ELSA
Schadstoffsanierung Elbsedimente

# The Elbe gives, the Elbe takes …

## The impact of flood events on backwaters

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SedNet Conference 2017

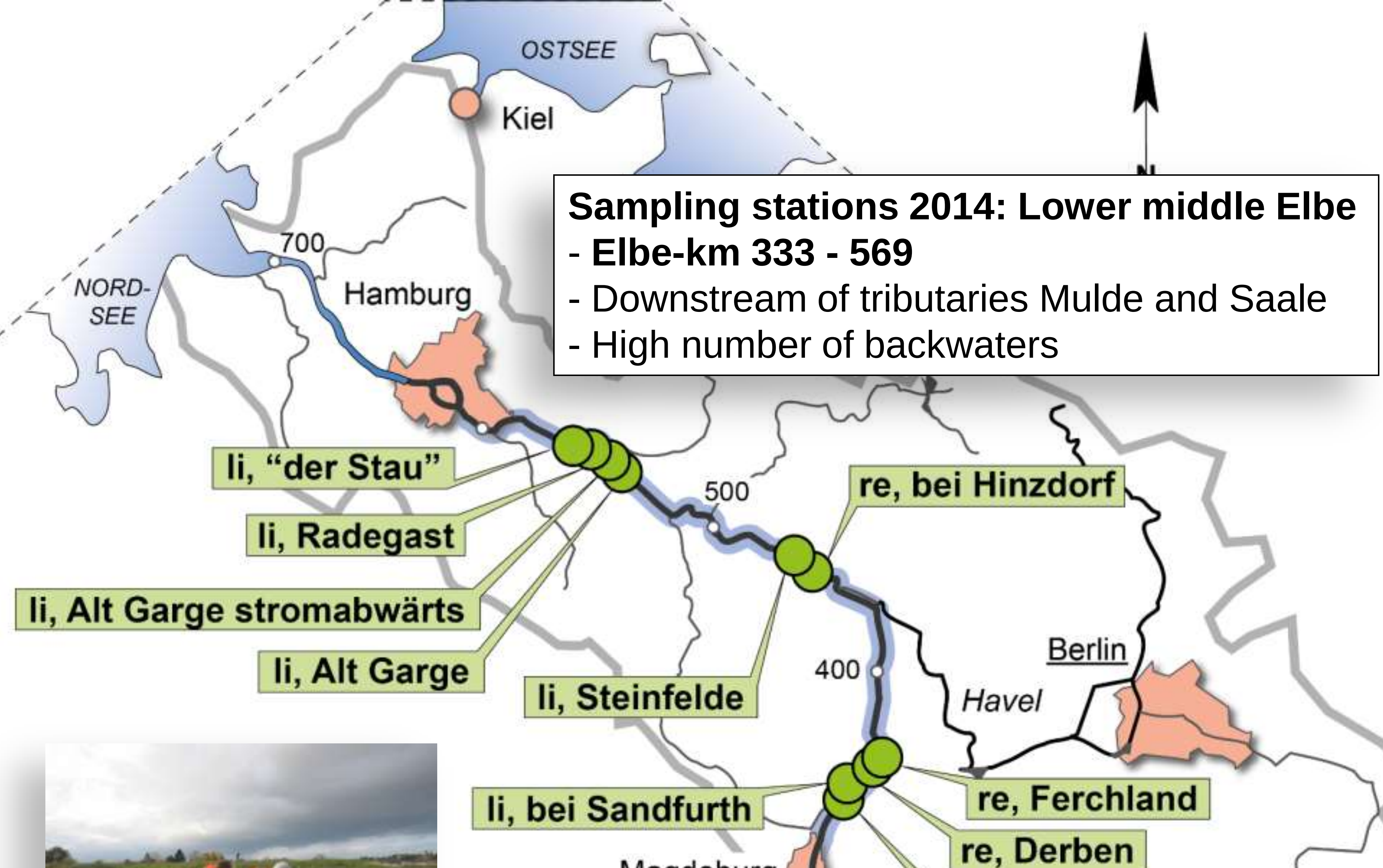
# In the centre of investigation: backwaters of the Elbe

- „Altwässer“: Standing water bodies, not connected to the Elbe at average discharge (MQ)
- „Altarme“: (one-sided) connection at MQ

- Number: ca. 1000 side structures in the floodplain of the German part of the Elbe
- Area: ca 50 km$^2$

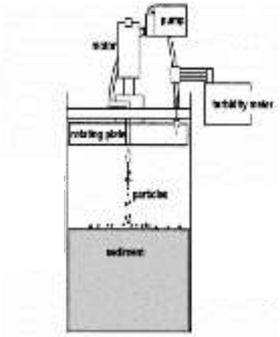
**15 Backwaters sampled in summer 2014**

**Sampling stations 2014: Lower middle Elbe**
- **Elbe-km 333 - 569**
- Downstream of tributaries Mulde and Saale
- High number of backwaters




# Methods

Measurement of erosion stablility „on site“



**Dating of sediment cores**
XRF-Analysis: HM-Profile
$Cs^{137}$-Profile (γ-Detector)

**Ecotox tests**

Algae & Bacteria

Eluatriates & Sediments


**Chemical Analyses**

0-10 cm

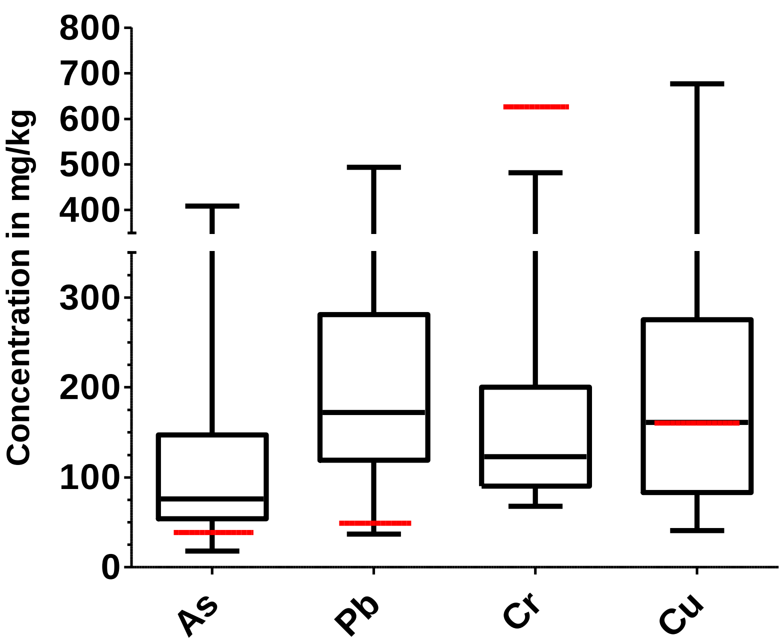
10-20 cm

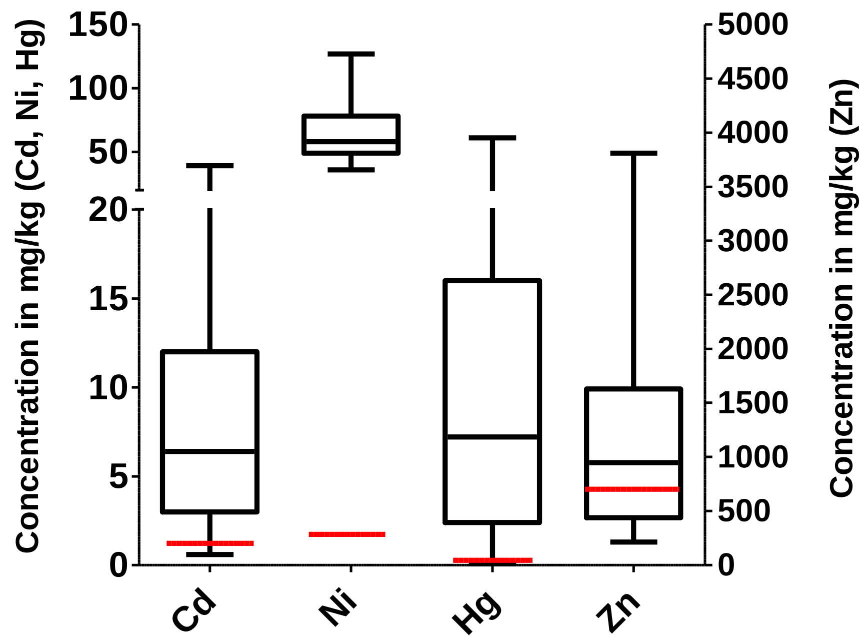
Historic contamin. (HM, HCB, PAH, PCB, DDX, HCH)

Deep sed. sample
> 50 cm

# Chemical contamination: Heavy metals and As

Upper threshold level (ICPE)



