Storm Water Management in Germany

International Workshop on Ecological Technologies

November 26th-28th , Taipeh, Taiwan

presented by
Dipl.-Ing. Harald Sommer

Universität Hannover

Institute for watermanagement, hydrology and agricultural hydraulic engineering

Content

- Storm Water Management, Overview
- Examples: infiltration, retention and treatment, details for source controls
- Potential maps, Implementing, Simulation
- Treatment in the inlet
- Erosion and Flooding

Until a few years ago: Storm water drainage

- Usual way handling storm water: drainage
- Disadvantage of classical drainage:
  - Reduction of ground water formation
  - Increasing of flow intensity
  - Pollution of water bodies
  - Reduction of water levels in summertimes
  - High costs

Sewer systems for storm water in Germany:

Sewer system	1991 in km	1995 in km	Growth in km	Growth in %
Storm water sewer	67.045	76.339	9.294	13,9
Combined sewer	199.906	213.491	13.585	6,8
Sum of sewer for Storm water runoff	266.951	289.830	22.879	8,6

Source: ATV

Tendency in the last (10) years

- Basic change in handling storm water in recent years
- demand of infiltration in legislation of water authorities

Main aspects:
• retaining the natural water cycle
• avoid increase and accelation of water flow

WHG, §1a, (2):

Jedermann ist verpflichtet, bei Maßnahmen, mit denen Einwirkungen auf ein Gewässer verbunden sein können, die nach den Umständen erforderliche Sorgfalt anzuwenden, um eine Verunreinigung des Wassers oder eine sonstige nachteilige Veränderung seiner Eigenschaften zu verhüten, um eine mit Rücksicht auf den Wasserhaushalt gebotene sparsame Verwendung des Wassers zu erzielen, um die Leistungsfähigkeit des Wasserhaushalts zu erhalten und um eine Vergrößerung und Beschleunigung des Wasserabflusses zu vermeiden

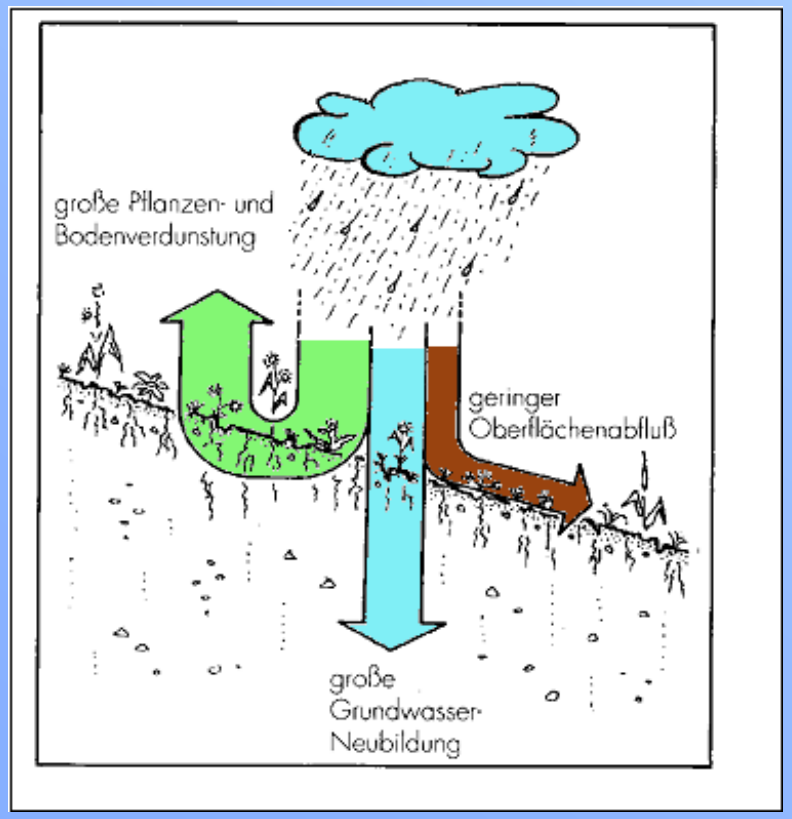
Surface sealing

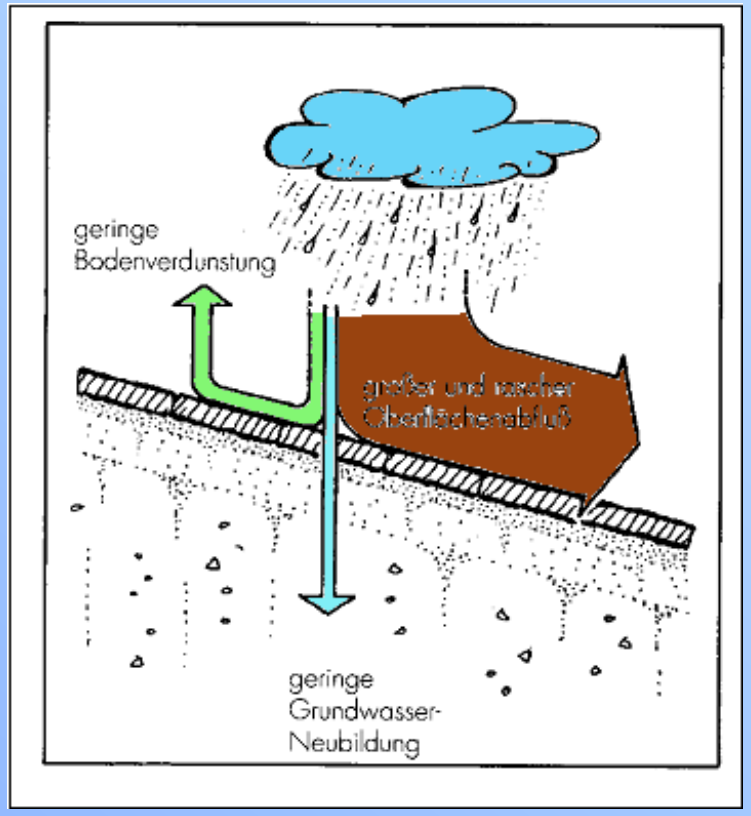
Sealed areas in Germany:

- approx. 12 % of Germany are urban areas
- 50% are sealeded: approx. 6 % = 21.500 km^2
- Daily increase of urban area: ~130 hectare
  $\Rightarrow$ ~235.000.000 m^2 new sealed area/year
- ~ 300.000 km public sewers (combined+ separated system)

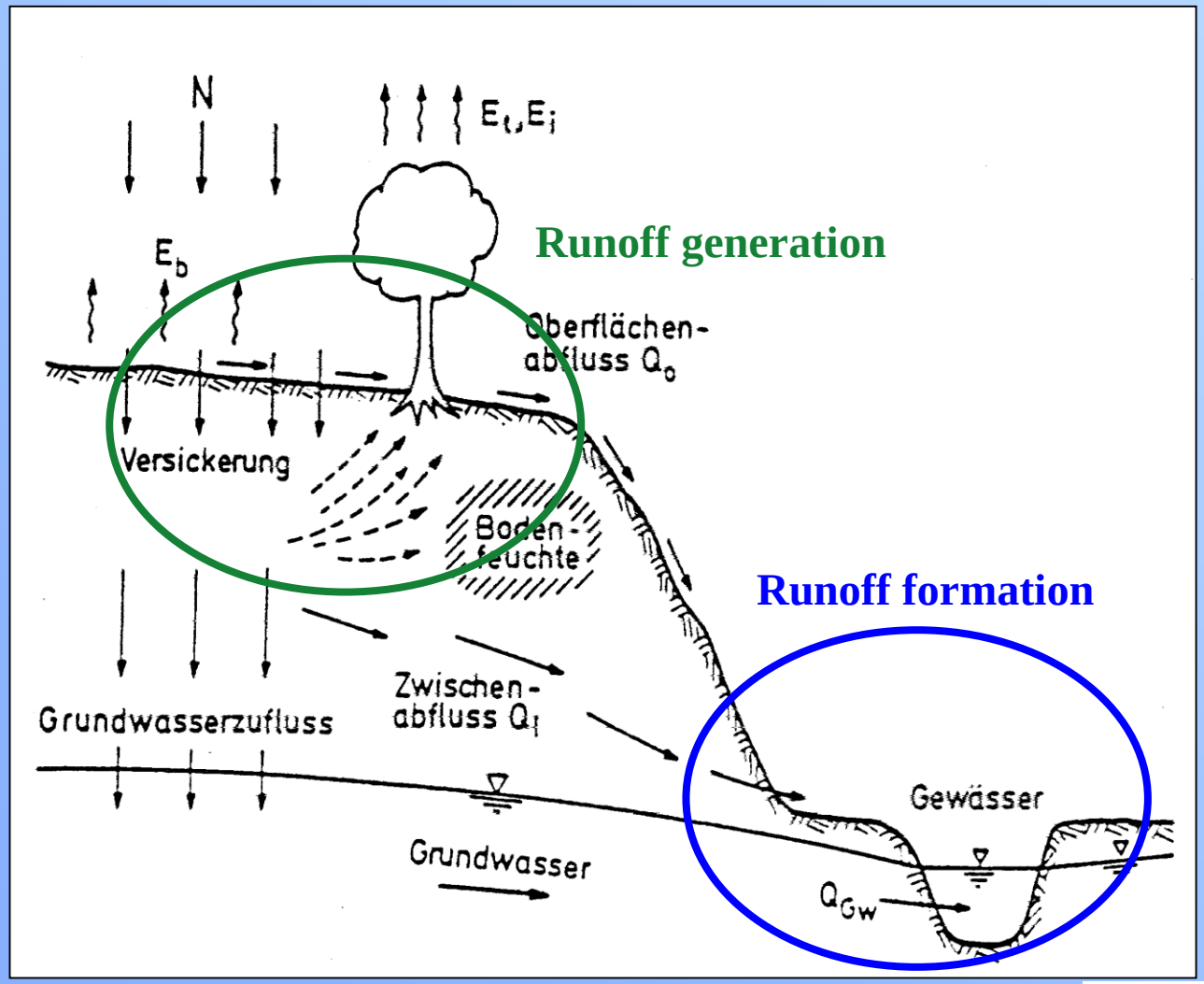
$\Rightarrow$ *Effects on the water cycle !*

Effects on the water cycle





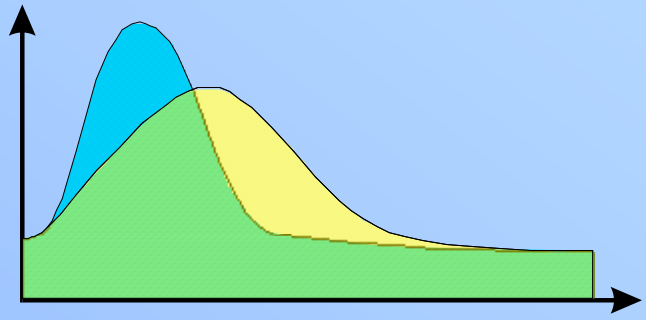
Effects on the water cycle



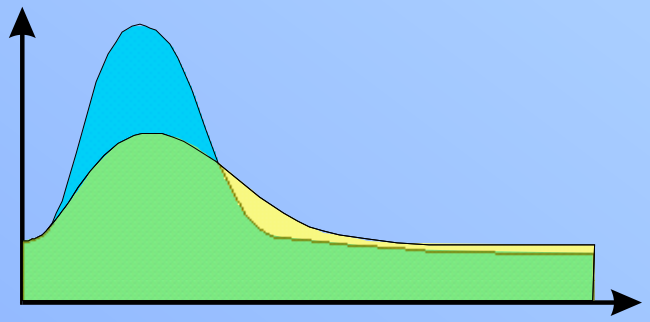
Flood defense

I you have flood problems, what can you do ?

a) ***Downstream measures***
(end-of-pipe measures:
ponds, dikes)
= only retention



b) ***Source control measures:***
reduction of runoff “on-site”
= retention and volume reduction



Costs of urban drainage

- Value of existing system
  $\Rightarrow$ 300 Billion €
- Costs for renovation of existing systems
  $\Rightarrow$ 45 Billion €
- Costs for draining the new sealed areas
  ~25 €/m² $\Rightarrow$ 6 Billion €/year
- Compare: Turnover of the German Professional Soccer League
  $\Rightarrow$ 1.3 Billion €/ year

>> Urban drainage with sewer systems is very expensive!!

Discharging Storm Water by Sewers

- Disturbs the water balance and can cause floods
- Costs a lot of money
- Pollutes the rivers

What are the alternatives ?

New:

Storm Water Management

What means

Stormwater management

Instead of

Storm water drainage?

Aims of Storm Water Management

- Safety and Comfort of urban drainage
  - Handling of design rainfall events
  - Frequence of overflow
- Protection of water bodies (Groundwater, rivers, lakes)
  - Demand of a treatment technology (i.e. sandfilter)
  - Demand of emission (load, concentration, frequency)
  - Aim for immision (aims for quality of water body, limitation of hydraulic load)
- Aims for Water Cycle Management
  - Retention (selecting specific throttled flows)
  - Reaching the natural water cycle (sustainability)
- Minimising of costs

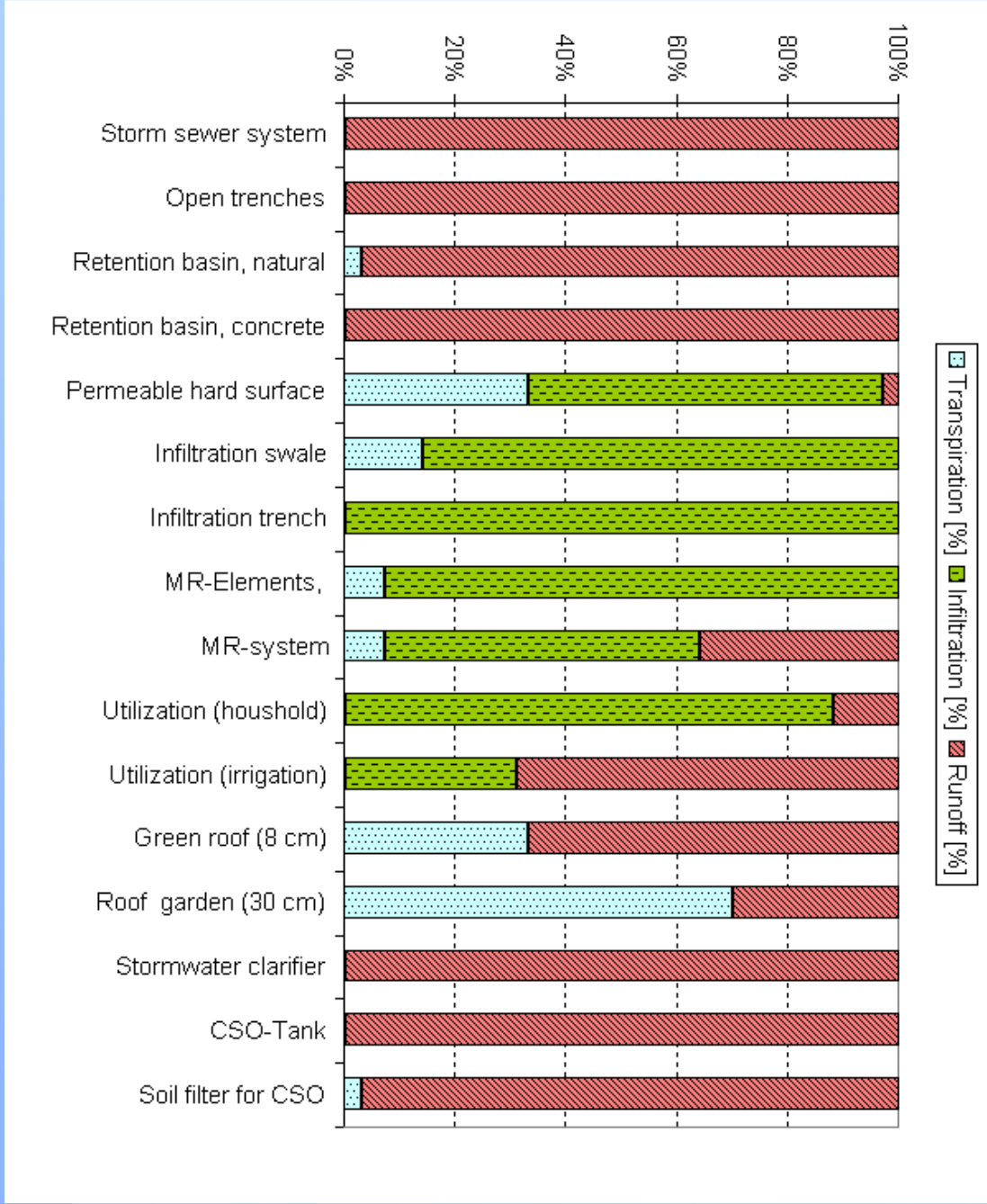
Meassures for Storm Water Management

- Strom water drainage und central Retention
- Decentralized Retention
  - Infiltration systems (troughs, trough-trench-system)
  - Green roofs, cisterns, reducing sealed areas
- Treatment of storm water in separate sewer system
- Treatment of storm water in combined sewer system (CSOs)
- Treatment of storm water on WWTP (waste water treatment plant)
- Decentrale storm water messearus outside urbanized areas
- Meassures in or at the water bodies
- Meassures for reducing pollution loads

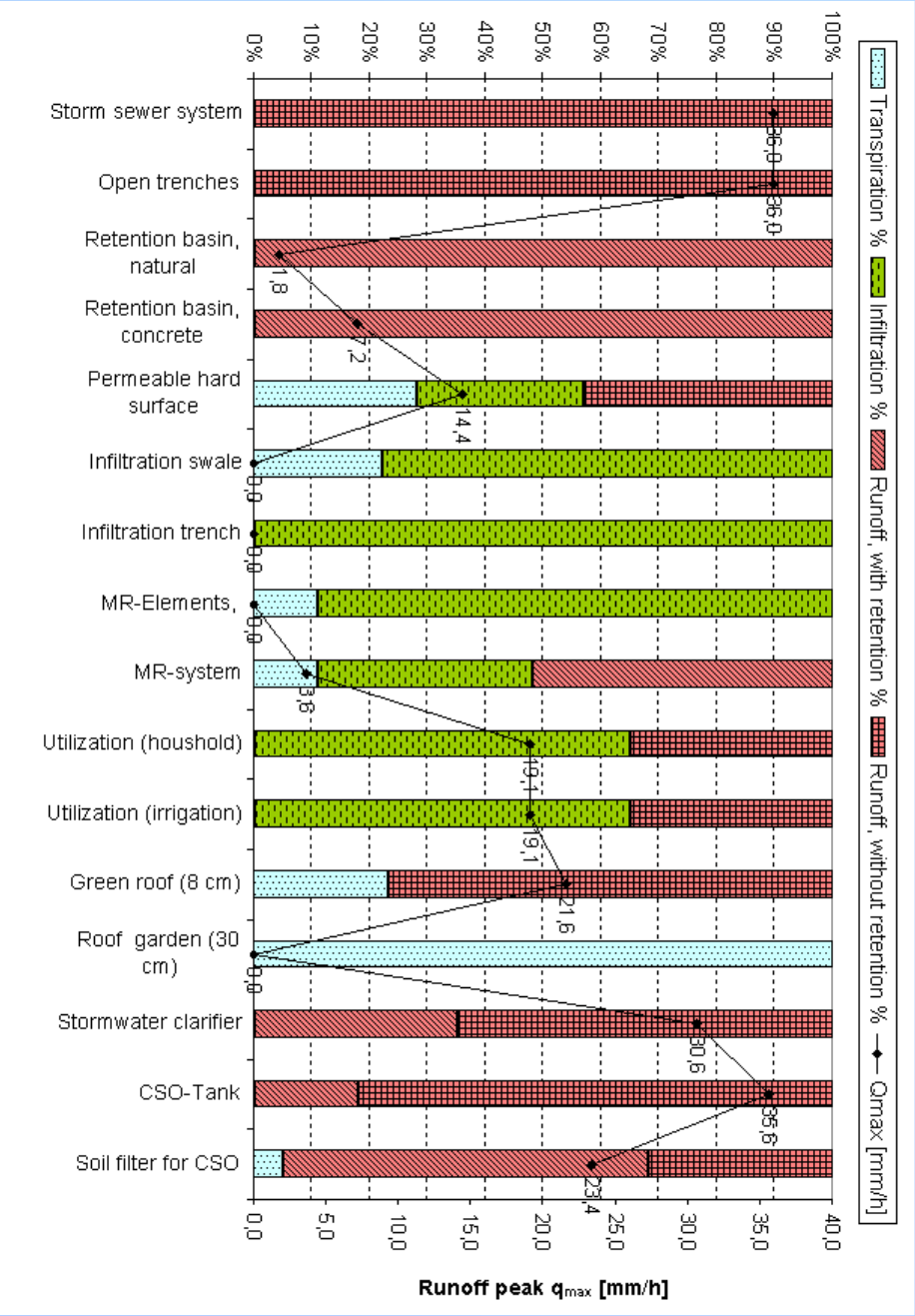
Storm Water Management

Details source controls

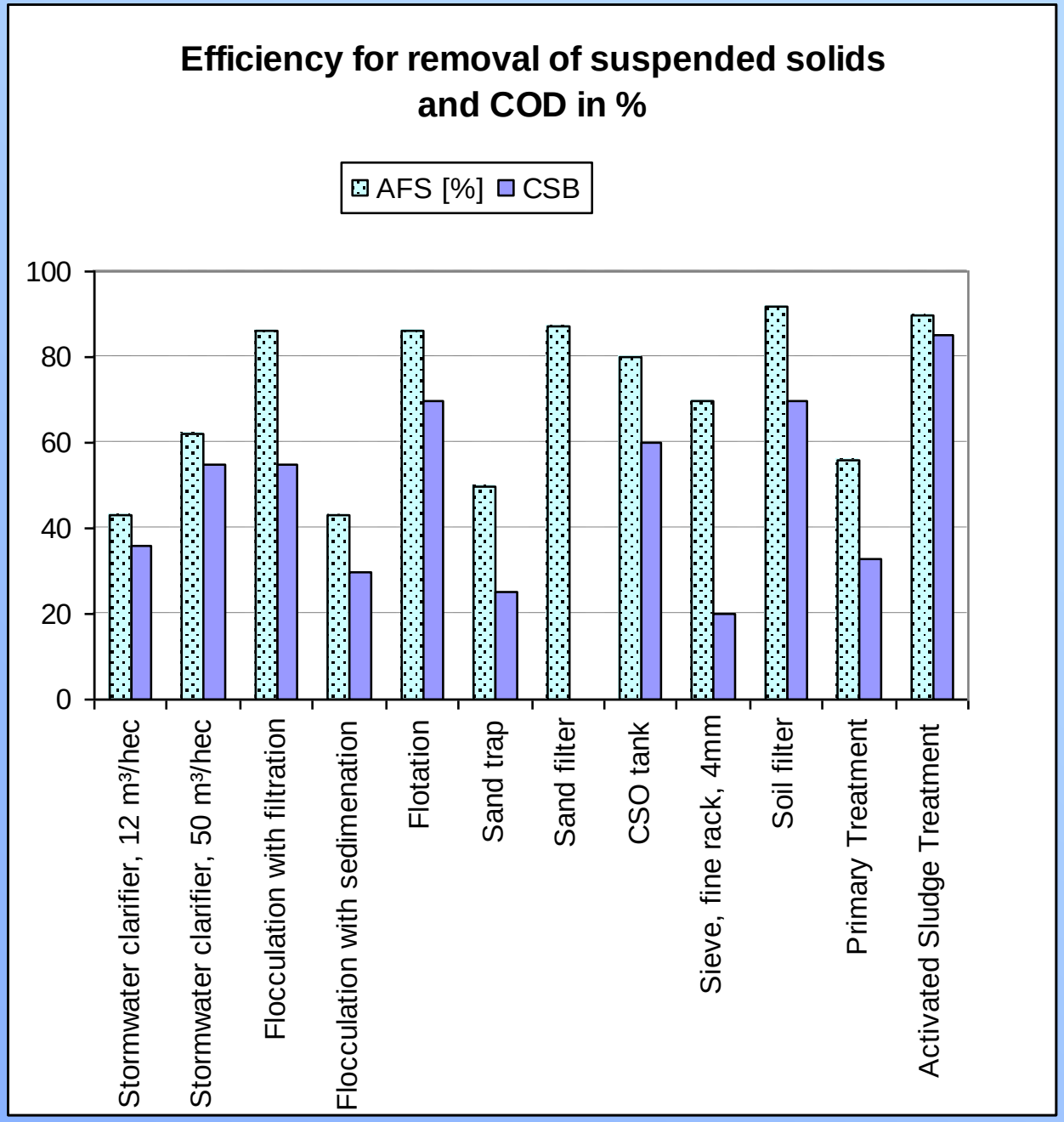
Waterbalance for examples of storm water infiltration, retention and treatment



Runoff peak flow in a design-storm



AFS=TSS
CSB=COD



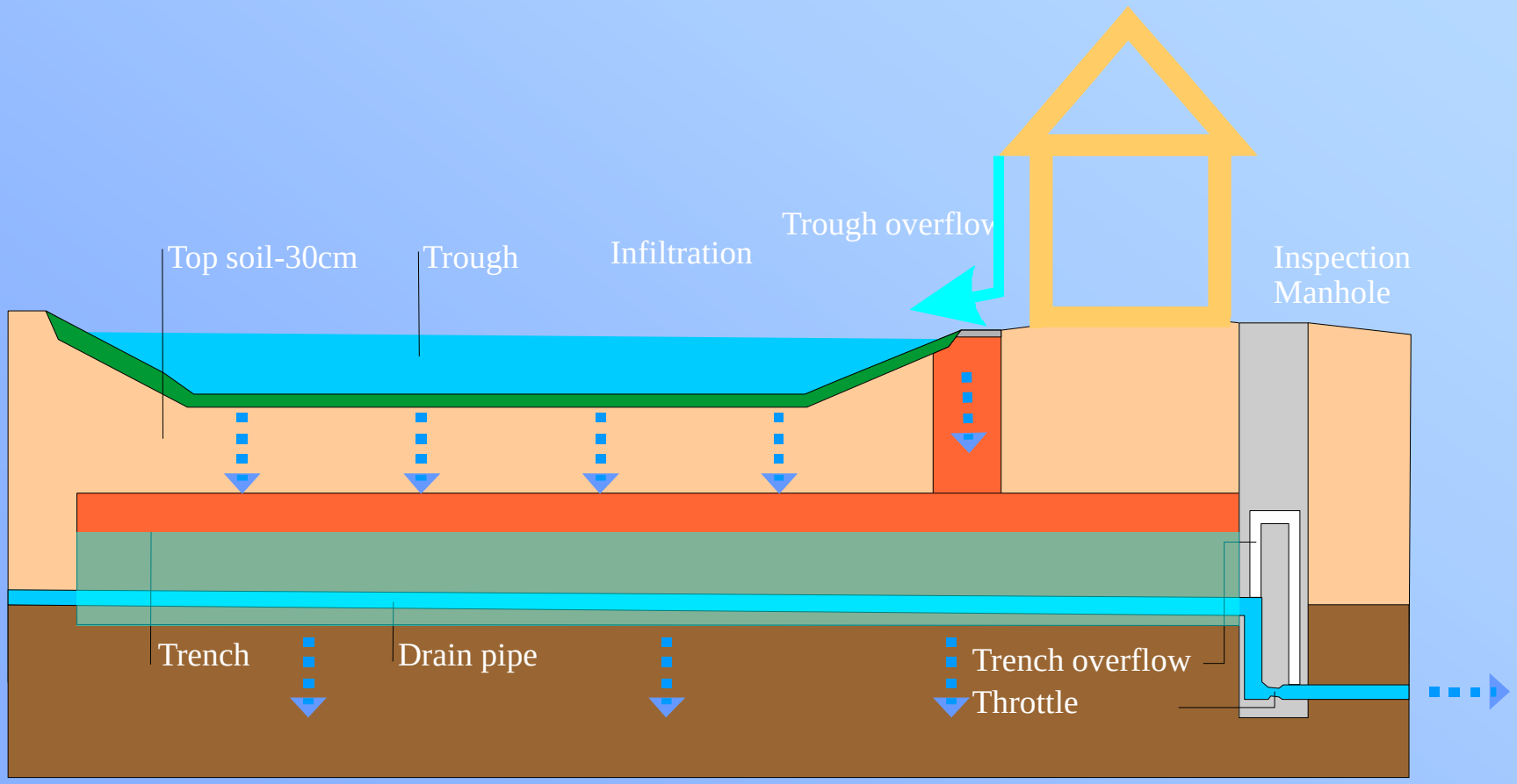
Usage o infiltra-tion BMPs

				Surface infiltration			Underground infiltration	
	Fläche	Contant of pollutants	Quality assessment	wid infiltration A_s:A_i=5	5<As:Ai=15 swales, swale-trench-systems	5<As:Ai=15 central infiltration ponds	trenches	infiltration drains (shafts?)
	1	2	3	4	5	6	7	8
1	Green roofs, meadows, unpaved areas		harmless	+	+	+	+	+
2	Roofs without metall; Terraces in housing areas		harmless	+	+	+	+	(+)
3	Roofs with common shares of metal (uncoated, <10%)		tolerable	+	+	+	(+)	(+)
4	Footpathes in housing areas		tolerable	+	+	(+)	(-)	(-)
5	Yards, parking lots and streets with less than 300 cars/day		tolerable	+	+	(+)	(-)	-
6	Streets with 300 - 5.000 cars/day		tolerable	+	+	(+)	(-)	-
7	Runways on airports		tolerable	+	+	(+)	(-)	-
8	Roofs in industrial areas		tolerable	+	+	(+)	(-)	-
9	Streets with 5.000 - 15.000 cars/day		tolerable	+	+	(+)	-	-
10	Parking lots with heaxy traffic (e.g. shopping malls)		tolerable	+	(+)	(+)	-	-
11	Metal roofs; heavy polluted streets and yards (e.g. farms, markets)		tolerable	+	(+)	(+)	-	-
12	Streets with more than 15.000 cars/day; autobahns		tolerable	+	(+)	(+)	-	-
13	Streets and yards in industrial areas		not tolerable	(-)	(-)	(-)	-	-
14	special areas, e.g. parking lots for trucks, de-icing areas on airports		not tolerable	-	-	-	-	-

