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Terv tárgya:

Development of the environment of the demonstration sites designated under the UPSURGE project

Tervfázis:

PERMISSION DESIGN

Megnevezés:

Technical description - Margó Tivadar street,Tomory Lajos Museum, Szálfa street

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1. Background

In the project titled **"UPSURGE – Innovative nature-based solutions for carbon neutral cities and better air quality"** implemented within the framework of the *Horizon 2020* program of the European Union, the Local Municipality of Pestszentlőrinc – Pestszentimre, XVIII. district of the capital city of Budapest, as consortium partner, is responsible for the pilot implementation and maintenance of climate-adaptive, green infrastructure investments in the 3+50 demonstration sites in the district.

In the design competition announced by the Municipality, UTIBER Kft. was awarded the planning task related to the various solutions for improving air quality, retaining water, increasing local biodiversity and reducing the heat island effect, in connection with the preparation of the **planning documentation for the preparation of the permit design documentation for the development of the environment of the demonstration sites selected for the project**.

The project will be implemented from 1 September 2021 to 31 August 2025.

The design task includes obtaining the expert opinion and approval of the special authorities necessary for preparing the permission design, as well as the consent or permit of all relevant utility or public service providers for the demonstration sites, if required. In addition to the design tasks, UTIBER Kft. has also undertaken to carry out the designer project management tasks necessary for the implementation of the plans at the demonstration sites (on max. 6 occasions).

This design documentation contains the permission designs for **hydro-engineering (rainwater management) and landscaping.**

1.1. Design task

The design task is focused on 3 main areas:

- Bp. District XVIII, garden of Tomory Lajos Museum, Margó Tivadar u. (street) 116. (lot no.: 150230/16)
  Construction of a rain garden for rainwater management
- Bp. District XVIII, the common are infront of Margó Tivadar u. (street) 116. (lot no.: 150255)
  construction of a parking lot with gravel lawn surface
- Bp. District XVIII, section of Szálfa u. between Kettős-Körös u. and Oszkó u. (lot no. 140056)
  construction of infiltration trenches with trees planted, on both sides of the road

An additional task is to prepare type plans for small, public and residential rain gardens, which can be adapted to the locations selected by the residents.

1.2. Background information

The geodetic survey of the design areas and an expert opinion on soil mechanics – also containing the results of the infiltration tests – have been completed. *The soil testing report is contained in the annex attached at the end of the documentation.*

The Client has provided us with the architecture, landscape architecture, landscaping and water drainage plans prepared for the garden of Tomory Lajos Museum.

The utility data included in our designs were obtained through the e-public utility system. The designer does not assume responsibility for the correctness of the data provided, the actual pipeline routes must be determined by manual exploration, and in case of discrepancies, the designer must be notified.

2. Planned rainwater management (water management plan)

2.1. Garden of Tomory Lajos Museum

2.1.1. Current condition, problems

Water drainage in the garden of Tomory Lajos Museum is currently not provided. Previously, as a result of landscaping, rainwater was concentrated around the entrance from Makói street. However, as a result of the conditions caused by everyday use and by the often extreme weather, the even terrain turned into highly uneven terrain with newly formed local low points where sometimes accumulating water stagnates. It is a serious problem that a significant amount of rainwater from the north-eastern side, from the direction of Bókay-kert (Bókay Garden), gravitates towards the Museum's garden. Since the water drainage of Bókay-kert is also considerably deficient, the significant load caused by the water mass coming from that area causes serious water stagnation and wash-off in the area of the Museum.

Another serious problem is that there is no water supply area available during the hot summer periods lacking rain. Precipitation surplus caused by rain is not collected and utilized, therefore water consumption in the summer is significant. There is a well on the east side of the Herrich-Kiss mansion, but it is currently out of operation, and cannot be used. The operator tries to utilize rainwater locally, however, there is no harmonized, elaborated concept is currently available.


Interestingly, it is the north and west sides of the Herrich-Kiss mansion that are most exposed to the problems caused by precipitation. On the east side, where the terrain is heavily sloping towards the building, there is no such problem, because the trees and the slope covered with ivy absorb even higher volumes of precipitation, so the mansion is not affected by any significant precipitation effect.

2.1.2. The impact of Bókay-kert

Due to the terrain conditions, the amount of precipitation coming from the direction of Bókay-kert basically determines the water balance of the garden of Tomory Lajos Museum. On the north and east sides of the garden, the drainage of Szélmalom and Kiss István streets is in place; the school and its hill can be considered the high point from water catchment aspect. In front of the central building of Bókay-kert, the wooded area on the north and north-east side is relatively deep; to the east of it there is an artificial pond. The lake does not receive rainwater from the hillside gravitationally, or only with some difficulties, so artificial water replenishment is necessary. Rainwater draining from the school is primarily collected in the deep area with trees and benches.

The central building of the garden is located in a relatively flat area, from where rainwater flows in three directions. Part of it is located towards the tennis courts in the south direction, the other part, which is the largest one, towards the obstacle course and swimming pool on the north side, while the third part is towards Tomory Lajos Museum. For this reason, in the hydrological calculations, it is difficult to determine the actual volume of water. To be on the safe side, the way we calculated is that we ignored the lake shown in the pictures above and the deep area, and for the calculation, we used 10% of the water catchment area delimited up to the central building as the load affecting the area of the Museum. This is an amount calculated with a safe margin, which, although was not confirmed by the site visit, but we believe that it is essential to be taken into account in the dimensioning process to ensure a reassuring, near-accurate final result. The solid fence between the Museum and Bókay-kert retains and guides rainwater, so there is an entry point at the gate between the two properties. Rainwater is collected here, then flows into the museum garden – which is considered the main source of the problems.

It should be noted that, in order to achieve a permanent solution to the drainage of the garden of Tomory Museum in terms of hydro-engineering, interventions needed to be performed in the area of Bókay-kert, too. It is considered important to catch rainwater received from the hillside of the school, already in front of the central building, using an artificial pond for this purpose. In addition, drainage and dewatering for the area between the central building and Tomory Lajos Museum should also be completed. However, this requires careful planning with regard to the fact that although water retention will alleviate the water load on the garden of the Museum, but precipitation will be concentrated in Bókay-kert during collection, so its drainage and management is essential.

2.1.3. Hydrology calculations

The amount of rainwater received from the surrounding areas was determined based on hydrology calculations. With this knowledge, we were able to calculate the size and quantity of hydro-engineering structures required for the collection and storage of rainwater.

The area of the Museum was divided into two parts for water management aspects. Solving the basic problem is of primary importance: the catchment and management of precipitation received from the direction of Bókay-kert. Once this problem is solved, rainwater generated in the area of the garden of the Museum becomes easy to handle, creating a typically smaller catchment area.

The first step was to delimit the catchment area. It has already been mentioned in the above point that Bókay-kert itself forms a significant part of the water catchment area. According to the criteria described above, 10% of the hillside east of the central building of Bókay-kert, the central building and the area between the building and the Museum were taken into account in the calculations. Based on this, we determined the amount of precipitation received in the garden of the Museum.

The surface calculated in this way is:

- V 1 = 1.23 ha / 10 = 0.123 ha – to the east of the central building (area with trees and grass)
- V 2 = 0.1 ha – central building and the area in front (paved surface)
- V 3 = 0.07 ha – area between the central building and the garden of the Museum (area covered with grass)

Since the surface characteristics of the sub-units are different, they were taken into account with a different runoff factor.

- from areas with trees, grass and plants $\alpha = 0.2$
- from roof, pavement $\alpha = 0.9$
- Area covered with grass $\alpha = 0.25$

Since the technical specifications give values on a “from – to” scale, we took into account the higher values, just to be on the safe side.

The intensity of rainwater is determined based on the precipitation values on the website met.hu. Since the sloping of the catchment area is significant (level difference of ~9 m) and the runoff length is relatively short (~200 m), we used a 10-minute accumulation time. The precipitation data were queried from the database of no. 53 Budapest Pestszentlőrinc-outer area meteorological station which is located ~650 m from the Museum and therefore provides relatively accurate values for the site.

intensity (mm/h)	10 minutes	20 minutes	30 minutes	60 minutes
1 year, 100%	39.47	28.85	22.03	12.36
2 years, 50%	68.66	50.55	40.70	24.38
4 years, 25%	89.34	65.92	53.93	32.90
5 years, 20%	95.31	70.36	57.75	35.36
10 years, 10%	112.96	83.48	69.04	42.63
20 years, 5%	129.89	96.06	79.88	49.60
50 years, 2%	151.80	112.35	93.89	58.62
100 years, 1%	168.22	124.56	104.40	65.38

We planned to collect rainwater in a reservoir-evaporator-infiltration trench. There is no valid technical specification for its dimensioning. In our calculations, following consultation with the Client, we calculated the collected water volumes with a **10-year 10-minute** intensity, which is considered to be the standard by Budapest Sewerage Works.