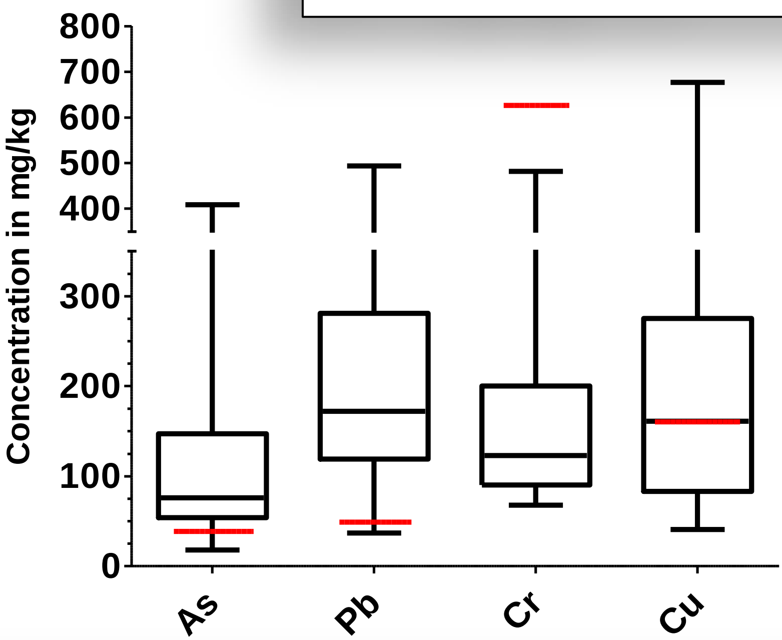



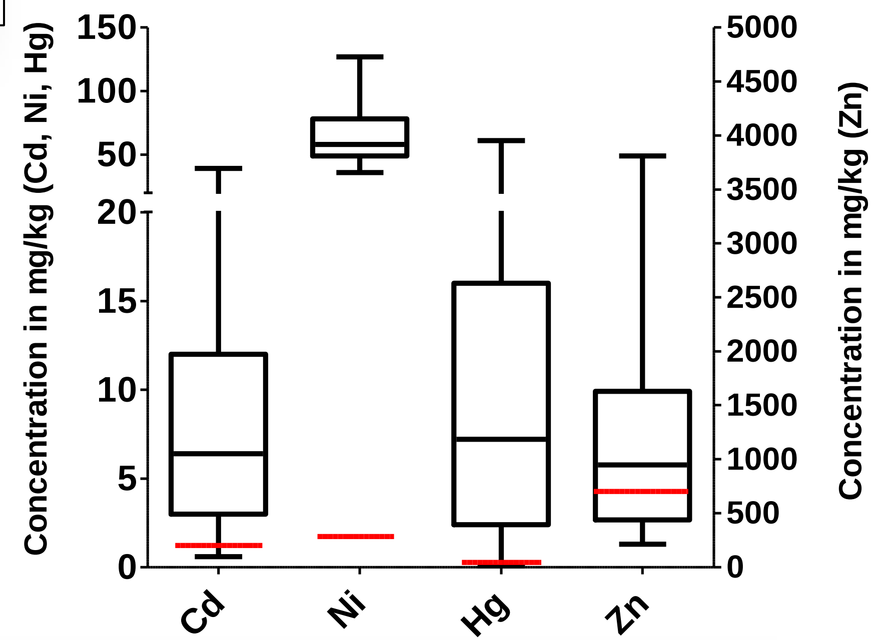

90 sediment samples, 15 backwaters (2014) (<20 µm fraction)

# Chemical contamination: Heavy metals and As

Upper

51 mg/kg Hg
25 mg/kg Cd
400 mg/kg As
500 mg/kg Pb




75 % of all samples exceeded the quality criteria for As, Pb, Cd, Hg (Ni)

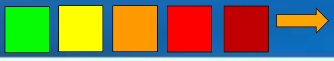
# Example: Organics (River-km 376, Ferchland)

| Organic substance | Concentration | Upper Threshold Value (ICPE) | Exceedance |
|---|---|---|---|
| Fluoranthene | 27 mg/kg | 0.18 mg/kg | up to 150 |
| Benzo(a)pyrene | 12 mg/kg | 0.6 mg/kg | up to 20 |
| PAK (16, acc. to EPA) | 152 mg/kg | | |
| β-HCH | 730 µg/kg | 5 µg/kg | up to 146 |
| pp-DDD | 2200 µg/kg | 3.2 µg/kg | up to 687 |
| pp-DDT | 760 µg/kg | 3 µg/kg | up to 253 |
| Hexachlorobenzene | 1200 µg/kg | 17 µg/kg | up to 70 |

**All these substances are accumulative in organisms**

# Trends in chemical contamination?

Increasing chemical contamination

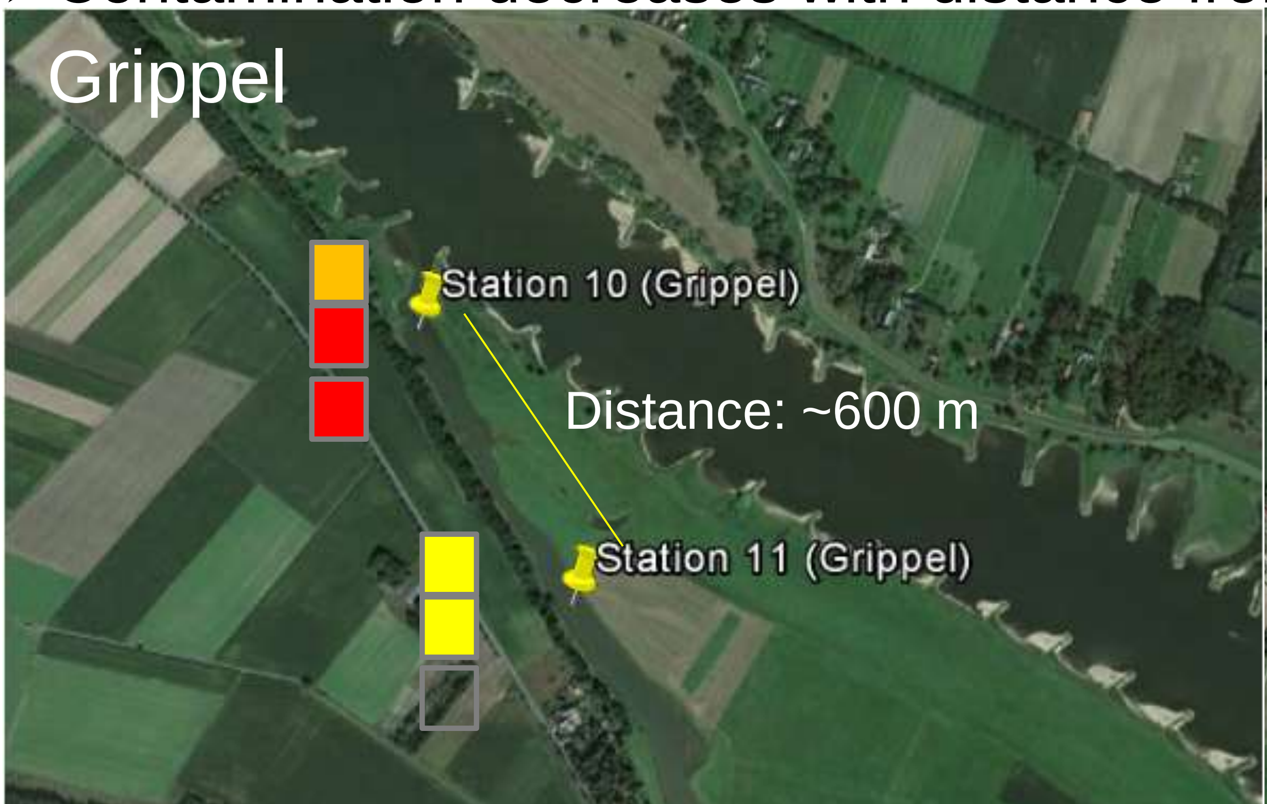


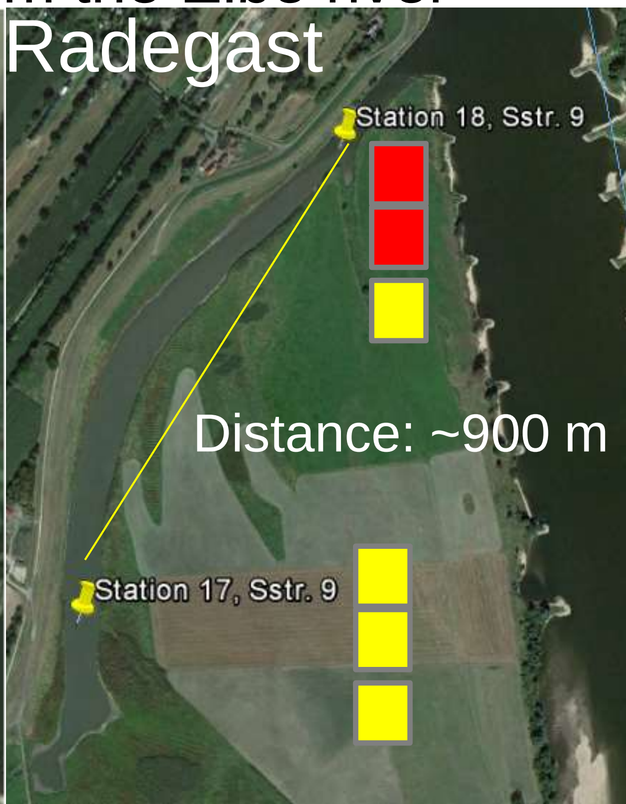
Partly very high contamination with historic substances

➢No decrease with depth

➢Partly higher contamination when large opening to the Elbe at slip-off slope.

