Risk Assessment of Contaminated Sediments in River Basins

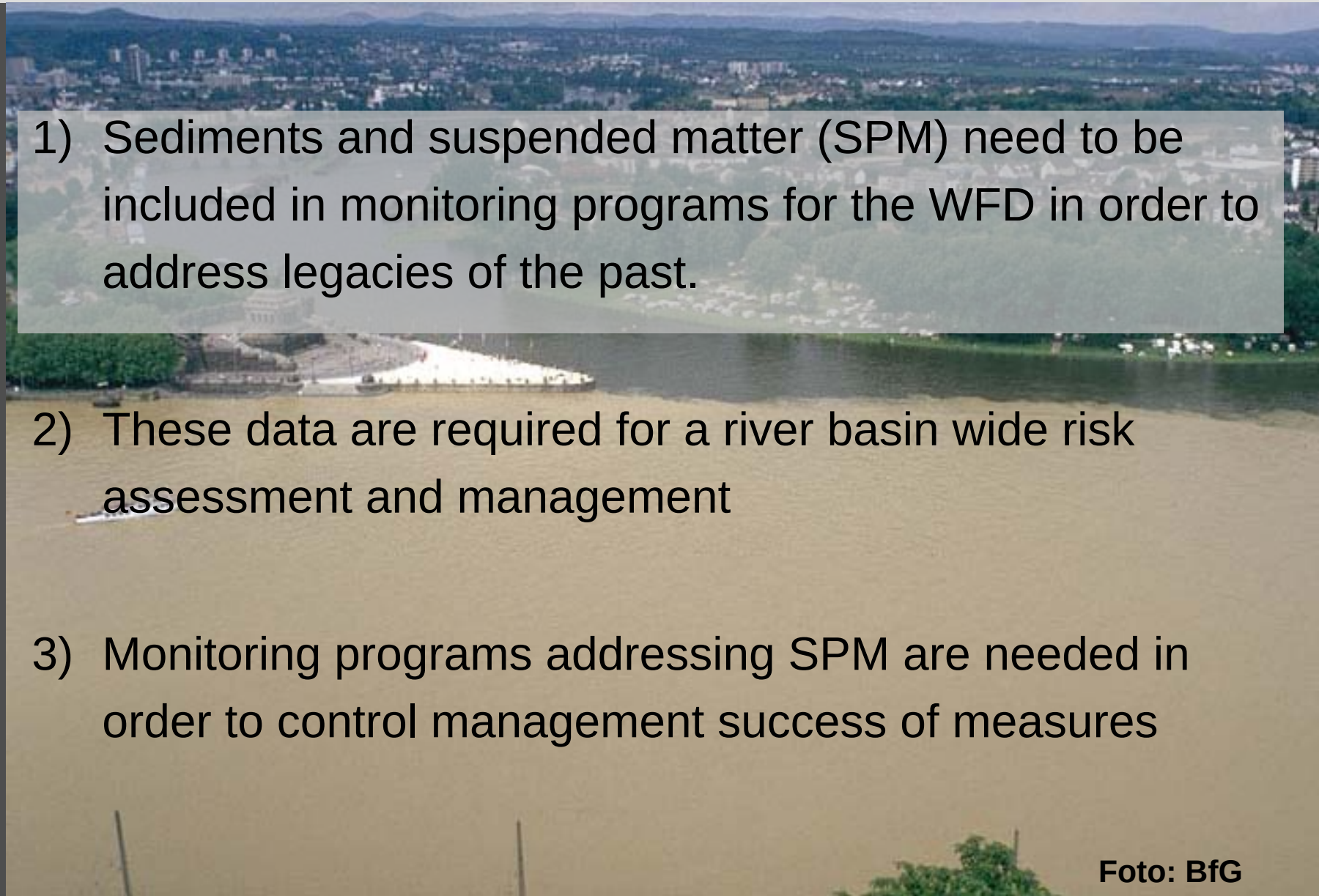
Theoretical Considerations and Pragmatic Approach

Ulrich Förstner (TUHH) & Susanne Heise (BIS)

et al.

Ljubljana, NATO-Workshop 19.06.07

River Basin Management and Monitoring of Sediments



1) Sediments and suspended matter (SPM) need to be included in monitoring programs for the WFD in order to address legacies of the past.

