Stormwater fees: One of the many possibilities in the water sector which can be improved with digital tools

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Stormwater

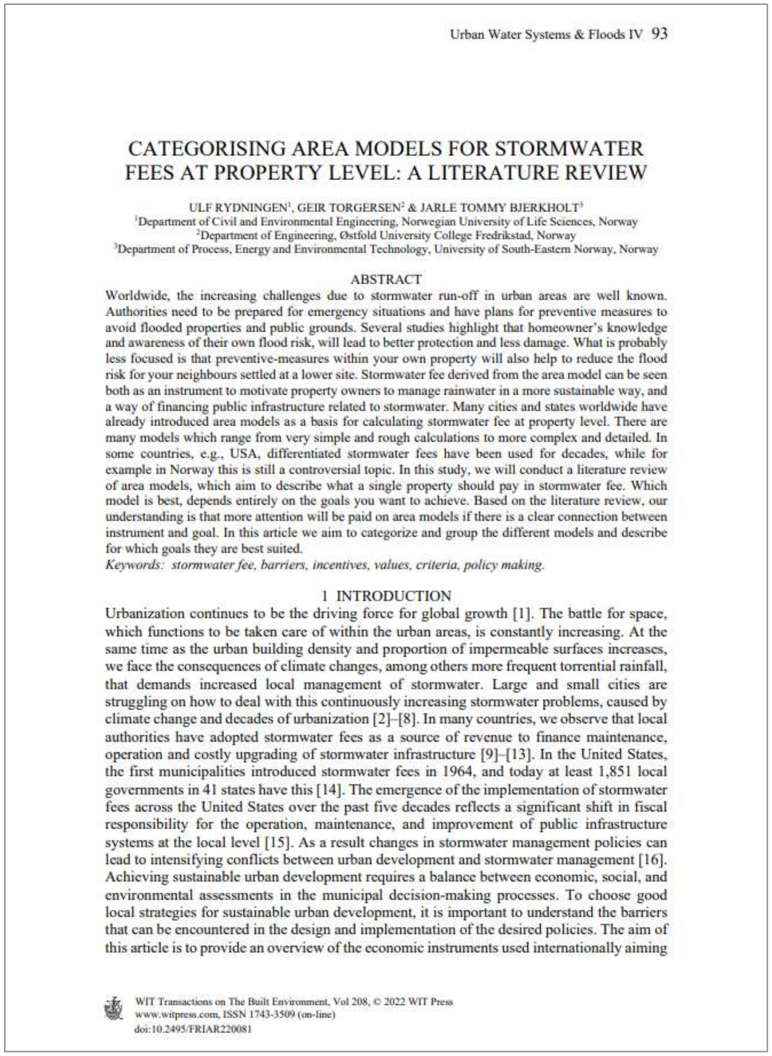
- Stormwater is water that originates from precipitation and meltwater from hail and snow
- Stormwater can soak into the soil (infiltrate) and become groundwater, be stored on depressed land surface in ponds, and puddles, and evaporate back into the atmosphere, or contribute to surface runoff

Stormwater fee models (literature review 2022)

Fee models	Purpose of the stormwater fee models					Criteria for calculation				
	Economic goals		Environmental goals			Property			Hydrology/ stormw. vol.	
	Financing	Incentive – reduced fee	Reuse stormwater	Prevent floods	Prevent pollution	Total area	Impervious area	Stormwater runoff	SUDS measures	Terrain slope/ hydrolog. proc.
1 Equivalent residential unit [10], [11], [13], [14], [26], [27], [29], [38], [42]	x			x		x	x	x		
2 Residential equivalent factor [10], [14], [29]	x			x		x	x	x		x
3 Gross property area [31], [35]	x			x		x				
4 Distributed transportation alternative [10], [13]	x			x				x		
5 Hydrologic alternative [10], [11], [36]	x	x		x		x	x	x		x
6 Incentive scheme [4], [9]–[13], [25], [32], [35], [37], [43], [44]	x	x		x	x				x	
7 Intensity of development [31], [35]	x			x		x	(x)			
8 Tier fee [24], [29]	x			x		x	x			
9 Flat fee [11], [24], [28], [29], [31], [32], [39], [45]	x			x		x		(x)		
10 Dual fee [24], [29]	x			x		x	x			
11 Water usage fee [13], [24], [29], [31], [36]	x	x	x	x						
12 Cap and trade [9], [15], [46]	x	x		x				(x)		
13 Offset program [4], [9], [12], [29], [34], [47], [48]	x	x		x						
14 Pigouvian instrument [9], [11], [15]	x	x	x	x	x					
15 Command and control [9], [15], [41], [46], [49], [50]	x	x		x				x		
16 Ad valorem tax [27], [32]	x			x		(x)				

Stomwater fees

- There exists many stormwater fee models, but none of them are really comprehensive
- There is often a lack of available, reliable, low-cost, local data to construct a comprehensive mathematical model for stormwater fee calculations
- One should take several factors into account - i.e. combine them - and the best way to do that is to use a modeling program that includes several of the relevant models - but it has not yet been done – therefore there is a great potential to develop one….



Urban Water Systems & Floods IV 93

CATEGORISING AREA MODELS FOR STORMWATER FEES AT PROPERTY LEVEL: A LITERATURE REVIEW

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ABSTRACT

Worldwide, the increasing challenges due to stormwater run-off in urban areas are well known. Authorities need to be prepared for emergency situations and have plans for preventive measures to avoid flooded properties and public grounds. Several studies highlight that homeowner's knowledge and awareness of their own flood risk, will lead to better protection and less damage. What is probably less focused is that preventive-measures within your own property will also help to reduce the flood risk for your neighbours settled at a lower site. Stormwater fee derived from the area model can be seen both as an instrument to motivate property owners to manage rainwater in a more sustainable way, and a way of financing public infrastructure related to stormwater. Many cities and states worldwide have already introduced area models as a basis for calculating stormwater fee at property level. There are many models which range from very simple and rough calculations to more complex and detailed. In some countries, e.g., USA, differentiated stormwater fees have been used for decades, while for example in Norway this is still a controversial topic. In this study, we will conduct a literature review of area models, which aim to describe what a single property should pay in stormwater fee. Which model is best, depends entirely on the goals you want to achieve. Based on the literature review, our understanding is that more attention will be paid on area models if there is a clear connection between instrument and goal. In this article we aim to categorize and group the different models and describe for which goals they are best suited.
Keywords: stormwater fee, barriers, incentives, values, criteria, policy making.

