SUSTAINABLE URBAN DRAINAGE SYSTEMS AT PRØVESTENS AND KONGEDYBS AL

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Location

Fig. 1. Location plan, red dot marking the project site

Fig. 2. Ortophoto of the project area

Fig. 3. Close photo of the projet area

The project area is situated in a low-density residential area in the South-East part of Copenhagen, on the island of Amager.

Kongedybs Allé and Prøvestens Allé are bounded by Øresundsvej in the North and by Backersvej in the East.
They are private and managed by a association of homeowners (GF-Øresund). This status makes it easier to implement any plan of construction because the municipality is not as much involved as in public streets.

Existing conditions

This area of Copenhagen is equipped with combined sewers: both stormwater and domestic water are discharged in the same pipe. This means that during a heavy rain event, when the flows are bigger than the capacity of the pipes, this mix of water is discharged into the ocean without any treatment.

According to the 'LAR-Projekthåndbog', the ground water level on the project site is at least 3 m below terrain. If the ground water level is too close to the surface, it could be contaminated by the polluted stormwater. In the case of Amager, the depth is enough to assure a good treatment of the stormwater.

As for the soil conditions in the area of Kongedybs Allé and Prøvestens Allé, there are no exhaustive studies available. However, according to the LAR-Projekthåndbog the area could be suitable for infiltrationg stormwater.

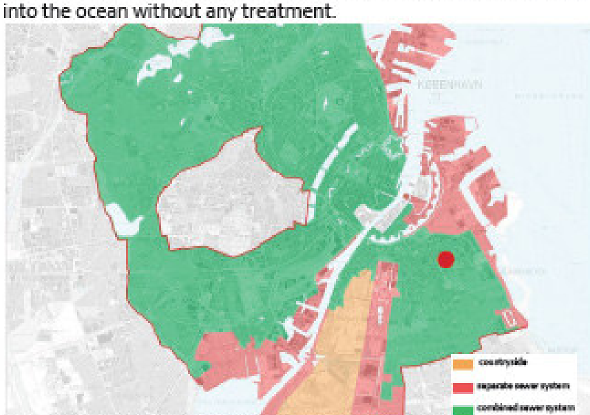


Fig. 4. Map of the sewer systems in Copenhagen. Red dot marks the project area.

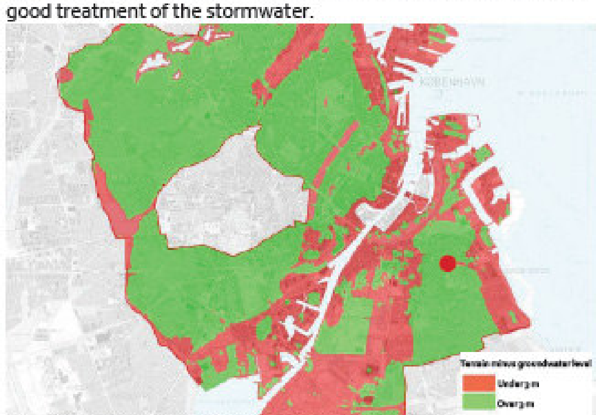


Fig. 5. Map of groundwater levels. Red dot marks the project area

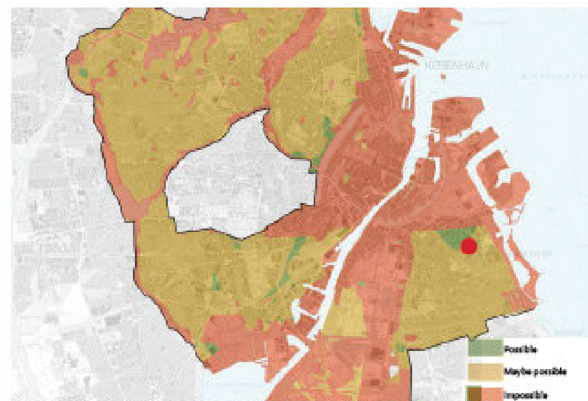


Fig. 6. Map of water infiltration possibilities: Red dot marks the project area

Site history

GF-Øresund association was established 1.st of july 1899 and includes the houses on both Kongedybs Allé and Prøvestens Allé.
Most of the houses were built by the architect Herman Ebert, and were originally meant for accommodating the working class.
Today, the association has started their own climate group, which has a focus on bringing down the CO_2 outlet from the houses and making some changes, in order to make the neighbourhood more sustainable for the future.
(Ref. 9)

