

Economical rehabilitation of sewer systems by ground penetration radar investigations

**Hermann Stepkes,
Jochen Zimmermann, Karsten Müller, Marko Siekmann, Johannes Pinnekamp**



Institute of Environmental Engineering RWTH Aachen University

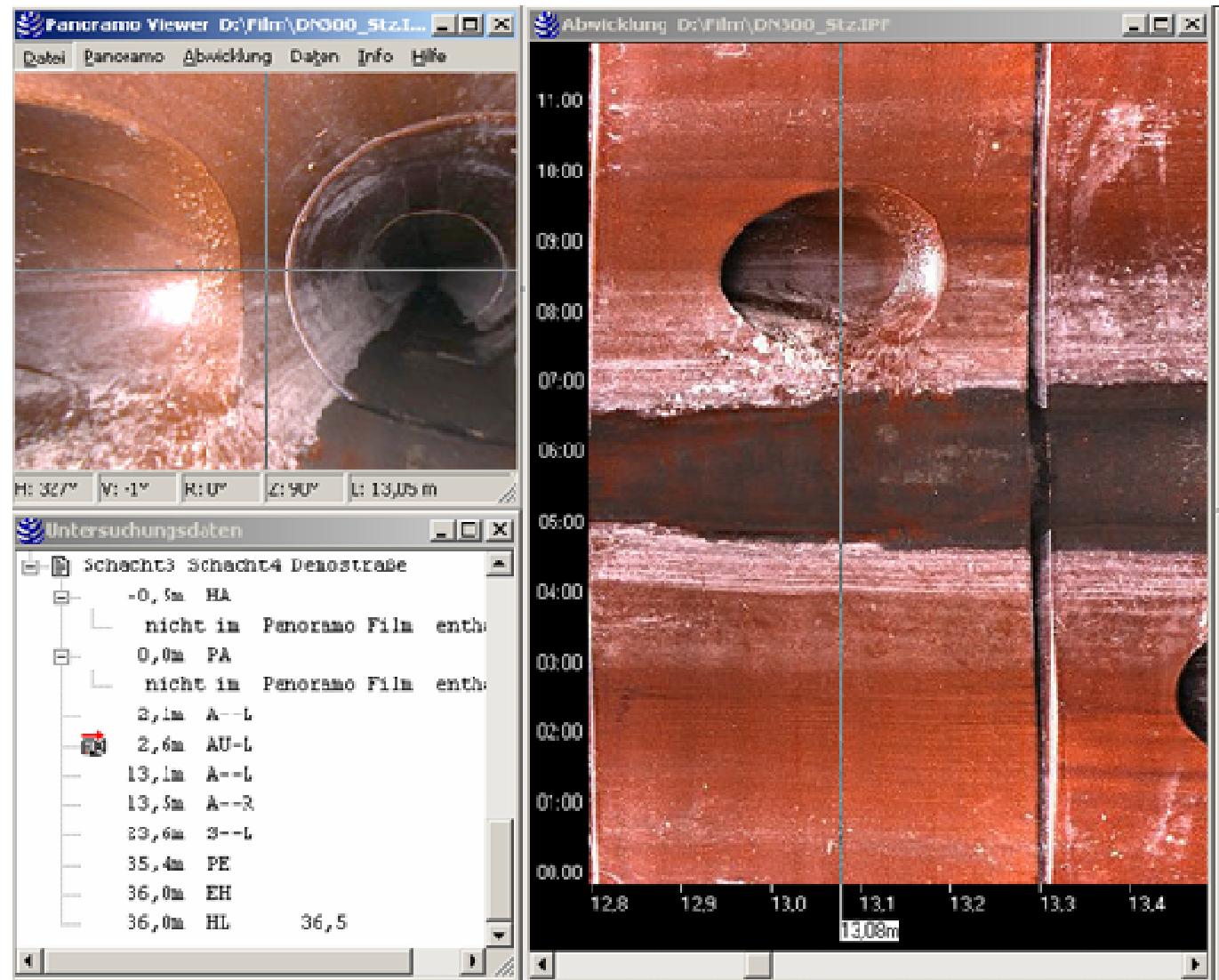
**RWTHAACHEN
UNIVERSITY**

LESAM 2007 – Lisbon 17-19 October 2007

Outline

- Sewer inspection
- Influence of damages to the sewer bedding
 - Pilot scale investigations
- Ground Penetrating Radar (GPR)
 - Investigations in locations
- Costs
- Conclusion

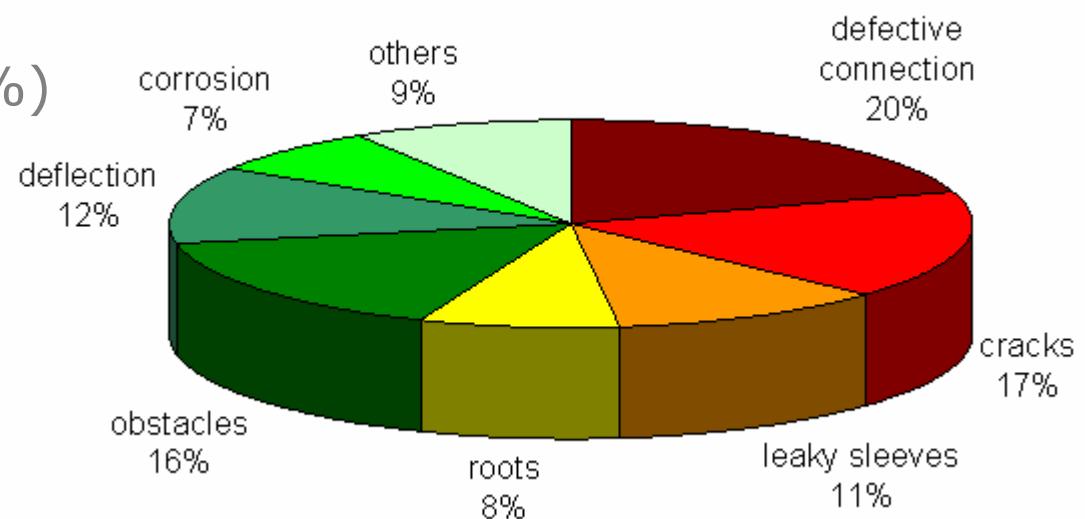
Sewer inspection results



Sewer inspection results

■ Distribution of sewer damages

- Defective connection (20%)
- Cracks (17%)
- Leaky sleeves (11%)
- Roots (8%)



■ Leaky sewers and pipes cause exfiltration of waste water or infiltration of groundwater