$i_{10\%}$ = 112.96 mm/h (from the above table) = 314 l/s*ha (this includes the climate risk factor 1.1)

Based on the above, the cumulative precipitation amount according to the rational method for small reservoirs:

$$Q_{10\%} = \alpha * A * i_{10\%} \quad [l/s]$$

where: A – Catchment area [ha]

α – Runoff factor [-]

$i_{p\%}$ – specific rainwater yield [l/(s*ha)]

$Q_{10\%}$ = (0.123*0.2 + 0.1*0.9 + 0.07*0.25) * 314 = 41.48 l/s = **0.0415 m^3/s**

Within 10 minutes it results in a water volume of 0.0415*60*10 = **24.89 m^3**

This water volume is not large enough to cause serious problems. In recent years, large volumes of precipitation falling within a relatively short period of time, called flash floods, have become increasingly common. This is considered a kind of emergency, showing extreme values in statistical data. It cannot and should not be scaled up to flash floods because it would significantly increase both cost and maintenance costs, while it only occurs a few times a year, making the dewatering system uneconomical.

To be on the safe side, we checked the values of the meteorological station for heavy precipitation. According to the Meteorological Database, the 10 minutes with the highest precipitation in the period from 01.01.2002 to 31.12.2022 occurred on 23.06.2006, when 22.8 mm of precipitation fell. Multiplying this (theoretically, because practice shows that not six times this amount fell in one hour) and converting it, we obtain an intensity value of **380.3 l/s*ha**.

Substituting this into the above formula gives a volume of **30.15 m 3** water, which is 21% higher than the reference case, and therefore, we also carried out a check for this volume of precipitation.

After catching the rainwater received from the surrounding areas, an important aspect is the disposal and management of the rainwater collected from the garden of the Museum. After examining the sloping of the area, it can be concluded that three basic catchment areas can be distinguished.

- The area east of the Herrich-Kiss mansion is a wooded garden densely overgrown with ivy. Experience shows that rainwater does not accumulate from this 0.13 hectare area (V 4) because the dense vegetation absorbs it almost completely and therefore does not cause visible erosion. Over the years, no hydro-engineering problems were experienced in respect of this surface, so we did not plan any intervention in order to maintain the natural state.
- The low point of the terrain is formed along the sidewalk from the gate on Makói street to the mansion. The sidewalk essentially divides the catchment area into two nearly equal areas on the east and west sides (V 5=0.13 ha, V 6=0.16 ha). Due to the grass cover, the runoff coefficient is α = 0.15. Therefore, the volume of accumulating precipitation:

E-NE side (V 5):

$\mathbf{Q_{10\%}}$ = (0.13*0.15) * 314 = 6.123 l/s = **0.006123 $\mathbf{m^3/s}$**

Within 10 minutes it results in a water volume of 0.006123*60*10 = **3.67 $\mathbf{m^3}$**

W-SW side (V 6):

$\mathbf{Q_{10\%}}$ = (0.16*0.15) * 314 = 7.536 l/s = **0.007536 $\mathbf{m^3/s}$**

Within 10 minutes it results in a water volume of 0.007536*60*10 = **4.52 $\mathbf{m^3}$**

2.1.4. Technical design, details

Based on the hydrology calculations, the task is to design a trench (rain garden) which safely collects and stores the standard precipitation volume.

In order to accommodate the rainwater received from the direction of Bókay-kert, we designed the location of the reservoir-infiltration trench (rain garden) near the gate between the two properties, on the southwest side of the educational trail to be constructed, in accordance with the previously prepared landscape design and the needs of the operator. In this way, rainwater flowing here from the garden can be managed instantly by guiding it in SW direction, with minimal landscaping, and it will not affect the lower parts of the garden of the Museum. According to the hydrology calculation, 24.89 m^3 of rainwater should be arranged.

Such precipitation volume produces a water depth of 38 cm in a nearly triangular, of 60 m^2 floor area, 40 cm deep, 1:2 sloping trench (rain garden marked “A”). This is a theoretical dimension that does not take into account infiltration.

A soil testing report has been prepared for the area, which is attached as an annex to the technical specification. Based on the soil testing report, the infiltration test carried out in the area determines a filtration coefficient of 2*10-5 m/s Based on the calculations, the wetted surface of the ditch is 63.62 m^2, in this way, the infiltrating water volume is 1.2724*10^{-3} m^3/s. The reference volume of stored water infiltrates in 24.89 / 1.2724*10^{-3} = 19561 s = 326 min = 5 h 26 min minutes in typically sandy soil.

The optional rain gardens (marked “B” and “C”) designed next to the sidewalk running from Makói street are much smaller than that, as they must serve the placement of 3.67 m^3 and 4.52 m^3 of rainwater. For the temporary storage and the following infiltration of this amount a trench of 5.5 m or 6.5 m long, 30 cm deep, with a bottom width of 1 m and 1:2 sloping is required.

According to the dimensioning, the wetted surface is 13.21 m^2 on the left side of the sidewalk (rain garden “B”) and 15.55 m^2 on its right side (rain garden “C”). The amount of infiltrated water calculated with a filtration coefficient of 2*10-5 m/s is 2.642 *10-4 and 3.11*10-4 m 3/s.

From the rain garden on the left (marked “B”), it takes 3.67 / 2.642 $*10^{-4}$ = 13891 s = 232 min = 3 h 52 min, and from the rain garden on the right (marked “C”), it takes 4.52 / 3.11$*10^{-4}$ = 14534 s = 242 min = 4 h 2 min for the accumulated water volume to infiltrate in the reference case.

The construction of rain gardens is described in detail in Chapter 3.1.

It was considered that the rainwater collected from the roof of the mansion could be piped into the planned rain garden, but this would be unfeasible, since the gutter would be buried so deep that it would not be possible to connect it to the shallow trench.

2.1.5. Public utilities

According to data provided, the planned structures do not affect any utilities and there is no need to replace them. No other utilities are known to be affected.

2.1.6. Permitting

The planned rain gardens do not affect the water catchment and the drainage conditions of the area, they only provide local solutions for the management of rainwater that also flowed there previously. Since all these functions are covered within own territory, without the use of areas owned by others, they cannot be considered independent hydraulic engineering structures, and therefore, it is not necessary to obtain a water construction permit for them.

Pursuant to *Annex 1 of Government Decree 312/2012 (XI.8.)* on authority procedures and inspections for construction and construction supervision, as well as on official services for construction, the permanent modification of the natural terrain of the plot in relation to the construction activity, not exceeding 1 m, and the construction of terrain stairs are activities that can be carried out without a construction permit. Since the depth of the rain gardens does not exceed 1 m, it is not necessary to carry out a construction permitting procedure.

2.2. The shoulder in front of Tomory Lajos Museum

2.2.1. Current condition, problems

The shoulder in front of Tomory Lajos Museum is currently not orderly. It does not have solid paving, is covered with slag at some places, but is mainly a dirt road without water drainage. Margó Tivadar u. (street) is partly crowned and partly sloping to one side. The transition, according to the geodetic survey, takes place right in front of the shoulder. There is a sidewalk on the side in the direction of the Museum; it is in proper condition for walking, slightly uneven at places, typically sloping towards the shoulder. Basically, it can be stated that the drainage of the street is not provided. Precipitation flowing off the pavement infiltrates through the green surfaces if the soil is suitable for absorbing it.

