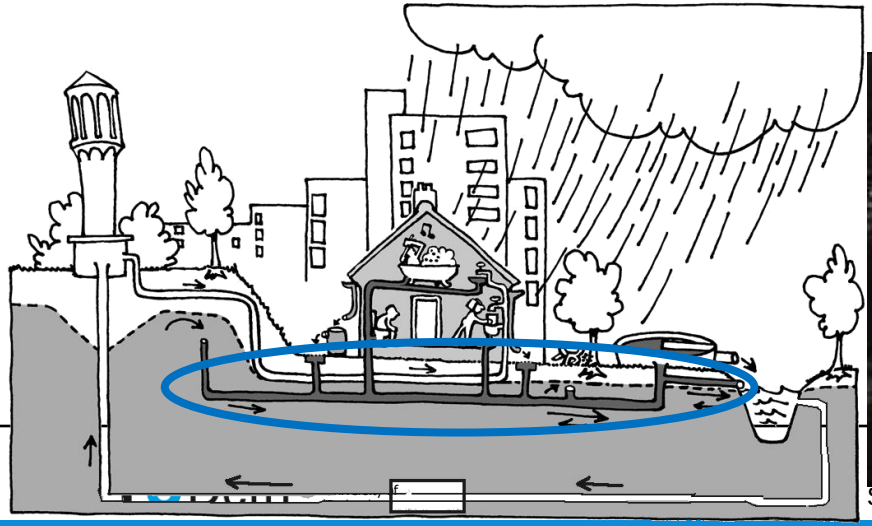
CT4491 Urban Drainage and Watermanagement

Marie-claire ten Veldhuis, Watermanagement Dep., Sanitary Engineering Section

17-9-2013



Source: news.bbc.co.uk

Source: www.nu.nl

CT4491

Lecture 1. Course introduction and principles of urban water systems

Marie-claire ten Veldhuis

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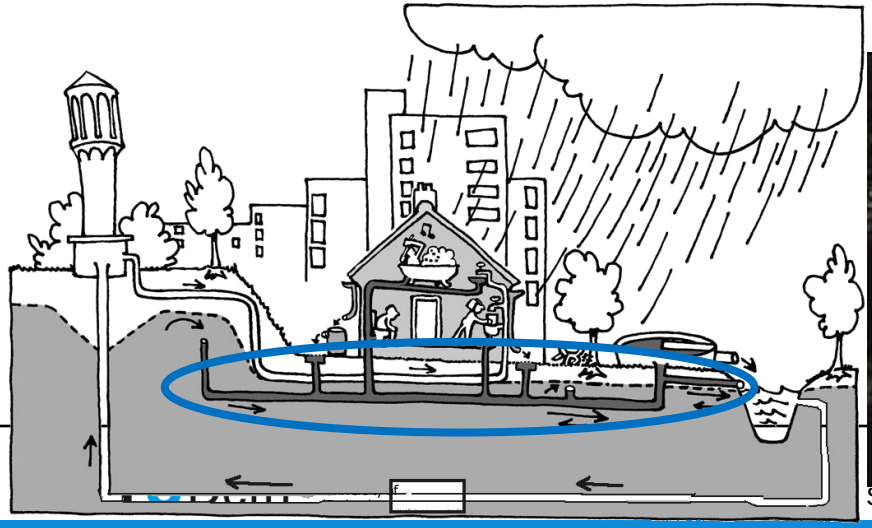
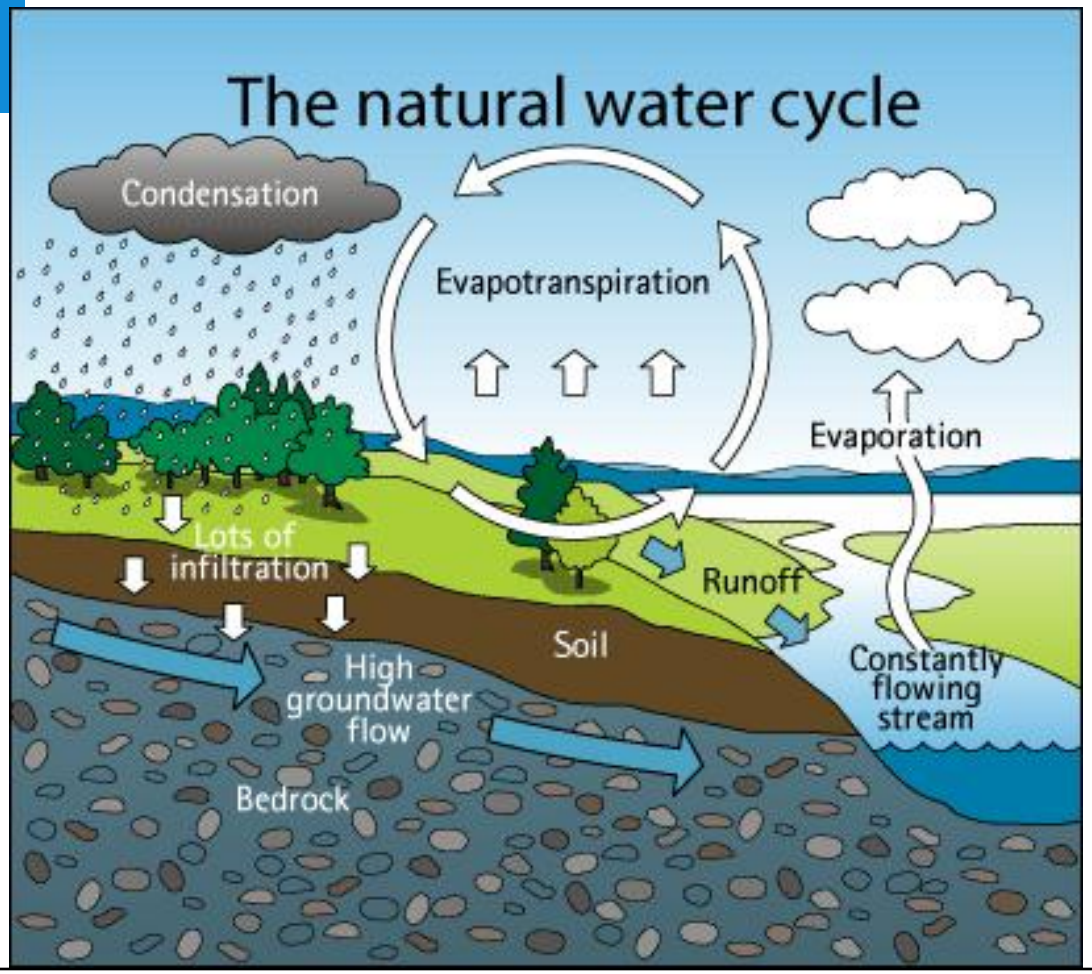