1 INTRODUCTION

Urbanization continues to be the driving force for global growth [1]. The battle for space, which functions to be taken care of within the urban areas, is constantly increasing. At the same time as the urban building density and proportion of impermeable surfaces increases, we face the consequences of climate changes, among others more frequent torrential rainfall, that demands increased local management of stormwater. Large and small cities are struggling on how to deal with this continuously increasing stormwater problems, caused by climate change and decades of urbanization [2]–[8]. In many countries, we observe that local authorities have adopted stormwater fees as a source of revenue to finance maintenance, operation and costly upgrading of stormwater infrastructure [9]–[13]. In the United States, the first municipalities introduced stormwater fees in 1964, and today at least 1,851 local governments in 41 states have this [14]. The emergence of the implementation of stormwater fees across the United States over the past five decades reflects a significant shift in fiscal responsibility for the operation, maintenance, and improvement of public infrastructure systems at the local level [15]. As a result changes in stormwater management policies can lead to intensifying conflicts between urban development and stormwater management [16]. Achieving sustainable urban development requires a balance between economic, social, and environmental assessments in the municipal decision-making processes. To choose good local strategies for sustainable urban development, it is important to understand the barriers that can be encountered in the design and implementation of the desired policies. The aim of this article is to provide an overview of the economic instruments used internationally aiming

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Municipal water/wastewater fees in Norway

Figure: Mechanical houshold water meter

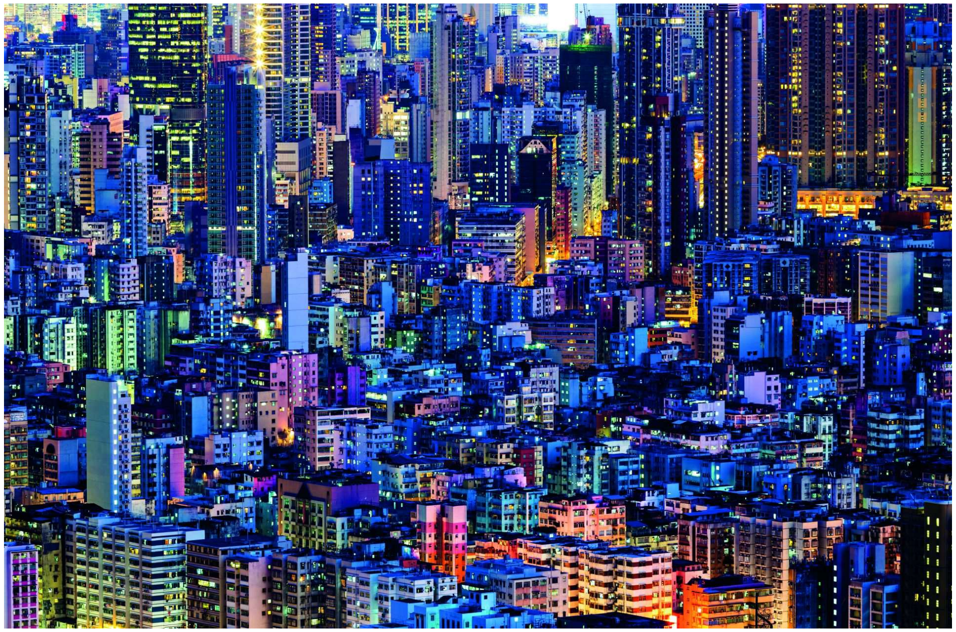
Figure: Digital household water meter

Figure: An electromagnetic instrument that converts the amount of water from a sensor

Figure: Zonal water meter

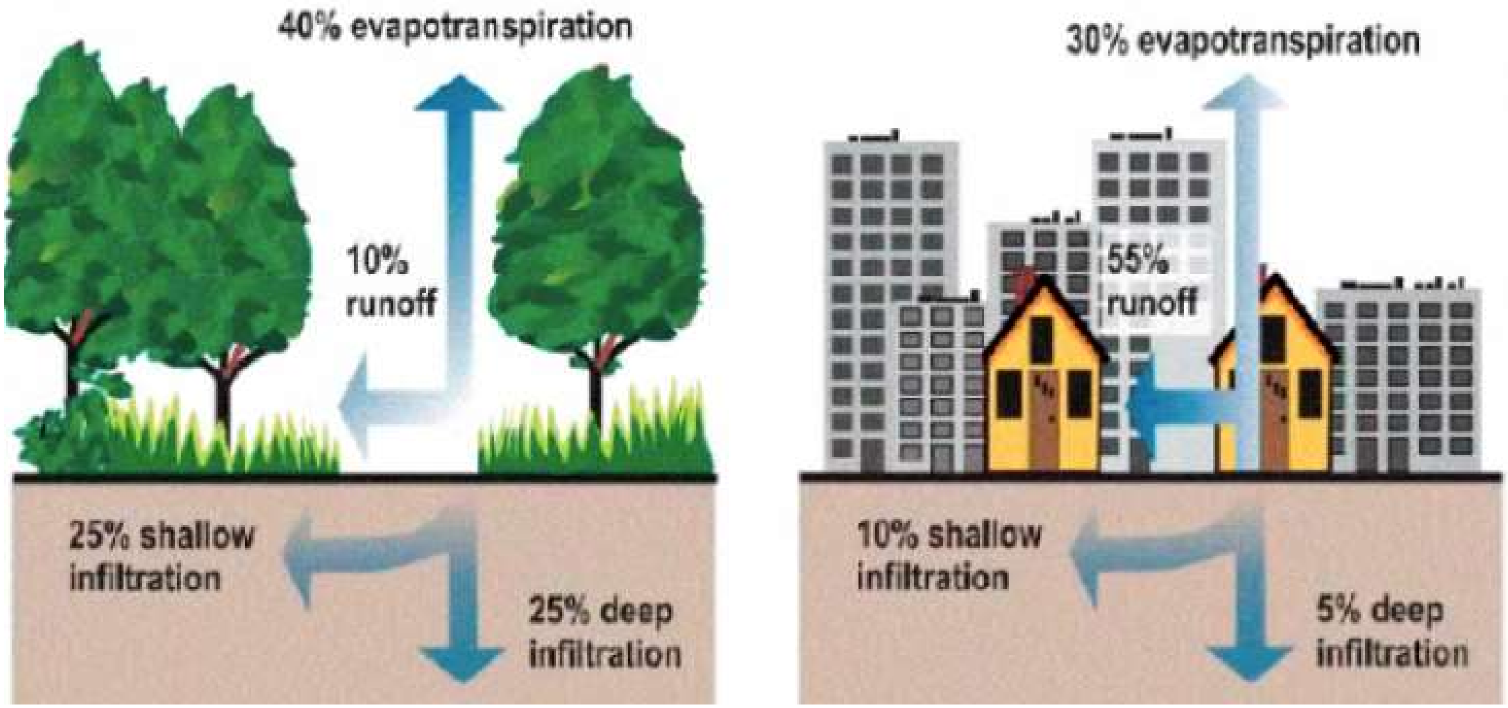
- Municipal wastewater fees set by the municipal authorities are in accordance with full cost regulations (the municipality's total costs; construction costs, operation and maintenance costs)
- Water- and wastewater fees: The charge is either based on stipulated consumption or on **actual consumption**
- The Municipality's **stormwater infrastructure costs** in either covered by;
  - separate stormwater fees
  - as part of municipal street infrastructure construction costs
  - as part of the wastewater fees, or
  - partly included in the construction costs for company buildings, or
  - as a municipal council's additional allocations to new stormwater infrastructure

