Efficiency of Urban Runoff Interception Devices - Link to 1D Modelling

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ABSTRACT

The need to improve the performance of drainage systems is a growing concern in urban areas, due to the economic and social impacts of flooding phenomena in large cities. Thus, the preparation of this document aims to contribute to the optimization of the performance of storm drainage systems in urban areas, with special emphasis on the impact that the hydraulic efficiency of the intercepting devices has on this issue. This theme arises from the fact that, generally, they are neglected components in the context of urban planning.

Having thus defined the objective, it was considered necessary, in a practical context, to develop a tool for sizing these devices, based on the efficiency values obtained for each type of device, thus analysing the applicability of each one and also alerting to the need to consider their choice.

Next, to validate the values obtained by the abacuses elaborated in the previous section, experimental campaigns were carried out with certain existing devices in the Alameda campus of the Instituto Superior Técnico.

Finally, an analysis of the impact of hydraulic efficiency on the capacity of the existing collectors in Santa Marta St./ São José St./ Portas de Santo Antão St. was performed, using the 1D Storm Water Management Model (SWMM) tool, to obtain methodologies that allow, in future studies, the introduction of the efficiency of these components in the dynamic modelling of drainage systems.

Keywords: Inlets; storm drainage system; Storm Water Management Model; hydraulic efficiency; hydraulic 1D modelling.

1. INTRODUCTION

Climate change, in which flood phenomena are included, is a current problem and society, besides being increasingly aware of the problem, is increasingly committed to address the situation and mitigate / reduce its impact. The study of the impact of flood phenomena and the performance of several urban drainage systems grows in importance when we approach the problem in the city of Lisbon. As it is known, there are certain locations referred to as susceptible to flooding, such as the riverside area and Baixa, among others. In the urban context, the prevention of flood phenomena requires, not only, but also the correct design of urban drainage systems, as well as their correct operation during their useful life. In this theme arise the interception devices, which play a key role in the efficiency of these systems and that, in the context of sizing, are often placed in the background or even neglected. For this purpose, there are calculation methodologies that can be used in order to fill this gap.

Interception devices, such as drains and curb gullies, allow surface runoff to be captured and routed to the collectors, aided by devices such as ditches, drains and berms (Matos 2006)

One of the problems associated with the design of drainage networks in urban areas is the fact that, as a rule, stormwater projects are limited to the design of collectors, putting in second place the in-depth study of these devices in terms of location and hydraulic capacity (Matos 2006).

Interceptor devices allow reducing the dispersion of water on the surface, so their location and sizing are dependent on the geometry of the roadway (Brown et al. 2013). In this sense, and according to DR No. 23/95, Article 162, the implementation of drains and gutters should be provided in the following situations (Ministério das Obras Públicas Transportes e Comunicações 1995):

- in low points of streets;
- at intersections, thus allowing the roadway not to be crossed by surface runoff;
- distributed in the gullies, allowing the width of the liquid slide not to exceed the maximum allowable values for this variable.

It should also be noted that their implementation may be considered in the presence of intersections and crosswalks (Brown et al. 2013), as well as in places where water is expected to accumulate at certain points, from lots, gutters, downspouts, green areas, among others (Padrão 2016).

Interceptor devices can be divided into curb gutters, which collect surface runoff laterally, grate inlet, where the surface runoff enters through an existing grid in the sidewalk, and also a combination of grate and gutter inlets (Barreiro 2017; Matos 2006). Drains can be single or double and may or may not have a depression; gutters can also be without or with depression, the latter being of type 1 or 2; finally, the combination of drain and gutter may or may not have a depression.

Technological advances in the last decades have allowed researchers and designers the use of computers and a substantial improvement of computational methods. In this context, dynamic models for simulating the performance of urban drainage systems have emerged (Chow, Maidment, and Mays 1988). Thus, for the assessment of risks and consequences of flooding in urban environments, hydraulic modeling is usually used as a support tool in flood risk management (Coutinho 2015), not only for the design of new systems, but also for the analysis of existing ones (Girão 2014).

In this paper, 1D modeling will be addressed using the Storm Water Management Model (SWMM) software, which allows simulating point or continuous precipitation and runoff events for separative and mixed unit systems (Barreiro 2017; Shahed Behrouz et al. 2019). The software, in addition to providing flow data, also allows the determination of runoff height and water quality during the simulation time and for a given channel or collector (Rossman 2015). However, one of the simplifications of one-dimensional modeling is the fact that the capacity of the interceptor devices is not taken into account (Beceiro 2016). Therefore, a methodology was created to allow the introduction of the hydraulic efficiency variable of the interceptor devices in the 1D modeling.

2. CALCULATION OF THE HYDRAULIC EFFICIENCY OF INTERSECTION DEVICES

The application of the calculation tool developed from the equations discussed in this document allows obtaining estimates of the hydraulic efficiency of the interceptor devices under analysis. This methodology was applied using Microsoft Excel software. Thus, through the introduction of the geometric variables necessary for the determination of the hydraulic efficiency, discussed in this subchapter, it was possible to obtain matrices and efficiency abacuses for each of the mentioned devices. The efficiency of the inlet devices was analysed for values of the inflow flow between 0.005 and 0.1 m3/s and the longitudinal slope of the street between 0.005 and 0.1 m/m.

2.1. Curb gutter

To determine the hydraulic efficiency of simple drains, certain variables had to be defined. In the case of a gully without depression, the efficiency of the device is influenced by the length of the mouth of the curb gully since this variable directly influences the captured flow rate of these devices. Note that, besides the variables associated with the street, this is the only one that interferes with the efficiency of this type of device. It should also be mentioned that it also influences the two types of gutters with depression.

In the presence of a gully with depression, the variables that interfere with the hydraulic efficiency of these devices, in addition to the one mentioned above, are:

- height of the upstream and downstream depression (a_s and b_s, respectively);
- length of the upstream and downstream sections of the depression (L_1 and L_2, respectively);
- width of the gully depression (B_1).

2.2. Grate inlet

As with the gutters, the definition of certain variables is essential for determining hydraulic efficiency, among which the following stand out:

- number of cross bars
- width of the grid opening (B);
- distance between the first grate opening and the kerb (d_1);
- length of the grid opening (L);
- height of the depression ($h_{depression}$).

In the analysis of a double drain, in addition to the definition of the above criteria, it is added that

- it was considered that the spacing between drains would be zero, in order to disregard the runoff generated between drains;
- the runoff flowing into the second drain is the difference between the upstream flow of the first drain and the flow captured by the latter.

