Megbízó:

Budapest Főváros XVIII. kerület Pestszentlőrinc–Pestszentimre Önkormányzata

Tervező:

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Terv tárgya:

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

Tervfázis: PERMISSION DESIGN

Megnevezés: Standard designs - Technical description

Dátum:	**Méretarány:**	**Rajzszám:**
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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 current planning documentation includes those small-scale (typically between 5-15 square meters) rain-garden designs that can be adapted to 25 selected locations in the 18th district of Budapest, based on community consultations. The locations are partly on public land (around bus stops, in public parks, institutional areas, playgrounds) and partly on 25 additional properties owned by residents. The construction of the gardens will not be the responsibility of the residents, but the maintenance will be carried out by them in consultation with the local government.

2. About rain gardens in general

2.1. What are rain gardens?

When rain falls on natural areas such as a forest or meadow, it is slowed down, filtered by soil and plants, and allowed to soak back into the ground. When rain falls on impervious surfaces such as rooftops, roads, parking lots and driveways, rain does not soak into the ground and storm water runoff is created. Stormwater runoff picks up pollution such as fertilizer, pesticides, sediment, motor oil, litter, pet and yard waste. In many Massachusetts towns, stormwater runoff does not go to a treatment plant. Instead, water and the pollution in it flows directly into storm drains, which eventually can deliver these pollutants to bodies of water.

Rain gardens are attractive, functional landscaped areas designed to capture and filter stormwater before it runs off into storm drains. They collect water in natural or constructed shallow vegetated depressions and allow it to soak into the ground slowly. This reduces the potential for erosion and minimizes the amount of pollutants flowing from a yard into a storm drain, and ultimately into our waterways. They may also be used as a buffer in shoreline areas to capture runoff from the home landscape before it enters a lake, pond, river or estuary.

Rainwater gardens are being incorporated into many new and existing areas for their environmental benefits, as well as their natural beauty. Although a single rain garden may seem small, their collective im-

pact provides significant environmental benefits both in the immediate vicinity and in the wider residential community.

2.2. What makes a rain garden to a rain garden?

A rain garden resembles a regular perennial garden or mixed border in many ways. It is designed with deep-rooted plants that come back year after year; it is pretty to look at; it often has lovely flowers, grasses, trees and shrubs. So what makes it different from any other perennial garden?

There are certain qualities that make a rain garden unique:

- A Rain gardens have a ponding area, but they are not ponds. They often are planted with wetland plants, but they are not wetlands (although you can design a rain garden that mimics a wetland).
- The garden absorbs and filters rain that would otherwise run off your property and down the storm drain.
- Many of the plants in the garden might be native to the region and have extensive deep roots that help the garden absorb rain. The native plants do not need special attention once they are established. Non-native plants may be used as long as they are also non-invasive and pest free.
- There is a bowl-shaped dip in the garden, which holds the rain while it soaks into the soil.
- The garden bed is prepared or sometimes replaced to a depth of up to 60 cm in order to relieve soil compaction and make the garden able to absorb water.

A garden that does not have rain directed into it from a hard surface of your property will still be a valuable asset. However, unless stormwater runoff is directed into the garden, it is not a rain garden. In addition to reducing and filtering stormwater runoff and increasing groundwater recharge, rain gardens provide many other benefits. They provide habitat for wildlife and, with the proper selection of plants, increase the number and diversity of birds and butterflies for those who enjoy watching them. Rain gardens provide an attractive and creative alternative to traditional lawn landscapes and require less maintenance because they do not need to be mowed, fertilized, or watered once established. They may also increase property values with creative landscaping designs.

3. Locating the rain garden

Place rain gardens near your home to catch runoff from your roof, or farther out in your lawn to collect surface water draining across your property. Examine your yard while it is raining to discover the drainage pattern on your property. Find out where runoff flows and locate areas where water collects. If the rain does not flow naturally to your chosen spot, you can install piping underground or send the rain along a constructed channel or swale. Typically, the largest sources of runoff are rooftops, paved surfaces, slopes, and compacted soils. Some helpful tips are listed below to help you determine the best location for your rain garden:

- Rain gardens should be at least 3 meters away from the foundations of nearby buildings to avoid damage caused by water infiltration.

- Because these areas are already poorly drained, rain gardens should not be placed in an area of your yard where water collects. They should be placed up-slope of these areas to reduce the amount of water that flows into them.
- Sunny or partly sunny locations are best for rain gardens, but shade gardens are possible.
- Rain gardens should be integrated with your landscape. They can have a formal or informal look based on your preference.
- Rain gardens should not be installed under large trees. Trees have extensive root systems that may be damaged in the garden excavation process. In addition, they may not be able to adapt to the extra moisture being held by your rain garden.
- Make yourself aware of underground service lines or utilities. Do not place rain gardens over or near sewer pipes or septic tanks, and maintain a safe distance from them.

Consider how the rain garden will fit in the overall landscape when looking for a location. Determine if you want it near outdoor gathering places where the beauty of the plants can be appreciated. Look out of your windows to see what views the rain garden can provide. The rain garden is more than just a stor-mwater management tool; it will be an integral part of your landscape.

Once you select a location, you may decide to send additional water to this site. Use flexible plastic pipe to direct water from downspouts and collecting areas to the rain garden. Be sure to factor this additional water flow into your garden sizing calculations.

4. Soils and drainage

Rain gardens work best when constructed in well-drained or sandy soils, but they can also be installed on sites with less permeable soils such as clays. Your rain garden needs to be able to absorb the water coming off your roof and driveway. Sandy soils drain well, while clay soils may become waterlogged. If your soil is sandy, you may be able to simply loosen the soil and improve it with some compost to prepare your rain garden for planting. If your soil is clay, you will have more work to do. Even light clay soils may create drainage problems if a lot of water is directed to the rain garden. Soil removal and replacement may be needed if your soil is clay. The recommended soil replacement mix is 50-60% sand, 20-30% topsoil, and 20-30% compost. Be sure no clay is in your replacement soil.

You can test your soil's infiltration rate by digging a hole 20 cm wide and 20 cm deep. Fill it with water and see how long it takes to sink in. The water needs to go down 2 cm per hour. If it takes longer than that, you will need to do additional site preparation to improve infiltration.

There are three signs of an impermeable soil:

- The site ponds water or remains saturated for several days after a storm event.
- Dry soil is difficult to crumble, while it becomes slick and slippery when it gets moist.
- Water poured in the test hole is still there after two days, provided it has not rained.