Basic problems - Urbanization affects the hydrological cycle



- Growing urbanization is a process whereby populations move from rural to urban areas, enabling cities and towns to grow
- Urbanization is on the rise all over the globe. More than half of the world's population now live in urban areas — increasingly in highly-dense cities. By 2050, urbanization could add another 2.5 billion people to urban areas (≈70%)

Basic problems - Urbanization affects the hydrological cycle



Impervious surfaces replace natural land cover. Urbanization results in increased runoff rates and volumes, and losses of infiltration. The creation of impervious areas results in much faster runoff response, leading to shorter time to concentration and reduces recession times

Basic problems – climate change

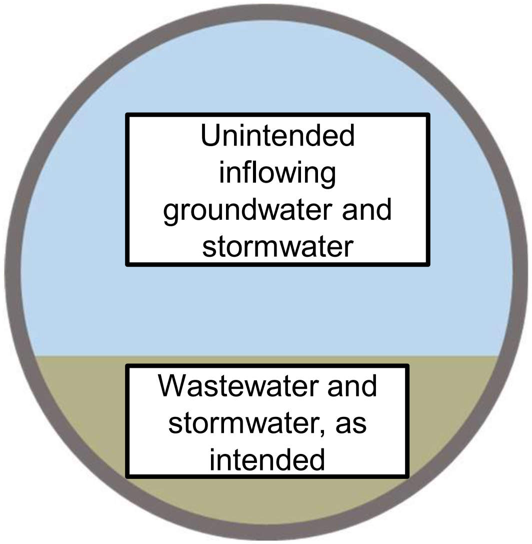
- Extreme precipitation is expected to intensify with global warming over large parts of the globe
- Changes will also be found in observed annual maximum flows
- Consequences: Increased flooding in streets due to a lack of capacity for runoff stormwater in stormwater pipes, and less ability to infiltrate through the ground

Photo: Copenhagen flooding 2.july 2011

Photo: Southwestern Romania was hit by severe flooding in june 2014

The need for separate stormwater fees

Photo: The wastewater pipe system is in bad shape, the capacity is deminishing



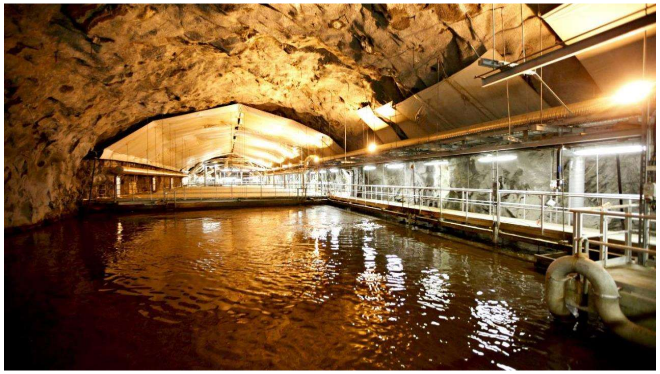
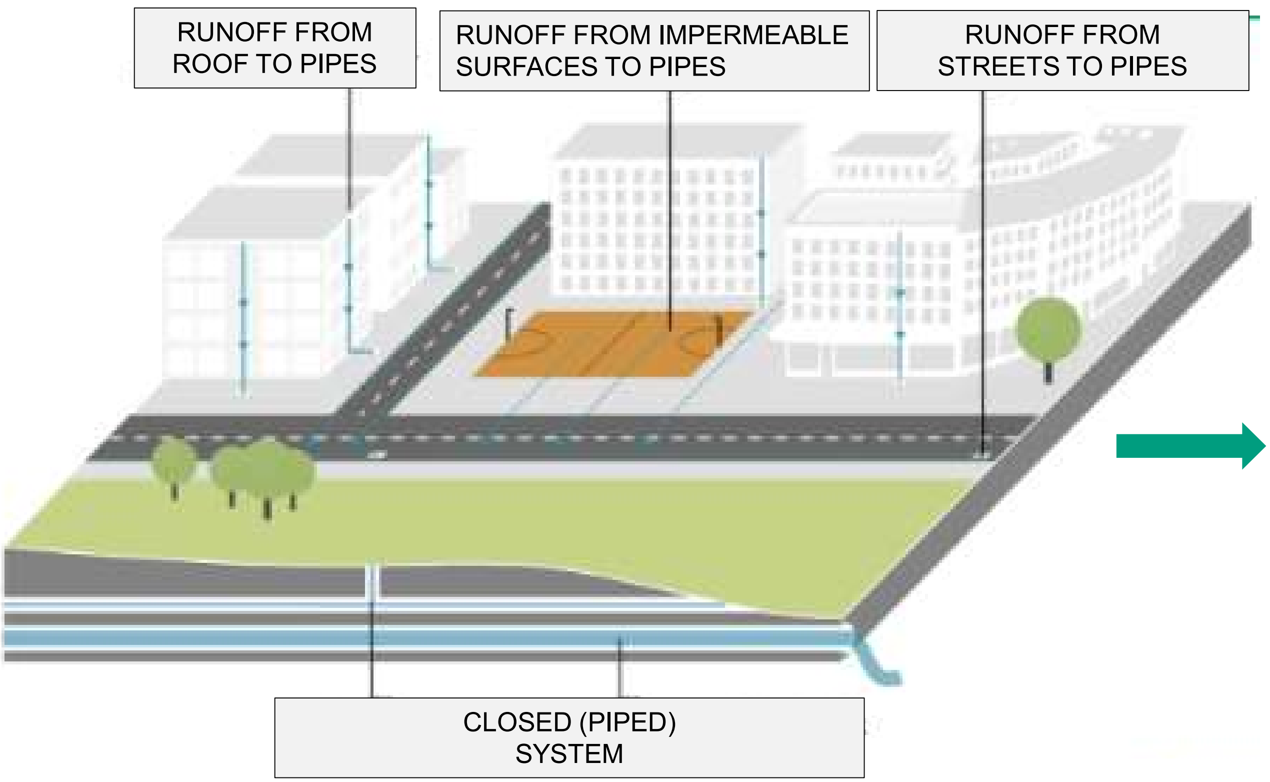


Photo: Increased costs to wastewater treatment, Challenges related to variations in hydraulic load, water quality and water temperature