2.3. Combination of grate and gutter inlet

The hydraulic efficiency of the combination of grate and gutter inlets was determined by adding the efficiency recorded in the grate and in the gutter, considering that the inflowing flow is first captured by the grate and the rest by the gutter. In this type of device, the analysis was made both in case there was a depression and in case there was not. It should be noted that, for the first situation, it was assumed that the gutter would be a type 1 depression because, as will be seen, there are no significant changes in efficiency values between the two types of existing depression.

2.4. Evaluation of the results

Gutters are interceptor devices mostly associated with older urban areas and are currently in disuse because they have lower efficiencies than other solutions, such as drains.

Comparing the efficiency values of gutters and simple drains, the former present significantly lower values of hydraulic efficiency for the range of values presented. It is also seen that there is a significant difference between those presented in the case of the curb gutter without depression and that of the gutter with depression (type 1 and 2). These results demonstrate the need to evaluate the efficiencies of the devices when making choices in their implementation in certain circumstances.

With these results in practice, gullies show very poor performances and, as such, should not be used, with minor exceptions: they can be considered when combined with drains and can also be considered when a high number of solids and debris is expected to be present in the runoff, in order to avoid clogging the intercepting devices.

Finalizing with the analysis of depressed sidewalk gutters in terms of hydraulic efficiency, the differences between the two types are evident.

Looking at the grate inlets, the hydraulic efficiency of depressed grates is higher than that of drains without depression. It can also be seen that, for both situations, for high longitudinal gradients of the street and for high flows, the efficiency decreases substantially in both situations, which can be explained by the increase in the portion related to the runoff over the grid, which shows its importance in the collection capacity of the grate inlets. By analysing the results for small flows, both cases present quite satisfactory results, even for high longitudinal slopes of the street (around 10%). However, the same cannot be said for grates without depression, in case of high flow rates, as they result in efficiencies below 65%. The efficiency of depressed grates is satisfactory, with only lower efficiencies being noted for extreme situations (longitudinal slope and inflow of 10% and 100l/s, respectively).

Analysing the values obtained, it can be seen that the choice of the type of grates can vary: on the one hand, grates with depression may be advantageous in situations where a high inflow is expected (e.g. in a street where flow from other streets is expected to be collected) or where streets with a high longitudinal slope must be used; on the other hand, grates without depression can be advantageous in places where it is not advisable to have a depression (for example, on bicycle paths or where motorcycles are expected to circulate, as long as they do not interfere with the safety of these vehicles). It should be noted that the choice may also be influenced by the return period chosen for the project, since for longer return periods, the design flow of the interceptor devices is also higher.

It is also important to highlight the fact that the analysis was performed assuming that the interceptor devices were completely unobstructed.

In addition to single grates without and with depression, it is also possible to consider double grates. When analysing the efficiency of double grates, the existence of a depression in the grates is beneficial to the hydraulic efficiency of these devices. In fact, it is verified that, for both situations, grates are an excellent option when it comes to capturing the flow. The suggestions made about the applicability of grates with and without depression can be extrapolated to the case of double grates. However, because they have higher efficiencies than single grates, they are more suitable where there are recurring flooding problems or where flooding is expected. In both cases, it should be noted that their implementation is not recommended when grates obstructions are expected.

To fill the gaps of the two types of devices mentioned above, it is possible to consider the combination of grate and gutter, with or without depression.

By analysing the results obtained, the behaviour of the combination of grate and gutter without depression is similar to that of the simple grate without depression, with the nuance of presenting slightly higher hydraulic efficiency values. However, the efficiency values of the combination grate and gully with depression are quite high for the range of values studied, confirming that this is an excellent option when high rates of runoff collection are desired.

The great advantage of this type of device is the possibility of overcoming flaws inherent to the devices when considered individually: on the one hand, they allow the collection of effluent even if the grate is obstructed, making their implementation feasible in conditions that were not for grates (for example, in low points where the accumulation of trash and sediment carried by surface runoff is expected); on the other hand, it allows to obtain higher efficiencies than simple grates. This type of device also allows the consideration of the combination of double grate and gutter. As a disadvantage, it should be noted that this type of device requires a higher initial investment, when compared with those that have already been analysed.

