The use of UV-VIS spectrometer probes to estimate additional loads drained by the central storage tunnel (CST) Graz to the WWTP Graz, Austria

from the CST MONITORING Project

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Thomas HOFER, **Günter GRUBER** and Dirk MUSCHALLA

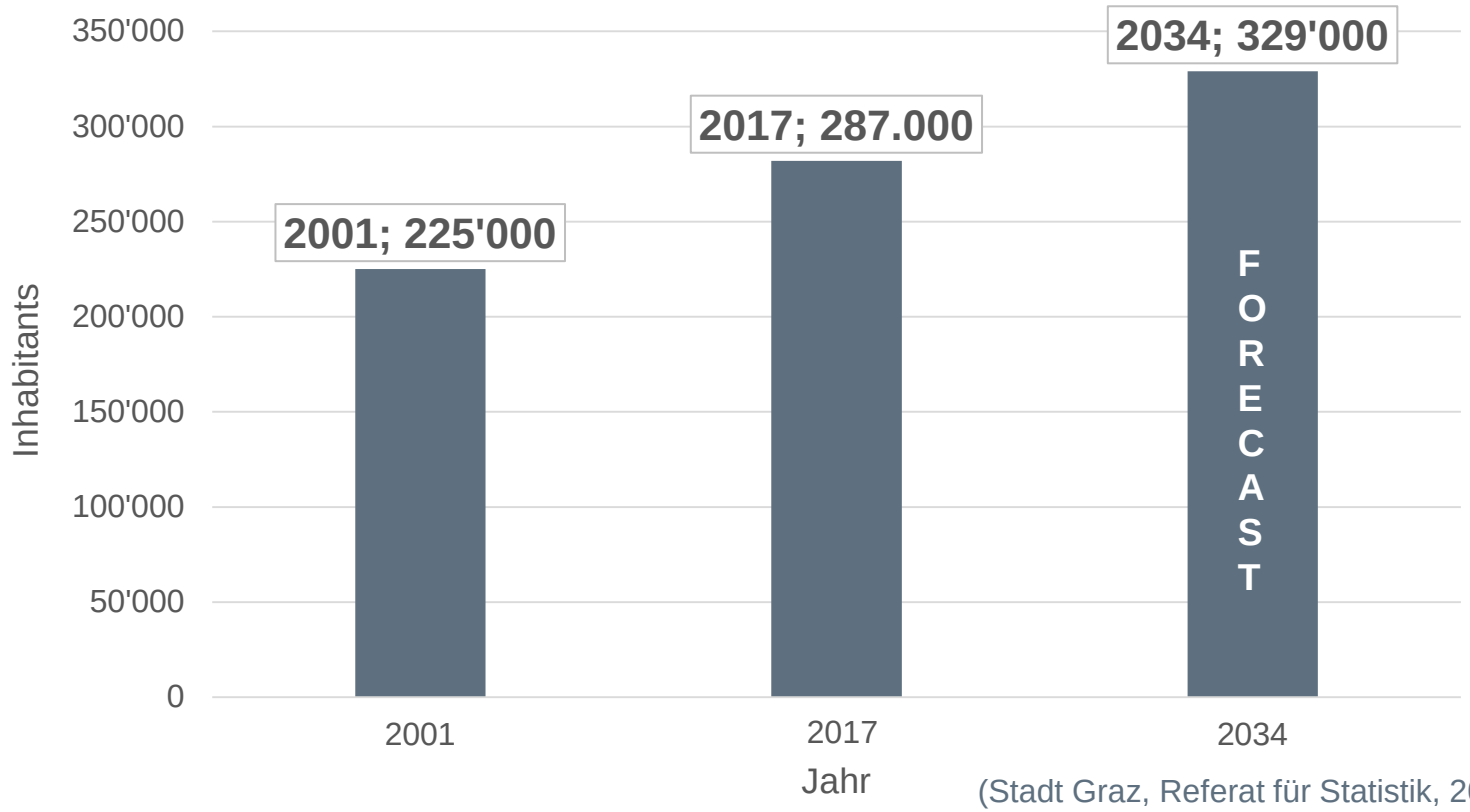
Challenges for WWTP Graz

High population growth

Increase of flowrates and pollution loads due to new Central Storage Tunnel (CST)

Capacity of 500 000 PE (last expansion 2007 based on 2001)
max Q_{dwf} = 1,6 m³/s; max $Q_{d,dwf}$ = 90 000 m³/d
max Q_{wwf} = 3,2 m³/s; max $Q_{d,wwf}$ = 276 480 m³/d

Challenge 1: Population growth



(Stadt Graz, Referat für Statistik, 2015)

=> Current loading (2016): 560 000 PE (BOD) and 480 000 PE (COD)

=> No problems regarding carbon removal but sometimes problems with nitrification and the NH4-N threshold values during winter season

Challenge 2: Central Storage Tunnel (CST)

- Collection and temporal storage of **3 + 16 = 19 CSOs** from **35 CSO** along river Mur

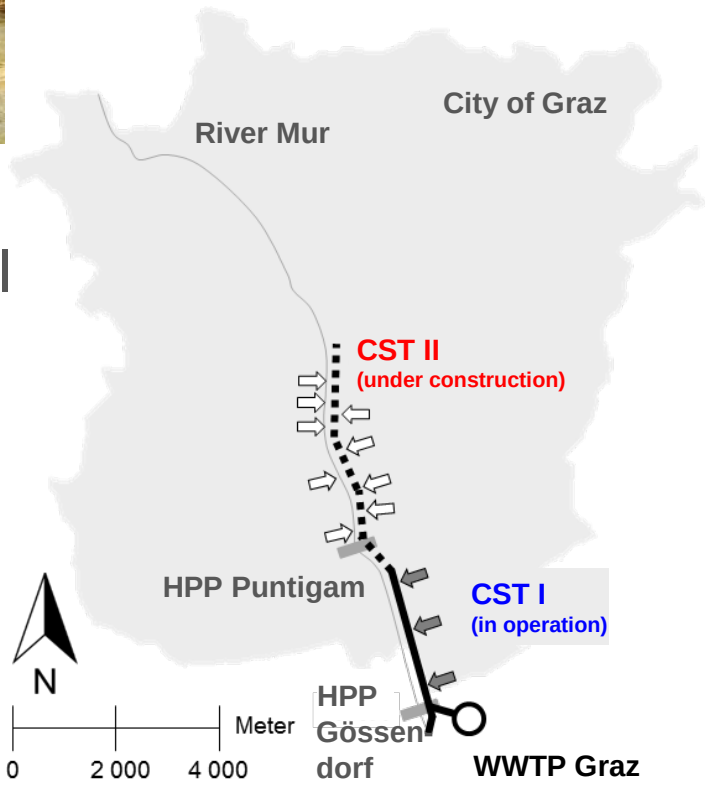


© Butler & Davis (2010)

- Routing and treatment of the temporal stored volumes at WWTP Graz

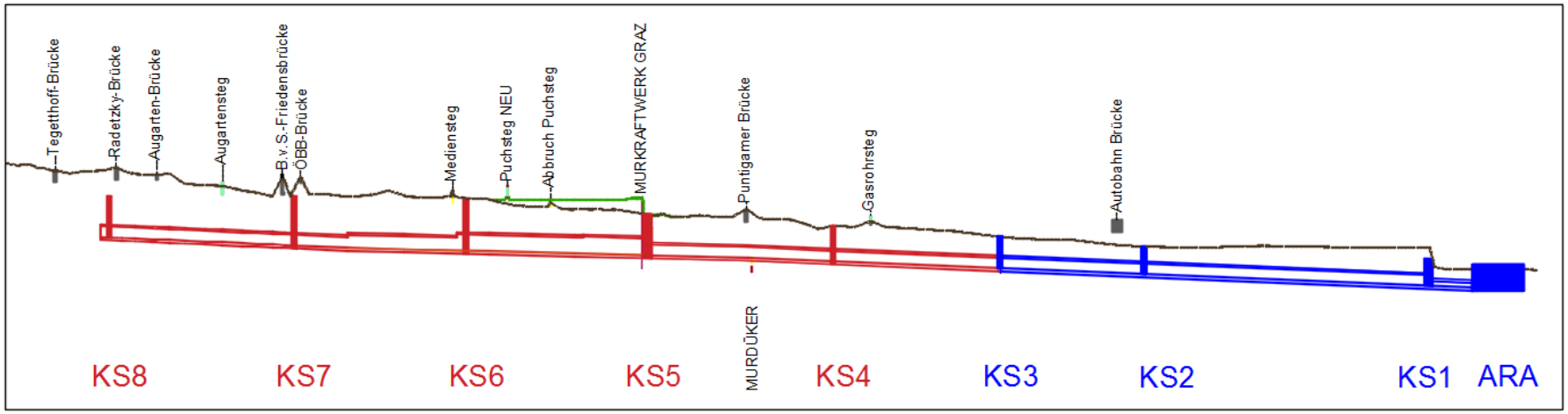
- **94 000 m³ additional storage volume in the sewer system**

