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Treatment of Municipal Wastewater Using MBBR and Natural Base Solution Constructed Wetland in Sulaimania as a Case Study

Prof. Dr. Ako Rashed Hama

Department of Civil Engineering, Komar University of Science and Technology, Sulaimani,
K.R. Iraq

MBBR Newest Technology Project

LOCATION

Komar University of Science and Technology

Wastewater Treatment

DESIGN CAPACITY

Average flow of 150,000 Liters per day (150 m³/day)

CORE TECHNOLOGY

MBBR

PRIMARY OBJECTIVE

Eco-friendly, low-cost household wastewater processing to serve as a scalable blueprint for Sulaimani city.

SYSTEM ARCHITECTURE

SSCWL Project Parameters & Scope

LOCATION

University of Sulaimani

PROJECT TYPE

Environmental Nature-Based Wastewater Treatment

DESIGN CAPACITY

Average flow of 4,000 Liters per day (4 m³/day)

CORE TECHNOLOGY

Hybrid Multi-Stage Subsurface Flow System

PRIMARY OBJECTIVE

Eco-friendly, low-cost household wastewater processing to serve as a scalable blueprint for Sulaimani city.

MBBR is Newest Technology in Wastewater Treatment Projects , Used in Komar University of Science and Technology



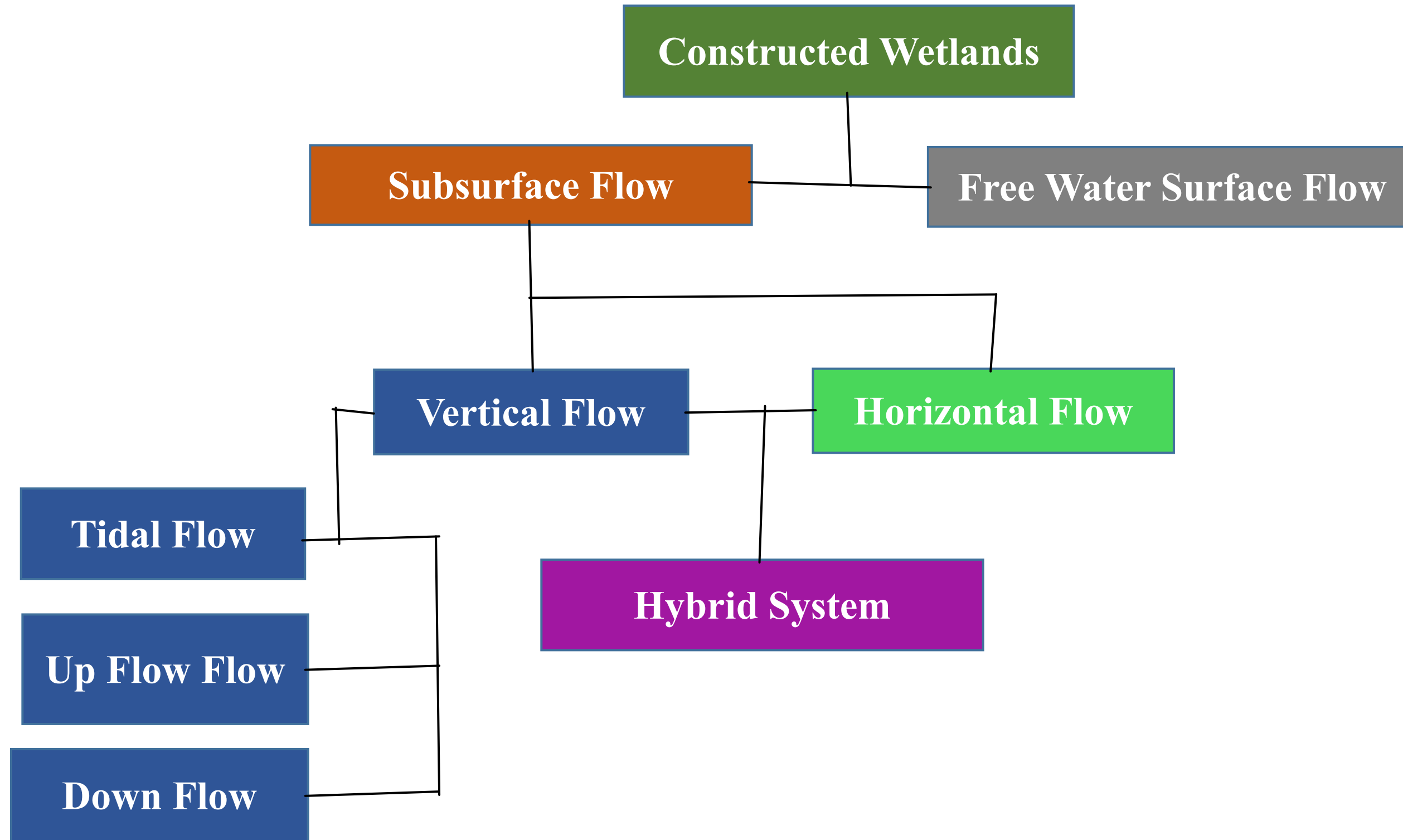
Newest Technology Project



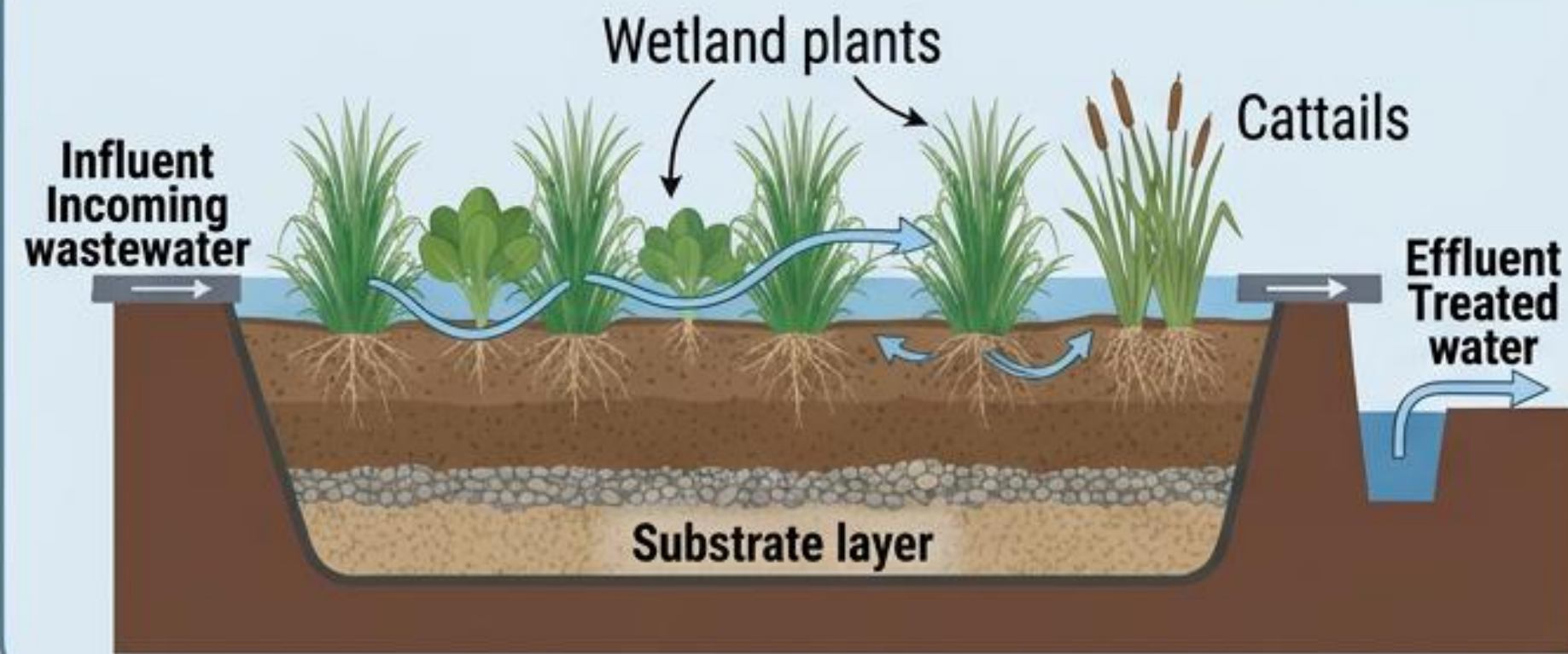
MBBR is the Newest Technology as in KUST



Types of Constructed Wetland

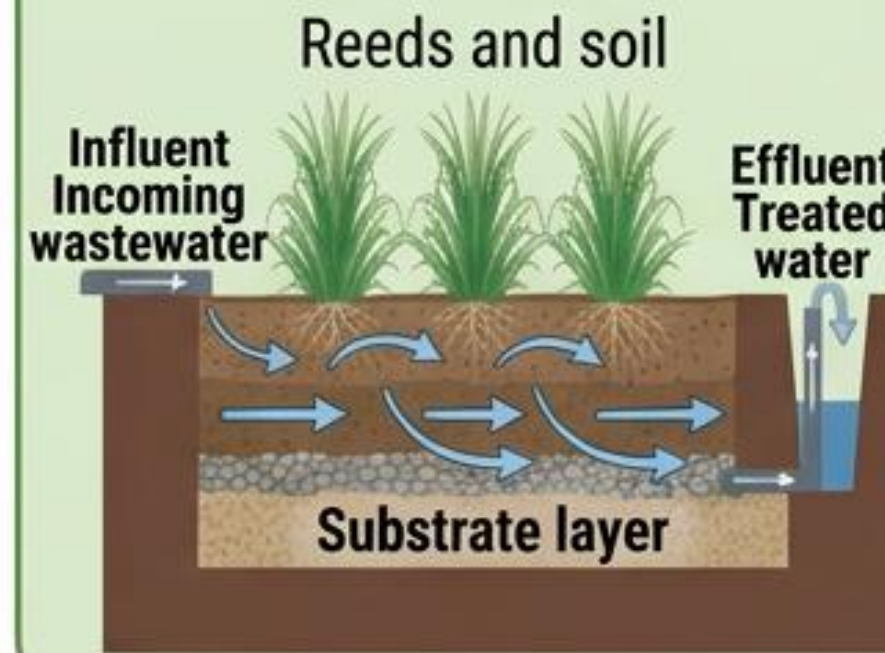


Free Water Surface Constructed Wetland (FWSCWs)

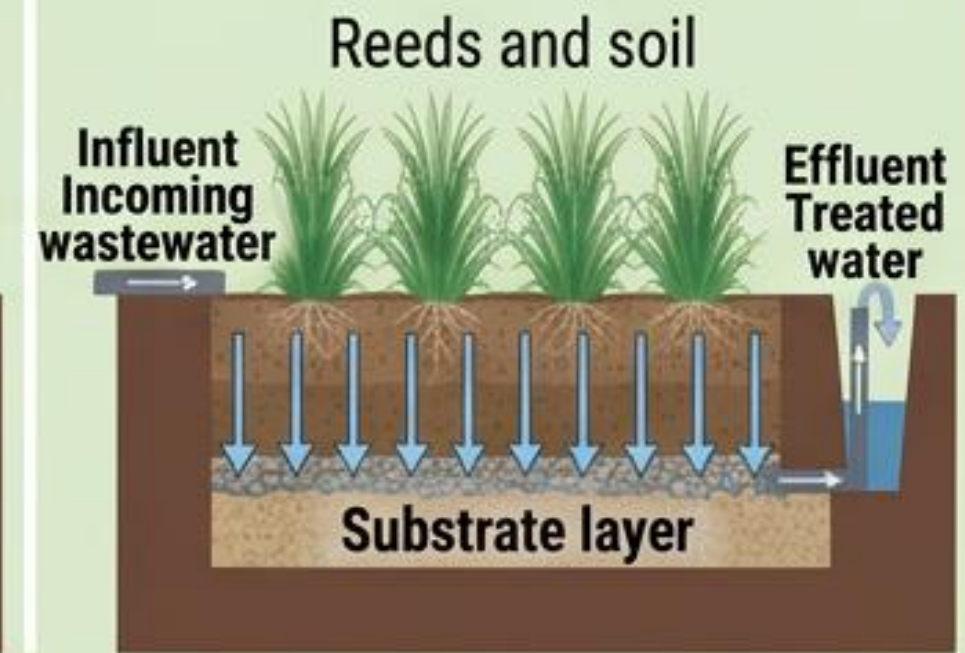


Subsurface Flow Constructed Wetland (SSFCWs)

