GOOD PRACTICES IN URBAN DRAINAGE PLANNING

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1. ABSTRACT

This document develops good practices on how to approach urban drainage network projects (sewage and rainwater drainage) to determine what aspects need to be considered based on the experience of Canal de Isabel II S.A.M.P. (hereinafter CANAL) in the Madrid Region. The conditioning factors that affect the design of the networks, as well as the problems in their operation and ways of resolving them, are presented.

Although we focus on the Madrid Regionand the legislation that applies there, many of the aspects considered can be extrapolated to other places, depending on their own environment and their own legislation. In addition, Canal has its own regulations to support the design of drainage networks: Canal de Isabel II Standards for Drainage Networks (NRSCYII).

With the growth of cities, the natural land surface that collected and infiltrated rainwater has been transformed into impermeable surfaces that generate greater flows of rainwater runoff towards the sewerage networks, compared to their initial situation. This causes problems in these networks due to a lack of capacity, causing flooding in the city during rainy periods and overflows of the unitary collector systems, which pollute the water bodies.

Good planning must foresee the necessary infrastructures and the land reserves required for new urban developments, considering time aspects for their execution and financing. In this sense, it is necessary to conduct an analysis of the situation to reduce, retain and/or laminate the rainwater flows that are captured in the new developments, establishing how to act, both internally and in the pre-existing external networks that receive their sewage and rainwater.

One solution for the management of urban runoff, acting from the source, and in a rational and more sustainable way, is the implementation of sustainable urban drainage systems (SUDS), by means of which the quantity of rainwater runoff is reduced, retained, and laminated and its quality is improved.

The studies carried out on the network and its operation, the type of terrain in the area, the type of treatment required for rainwater before it is discharged into a watercourse, etc., will make it possible to plan and simulate whether it will be necessary to renew or extend the network, retain or infiltrate rainwater, or laminate it before it is connected to the sewerage network. One of the tools used are the hydraulic models of the sewerage networks, which require knowledge of the existing network, both in terms of its characteristics and its state.

The calculation modes and design of the infrastructures (retention/lamination tanks, SUDS, etc.) depend on the main function to be emphasised, either for the retention of runoff water or to regulate its incorporation into the network.

Keywords: Drainage networks, rainwater, sewage, sanitation, SUDS, tank.

2. INTRODUCTION

CANAL is the company in charge of managing the sanitation process in the Madrid Region, covering all its territory.

Sanitation covers the transport of wastewater through the urban drainage networks to the wastewater treatment plants (WWTP) to return it to the rivers in optimum conditions.

CANAL is the company in charge of managing and maintaining the municipal sewerage networks of those municipalities with which it has signed a management agreement (some 135 municipalities out of 179 that make up the Madrid Region), currently totalling 14,792 km. It also manages the network of collectors and outfalls of the Madrid Region, which receive wastewater from the municipalities and take it to the treatment plants for treatment, currently totalling 874 km.

CANAL manages 182 wastewater pumping stations (EBAR), designed to lift the water, allowing it to be transported to the WWTPs if it is not possible to do so by gravity. It also manages 100 storm tanks and laminators, the aim of which is to prevent flooding and discharges into watercourses. Thanks to these facilities, the first rainwater, which is the most polluting, is retained and large volumes of water are stored during the rainy season to prevent flooding, for subsequent discharge into the network for treatment. CANAL manages more than 150 wastewater treatment plants (WWTP).

The territory of the Madrid Regioncan be summarised in two principal areas: the mountains and the plains of the Tagus valley. There is little rainfall throughout the year. Annual rainfall is around 400 mm, with a marked minimum in summer (especially in July and August), characteristic of Mediterranean climates. The maximum rainfall occurs in autumn (October to December) and in the spring months of April and May. The average annual temperature is approximately 14.5ºC.

The Madrid Region in the central part of the Iberian Peninsula. The population centre of the city of Madrid is located 657 m above sea level. The nearest coastal point is about 300 km away.

The Madrid Region (CAM, Comunidad de Madrid)) is an urban society, densely populated and organised around a nodal centre which is the municipality of Madrid. It is made up of 179 municipalities, covering 8,028 km2 of territory, with a population of almost 7 million inhabitants.

It is thus one of the most densely populated regions in Europe with a population density of about 870 inhabitants per square kilometre. Most of the population is concentrated in the city of Madrid (approximately 55 % of the population) and in the neighbouring large cities (35 % of the population). The rest of the population (approximately 10%) is dispersed over the rest of the area, in numerous small municipalities. In the municipality of Madrid, the population density is about 6,000 inhabitants per km^2.