If you see any of these signs, your garden will need to be designed as a backyard wetlands garden, or another location should be selected. Otherwise, your site is suitable for a rain garden.

5. How large should the rain garden be?

The size of rain gardens primarily depends on the size of the location's watershed area. The amount of precipitation to be collected roughly equals the amount of precipitation that falls on impermeable surfaces such as paved surfaces, roofs, and grassy areas created on slopes.

To determine the amount of water to be collected, first calculate the area of the surfaces from which water can reach the garden when flowing. If the water from the gutter goes directly into the garden, we will need to know the horizontal projection of the roof area connected to the gutter.

Measure the area of your home, and then calculate how much of this area is where precipitation enters the garden. Then divide this area by six. The calculation is based on the fact that a 15 cm deep rain garden is suitable for handling the maximum of 25 mm of precipitation amount that falls on a unit surface (with 10-minute accumulation time) at a maximum precipitation intensity of approximately 150 mm/h (25 x 6 = 150 mm) per hour. The precipitation intensity data for the design area can be obtained from the website of the Hungarian Meteorological Service: https://www.met.hu/eghajlat/csapadekintenzitas/.

For example, let's assume that a house has an area of 162 m2. Precipitation falls on 40.5 m2 of the roof surface, which is a quarter of the total roof area and reaches the gutter near the planned location of the rain garden. Divide this area by six, and the calculated area of the rain garden will be 6.75 m2. In this example, a rain garden with a proportional shape could have an area of 3 m x 2.25 m, but it can be designed in any shape within the calculated size. A good rule of thumb is that the rain garden should be about twice as long (perpendicular to the slope direction) as it is wide.

If we want to take into account the rainfall runoff from paved surfaces or grassy areas, we should add their area to the roof's relevant area to get the total water collection area of the garden. Then, we can use the following simplified formula to determine the size of a 15 cm deep rain garden:

Water collection area / 20 = Rain garden area

(Of course, a rain garden with twice the depth will be half the size in area.) In the case of adobe soil, it is necessary to increase the area of the rain garden by about 50%, and in the case of clay soil, by up to 100%.

A good estimate for the size of the rain garden can be obtained by calculating 2% of the green area and 5% of the paved area as the rain garden area.

6. Installing the rain garden

Once you feel confident in the placement of the garden, lay out the shape to define where to dig. Outline the area of the proposed garden by spraying with non-toxic soccer-field paint. Another method is to lay a hose along the shape of the garden, then dig along the hose. This gives a nice flowing border to the garden area. Alternatively, you could simply choose a rectangle as the shape of your garden.

If the yard is fairly level, you can just dig out the bowl to the proper depth, which is 12 cm deep, or a couple of cm deeper if mulch will be used. If the yard is sloped, you may need to construct a small berm (mound) at the down-slope side of the garden to prevent the soil from washing away after a storm. Use the soil that was removed from the upslope side of the garden and add it to the down-slope side. The bottom of the garden should be fairly level to maintain the storage area inside the garden. Slope the edges of the garden, but do not make them too steep. Steep slopes tend to erode easily. Mulch or a ground cover will help to stabilize the soils.

If the selected area is lawn, you will have to remove the turf. Either you can use this in another area of your yard, or it can be composted to help improve your soils. If your soil drains well, simple soil preparation is all that is needed. Incorporate compost into the garden bed to improve the quality of the soil. If your soils are clay, soil replacement is probably in order. You may also want to add a reservoir of gravel at the bottom of the garden bed, or add tiles or an under-drain that leads to another area. This will avoid having your rain garden become waterlogged. The idea is to create a living sponge of soil, plants, roots and mulch, not a soggy bog.

Grade the surface of your prepared rain garden bed in such a way that the water entering it can spread out over a large flat area and soak into the soil. This may involve removing a lot of soil. When your ponding area is ready and the soil is nice and loose, it is time to plant. You can prepare a rain garden bed and then cover it with mulch until later; then, plant through the mulch. On the other hand, you can plant immediately, and then mulch the plants. The choice is yours. The sooner the plants are in, the faster your rain garden will become established.

6.1. Planting

The rain garden not only has a functional role but it should also become a decoration of our garden, therefore, its planting should be carefully planned to match the style and existing plants of the garden. When selecting plants for the garden, it is important to consider the height, flowering time, color, and habitus of each plant. To create a long flowering period, use plants that bloom at different times. Plant a mixture of plants with different heights, leaf and flower colors, and shapes to increase the spatial effect of the rain garden, so that it remains interesting even when few flowers are blooming. Perennial plants are recommended to be planted in the rain garden, but if the area is large enough, a smaller tree or a few flowering shrubs can also be included among the perennials and ornamental grasses.

It is important to note that the plants in the rain garden must be able to tolerate fluctuations in soil moisture. Typically, plant species with dense roots that can tolerate periodic shallow water coverage and drier periods are planted in the rain garden bed.

The rain garden can be divided into different moisture zones. In the deepest part of the garden (Zone 1), plant species that can tolerate occasional root waterlogging for a few days should be planted. In the transitional, higher Zone 2, plants that typically prefer moist soil conditions and are characteristic of waterside environments can be placed, while drought-tolerant plants are more suitable for the mediterranean areas of the garden (Zone 3). Many native plants are excellent for the rain garden and generally adapt to local conditions, but cultivated ornamental plants can also be used if they do not have invasive characteristics or problematic pests.

The planned location of the rain garden is typically sunny, so plant species that prefer a lot of sunlight and loose, moist soil but are also drought-tolerant are the most suitable for planting.

To promote biodiversity, 8-10 perennial plant species should be planted in a 10-15 m2 rain garden, with an average planting density of 9 plants/m².

When planting the plants, create groups of 3-7 plants from each species, then randomly arrange them, boldly combining colors. Make sure that the same groupings are repeated, which can achieve a more uniform, orderly, and less random appearance.

Use container plants that have a strong root system. For each plant, dig a hole twice as wide as the container and plant it at a depth so that the base of the plant is at the same level in the soil as it was in the container. After planting the plant, gently press the soil around the roots to prevent air pockets from forming. Water the plants immediately after planting, and then water our rain garden weekly to a depth of a few centimeters until the plants are well established.

