Chapter 1. Water Demand

What you will learn
Estimate the different information needed to define precisely the water demand of a community.

Why
This will give the term of reference for the complete Water Supply System, make it working or not, sustainable or not.

Duration of chapter 1
2 to 3 hours

1.1. Generality

Defining properly the demand at the beginning is the most important and sensitive part of the design as it is at the base of all further steps. It is essential to do it carefully and not to rush through it in order to:
make reasonable design for the existing population so that it is not too expensive to maintain and operate; keep a good quality of water; but also with the capacity to expand it in the future for an increased demand. It needs an exhaustive knowledge of the geographical situation of the project area (sat pictures) as well as repeated discussions with authorities, technical services and users to define habits, specific needs and reasonable future planning. The following steps have to be followed, more or less deeply according to the complexity of the situation:

1) Define the significant types of demands that the system connections will have to fullfil such as household connection, street fountain, public building, irrigation, etc. Describe them precisely.
2) Evaluate the average daily consumption of the demands and estimate the expected leakages.
3) Define the existing number of users, the life span of the project, and accordingly the maximum number of users. If necessary (when the increase is too big), define a specific life span and maximum number of users for each part of the system.
4) For each type of demands, define the daily pattern and the seasonal variation, for short and long-term.
5) Define the type of water points connected to the system, specifying the expectation in term of pressure and instantaneous flow.
6) Map the project area to locate the users and the water points. For urban area, it has to be divided by zone of relevant types and similar properties (density of population), and as much as possible coinciding with distribution zone of the existing or planned water network. For each zone, define the size (in hectare), the present number of inhabitants and the estimated number of distribution points. Then an extrapolation should be done at the life span of the project and crosschecked with the density of population.
7) Main design figures can then be summarised such as maximum daily demand to define the size of the tank, minimum daily demand to check the quality of the water, maximum and minimum hourly peak demand to design the pipes.

1.2. Types of demand

To get a realistic model of the system, the most significant types of demand should be defined. These types of demand are usually attached to a type of customer with specific needs.
Leakages can be either define as a specific type of demand or included in the demand patterns for each area. The main types of demands and their specification are shortly described hereunder:

- **Household connection**: It is a water connection directly tapped on the water network for a household. It is then assumed that the people can have direct access to the water when they need it, making usually peaks at specific hours. To define the demand per capita and its pattern, it is essential to know if they have water meter, break pressure valve or storage tank; number of taps and their quality, presence of garden can also have significant effect.
- **Street fountain**: (also called tap stands or stand post) In this case, the distribution point is public and people have to fetch water with jerrycans or buckets. The distance from their house, the mean of transport and the existence of free alternative source of water (river for washing) might have a significant impact on the quantity of water collected. If the points are limited and the people are queuing, the pattern might be quite flat during the day and nil during the night except leakages.
- **Special consumer** such as schools, hospitals, health centres, military compounds or industrial complexes: These special types of consumer should be used only when they represent a significant water demand. If they are small, they can be considered as a normal consumer (like a household). If demand is significant the quantity and pattern of water use is then very specific and have to be defined case by case.
- **Irrigation**: In some cases, water from piped network is used for irrigation of green houses, orchard or garden. Then it will depends on the area, type of crops and weather, might vary a lot across the year. The pattern is usually quite flat as the water is done constantly for few hours.

1.3. Average daily usage

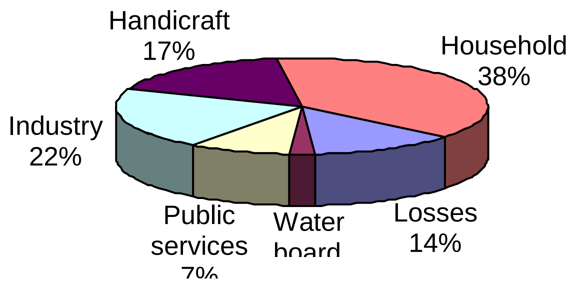
The average daily usage is the total quantity of water produced per year divided by the number of people and days. It represents the average quantity of water throughout the year that should be produced and distributed by the system all needs included. For instance in Switzerland, it was 470 l/day/pers in 1990 and about 325 in 2010. In our case for simplification reason, we will not make the difference between the water demand, consumption or usage.

YWp: yearly water production [m^3]
YWd: yearly water demand per person [m^3/per]
Pop: total number of people or users
DWp_{avg}: average daily water production [m^3/day]
DWd_{avg}: average daily water demand per person [m^3/day/per]

$$DWp_{avg} = \frac{YWp}{365.25} = DWd_{avg} \cdot Pop$$
$$DWd_{avg} = \frac{YWd}{365.25} = \sum DWd_{specific}$$
Eq. 1-1

The breakdown for a urban supply could be, for example, leakage (14%), treatment plant usage(2%), public services (fire-fighters, fountains 7%) and commercial needs (39%). At the end, only 38% is used for households.