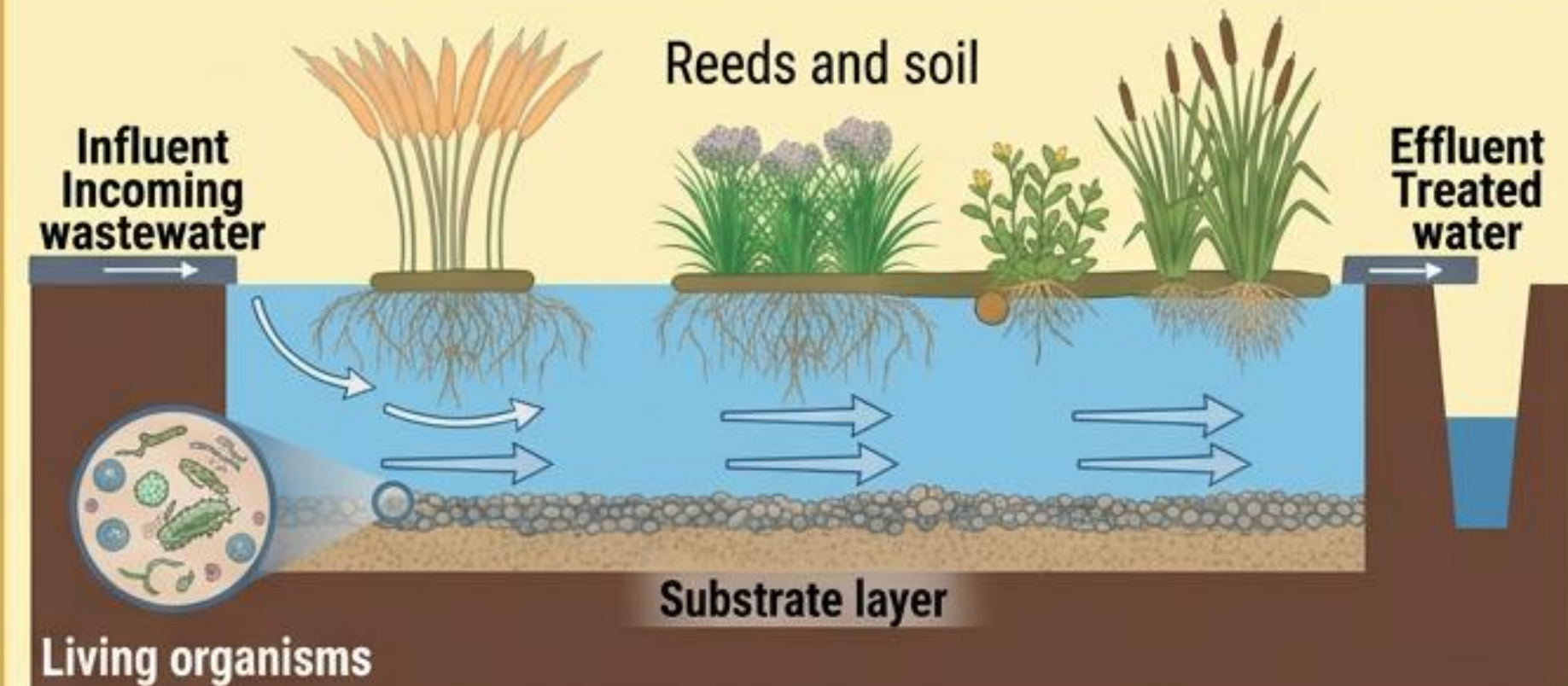
Horizontal flow (HFCWs)



Vertical flow (VFCWs)

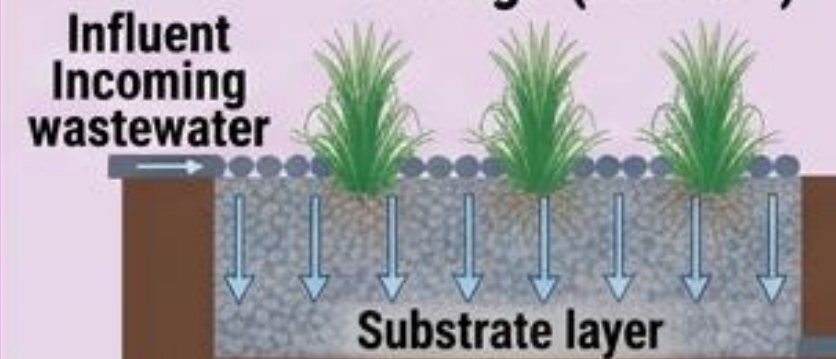


Floating Constructed Wetland (FCWs)

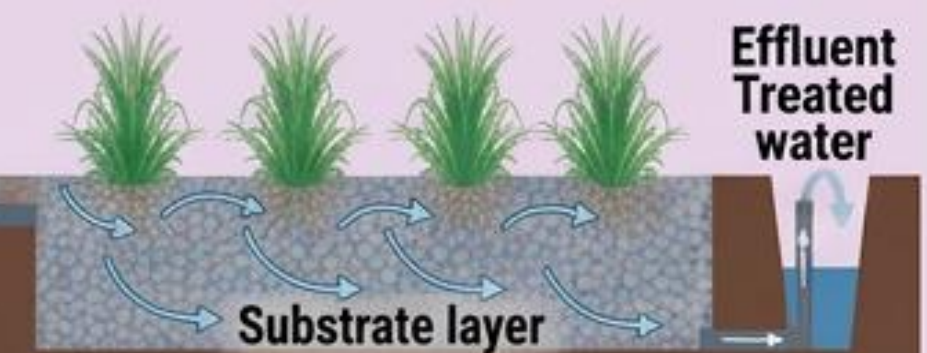


Hybrid Constructed Wetland (HCWs)

First stage (vertical)



Second stage (horizontal)



Type	Wetland Plant	Water Level
FWSCW	Emergent and floating	Above surface
SSFCW	Emergent	Below surface
FCW	Emergent	Below floating mat
HCW	(as above)	(as above)

Note: an example of a vertical-horizontal (VF-HF) system

Advantages of Constructed Wetland

- High reduction of BOD, Suspended solid and pathogen.
- Dose not have the problem of mosquito of the surface flow horizontal constructed wetland (SF).
- Low operating cost
- Required less area than the SF type
- Great Pathogen removal can be expected
- Do not require a skilled workers for maintenance.
- Tolerates climate variation
- Water reuse potential
- Does not have a potential of bad odor release

Subsurface Constructed Wetlands - Design Criteria Matrix			
Summary comparison of Vertical Flow (VF) vs Horizontal Flow (HF) wetlands for municipal wastewater			
Design Parameter	Vertical Flow (VF) Wetland	Horizontal Flow (HF) Wetland	Design Notes / Considerations
Primary Target Pollutants	BOD, TSS, Ammonia (Nitrification)	BOD, TSS, Nitrate (Denitrification)	VF is aerobic; HF is predominantly anaerobic
Pre-Treatment Requirement	Septic Tank / Imhoff Tank + Fine Screen (1-2mm)	Septic Tank / Imhoff Tank / Settling Basin	Essential to remove solids and prevent clogging
Specific Area Requirement	1.5 – 3.0 m² / PE	3.0 – 5.0 m² / PE	PE = Population Equivalent (approx. 120-150 L/person/day)
Organic Loading Rate (BOD)	20 – 40 g BOD/m²·day	6 – 10 g BOD/m²·day	Higher loading capacity in VF due to aeration
Hydraulic Loading Rate (HLR)	80 – 120 L/m²·day	40 – 60 L/m²·day	Peak flow sizing must be verified
Filter Bed Depth	0.8 – 1.0 m	0.5 – 0.8 m	Deeper bed for VF sand filtration; shallow for HF gravel
Primary Substrate Media	Washed Coarse Sand (0.2–2 mm)	Medium Gravel (4–16 mm or 8–20 mm)	VF requires clean sand; HF requires uniform gravel
Flow Regime	Intermittent batch dosing (3–6 pulses/day)	Continuous horizontal subsurface saturated flow	VF needs siphon/pump dosing; HF operates via gravity
Oxygen Transfer Mechanism	Convective air intake during batch draining	Plant root release (limited oxygen transfer)	VF has 10x higher oxygen transfer capacity
Bed Surface Slope	0% (Flat top), 1% sloped drain bottom	0.5% – 1.0% bottom slope from inlet to outlet	Ensures proper hydraulic gradient across bed
Vegetation Species	Phragmites australis, Typha, Scirpus	Phragmites australis, Typha latifolia	Planting density: 4 – 6 plants/m²
Liner Requirement	HDPE 1.5mm or Compacted Clay (K <= 1e-9 m/s)	HDPE 1.5mm or Compacted Clay (K <= 1e-9 m/s)	Protects groundwater from contamination

Vertical Flow (VF) Constructed Wetland Design Guidelines				
Detailed media layering, dosing mechanics, and design specifications				
1. Layering Specifications (Top to Bottom)				
Layer Name	Depth (cm)	Media Specifications	Grain Size (mm)	Function / Description
Distribution Layer	10 – 15	Fine washed gravel	4 – 8 mm	Protects main layer, distributes influent evenly from distribution pipes
Main Filtration Layer	50 – 80	Clean washed coarse sand (d10 = 0.2-0.3 mm, U < 5)	0.2 – 2.0 mm	Primary biological filtration and nitrification layer
Transition Layer	10 – 15	Medium clean gravel	4 – 8 mm	Prevents sand migration into bottom drainage pipes
Drainage Layer	15 – 20	Coarse gravel containing perforated pipes	16 – 32 mm	Collects treated effluent and allows aeration from bottom pipes
2. Key Design Operating Criteria				
Parameter	Design Value	Unit	Operating Remarks	
Design BOD Loading	20 – 40	g BOD/m²·day	Keep <= 20 g BOD/m²·day for cold climates	
Hydraulic Load (HLR)	80 – 120	L/m²·day	Includes daily batch pulse volume	
Dosing Frequency	3 – 6	doses / day	Batch dosing sucks oxygen into the filter matrix	
Dose Depth per Batch	2 – 5	cm / pulse	Floods surface quickly, then drains completely	
Resting Period	4 – 6	hours between doses	Allows oxygen replenishment in sand pore spaces	