+	usually allowed
(+)	usually allowed with pre-treatment
(-)	usually not allowed
-	not allowed

A_s	sealed area
A_i	infiltration area

Trough-Trench-System



Trough

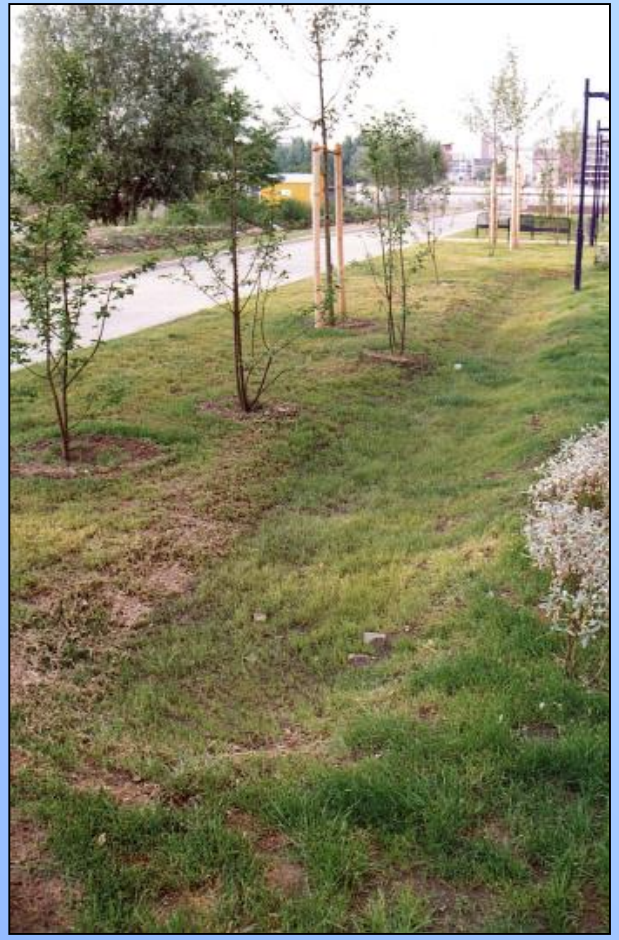
- Search for location where surface inflow is possible
- Protect against parking e.g. by wooden pillars
- Avoid to concentrate inflow

Dimensioning of Trough

- Use “Design storm” or “Longtermsimulation” software (i.e TRINTSIM)
- Roughly: Volume necessary is difference between design storm and sum of infiltration volume and discharge
- Depth not more than 40 cm because of time to empty
- Storage volume in Berlin: ~ 150-250 m³/hectare
- Area needed ~ 10% of sealed area

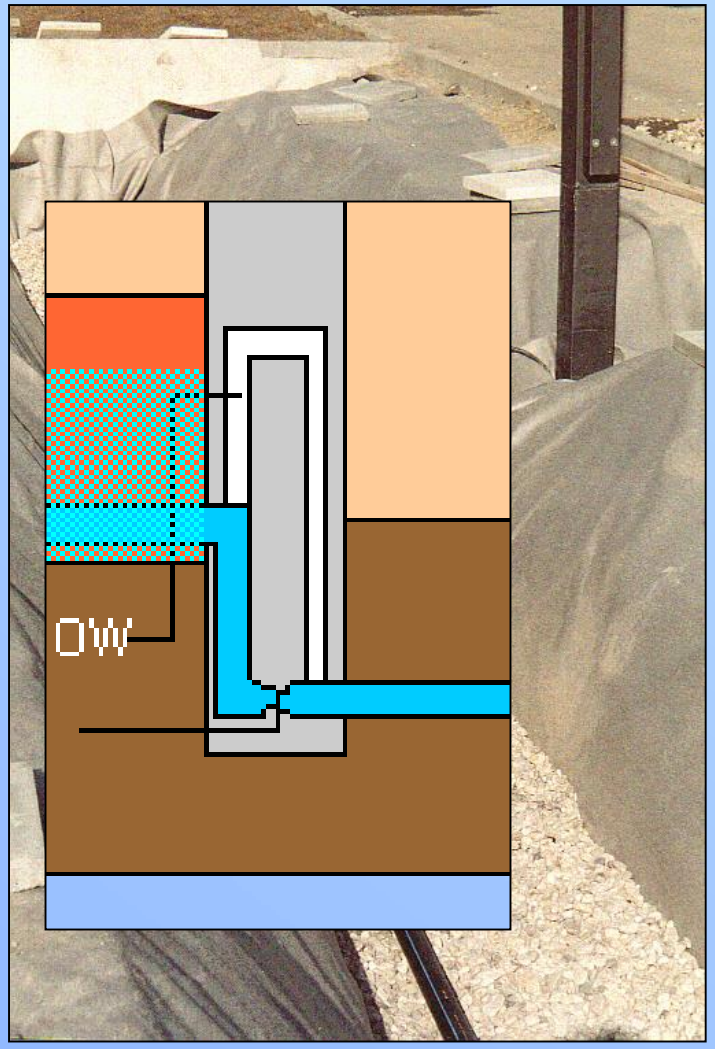
Topsoil

- Use „normal“ topsoil
- If necessary: mix with sand until kf=10E-5 m/s
- Bring in in layers and condense with light pressure
- Plant with grass or shrubbs
- Cut grass 2-4 times a year (in Germany)



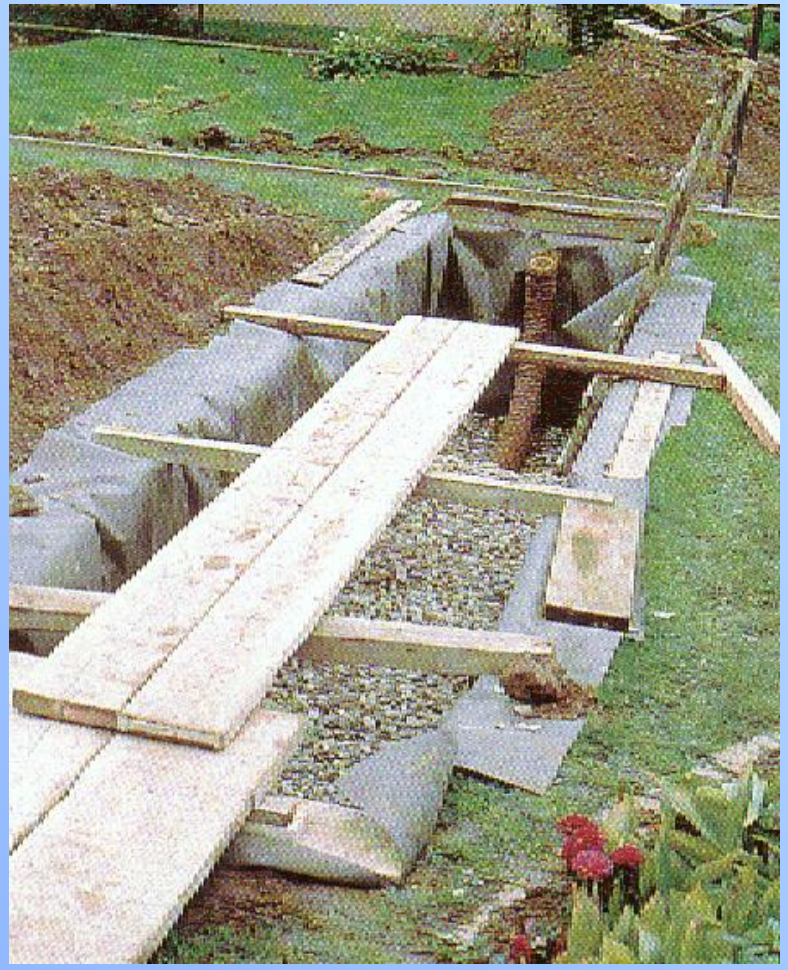
Trench

- Use gravel of unique size
- Avoid fine material around gravels
- Wrap with geo-textile
- Porous drain pipe
- Inspection manhole with
  - Throttle
  - Overflow

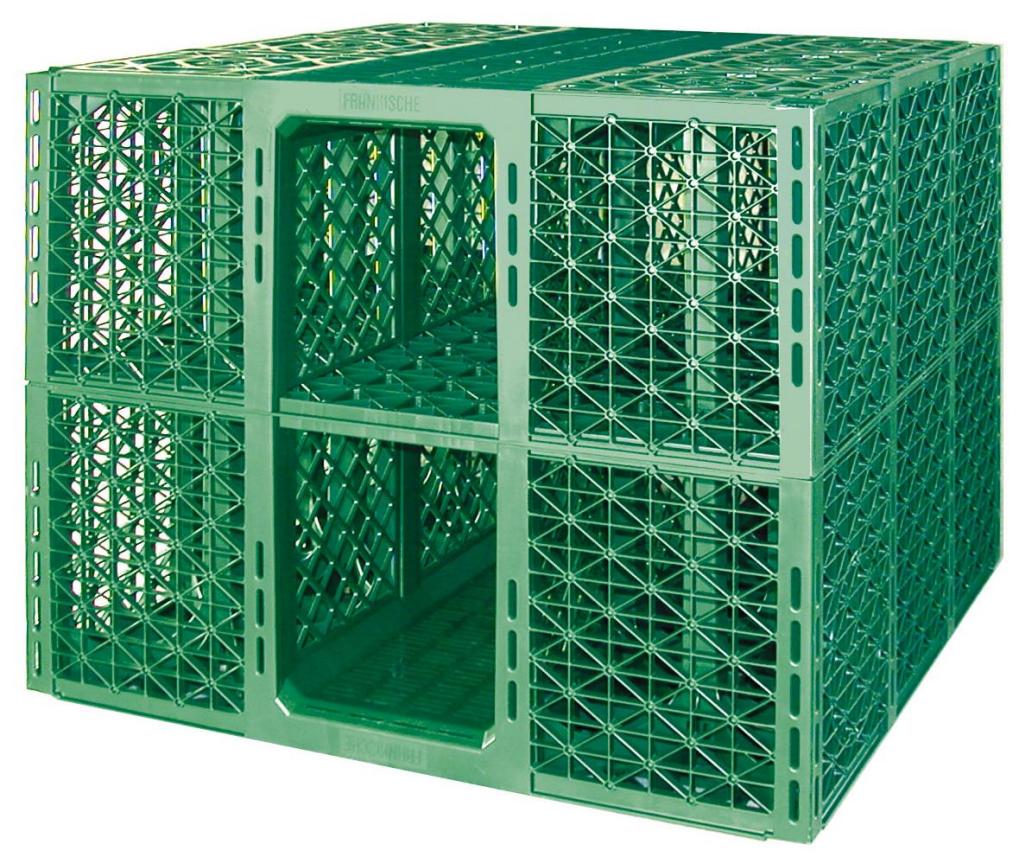


Dimensioning of Trench

- Use design storm or simulation software
- Volume necessary is difference between design storm, infiltration and drainage volume
- Storage volume in Berlin: ~ 150-250 m^3/hectare



Trench-Filling



96% Storage volume !

Manufacturer:

FRÄNKISCHE

Example: industrial area Dahlwitz-Hoppegarten

Example: industrial area Dahlwitz-Hoppegarten

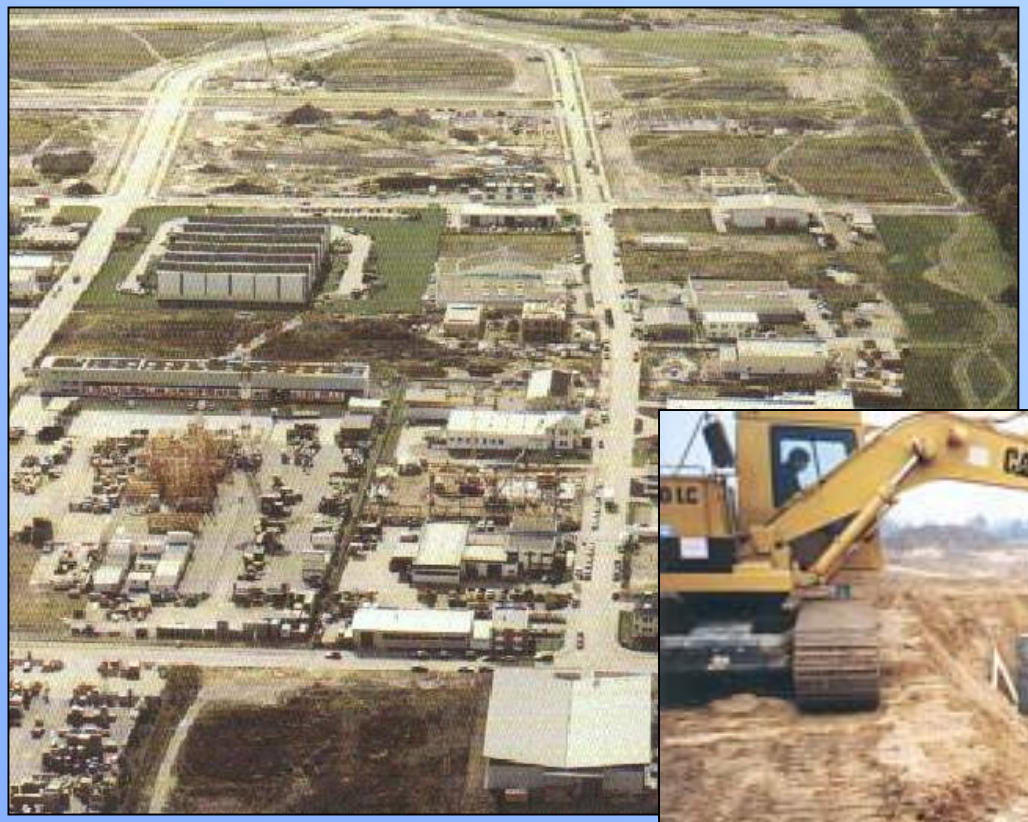
- Difficult hydrological conditions
  - Receiving waters with low capacity
  - max. discharge 40 l/s for 100 hectare development area
  - One year design storm for 100 hectare: leads to 10-15 m^3/s

  ➔ Retention necessary

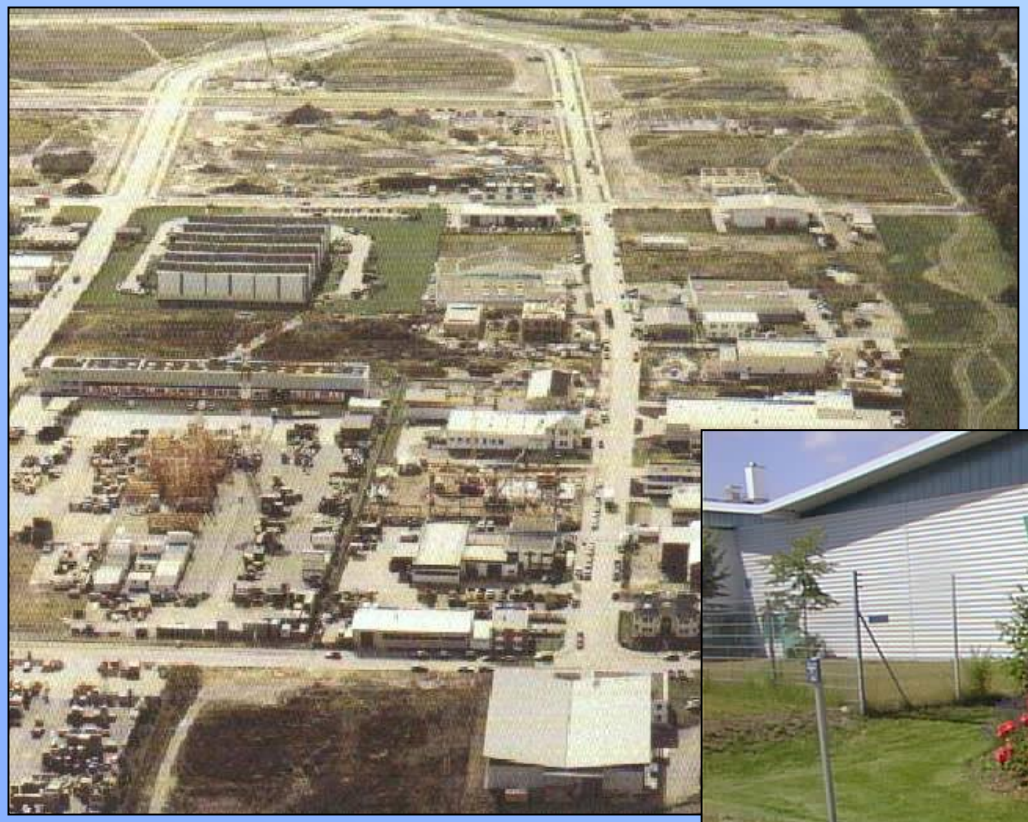
- Difficult geological conditions
  - Glacial soils: poor infiltration capacity
  - Swampy areas with high groundwater levels (tables)

  ➔ Storm water infiltration not or only partly possible

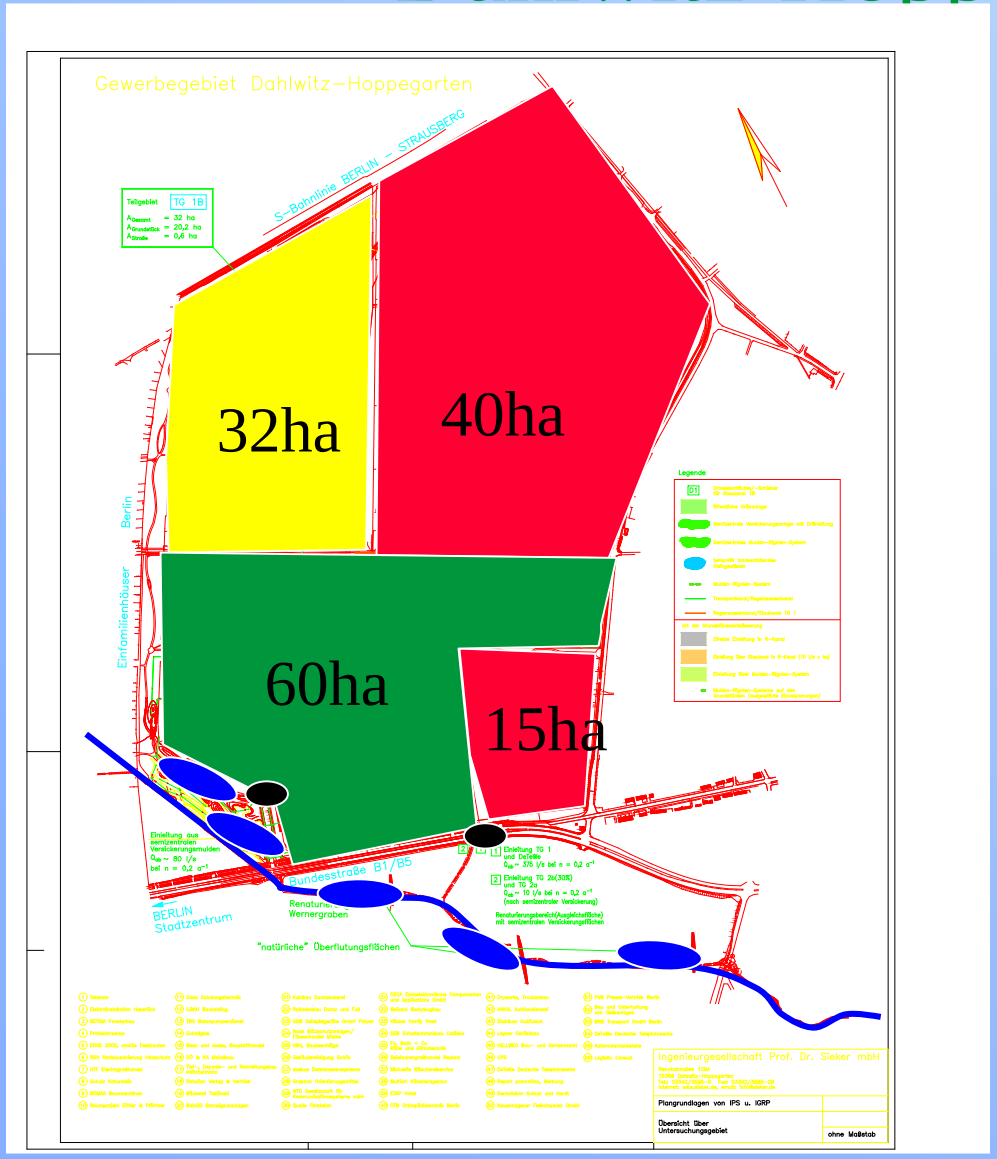
Classical Approach of Urban Drainage



Modern Approach of Urban Drainage



Example: industrial area Dahlwitz-Hoppegarten



conventional

Conventional
+ source controls

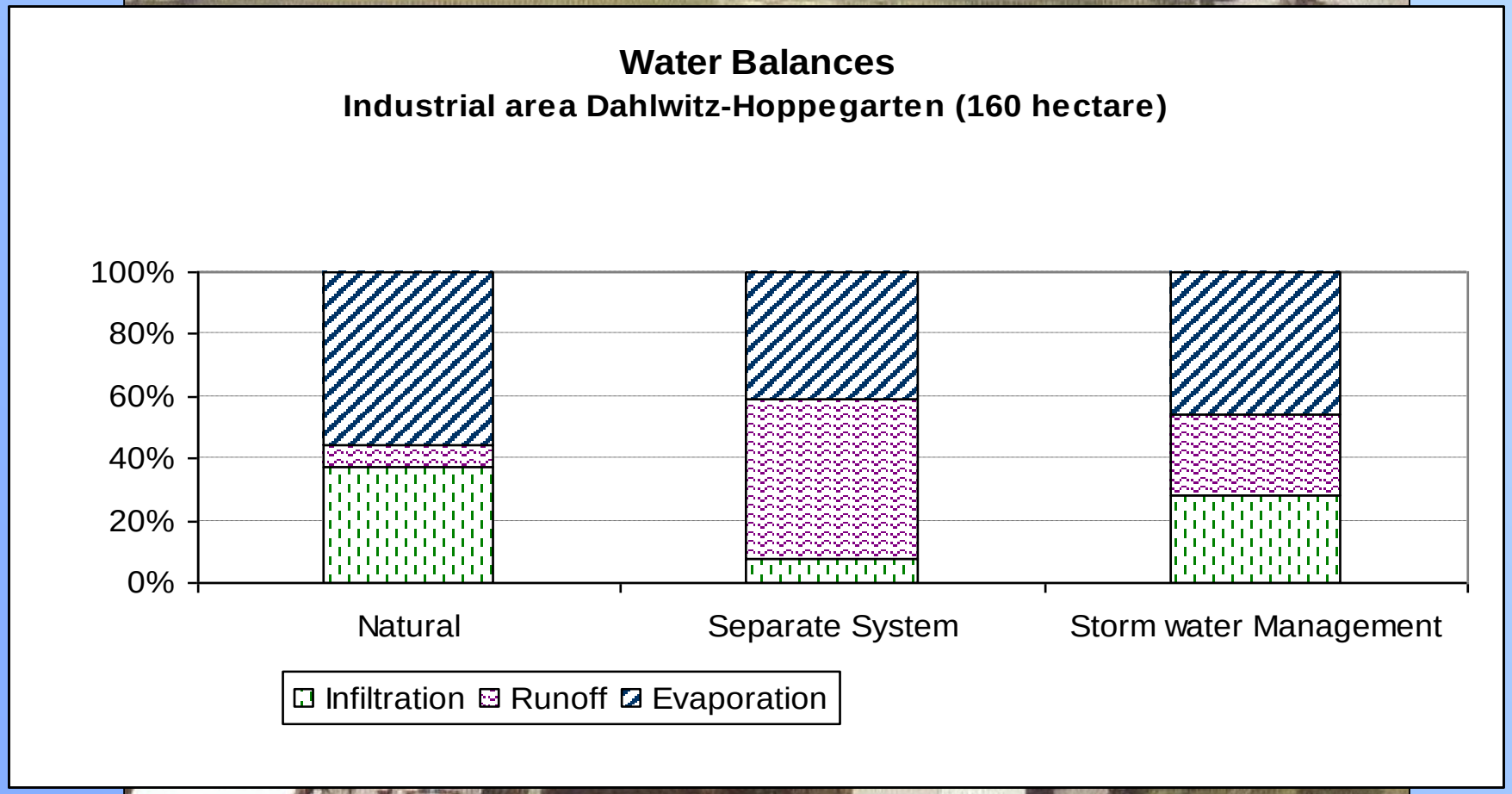
only source controls

outlet

Effects on the water cycle

- Longterm-Simulation on PC over 30 years
- Infiltration approx. 30 %
- High groundwater renewal
- Discharge reduced to 30 %
- Reduced floods, but better base flow
- storm water treatment

Water balances



Economical Aspects

Variant	Classical sewer	On-Site
Total costs	20 €/m²	17 €/m²
On public ground	17 €/m²	5 €/m²
On privat ground	3 €/m²	12 €/m²

Advantages of on-site measures:

- Investment can be made step by step!