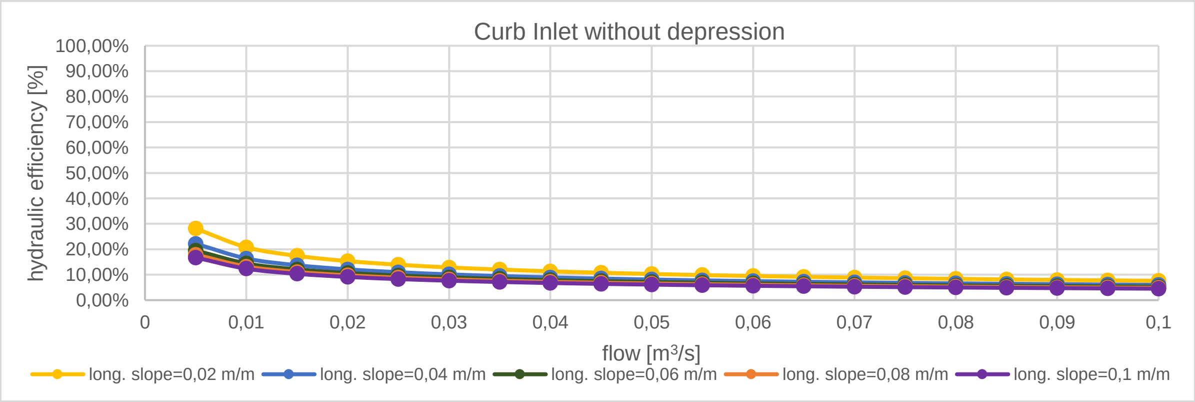

Figure 1 - Hydraulic efficiency of curb inlet without depression

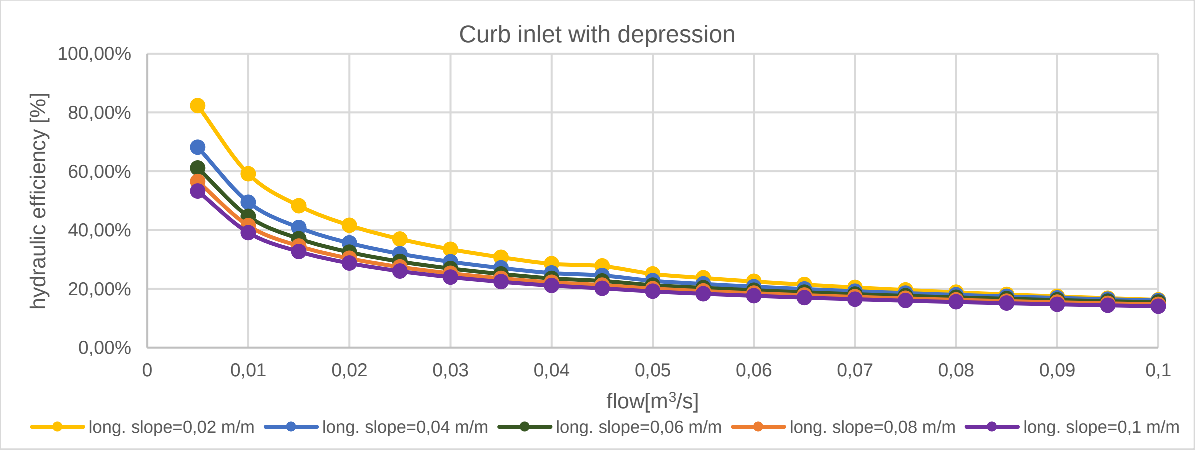

Figure 2 - Hydraulic efficiency of curb inlet with depression

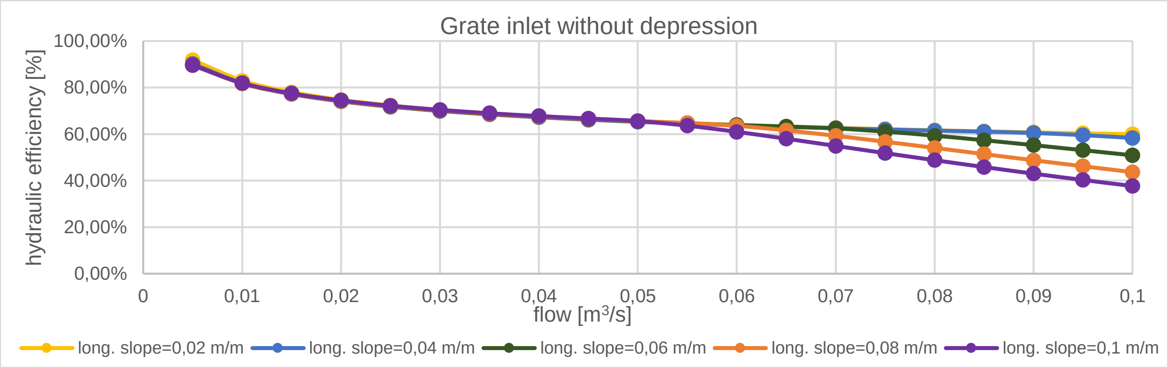

Figure 3 - Hydraulic efficiency of grate inlet without depression

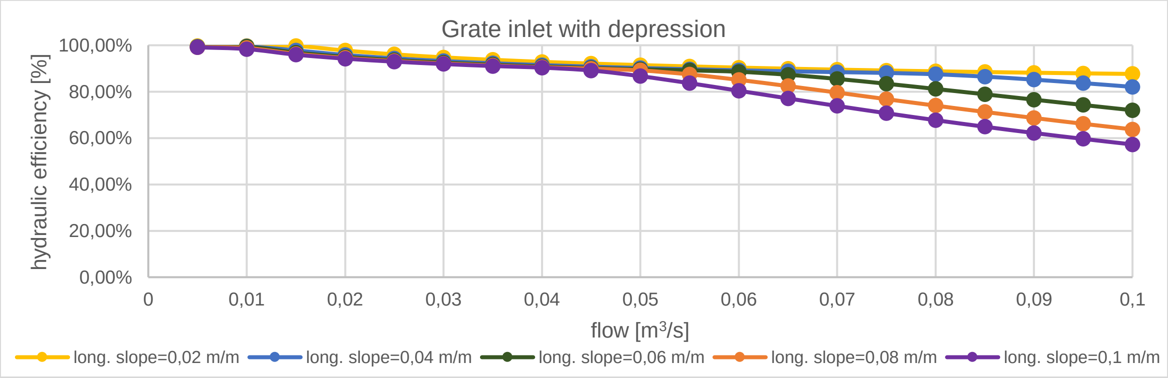

Figure 4 - Hydraulic efficiency of grate inlet with depression

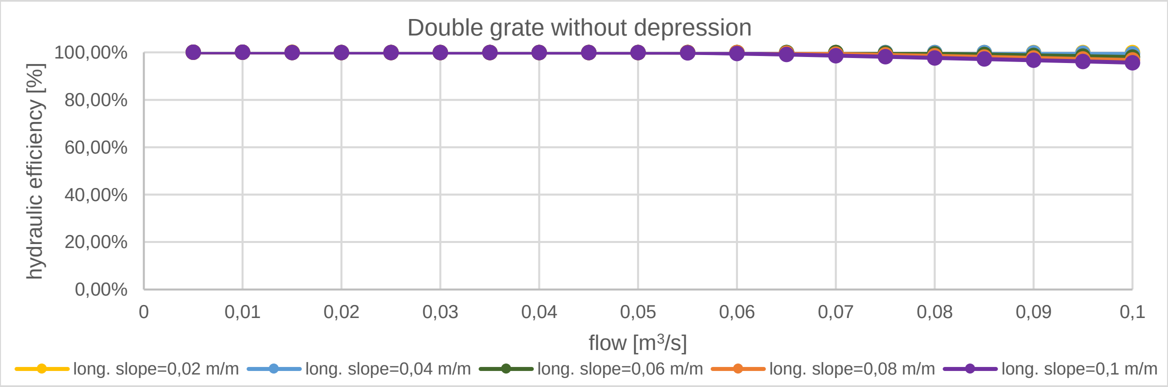

Figure 5 - Hydraulic efficiency of double grate without depression

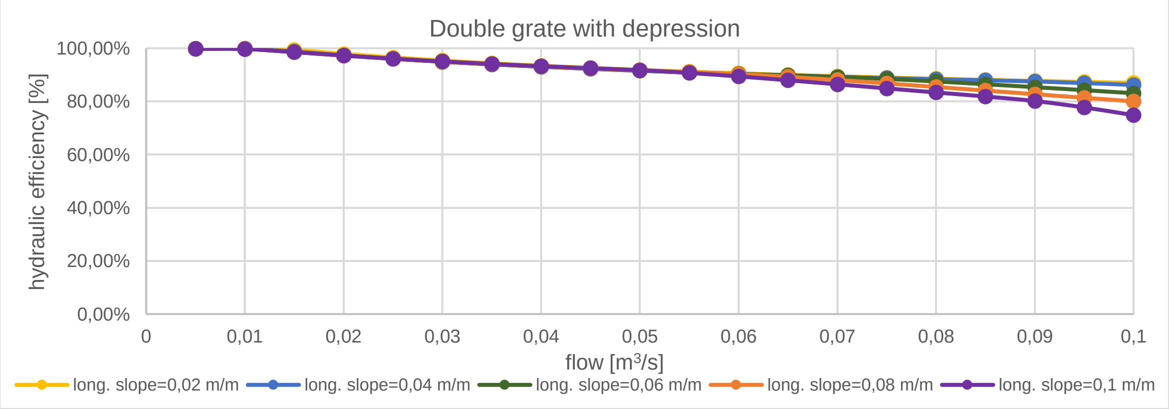

Figure 6 - Hydraulic efficiency of double grate with depression

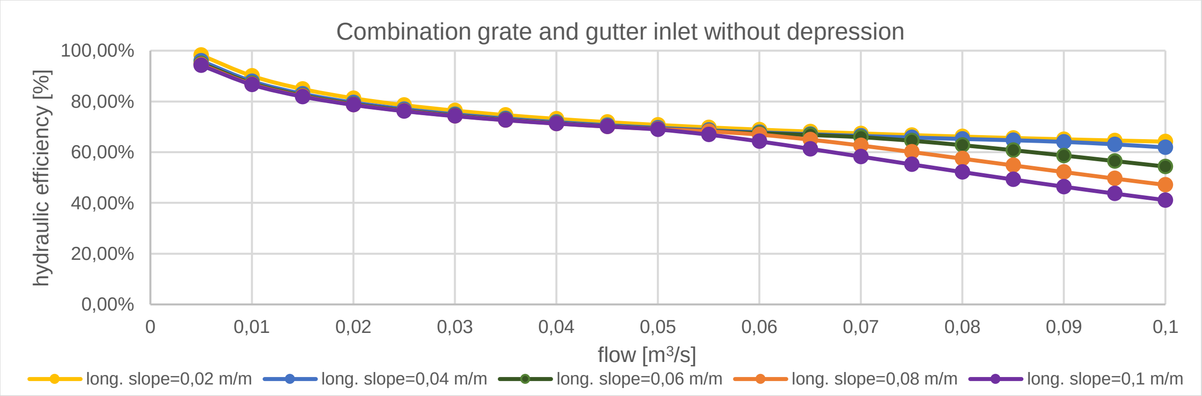

Figure 7 - Hydraulic efficiency of combination grate and gutter inlet without depression

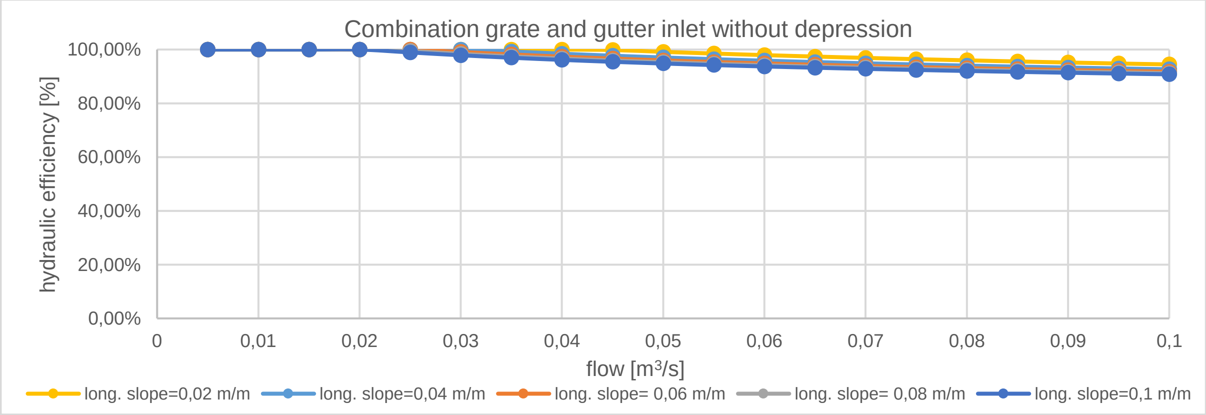

Figure 8 - Hydraulic efficiency of combination grate and gutter inlet with depression

3. EXPERIMENTAL CAMPAIGNS

The validation of the results obtained by the calculation methodology for several devices can be done through experimental campaigns. In this way, it was decided to select five interception devices located at Instituto Superior Técnico (IST), located in the city of Lisbon.

In this work, two distinct campaigns were conducted, on different days. Since the results of the first campaign did not show satisfactory values, new campaigns were carried out, this time with two drains, because it was found that they would be less likely to occur the errors recorded in the first campaign.

3.1. Campaigns results

The second campaign allowed a new comparison between the experimental and theoretical values, which was performed as follows:

- a gutter was used to direct the runoff towards the drain, thus ensuring that the portion referring to the runoff outside the grid, through the street, is zero (i.e., q2 = 0). In this way, it was also possible to eliminate the occurrence of spreading;