2) These data are required for a river basin wide risk assessment and management

3) Monitoring programs addressing SPM are needed in order to control management success of measures

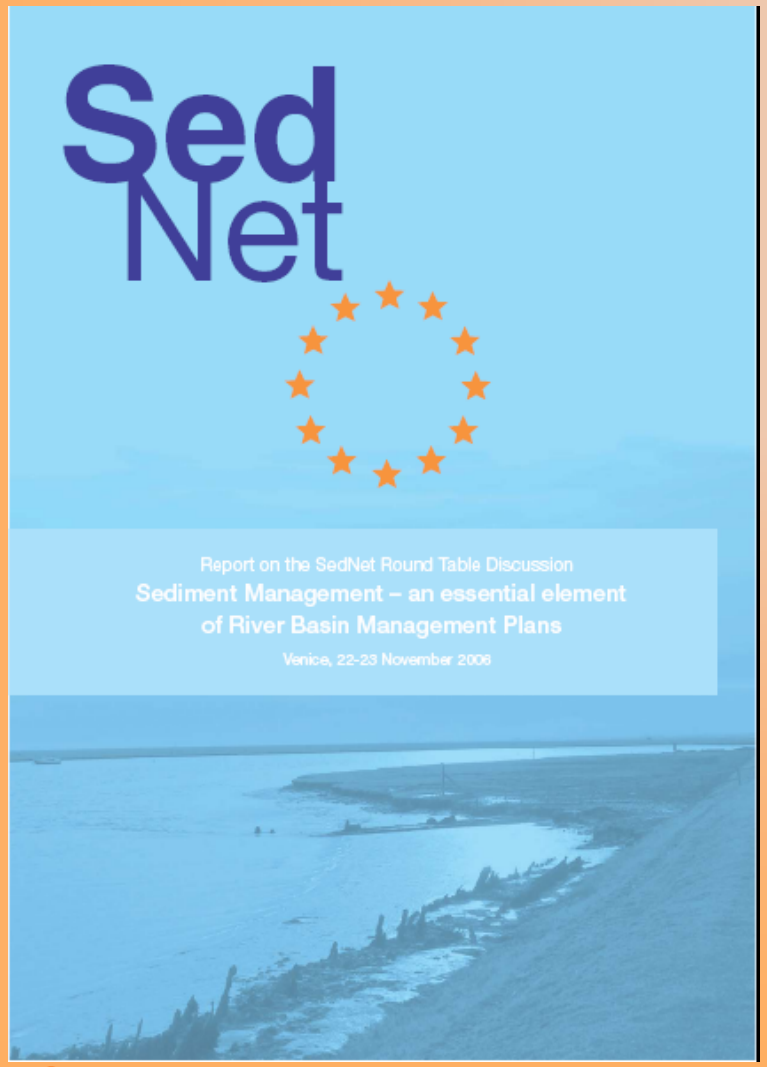
Foto: BfG

The objective of Sediment RB management

Prioritization of contaminated sites in a RB with regard to the risk that they pose to the WFD-objective and to uses of societal interest

(fishery, agriculture, recreation, shipping …)

Foto: Heise



Report on the SedNet Round Table Discussion
Sediment Management – an essential element of River Basin Management Plans
Venice, 22-23 November 2006