After the first growing season, it is no longer necessary to water the plants, except in the case of prolonged drought. Spread a 6-8 cm thick soil cover mulch layer around the base of the plants, which can also increase the soil's water retention capacity. Any material that does not easily wash off the soil surface in case of water coverage can be used as mulch, for this purpose, mineral mulch (crushed stone, gravel) and hardwood mulch are the best.

6.2. 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 beautyberr

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 – silver scrolls

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

7. Maintenance instruction

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.

8. Annexes

Annex 1: Hydrology calculations

Annex 2: Visual Plans

Annex 3: Standard Designs

Annex 4: Bioretention

Annex 5: General section of the rain garden

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.

In the case of ditches to be created in gardens, rainwater from the roof, rainwater collected from internal sidewalks, terraces, and driveways can form part of the water catchment. These are to be taken into account with different multipliers and flow factors.

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

- from roof, pavement α = 0,9
- green area (due to mixed coverage) α = 0,4

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 and the runoff length is relatively short, 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 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 year, 50%	68,66	50,55	40,70	24,38
4 year, 25%	89,34	65,92	53,93	32,90
5 year, 20%	95,31	70,36	57,75	35,36
10 year, 10%	112,96	83,48	69,04	42,63
20 year, 5%	129,89	96,06	79,88	49,60
50 year, 2%	151,80	112,35	93,89	58,62
100 year, 1%-os	168,22	124,56	104,40	65,38

When sizing trenches 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 Wor.

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:

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

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

An accurate calculation can be made by knowing the catchment area. For the sake of simplicity, we used 80 m2 paved surface and 200 m2 green surface in our example. The amount of precipitation reaching the rain garden is based on these:

$\mathbf{Q_{10\%}}$ = (0,008*0,9 + 0,02*0,4) * 314,0 = 4,77 l/s = **0,00477 $\mathbf{m^3/s}$**

Within 10 minutes it results in a water volume of 0,00477*60*10 = **2,86 $\mathbf{m^3}$**

Based on the sample examples, we distinguish between two types of trenches:

- The small rain garden is built with a bottom width of 0.6 m and a depth of 0.18 m. The bending ratio is 1:2.5, so its total width is 1.5 m. Based on this, the capacity of the reservoir is 0.189 m2.

- The larger rain garden is built with a bottom width of 1.5 m and a depth of 0.30 m. Its bending ratio is also 1:2.5, so its total width is 3.0 m. Based on this, the capacity of the reservoir is 0.675 m2.

The reservoir capacity of the trenches:

- Small rain garden: 2,86 m^3 / 0,189 m^2 = 15,13 m
- Large rain garden 2,86 m^3 / 0,675 m^2 = 4,24 m

According to the calculations, the amount of precipitation collected from the surface in our example can be collected in the following two rain gardens:

- in a **1,5 m * 15,13 m**
- or a **3 m * 4,24 m** rain garden.

Based on the above calculation, knowing the size and covering of the surfaces within the plot, the sizing can be done easily and individually.