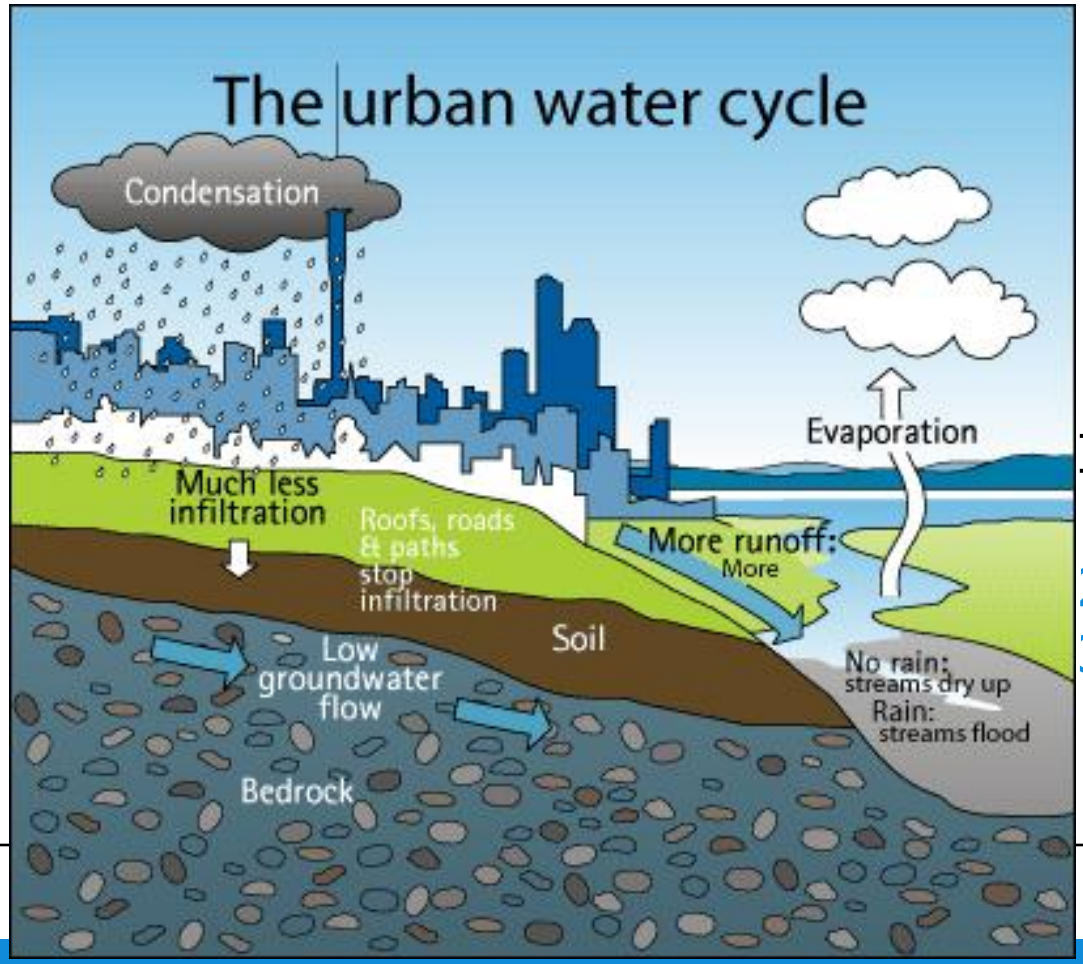
Source: news.bbc.co.uk

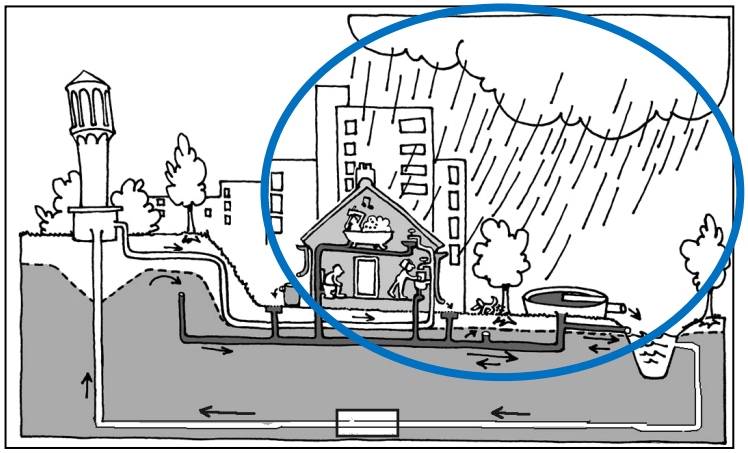
Source: www.nu.nl

Natural water cycle



Urban Water cycle

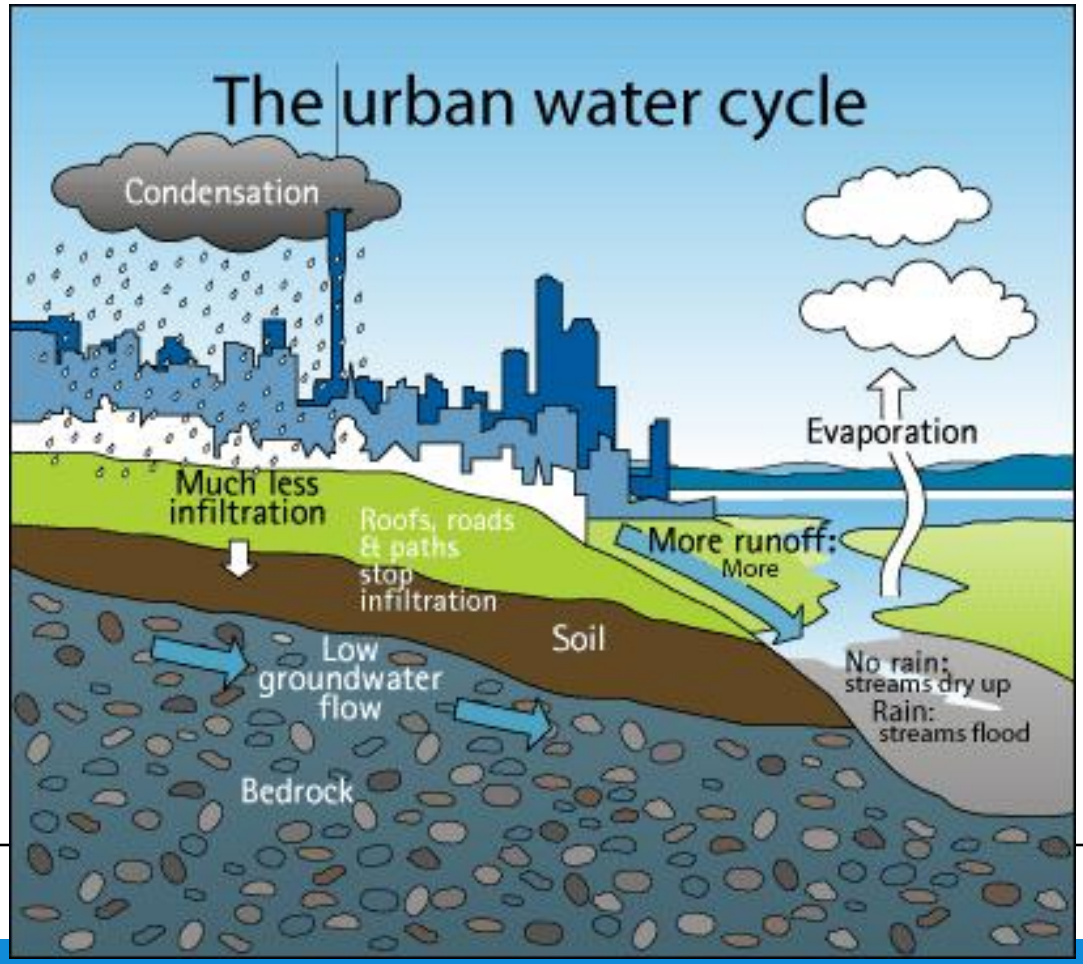


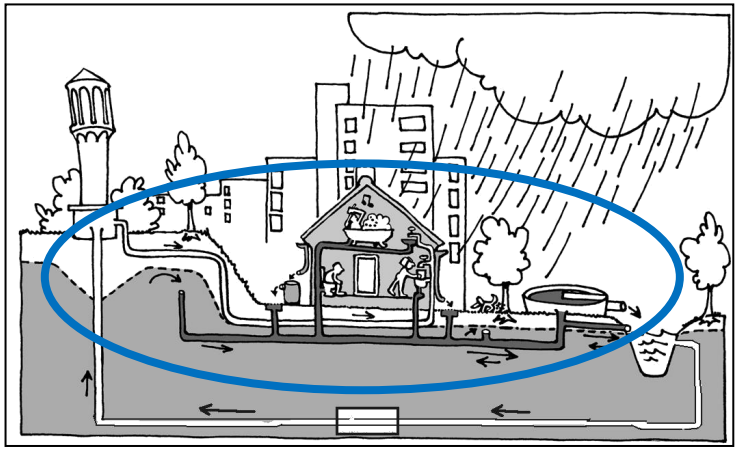


Impact of urbanisation:

1. Infiltration, evaporation ↓↓
2. Runoff ↑↑
3. Polluted discharge: sediments, heavy metals, insecticides ↑↑

Urban Water cycle



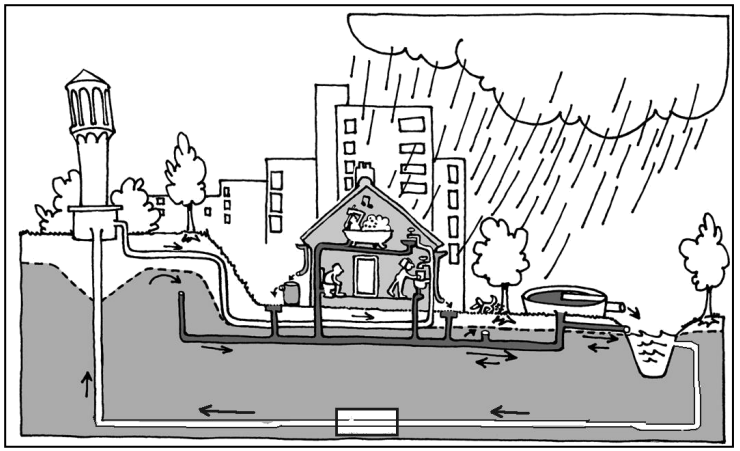


Impact of urban water use:

1. Water pollution - pathogens, nutrients, organic matter ↑↑
2. Energy use ↑↑


The
Forgotten
Cycle

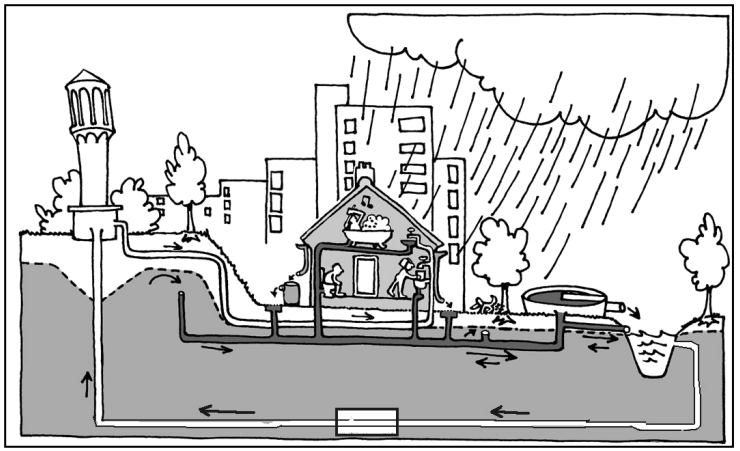
Urban Water Cycle



Example: Prinseneiland Amsterdam
Year 2011

Total surface area: 34,000 m2
80% paved/buildings
(60% connected to combined sewer system; 20% not connected to sewers (e.g. garden terraces, sheds)
20% unpaved

Urban Water Cycle



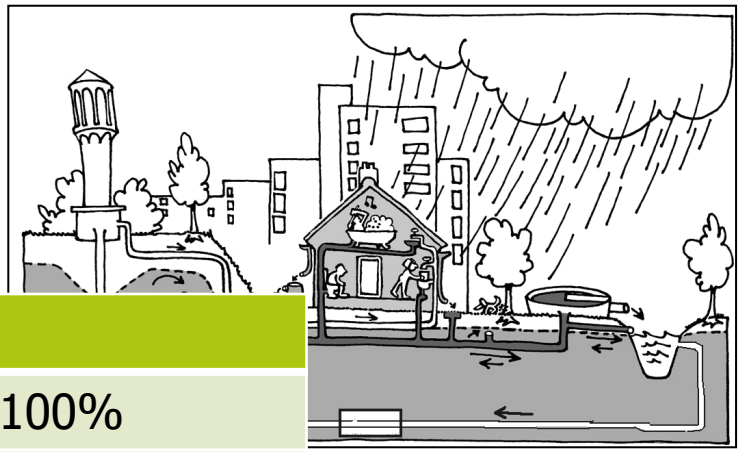
Example: Prinseneiland Amsterdam
Year 2011

Total surface area: 34,000 m2
80% paved/buildings
20% unpaved
Equipped with combined sewer system

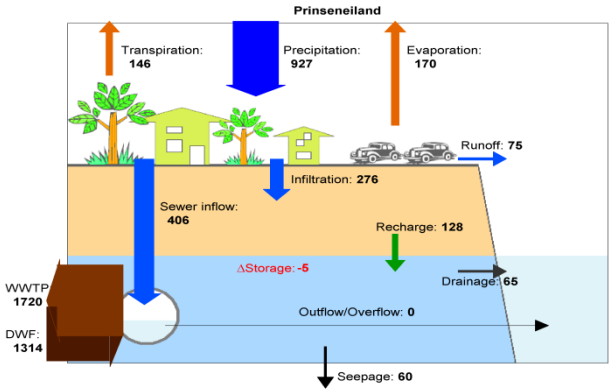
Urban water balance:

- What % of yearly precipitation goes to:
  - Evaporation/transpiration
  - Infiltration
  - Sewer discharge

