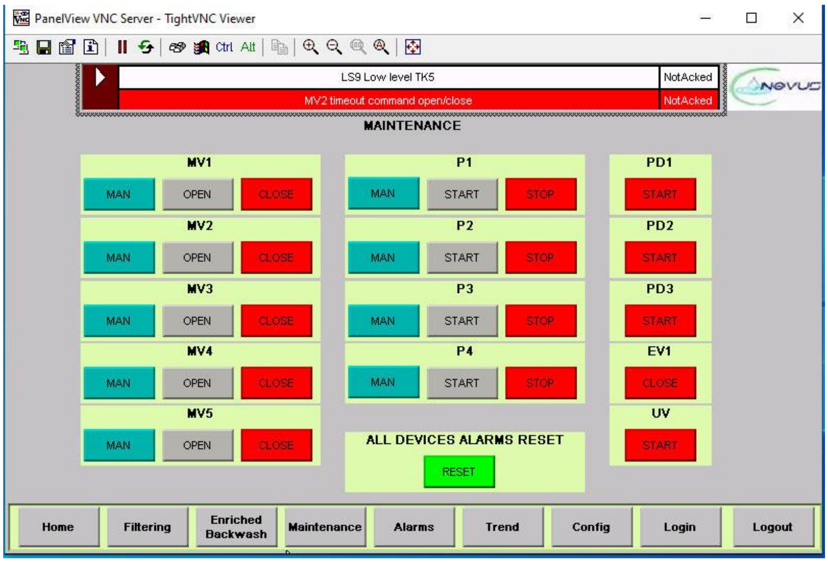

Figure 2.10. Main panel view for operation mode selection

In configuration 1a) the influent is sent to a microfiltration (MF) with cartridge filter (both mesh of 125 µm or 80 µm are provided) placed downstream of the inlet pumps P1 and P2. The MF is installed as a pre-treatment prior to UF to guarantee a wastewater quality with adequate characteristics that is suitable for downstream UF membranes. On the inlet MF pipe, a sampling point (SP1) with manual valve (HV4) is provided to monitor the influent quality as well as a pressure gauge (PI1) and a pressure transmitter (PT1) to send values to the main PLC.

Downstream of the filter there are both a direct read flow meter (F1) for monitoring of the input flow rate to the UF unit and a manometer with transmitter (PI2+PT2) for pressure monitoring.

Two modules of "dizzer® XL 1.5 MB 40 W" multibore membrane with pore size of 0.02 µm are installed and equipped with a PLC that can be automatically controlled and enables to manage the operations of the following unit:

a. Ultra-filtered water tank (TK1) level signals (both minimum LS3 and maximum level LS4);
b. Backwashing cycles of the membranes including the control of all automatic valves;
c. Backwash discharge relaunch pump (P4) and level sensors (minimum LS5 and maximum LS6) in the discharge accumulation tank (TK2);
d. Backwash pump (P3);
e. Dosing pumps "Injecta Athema AT-MT" (PD1; PD2; PD3), related chemicals level (LS7; LS8; LS9) in the tanks (TK3; TK4; TK5).

The permeate of the UF unit is then sent to two UV lamps "Viqua F4 +". The lamps are provided with "Power Supply" case to handle start & stop modes (CUV1, CUV2) together with intensity transmitter (UVT 1, UVT2).

The disinfected effluent is collected in the storage tank (TK1) in which a non-return valve (CV8) coupled with an electric valve (EV1) allows to send water to pump P3 for the UF backwash.

Finally, different sampling points with manual valves are placed along the line:

- HV4-SP1, HV6-SP2: Effluent from UASB or CW;
- HV10-SP3: Effluent (backwash discharge) from UF membranes;
- HV13-SP4: Permeate of UF membranes;
- HV10-SP5: Effluent from UV Disinfection.

In configuration 1b) after the microfiltration, the integrated pre-treatment system includes the by-pass of UF membranes to allow the influent wastewater to be treated directly by UV-disinfection.

In this case, the valves MV1 and MV2 should be closed and HV8 should be opened.

Backwash Line

Part of the disinfected water is collected in the storage tank (TK1) and used for backwashing of the membranes. Pump “Lowara CEA 210/5” (P3) is provided for the backwash. During the backwash step, the motorized valve (MV5) at the upstream of the UV lamps is disabled; while at the downstream of the backwash pump (P3), the valves (EV1 and HV11) are enabled.

A flow meter (FI2) and a pressure meter (PI3) display the backwash condition of the UF cleaning.

Depending on the preferred backwashing (i.e. standard backwash with filtered water or chemical backwash), dosing pumps of the reagents can be activated.

In order to reduce the risk of membrane fouling, filtration cycles are performed by alternating the flow between the upper and lower inlet.

Filtration step

The filtration sequence starts by selecting the related command on the control panel.

At the end of the cycle, before the flow change, a flushing cycle and a backwash cycle are performed. The flushing and backwashing phases are also activated by exceeding the differential pressure setpoint downstream / upstream of the membranes.

Once the full-scale unit starts, the system automatically adjusts all the components by alternating the configuration of the motorized valves and the pumps activation according to the following steps (Tables 2.5-2.10, Figures 2.11-2.16):

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776643

Table 2.5. Filtration at N cycle

VALVE	STATUS
MV1	Open
MV2	Closed
MV3	Closed
MV4	Closed
MV5	Open
P1	On
P2	Off
P3	Off
EV1	Off
UV	On

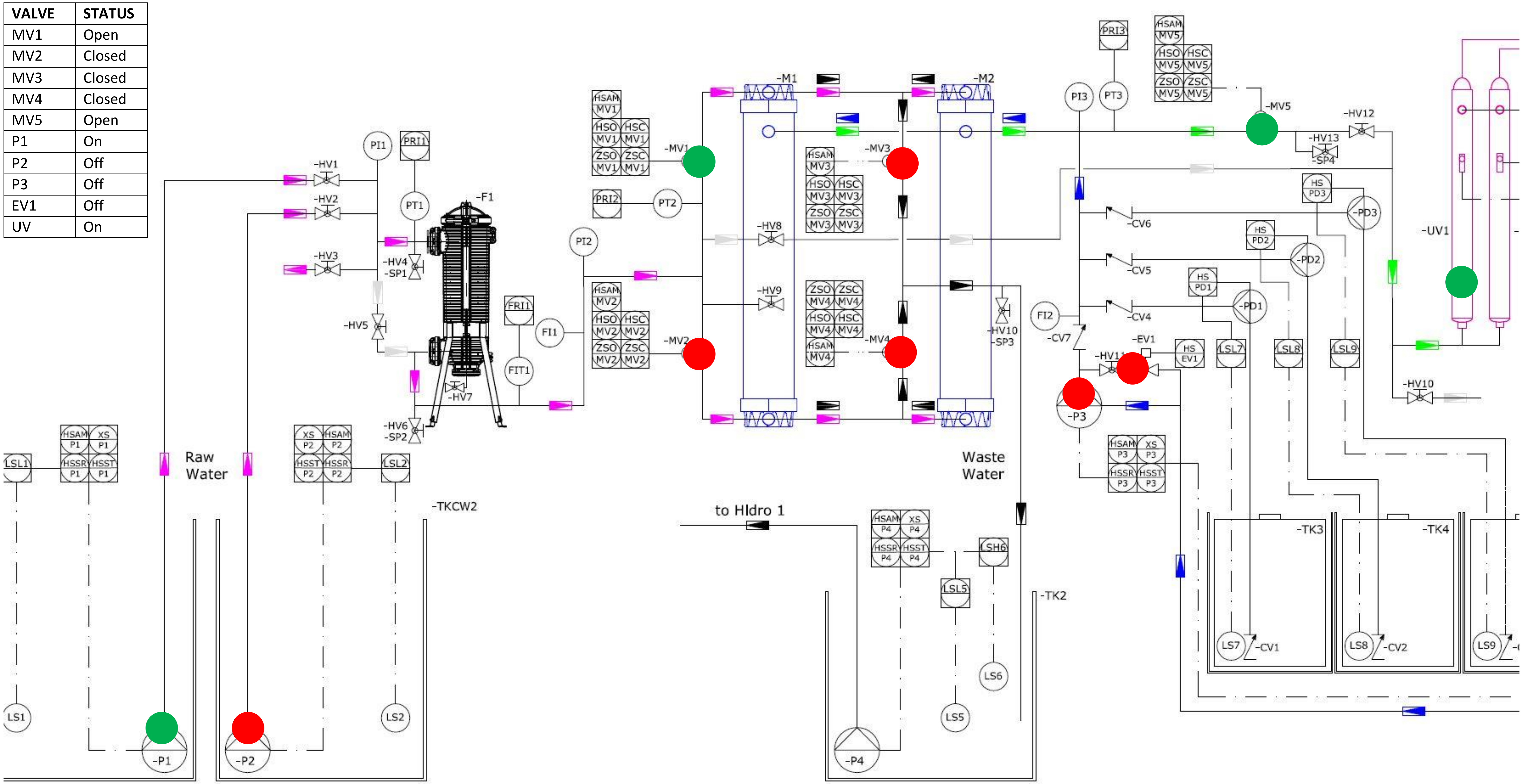

Figure 2.11. Operation mode: Filtration at N cycle

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776643

Table 2.6. Flushing after filtration N

VALVE	STATUS
MV1	Open
MV2	Closed
MV3	Closed
MV4	Open
MV5	Closed
P1	On
2	Off
3	Off
EV1	Off
UV	Off

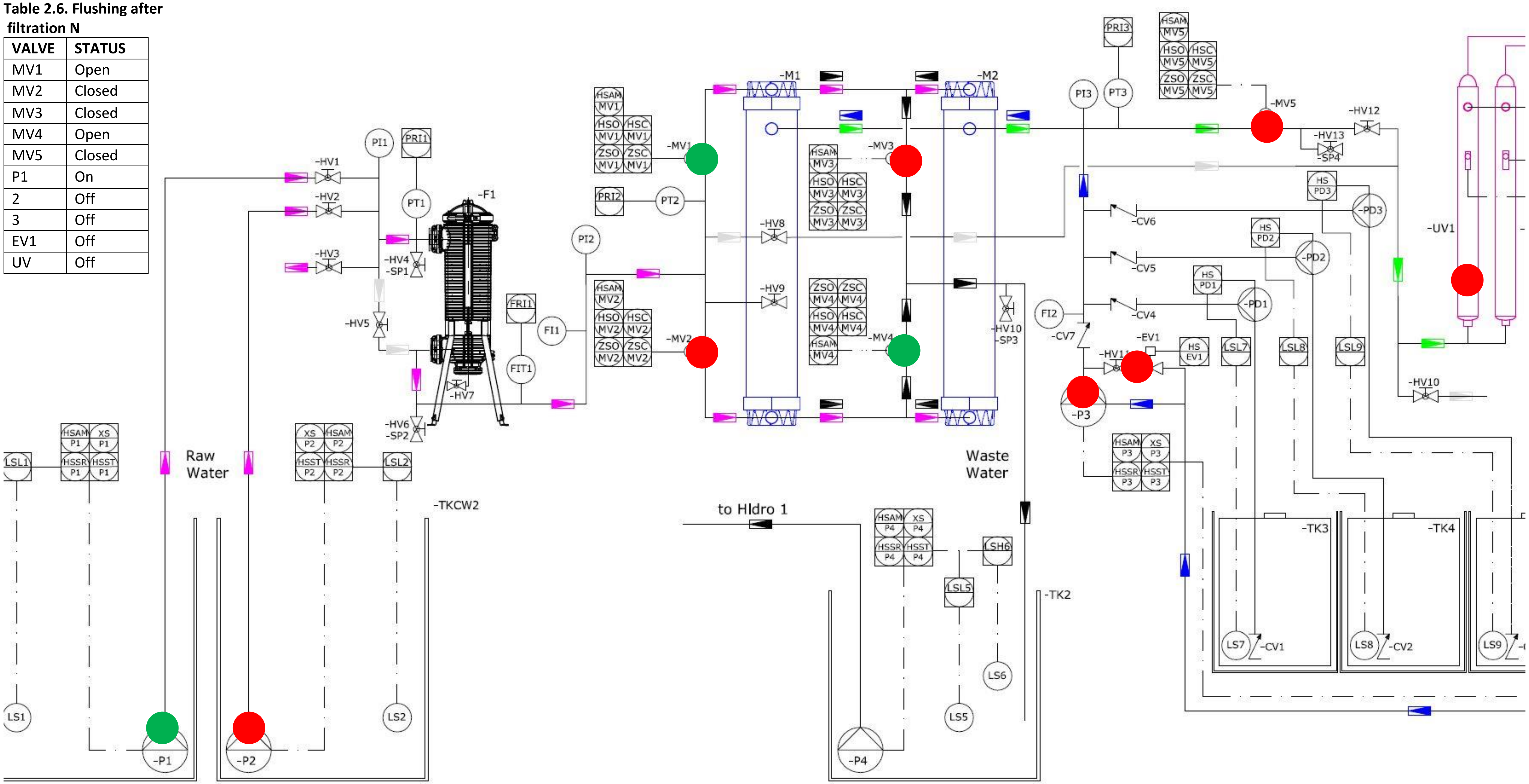

Figure 2.12. Operation mode: Flushing after filtration N

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776643

Table 2.7. Backwash after filtration N

VALVE	STATUS
MV1	Closed
MV2	Closed
MV3	Closed
MV4	Open
MV5	Closed
P1	Off
P2	Off
P3	On
EV1	Off
UV	Off