Sewer Collapse

Tucson, Arizona, September 2002



http://www.sewerhistory.org/images/mi/mid/mid_spdwy08.jpg

Sewer Collapse

Tucson, Arizona, September 2002



http://www.sewerhistory.org/images/mi/mid/mid_spdwy04.jpg

Sewer inspection

unseen damages



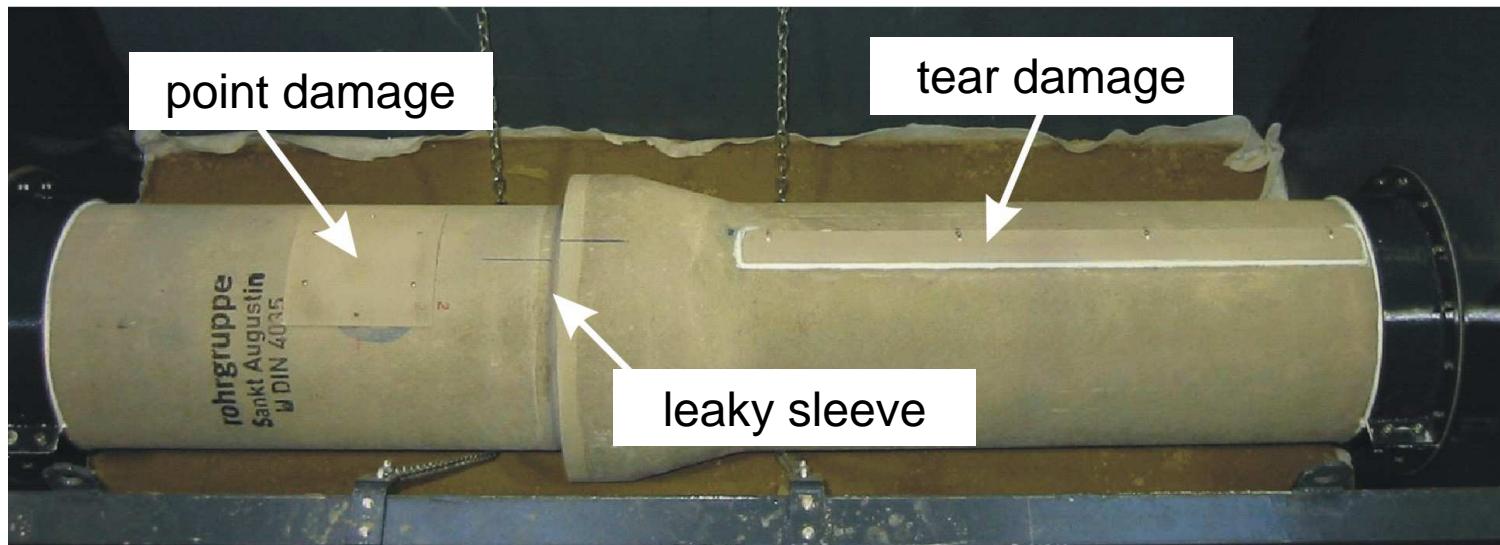
Sewer inspection

unseen damages



Pilot scale investigations

influence of damages to the sewer bedding

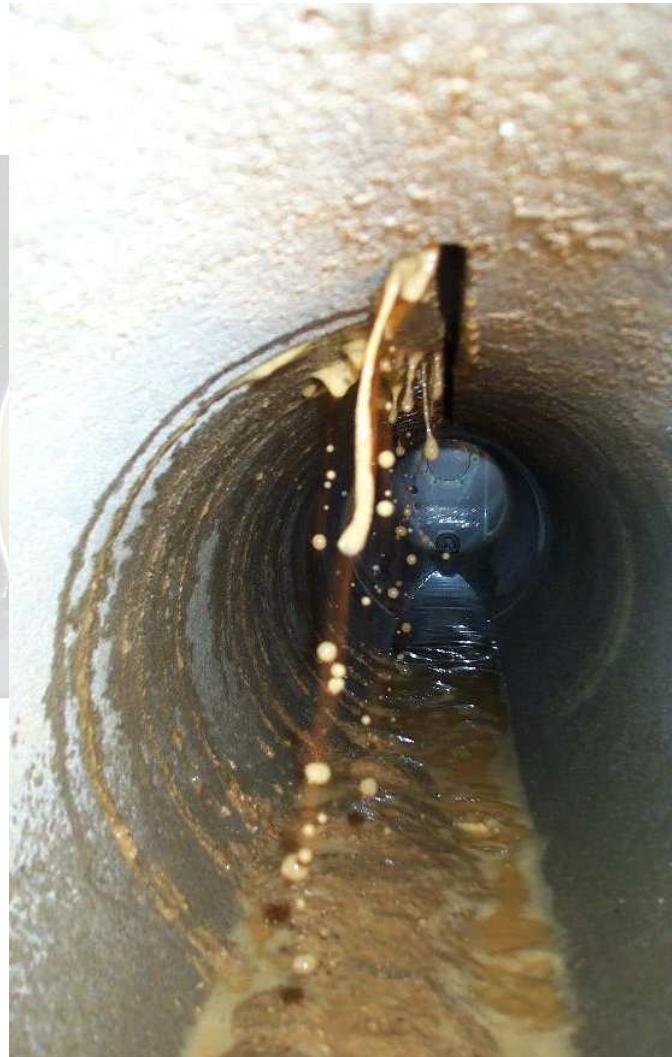


J. Henerkes, 2005

Pilot scale investigations

Results

J. Henerkes, 2005



point damage 30 mm (soil SU)



195 min.

205 min.

250 min.

Tear damage 8 mm (soil SE)



Pilot scale investigations

Results

Damage	Classification regarding an endangerment of the stability of the soil body	Extent of the damage	
		Soil I (SU) (weak cohesive)	Soil II (SE) (loose)
Point damage	safe	$\leq 10 \text{ mm}$	$\leq 10 \text{ mm}$
	at risk	11 - 20 mm	11 – 14 mm
	critical	$> 20 \text{ mm}$	$\geq 15 \text{ mm}$
Tear damage	safe	$\leq 5 \text{ mm}$	$< 3 \text{ mm}$
	at risk	6 – 8 mm	3 – 5 mm
	critical	$> 8 \text{ mm}$	$\geq 6 \text{ mm}$
Leaky sleeve	critical	●	●
safe	below 1 litre of solid infiltration		
at risk	$> 1 - 10 \text{ litres of solid infiltration with a steady state}$		
critical	$> 10 \text{ litres of solid infiltration, no steady state}$		