Example: industrial area Dahlwitz-Hoppegarten

Example Dahlwitz-Hoppegarten

Fa. Multi-Art

Fa. Schlei

Example: industrial area Dahlwitz-Hoppegarten

Berlin, Rummelsburg

Berlin, Rummelsburg

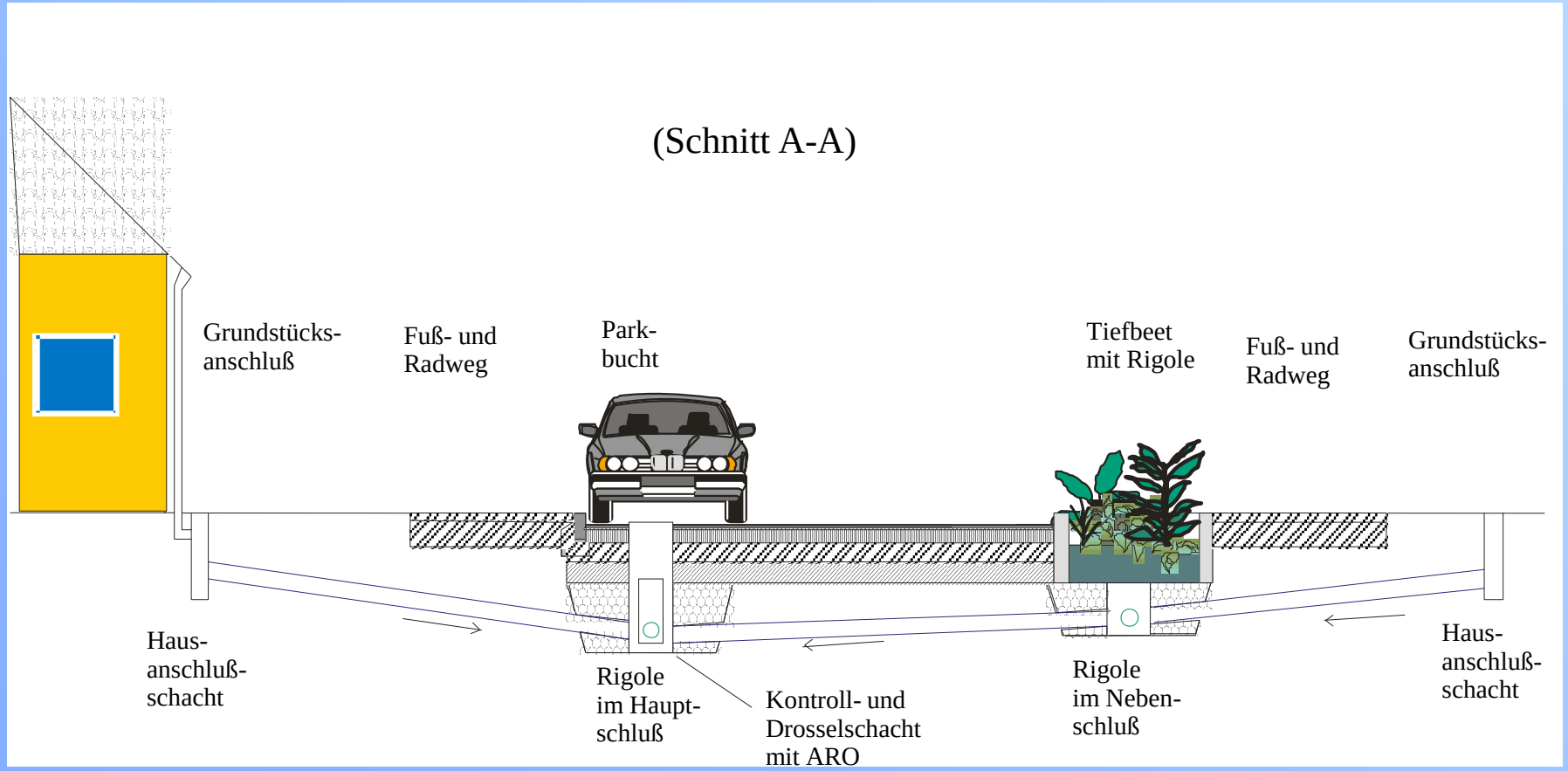
Chemnitz

Traverse City, Mi, USA

Example, Birkenstein

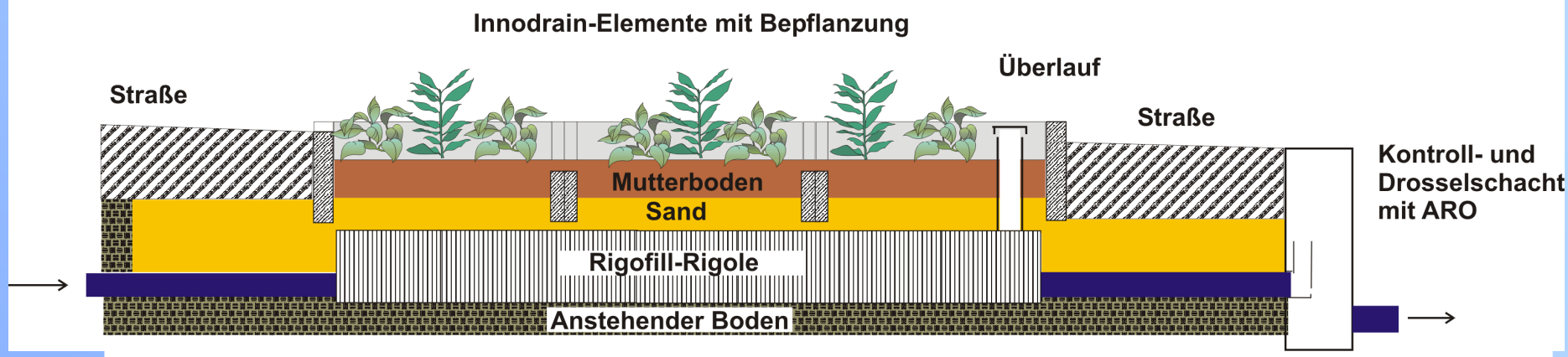
Innodrain

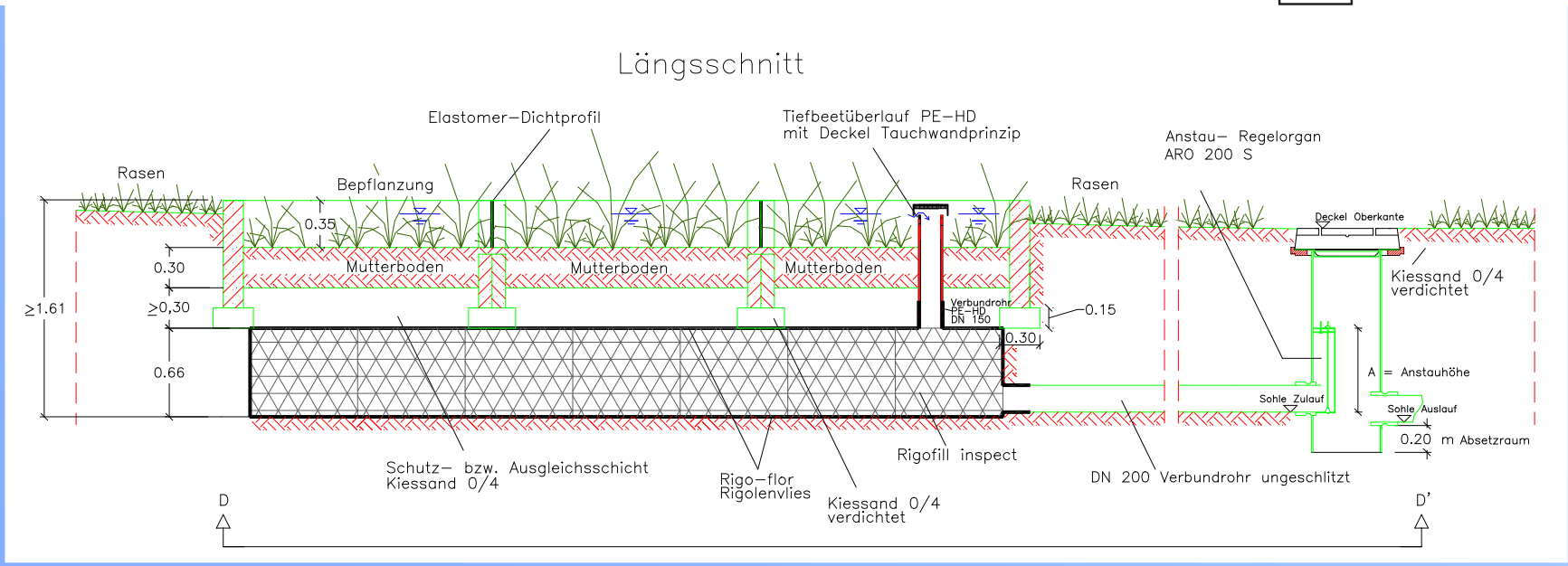
Innodrain®– Scheme
Section of the road



Innodrain

INNODRAIN®-SYSTEM - Schematischer Längsschnitt

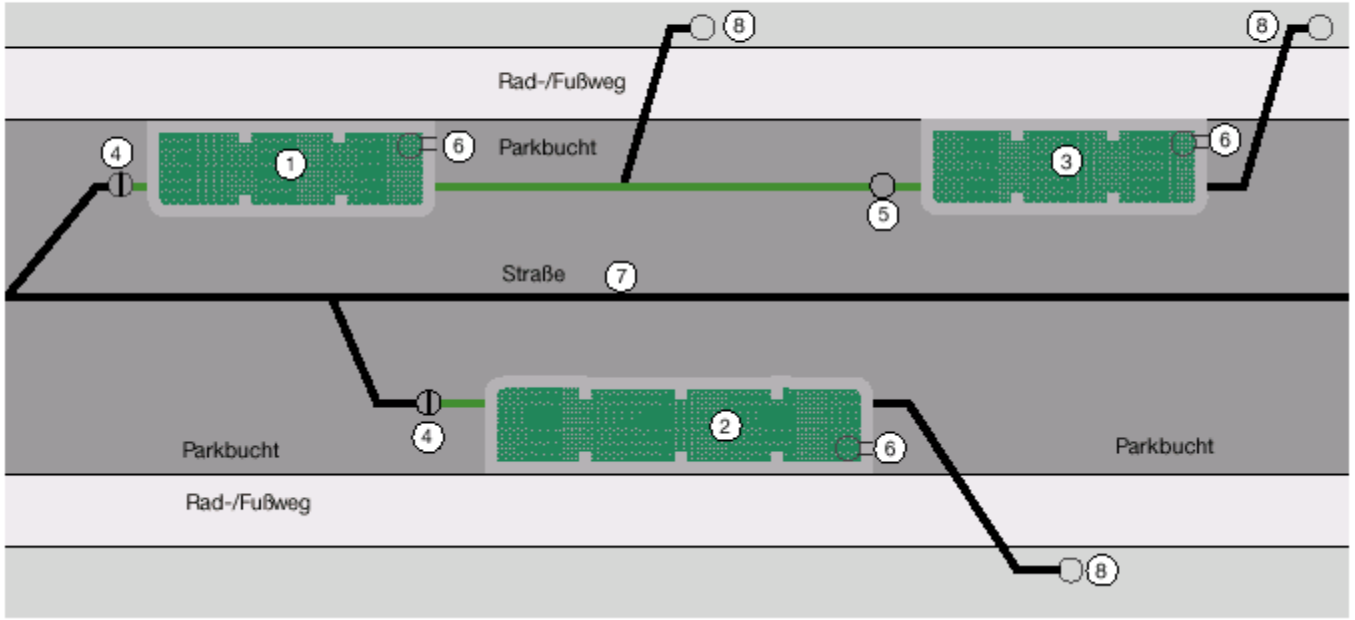




Innodrain®– Scheme

Schematischer Lageplan

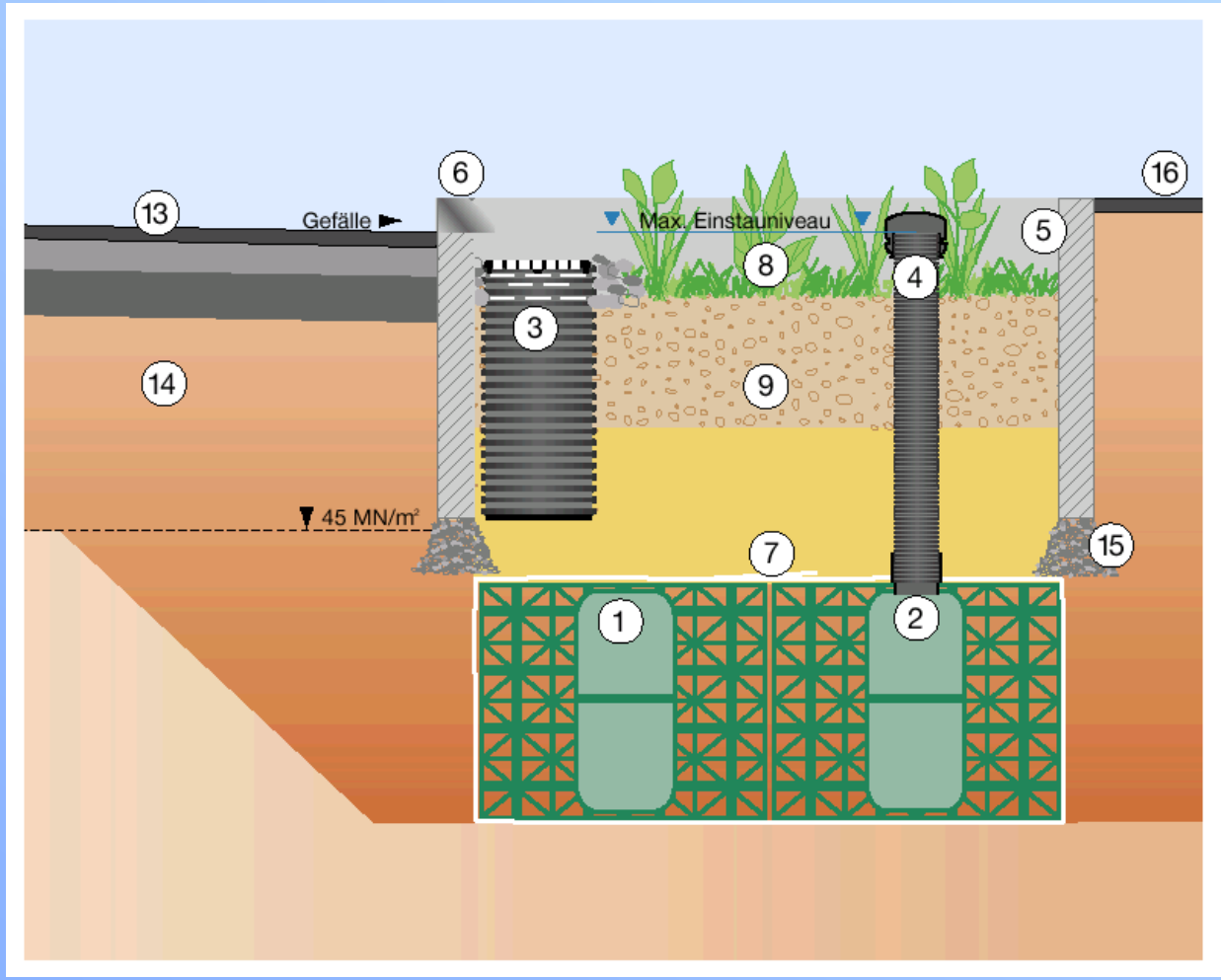
Beispiel: **INNODRAIN®**-Elemente im Nebenschluß an Regenwasserkanal



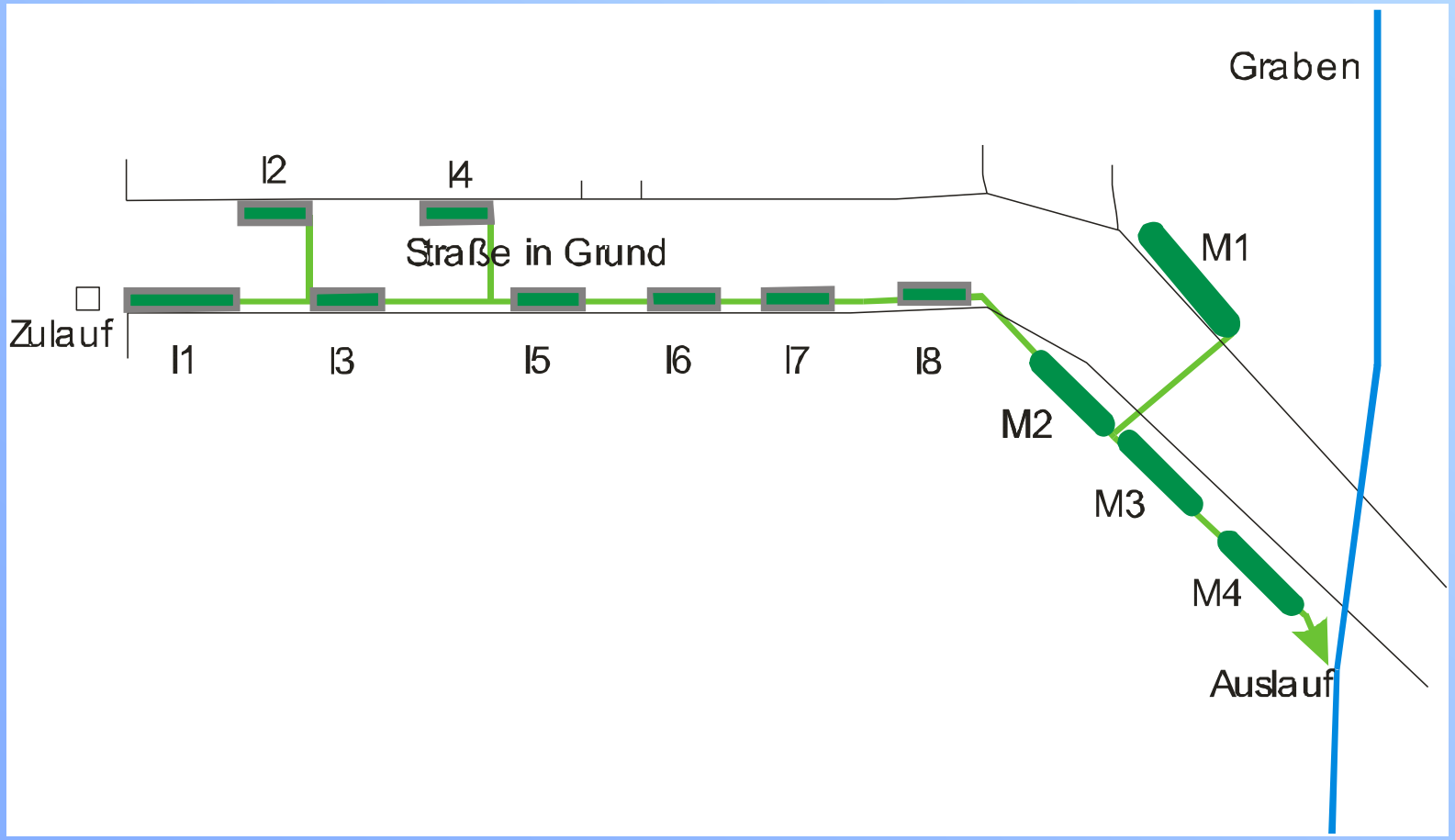
1. Basis-Set
2. Basis-Set mit Verlängerungselement
3. Erweiterungs-Set
4. Drosselschacht
5. Kontrollschacht
6. Zulauf
7. Regenwasser-Kanal
8. Grundstücksanschluß

Innodrain®– Scheme, section

1. **Rigo-*fill inspect***
   ein- oder zweireihig
2. **Rigo-*fill inspect***
   mit Notüberlaufanschluß
3. Zulauftopf
4. Notüberlauf
5. Betonrahmenelement
6. Zulauf
7. Rigolenvlies
8. Tiefbeetbepflanzung
9. Belebte Bodenzone
10. Kontrollschacht
11. Drosselschacht
12. Stauwandschürze
13. Straßenaufbau
14. Frostschutzschichten
15. Kiesauflager
16. Gehsteig



Example Birkenstein



Building Innodrain®

Bauvorhaben Strasse Im Grund, Birkenstein, Dahlwitz-Hoppegarten

Building Innodrain®

Bauvorhaben Strasse Im Grund, Birkenstein, Dahlwitz-Hoppegarten

Building Innodrain®

Bauvorhaben Strasse Im Grund, Birkenstein, Dahlwitz-Hoppegarten

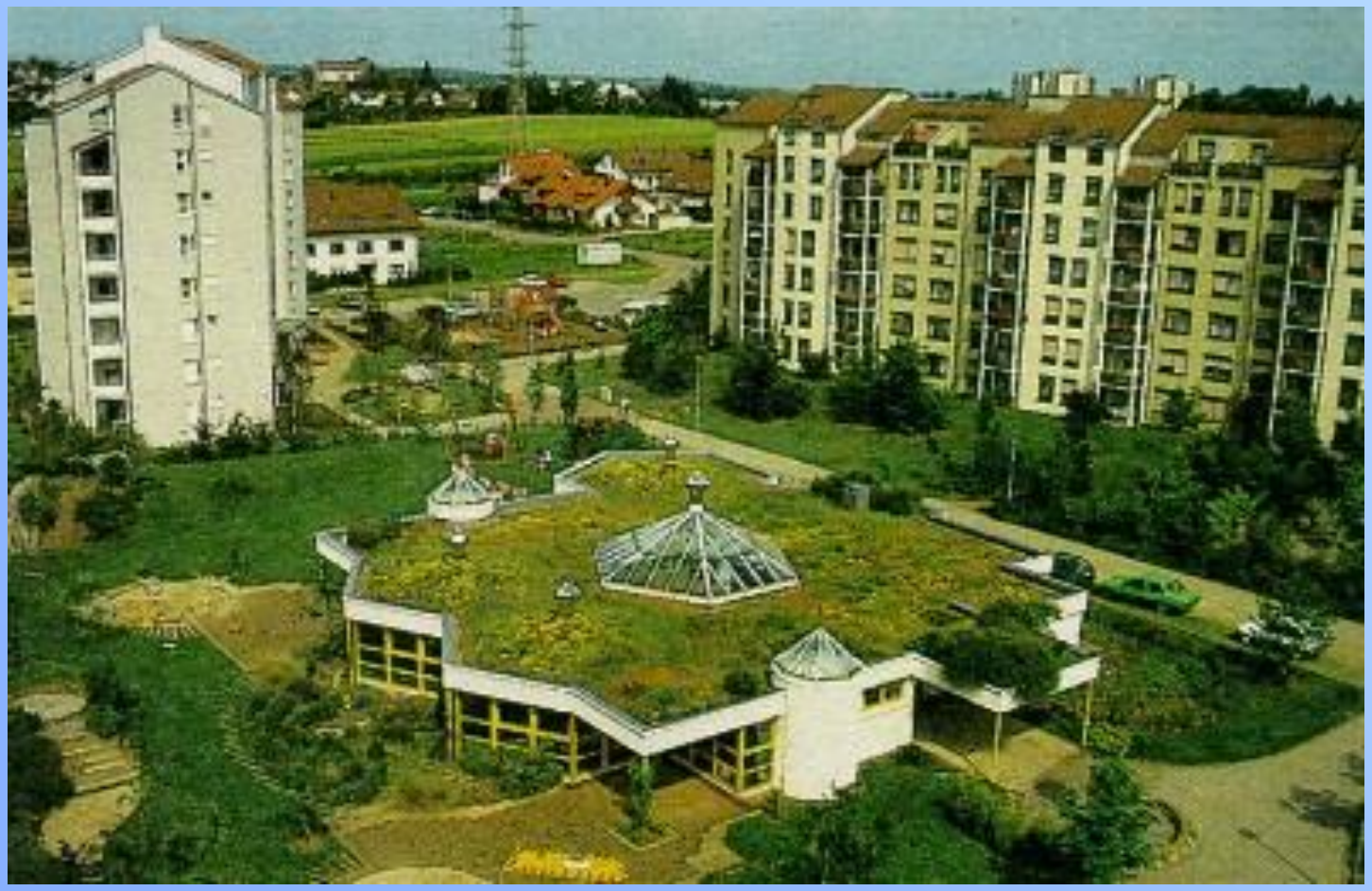
Cost comparision

- Storm sewer
  - Total costs: 200.000 €
  - Specific costs: ca. 300 € / meter
    ca. 15 € / m²

- INNODRAIN®
  - Total costs : 125.000 €
  - Specific costs : ca. 190 €/ meter
    ca. 10 € / m²

Greenroofs

Green roof



Roofs with infiltration on Greengarage

Porous pavement

Storm Water Management

Potential maps

Problems of planning storm water management

- Different boundary conditions:
  - Natural factors
    - Infiltration capacity,
    - slope,
  - Water quality aspects
    - Groundwater protection zone
    - Contaminated soils,
  - Urban factors
    - Existings sewer systems
    - Available space
    - Age of buildings
  - …

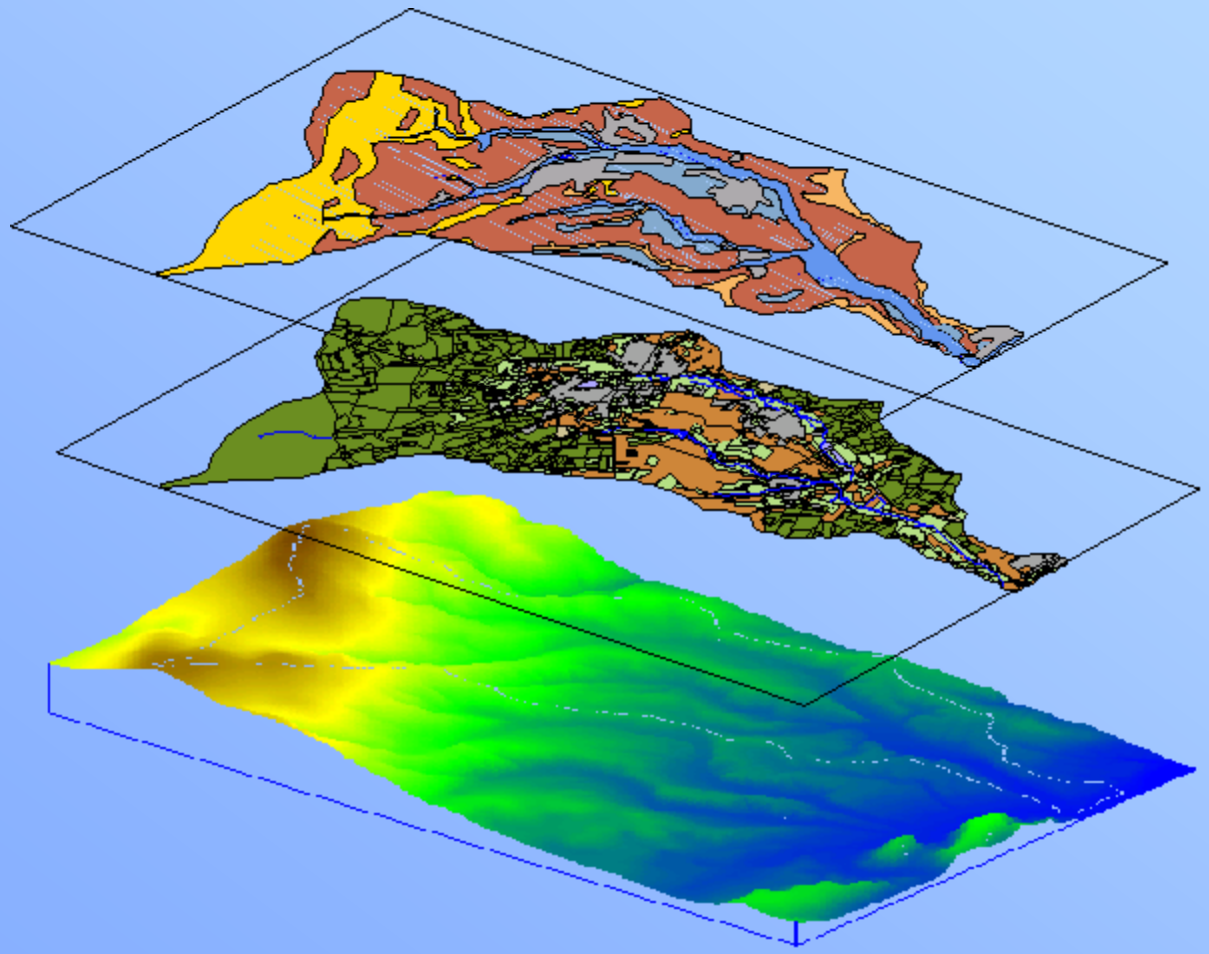
Problems of planning storm water management

- For greater areas large amount of data is to be handled
- Different possibilities for storm water management
  - Optimized solution is usually a combination of different meassures
  - Storm water management: not only infiltration
- Different concurrent aims to consider
- Question: Which is the best solutions for my aims?
- GIS supports solution finding

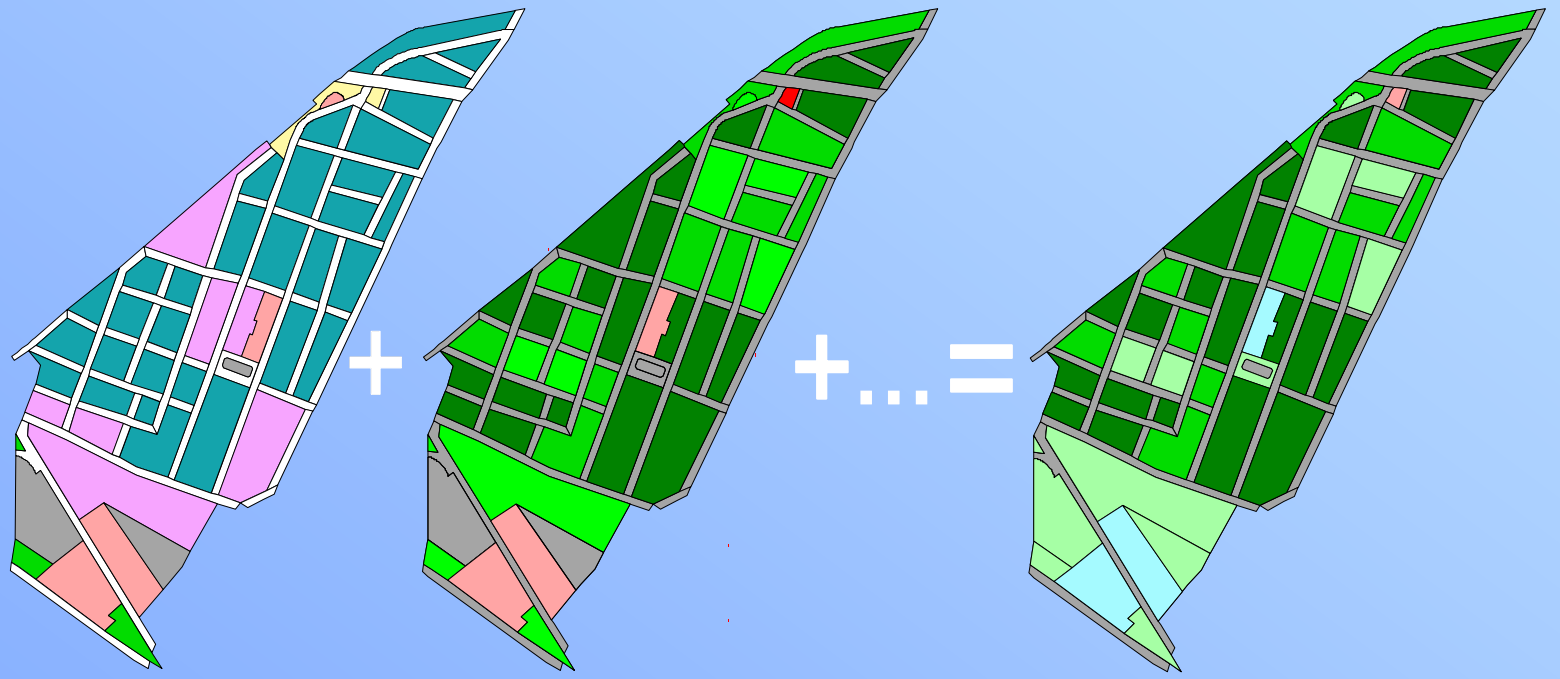
Boundary conditions

- Natural factors
  - Infiltration capacity,
  - slope,
- Water quality aspects
  - Groundwater protection zone
  - Contaminated soils,
- Urban factors
  - Available space
  - Age of buildings
- …

