Tailor-Made Socio Economic Approaches for Integrated Water Management in Rural to Urban Driven Mutations "SoWat" 2020 - Hydraulic design of Nagaa Diab pilot field for wastewater reuse (dark & grey

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Africa-EU Innovation Alliance for Water and Climate

Tailor-Made Socio Economic Approaches for Integrated Water Management in Rural to Urban Driven Mutations

"SoWat"

2020

Hydraulic design of Nagaa Diab pilot field for wastewater reuse (dark & grey)

By Pascal Breil (INRAE)

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Identified problems to solve

Local physical limitations:
Soil, irrigation water and groundwater with high salt content.
Limitation of fruits and vegetables, even in small quantities for self-consumption.

Potential solution:
1- Improve soil quality
2- Irrigate with better quality water

Constraint: develop an affordable solution for low-income people.

Potential solution to be tested

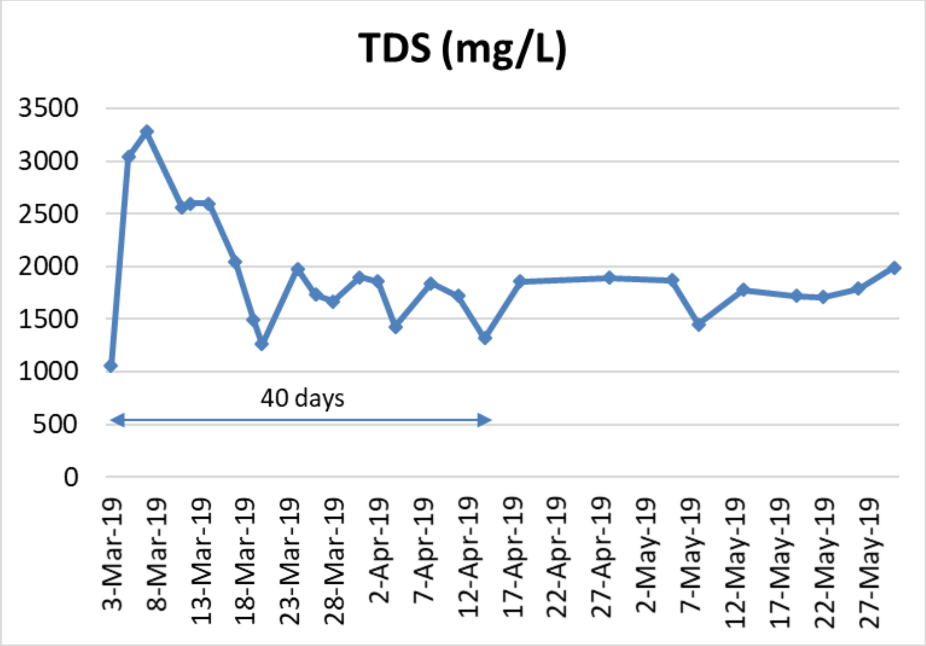
Water supplied for domestic services has a low level of salinity. It can be reused after adequate treatment, depending on its pollution load.

Low cost treatment to reduce the pollution carried:

1- For grey water: filtration, decantation of suspended particles
2- For black water: septic tank followed by a sand bio-filter

These solutions are normally sufficient, but this must be confirmed by analyses to verify the compatibility of the final uses with the regulations.

Feasability test for soil recovery



Given this result, we considered a water use scenario for a family of 4 with a European standard, in the absence of sufficiently accurate data from the field in Nagaa Diab.

This represents 0.37 m3 of wastewater per day that we can use after treatment to reduce soil salinity and irrigate small agricultural plots.