- an object was placed to prevent the existence of runoff between the kerb and the grating of the device, so that q1 = 0;
- two measurements were performed for one of the drains in order to be able to compare the values taken. Multiple measurements of the time taken by the velocity tracer over the length of the reference section were also made. In this way, it was possible to determine the average time travelled in the reference section;
- reasonable reference section lengths were considered in order to decrease the error coming from the speed tracer's travel time reading;
- a bucket of considerable capacity was used to allow a more accurate reading of the inflow from the hydrant;
- a white sheet of plasticized paper with visible markings was chosen to measure the flow height more accurately.

The values of the second campaign are shown in Table 1.

Table 1 - Results obtained with the second campaign conducted

Inlets (measurements)	Q (fire hydrant) [m^3/s]	Q (theoretical) [m^3/s]	Experimental Efficiency	Theoretical Efficiency ($q_1 = 0$ e $q_2 = 0$)
Grate inlet 1 (measurement 1)	0,00916	0,00898	100%	99,89%
Grate inlet 1 (measurement 2)	0,00870	0,00856	100%	99,89%
Grate inlet 2	0,00810	0,00569	100%	99,97%

After analysing these results, it is possible to see that the values obtained by the experimental route are very close to the values obtained by the theoretical route, which validates the values obtained by the methodology.

4. APPLICATION TO CASE STUDY: SANTA MARTA STREET TO PORTAS DE SANTO ANTÃO STREET

Dynamic modelling of urban drainage phenomena is a particularly interesting approach to verify the functioning of existing drainage systems. However, the efficiency of intercepting devices is neglected in the design process of these models. Thus, to analyse the impact of intercepting devices in these models, we selected an area of the city of Lisbon (Figure 9) referenced by recurrent flooding in the downstream section, using the SWMM software.