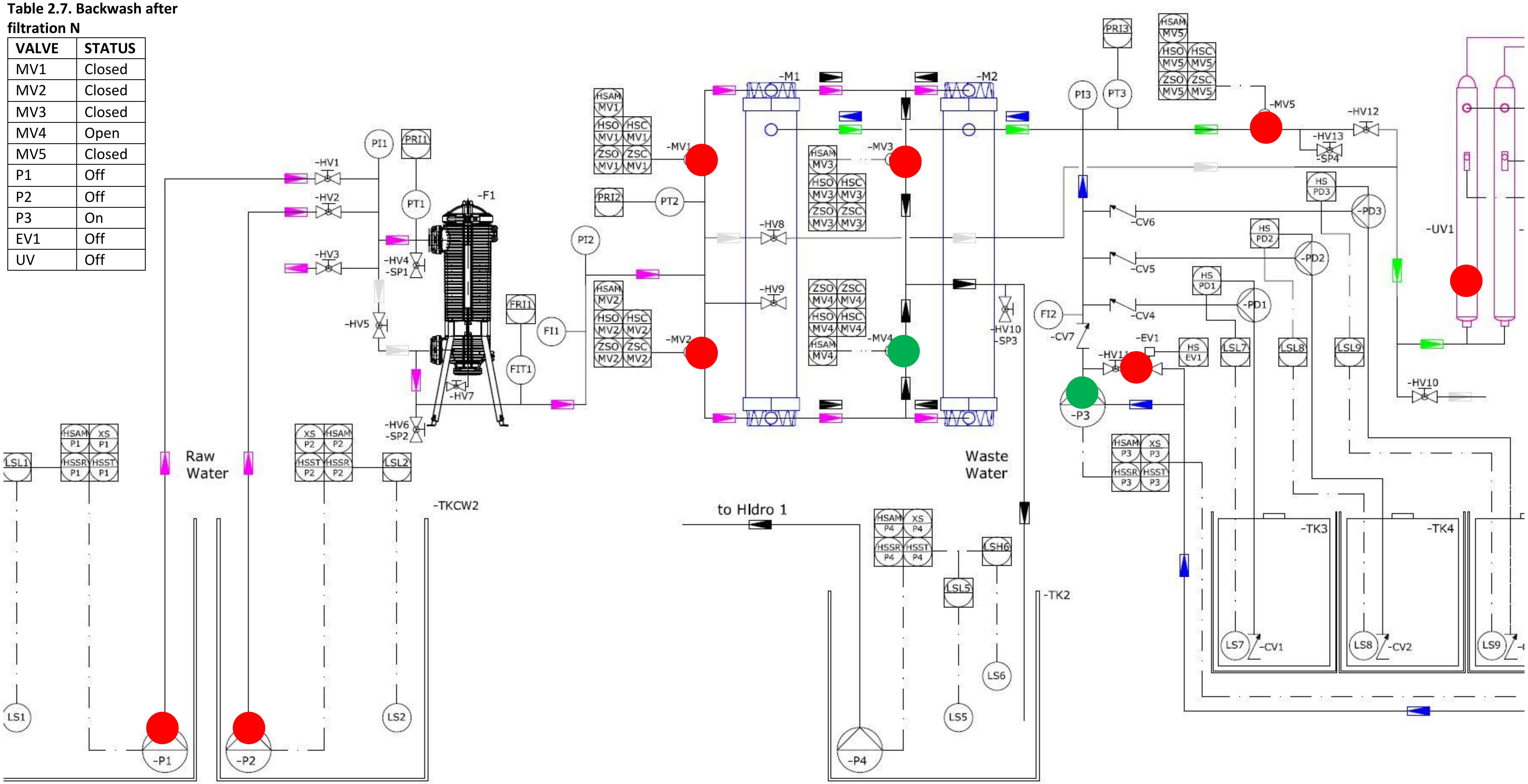

Figure 2.13. Operation mode: Backwash after filtration N

Table 2.8. Filtration at N+1 cycle

VALVE	STATUS
MV1	Closed
MV2	Open
MV3	Closed
MV4	Closed
MV5	Open
P1	On
P2	Off
P3	Off
EV1	Off
UV	On

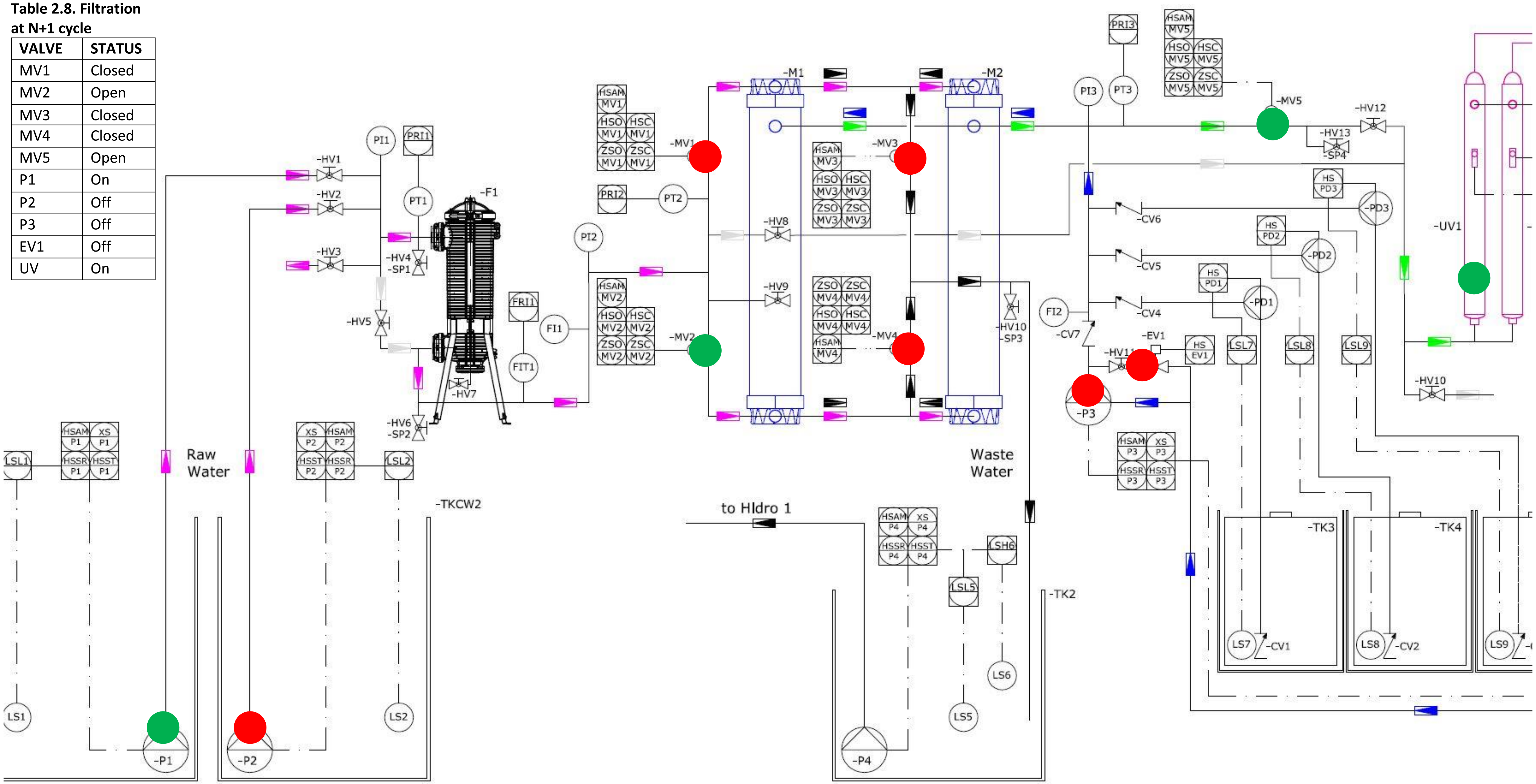

Figure 2.14. Operation mode: Filtration at N+1 cycle

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Table 2.9. Flushing after filtration N+1

VALVE	STATUS
MV1	Closed
MV2	Open
MV3	Open
MV4	Closed
MV5	Closed
P1	On
P2	Off
P3	Off
EV1	Off
UV	Off

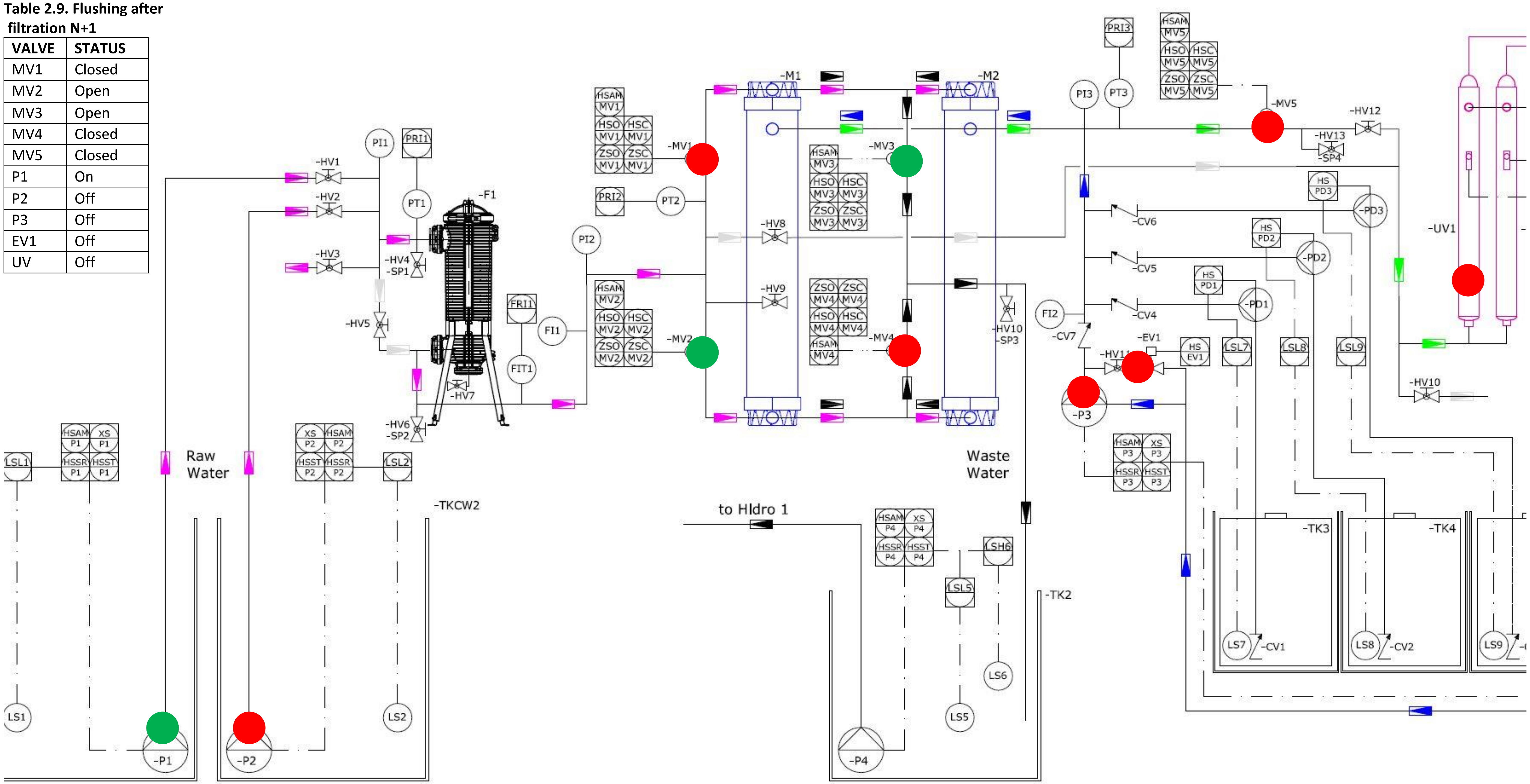

Figure 2.15. Operation mode: Flushing after filtration N+1

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under Grant Agreement No 776643

Table 2.10. Backwash after filtration N+1

VALVE	STATUS
MV1	Closed
MV2	Closed
MV3	Open
MV4	Closed
MV5	Closed
P1	Off
P2	Off
P3	On
EV1	Off
UV	Off