HPP … Hydro Power Plant



Central Storage Tunnel Graz

- In total 8.4 km (3.2 km + 5.2 km)
- In total 94 000 m³ (25 000 m³ + 69 000 m³)
- Slope: 0.16%
- 7 cascades equipped with movable weirs to activate volume



CST II: Under construction: 2017 – 2022

CST I: In operation since 2016

Goals for CST-MONITORING Project

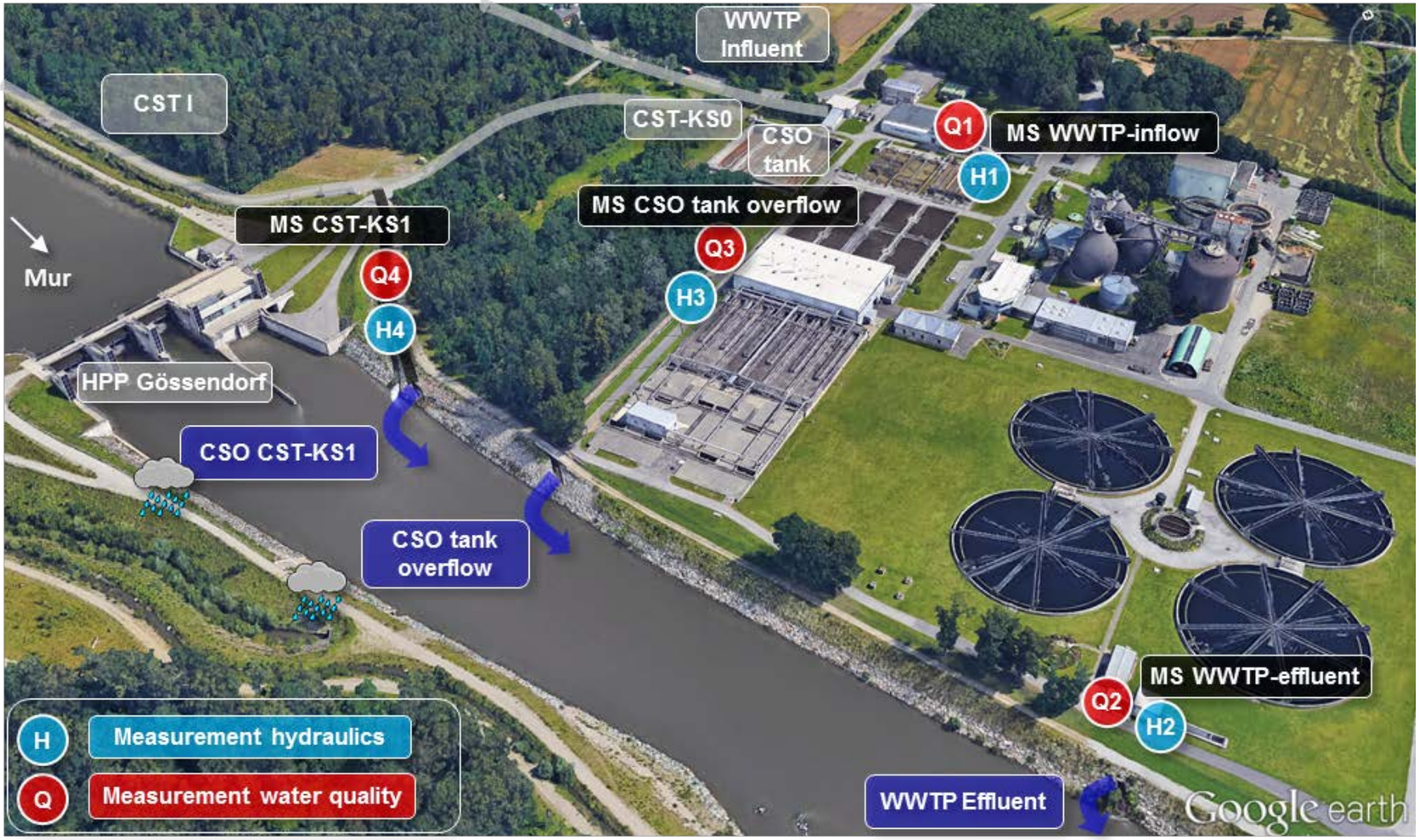
- Influence of additional pollution loads resulting from the CST I+II on the purification capacity of WWTP Graz
  => iCST-Project (2015)

- Calibration and validation of the integrated iCST-model

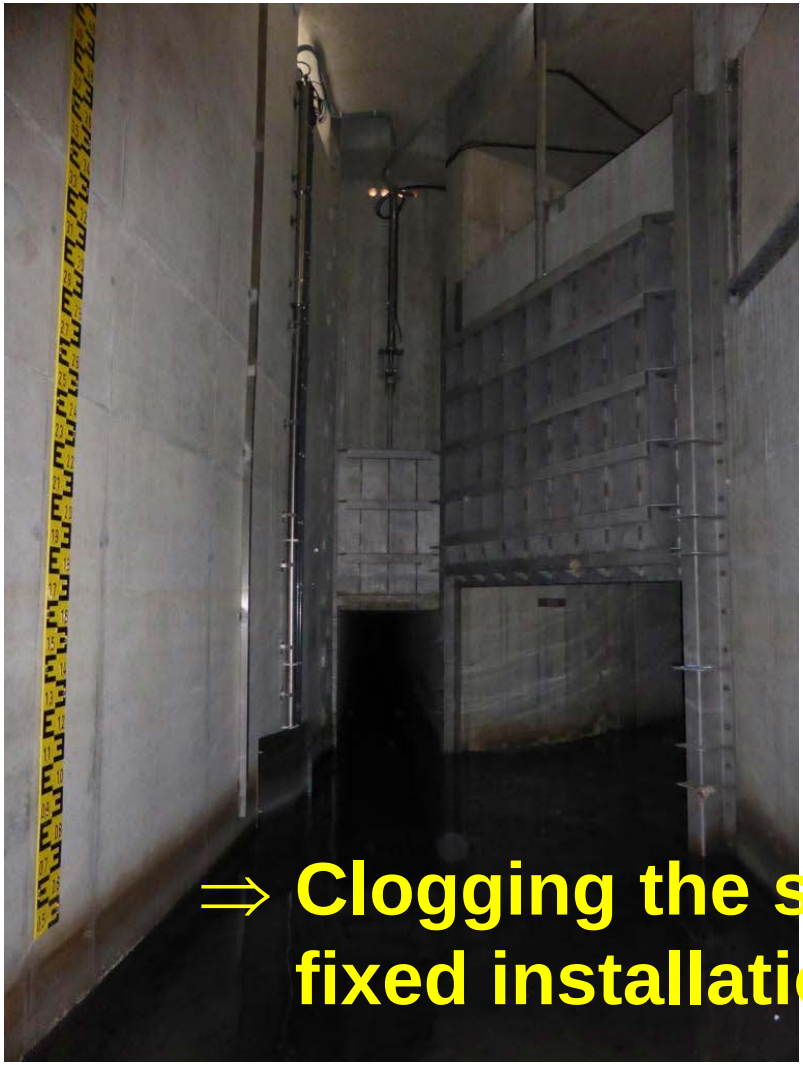
- Estimation of the additional pollution loads routed by the CST I+II to WWTP Graz

- => Online-Monitoring in CST and at WWTP Graz (since 2015)