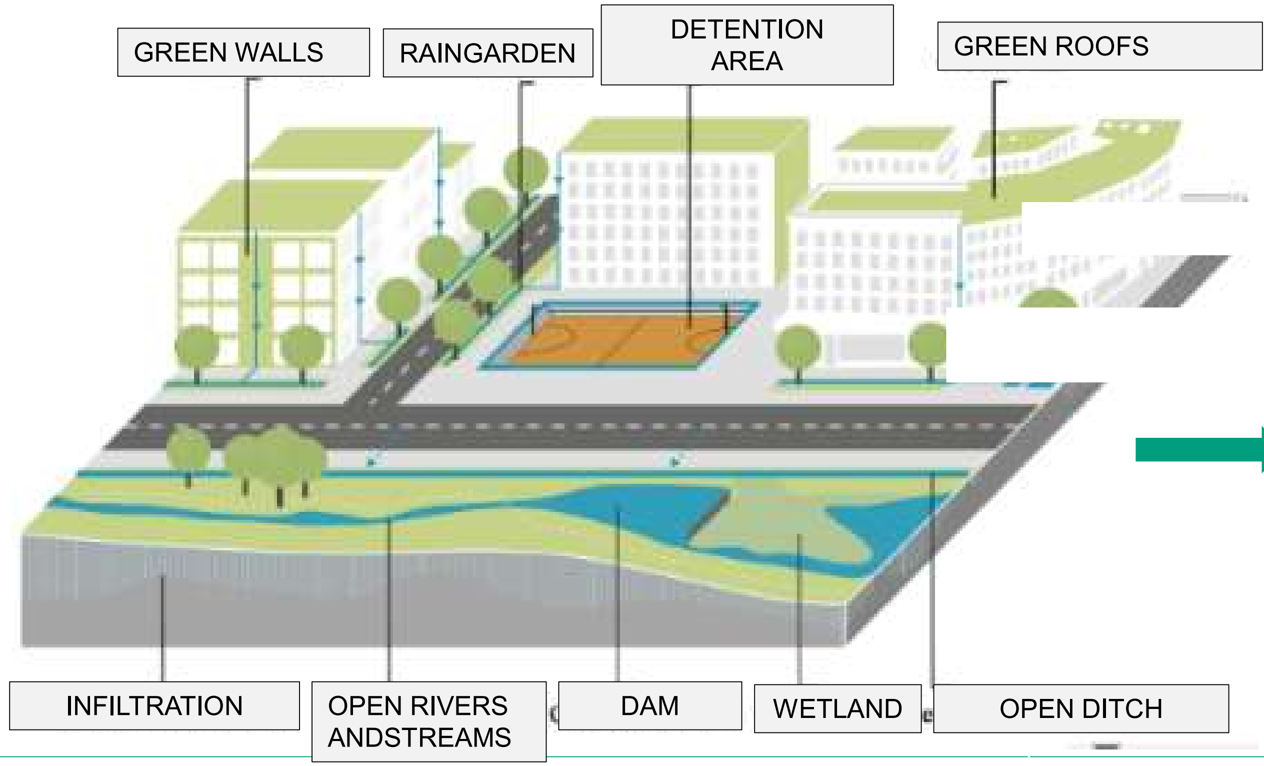
- Norway's municipal water and sewage network needs a major overhaul in the next two decades. The estimated cost of the upgrades amounts to 332 billion kroner (28.2 billion Euro)
- Inflow of stormwater and infiltration of groundwater into sewers is a constant operational challenge and can add considerable cost to water utilities in pumping, wastewater treating, and discharging excess water

A paradigm shift in stormwater management



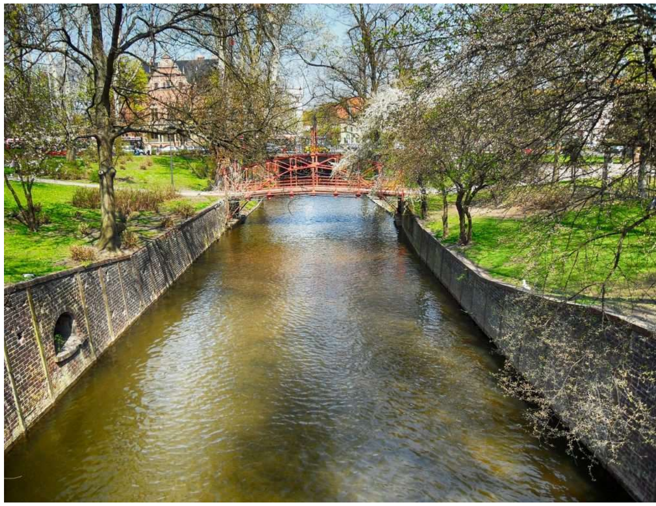
Traditional stormwater management

A paradigm shift in stormwater management



Sustainable, climate adapted stormwater management

«learn from the nature»



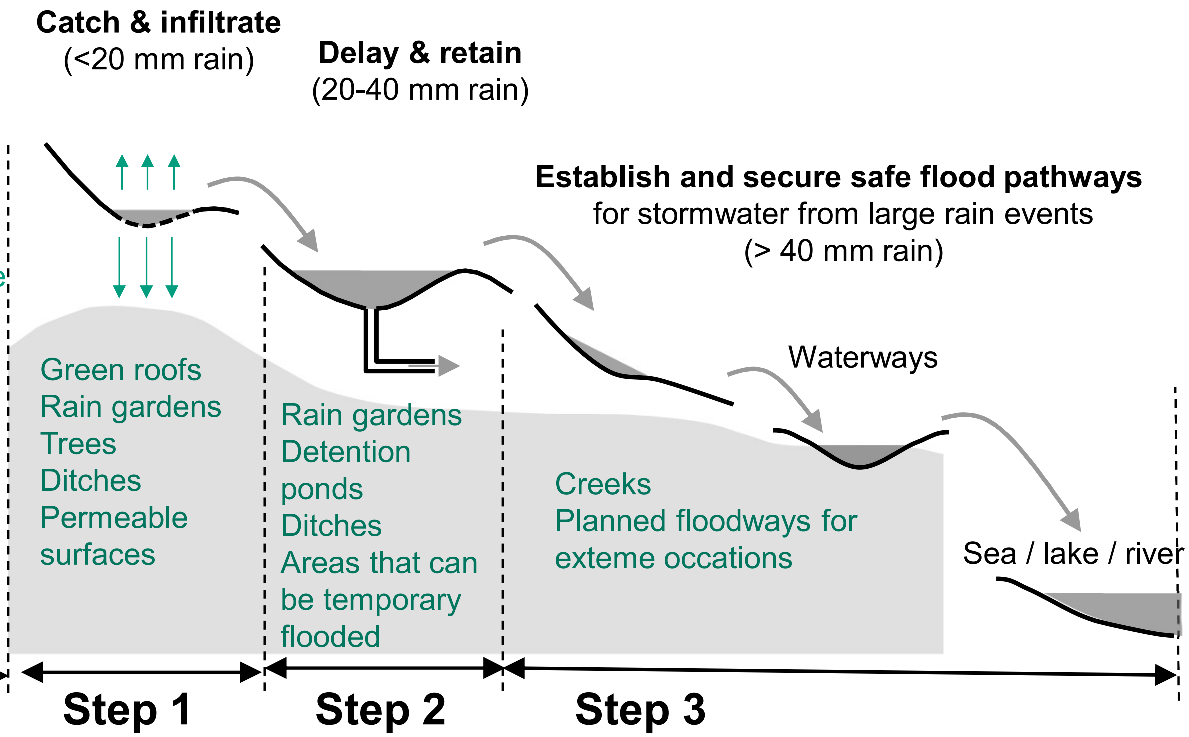
Local recipient

A paradigm shift – «learn from the nature» (biomimics)