BEFORE


AFTER

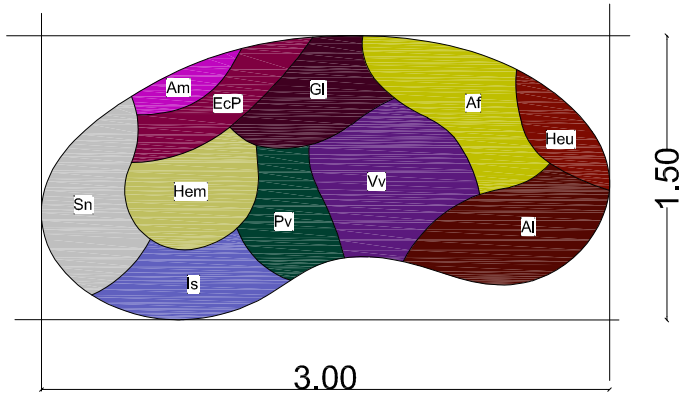

BEFORE


AFTER


BEFORE

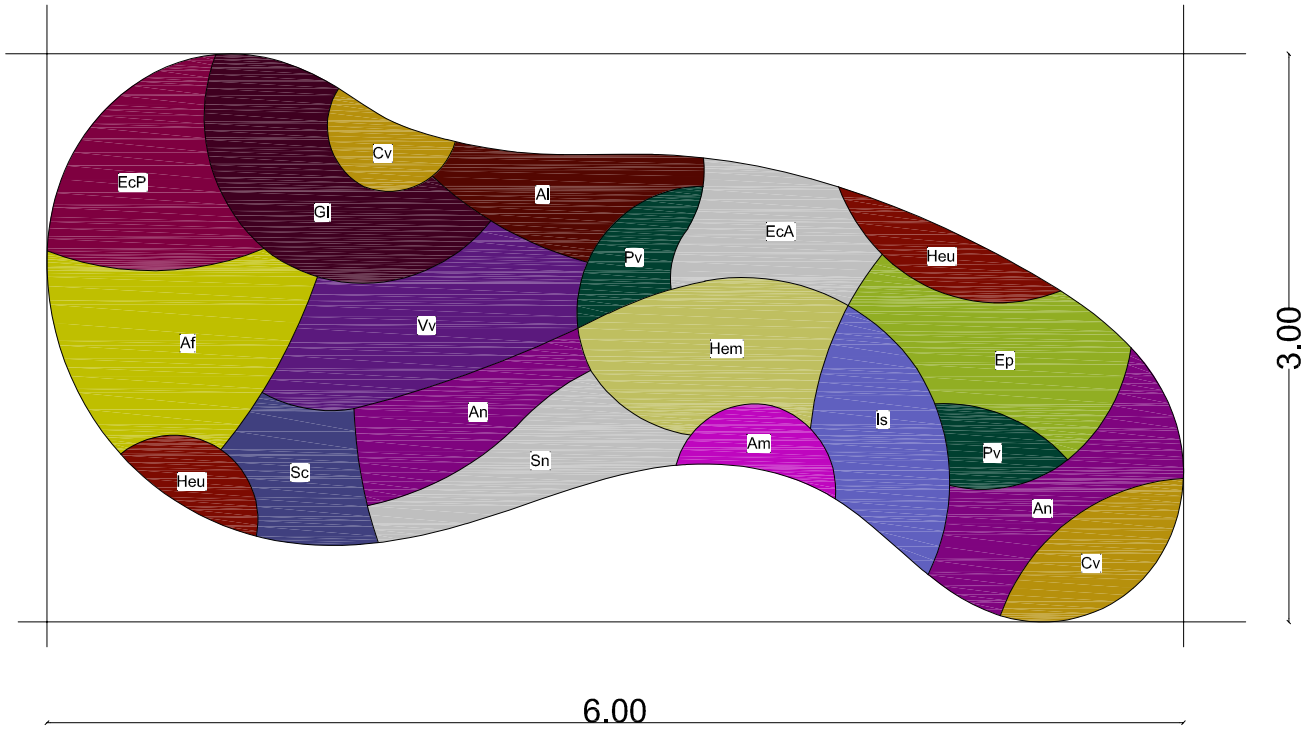

AFTER

Annex 3.1: In a sunny location, on loose, permeable soil



RAIN GARDEN PLANTING PLAN
In a sunny location, on loose, permeable soil

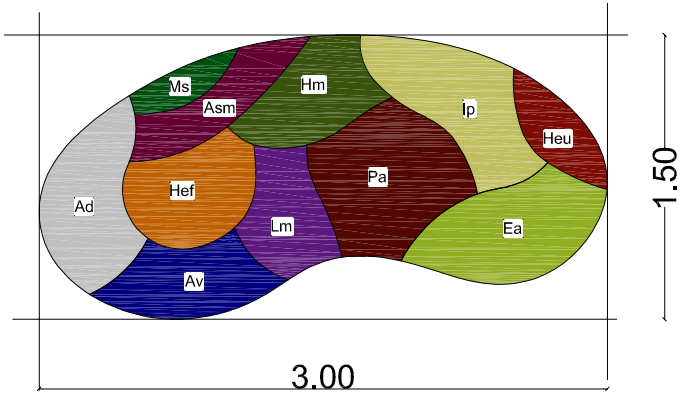
Af	Achillea filipendulina
Al	Anemanthele lessoniana
Am	Armeria maritima
EcP	Echinacea purpurea 'Pow Wow Wild Berry'
Gl	Gaura lindheimeri 'Gaudi Red'
Hem	Hemerocallis 'Cartwheels'
Heu	Heuchera 'Forever Red'
Is	Iris sibirica - szibériai nőszirom
Pv	Panicum virgatum 'Northwind'
Sn	Salvia nemorosa 'Sensation Compact White'
Vv	Veronicastrum virginicum 'Fascination'



RAIN GARDEN PLANTING PLAN
In a sunny location, on loose, permeable soil

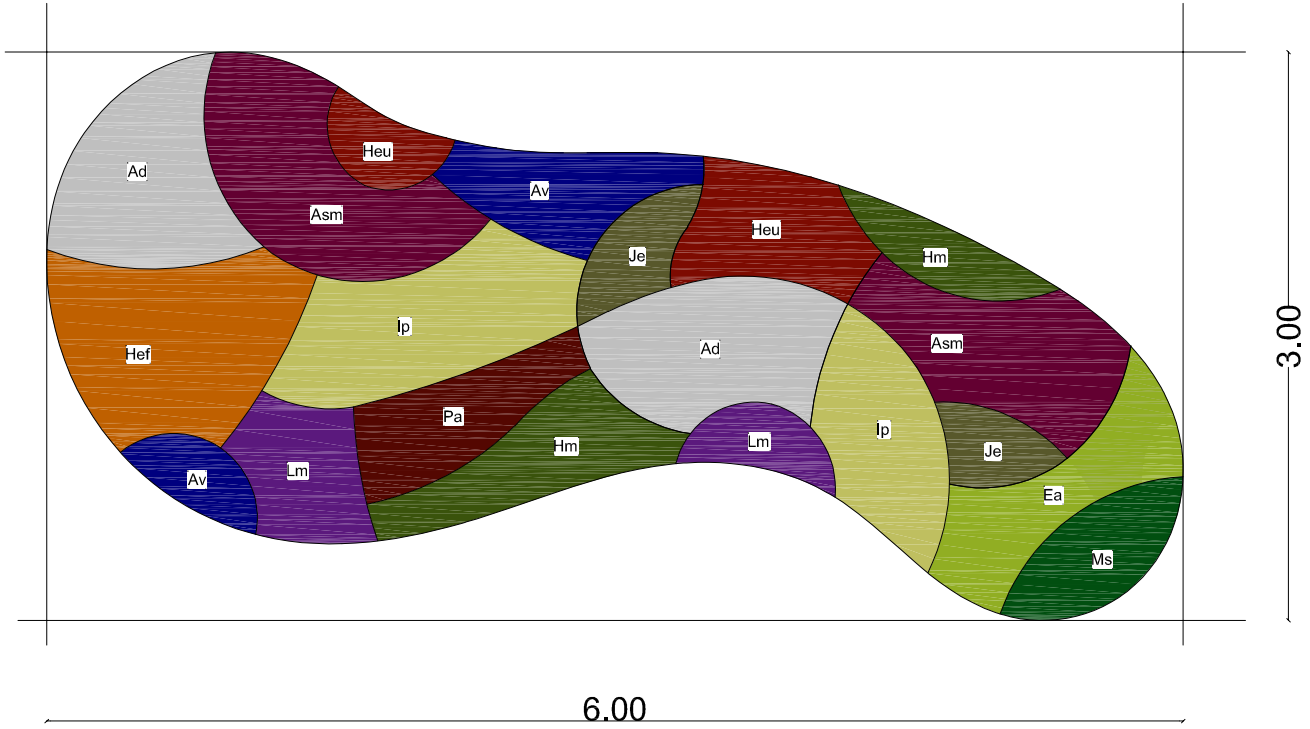
Af	Achillea filipendulina
Al	Anemanthele lessoniana
Am	Armeria maritima
An	Aster novae-angliae 'Alma Pötschke'
Cv	Coreopsis verticillata 'Moonbeam'
EcA	Echinacea purpurea 'Alba'
EcP	Echinacea purpurea 'Pow Wow Wild Berry'
Ep	Euphorbia palustris
Gl	Gaura lindheimeri 'Gaudi Red'
Hem	Hemerocallis 'Cartwheels'
Heu	Heuchera 'Forever Red'
Is	Iris sibirica
Pv	Panicum virgatum 'Northwind'
Sn	Salvia nemorosa 'Sensation Compact White'
Sc	Scabiosa columbaria 'Butterfly Blue'
Vv	Veronicastrum virginicum 'Fascination'

Annes 3.2: In case of semi-shaded to shaded location with loose, permeable soil



RAIN GARDEN PLANTING PLAN
In case of semi-shaded to shaded location with loose, permeable soil

