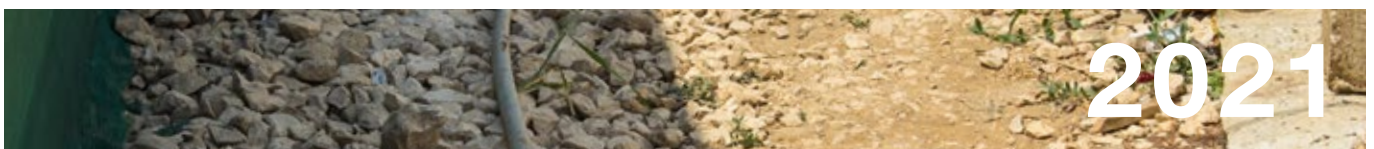UPM

Nº3

Design Considerations for Simplified Sewer Network in Informal Settlements

2021

Design Considerations for Simplified Sewer Network in Informal Settlements

is part of the series

Methodologies & Application from Documented Experience
MADE by UPM

Revised Edition — January 2021

Table of Contents

Abbreviations & Acronyms

ABR	Anaerobic Baffled Reactor
C	Column
D	Inner Diameter of pipe in mm
DN	Diameter Nominal
DU	Design Units
e.g.	exempli gratia; for example
h	height of filling im mm
HT	Holding Tank
INGO	International Non-Governmental Organization
ITS	Informal Tented Settlements
KS	Kitchen Sink
LD	Laundry Drain
l/s	liters per second
m	meter
mm	milimeter
NCSN	Non-conventional Sewer Network
PSN	Pipe Section Number
q	flow rate l/s
R	Row
SD	Shower Drain
SDGSS	Small Diameter Gravity Sewage System
T	Trap
TL	Toilet(s)
u	usage ratio calculated as h/D=0.5
WASH	Water, Sanitation and Hygiene

Preface

This publication is the result of the technical assistance provided by UPM Umwelt-Projekt-Management GmbH (UPM) and its partners, the Centre for Sustainable and Ecological Sanitation (CSES) of the University of Science & Technology Beijing (USTB), and the Lebanese Appropriate Technology Association (LATA) to WASH and Emergency Grantees of the Bill & Melinda Gates Foundation in Lebanon and in Bangladesh.

The present manual "Simplified Sewer Networks for Informal Tented Settlements" has been elaborated after implementation of on-site training on "Simplified Sewer Networks" which was organized in June 2019 for UNICEF Lebanon and local WASH partners working with Syrian Refugees living in informal settlements and the local communities in the Bekaa Valley in Lebanon. The content was prepared in order to be presented to the WASH community in Cox's Bazar, Bangladesh but related training had to be cancelled due to the COVID-pandemic.
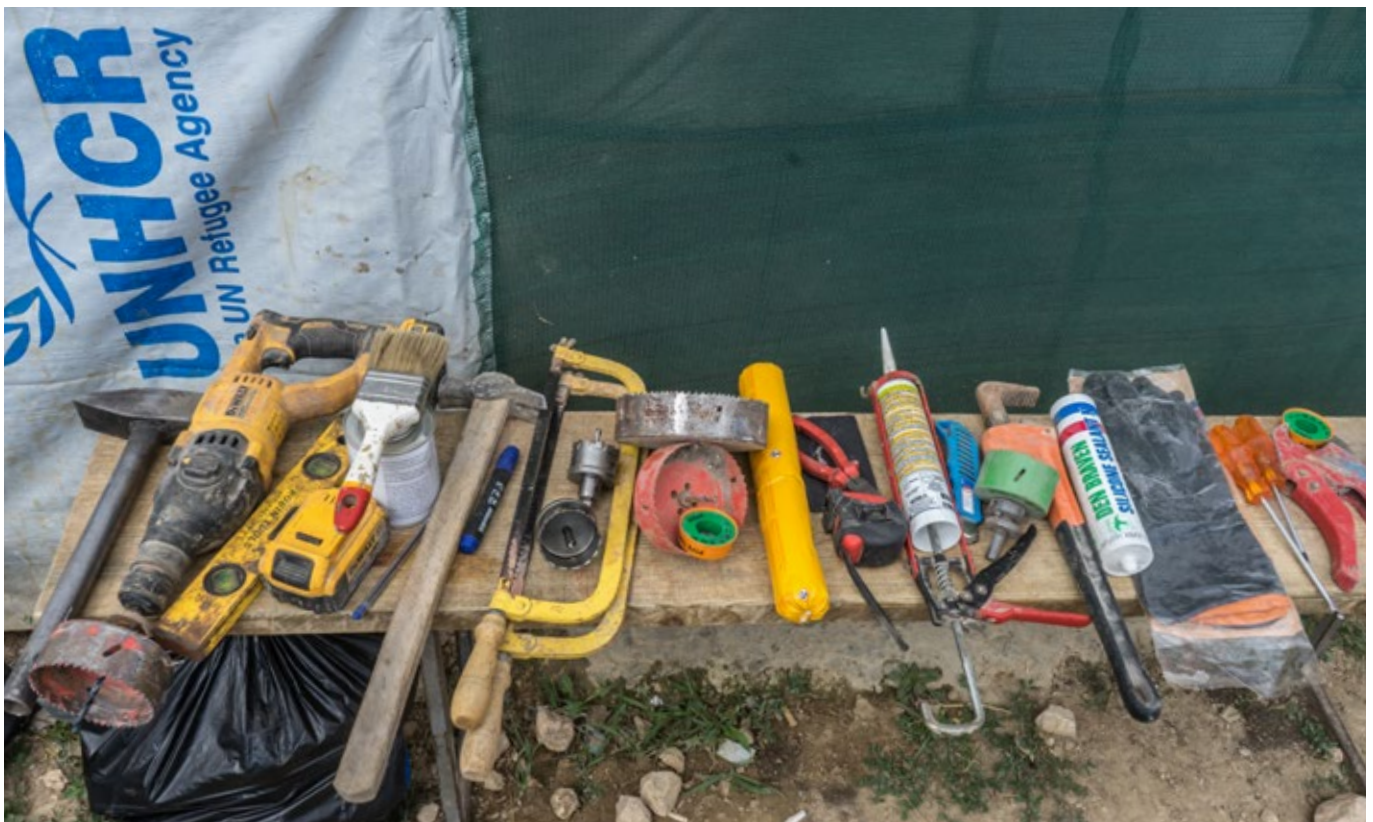
L E B A N O N

BEIRUT

Bekaa Valley

FIGURE 1: Toolkit for practical knowledge applied during field work.

FIGURE 2:
ITS street view during summer in
Bekaa Valley. In winter, the zone is
severely affected by heavy snow.

Introduction

A simplified sewer network describes a sewerage network that is constructed using smaller diameter pipes laid at a shallower depth and at a flatter gradient than Conventional Sewers. Simplified sewer network allows for a more flexible design at lower investment costs.