Case Studies

- Danube
- Douro
- Elbe
- Humber

The challenges to River Basins in Europe

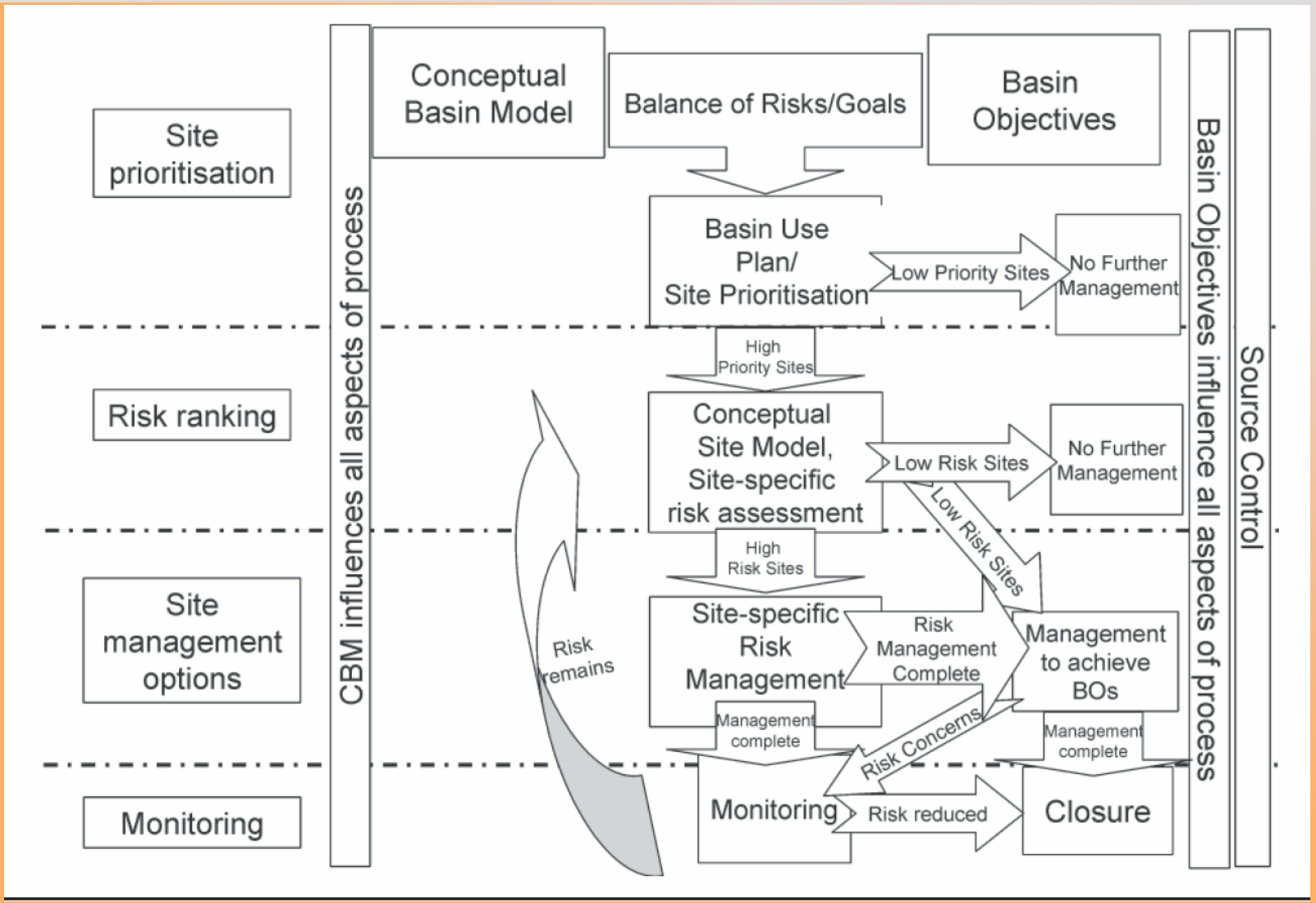
With regard to risk from contamination

- Legacies of the chemical industry
- Historic pollution around urban areas (e.g. Paris→ Seine; Dresden, Hamburg → Elbe; ….)
- Mining activities

With regard to management

- liability? (e.g. GDR → FRG, sold companies)
- No financial ressources at sites (e.g. poor federal states)
- increasing pressures from affected, downstream sites

Conceptual approach



Apitz & White, JSS (3), 2003

Requirements for a practical approach

Sediment Risk Assessment on River Basin Level

There is a high uncertainty!

Reduce it amap & live with the rest.

- Loads of SPM in the catchment → Use of different kind of data (centrifuge sampling, sediment traps, turbidity)
- Transport of SPM (resuspension / sedimentation) → Data on erosion potentials, catchment models, grain size data …
- Particle bound contaminants concentration / loads (sources, distribution) → Long-term SPM-analysis & event-based data
- Risks from contaminated SPM →Use different lines of evidence! →Transparent definition of risk (target levels)

For the moment!