Horizontal Flow (HF) Constructed Wetland Design Guidelines				
Hydraulic kinetics, Darcy's Law criteria, and bed construction details				
1. Zonal Media & Bed Layout				
Zone	Length / Depth	Media Specification	Grain Size (mm)	Function
Inlet Zone	1.0 – 1.5 m (Length)	Coarse stones / Gabion wall	50 – 100 mm	Prevents surface clogging, distributes raw wastewater across width
Main Treatment Bed	0.5 – 0.8 m (Depth)	Uniform washed gravel	4 – 16 mm	Main matrix for attached-growth anaerobic bacteria and plant root interaction
Outlet Zone	1.0 – 1.5 m (Length)	Coarse stones with drainage pipe	50 – 100 mm	Collects treated water evenly; adjustable outlet tube controls water level
2. Sizing Equations & Hydraulic Parameters				
Parameter / Equation	Formula / Value	Units	Description / Standard Range	
Kickuth Sizing Formula	$A_h = [Q * (\ln(C_i) - \ln(C_e))] / kBOD$	m²	Area calculated from BOD kinetic removal rate	
First-Order Rate (kBOD)	0.08 – 0.10	m / day	BOD reaction rate constant at 20°C	
Darcy's Law Cross Section	$A_c = Q / (K_s * S)$	m²	Cross-section area (Width x Depth) to prevent surface ponding	
Hydraulic Conductivity (Ks)	100 – 300 (New) / 10 – 30 (Clogged)	m / day	Conductivity drops over time due to root growth and solids	
Hydraulic Gradient / Slope (S)	0.005 – 0.01 (0.5% - 1.0%)	m / m	Bottom slope from inlet to outlet to drive flow	
Aspect Ratio (Length : Width)	2:1 to 3:1	Ratio	Prevents short-circuiting while maintaining hydraulic cross section	

University Campus Pilot Plant

The Project

The project is located in Sulaimani

The project capacity is to treat average flow of 4000 L/day

The Preliminary Pretreatment :

Screen :

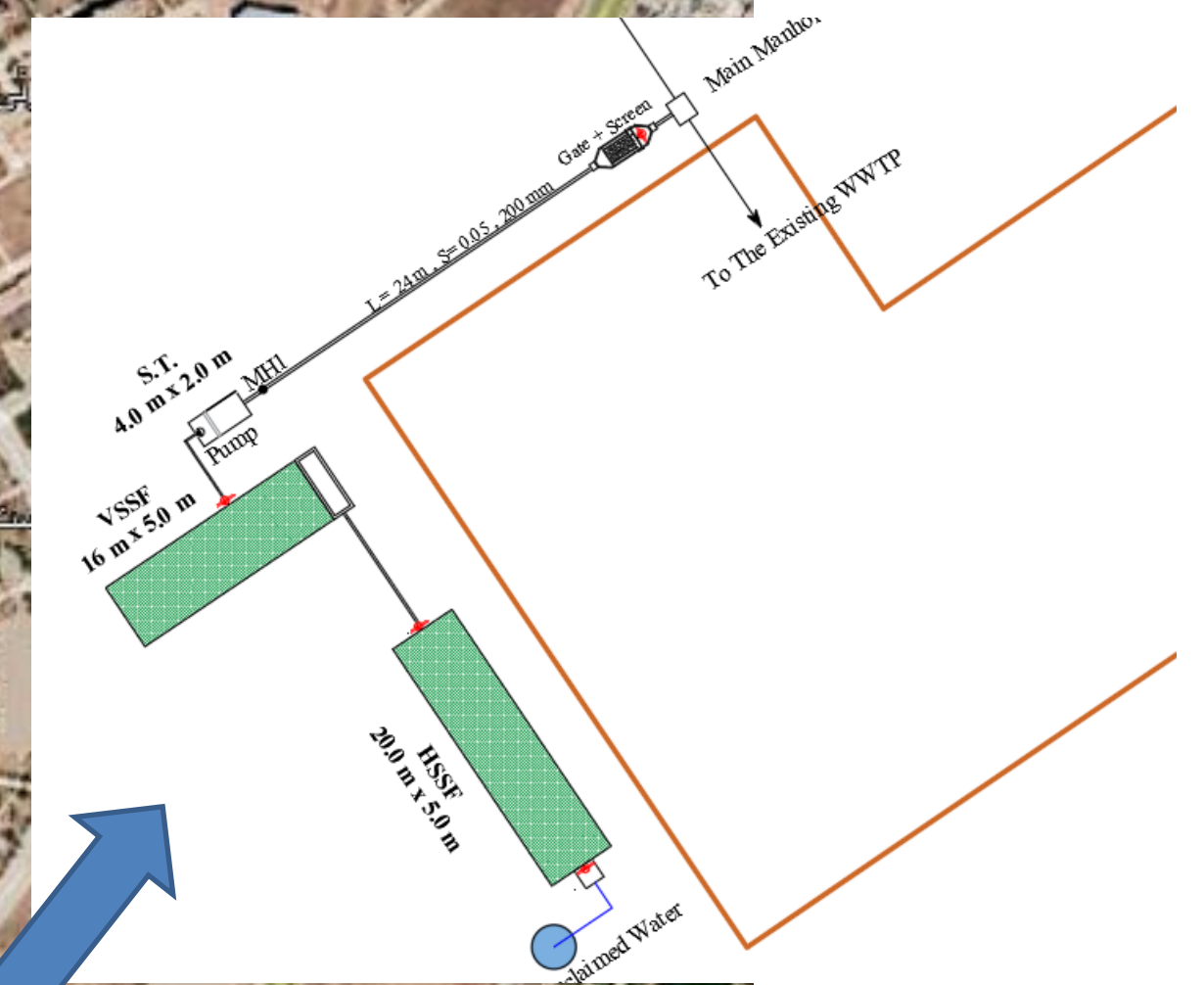
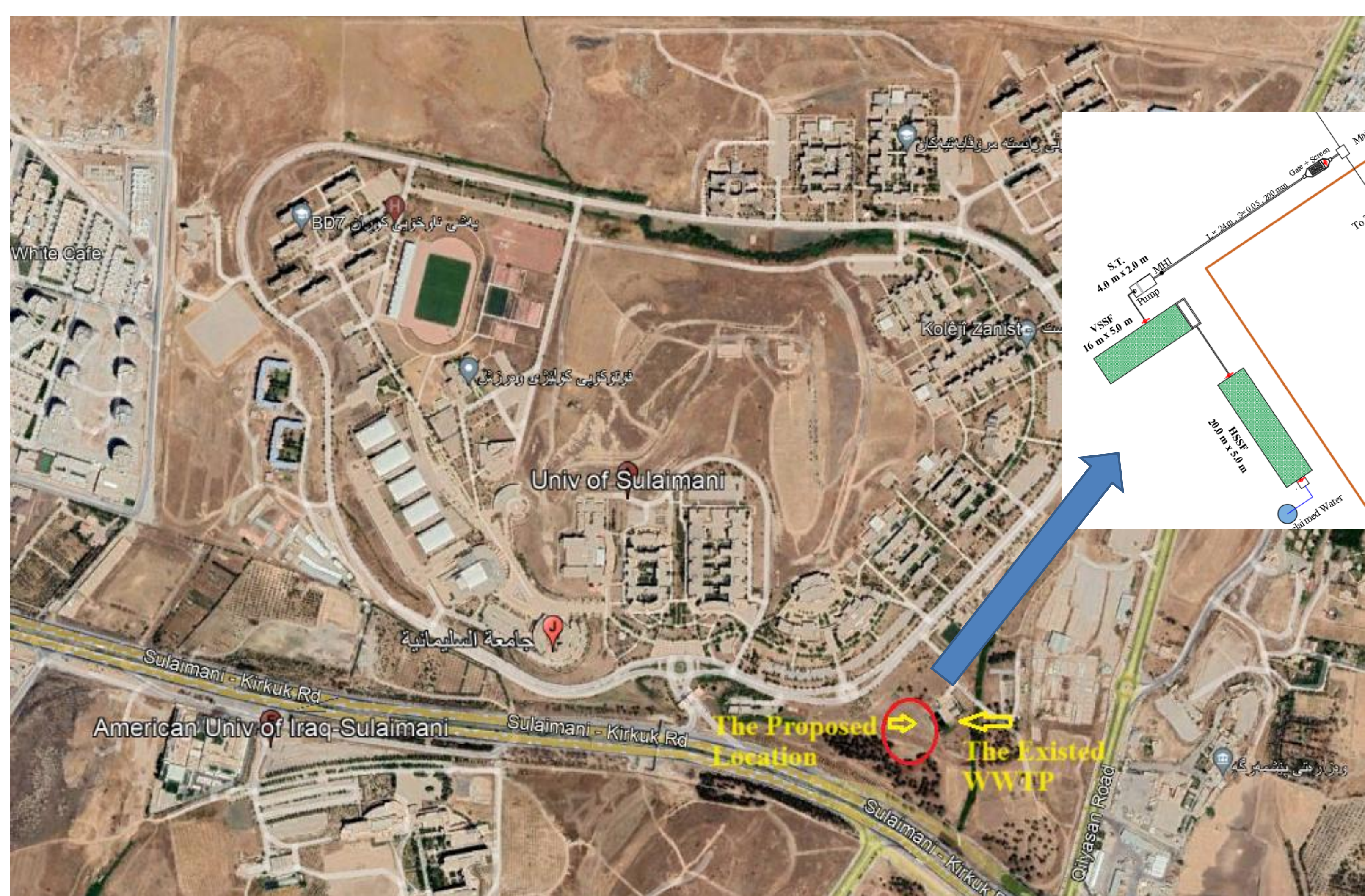
Septic tank 4m x 2m x 2m

The Constructed Wetlands :

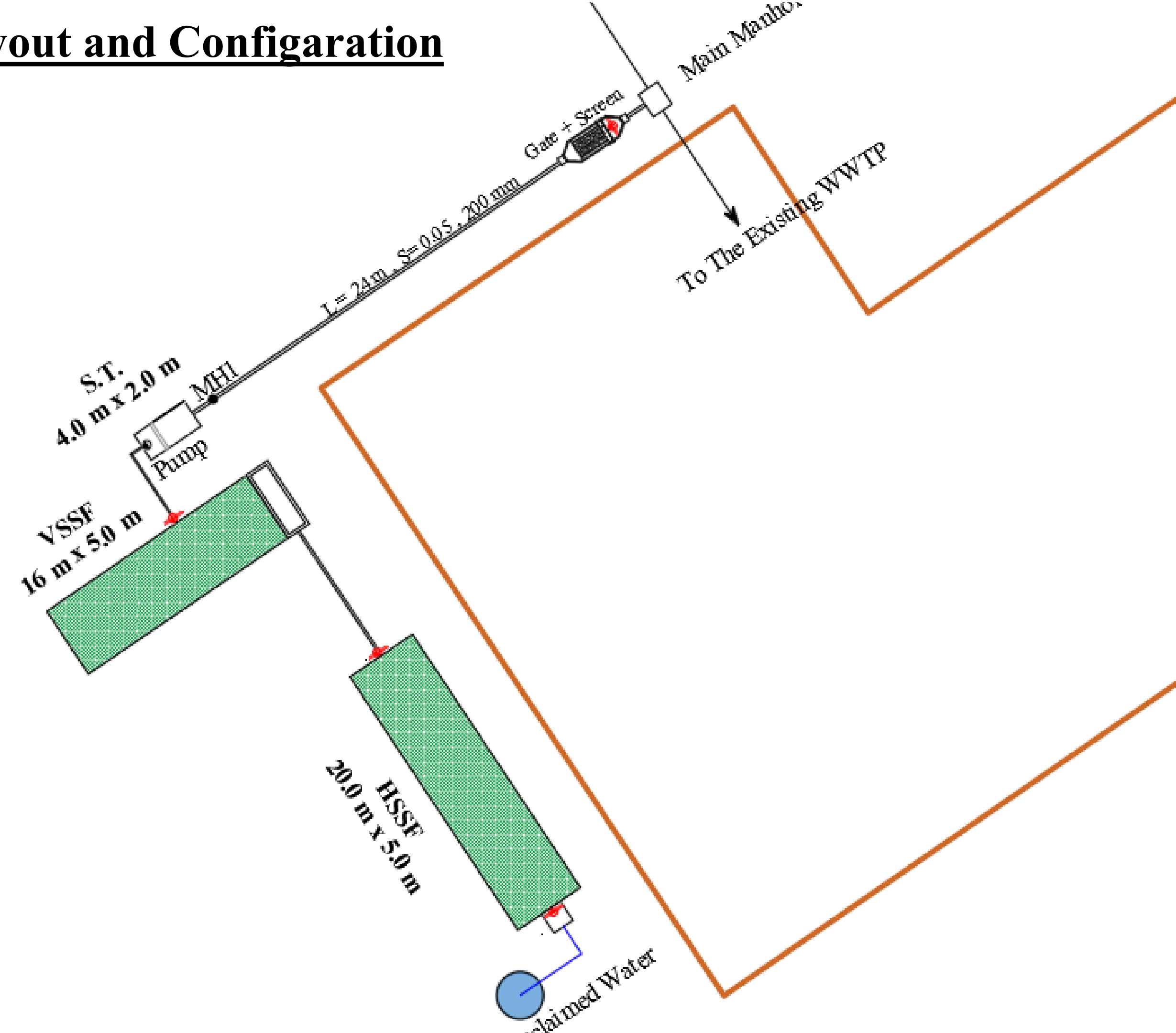
VSSF constructed wetland : 16 m x 5 m=80 m²