Fig. 7. Map of Copenhagen in 1860. Red circle marks the project area

On the map from 1860-1900 it can be seen, that the area is well drained. The groundwater level in large parts of Amager tends to be quite high, in contrast to our project area. Most of the area on Amager was used for agriculture.
Today, that part of Amager has grown to be a part of Copenhagen.

Fig. 8. Map of Copenhagen nowadays. Red circle marks the project area.

Site appearance

It's clear to se, that most of the houses are build by one architect. They are two family houses, with private front- and backyards. Between these, a few single family houses are put in. Generally the buildings are made of red tiles and the general impression is that house and garden areas are the same. This is useful in the context of calculations later in design phase.
The quite linear line of houses, the unbent street framed by the rows of Tilia, gives a straight, classical, traditional street impression.

Fig. 9. Example of typical house in project area

Athmosphere on the site

Fig. 13. Photo of Kongedybs Allé

Today, the asphalt of the roads has become quite old and the road bumps are higher than normal. The owners' association has planned to restore the streets within two years. They haven't yet any precise idea about what they would like the future design to be. However, the owners would like to reduce their ecological footprint in the process.

In this neighbourhood, the social life is very active. Social events like flea markets, neighbourhood parties, barbecues, children's games, etc take place in the street. Some little areas on the side of the road are fitted out with tables, flower pots and even a bowls pitch.