➢Contamination decreases with distance from the Elbe river



# Sediment dynamic during high water discharge?

## Sink or source?

# Dating of Sediment Cores

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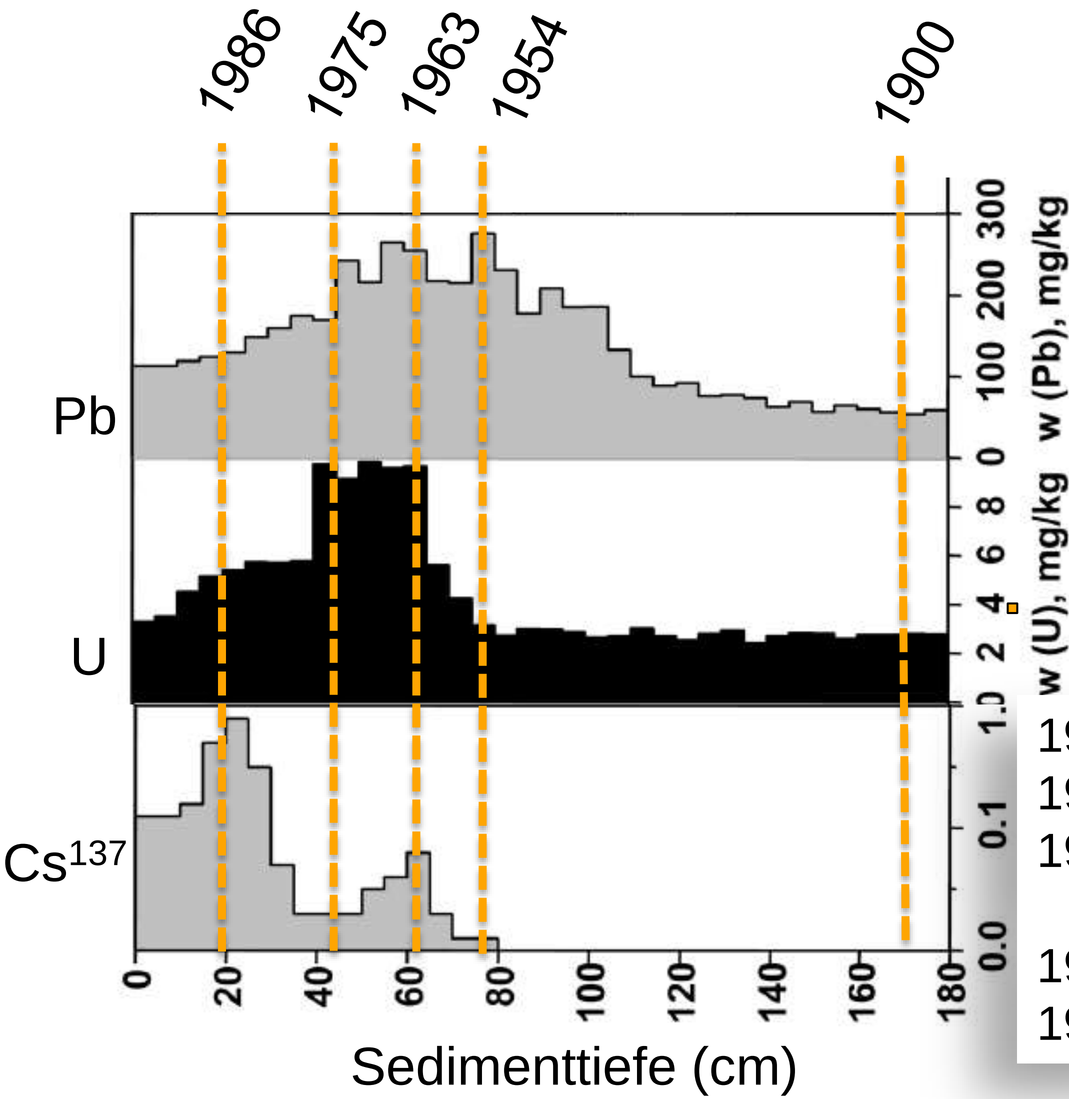
Sediment cores, river-km 438, from 1998 (Krüger et al. 2006):




1900 start of mining at the Elbe
1954 high water discharge at Mulde
1963 End of nuclear testing
Emission radioaktive effluents
1975 Mulde reservoir in operation
1986 Chernobyl catastrophe

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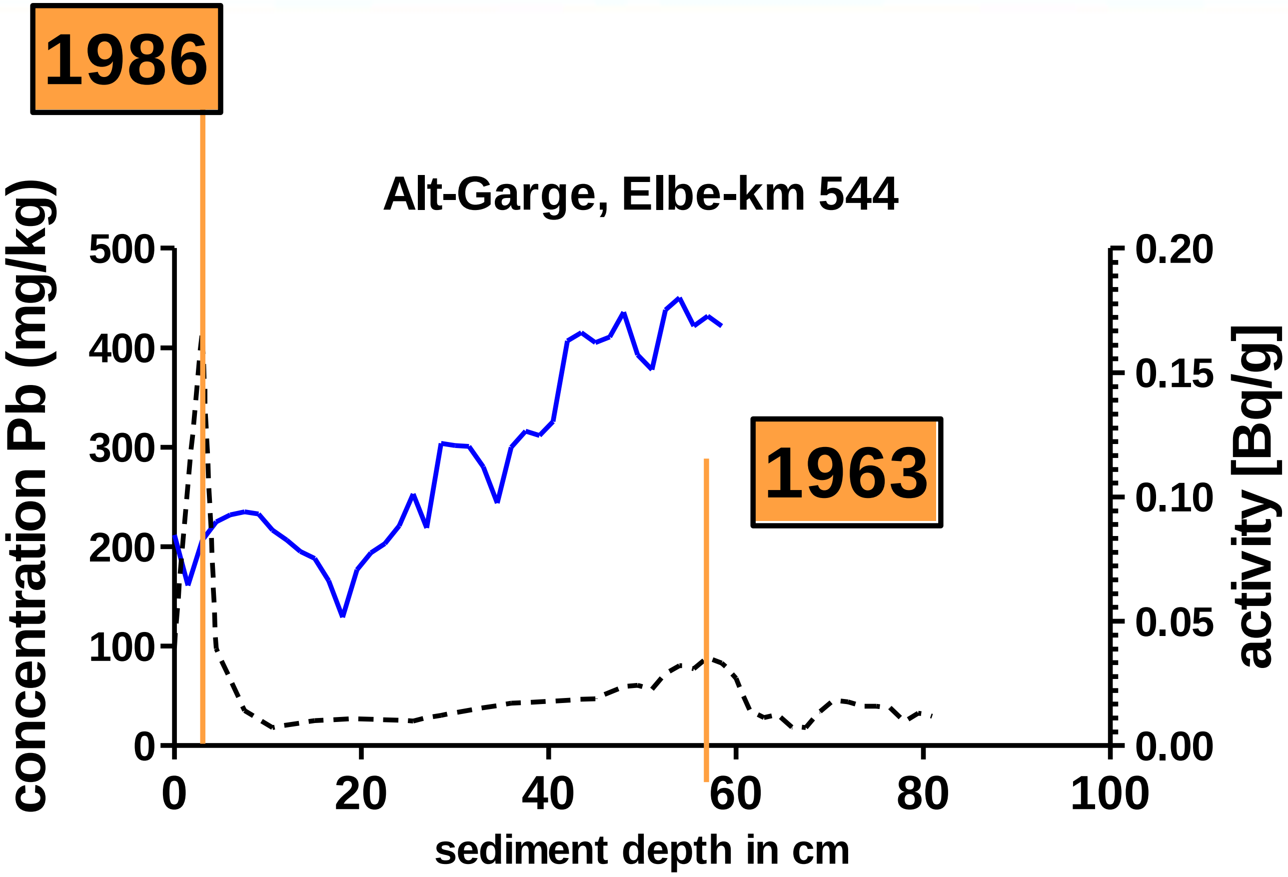

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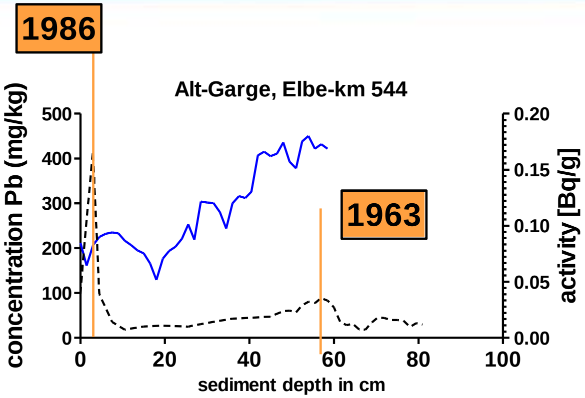


Two $^{137}Cs$ peaks (1986, 1963)

Pb-peak in ca. 50 cm depth

1975: Upstream reservoir, „Muldestausee“, was set into operation, reducing Pb concentrations in suspended matter

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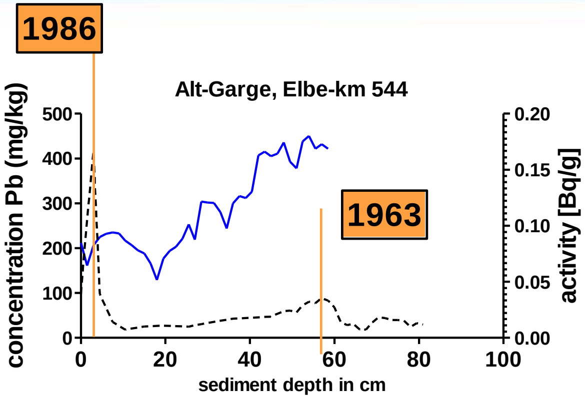


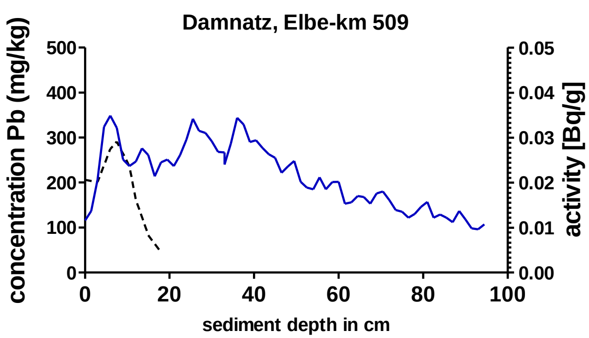


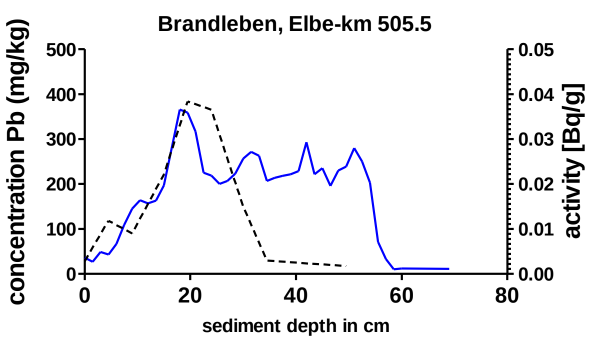


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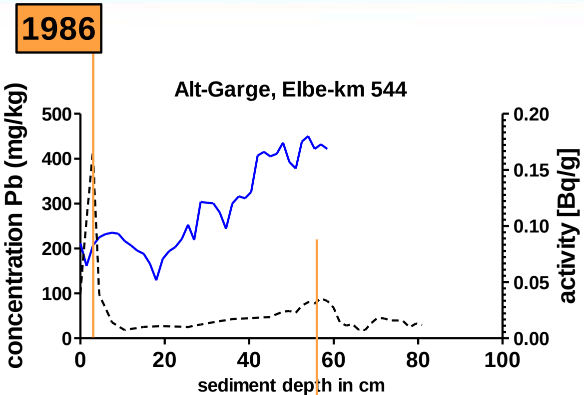