Over the years, cities grow through new developments, which imply more population and more built-up area. Therefore, as far as the sewerage network is concerned, this growth is interrelated, as new developments depend on and are conditioned by the existing city and the surrounding environment. This aspect is approached with a global perspective, considering the transformation that they imply in the area that becomes more impermeable, determining the new services that are necessary for the new developments, and studying which existing city services need to be extended.

3. OBJECTIVE

The aim of this document is to develop good practices in relation to urban drainage planning, considering the experience of CANAL, setting out the problems and solutions used, focusing on the following aspects:

- Basic studies of urban drainage projects and the networks that make up the rainwater drainage system in urban areas, considering aspects such as geomorphology, climatology, hydrography and water quality, in order to provide solutions to the different problems that frequently arise such as flooding, the impact of which can be considerably mitigated if appropriate risk reduction measures are followed to minimise water damage as much as possible.
- To contribute to the prevention of flooding in urban areas through the use of Sustainable Urban Drainage Systems (SUDS) to improve land-use planning and exposure management in flood-prone areas, to reduce the risk of flooding or mitigate its effects in case it occurs and to contribute to the improvement or maintenance of the good condition of water bodies to achieve better management of rainwater in cities, taking into account the climatology and environment of the place.

4. THE DESIGN OF THE SEWERAGE NETWORK

General Conditionalities

- The growth of cities is generally conducted through new urban developments, which in many cases means a considerable increase in the impermeable surface area of cities, and it is necessary to study their influence on the city's existing infrastructures.

- In most cases the existing city networks do not have the capacity to cope with the new flows brought by the new developments, so new infrastructures must be built.

- Sewerage networks can be of a single type, which collect both sewage and rainwater together, or they can be of a separate type, in which there are two networks, one for sewage and the other for rainwater.

- The design of these networks is gravity-fed, and pumping facilities are only provided in cases where it is not possible to solve the problem by gravity. It is therefore highly dependent on the geomorphology of the area.

- Stormwater depends on the climate of the area, and a proper analysis of rainfall is necessary for the design of the networks.

- Sewage depends on the population and industry expected in new developments.
- In the Madrid Region, it is estimated that there is an approximate ratio between the peak flows of sewage and rainwater produced of 1:100.
- Another important aspect in the design is the hydrography of the area, which conditions both the location of the discharge point and the quality and quantity of rainwater to be discharged into the watercourse.
- During the rainy season, the flows increase, and it is necessary to foresee in the design the necessary measures to avoid uncontrolled overflows of the drainage networks into the watercourses.

Details of the area in which the urban development is located:

To design the sewerage network in a new development, it is necessary to collect the data that affect the sector and that will provide information for the design of the network, related to cartography and topography, geology, hydrography, climatology, and water typology.

- The cartography and topography of the terrain make it possible to define the basins through which rainwater runs until it reaches the possible collectors that collect it, and make it possible to define the layout in plan and longitudinal profile of the collectors, conditioning the depths at which they must run, etc. Depending on the new layout of the sewerage network, new rainwater and sewage collection basins will be generated.
- The geological and geotechnical information of the area will define the type of soil in the sector. Soil infiltration data will affect the runoff coefficients necessary for the calculation of stormwater to be collected; the properties of the soil materials affect the choice of the material of the collectors to be installed (e.g. presence of sulphates that degrade concrete if it is not sulphate resistant), etc.
- The hydrographic information will define the river and stream courses and their flow rates. Streams and rivers may be used as discharge points for rainwater, provided they are authorised.
- The design of the sewer network will depend on the location of the WWTP or the location of the pre-existing sewer network to which the sewage is connected. It will also depend on the location of the destination of the rainwater, and on the quantity and quality conditions to be able to discharge the water into the watercourse in compliance with current legislation.
- The weather conditions the rainwater generated in each area. Climatology is related to rainfall, the distribution and intensity of which are used to obtain rainwater flows.

  Rainfall data can be derived from actual records from rainfall stations or synthetic rainfall data from a representative Intensity-Duration-Frequency (IDF) curve. The rainfall data is used to obtain the hydrograph of the catchment.

The IDF curves relate the intensity to the duration of rainfall for different return periods. For the same return period, rainfall of longer duration has a lower intensity and rainfall of shorter duration corresponds to a higher intensity.

The approximate maximum average intensity in the city of Madrid, for a rainfall duration of 10 minutes and return period T=10 years, is about 180 l/s-ha.

- To obtain the rainfall flows, it is also necessary to know the characteristics of the catchment basin, such as: surface area, runoff coefficients, time of concentration, etc.

Flow calculations.