Conceptually, simplified sewerage is the same as Conventional Gravity Sewerage, without considering the unnecessary conservative design standards, and with design features that are better adapted to the local situation. The pipes are usually laid within the property boundaries, through either the back or front yards, rather than beneath the central road, allowing for fewer and shorter pipes. Because simplified sewers are typically installed within the condominium, they are often referred to as condominial sewers. [1] The pipes can also be routed in access ways, which are too narrow for heavy traffic, or underneath pavements (sidewalks). Since simplified sewers are installed where they are not subjected to heavy traffic loads, they can be laid at a shallow depth and little excavation is required. [2]

Simplified sewerage is also an important sanitation option in peri-urban areas of developing countries, especially as it is often the only technically feasible solution in these high- density areas. It is a sanitation technology widely known in Latin America, but it is much less well known in Africa and Asia. The purpose of this Manual is to introduce this technology and its advantages, so that it can be used more widely in peri- urban sanitation programs and projects to improve the health of disadvantaged communities. However, simplified sewerage is not just for peri-urban areas – it can be successfully and appropriately used in middle-and upper-income areas as well. [3]

[1] Source: https://en.wikipedia.org/wiki/Condominial_sewerage
[2] Source: https://akvopedia.org/wiki/Simplified_Sewer
[3] Source: The World Bank – Duncan Mara / Andrew Sleigh / Kevin Tayler; Simplified Sewer Manual, December 2000.

Simplified and Condominial Sewers

Describe a sewer system that is constructed using smaller diameter pipes laid at a shallower depth and at a flatter gradient than conventional sewers.

Allow for a more flexible design associated with lower investment costs, and a higher number of connected households.

Because the sewers are generally communal, they are often referred to as Condominial sewers.

Basic Design Principles

→ They operate as conventional sewers but with a number of modifications: the minimum diameter and the minimum cover are reduced.

→ Expensive manholes are replaced with simple inspection chambers or flushing points.

→ Sewers are laid within the property boundaries and sidewalks, rather than beneath the central road.

→ The slope is determined by using the tractive force concept rather than the minimum velocity concept.

→ Sewers should be designed to take into account the extra flow that may result from storm water infiltration.

→ Because simplified sewers are laid on or around the property of the users, higher connection rates can be achieved, fewer and shorter pipes can be used, and less excavation is required as the pipes will not be subjected to heavy traffic loads.

Costs

→ The costs of simplified sewerage systems are low (50 to 80% less expensive than conventional gravity sewerage), sometimes even lower than those of on- site sanitation.

→ This is because simplified sewerage uses flatter gradient, shallow excavation depths, small diameter pipe and simple inspection units.

Operation & Maintenance

→ Blockages need to be removed, and the system needs to be flushed periodically.

→ The pipeline system components, such as cleanouts or ventilation points, should be regularly checked and maintained.

Applicability

→ Where the ground is rocky or the groundwater table is high.

→ They can be installed in almost all types of settlements, and are especially appropriate for dense urban settlements.

→ It is recommended that the scum from greywater, heavy solids and garbage be removed from the wastewater prior to entering the sewer to avoid frequent clogging.

TABLE 1: Advantages & Disadvantages of Simplified and Condominial Sewers. [4]

Advantages	Disadvantages
• Can be built and repaired with locally available materials. • Capital costs are between 50 and 80% less than conventional gravity sewers. • Operating costs are low. • Can be extended as a community changes and grows.	• Requires enough water for flushing. • Requires expert design and construction supervision. • Requires frequent repairs and removals of blockages. • Only suitable where there are interceptor tanks, septic tanks or other on-site pre-treatment systems.

Solids-free Sewers

These are similar to conventional sewer systems, except that the wastewater is pre-settled and solids removed before entering the system.

Basic Design Principles

→ As solids are removed, sewer diameter can be much smaller, and they can be constructed using less conservative design criteria (lower gradients, fewer pumps, less pipe depth, etc.) resulting in significantly lower investment costs.

→ A precondition is an efficient pre-treatment at the household level. The interceptors remove settleable particles that may clog the small pipes. If well used and maintained, there is little risk of clogging; hence, the sewers do not have to be self-cleansing. They can be laid at shallow depths, can have fewer inspection points (manholes), can follow the topography more closely and can even have inflective gradients (i.e. negative slope).

Costs

→ Due to the simplified design, solids-free sewers can be cheaper to build.

Operation & Maintenance

→ The pre-settling units must be maintained and emptied regularly to ensure optimal performance.

→ The risk of pipe clogging is low if the sewers are well operated and maintained, however, some maintenance is required periodically.

→ Regardless of performance, the sewers should be flushed once a year.

Applicability

→ They are well suited for areas where soak pits are inappropriate due to sensitive groundwater or lack of space for on-site infiltration.

→ Discharge of non-pre-settled wastewater into the sewers should be prevented.

→ Discharge of non-pre-settled wastewater into the sewers should be prevented.

→ Require a constant supply of water, although less water is needed compared to conventional sewers.

[4] Source: Solomon Seyoum; Type of Sewer Systems.

TABLE 2: Advantages & Disadvantages of Solids-free Sewers.

Advantages	Disadvantages
• Can be built and repaired with locally available materials. • Low operating costs if well maintained. • Can be extended as a community changes and grows. • Appropriate for densely populated areas with sensitive groundwater or no space for a soak pit or leaching field.	• Requires repairs and removals of blockages more frequently than a conventional sewer. • Requires expert design and construction supervision. • Requires education and acceptance to be used correctly. • Effluent and sludge (from interceptors) require secondary treatment and/or appropriate discharge.

Pipe Sizing for Simplified Sewer Networks in Informal Tented Settlements (ITS)

Case Study:
Camp in Bekaa Valley, Lebanon

By UPM
November, 2019

FIGURE 3: The toilet is installed in a corrugated tin roof shelter. The holding tank is located under the concrete platform.

FIGURE 4: Typical pour flush toilet installed in the shelter. Water container for anal cleaning and hand washing. Broom in the back for cleaning.

FIGURE 5: Shower drain without trap (left). Water pipe from the tank.

FIGURE 6: Greywater coming from a shelter some distance away. The pipe is broken, because it is not protected (right). The pipe diameter is not appropriate to the little amount of greywater flow.

FIGURE 7: Stagnant water mainly from broken greywater pipes. The greywater is not treated, and it is freely discharged into the open drain.

Framework

In most National Sewerage Design Codes, the minimum sewer pipe diameter is specified with 100 mm. However, in an ITS environment typical flushing toilets with 6–9 liters per flush do not exist. Therefore, the sewer design has to consider small flow rates, low population numbers, no future expansion and no infiltration.

First rule to be observed:

> Small flows flow better in small sewers.

Wastewater should be treated on-site in accordance to Lebanese standards. If possible, black- and greywater should be separated already at household level.

ITS in the Bekaa Valley host a varying number of tents: from very few, up to 70 tents. The tents are usually occupied by families of up to 6–7 people including young, old and disabled people.

In the location selected for the case study, an International Non-Governmental Organization (INGO) plans to install for each family a pour flush toilet (1.5–2.5 liters per flush) on a 1,000 liters horizontal Holding Tank (HT) close to the tent with the possibility of discharging kitchen or dish washing water so that no grease trap is needed.

At present, cooking and dish washing, laundry, and personal hygiene are carried out partly outside the tents.

> The Holding Tank should not act as a Solid Waste Collection Bin.

> The Holding Tank should be emptied at least once a year.