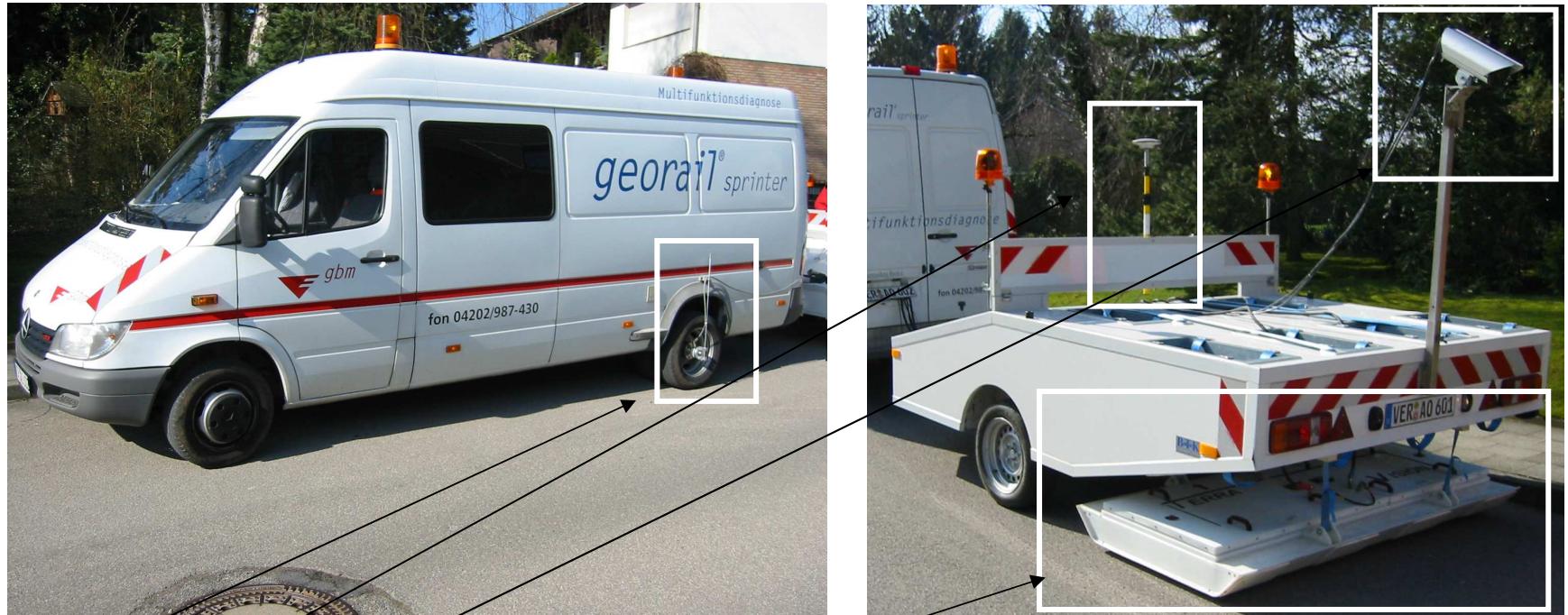
Pilot scale investigations

Results

- Normal bedding of sewers is basic condition for
 - Stability
 - Tightness
- Impairment of the bedding zone through
 - Infiltration of groundwater and
 - Entry of bedding material
- Early recognized defects in the bedding zone allows
 - Cost-effective rehabilitation and
 - Minimization of subsequent costs
- Suitable technique is the GPR

Measuring technique

Measuring vehicle and trailer



1. Control unit, position indicator
2. GPS receiver
3. Camera
4. "TerraVision" Antenna Array (14 channels)

Collected data

■ GPS data

ID_GPS	Pc_Time	Pc_Date	Zaehler	KM	Filename	GPS_String
35733	15:05:54.234	04/04/2006	312612	311,37	Friesen002	\$GPGLL,130547,90,5158,3977434,N,00737,8979386,E,2,06,19,97,735,M,,0,00,0451*1F0
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35835	15:06:04.453	04/04/2006	330852	329,53	Friesen002	\$GPGLL,130558,10,5158,3948200,N,00737,9127807,E,2,06,19,97,893,M,,0,00,0451*120
35781	15:05:59.046	04/04/2006	317515	316,25	Friesen002	\$GPGLL,130552,70,5158,3969593,N,00737,9017855,E,2,06,19,97,831,M,,0,00,0451*180
35780	15:05:58.937	04/04/2006	317283	316,02	Friesen002	\$GPGLL,130552,60,5158,3969877,N,00737,9016163,E,2,06,19,97,856,M,,0,00,0451*120
35779	15:05:58.843	04/04/2006	317087	315,82	Friesen002	\$GPGLL,130552,50,5158,3970326,N,00737,9014540,E,2,06,19,97,840,M,,0,00,0451*160
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35777	15:05:58.640	04/04/2006	316879	315,42	Friesen002	\$GPGLL,130552,30,5158,3970385,N,00737,9011294,E,2,06,19,97,840,M,,0,00,0451*130
35776	15:05:58.546	04/04/2006	316495	315,23	Friesen002	\$GPGLL,130552,20,5158,3971241,N,00737,9009704,E,2,06,19,97,862,M,,0,00,0451*1ED
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35773	15:05:58.234	04/04/2006	315907	314,65	Friesen002	\$GPGLL,130551,90,5158,3972183,N,00737,9005127,E,2,06,19,97,855,M,,0,00,0451*120
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35771	15:05:58.046	04/04/2006	315571	314,31	Friesen002	\$GPGLL,130551,70,5158,3972830,N,00737,9002279,E,2,06,19,97,855,M,,0,00,0451*170
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Collected data

- GPS data
- Video

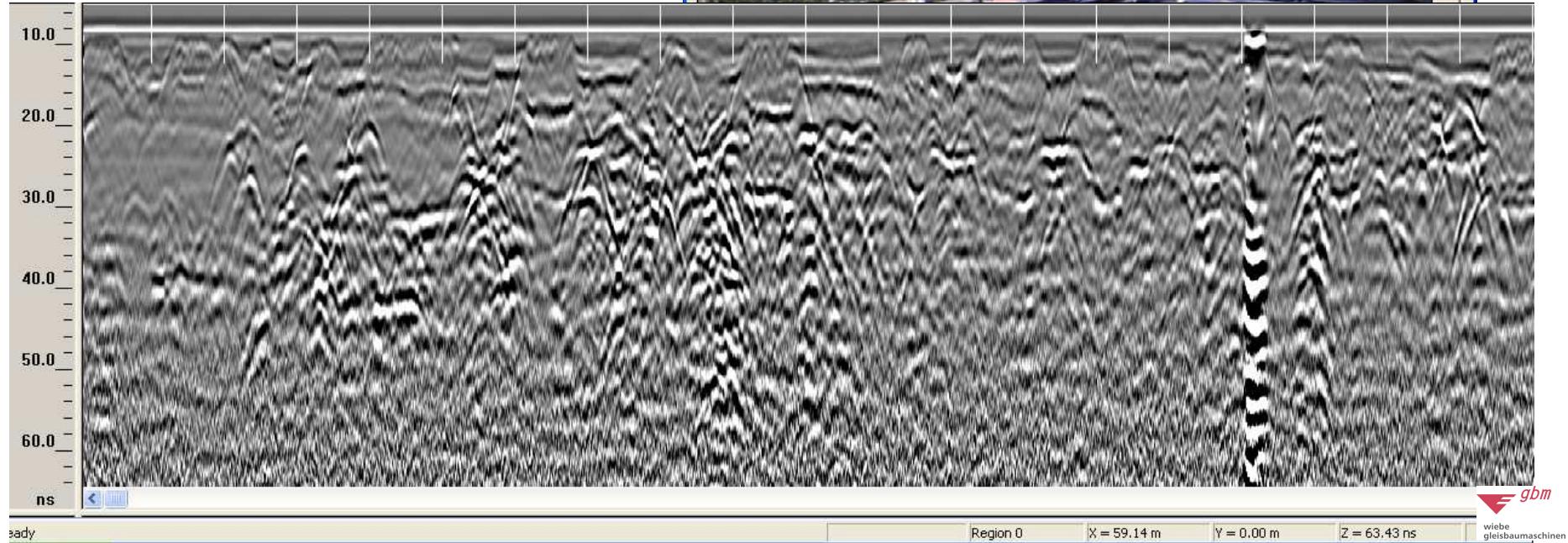
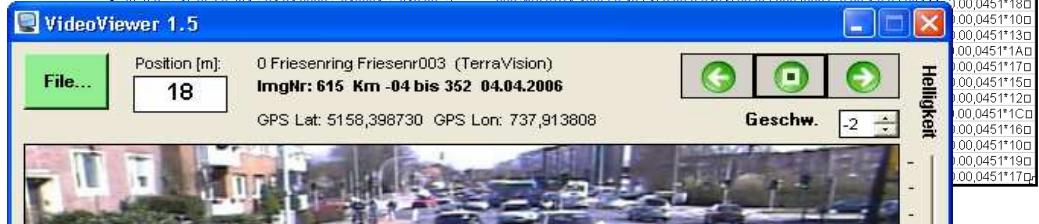
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35770	15:05:57.937	04/04/2006	315379	314,12	Friesen002	\$GPGLL,130551,60,5158,3973083,N,00737,9000939,E,2,06,19,97,857,M,,0,00,0451*19D
35835	15:06:04.453	04/04/2006	330852	329,53	Friesen002	\$GPGLL,130558,10,5158,3948200,N,00737,9127807,E,2,06,19,97,893,M,,0,00,0451*12D
35781	15:05:59.046	04/04/2006	317515	316,25	Friesen002	\$GPGLL,130552,70,5158,3969593,N,00737,9017855,E,2,06,19,97,831,M,,0,00,0451*18D
35780	15:05:58.937	04/04/2006	317283	316,02	Friesen002	\$GPGLL,130552,60,5158,3969877,N,00737,9016163,E,2,06,19,97,856,M,,0,00,0451*12D
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35777	15:05:58.640	04/04/2006	316879	315,42	Friesen002	\$GPGLL,130552,30,5158,3970385,N,00737,9011294,E,2,06,19,97,840,M,,0,00,0451*13D
35776	15:05:58.546	04/04/2006	316495	315,23	Friesen002	\$GPGLL,130552,20,5158,3971241,N,00737,9009704,E,2,06,19,97,862,M,,0,00,0451*1ED
35775	15:05:58.453	04/04/2006	316315	315,05	Friesen002	\$GPGLL,130552,10,5158,3971517,N,00737,9008160,E,2,06,19,97,843,M,,0,00,0451*1FD
35774	15:05:58.343	04/04/2006	316109	314,85	Friesen002	\$GPGLL,130552,00,5158,3971873,N,00737,9006617,E,2,06,19,97,853,M,,0,00,0451*19D
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35771	15:05:58.046	04/04/2006	315571	314,31	Friesen002	\$GPGLL,130551,70,5158,3972830,N,00737,9002279,E,2,06,19,97,855,M,,0,00,0451*17D
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Collected data