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Soil rincing and irrigation strategy

Daily discharge of cleaned water is	0.37	m3
Water requirement for vegetables in desert conditions is 5 cm / week (FAO data)	0.7	cm/day

This means that after 40 days of soil flushing, the first plot can be irrigated with less water. The excess water can be used to flush another plot, and so on...

	m2	cumulated area m2	required water volume /m2	Total required volume m3	outflow m3/j	days	Plot irrigation m/day	cumulated days	years
Plot1	5	5	3	15	0.37	40.5	0.035	40.5	0.1
plot2	5	10	3	15	0.335	44.8	0.035	85.3	0.2
Plot3	5	15	3	15	0.3	50.0	0.035	135.3	0.4
Plot4	5	20	3	15	0.265	56.6	0.035	191.9	0.5
Plot5	5	25	3	15	0.23	65.2	0.035	257.1	0.7
Plot6	5	30	3	15	0.195	76.9	0.035	334.1	0.9
Plot7	5	35	3	15	0.16	93.8	0.035	427.8	1.2
Plot8	5	40	3	15	0.125	120.0	0.035	547.8	1.5
Plot9	5	45	3	15	0.09	166.7	0.035	714.5	2.0
Plot10	5	50	3	15	0.055	272.7	0.035	987.2	2.7

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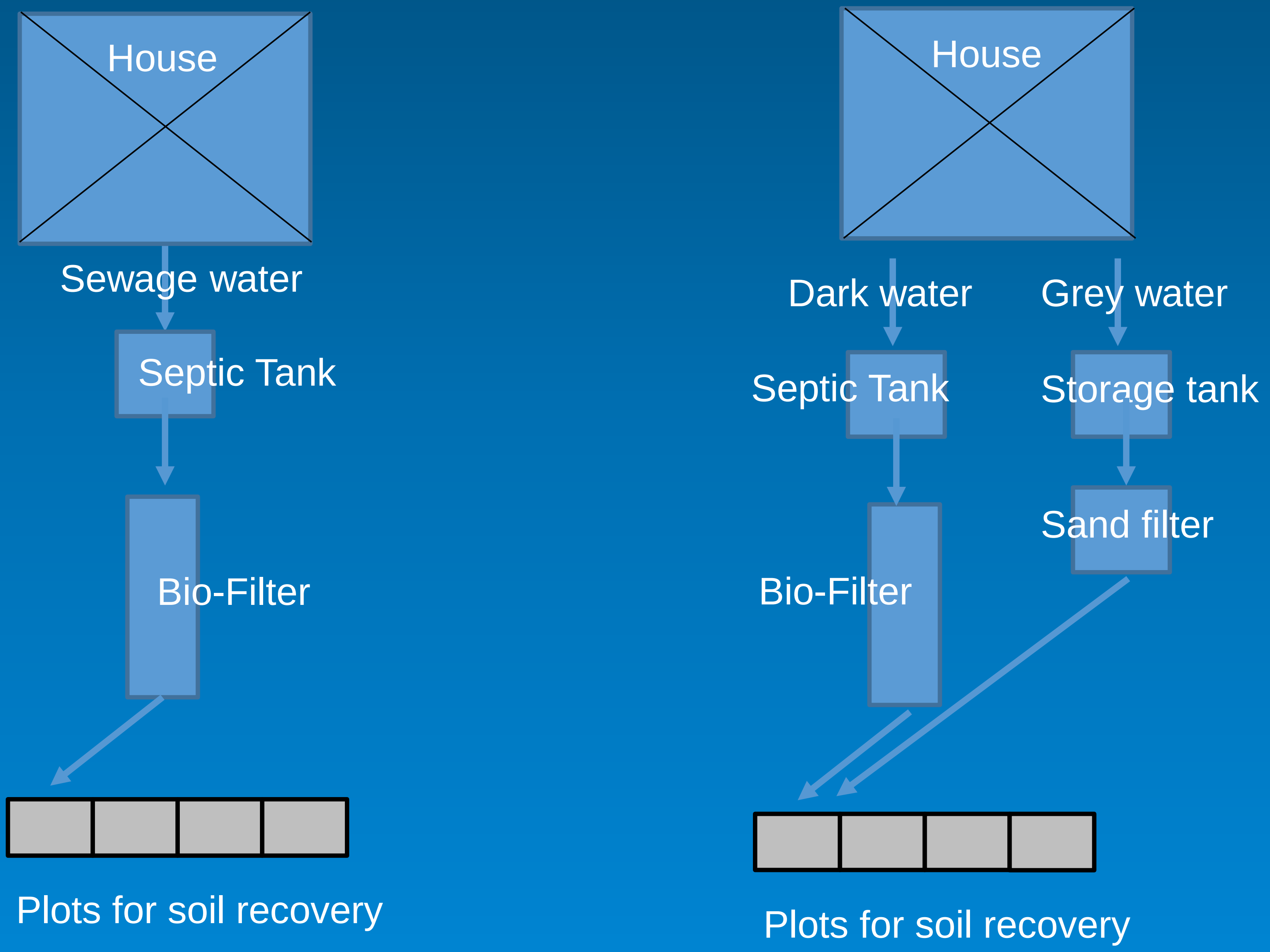
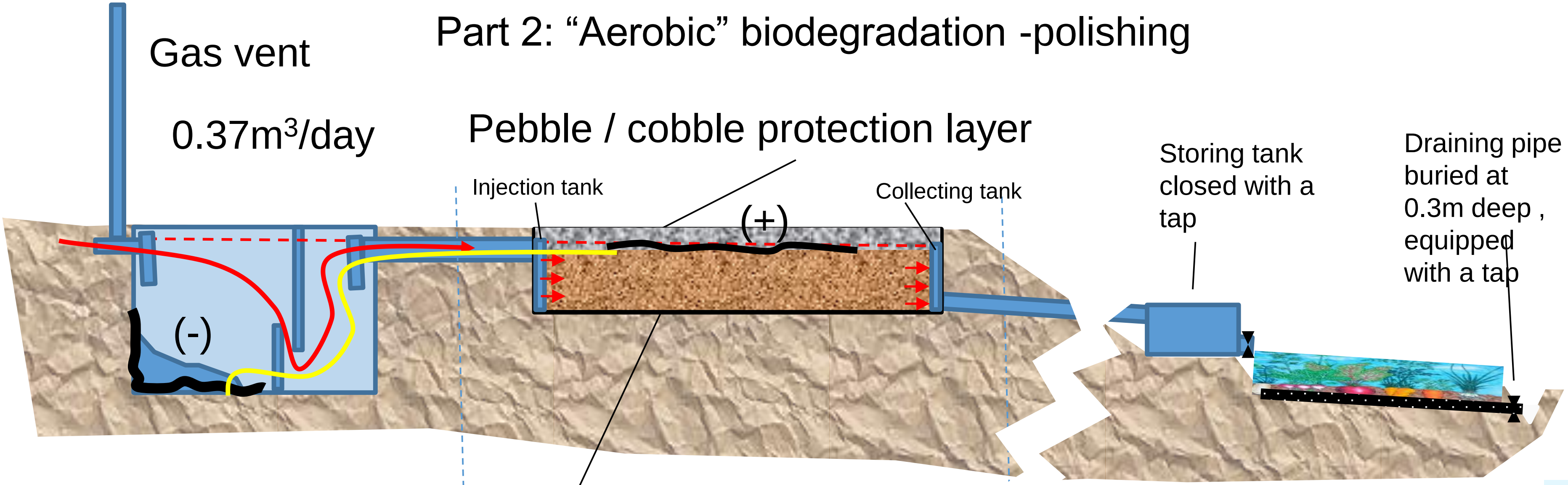
Initial and new strategy to implement proposed solution



Part 1: Anaerobic biodegradation

Part 3: Rincing & irrigation part

Part 2: “Aerobic” biodegradation -polishing



Sceptic tank principle

Anoxic biodegradation phase

Design
3-4 m^3 for 5 people

Must be cleaned every 3 years

Medium to coarse sand (0.25<∅<1mm)

Oxic mineralization phase

Design assuming
Hydraulic conductivity of 10^{-4} m/s
Sand Volume of 0.5 m X 2.0 m X 12.0 m
Hydraulic gradient of 0.5 m