- Sewerage networks must be designed in such a way that the total wastewater flows generated in the areas served by them (from domestic, tertiary, residential and industrial sources) and the rainwater flows associated with the return period considered are considered in their calculation. The total peak flow is obtained as the sum of the peak flows of wastewater (sewage) and rainwater flows.

- According to the Canal Standards, the wastewater (sewage) flows are calculated based on the required supply for dwellings/population and/or industry, the return flow coefficient, and the surface area.

- The total average wastewater flow (QTm) shall be the sum of the domestic wastewater flow and the industrial wastewater flow. The minimum flows shall be calculated by applying a coefficient of 0.25 to the average flows. The peak wastewater flow is obtained by following the formulation included in the NRSCYII:

$$Q_p = 1{,}6 \times \left(\sqrt{QT_m} + QT_m\right) \leq 3 \times QT_m$$

- The stormwater flow is calculated considering rainfall intensities for the return period T considered, 10 years, and there are different calculation methodologies.

- To obtain the rainwater flow rate, different calculation methods can be used, such as the Rational method, statistical methods, or other hydrological methods. In CANAL, the most used method to obtain the stormwater flow is the Rational Method, considering homogeneous basins, in which.

$$Q = k \cdot C \cdot I \cdot A,$$

where Q is the flow rate, C is the runoff coefficient, I is the rainfall intensity, and A is the surface area, and k is a coefficient representing the degree of uniformity with which the runoff is distributed (whose value is between 1 and 2).

The rainfall intensity depends on the return period T and the duration D of the rainfall. For the peak flow considered in the rational method, the intensity is used for a duration equal to the time of concentration of the catchment tc. There are different methodologies for the calculation of rainfall intensity.

Rainfall intensity can be obtained using statistical procedures, empirical formulas, or others. It can be based on real rainfall series or on IDF curves designed for the area under study.

For the sizing of collectors, the starting point is a hydrograph (flow-duration) in which the peak flow is obtained from a rainfall duration equal to the time of concentration. However, for the sizing of other types of infrastructures, such as storm tanks, it will be necessary to obtain a hydrograph in which different rainfall durations are considered (with real rainfall or by iterating different rainfall durations with the IDF curves) which results in obtaining the maximum volume of the installation.

The Roads Directorate of the Ministry of Public Works has published *Standard 5.2-IC of the Roads Instruction Surface drainage, of the Ministry of Public Works of the _Dirección General de Carreteras. Spain*. In which the methodological bases of the Rational Method for the calculation of the stormwater flow QP of the pipes that make up the sewerage network are described.

- Currently there are tools that allow the development of hydraulic models (such as SWMM, INFOWORKS, or others) that are used in the design of sewerage networks through the detailed simulation of pluviometric events, which have graphic support on GIS with an associated database. These models provide a visual environment that allows inputting data for the drainage area, simulating the hydraulic behaviour of the network, estimating water quality, assessing the impact on water bodies during rainfall events, visualising all the results with a wide variety of graphics and generating output files for their visualisation and subsequent processing with other tools such as spreadsheets.

In addition to the visualisation of the results in the form of hydrographs, thematic maps of the network and tables, it also allows the determination of the number of unit system overflows (SUDs) or discharges that occur and the design of strategies for their minimisation. In addition, they allow the modelling of sustainable drainage elements, such as SUDS techniques.

Design and dimensioning.

- In general, the network is designed so that the water flows by gravity in free sheet, so the methodology for the design of the collector networks is carried out considering the downstream data, i.e. the levels that need to be reached at the discharge points or connection points to the external network or to the WWTP.

- Starting from the information on the downstream elevations, the upstream layout is assessed, combining diameters, depths, slopes, etc. Firstly, an initial layout is designed in plan, which is adjusted according to the necessary connections, interferences with other services, with existing infrastructures, etc. For the longitudinal profile, initial slopes are established between 1% and 4% approximately (pre-dimensioning), which are adjusted according to the hydraulic checks of maximum and minimum water circulation speed for the design flow rates.

· Another factor in the design is the resulting depth, trying to avoid both excessive depths and too shallow depths. For example, it will be checked that sufficient minimum cover is provided for the collectors, and the layout will be adjusted, or reinforcements provided so that the collectors are not affected by loads transmitted from the surface. To reduce excessive depths or slopes, shoulders may be used (between the inlet and outlet collector heights in the sewer hole).

According to the NRSCYII, when the depth of the sewers exceeds 5 m, visitable sewers, i.e., passable by personnel to ensure maintenance from inside the sewers, are designed. In this way, very deep trench excavations are avoided, which might be necessary to repair them throughout their useful life, and which would avoid affecting traffic, passers-by, and existing services.