- GPS data
- Video
- Radargram

ID	GPS	Pc_Time	Pc_Date	Zaehler	KM	Filename	GPS_String
35733		15:05:54.234	04/04/2006	312612	311.37	Friesen002	\$GPGLL,130547,90.5158,3977434,N,00737,8979386,E,2,06,19.97,735,M,,0.00,0451*1F0
35738		15:05:54.734	04/04/2006	312784	311.54	Friesen002	\$GPGLL,130548,40,5158,3977179,N,00737,8980935,E,2,06,19.97,755,M,,0.00,0451*130
35746		15:05:55.546	04/04/2006	313036	311.79	Friesen002	\$GPGLL,130549,20,5158,3976693,N,00737,8982955,E,2,06,19.97,760,M,,0.00,0451*140
35770		15:05:57.937	04/04/2006	315379	314.12	Friesen002	\$GPGLL,130551,60,5158,3973083,N,00737,9000949,E,2,06,19.97,857,M,,0.00,0451*190
35835		15:06:04.453	04/04/2006	330852	329.53	Friesen002	\$GPGLL,130558,10,5158,3948200,N,00737,9127807,E,2,06,19.97,893,M,,0.00,0451*120
35781		15:05:59.046	04/04/2006	317515	316.25	Friesen002	\$GPGLL,130552,70,5158,3969593,N,00737,9017855,E,2,06,19.97,843,M,,0.00,0451*180
35780		15:05:58.937	04/04/2006	317283	316.02	Friesen002	\$GPGLL,130552,60,5158,3969877,N,00737,9016163,E,2,06,19.97,856,M,,0.00,0451*120
35779		15:05:58.843	04/04/2006	317087	315.82	Friesen002	\$GPGLL,130552,50,5158,3970326,N,00737,9014540,E,2,06,19.97,840,M,,0.00,0451*160
35778		15:05:58.734	04/04/2006	316865	315.6	Friesen002	\$GPGLL,130552,40,5158,3970552,N,00737,9012876,E,2,06,19.97,848,M,,0.00,0451*140
35777		15:05:58.640	04/04/2006	316879	315.42	Friesen002	\$GPGLL,130552,30,5158,3970385,N,00737,9011294,E,2,06,19.97,840,M,,0.00,0451*130
35776		15:05:58.546	04/04/2006	316495	315.23	Friesen002	\$GPGLL,130552,20,5158,3971241,N,00737,9009704,E,2,06,19.97,862,M,,0.00,0451*160
35775		15:05:58.453	04/04/2006	316315	315.05	Friesen002	\$GPGLL,130552,10,5158,3971517,N,00737,9008160,E,2,06,19.97,843,M,,0.00,0451*170
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35773		15:05:58.234	04/04/2006	315907	314.65	Friesen002	\$GPGLL,130551,90,5158,3972183,N,00737,9005127,E,2,06,19.97,850,M,,0.00,0451*120
35757		15:05:56.640	04/04/2006	313547	312.3	Friesen002	\$GPGLL,130550,30,5158,3975942,N,00737,8986646,E,2,06,19.97,832,M,,0.00,0451*1C0
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Geographic Correlation