HSSF constructed wetland : 20 m x 5 m= 100 m²

Storage Tank = 4000 L

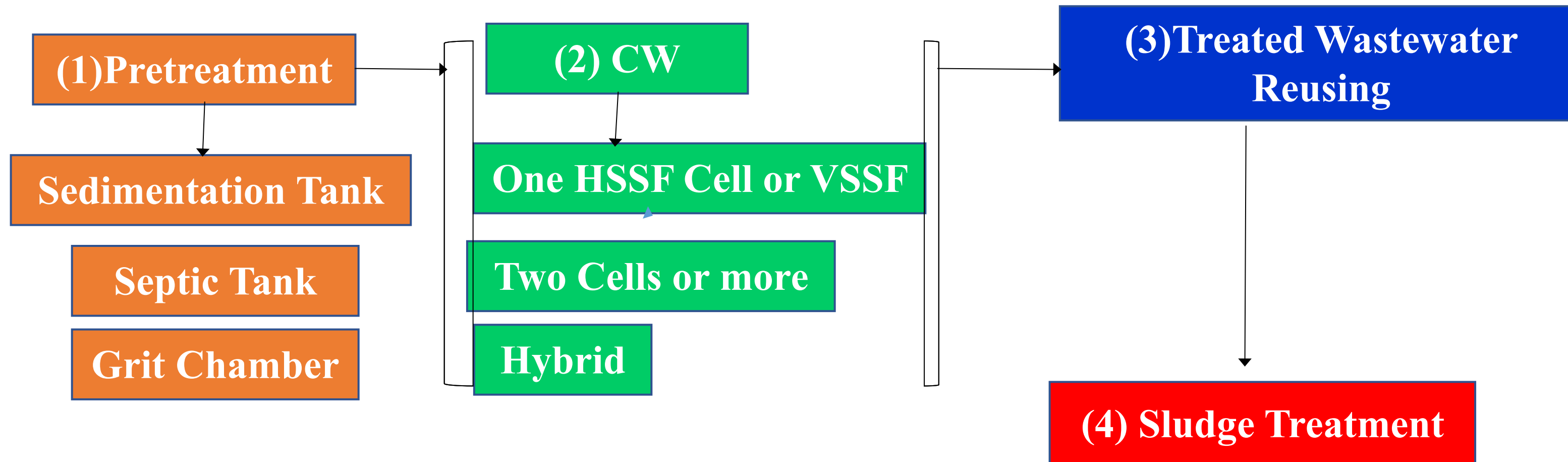


The Project Layout and Configuration

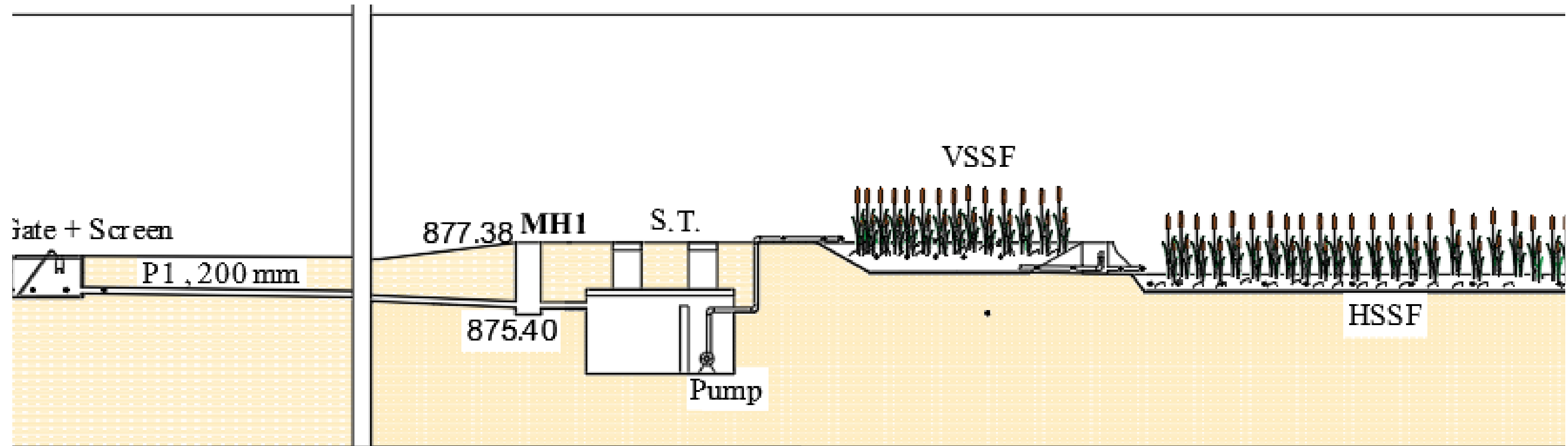


The System Configuration

The system consists of four major elements :



The Project Cross Section

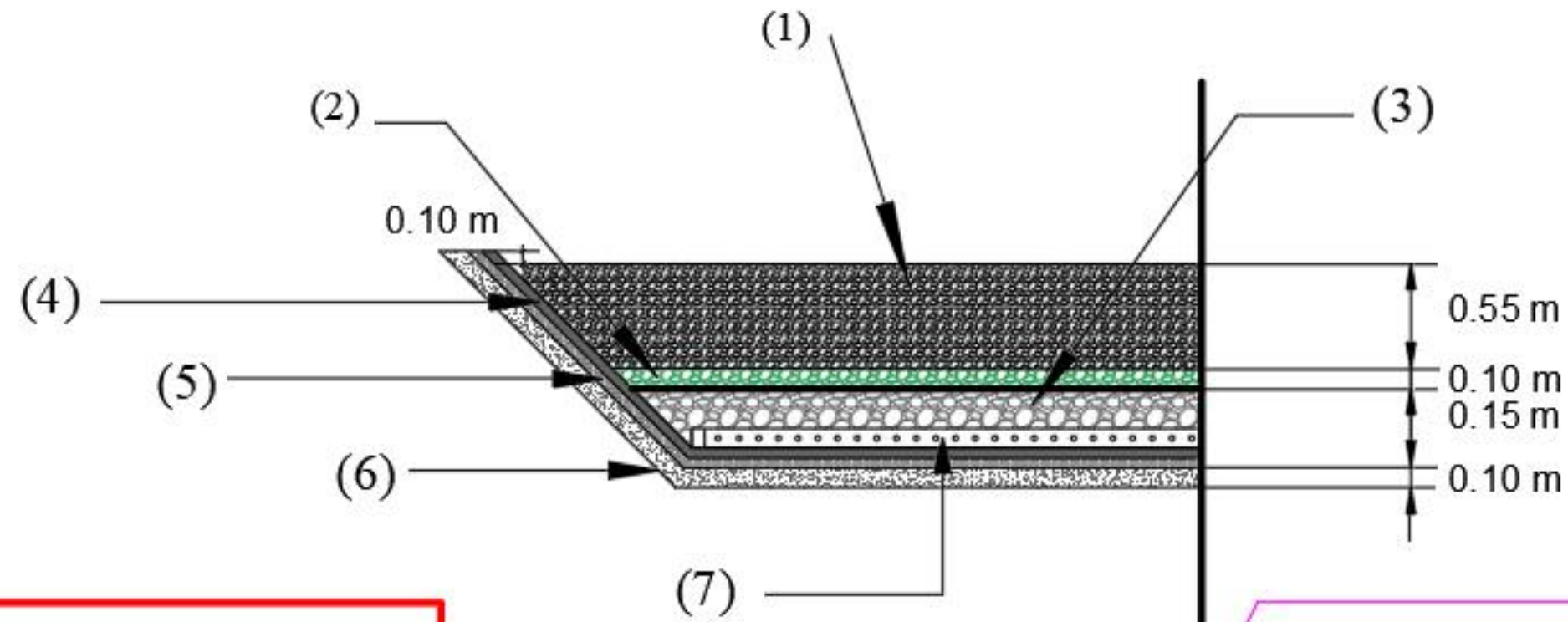
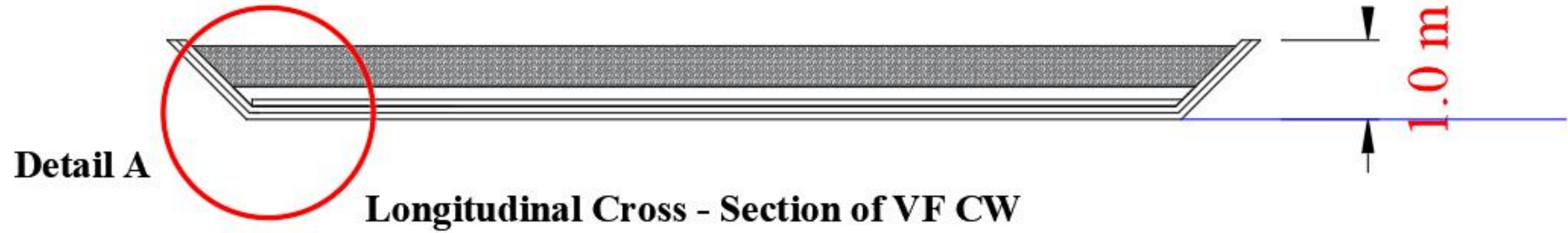