In that context, the best option should be the installation of a solid-free "Small Diameter Gravity Sewage System" (SDGSS).

Pre-Preparation for the Sewer Pipe Sizing

All shelters need some sanitary appliances where the wastewater can be collected and then discharged to their respective sewer.

These are the sanitary appliances:

- Pour Flush Toilet discharging to the Underground Holding Tank (HT).

- Kitchen Sink (KS) discharging to the HT (no grease trap needed).

- Shower Drain (SD) discharging to the sewer pipe.

- Laundry Drain (LD).

All sanitary appliances must have a trap.

The position of the sanitary appliances should be decided by the tenant and the WASH expert.

Before starting with the pipe sizing, the tenants and WASH expert should decide where the pipe route will be and the position of the ABR treatment plant or alternative treatment set-up.

The WASH expert will make a sketch of the proposed pipe layout. The tenants and landlord will get a copy of layout and will be able to comment on it. That is important because some of the pipes may have to pass through a shelter.

In this case, the landlord did not agree to the proposed pipe layout for two of the shelters, because the excavation would be close to the road tarmac.
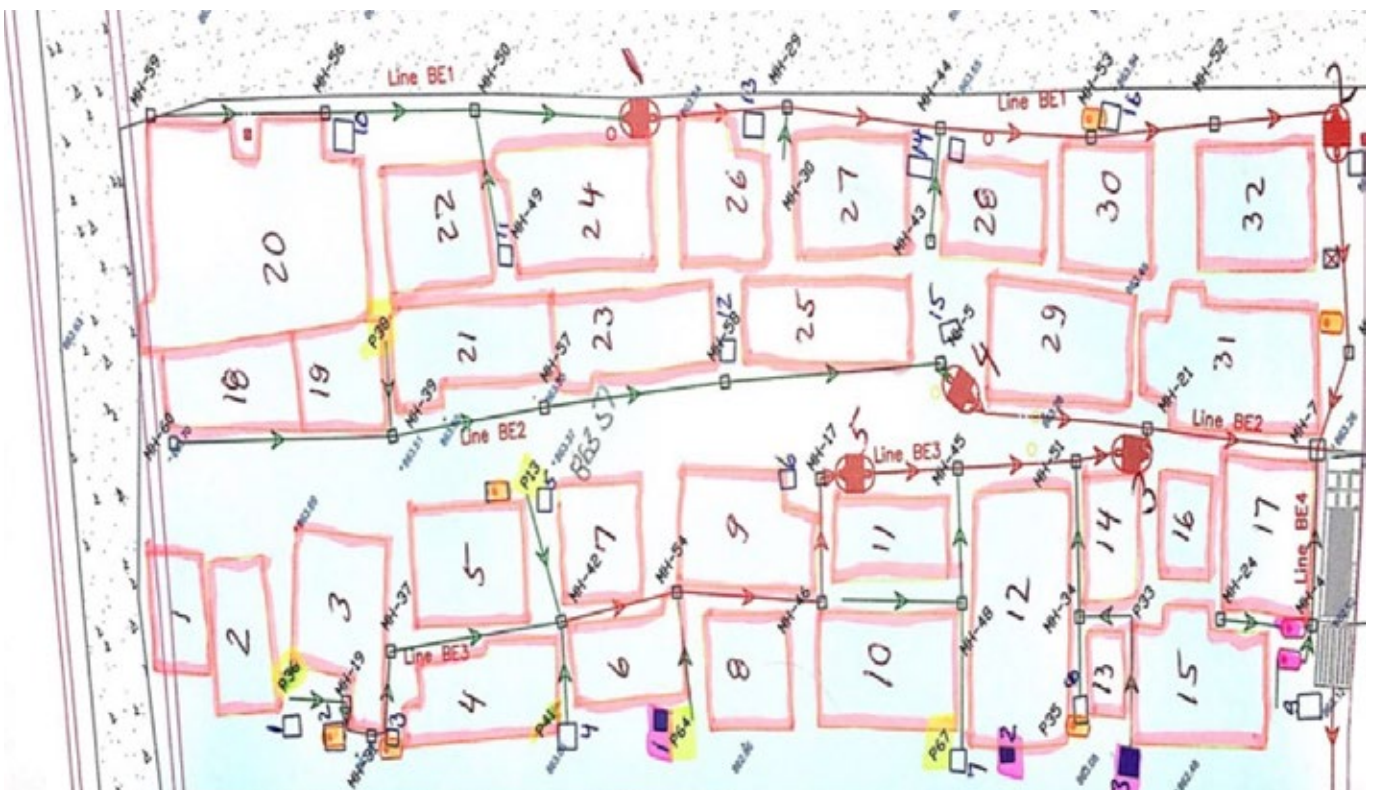
FIGURE 8: Example of sewer layout for an ITS.

Pipe Sizing of Sewer Pipes for a "Non-conventional Sewer Network" (NCSN) or "Small Diameter Gravity Sewer System" (SDGSS)

Basic Information

There are many formulas for calculating the design peak flow in a gravity system, depending on local conditions and standards. In the ITS, sanitary appliances mostly do not correspond to the usual standards. Consequently, Design Units (DU) for standardized sanitary appliances cannot be used for pipe sizing.

EXAMPLE: Conventional Wastewater Flow Calculation

$$q = k1 \times k2 \times P \times w / 86{,}400$$

where

→ q = daily peak flow, in l/s

→ $k1$ = peak factor = daily peak flow divided by average daily flow (1.5–4)

→ $k2$ = return factor = wastewater flow divided by water consumption (75–95%)

→ P = population served by length of sewer under consideration (200 people)

→ w = average water consumption, liters per person per day (40 l/c+d)

→ $86{,}400$ = the number of seconds in a day

q for Case Study 1

$q = 1.7 \times 0.8 \times 200 \times 40 / 86{,}400$

$q = 0.1259$ l/s

q for Location 2 ABR

$q = 1.7 \times 0.8 \times 307 \times 35 / 86{,}400$

$q = 0.1691$ l/s

Very difficult to find a pipe size in the **conventional application;** and remember: in a conventional sewer, the minimum diameter is 100 mm

The ITS has its own environment and, based on habitants' needs and habits, a cycle of 2 to 3 peaks per day will occure. The peak flow should be calculated only for 1 hour (1 peak) = 3,600 seconds, instead than for the whole day. The total wastewater production per person is estimated at a 40 l/c+d.

The average wastewater consumption should be divided by 3 cycles, and would be:

$40 l/c+d/3 = 13.3 l/c+d$

EXAMPLE: Flow Rate for 200 people

q for Case Study

$q = 1.7 \times 0.8 \times 200 \times 13.3/3{,}600$

$q = 1.009 l/s$

EXAMPLE: Flow Rate for one person

q per person + day

$q = 1.0049/200$

$q = 0.005 l/s$

The most important aspect in the pipe sizing of a **NCSN** or **SDGSS** is to have a functional **Pre-Treatment System** in form of an Inceptor Tank, i.e. a Holding Tank, a Septic Tank or a Biogas Tank. Regular emptying of sludge should be done once a year.

The pipe network should be installed with a gradient of 0.5% (minimum) and should have at intervals rodding eyes and ventilation, depending on the number of connection points.

The whole network should be **watertight** so that **no infiltration** and **no exfiltration** can occur.