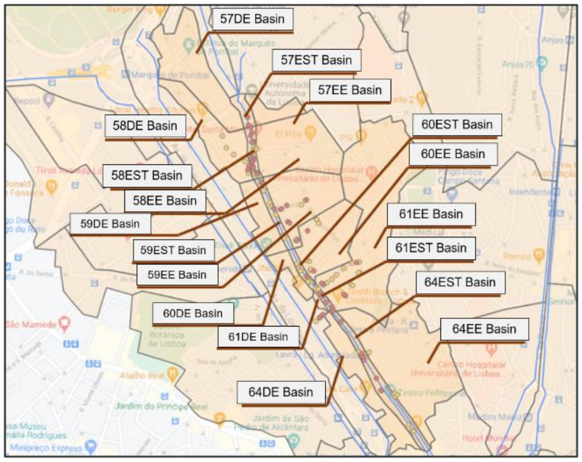

Figure 9 - Case study location and basins

Analysing the results of the simulation performed in SWMM, for return periods of 2 and 10 (the most conditioning situation) for the current situation (without any interventions), allow us to identify, for events with return period of 10 years, that there is a lack of capacity of some sections of the collector on Santa Marta Street and Portas de Santo Antão Street, particularly on São José Street and Portas de Santo Antão Street, where we can see the loading of some sections and overflows at certain points. However, as already mentioned, the software admits that all the runoff generated in a certain basin is transported by the collector in a certain fictitious point (called outlet), which does not correspond to reality. Thus, it is expected that the recurrent problems in the area can be, in part, explained by the insufficient collection capacity of the intercepting devices and not by the transport capacity of the collector. Thus, we surveyed the intersection devices of the streets of Santa Marta, São José and confluent streets, in order to assess their density, as well as their typology and state of conservation/maintenance.

In this study, a return period of 2 and 10 years was considered. To insert the variable related to the hydraulic efficiency of the interception devices, it was considered the methodology illustrated in Figure 10.

By obtaining the surface runoff in each sub-basin, it was possible to analyse the efficiency of the devices. Note that this evaluation was done based on the following parameters:

- the surface runoff was divided uniformly by all the existing devices in a given basin (i.e., the flow rate tributary to each device was calculated using the ratio between the surface runoff for a given period and the number of existing interceptor devices in the sub-basin);
- the longitudinal slope used for each device is equal to the slope of the sub-basin in question, regardless of its location;
- the affluent flow not captured by a given device does not contribute to the affluent flow of the next device. This simplification facilitates the application of the methodology, but does not accurately represent reality. However, at the outset, it will contribute to higher efficiencies of the devices by causing lower tributary flows, and therefore higher overall efficiencies of the basins. It is worth noting that, in a practical context, the efficiencies will be lower than those recorded in this methodology;
- it was considered that all devices were in perfect state of conservation and completely unobstructed;
- the average efficiency of each sub-basin, for a given period, was calculated by averaging the efficiencies of all the devices present in it. The efficiency of each device was done using the methodology discussed in chapter 2.

In this way, it was possible to obtain the flow that enters the collector after the insertion of the efficiency variable of the interceptor devices in each sub-basin, considering the variation of the inflow flow to each device over time. Note that the model run was performed for 24 hours.

In order to analyse the impact of the choice of the typology of the inflow devices, an optimized situation for T=10 years was also evaluated, i.e. several modifications were made to the current situation to evaluate the implications arising from it:

- in all sub-basins without any inflow device, only 3 double drains without depression were inserted. The choice was made because it has relatively high efficiencies and does not involve the introduction of depressions (i.e., it does not require repaving the street); on the other hand, double drains were chosen because it was found that, as a rule, sidewalks are not high enough for the introduction of gutters, so that a combination of drain and gutter was excluded;
- The existing gutters on site (with and without depression) were replaced by double drains without depression, as they do not require repaving, as explained in the previous section, and have higher efficiencies than the combination of drain and gutter without depression. On the other hand, the poor condition of most of the existing gutters does not allow their use for the latter solution;

Based on these changes, it was then possible to analyse their implications. The methodology used to evaluate the impact of efficiency in the dynamic simulation using the SWMM, in the optimized situation, is very similar to the methodology used for the current situation for return periods of 2 and 10 years.

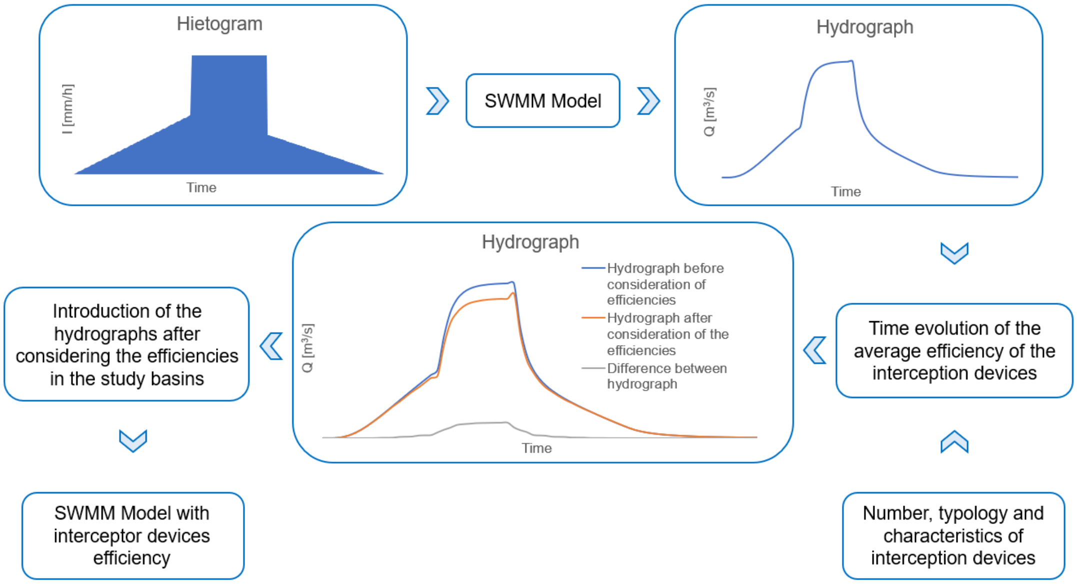

Figure 10 - Methodology used to introduce the variable of the efficiencies of the input devices in the case study

4.1. Results analysis

For the analysis of the results, we collected the data provided by SWMM, before and after the introduction of the hydraulic efficiency of the intercepting devices in the study area, for a return period of 2 and 10 years and also for the optimized situation (for T=10 years). It should be noted that the results are presented for the period of 2 hours and 40 minutes after the start of the simulation, in both situations, because this is the moment when, in all nodes, the collector reaches the maximum value of runoff in the simulation.