The Norwegian strategy for stormwater management

Municipal land use and urban planning

- Location desicions (which areas can be developed, and which should be preserved)
- Blue-green area factor
- Planning regulations
  - floor area ratio,
  - minimum green area ratio
- Stormwater fee
- Requirements for mandatory green roofs in the city center for new constructions or building rehabilitations

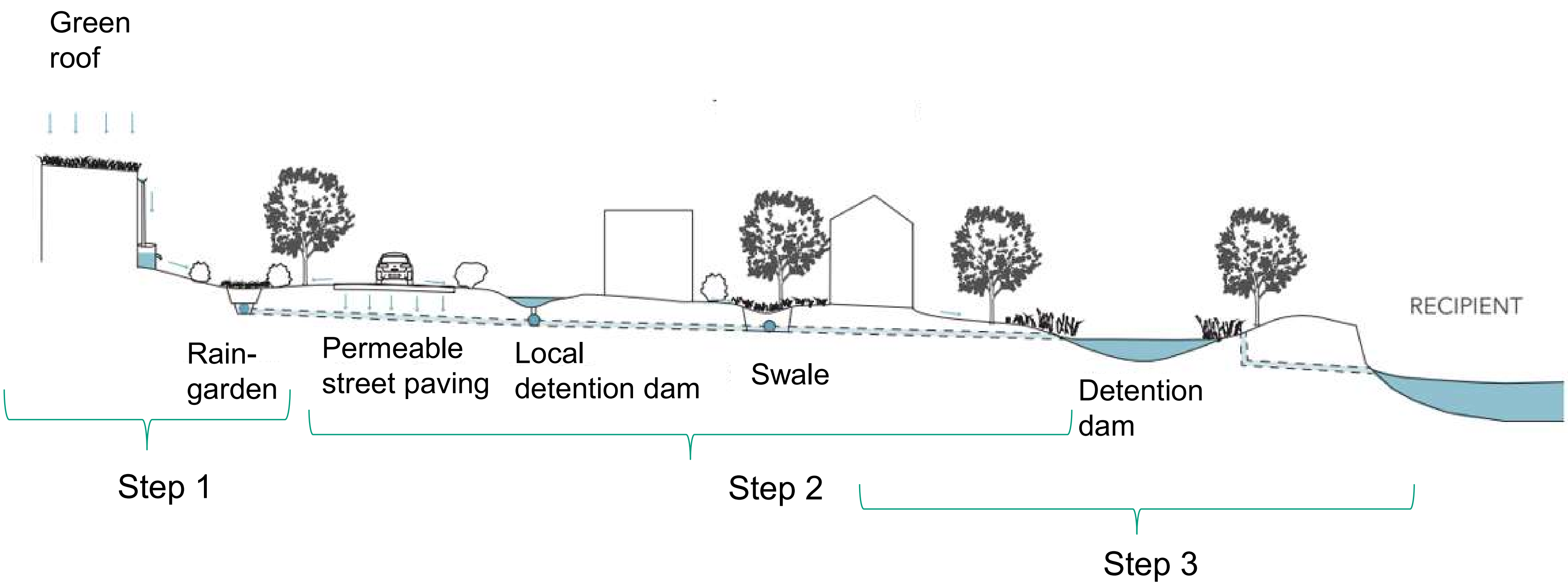


Geographical level:	**Municipality**	**Individual properties**	**An urban / dwelling district**	**Catchment / runoff area to the resipient**

Step 1 measures – e.g. raingardens

Step 2 measures - Temporary retention of storm water

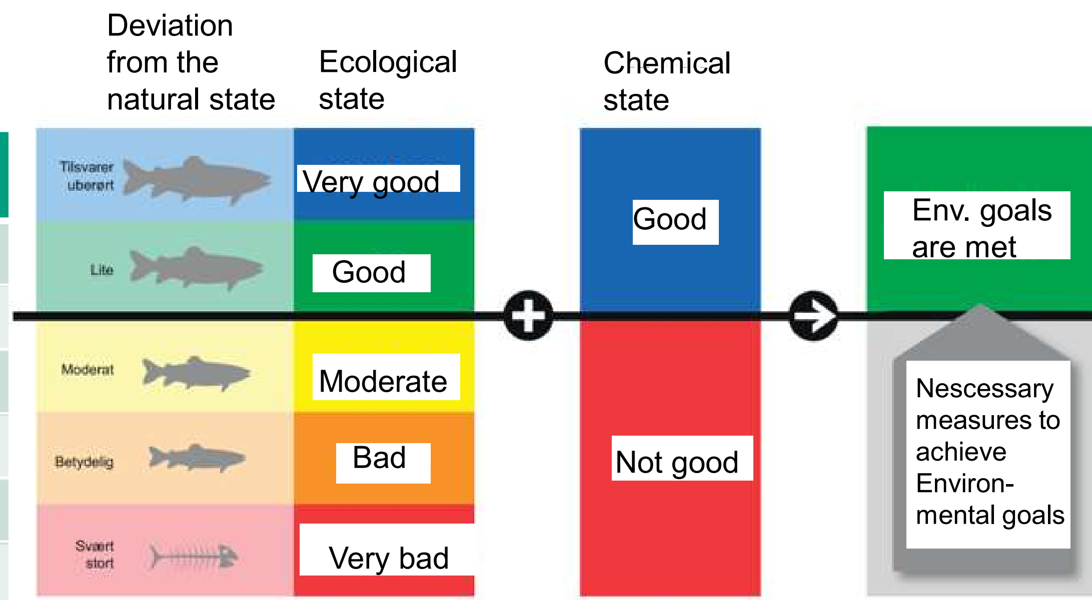
LID measures within a drainage area up to the recipient



Recipient quality – EU Water directive criteria

Recipient classification - maximun pollutants concentration (µg/l) in upper layer of the resipient

	Very good	Good	Moderate	Bad	Very bad
Total P	<11.5	11.5-16	16-29	29-60	>60
Phosfate P	<3.5	3.5-7	7-16	16-50	>50
Total N	<250	250-330	330-550	500-800	>800
Nitrate N	<12	12-23	23-65	65-250	>250
Ammonium N	<19	19-50	50- 200	200-325	>325
Water transparency (m)	>7.5	7.5-6	6-4.5	4.5-2.5	<2.5



Todays lack of data means that a municipal stormater fee model must be based on some prioritized values