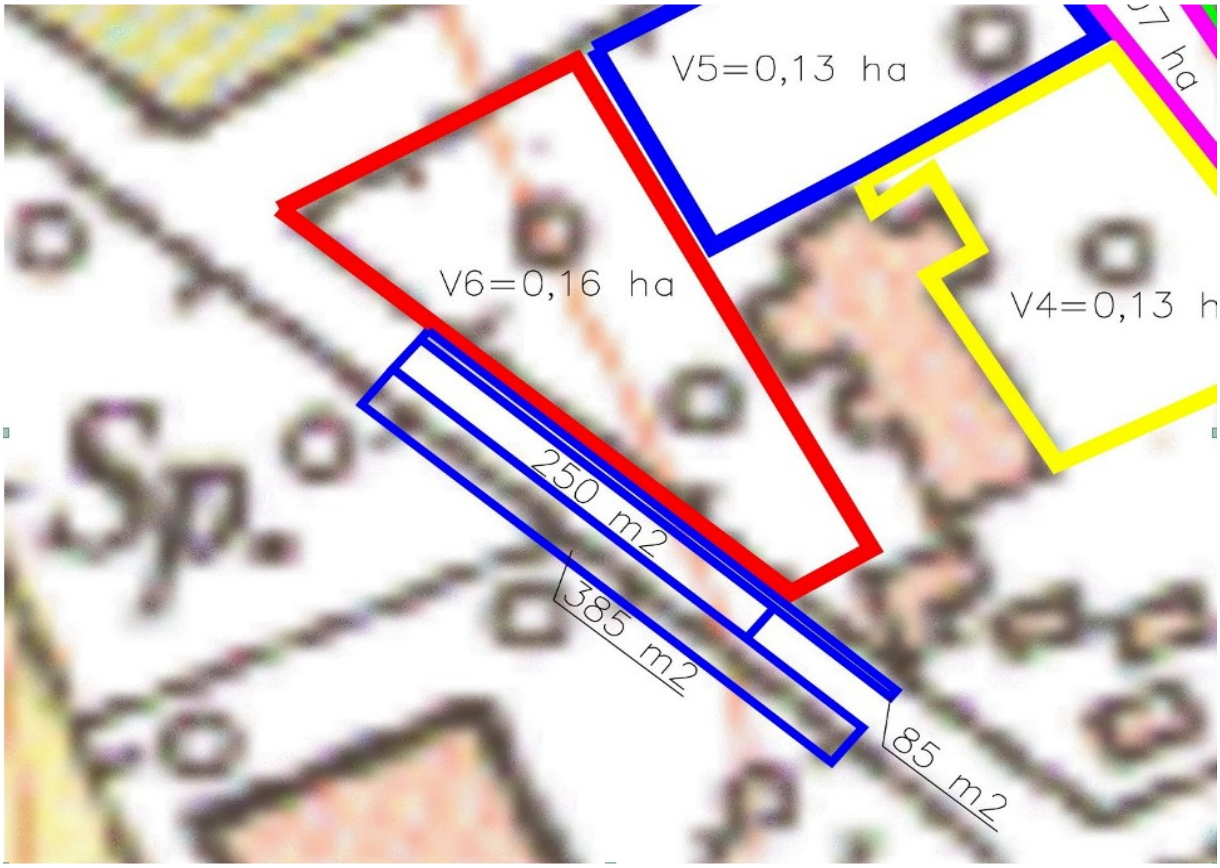
Due to the lack of paving and disorderly state, parking cars sometimes form ruts on the shoulder in which rainwater stagnates. For this reason, muddy surfaces with puddles are most common in the parking lot.

There is an old infiltration trench leading to the intersection of Makói street, separated from the shoulder by concrete columns – it is heavily muddy, has minimal depth, so it has almost completely lost its former reservoir function. It functions as an almost flat green surface.

Various utilities run in longitudinal and transverse directions under the shoulder. Near the pavement of Margó Tivadar u. (street), almost parallel to it, a water pipeline runs at a distance of 0.7-1 m. According to the data provided by Budapest Waterworks, the top of the pipeline is located at a depth of ~1.5-1.6 m from the terrain surface. Under the sidewalk and right next to it there are electrical and telecommunications cables. Their laying depth is unknown, but it should be min, 0.8 m.

2.2.2. Hydrology calculation and technical design

The precipitation load on the shoulder is received primarily from the pavement of Margó Tivadar u. (street) and the sidewalk in front of the Museum. Due to the uneven paving of the street, its sloping is difficult to clearly identify. It is clear that height decreases from Cziffra György street towards the Museum, but most of the rainwater flows to the deeper area opposite the Museum. For this reason, we are only able to identify approximate values; however, just to be on the safe side, we calculate with precipitation collected from a greater length, and we do not only take into account the area directly in front of the Museum. Based on this, rainwater received from a surface of 385 m ^{2} is considered to be the reference value, which means a surface of about 70 m long and 5.5 m wide. Assuming a similar length of the sidewalk, but only with a variable width of 1-1.5 m, a surface of 85 m^2 is received. Based on the delimitation, the surface of the shoulder is approximately 250 m^2.



Runoff coefficients:

- from the paved area α = 0.9
- from the area covered with grass (near sidewalk) α = 0.4

The intensity of rainwater is determined based on the precipitation values on the website met.hu. Since it is a relatively small surface area with a small runoff length, we used the 10-minute accumulation time as a basis. The precipitation data were queried from the database of no. 53 Budapest Pestszentlőrinc-outer area meteorologycal station which is located ~700 m from the design area, and therefore provides relatively accurate values for the site.

intensity (mm/h)	10 minutes	20 minutes	30 minutes	60 minutes
1 year, 100%	39.47	28.85	22.03	12.36
2 years, 50%	68.66	50.55	40.70	24.38
4 years, 25%	89.34	65.92	53.93	32.90
5 years, 20%	95.31	70.36	57.75	35.36
10 years, 10%	112.96	83.48	69.04	42.63
20 years, 5%	129.89	96.06	79.88	49.60
50 years, 2%	151.80	112.35	93.89	58.62
100 years, 1%	168.22	124.56	104.40	65.38

Although no trench was designed for the surface of the shoulder, its construction itself is similar to an infiltration-reservoir trench. There is no valid technical specification for its dimensioning. In our calculations, following consultation with the Client, we calculated the collected water volumes with a **10-year 10-minute** intensity, which is considered to be the standard by Budapest Sewerage Works.

$i_{10\%}$ = 112.96 mm/h (from the above table) = 314 l/s*ha (this includes the climate risk factor 1.1)

Based on the above, the cumulative precipitation amount according to the rational method for small reservoirs:

$Q_{10\%} = \alpha * A * i_{10\%}$ [l/s]

where:	A – Catchment area	[ha]
	α – Runoff factor	[-]
	$i_{p\%}$ – specific rainwater yield	[l/(s*ha)]

$Q_{10\%}$ = (0.047*0.9 + 0.025*0.4) * 314 = 16.42 l/s = **0.0164 m^3/s**

Within 10 minutes it results in a water volume of 0.0164*60*10 = **9.84 m^3**

This water volume is not large enough to cause serious problems. In recent years, large volumes of precipitation falling within a relatively short period of time, called flash floods, have become increasingly common. This is considered a kind of emergency, showing extreme values in statistical data. It cannot and should not be scaled up to flash floods because it would significantly increase both cost and maintenance costs, while it only occurs a few times a year, making the dewatering system uneconomical.

To be on the safe side, we checked the values of the meteorological station for heavy precipitation. According to the Meteorological Database, the 10 minutes with the highest precipitation in the period from 01.01.2002 to 31.12.2022 occurred on 23.06.2006, when 22.8 mm of precipitation fell. Multiplying this (theoretically, because practice shows that not six times this amount fell in one hour) and converting it, we obtain an intensity value of **380.3 l/s*ha**.

Substituting this into the above formula gives a volume of **11.93 m^3** water, which is 21% higher than the reference case, and therefore, we also carried out a check for this volume of precipitation.

The design volume of 9.84 m^3 water on the surface of the 148 m^2 shoulder results in a water cover of about 7 cm, and the amount of 11.93 m^3 water in case of a flash flood is an additional 1 cm. The layer sequence of the parking lot takes up this volume, and therefore, no separate drainage or overflow need to be provided.

A soil testing report has been prepared for the area, which is attached as an annex to the technical specification. Based on the soil testing report, the infiltration test carried out in the area determines a filtration coefficient of 2*10-5 m/s Based on the calculations, the wetted surface of the parking lot is 148 m^2, in this way, the infiltrating water volume is $3*10^{-3}$ m^3/s. The reference volume of water accumulated for the surface of the parking lot infiltrates in 9.84 / $3*10^{-3}$ = 3280 s = 55 min, that is ~1 hour in the typically sandy soil.

The layer sequence of the shoulder is described in detail in Chapter 3.2.

2.2.3. Permitting

Replacing the paving of the existing shoulder does not affect the water catchment and the drainage conditions of the area, it only provides local solutions for the management of rainwater that also flowed there previously. Since this is completed within own territory, without the use of areas owned by others, it can-

not be considered independent hydraulic engineering structure, and therefore, it is not necessary to obtain a water construction permit.
Pursuant to Article 4 of Section (1) of Government Decree 93/2012 (V. 10.) on the licensing of the construction, putting in service and termination of roads: If no public utility is required to be replaced during the works, and the intervention does not change the connecting of the road to the public road network, no authority permission is required for the following works carried out in the area of the existing road:
c) in inner areas:
ca) widening of the paving of the existing road without the establishment of additional traffic lanes, including special traffic lanes, strengthening and renewal of its road structure.

In respect of those described above, the intervention affected by the design is not subject to obtaining a road construction permit.