Results need to indicate

- Prioritization of sites for measures
- The degree of confidence

BIS

The practical approach to prioritization

1) Identification of Substances of Concern

- RB specific contaminants
- Contaminants which endanger RB objectives

2) Identification of Areas of Concern

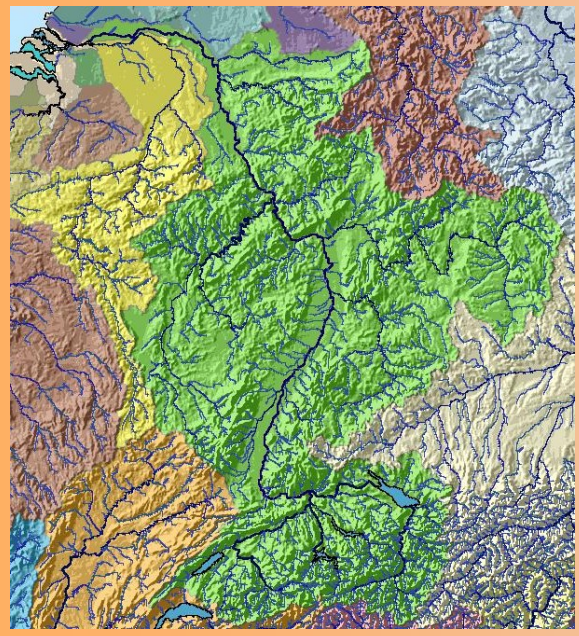
- Contaminated sites in the catchment

3) Identification of Areas of Risk

contaminated sites, from which sediments are transported downstream and under certain conditions (floods, low water levels) lead to exposure to hazards

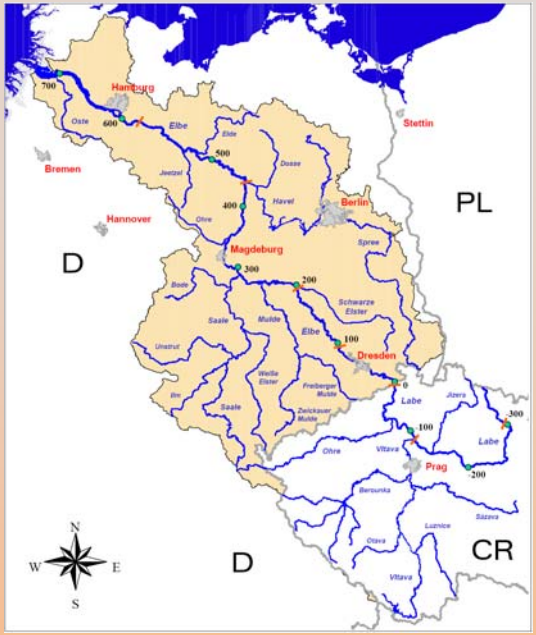
Examples

The Rhine basin



(commissioned by POR)

The Elbe basin



(commissioned by HPA and FGG)

Assessment of
1) Substances of Concern
2) Areas of Concern
3) Areas of Risk (in prep for the Elbe)

BIS

Rhine Basin: 1) Classification of S.o.C.

Table ES.1 Substances of concern and their ranking

Substances of concern	Hazard class
Cadmium	2
Chromium	1
Copper	1
Mercury	2
Nickel	1
Lead	1
Zinc	1
DDT+DDD+DDE (SUM)	2
Dioxins and Furans	2
Hexachlorobenzene	2
Polycyclic aromatic hydrocarbons	2
Polychlorinated biphenyls	2
TBT	1
Aldrin (Dieldrin, Endrin)	1
γ-hexachlorocyclohexane	1
Nonyl-phenol compounds	1

Class 2:

Cd and Hg:
High bioaccumulative potential
high toxicity

DDT, dioxins, HCB, PAH, PCB:
Highly persistent,
strongly adsorb to sediment
bioaccumulative potential

BIS

2. Classification of Areas of Concern:

Sediment Risk Assessment on River Basin Level

Criteria:

Exceedance of target value

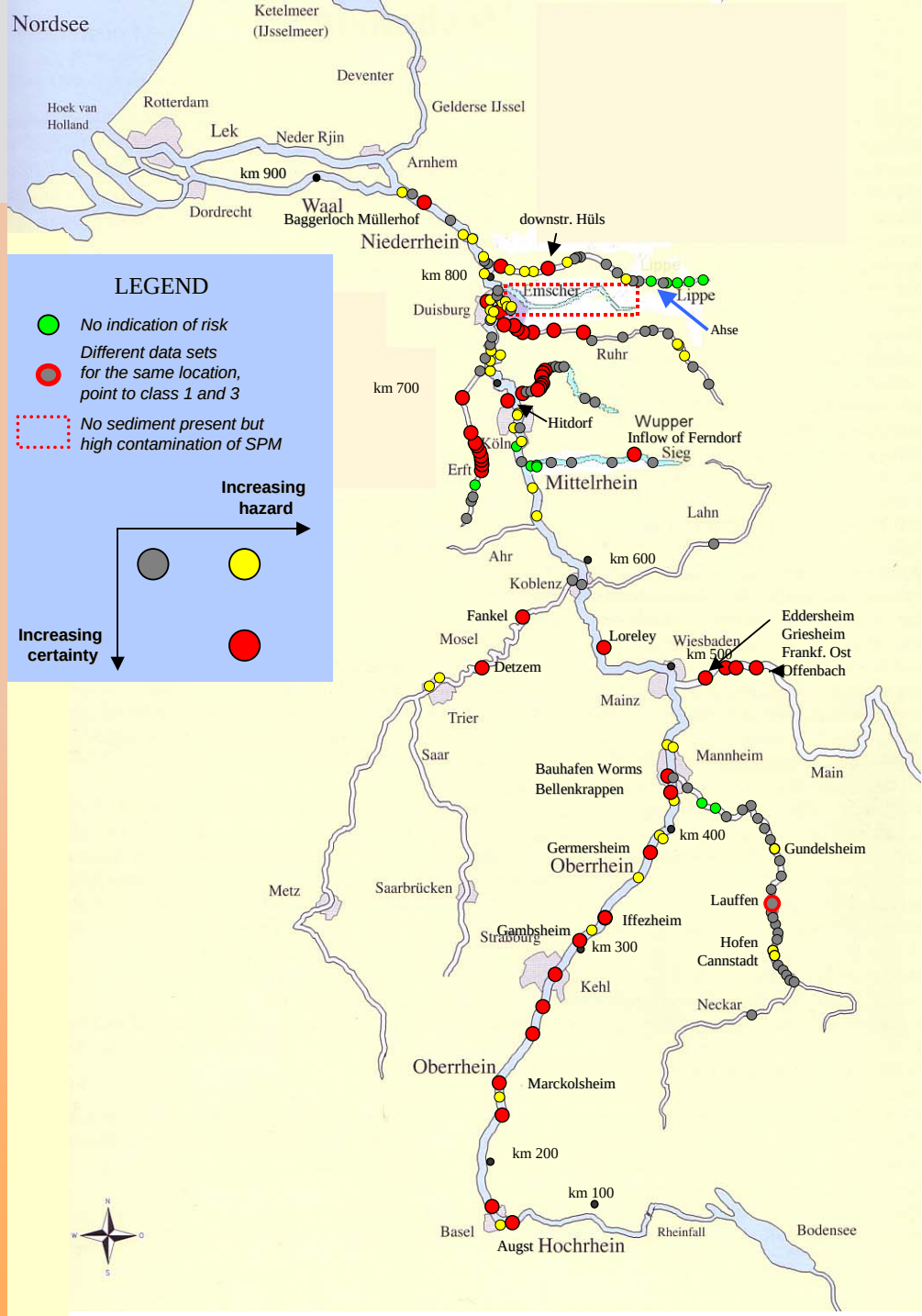
Hazard rank of compound

Certainty of conclusion

(number of compounds, number of measurements)