Values	Explanation
Simplicity	The calculation of the stormwater fee should be easy to understand for the residents and easy to calculate and implement for the local municipality’s administration
Suffiency	The fees collected must cover both investments, operating and maintenance cost
Equity	Moving away from a fee structure that charges flat fees to all
Legal	Implementation must be legally justifiable
Provency neutral	Total water and sewage fees should not be changed after the introduction of a separate stormwater fee
Behavior change	Incentives should lead people to change their behavior, e.g. reducing stormwater runoff from their own property
Polluter pays	The one responsible for the pollution should be paying for the damage of the natural environment
Precautionary principle	Approach to innovations with potential to cause harm when extencive scientific knowledge on the matter is lacking

Stormwater fee implementation – The barriers that are present must be overcome

Barriers	Policy implementation
Cultural	Lack of support from implementing actors. Low public acceptance
Political	No political champion for stormwater fee policy making and implementation
Legal	Missing or illegal basis for implementation of measures
Organisational	Unclear placement of responssibilities, lack of capacity or conflict-filled areas of cooperation
Knowledge	Lack of knowledge about methods of implementation. Underestimation of the extent to which a new legal framework should be needed
Economic	Lack of or insufficient financing of implementation despite formal committments
Technological	Implemented technology is inadequate or inefficient

A widely used stormwater fee – the ERU (the **E**quivalent **R**unoff **U**nit) - a very simple model based on a few data

- An ERU is a measure of the amount of impervious surface on a property. Impervious surfaces, like a concrete parking area or a rooftop, do not allow stormwater to soak into the ground. These surfaces increase the amount of stormwater that runs off of the property and must be managed by the stormwater system
- Introduced in USA in 1964
- Today, at last 1,851 local governments in 41 US states are using ERU

- **PROS**
  - Easy for the public to understand – you pave, you pay
  - Billable ERUs can be determined by limiting parcel review to impervious area only
  - Minimum time needed to determine total number of billable costs
- **CONS**
  - Stormwater runoff from pervious areas is not reviewed
  - Runoff-related expences are recovered from a smaller base area
  - Vacant properties with no impervious cover do not get charged

ERU (the **E**quivalent **R**unoff **U**nit) - example

$$ERU = \frac{Total\ Residential\ Impervious\ Area}{\text{Total Dwelling Units}}$$

Example from a municipality;

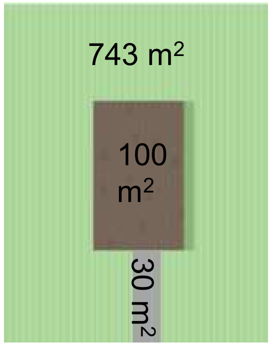
- The total impervious area is: 3.72 km^2
- 18,407 Total Dwelling Units

$$ERU = \frac{3716122\ m^2}{18407} = 202\ m^2$$

$$Base\ rate = \frac{Total\ Anticipated\ Expences}{Total\ ERUs\ in\ Locality}$$

$$ERU\ value\ for\ property = \frac{Impervious\ area\ of\ property\ in\ m^2}{202\ m^2\ (1\ ERU)}$$

$$ERU\ value\ for\ property\ \cdot customer\ monthly\ fee\ \left({}^{Euro}/_{month}\right)$$



743 m^2 lot, 100 m^2 floor area, 30 m^2 walkway.
Monthly Base Rate e.g.: 4 Euro

$$ERU\ value\ for\ property = \frac{130\ m^2}{202\ m^2} = 0.64$$

$$Property\ monthly\ fee = 4\ Euro\ \cdot 0.6\ 4 = 2{,}56\ Euro$$

ERU calculations using GIS

- ArcGIS software can be employed to build an application that calculates stormwater fee for property owners. A web-based mapping service can be built using the stormwater results to disseminate the information to the public.
- Following data are required:
  - Aerial imagery showing the building and impervious area in the parcel
  - Building footprint layer
  - Parcel boundary layer
  - Tax assessor data for parcels
  - Impervious surface
  - ArcGIS online base maps

Annual Charge

Address: 773 SADDLE CRES
Property ID: 3056500
Estimated Annual Charge: $140.16
Estimated Daily Charge: $0.38

The coloured area of your property shows the rooftop area used to estimate your stormwater charge.
Area (m^2): 197.2
Tier: Large

How is this calculated?

Residential properties are grouped in tiers based on the amount of rooftop area. Each tier has a standard charge.

Large Tier Billing Units:	1.2
Annual Rate per Billing Unit:	x $116.80
Estimated Annual Charge:	$140.16

Incentive fee models – credits for stormwater measures

A Step 0 (Urban Planning) measure

An **example** on how credits work:

- Direct reduction of user fees
- Applied after user fees are calculated
- Maximum credit of 50%
- Not available to single family residential and duplex properties
- Must be applied for;
  - Qualifying criteria set by the city
  - Maintenance of stormwater controls required

Raingarden

- Reimbursement up to 250 Euro
- 9.3 m^2 min. size
- Min. of 46 m^2 drainage area
- Must drain in 24 hours