On the other hand, depending on the resulting diameters and depths, as well as the necessary connections between collectors, the sewer holes or access chambers to be provided along the route will be larger or smaller and must be designed considering adequate access and maintenance.

 The purpose of the sizing is to obtain the diameters and slopes suitable for the optimum functioning of the network. To this end, the following aspects are considered:

 Verification of maximum velocities (protection against erosion) and minimum velocities (self-cleaning condition). The range of velocities considered adequate by CANAL is 3 m/s for peak flows of sewage and 5-6 m/s for rainwater flows. The minimum velocity shall not be less than 0.6 m/s under the minimum wastewater flow.

- Verification of the capacity of the designed network by obtaining its degree of filling. Considering maximum flows, the degree of filling shall not exceed 75%-85% of the cross-section.

- When the designed network connects to existing sewerage networks, it is essential to check the capacity of this network to verify the possible need to extend it or to consider the retention at source or lamination of the flows generated by the new sector.

In the Madrid Region, in the case of unitary networks, which during rainy periods will transport sewage and rainwater, tanks and spillways are available to prevent overflows of diluted unitary water and flooding.

In the case of separate rainwater networks, in the Madrid Region their design depends on the legal limitations regarding quantity and the limitations regarding the quality of the water so that it can be discharged into a watercourse, i.e. whether it is necessary to treat the rainwater beforehand.

5. PROBLEMS IN THE OPERATION OF THE NETWORK. PROBLEMS ANALYSIS AND THEIR CAUSES.

In municipalities, sewerage networks were designed for the needs of the original situation at the time, without considering new future developments that were not foreseen in time, nor were strategic infrastructure plans drawn up to consider the evolution of the needs of cities through large urban developments.

New urban developments transform the natural terrain, leaving the area highly impermeable, thus increasing its runoff coefficient, and generating higher peak flows of rainwater compared to its initial situation. In addition, it is necessary to consider the variation in the form of rainfall that could be related to climate change, with higher rainfall intensity, which also means higher rainfall flows.

For years, the standard practice in urban drainage design has been to capture and convey water rapidly out of the city through surface runoff systems. When a natural environment is developed, there is a progressive waterproofing of the ground, which means that water that was previously retained in the ground and infiltrated, now flows rapidly over the surface, and needs to be collected, conveyed, and discharged to the receiving environment at specific points. The reduction of vegetated green space reduces natural interception and evapotranspiration, and the increase in imperviousness reduces the volume of infiltration. Consequently, higher volumes of runoff and higher peak flows are produced, generating problems in the sewerage networks due to a lack of capacity, which causes flooding and overflows of the unitary systems during rainy periods that contaminate the water bodies.

Other problems that cause poor functioning of sewerage networks are: insufficient maintenance and cleaning of the network; industrial discharges connected to the network without prior treatment that affect the materials of the network; materials used in the collectors that are not compatible with the properties of the land; lack of watertightness in the network; collectors and spillways located in flood zones, etc.

It is important to highlight other types of problems caused by bad practices, such as: connections of channelled streams to the sewerage network in urban areas; direct connections to the sewerage network of drains from road works, railways, etc.; buildings in flood-prone areas.

These problems cause material damage, damage to ecosystems and personal injury.

6. GOOD PRACTICE IN URBAN DRAINAGE PLANNING.

Ways of addressing solutions

The impact of damage caused by network malfunctions can be significantly mitigated if appropriate risk reduction measures are followed to minimise water damage as much as possible. The main aspect to be addressed is to limit the input of stormwater into the sewerage network.

Stormwater from new developments cannot always be conveyed to a nearby stream, and in many cases ends up being conveyed to the city's pre-existing unitary networks, as these are the most common type of networks, and whose capacity may already be exceeded.

If the receiving networks or the WWTP do not have sufficient capacity, flooding, overflows of unitary systems and pollution of watercourses will occur. This implies the need to address stormwater management.

Through good planning, the necessary infrastructures and the required land reserves must be foreseen, both in new developments and in the consolidated city, considering time aspects in their execution and financing. In this sense, an analysis will be conducted to reduce, retain and/or laminate the rainwater flows captured in the new developments, establishing how to act, both inside the new developments and in the existing external networks receiving their discharges.

To reduce the quantity of rainwater runoff and improve the quality of rainwater runoff at source, infrastructure can be designed for sustainable urban drainage techniques. The approach to solutions may involve the need for new or larger collectors in the existing network, tanks or SUDS, and space is always required for their installation.

There are several types of tanks depending on the function sought (anti-flooding or anti-pollution), as well as several types of SUDS to retain runoff water or to regulate its incorporation into the network, which may or may not be interconnected with each other.