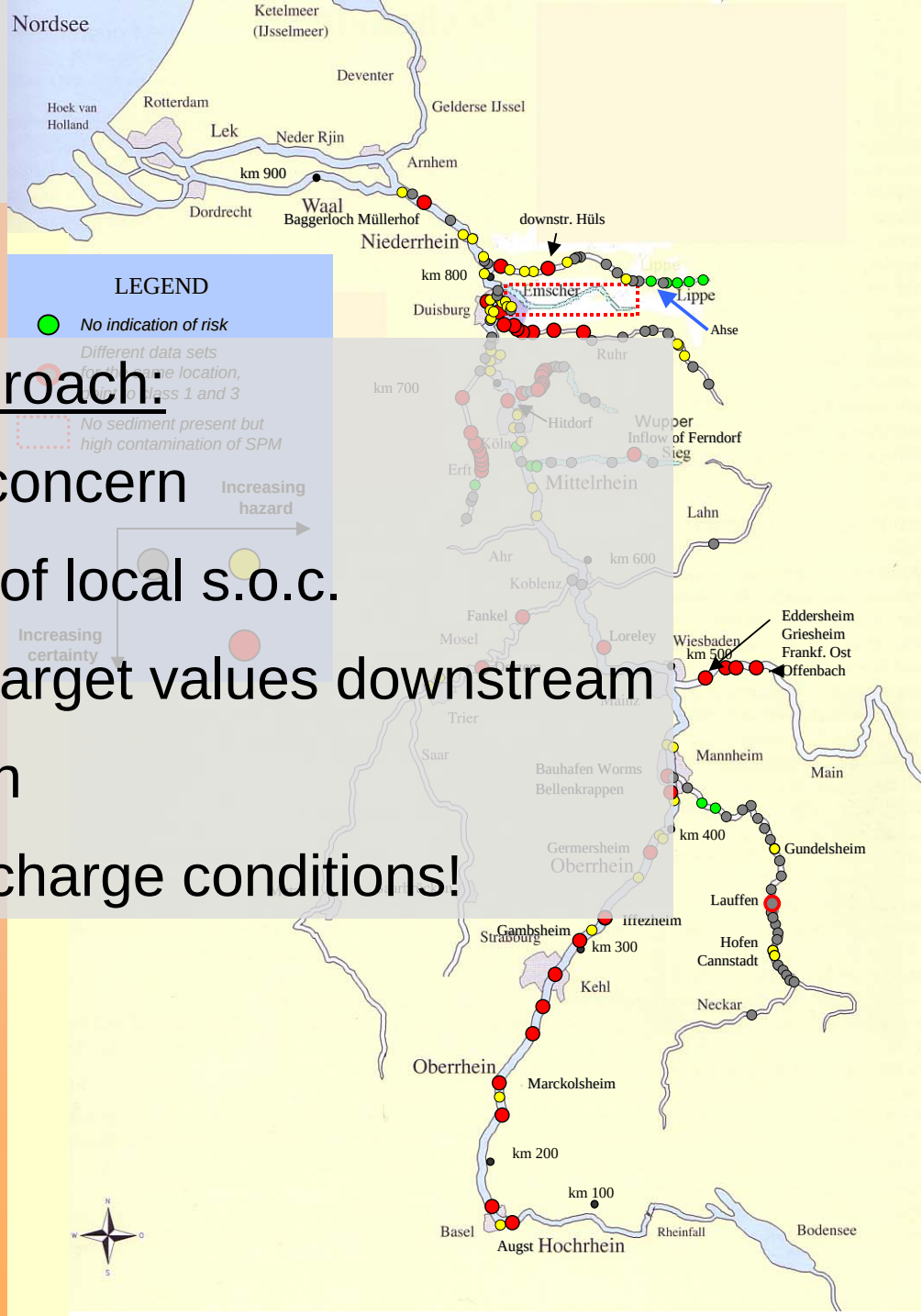
Class 1: potential hazard
Class 2: potentially high hazard
Class 3: high hazard with high certainty.

BIS



3. Areas of Risk

Sediment Risk Assessment on River Basin Level



Weight of evidence – approach:

Classification as area of concern

Dominating hazard class of local s.o.c.

Potential exceedance of target values downstream

Indication of resuspension

under different discharge conditions!