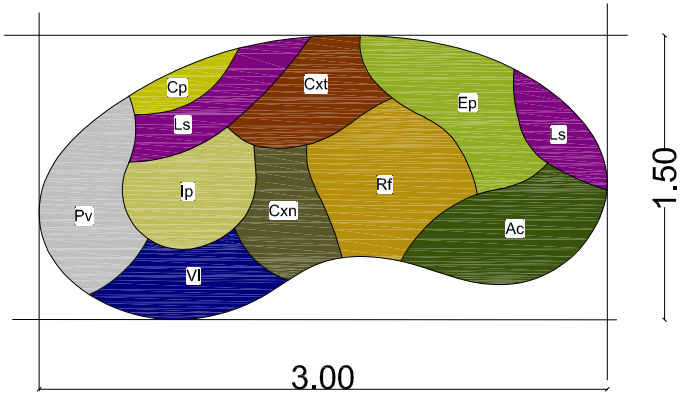
Av	Aquilegia vulgaris
Ad	Aster divaricatus 'Eastern Star'
Asm	Astrantia major 'Rubra'
Ea	Euphorbia amygdaloides 'Purpurea'
Hm	Hakonechloa macra 'Aureola'
Hef	Hemerocallis fulva
Heu	Heuchera 'Forever Red'
Ip	Iris pseudacorus
Lm	Liriope muscari 'Gold Band'
Ms	Matteuccia struthiopteris
Pa	Persicaria amplexicaulis 'Summerdance'



RAIN GARDEN PLANTING PLAN
In case of semi-shaded to shaded location with loose, permeable soil

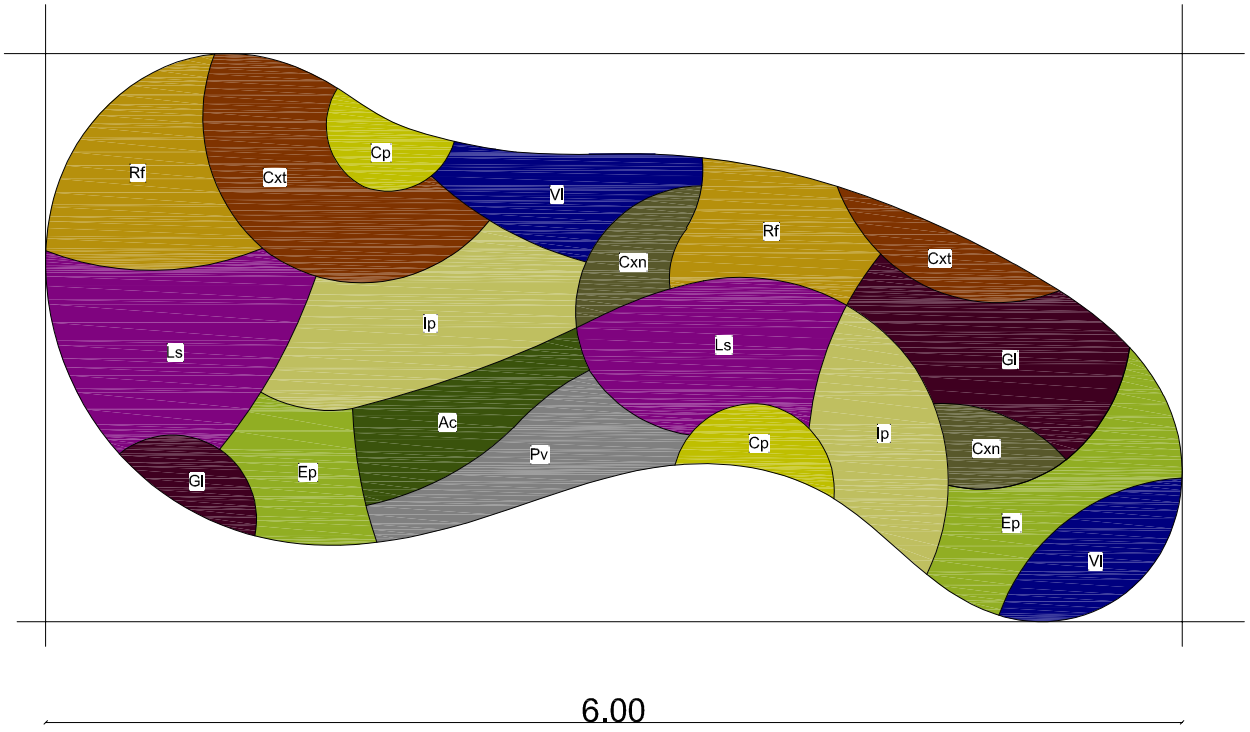
Av	Aquilegia vulgaris
Ad	Aster divaricatus 'Eastern Star'
Asm	Astrantia major 'Rubra'
Ea	Euphorbia amygdaloides 'Purpurea'
Hm	Hakonechloa macra 'Aureola'
Hef	Hemerocallis fulva
Heu	Heuchera 'Forever Red'
Ip	Iris pseudacorus
Je	Juncus ensifolius
Lm	Liriope muscari 'Gold Band'
Ms	Matteuccia struthiopteris
Pa	Persicaria amplexicaulis 'Summerdance'

Annex 3.3: In case of a sunny location and a compacted soil



RAIN GARDEN PLANTING PLAN
In case of a sunny location and a compacted soil

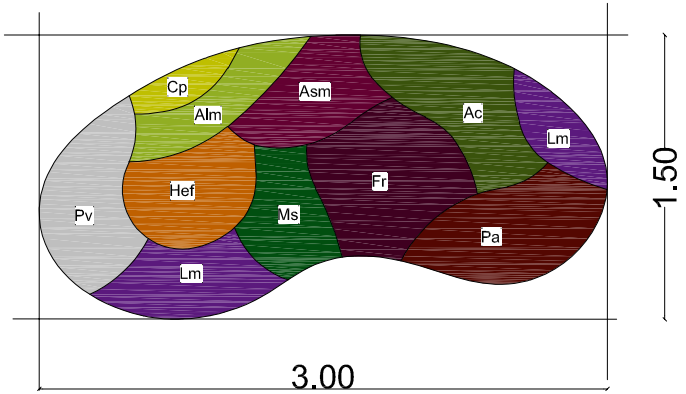
Ac	Acorus calamus 'Variegatus'
Cp	Caltha palustris
Cxn	Carex nigra
Cxt	Carex testacea 'Prairie Fire'
Ep	Euphorbia palustris
Ip	Iris pseudacorus
Ls	Lythrum salicaria 'Robert'
Pv	Physostegia virginiana 'Alba'
Rf	Rudbeckia fulgida 'Goldsturm'
Vl	Veronica longifolia 'Blue Indigo'