Fig. 14. Photo of petanque field and benches on Kongedybs Allé

Fig. 15. Example of an semi-open front yard in Kongedybs Allé

Fig. 16. Example of an open front yard in Kongedybs Allé

Spacial structure of the streets

Fig. 17. Example of a closed front yard on Prøvestens Allé

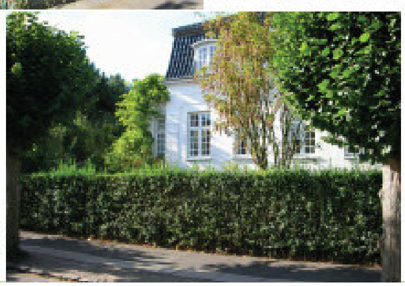


Fig. 18. Example of a closed front yard on Prøvestens Allé

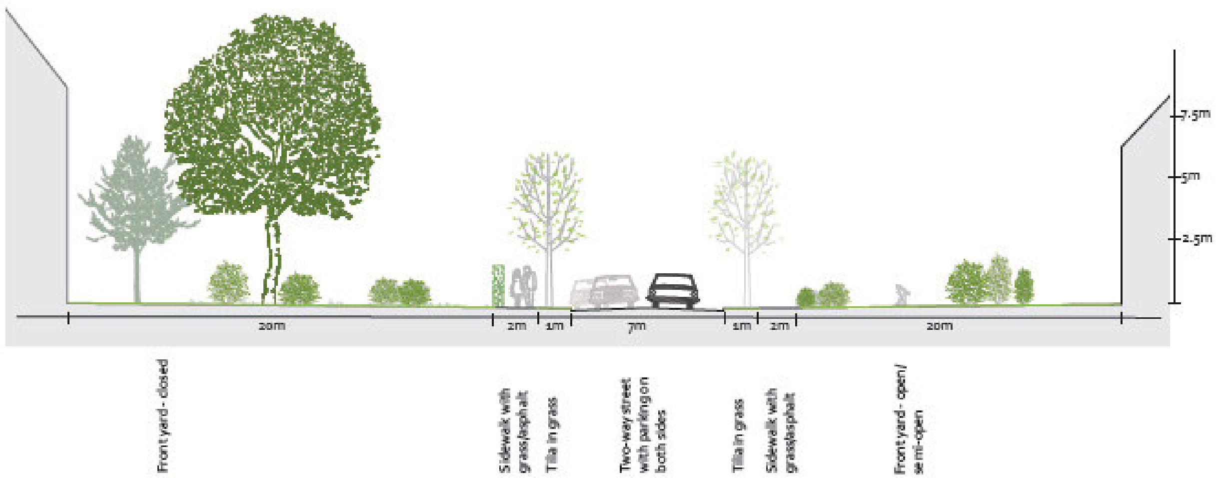


Fig. 19. Cross-section of the typical features of the street

Possible SUDS placing options on project site

Fig. 39. The road is narrowed a little, to make room for the SUDS elements on both sides of the street. The width of the SUDS elements is the same along the road; therefore the overall image of the street is not altered much. The size of the SUDS elements might be too narrow for large amounts of stormwater.

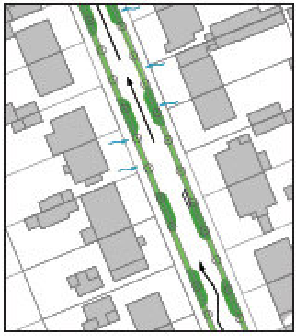


Fig. 40. SUDS elements are placed on both sides on the street either alternately or face-to-face. As the road is notably narrowed, it slows down the traffic. Placing the SUDS elements alternately, makes the street look curvy, whereas the face-to-face version leaves the street straight. Angle parking might be possible.

Fig. 41. SUDS elements are placed only on one side of the street, leaving the other side untouched. The road is also sloping on one side - in case of heavy rain, only half of the road would be flooded.

Fig. 42. A wide SUDS is placed on the sidewalk area, appearing on both sides of the sidewalk. The road has remained the original width. In case of necessity, open front yards could be integrated.

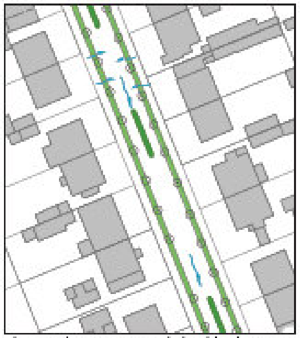
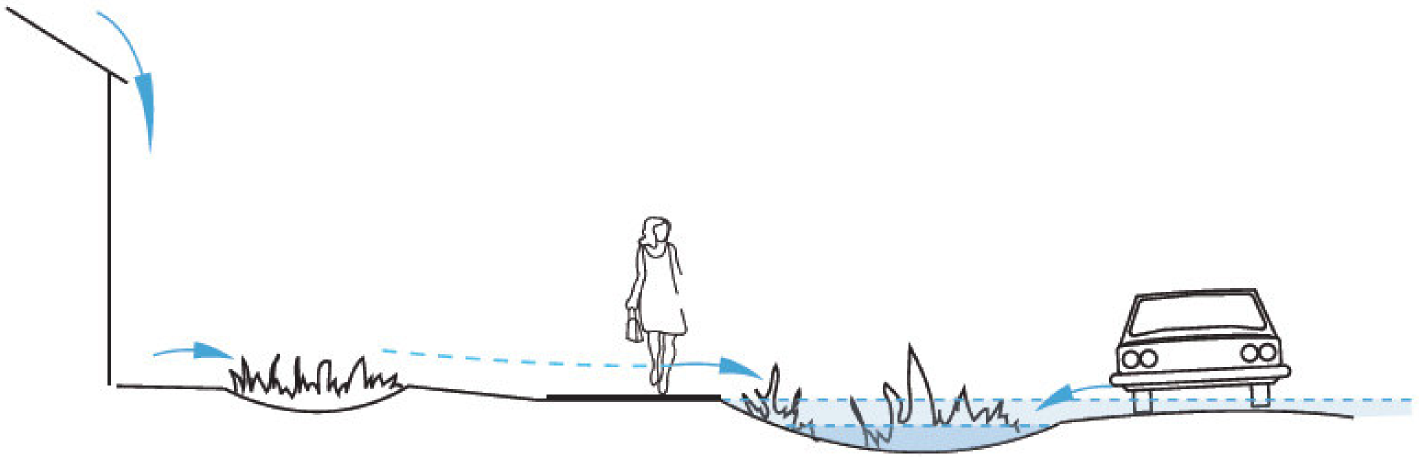


Fig. 43. The stormwater is lead in the SUDS that is placed in the middle of the road. In that case, the SUDS elements function also as a speed control. However, that kind of design could be suitable for wider roads and boulevards.