2.3. Szálfa utca (street)

2.3.1. Current condition, problems

The rainwater drainage of Szálfa street is currently provided in part. Without a receiving reservoir, there are infiltration-storage trenches for each section; these receive rainwater flowing from the paving of the road and from the surrounding plots, that gravitate towards the road. Swale ditch beds are mostly made of earth, have relatively large bottom width and a steep slope. However, there are also a high number of paved ditches. These are lined with prefabricated solid sheets or grassy ditch paving elements. At some points, under driveways, culverts or PVC pipes serving as culverts connect the short ditch sections, also serving a relief function.

Swale ditches are typically found in larger numbers on the right side (south side). Between Kölcsey street and Címer street, and between Ady Endre street and Póth Irén street, there are swale ditches of different sizes and materials along almost the entire section. At the beginning section covered by the design, ditches are mostly missing up to Kölcsey street and between Címer and Ady Endre streets.


On the left side, despite the fact that the green area between the road and the fences is wider, the ditches exist only here and there. Except for a few paved sections, their beds are earth on almost the entire length of the section. Typically, they are completely filled up (or were never constructed) in driveway areas and road intersections.

The paving of the road has been recently renovated. Although sloping toward the beginning of the section covered by the design seems continuous to the eye, according to the geodetic survey, it is not. There are local low points. In some places, the residents or the road manager provided unobstructed runoff from the pavement by digging small grooves for “rivers” on the roadside towards the ditches. This solution is useful, but is not visually appealing.


Overall, it can be stated that despite the high number of swale ditches, the system is undersized in terms of drainage. Due to their design and the slope of the curb, the ditches are not always capable of containing the standard volume of rainwater. Local low points are formed because the sloping of the paving is not continuous, and their surrounding becomes overloaded during heavy rainfalls. Due to the poor drainage of the upper part of the street, rainwater collects at the intersection of Kettős-Körös street (on the left side) and Vágány street (on the right side), causing continuous, large flooding on the surfaces.

2.3.2. Hydrology calculations

A fundamental question is how much water load is received by the existing swale ditches. To determine this, it is first necessary to determine the area from which rainwater may gravitate to the ditch. This can basically be divided into two parts.

In terms of intensity, the most significant volume is created by the rainwater running off from the pavement of Szálfa street. The paving of this street has been reconstructed recently. It can be concluded from the geodetic survey that the paving structure of the road is crowned, i.e. the ditches on both sides receive almost similar loads. On average, the paving width is 5.0 m, therefore 1 m of ditch section receives rainwater from a surface of 2.5 m^2 of paving.

On the other hand, in addition to rainwater received from the paving, runoff from the terrain must also be taken into account. This obviously includes the sections up to the fence, but it is also expected that rainwater will enter the ditches from the gardens and roofs. These are difficult to calculate because of the different conditions at each property. In addition, the paving and vegetation cover of gardens and front yards varies, so different runoff coefficients have to be taken into account. Just to be on the safe side, where a uniform 10 m lane is calculated, 1 m of a ditch section receives water from 10 m^2 of green space.

The following were considered as runoff coefficient:

- from the paved area $\alpha = 0.9$
- from the green surface (du a mixed coverings) $\alpha = 0.4$

The intensity of rainwater is determined based on the precipitation values on the website met.hu. Since it is a relatively small surface area with a small runoff length, we used the 10-minute accumulation time as a basis. The precipitation data were queried from the database of no. 53 Budapest Pestszentlőrinc-outer area meteorologycal station which is located ~2500 m from Szálfa street, and therefore provides relatively accurate values for the site.

intensity (mm/h)	10 minutes	20 minutes	30 minutes	60 minutes
1 year, 100%	39.47	28.85	22.03	12.36
2 years, 50%	68.66	50.55	40.70	24.38
4 years, 25%	89.34	65.92	53.93	32.90
5 years, 20%	95.31	70.36	57.75	35.36
10 years, 10%	112.96	83.48	69.04	42.63
20 years, 5%	129.89	96.06	79.88	49.60
50 years, 2%	151.80	112.35	93.89	58.62
100 years, 1%	168.22	124.56	104.40	65.38

Based on the existing situation, since there is no receiving watercourse, the collection of rainwater into reservoir-evaporator-infiltration trenches is provided. There is no valid technical specification for their dimensioning. In our calculations, following consultation with the Client, we calculated the collected water volumes with a **10-year 10-minute** intensity, which is considered to be the standard by Budapest Sewerage Works.

$i_{10\%}$ = 112.96 mm/h (from the above table) = 314.0 l/s*ha (this includes the climate risk factor 1.1)

Based on the above, the cumulative precipitation amount according to the rational method for small reservoirs:

$$Q_{10\%} = \alpha * A * i_{10\%} \quad \text{[l/s]}$$

where: A – Catchment area [ha]

α – Runoff factor [-]

$i_{p\%}$ – specific rainwater yield [l/(s*ha)]

Based on this, the volume of precipitation received by one meter of ditch is:

$Q_{10\%}$ = (0.00025*0.9 + 0.001*0.4) * 314.0 = 0.19625 l/s = **0.000196 m^3/s**

Within 10 minutes it results in a water volume of 0.000196*60*10 = **0.118 m^3**

This water volume is obviously not large enough to cause serious problems. In recent years, large volumes of precipitation falling within a relatively short period of time, called flash floods, have become increasingly common. This is considered a kind of emergency, showing extreme values in statistical data. It cannot and should not be scaled up to flash floods because it would significantly increase both cost and maintenance costs, while it only occurs a few times a year, making the dewatering system uneconomical.

To be on the safe side, we checked the values of the meteorological station for heavy precipitation. According to the Meteorological Database, the 10 minutes with the highest precipitation in the period from 01.01.2002 to 31.12.2022 occurred on 23.06.2006, when 22.8 mm of precipitation fell. Multiplying this (theoretically, because practice shows that not six times this amount fell in one hour) and converting it, we obtain an intensity value of **380.3 l/s*ha**.

Substituting this into the above formula gives a volume of **0.143 m 3** water, which is 21% higher than the reference case, and therefore, we also carried out a check for this volume of precipitation.

As mentioned in the previous point, sloping is not uniform, so local low points are formed. We determined the catchment areas for these low points, which are as follows:

- on the left side (beginning of the sectioning is the rounding arc of Kettős-Körös street junction):
    - 0+075 km mark (boundary between lot numbers 140023/2 and 140024)

At this location, in front of the property with lot number 140023/2, there is a ditch with a minimum depth of 0.40 m, a roughly vertical wall, a bottom width of 0.40 m, which is lined with grass porous paving. In front of the property with lot number 140024, there is a ditch with a larger bottom width and earth bed.


Based on the longitudinal section projected on the edge of the paving, water flows to the area from the part between the 0+000 and 0+136 km section marks. Therefore, a volume of 136 * 0.118 = **16.05 m ^{3}** water needs to be placed.

- 0+167 km section mark (lot no. 140026/7)

Local low point, into which rainwater gathers both from the 0 +0136 km section mark and Kislippó street. In front of lot number 140026/8, the driveway is completely paved, and therefore, water flows and is concentrated here, which currently results in a significant stagnation of water locally.

The catchment area is the section between the 0+136 and 0 +222 km section mark and a part of Kislippó street, where the green surface on the two sides of the street in not capable of infiltrating the rainwater received. We used a 40-meter section in our calculations.

Therefore, a volume of 126*0.118 = **14.87 m ^{3}** water should be placed.


- In the picture above, on the right, the following low point is present in 0+250 km section mark. It shows a really beautiful, practically finished rain garden complete with plants. It is clearly well-kept. There is no need for remodeling it.
- According to the survey, the next rainwater accumulation point is possible in the 0+374 km section mark. This is in front of the plot at lot no. 140048/4. Currently, there are three relatively nicely constructed and maintained ditches lined with grass porous paving and connected by Ø0.20 m pipes.

The ditch receives rainwater from the area between the 0+285 and 0+380 km section marks and from Kérész street. There are no ditches in Kérész street, rainwater running off the road flows to the green area and is infiltrated there. Excess precipitation is guided to Szálfa street, however, its volume cannot be determined clearly, so we took into account 40 m of additional flow here, similarly to the case of Kislippó street.
Therefore, a volume of 135*0.118 = **15.93 m ^{3}** water should be placed.

Since the ditches are well-kept and they are not objectionable aesthetically, the need for intervention and remodeling may not be necessary. Widening the ditch would also be difficult due to the proximity of the power pole and the mature size trees.

- The last low point on the left side was formed in the vicinity of the 0+430 km section mark, after the Olaszfa street junction. There is a continual system of ditches here, with earth or paved beds. There is a culvert for providing connection with the right side.

The catchment area on the left side is the area between Olaszfa street and Oszkó street (~100 m). According to the geodetic survey, no rainwater runoff is received from the two road intersections. On the right side, due to the culvert under Szálfa street, about 20 m can be counted.

Based on these, a volume of 120*0.118 = **14.16 m ^{3}** rainwater should be placed.