The Collection System of VSSF



(Source: Limn

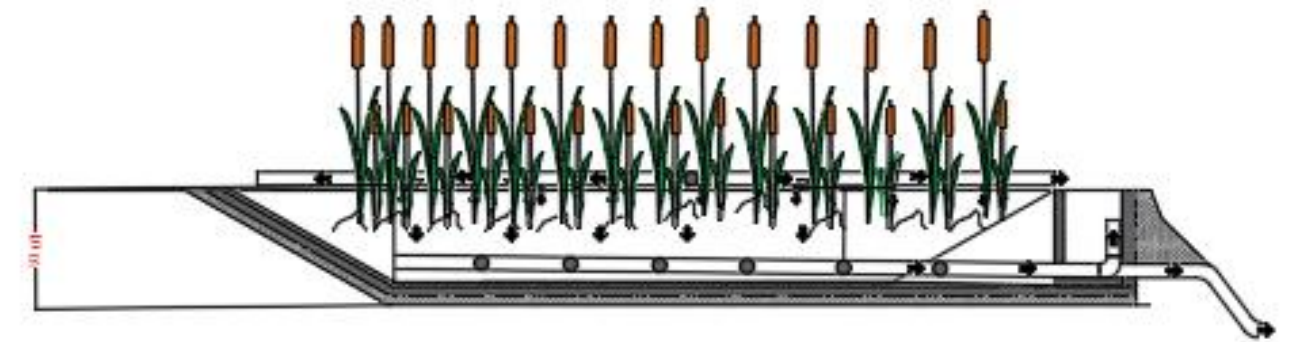
VSSF CW – Cross Section



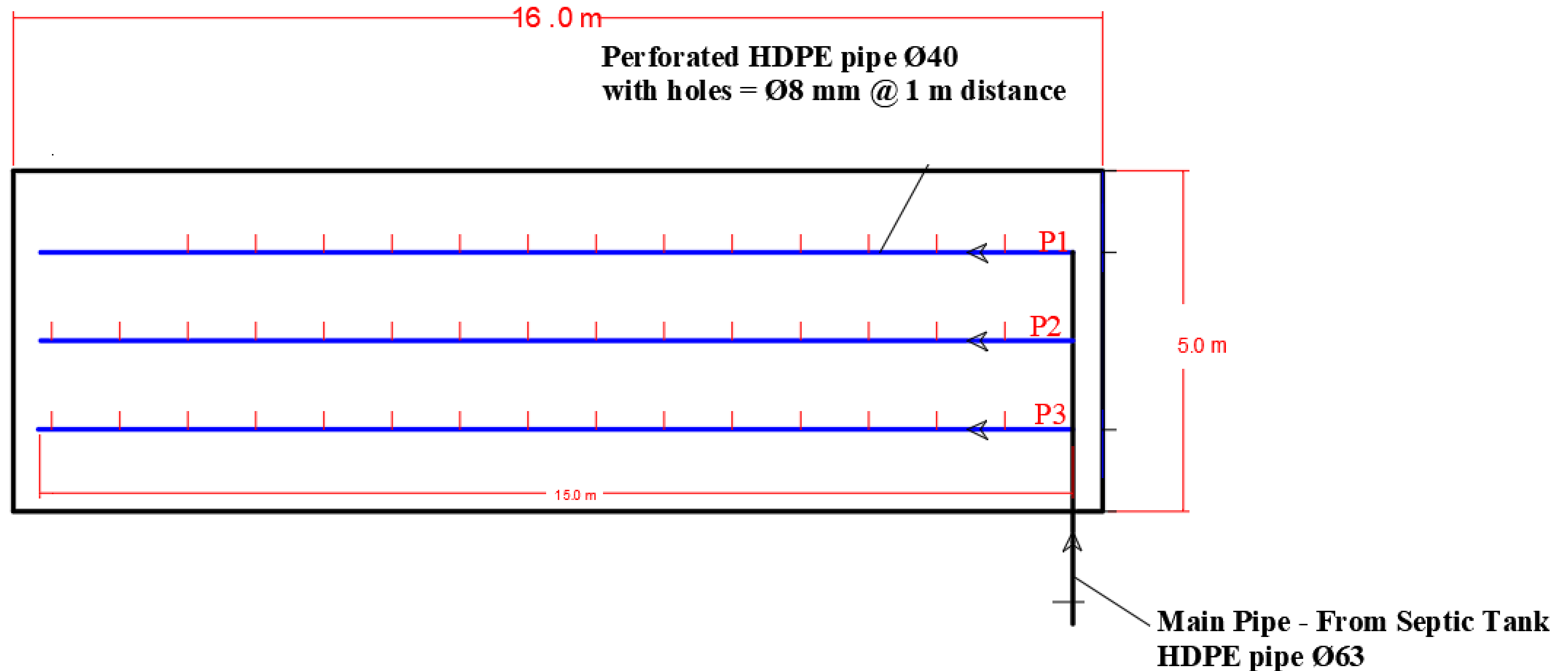
Details

- (1) Gravel with size (4 - 6) mm and a UC of 4
- (2) Gravel with size (8 - 15) mm and a UC of 4
- (3) Coarse gravel with size (16 - 40) mm and a UC of 4
- (4) HDPE Geomembrane of 3 mm, density $\geq 0.94 \text{ g/cm}^3$
- (5) Geotextile of 300 gm/m^2
- (6) 10 cm Lean Concrete + BRC
- (7) HDPE pipe of $\text{Ø}80 \text{ mm}$

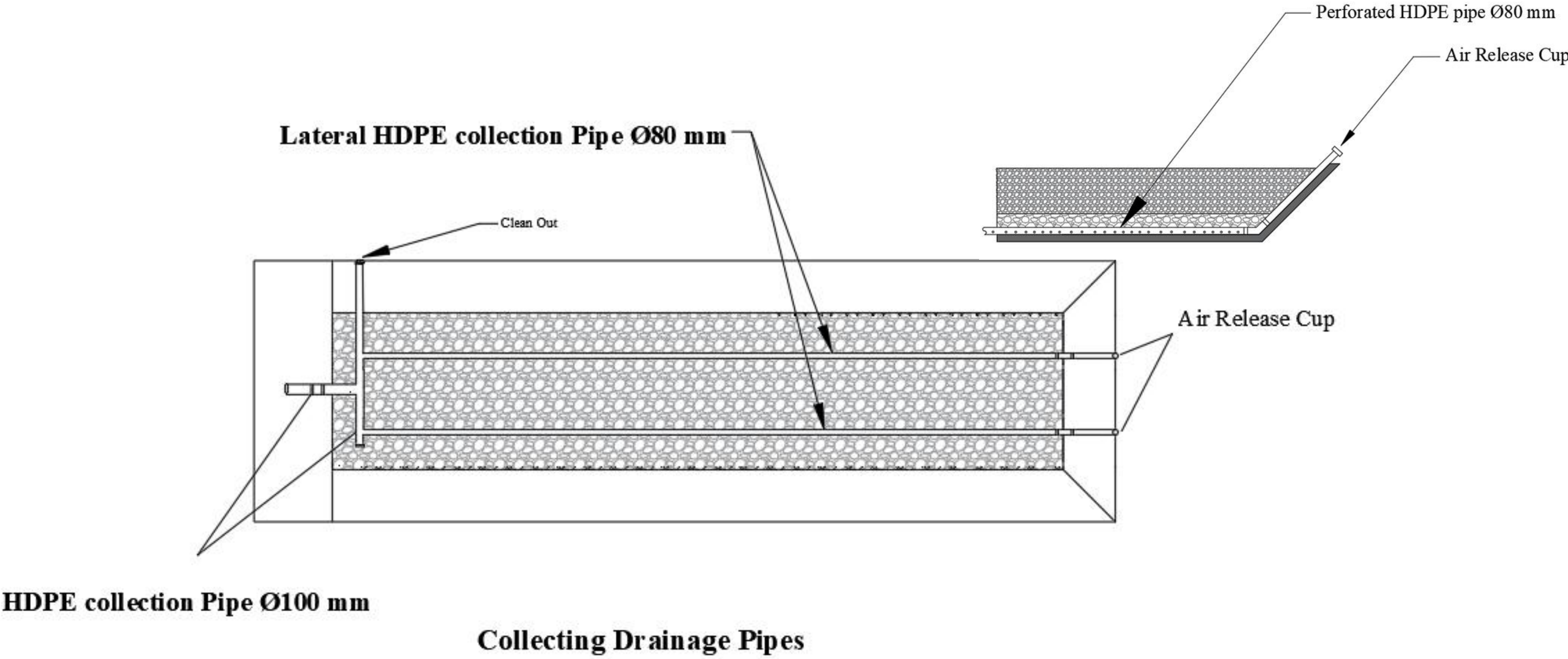
Detail A



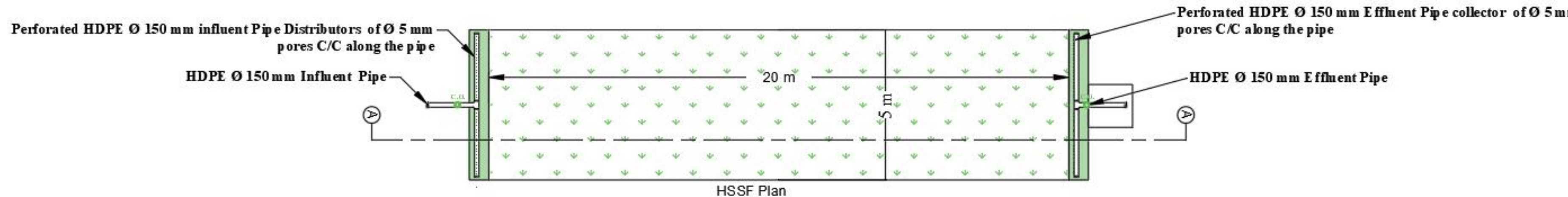
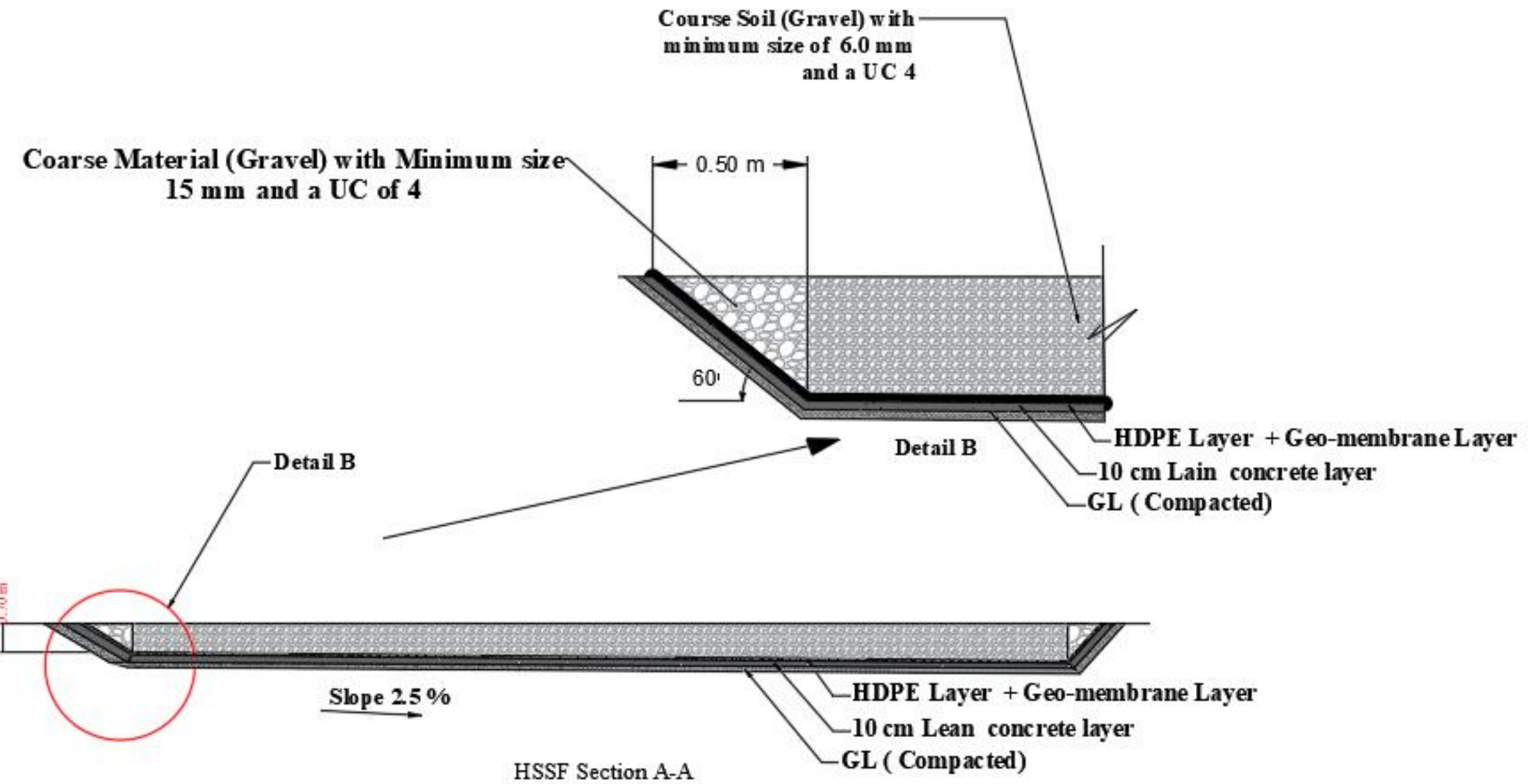
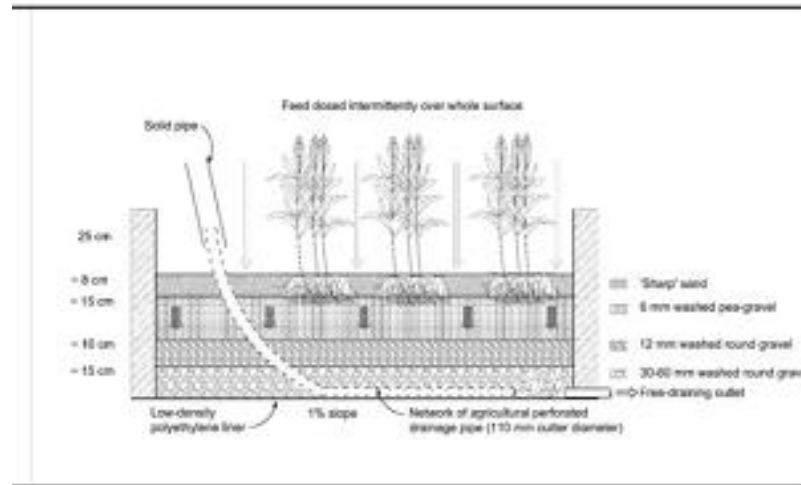
The Flow Distribution System of the VSSF - CW