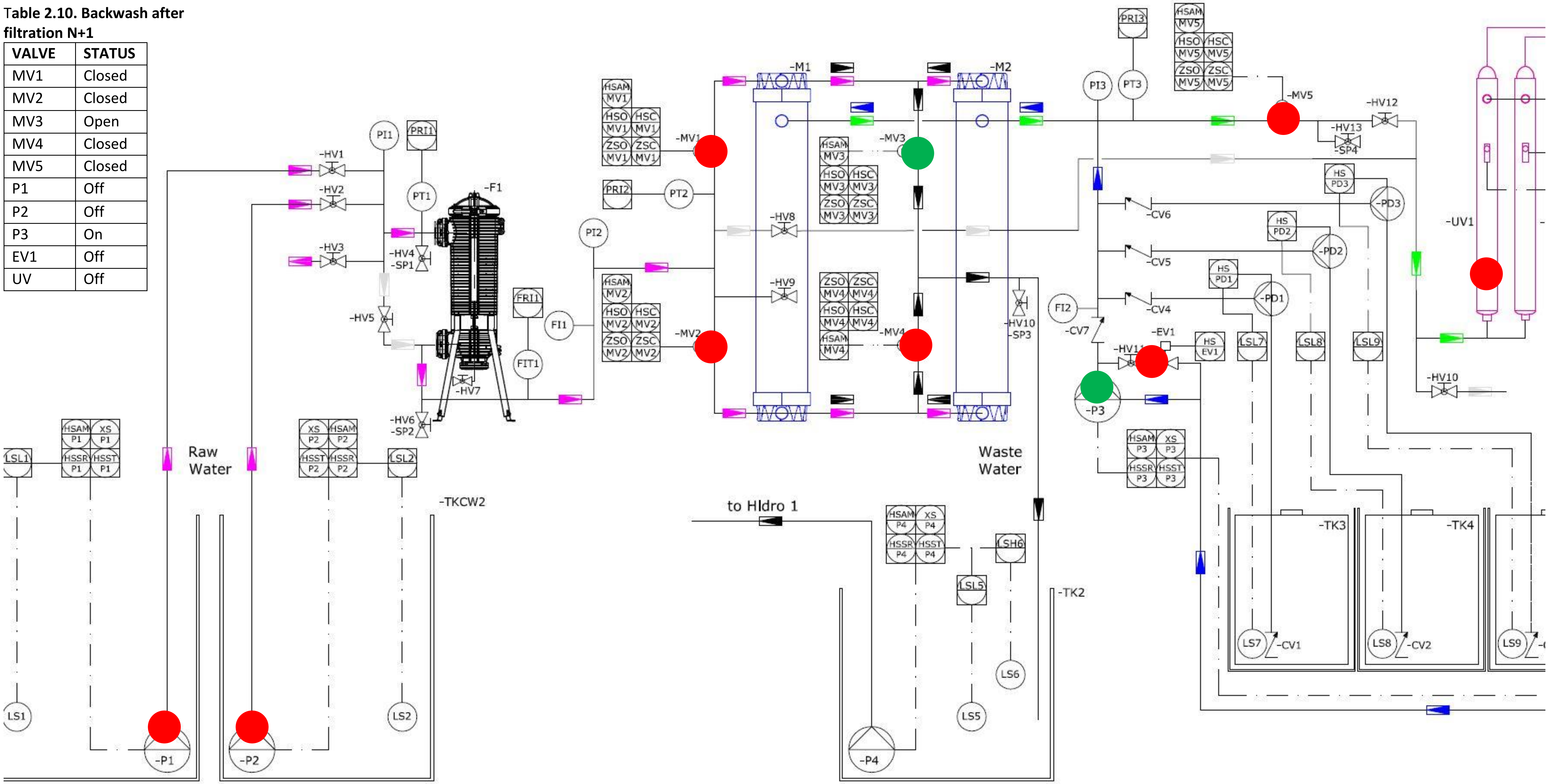

Figure 2.16. Operation mode: Backwash after filtration N+1

Steps previously highlighted consider the UASB feeding. When considering the CW effluent P2 is involved instead of P1.

A standard operation involves a backwash time of 120 seconds in every 30 minutes of filtration, but backwash intervals can be adjusted (e.g. between 30 and 60 minutes) according to local necessities and the fouling on the membrane.

Flushing step

The membrane flushing is implemented in the operating cycles to rapidly clear the membranes from the solids that could accumulate inside the channels during the filtration step.

The flushing direction is the same with the previous filtration step.

Once the filtration time is over, following steps are automatically followed:

a. stop the feeding pump;
b. close the valve MV5;
c. open valve MV3 or MV4 depending on the direction of the filtration flow.

Backwashing step

During the backwashing, the impurities accumulated on the membrane fibres are removed and sent to the “Recirculation Line”. Specifically, the reclaimed water effluent is fed to UF membranes in counter direction of the filtration.

If chemical backwash is needed, a specific sequence of phases can be selected for CEB (Chemical Enriched Backwashing).

This sequence is divided into three steps for a maximum duration of 2 hours.

Each single step is characterized by the dosage of a chemical reagent (e.g. HCl, NaCl, NaOH) that can be selected to remove target fouling. A generic sequence is described below:

a. Flushing;
b. Backwashing;
c. UP / DOWN enriched backwashing: Once the backwashing step is completed, the flow delivered by the pump P3 is cut and the chemical reagent dosage is enabled. Valves configuration is following reported (Table 2.11-2.12).

Table 2.11 CEB – UP

VALVE	STATUS
MV1	Closed
MV2	Closed
MV3	Open
MV4	Closed
MV5	Closed
P1	Off
P2	Off
P3	On
EV1	On

Table 2.12 CEB – DOWN

VALVE	STATUS
MV1	Closed
MV2	Closed
MV3	Closed
MV4	Open
MV5	Closed
P1	Off
P2	Off
P3	On
EV1	On

d. **Pause:** After dosing the chemical reagents, the sequence involves a pause to allow the chemicals to react with the impurities, before proceeding with the backwash step without chemicals.
e. **Backwash UP / Backwash DOWN:** In order to definitively wash out the impurities removed by the chemicals used in the previous step, alternative cycles of Up / Down backwash is provided.
f. **Filtration:** Between a CEB sequence and the next, a filtration step is carried out in order to regulate pH inside the membrane vessels.

The automatic valve status is summarized in the operating manuals with more details on cleaning phases. Finally, at the downstream of the modules, the permeate is then sent to the UV disinfection unit.

Recirculation Line (Concentrate Flow)
The concentrate resulted from the backwashing discharge of the UF is then sent to the accumulation tank (TK2) and then to the inlet of the HYDRO 1 by the P4 submerged pump “Dreno DNA 50-2/110T”. The logic of the pump activation is managed by the main PLC and connected to the level sensors (LS5 and LS6) installed in the tank whose signals are sent to the PLC.

2.2.2. Pilot line (1 m^3/d): Sand Filtration (SF) and UV Disinfection (UV)

The PILOT unit operation involves three main flows as follows:

1- Water Line
The configuration of this line includes the treatment of the influent with SF and further with UV Disinfection.

2- Washing Line
This line is dedicated to the cleaning of the filter. It involves a complete washing of piping, valves, pumps and tanks.

3- Recirculation Line
This line includes the piping, pump and tank provided to recirculate the backwash discharge to the inlet of HYDRO 1.

Furthermore, the system has a relay control system to allow the operator to run the unit by acting on only 4 selectors and the electronic head of the sand filter.

Water Line

The water line is provided by inlet pipes from storage tanks of different CWs and controlled by manual valves (HV1, HV2 and HV3) to introduce the influent wastewater into the water line. The valves located downstream of each influent storage tank (different CWs) allow to feed the units (Sand Filtration + UV Disinfection) with different CW effluents depending on the valves to be chosen manually.
The influent is therefore fed by a self-priming pump “Lowara BGM5/A” (P1). This pump will be connected to a manifold (supplied by third parties), in order to draw different types of influent simply by acting on the valves placed on the influent pipeline.
Specifically, S1, S2, S3 and S4 selectors can be manually turned on/off to start any of the system's running phases (Figure 2.177).

Figure 2.17. Selectors for different influent feedings

The activation of these selectors will enable the corresponding levels previously installed inside the CWs collection tanks. The presence of water inside the tanks will allow the P1 pump to start, preserving it from the possibility of running empty.
It is important to ensure that the influent pipeline is always under hydraulic head, to guarantee the priming of the pump.
The influent flowrate can also be regulated by a manual valve (HV4), which is operated as a by-pass that can be manually adjusted (open / closed) to regulate the flowrate of the pump and recirculate a part of it in the storage tanks of the influent.
The flow is then sent to the Sand Filtration unit (SF1) which works in down flow configuration. The effluent flow pipe is provided by both direct read flow meter (FI1) for flow rate monitoring and a manometer (PI1 and PI2) for the pressure monitoring prior to SF and UV disinfection units, respectively.
It is necessary to set standard flow and pressure conditions, in order to optimize the operation of the system. Below are the indications for the main settings of the manual valves (Table 2.13 & 2.14):

Table 2.13 FILTRATION

VALVE	STATUS
HV1	Open
HV2	Closed
HV3	Open 1/4
HV4	Open 1/4
HV5	Open 3/4
HV8	Open 3/4

Table 2.14 BACKWASH

VALVE	STATUS
HV1	Open
HV2	Closed
HV3	Open 1/4
HV4	Open 1/4
HV5	Open 3/4
HV8	Closed

It has to be noticed that HV3, HV4, HV5 and HV8 have to be adjusted until following values are reached:
PI1 = 2.5 bar,
PI2 = 2.5 bar,
FI1 = 4 l/min.
Following the Sand Filter, the effluent is then sent to the UV disinfection unit that is composed of a UV "Viqua E4+" lamp provided with an intensity meter (UVT1).

Washing Line

Once the pressure variation between PI2 and PI1 reaches value greater than 1.5 bar, it is necessary to carry out the sand filter washing.
To correctly start the washing procedure, following steps should be followed:

a. Stop pump P1 by turning off one of the previously described selectors
b. Close the HV8 valve
c. Press the regeneration button on the electronic head of the filter for 5 seconds (Figure 2.188).

Figure 2.18. Electronic head of the Sand Filter

Once the washing cycle has started, an internal valve placed in the filter head will be activated to automatically perform a series of co-current and counter-current washes.
Part of the effluent collected in a storage tank (TK1) is used for the SF washing by means of the "Lowara 5HM06" pump (P2).
The activation of the washing pump is strictly connected to the enabling of the level switch (LS2) placed inside the filtered water tank (TK1).

Recirculation Line

The discharge of the Sand Filter backwash is then sent to the accumulation tank (TK2) and then finally to the inlet of the HYDRO 1 or to the CW by a "DRENO DNA 50-2/110M" submerged pump (P3). The pump is controlled by a level switch placed inside the collection tank TK2.

Finally, different sampling points with manual valves are placed along the line:

- HV6-SP1: Effluent from CWs;
- HV7-SP2: Filtered effluent from SF;
- HV9-SP3: Effluent from UV Disinfection.

2.2.3. List of as built Drawings

The design layout of Lesbos full-scale and pilot-scale system are shown in Figure 2.19 and Figure 2.20, respectively. P&ID of each section are shown from Figure 2.21 to Figure 2.24. The complete drawings are included in Annex 1.