Which gives:
A flux of 0.36 m^3/day
Residence time of 10 days
Storage capacity of 3.7 m^3

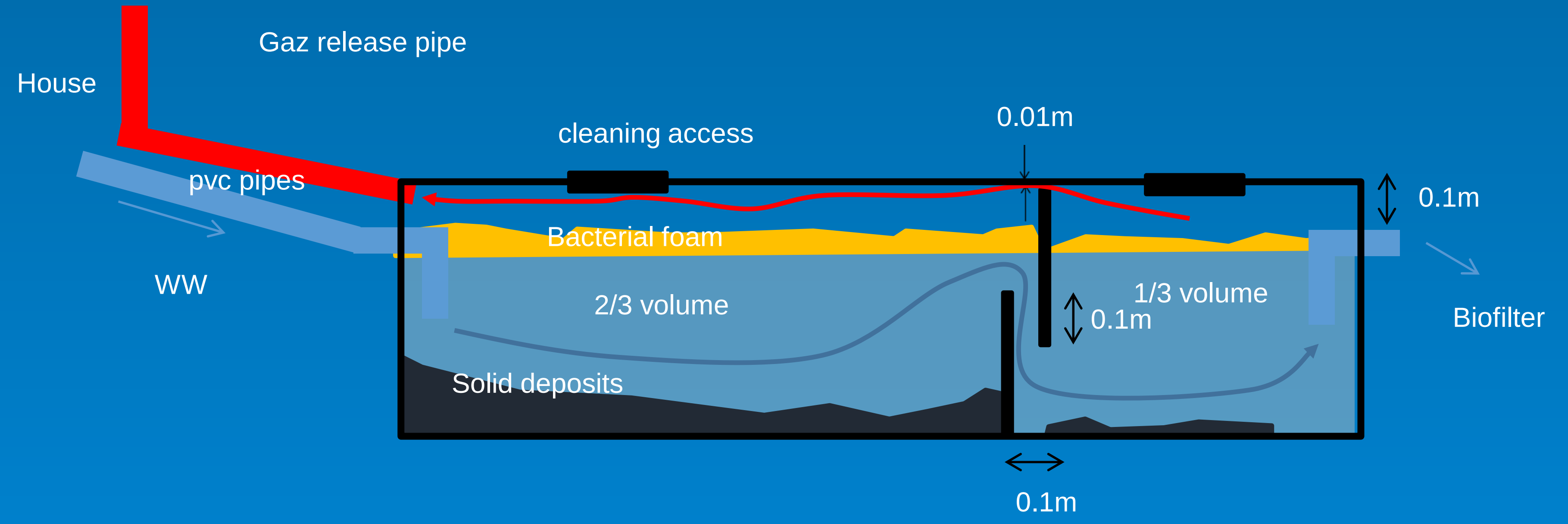
Phase 1 : washing soil by flooding irrigation (as it is practice by local people). Duration is 40 days for a plot of 5m2 flooded each night under 0.07 m of treated WW.

Phase 2 : drip irrigation with 0.007 m / day (0.7 cm) required for vegetable growing in arid zone (FAO data).

Part 1: Septic tank design

- Total volume is equal to ten times the daily wastewater flow. This ensures a residence time of more or less ten days for the incoming water before it reaches the outlet.