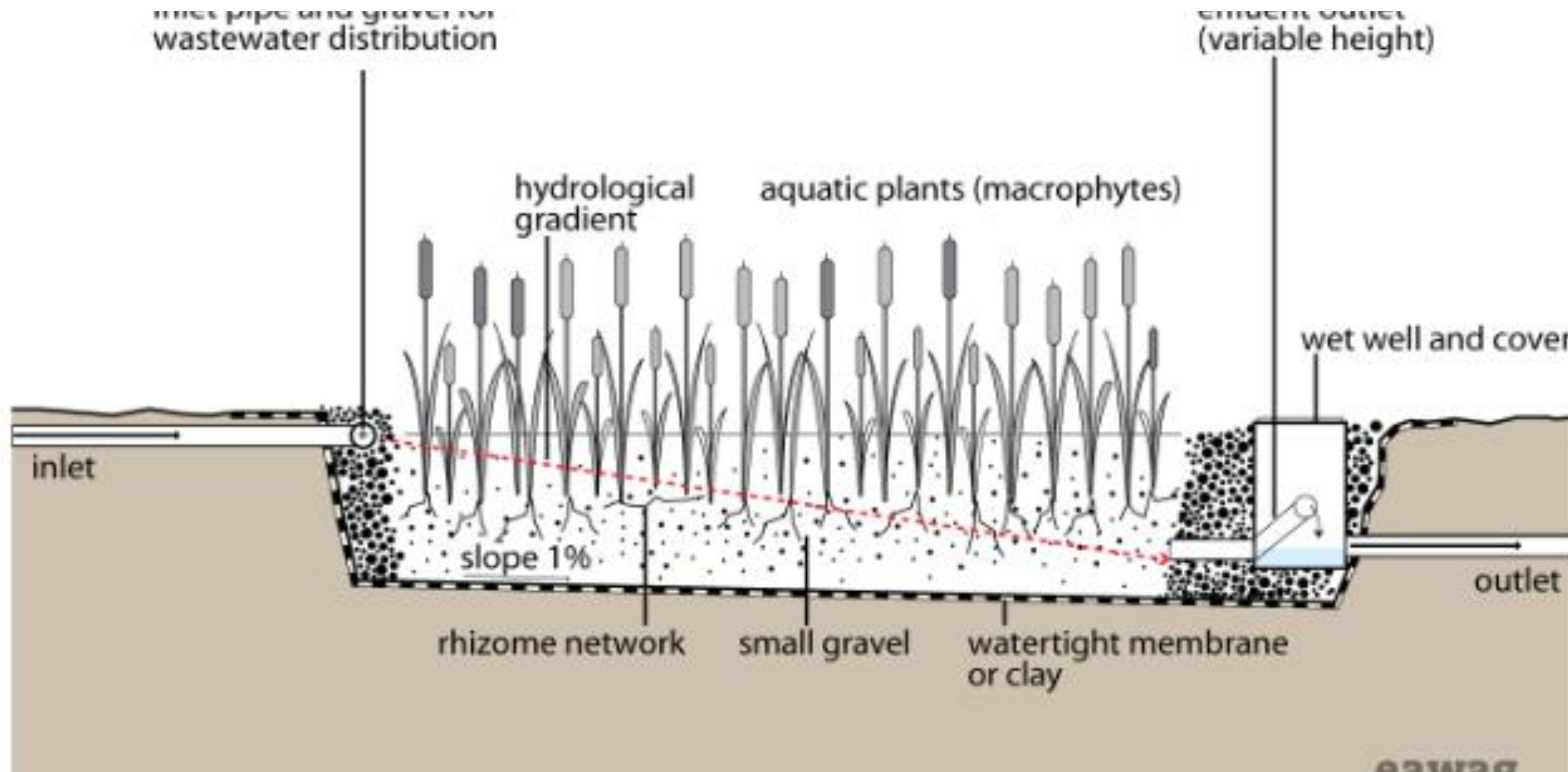
The Collection Pipe System of the VSSF CW



HSSF CW – Cross Section



HSSF Cross Section and Components



Types of aquatic plants used for phytoremediation

Plant Name	Type	Characteristics	Phytoremediation Uses
Water Hyacinth	Free-floating	Broad, thick, glossy leaves	Removes heavy metals, nutrients, organic contaminants
Duckweed	Free-floating	Small, forms dense mats on water surfaces	Highly effective in nutrient removal, also removes heavy metals
Water Lettuce	Free-floating	Thick, velvety leaves resembling lettuce	Removes heavy metals, nutrients, pathogens
Cattails (Typha spp.)	Emergent	Long, slender leaves, brown flower spikes	Absorbs nutrients, heavy metals, organic contaminants
Bulrush (Schoenoplectus spp.)	Emergent	Tall, cylindrical stems, small flower clusters	Removes heavy metals, nutrients, other pollutants
Common Reed (Phragmites australis)	Emergent	Tall grass, feathery flower plumes	Used in constructed wetlands, removes nutrients, heavy metals
Water Fern (Azolla spp.)	Free-floating	Small, forms dense mats on water surfaces	Fixes nitrogen, removes heavy metals, nutrients
Eelgrass (Vallisneria spp.)	Submerged	Long, ribbon-like leaves	Stabilizes sediments, removes nutrients, contaminants
Pondweeds (Potamogeton spp.)	Submerged	Varying leaf shapes and structures	Nutrient uptake, improves water clarity by stabilizing sediments
Lotus (Nelumbo spp.)	Floating-leaved	Large, circular leaves, prominent flowers	Absorbs heavy metals, organic pollutants

Why cattail and common Reed (Phragmite and Typha)

Phragmite and Typha offer several advantages for phytoremediation:

- **Extensive Root System:** Their dense root system can absorb and filter contaminants.
- **High Biomass Production:** Above-ground biomass provides additional storage capacity.
- **Tolerance to Wet Conditions:** Thrive in waterlogged environments where contamination often occurs.



Contaminant Uptake:

Phragmite and Typha are known for their ability to absorb and accumulate various contaminants, including:

- Heavy Metals
- Nutrients (e.g., nitrogen and phosphorus)
- Organic Pollutants.

PHYTOACCUMULATION

Contaminants are absorbed and stored in plant tissues

RHIZOFILTRATION

Roots absorb or adsorb pollutants from water

PHYTOSTABILIZATION

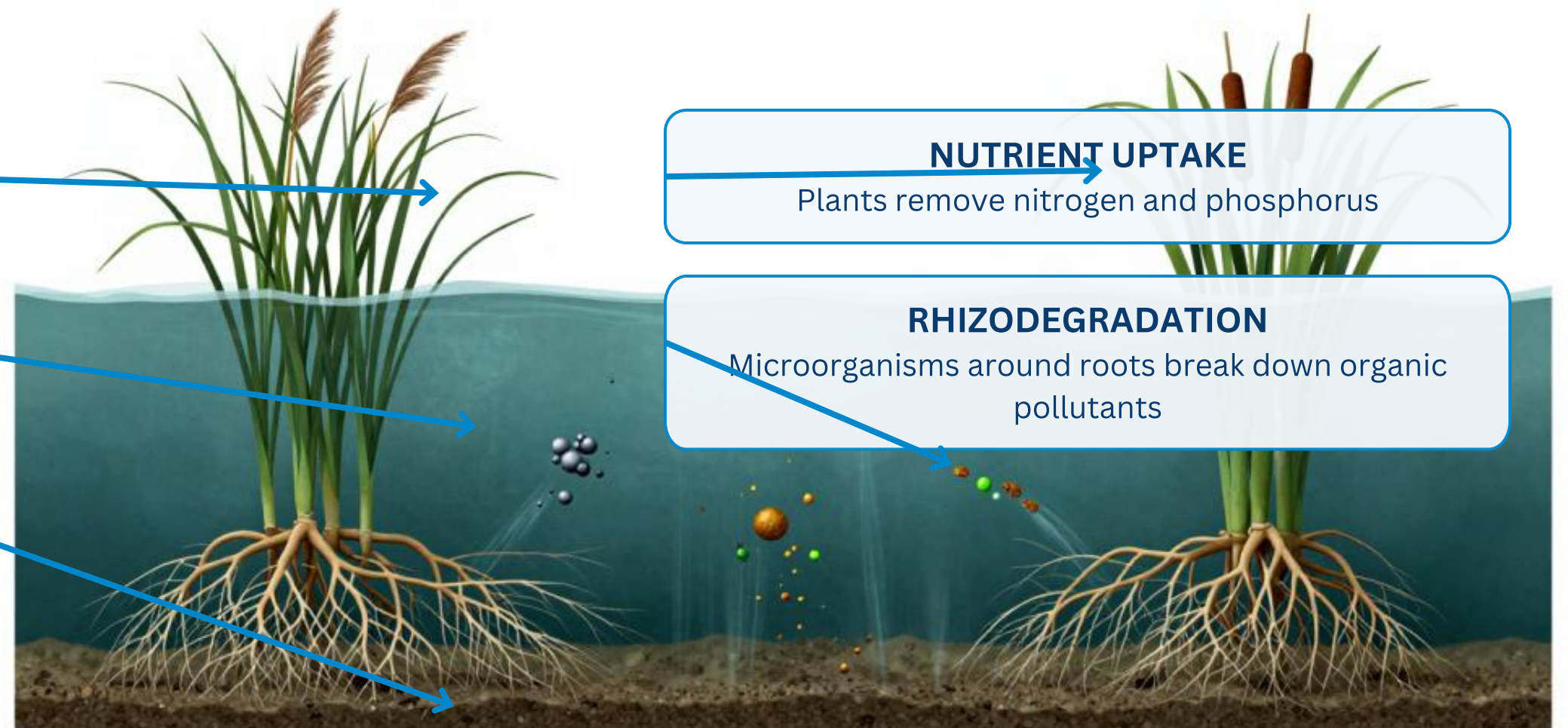
Roots immobilize contaminants in the sediment