Usage of water in a household	
5%	House cleaning & watering
12%	Body care
15%	Drinking and kitchen
18%	Laundry
20%	Bath & shower
30%	Toilet



Source SSIGE 2010

In general, the average daily consumption figures exist for all countries and can be found easily, sometimes as national standards. Sphere projects (emergency supply) recommend a minimum of 15 litres at household level.

This evaluation has to be done per type of demand:

For household connections, the demand per capita might vary a lot according to the country and users from 40 up to 400 litre/day/person, reasonable figures for ICRC projects might range from 50 to 200 l/d/p. In developed country it is decreasing for the last 10 years, in Switzerland it passed from 180 to 160 l/d/p.

For street fountain, it depends on the distance and transport means but it is taken usually between 10 to 50 l/d/p.

Special consumers			
Types of consumer	**Litre/day/type**		
	Min	**Med**	**Max**
Out patient	5		25
In patient	40	150	350
Schools per pupil	3	25	75
Mosque	3		
Live stock	5	20	30
Offices	5	30	65

In any case, it is always good to have a critical eye on the standards and to discuss it with the users. For the sustainability of the system this quantity should not be exaggerated so that the people can afford to pay the operation and maintenance cost. The simplest way to check is to compare it with a nearby community with the same lifestyle

Losses and leakages

Losses are the difference between what is produced and what is received (the water that can be "counted"), they are generally the leakages but sometimes they include also public services (fountain, water garden, fire-fighters), people not paying (illegal connection) and mistakes in the meters.

There are two types of leakages, the one in the network and the one at the taps. The one in the network is usually situated at pipes connections and is due to soil movement, bad compaction and poor fittings. If the soil is impermeable, the water will come out of the ground, and if the road is not paved, will be quickly identified and hopefully repaired. On a contrary, when the soil is permeable (sand, limestone) it will be more difficult to identify them, therefore it can be expected to have a higher leakage rate. Networks done with brittle pipes such as asbestos cement, GRP or PVC are also more prone to leakages. Finally, the longer the network per consumer or more specifically the lower the ratio of water demand to meter of pipe, the larger will be the ratio of water losses over water distributed. Therefore, a small network in clayish ground done with PE can be expected to have no more than 5% leakages, compared to an extended water network done with PVC pipes in limestone area prone to earthquake where once can easily count on a minimum of 20% leakages.

The second type of leakage is the leaking taps or float valves (like in flush toilets tank). A reasonable drop-by-drop leaking tap can easily waste from 50 to 200 litres per day. Depending on the quality of the taps and valves up to 10% of them can be faulty, this type of leakage will mainly depend on the quantity and quality of taps and valves, and their utilisation ratio, a tap used 12 hours a day will leak only 12 more hours, as a tap only used one hour a day, will leak 23 more hours. It has to be noticed that this second type of leakage might not be considered as losses as they happen at the user point, usually after the water meter.

A simple way to measure the level of leakages is to see the consumption at night, however, this measure might overestimate them, as the pressure will be higher during this time than it is during the day.

1.4. Number of users and life span

Assessing the number of inhabitants and household in a village might not be an easy task as quite often it is exaggerated in the hope of getting more funds. Different means can be used to crosscheck the information, such as existing census (election list), counting households on sat pictures for rural communities, defining zones and density as explain further is well adapted for urban context. Requesting an initial sum of money per household for the start up costs of the project is also a good way to have a value closer to the reality and to start to have the authorities responsible for the future system.

The life span of the project has to be defined and the future population has to be estimated so that the system will still supply enough water in 10, 20 or 30 years for the all population. Mathematically, the exponential growth formula should be used as it takes in consideration the new population as a factor of growth. However, the growth rate might decrease with time for several reasons, such as limited resources such as field or family planning pushing to have fewer children. In this case linear growth rate might be more realistic.

Pop_0: initial or actual population
Pop_n: population after n years
i: growth rate
n: number of years

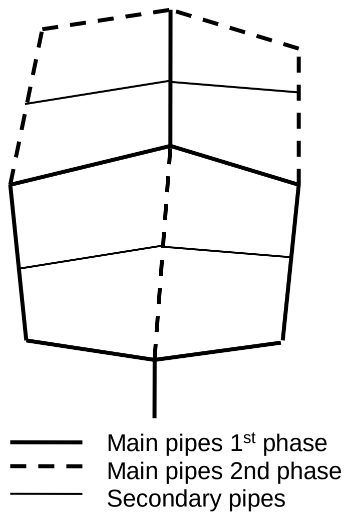
Exponential growth rate $$\boxed{Pop_n = Pop_0 (1+i)^n}$$ **Eq. 1-2**

Linear growth rate $$\boxed{Pop_n = Pop_0 (1+i \cdot n)}$$ **Eq. 1-3**

In periurban situation, displaced population or rural exodus might increase quickly the population, especially when a new water system is built. In this situation, it is better to work with the maximum density of population in the served area, as explained later.