- on the right side (beginning of the sectioning is the rounding arc of Vasút street junction):

The low points are located at places similar to those on the left side, but there is a much smaller green area available. In contrast, there a more active ditches, so it is much easier to turn them into rain gardens, then creating new ditches.

  - 0+082 km section mark in front of the property at lot no. 141456.

There is an existing ditch at the low point. There is a relatively large water catchment area here, because confluence may be expected from Vasút street to Címer street, that is, the section between 0+000 and 0+221 km section marks. The ditches, as shown in the pictures attached, are relatively spacious and wide.

The volume to be stores is 221*0.118 = **26.08 m ^{3}**.

There are several existing ditches not only in the vicinity of the low point, but also along the entire length of the catchment area. They are identical in nature. In this area we found 8 smaller ditch sections.

- 0+257 km section mark in front of the property at lot no. 141401

This a relatively small catchment section. Rainwater from the area between 0+221 and 0+313 km marks is received here. However, its disadvantage is that there are few ditches in this section.

Therefore, a volume of 92 * 0.118 = **10.86 m ^{3}** rainwater needs to be placed. The small ditch in the picture on the right, and the ditch in the same picture above is only capable of taking a fraction of this.

  - 0+407 km section mark in front of the property at lot no. 141359/ 1

Since there is a small runoff towards Ady Endre street located near the 0 +345 km section mark, the catchment area between Ady Endre – Póth Irén streets is about 230 m. There are ditches almost in the entire length. In the beginning of the section these are lined with earth, and in the section after Rákóczi street they are paved.

They have relatively large surfaces and are well-kept, however, due to the covering, rapid accumulation and drainage towards the deeper ditch sections is assumed, which are connected by culverts with Ø0.30-0.40 m openings under driveways. They have no reservoir capacity and prevent infiltration into the soil, and therefore respective remodeling is recommended. The section can be divided into two subsections, as the ditch located at the junction of Rákóczi street, in front of the property at lot number 141332/2, is connected to the left side. In this way, the 0+465 km section mark can be considered as a drainage divide, separating the entire area into a 120 m and a 110 m subsection.

The storage of 120*0.118 = **14.16 m ^{3}**, and 110*0.118 = **12.98 m ^{3}** rainwater should be provided.

2.3.3. Technical design, details

Based on the hydrology calculations, the task is to design ditches which safely collect and store the standard precipitation volume.

In summary, according to the previous point, rainwaters generated by different catchment areas:

- left side
  - V 1 b = 0+000-0+136 km mark 16.05 m ^{3}
  - V 2 b = 0+136-0+222 km mark 14.87 m ^{3}
  - V 3 b = 0+285-0+380 km mark 15.93 m ^{3}
  - V 4 b = 0+440-0+540 km mark 14.16 m ^{3}
- right side
  - V 1 j = 0+000-0+221 km mark 26.08 m ^{3}

- V 2 j = 0+221-0+313 km mark 10.86 m^3
- V 3 j = 0+345-0+465 km mark 14.16 m^3
- V 4 j = 0+465-0+575 km mark 12.98 m^3

Existing vegetation and utilities had to be taken into account when dimensioning the ditches. In accordance with the consultations, we avoided the felling of existing trees, so we had to design rain gardens in relatively narrow areas. Under the existing ditches, there is a gas pipeline on the left, and a water pipeline on the right. The height of the gas pipeline is not known. Based on the data provided, the water pipeline is located below the existing ditch (with an average depth of 50 cm), at a depth of an additional 70 cm. During the planning, we strived to maintain the basic starting condition and not to change the covering of the utilities, especially not negatively.

Accordingly, swale ditches shall be constructed as follows:

On the right side, in line with prior coordinations, no intervention in the existing ditches was planned. Their quantity and dimensions correspond to the calculations, so they do not need to be altered. Their bottom width varies between 0.5-1 m, and their slope inclination between 1:1-1:1.5. Their average depth is 0.4 m. A surface area of 0.5 m^2 can be calculated per meter. An exception is the catchment section marked V2j which has only two short sections of ditch. These are not capable of depositing the accumulated rainwater. For this reason, the construction of two new grassed ditches on the right-hand side is envisaged.

The following ditches and surfaces are available for each section:

- **V 1 j**
  - 0+019.5-0+024 km mark – 10 m^2
  - 0+053.5-0+061 km mark – 15 m^2
  - 0+072-0+081.5 km mark – 19 m^2
  - 0+103-0+108 km mark – 8 m^2
  - 0+120.5-0+125 km mark – 10 m^2
  - 0+133-0+150.5 km mark – 33 m^2
  - 0+172.5-0+179 km mark – 13.5 m^2
  - 0+188-0+204 km mark – 33.5 m^2

Total: 71 m, 142 m^2 surface area, 35.5 m^3 volume – **Complies**

- **V 2 j**
  - 0+256-0+258.5 km mark – 5.5 m^2
  - 0+271-0+279 km mark – projected grassed ditch - 16.5 m^2
  - 0+311-0+319 km mark – projected grassed ditch - 15.5 m^2

Total: 18.5 m, 37.5 m^2 surface area, 23.25 m^3 volume – **Complies**

- **V 3 j**
  - 0+367-0+372 km mark – 10.5 m^2
  - 0+384-0+395 km mark – 22.5 m^2
  - 0+407-0+418.5 km mark – 22.5 m^2
  - 0+425-0+436 km mark – 21 m^2
  - 0+446-0+456 km mark – 17 m^2 – existing paved ditch

Total: 48.5 m, 93.5 m ^{2} surface area, 26.75 m ^{3} volume – **Complies**

- **V 4 j**
  - 0+471.5-0+484 km mark – 24 m ^{2} - existing paved ditch
  - 0+502.5-0+517.5 km mark – 30 m ^{2} - existing paved ditch
  - 0+524-0+539 km mark – 29 m ^{2}- existing paved ditch
  - 0+540.5-0+544.5 km mark – 9 m ^{2}- existing paved ditch
  - 0+546.5-0+561.5 km mark – 28.5 m ^{2}- existing paved ditch

Total: 62.5 m, 120.5 m ^{2} surface area, 31.25 m ^{3} volume – **Complies**

When the ditch improvements are completed, it is advisable to remove the existing lining and replace them with earthen, grassed swale ditches to provide more depositing and soaking-away capacity. The profile sleceted for these ditches is of 1:1.5 slope, a depth of 0.4 m and a bottom width of 0.6 m. Thus the size of the ditches is similar to those of the existing ones.

On the left side, the number of existing ditches is significantly less than on the right side. On this side, new ditches (rain gardens) need to be designed in addition to renewing the existing ditches. Their design depends on existing utilities, vegetation, residents' habits and needs. In order not to affect the existing utilities, we do not want to disturb the existing terrain in a depth of more than 0.4 m, so there is no need to involve utility operators. For this reason, the selected ditch profile is of 1:2.5 slope, a depth of 0.4 m and a bottom width of 1 m.

The projected new rain gardens and the existing ditches, which can be optionally re-arranged to grassed ditches/rain gardens shall be constructed/found between the following km stations, broken down by catchment areas:

- **V 1 b**
  - 0+012-0+022.5 km mark – projected rain garden (Rg1) – 36.5 m^2
  - 0+028.5-0+043 km sz. – projected rain garden (Rg2) – 49.5 m^2
  - 63.5-0+069.5 km mark – optional grassed ditch/rain garden – 11.5 m^2
  - 0+081.5-0+096 km mark – optional grassed ditch/rain garden – 29.5 m^2
  - 0+112-0+123.5 km mark - optional grassed ditch/rain garden – 19 m^2

Total: 57 m, 146 m^2, of this 86 m^2 projected rain garden, 61.2 m^3 volume **– Complies**

- **V 2 b**
  - 0+165.5-0+174 km mark - – projected rain garden (Rg3) – 27 m^2
  - 0+179.5-0+185 km sz. – optional grassed ditch/rain garden – 10 m^2
  - 0+192-0+204 – projected rain garden (Rg4) – 36 m^2

Total: 26 m, 73 m^2, of this 63 m^2 projected rain garden, 27,6 m^3 volume **– Complies**

- **V 3 b**
  - 0+252-0+263.5 km mark – projected rain garden (Rg5) – 35 m^2
  - 0+284-0+292 km mark – optional grassed ditch/rain garden – 20 m^2
  - 0+303,5-0+320 km mark. – optional grassed ditch/rain garden – 21,5 m^2
  - 0+342,5-0+352 km mark – optional grassed ditch/rain garden – 18,5 m^2
  - 0+357,5-0+363 km mark – optional grassed ditch/rain garden – 8 m^2

- ◦ 0+368-0+371.5 km mark – optional grassed ditch/rain garden – 5 m^2
- ◦ 0+380-0+385.5 – projected rain garden (Rg6) – 16 m^2
- ◦ 0+390-0+395 – projected rain garden t (Rg7) – 16 m^2

Total: 65 m, 140 m^2, of this 67 m^2 projected rain garden, 56.4 m^3 volume **– Complies**

- **V 4 b**
  - ◦ 0+449-459 km mark – optional grassed ditch/rain garden – 18 m^2
  - ◦ 0+466.5-0+474 km mark. – optional grassed ditch/rain garden – 11.5 m^2
  - ◦ 0+478.5-0+483 km mark – optional grassed ditch/rain garden – 8,5 m^2
  - ◦ 0+484.5-0+495 km mark – optional grassed ditch/rain garden – 11 m^2
  - ◦ 0+523.5-0+543 km mark – optional grassed ditch/rain garden – 24.5 m^2

Total: 53.5 m, 73.5 m^2, 44.1 m^3 volume **– Complies**

Between the catchment areas V3b and V4b, along the section between km stations 0+416-0+419 and 0+424-0+432.5 there two existing swale ditches which can be optionally re-arranged to grassed ditch/rain garden in the future. Their total length is 11.5 m, with a volume of 10.35 m^3.