Studies of the network and its functioning will make it possible to plan and simulate whether it will be necessary to extend pre-existing networks, to retain and infiltrate rainwater, more suitable connection points, etc. One of the tools used are the hydraulic models of the sewerage networks, for which a factual knowledge of the existing network is required, in terms of its characteristics as well as its state. An example image is included below:

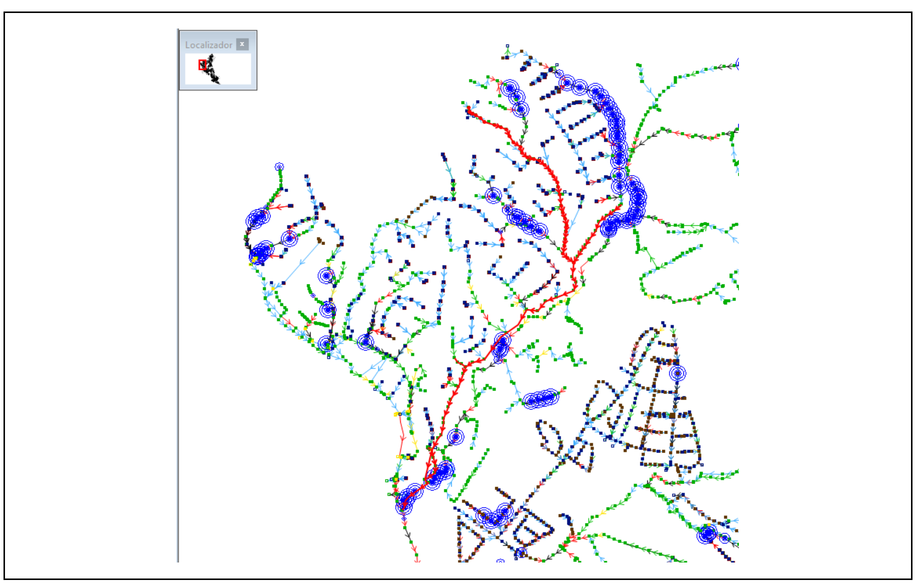


Image of the hydraulic model of a sewerage network of a municipality, showing overflows in sewer holes (blue circles) and lack of capacity of the network in the highlighted sections according to the degree of affection of the network (in yellow, red, and black).

To minimise the risks in sensitive areas, the design of the necessary infrastructures, such as storm tanks, can use return periods longer than those considered in the sizing of the network, to minimise the impact.

In addition to the sizing and design of the network and its associated infrastructures (spillways, WWTP, etc.), other important points to avoid problems in the operation of the network are: proper execution of the works; providing access through public areas to the sewerage network for proper maintenance; carrying out regular maintenance and cleaning; avoiding unwanted discharges that connect to the network, etc.

The importance of planning

Urban drainage planning and studies will be conducted in a gradual and successive manner according to the different planning stages. It is important that the problems and needs affecting new developments and existing city networks are detected from the outset, so that the necessary infrastructure can be planned and organised over time and so that the growth of cities can be viable. In good planning it is important to consider the following general aspects:

- Stormwater retention infrastructures may need to be arranged in public areas or in restricted areas, which should be foreseen already at the planning stage, and have land available, analogous to building, green space surfaces, etc.

- The elements to be provided in restricted areas should be included in the municipal by-laws or in the sector's planning sheets, so that they can be considered in the subsequent development project.

- Specify the data to be used to ensure consistency between successive calculations, such as, for example:

    - The rainfall data (hyetograms, IDF curves, real rainfall series, etc.) considered in the hydraulic models, those considered at the planning level and those to be used in subsequent projects.

    - The conditioning factors for water outflow: volumes to be retained, areas required for their implementation, emptying flows, when discharge can begin, duration of emptying, etc.

    - SUDS may or may not be connected to the urban drainage network. These aspects should be addressed from the initial planning stages.

- Consider the technical feasibility of the elements for regulating the emptying of tanks or other installations that may be executed, since if the flow to be regulated is very small it will entail the installation of equipment (vortex valves, sluice gates in extremely small orifices, etc.) that may cause maintenance problems due to clogging. It is also necessary to conside4r: emptying time, where to empty, health conditions derived from the type of water to be retained and the time it will be retained, etc.

· Plan a control of tanks emptying, in the event that this results in the arrangement of many retention tanks along the collectors, in which case it will be necessary to consider a control system for these tanks so that the emptying of some, which influences the emptying of others, does not involve danger in the maintenance work of the sewerage network, and it is considered that they may have different ownership or management.