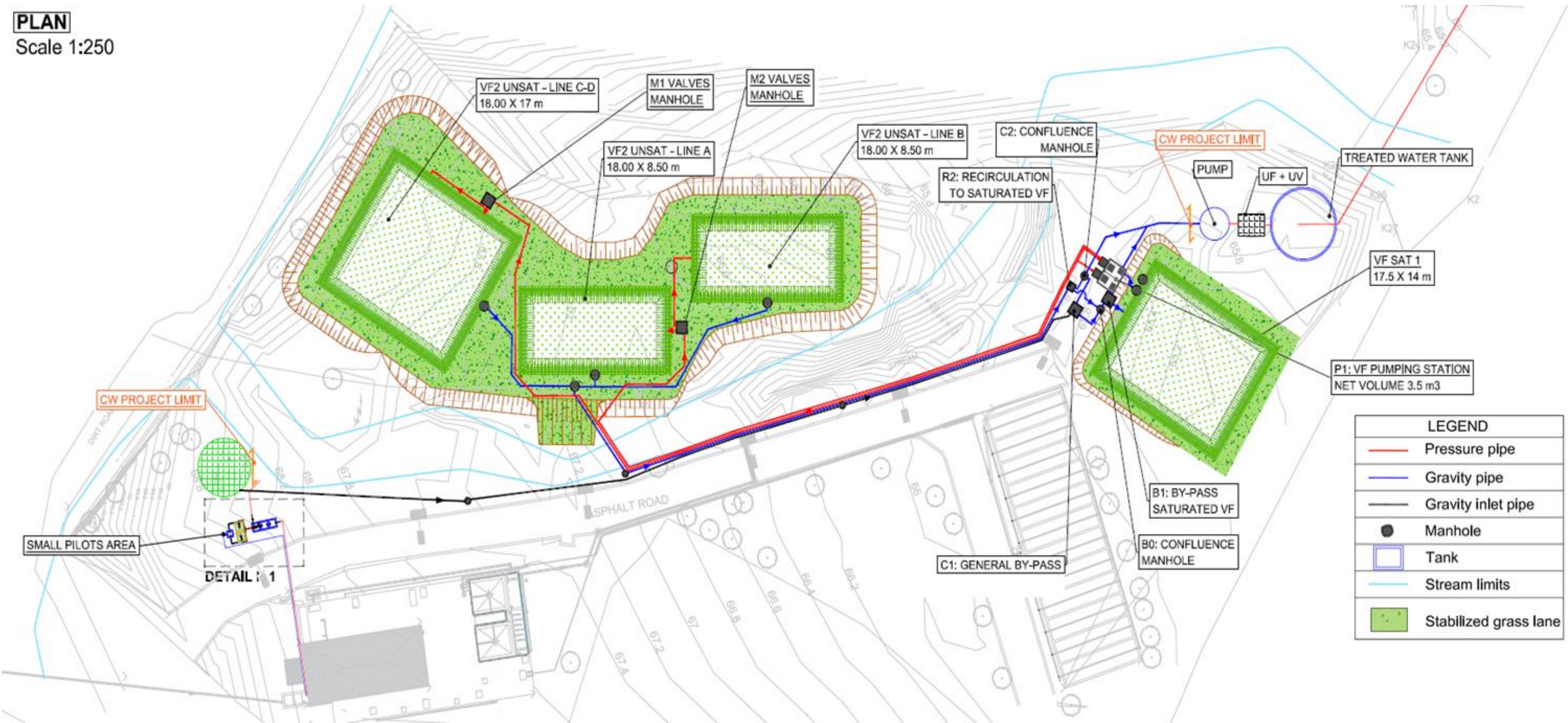

Figure 2.19. Layout of Lesbos full-scale system – final detailed design

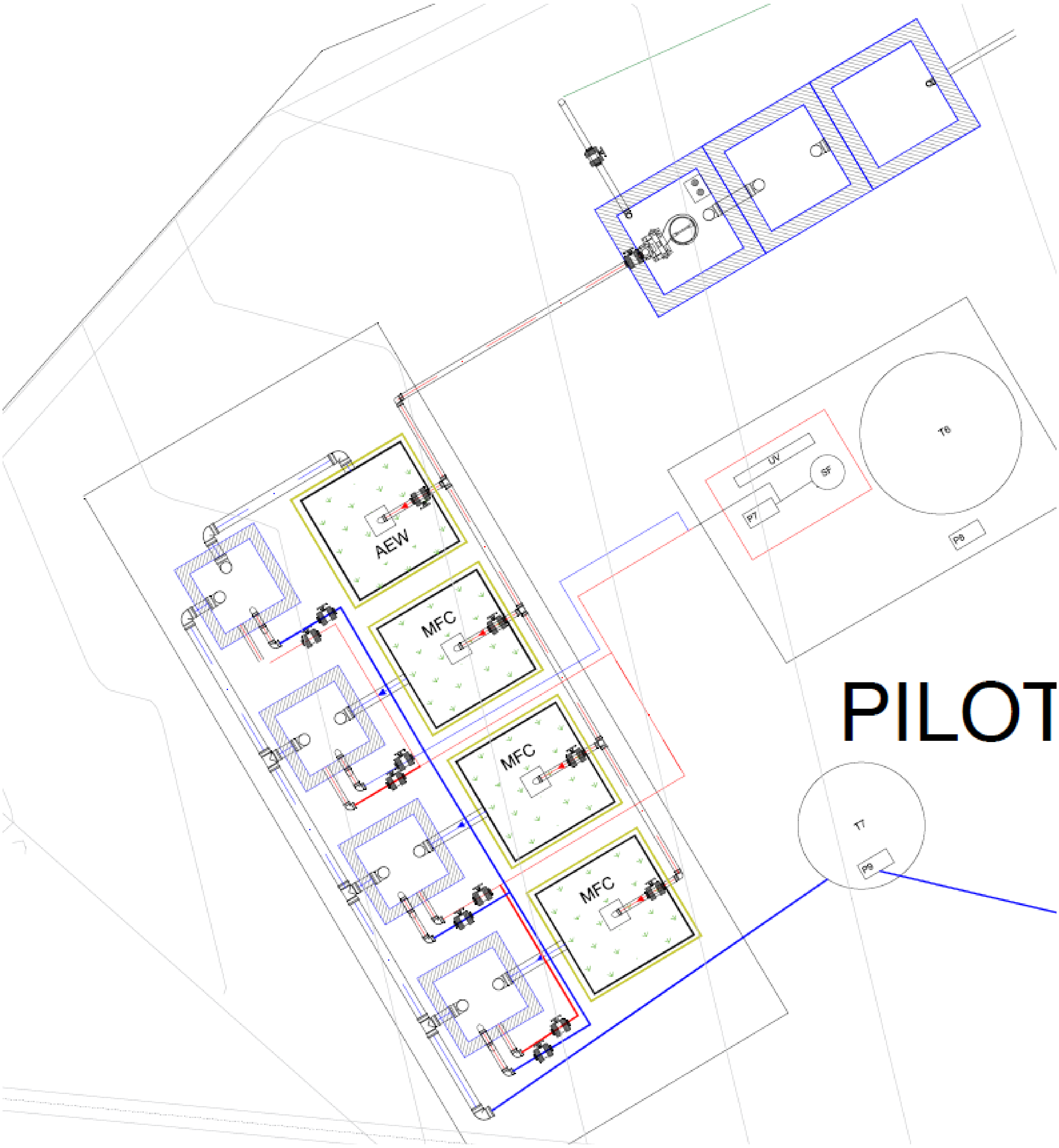

Figure 2.20. Layout of Lesbos pilot scale system – final detailed design

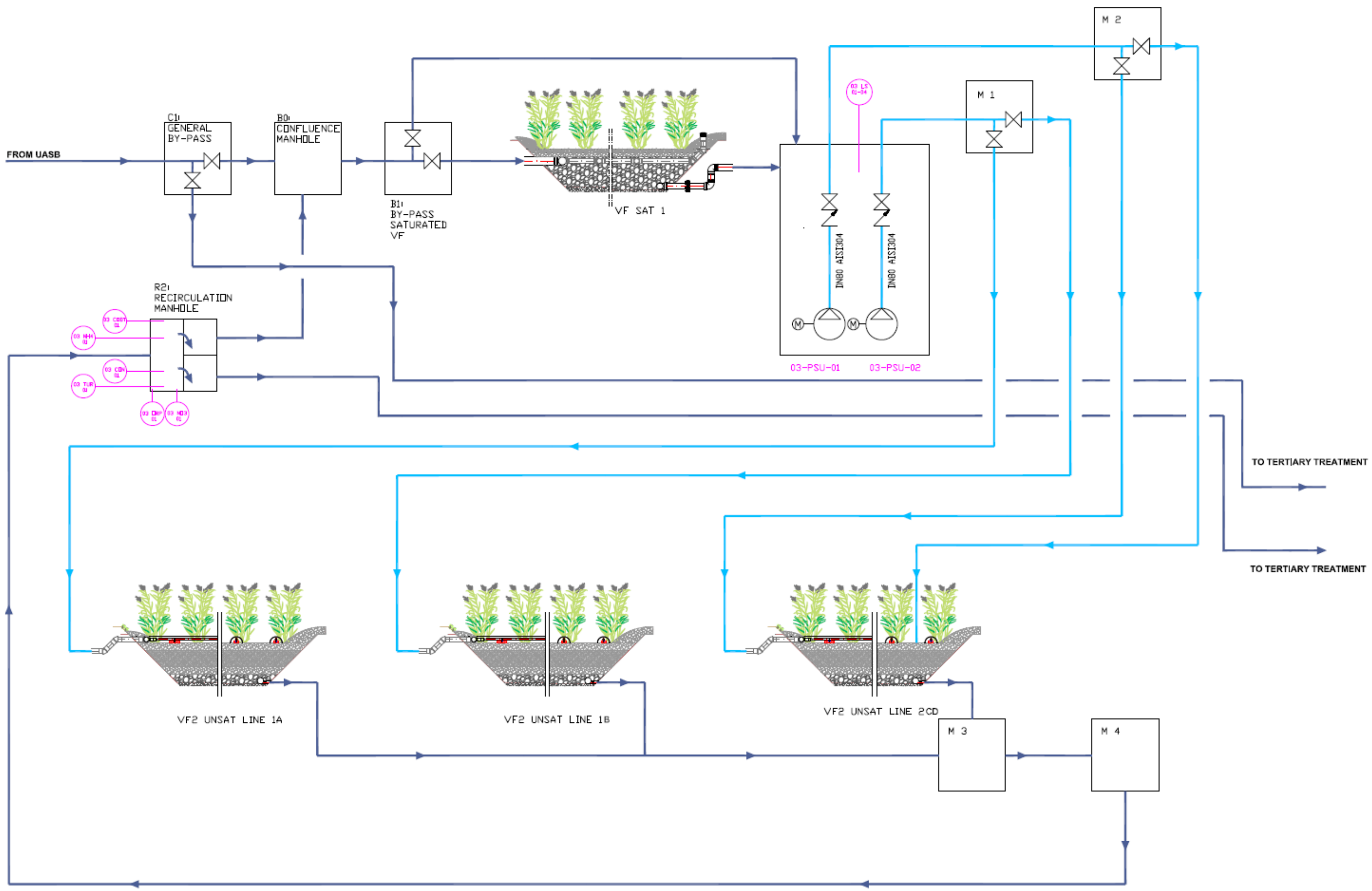

Figure 2.21. CW Line P&ID

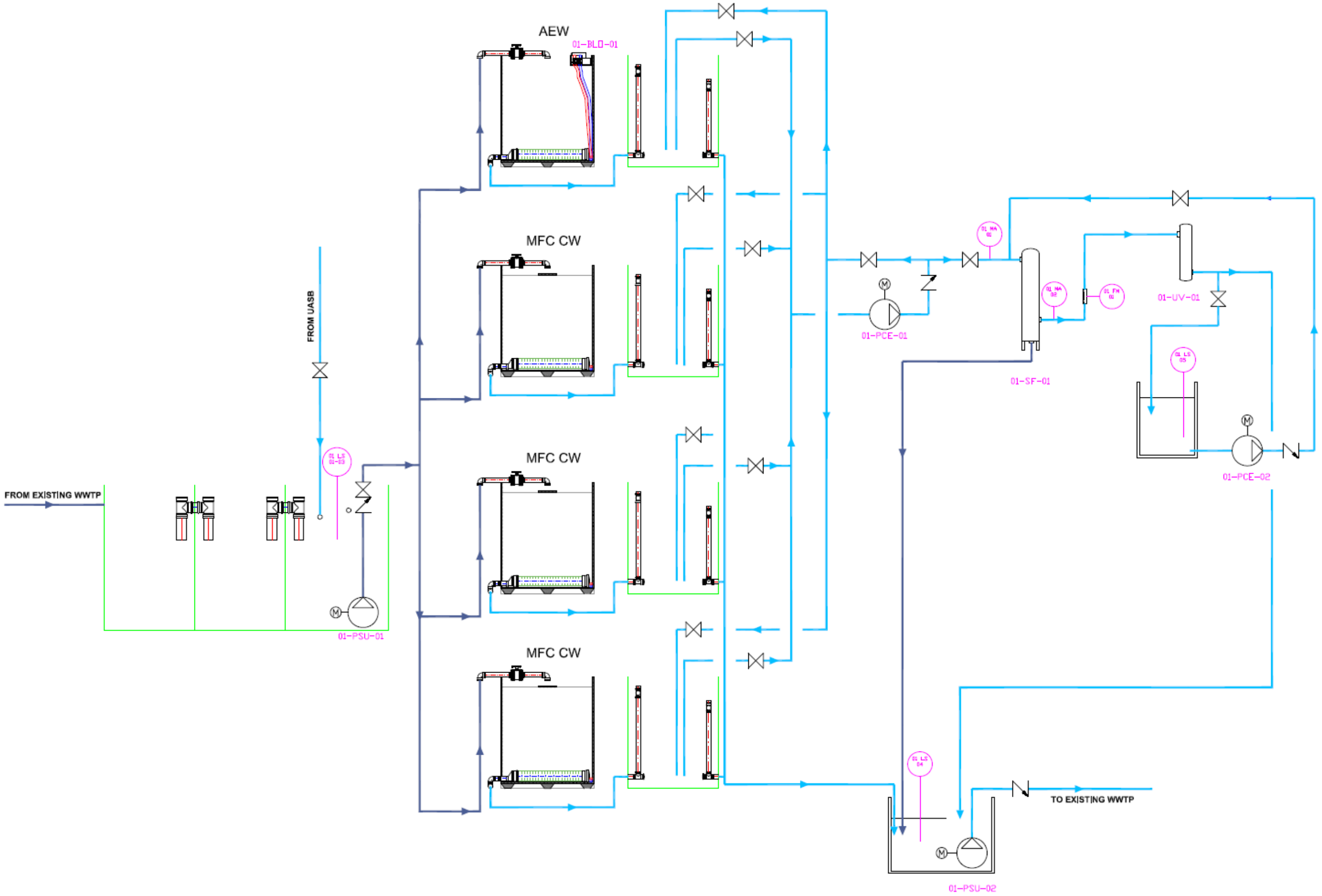

Figure 2.22. CW pilots P&ID

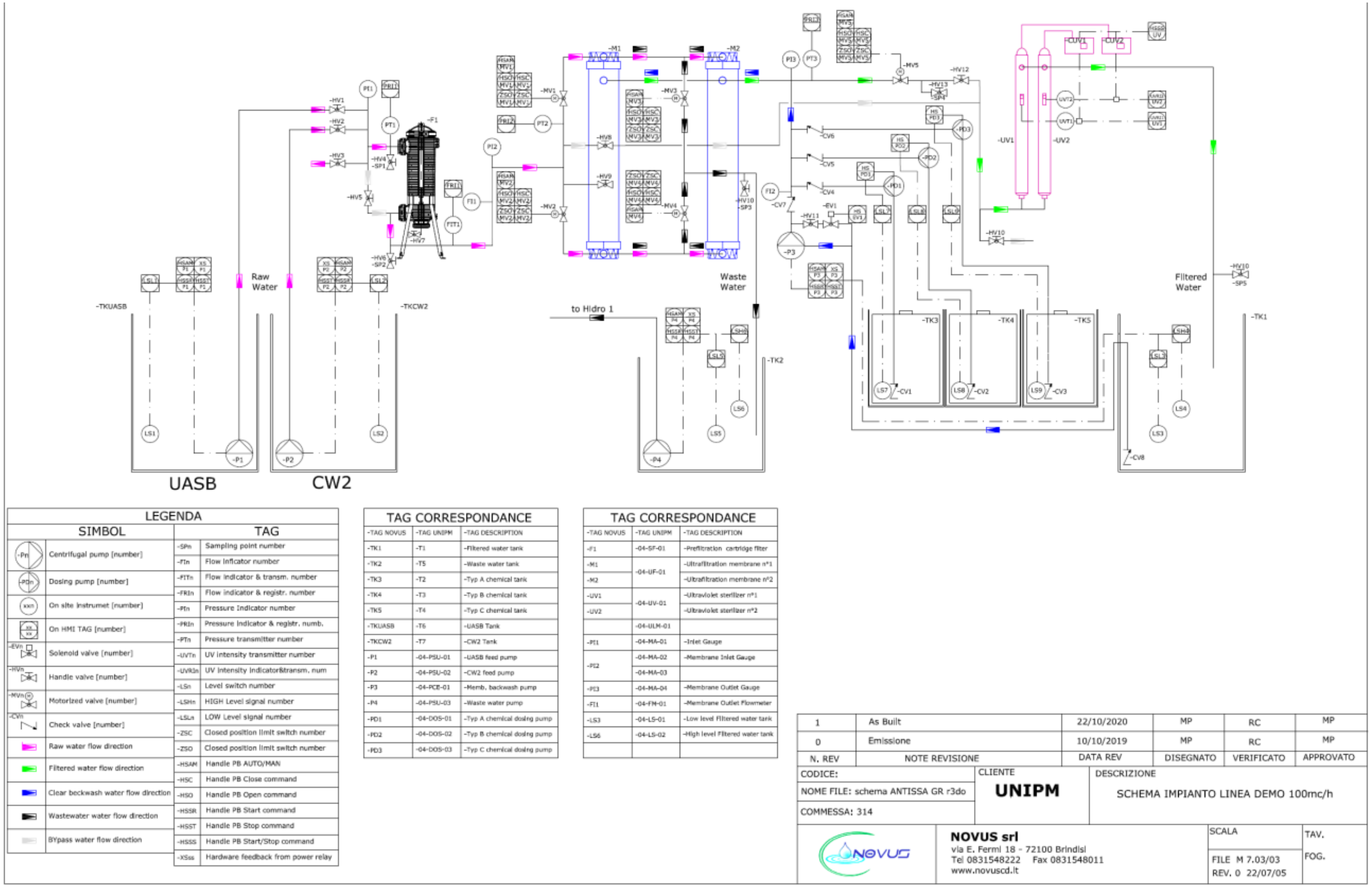

Figure 2.23. post-treatment FULL-SCALE Line P&ID

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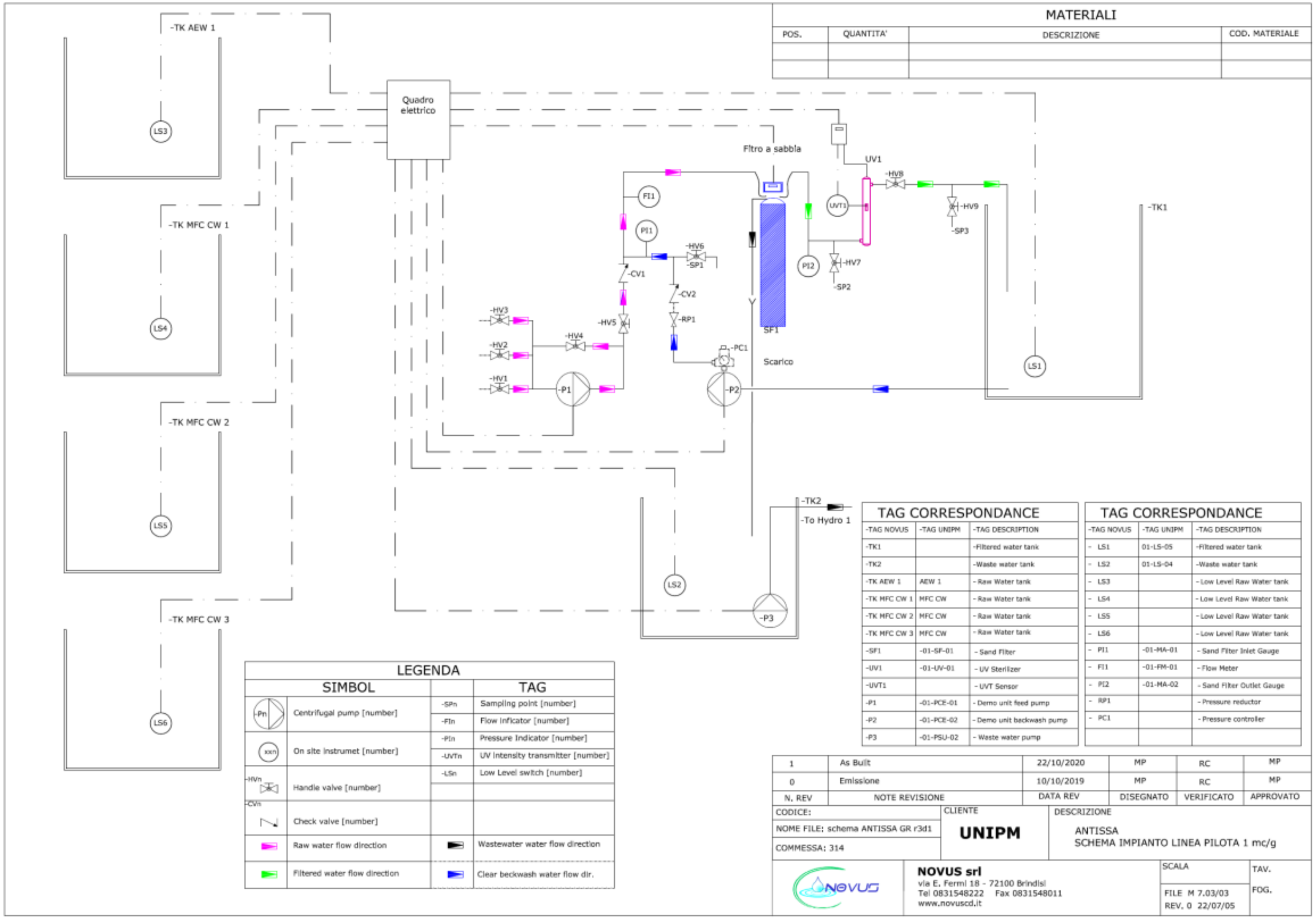

Figure 2.24. post-treatment PILOT Line P&ID

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3. EQUIPMENT

3.1Full scale CW system

The electro-mechanical equipment present in the full-scale system are:

- Submersible pumps;
- Floating valves;
- Check valve;
- Ball valves;
- Gate valves;
- Pressure Gauges.

3.1.1. Submersible pumps

To load VF2 UNSAT beds in each line of the treatment system, n°2 submersible pumps controlled by a control unit are installed in a reinforced concrete tank. The reinforced concrete tank is 2.5x3.25 m (external dimensions); the internal height has to be min. 2.5 m; the maximum water level of 1.85 m is controlled by an overflow pipe, which is connected to the finale effluent pipe towards tertiary treatment.

The pumping station for VF UNSAT loads the bed in a batch mode, controlled by switch level regulators, ensuring a resting period between every flush of approximately 3 h. Flush volume will be 6300 L.
The pumps are 2 (one per each couple of reed bed sectors) and they are centrifugal submergible with cast iron open channel impeller; flow 20 L/s Head 12 m, Nominal power 4.7 Kw, motor 400 V 50 Hz 3-phase.The design characteristics of the pumping station is shown in Table 3.1.

Table 3.1. Design characteristics of the pumping station

<table>
<tr><th colspan="2">DESCRIPTION</th><th>TAG NUMBER</th><th colspan="2">MODEL</th><th>MANUFACTURER</th></tr>
<tr><td colspan="2">Unsat VFCW loading pumping station</td><td>P1.1 – P1.2</td><td colspan="2">XYLEM NP 3127 HT 3~ 488 or similar</td><td>FLYGT OR SIMILAR</td></tr>
<tr><th colspan="6">OPERATING CONDITIONS</th></tr>
<tr><td>NUMBER OF UNITS</td><td>3</td><td></td><td>TYPE OF PUMP</td><td></td><td>Submersible Centrifugal with semi-open channel</td></tr>
<tr><td>LOCATION / DUTY</td><td>PS-A16</td><td>VFCW LOADING</td><td>CAPACITY (NORMAL / RATED)</td><td>m^3/h</td><td>72</td></tr>
<tr><td>MEDIA / MAX. DRY SOLID</td><td>SWA</td><td>1%</td><td>DISCHARGE PRESSURE</td><td>barg</td><td></td></tr>
<tr><td>VAPOUR PRESSURE</td><td>bara</td><td>0.0234</td><td>MIN. SUCTION PRESSURE</td><td>barg</td><td></td></tr>
<tr><td>VISCOSITY</td><td>Kg/(m x s)</td><td>0.001</td><td>MAX. SUCTION PRESSURE</td><td>barg</td><td></td></tr>
<tr><td>SPECIFIC GRAVITY</td><td></td><td>1 gr/cm3</td><td>DIFFERENTIAL PRESSURE</td><td>bar</td><td></td></tr>
</table>

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OPERATING TEMPERATURE (MIN/MAX)	°C	0 – 40	**TOTAL DIFFERENTIAL HEAD**	m	12
DESIGN TEMPERATURE	°C	6 – 25	**NPSH AVAILABLE**	m	
CONSTRUCTION DATA					
DESIGN STANDARD	Manufacturer Standard		**NUMBER OF STAGE**	Single Stage	
MOUNTING	Vertical		**TYPE OF IMPELLER**	self cleaning semi-open channel	