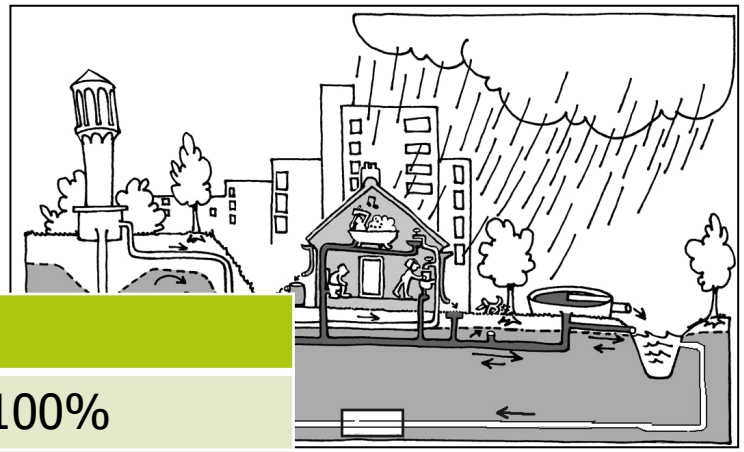
Urban Water Cycle



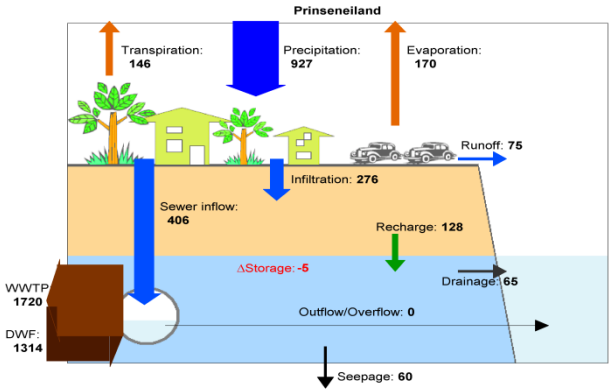
Prinseneiland	2011	
Precipitation	927 mm	100%
Evaporation/Transpiration		?
Runoff		
Infiltration		?
Sewer inflow		?
DWF		
WWTP		



Urban Water Cycle

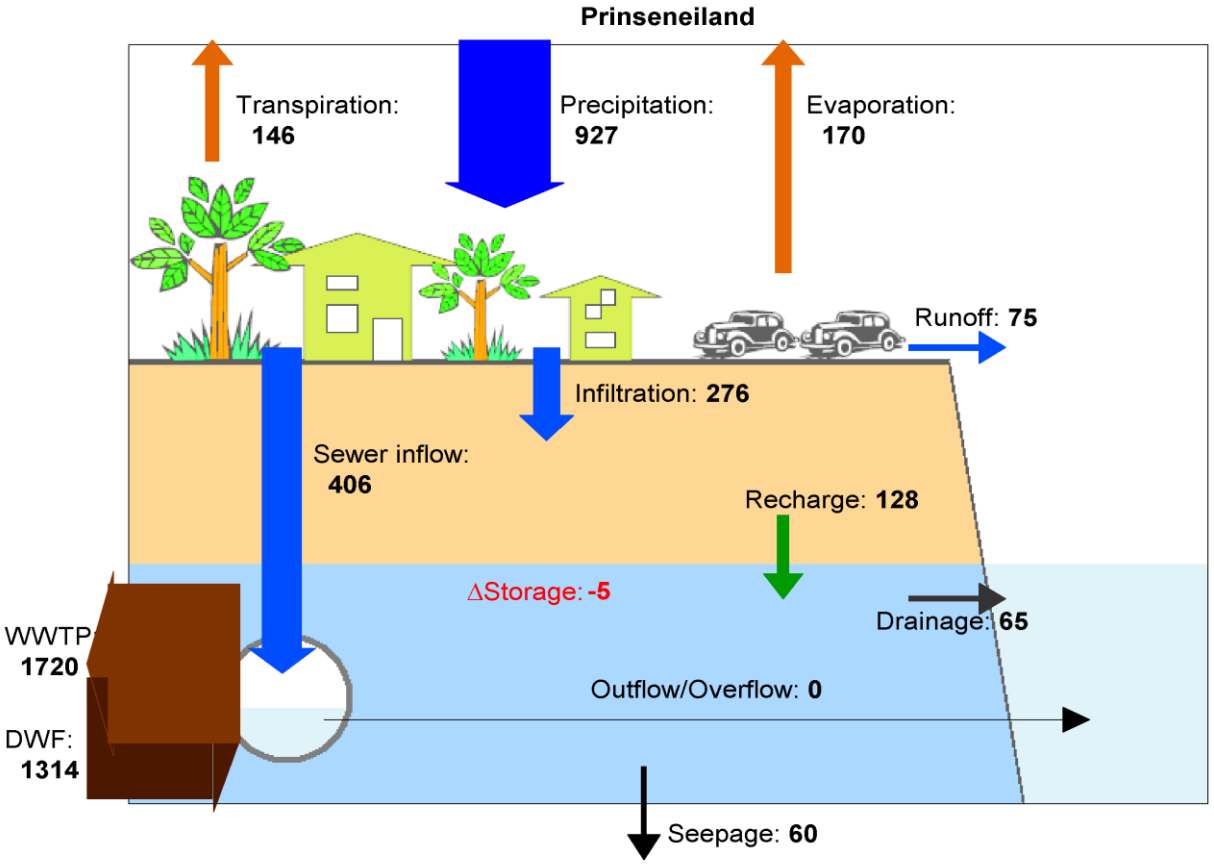


Prinseneiland	2011	
Precipitation	927 mm	100%
Evaporation/Transpiration	316 mm	34%
Runoff	75 mm	8%
Infiltration	276 mm	30%
Sewer inflow	406 mm	44%
DWF	1314 mm	
WWTP	1720 mm	



Urban Water Cycle

Prinseneiland	2011
Precipitation	
Evaporation/Trar	
Runoff	
Infiltration	
Sewer inflow	
DWF	
WWTP	



Urban Water Cycle

So we disturb the natural water cycle, we pollute natural waters:

Should we return to natural water cycles in cities?

- Yes
- No

Urban Water Cycle – natural or technological?

Should we be prepared to accept frequent flooding by rainfall?

OR:

Should we build large sewer systems and stormwater drainage channels?

Urban Water Cycle – natural or technological?

Should we adjust our roads and buildings to support rainfall infiltrating to groundwater?

OR:

Should we use concrete pipes and channels to transport rainfall to surface waters outside urban area?

Urban Water Cycle – natural or technological?

Should we accept natural fluctuations of groundwater tables in cities (below roads, buildings)?

OR:

Should we control groundwater tables at predetermined levels?

Urban Water Cycle – natural or technological?

Should we treat all urban waters (wastewater, runoff) to prevent pollution of natural waters?

OR:

Should we treat only concentrated wastewaters?

Urban Water Cycle – natural or technological?

Should we be prepared to pay high taxes to support investments for flood prevention?

OR:

Should we be prepared to pay high taxes to support investment for water treatment?

Learning objective of this course:

design and analyse urban drainage system - for real-life case in Delft

⟶ Make your own design choices

1. Preliminary design:
   - Set design requirements
   - Choose system type, system components
   - Choose layout

2. Detailed design, rational method manual calculations

3. Detailed design, hydrodynamic computer model calculations (Sobek)

Course Overview: on BB

Lecture	Background mat.	Assignment
Intro urban water systems and interactions	Butler and Davies: Chapters 1, 2, 4, 10.1-10.3, 13, 14. Recomm: 23	Week 1: Preliminary design: motivated choice of system for wastewater and stormwater drainage. Design requirements, system lay-out
Requirements for wastewater and stormwater drainage		
Review IDF curves, runoff processes, rational method	Butler and Davies: Ch 5 (NOT 5.3.3-5.3.5), 6, 11, 12, 22.	Week 2: IDF curve, runoff areas and runoff characteristics, quantification of wastewater and stormwater flows,
Hydraulic design of piped systems		
Urban flooding and flood damage estimation	B&D: 8.3 (NOT 8.3.4), 8.4, 8.5, 9, 15 Recomm: 8.1, 8.2	Week 3: Rational method calculations
Pumping stations, pressurised flow		
Submit assignment - manual calculations		Week 3 (deadline 20 Sep): Deliverables: sketch system layout, rational method and hydraulic calculations
Sobek workshop	Sobek tutorial Recomm: B&D Ch 20	Week 4 (deadline 27 Sep): report Sobek workshop Prepare input of designed stormwater system in Sobek
Asset management: sewer condition, sewer inspections	-	Week 5: Sobek modelling of stormwater system for various rainfall inputs: stationary rainfall, design storm, climate change scenario. (see assignment manual)
Asset management: rehabilitation decisions		
Review scientific paper on urban drainage	B&D: Ch 18, 19 Recomm: 7 (not 7.4.2)	Week 6: Sobek model calculations for various scenarios: system degradation, settlement
Assignment supervision meetings		Week 6: Deliverables: Sobek calculation results for stormwater system
Group discussion designs per case study areas	-	Week 7: Finalise Sobek calculations, prepare assignment report
Assignment results discussion meetings		Week 8-9: Deliverables: Assignment report

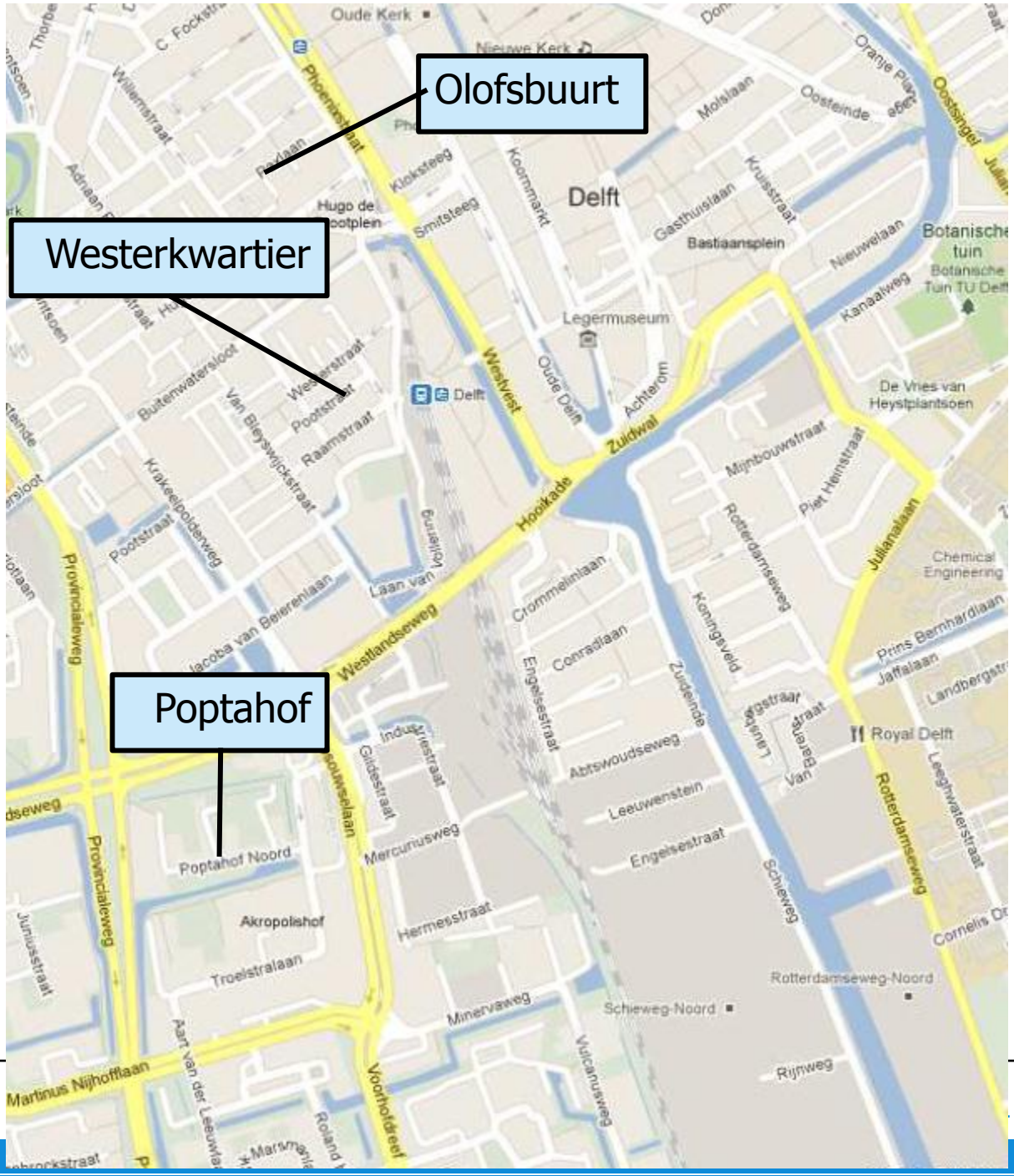
Introduction design assignment

CIE4491 – Design Assignment

Choose 1 of 3 project areas for design assignment:

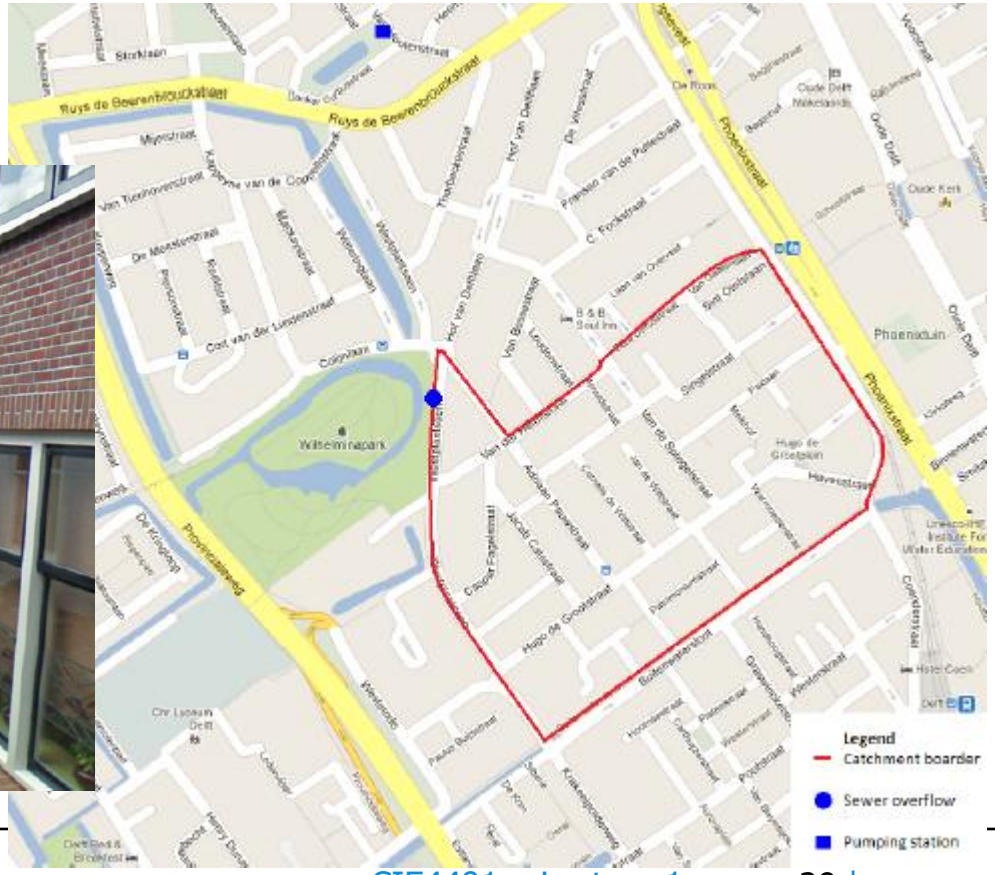
- Poptahof: redevelopment of existing residential/commercial area
- Westerkwartier: redevelopment of existing, densely built residential area
- Olofsbuurt: redevelopment of existing, densely built residential area

Manuals for each project on BB (Assignments)


Olofsbuurt
Westerkwartier
Poptahof
Oude Kerk
Nieuwe Kerk
Delft
Hugo de Grootplein
Smitsteeg
Koornmarkt
Gasthuislaan
Bastiaansplein
Molslaan
Oosteinde
Botanische tuin
Botanische Tuin TU Delft
Legermuseum
Westvest
Oude Delft
Achterom
Zuidwal
De Vries van Heystplantsoen
Hoornkade
Mijnbouwstraat
Piet Heinstraat
Rotterdamseweg
Julianalaan
Chemical Engineering
Prins Bernhardlaan
Jaffalaan
Westlandseweg
Crommelinlaan
Conradlaan
Engelsestraat
Koningsveld
Zuideinde
Royal Delft
Abtswoudseweg
Leeuwenstein
Engelsestraat
Leeghwaterstraat
Schieweg
Rotterdamseweg
Cornelis D
Provincialeweg
Poptahof Noord
Akropolishof
Troelstralaan
Mercuriusweg
Hermesstraat
Minervaweg
Vulcanusweg
Schieweg-Noord
Rotterdamseweg-Noord
Rijnweg
Martinus Nijhoffiaan
Voorhofdreef
Aart van der Leeuwlaan
Juniusstraat
Gildestraat
Industriestraat
Buitenwatersloot
Van Bleyswijckstraat
Krakeelpolderweg
Poststraat
Raamstraat
Jacoba van Beierenlaan
Provincialeweg

CIE4491 – Design Assignment

Olofsbuurt: redevelopment of existing, densely built residential area

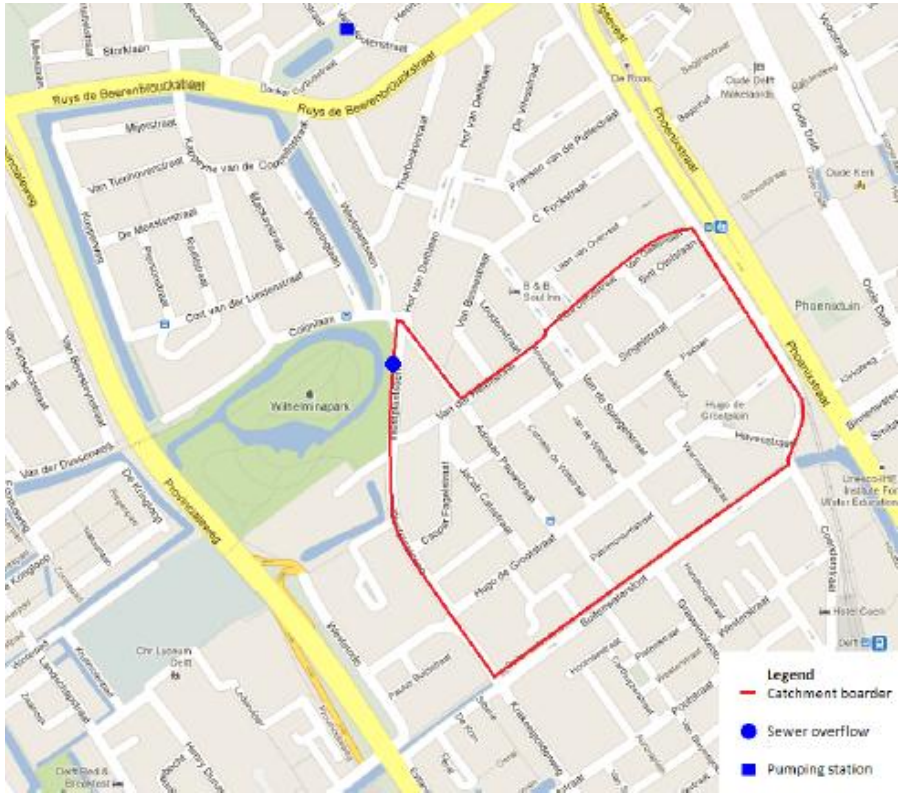


CIE4491 – Design Assignment

Olofsbuurt: redevelopment of existing, densely built residential area

Challenges:

- Find solutions for current flooding problems
- Deal with limited available space for infrastructure and storage



CIE4491 – Design Assignment

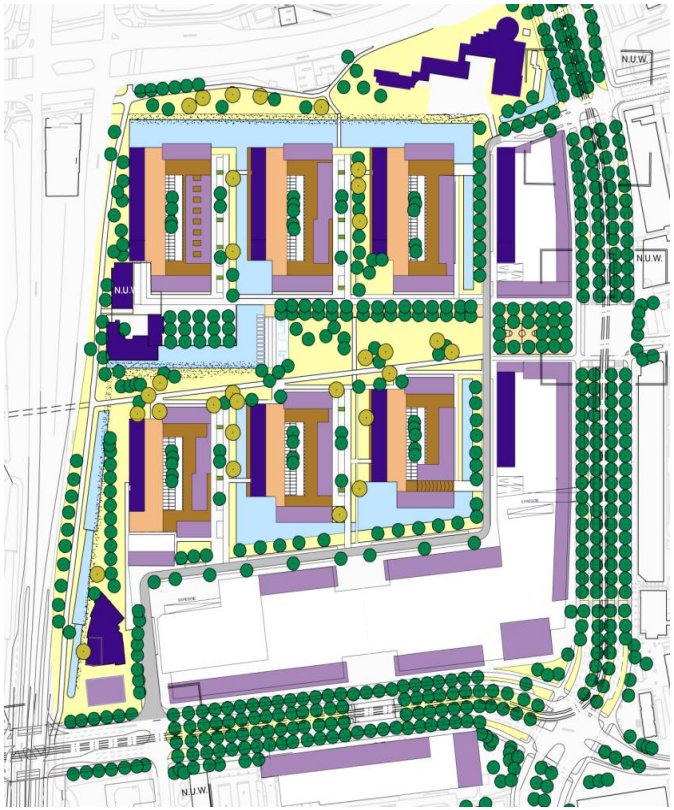
Poptahof: redevelopment of urban drainage system in existing high rise area

CIE4491 – Design Assignment

Poptahof: redevelopment of urban drainage system in existing high rise area

Challenges:

- Deal with stormwater from large impermeable areas - shopping centre roofs and roads
- Crossing pressurised wastewater transport main
- Find solution for polluted water from tramline
- Develop plan for construction phases in accordance with building phases of urban redevelopment plan



CIE4491 – Design Assignment

Westerkwartier: redevelopment of existing, densely built residential area

CIE4491 – Design Assignment

Westerkwartier: redevelopment of existing, densely built residential area

Challenges:

- Find solutions for current flooding problems
- Deal with limited available space for infrastructure and storage
- Deal with intermittent peak loads from underground thermal heat storage system

CIE4491 – Design Assignment

Design steps: preliminary design, detailed design rational method (manual), detailed design computer calculations (Sobek)