Fig. 44. The SUDS is placed in the backyard of the building block, receiving stormwater from all directions. Needs approval from all the stakeholders. Every household could also have their own SUDS in the front yard, capable of coping with the stormwater from the roof. Overflow is allowed to the street.

Several SUDS placing options with different qualities were considered during the phase of elaborating the concept. Option with alternately placed SUDS elements (fig. 40) combined with the idea of using the front yards (fig. 44) was determined to be the most suitable for the project area because of the great amount of stormwater and need for slowing down the traffic.

Design concept

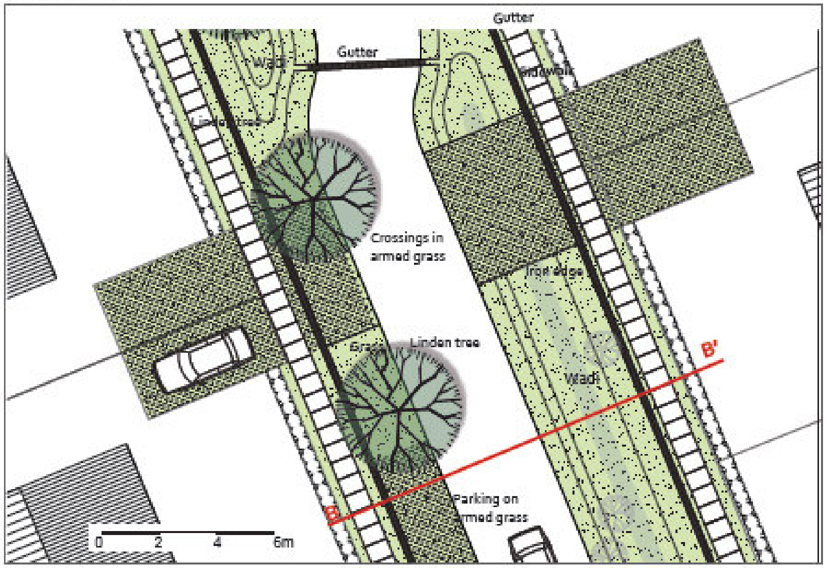


Design plan

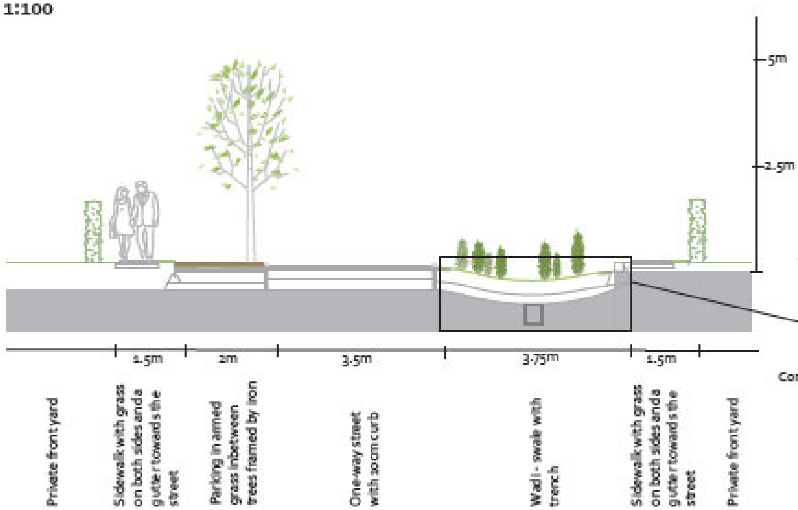
Øresundsvej
Parking on armed grass
Place for social activities
Crossing in armed grass
Plan section 1
Place for social activities
Place for social activities
Plan section 2
Place for social activities
Place for social activities
Place for social activities
Place for social activities
Sixtusvej
N
1:750