If the overall growth of the demand is significant, more than 50% of the initial demand, it starts to be difficult to build a system ensuring good working condition over of the present and future range of population, ensuring enough pressure in the network at the lifetime but keeping a good quality of water at the beginning by avoiding low velocity in the pipes. For instance, in a given distribution system, if the demand passes from 100% to 150%, the head losses will double and for an increase demand of 200%, the head losses will be increased of 350%.
In these cases, a step-by-step approach should be proposed, defining a specific capacity for the different part of the system:

- Main transport pipeline should be usually design for the life span.
- Pumping systems are quite flexible as working hours can be adapted.
- Storage tanks can be done with two chambers or in two stages, having a capacity from 40% to 60% of the daily demand.
- The distribution network is the most difficult to handle, solution as illustrated should be considered. This will be further developed in the distribution chapter.



Therefore, the life span of each part of the system should be estimated, rough estimations are given here.
This estimation is also important to evaluate the maintenance cost of the system and amortization, thus allowing planning further development stages.

Parts of the system	Life span
Main transport pipeline	20 to 40 years
Main storage tank	30 to 50 years
Pumping system	15 to 25 years
Main distribution pipeline	20 to 30 years
Secondary distribution pipes	10 to 20 years

1.5. Daily pattern and seasonal variation

Water usage varies during the day, usually small during the night, there is one or two peaks in the day, depending on habits and connection type. The average demand per hour (HWd_{avg}) is defined as the daily consumption divided by 24 hours and represents the 100% in following charts (called base demand in Epanet). The daily peak value is the maximum hourly demand divided by the HWd_{avg}. The daily pattern is represented as a chart showing the consumption per hour in percentage of the HWd_{avg}. Having it as percentage makes it independent from the actual quantity, so a same pattern can be used with different number of people or daily demand.

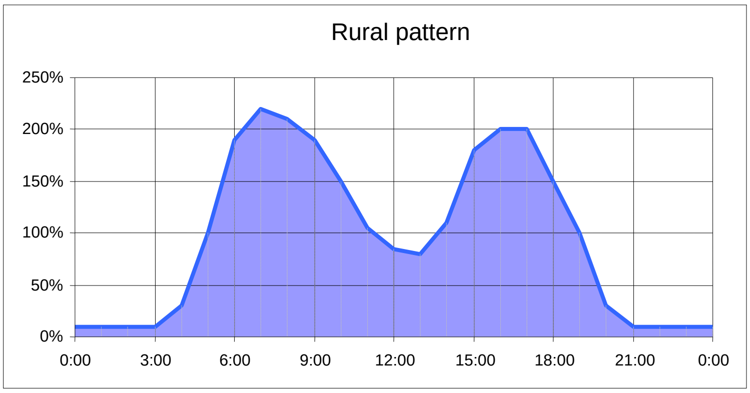
HWd_{avg}: average hourly water demand [m^3/h]
DWd: daily water demand [m^3/d]
HWd_{max}: hourly maximum water demand [m^3/h]
$C_{Daily\ Peak}$: coefficient of daily peak [-]

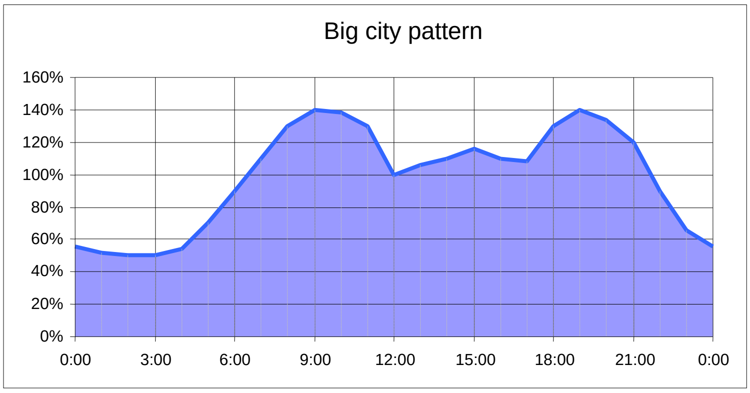
$$HWd_{avg} = \frac{DWd}{24}$$
$$C_{DailyPeak} = \frac{HWd_{max}}{HWd_{avg}}$$

Eq. 1-4

A good knowledge of this pattern is important to size correctly water tanks and main pipes of the distribution network. A pattern with one-hour step, with a precision of 5 to 10% is usually good enough for the design. The most important values are the peak and minimum demand hours.

Here is an example of a daily pattern, characteristic of a rural community where the people would be in the field during the day, thus having a low consumption at noon and two peaks, one in the morning at 215% and one n the afternoon at 200%. The consumption during the night is limited at the leaks representing in this case 10%.