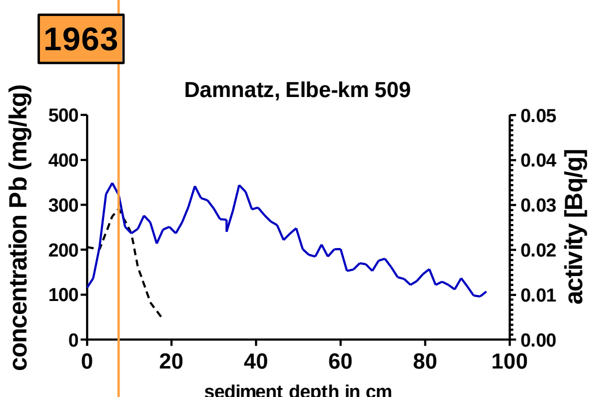


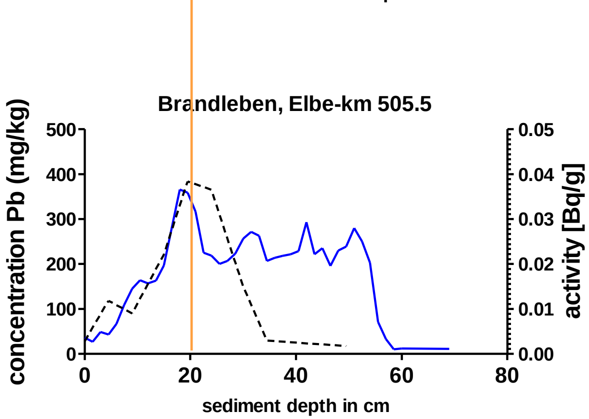


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1975: Upstream reservoir, „Muldestausee“, was set into operation, reducing Pb concentrations in suspended matter

Pb peaks close to the surface

No $^{137}$Cs signal from 1986

$^{137}$Cs peak from 1963 would have been expected in 1 m depth

Similar pattern in 6 from 8 backwaters

What happened?

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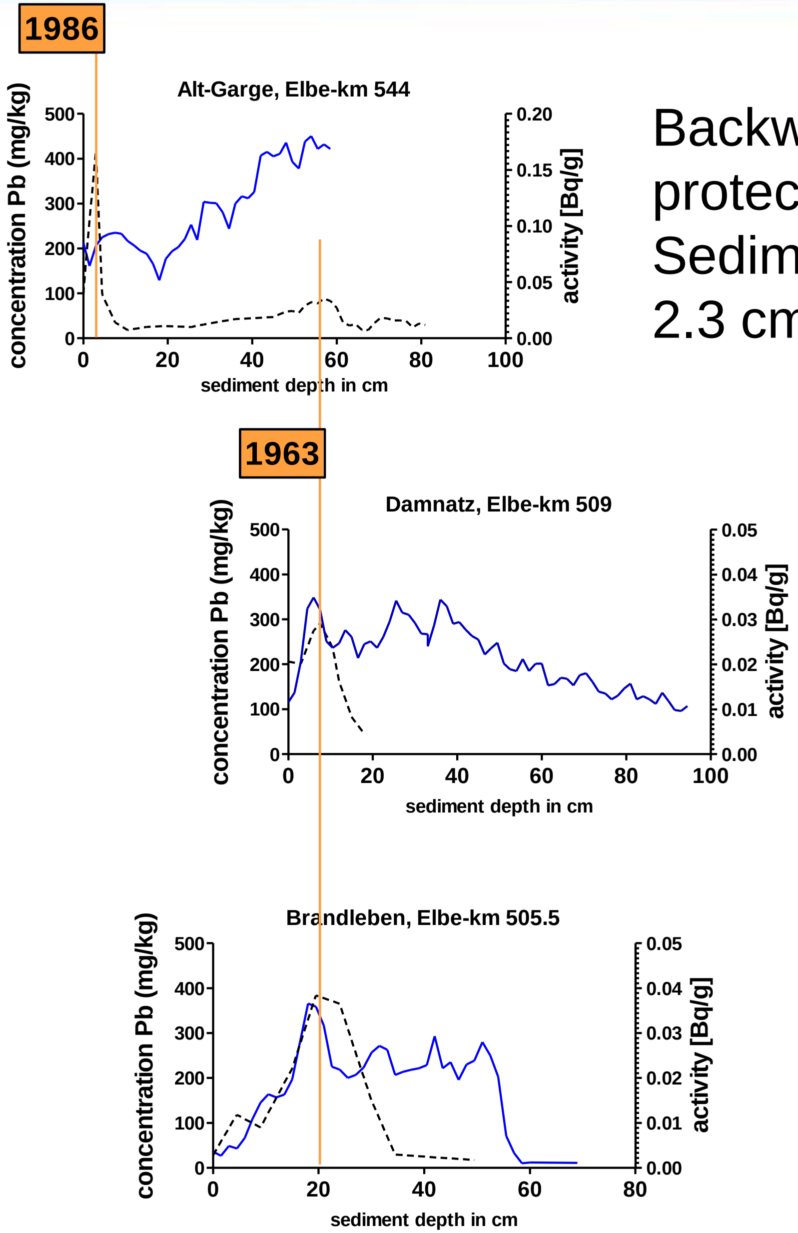


Backwater sediment
protected by dam from flooding
Sedimentation rate (calculated):
2.3 cm/year


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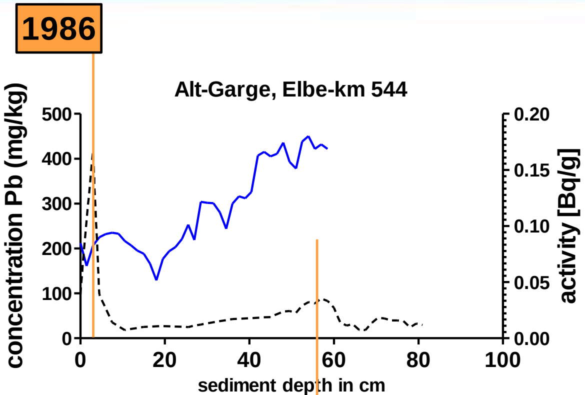


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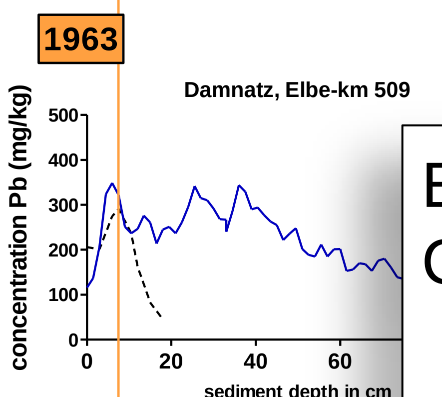
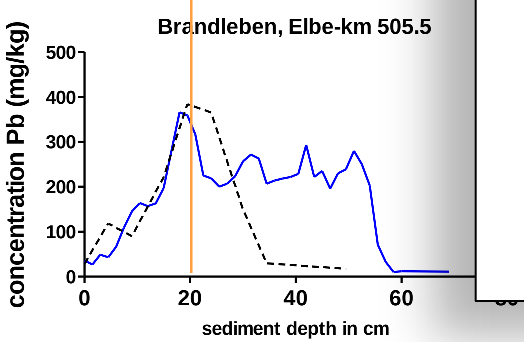


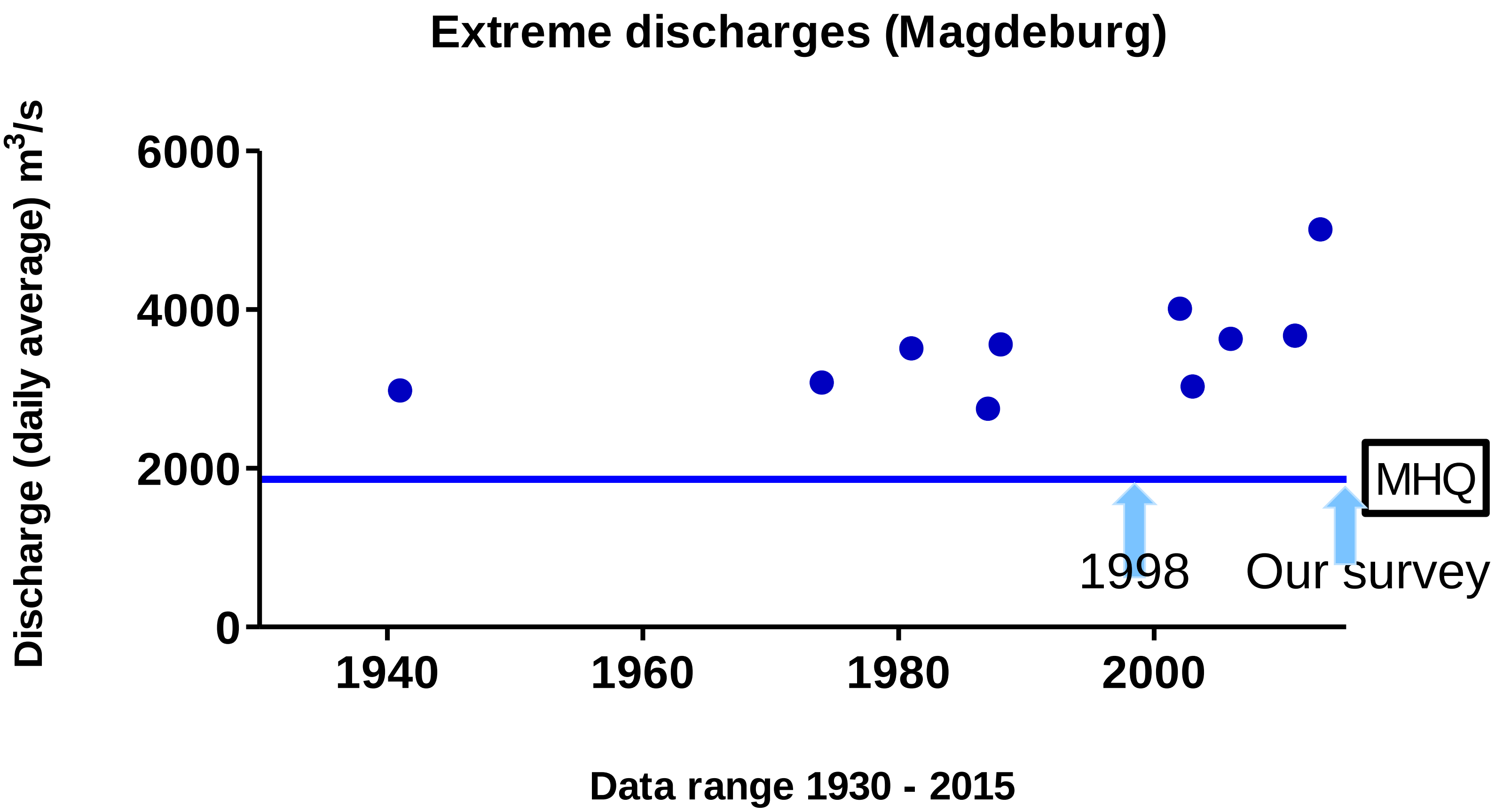

Earlier investigations had detected the Chernobyl-Peak

- Prior to 1993 (Prange et al. 1997)
- 1997/98 (Zachmann et al. 2013)
- 1998 (Krüger et al. 2006)