Plan- and cross-sections and diagrams

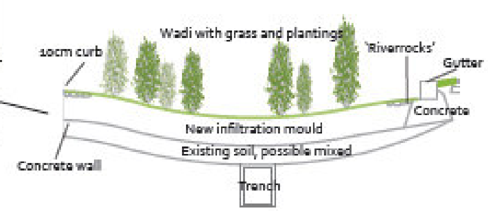
Plan section 2



Cross-section B-B'
M 1:100



Detailed cross-section - wadi
M 1:50



Treatment of the water

The swale has the triple function of storing, infiltrating and treating the water. Indeed, the water that has run on the roofs or in the street is charged with polluted particles. Particles are tiny elements where pollutants are fixed. It could be heavy metals such as zinc and cooper from roofs and gutters; organic pollutants from birds faeces or pathogens.

When the water percolate thought the soil of the swale pollutants are removed thanks to two processes:

- Mechanical process: by sedimentation, particles stay fixed to the soil elements and water keep going down.
- Biological process: the underground life which mainly consists in roots, micro-organisms and worms, is able to degrade lots of pollutants. These organisms are discharge the water from pollutants thanks to different mechanism: they can use elements for their metabolism (nitrogen, phosphorous), degrade them in innocuous smaller elements (xenobiotic organic compounds like oil or fuel) or simply accumulate them (heavy metals). (Ref. 1)

In order to ensure a good treatment of the stormwater before it reaches the ground water we assume that 50 cm of percolation are necessary. The first 30 cm should be a loam. This top soil will enable a good development of the underground life and thus a good degradation of the pollutants. The next 20 cm could be either existing soil or a mix of existing soil with sand if the hydraulic conductivity needs to be improved.

In our design, the capacities of storage and infiltration are enhanced by an underground trench. To ensure a good treatment, the trench has to be placed below the first 50 cm of soil so the water is depolluted when it reaches the trench (Ref. 2). In the deeper soil, the lack of oxygen limits the development of life and by the way the removing of pollutants by micro-organisms.

Plan section 1

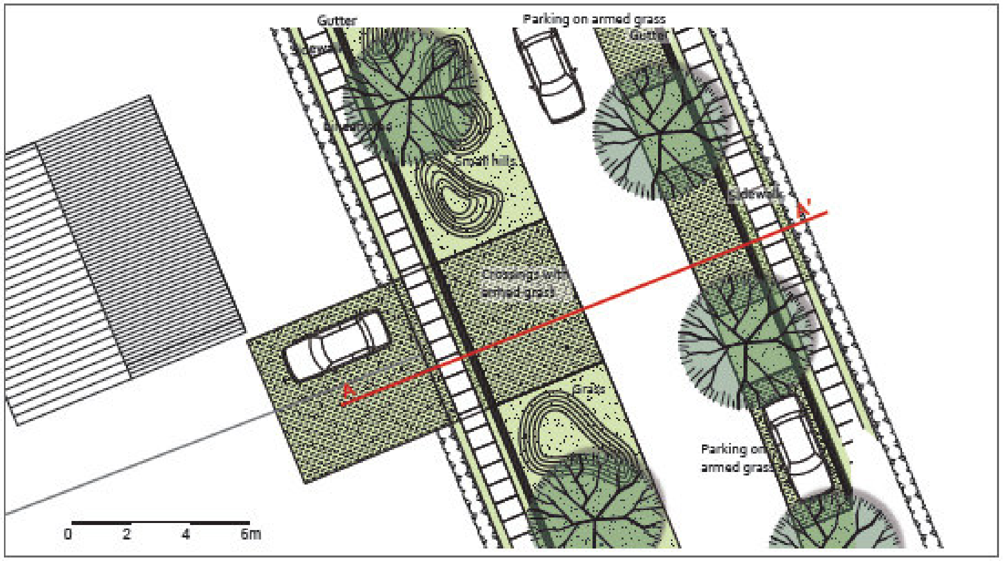
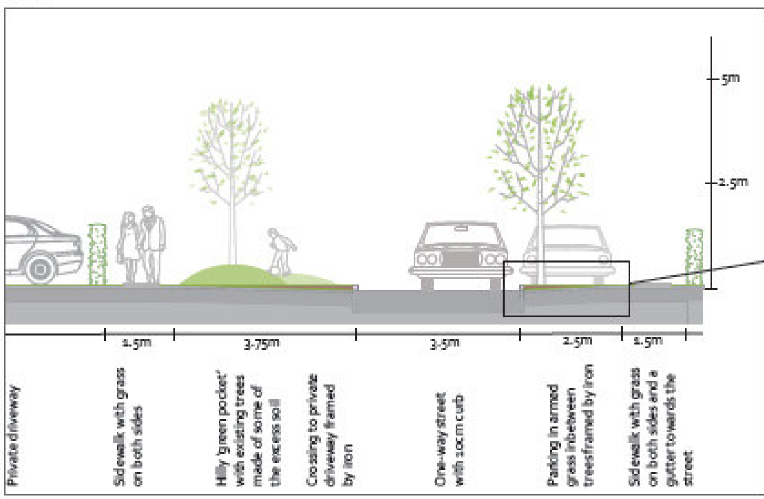