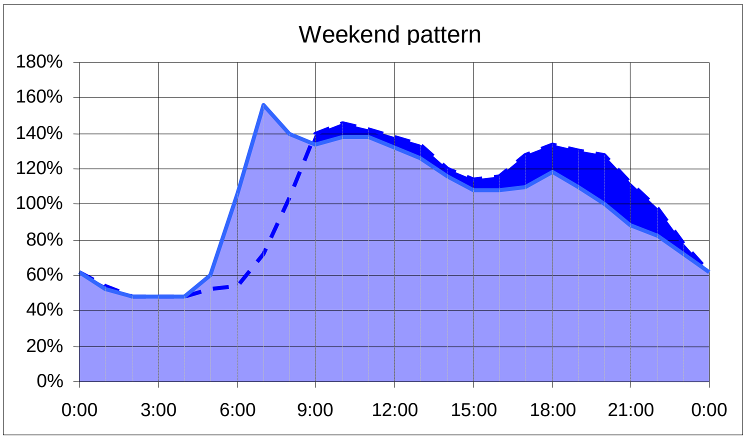




The larger the population and the more diversified the activities, the flatter will be the pattern. Leakages will have a similar effect.

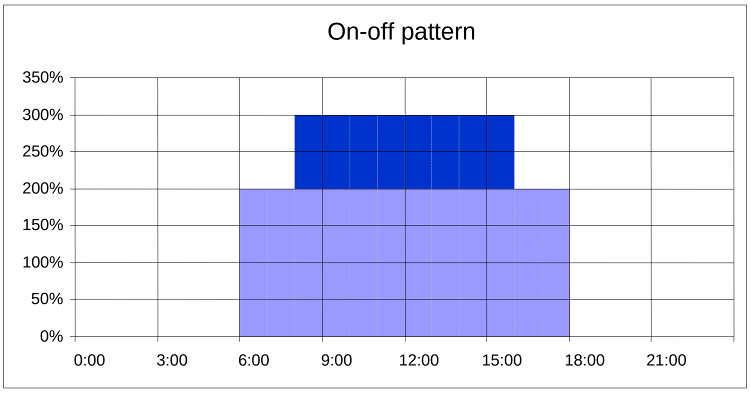
Here is represented an example of a big city pattern. The whole profile is smoother; the peak value is only of 140% while the consumption during the night does not drop below 50% due to bigger leakages, night activities and fountains.

The daily pattern might also **vary with the season or the day of the week**. In the attached pattern, we can see in light blue the daily pattern in Geneva, during a working day, and in dark blue during the weekend. Obviously, the people wake up later the weekend and the peak hour passes from 7 to 10 o'clock. As the consumption is more distributed during the weekend, the peak value decreases from 156% to 146%.



It is good to collect the different pattern that the system might face but the most significant for the design are usually the one with the biggest absolute demand (the biggest cubic meter per day).

The cases seen so far are "ideal" situations were the water is available 24 hours a day in the all network and with a sufficient number of taps so that the people should not wait to get the water. However the **number of taps available and limited distribution** hours influence greatly the pattern. If the people have to wait during rush hours, this will flatten the pattern during peak hours thus reducing the peak value.



When the distribution time is limited, for instance in a displaced camp where the water would be only available during 12 hours and the people would be queuing the all time, the taps would be constantly used, then the pattern would be as represented in light blue, constant during 12 hours at 200%. If in the same conditions, the time is reduced at 8 hours (in dark blue) then the peak will reached 300%.

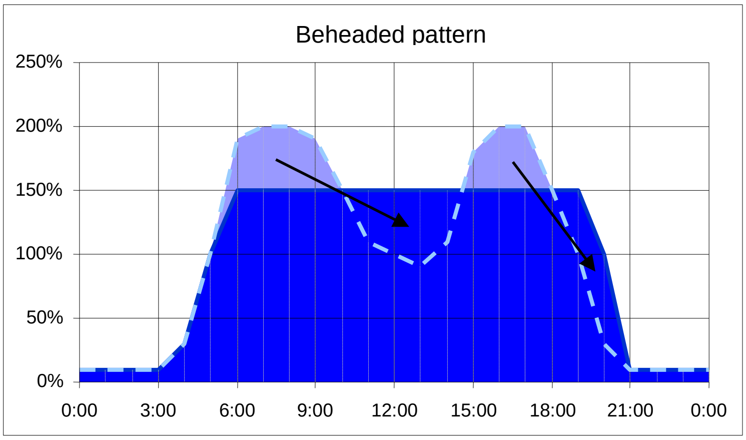
In some places, water is only available one or two hours per day. This means that the peak factor reaches form 1 200% to 2 400%. On the opposite, if the houses or the street fountains are equipped with a small buffer tank, the demand can be distributed throughout the day, reaching in theory a peak factor of 100% thus equal to the hourly average consumption.

As seen in the Basics of Hydraulics §4, the relation between the flow and the pipe diameter of a given system is roughly power two over power five. Thus if a system has a peak factor of 200% the pipe diameters should be 132% bigger than with a constant distribution. Furthermore, if the distribution time is limited to one or two hours, the pipe diameter should be 3 times bigger.

Therefore, when possible, it is recommended to distribute the water throughout the day to limit the peak factor between 200% and 300%.