→ Erosion of ca. 1 m sediment since 1998

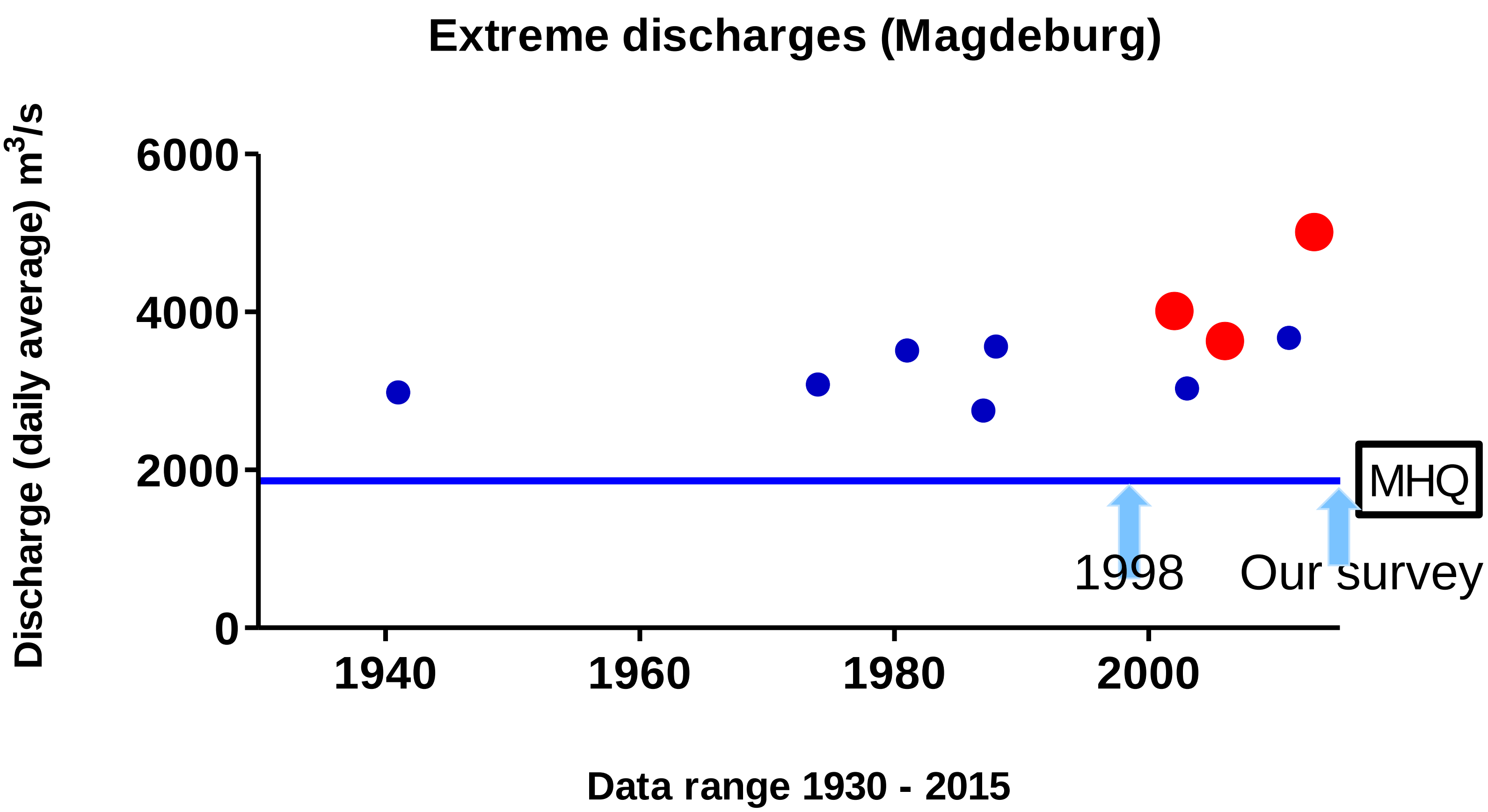
→ What happened?

# Flood events in the middle Elbe




Data: Undine, BfG

# Flood events in the middle Elbe




Data: Undine, BfG

Extreme event impacting the whole catchment

# Conclusion

**Quick succession of extremely high water discharges in the Elbe river between 2002 and 2013 probably eroded highly contaminated material from backwaters (Altarme).**

Rough estimate (only connected backwaters):

60 cm erodible layer, 10 $km^2$ area

→Mobilization of 6 mio $m^3$ highly contaminated material

(Probably a conservative estimation)

Is this process continuing?

What happens at the next flood events?

Measures? 1000 side structures ….

# Prioritization - Identification of hotspots

Integrated assessment based on
contamination, toxicity, erodibility (& depth of sediment layer)

| Station | backwater | Contamination | Ecotoxicity | Erodibility |
|---|---|---|---|---|
| 1 | 1 | | | |
| 2 | 1 | | | |
| 3 | 2 | | | |
| 4 | 3 | | | |
| 6 | 4 | | | |
| 7 | 5 | | | |
| 8 | 6 | | | |
| 9 | 6 | | | |
| 15 | 7 | | | |
| 16 | 8 | | | |
| 17 | 9 | | | |
| 18 | 9 | | | |
| 19 | 10 | | | |
| 20 | 10 | | | |

# Many thanks for your attention

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Assistance during sampling surveys:
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Nadine Heuer
Judith Angelstorf
Henning Tien
Kamelia Samet
Silvia Materu

**and**

ELSA
Schadstoffsanierung Elbsedimente

Report available at
http://www.elsa-elbe.de/dokumente.html
(German)

# When is the emission „bad“?

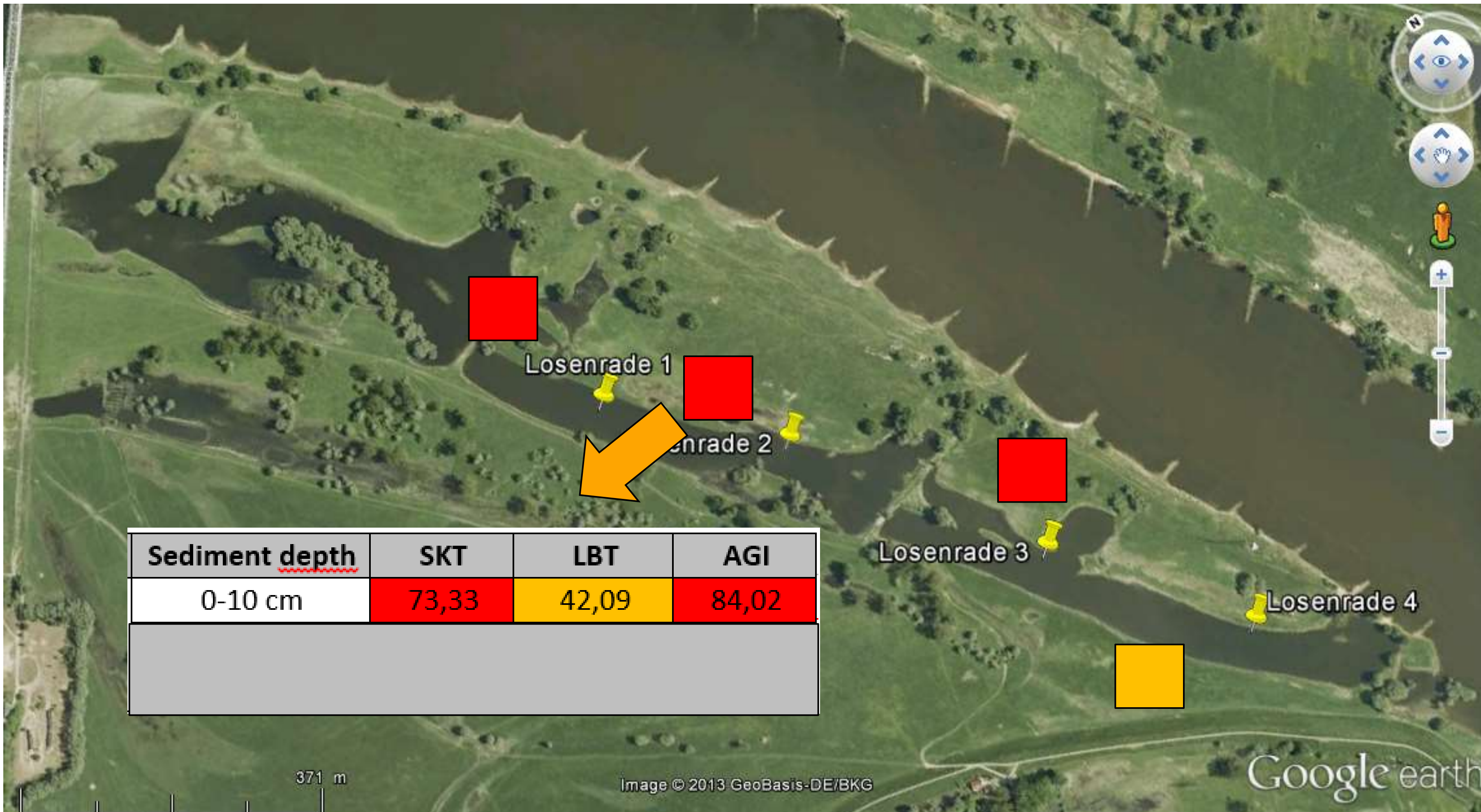
It is not the chemicals that are of concern,

it is their impact on the ecosystem.