SPLIT TYPE	/		**IMPELLER DIAMETER (MIN / RATED / MAX)**	200 / 215 / 250	
TYPE OF INSTALLATION	Fix		**TYPE OF LUBRICATION**	Oil	
TYPE OF SEALING	Mechanical Seal		**BEARING TYPE (Radial/Thrust)**	Anti-friction	
MANUFACTURER OF SEAL	Manufacturer Standard		**TYPE OF COUPLING**	Closed Couple	
MOTOR DRIVE			**MATERIAL**		
MANUFACTURER		FLYGT OR SIMILAR	**CASING PUMP / MOTOR**	GREY CAST IRON ASTM 35B / GREY CAST IRON ASTM 35B	
MOTOR POWER	kW	4.7	**IMPELLER**	GREY CAST IRON ASTM 35B	
SPEED	rpm	1455	**SHAFT**	Stainless steel AISI431	
FEEDING VOLTAGE	V/ph/ Hz	400 / 3 / 50	**WEAR RING (IMPELLER / CASING)**	Nitrile rubber (NBR) 70°IRH / GREY CAST IRON ASTM 35B	
STARTING METHOD		DOL	**SEALING SYSTEM**	Corrosion resistant cemented carbide	
PROTECTION CLASS		IP 68	**DUCKFOOT, CLAW, SCREWS, NUTS**	STAINLESS STEEL AISI316L	
INSULATION CLASS / TEMP. RISE		F / B	**LIFTING CHAIN**	STAINLESS STEEL AISI316L	
SITE CONDITION			**INSPECTION AND TEST**		
AVERAGE AMBIENT TEMP. (MAX.)	°c	35	**PERFORMANCE TEST**	INCLUDED ☐	NOT INCLUDED ■
AVERAGE AMBIENT TEMP. (MIN.)	°c	0	**HYDROTEST**	INCLUDED ■	NOT INCLUDED ☐
RELATIVE HUMIDITY (MIN. / MAX.):	%	Unknown	**MECHANICAL RUNNING TEST**	INCLUDED ☐	NOT INCLUDED ■
AVERAGE ALTITUDE	m	68	**MATERIAL TEST CERTIFICATE**	INCLUDED ■	NOT INCLUDED ☐

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PERFORMANCE DATA					
CAPACITY @ BEP	m^3/h	72	**EFFICIENCY @ RATED POINT**	%	70
MIN. SUBMERGENCE LEVEL	m	0.38	**SHUT-OFF HEAD**	m	17.5
NPSH REQUIRED	m	2.74	**MAWP**	barg	
FREE PASSAGE SIZE	mm	215	**HYDROTEST PRESSURE**	barg	2.4
INSTALLATION DEPTH	m	3.3	**HYDROTEST DURATION**	min.	60
HYDRAULIC POWER	kW	4	**WEIGHT (PUMP / CLAW & FOOT)**	kg	147 / 35
ACCESSORIES			**SENSOR**		
LIFTING CHAIN	INCLUDED ■	NOT INCLUDED □	**MOTOR TEMP. SENSOR**	INCLUDED □	NOT INCLUDED ■
CLAW	INCLUDED ■	NOT INCLUDED □	**BEARING TEMP. SENSOR**	INCLUDED □	NOT INCLUDED ■
DUCK FOOT BEND	INCLUDED ■	NOT INCLUDED □	**WATER IN OIL SENSOR**	INCLUDED □	NOT INCLUDED ■
GUIDE RAIL	INCLUDED ■	NOT INCLUDED □	**MOISTURE SENSOR**	INCLUDED □	NOT INCLUDED ■
NOZZLE SPECIFICATION					
DESCRIPTION	**SIZE**	**RATING OF FLANGE**	**FACE OF FLANGE**	**LOCATION**	**STANDARD**
SUCTION	-	-	-	Bottom	-
DISCHARGE (DUCKFOOT BEND)	DN100				
NOTES					
1. Data sheet shall be fulfilled by vendor					
2. Deviation list to project documents to be submitted by vendor					
3. Following documents shall be submitted by vendor as minimum :					
●Performance curve ●Catalogue ●Name plate drawing ●Installation and operation manual ●Outline drawing ●Spare part list for commissioning / five years operation ● Paint procedures					
●Lubricant List including type and consumption ●Country of origin ● Cross section drawing including part list ● Sub supplier list ● Oil first filling ● Test procedures ● Packing procedures					

The pump is controlled by a control panel comprehensive of:

- Electrical protection and automatic or manual command of no. 2 pump 4.7 kW each, 400 V, 50 Hz
- Type of custody: Cabinet in SMC (fibreglass-reinforced plastic) in protected execution IP65 with hinge door. Type of custody: For external installation.
- The Local switchboards shall meet the requirements of degree of protection index IP55.