Peak factor	Pipe diameter
100%	100%
150%	118%
200%	132%
300%	155%
400%	174%
600%	205%
1 200%	270%
2 400%	357%

Another critical situation is when the system cannot provide the required water demand in the all network during the peak hours. In this case, the remote or higher points will not get water, the people will wait till the water is coming again, shifting the demand and beheading the demand pattern.



This is illustrated in the attached chart were the demand between 6h00 and 10h00 was shifted between 10h00 and 15h00, this means that the last houses will have no water between 6h00 and 14h00.
This situation might be caused by an important increase of the demand, a bad design of the distribution network, an under designed main storage tank or big leakages.

It is important to mention that in the cases of limited distribution time and beheaded situation, pipes in the distribution network will not be under pressure, letting the water coming inside the pipes were leakages are present and thus contaminating the "drinking water". This should obviously be avoided when possible and if not possible; water should be well chlorinated and regularly tested at the critical distribution points (highest and remotest).

How to define the daily pattern
A first draft can be done by using the common sense and a good local knowledge, but it can be misleading. Therefore, it is highly recommended to use one of the following methods.
To define an existing pattern, four methods are proposed:

- For a system with street fountains, people can be placed at the most significant points and count the number of jerrycans fetched during each hours. This method does not necessitate any special devices but has to be done carefully for a result and it is not always precise as some factors as leakages are unknown.
- If a main water meter is installed or if it is possible to install one, then a reading every hour can be done. This method will take in account the all quantity of water but the reading of the water meter might be not so precise.
- If the network is supplied directly by one tank, the water level in the tank can be measured every hour. This method is quite simple but not so precise and it is a bit more complicated to interpret the results.
- Finally, it is possible to install a portable flow meter with data logger on the main pipes. This has the advantage to be done automatically without having somebody reading data throughout the day and the night, and it can be done several times at different position. However, those flow meters are usually expensive and not simple to install.

For a new system, it is obviously not possible to measure it, therefore an existing system, similar to the new one, should be found in the area and can then be measured as proposed above.

Daily and seasonal variation
Not only might the pattern change from one day to another, but also the total consumption.
Daily variation might be due to a variation of the number of people present (tourism or movement to field or grazing) or in areas with industrial and commercial activities.
Seasonal variations are often due to climatic changes, more water will be used during the hot and dry season and less during the cold or rainy season. Watering of garden or crop might also have a great impact.
As the storage and distribution facilities will have to be able to cope with this maximum demand, a daily peak coefficient has to be defined. For a city, it is often between 130% and 180%, in Switzerland it is about 150% in average.
If the specification gives already the maximum demand, the average one should then be estimated. This value will be important to define the instantaneous peak flow in the distribution network.

$C_{Seasonal\ Peak}$: coefficient of seasonal peak [-]
DWd_{avg}: average daily water demand [m^3/d]
DWd_{max}: maximum daily water demand [m^3/h]

$$C_{SesonalPeak} = \frac{DWd_{max}}{DWd_{avg}}$$ **Eq. 1-5**

1.6. Water point specifications

To design the distribution network and locate the storage tank, specifications of water points should be defined as follow:

- **Average daily consumption per tap or per household,** can be estimated roughly in case of household with several taps but should be precise for street fountains installation.
- **Duration of the peak time**, can be estimated as when the daily pattern is over 100%
- **Instantaneous flow**: in general a standard type should have a flow of 0,2 l/s. For household, schools or hospitals with several taps, a more detailed system can be defined according to the attached table.

Device name	Min flow(l/s)
Wash bowl	0,10
Sink / washbasin	0,20
Shower	0,20
Bathtub	0,33
Tap ½ inch	0,33
Tap ¾ inch	0,42
Toilet with tank	0,12
Toilet with flush valve	1,50
Washtub	0,33
Dishwashing machine	0,10
Laundry washing machine	0,20

These parameters will be used to define the simultaneous factor. This factor might exist as a country standard (DTU in France) but it is good to check it in specific cases.

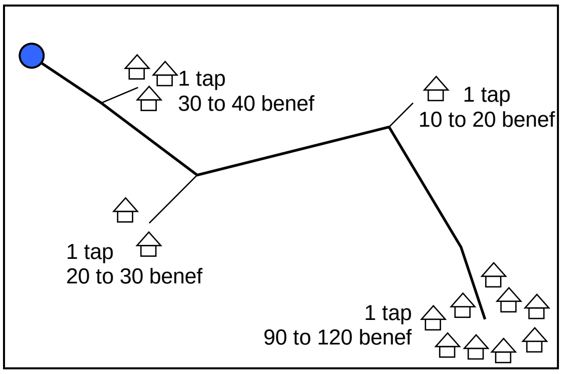
- **Minimum required pressure**: this pressure will be defined according to the type of water points; it can be only 2 meters for street fountain but need to be much more for household with several floors.