Chemical concentration ≠ adverse effect to organisms

# Example: Backwater close to Losenrade (Elbe km 451.8)

**Increasing chemical contamination**

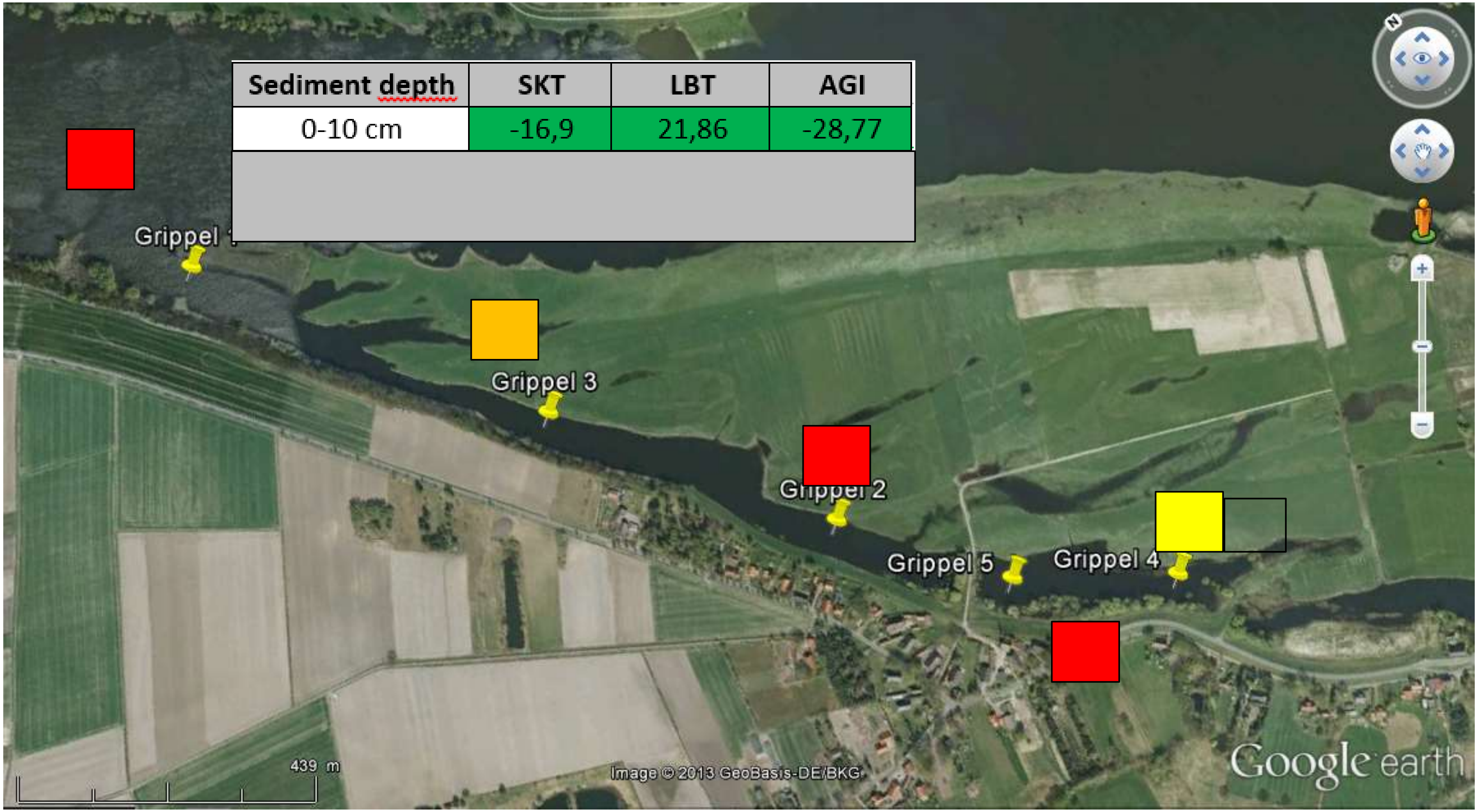



| Sediment depth | SKT | LBT | AGI |
|---|---|---|---|
| 0-10 cm | 73,33 | 42,09 | 84,02 |

# Example: Backwater close to Grippel (Elbe km 497.8)

**Increasing chemical contamination**

| Sediment depth | SKT | LBT | AGI |
|---|---|---|---|
| 0-10 cm | -16,9 | 21,86 | -28,77 |



# Conclusion

- High water discharge events in quick succession probably caused extensive erosion of sediments from backwaters
- High contamination → significant input of hazardous substances
- Partly high toxicity of sediments: Contaminants are available
- For measures, sites should be prioritized on the basis of

- contamination
- sediment toxicity
- erodibility
- depth of sediment layer.

# Referenzen

Heise S, Krüger F, Baborowski M, Stachel B, Götz R & Förstner U (2007) Bewertung der Risiken durch Feststoff-gebundene Schadstoffe im Elbeeinzugsgebiet. 349. Im Auftrag der Flussgebietsgemeinschaft Elbe und Hamburg Port Authority, erstellt vom Beratungszentrum für integriertes Sedimentmanagement (BIS/TuTech) an der TU Hamburg-Harburg, Hamburg.

Krüger F, Schwartz R, Kunert M & Friese K (2006) Methods to calculate sedimentation rates of floodplain soils in the middle region of the Elbe River. *Acta hydrochimica et hydrobiologica* ***34: 175-187.***

Prange A (1997) Erfasssung und Beurteilung der Belastung der Elbe mit Schadstoffen. Teilprojekt 2: Schwermetalle - Schwermetallspezies. Zusammenfassende Aus- und Bewertung der Längsprofiluntersuchungen in der Elbe. GKSS-Forschungszentrum, Geesthacht.

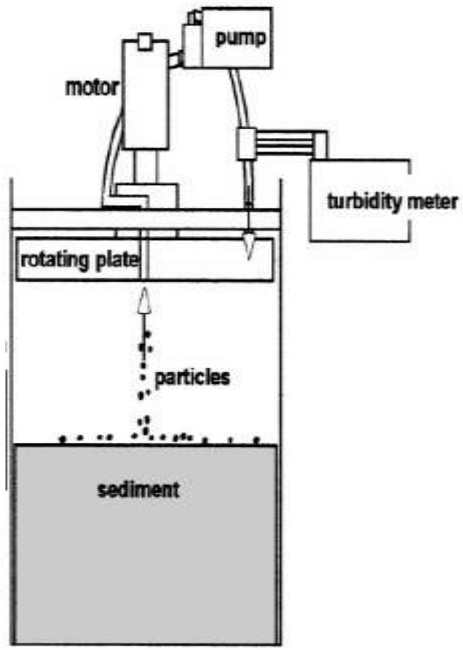
Zachmann DW, van der Veen A & Friese K (2013) Floodplain lakes as an archive for the metal pollution in the River Elbe (Germany) during the 20th century. *Applied Geochemistry* ***35: 14-27.***

# Herangehensweise

**Untersuchung von 15 Seitenstrukturen bzgl.** :

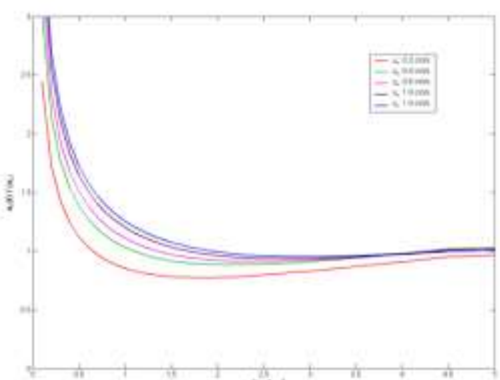
- Erodierbarkeit der Sedimentoberfläche
- Tiefe der Sedimentschicht
- Chemische Kontamination
- Ökotoxikologische Effekte (Mikrotoxtest: 2013; Testbatterie: 2014)