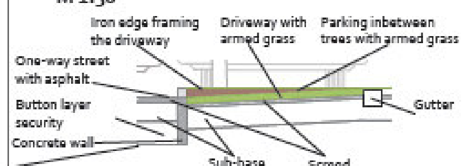
Fig. 49. Example of armed grass

Cross-section A-A'

1:100



Detailed cross-section - driveway crossing
M 1:50



Framing of the crossing and parking with iron edges is shown. Both of these areas are covered with armed grass.

Rain event diagrams

2-year rain event

5-year rain event

20-year rain event

The run off from the roofs is managed the private area (in the drawing, in raingardens). The water from the street runs on the road sides and goes in the wadis. The gutters placed on the walking way and across the street ensure a homogeneous repartition of the water between the wadis.
No water from the properties goes to the wadi.

The run off from the roofs has filled the raingardens. The overflow is conveyed to the wadis by a gutter. All the wadis are at their maximum capacity (20 cm). The wadis need 2 to 3,5 days to empty.

The amount of water is bigger than the capacity of the wadis. The overflow floods the road (parking spaces included). The maximum high is 10 cm of water in the street. As the water is infiltrated in the wadis, the water from the road flows to them. It could be necessary to pump out the water from the road if the emptying time exceeds a week.

Suggested plants

The existing impression of the streets is very much formed by the pruned tilia allé. The trees are healthy looking and the design suggestion will keep as many as possible.

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The WADIs will not only be lined with grass, but will be planted with a wider range of vegetation, both for the purpose of water cleaning, increase of evaporation and aesthetic/recreational values.
The vegetation is mainly low (under 100cm) supplemented with a few larger scrubs for a more spatial effect. This will insure the visibility of the existing tilia allé and the view both lengthwise and across the street

The vegetation for the WADIs is chosen primarily for its tolerance to both dry and wet conditions but also their ability to clean the water, salt tolerance, a reasonable level of maintenance and of course for their aesthetics: height, structure and colors. Their dry/wet tolerance differs and some are evergreen.

The Tilias can not tolerate standing in water, and will therefore be removed where the WADIs are placed. In the other green pockets the tilias are kept and strategically supplemented with Amelanchier and black current (ribes nigrum) e.g. in connection with social seating areas and playgrounds/the hilly pockets. The amelancier have beautiful flowers in spring and nicely scented flowers and the black currant will be fun especially for the children and attract birds.
(Ref. 3; 4; 5; 6)
Cf: Appendix

Grasses

Fig. 50. Equisetum hyemale (skavgræs)

Fig. 52. Hakonechloa macra 'Gold'

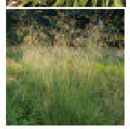

Fig. 53. Deschampsia cespitosa

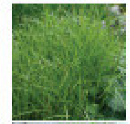

Fig. 54. Carex muskingumensis

Fig. 55. Carex pendula

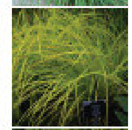

Fig. 56. Carex elata (stiv star)

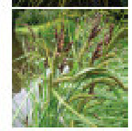

Fig. 57. Carex riparia

Water cleaning grasses

Fig. 58. Glyceria maxima (water cleaning)