Installed Sensor Network

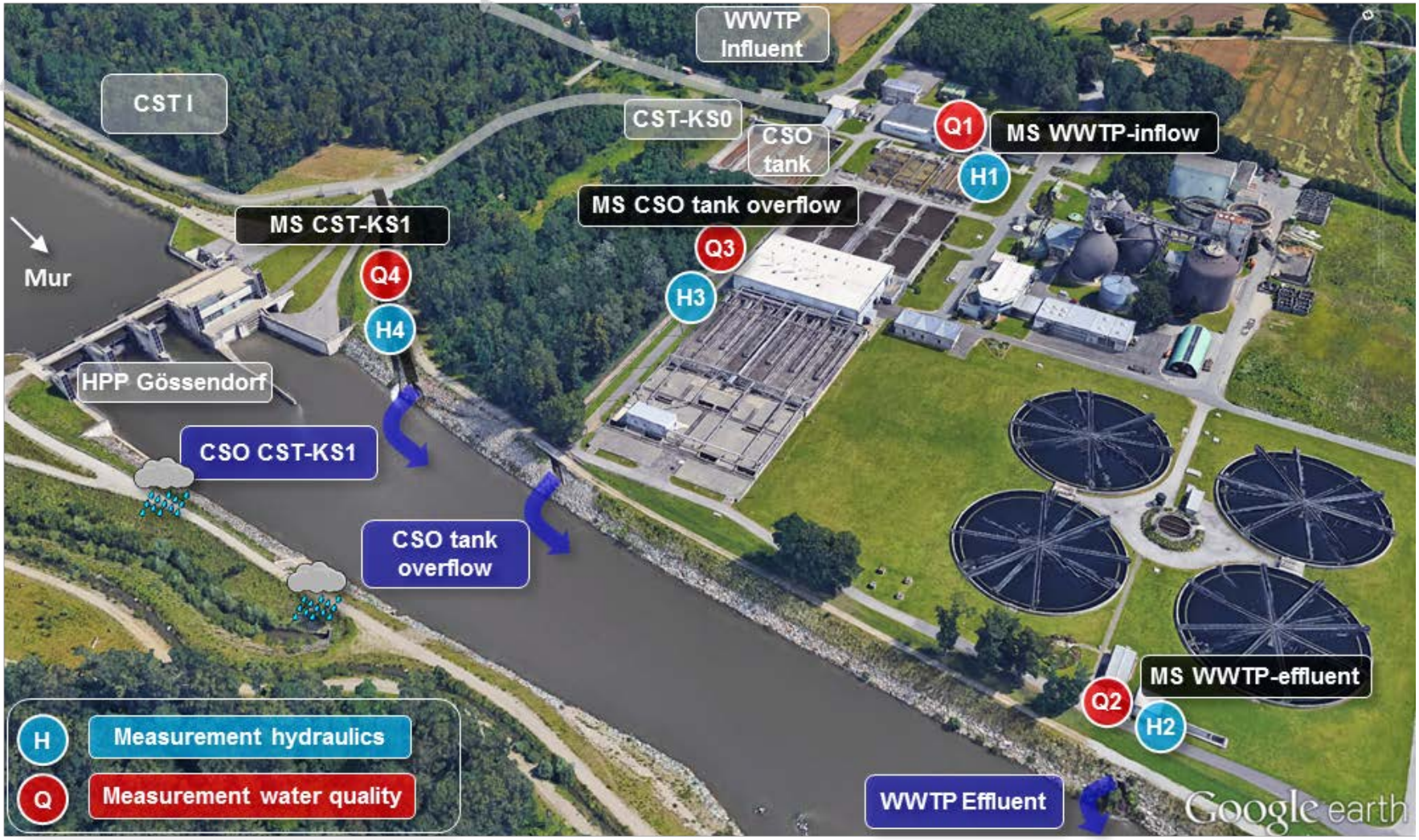


MS-CST-KS01 failed due to clogging ☹



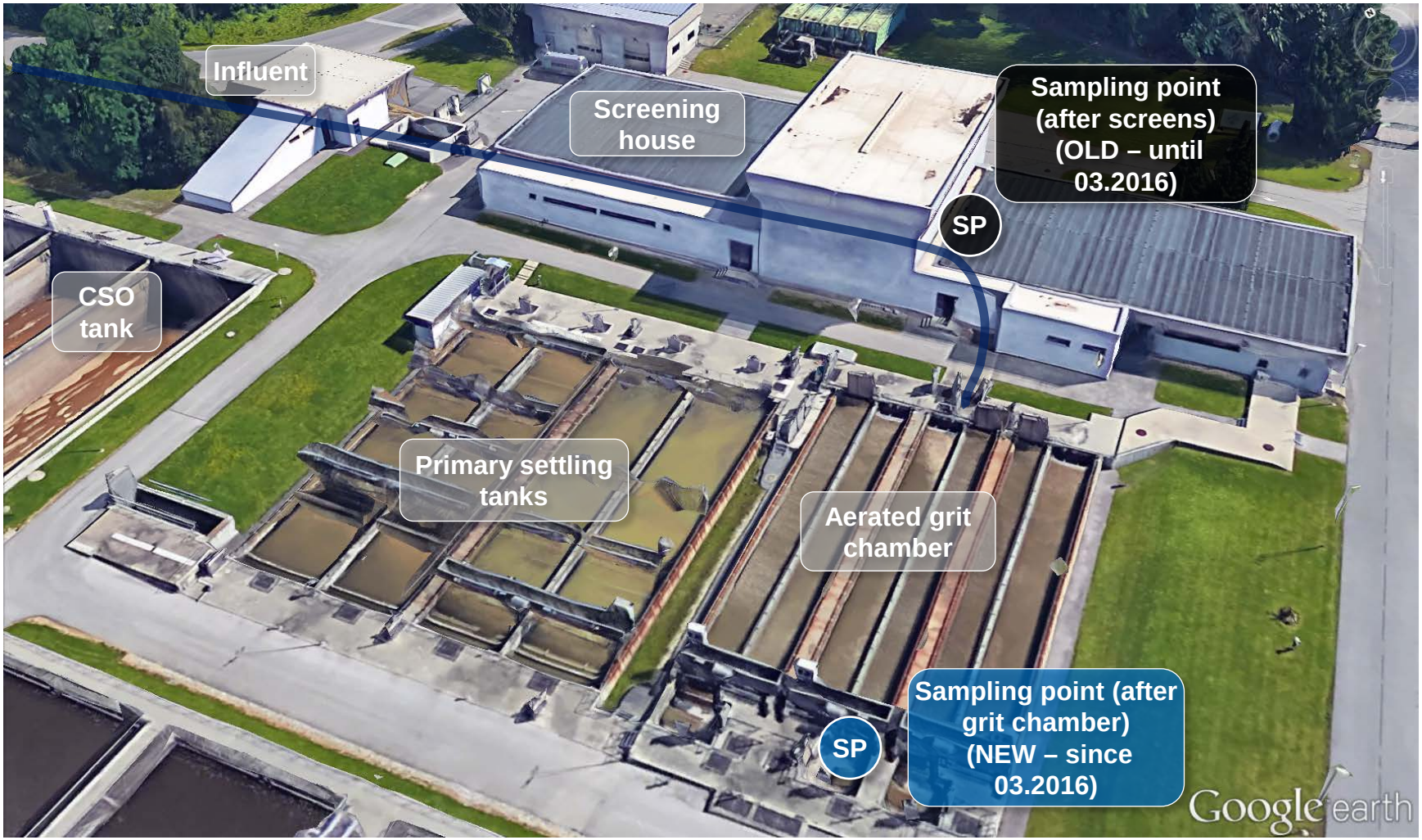
⇒ Clogging the sensors due to fixed installation in the CST ☹