Overlaying Boundary conditions



Overlaying and assessing

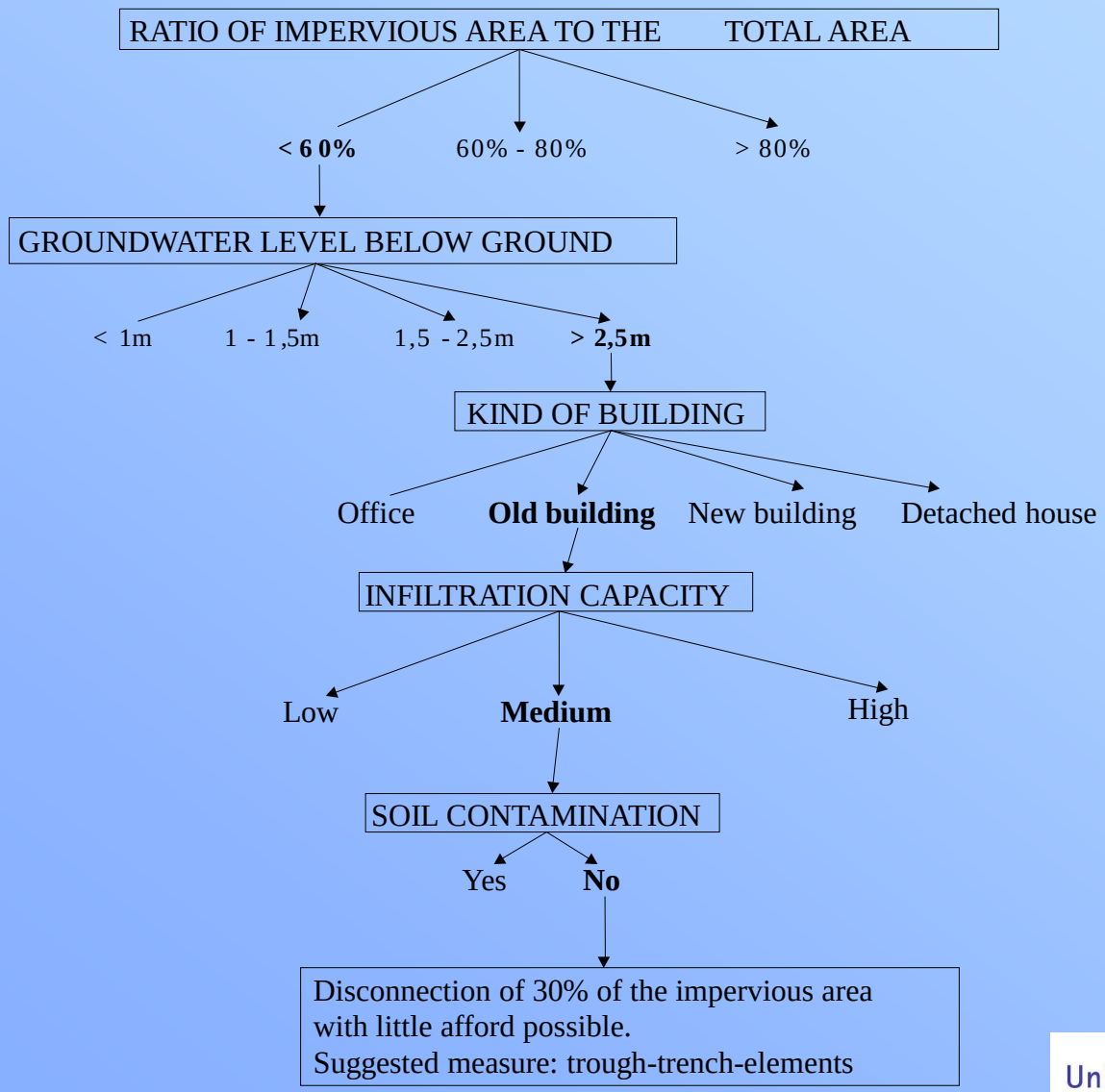


Legende
- Sraßen
- keine Daten vorhanden
- Wohngebiete
- Mischgebiete
- Gemeinbedarf und Sondernutzung
- Verkehrsflächen
- Grünflächen

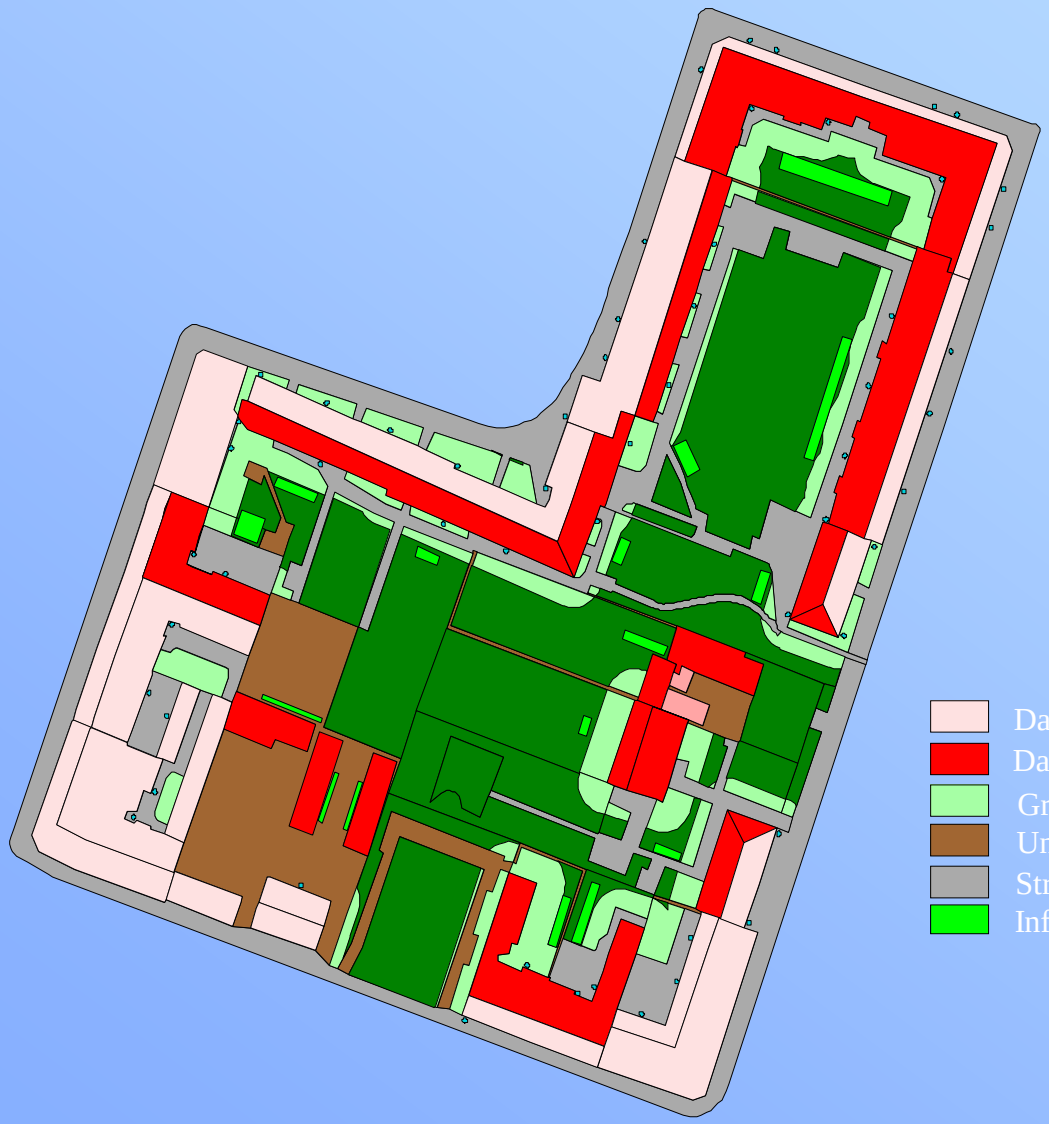
Legende
- keine Angaben
- < 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 90 %
- > 90 %
- Straßen

Legende
- Muldenversickerung
- Mulden/MRS
- MRS
- ev. MRS
- semizentrale Lösung/Ableitung
- Strassen

Decision Tree

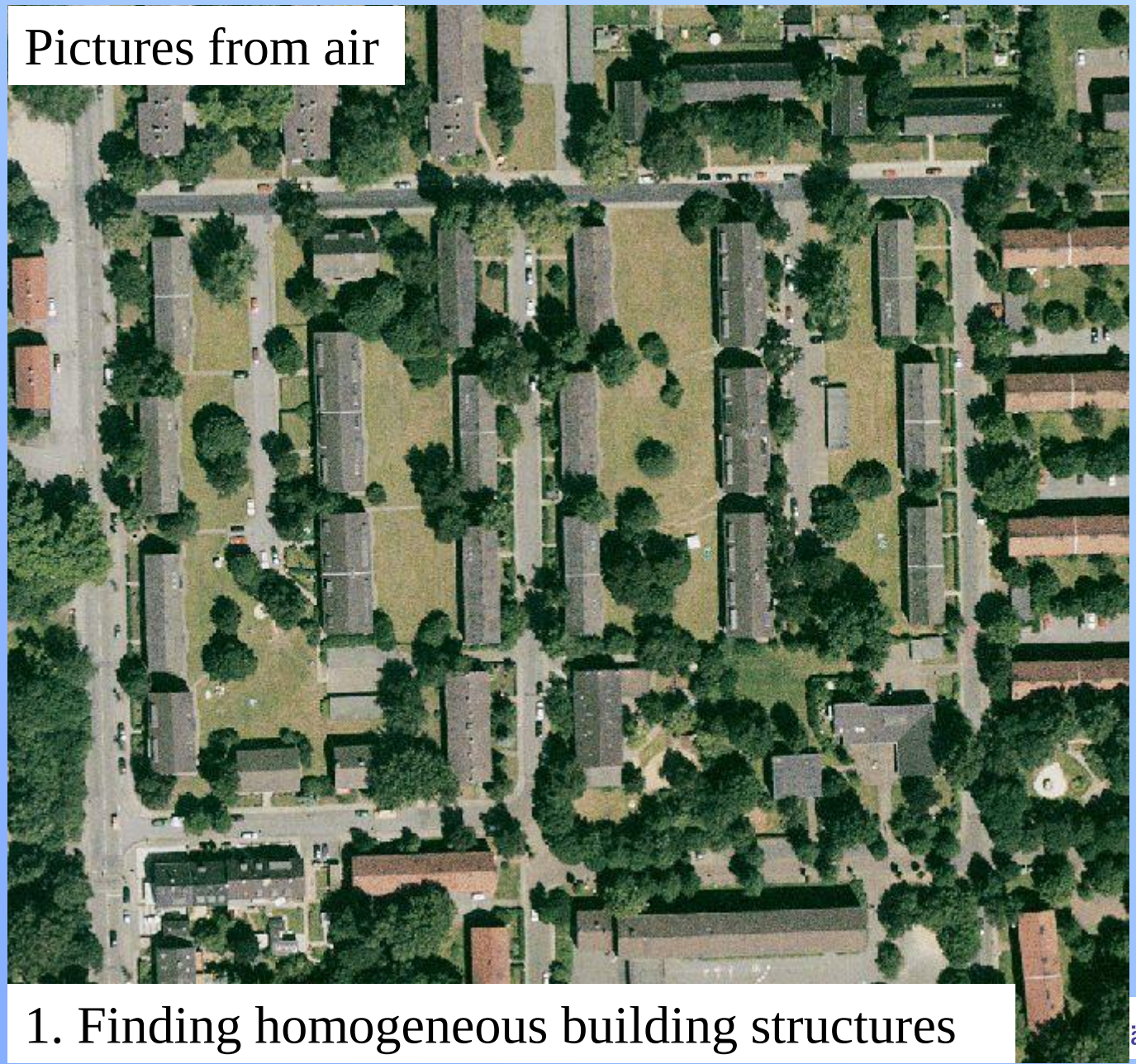


„Calibration“ of Decision Tree



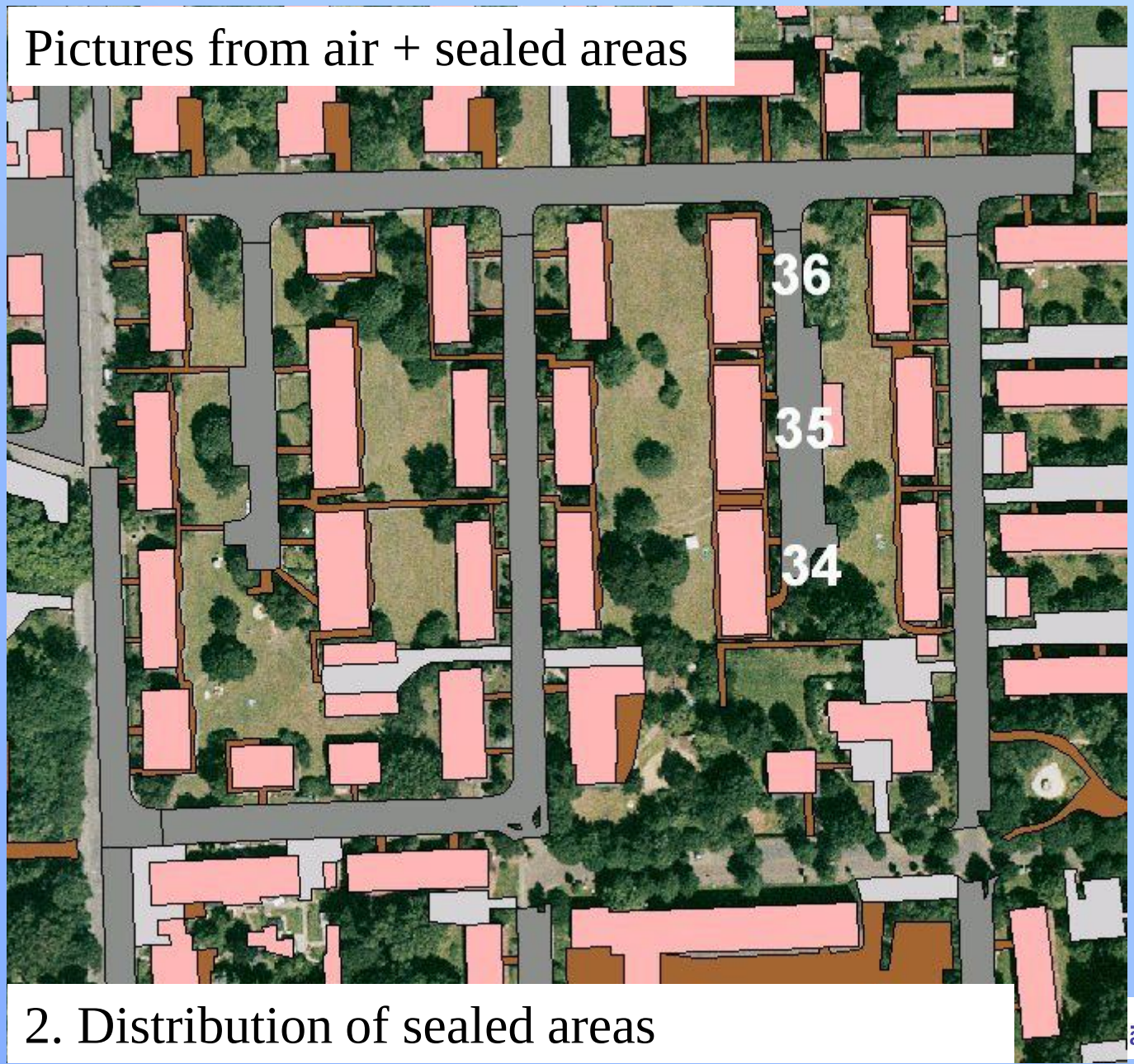
- Dachflächen: nicht abkoppelbar
- Dachflächen: abkoppelbar
- Grünfläche
- Undurchlässige Hofflächen
- Straßen, Wege
- Infiltrationsflächen

Proceeding to evaluate airpictures



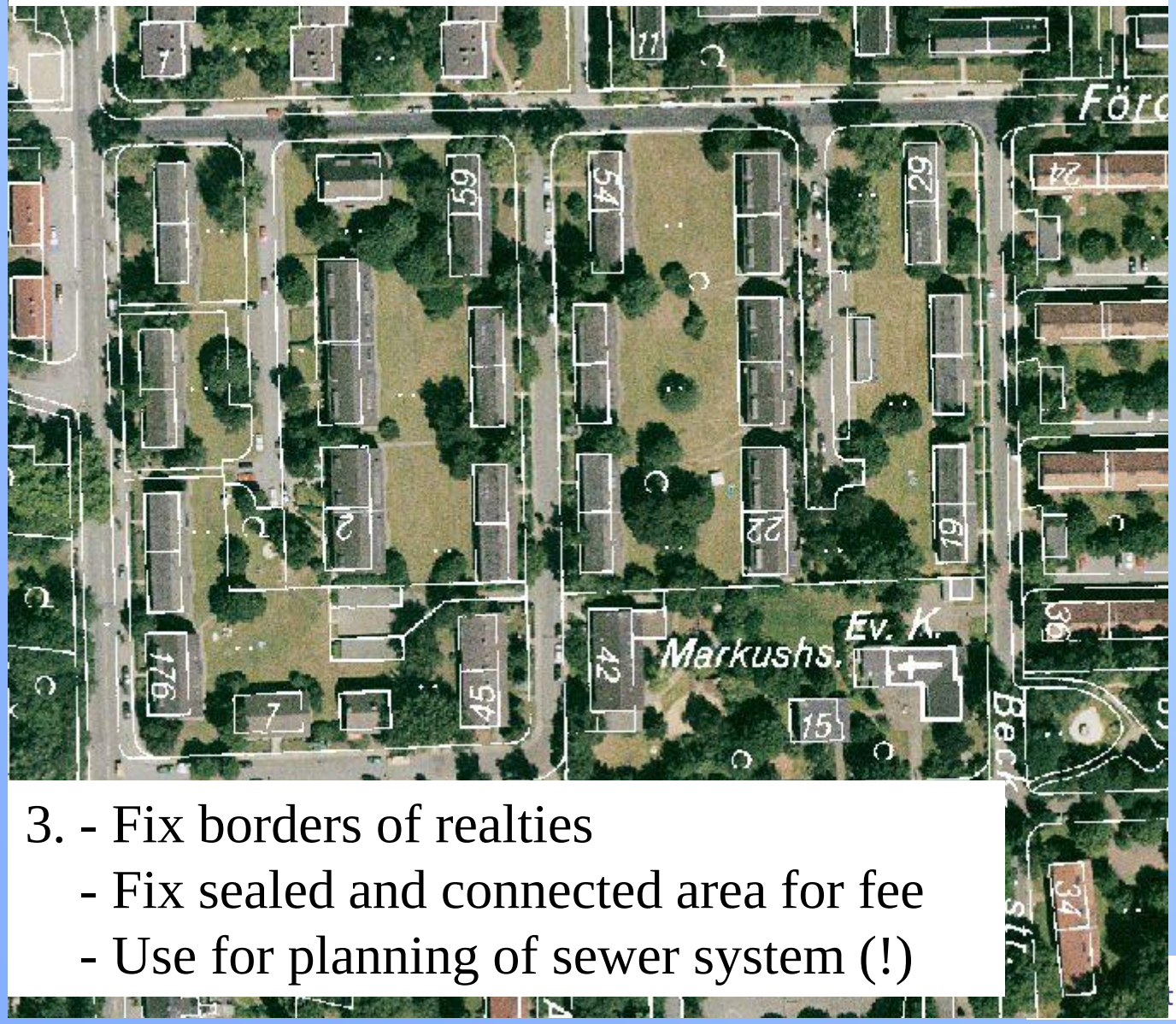
1. Finding homogeneous building structures

Proceeding to evaluate airpictures



Proceeding to evaluate airpictures

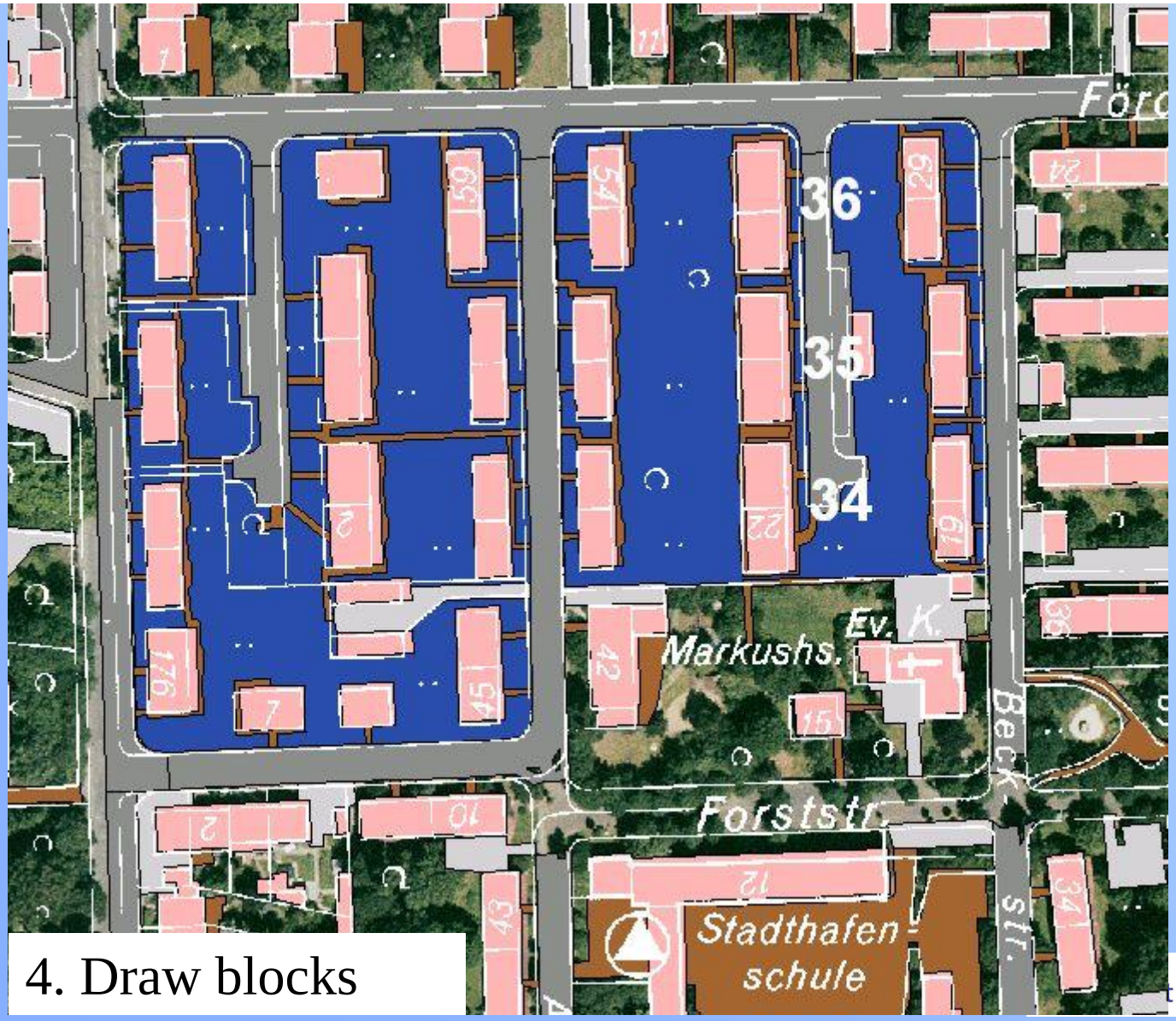
Pictures from air + digital surface maps (DGK5)



3. - Fix borders of realties
   - Fix sealed and connected area for fee
   - Use for planning of sewer system (!)