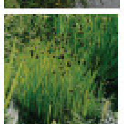

Fig. 59. Juncus ensifolius (water cleaning)

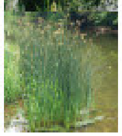

Fig. 60. Schoenoplectus lacustris (water cleaning)

Perennials

Fig. 61. Alchemilla mollis

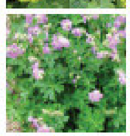

Fig. 62. Geranium macrorrhizum

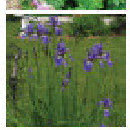

Fig. 63. Iris sibirica

Fig. 64. Lychnis flos cuculi

Trees and bushes

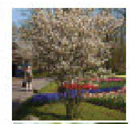

Fig. 65. Amelanchier laevis (bærmispel)

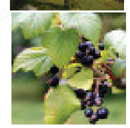

Fig. 66. Ribes nigrum

Visualization

Illustration of the design: narrow, curvy road and green pocket with a wadi (curb cut for runoff inlet). In the background a green pocket for social events can be seen.

Visualization

Illustration of the design with water and plants: narrow, curvy road and green pocket with a wadi (curb cut for runoff inlet). In the background a green pocket for social events can be seen.

Calculations

PROPERTIES	Area m²	Volume m³	
Frequency		*2 year*	*5 year*
Roof	6884	129	164
Pavement	500	6	7
Garden	20 338	38	45
TOTAL		**173**	**216**

STREET (5 year event)	BEFORE		AFTER	
	Area m²	Volume m³	Area m²	Volume m³
Road	3005	64	1240	27
Porous pavement	-	-	660	5
Green pockets	-	-	1105	3
TOTAL		**64**		**35**
TOTAL WITH PROPERTIES		**280**		**251**

WADIS CAPACITY	
Length	108 m
Capacity swale	
(3m wide x 0,2m deep)	0,60 m³/m
Capacity trench	
(0,3m wide x 0,4m deep)	0,12 m³/m
Capacity WADI	0,72 m³/m
TOTAL CAPACITY	**78 m³**

- Decrease of 10% of the run off
- In a five year rain event, 70% of the total run off handle on private area
- For a average size property, a raingarden would need to be 10m²
- Volume to infiltrate in the wadi in a 5-year rain event : 251 – 173 = 78m3
- Capacity of the wadis : 78 m3
- Emptying time : 1,8 days to 3,5 days (hydraulic conductivity of 10-6 or 5.10-7 m/s)

Discussion

Estimated amount of materials

Total project area	4234m²
Elements:	
Armed grass	660m²
- constructed after T1 recommondations	
Swales (wadi)	535m²
- price should include:	
* new soil	
* trenches	
Gutters	710m
Sidewalk	552m²
- constructed after To recommondations	
Asphalt/roads	1240m²
- constructed after T1 recommondations	
Iron curbs	341m
Concrete curbs	700m
Vegetation:	
Grass	1105m²
Green areas other than	
- Wadi	
- Armed gras	
Wadi vegetations	535m²

SWOT-analysis of the project solution

STRENGHT
- Cases studies show that it is possible and work in other places – not just fantasy
- The design provides room for social events
- Security is increased with one-way streets and curves
- Able to handle a 20-year rain event
- Appearance and atmosphere of the allé is extant
- Water is visible → easy to maintain and increases the awareness
- We have planned maintenance

WEAKNESS
- Original number of parking spaces not respected
- Necessary involvement of ALL the owners
- Necessary use of trenches (against our intention to make SUDS entirely visible)
- Private gutters

OPPORTUNITIES
- Renovation of the road within 2 year
- Ecological awareness of the owners
- Neighbourhood relationship: enables common solution – people might more become open to involving their private property
- Situated in an area where infiltration is possible (ground water level, authorization from the municipality)
- Subsidies

THREAT
- Real hydraulic conductivity not known (time of emptying could be longer than planned)
- High costs (although we tried to use simple materials)
- People might not like having water in their garden/street and want to come back to a sewer discharge (construction should enable an easy re-connection to the sewers)