1.7. Mapping

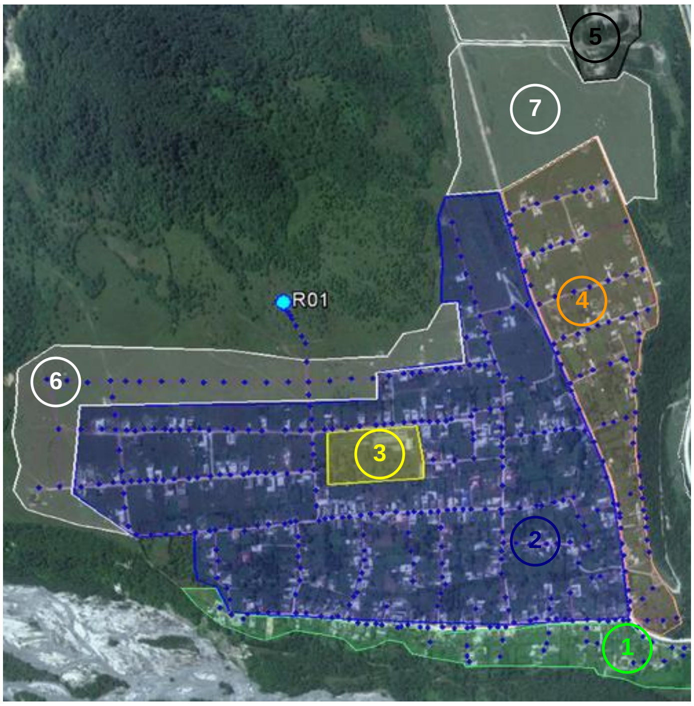
To see how the population is distributed in the area covered by the water supply system, a map locating the population and the water point has to be prepared. Two main situations can be defined:

A. Small number of people

When the number of people and water point is small enough and can therefore be precisely located, a specific demand can be defined for each water point. This is usually the case for rural projects with scattered group of houses with one tap for each group.
In this case, a map has to be done showing each water point and users with their demand type and figures and number of users.



B. Large number of people



In urban areas or high-density populated town, it is not feasible to locate precisely each house with its number of inhabitants.
A 5 step methodology has to be followed:

1. In this case, the area has to be divided in different zones matching as much as possible the following :
    - types of demands
    - existing suburbs
    - natural feature
    - network distribution areas
    - density of population.

2. The size of each zone can then be measured and put in a table, adding also the estimated maximum density estimated for each zone.
Attached is an example representing a town with three main areas, as school in the middle, a industrial zone and two future extension zones.

Ref	Description	Type	Size [ha]	Max Density [p/ha]
1	Lower part	HH poor	11.85	30
2	Central area	HH average	73.58	30
3	East side	HH rich	22.65	25
4	Extension 1	HH average	25.50	20
5	Extension 2	HH rich	15.30	10
6	School area	School	2.98	0
7	Industrial zone	Factory	6.80	0

3. The number of inhabitants has to be found for each zone. The best is to do it with the local authorities or communities to be sure to have good figures. Preliminary evaluation can be done by counting the number of houses and multiplying it by the average size of household. The density can then be calculated and be crosschecked with the maximum density.

4. The future or long-term population can now be estimated according to the growth rate calculated before, but limited by the maximum density. The remaining people should be placed in an extension zone. When a high growth of the population is expected within the lifespan of the distribution network, the population can be taken as the maximum.

5. Finally, the expected number of distribution points should be estimated for each zone, for the present and long-term situation. The ratio person per Distribution Point (DP) allows crosschecking the values; it can be expected to have a small number of people per DP in wealthier zone.

Compiling the information for the previous example should give a table as following:

Zones					Existing population						Long-term population					
Ref	Name	Type	Size [ha]	Max density [p/ha]	Number	Demand [l/cap]	Distrib Points	Density [p/ha]	Demand [m3]	Pers/ DP	Number	Demand [l/cap]	Distrib points	Density [p/ha]	Demand [m3]	Pers/ DP
1	Lower part	HH poor	11.85	30	240	80	31	20.3	19.2	7.7	320	80	40	27.0	25.6	8.0
2	Central area	HH average	73.58	30	1'188	100	150	16.1	118.8	7.9	1'584	100	197	21.5	158.4	8.0
3	East side	HH rich	22.65	25	335	120	35	14.8	40.2	9.6	446	120	46	19.7	53.5	9.7
4	Extension 1	HH average	25.50	20							300	100	20	11.8	30.0	15.0
5	Extension 2	HH rich	15.30	10												
6	School area	School	2.98	0	106	5	2	35.5	0.5	52.9	159	5	3	53.4	0.8	53.0
7	Industrial zone	Factory	6.80	0	10	2'000		1.5	20.0		10	2'000		1.5	20.0	0.0
Total			158.66		1'763		216		199		2'650		306		288	
Average				23.90		112.7		11.1		8.2		108.8		16.7		8.7

The yellow cells contain the information collected as the blue one, the information calculated. The population will increase of 50% but the average demand per person will slightly decrease.