Installed Sensor Network



MS-WWTP-inflow (2015) failed due to sand and grit in the old flume ☹

Inflow sampling points at WWTP

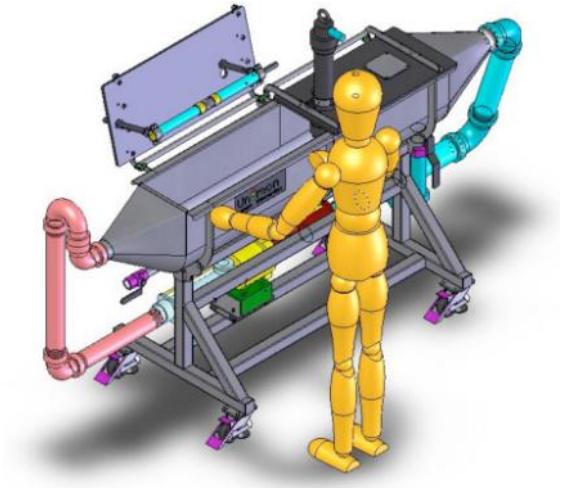


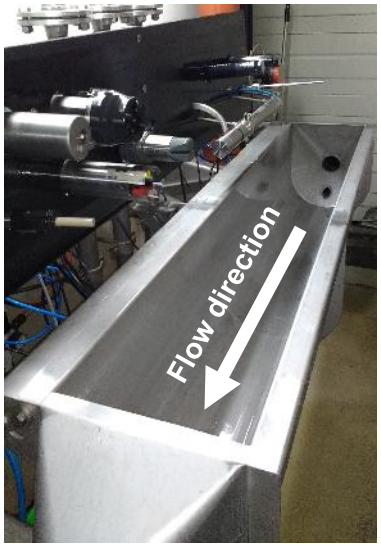
Quality-Station – „WWTP-inflow“ ☺

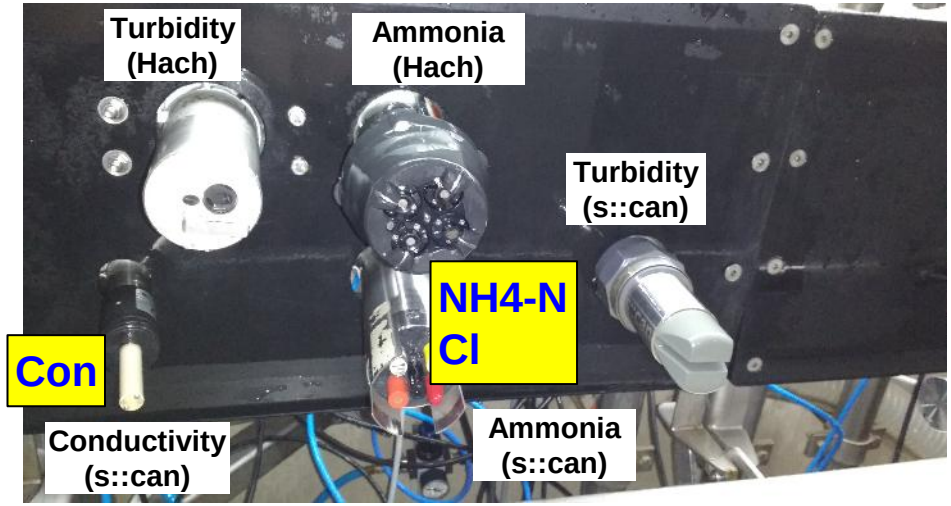
Bypass-installation (Flume)

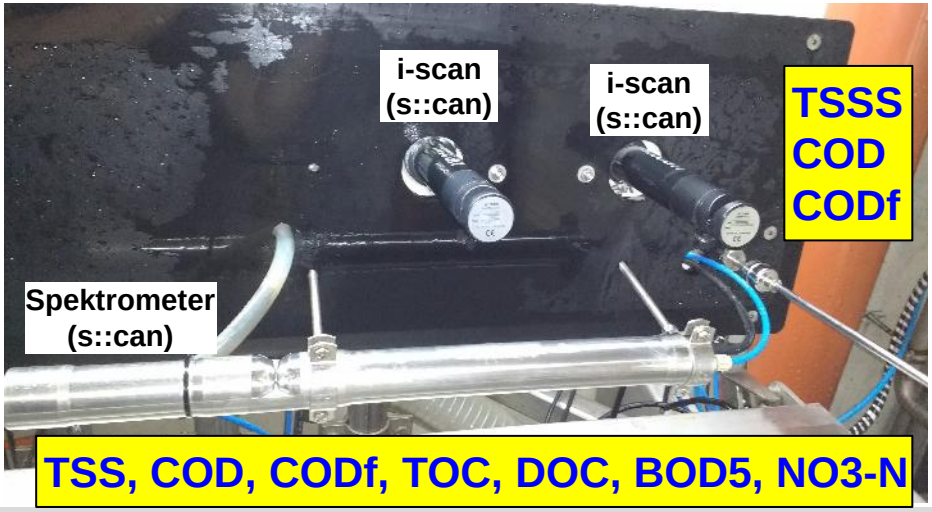
System „uni-pass“
(Fa. unimon GmbH)

Volume = 120 L
Q = 2 L/s
v = 3 cm/s
A = 600 cm²







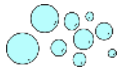


Quality-Station – „WWTP-inflow“

Bypass-operation

Measurement interval: 2 min

- Bypass-operation
  - Automatic emptying and backwashing of the flume each 6 hours.
- Automatic sensor-cleaning
  - By compressed air::



    - Interval: 300 s
    - Duration: 3 s
    - Pressure: 6,0 bar

  - By wiper (Turbidity probe from Fa. Hach)
- Additional manual cleaning of the flume and the sensors:
  - Approx. once a week

Measurement campaigns and maintainance

WWTP-inflow

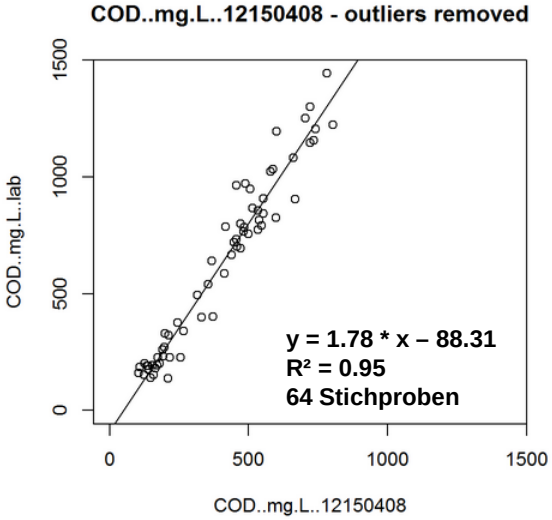
Measurement campaigns and maintainance

K Campaigns for local calibration S Special campaigns W Maintainance

	KW-Woche		Mo	Di	Mi	Do	Fr	Sa	So
05 2016	KW 17	25.04. - 01.05.							
	KW 18	02.05. - 08.05.		S					
	KW 19	09.05. - 15.05.	W						
	KW 20	16.05. - 22.05.		W					
	KW 21	23.05. - 29.05.			W				
	KW 22	30.05. - 05.06.				S			
06 2016	KW 23	06.06. - 12.06.	W						
	KW 24	13.06. - 19.06.	W K	K S	S				
	KW 25	20.06. - 26.06.	W						
	KW 26	27.06. - 03.07.		W		W			
07 2016	KW 27	04.07. - 10.07.	W						
	KW 28	11.07. - 17.07.	W	S		W			
	KW 29	18.07. - 24.07.		W					
	KW 30	25.07. - 31.07.	W K S	K		W S			
08 2016	KW 31	01.08. - 07.08.	W	S	W S	S			
	KW 32	08.08. - 14.08.	S	W S	S				
	KW 33	15.08. - 21.08.		W K	K				
	KW 34	22.08. - 28.08.	W						
09 2016	KW 35	29.08. - 04.09.	W						
	KW 36	05.09. - 11.09.	W K	S					
	KW 37	12.09. - 18.09.	W						
	KW 38	19.09. - 25.09.	W K	K					
10 2016	KW 39	26.09. - 02.10.		W		W			
	KW 40	03.10. - 09.10.	W S						
	KW 41	10.10. - 16.10.	W K	K	S				
	KW 42	17.10. - 23.10.	W			K			
	KW 43	24.10. - 30.10.		W					

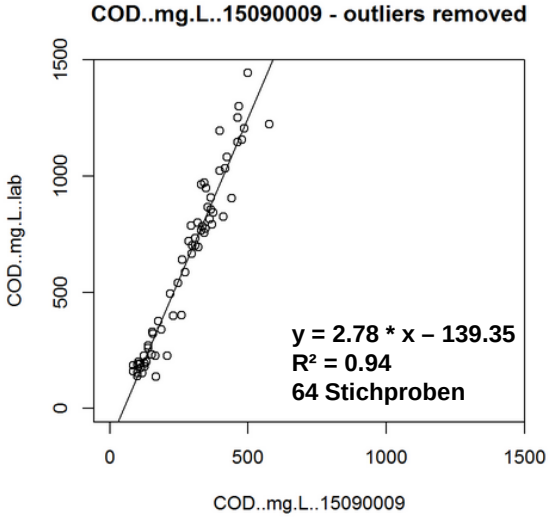
Local calibration – „WWTP-inflow“

Spectrometer probes → COD



s::can spectro::lyser V2 – 2 mm
(INFLU004V16T.glb)

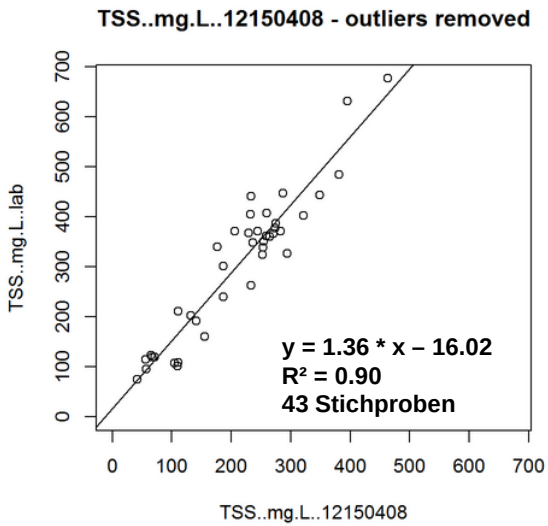
s::can i::scan_AFS+CSB_eq V1 – 5 mm
(Influent-calibration)