RAIN GARDEN PLANTING PLAN
In case of a sunny location and a compacted soil

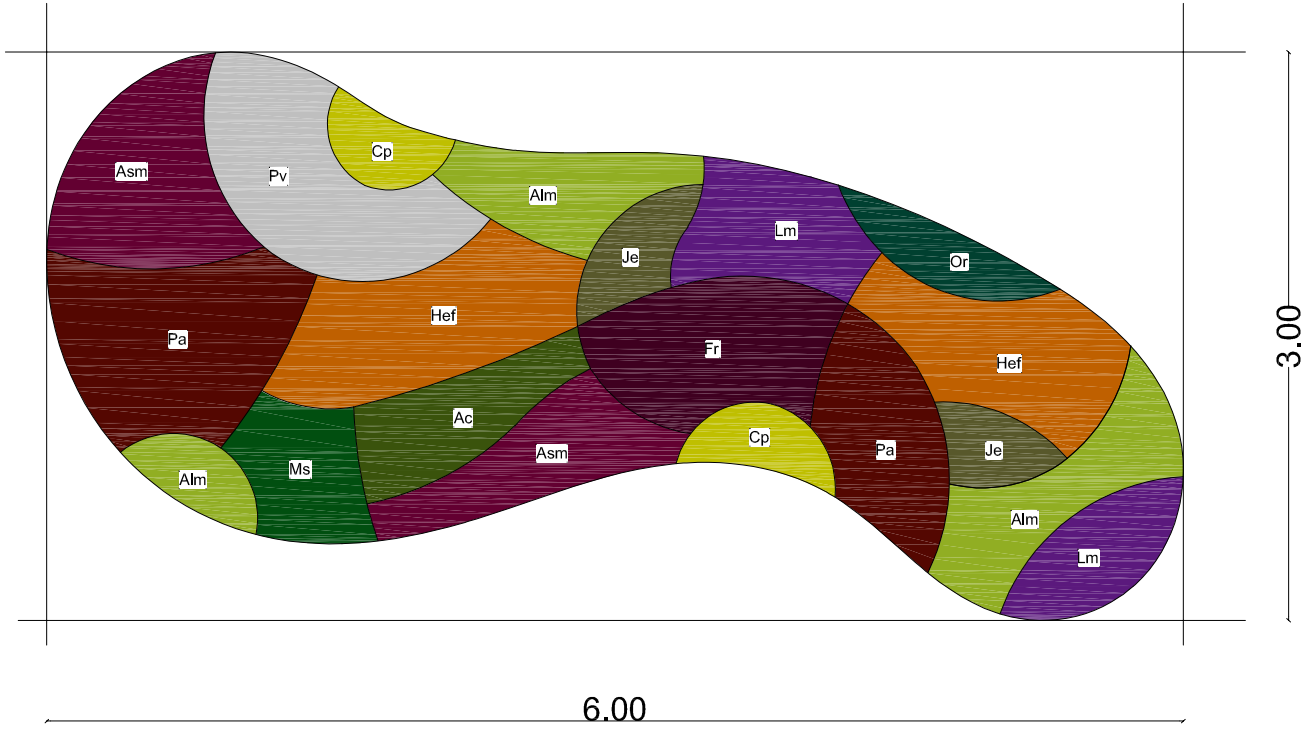
Ac	Acorus calamus 'Variegata'
Cp	Caltha palustris
Cxn	Carex nigra
Cxt	Carex testacea 'Prairie Fire'
Ep	Euphorbia palustris
Gl	Gaura lindheimeri 'Gaudi Rose'
Ip	Iris pseudacorus
Ls	Lythrum salicaria 'Robert'
Pv	Physostegia virginiana 'Alba'
Rf	Rudbeckia fulgida 'Goldsturm'
Vl	Veronica longifolia 'Blue Indigo'

Annex 3.4: In a partially shaded to shaded location with a compact soil



RAIN GARDEN PLANTING PLAN
In a partially shaded to shaded location with a compact soil

Ac	Acorus calamus 'Variegatus'
Alm	Alchemilla mollis
Asm	Astrantia major 'Rubra'
Cp	Caltha palustris
Fr	Filipendula rubra 'Venusta'
Hef	Hemerocallis fulva
Lm	Liriope muscari 'Gold Band'
Ms	Matteuccia struthiopteris
Pa	Persicaria amplexicaulis 'Summerdance'
Pv	Physostegia virginiana 'Alba'



RAIN GARDEN PLANTING PLAN
In a partially shaded to shaded location with a compact soil

Ac	Acorus calamus 'Variegatus'
Alm	Alchemilla mollis
Asm	Astrantia major 'Rubra'
Cp	Caltha palustris
Fr	Filipendula rubra 'Venusta'
Hef	Hemerocallis fulva
Je	Juncus ensifolius
Lm	Liriope muscari 'Gold Band'
Ms	Matteuccia struthiopteris
Or	Osmunda regalis
Pa	Persicaria amplexicaulis 'Summerdance'
Pv	Physostegia virginiana 'Alba'

Semi-Arid Green Infrastructure Toolbox

Bioretention in the right-of-way

What is bioretention?

Bioretention includes a family of practices that treat stormwater naturally by filtering runoff through vegetation and soil before it either recharges groundwater through deep infiltration or is discharged to a surface drainage system such as culverts or ditches. Bioretention systems typically include an overflow device to bypass runoff volumes larger than the storage capacity of the practice to prevent ponding and scour of the bioretention surface.