The panel contains mounted and connected the following materials:

- n°1 Rotary knife, lockable door blocking maneuver
- n°1 Fuse 3 pole with fuse to feature delayed
- n°1 Complete thermal relay contactors
- n°1 Selectors man-o-aut (manual position not stable) for each pump
- n° 2 Beamers with lamps for each pump
- 1 lights (pump marching) for each pump
- 1 lights (pump stopped) for each pump
- n° 1 single-phase transformer for auxiliary circuits adequate power - q.s. relay shutter operation (alternation)
- Control unit for pump switching and connection with start and stop switch levels

3.1.2. Valves

The valves type present are:

- Check valve;
- Ball valve;
- Floating valves;
- Butterfly valves;
- Gate valves.

Each pump is equipped with:

- check valve
- ball valve

The pumps control unit receives inputs from n° 4 **floating valves**, which regulate the water level within the tank as follow:

- Float 1 – LSLL: level switch lowest, emergency stop of pumps for lowest allowed level within the tank;
- Float 2 – LSL: level switch low, stop of the pumps for ending of the design flush volume to be feed;
- Float 3 – LSH: level switch high, start of the pumps for reaching of the design flush volume to be feed;
- Float 4 – LSHH: level switch highest, start of the pumps for highest allowed level within the tank

The butterfly valve is mainly used or installed for open or close pipes or part of the network but having a sensible capacity for controlling flow.

The feeding system of the VF bed is constituted by several small pipelines with hole every 1 m connected to a main distribution pipe. The branches are closed at the end through plags for allowing regular washings. A line can be stopped by simply closing the corresponding **gate valve** in the valve manhole. Gate Valves have been resilient seated with smooth straight through bore. Body and bonnet is of cast iron with non-rising stem of stainless steel spindle. The wedge is of ductile iron, inside and outside fully rubberised with vulcanised elastomer, the wedge guide of wear resistant plastic with high gliding features both suitable for potable water.

3.1.3. Pressure Gauges

Pump delivery pressure gauges have been mounted direct on to the pressure tapping in the delivery mains and be corrected to show actual pressure at the delivery flange of the pump. Each gauge has been fitted with a stainless steel isolating cock. Gauges ar of the Borden tube type with isolating diaphragm, brass case with flanged neck and stainless steel bezels. They have removable backplate to facilitate inspection and adjustment. Pressure range shall not exceed system working pressure more than 1.5 times.

3.2. Post-treatment of Full scale system

The electro-mechanical equipment present in the full-scale system are:

The list of all the equipment and their functions in the plant are reported below:

3.2.1. Full scale Line

- Pumps (P1 and P2): Influent pumps
- Pumps (PD1, PD2 and PD3): pumps for chemical reagents dosage during CEB;
- Pump (P3): UF Backwash pump;
- Pump (P4): Relaunch backwash discharge pump to inlet of HYDRO 1;
- Cartridge MF (F1): Pre-treatment to ensure adequate influent to UF membranes;
- UF Membranes (M1 and M2): Membrane modules for UF;
- Lamps (UV1 and UV2): Disinfection lamps;
- Tank (TK1): Disinfected reclaimed water storage tank;
- Tank (TK2): Backwash discharge storage tank;
- Tanks (TK3, TK4 and TK5): Chemical reagents storage tanks for CEB;
- Level sensors (LS1 and LS2): low level sensors in the influent tanks for influent pump activation;
- Level sensors (LS3 and LS4): low- and high-level sensors in TK1 for backwash pump operation;
- Level sensors (LS5 and LS6): low- and high-level sensors in TK2 for pump activation;
- Level sensors (LS7, LS8 and LS9): low level sensors in TK3, TK4 and TK5 for dosage pumps activation, respectively;
- Manual valves (HV4-SP1, HV6-SP2, HV10-SP3, HV13-SP4 AND HV10-SP5): sampling points;
- Flowmeter (FI1 and FI2): analogic flowrate indicator for influent to UF and backwash, respectively;
- Flowmeter (FIT1): Digital flowrate indicator and transmitter;
- Pressure gauge (PI1, PI2 and PI3): pressure indicator at microfilter inlet, UF inlet and UF outlet, respectively;
- Pressure meter (PT1, PT2 and PT3): pressure transmitters at microfilter inlet, UF inlet and UF outlet, respectively;
- UV transmittance (UVT1 and UVT2): intensity transmitters for the two UV lamps;
- PLC: Main control panel for monitoring and/or management of FULL-SCALE line units.

3.3. Pilot systems

The electro-mechanical equipment present in the pilot system are:

Pumping station for pilot system is controlled by timer and time switch, with emergency switch level on the bottom, ensuring n°12-24 starts per day per 90 seconds.

The selected pump has the following characteristics:
PUMP BODY: stainless steel AISI 304.
MOTOR FRAME: stainless steel AISI 304.
CHASSIS: cast iron
IMPELLER: cast iron or nylon impeller with technopolymer open type.
MOTOR SHAFT: stainless steel AISI 420.
DOUBLE SEAL: mechanical seal ceramic-graphite or silicon carbide with oil barrier chamber and inner lip seal to protect the seal in the event of dry running.
MOTOR: submersible asynchronous for continuous duty.
V: single-phase 220 V - 50 Hz with capacitor and thermal overload protector.
INSULATION: class F
PROTECTION: IP 68
Nominal flow: 1.8 m^3/h; Nominal Head: 3 m; Power nominal capacity: 0.3 KW
Coupling and cable:
Coupling system complete with base, sled scrollable and brings top guides.
Electric submarine cable neoprene H07RN-F
Limits of use
Immersion depth up to 5 m
Liquid temperature up to +40
Passage of suspended solid bodies up to 30 mm
For continuous duty: minimum immersion 290 mm from pump base

The pump is controlled by a control panel, contained in a Box in protected execution IP55 with hinge door, for external installation, including:
1. Electrical protection and automatic or manual command of no. 1 pump
Type of custody: Cabinet in SMC (fibreglass-reinforced plastic) in protected execution IP44 with hinge door.
Type of custody: For external installation.
Motoring start-up: Star/Triangle
The Local switchboards shall meet the requirements of degree of protection index IP55.
Power supply: 400 V - 50 Hz.
2. The panel contains mounted and connected the following materials:
n°1 Rotary knife, lockable door blocking manoeuvre
n°1 Fuse 3 pole with fuse to feature delayed
n°1 Complete thermal relay contactors
n°1 Selectors man-o-aut (manual position not stable)
n° 2 Beamers with lamps
1 lights (pump marching)
1 lights (pump stopped)
n° 1 single-phase transformer for auxiliary circuits adequate power - q.s. relay shutter operation (alternation)
n°1 digital timer that control the duration of cyclical pause-work phases. The timer has to permit to put data in minutes.

The pump is equipped with a PVC ball valve 2" and electromagnetic flowmeter 2".
The pilot system will receive a total maximum flow rate of **4 m^3/d**; therefore, a total of maximum 1 m^3/d are diverted to feed each pilot systems. The influent is derived by a small pump from the wastewater entering the main WWTP, after the preliminary treatments, and it is pre-treated in a septic tank.

3.3.1. Pilot Line post-treatment

The list of all the equipment and their functions in the plant are reported below:

- Pump (P1): Influent pump
- Pump (P2): SF Washing pump;
- Pump (P3): Relaunch backwash discharge pump to head of HYDRO 1;
- Sand filter (SF1): Sand filtration;
- Lamp (UV1): Disinfection lamp;
- Tank (TK1): Disinfected reclaimed water storage tank;
- Tank (TK2): Backwash discharge storage tank;
- Level sensors (LS3, LS4, LS5 and LS6): level sensors in the influent tanks for influent pump activation;
- Manual valves (HV6-SP1, H7-SP2, HV9-SP3): sampling points;
- Flowmeter (FI1): analogic flowrate indicator for sand filtration effluent;
- Pressure gauge (PI1 and PI2): pressure indicator at sand filtration inlet and outlet, respectively;
- UV transmittance (UVT1): intensity transmitters for the two UV lamp;
- Panel: control panel for manual management of PILOT line pumps and UV lamp.

3.3.2. AEW pilot system

- Membrane blower BIBUS JDK50;
- pressure gauge;
- pressure relief valve;
- filter;
- check valve;
- ball valve

3.3.3. MFC WETLAND pilot system

- Siliceous gravel as filling material
- Electro-conductive carbon as filling material
- 3 ball valves
- Bio-electrochemical sensors and hardware

3.4. Operating manuals

Full scale CW plant

The pump should be checked at least once per year:

- Impeller and bearings;
- External appearance.

All controls and the maintenance on the pumps and control panel has to be done by skilled labour, following the user instructions of the component (see **Annex 2**).

Valves and pressure gauges are mainly equipment of the pumping system. Control and maintenance operation to be carried out for the pumping system are described in the maintenance manual (see **Annex 2**).

Operating manuals of post-treatment units are reported for both FULL-SCALE and PILOT lines in **Annex 2**.

4. CONSTRUCTION AND START-UP

4.1. Construction and installation process

4.1.1. Construction activities for constructed wetlands

The construction activities for the VF1 SAT unit were:

- Realization of the terrace, according to the project drawings after appropriate regularization of the surface eliminating sharp rocks (Figure 4.1);
- Along the edges of the bed, dig a small trench to tuck in the geotextiles and the liner
- Installation on the bottom and the banks of nonwoven geotextile (minimal density 300 g/m^2);
- Placing on the bottom a sand layer of averagely 10 cm depth, according to the slopes indicated in the drawings (Figure 4.4)
- Installation of the waterproofing layer by HDPE liner 1.5 mm, on site thermo-welded (Figure 4.5)
- Realization of pipe passage by HDPE sheets 0.5x0.5 m thickness 1.5 mm pre-welded to a HDPE pipe
- Installation of second layer of geotextile (minimal density 300 g/m^2) (Figure 4.6)
- Placing of the HDPE liner margins inside the boundary trench and backfilling with the excavated material
- Installation of the drainage system (Figure 4.7)
- Filling the bed with the different layers of gravels (Figure 4.9):
    - 10 cm fine gravel ∅ 5-10 mm;
    - 10 cm gravel ∅ 10-20 mm;
    - 80 cm coarse gravel ∅ 30-50 mm;
- Installation of the feeding system on the surface of the bed, and covering with the final gravel layer (Figure 4.8)
- On the perimetral banks: placing of gravel as protection versus rainwater runoff
- Plant the reeds (*Phragmites Australis spp)* in the gravel, with a density of 4 plants/m^2 (Figure 4.11)

The construction activities for the VF2 UNSAT unit were:

- Realization of the terrace, according to the project drawings after appropriate regularization of the surface eliminating sharp rocks;
- Along the edges of the bed, dig a small trench to tuck in the geotextiles and the liner
- Installation on the bottom and the banks of nonwoven geotextile (minimal density 300 g/m^2);
- Placing on the bottom a sand layer of averagely 10 cm depth, according to the slopes indicated in the drawings
- Installation of the waterproofing layer by HDPE liner 1.5 mm, on site thermo-welded
- Realization of pipe passage by HDPE sheets 0.5x0.5 m thickness 1.5 mm pre-welded to a HDPE pipe
- Installation of second layer of geotextile (minimal density 300 g/m^2)
- Placing of the HDPE liner margins inside the boundary trench and backfilling with the excavated material
- Installation of the aeration and drainage system
- Fill the bed with the different layers of gravels and sand:
    - 20 cm fine gravel ∅ 5-10 mm;
    - 40 cm fine gravel ∅ 0.2-5 mm;
    - 20 cm fine gravel ∅ 5-10 mm;

- 20 cm coarse gravel ∅ 20-40 mm;
- Installation of the feeding system on the surface of the bed
- On the perimetral banks: placing of gravel as protection versus rainwater runoff

- Plant the aquatic species (*Typha, Iris, Carex, Scirpus)* in the gravel, with a density of 4 plants/m^2 (Figure 4.11)

The construction activities for the pumping station unit were in strict accordance with the manufacturer's instructions. Equipment installation and required connections have been made by skilled tradesmen to the best standard. The works were accurately carried out to produce a neat, accurate, secure, functional installation.
The anchor bolts and concrete bases for the pumping units cast iron or steel bases were prepared in advance. The pump and motor bases have been set in place and shimmed to correct elevation. The bases have been grouted in place with non-shrink grouting.
Upon completion of installation of the pump equipment, checking of equipment requiring oils, coolants, greases etc has been implemented. The types and amount used were in strict accordance with the manufacturer's instructions.
Proper attention has been given to the pressure flange that the pump is set to in order to ensure that the pump submergence conforms to the manufacturer's recommendations. The waterproof power and control cables has been securely attached to the discharge pipe free of kinks.

4.1.2. Construction activities for pilot systems

Inlet facilities

Prior to the four pilot units, a tank has been constructed for primary treatment of the raw municipal wastewater. The tank consists of two chambers (serving as septic tank) and an adjacent pumping station, with a total net volume of 2.30 m^3. The pumping station is equipped with a submerged centrifugal pump made of stainless steel that has been placed for feeding the pre-treated wastewater from the septic tank to the four pilot units. Furthermore, a concrete base for the installation of the pilot units was constructed.

Bio-electrified constructed wetlands

Installation activities:

- Construction of the three pilot units at the workshop
- Shipment of the units
- Unloading of the units
- Placement of the three units on the concrete basis
- Hydraulic connections (distribution and effluent pipes)
- Planting of the pilot units

Aerated constructed wetland

Construction phases:

- Realization of n°1 outlet pipe;
- Installation of the air distribution system on the bottom of the bed as per drawing;
- Fill the bed with selected medium gravel and sand layers, as per drawings, until an average height of 1.05 m from the bottom.
- Installation of the distribution system;
- Installation of outlet control chamber.