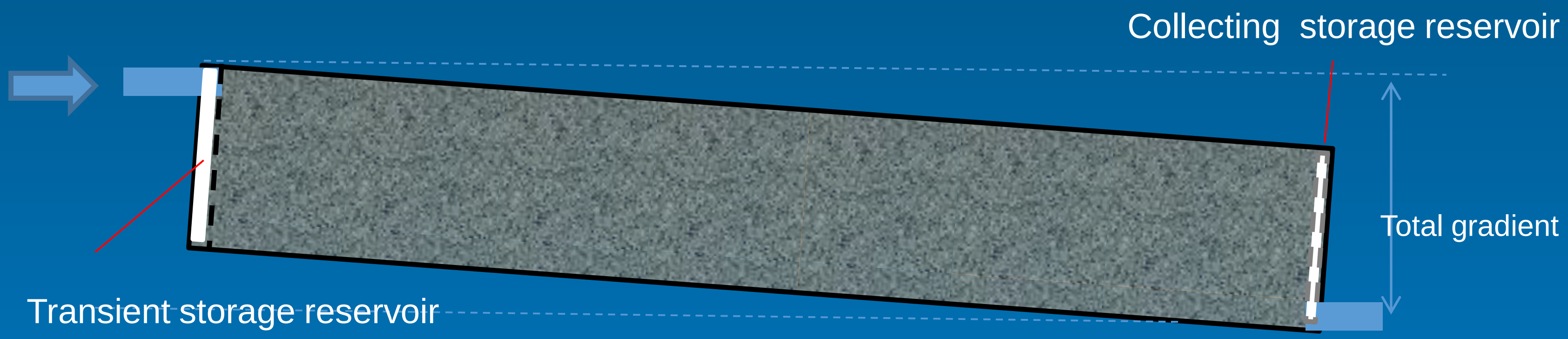
- Panels are used to force the direction of flow and the settling of solid waste.



Part 2: Biofilter profile design

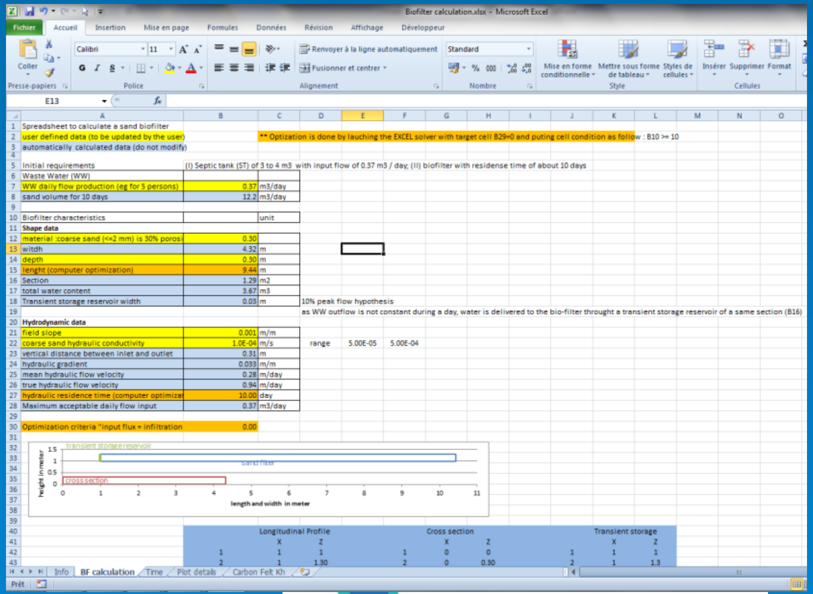
The shape of the BF depends on the available free area and the topography to allow gravity flow from ST to BF to the irrigated plot.

The flow capacity is calculated using Richard's equation….$Q = - Kh * dH/dL * FS$