Transportation rights of way provide a number of areas where bioretention practices can be implemented to manage stormwater runoff originating from the paved travel lanes, adjacent parking spaces and roadside sidewalks. Placing bioretention in the right-of-way (ROW) may preserve adjacent open lands which would otherwise need to be dedicated to stormwater management. Specific locations/settings where bioretention can be incorporated into the roadway right of way include:

- Medians and traffic islands
- Curb "bump-outs" and back of curb bioretention beds
- Tree trenches located at the back of curb

Benefits

- Bioretention practices provide a number of benefits in a roadway setting including:
  - Create inviting and pleasant streetscapes
  - Reducing downstream flooding
  - Recharging groundwater
  - Improving water and air quality
  - Reduce heat island effect

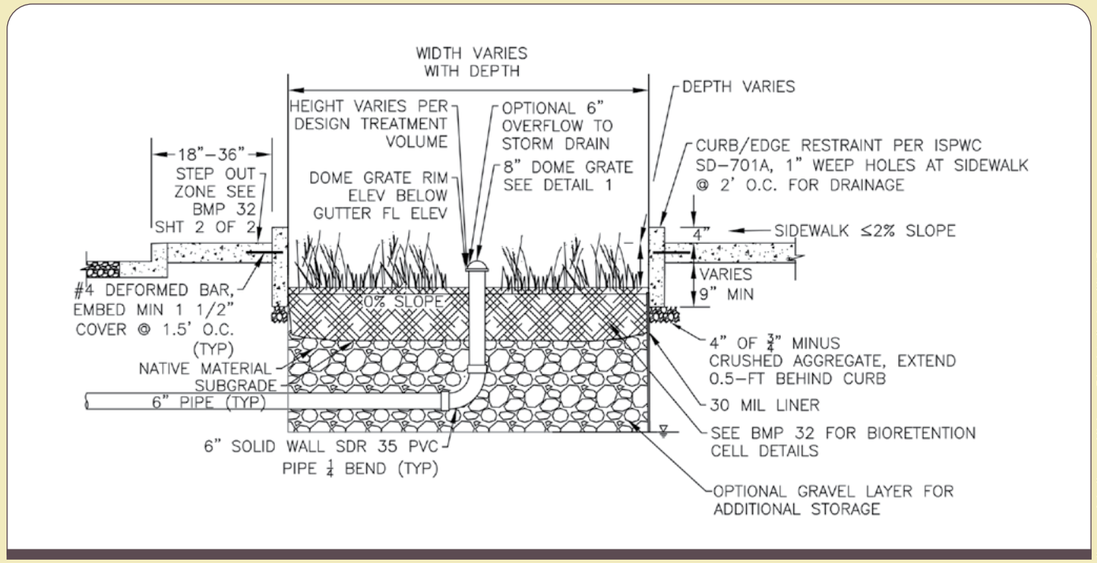
from pavement and buildings

Siting and Design considerations

- Bioretention practices should be placed adjacent to and downslope of impervious surfaces. In roadway settings this is often in traffic medians and outside of the roadway edge. Consideration should be made for placement over underground utilities. If existing soils exhibit limited permeability (typically less than 0.5 inches/hr.) an underdrain must be connected to a downstream drainage system or outlet. Care should be taken to avoid selecting sites that receive significant sediment load or are downstream of eroding areas.

Maintenance requirements

- Like all infrastructure bioretention practices require regular maintenance to perform as designed. Specific maintenance tasks include:
  - Regularly clearing out debris from inlets and outlets
  - Inspecting for long term ponding (evidence of practice failure)
  - Replacement of wood/rock mulch and dead vegetation
  - Avoiding placing snow piles which can cause compaction



Source: Ada County Highway District, Garden City, ID.

Planter Box configuration of a bioretention system exhibiting 6 in. vertical curb with openings and adjacent sidewalk. Note that an underdrain system is required if existing soil is low permeability.

Source: Watershed Management Group , Tucson , AZ

Shallow bioretention in a verge using flat curb. Runoff from the street flows directly into the bioretention area.

Source: Virginia DOT

Bioretention placed within a vegetated median on a highway. This configuration requires that a portion of the roadway be sloped toward a depressed median.

Source: University of New Hampshire Stormwater Center

Bioretention may be integrated in the ROW in many forms. This low cost tree trench retrofit consists of a section of RCP culvert in which a streetside tree is planted in a soil media. Roadway runoff is routed into the tree trench where it infiltrates to provide water to the tree.

Plants well-suited to bioretention projects in the northern plains:

Alder-leaved serviceberry
Amelanchier alnifolia 'Regent'

Snowberry
Symphoricarpos albus

Tatarian dogwood
Cornus alba 'Argenteo-marginata'

Prunus virginiana
Choke Cherry

Rocky Mountain juniper
Juniperus scopulorum

Silver buffaloberry
Shepherdia argentea

Sand cherry
Prunus besseyi 'Pawnee Buttes'

Schizachyrium scoparium
Smoke Signal

Calamagrostis acutiflora
Karl Foerster

Semi-Arid Green Infrastructure Toolbox

Bioretention in the right-of-way

How to plan, implement, and maintain bioretention in the ROW

Planning and Design: Design guidance and criteria for bioretention in the ROW varies from one community to another due to variations on climate, soils, vegetation, and local street design standards. Generally bioretention is designed to capture and treat the runoff from a specific rainfall depth. A common precipitation depth is 1 inch. There are a variety of design manuals and sizing tools/calculations which may be appropriate for your site. Refer to guidance provided by available municipal design manuals such as those provided by Mile High Flood District for more guidance on bioretention sizing, material selection, and dimensions. In areas in which stakeholders are not well versed in low impact development it may be beneficial to implement a public education program including public meetings or informational signs where practices are installed to provide information on how bioretention functions.

Maintenance: Maintenance of bioretention within the right of way requires additional consideration related to transportation and roadway maintenance activities. For example where snowplows are used regularly they may push snow to the roadway edge. Bioretention media is susceptible to compaction from piled snow which can significantly reduce its permeability leading to ponded water and structural failure. Other considerations include: planning for maintenance activities which don't block traffic, ensuring a supply of materials and vegetation stock/seed, and setting up a regular inspection and maintenance schedule.

Design Criteria:		
	Maximum contributing area	1 Acre typically *
	Maximum ponding depth	12 inches
	Filter media	Engineered soil media specific to bioretention, see applicable state or local specification
	Media depth	2 feet or more depending on pollutants of concern and vegetation rooting needs
	Underdrain system	Required if existing soils won't drain ponding within 6 hours
	Gravel layer	Washed #57 or similar typically 6-12 inch depth or more if additional runoff storage desired
	Bypass	Can be accomplished with an overflow riser attached to the underdrain or designing the system so that when it is full, excess will run off

**Bioretention in the ROW is typically much smaller*

Vegetation selection: Vegetation in bioretention areas undergo significant stress including periods of inundation and generally dry conditions between precipitation events. As a result native species which thrive in similar conditions are often used. The use of non-native plants is generally avoided due to concerns about colonization and potential displacement of native species in surrounding areas. Vegetation placed in bioretention in the right of way should consider the impact on vehicular sight lines, pedestrian safety, and frequency of maintenance required.