The second most important aspect in the pipe sizing of a **NCSN** or **SDGSS** is that the pipework is not carrying any heavy solids (from toilets, grease traps etc.) as in a conventional gravity system.

Comparison

CONVENTIONAL SEWER

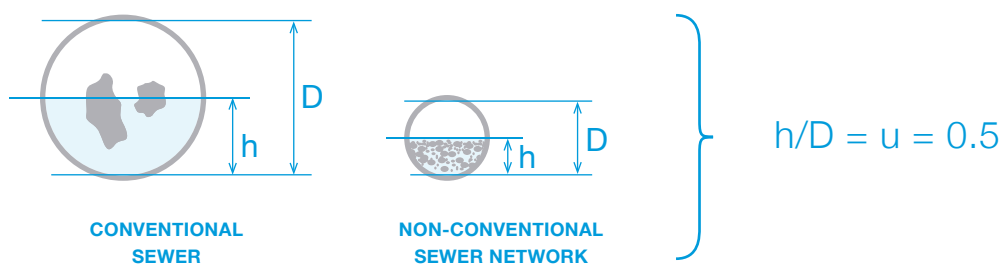NON-CONVENTIONAL SEWER NETWORK

$h/D = u = 0.5$

FIGURE 9: Comparison of pipe half full in CS and in NCSN.

Pipe Sizing of Sewer Pipes for a "Non-conventional Sewer Network" (NCSN) or "Small Diameter Gravity Sewer System" (SDGSS) using PVC U Soil & Waste Pipes and Fittings

The pipe sizing for our NCSN or SDGSS will be done with the help of a Design Table, which includes pipe diameters from DN 32 up to DN 125, and flow rates under different gradients for half full load.

Explanation of the Design Table

Table 3 presents information on PVC U pipes in a range of 32 mm – 125mm, at different gradients for half full load. The use of solvent weld fittings is suggested: they are more economical than the O-ring fittings.

TABLE 3: Design Table.

		Columns										
		1	2	3	4	5	6	7	8	9	10	11
Rows	1			Conventional PVC Soil & Waste Pipes						Additional Information		
	2			Gradient = J, considering u=0.5								
	3	DN	Flow Rate	0.50%	1%	1.5%	2%	2.50%	3%	Area (m²)	Volume (l) in 10 m pipe + u=0.5	Velocity (m/s)
	4	32	l/s	0.19	0.27	0.34	0.39	0.43	0.48	0.00049	2.45	0.50
	5	40	l/s	0.30	0.43	0.54	0.61	0.67	0.74	0.00091	4.54	0.50
	6	50	l/s	0.47	0.66	0.84	0.95	1.04	1.16	0.00152	7.60	0.50
	7	63	l/s	0.54	0.76	0.95	1.08	1.19	1.32	0.00204	10.21	0.50
	8	75	l/s	0.92	1.29	1.63	1.85	2.03	2.26	0.00374	18.69	0.50
	9	80	l/s	1.21	1.70	2.14	2.43	2.67	2.96	0.00430	21.49	0.50
	10	100	l/s	1.90	2.67	3.35	3.81	4.19	4.65	0.00694	34.68	0.50
	11	110	l/s	2.47	3.46	4.04	4.59	5.44	5.60	0.00849	42.45	0.50
	12	125	l/s	2.97	4.16	5.24	5.95	6.54	7.26	0.01112	55.58	0.50

To find the flow rate for a pipe at a certain gradient:
Make a horizontal line from the Row (R) and a vertical line from the Column (C), and where they meet is the value of the flow rate for that pipe.

Columns (C) & Rows (R)

→ **C1**: In Column 1 we have the Diameter Nominal (DN) of the pipes from 32 mm to 125 mm. That DN is the outside diameter of the pipes in milimeters.

→ **R2**: Different Gradients below, considering the pipes half full: u=0.5.

→ **R4 to R12** and **C3 to C8**: the Flow Rate in l/s.

→ **C3 to C8** and **R3**: the different Gradients J and slopes from 0.50% to 3%.

→ **C9 to C11** and **R3 to R12**: Additional information. See examples.

Examples

→ R4*C3: DN 32 and 0.5% gradient = flow rate of 0.19 l/s.

→ R4*C4: DN 32 and 1% gradient = flow rate of 0.27 l/s.

→ R5*C3: DN 40 and at 0.5% gradient = flow rate of 0.3 l/s.

→ R5*C6: DN 40 and 2% gradient = flow rate of 0.61l/s.

→ R8*C3: DN 75 and 0.5% gradient = flow rate of 0.92 l/s.

Additional Information for the Columns 9, 10 & 11

→ **C9**: Area in m^2 for DN 32 up to DN 125, all for internal measurement; all pipes have a wall thickness of 3 mm.

→ **C10**: Volume in liters for 10 m long pipe, gradient 0.5% and half full (u=0.5).

→ **C11**: Velocity is the same for all the pipes with a gradient of 0.50% and half full load (u=0.5).

→ See also Appendix A: Wastewater Collection System Layout.

Practical Example for Case Study

q for Case Study

$q = 1.7 \times 0.8 \times 200 \times 13.3/3,600$

$q = 1.009 l/s$

To find the diameter of the Main sewer pipe, we have only the flow rate of q = 1.009 l/s

TABLE 4: Design Table for Case Study.

		Columns										
		1	2	3	4	5	6	7	8	9	10	11
	1			Conventional PVC Soil & Waste Pipes						Additional Information		
	2			Gradient = J, considering u=0.5								
	3	DN	Flow Rate	0.50%	1%	1.5%	2%	2.50%	3%	Area (m²)	Volume (l) in 10 m pipe + u=0.5	Velocity (m/s)
Rows	4	32	l/s	0.19	0.27	0.34	0.39	0.43	0.48	0.00049	2.45	0.50
	5	40	l/s	0.30	0.43	0.54	0.61	0.67	0.74	0.00091	4.54	0.50
	6	50	l/s	0.47	0.66	0.84	0.95	1.04	1.16	0.00152	7.60	0.50
	7	63	l/s	0.54	0.76	0.95	1.08	1.19	1.32	0.00204	10.21	0.50
	8	75	l/s	0.92	1.29	1.63	1.85	2.03	2.26	0.00374	18.69	0.50
	9	80	l/s	1.21	1.70	2.14	2.43	2.67	2.96	0.00430	21.49	0.50
	10	100	l/s	1.90	2.67	3.35	3.81	4.19	4.65	0.00694	34.68	0.50
	11	110	l/s	2.47	3.46	4.04	4.59	5.44	5.60	0.00849	42.45	0.50
	12	125	l/s	2.97	4.16	5.24	5.95	6.54	7.26	0.01112	55.58	0.50

Choice & Remarks

→ **DN 75**: Flow rate at **u=0.5** and 0.5% gradient is **0.92 l/s**

Remark: The flow rate is smaller but in peak situation the pipe can be filled more than **u=0.5** and the velocity will increase from **0.5m/s**.

→ **DN 63**: Flow rate at **u=0.5** and 2% gradient is **1.08 l/s**

Remark: The flow rate would be efficient but the gradient of 2% could be a problem. Over 100 m that would mean 2 m height difference and relative deep excavation, which might not be approved by governmental offices or landlords.