Situation T = 2 years

Figures 11 and 12 show, respectively, the longitudinal profiles for the collector from Santa Marta Street to Portas de Santo Antão Street for T = 2 years for the situation where the efficiency of the intercepting devices is not accounted for and for the situation that considers the said efficiencies.

By analysing the results obtained above, it is evident the difference between the situation where the efficiency of the interception devices is not accounted for (i.e., the situation assumed by the SWMM software) and the situation where the efficiency of the interception devices is accounted for. In the case where the efficiencies are considered, the collector presents a large gap in terms of its flow transport capacity, thus evidencing that the problem of recurring floods recorded at the site under analysis can be explained by the inability of this drainage system to capture the surface runoff generated there.

In this analysis, it is possible to draw several conclusions: the choice of the typology of the inlet devices is crucial to obtain more efficient drainage systems, since it is notorious the difference in efficiencies between basins with a higher number of devices with low efficiencies; it is also concluded that the arrangement of devices is crucial to obtain satisfactory efficiencies in an urban drainage system.

These data allow us to conclude that the operation of this system could be improved by introducing a greater number of drains, double drains, or even the combination of drain and gutter in order to minimize surface runoff. It should also be mentioned that, as shown by the evaluation of the hydraulic efficiency values of the interceptor devices, the functioning of the devices is expected to worsen substantially for larger inflows, so for longer return periods, it is expected that the transport through the network of collectors will decrease compared to the runoff generated. Thus, the situation T = 10 years was evaluated.

Situation T = 10 years

Figures 13 and 14 show, respectively, the longitudinal profiles of the collector from Santa Marta Street to Portas de Santo Antão Street, for T = 10 years for the situation where the efficiency of the intercepting devices is not accounted for and for the situation that considers the said efficiencies.

As would be expected from the variations registered in the efficiency of the intercepting devices with the increase in the inflows, there are substantially lower capacities to capture this flow, which explains the noticeable difference between the situation before and after the consideration of the average efficiencies of the intercepting devices, when compared to the T = 2 years situation. In fact, the changes registered in both cases (T = 2 and 10 years) after the introduction of the efficiencies are negligible, which causes, in the situation where the analysis is carried out for a return period of 10 years, the ratio between transported flow and surface runoff to be substantially lower than the previous situation, causing flooding and potential accumulation of water in low areas, caused by the poor efficiency of the system in passing surface runoff to the collector. In this situation, it is still possible to reiterate all the conclusions acquired for the situation T = 2 years: the importance of the number of types, their arrangement, and their typology for the optimization of drainage systems in urban environments.

In this sense, and to verify the impact of the introduction of inflow devices in critical locations and the importance of their typology in the improvement of urban drainage systems, an analysis was elaborated for the optimized situation, as previously described, for a return period of 10 years.

Optimized situation T = 10 years

Figure 15 shows the longitudinal profile of the collector from Santa Marta Street to Portas de Santo Antão Street, for

T = 10 years for the situation where the efficiency of the interceptor devices is accounted for and where changes were made in order to assess the impact of introducing devices in critical locations and replacing gutters with more efficient devices.

Analysing the figures, the differences recorded between the current situation and the optimized situation are striking. Note that the changes are due to the introduction of only 3 devices in sub-basins where there were no inflow devices and the replacement of gutters, with and without depression, by double grates without depression. Thus, it is emphasized that the optimization of drainage systems will pass, in part, by the choice of the typology of devices and the introduction of a number of these devices that satisfies, at the same time, economic criteria and optimization of the capture of surface runoff, to minimize damage caused by floods and accumulations in low-lying areas. It is also concluded that, as was done in this situation, the choice of devices should consider, in addition to their efficiency, an analysis of the area to be studied, such as topography, characteristics of the surroundings (nearby streets), land use and geometric characteristics of the street and sidewalk.

By analysing the 3 situations, it is also possible to conclude that, in spite of being useful and easy to use and access, because it is free, the values provided by SWMM should always be analysed with due caution: on the one hand, that the fact of considering that all surface runoff is captured, induces the error of not considering, in most cases, the excess of surface runoff, which could affect the well-being of the population and the buildings adjacent to the analysed areas, increasing the costs associated with the repair of damage caused by flooding; on the other hand, the values presented by the software may induce the user not to consider the importance of sizing urban storm drainage systems, and even to consider that the drainage system is oversized, which corroborates the need for the correct implementation of intercepting devices.

The results of this study also highlight the importance of other issues such as, for example, the relevance of an adequate and timely maintenance of the interception devices, since it is common the occurrence of surface runoff due to insufficient cleaning of them, as well as the improper placement of objects and cars, which hinder its proper functioning. Still on the same topic, it is interesting to reflect on the decision making by design engineers about rainwater drainage in a building context, which in certain situations is routed into gutters, contributing to surface runoff, instead of being directly directed to buried collectors, drastically increasing surface runoff that, in extreme conditions, will not be directed to storm drains in a short period of time.

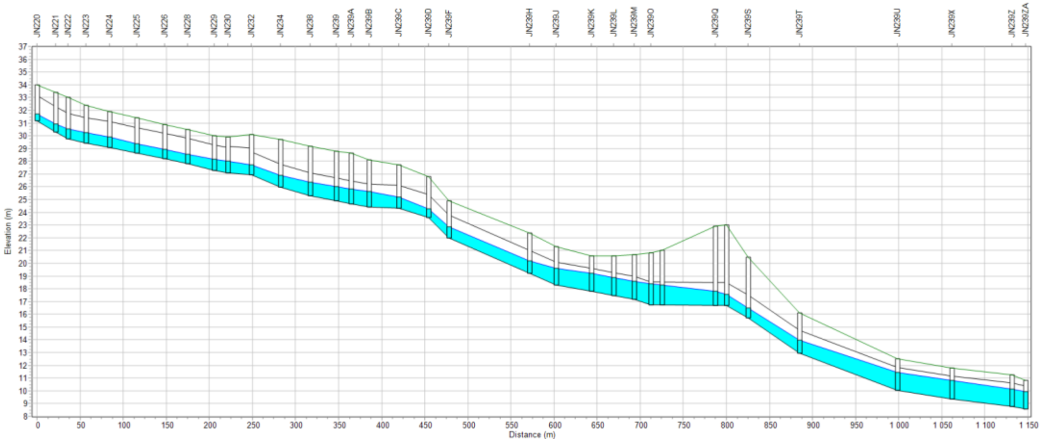

Figure 11 - Longitudinal profile of the analysed collector in the case study before the consideration of the hydraulic efficiency of the intercepting devices for a return period of 2 years