Do		Don't	
Limit contributing drainage to 1 acre or less ☑	Consider alternative, preferably native, plant species to replace those which do not thrive ☑	Install in areas where temporary ponding could cause negatively impact adjacent structures and subgrade integrity ☒	Disturb or otherwise expose upstream drainage area to easily erodible materials ☒
Regularly inspect for loss of integrity of structural components ☑	Trim and remove vegetation to retain vehicular sight lines and storage capacity ☑	Install over top of critical underground infrastructure ☒	Allow or promote regular pedestrian access to vegetated area ☒
Remove trash and debris at inlets and outlets after every precipitation event to prevent clogging ☑	Replace mulch layer annually ☑	Install without evaluating existing soil infiltration/permeability ☒	Fail to remove collected sediment which collects on top of mulch layer ☒
Remove and replace dead or dying vegetation ☑	Provide irrigation to vegetation during establishment and if necessary for the life of the practice ☑	Install in areas with shallow groundwater levels (typically at least 2 feet below bottom of underdrain or soil media) ☒	Place plowed snow on bioretention surface ☒

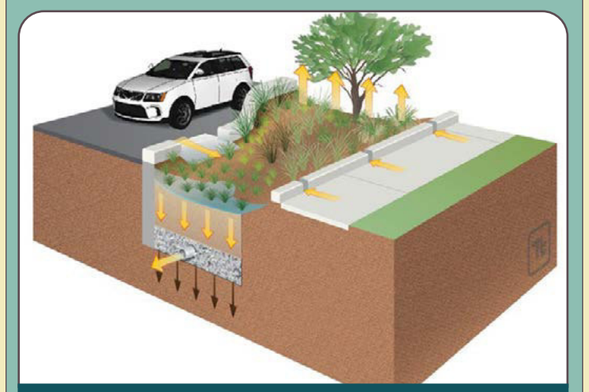
Additional examples of bioretention in the ROW:

Source: Watershed Management Group

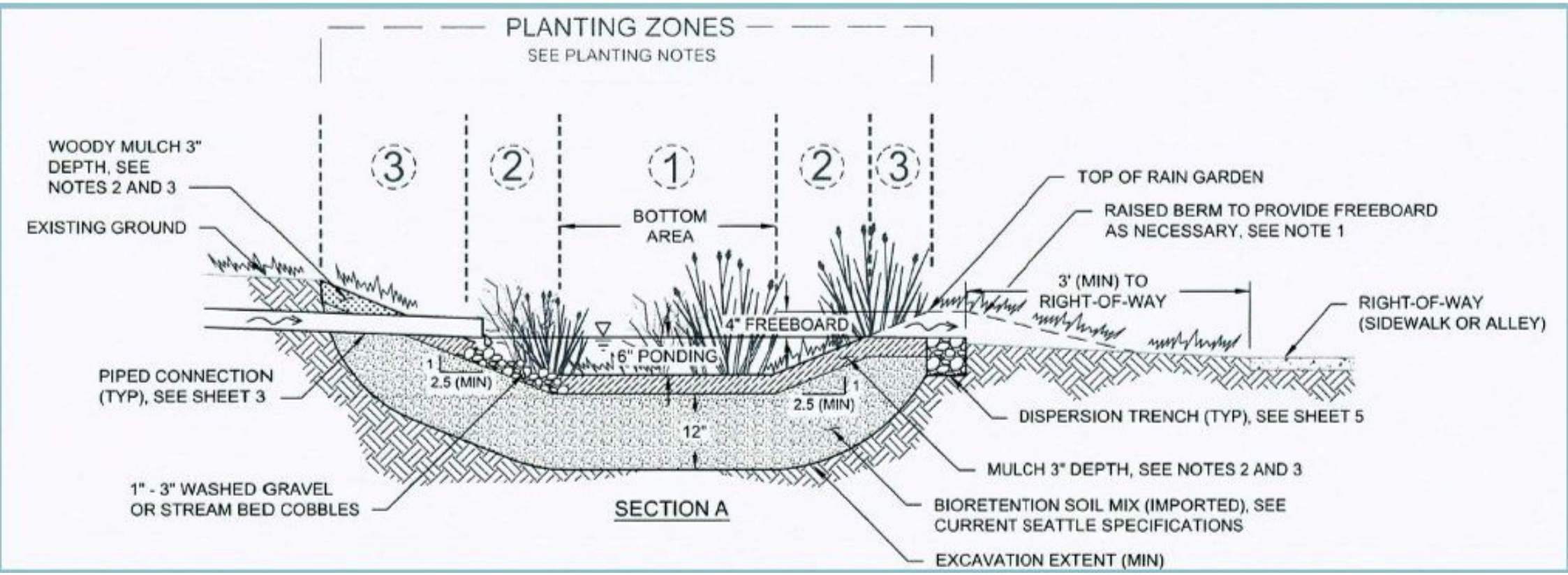
Where vertical curbs are needed curb openings or cuts can be implemented to allow runoff to flow into bioretention systems

Covered curb cut flumes can be used where sidewalks are adjacent to roadway

In arid areas stone may be used as surface cover in lieu of mulch



Planter box/tree trench schematic including an underdrain


PLANTING ZONES
SEE PLANTING NOTES
3
2
1
2
3
WOODY MULCH 3" DEPTH, SEE NOTES 2 AND 3
EXISTING GROUND
BOTTOM AREA
TOP OF RAIN GARDEN
RAISED BERM TO PROVIDE FREEBOARD AS NECESSARY, SEE NOTE 1
3' (MIN) TO RIGHT-OF-WAY
RIGHT-OF-WAY (SIDEWALK OR ALLEY)
4" FREEBOARD
6" PONDING
PIPED CONNECTION (TYP), SEE SHEET 3
1
2.5 (MIN)
1
2.5 (MIN)
12"
DISPERSION TRENCH (TYP), SEE SHEET 5
MULCH 3" DEPTH, SEE NOTES 2 AND 3
1" - 3" WASHED GRAVEL OR STREAM BED COBBLES
SECTION A
BIORETENTION SOIL MIX (IMPORTED), SEE CURRENT SEATTLE SPECIFICATIONS
EXCAVATION EXTENT (MIN)