=> Local COD all weather calibration based on 74 reference samples

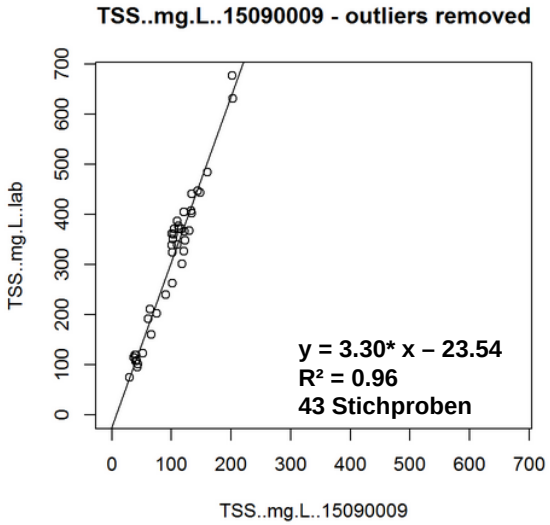
Local calibration – „WWTP-inflow“

Spectrometer probes → TSS



s::can spectro::lyser V2 – 2 mm
(INFLU004V16T.glb)

s::can i::scan_AFS+CSB_eq V1 – 5 mm
(Influent-calibration)



=> Local TSS (and BOD_5) all weather calibration based on 50 reference samples

Results I

Daily dry weather pollutographs

WWTP-inflow

Daily dry weather pollutographs WWTP-inflow

Criterions for dry weather definition:

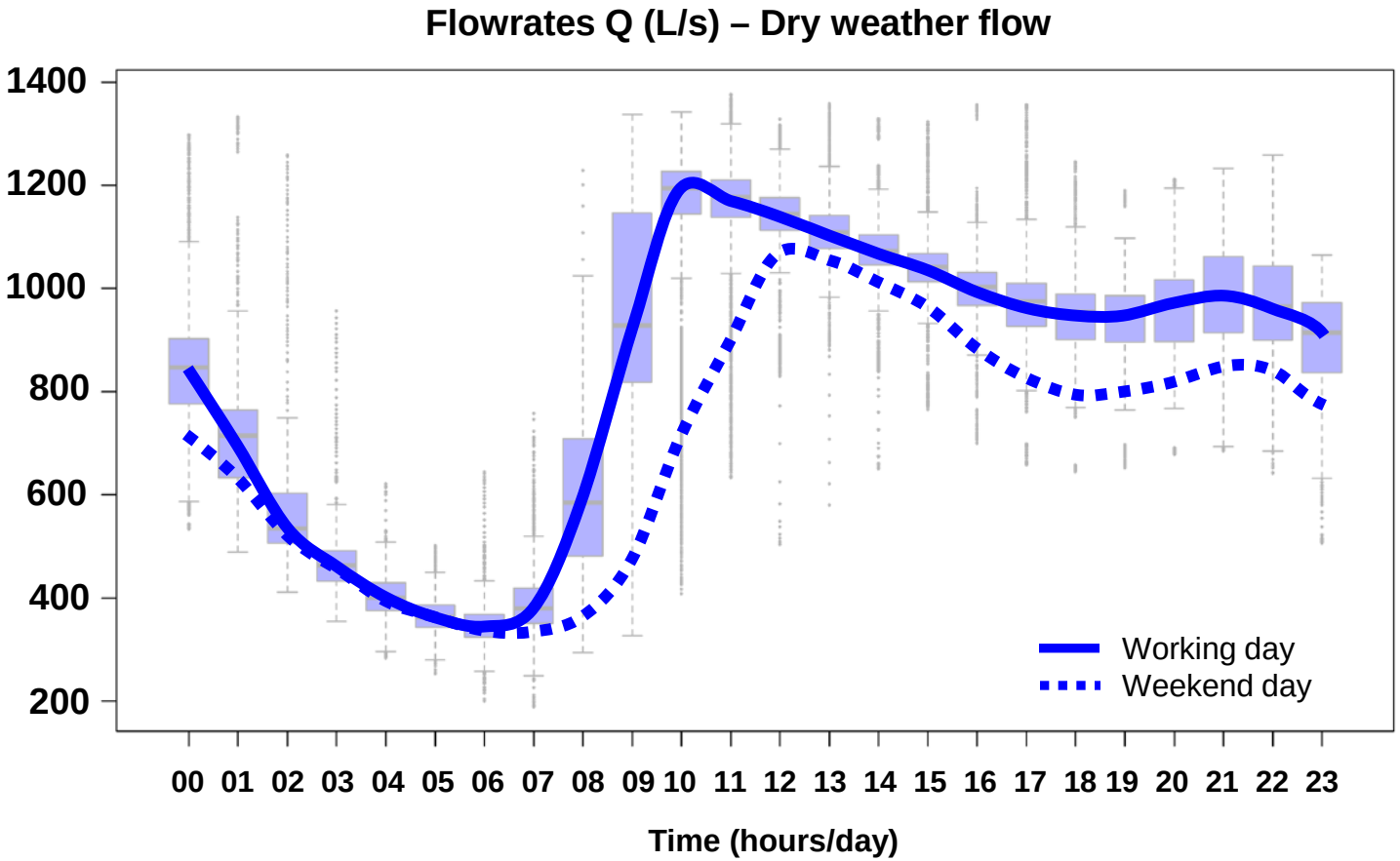
- **Criterion 1:** Maximum flowrate **Q_{max} < 1 400 L/s**
- **Criterion 2:** Maximum daily flow volume **Q_d < 80.000 m³/d**

Monitoring-period:

- 30.04.2016 – 30.04.2017 (366 days, 361 proofed to be valid)
- Dry weather days: 238 days
  - Working days: 174 days
  - Weekend days: 64 days
- Wet weather days: 128 days

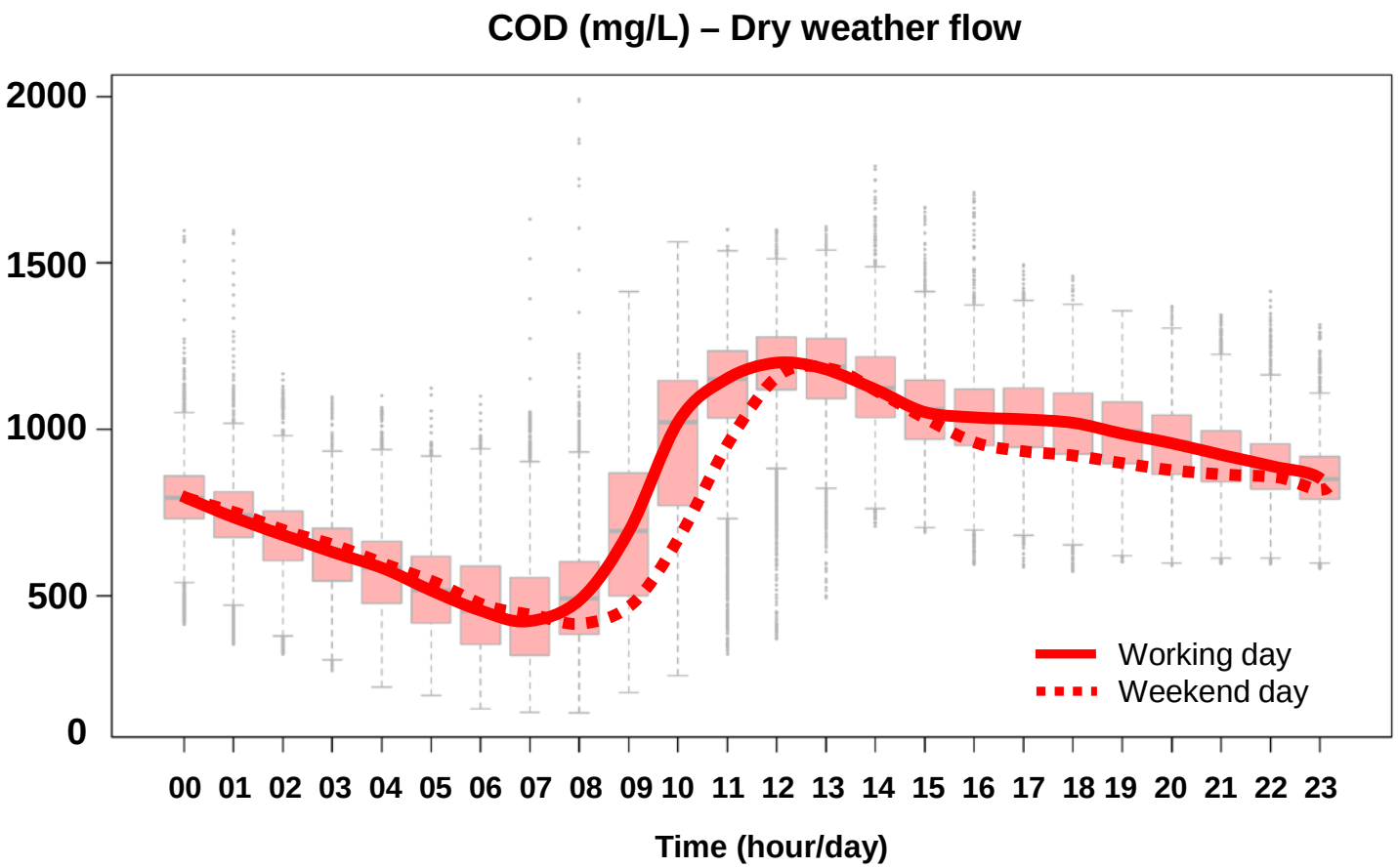
WWTP inflow: Daily dry weather pattern

Flowrates (Data base: 172 working and 64 weekend days)