→ **DN 80**: Flow rate at **u=0.5** and 0.5% gradient is **1.21 l/s**

Remark: The pipe will be oversized. When the peak is over, there is a risk of sedimentation because the velocity will be too low.

The next step for the pipe sizing of the whole project would be:

• After the position of the sanitary appliances has been decided, the pipe layout can be drafted/designed and agreed upon.

• For the purpose of the exercise, the layout as shown in Figure 10 has been confirmed. Additional discussion regarding possible separation of Black- and Greywater to reduce the overall size of the following Wastewater Treatment System might still occur.

FIGURE 10: Wastewater Layout (See enlarged version in Appendix A).
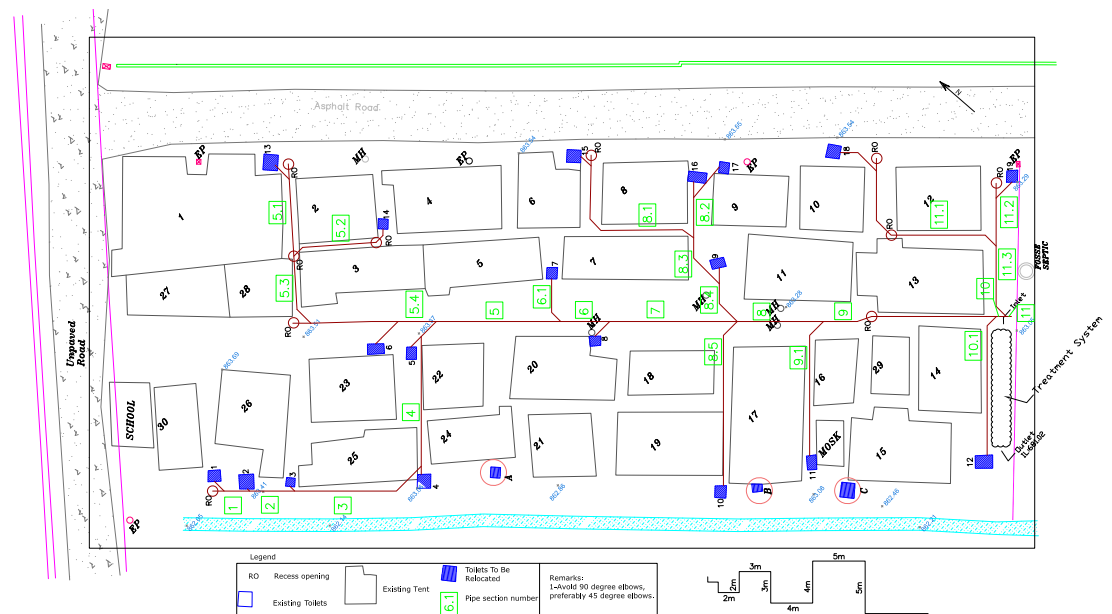
In Figure 10, not all sanitary appliances are indicated but all toilets. The sanitary appliances (SD + LD) not flowing to the Holding Tank (under the Toilet) will flow to the sewer pipe and have a diameter of 40 mm. See sketch in Figure 11.

FIGURE 11: Proposed shelter layout (The Kitchen Sink to Holding Tank solution is preferred).
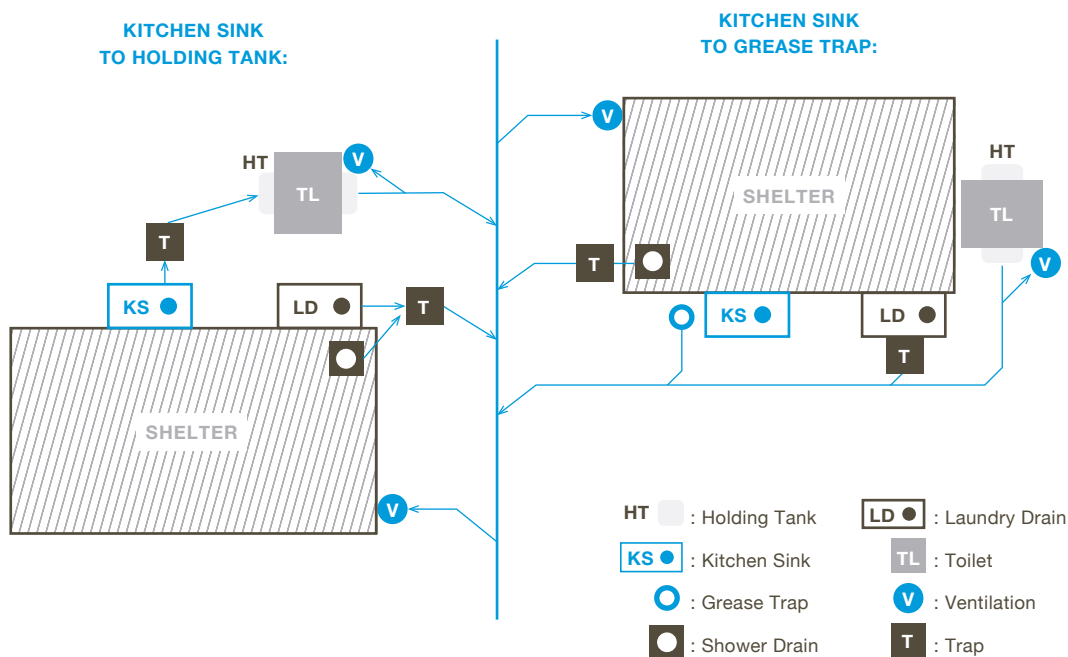
Remark: The Holding Tank under the toilet needs its own ventilation but it can be connected to the vertical vent pipe from the sewer pipe.

Calculation Table for Wastewater Layout

In relation with Figure 10, Wastewater Layout:

→ People per Toilet (TL)　　: **11**

→ Flow per person (l/c+s) : **0.005**

TABLE 5: Example Calculation Table.