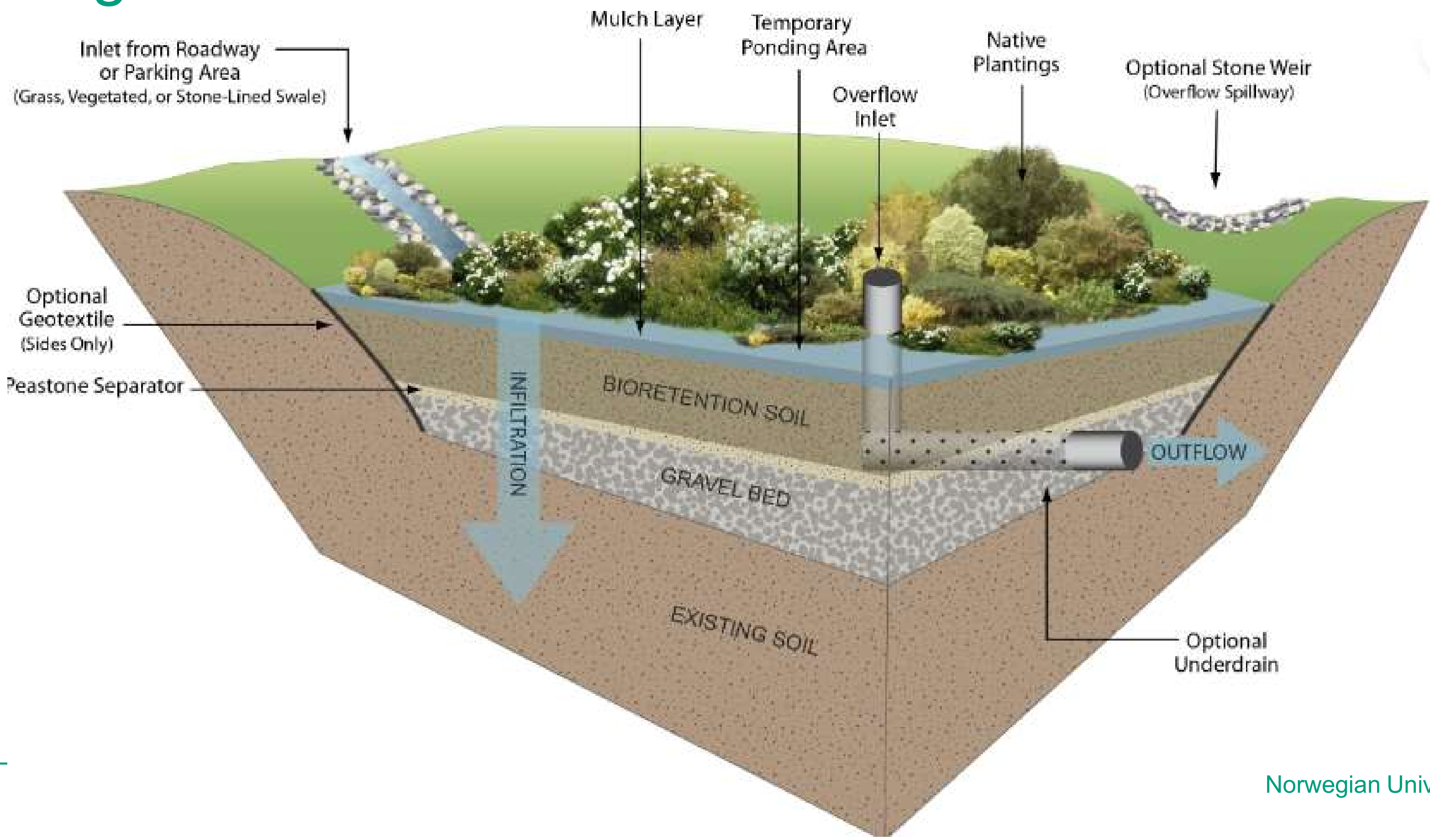
Rain Barrel

- Rebate of 25 Euro per barrel
- Limit of two barrels per property
- Must be purchased at preapproved supplier

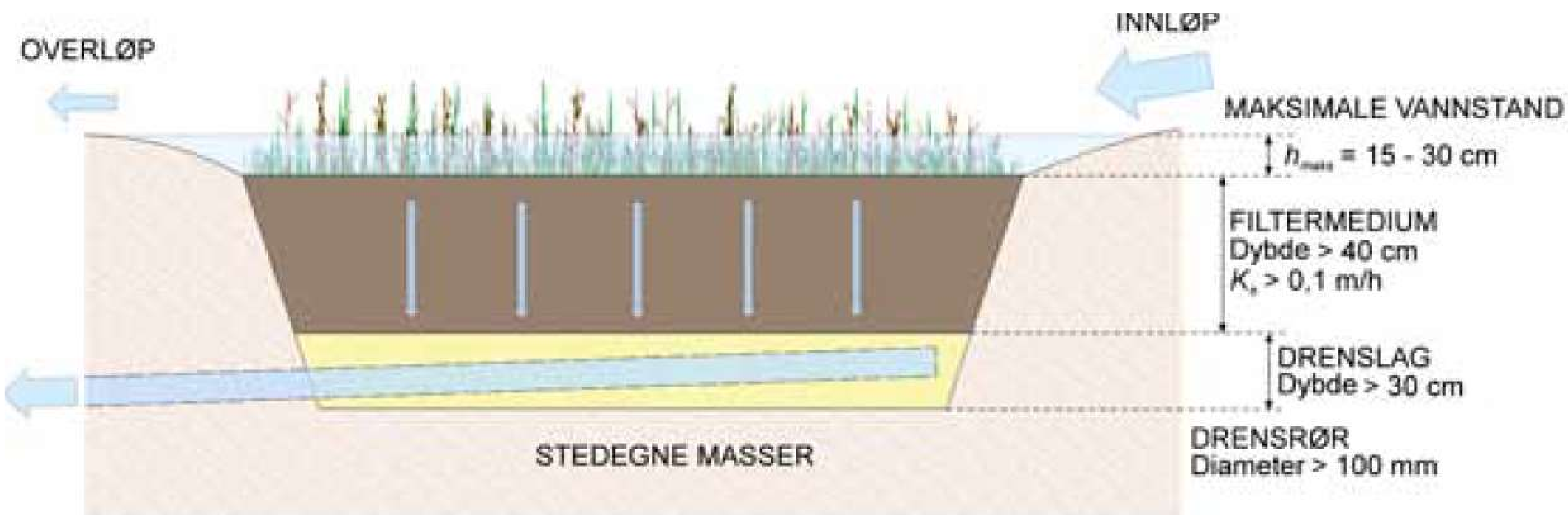
Water Quality Credits

- Up to 10% credit
- Can be added to rate or volume credits
- 75% reduction in total suspended solids on an annual basis

Raingarden construction

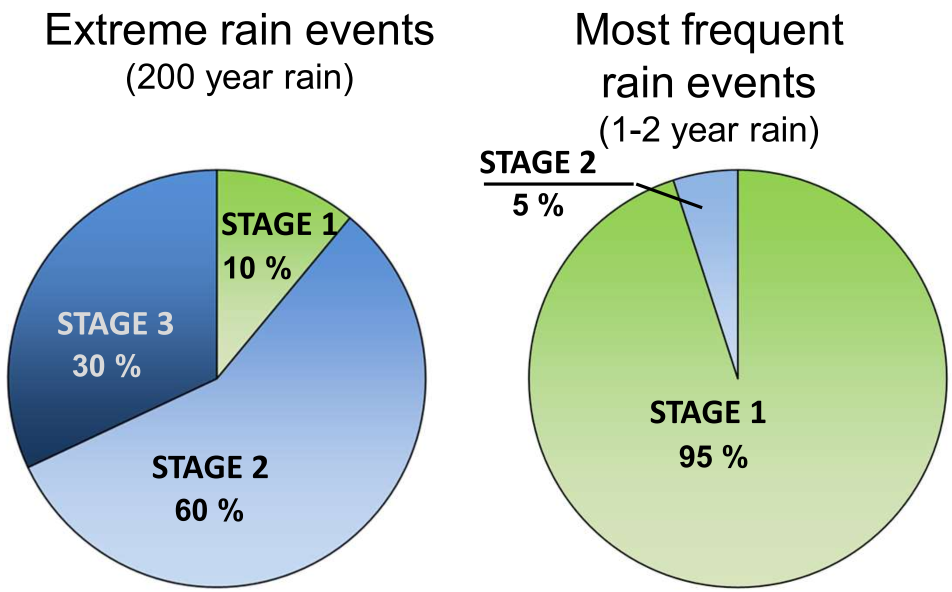


Rainbeds – nescessary surface area is based on hydraulic capacities (stormwater depth and infiltration rate)



Future Stormwater fee models – giving credits for (typical/actual) pollution removal?