Planning:

#	Date	Assignment planning
0	Tue 3 Sep	Introduction of design assignment, choose your project and get familiar with project area
1	Week 3 Deadline 20 Sep	Deliver first results: sketch of system layout, results rational method calculation
2	Week 4 Deadline 27 Sep	Sobek workshop (all day, room 1.97) Deliver workshop report
3	Week 6	Assignment supervision meetings: discuss Sobek calculation results (for combined/stormwater system)
4	Week 7	Poster presentation and discussion of all designs for the 3 case study areas
5	Week 8-9 (-10) Deadline 1 Nov	Assignment supervision meetings: discuss final report Delivery final assignment report

CIE4491 – Design Assignment

Date	Assignment planning
Week1	Choose case study area, prepare preliminary design (design requirements, layout, system type and components)
Week 2	Quantify design parameters: wastewater flow, stormwater flow (IDF-curves+rational method)
Week 3	Apply rational method, calculate system dimensions, hydraulic calculation to check for flooding
Week 4	Sobek workshop, prepare and hand in workshop report Assignment: Set up combined/stormwater system in Sobek
Week 5	Sobek model calculations: vary rainfall inputs (stationary rainfall, design storms, climate scenario
Week 6	Sobek model calculations: vary parameters to simulate system degradation with lifetime
Week 7	Prepare for design presentation; prepare final report
Week 8	Prepare final report; deliver final report; supervision meeting
Week 9	Deliver final report; supervision meeting

A short history of urban drainage and schemes for urban wastewater and stormwater collection

Approaches to urban drainage:

- Wastewater and stormwater collection

Source: columns.skynetblogs.be

Approaches to urban drainage: a short history

Rome:

Source: Richard Ehrenberg, Aug 2005

Pompeï:

Photos: Francois Clemens

Approaches to urban drainage: a short history

After the fall of the Roman Empire until the 19th century: sanitary darkness

London 1853-1854

The third outbreak of cholera in London: 10,738 die. Committee for Scientific Enquiry denies Snow's theory that cholera is water-borne.

London, 1858: 'The Great Stink'

Metropolis Management Amendment Act permits the commencement of Bazalgette's work, design of London's sewer system
(still operational today)

19th-century image of 'Death' – a constant presence in the cities of Victorian Britain

'Punch' cartoon, 1848: Dirty Father Thames

Approaches to urban drainage: a short history

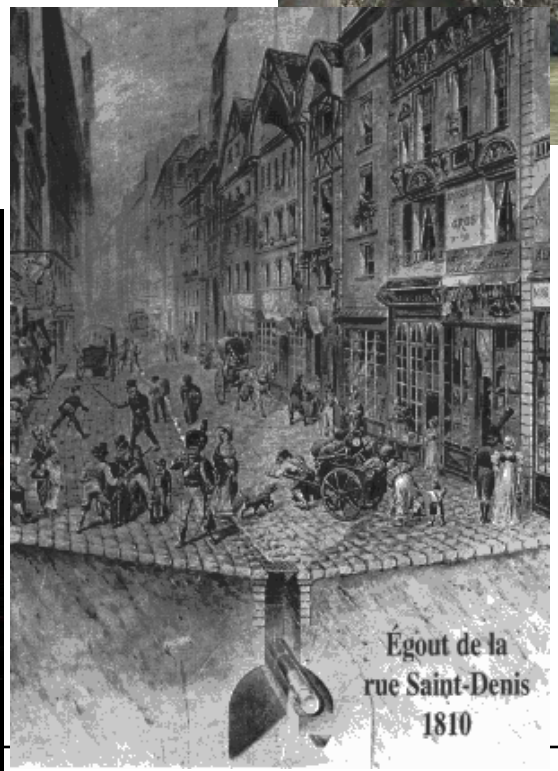
Principle of collection, from 19th century on:

Combined sewer systems:

"Tout-à-l'égout" (Paris: Belguard)

"all-in-one-sewer" (London: Bazalgette)

Rome: Cloaca Maxima



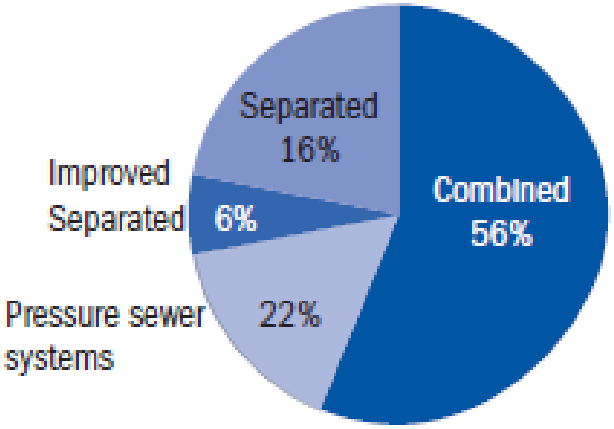
Paris: Rue St.-Denis, 1810

Source: Musee des Egouts

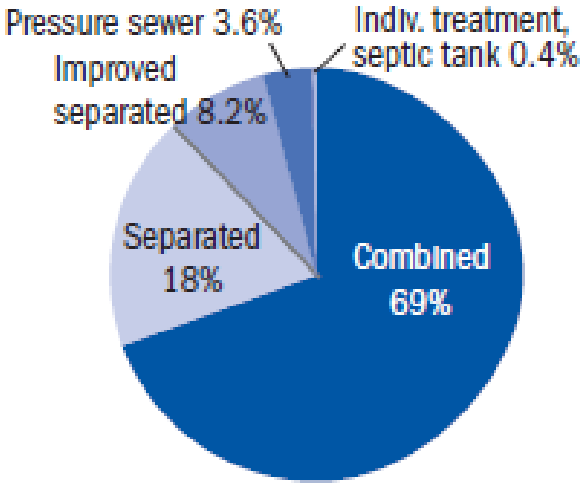
Source: Breda.nl

Length sewer mains

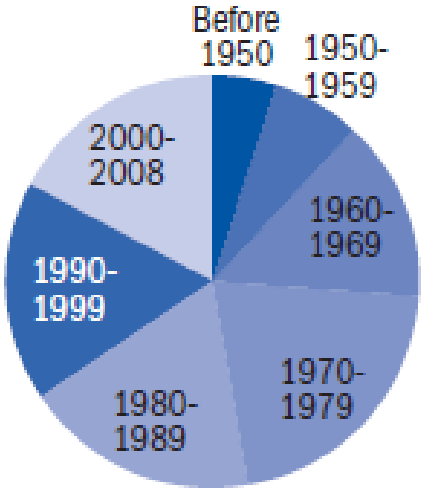
Based on km mains



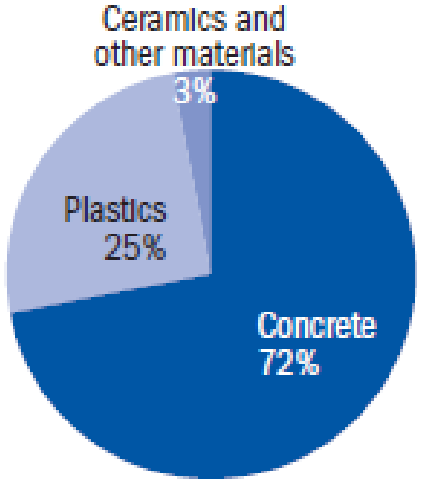
Sewer connections



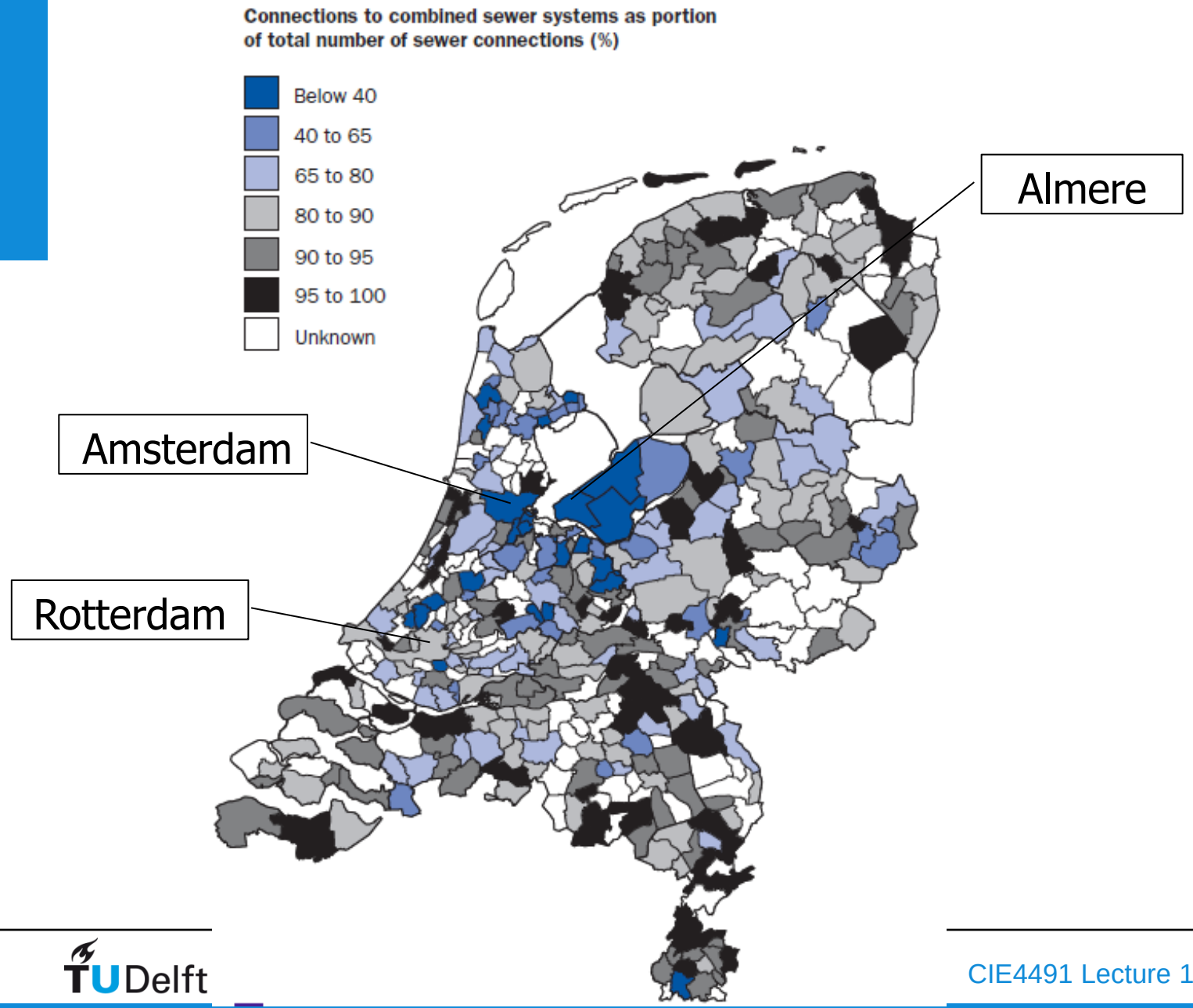
Year of construction



Construction materials



Connections to combined sewers (2005)