# Prinzip der Bestimmung der Erosionsstabilität mit dem „Gust‘schen Mikrokosmos“



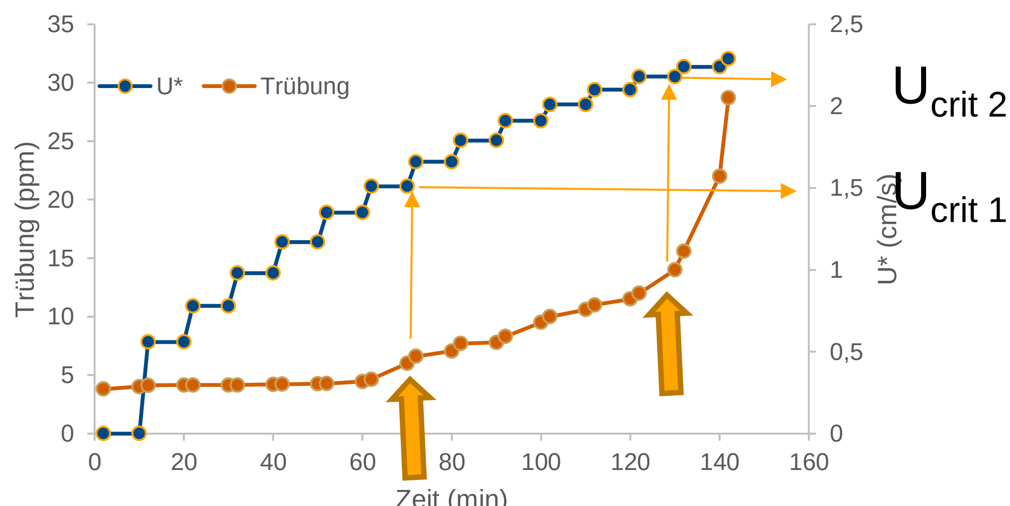

From Thomsen & Gust, 2000, modified

Feldmessungen

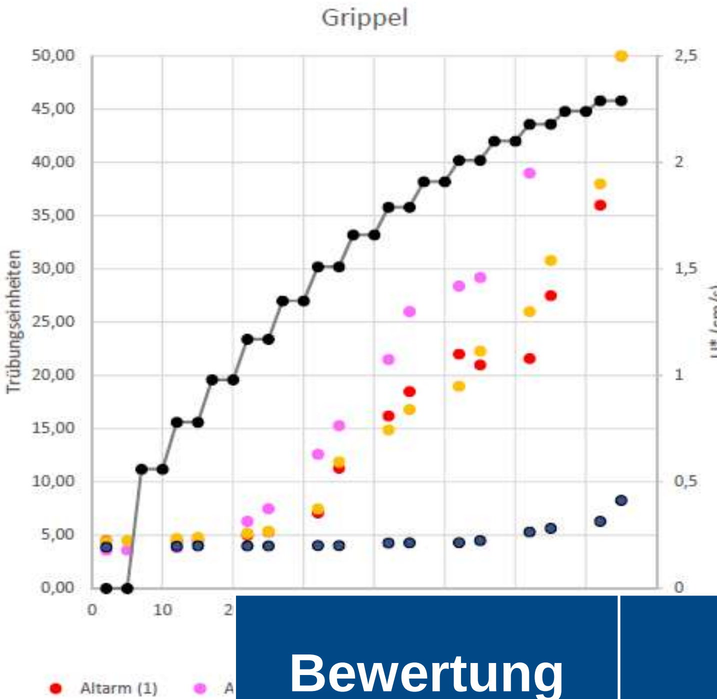


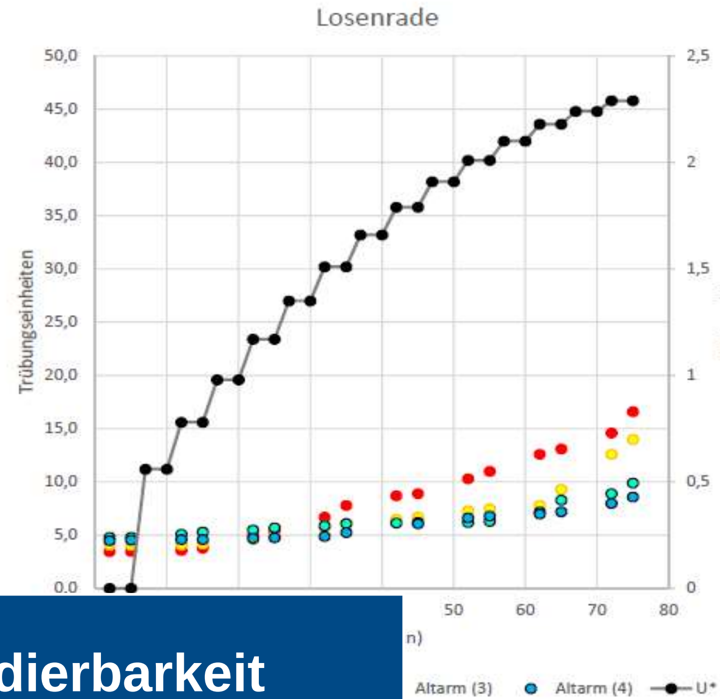
Radiale Verteilung der Schubspannungsgeschw.

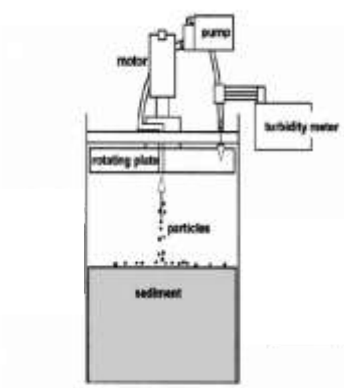
Prinzip:
Schrittweise Erhöhung der Scherkräfte
Montoring der Trübung



# Klassifikation der Erosionsmessungen



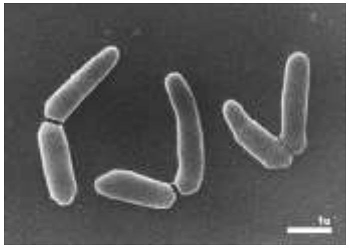




| Bewertung | Erodierbarkeit |
|---|---|
| | Hohe $u_{crit}$ (>2 cm/s), geringe erodierte Masse |
| | Mittlere $u_{crit}$ (1 bis 2 cm/s), Moderate erodierte Masse |
| | geringe $u_{crit}$ (<1 cm/s), Hohe erodierte Masse |

# Measurement of Ecotoxicity

**Sediment bacteria**



Sediment Contact

*Arthrobacter globiformis*

**Green algae**

Elutriate

*Raphidocelis subcapitata*

**Luminescent bacteria**

Elutriate

and Methanol-extract

*Allovibrio fischeri*

**Integrated assessment:**

(based on Ahlf and Heise 2005)

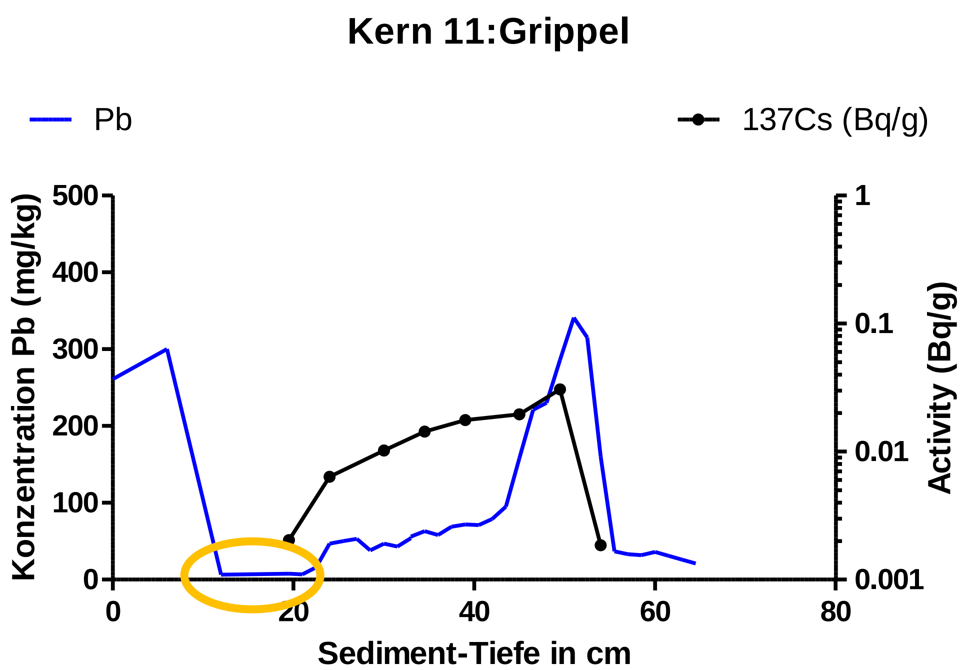
| Test: 1 | 2 | 3 | | Tox.class |
|---|---|---|---|---|
| Green | Green | Green | | 1 – not toxic |
| Yellow | Green | Green | | 1 – not toxic |
| Yellow | Yellow | Green | | 2 – slightly toxic |
| Yellow | Yellow | Yellow | | 3 – moderately toxic |
| Red | Yellow | Yellow | | 4 - toxic |
| Red | Red | Yellow | | 5 – very toxic |
| Red | Red | Red | | 5 – very toxic |
| Green | Red | Red | | 4 - toxic |
| Green | Yellow | Red | | 3 - moderately toxic |
| Green | Green | Red | | 2 - slightly toxic |

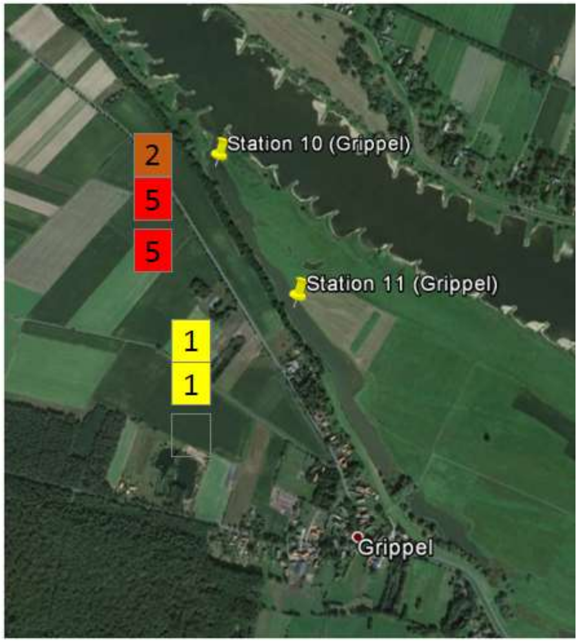
## → Need for prioritization of sites on RB scale on the basis of

- Size of backwater
- Location towards the river

  (large opening at slip-off slope of the river?)
- Depth of sediment layer
- Contamination
- Erodibility
- Toxicity of resuspended material