Proceeding to evaluate airpictures

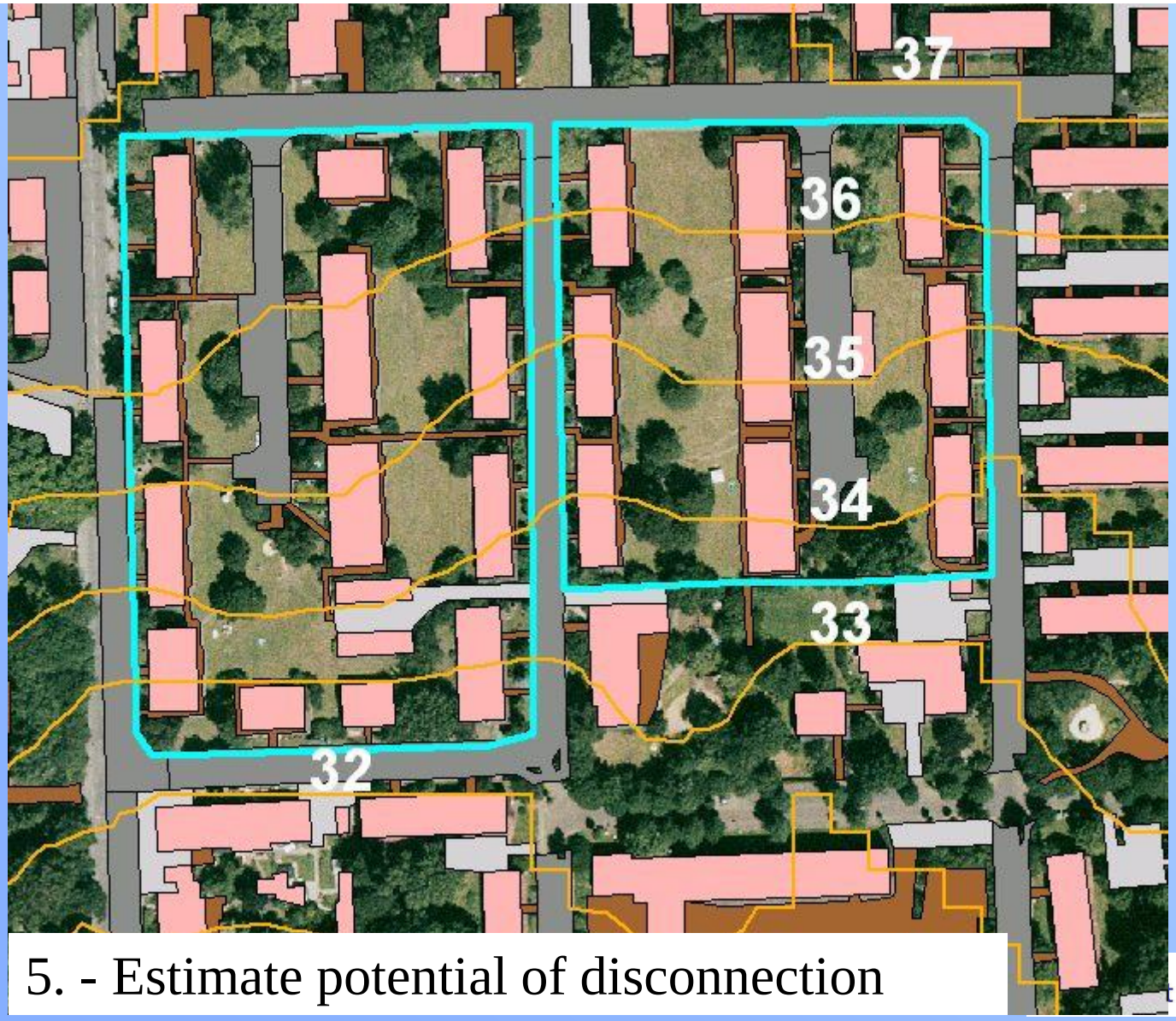
Pictures from air + digital surface maps (DGK5) + blocks



4. Draw blocks

Proceeding to evaluate airpictures

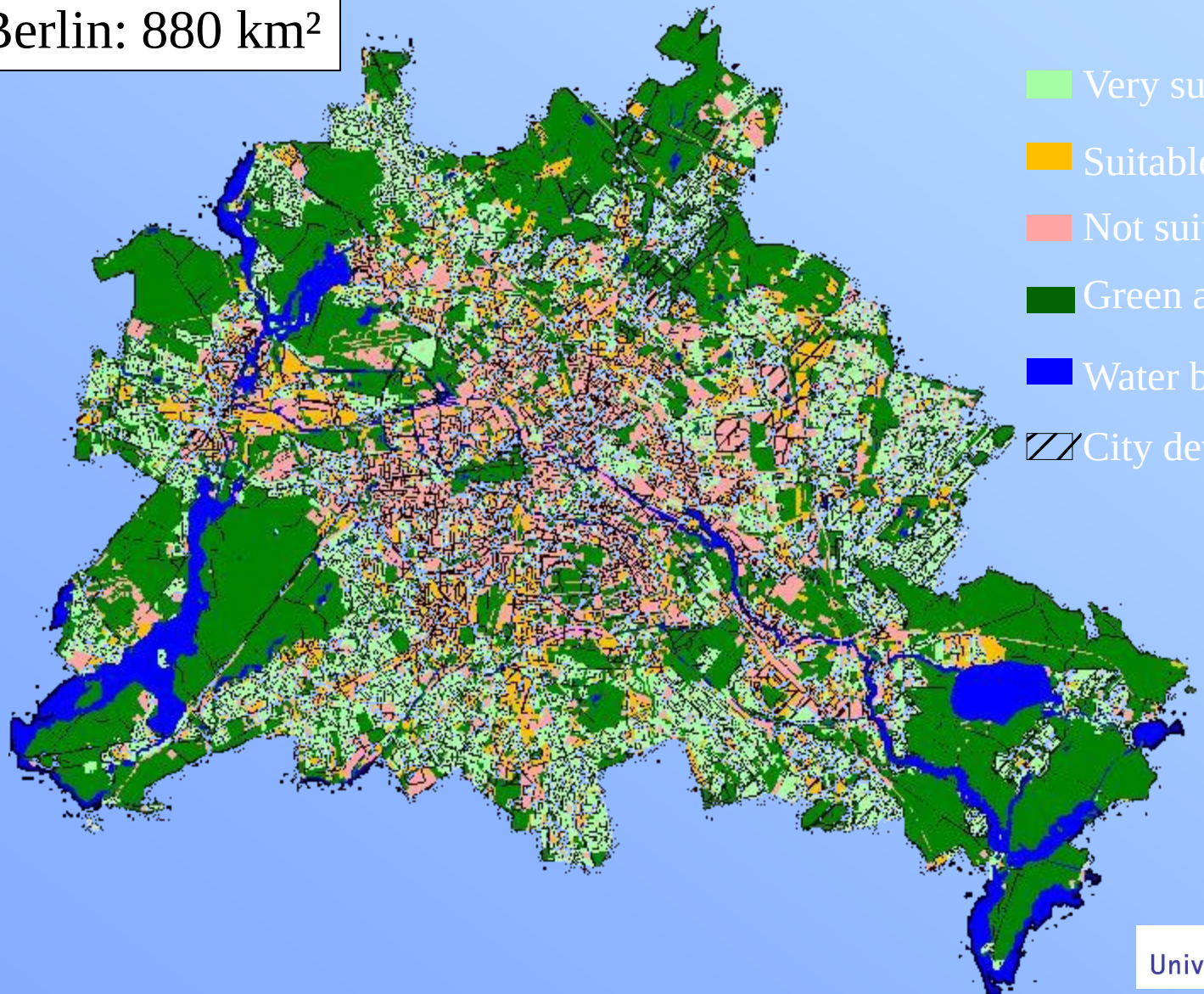
pictures from air + sealed areas + level curves + blocks



5. - Estimate potential of disconnection

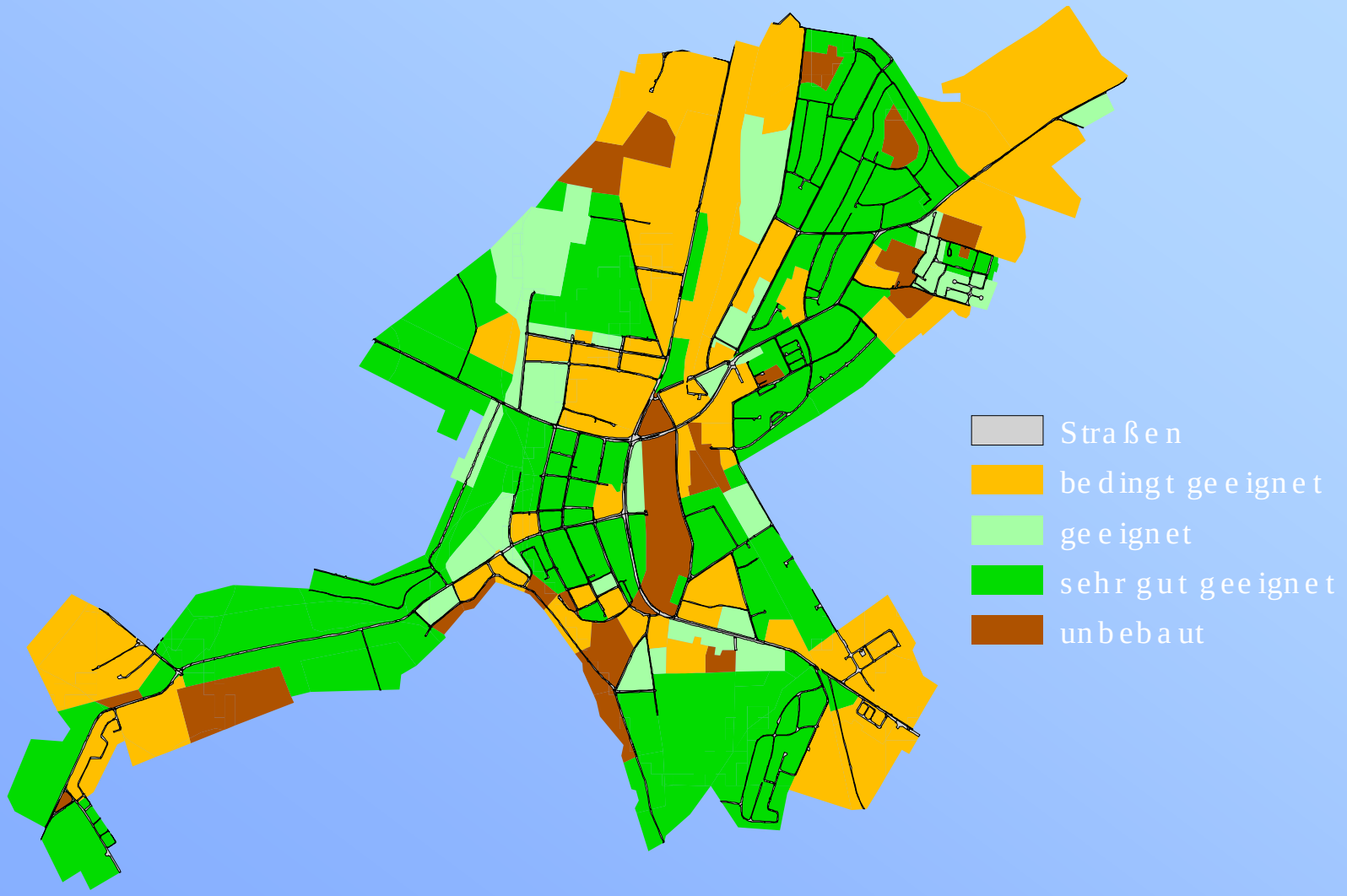
Locations for Storm Water Management

Berlin: 880 km²

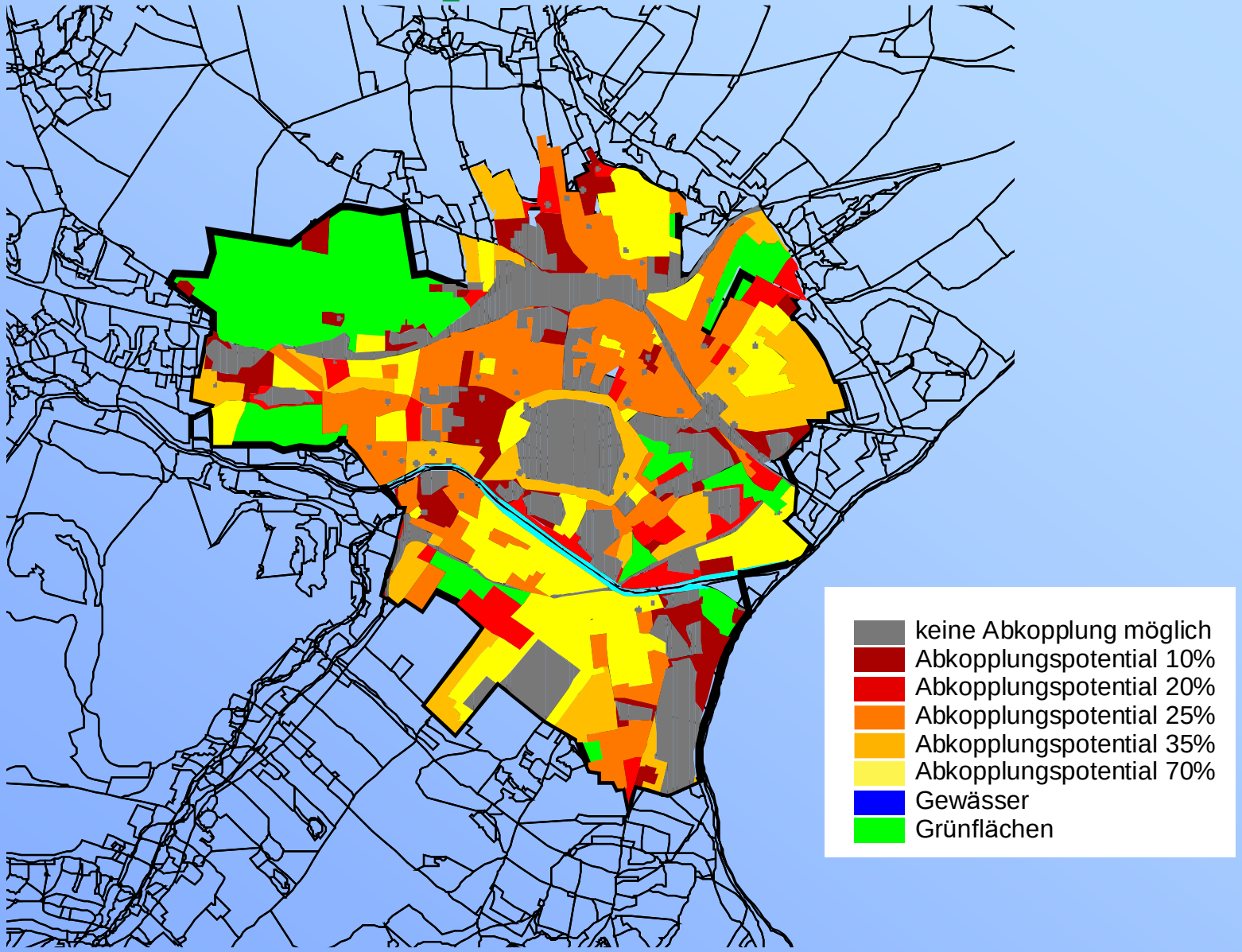


- Very suitable
- Suitable
- Not suitable
- Green areas
- Water bodies
- City develop. areas

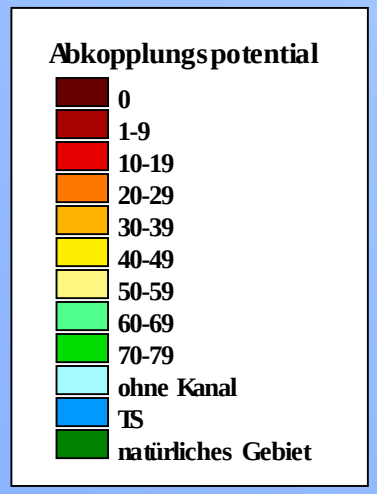
Example: Prenzlau

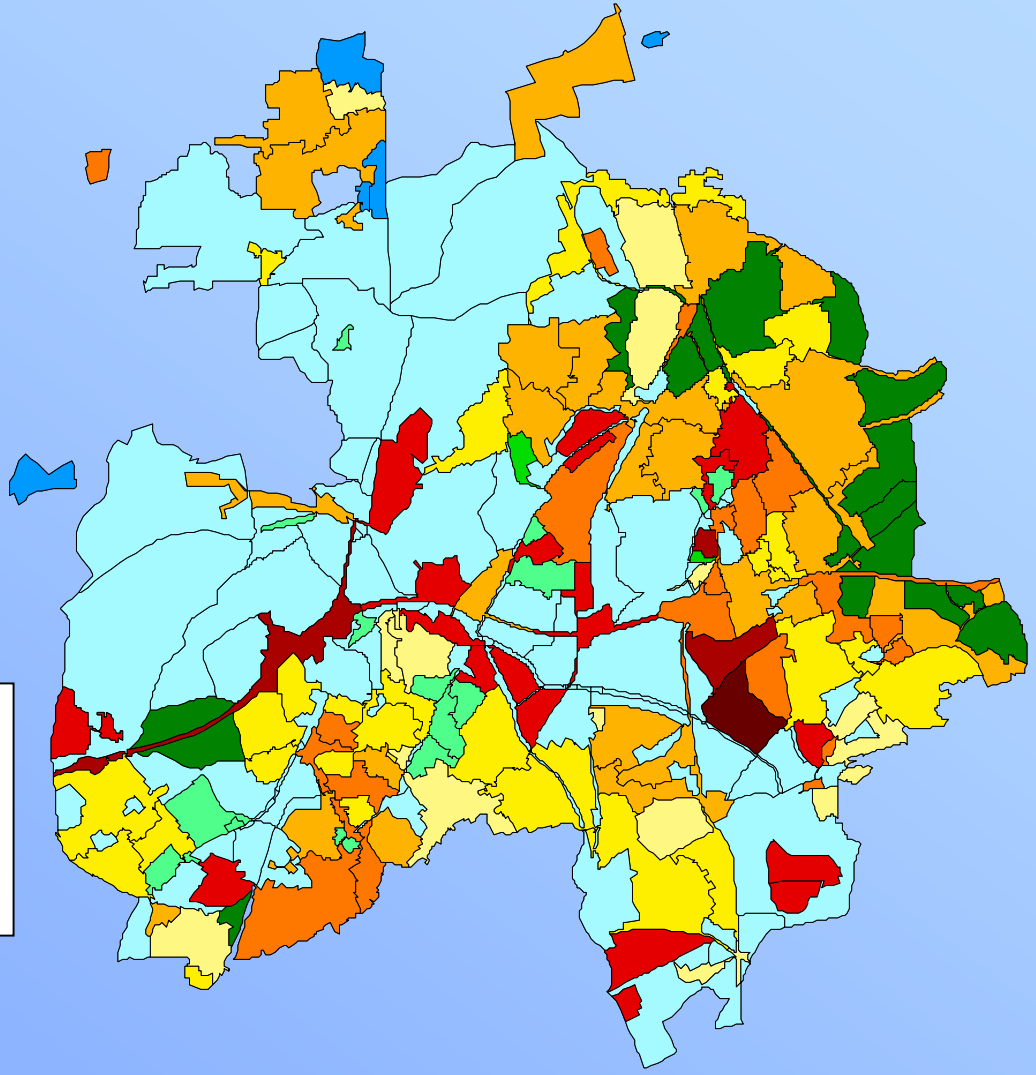


Example: Zittau



Example: Boye





2 Sceneriis:

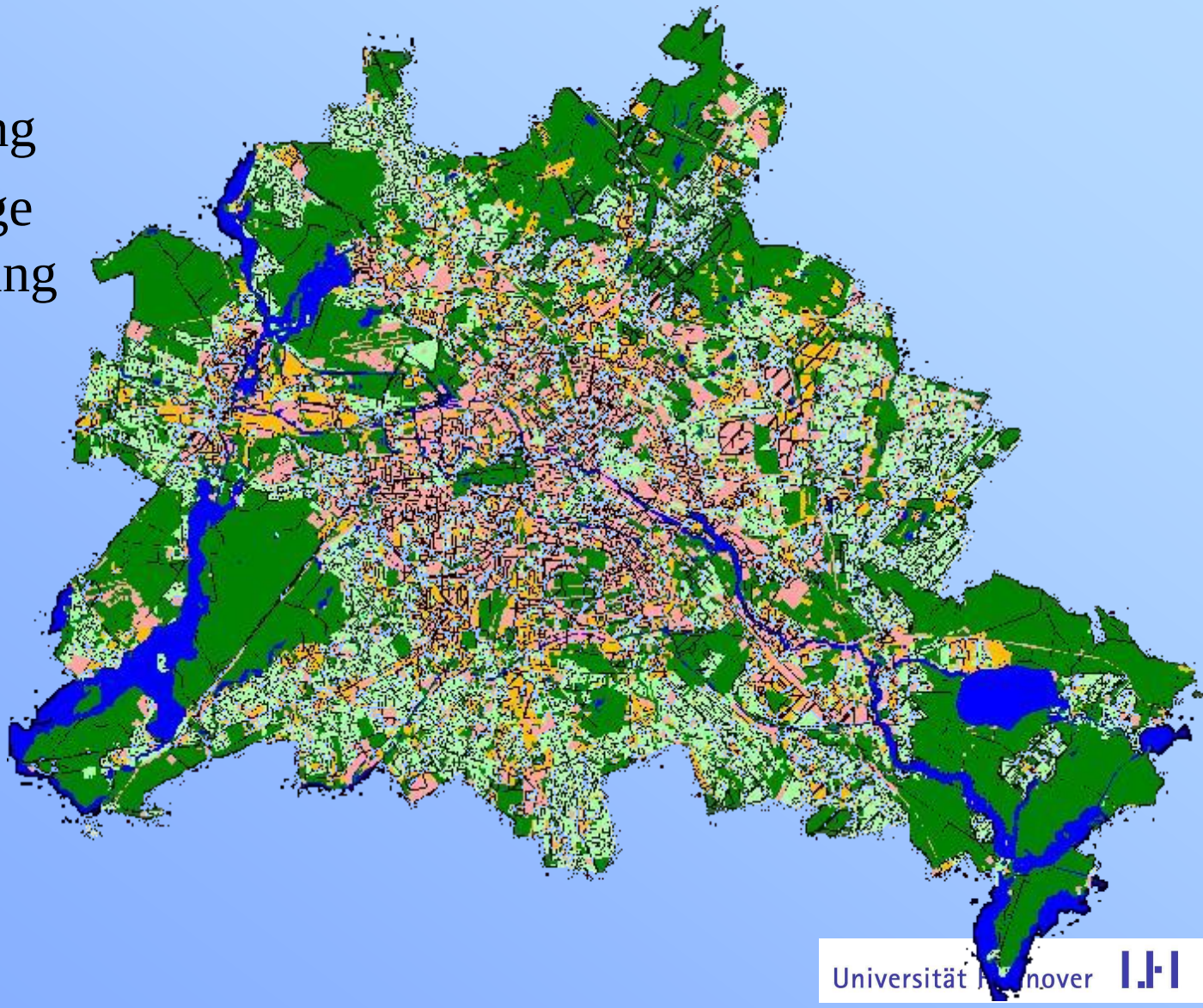
realisable until 2006: ~12%

Realisable in long terms: ~36%

Use of SWM Potential maps

Usage:

- urban planning
- urban drainage master planning
- marketing



Implementation method: separate Storm water fee

- Waste water fee:
- EUR/ m^3 for used freshwater

- storm water fee :
- EUR/ m^2 per area per year

Calculation of specific costs for sewer system

Consideration of connected areas, also useful for dimensioning sewer systems

Implementation method: separate Storm water fee

- Reduction for
  - Disconnection 100%
  - Retention ~50%
  - Green roofs ? %
  - Porous pavement 100%
  - Rain water usage 0-50%

- storm water fee in Germany:
  0,5-2 EUR/ m^2 per year

Potentials for SWMM

Pressemitteilung des Bayerischen Landesamtes für Wasserwirtschaft:

... Die Landeshauptstadt München unterstützt diese wasserwirtschaftlichen Ziele bereits seit langem durch die Aufteilung der Entwässerungsgebühr in Schmutzwasser- und Niederschlagswassergebühren. Die MünchnerInnen können durch die Entsiegelung von Flächen sowie durch die Versickerung von unverschmutztem Regenwasser vor Ort sparen. Und sie tun es auch! So gehen die versiegelten, an das Kanalnetz angeschlossenen Flächen jährlich um mehr als 1 %, das sind ca. 300.000 Quadratmeter, zurück. ...

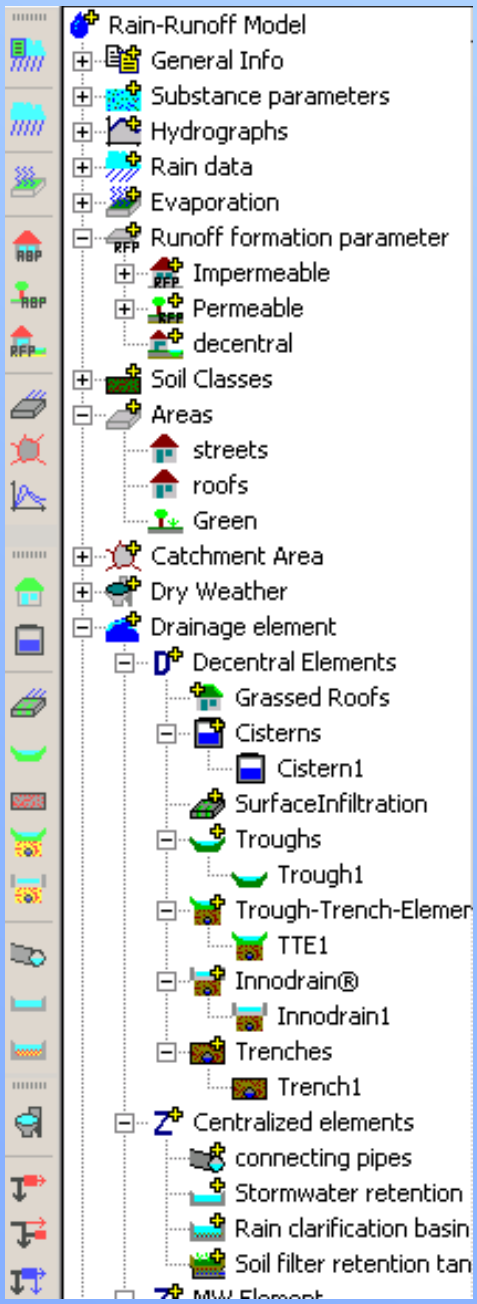
Source: Pressemitteilung des Bayerischen Landesamtes für Wasserwirtschaft vom 10.10.2000

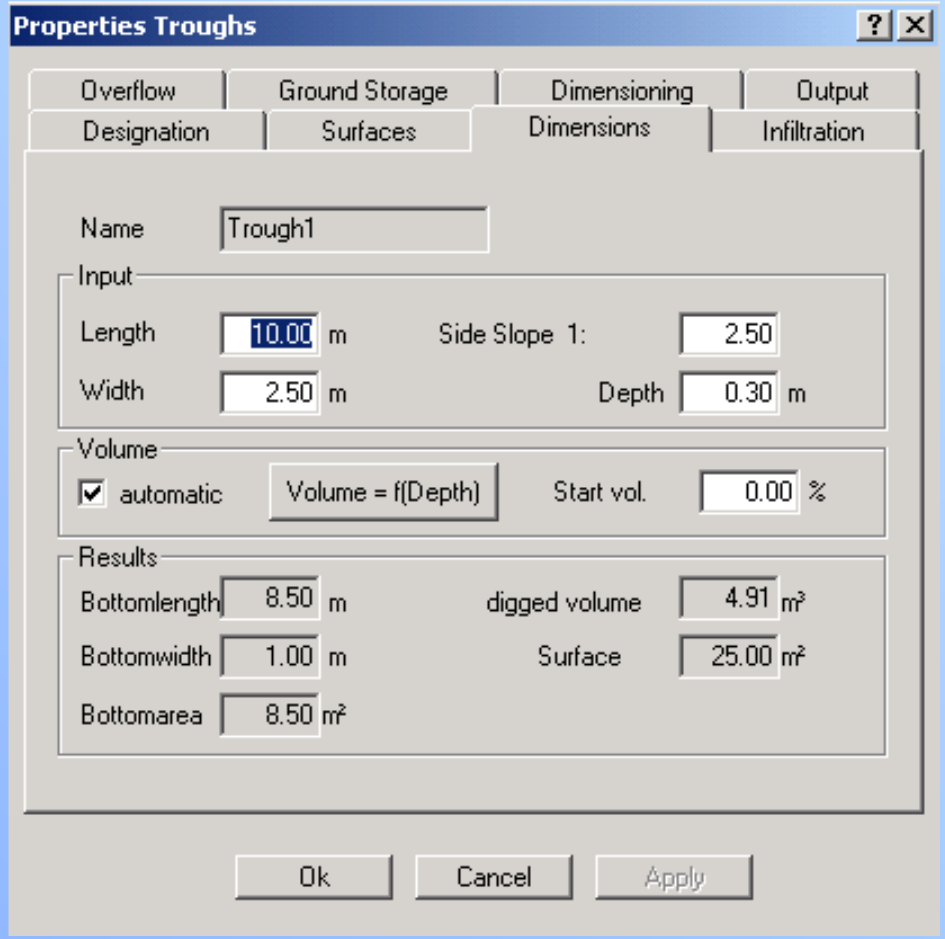
Master planning for seperated and combined sewer systems

with:

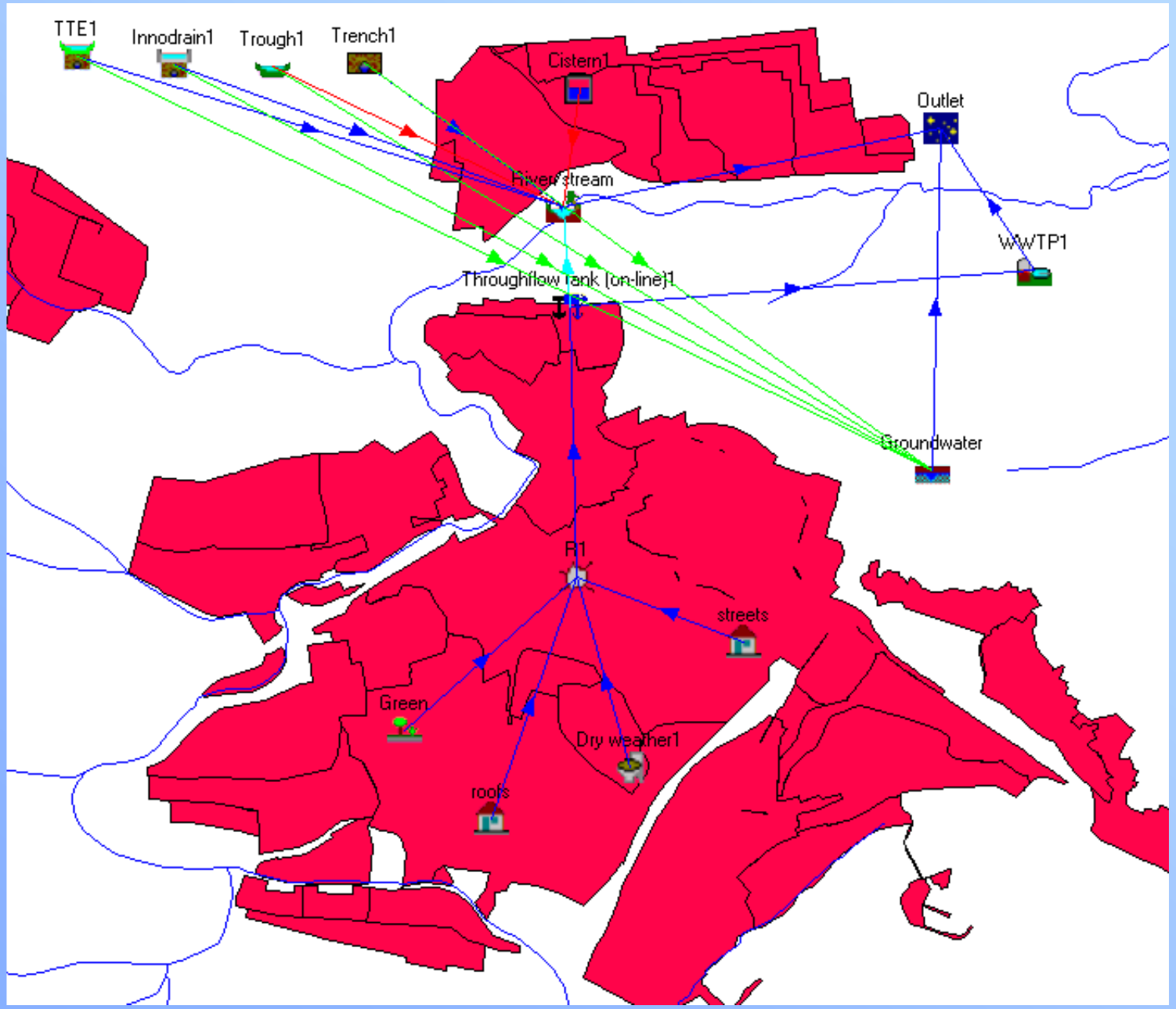
- **source control meassures**
- **BMPs**
- **CSOs**