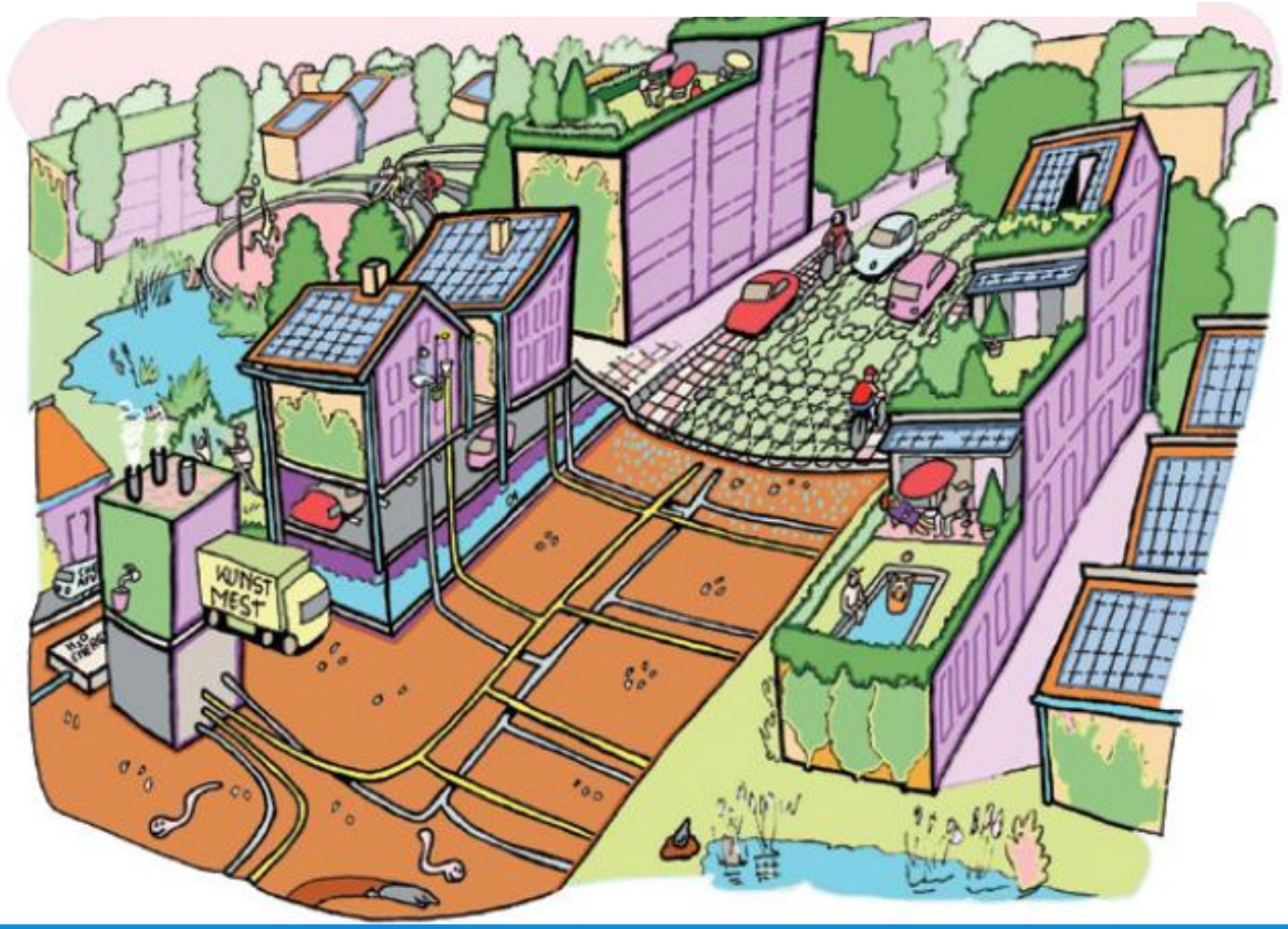
Approaches to urban drainage: a short history

20th century: integrated urban water management, water sensitive urban design

Source: Melbourne Water

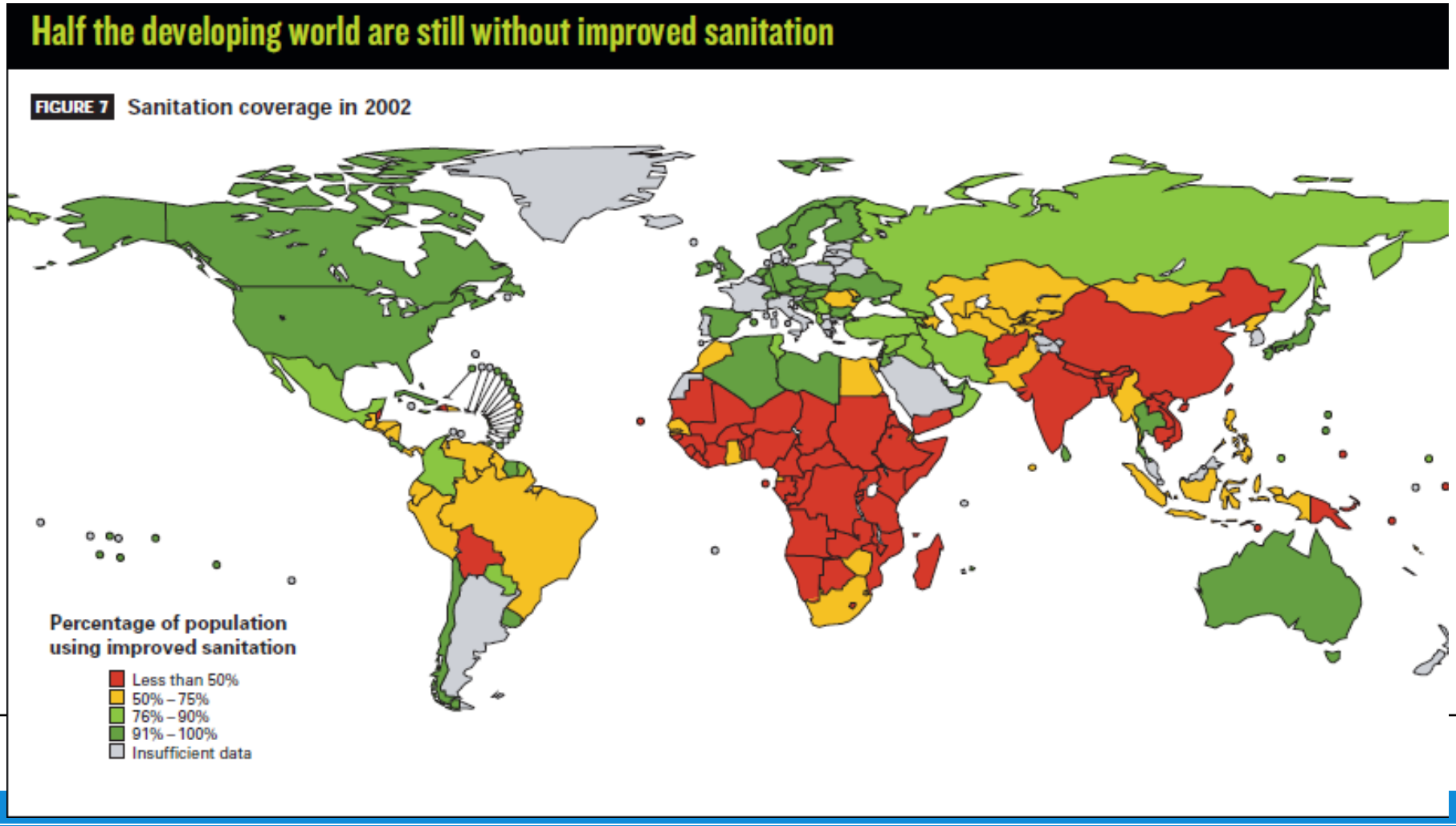
Approaches to urban drainage: a short history

21st century: integrated urban water cycle



Millenium Development Goals

Target 7c: Reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation



Millenium Development Goals

Target 7c: Reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation

Urban Water Cycle – developments worldwide

More than 50% of world population lives in cities
In all these cities, we disturb the natural water cycle, we pollute natural waters:

Should we return to natural water cycles in cities?
- Yes
- No

Accept frequent flooding/ build large scale infrastructure/ …small scale solutions?
Treat all waters/some flows/…centrally/locally?

"Night workers remove human wastes from cesspits that is sold as fertilizer for crops. It is a filthy job that involves crawling through cesspits and sewers or descending into them from ladders.
The city's one million inhabitants have 200,000 cesspits. The pressure on these causes the pits to overflow into street drains designed originally to cope with rainwater. WC's discharge human waste directly into rivers, while much of the water is being extracted from these same rivers, often downstream from the sewage discharge points"

Kas eloos 'Dalits' horen in het Indiase kastenstelsel nergens bij. Zij mogen alleen het vieze werk opknappen

Sheela Athwal: „In het begin moest ik vrijwel dagelijks overgeven door de stank."

Er zijn zo'n half miljoen Indiërs die feces weghalen bij particulieren. Foto's Terry Boopnarain

Manatha Chanwaria: „Soms begin je meteen te kokhalzen."

Kastelozen in India zijn geboren poepophalers

Outcasts in India are born to be excreta collectors in India

Kastelozen die in de grote stad hun geld verdienen met het ophalen van menselijke uitwerpselen.

Door onze correspondent
PHILIP DE WIT

ALWAR, 12 JAN. De regen viel onverwachts en hard. In luttele seconden was de koperen schaal op haar hoofd volgelopen. Op haar kleurrijke sari verscheen steeds

werk: uitwerpselen opvegen bij huishoudens die geen wc's hebben met waterspoeling en een afvoer. Zij zegt: „Het eerste half jaar, nadat ik dit werk was gaan doen, had ik voortdurend huidinfecties. Ik moest bijna dagelijks overgeven door de stank."

In de Indiase stad Alwar (200.000 inwoners) van de deelstaat Rajasthan, heeft Athwal haar eigen wijk (een vrij, Sanskriet voor cirkel) met klanten. Zij is één van

gens het geloof daardoor 'vervuild' worden.

Met nog zo'n 1.600 andere Da-

Wij zijn geboren om dit werk te doen

Sheela Athwal

hiërarchie. Zoals je er ook ziet in miljoenensteden als Mumbai, New Delhi, Bangalore en Chennai.