Investigation Area



J. Zimmermann, 2006

Geographic Correlation

Investigation Area



J. Zimmermann, 2006

Geographic Correlation

Investigation Area

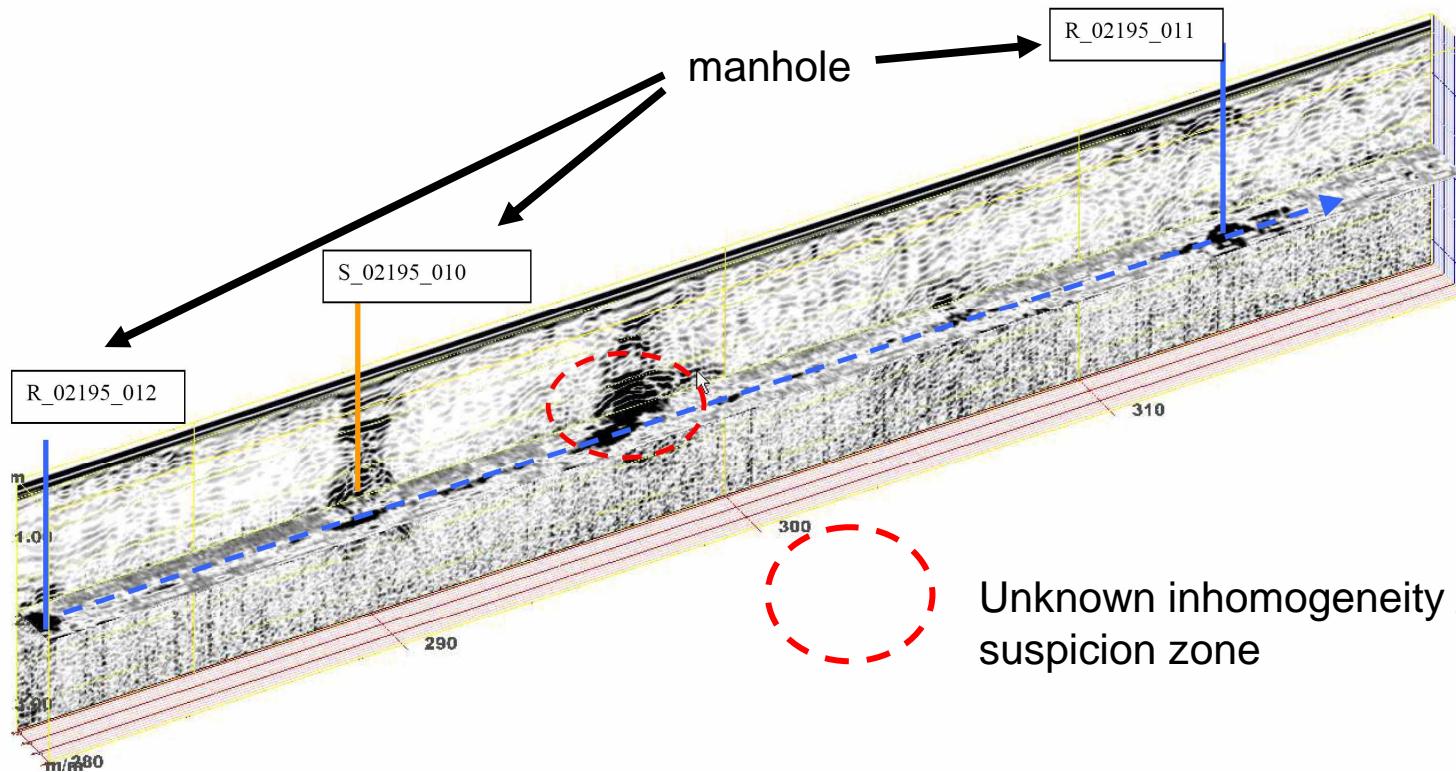


J. Zimmermann, 2006

Radargram

Representation of the GPR investigations

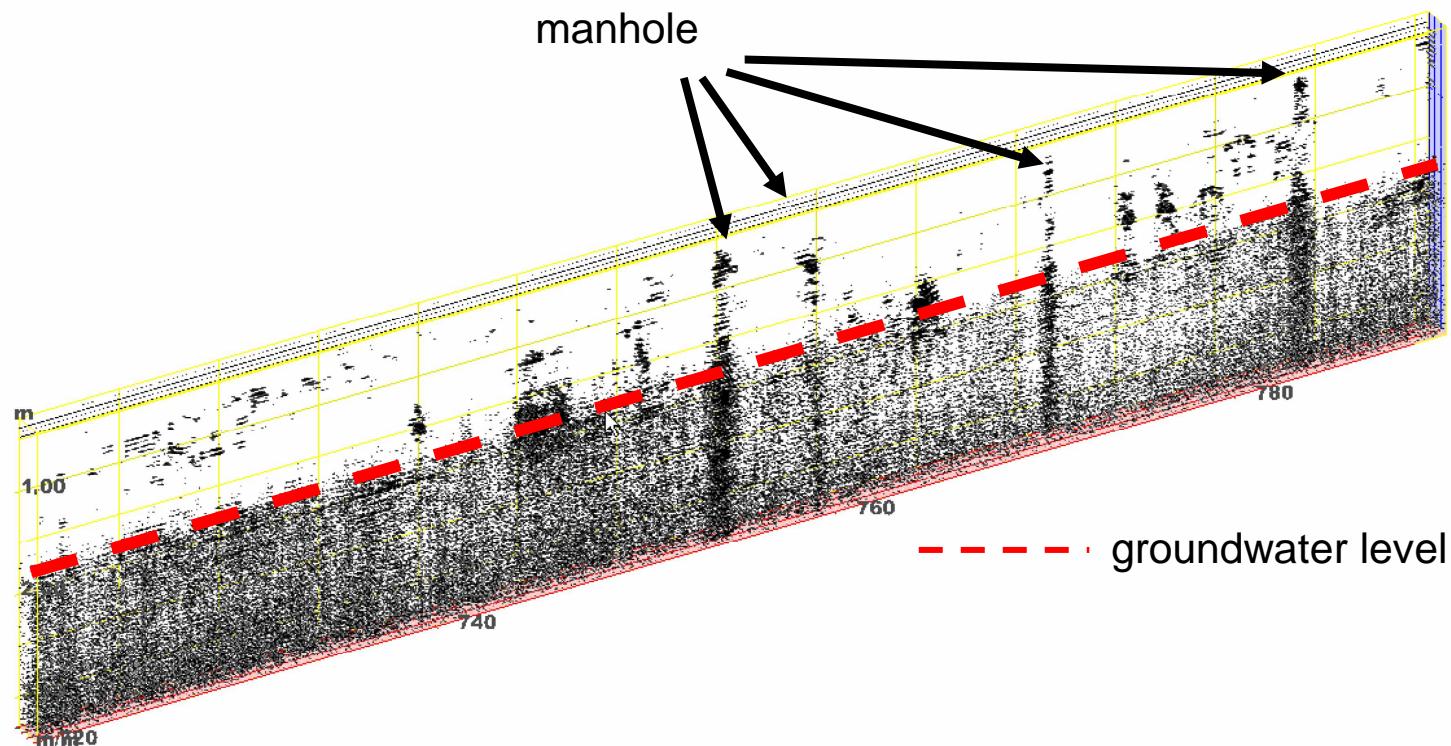
- 3-D representation in form of the radargram



Radargram

Representation of the GPR investigations

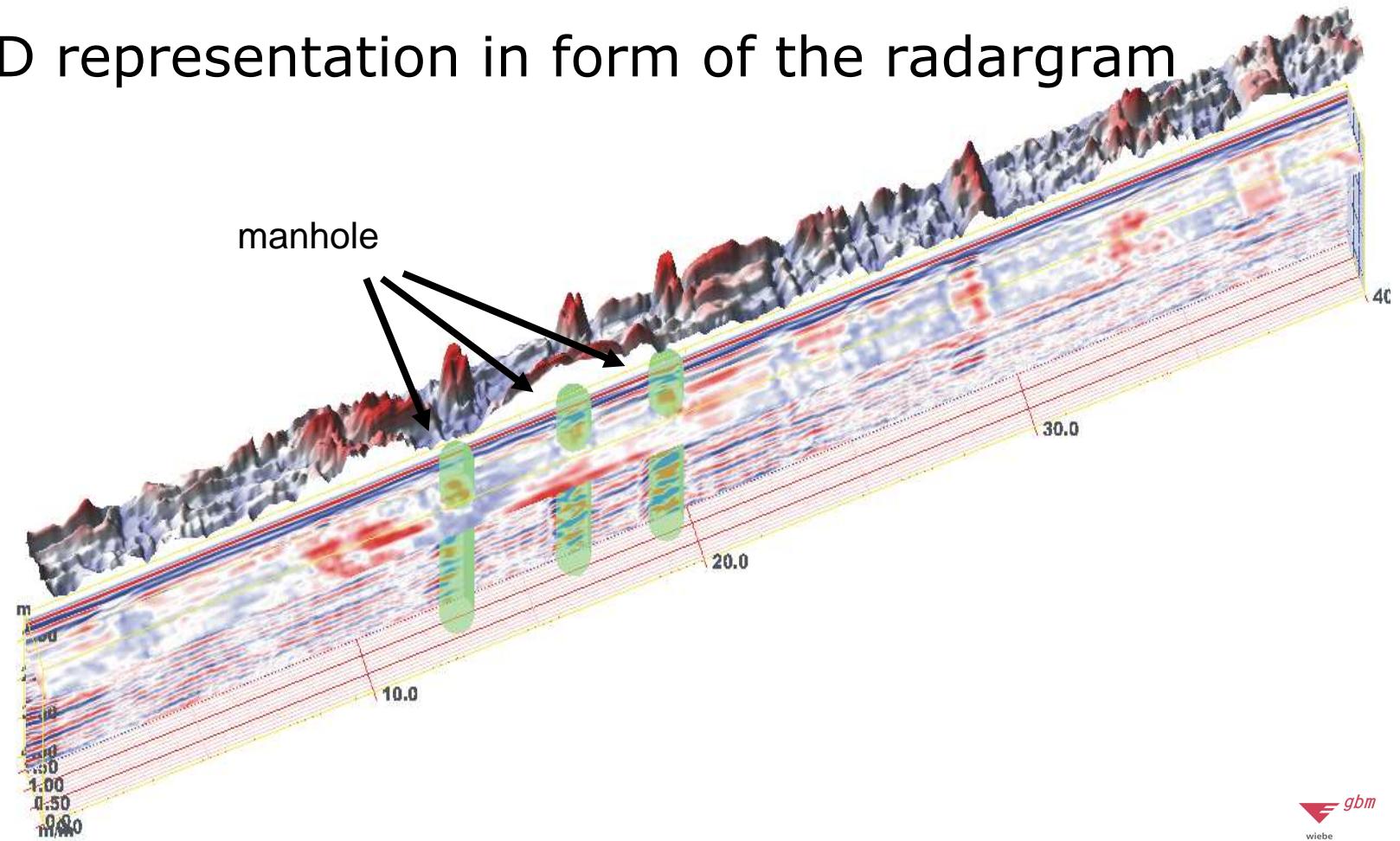
- 3-D representation in form of the radargram