Raingarden – may be a Step 1 (single lot measure) and/or a Step 2 (urban district measure)



Stormwater fees – giving credits for pollution removal?

Table: Typical stormwater pollution concentrations from impervious surfaces runoff (µg/l)

Emission source	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PAH	PCB
City center	0.50	5	30	0.10	10.0	20.0	140	0.60	0.01
Residential area, detached housing	0.15	4	10	0.05	6.0	4.0	30	0.20	0.01
Residential area, semi-detached housing	0.20	5	15	0.05	7.0	5.0	40	0.25	0.01
Residential area, block of flats	0.25	6	20	0.05	9.0	7.0	45	0.60	0.01
Areas with commercial buildings	0.50	5	30	0.10	10.0	20.0	140	0.60	0.01
Streets, AADT < 5000	0.25	1	38	0.10	1.2	13.5	62	0.30	0.01
Streets, AADT [5000, 30000]	0.44	5	72	0.10	4.4	31.0	197	1.50	0.01

A new raingarden located to one of these areas: Whaat's the main stormwater pollution problem?

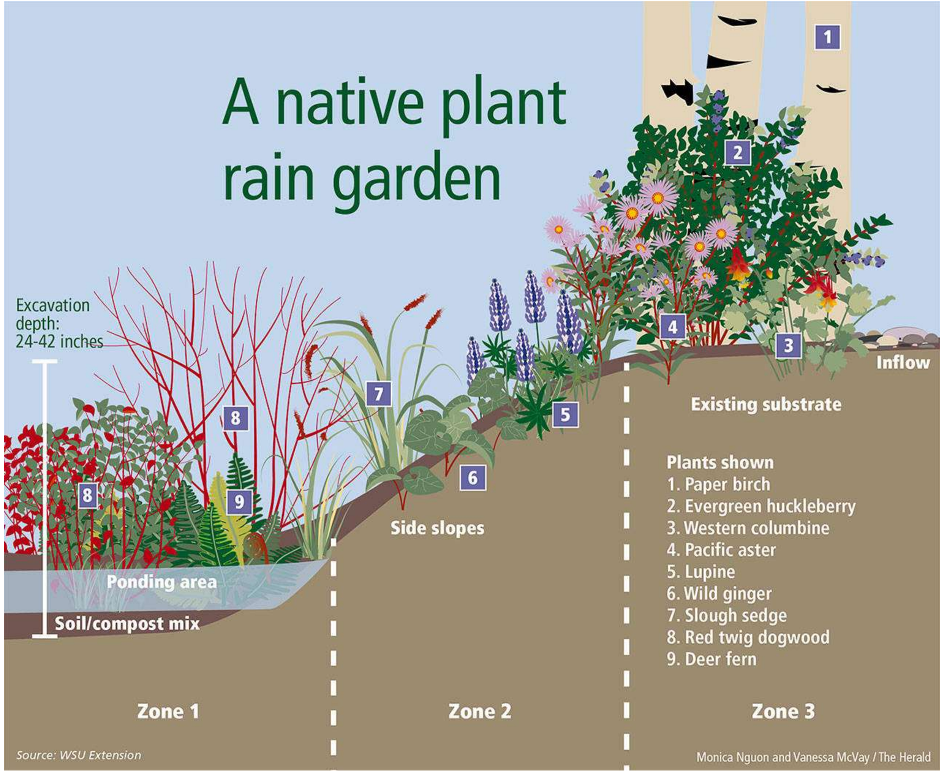
Stormwater fees – giving (more) credits for pollution removal, if using the right raingarden vegetation that can absorb the pollution present?

Phytoremediating perennials suitable for raingardens in Norway	P	N	PAH	Hg	As	Pb	Cd	Cr	Zn	Cu
Duchesnea indica	x					x	x		x	x
Geranium robertianum						x	x		x	
Helianthus tuberosus L.	x			x		x	x		x	x
Iris pseudacorus						x	x		x	x
Medicago sativa		x		x	x	x		x	x	x
Sanguisorba officinalis						x	x		x	x
Taraxacum officinalis			x							

My suggestions for criteria for plant selection, which are made by landscape architects :

1) Be tolerant to flooding and drought, & cold climate
2) Ability for uptake of relevant pollutants in plants/filter materials:

- Then should satisfy some of these criteria e.g.:
  - Good root systems (more oxygen, less erosion)
  - Growth characteristics
  - Local species
  - Esthetic quality
  - Sun/shadow areas
  - Non-allergenic
  - Tolerance for road salt
  - Non-toxic



Modular raingarden systems




- The filter materal should also be designed for pollution uptake (phytoremediation in the soil)
- More research needed for the living time for a rainbed infiltration zone, based on chosen vegetation and the composition of the materials in the infiltraton zone
- The filter media need to be renewed after some years – modular systems may be recommendable

Stormwater measures – calculating the surface area of a raingarden

Now

- The raingarden surface area is based on stormwater detention volume and infiltration velocity; the hydraulic capacity only

$$A_{regnbed} = A_{felt} \times c \times P/(h_{maks} + K_h \times t_r)$$

- Raingarden surface area is limited by the available area on the planned location

In the future, when calculating the raingarden surface area, we should choose the largest area of these two:

1) The calculated area needed for stormwater detention volume and infiltration velocity, and

2) The calculated area needed for the chosen vegetation, with its ability to take up the typical stormwater pollution on the location

   – This surface area is based on the required density of vegetation, and the amount of plants to uptake the pollution

Comprehensive fee models damands more parameters and more detailed data

- Resarch for deciding typical data

NMBU's Landscape lab

- Developing a more comprehensive models for fee calculations is needed. e.g.:

$$p_j = K_{ll} \cdot \frac{l_j \cdot Q_j}{\Sigma_1^N (l_j \cdot Q_j)} + K_{rl} \cdot \frac{Q_j}{\Sigma_1^N Q_j} + k_{rd} \cdot Q_j + k_m \cdot f \cdot Q_j$$

Purpose of the stormwater fee models					Criteria for calculation					
Economic goals		Environmental goals			Property			Hydrology/ stormw. vol.		
Financing	Incentive – reduced fee	Reuse stormwater	Prevent floods	Prevent pollution	Total area	Impervious area	Stormwater runoff	SUDS measures	Terrain slope/ hydrolog. proc.	Pollution uptake by species and filtermedia
x	x	x	x	x	x	x	x	x	x	x

Possible data capture from «smart» raingardens

- Water Quality Monitoring:
  - Sensors can be installed in the rain garden to monitor water quality parameters such as pH levels, turbidity, and nutrient concentrations.
- Plant uptake of polluted stormwater (phytoremediation):
  - Fluorescence resonance energy transfer (FRET)-based sensors have also provided a new avenue for sensitive and quantitative detection of specific heavy metals that pose environmental risks
- Remote Monitoring and Control:
  - Smart rain gardens can be connected to a central control system that allows remote monitoring and control of various parameters.
  - This enables real-time data collection, analysis, and adjustments

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