7. SOLUTIONS THROUGH SUSTAINABLE URBAN DRAINAGE SYSTEMS (SUDS) AND TANKS:

SUDS Typologies

Sustainable Urban Drainage Systems (SUDS) provide a solution for the management of urban runoff from a more nature-friendly approach, acting from the source, and in a rational and more sustainable way.

The SUDS philosophy is based on reproducing the natural hydrological cycle prior to urbanisation or human action, encouraging the use of permeable systems in the urbanisation process that allow for more sustainable management of rainwater by reducing surface runoff, both at source and during its transport and destination, with the aim of increasing infiltration into the ground, laminating peak flows to be managed and increasing the quality of rainwater discharges.

SUDS can be located on public plots or areas and on private plots. In the overall sewerage network, they may or may not receive connections from networks or other SUDS from upstream. In addition, the water collected in the SUDS can be infiltrated into the ground, or conveyed to a watercourse, or conveyed to the sewerage network, or a combination of these.

SUDS can be classified according to their main function as:

- Infiltration techniques (infiltration wells or ditches, reticulated tanks)
- Filtration techniques (filter soils, filter drains or ditches, permeable pavements)
- Measures using vegetation (wetlands, rain gardens, vegetated roofs)
-

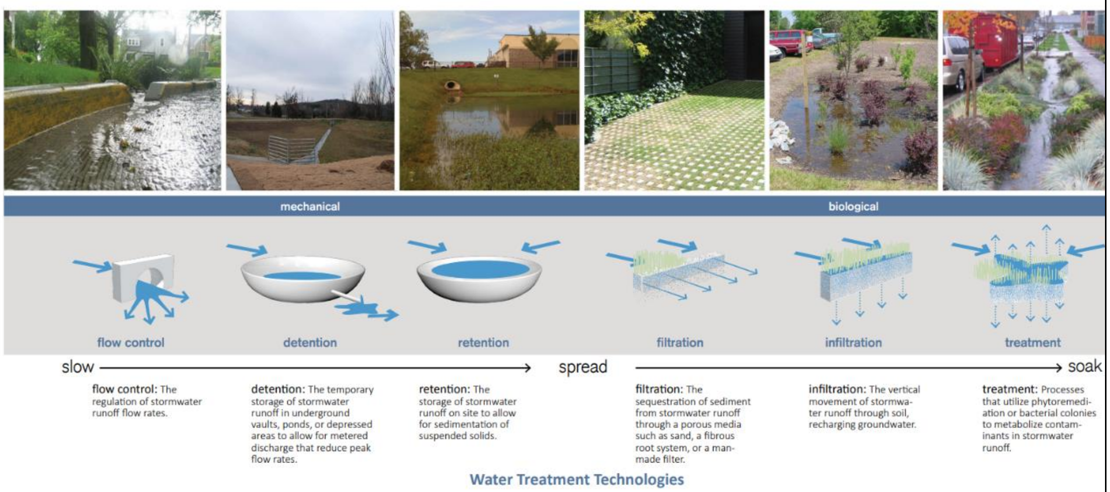
Infiltration promotes the vertical movement of runoff through the soil, contributing to the recharge of aquifers.

The **filtration** function is based on retaining sediment present in stormwater through a porous medium, artificially created soil or vegetation.

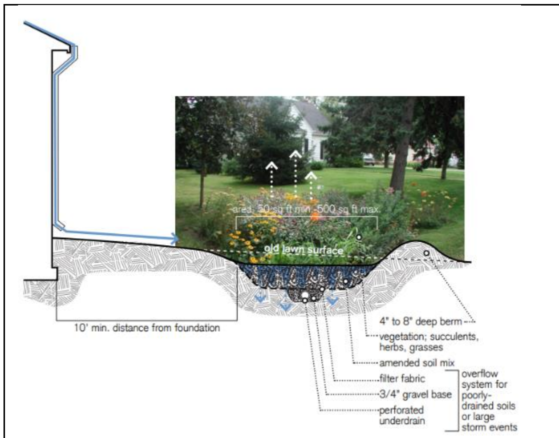
The function of measures using **vegetation as treatment**, phytoremediation processes or bacterial colonies are used to metabolise pollutants in stormwater runoff.

The **retention/detention** function consists of storing rainwater in situ for uses that do not require drinking water quality or to laminate it so that runoff is temporarily stored and then discharged slowly, encouraging sedimentation of particles, and reducing peak flow.