Existing pavings need to be demolished before construction.

Based on the soil testing report, nine soil mechanical borings and nine infiltration tests were carried out throughout the area. Based on the results of the infiltration tests for different catchment areas:

- V 1 b (boring 6 F) The filtration coefficient is: $1*10^{-5}$ m/s. Based on the calculations, the wetted surface of the trench is 2 m * 57 m = 114 m^2, in this way, the infiltrating water volume is $1,14*10^{-3}$ m^3/s. The reference volume of stored water infiltrates in 61,2 / $1,14*10^{-3}$ = 53684,2 s = 894,7 min = 14 h 54 min in typically sandy soil.
- V 2 b (boring 5 F) The filtration coefficient is: $2*10^{-5}$ m/s. Based on the calculations, the wetted surface of the trench is 2 m * 26 m = 52 m^2, in this way, the infiltrating water volume is $1,04*10^{-3}$ m^3/s. The reference volume of stored water infiltrates in 27,6 / $1,04*10^{-3}$ = 26538,46 s = 442,31 min = 7 h 22 min in typically sandy soil.
- V 3 b (boring 3 F) The filtration coefficient is: $5*10^{-5}$ m/s. Based on the calculations, the wetted surface of the trench is 2 m * 53,5 m = 107 m^2, in this way, the infiltrating water volume is $1,07*10^{-3}$ m^3/s. The reference volume of stored water infiltrates in 56,4 / $1,07*10^{-3}$ = 52710,28 s = 878,5 min = 14 h 38 min in typically sandy soil.
- V 4 b (boring 1 F) The filtration coefficient is: $7*10^{-6}$ m/s. Based on the calculations, the wetted surface of the trench is 2 m * 52 m = 104 m^2, in this way, the infiltrating water volume is $7,28*10^{-4}$ m^3/s. The reference volume of stored water infiltrates in 44,1 / $7,28*10^{-4}$ = 10285,71 s = 171,43 min = 2 h 51 min in typically sandy soil.
- V 1 j (boring 8 F) The filtration coefficient is: $2*10^{-5}$ m/s. Based on the calculations, the wetted surface of the trench is 142 m^2, in this way, the infiltrating water volume is $2,84*10^{-3}$ m^3/s. The reference volume of stored water infiltrates in 35,25 / $2,84*10^{-3}$ = 12412 s = 206,97 min = 3 h 27 min in typically sandy soil.
- V 2 j (boring 4 F) The filtration coefficient is: $1*10^{-5}$ m/s. Based on the calculations, the wetted surface of the trench is 37.5 m^2, in this way, the infiltrating water volume is $3,75*10^{-4}$ m^3/s. The reference volume of stored water infiltrates in 23,25 / $3,75*10^{-4}$ = 62000 s = 1033,33 min = 17 h 13 min in typically sandy soil.
- V 3 j (boring 4 F) The filtration coefficient is: $1*10^{-5}$ m/s. Based on the calculations, the wetted surface of the trench is 93.5 m^2, in this way, the infiltrating water volume is $9,35*10^{-4}$ m^3/s. The

reference volume of stored water infiltrates in 26,75 / 9,35*10^{-4} = 28610 s = 476,8 min = 7 h 57 min in typically sandy soil.

- V 4 j (boring 4 F) The filtration coefficient is: 5*10^{-5} m/s. Based on the calculations, the wetted surface of the trench is 120.5 m ^{2}, in this way, the infiltrating water volume is 6,025*10^{-3} m ^{3}/s. The reference volume of stored water infiltrates in 31.25 / 6,025*10^{-3} = 5187 s = 86,45 min = 1 h 26 min in typically sandy soil.

2.3.4. Permitting

Since the planned rain gardens do not affect the water catchment and drainage conditions of the area, and they only provide local solutions for the management of rainwater that also flowed there previously, and all these functions are covered in common areas, within own territory, without the use of areas owned by others, and therefore they cannot be considered independent hydraulic engineering structures. Therefore, it is not necessary to obtain a water construction permit for them.

As written above, the design area is densely webbed with utilities. In addition to utility connections to the residential houses, the intervention sites are affected by a gas pipeline on the left side and a water pipeline on the right side. At the beginning of the design phase, we made efforts to obtain the related data. Height values for the gas pipeline were not available. We obtained complete data on the water pipeline. From these, it can be concluded that the covering of the utility pipeline under the existing ditches ranges from 0.7 to 0.8 m, which does not comply with the service provider's requirement (min. 1 m). During the design phase, the primary aspect was not to deteriorate the existing condition – once the required covering height is not feasible. We were able to meet this objective in each case.

3. Landscape architecture

3.1. Garden of Tomory Lajos Museum – creating rain gardens

3.1.1. Landscaping and technical implementation

The purpose of rain gardens is to collect, retain and infiltrate precipitation from the roofs of surrounding buildings and pavings. They reduce the negative effects of climate change, increase water retention, improve air quality and reduce the heat island effect of pavings. The use of diverse plant species increases biodiversity and provides habitat for different animal species (e.g. butterflies, bees, birds). Rain gardens will be constructed and later maintained with the involvement of local population, and will have a significant community building effect.

3 small rain gardens with a total infiltration surface of 83 m^2 will be constructed on the design area – as a means of rainwater retention as a nature-based solution – based on the results of hydro-engineering calculations and soil mechanics tests. At the request of the Museum's management, smaller rain gardens with a total area of 57 m^2 were planned.

The location of the planned rain garden A, with an area of 34 m^2 (~3.05 m x 11 m) is in the north-eastern part of the garden of the Museum, adjacent to Bókay-kert, near the gate at the meeting point of the planned footpath to lead to the gate and the educational trail. This area slopes gently towards the Museum building, and a significant proportion of rainwater may be retained in the area closest to the point of entry for rainwater runoff.

The ditch of the rain garden is 110 cm deep, and must be filled with a 60 cm thick soil mixture of special composition. The bottom of the resulting ditch bed is 0.65-3 m wide and almost flat. The side walls of the bed are sloping in design, with a 1:3 angle of inclination. Based on preliminary calculations, the maximum water level stagnating in the rain garden is 38 cm, which in the current soil conditions will soak away in about 5.5 hours (this time may be slightly increased by the addition of a soil mixture with compost).

The composition of the soil mixture should be adapted to the existing subsoil composition, which is typically sandy and has medium water drainage properties. It is not necessary to lay a gravel drainage bed under the soil layer. Between plants, the soil should be covered with 6-8 cm of hardwood (e.g. acacia) or mineral (e.g. washed gravel) mulch to improve water retention. Mulching facilitates rainwater infiltration, prevents soil compaction and reduces weed infestation.

The proposed layout of the rain garden is shown on site plan No *43714.F.04.02 and earthworks drawingn No 43714.F.05.02 while the planned structure of the layers on sectional drawing No 43.714.06.02.*

The planned optional (outside of the scope of „UPSURGE” project) rain gardens B és C with a surface area of 11 m^2 (~2.2 m x 5.5 m) and 12 m^2 (~2.2 m x 6.5 m) are located at the local low point of the garden of the Museum, near the gate on Makói street. Most of the rainwater coming from the direction of the Museum building and from the pavings is accumulated in this area, and therefore, it is worth infiltrating and storing it here.

The ditches of the rain gardens are 70 cm deep each, and must be filled with a 30 cm thick soil mixture of special composition. The bottom width of the resulting beds is approximately 1 m and almost flat. The side walls of the bed are sloping in design, with a 1:3 angle of inclination. Based on preliminary calculations, the maximum water level stagnating in the rain gardens is 28 cm, which in the current soil conditions will soak away in about 4 hours (this time may be slightly increased by the addition of a soil mixture with compost).