Radargram

Representation of the GPR investigations

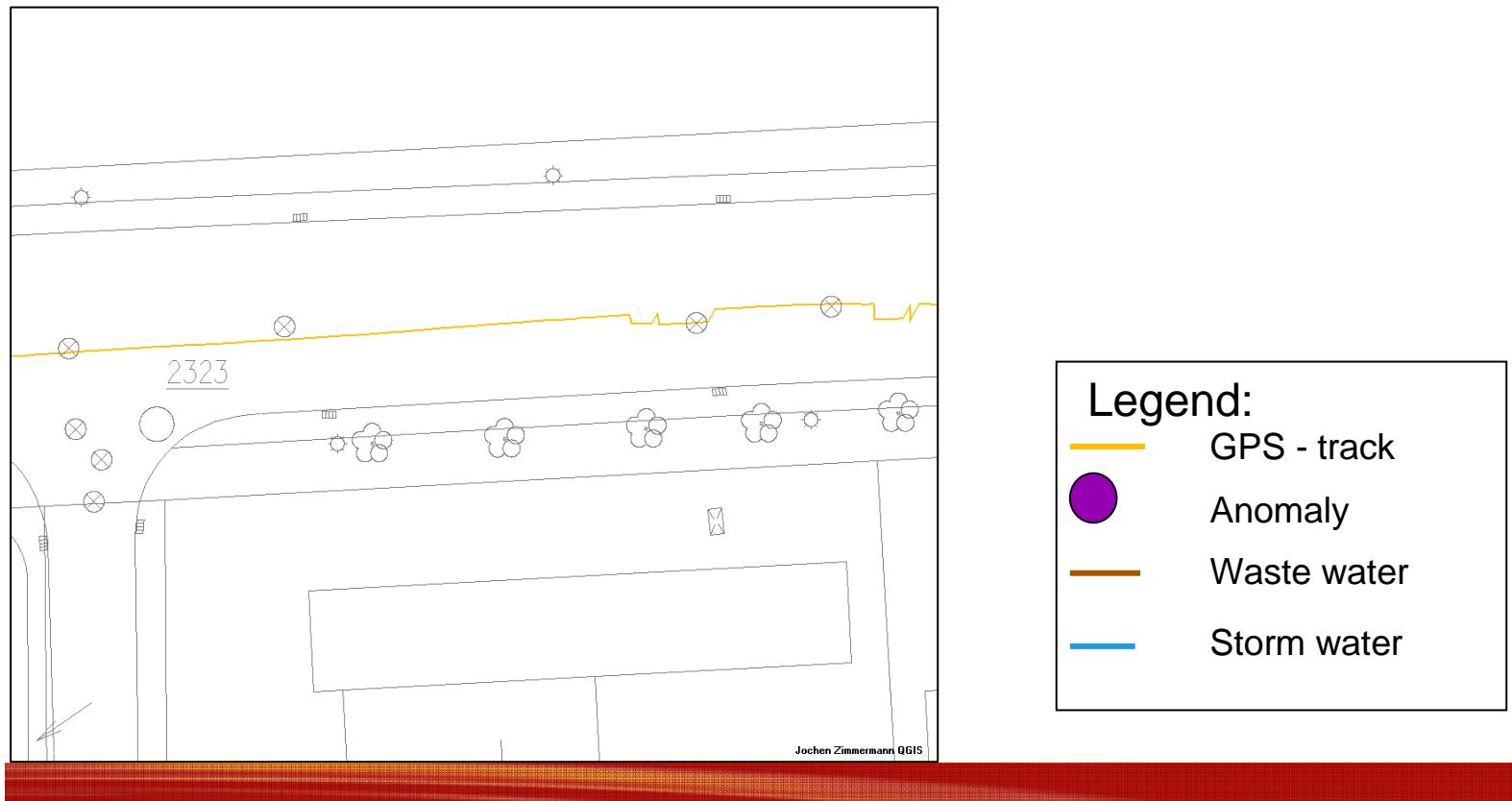
- 3-D representation in form of the radargram



Visualization

Representation of the GPR investigations

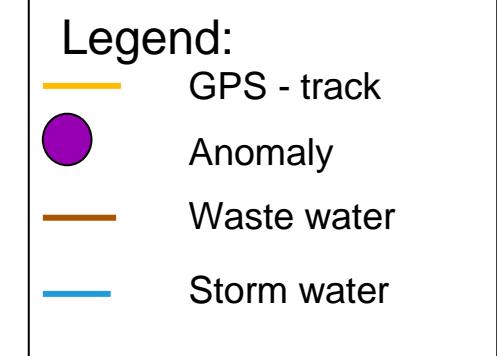
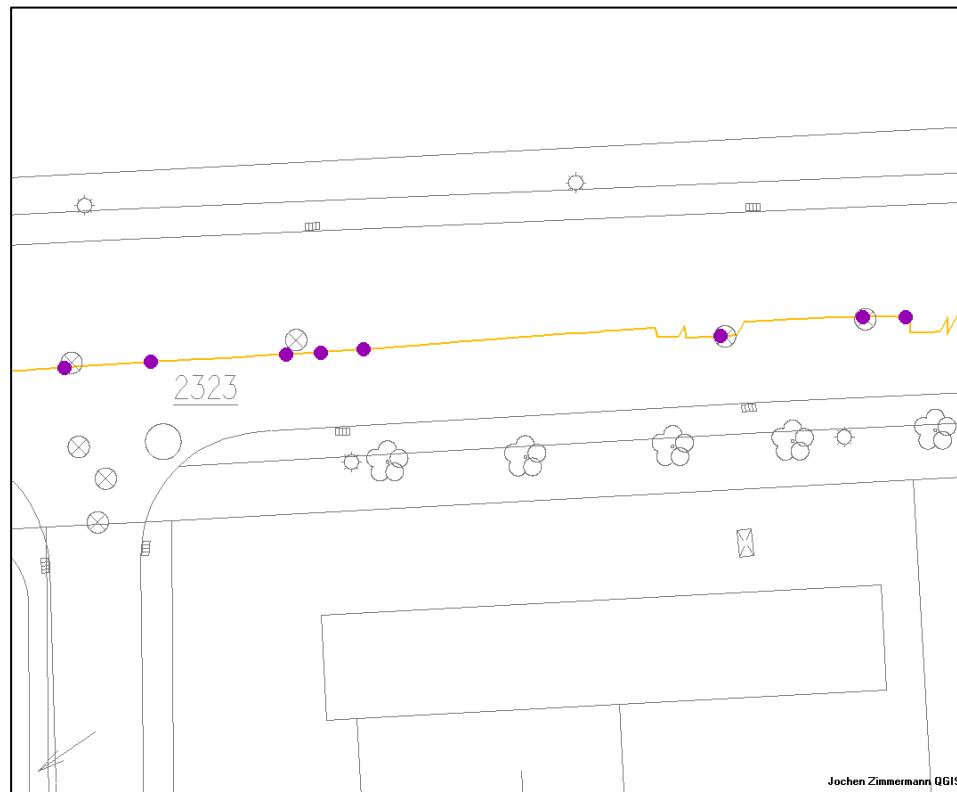
- 2-D representation, anomalies with additional card information