NB It is possible to have two or more types of distribution in one zone, for instance 80% of the people fetching water from street fountains and 20% having a household connection.

Street fountain for populated area

When the density of population is high but the demand or the possible supply is low, the most sustainable solution is the street fountain system. This will limit the leakages and the installation cost, ensure an easy way to collect money and to share the water fairly. Thus in a way the aim is to have the minimum number of street fountains, however, two criteria have to be respected to maintain an acceptable level of service: the maximum distance to the next water point and the number of people per tap. Therefore, the following calculation should be done for each zone.

A. It is important to limit the **maximum distance** from a house to the next water point so that it is reasonably accessible in a safe way. In big area with homogenous density, it can be estimated by using the following equation. If the population is too scattered it should be done "manually", point by point on a map. This distance can be between 100m to 500m, depending also on the number of people per tap.

d_{max}: maximum distance to the next water point $[\mathrm{m}]$
S: total area of the zone in square metres $[\mathrm{m}^2]$
N: number of street fountain

$$d_{max} \approx \sqrt{\frac{S}{2N_{fountain}}} \qquad N_{fountain} \approx \frac{S}{2d^2_{max}}$$

Eq. 1-6

B. To limit the **number of people per tap**, will mainly limit the queuing time. Thus, it will depend on the total demand, the actual flow at the tap and the period (number of hours) when people take water.

N: number of tap
Pop: total number of population
Q: flow at the tap $[\mathrm{l/s}]$
t: time duration when people are collecting water [hour]
D: average water demand [litre]

$$\frac{Pop}{N_{tap}} < \frac{Q \cdot t \cdot 3600}{D} \qquad N_{tap} > \frac{D \cdot Pop}{Q \cdot t \cdot 3600}$$

Eq. 1-7

For instance, assuming a flow of 0,2 l/s, a demand of 20 litres and a duration of 6 hours, a tap will cover a maximum of 200 people. The sphere indicator gives a number of 250 people per tap.

If $N_{street\ fountain}$ is bigger than N_{tap}, then the first figure should be used and the distance would be the determining factor.

If $N_{street\ fountain}$ is slightly smaller than N_{tap}, is, then the distance should be reduced and the number of street fountains increased to match the number of taps.

If $N_{street\ fountain}$ is much smaller than N_{tap}, then several tap will be installed for each street fountain.

1.8. Influence of the different values on the design

As stated before, a WSS should work under every condition (maximum and minimum), find attached an example summarising the use of the different parameters in the design:

	Unit	Min n° of user	Max n° of user	Comments
Beneficiaries	**people**	10'000	13'459	Explain the time, type and growth rate
Distribution pts	**units**	100	135	Describe the type of distribution points
Daily demand	**l/d/p**	25	30	Total daily demand and its variation with time to be explained
Daily min	**rate**	10%	20%	Explain this estimation, link with leakages ?
Daily max	**rate**	200%	188%	Explain the type of pattern and peak value with variation
Seasonal min	**rate**	95%	95%	Explain seasonal impact
Production hrs	**hour**	12	20	Number of working hours

Daily min Min user	**m3/day**	237.5		Min volume to manage with the storage keeping good water quality
	m3/h	19.8		To use as min flow for the main transport pipe
Daily max Max user	**m3/day**		403.8	Max volume to manage with the storage without overflow
	m3/h		20.2	To use as max flow for the main transport pipe
Max hourly Min user	**m3/h**	19.8		To use to check that the minimum speeds in the network are not too low
Max hourly Max user	**m3/h**		31.6	To use to check that the minimum pressure in the network are big enough

In order to facilitate calculations, the "*Demand Patter.xls*" excel sheet can be used for simple cases. However, prior to starting it, the data must be gathered, in each case for the minimum and maximum number of users. The dark blue cells are the one indicating important cells to design the water supply network.
As already stated, the assessment report should be done reviewing all points mentioned and should be shared and approved by the users.

Basic exercises

1. For a medium town in Switzerland, using the figures from §1.3, what would be the expected daily water production, quantity of looses per day, demand per day per person for households, total quantity of water used for toilets and quantity used for toilets per person?
2. A WSS for a rural area for 15'000 people (it will be estimated the usage is only for household and losses) is producing in average 1 800 m^3 per day. They have seen that during the night the flow was never going lower than 22.5 m^3/h. The evaluation of monthly consumption per water meter is of 12.81 m3 with an average of 5 people per meter. What is the proportion of losses and leakages?
3. What will be the estimated population in rural village (exponential growth) of 10 000 inhabitant with a growth rate of 3% in 5, 10, 20 years?
4. What will be the estimated population in urban area exposed to migration (linear growth) of 100 000 inhabitant with a growth rate of 3% in 5, 10, 20 years?
5. Define the DWd_{avg} for a village of 20 000 inhabitant taking in to consideration the following points. A similar type of WSS was built recently for a neighbouring village of 30 000 inhabitants,
6. Define the hourly demand pattern in a village of your region with 5% leakages and a daily peak of 250%
7. Define the hourly demand pattern with the counting of the jerrycans taken at the street fountains, indicated in the following table. NB There is two types of Jerrycans the 10 litres and the 20 litters that are reported in the table.