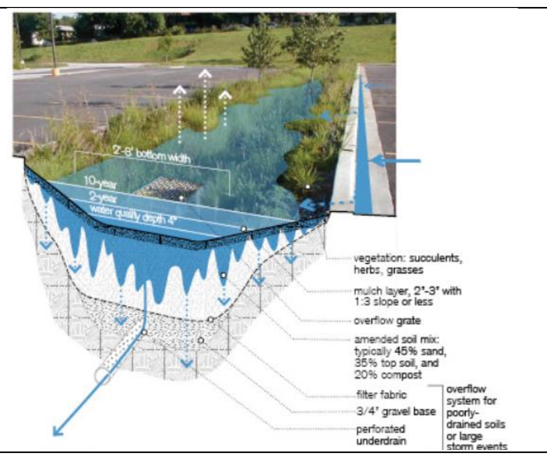
The following are examples of several types of SUDS (images from the University of Arkansas Community Design Center: https://uacdc.uark.edu/):



Example of the main SUDS functions of SUDS



Rain garden

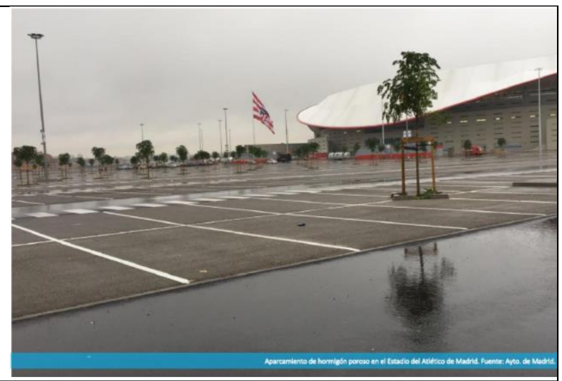


Bioswale

The different guides or technical standards for SUDS design establish similar classifications, based on the main function of SUDS, which can be consulted as indicated in the bibliography section.

Below, as an example, we include images of several types of SUDS implemented in the city of Madrid (images from the "Basic guide to the design of sustainable rainwater management systems in green areas and other open spaces". November 2018. Dirección General de Gestión del Agua y Zonas Verdes. Madrid City Council):

	
Green roof	Reticulated deposits using retention cells.

	
Cistern.	Permeable pavement.

	
Permeable tree bed.	Filtering drainage

	
Rain garden	Rain garden

Tanks

Tanks are infrastructures whose mission is to store volumes of water to make up for the lack of capacity of a collector (anti-flooding or laminator), or that cannot be treated in a treatment plant in rainy weather because the flows generated exceed the treatment capacity of the latter (anti-pollution). In other words, the function of each tank is a combination of flow regulation (laminator) and retention of water volumes (anti-pollution).

The design of each tank will depend on which mission it is intended to fulfil, there being several calculation criteria, to be used depending on the case. For example:

> The design of the tanks to be installed in the sewerage networks to solve the lack of capacity of the collectors, will have an individualised treatment that will depend on the expected hydrograph of arrival, the capacity of the collector, and the space available within the urban fabric.
>
> Tanks that seek to avoid discharges prior to the WWTP can be sized with the criterion of using a maximum number of annual discharges established by the regulations (for example, less than 15 discharges per year), using an average year's rainfall corresponding to the last decade of ten-minute records available.
>
> Or it can be checked that there is no discharge for critical rainfall as defined in the German Standard ATV-128; or use a ratio of retention hours; etc.

Interior of storm tank. Source: Canal´s website

SUDS and tank considerations

The exponential increase in the implementation of SUDS and storm tanks affects the management of the sewerage network, and can cause problems in the management of SUDS and sewerage networks due to:

- Effects on the upstream network, since a malfunctioning of the SUDS would lead to the inadequate functioning of the drainage network that reaches it.

- Effects on the downstream network, produced by the malfunctioning of the SUDS, which would not laminate according to design.

- Difficulty in maintaining the SUDS due to lack of experience or due to a design that does not allow them to be properly maintained.

- Inadequate selection of SUDS that may cause damage to third parties because of damage to neighbouring structures (foundations) due to infiltrated water; damage to the environment because of possible contamination of soil and groundwater due to the transfer of pollutants in the infiltrated water.

Sizing of SUDS: Guide by the Madrid City Council

For the sizing of SUDS there are several calculation methodologies, approximate for each case and depending on the type of SUDS. For example, in "*La guía básica de diseño de sistemas de gestión sostenible de aguas pluvias en zonas verdes y otros espacios libres*. November 2018. Dirección General de Gestión del Agua y Zonas Verdes. Ayuntamiento de Madrid", approximations are used to estimate the volumes to be laminated, based on the verifications that have been conducted with real rainfall.