The design of the rain gardens is similar to those of rain garden A. It is not necessary to lay a gravel drainage bed under the top soil..

The layout of the rain gardens are shown in the *site plan No 43714.04.02* and earthworks drawing *No 43714.F.05.02.*

3.1.2. Planting

Rain garden beds are typically planted with highly tolerant, native, perennial species with dense roots that can tolerate intermittent shallow water cover, as well as drier periods. In the deepest part of the bed (zone 1), plants that can tolerate occasional 10-15 cm of water cover are planted, in the middle, transitional zone 2, plants that generally prefer wet soil conditions are planted, while in the areas near the banks (zone 3), more drought tolerant plants are planted. In order to promote biodiversity, 9 species of plants should be planted in the 34 m^2 area, at an average planting density of 7 plants/m².

The proposed location of the rain gardens is typically sunny, and therefore, depending on soil and light conditions, plant species that prefer high sunlight and loose, moist soil but are still drought tolerant are best suited for planting.

3.1.3. Recommended plant species

Zone 1-2 (rather wet)

Astrantia major– great masterwort

Iris sibirica – Siberian iris

Veronica longifolia – long-leaved veronica

Zone 2-3 (rather dry)

Aster novae-angliae – grandular aster

Echinacea purpurea – purple coneflower

Echinacea purpurea 'Alba' – purple coneflower with white flowers

Euphorbia amygdaloides 'Purpurea' – wood spurge

Gaura lindheimeri – Lindheimer's beeblossom

Heuchera 'Forever Red' – coral bells with red leaves

Panicum virgatum 'Northwind' – switch grass

Zone 3 (dry):

Achillea filipendulina – fernleaf yarrow

Armeria maritima – sea thrift

Coreopsis verticillata – threadleaf coreopsis

Salvia nemorosa – woodland sage

Total number of perennials to be planted in rain garden A: 230 pcs.

Total number of perennials to be planted in optional rain gardens (B and C): 185 pcs.

The recommended plant species are shown in the *planting plan No 43714.07.02.*

3.1.4. Maintenance instructions:

The mulch layer needs to be replaced annually to prevent weeding and keep the soil moist. Before applying the new mulch layer, the old one must be removed or loosened with a rake. The mulch layer should be 6-8 cm thick.

The rain gardens should be weeded regularly, especially in the period following planting, because it is difficult for newly planted plants to compete with weeds. As the plants grow stronger, less weeding is required.

Plants in the rain garden should be watered regularly once or twice a week for the first 2-3 years after planting, occasionally with a higher amount of water, so that water can enter the deeper layers of the soil. Once the plants have strengthened, it is enough to water them during prolonged periods of drought.

From time to time, rain gardens should be cleaned from dead vegetation and any sediment that may have accumulated. Over time, it may be necessary to replace or replant plants. If a plant does not grow well enough, it may need to be transplanted to another location.

3.2. Margó Tivadar utca (street) – construction of a gravel-grass surface lining

3.2.1. Landscaping and technical implementation

The design is aimed at creating parking spaces in front of Tomory Museum, in an area currently used for parking, covered with slag and compacted; the new parking lot will be covered with a so-called gravel-grass surface with no or low irrigation requirements, covered with a grass seed mix that is easy to maintain. The gravel-grass cover reduces the negative effects of climate change, increases water retention, improves air quality, reduces the heat island effect of pavings and the rich grass surface rich in species increases biodiversity.

In the design area, an infiltration surface of 156.5 m^2 (gravel-grass covered) and 53 m^2 green area with plants and tree shall be constructed, as a nature-based solution of rainwater retention – based on the results of hydro-engineering calculations and soil mechanics tests.

A total of 7 parallel parking spaces can be constructed with gravel-grass surface.

Near the parking spaces one deciduous tree per 4 parking spaces and low, ground-covering shrubs can provide a green area. The parking lot is separated from the connecting pavings and green surfaces by a depressed curb and, from the green area, by a raised curb with interruptions (depressed curb sections).

The gravel-grass surface is green, flexible and infiltrates actively, with a bedding created from a 30-50 cm thick crushed stone layer; it is suitable for less frequently used parking lots as an alternative to asphalt or concrete paving stone. (Gravel-grass surfaces are not suitable for long-term parking of cars, because the plant surface needs light to grow.)

The base layer of gravel-grass can also be made from recycled materials or natural gravel, mixed with soil and compost in a certain proportion. Depending on the load capacity, it may be constructed with one or two layers. The components must be layered according to the specified grain size, and then the seed mixture of appropriate grasses and dicotyledonous plants shall be sown. Unlike traditional pavements (asphalt, concrete), gravel-grass allows for even infiltration of precipitation into the soil, and in addition to its favorable microclimatic effect, the appearance of a green surface is also more pleasant to the eye.

Structural properties:

- Load capacity: 25 MN/m^2 (250 kg/m²) or 45 MN/m^2 (450 kg/m²) (in case of a 1 or 2 layer structure)
- Water permeability: $k \geq 1 \times 10^{-6}$ m/s
- Water storage capacity: 20-40 %

The materials must be added in earth-moist condition; the layers can be compacted without vibrating. The top layer woven with roots and mixed with plant seeds should be 15-30 cm thick; the recommended thickness is 30 cm *(https://boku.ac.at)*.

Recommended layer sequence of gravel-grass (https://boku.ac.at):

The layout of the parking lot is shown in *site plan No 43714.04.01,* earthworks drawing No *43714.F.05.01, while the planned structure of layers on sectional drawing No 43714.F.06.01.*

3.2.2. Planting and maintenance instructions:

Seeds should be sown by hand in a quantity of 30-50 g/m 2 during frost-free periods. The grass base layer should be watered before and after sowing. During the growing period, it is compulsory to perform lawn maintenance tasks. At least 50% of the gravel-grass surface should be green.

It is recommended to avoid use for 3-4 months after sowing, and to water the surface regularly. Following this period, watering is only necessary in dry periods, mowing is required 2-3 times a year depending on use. In winter, snow removal should be carried out 10 cm above the ground. Wood shavings are suitable for de-icing, avoid sprinkling the surface with salt.

3.2.3. Recommended plant species

Medium-sized (10-15 m tall), city-tolerant roadside shade trees for the car park: 2 pcs

Acer campestre 'Elsrijk' – field maple

Low shrubs, ornamental grasses: 260 pcs

Anemanthele lessoniana – New Zealand wind grass

Cotinus coggygria 'Lilla' – smoke bush

Perovskia atriplicifolia – blue spire

Photinia fraseri 'Little Red Robin' – juneberry 'Little Red Robin'

Pinus mugo – dwarf pine

Rosa 'The Fairy' – ground cover rose

The recommended plant species are shown in the *planting plan No 43714.07.01.*

3.3. Szálfa utca (street) – construction of infiltration trenches with trees planted

3.3.1. Landscaping and technical implementation

The design is aimed at creating infiltration trenches with grass and plants along the approximately 900 m long section of Szálfa street between Kettős-Körös and Oszkó street, by transforming the currently existing, paved or unpaved infiltration trenches by retaining the flora as much as possible, on both sides of the road.

Vegetation of different height is to be created in and near the trenches, with trees, shrubs and perennials. Rainfall is not accumulated or evaporated from the paved surfaces, but partly infiltrates in the trench and is partly evaporated by the vegetation. This solution reduces the negative effects of climate change, increases water retention, improves air quality and reduces the heat island effect of pavings. The use of diverse plant species increases biodiversity. Provides habitat for different animal species (e.g. butterflies, bees, birds). It is planned that local residents will also participate in the subsequent maintenance of vegetation in the trenches.

A total of 9 infiltration trenches with a total area of approx. 248 m^2 may be constructed on the design area – as a means of rainwater retention as a nature-based solution – based on the results of hydro-engineering calculations and soil mechanics studies. All of these can be constructed on the north, even side of the street, since a min. 2.5 – 3 m wide area is available there for the construction and widening of the trenches.

Two types of the trenches to be constructed were separated during the design:

- newly constructed soak-away ditches with vegetation (rain gardens): 7 pcs, with a total area of 216 m^2, on the north side of the street
- soak-away ditches/rain gardens created by re-arrangement of existing ditches or newly constructed: 2 pcs, with a total area of 32 m^2, on the south side of the street

The gas pipeline runs in the ground on this side of the street, probably at a depth of 80-90 cm. For this reason, the design of the newly constructed ditches is more similar to rain gardens; large plants, trees can only be planted on the edge of the trench, outside the protection distance of the gas pipeline. In this way, the transformation does not affect the utility lines.