NUTRIENT UPTAKE

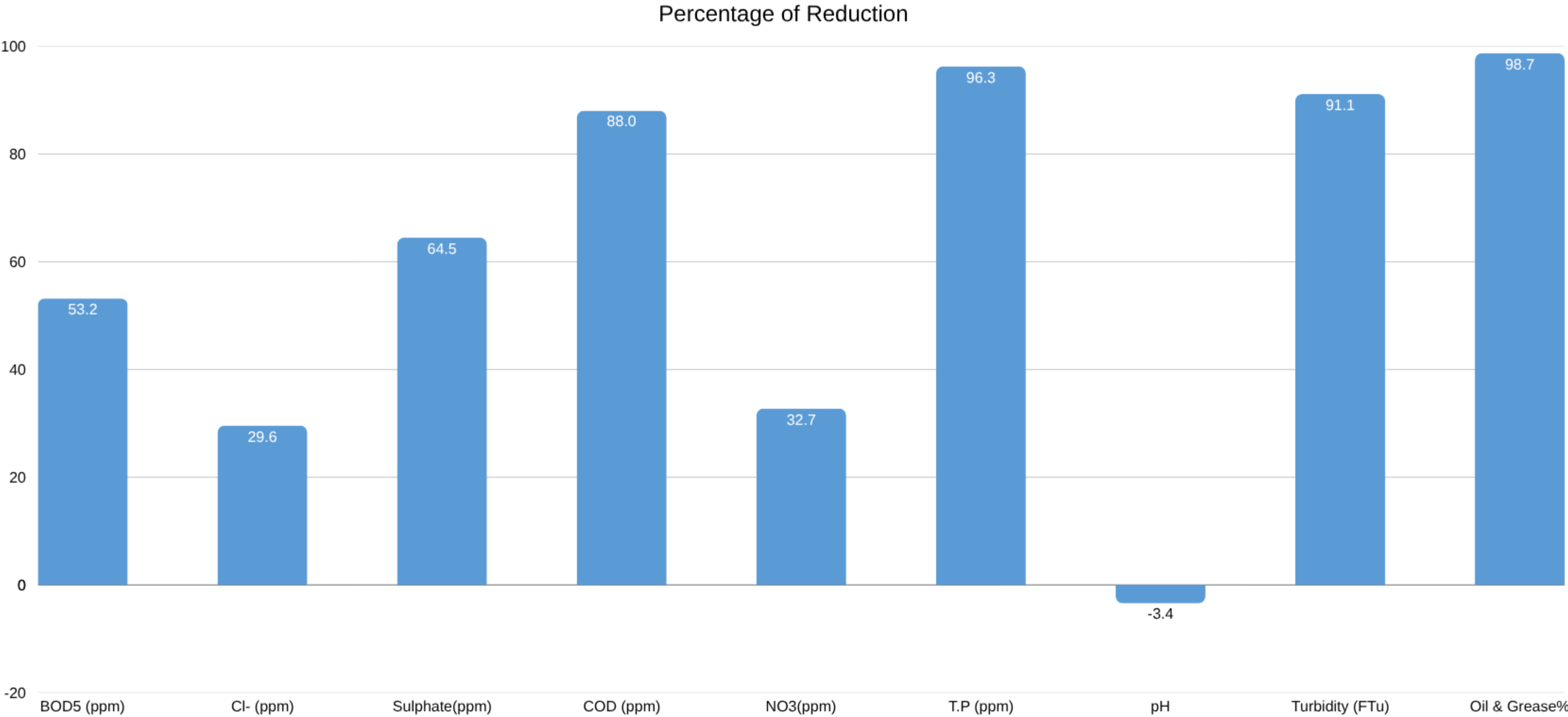
Plants remove nitrogen and phosphorus

RHIZODEGRADATION

Microorganisms around roots break down organic pollutants



Water Quality Reduction After Pilot Implementation



Reduction percentage measured between Point 1 and Point 3 of the constructed wetland.

Planting Design for Phragmites and Typha in a Subsurface Constructed Wetland?

- Collect native Phragmites and Typha from a nearby wetland.
- Choose young plants with part of the root system attached.
- Place the plants in pots containing the same wetland water.
- Keep them for one week and monitor new root growth.
- Transplant only healthy, well-rooted plants into the constructed wetland.



Planting Design for Phragmites and Typha in a Subsurface Constructed Wetland?

To design a planting layout for Phragmites and Typha in a subsurface constructed wetland with the specified requirements, we will create a grid that ensures each plant is spaced 40 cm apart.



Planting Design for Phragmites and Typha in a Subsurface Constructed Wetland?

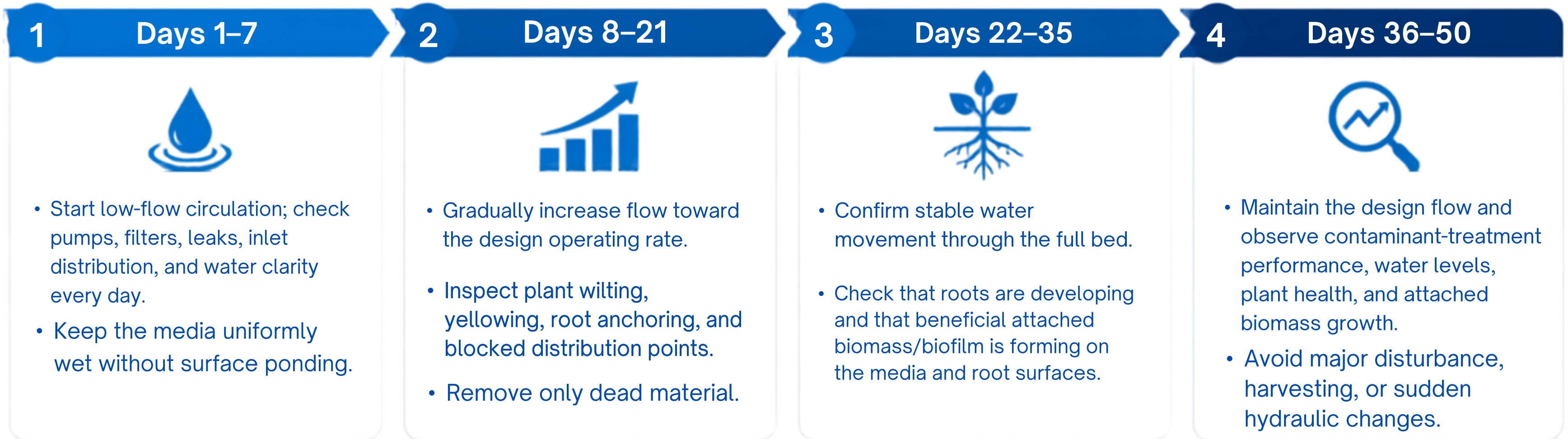
The scaled planting design is complete. It uses planting lines parallel to the pond length, alternating Typha and reed, with 0.40 m centre-to-centre spacing in both directions and a 0.20 m edge offset for the first and last plant centres

Pond	Dimensions	Rows	Plants per row	Typha	Reed	Total
Pond 1 — VSSCW	8 m × 18 m	20	45	450	450	900
Pond 2 — HSSCW	12 m × 24 m	30	60	900	900	1,800
Total	—	50	—	1,350	1,350	2,700

Pond 1 — Reed SSVCW

Adaptation monitoring phas

1. Plant Adaptation and Attached-Biomass Establishment: First 50 days



Before full plantation

- ✓ Confirm that the starter biomass is firmly attached and actively growing in the system.
- ✓ Pumps and filters operate continuously.
- ✓ Flow is evenly distributed.
- ✓ No persistent surface clogging or stagnant zones are present.

Add the remaining plants only after these checks pass.

2. Water-Level and Flow Control



- Maintain the operating water level within the design range and below the media surface in a subsurface wetland; prevent prolonged surface ponding.

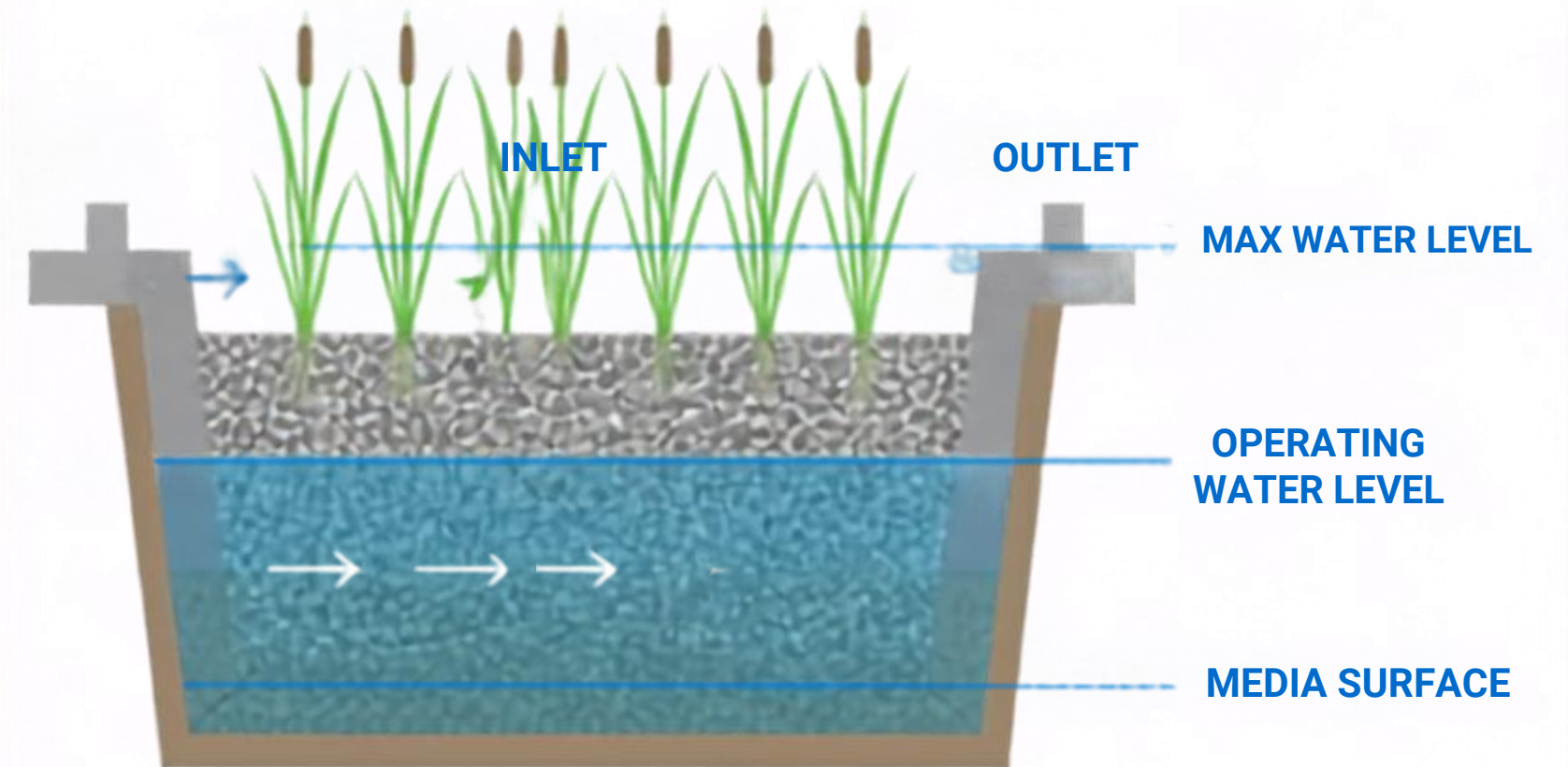
- **Daily:** record inlet level, outlet level, pump status, flow appearance, and any difference between inlet and outlet levels.

- **If the level rises:** inspect the inlet, filter, outlet, and media for blockage; remove debris and reduce flow only if necessary.