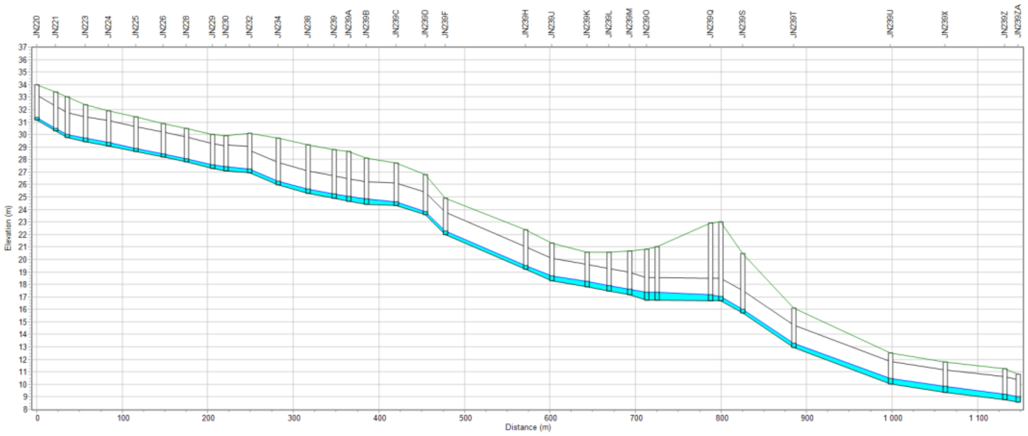

Figure 12 - Longitudinal profile of the analysed collector in the case study after taking into account the hydraulic efficiency of the intercepting devices for a return period of 2 years

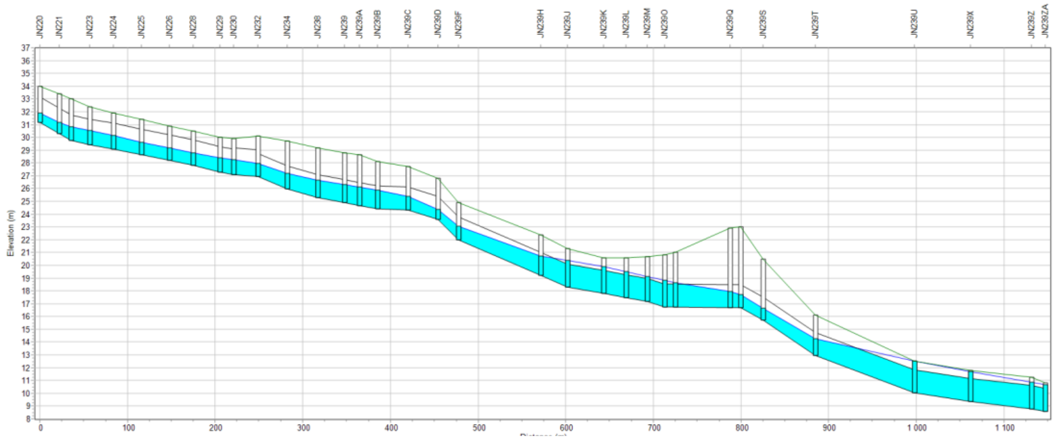

Figure 13 - Longitudinal profile of the analysed collector in the case study before the consideration of the hydraulic efficiency of the intercepting devices for a return period of 10 years

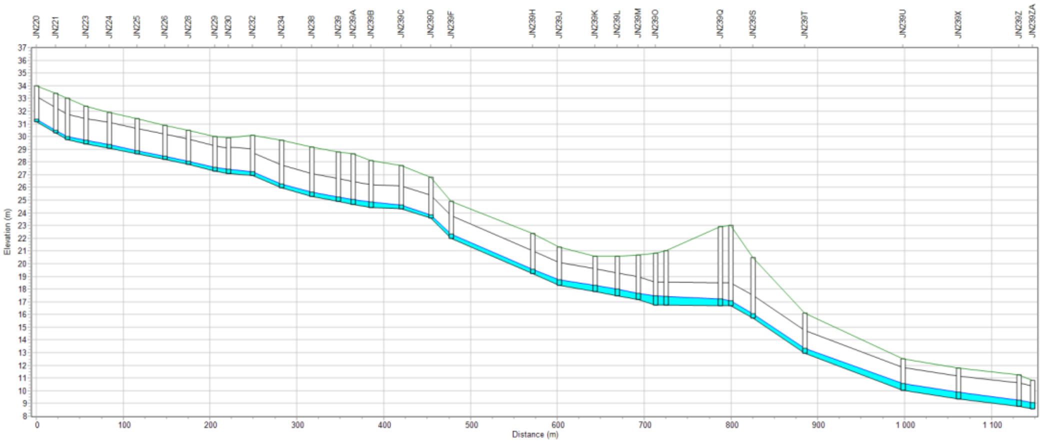

Figure 14 - Longitudinal profile of the analysed collector in the case study after consideration of the hydraulic efficiency of the intercepting devices for a return period of 10 years

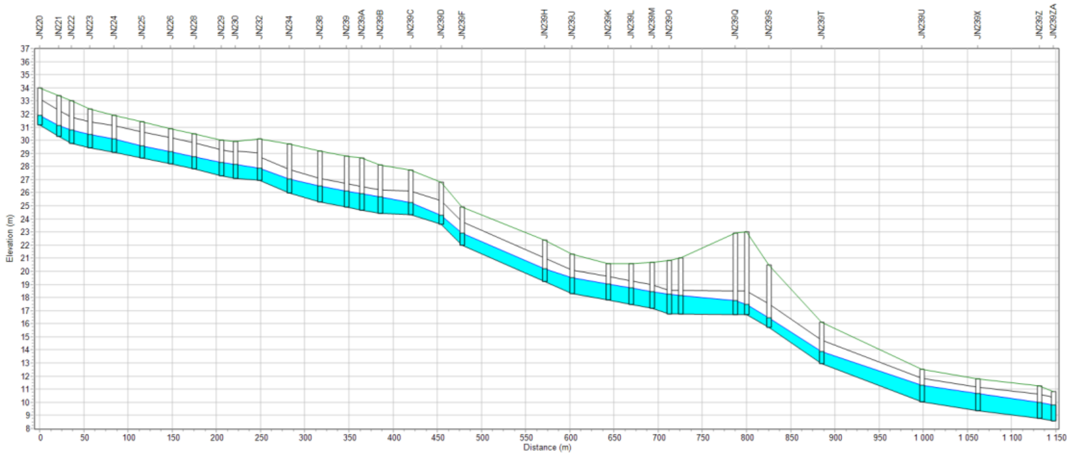

Figure 15 - Longitudinal profile of the analysed collector for the optimized case situation for a return period of 10 years