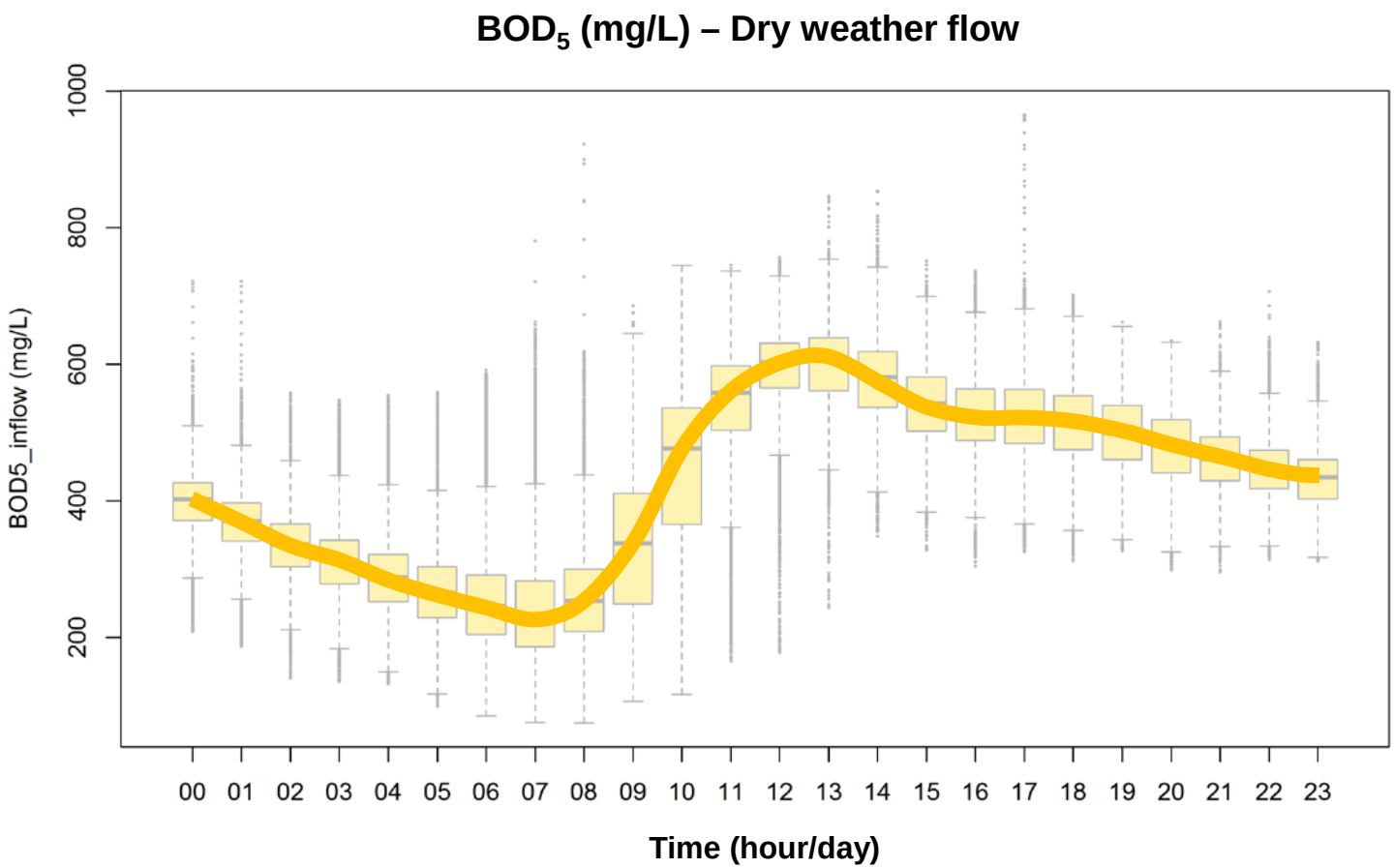
WWTP inflow: Daily dry weather pattern

COD (Data base: 172 working and 64 weekend days)



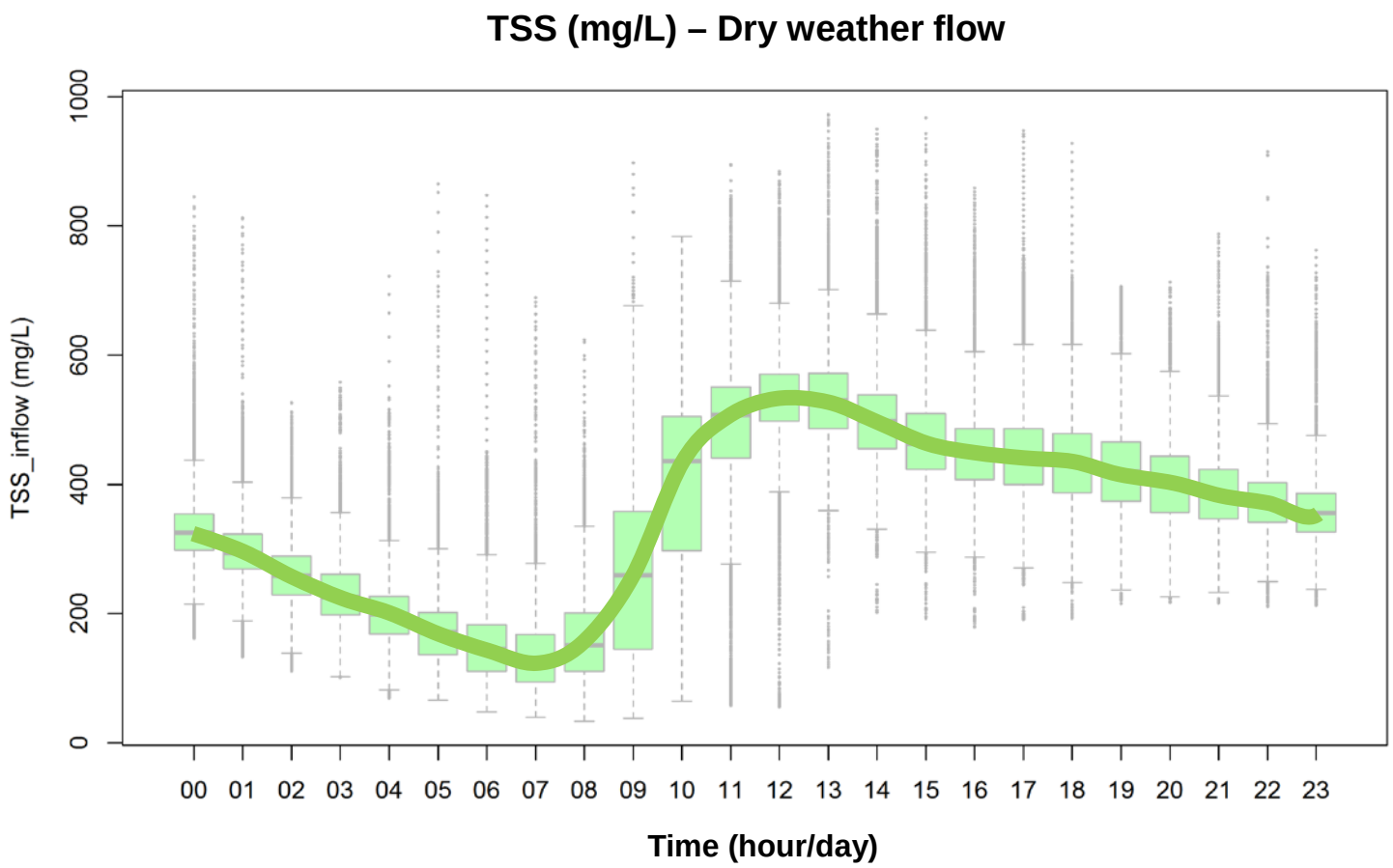
WWTP inflow: Daily dry weather pattern

BOD_5 (Data base: 238 dry weather days)