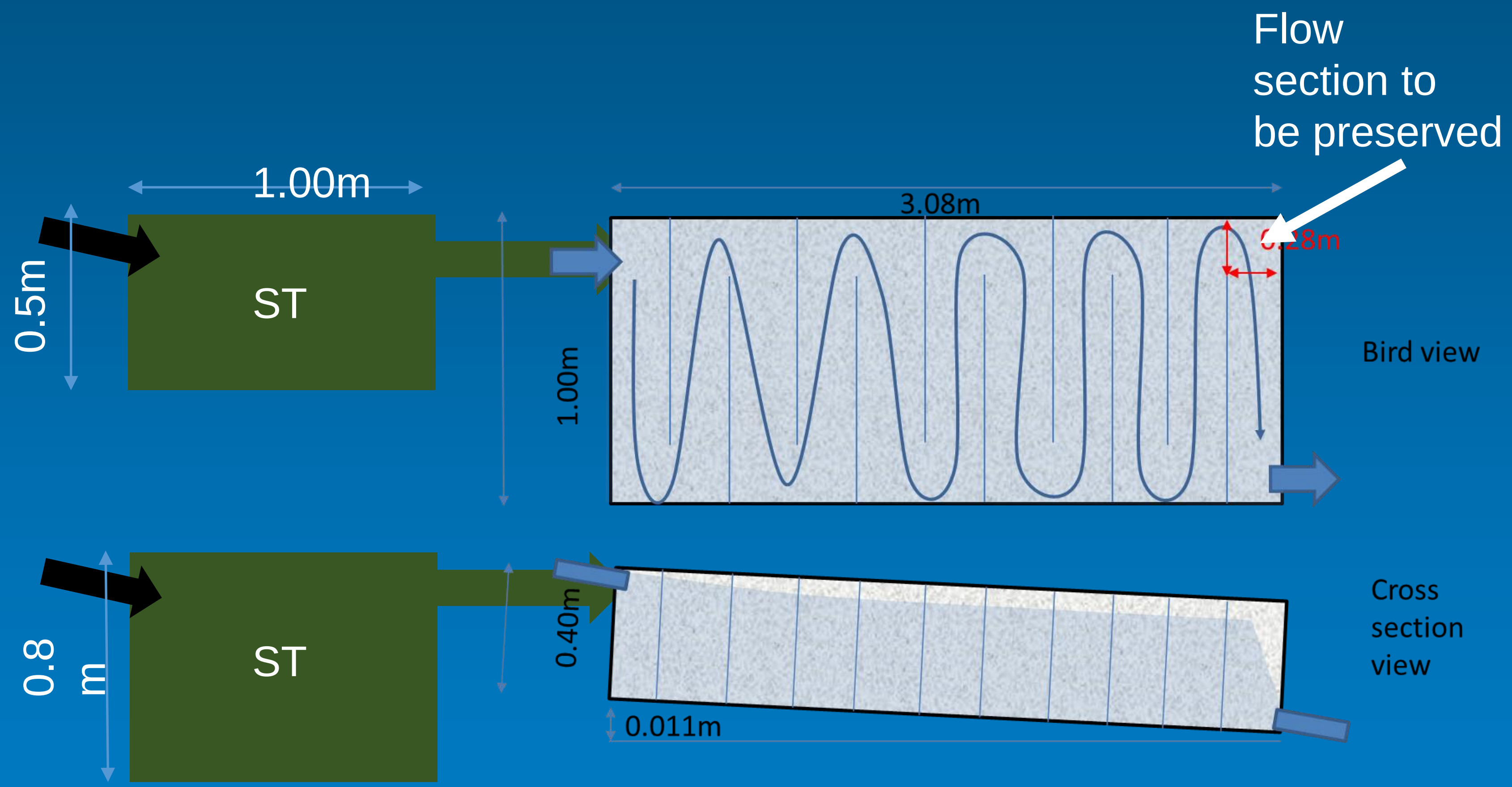
A spreadsheet has been developed. The input data are :

- The depth of the biofilter (not more than 0.6m to avoid anoxic zones.
- The hydraulic conductivity at saturation of the selected sand material (Khs)
- Gradient of the bottom of the BF, which should not deviate too much from the natural gradient of the land to limit the amount of earthwork.