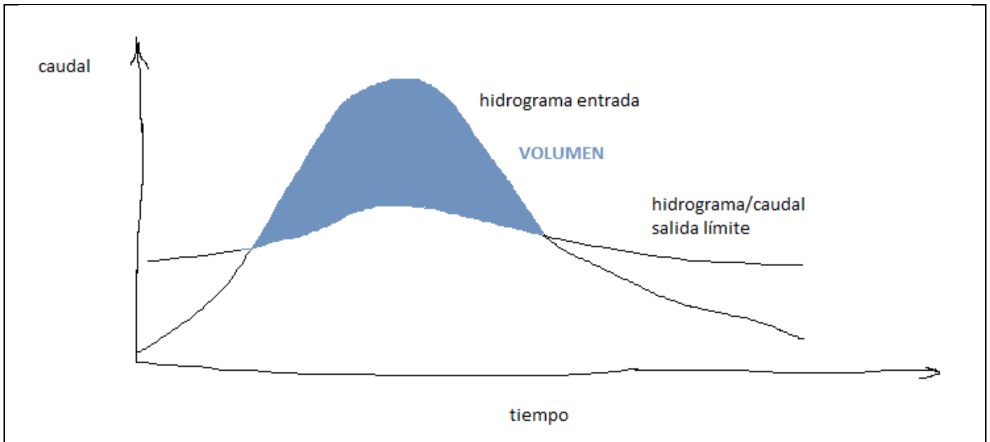
This takes into account the cumulative effect of the volume to be retained by long rains and those occurring in a time interval of less than 24 h (long rains with lower intensity require greater volume than more intense short rains, also considering the effect of consecutive rains that do not allow time to empty the infrastructure). For the city of Madrid, it is established that the volume V80 corresponds to 15 l/m2 of net surface area, which in small areas would be equivalent to retaining rainfall of 48 mm/h=133 l/s/ha for a T of 10 years and a duration of 20 min.

In any case, the infiltration to the ground to be considered must be validated by the corresponding studies of the ground.

Philosophy for calculating the volume to be laminated, due to lack of capacity of the receiving network or limitation of the discharge flow, by means of tanks.

The calculation methodology used to determine the volume of tanks whose function is to make up for the lack of capacity of a receiving collector, considering a discharge flow that needs to be limited, is generally based on the following: considering different scenarios of rainfall hydrographs, from which the outflow is subtracted, thus obtaining the volume to be retained in each scenario (area between the rainfall hydrograph curve and the outflow curve), from among the volumes obtained for the different scenarios, the volume of the tank is selected (the worst or other volume to be considered).

The different rainfall hydrograph scenarios can be obtained, for example, from actual rainfall series or from IDF curves.



Sketch of tank volume calculation philosophy

In simplified form, the calculation steps would be as follows:

- Obtaining rainfall intensity data (I): using data from real rainfall series or using data from IDF curves (for which the rainfall is iterated for different durations, obtaining the intensity I for each duration D).

- Obtaining the rainfall hydrographs:

  The hydrograph of each event can be approximated using the Rational formula (Q=k*Ce*I*A), to a rectangular hydrograph, or to a trapezoid-shaped hydrograph.

  Each hydrograph is obtained by considering the basin parameters (time of concentration, area, and runoff coefficient) as well as the different rainfall durations.

- Obtaining the outflow:

  The outflow depends on the limitation of the network and/or the discharge to watercourse allowed by legislation. In a simplified way, a constant outflow could be considered, regulated by the corresponding element, or the outflow curve of the regulating element, which depends on the water filling height in the tank, could be introduced in the calculations.

- Selection of the tank volume:

  The retention volume for each rainfall event or duration is the area between the rainfall hydrograph curve and the outflow curve.

  Once the volumes for each rainfall event or duration have been obtained, the tank volume is chosen from all those obtained, either as the worst (maximum) volume or as the volume that is not exceeded by a certain percentage of the cases to be established.

8. CONCLUSIONS

The importance of planning urban drainage infrastructures and the need for land is highlighted to address the growth of cities, both in new developments and those to be conducted in the existing city, considering temporal aspects for their execution and financing. Due to the increase in rainwater flows because of the waterproofing of the natural terrain caused by such growth, the implementation of SUDS can be considered to reduce and laminate runoff at source, to avoid problems of flooding and overflows in unitary systems during the rainy season.

In this sense, it is necessary to conduct an analysis from the outset to reduce and/or laminate the rainwater flows captured in new developments, establishing how to act, both inside the new developments and in the existing external receiving networks.

One of the fundamental tools to be used are the hydraulic models of the sewerage networks, which enable studies of the network to be conducted and its operation to be analysed. This requires knowledge of the existing network, both in terms of its characteristics and its condition, to conduct simulations and diagnoses that allow the necessary actions to be implemented in the network to be determined and planned.

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