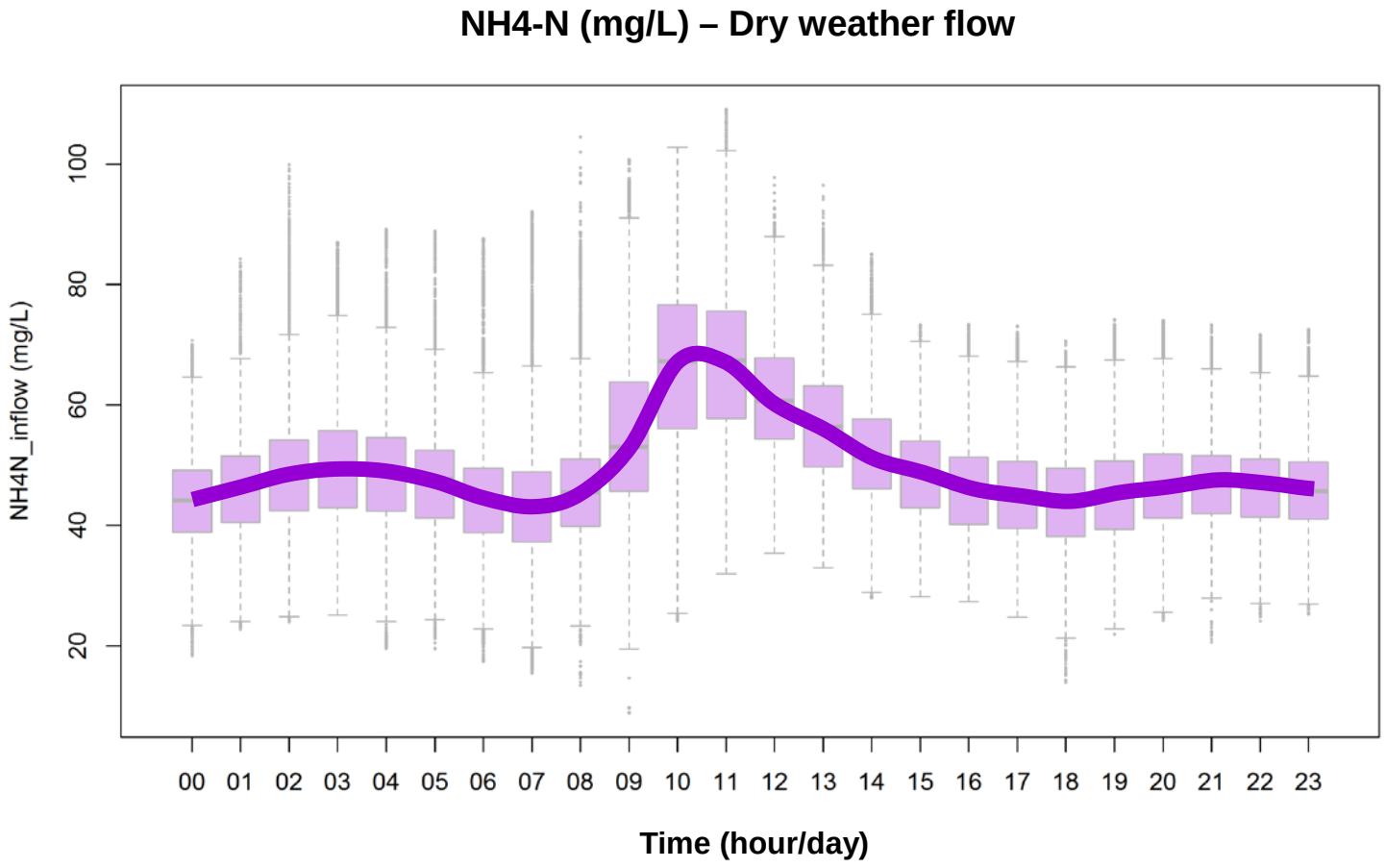
WWTP inflow: Daily dry weather pattern

TSS (Data base: 238 dry weather days)



WWTP inflow: Daily dry weather pattern

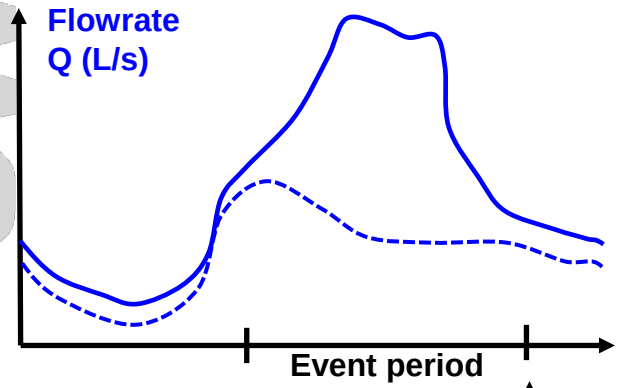
NH4-N (Data base: 166 dry weather days)

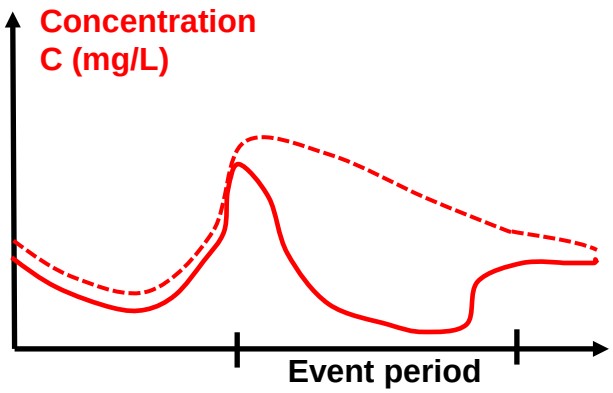


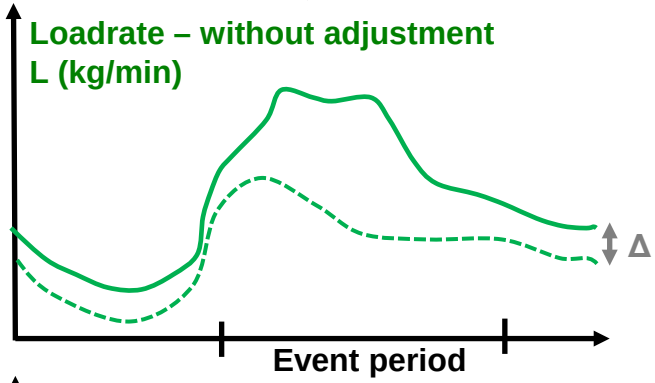
Results II

Estimation of additional loads resulting from CST I+II emptying to WWTP Graz

Method: Load Estimation





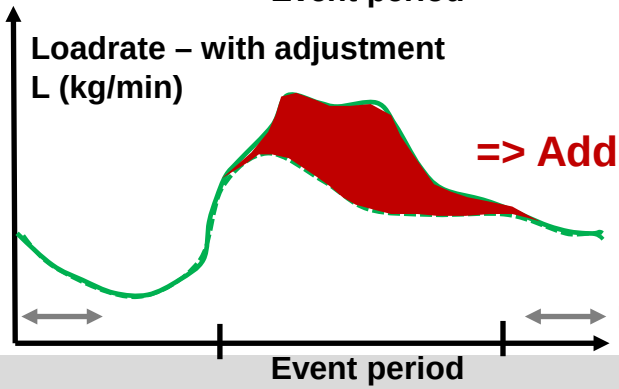


Method based on:

Metadier M. and Bertrand-Krajewski J. L. (2011) Assessing dry weather flow contribution in TSS and COD storm events loads in combined sewer systems. Water Science and Technology, **63**(12), 2983–2991.