- **If the level falls:** check for leaks, pump failure, dry media, blocked suction lines, or excessive evaporation; restore uniform wetting gradually.

- Keep water moving through the entire bed, with no bypass flow, stagnant pockets, or exposed dry zones.
- Adjust valves slowly and record every change.

WATER-LEVEL CONTROL



3. Routine Maintenance Schedule



Daily:

- inspect pumps, filters, valves, pipes, water levels, flow distribution, odour, visible clogging, and plant condition; record abnormalities.



Weekly:

- remove leaves and debris, clean screens and accessible filters, inspect inlet and outlet structures, check pipe connections, and verify uniform flow across the bed.



Monthly:

- inspect root and plant growth, media condition, water-level records, piping, pump vibration/noise, and signs of short-circuiting or surface clogging. Calibrate or verify monitoring instruments.



Quarterly:

- review contaminant results and hydraulic performance, complete preventive pump maintenance, inspect structural components, and update the O&M log and corrective-action plan.



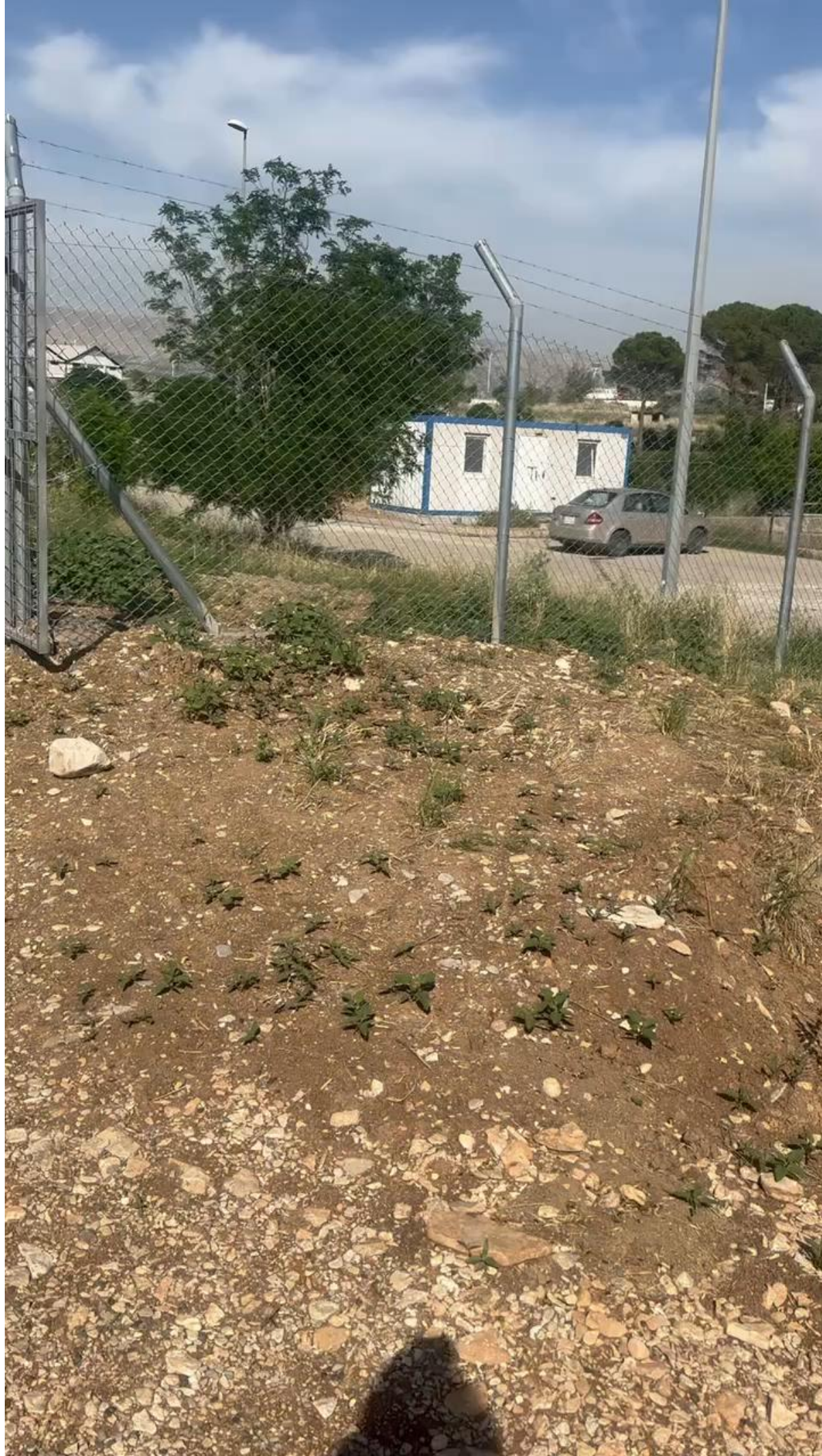


Efficiencies of the CWL system / in the beginning after two month run

23-5-2024						
Element	1	2	3	% Removal V SSF	% Removal HSSF	Total % of Removal
Fe (ppb)	238.2	238.2	238.2	0.00	0.00	0.00
Pb(ppb)	220.4	220.4	220.4	0.00	0.00	0.00
Ni(ppb)	231.6	231.6	231.6	0.00	0.00	0.00
Cr(ppb)	267.7	267.7	267.7	0.00	0.00	0.00
Cu(ppb)	327.4	327.4	327.4	0.00	0.00	0.00
Mn(ppb)	257.6	257.6	257.6	0.00	0.00	0.00
Cd(ppb)	228.8	228.8	228.8	0.00	0.00	0.00
Zn(ppb)	206.2	206.2	206.2	0.00	0.00	0.00
pH	7.34	7.52	7.59			
NO ₃ (ppm)	41.97	41.55	28.24	1.00	32.03	32.71
Sulphate(ppm)	76	37	27	51.32	27.03	64.47
T.P (ppm)	11.5	2.3	0.43	80.00	81.30	96.26
Cl ⁻ (ppm)	71	63	50	11.27	20.63	29.58
COD (ppm)	117	50	14	57.26	72.00	88.03
BOD ₅ (ppm)	203	152	95	25.12	37.50	53.20
Oil & Grease%	1158	85	15	92.66	82.35	98.70
Turbidity (FTu)	11.96	6.75	1.06	43.56	84.30	91.14

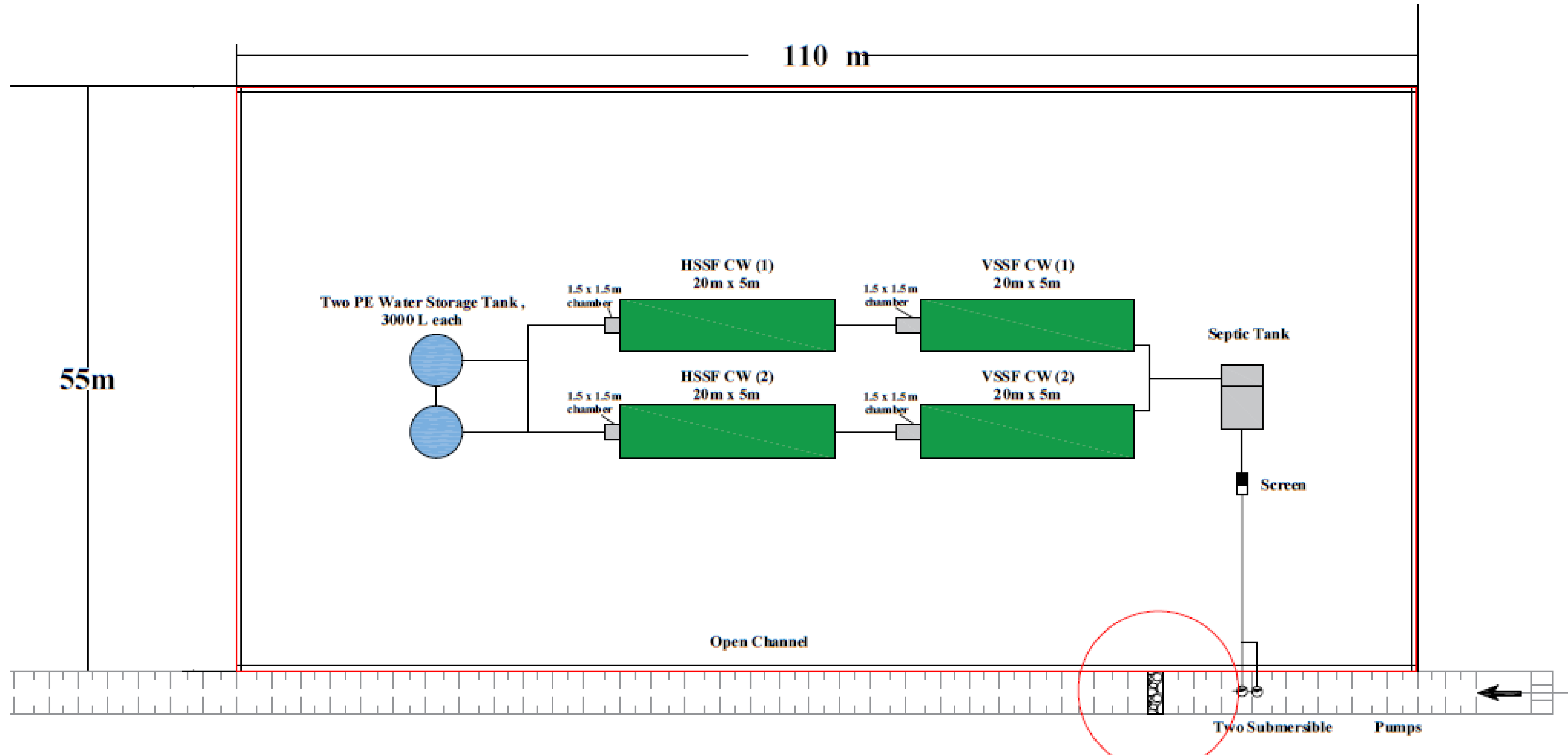
Efficiencies of the CWL system / in the beginning after adaptation 6 months run

18/8/2024							
No.	Element	1	2	3	% Removal V SSF	% Removal HSSF	Total % of Removal
1	Fe (ppb)	159.42	119.18	59.2	25.2	50.3	62.9
2	pb(ppb)	30.49	29.88	22.98	2.0	23.1	24.6
3	Ni(ppb)	24.85	4.81	<0.01	100.0	99.8	100.0
4	Cr(ppb)	<0.01	<0.01	<0.01	0.0	0.0	0.0
5	Cu(ppb)	6.68	<0.01	<0.01	99.9	0.0	99.9
6	Mn(ppb)	581.4	199.47	44.07	65.7	77.9	92.4
7	Cd(ppb)	2.94	1.62	0.96	99.7	0.0	99.7
8	Zn(ppb)	47.07	31.32	19.29	33.5	38.4	59.0
9	pH	6.99	7.14	7.19	-2.1	-0.7	-2.9
10	NO ₃ (ppm)	13	12	6	7.7	50.0	53.8
11	Sulphate(ppm)	37	20	12	45.9	40.0	67.6
12	T.P (ppm)	2.6	2.4	0.3	7.7	87.5	88.5
13	TSS	2	2	2	0.0	0.0	0.0
14	Cl ⁻ (ppm)	18	12	10	33.3	16.7	44.4
15	COD (ppm)	19	4	2	78.9	50.0	89.5
16	BOD ₃ (ppm)	17	3	1	82.4	66.7	94.1
17	Oil & Grease%	15	12	5	80.0	58.3	96.7
18	Turbidity (NTU)	2.9	2.6	1.5	10.3	42.3	48.3



**Real Life video of the
project**

Bzian Constructed wetland





**Bzian
Constructed
wetland
10000 L/day**





Bzian Constructed wetland





Thank
you