Storm 2000

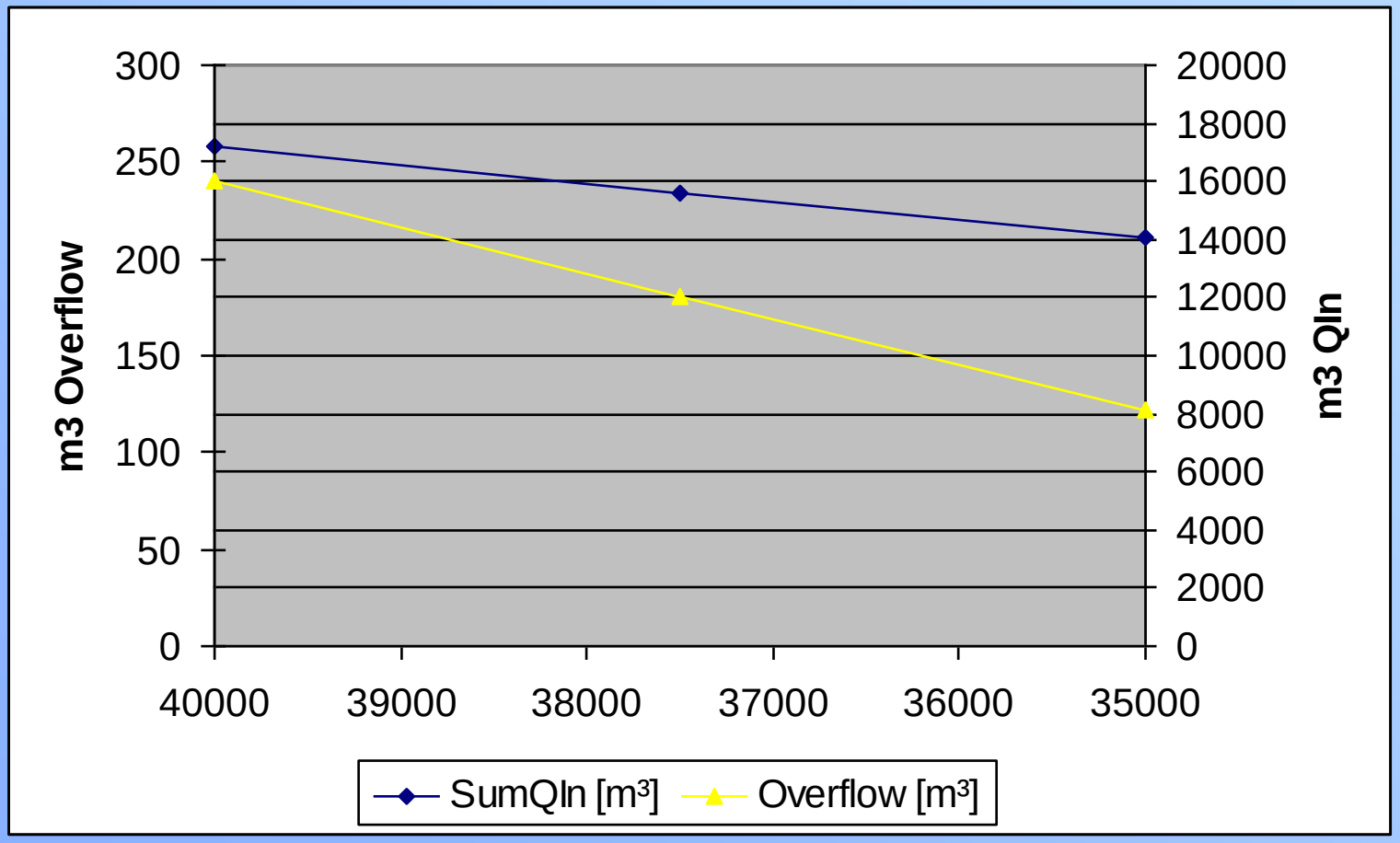

Rain-Runoff Model
General Info
Substance parameters
Hydrographs
Rain data
Evaporation
Runoff formation parameter
Impermeable
Permeable
decentral
Soil Classes
Areas
streets
roofs
Green
Catchment Area
Dry Weather
Drainage element
Decentral Elements
Grassed Roofs
Cisterns
Cistern1
SurfaceInfiltration
Troughs
Trough1
Trough-Trench-Elemer
TTE1
Innodrain®
Innodrain1
Trenches
Trench1
Centralized elements
connecting pipes
Stormwater retention
Rain clarification basin
Soil filter retention tan


Properties Troughs
Overflow
Ground Storage
Dimensioning
Output
Designation
Surfaces
Dimensions
Infiltration
Name
Trough1
Input
Length
10.00
m
Side Slope 1:
2.50
Width
2.50
m
Depth
0.30
m
Volume
automatic
Volume = f(Depth)
Start vol.
0.00
%
Results
Bottomlength
8.50
m
digged volume
4.91
m³
Bottomwidth
1.00
m
Surface
25.00
m²
Bottomarea
8.50
m²
Ok
Cancel
Apply

Storm 2000


TTE1
Innodrain1
Trough1
Trench1
Cistern1
Outlet
River/stream
WWTP1
Throughflow tank (on-line)1
Groundwater
P1
streets
Green
Dry weather1
roofs

Overproportional decrease of overflow volume by disconnecting areas



Impacts on receiving waters

Regulation M3 of DVWK

- Reducing inflow speed in comparision with flow dynamics in the receiving water
- Reducing volume, increase speed and duration of inflow
- Aim: not damaging water body or spoiling organisms receiving waters by impact of sewer outlets

Importance of Storm Water Treatment

- Improvement of waste water treatment has rearched the economic limit
- CSO‘s (Combined sewer overflows) are discharging a high amount of pollutants and nutritions
- Storm water runoff from highly frequented streets discharging without treatment into receiving waters cause eutrofication and contaminated sludge and is getting focussed by authorities

Contamination of rivers by storm water

- 3 ways, storm water pollutes rivers:
  - Direct discharges in separate systems
  - Combined sewer overflows
  - Outlet of Waste water treatment plant (WWTP)
- mean concentrations (after Brombach, 2002):

	COD (mg/l)
Storm water runoff (separate)	80
Combined sewer overflow	140
WWTP outlet	75

Contamination of rivers by storm water

- Pollutant loads by storm water (in t_{COD}/year) :

Direct discharges in separate systems	257.000
Combined sewer overflows	225.000
WWTP outlet (storm water part)	280.000
Storm water total.	762.000

- Pollutant loads by sewerage:

WWTP outlet (sewerage part)	285.000

- Ratio t_{COD} between storm water / sewerage 2,7:1

Methods of storm water treatment: Examples BMPs

Decentralized treatment by BMPs (Best management practices)

- infiltration, i.e. by swales and swale-trench-systems, INNODRAIN(R)

Centralized treatment

- Retention tanks
- Centralized soil filters

Methods of storm water treatment: Examples BMPs

Swale-trench-systems, INNODRAIN(R)
Soilfilters:

Good to excellent reduction for:

- TSS
- heavy metals
- AOX, PAC, COD, BOD
- NH4

Problems with:
- NO3, P

Methods of storm water treatment: Disadvantges BMPs

Dezentralized treatment of runoff from streets

- infiltration, i.e. by swales and swale-trench-systems
  -> not applicable on all sites
- Retention tanks
  -> the treatment is not very effective
- Centralized soil filters
  -> missing natural outlet level to receiving water causes high cost for pumping the water

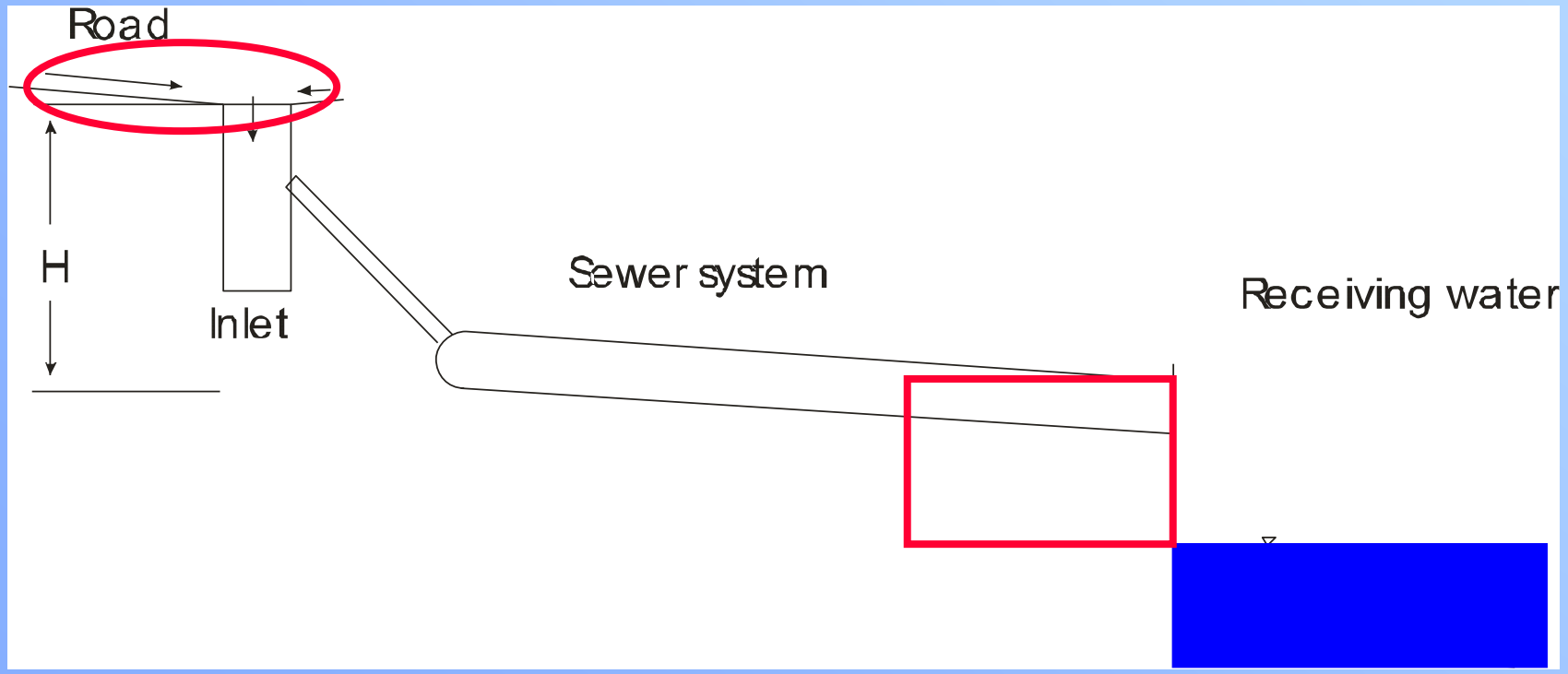
Aim for Inlet-Filtration-System

Dezentralized treatment of runoff from streets by inlet-filtration-system

- usage of leveldifference from surface to sewer
- Treatment of highly polluted runoff from highly frequented roads and highways
- Development of a simple to handle filtration technique

Level difference 1

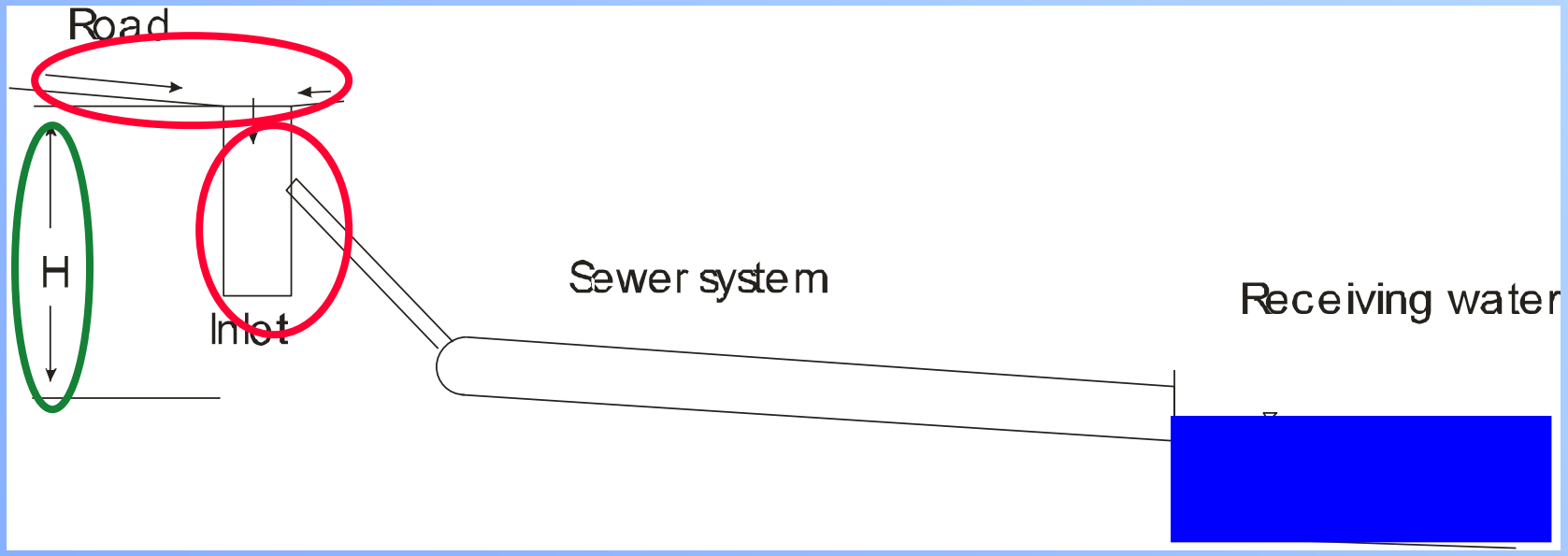
- usage of level difference (H) from sewer receiving water



Soil Filter

Level difference 2

- usage of level difference (H) from surface to sewer



Aim for Inlet-Filtration-System

Dezentralized treatment of runoff from streets by inlet-filtration-system

- usage of leveldifference from surface to sewer
- Treatment of highly polluted runoff from highly frequented roads and highways
- Development of a simple to handle filtration technique

Aim – treatment - pollution

		streets				roofs			
	unit	count	Medium	Minimum	Maximum	count	Medium	min	max
pH		4	7,0	6,4	7,6	3	6,1	5,9	6,3
cond.	µS/cm	8	136,6	69,2	342,5	3	91,7	66,0	129,0
AFS	mg/l	11	210,2	37,5	980,0	2	51,6	43,2	60,0
TOC	mg/l	2	17,2	6,6	27,8	0	n.v.	n.v.	n.v.
COD	mgO_2/l	17	88,1	13,2	260,0	3	30,8	22,0	37,0
chloride	mg/l	3	30,0	12,0	47,0	0	n.v.	n.v.	n.v.
AOX	µg/l	6	136,5	12,8	600,0	0	n.v.	n.v.	n.v.
Ptot	mg/l	8	0,9	0,1	3,0	1	0,1	0,1	0,1
PO4-P	mg/l	6	0,1	0,0	0,2	0	n.v.	n.v.	n.v.
Ntot	mg/l	3	2,8	1,8	4,1	1	9,0	9,0	9,0
NO3-N	mg/l	11	0,8	0,4	1,5	1	0,2	0,2	0,2
NH4-N	mg/l	11	1,0	0,2	2,4	1	4,0	4,0	4,0
HC	mg/l	8	0,3	0,0	0,7	0	n.v.	n.v.	n.v.
BOD5	mg/l	11	15,0	1,1	28,0	0	n.v.	n.v.	n.v.
PAC	µg/l	5	1,9	0,6	3,1	1	0,5	0,5	0,5
Cd	µg/l	10	5,2	0,0	20,0	1	1,0	1,0	1,0
Zn	µg/l	14	687,9	80,0	1950,0	1	24,0	24,0	24,0
Cu	µg/l	11	76,0	6,0	380,0	1	35,0	35,0	35,0
Pb	µg/l	14	180,2	9,4	980,0	1	104,0	104,0	104,0

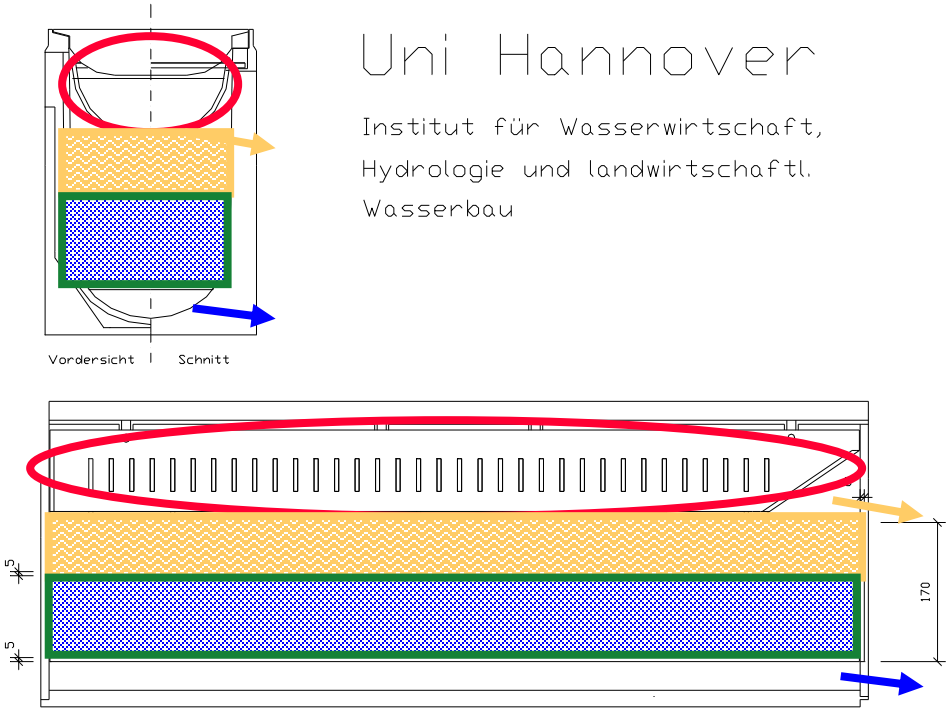
n.v. = no value, cond. = conductivity, AFS = filtrated particles, HC = Hydrocarbon

Aim for Inlet-Filtration-System

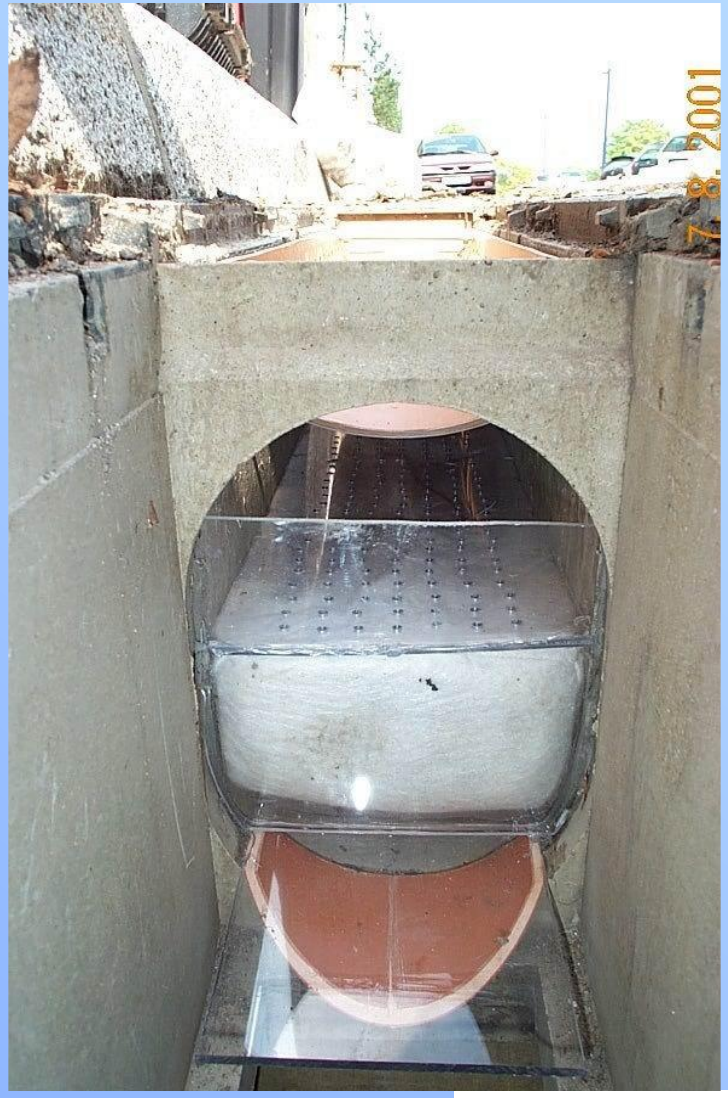
Dezentralized treatment of runoff from streets by inlet-filtration-system

- usage of leveldifference from surface to sewer
- Treatment of highly polluted runoff from highly frequented roads and highways
- Development of a simple and easy to handle filtration technique