Visualization

Representation of the GPR investigations

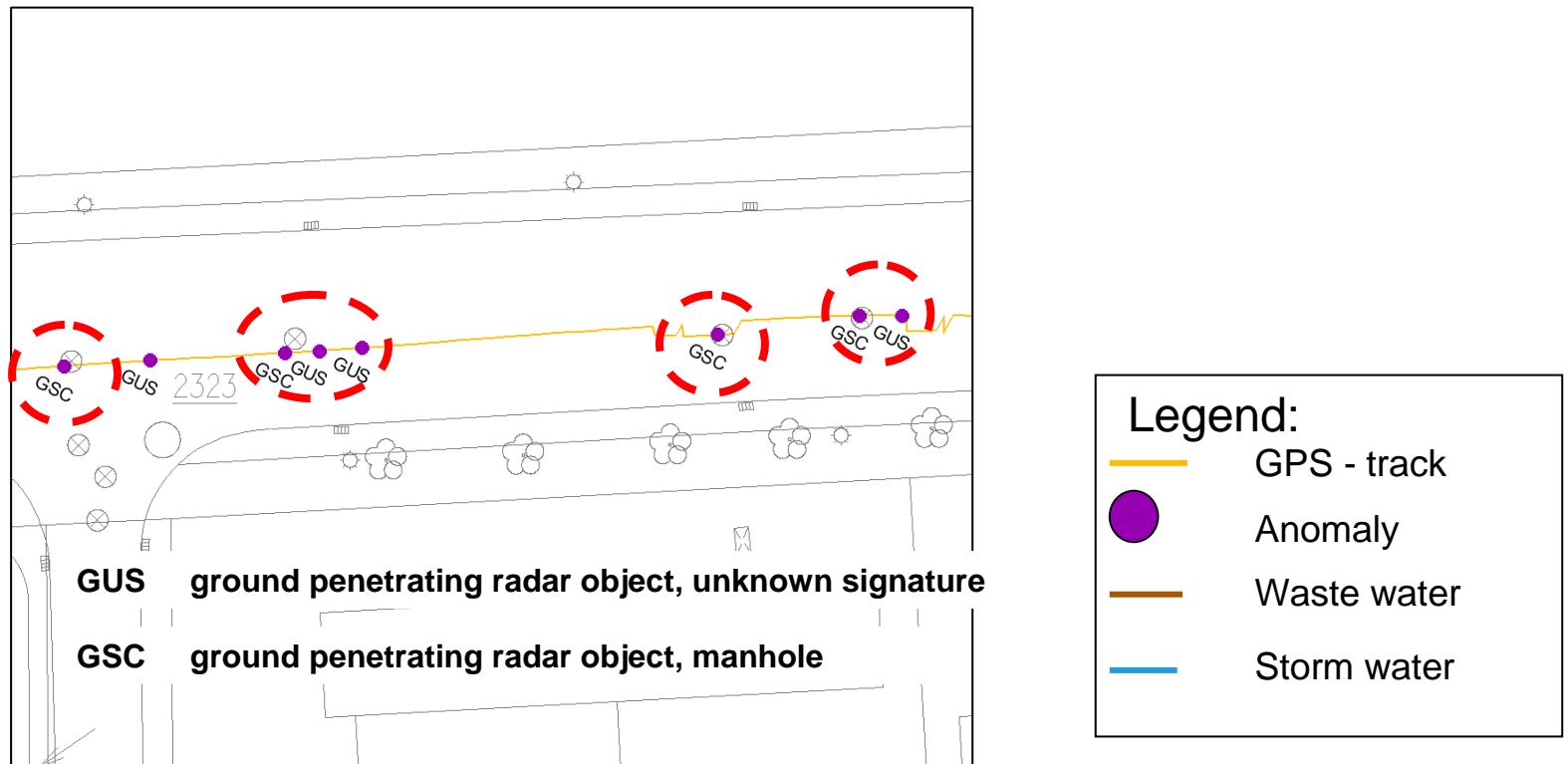
- 2-D representation, anomalies with additional card information



Visualization

Representation of the GPR investigations

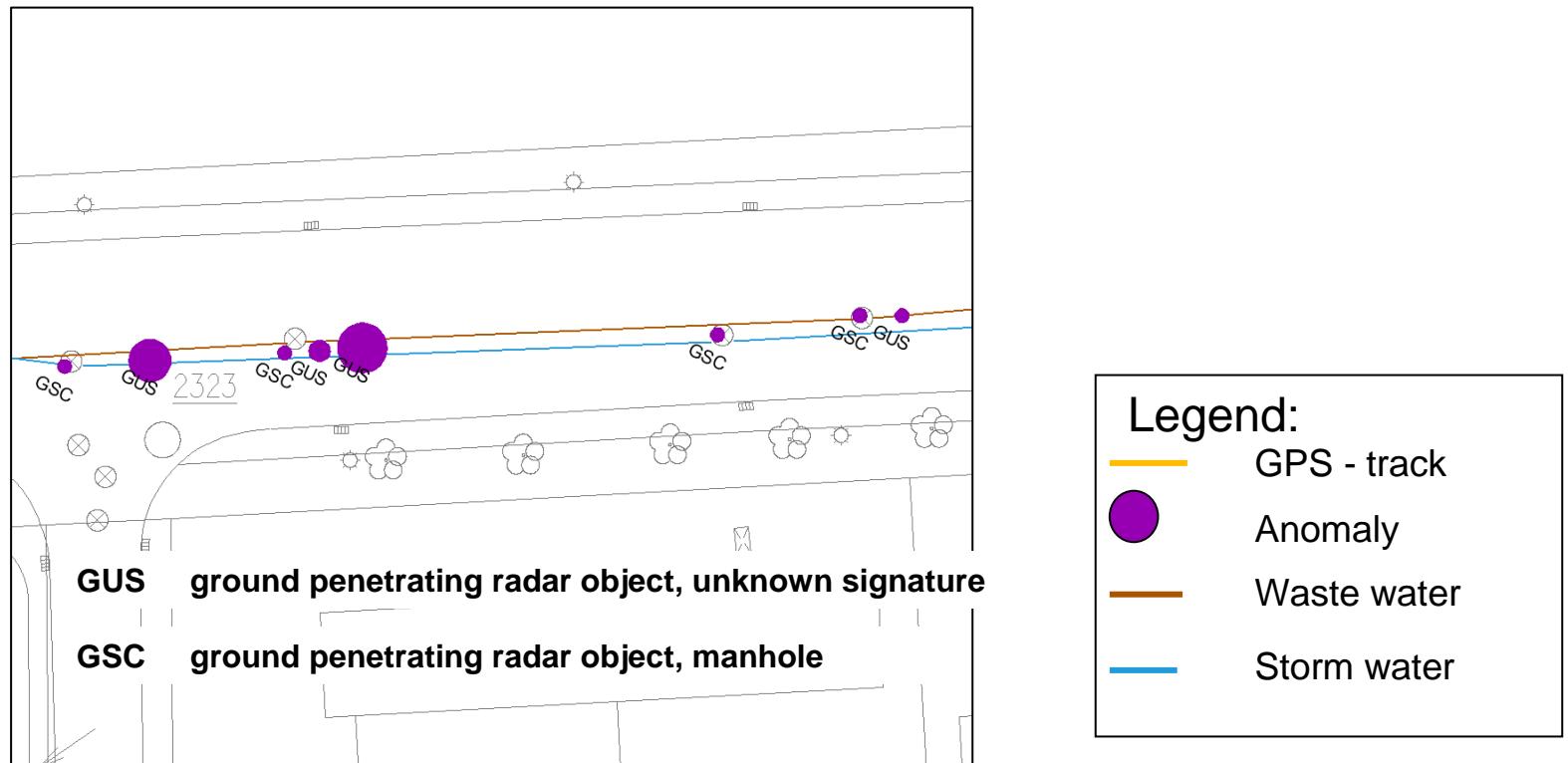
- 2-D representation, anomalies with additional card information