When designing new construction soak-away ditches, the bottom width can be set at 1-1.5 m and the width of the ditch projection at 2.5-3 m. The side walls of the bed to be constructed are sloping in design, with a 1:2.5 , 1: angle of inclination. Between the crown line of the slopes of the trenches and the road, a min. of 1 m wide curb should be left. The trenches should be filled with a special composition of planting medium in a thickness of 30-40 cm, thus creating shallow trenches with a depth of 15-20 cm, but these have an infiltration and water retention effect on a wider surface. Based on preliminary calculations, the maximum water level stagnating in the rain gardens is 15 cm, which in the current soil conditions will infiltrate in about 1 – 6 hours (this time may be slightly increased by the addition of a 50-50% compost-soil mixture).

The composition of the soil mixture should be adapted to the existing subsoil composition, which is typically loose, sandy, silty, gravelly, and has medium water drainage properties. It is not necessary to lay a gravel drainage bed under the soil layer. Between plants, the soil should be covered with 6-8 cm of hardwood (e.g. acacia bark) or mineral (e.g. crushed stone) mulch to improve water retention. Mulching facilitates rainwater infiltration, prevents soil compaction and reduces weed infestation.

The design of the infiltration trench is basically the same as the design of the rain garden, but the planting medium is thicker and the mineral ground cover is more favorable, especially in the deeper part of the trench. Debry and sludge traps constructed from larger river pebbles and stones are to be built near the roadside edge of the trenches, which will prevent the sludging the bed, and also help to keep the trenches clean.

The 1 m wide curb along the road should be slightly sloped towards the trench.

Since there is only a narrow available area on the south, odd side of Szálfa street and there is the water pipeline in the ground, only the beds of the existing, partially paved ditches may be put in order, and the transformation of the pavings into grassed ditches can be carried out. 2 such ditches were selected, from which a total of 32 m ^{2}. Optionally, a further 35 existing trenches can be converted to create a total of 693.5 m ^{2} of diches with vertical walls on one side and grassy slopes on the other.

The location, type and layout of these ditches are shown in the *site plans marked 43714.04.03 and 43714.04.04., earthworks drawing No 43714.F.05.03 and No 43714.F.05.04, while the planned structure of layers on sectional drawing No 43714.F.06.03.*

3.3.2. Planting of plants

The beds of infiltration trenches are typically planted with highly tolerant, native, perennial species with dense roots that can tolerate intermittent shallow water cover, as well as drier periods. In the deepest part of the bed (zone 1), plants that can tolerate occasional 10-15 cm of water cover are planted, in the middle, transitional zone 2, plants that generally prefer wet soil conditions are planted, while in the areas near the banks (zone 3), more drought tolerant plants are planted. In order to promote biodiversity, 10 to 12 species of plants (shrubs and perennials mixed) should be planted in each area, at an average planting density of 6 plants/m².

The proposed location of the trenches is typically sunny, and therefore, depending on soil and light conditions, plant species that prefer high sunlight and loose, moist soil but are still drought tolerant are best suited for planting. Calculated for a total floor area of 216 m^2, a total of 4 leafy trees, 7 larger, solitary shrubs, and 1,145 perennial plants can be planted in the ditches and on their banks.

3.3.3. Recommended plant species

Trees, tree-like shrubs:

Acer palmatum – Japanese maple

Acer ginnala – manchu maple

Alnus glutinosa – common alder

Alnus x spaethii – spear leaf alder

Betula pendula – common birch

Carpinus betulus – common hornbeam

Cercis siliquastrum –common Judas tree

Cornus kousa – kousa dogwood

Euonymus alatus – winged spindle

Gleditsia triacanthos 'Skyline' – common honeylocust

Magnolia kobus – Japanese lily tree

Quercus palustris – marsh oak

Salix sp. – willows

Shrubs:

Aronia arbutifolia – red chokeberry

Aronia melanocarpa – black chokeberry

Buddleja davidii – summer lilac

Callicarpa bodinieri – Chinese beautyberry

Clethra alnifolia – coastal sweetpepperbush

Cornus stolonifera – red-osier dogwood

Hamamelis x intermedia – hybrid witch hazel

Hamamelis virginiana – large-leaved witch hazel

Hydrangea arborescens – shrub hydrangea

Hydrangea paniculata – panicled hydrangea

Hydrangea quercifolia – oakleaf hydrangea

Ilex verticillata – winterberry

Itea virginica – Virginia willow

Photinia x fraseri –red tip photinia

Physocarpus opulifolius – common ninebark

Pinus mugo – dwarf pine

Sambucus nigra 'Black Beauty' – black elderberry

Sarcococca hookeriana – Himalayan sweet box

Perennials:

Achillea filipendulina 'Coronation Gold' – fernleaf yarrow

Acorus calamus 'Variegatus' – sweet flag

Alchemilla mollis – garden lady's-mantle

Amsonia hubrichtii – Arkansas bluestar

Anemanthele lessoniana (Stipa arundinacea) – New Zealand wind grass

Aquilegia vulgaris – common columbine

Armeria maritima – sea thrift

Aster amellus – star aster

Aster divaricatus (Eurybia divaricata) – white wood aster

Aster novae-angliae – grandular aster

Astrantia major – great masterwort

Calamagrostis x acutiflora 'Overdam' – feather reed-grass,

Caltha palustris – marsh marigold

Carex muskingumensis – Muskingum sedge

Carex nigra – black sedge

Carex testacea 'Prairie Fire' – orange sedge

Coreopsis verticillata – threadleaf coreopsis

Echinacea purpurea – purple coneflower

Eupatorium maculatum 'Atropurpureum' – spotted joe-pyeweed

Euphorbia amygdaloides 'Purpurea' – wood spurge

Euphorbia palustris – marsh spurge

Filipendula rubra 'Venusta' – queen-of-the-prairie

Gaura lindheimeri – Lindheimer's beeblossom

Geranium palustre – meadow cranesbill

Hakonechloa macra 'Aureola' – bunchgrass

Hemerocallis hybrida – hybrid daylily

Heuchera hybrida – coral bells

Iris pseudacorus – yellow flag

Iris sibirica – Siberian iris

Juncus ensifolius – swordleaf rush

Liriope muscari – big blue lilyturf

Lythrum salicaria – purple loosestrife

Matteuccia struthiopteris – European ostrich fern

Molinia caerulea – purple moor-grass

Osmunda regalis – royal fern

Panicum virgatum – switchgrass

Persicaria amplexicaulis – knotweed

Physostegia virginiana – obedient plant

Rudbeckia fulgida 'Goldsturm' – orange coneflower

Salvia nemorosa – woodland sage

Sanguisorba officinalis 'Tanna' – great burnet,

Scabiosa columbaria – dwarf pincushion flower

Veronica longifolia 'Blue Indigo' – long-leaved veronica

Veronicastrum virginicum 'Fascination' – Culver's root

Ground cover plants:

Ceratostigma plumbaginoides – hardy blue-flowered leadwort

Geranium macrorrhizum – fragrant cranesbill

Epimedium x versicolor 'Sulphureum' – horny goat weed

Persicaria affinis 'Darjeeling Red' – knotweed

The recommended plant species are shown in the *planting plan No 43714.07.03.*

3.3.4. Maintenance instructions:

The mulch layer needs to be replaced annually to prevent weeding and keep the soil moist. Before applying the new mulch layer, the old one must be removed or loosened with a rake. The mulch layer should be 6-8 cm thick.

The infiltration trenches planted with trees (rain gardens) should be weeded regularly, especially in the period following planting, because it is difficult for newly planted plants to compete with weeds. As the plants grow stronger, less weeding is required.

The planted plants should be watered regularly once or twice a week for the first 2-3 years after planting, occasionally with a higher amount of water, so that water can enter the deeper layers of the soil. Once the plants have strengthened, it is enough to water them during prolonged periods of drought.

From time to time, the trenches should be cleaned from dead vegetation and any sediment that may have accumulated. Over time, it may be necessary to replace or replant plants. If a plant does not grow well enough, it may need to be transplanted to another location.

4. Protection of the environment

Pursuant to *Government Decree 314/2005. (XII.25.)*, the planned investment is not an activity subject to inspection from the aspect of environmental protection.

5. Applicable legislation

This design documentation has been prepared observing the following legal regulations:

Act LXXVIII of 1997 on the shaping and conservation of the built environment

Act LVII of 1995 on water management

Government Decree 253/1997 (XII. 20.) on the national urban development and building requirements (OTÉK)

Government Decree 191/2009 (IX. 15.) on construction industry contracting activities

Decree 41/2017 (XII. 29.) of the Ministry of the Interior on the content of the documentation required for water rights authorization procedure

Bp. District XVIII Municipal decree no. 5/2022 (III. 9.) on the District Building Regulations

Budapest, 28 February 2023