Over haar werk zegt Sheela Athwal: „Wij zijn geboren om dit werk te doen, dus wat valt er over te zeggen?" De reactie is gelaten, fatalistisch en sluit aan bij haar geloof. Haar huis, een kamer van 16 vierkante meter, hangt vol met afbeeldingen van goden van het hindoeïsme. Wellicht, zo redeneert

rupees, nog geen 13 euro per maand, met haar werk. Elk huishouden waar zij langsgaat, betaalt 20 eurocent per maand per per-

Eens wil ik met dit vieze werk stoppen

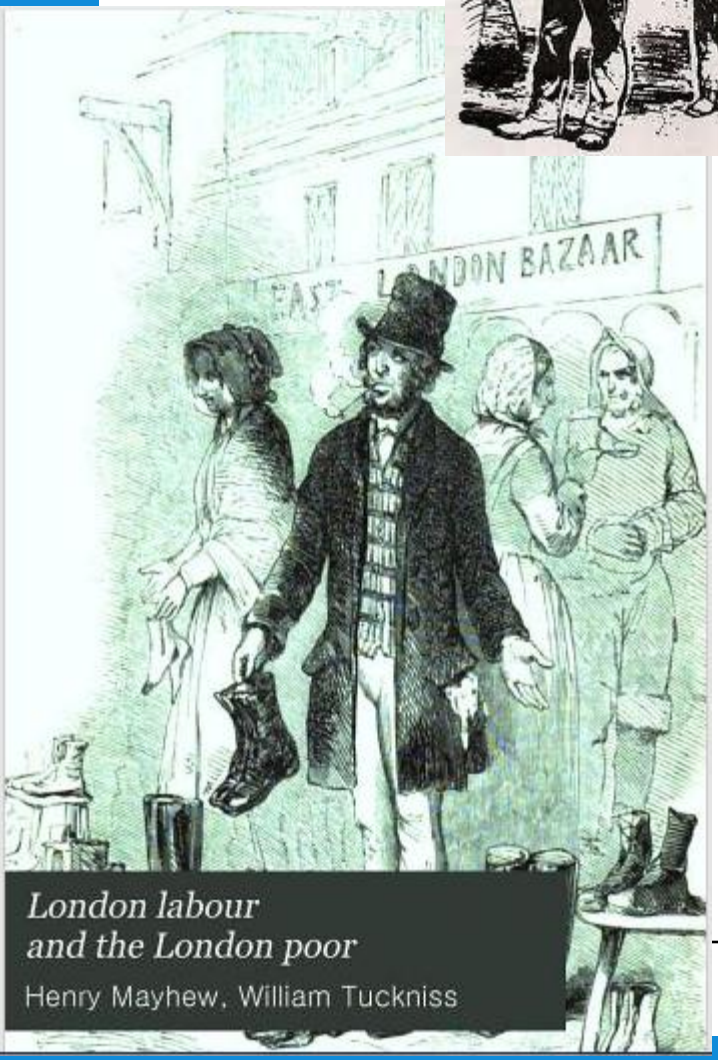
Manath Chanwaria

zakjes, in het mandje vallen, zodat ze niet in aanraking hoeven te komen met Athwal.

Een van de buurvrouwen en collega's van Sheela Athwal is de twintiger Manatha Chanwaria. Als het aan haar had gelegen, deed zij wel ander werk. Maar ja, zij kreeg de wijk van haar schoonmoeder. Hoe kan zij weigeren? Dat zou haar man in de problemen brengen. En tegelijkertijd: ze heeft het geld nodig. Haar man verdient

kan zij de uitwerpselen makkelijker bij elkaar schrapen. Een smalle steeg van het binnenplaatsje leidt naar de achterkant van een op een verhoging gebouwde wc. Een vierkant gat onder het toilet geeft uitzicht op de feces van het gezin.

Dan klinkt er ineens een rochel in het kamertje, gevolgd door een plens water die de ruimte onder de wc uitstroomt. De wc blijkt in gebruik te zijn. Chanwaria springt opzij, om te voorkomen dat de mix



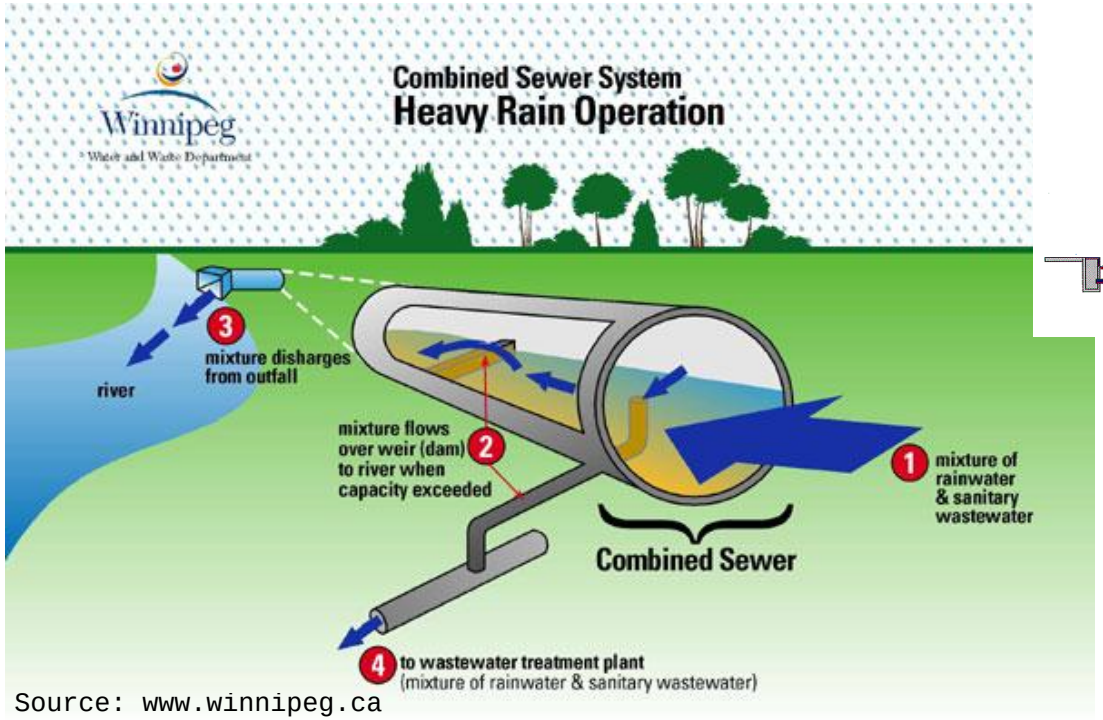
The Darker Side of 19th Century London - The Great Stink

"In addition to saltpetre men, night soil men removed human waste that they then sold as fertilizer for crops. It was a filthy job that involved crawling through cesspits and sewers or descending into them from ladders. By 1810, the city's one million inhabitants had 200,000 cesspits. The pressure on these caused the pits to overflow into street drains designed originally to cope with rainwater. WC's discharged human waste directly into the Thames, while much of London's drinking water was still being extracted from the Thames, often downstream from the sewage discharge points"

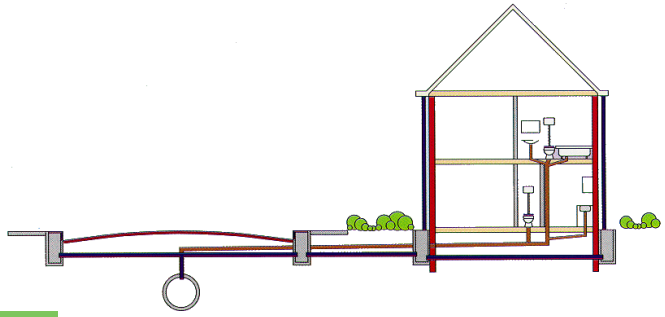
Currently applied solutions for urban drainage