# Ergebnisse 2: Hinweis auf Sedimentumlagerung



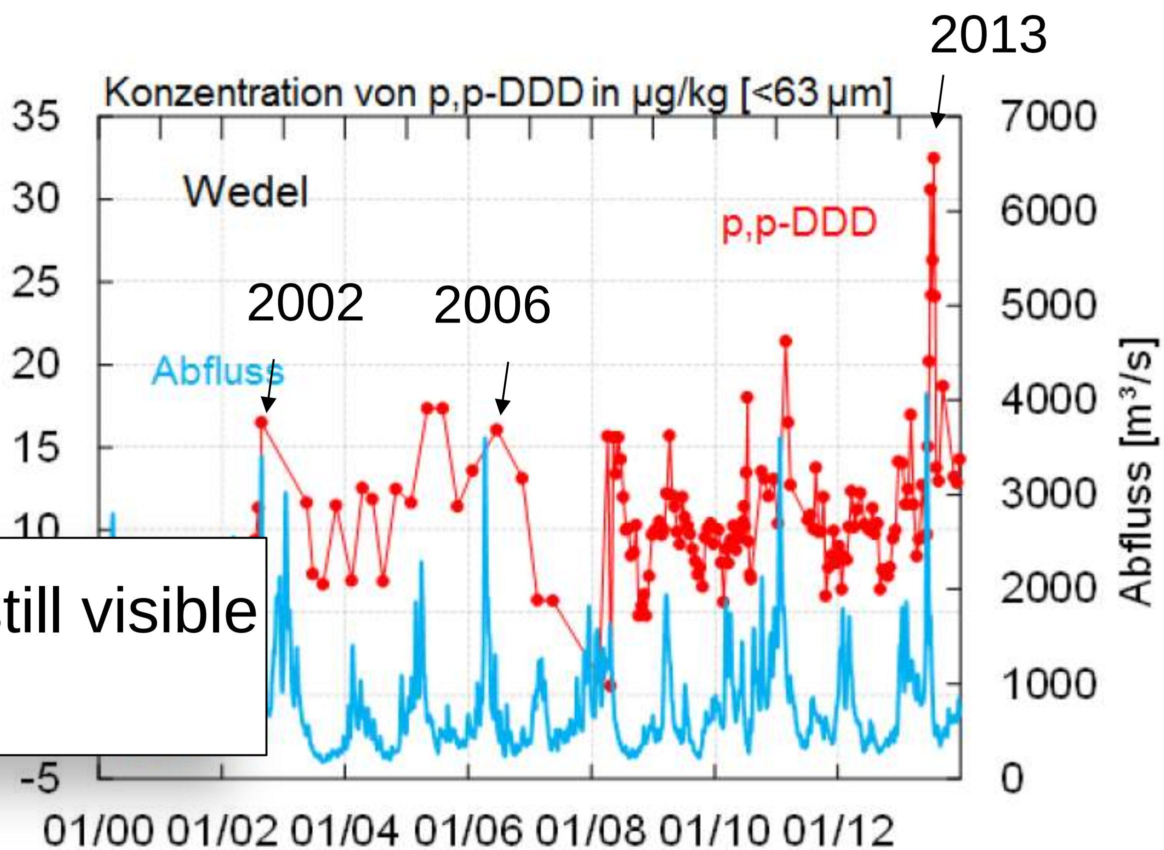

Station 600 m entfernt von der Mündung
•zwischengelagerte Sandschicht
•Erhöhung des Feinsandanteils von 2013→ 2014
•breiter Cs-Peak von 1963
•schmaler Pb-Peak bei 50 cm

→Abtrag von Material, Umlagerungen zwischen 2013-2014

# Impact of high water discharges?

Extreme high water discharges affecting the whole river basin since 1998:

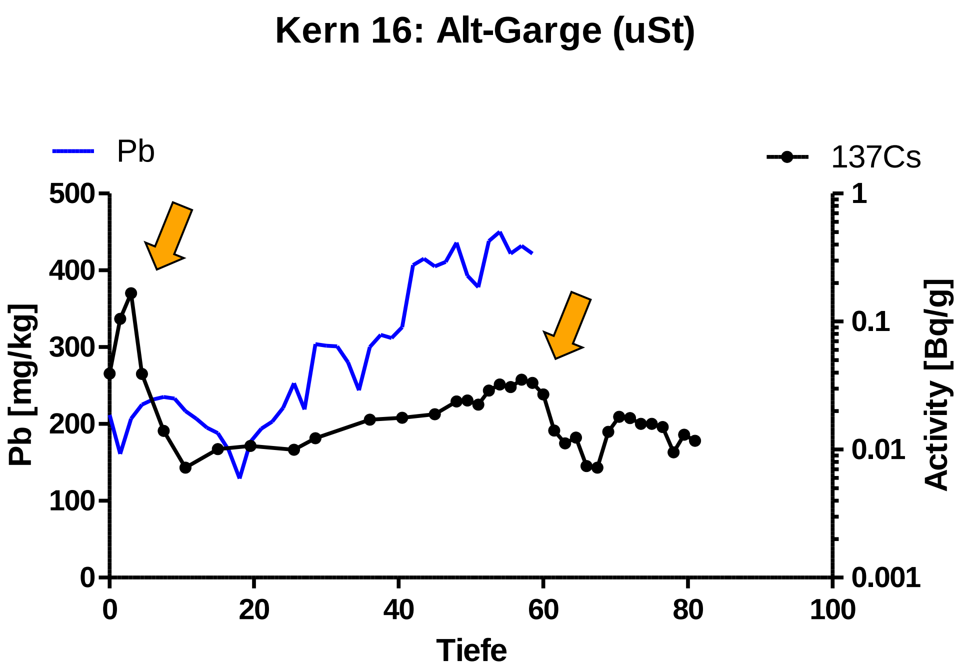
- 2002
- 2006
- 2013

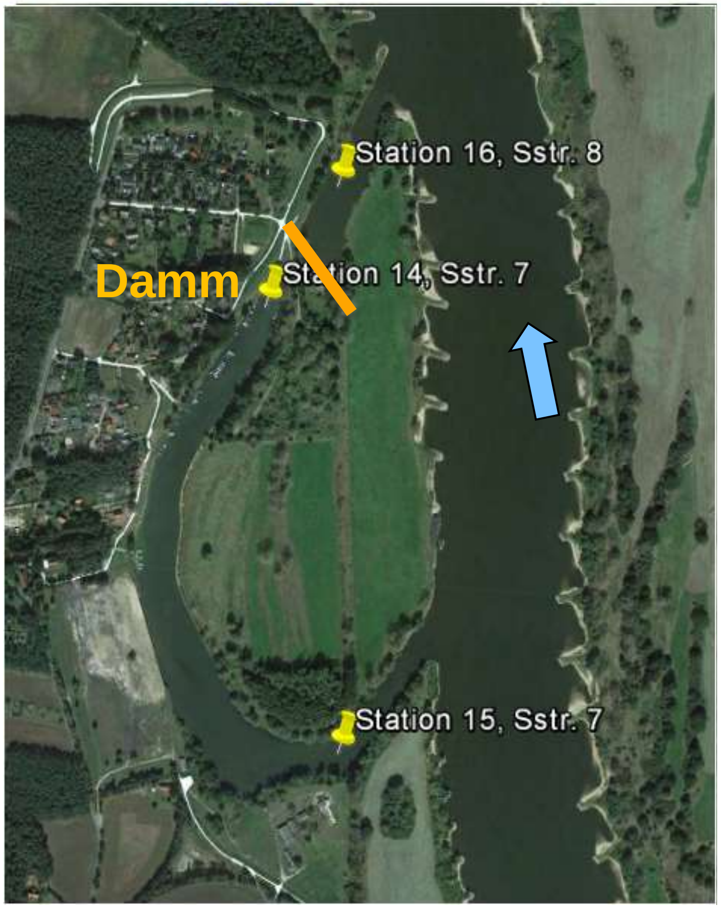



Contamination signal still visible in the Elbe estuary

Concentration of pp-DDD in the **Elbe Estuary** between 2000 and 2012 (from BfG 2014)

# Dating of Sediment Cores: Alt-Garge




Alt-Garge

Two $^{137}Cs$ peaks (1986, 1963)
Pb-Peak in ca. 50 cm depth

Backwater protected by dam from flooding
Sedimentation rate (calculated): 2,3 cm/year

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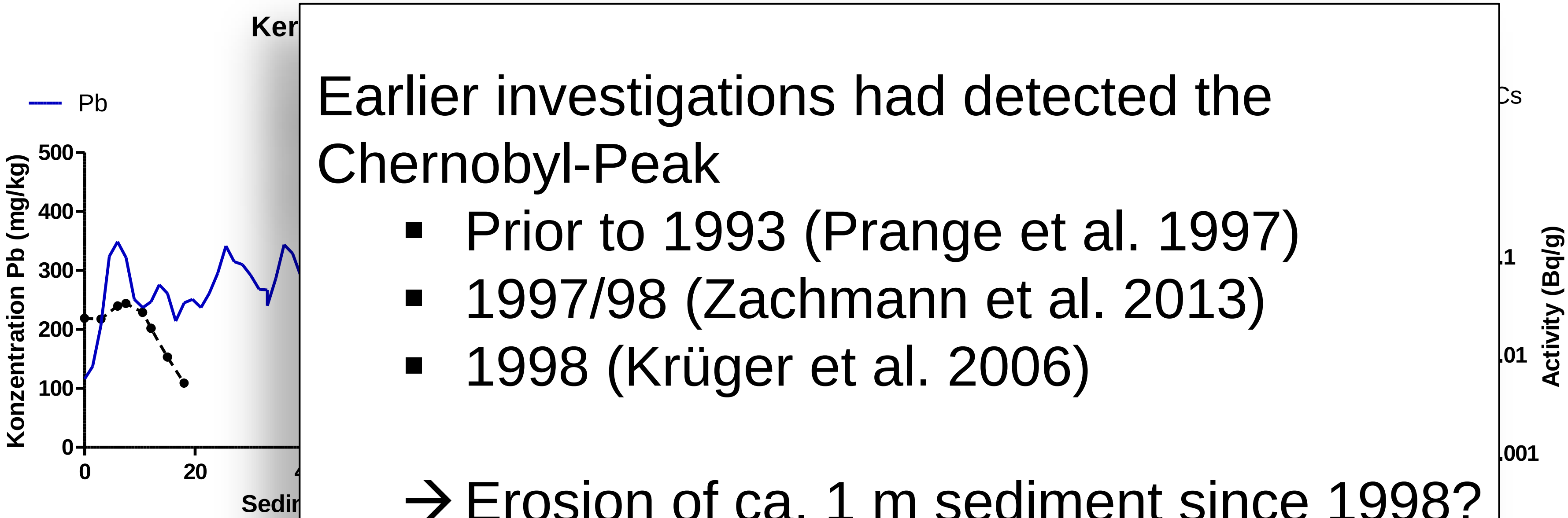


Earlier investigations had detected the Chernobyl-Peak

- Prior to 1993 (Prange et al. 1997)
- 1997/98 (Zachmann et al. 2013)
- 1998 (Krüger et al. 2006)

→ Erosion of ca. 1 m sediment since 1998?

- Pb peaks close to the surface.
- No $^{137}$Cs signal from 1986
- $^{137}$Cs peak from 1963 would have been expected in 1 m depth
- Similar pattern in 6 from 8 backwaters

# Successon of high water discharges in the Elbe river

- Sediments in backwaters mostly high contaminated (>>upper treshold value)
- Increasing contamination close to the Elbe
- Large volumes (1 m depth?) of sediments are missing since 1998

  (no 1986-peaks)

Likely candidate: 4 high water discharges since 1998: 2002, 2006, (2011,) 2013

Rough estimate (only connected backwaters):

60 cm erodible layer, 10 $km^2$ area

→ Mobilization of 6 mio $m^3$ highly contaminated material

How “bad“ is that?