5. CONCLUSIONS

Population growth in certain locations, associated with the increase of large urban areas, inevitably leads to an increase in impermeable areas which, in turn, lead to an increase in surface runoff. Thus, it is essential the correct design of storm drainage networks, as well as the maintenance and/or rehabilitation of existing infrastructures, emphasizing, in this document, the need to evaluate the hydraulic efficiency of the interception devices, to optimize the capture of the runoff flow.

Thus, in a first stage, the hydraulic efficiency values obtained for each inflow device under analysis (single and double drains, with and without depression, gutters with and without depression and combination of drain and gutter with and without depression) were evaluated, for different tributary flow demands and different longitudinal slopes of the street. In this way, it was possible to present the values obtained in abacuses, allowing verification that the choice of the type of device to implement depends on the inflow rate and characteristics of the surface runoff, the site to be analysed and the economic implications that these devices may entail in the project. The analysis of these values also allows us to see the importance of maintenance and cleaning actions in these devices, since the values presented were determined considering that they are totally unobstructed and in perfect state of conservation. In this sense, the values shown in the abacuses are the optimal situation for the respective devices, which may not occur in most cases.

To analyse the behaviour in practice, experimental campaigns were carried out in order to determine the capacity of several interceptor devices on the Alameda campus of the Instituto Superior Técnico and thus compare with the efficiency recorded by the methodology previously discussed. The first campaign allowed determining the velocity and height of the upstream and downstream flow of the analysed intercepting devices (grates with different geometric characteristics) and, thus, to determine their hydraulic efficiencies and compare them with the values obtained in the abacuses presented in chapter 3. However, after evaluating the results obtained in this campaign it was found that their validity is questionable, since several errors were made during the campaign. Thus, a second campaign was carried out to correct the problems encountered in the first campaign and, in this way, to achieve the goal of verifying that the experimental efficiency values are in line with the theoretically obtained values.

Finally, the calculation tool discussed in chapter 3 was applied to the dynamic modelling of storm drainage systems, using the SWMM software. In this work, it was intended to analyse the impacts of considering the hydraulic efficiency of the intercepting devices in the modelling of a section of the collector on Santa Marta Street to Portas de Santo Antão Street, to compare the values obtained before and after the insertion of this variable, for a return period of 2, 10 years and also for the optimized situation for a return period of 10 years. For this purpose, it was necessary to survey all the interceptor devices in the study area and, using the calculation tool discussed in this document, an analysis of the efficiency of these devices was performed and, subsequently, through the alteration of the hydrographs initially foreseen for the basins, the analysis of the collector capacity was carried out. The analysis of these values allowed us to verify that the impact of these components on a storm drainage system is considerable: on the one hand, it was verified that there is a notable difference between the situation of not considering the efficiencies and after the efficiencies in the cases where no change was made to the current situation, showing that the problems registered on site are not due to the collector's transport capacity; on the other hand, the difference registered in this analysis shows that a large part of the precipitated water does not effectively enter the collector, or will travel long distances in surface runoff until it is captured. This situation will contribute to flooding phenomena of low-lying areas, with material data in the areas in question, which may explain, in part, the problems frequently recorded at the site. In fact, although the results obtained are quite remarkable, it is important to emphasize that, as considered in the calculation tool, certain simplifications were made: the devices are not obstructed, so the whole area contributes to the capture of the affluent flow; the flow not captured by the device under analysis will not contribute to the flow of the downstream device; the flow generated by precipitation would be divided equally by all devices belonging to the same sub-basin, among others. With this, one can still expect that the values of surface runoff can be higher than those recorded, evidencing, once again, the importance of considering these components in urban drainage systems.

Another conclusion is the following: the choice of the type of devices, as well as their correct implantation, are crucial when one intends to optimize the performance of pluvial or unitary drainage systems. In fact, the analysis of the number of devices and their typology justifies in part the low values of capture recorded, with emphasis on sub-basins with few drains or improperly implanted devices (where the optimization of the capture of the device is not guaranteed).

For the optimized situation, it is concluded what was already expected after the analysis of the other two cases: the change of gutters by devices with higher efficiencies (in this case double drain without depression) contributes to a substantial improvement in the collection of surface runoff. On the other hand, it was also possible to conclude that the distribution of the devices in the study area is extremely relevant in improving the hydraulic behaviour of urban drainage systems.

Thus, it can be concluded with the work carried out in this dissertation that the evaluation of the capacity of the interceptor devices has shown to be of extreme importance in the correct design of storm drainage systems, from the point of view of the choice and its implementation, and that the optimization of these systems may involve the monitoring/cleaning of these devices, in a context of maintenance of the existing networks.

Regarding future recommendations, it is suggested, as expected by the results obtained, the realization of new experimental campaigns, where it is expected the correction of certain errors made or even the detection of other problems inherent in the realization of these campaigns. Thus, it is suggested that the first campaign carried out in this document be interpreted as a pre-campaign. On the other hand, it is also suggested that campaigns be carried out covering other devices that, due to the existing constraints on the Alameda campus of IST, prevented the realization of the same. Thus, it may be interesting, in the future, to conduct experimental campaigns in double grates, gutters with and without depression or a combination of grate and gutter, thus allowing a comparison of the results obtained in these campaigns with the values obtained by the methodology developed in this dissertation.

Another recommendation relates to the topic of dynamic modelling of storm drainage systems. The results obtained, although useful in 1D modelling (using SWMM software), do not allow obtaining concrete results when addressing the issue of 2D modelling. Although the inclusion of the efficiency of the devices can be expected to have an impact on the capacity of the collectors, the real implications in terms of runoff cannot be predicted. Thus, the analysis performed in chapter 3, through the creation of abacuses, may facilitate this work in the context of 2D modelling. On the other hand, the methodology used in 1D modelling (introduction of device efficiencies by changing the catchment hydrographs), exemplified in chapter 5, can be applied to 2D modelling, thus facilitating the design process of the methodology applied in this same study.

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