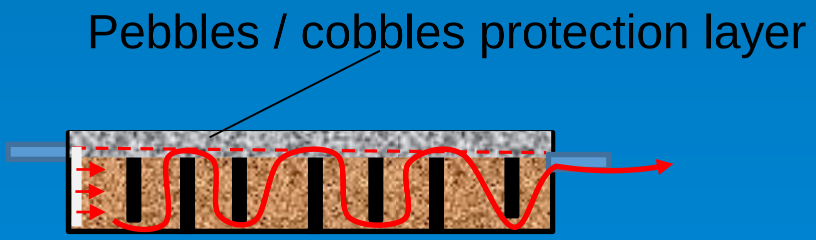
	A	B	C	D
1	Spreadsheet to calculate a sand biofilter			
2	user defined data (to be updated by the user)		** Optization is done by lauching the EXCEL solver with target cell B29=0 and puting cell condition as follow : B10 >= 10	
3	automatically calculated data (do not modify)			
5	Initial requirements	(I) Septic tank (ST) of 3 to 4 m3 with input flow of 0.37 m3 / day; (II) biofilter with residense time of about 10 days		
6	Waste Water (WW)			
7	WW daily flow production (eg for 5 persons)	0.37	m3/day	
8	sand volume for 10 days	12.2	m3/day	
10	Biofilter characteristics		unit	
11	**Shape data**			
12	material :coarse sand (<=2 mm) is 30% porosi	0.30		
13	witdh	4.32	m	
14	depth	0.30	m	
15	lenght (computer optimization)	9.44	m	
16	Section	1.29	m2	
17	total water content	3.67	m3	
18	Transient storage reservoir width	0.03	m	10% peak flow hypothesis
19				as WW outflow is not constant during a day, water is delivered to the bio-filter throught a transient storage reservoir of a same section (B16)
20	**Hydrodynamic data**			
21	field slope	0.001	m/m	
22	coarse sand hydraulic conductivity	1.0E-04	m/s	range 5.00E-05 5.00E-04
23	vertical distance between inlet and outlet	0.31	m	
24	hydraulic gradient	0.033	m/m	
25	mean hydraulic flow velocity	0.28	m/day	
26	true hydraulic flow velocity	0.94	m/day	
27	hydraulic residence time (computer optimizat	10.00	day	
28	Maximum acceptable daily flow input	0.37	m3/day	
30	Optimization criteria "input flux = infiltration	0.00		