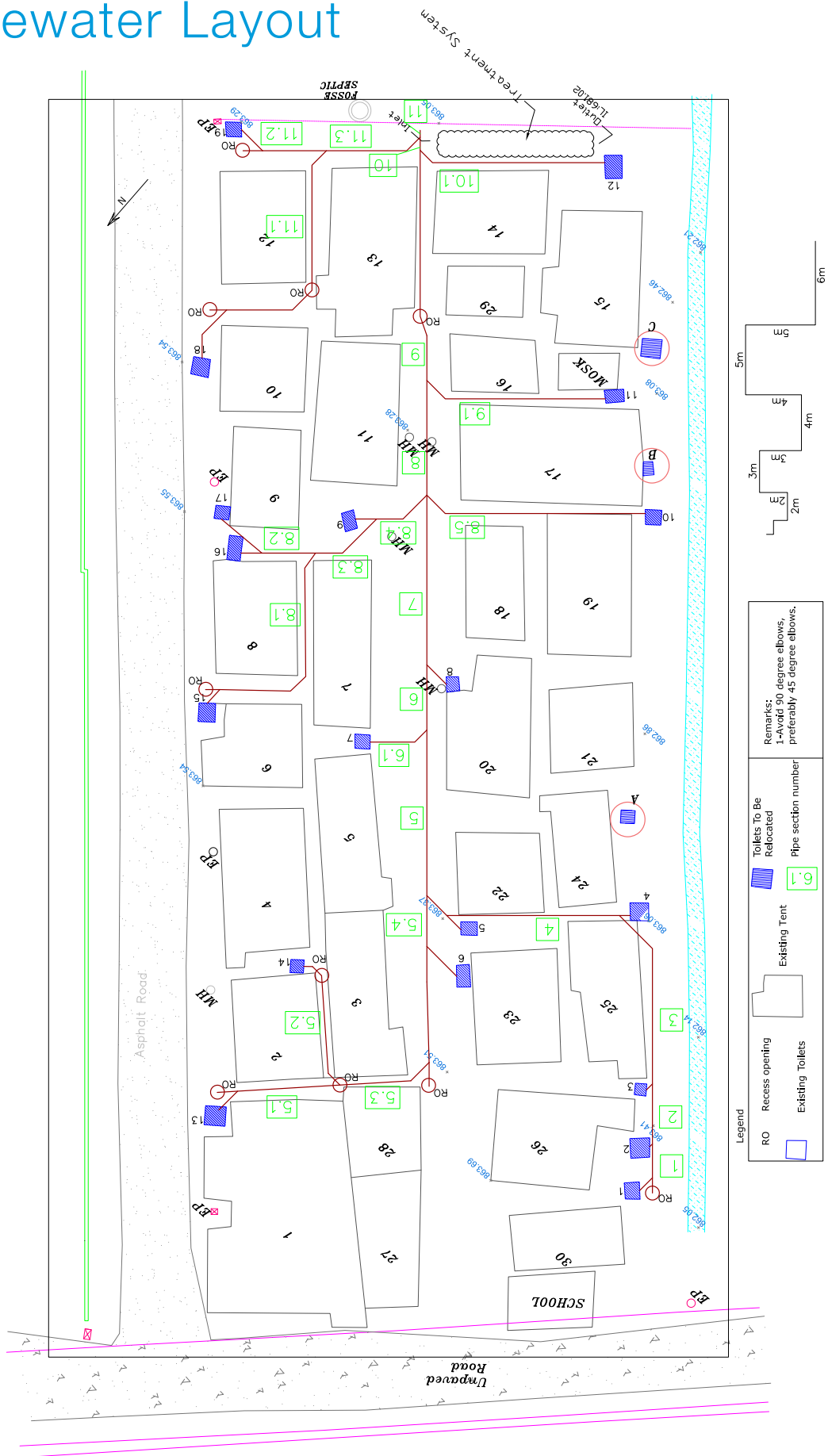| Column									
1	2	3	4	5	6	7	8	9	10
PSN	TL Number	# of Toilets	People	# of People	Flow l/c+s	Total Flow l/s	Ø pipe mm	Gradient %	Pipe length (m)
1	1	1	11	11	0.005	0.055	40	0.5	
2	1+2	2	22	22	0.005	0.11	40	0.5	
3	1-3	3	33	33	0.005	0.165	40	0.5	
4	1-4	4	44	44	0.005	0.22	40	0.5	
5.1	13	1	11	11	0.005	0.055	40	0.5	

Columns 1–10

→ **C1**: PSN stands for Pipe Section Number. The numbering starts from the furthest pipe section from the Discharge Point. Here it is the Treatment Plant.

→ **C2**: TL Number. Here it is the Toilet number(s) in the PSN.

→ **C3**: Number of Toilets. These are the numbers of toilets discharging to the PSN.

→ **C4 and C5**: People + # People are similar; these are the number(s) of people discharging to the PSN.

→ **C6**: Flow l/c+s. That is the flow rate per person and second.

→ **C7**: Total Flow l/s. That is result of Column 6 multiplied by Column 5.

→ **C8**: Ø Pipe mm. This corresponds to the diameter of the pipe selected from Table 3. It is very important to find out which pipes are available at the wholesaler, as not all dimensions are stored at all time. In our example, it would have been possible to start with a 32 mm pipe, nevertheless experience shows that when the trap is small, backflow to the appliance tends to occur. In the ITS's, the wastewater in LD and KS will be poured in, generating for a short period of time a very important flow rate. Table 3 shows the different flow rates at different gradients but the velocity will change with the gradient.

→ **C9**: Gradient %. In the example, a 0.5% gradient was assumed. If necessary, gradient could be increased to avoid higher load of the pipe. See Appendix C: Volumetric Changes.

→ **C10**: Pipe Length. It can be measured on the drawings.

→ The Wastewater Calculation may be found in **Appendix B**.

All systems need at least
one maintenance per year
which means:
- Emptying of Holding Tanks
- Flushing of Sewer Pipe

Methodologies & Application from Documented Experience – **MADE by** UPM

Appendix A:
Wastewater Layout

Appendix B:
Pipe Flow Calculation & Material List

Calculation Table for Case Study

→ People per Toilet (TL)   : **11**

→ Flow per person (l/c+s) : **0.005**

TABLE B1: Calculation Table for Case Study

Column									
1	2	3	4	5	6	7	8	9	10
PSN	TL Number	# of Toilets	People	# of People	Flow l/c+s	Total Flow l/s	Ø pipe mm	Gradient %	Pipe length (m)
1	1	1	11	11	0.005	0.055	40	0.5	
2	1+–2	2	22	22	0.005	0.11	40	0.5	
3	1–3	3	33	33	0.005	0.165	40	0.5	
4	1–4	4	44	44	0.005	0.22	40	0.5	
5.1	13	1	11	11	0.005	0.055	40	0.5	
5.2	14	1	11	11	0.005	0.055	40	0.5	
5.3	13+14	2	22	22	0.005	0.11	40	0.5	
5.4	13+14+6	3	33	33	0.005	0.165	40	0.5	
5	13+14+6+5	4	44	44	0.005	0.22	40	0.5	
6.1	7	1	11	11	0.005	0.055	40	0.5	
6	1––4+13–14+5–7	9	99	99	0.005	0.495	50	0.5	
7	13+14+6+5+7+8	10	110	110	0.005	0.55	63	0.5	
8.1	15	1	11	11	0.005	0.055	40	0.5	
8.2	16+17	2	22	22	0.005	0.11	40	0.5	
8.3	15–17	3	33	33	0.005	0.165	40	0.5	
8.4	15–17+9	4	44	44	0.005	0.22	40	0.5	
8.5	10	1	11	11	0.005	0.055	40	0.5	
8	15–17+9+10+SNO 7	15	165	165	0.005	0.825	75	0.5	
9.1	11	1	11	11	0.005	0.055	40	0.5	
9	15–17+9+10+ SNO 7+11	16	176	176	0.005	0.88	75	0.5	
10.1	12	1	11	11	0.005	0.055	40	0.5	
10	15–17+9+10+ SNO 7+11+12	17	187	187	0.005	0.935	75	0.5	
11.1	18	1	11	11	0.005	0.055	40	0.5	
11.2	19	1	11	11	0.005	0.055	40	0.5	
11.3	18+19	2	22	22	0.005	0.11	40	0.5	
11	SNO 10+18+19	19	209	209	0.005	1.045	75	0.5	

TABLE B2: Material List for Case Study.