Figures of the different construction phases are shown below (Figure 4.1 - Figure 4.11) along with the water level regulation device (Figure 4.12), the pumping station (Figure 4.13), the MFC units (Figure 4.14), and the Bio-electrified pilot units (Figure 4.15 and Figure 4.16).

Figure 4.1. Excavation of wetland basins

Figure 4.2. excavation for pumping station

Figure 4.3. preparation of the bottom of wetland basins

Figure 4.4. preparation of the sand bottom of wetland basins after placing of geotextile

Figure 4.5. waterproofing of wetland basins by HDPE liner

Figure 4.6. placing of geotextile 2nd layer in wetland basins

Figure 4.7. placing of drainage system in wetland basins

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Figure 4.8. preparation of the distribution system in VF SAT

Figure 4.9. placing of gravel and sand material in wetland basins

Figure 4.10. placing of plants in VF UNSAT wetland basins

Figure 4.11. placing of plants in VF SAT wetland basin

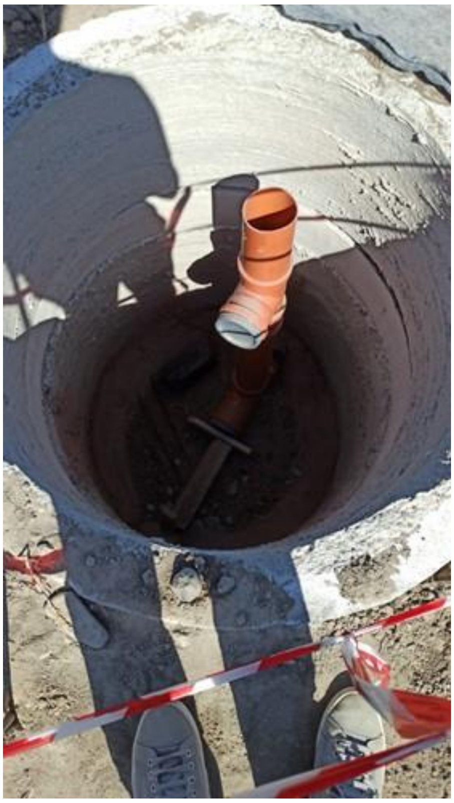

Figure 4.12. water level regulation device for wetland basins

Figure 4.13. pumping station

Figure 4.14. MFC units ready for shipping

Figure 4.15. Bio-electrified pilot units unloading

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Figure 4.16. Bio-electrified pilot units in place

Construction activities for post-treatment

Post-treatment units for both FULL-SCALE and PILOT plants were separately assembled in two metallic skids. Specifically, each single unit (e.g. Microfiltration, UF modules and UV lamps for FULL-SCALE line and SF and UV lamps for PILOT line) was installed on the skid and connected to the piping system. Valves were placed for both sampling and regulating flow and pressure.
Finally, electrical panels were installed on both the skids and electrical connections of the different units.
Following the completion of the two posts-treatment units in the workshop their shipping took place.
In order to install the two systems on-site two cement bases and shelters were constructed. Upon arriving on-site, the two systems were installed.

Following, some photos of the two post-treatment units are presented (Figure 4.17 - Figure 4.23).

Figure 4.17. FULL-SCALE unit at the lab

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Figure 4.18. PILOT unit at the lab

Figure 4.19. Post-treatment units transportation

Figure 4.20. Post-treatment units arrival on-site

Figure 4.21. Post-treatment units unloaded on-site

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Figure 4.22. Full-scale post-treatment unit installed on-site

Figure 4.23. Pilot post-treatment unit installed on-site

4.2. Start-up

Information regarding Start-up are included in Annex 2 and 3 for all the systems.

4.2.1. FULL scale CW SYSTEM

Vegetation start-up

To favour the start-up of the vegetation in the VF reed beds, clean fresh water has been used.

There were three phases to water level adjustment during vegetation start-up:
Phase 1: maintaining the water level minimum 10 cm below the gravel surface to permit the initial planting;
Phase 2: increase the water depth until approximately 5 cm above the gravel surface for about 1 month: the emergent shoots were above the water surface at all times to give the plants access to sunlight and oxygen.
Phase 3: Setting the water level at the design standard depth after plants are established and start of the loading with wastewater: in VF UNSAT reed bed it is suggested to maintain for the first 6 months a level of about 30 cm above the bottom inside the beds.

Sixty days after the completion of the planting, a satisfactory stand was defined as one in which: (1) spacing between plants averages 1 m or less; (2) the plant survival averages at least 80 percent; and (3) no areas of greater than 10 contiguous m^2 with a plant survival rate of less than 50 percent.

Once emergency plants were well established, replanting is not needed unless the plants are damaged by wild animals or the system is stopped for more than 2-3 months in the dry season. Planting and replanting operations have to be performed in the appropriate season (April-June or September-October); July and August are not recommended if the temperature is too high, whereas a plantation during October-November could be risky because the plants could not have the necessary time to well establishment and they could be damaged during the winter season.

During the first 1-2 years, it is very important to control the diffusion of weeds inside the beds that can make difficult the propagation of reeds. Weeds shall be removed manually, checking the surface of the beds one time per month during spring and summer.

Wetland basins water tightness

The constructed wetland basins have been tested for water-tightness in the following phases:

- at HDPE liner completion;
- at the end of filling phase.

The basins were filled according to the design. After filling to top water level, the water stood for 3 days. The liquid level was recorded every 24 h for the 3 days. The wetland basin was considered watertight as the total drop in surface level was equal zero after three days, excluding the evaporation losses related to the climatic conditions (in a dry period a loss of 1 cm/day is normally accepted).

Hydraulic testing

All sub-units of CWs system have been hydraulically checked. The hydraulic test of the UNSAT pump station took place successfully by setting the level of the pump start/stop level sensors to regulate the operational scheme of the pumps i.e., the automation. The pumping station was then filled with water (mixture of rainwater and clean tap water), coming from the effluent of the already full UNSAT beds, by gravity. Thus, UNSAT effluent piping was tested, as well. The closed loop, that was created, started with the routing of the UNSAT effluent routing through the recirculation manhole back to the SAT and – or directly – to the UNSAT subsystem, through the pump station. Finally, using this closed loop, the proper operation of the CW beds' feeding system was also confirmed (Figure 4.24, Figure 4.25).

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Figure 4.24. Hydraulic testing activities for CWs pumping station

Figure 4.25. Testing CWs feeding system

Start-up of the system

Figure 4.26. SAT CW effluent pit (left) and UNSAT CWs pumping station with SAT effluent (right)

4.2.2. Post-treatment

The start-up process of the post treatment for the Full-scale unit is reported below.

Firstly, the skid was placed on a levelled surface. Then, the metallic structure were connected to the grounding network of the system through the appropriate connection on the side upright.
The power supply was connected to the general panel as indicated in Figure 4.27, paying attention to respect the cyclical direction of the phases.

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Figure 4.27. Full-scale power supply panel

For the hydraulic connections, it was verified that the “IN UASB” was connected to the submerged pump installed in the UASB storage tank (P1). The "IN CW2" connection was connected to the submerged pump to be installed in the storage tank CW2 (P2). The “OUT RECIRCULATION” connection was connected to a pipe positioned in the treated flow tank.
The "IN CLEAN WATER FOR BACKWASH" was connected to the pipe installed on the filtered water tank. Before activating the system, the suction duct through the point set up near the filtered water tank was filled. The “WASTEWATER” connection was connected to the accumulation tank of the backwash discharge.
Finally, the “UV BYPASS” was connected to the filtered water tank in order to exclude the UV treatment (Figure 4.28).

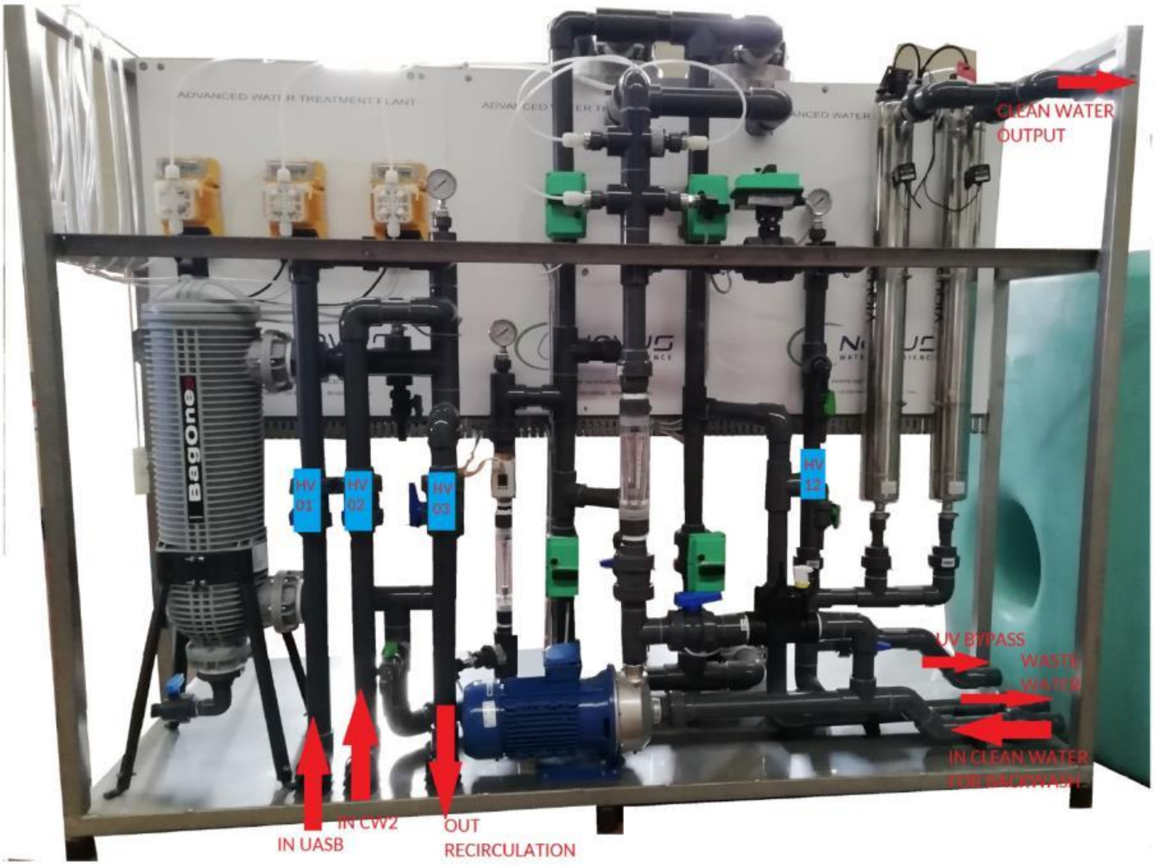

Figure 4.28. FULL-SCALE unit connections

The connections of the wastewater and filtered water tanks are highlighted in Figure 4.29. After installing the pipe which connects the filtered water tank to the P3 backwash pump, the suction pipe to ensure the priming of the P3 pump was filled.

Figure 4.29. FULL-SCALE wastewater and filtered tanks connections

Below the installation of the P4 pump from TK2 to HYDRO1 is shown (Figure 4.30).

Figure 4.30. FULL-SCALE P4 Pump installation

The start-up of the system is reported below.
Once the system was positioned and all the hydraulic and electrical pipes were installed, the following checks were performed:

- P1 and P2 pumps are correctly installed and connected,
- The P4 pump is correctly installed and connected,
- The LS1 level is correctly positioned as a minimum level sensor in the UASB tank where the P1 is installed,
- The LS2 level is correctly positioned as a minimum level sensor in the CW2 tank where the P2 is installed,
- The LS3 and LS4 levels are installed respectively as minimum and maximum level sensors of the TK1 tank,
- The level LS5 and LS6 are installed respectively as minimum and maximum level sensors of the TK2 tank,
- The LS7 level are installed on the suction port of the PD1 dosing pump and together positioned in the TK3,
- The LS8 level are installed on the suction port of the PD2 dosing pump and together positioned in the TK4,
- The LS9 level are installed on the suction port of the PD3 dosing pump and together positioned in the TK5,
- the manual valves are positioned as shown in the table below,

Table 4.1 UASB FEEDING

VALVE	STATUS
HV1	Open
HV2	Closed
HV3	Open 1/4
HV5	Closed
HV8	Closed
HV11	Closed
HV12	Open 1/4

Table 4.2 CW FEEDING

VALVE	STATUS
HV1	Closed
HV2	Open
HV3	Open 1/4
HV5	Closed
HV8	Closed
HV11	Closed
HV12	Open 1/4

- the free part of the flexible hose connected to the “OUT RECIRCULATION” line is positioned in the UASB tank,

- On the "FILTERING" page of the PLC panel (Figure 4.31), the "Pump selection" button was used, as shown in the center of the page in the "GENERAL SETTINGS" section, until the message "Pump P1 UASB Selected" appears in the box (if you want to work with tank CW2 select "Pump P2 CW2 Selected"),