From	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00
To	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00
J 20 l	0	0	0	0	15	80	132	160	156	178	132	95
J 10 l	0	0	0	0	6	44	66	56	74	6	20	16

From	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
To	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
J 20 l	60	75	80	165	175	180	110	75	18	0	0	0
J 10 l	64	24	44	18	46	18	50	28	6	12	0	0

8. Wit a growth rate of 2%, 4% and 8% estimate how long a main distribution pipe could be used if its working range should be between 0,5m/s and 1,5 m/s.
9. Wit a growth rate of 2%, 4% and 8% estimate how long a tank can work properly if its working range should be between 80% and 30% of the total daily demand.

Intermediate exercises

10. A WSS was built recently for a village of 30 000 inhabitants, they have a DWp of 3 600 m^3. The water board use 2% of it, there is 11 fountains for public services with a flow of 9 l/min, the specific consumers (school, mosque and handicraft) have a daily usage of 750m3, the total sell

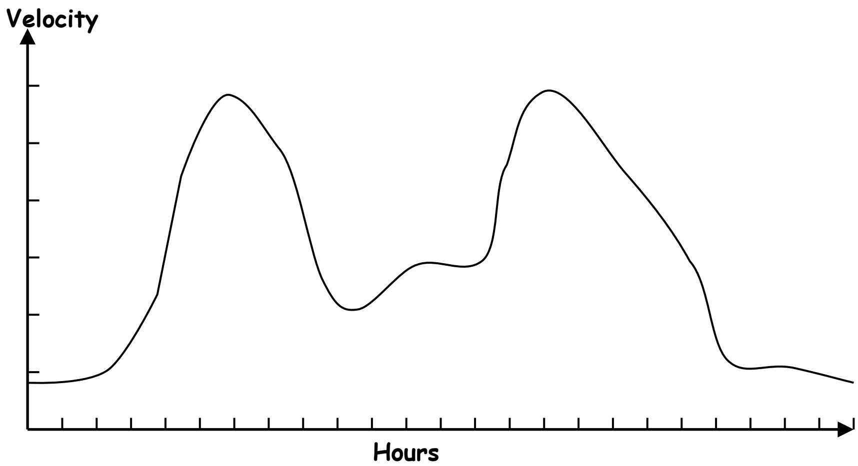
to households is of 70 000 m3 per month. Define the percentage of the different usage. What are the estimated losses?

11. You want to build a similar WSS in a neighbouring village of 20 000 inhabitants. The water board and losses should use the same percentage, there will be only 5 fountains, the specific consumers should have a daily usage of 200m3, the consumption per people should be identical. Define the percentage of the different usage and the DWp.
12. In a village of 25 houses (3 persons per house), a gravity system (spring 0.3 l/s and 3 m^3 reservoir) feed 5 tap stands (each serving 5 houses). The valve is open from 7h to 19 h to allow the reservoir to be filled in during night. Average water consumption 50 l/p/day. 10% leakages

    a) What is the daily water needs and the pattern?

    b) One of the tap stands is broken and always open. What the consequences on the daily water needs and on the pattern? and on the system in general ?

    c) With time, 15 families organise household connection (daily consumption increase to 100 l/p). 10 families water their garden (500 l/day) using a water tank they can fill early morning/night. An additional source supply the needed quantity to the reservoir, the network is now open 24h. What the consequences on the daily water needs and on the pattern ? and on the system in general ?
13. A village has seen its population growing from 20 000 to 25 000 people in 5 years, what is its growing rate (exponential and linear)? What will be the estimated population in 5, 10, 20 years?
14. For a village having a growth rate of 5%, what would be the life span of a WSS able to expand up to 200%, 300% of its initial capacity?
15. Same as question 7, but adding an estimated leakage in the network of 15%
16. Define the hourly demand pattern with the following chart of the velocity, measured with a flow meter. The size of the pipe is not known.



17. In a planned WSS, the main distribution pipeline was design to have a diameter of 100mm, considering a C_{DP} of 200%. Further to some discussion with the community, the village leader wants to limit the distribution time at two hours per day. In this case, what should be the expected size of the main distribution pipeline?

Advance exercises

18. A town of 100 000 inhabitants, with a DWd of 90 l/d/p, has an old WSS limiting the maximum distribution flow at XX m3/h. What is the value of the beheaded C_{DP}? Define the hourly demand pattern, estimating that the pattern is passing quickly from a 20% usage during the night to the beheaded value.

19. Measurements of the water height done in a storage tank providing the all network and supplied by a constant flow.

At	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00
Mm	1.021	1.243	1.464	1.685	1.868	1.920	1.724	1.464	1.230	1.178	1.217	1.217

At	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Mm	1.008	0.774	0.774	0.787	0.670	0.461	0.214	0.058	0.136	0.357	0.579	0.800