Pilote test with compact design

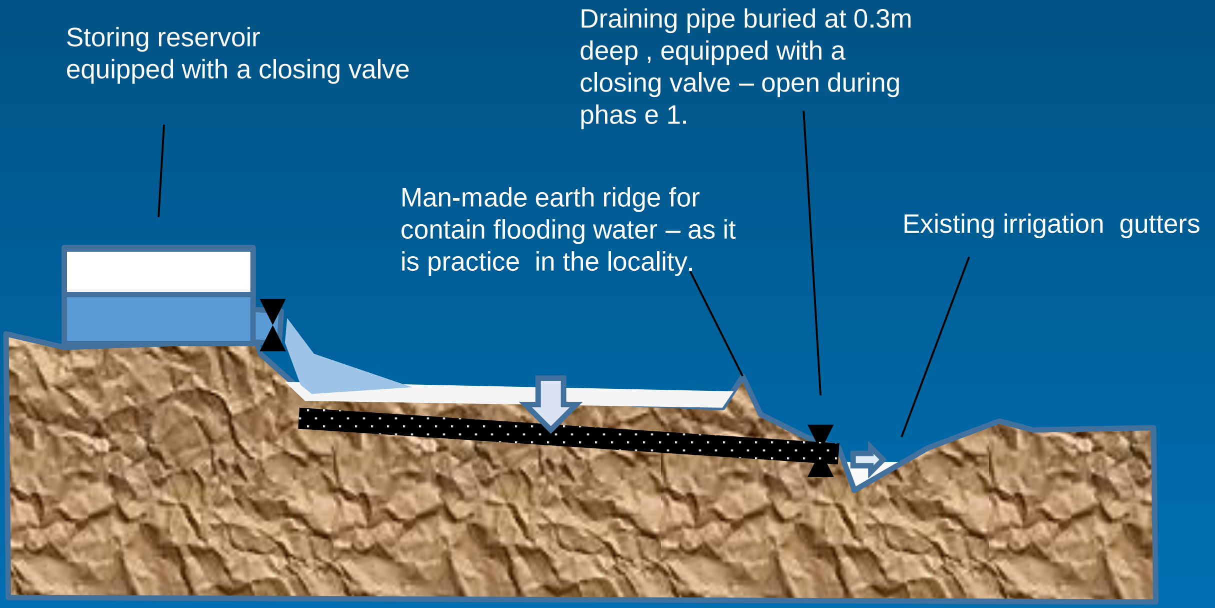


The flow cross-section and hydraulic gradient defined in the linear bio-filter must be maintained in the compact bio-filter. The possible width of the bio-filter depends on the space available laterally.

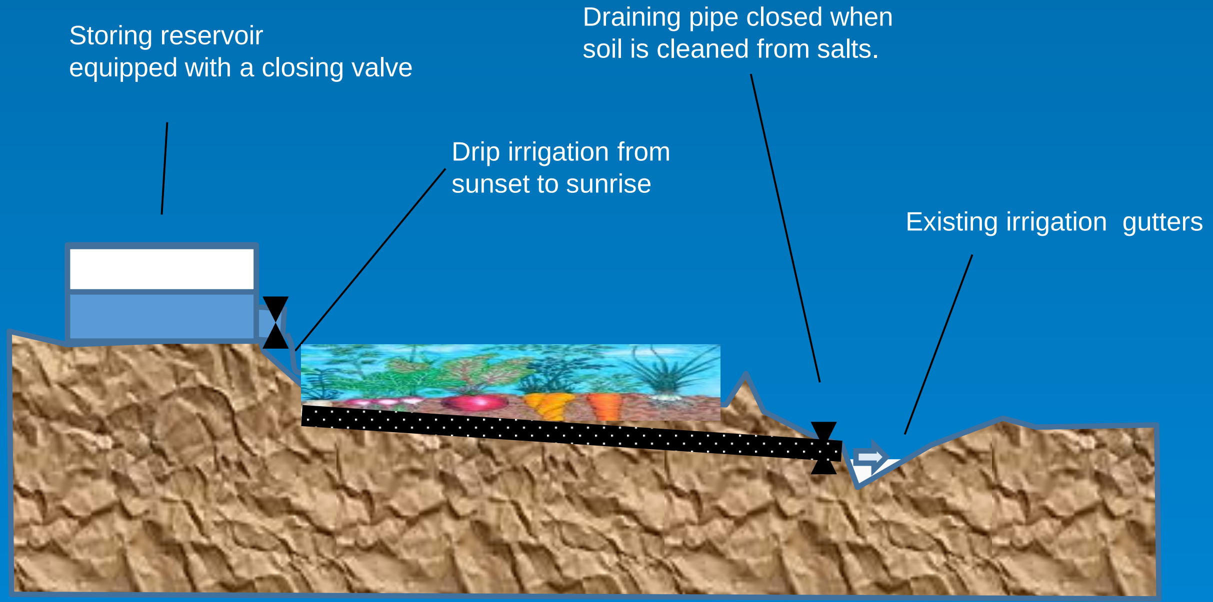
Other possibility :



Part 3 : plot rincing & irrigation



Phase 1:Soil cleaning
duration (from lab. experiment data) is 40 days over a plot of 5m2.
Plot must be flat and horizontal as possible to be completely flooded by the complete release of the storing reservoir just after the sunset to limit evaporation. Drains must have been buried at 0.3m depth before the flooding operation. A recommended inter-drain distance is 0.6 m for drain of 0.08m in diameter.



Phase 2:
Drip irrigation must be installed.
Drain outflow must be closed to avoid water drainage.
Irrigation is 0.7 cm / day over a plot of 5m2, while 7cm / day are delivered by the storing reservoir, allowing to irrigate 50m2 after this area soil has been washed. A calendar is proposed to progressively shift from phase 1 to phase 2. It is possible to complete 30m2 of irrigated cleaned soil after 1 year.
2.7 years to complete the maximum area of 50 m2.

Thank you!

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