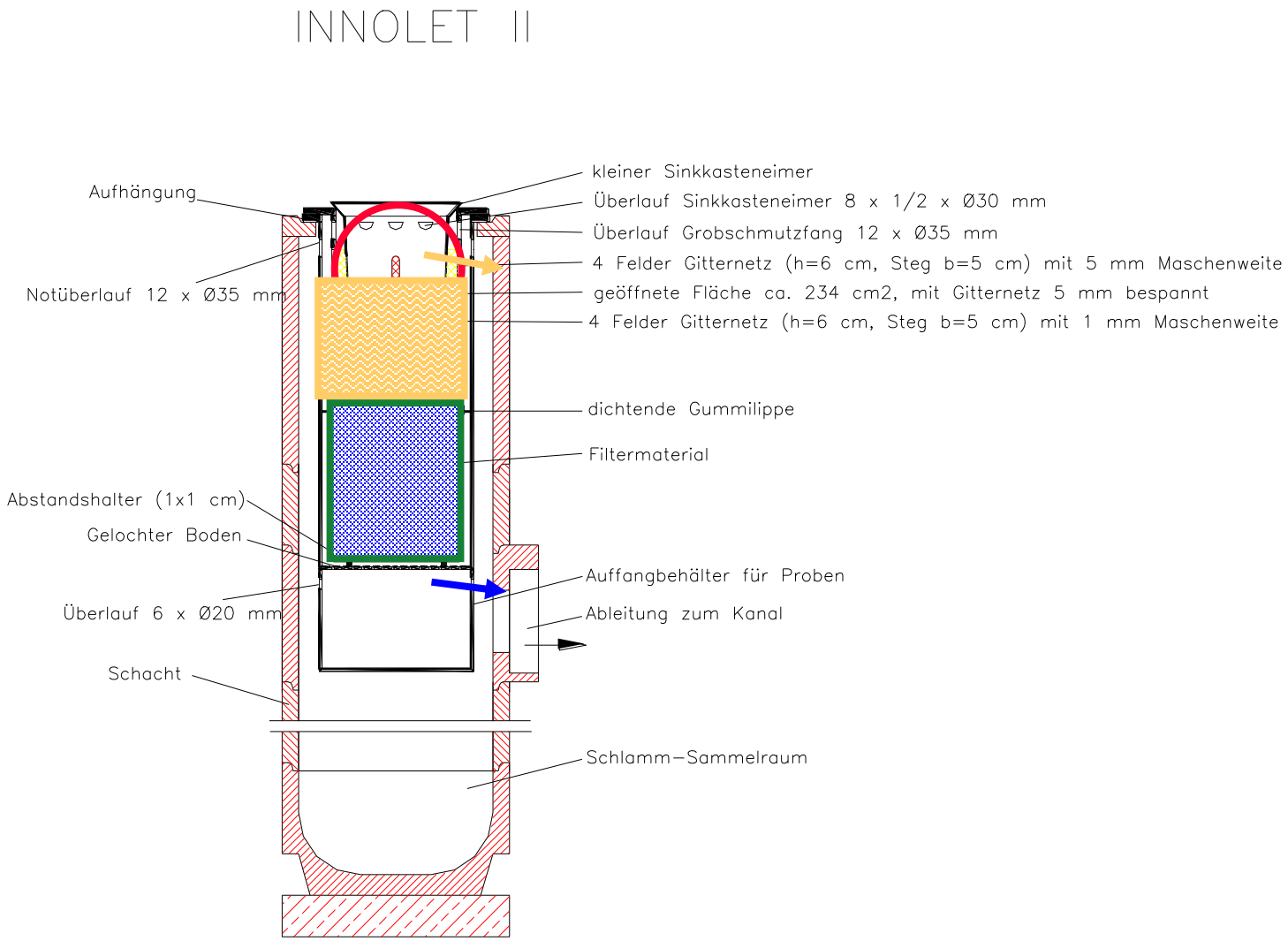
INNOLET 1, details inside



INNOLET 1, Fotos

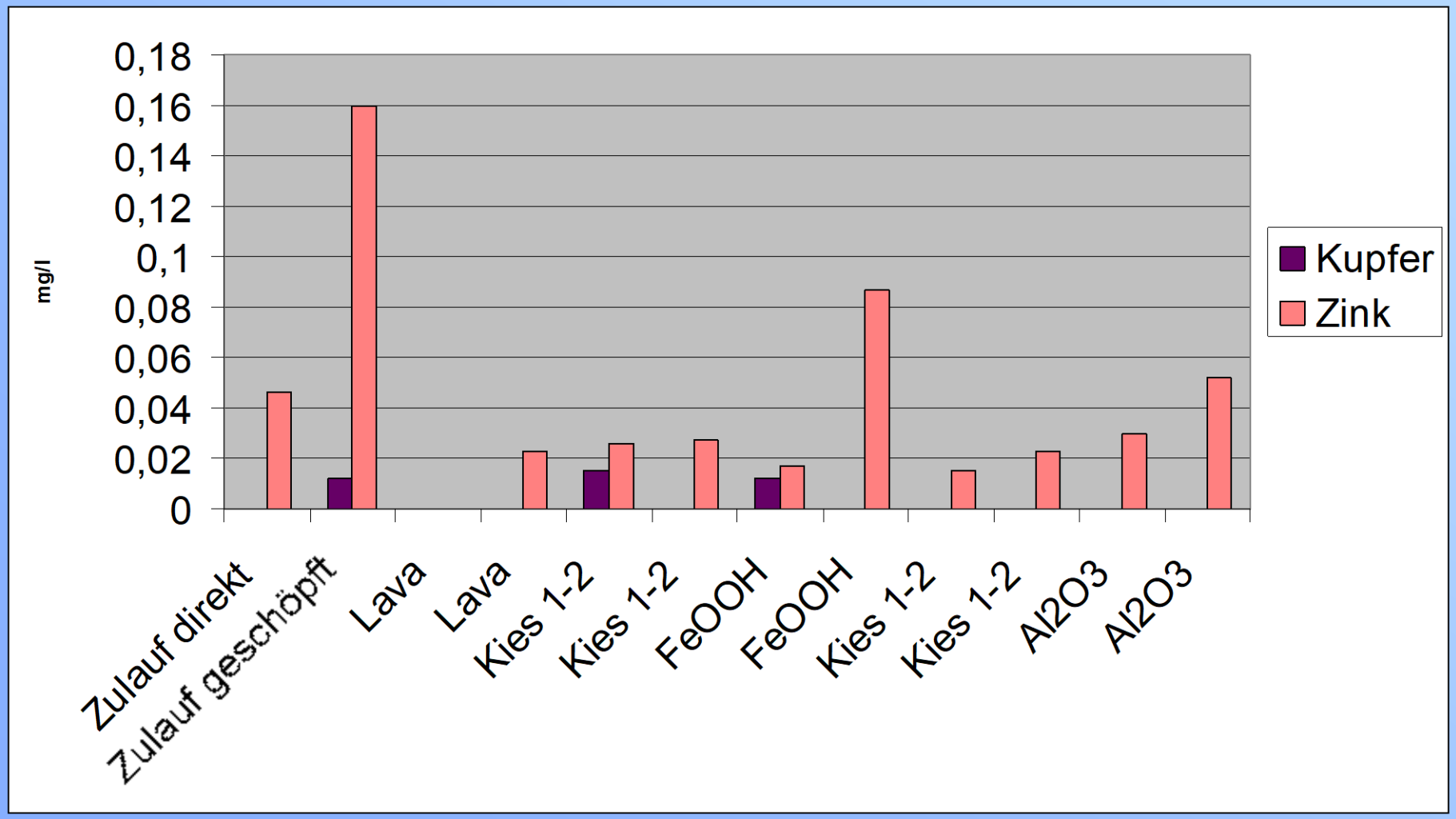


Innolet 2, details inside

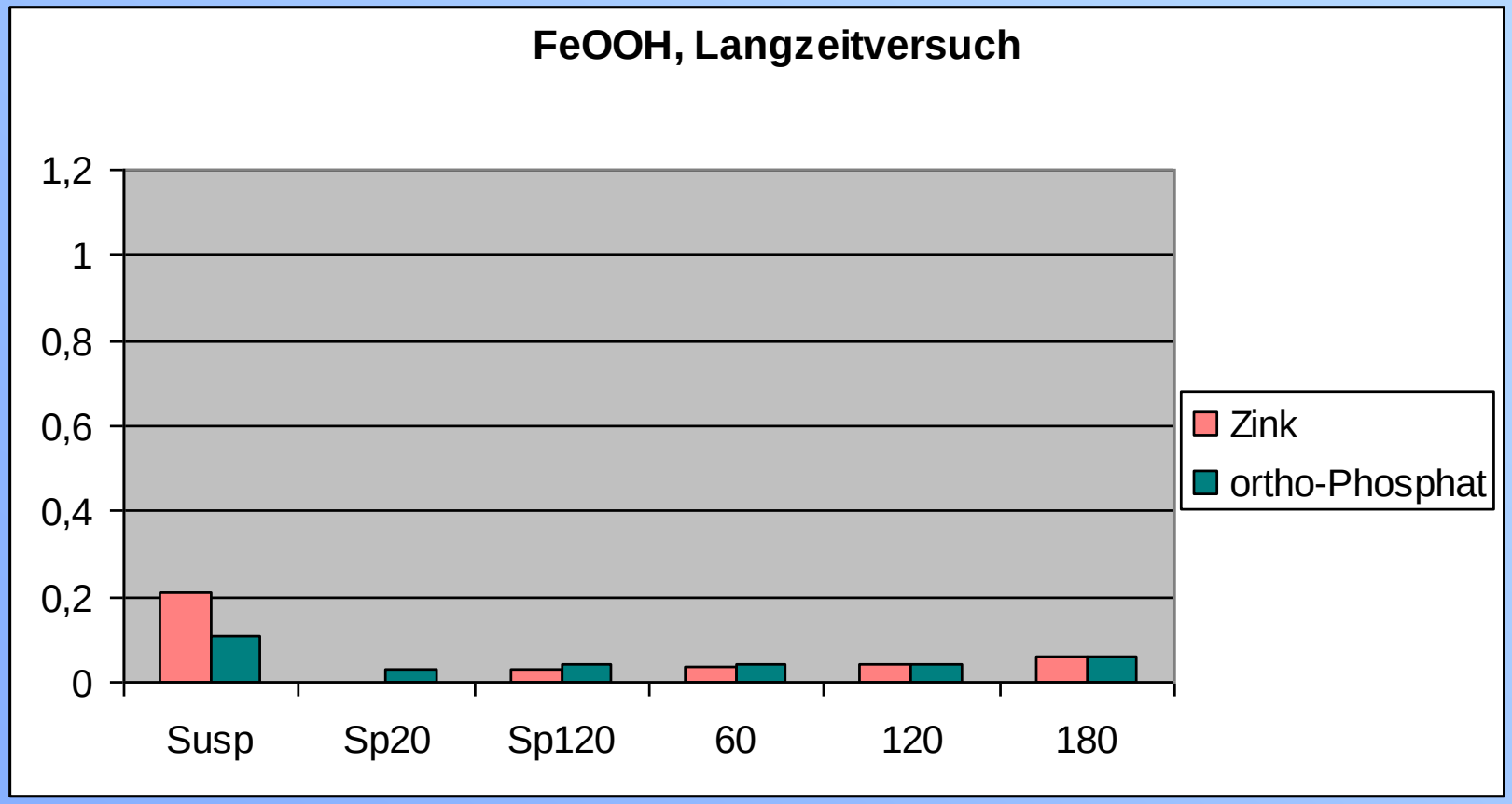


Innolet 2, parts

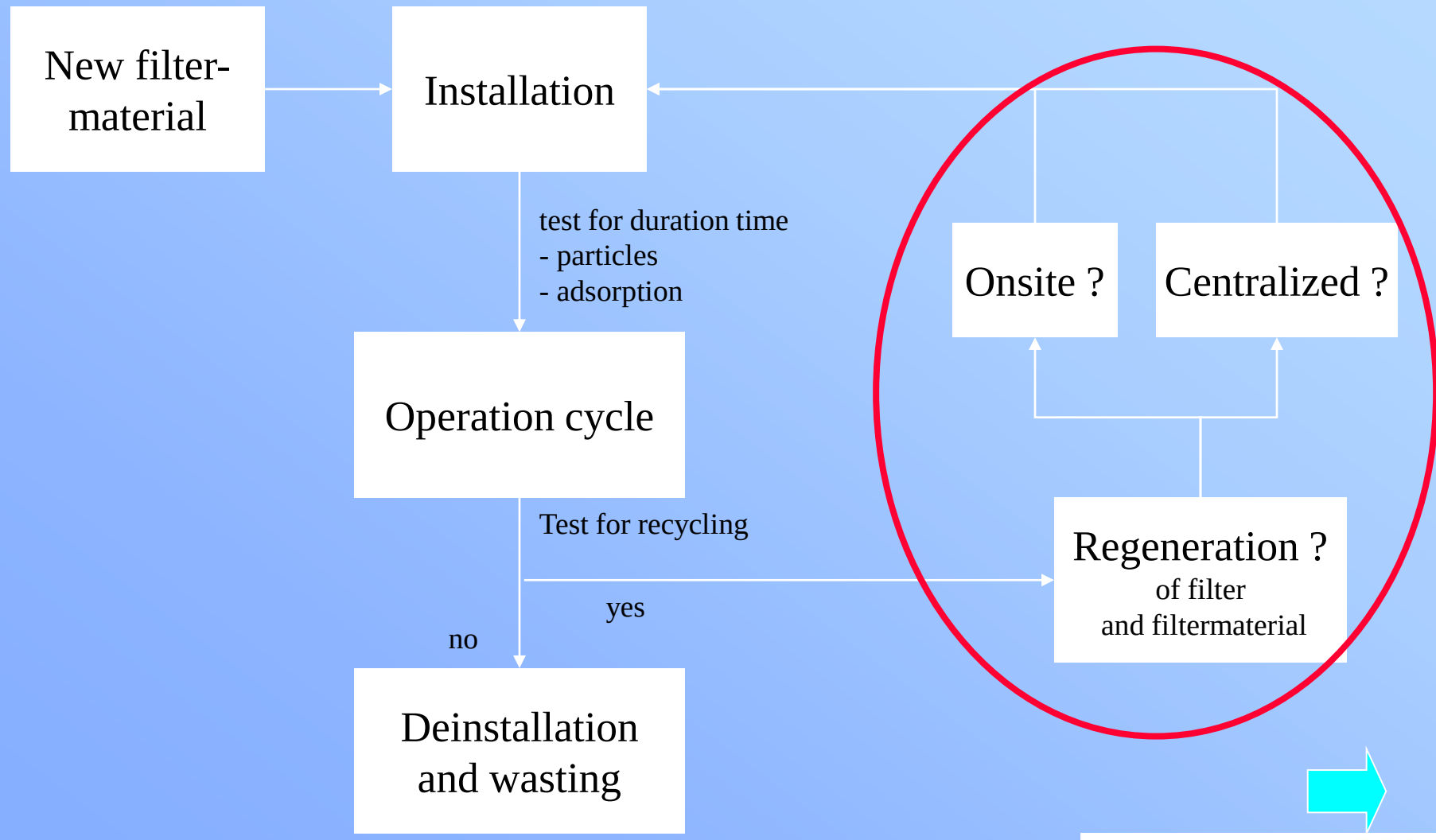
INNOLET 1
Cu, Zn



INNOLET 2
Test Site, FeOOH, Zn, o-PO4-P



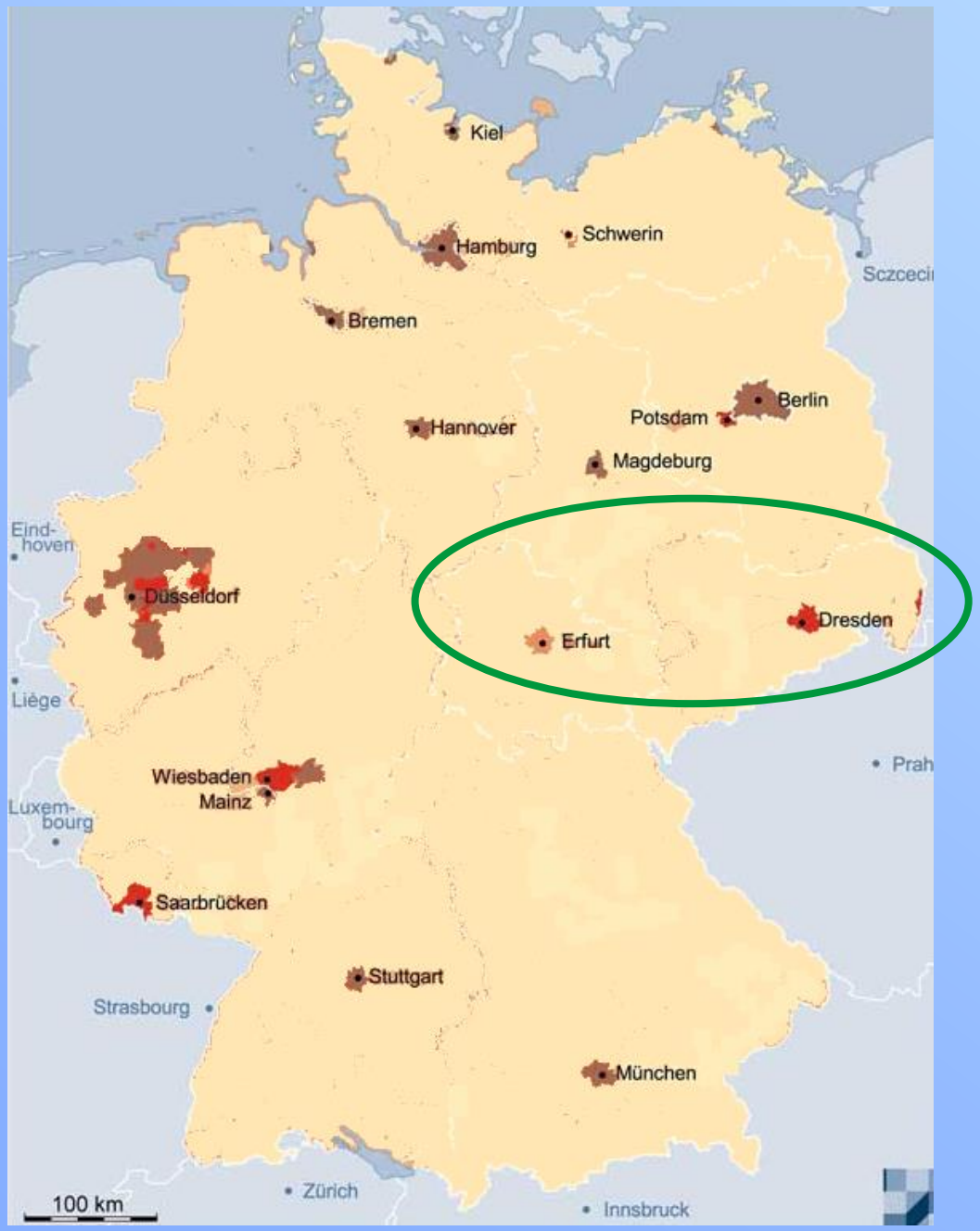
Material flow



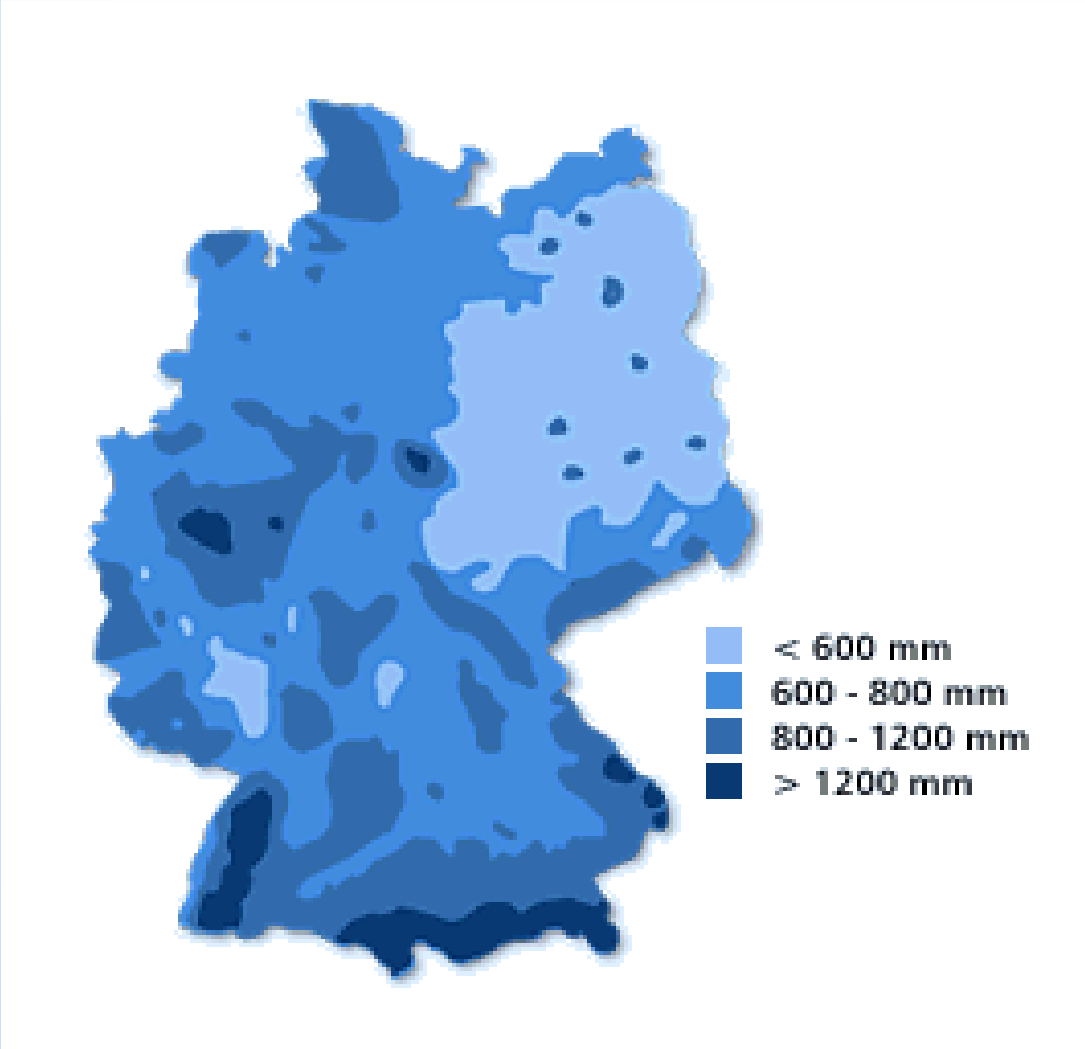
Erosion and Flooding

Erosion

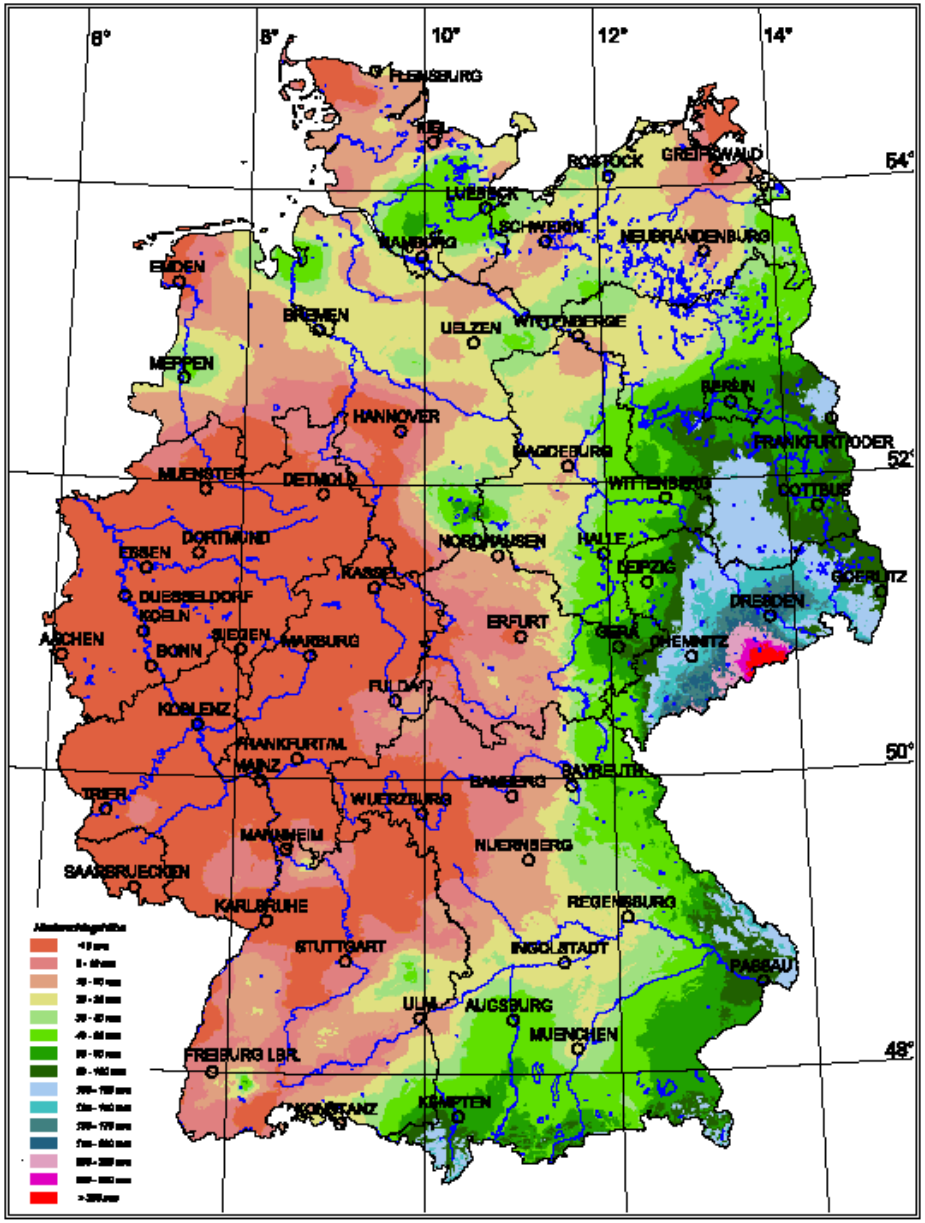
Loess areas in Germany



Annual Precipitation in Germany



Rainfall on August 11-13th 2002 in Germany and Tchechia



Flood in Saxony

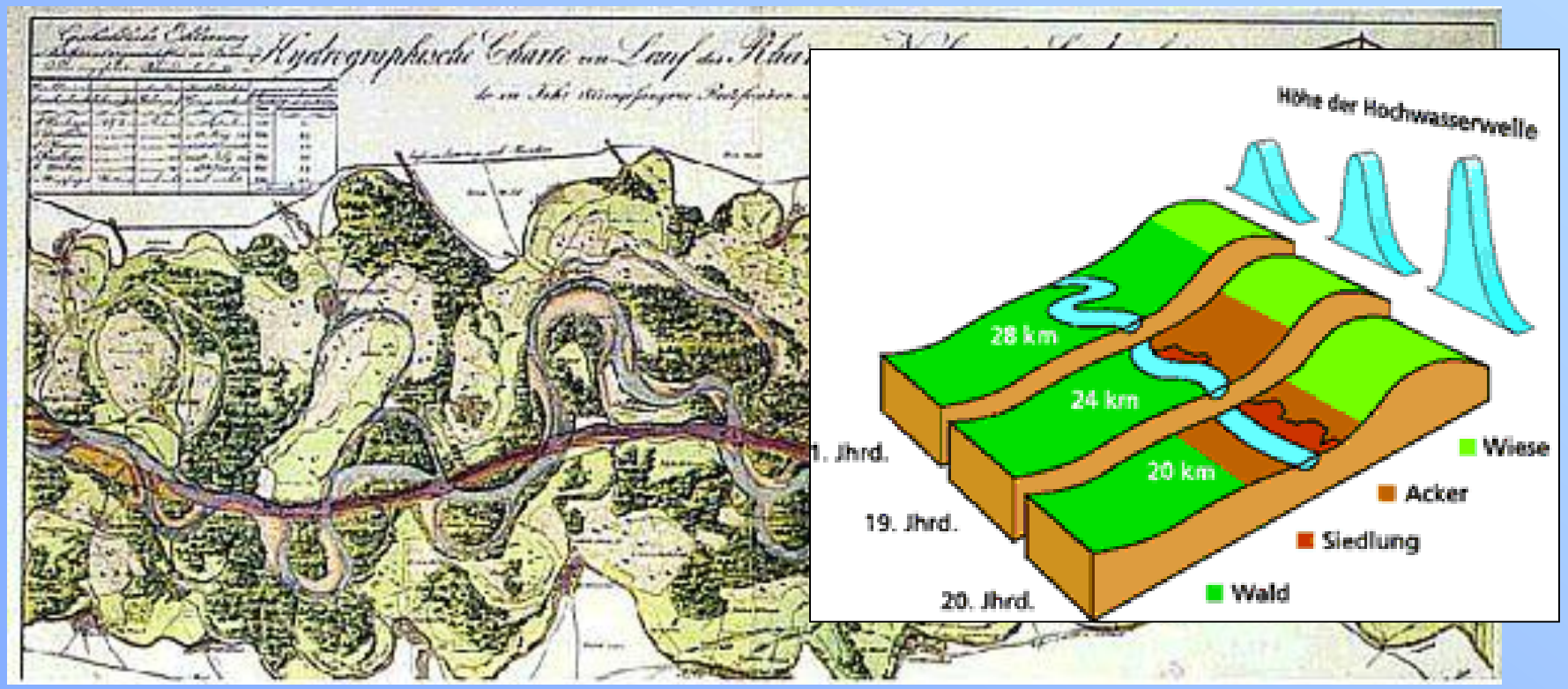
Floods in Europe

Flash-Flood

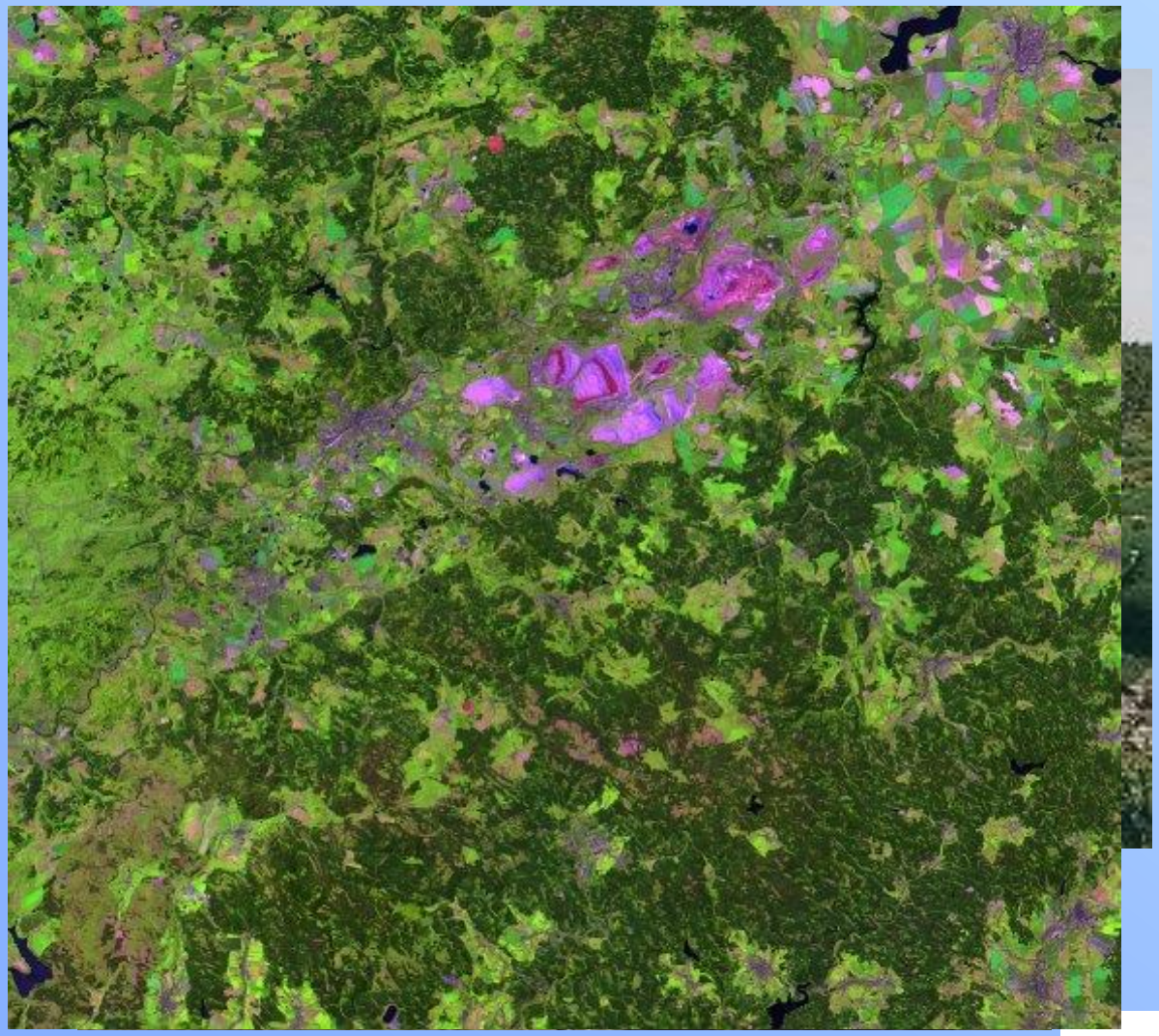
Discussion in Germany

- What are the reasons of floods ?
- Do they occur more often nowadays ?
- Do human activities cause floods ?