Visualization

Representation of the GPR investigations

- 2-D representation, anomalies with additional card information



Visualization

Representation of the GPR investigations

- sewer inspection report

Haltungsinspektionsprotokoll

Version 1.0

Haltungsnummer: R02195006.00R02195005.00

Auftraggeber: Stadtentwässerung A-Stadt **Datum:** 04.04.2006 **Uhrzeit:** 12:15:11

Firma: Geokanal GmbH **Inspekteur:** Herr Mustermann

Grund: N **Art:** Z **Richtung:** I **Kürzelsystem:** Z

Wetter: Trocken **Temperatur:** 20

Videospeichermedium: MOD **Speichermedium:** Festplatte01

Bemerkung:

Station	CODE:	Strescha.	Pos 1:	Pos 2:	Entfernung:	Durchm.:	Langtext:
0,23	GSC		11		1,46	1	Georadar, Schacht
2,12	GUS		4		1,63	0,83	Georadar, unbekannte Signatur
2,33	A--L		9				Abzweig, linker Kämpfer
3,87	GSC		11		1,04	1	Georadar, Schacht
4,13	A--R		13				Abzweig, rechter Kämpfer
4,23	A--L		9				Abzweig, linker Kämpfer
17,88	GUS		12		0,01	1,35	Georadar, unbekannte Signatur

Visualization

Representation of the GPR investigations

- ## ■ sewer inspection report

Haltungsinspektionsprotokoll						
Version 1.0						
Haltungsnummer: R02195006.00R02195005.00						
Auftraggeber: Stadtentwässerung A-Stadt			Datum: 04.04.2006	Uhrzeit: 12:15:11		
Firma: Geokanal GmbH			Inspekteur: Herr Mustermann			
Grund: N	Art: Z	Richtung: I	Kürzelsystem: Z			
Wetter: Trocken		Temperatur: 20				
Videospeichermedium: MOD			Speichermedium: Festplatte01			
Bemerkung:						
Station	CODE:	Strescha.	Pos 1:	Pos 2:	Entfernung:	Durchm.:
0,23	GSC		11		1,46	1
2,12	GUS		4		1,63	0,83
2,33	A--L		9			
3,87	GSC		11		1,04	1
4,13	A--R		13			
4,23	A--L		9			
17,88	GUS		12		0,01	1,35
GUS ground penetrating radar, unknown signature						
GSC ground penetrating radar, manhole						

Costs of GPR Investigations

Length of investigation	Costs [€/m]	Dynamic probing (150 € each)	TV-Inspection [€/m]	Total costs [€/m]
200 m	27,00	2		33,50
500 m	13,50	5		20,00
1.000 m	8,50	10		15,00
10.000 m	2,40	100		8,90

- TV-Inspection, Dynamic probing and GPR investigation with evaluation

Costs for rehabilitation

not men-accessible sewer

- Rehabilitation (live cycle < 50a)

- Relining with hose:

- 95 - > 305 €/m

- Relining with short- or long-pipe

- 140 - > 425 €/m

- Replacement (live cycle > 50a)

- open, sewer depth 3 m:

- 125 - > 850 €/m

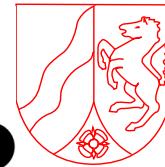
- closed, Berstlining

- 150 - > 900 €/m

Conclusion

- TV-Inspection shows all the visible damages from inside the sewer.
- Infiltrating bedding material can cause cave ins.
- GPR shows anomalies in the bedding zone.
- With help of GPR a economical decision for the right rehabilitation method can be done.
- GPR is an additional tool for making the right rehabilitation priorisation.

Financial support



Ministry of the
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Partner



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Beratende Ingenieure GmbH



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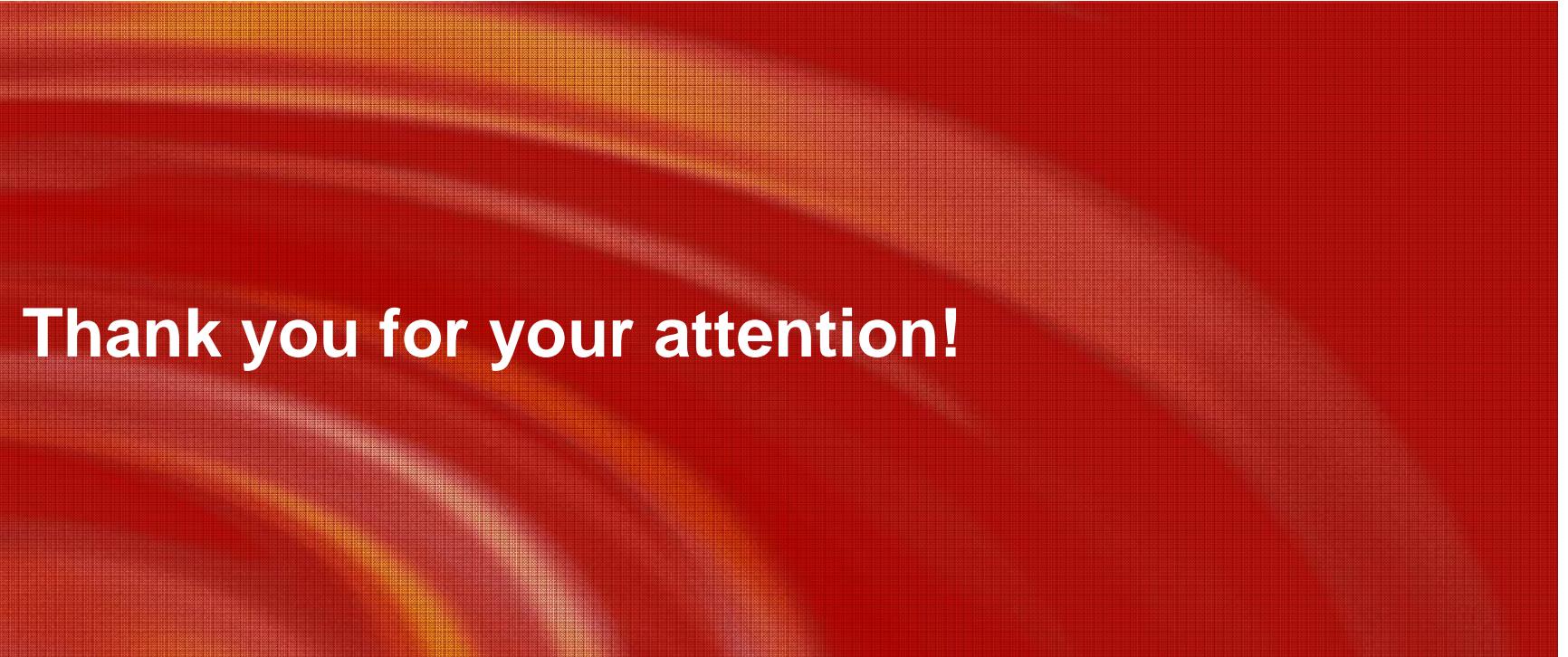


Stadtentwässerung
Braunschweig



Stadtentwässerungsbetrieb
Landeshauptstadt Düsseldorf





Thank you for your attention!

stepkes@isa.rwth-aachen.de
www.isa.rwth-aachen.de