Daily dry weather pattern (Statistics)

Measurements



=> Additional load due to emptying

Fitting before

Fitting after

Event loads resulting from CSO tanks and CST I emptying

55 Rain events from 30.04.2016 – 30.04.2017

7 Rain events with measurable emptying loads from CSO tanks and CST I

- Emptying event 01: 21.11.2016 07:30 – 21.11.2016 20:29
- Emptying event 02: 08.02.2017 08:00 – 09.02.2017 06:30
- Emptying event 03: 17.02.2017 23:39 – 18.02.2017 12:59
- Emptying event 04: 01.03.2017 05:39 – 01.03.2017 15:22
- Emptying event 05: 05.04.2017 09:11 – 05.04.2017 19:15
- Emptying event 06: 29.04.2017 10:09 – 29.04.2017 22:41
- Emptying event 07: 23.05.2017 00:36 – 24.05.2017 20:00

Event loads resulting from CSO tanks and CST I emptying

Estimation for COD and BOD_5 loads

- Currently maximum activatable storage volume = 23 000 m³
  - CSO tank: 12 000 m³
  - CST I: 11 000 m³ (volume which could by emptied by the already installed CSO tank pumps)

				COD		BOD5	
Event	Emptying Duration	Water level CSO tank	Emptied Volume	Emptied load	Emptied EMC	Emptied load	Emptied EMC
#	(min)	(%)	(m³)	COD (kg)	COD (mg/L)	BOD (kg)	BOD (mg/L)
01	780	65	16 500	5 000	303	2 600	158
02	1350	80	21 300	7 600	357	4 600	216
03	800	60	15 200	7 900	520	3 800	250
04	582	55	13 200	7 700	583	3 200	242
05	603	50	12 300	7 000	569	2 800	228
06	753	57	15 300	2 900	190	1 500	98
07	2603	90	23 000	6 100	265	4 000	174

32 mm prec.

Event loads resulting from CSO tanks and CST I emptying

Estimation for COD and BOD_5 loads

- Currently maximum activatable storage volume = 23 000 m³
  - CSO tank: 12 000 m³
  - CST I: 11 000 m³ (volume which could by emptied by the already installed pumps)

				COD		BOD	
Event	Emptying Duration	Water level CSO tank	Emptied Volume	Emptied load	Emptied EMC	Emptied load	Emptied EMC
#	(min)	(%)	(m³)	COD (kg)	CCOD (mg/L)	BOD (kg)	BOD (mg/L)
Minimum			12 300	2 900	190	1 500	98
Mean			16 700	6 300	398	3 200	195
Maximum			23 000	7 900	583	4 600	250

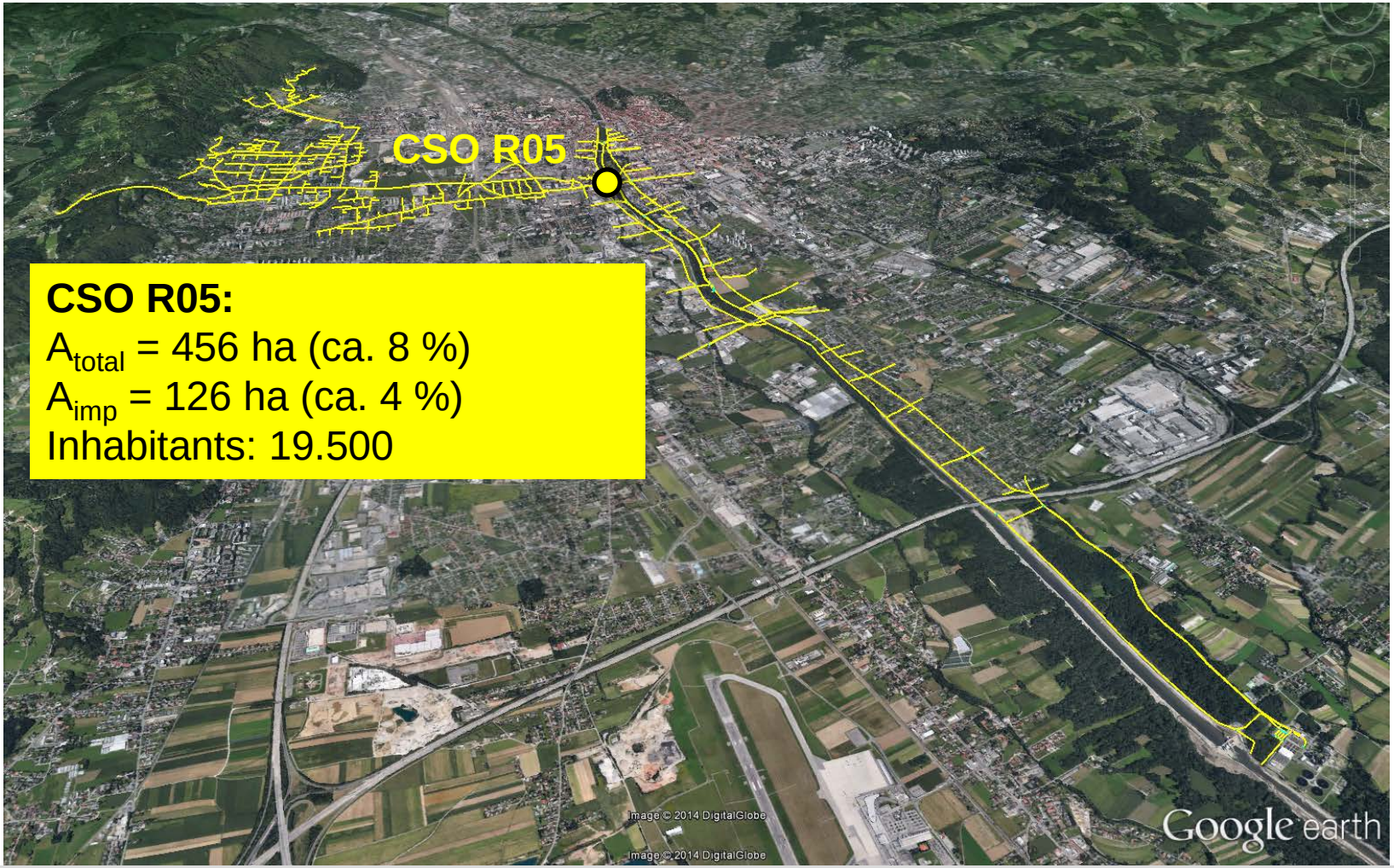
Shown minimum, maximum and mean values are independent!

Event loads resulting from CSO tanks and CST I+II emptying (careful extrapolation!)

- Maximum activatable storage volume = 106 000 m³
  - CSO tank: 12 000 m³
  - CST I+II: 94 000 m³
- Current daily mean loads to WWTP during dry weather: 58 000 kg COD/d and 33 000 kg BOD/d

			COD			BOD		
		Emptied Volume (m³)	Emptied EMC COD (mg/L)	Emptied load COD (kg)	% of current mean COD load to WWTP	Emptied EMC BOD (mg/L)	Emptied load BOD (kg)	% of current mean BOD load to WWTP
Minimum load		106 000	190	20 100	35%	98	10 400	31%
Mean load		106 000	398	42 200	73%	195	20 700	63%
Maximum load		106 000	583	61 800	107%	250	26 500	80%

Estimation of mean COD concentration from CSO R05



CSO R05:
A_{total} = 456 ha (ca. 8 %)
A_{imp} = 126 ha (ca. 4 %)
Inhabitants: 19.500

Estimation of mean COD concentration from CSO R05

- CSO R05 has to be connected to CST II
- Period: January 2009 – July 2011 (HOFER, 2012)
- Data base: 47 CSO events

			COD	
47 CSO events into river Mur	Duration of overflow (min)	Overflow volume (m^3)	Overflow load (kg)	EMC COD (mg/L)
Minimum value	**14**	**11**	**3**	**108**
Mean value	**83**	**2 113**	**433**	**292**
Maximum value	**291**	**15 229**	**3 097**	**921**

Shown minimum, maximum and mean values are independent!

Based on mean EMC for COD => 106 000 m^3 * 292 mg/L => **31 000 kg (53%)**

Summary so far

- We failed so far with direct quality measurements in the CST
- The installed sensor network in the influent of the WWTP is suitable to measure the quality dynamics resulting from CST emptying
- With the proposed method we are able to estimate even the additional loads which should be treated at the WWTP
- First results and careful extrapolations for the total CST show very challenging additional loads for the WWTP
- These first results have to be confirmed by more emptying events especially during the summer period
- If you can provide the i::scan with a comprehensive sample of good reference samples it is delivering comparable results as the UV/VIS spectrometer

Acknowledgements

The presenters would like to thank all colleagues from Holding Graz Water Management for funding and supporting this project. Special gratitude we want to express to the staff people from WWTP Graz and to the lab and IT team of our institute.

Thank you for your attention!

Graz University of Technology,
Institute of Urban Water Management and Landscape Water Engineering, Austria.

Contact:
Günter GRUBER
guenter.gruber@tugraz.at
www.sww.tugraz.at