PSN	Ø	Pipes				Bend 45°				Branch 45°				Pipe Recess				Invert Reducer				Fittings for HT				
		40 mm	50 mm	63 mm	75 mm	40 mm	50 mm	63 mm	75 mm	40 mm	50 mm	63 mm	75 mm	40 mm	50 mm	63 mm	75 mm	32/50	40/50	50/63	63/75	32 mm	40 mm	50 mm	63 mm	75 mm
1	40																									
2	40																									
3	40																									
4	40																									
5.1	40																									
5.2	40																									
5.3	40																									
5.4	40																									
5	40																									
6.1	40																									
6	50																									
7	63																									
8.1	40																									
8.2	40																									
8.3	40																									
8.4	40																									
8.5	40																									
8	75																									
9.1	40																									
9	75																									
10.1	75																									
10	40																									
11.1	75																									
11.2	40																									
11.3	40																									
11	75																									

Appendix C:
Volumetric Changes
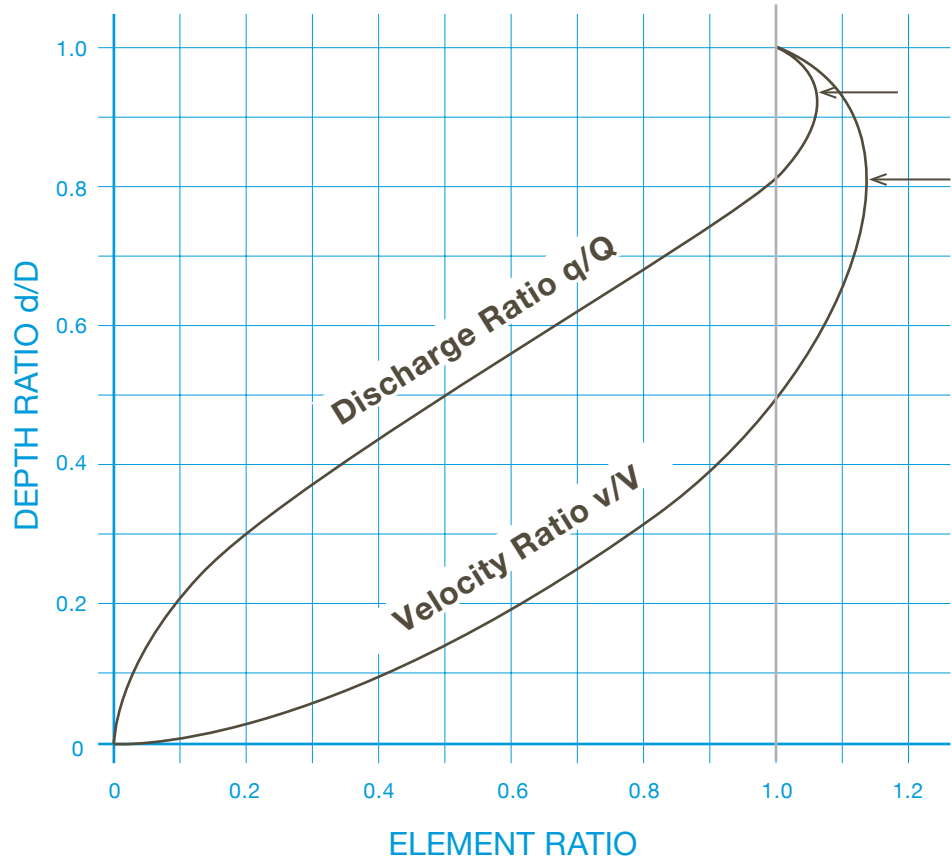
NOTE: $v = V$ at both $d/D = 0.5$ and $d/D = 1.0$

v_{max} at $d/D = 0.81$

$v_{max}/V = 1.14$

q_{max} at $d/D = 0.94$

$q_{max}/Q = 1.07$

Appendix D:
Calculation of Pipe Length & Angles

Calculation of pipe length using the Z Method and Pythagorean Theorem

The **Pythagorean Theorem** states that in any right triangle, the sum of the squares of the lengths of the triangle's sides is the same as the square of the length of the triangle's hypotenuse.

This theorem is represented in the formula:

$$c^2 = a^2 + b^2$$

$$c = \sqrt{a^2 + b^2}$$

$$c = \sqrt{1^2 + 1^2}$$

$$c = \sqrt{2}$$

$$c = 1.41421$$

APPLICATION WITH 45° FITTINGS

TABLE D1: Convert Degrees and Percent for PVC u Fittings:

Angle	Percent
1°30'	2.6186%
15°	26.7948%
22°30'	41.4214%
30°	57.735%
45°	100%

BEND DOUBLE SOCKET 45°

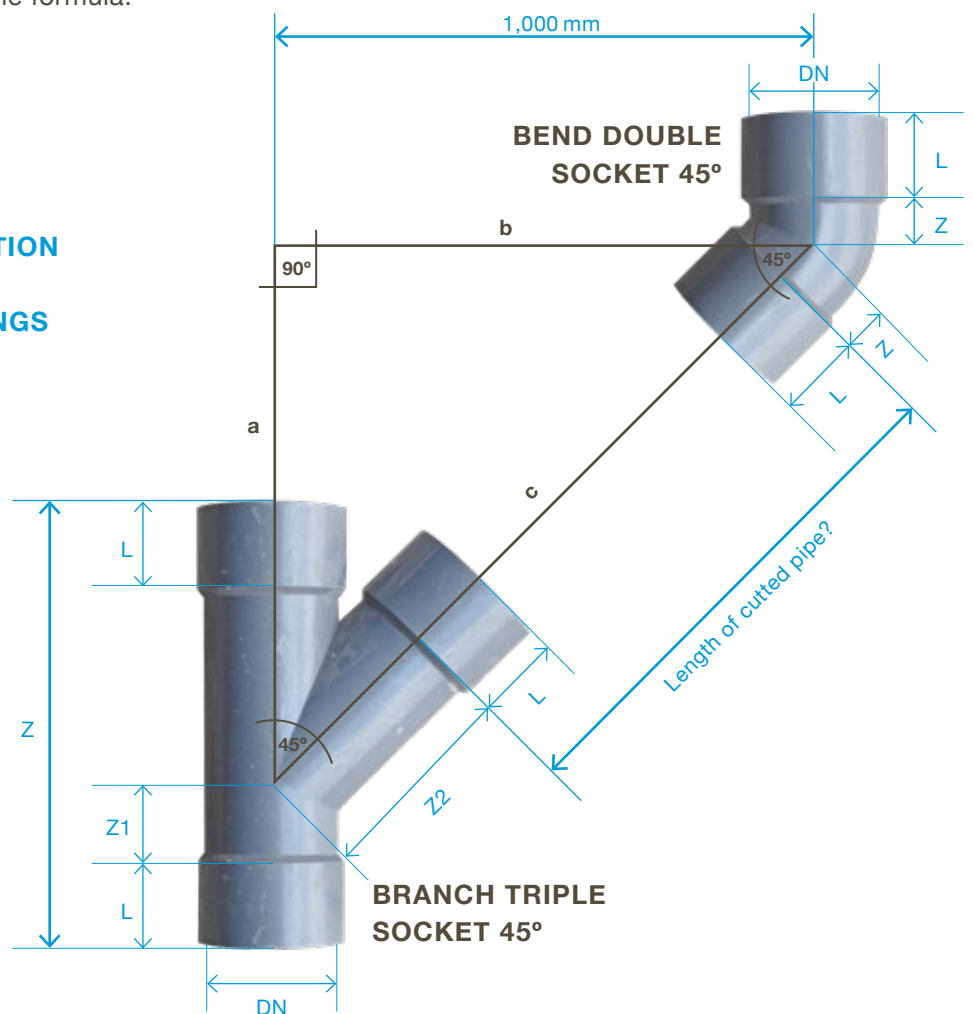BRANCH TRIPLE SOCKET 45°

Length of cutted pipe?