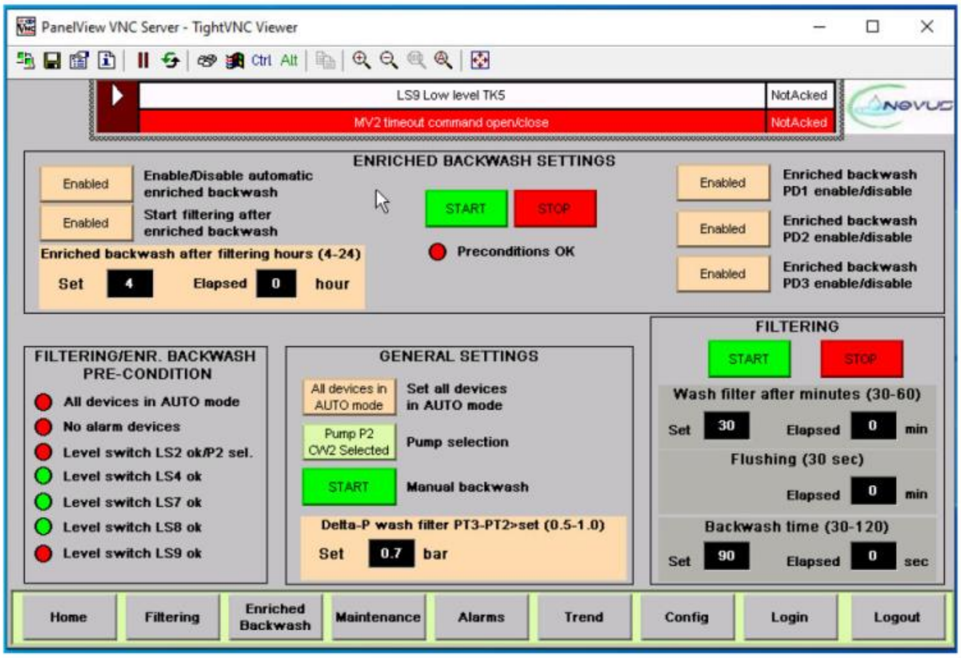

Figure 4.31. FULL-SCALE PLC Filtering Page

- Set the options dedicated to the backwash procedure enriched by the Enable / Disable buttons located on the "FILTERING" page of the panel, within the "ENRICHED BACKWASH" box,
- Make sure that the preconditions indicated in the “FILTERING / ENR. BACKWASH PRECONDITION "are all on (green). To simplify the automatic setting of all components, a special button has been set up in the" GENERAL SETTINGS "box, called" Set all devices in AUTO mode ". By clicking on this button, all the controls will be switched to automatic mode. If some or all of the dosing pumps are disabled, the chemical tank levels won’t be considered in the starting sequence, so even if a red indicator is detected, the conditions will be sufficient to start the process,
- Once the settings are all defined, the system can be started by pressing the green “START” button in the “FILTERING” box on the right,
- Once the flows reach stable conditions, adjust the valves HV1, HV3, HV12 in order to stabilize the pressures P1 = 1 bar, PI2 = 1 bar, PI3 = 0.8 bar and the flow rate FI1 = 80 L / min.

The installation process of the PILOT unit is described below.
Firstly, the skid was placed on a levelled surface.
Then, the metallic structure was connected to the grounding network of the system through the appropriate connection on the side upright.
The power supply was connected to the general panel as shown in Figure 4.32.

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Figure 4.32. PILOT power supply panel

For the hydraulic connections the following steps were verified.
The "RAW WATER INPUT" connection was connected to the CWs collection tanks.
The “CLEAN WATER INPUT FOR BACKWASH” connection was connected to the base of the TK1 tank.
The “WASTEWATER” connection was connected to the TK2 storage tank (Figure 4.33).

Figure 4.33. PILOT unit connections

In order to facilitate the installation of the pump for the washing discharge, firstly the hose to the pump was connected and then the pump was inserted into the tank and connected it as shown in Figure 4.34.

Figure 4.34. PILOT Pump installation

Once all the pipes were connected, the influent tanks were filled with CWs effluent and then, power was provided to the system.

To start running the system, the related valve placed on the influent pipeline was opened thus, the corresponding selector was switched on. It was important to ensure that the influent pipeline was always under hydraulic head, to guarantee the priming of the pump.

The influent flowrate was adjusted by manually regulating valve (HV4).

It was necessary to set standard flow and pressure conditions, by manually acting on HV3, HV4, HV5 and HV8 valves in order to reach following values:
PI1 = 2.5 bar,
PI2 = 2.5 bar,
FI1 = 4 l/min.

4.2.3. CW pilot systems

Start-up of the pilot systems does not require different activities from the ones described for the full-scale system. After testing of E&M equipment, they have been set up to start the monitoring based on the design values. Firstly the septic tank was filled and the pump was set in operation to feed the four pilot units. The actual flowrate to each pilot unit was adjusted by handling of the respective four valves (one at each system).

4.3. Operation manual and safety instructions

The Operation & Management Plan is an essential practice to assure:

- the right functioning of the wastewater treatment plant (WWTP) with a stable fulfilment of the chosen treatment goals;
- an enlargement of the WWTP operating period;
- a complete comprehension of the operating procedures;
- timely diagnosis of serious problems, e.g. continuous overloading.

Information about operation and maintenance are included in **Annex 1** for all the systems

4.3.1. Full scale CW system

Constructed wetlands are designed for an easy management with a discontinuous effort, but they require a certain care and observation due to their nature of complex dynamic ecosystems which involves a lot of different variables.

The system operates independently without the need for any intervention during operation: any chemical-physical parameters have to be kept under constant control and any operational modification has to be performed, on the contrary as it is common for traditional biological systems.

The routine operation and maintenance (O&M) requirements for submerged wetlands include hydraulic and water depth control, inlet/outlet structure cleaning, grass mowing on berms, inspection of berm integrity, wetland vegetation management, and routine monitoring.

The **water depth** in the VF2 UNSAT beds doesn't need periodic adjustment because the water is drained on the bottom of the bed, completely dewatering it after each loading; in VF1 SAT wetland, instead, the level is fixed by the regulation device in the outlet manhole, allowing a constant water level under the gravel surface.

Mosquito control should not be required for a subsurface flow (SSF) wetland system as long as the water level is maintained below the top of the media surface during each loading and the beds are maintained empty.

Vegetation management in these SSF wetlands does not include a routine harvest and removal of the harvested material. Plant uptake of pollutants represents a relatively minor pathway so harvest and removal on a routine basis does not provide a significant treatment benefit. Therefore one cut per year is enough. Removal of accumulated litter is also necessary. By the way, our suggestion is to cut and remove all the died plants every year, starting from the second year from plantation, cutting them over the bed surface and taking care in not damaging their roots.

Routine **water quality** monitoring has been organized in the context of Task 5.1.

Operation

Natural treatment systems are relatively simple to operate; in case of VF2 UNSAT, the most important activity is the control of the pumping system, the checking of the observance of rest/loading period and the uniformity of the wastewater distribution; in case of VF1 SAT the flow passes through the bed by gravity without any necessary regulation, checking only periodically if clogging issues are appearing in the inlet section. The simplest gravity flow control system in the wetland cell is either a simple weir or elbow pipe structure.

Constructed Wetlands must be managed if they are to perform well. Wetland management should focus on the most important factors in treatment performance:

- assuring the correct loading and resting periods for VF2 UNSAT beds
- respecting the maximum capacity in terms of organic and hydraulic loads
- assuring that flows reach all parts of the wetland
- maintaining a healthy environment for microbes
- maintaining a vigorous growth of vegetation.
- In VF1 SAT bed a precise water level control in the wetland cell is important to ensure the best results in term of removal: water level has to be kept 10 cm below the gravel surface, keeping open the 2nd plug from the top and the rest closed. In VF2 UNSAT beds the normal operating water depth for a VF wetland cell is about 5 cm and it is obtained maintaining the lower plug in the regulation manhole open. To enhance denitrification, it is possible opening the second plug from the bottom and closing the rest.
- Shallow flooding (2-5 cm) is a very occasional condition adopted for extraordinary maintenance closing all the plugs except the upper one, and it can limit invasion of weedy or terrestrial species once the wetlands plants have stems higher than 8-12 cm (it is absolutely essential that stems and leaves of desirable species rise up well above the water's surface to avoid drowning of new or even older established plants). In this case the extension of the beds is limited and we suggest to control the weeds manually, using flooding conditions only in extraordinary cases and in absence of people.
- Small submersible pumps provide a precise method of flow control. The control can consist simply of a submersible pump per 2 VF2 UNSAT sectors, allocated in the same tank, attached to four floating device. A control panel manages the alternate activation of each pump. The pump would direct flow to the VF feeding system, and then gravity flow would take over.

After the first year of operation, the operation and maintenance typically consists of walking around the boundary of the beds at least once a week to check for any damage on the structure or animal damage in the bed, to check to correct operation of the pump system weekly and to collect water quality samples as needed

- Routine weekly inspections are necessary to ensure appropriate flows through the inlet distributor and outlet collector piping as well as leaks in the piping itself.
- Flow distribution within cells should be occasionally inspected to detect if there are obstructions in the feeding pipes; pipes are covered so it is not possible any visual inspection without removing gravel and coverage pipes: in any case obstructions are very infrequent if the pumping system operates daily, and to check if there are some obstructed holes it is enough to check the uniform growth of the plant.
- wetlands vegetation should be checked at least once a week to identify any visible signs of stress or disease such as grass yellowing, chlorosis, leaf damage, etc. Should stress or disease be noticed, a specialist should be consulted.
- Pumps, valves. should be checked at least once each week to ensure that pumps and all piping are operating properly.
- The wetland should be operated with clean water or very low-strength wastewater for the first month after planting. During the fifth week, initiate operation with one-half the design flows and

continue for one month. After the end of the second month, begin operation with full-strength wastewater or with full design flows. Check proper operation of all piping, pumps and water control structures and monitor vegetation.

Operation and maintenance (O&M) are described in this O&M plan. The plan has to be updated to reflect specific system characteristics learned during actual operation.

HYDROLOGY
Constructed wetlands should be checked to see that surface flow is not developing. If water is noticed on the top of the surface except during each feeding phases, it means that clogging of the superficial media filter has occurred and the instructions included in the clogging section of this manual have to be followed in order to recover the perfect functionality of the system.
Stagnant water on the surface decreases removal and increases the likelihood of mosquitoes and unsightly conditions. Flows and water levels should be checked regularly!

STRUCTURES
Dikes, spillways, and water control structures should be inspected on a regular basis and immediately after any unusual flow event. Constructed Wetlands should be checked after high flows and after heavy rainfall. Any damage, erosion, or blockage should be corrected as soon as possible to prevent catastrophic failure and expensive repairs.

VEGETATION
Weed control is the key to determining the success of vegetation; vegetation should be inspected regularly and invasive species should be removed. Herbicides should not be used except in extreme circumstances, and then only with extreme care, since they can severely damage emergent vegetation. The roots of shrubs and trees can create damages to the waterproofing liner and subsequent leakage throughout the berms.
Considering the limited extension of the beds, this activity can be done manually and only in rare case in absence of people by temporary flooding conditions.

Annex 2 contains the Operational and Maintenance plan of full scale system.

4.3.2. Post-treatment

Operation and maintenance (O&M) of post-treatment units include the following periodical monitoring:

- **Pumps:** control of the wastewater level and level sensor in the tanks to ensure the priming of the pumps and avoid air pumping;
- **Valves:** control of the water tightness of all the valves;
- **Micro Filter:** monitoring of inlet pressure (< 6 bar). Values of PI1 = 1 bar, PI2 = 1 bar and flow rate FI1 = 80 l / min are recommended. Periodical sampling of the effluent quality is necessary;
- **UF:** monitoring of inlet pressure (< 5 bar) and TransMembrane Pressure (TMP) (e.g. < 0.1-1.5 suggested 0.7 bar). Values of PI2 = 1 bar and PI3 = 0.8 bar are recommended. Daily backwash cycle should be ensured (every 30-60 mins, suggested 45 mins to be defined also according to the fouling level). CEB suggested every 1 or 2 days, frequencies to be defined also according to the operative conditions and fouling. Periodical sampling of the effluent quality is necessary;
- **UV:** Check UV intensity values. If it lowers of about 15-20%, clean the sheath to avoid a reduction of UV light that reaches the water. The need to clean the sheath will be indicated by a low ultraviolet alarm (the red indicator light flashing next to the sensor on the control panel). When only cleaning is required, follow the instructions and reinstall the current lamp. Lamp replacement every 12 months. NOTE: The ultraviolet

system is designed to operate continuously and should not be turned off for short periods of time, for example a period of less than three weeks. Models D4, E4, F4 and Plus: the system warns automatically after 12 months to replace the lamp. Periodical sampling of the effluent quality is necessary;

- **SF:** Monitoring of the main operative parameters (e.g. PI1= 2.5 bar, PI2= 2.5 bar, FI1=4 l/min). Check the water meter, if present, and take note of the water meter settings. Check the total water consumption and record the static and dynamic pressure, noting the pressure drop. Make sure that the inlet pressure respects the valve limits. For any further details please refer to the related manual. Periodical sampling of the effluent quality is necessary. At the end of SF batch operation, washing cycle is always needed.

4.3.3. CW Pilot systems

Operation and maintenance of the pilots systems require at a smaller scale the same activities of large scale CW.

The primary treatment needs periodical desludging (generally once per year) and frequent checking (every 3 months) to check if scum or other floating material is obstructing influent and effluent device.

Pumping station needs to be periodically checked and the flow adjusted to the monitoring plan.

In aerated wetland, the membrane blower was set to operate in accordance with pump cycles; if the AEW pump starts every hour (Y=60 minutes), therefore the aeration start together with the pump for a duration of X minutes and a rest period of Y – X; suggested values X = 50 minutes, rest period = 10 minutes. Then X should be adjusted on the basis of inlet wastewater quality and outlet monitoring during the first year in order to guarantee the needed quality and to optimize energy consumption.

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ANNEXES

Annex 1: As built drawings

Annex 2: Operational and Maintenance plan of full-scale CW system

Annex 3: Operational and Maintenance manual of post-treatment system (full-scale and pilot scale)