River degration



Dying Forest



Intense Agriculture

Conservational Tillage

~~Plough~~

Ploughless, conservational Tillage

MaxEmerge2
VacuMeter

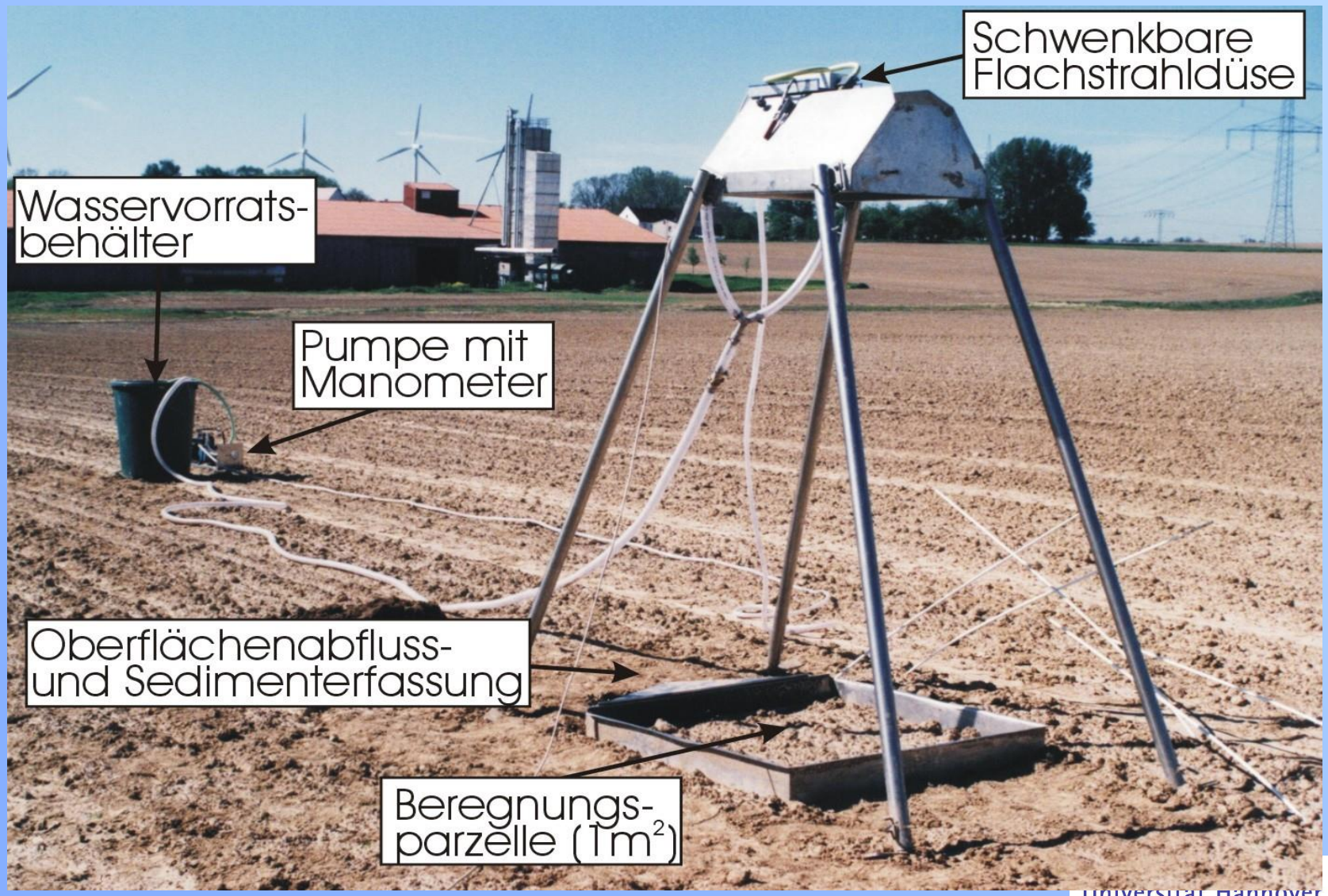
Runoff after thunderstorm

(Rainfall of 6,7 mm)

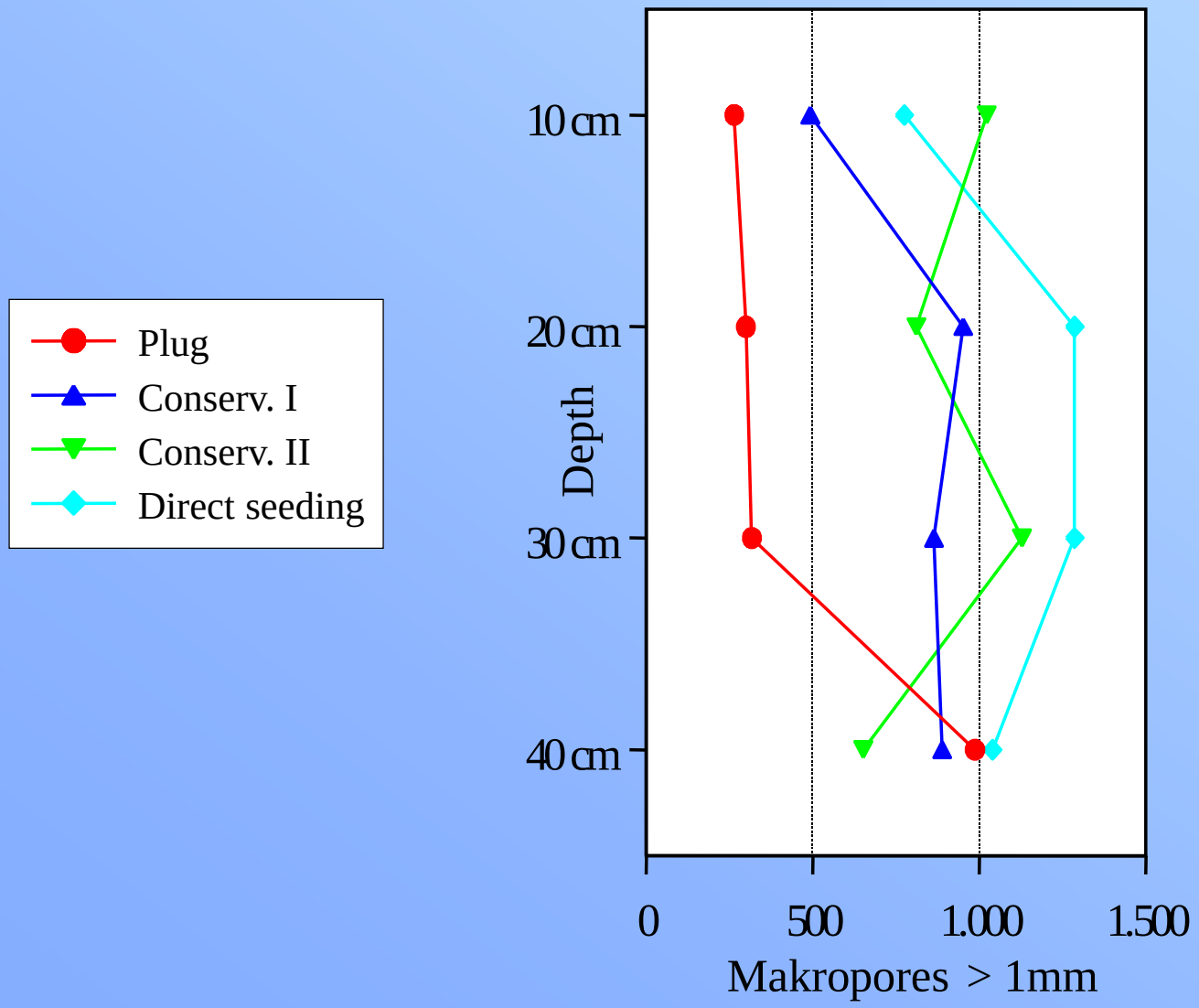
Plough

Conservational tillage

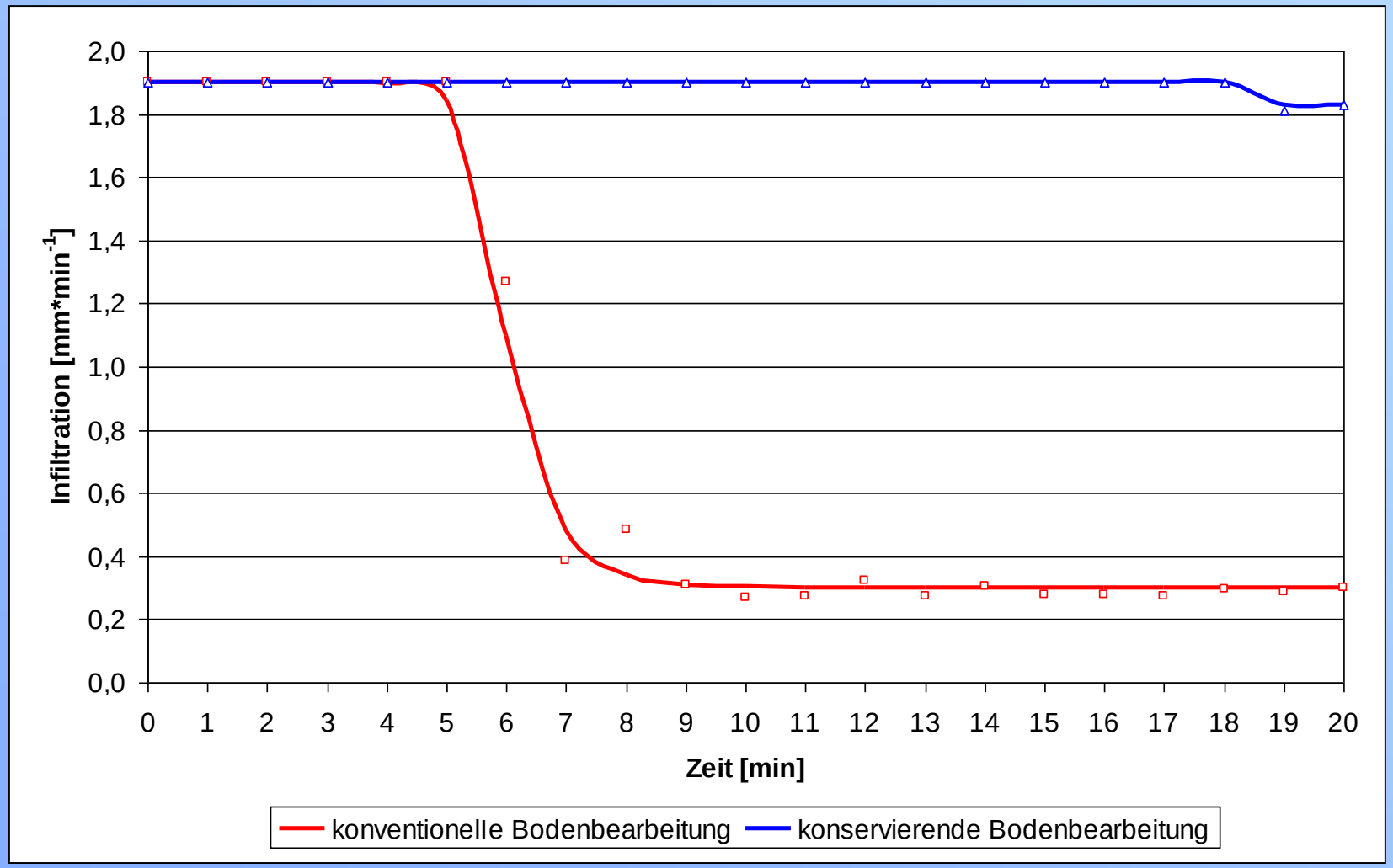
Experiments



Makropores


Plug
Conserv. I
Conserv. II
Direct seeding
10 cm
20 cm
30 cm
40 cm
Depth
0
500
1.000
1.500
Makropores > 1mm

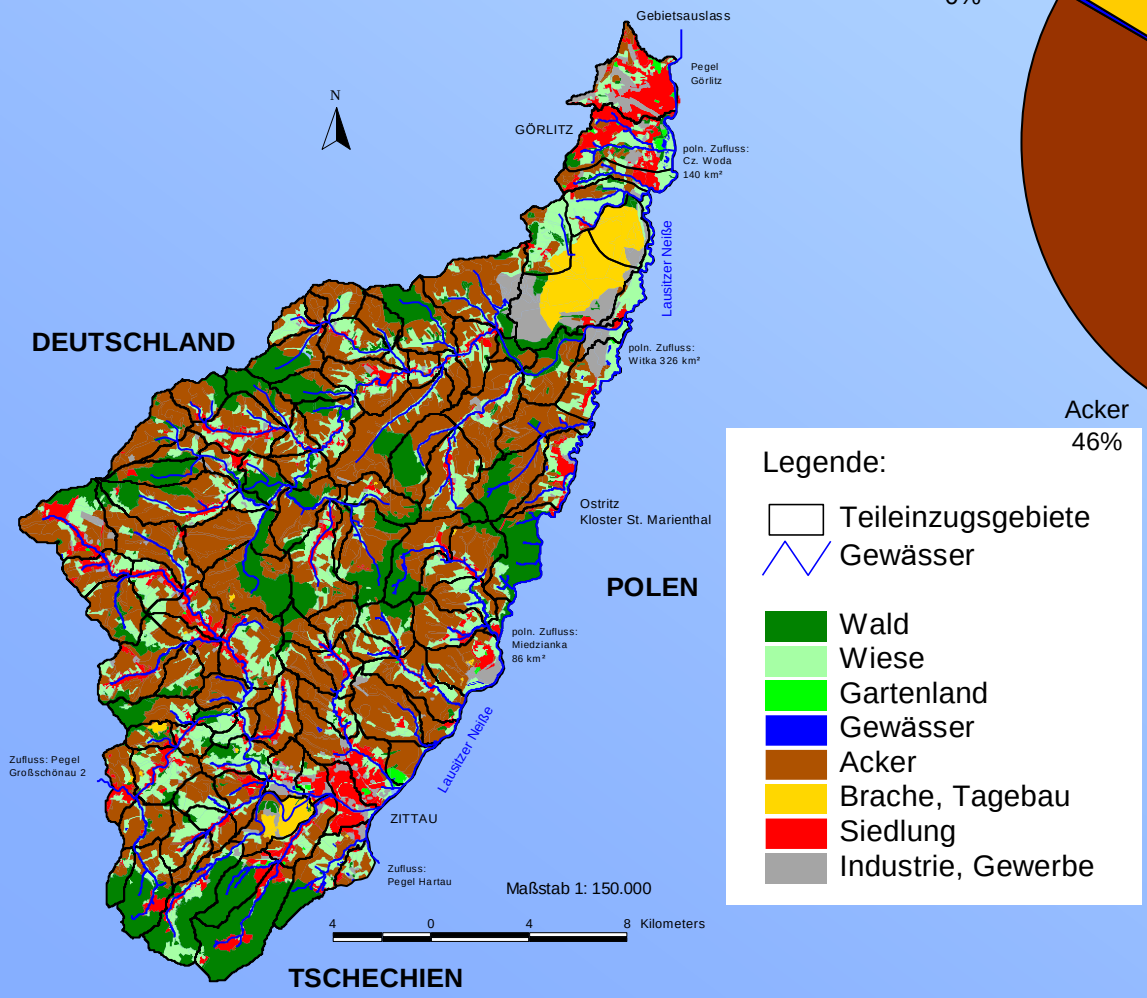
Infiltration

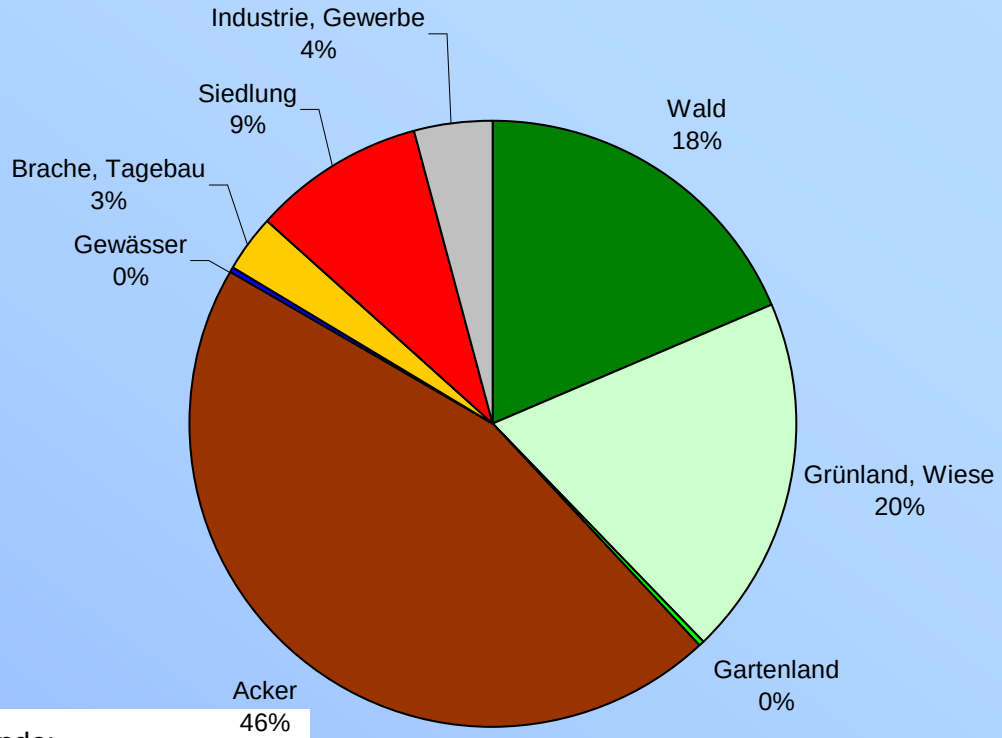


Test Catchment

- River catchment
  - Size: 4200 km²
  - Stream Length: 265 km
- Test catchment
  - Size: 400 km²
  - Stream length: 60 km

Landuse

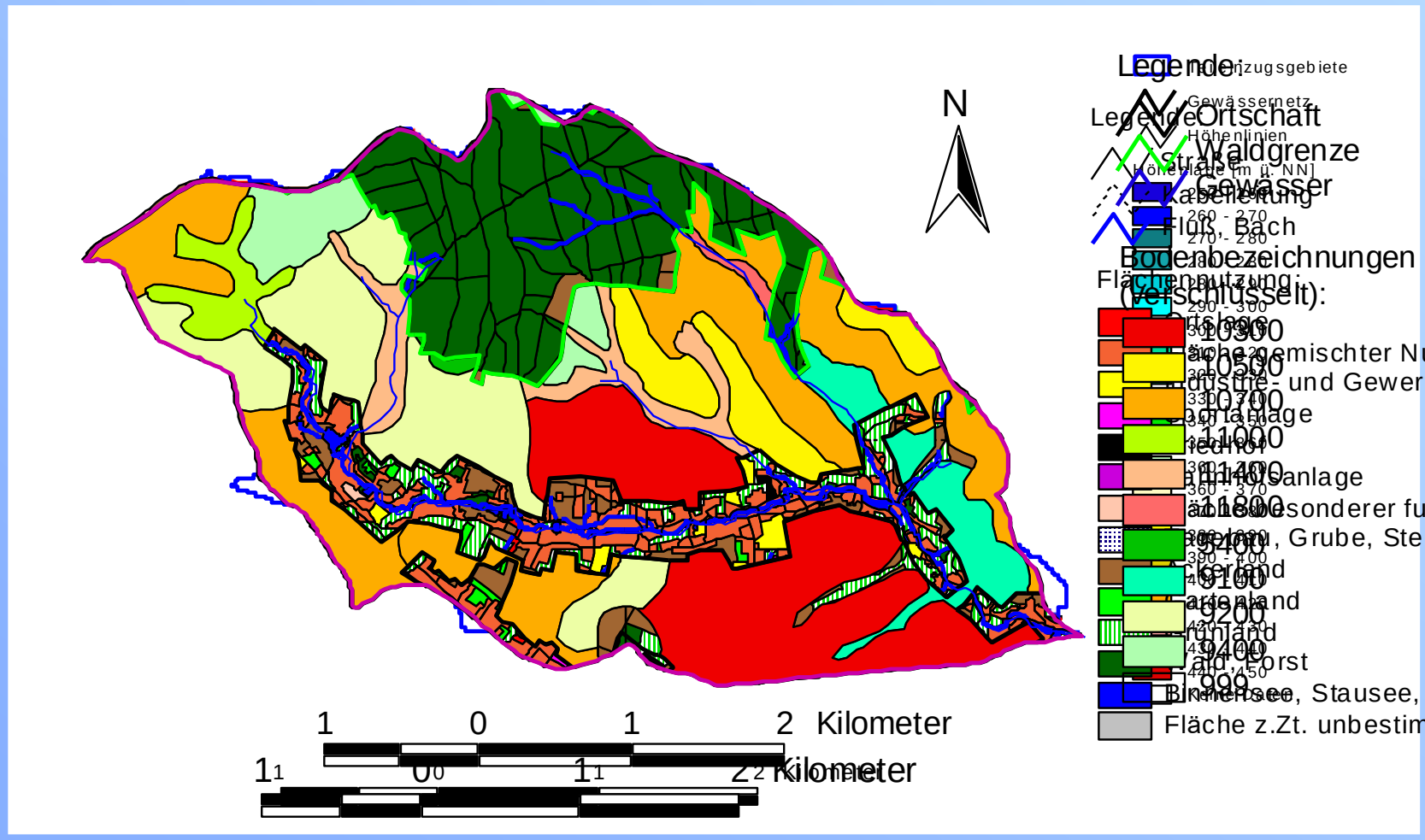




Legende:

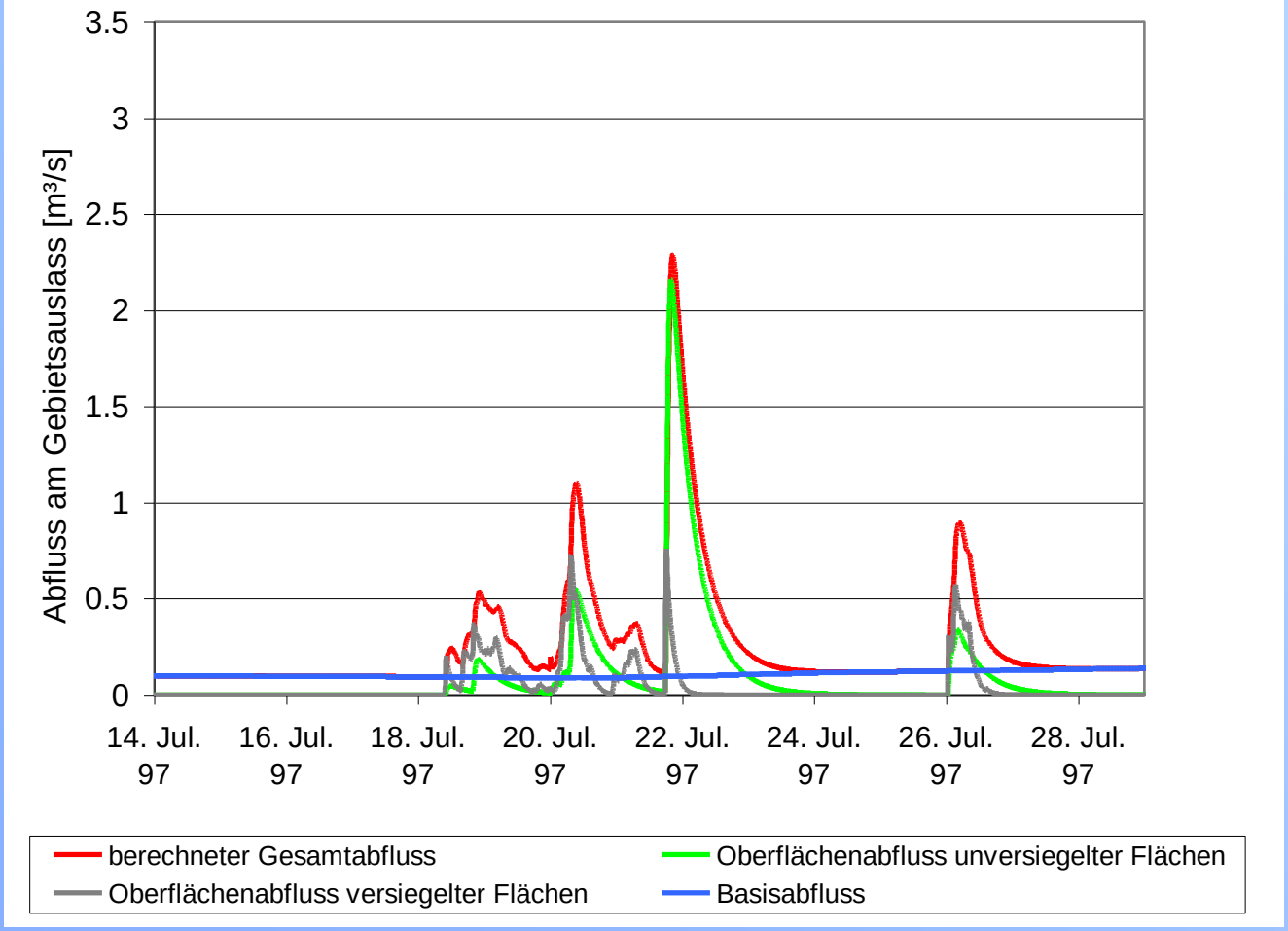
- Teileinzugsgebiete
- Gewässer
- Wald
- Wiese
- Gartenland
- Gewässer
- Acker
- Brache, Tagebau
- Siedlung
- Industrie, Gewerbe

Rainfall Runoff Model

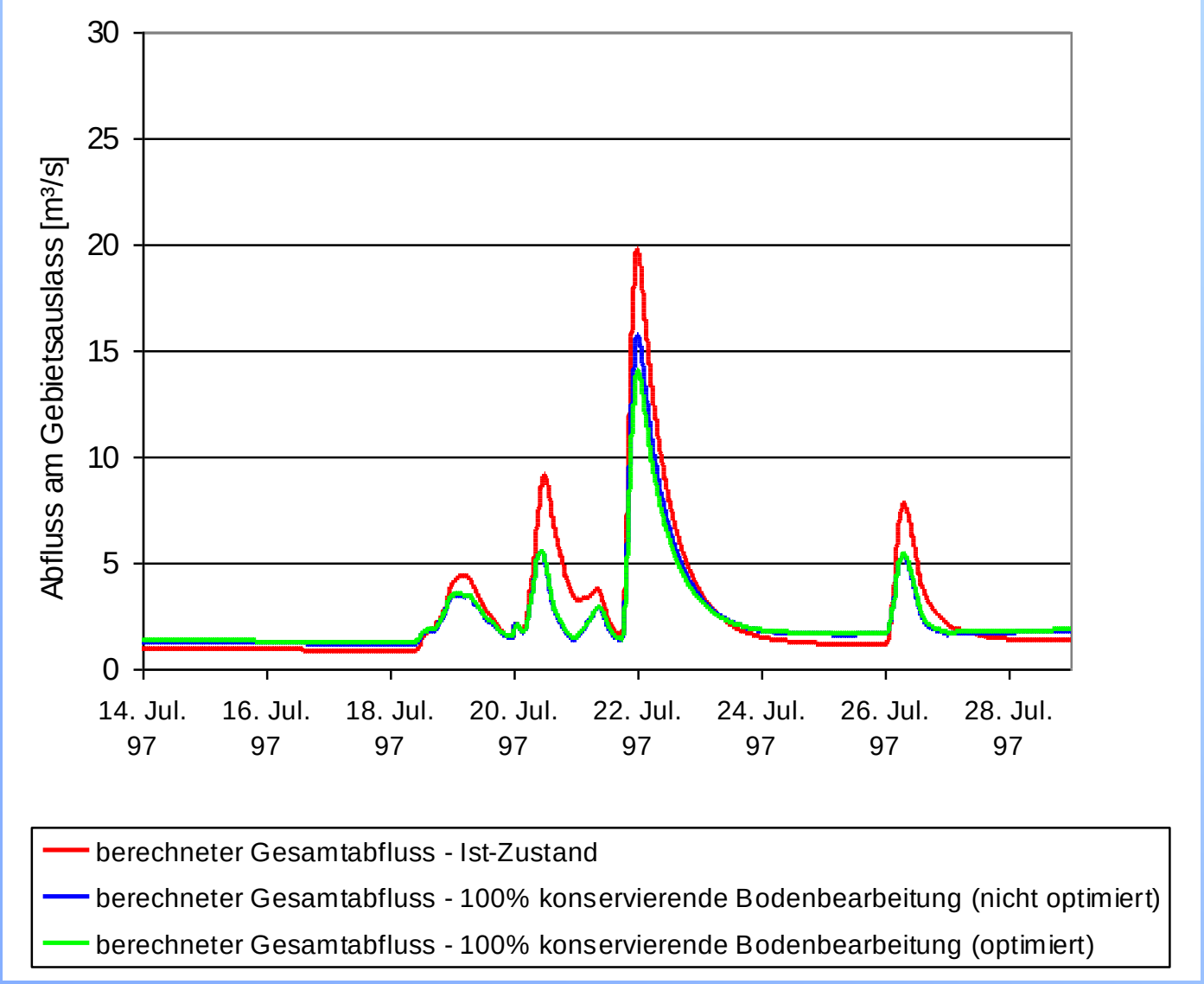


Area 13.3 km²

Components of runoff



Comparision



Reason for Floods

Floods are natural !

But: floods increased in recent years because of

- Heavier rainfall
- Change of land use and soil
  - Forest degration
  - Intensive Agriculture
  - Surface sealing in cities
- Degration of rivers

What can be done ?

1. Don‘t build anything in flood areas
2. Preventive flood protection
   - Conservational tillage
   - Erosion control
   - Stormwater management in cities
3. Technical flood protection
   1. Maintain dikes
   2. Retention ponds, reservoirs, dams
4. Better warning system during catastrophes
   1. Better forecasting
   2. Warn people

Conclusion

1. Storm Water management is possible!
2. A lot of different meassures are available
3. Hydaulic <u>and</u> quality Impact on receiving waters is to be considered
4. Floods can be reduced to a certain amount
5. Techniques for Decision Support (DSS) should be used for optimizing solutions