TABLE D2: Calculating the pipe length needed between Bend and Branch:

DN	c = mm	Socket L (mm)	Z Bend (mm)	Z2 Branch (mm)	Pipe to Cut (mm)
50	1,414	32	17	63	1,334
75	1,414	44.5	25	93	1,296
100	1,414	53	33	124	1,257

Appendix E:
DIY Device for Precision Pipe Cutting

A low cost Do-It-Yourself device facilitates
the pipe cutting, while ensuring straight cuts.

The measures will depend on the diameter
of the pipes to be used.
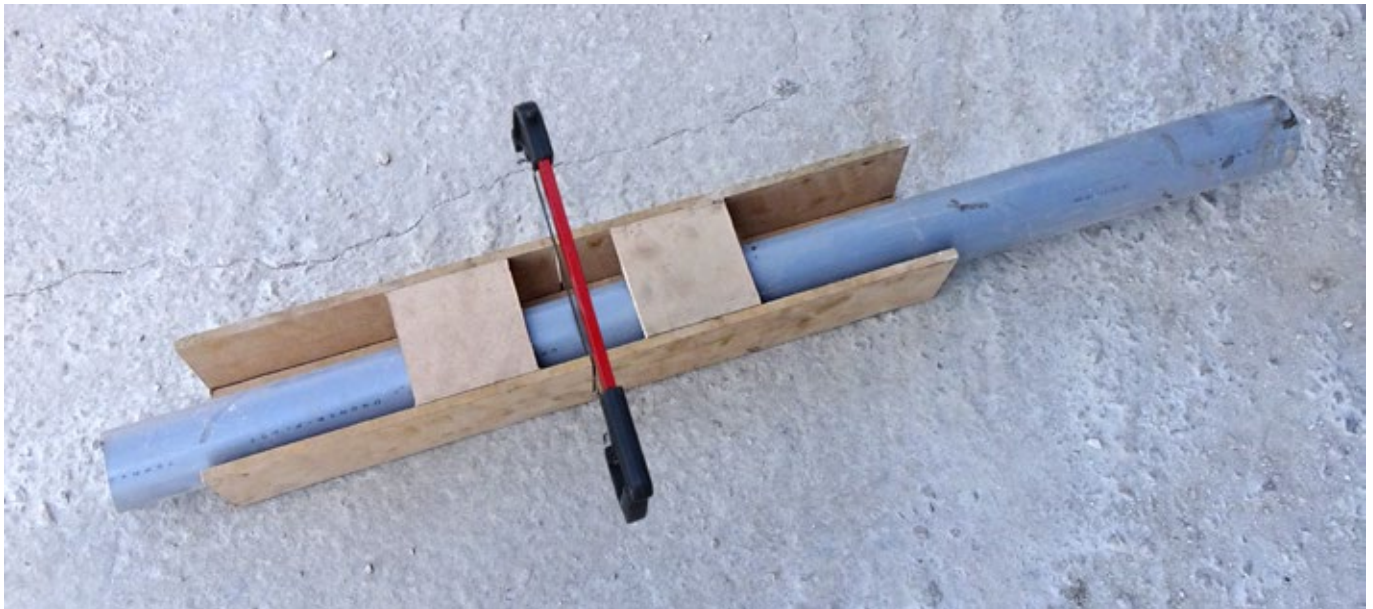
Materials

1. 1 long piece of wood plank for the base.
2. 2 pieces of wood plank for the sides
   (Same length as the base).
3. 2 smaller pieces of wood plank for the top
   (Same width as the base).
4. Nails.
5. Hammer.
6. Measuring tape.
7. Carpenter's square.
8. Saw.

Instructions

1. Mark a line exactly in the middle of each wood plank for the sides of the box, using the measuring tape and the carpenter's square, aiming at drawing a perfect 90° angle. With the saw, cut the line straight. Leave untouched the spot where the sides will be attached to the bottom.

2. Nail the sides to the bottom of the box.

3. Nail the small wood planks for the top of the box.

4. Test the device: it should allow to contain a pipe and to hold it with one hand, leaving enough space to cut with a hand saw comfortably.

Contributors

LATA Lebanese Appropriate Technology Association

LATA —Lebanese Appropriate Technology Association started in 1982 as MECTAT and was renamed in 2003 to LATA. Over the past 35+ years, in cooperation with international partners and donors, it has been advocating appropriate and environmentally sound technologies and concepts in Lebanon and the Arab world.

LATA has implemented a wide array of projects and trainings in the themes of awareness on marine life and coastal zone protection, protection of the atmosphere, conventional and renewable energy use, fresh water resources protection, solid waste management at school and at domestic levels, desertification control, biodiversity preservation, sustainable food production, sustainable land use, tree planting, biogas generation, and greywater reuse. LATA believes in the empowerment of vulnerable populations with information and practical knowledge.

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USTB was founded in 1952 following the amalgamation of the best departments in related fields of five eminent universities as a result of a nationwide reorganization of the higher education system. Over half a century of remarkable growth, it has developed into one of the most influential key national universities sponsored by the Chinese Ministry of Education. USTB is renowned for its study of metallurgy and materials science. Its main focus is on engineering while it also maintains a balanced programme of science, management, humanities, economics and law.

The Center for Sustainable Environmental Sanitation CSES integrated in the School of Environmental Engineering at the University of Science and Technology Beijing was created in 2007 with the objective to build capacity among young professionals in the interrelated sectors of sustainable environmental sanitation, food security, bioenergy and climate protection.

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FIELDS OF EXPERTISE INCLUDE:

Sectors: Climate Change Mitigation/Adaptation; Sustainable Development Goals (SDGs); Renewable Energies (biogas, biomass, wind, solar); Ecological Sanitation, Wastewater Treatment, Fecal Sludge Treatment/Management (FSM), Waste-to-Value in emergency context; Citywide Inclusive Sanitation (CWIS).

Activities: Project Planning and Development; Carbon Trading; Support to access to Climate & Development Finance; Technical Support; Feasibility Studies; Research and Studies; Capacity Building & Training; Monitoring; Tendering support; Due Diligence; Technical Design; etc.

Regional Experiences: Asia (China, Bangladesh, Pakistan, Mongolia, Nepal, Vietnam); Middle East (Jordan, Lebanon); Africa (West-Africa); Pacific Islands (Samoa, Tonga), Central and South-America (Chile, Bolivia, Cuba).

Design Considerations for Simplified Sewer Network in Informal Settlements Settings

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