Combined systems

Combined sewer system: Wastewater and rainwater through 1 conduit/pipe

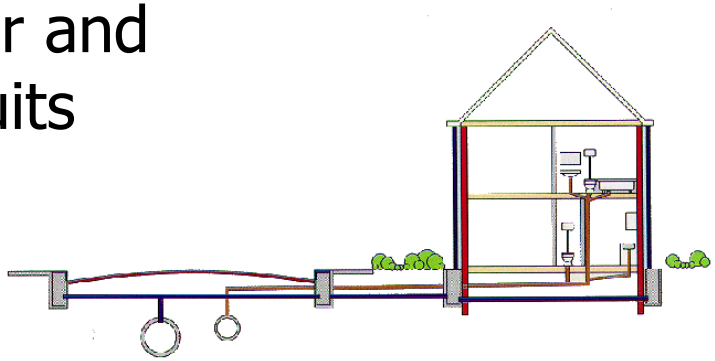


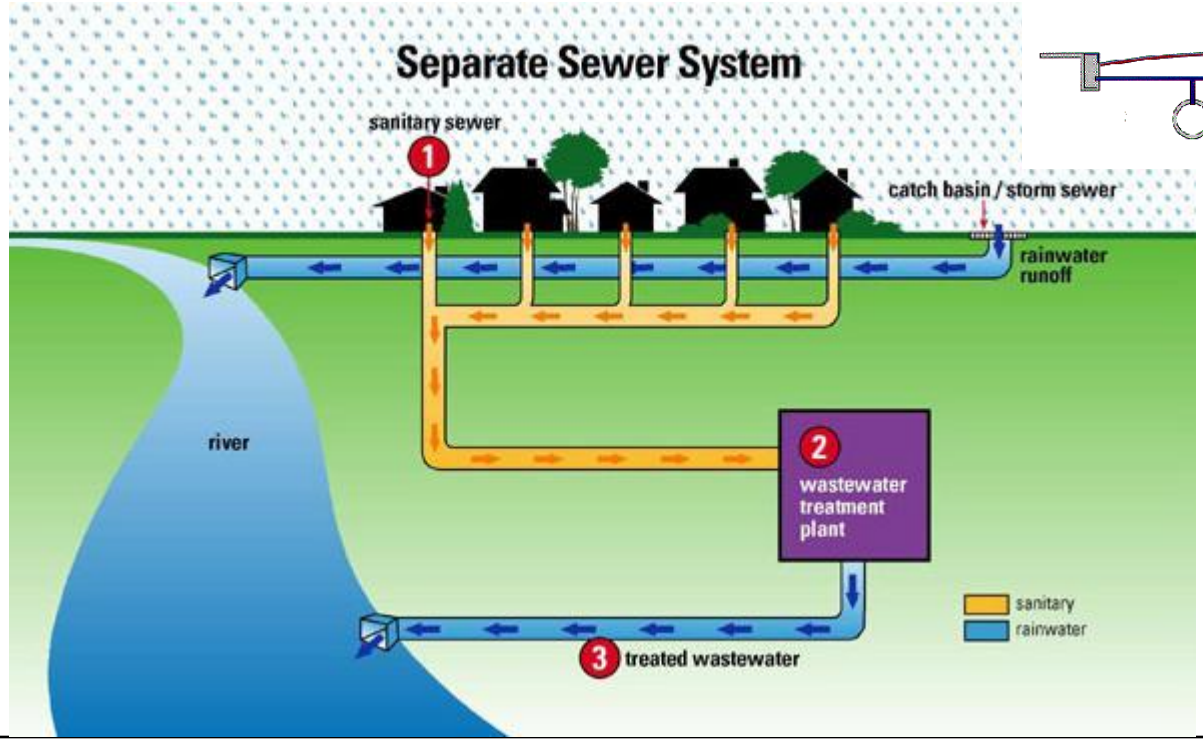
Source: www.winnipeg.ca



Separate systems

Separate sewer system: Wastewater and rainwater through 2 separate conduits

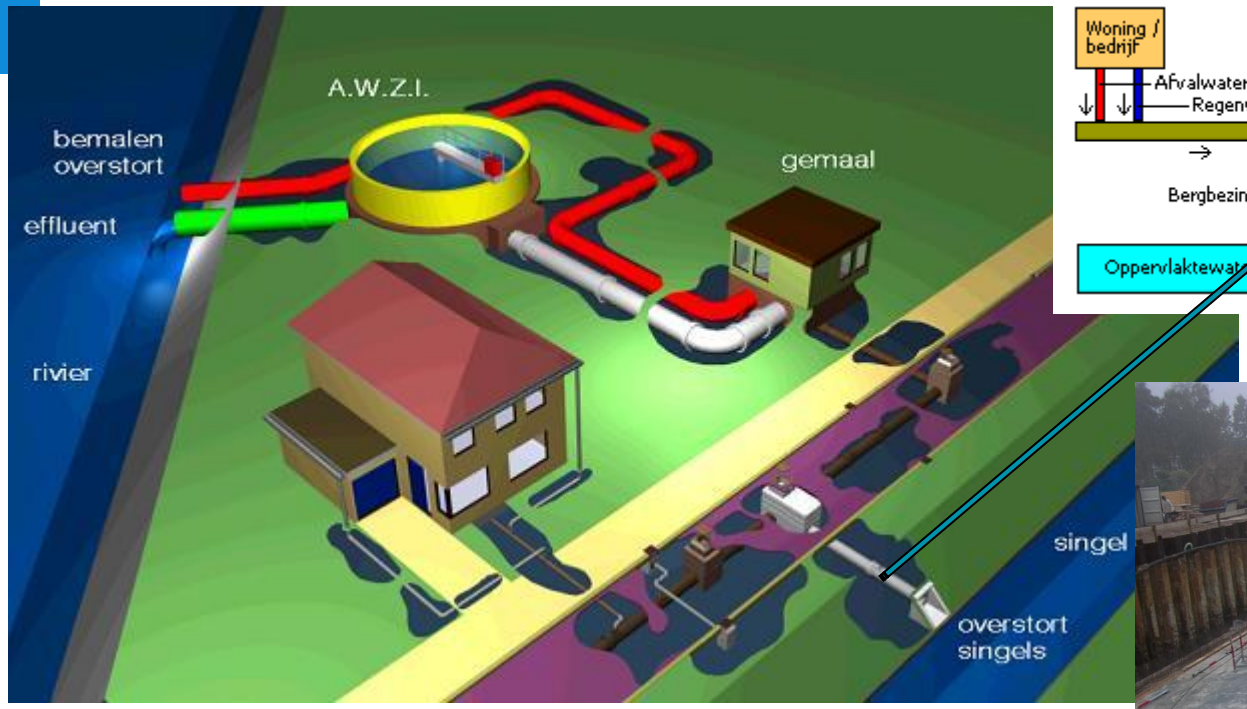


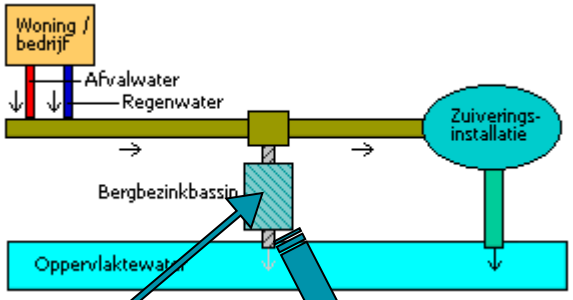


Typical stormwater drainage channel Singapore

Stormwater drainage, Campus IT Bandung

Combined systems

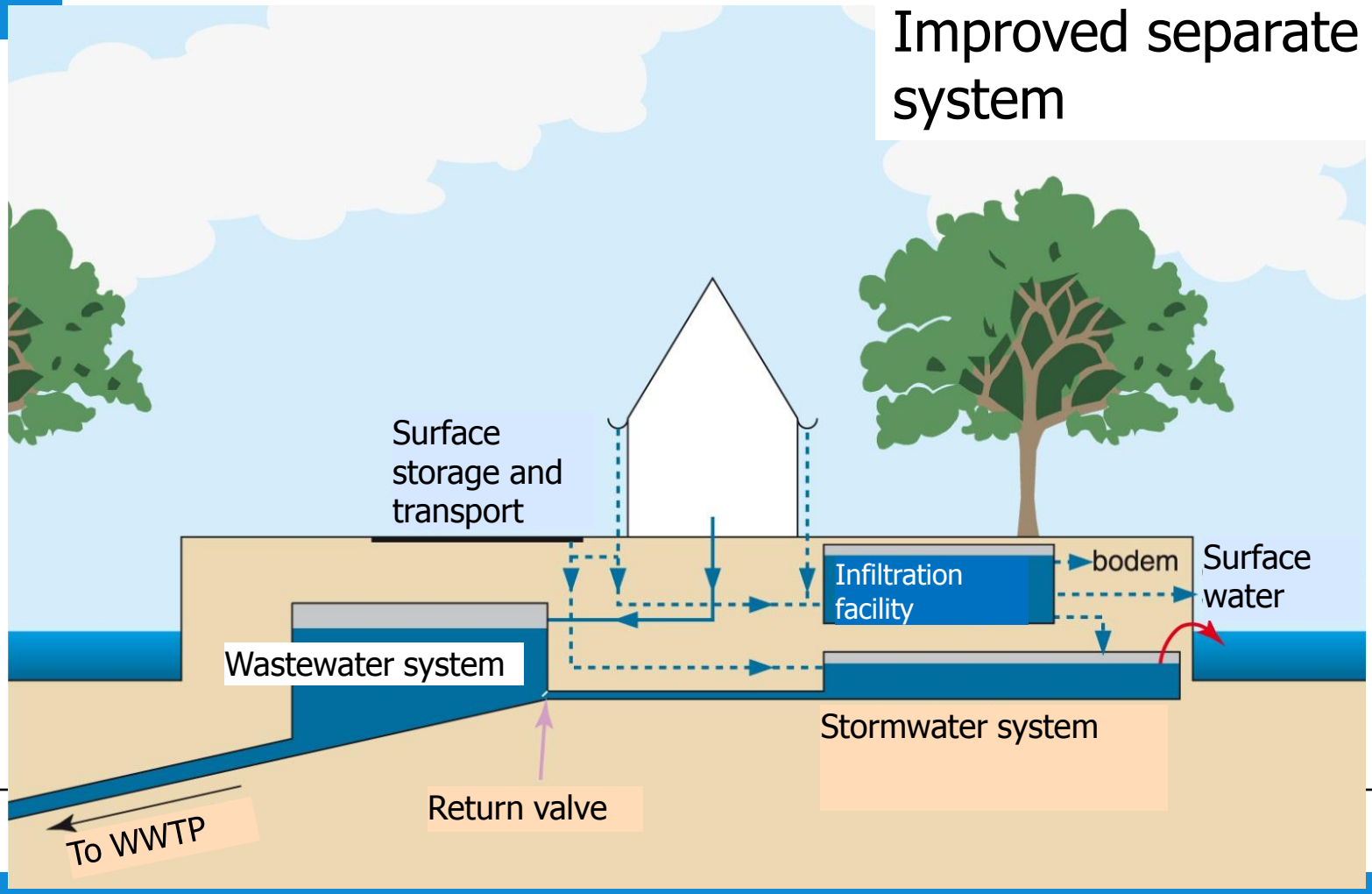




Improved combined sewer system

Separate systems

Improved separate sewer system



Stormwater handling

(Unintended) Surface storage

- Store rainwater and delay flow to sewer system and surface water

Stormwater handling

(Intended) Surface storage: Water squares

Remarks:

- Wash-off pollution from urban surfaces; Surface condition after emptying storage ?
- Health aspects ?

Photo: Rotterdam City

Stormwater handling

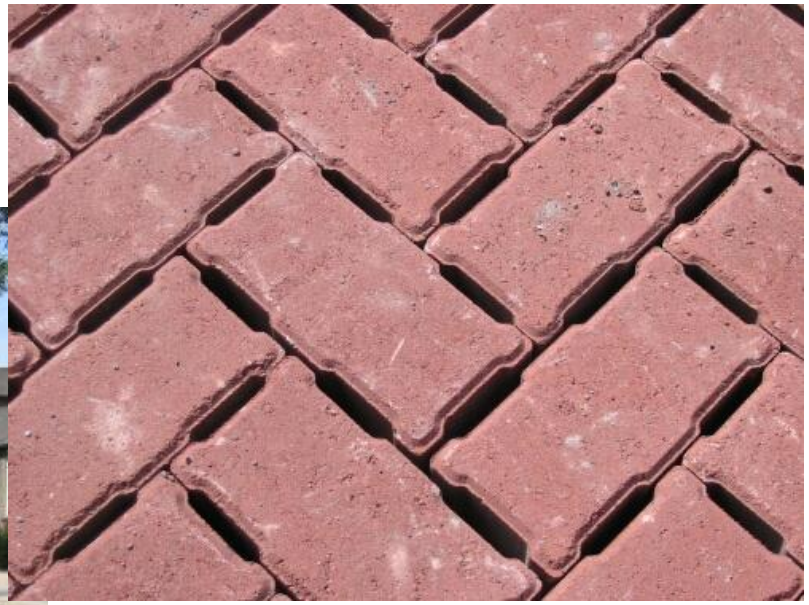
Underground storage

- Store rainwater
- Delay flow to sewer system and surface water

Photo: Rotterdam City

Stormwater handling

Infiltration: permeable pavements



- Infiltrate rainwater

Stormwater handling

Infiltration zone, swale (NL: wadi)

- Store and infiltrate rainwater

Stormwater handling

Infiltrating sewer

- Store and infiltrate rainwater

Stormwater handling

Green roofs

Photo: TU Delft

Photo: Rotterdam City

Of course there are downsides to every system type…

Source: www.tidydrivederby.co.uk

Photo: City of Lewiston

Source: www.everydaycareer.com

…downsides of every system type…


Olofsbuurt
Westerkwartier
Poptahof
Westerkwartier
Design assignment
Course CIE4491 Fundamentals of Urban Drainage
Author M.J. Pruijssen (4011561)
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Supervisor J.A.B. Post
Date 6 April 2013
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Assignment report
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Supervisor: Nikola Stanic
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Faculty of Civil Engineering
Department of Water Management
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Poptahof
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Oude Kerk
Nieuwe Kerk
Delft
Hugo de Grootplein
Legermuseum
Westvest
Oude Delft
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