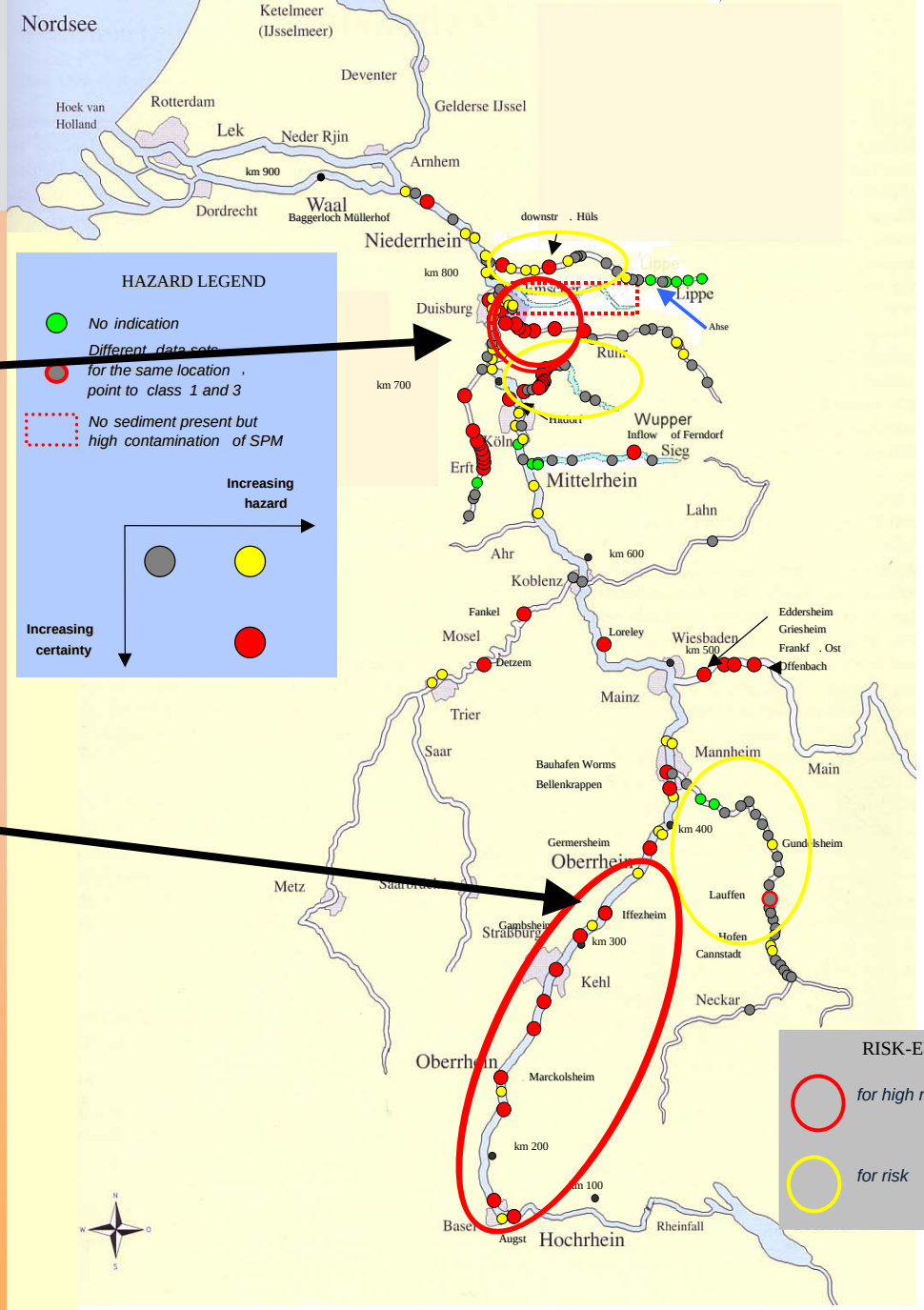
BIS

3) Areas of Risk

Sediment Risk Assessment on River Basin Level

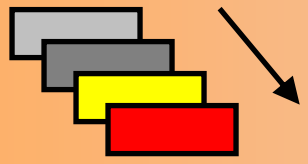
River Ruhr at HQ_{100} with regard to PAH and Cd

Barrages Upper Rhine Iffezheim at HQ_1 with regard to HCB



The Elbe Basin: S.o.C. and A.o.C.

Sediment Risk Assessment on River Basin Level



Increasing exceedance of target values

CR

North S

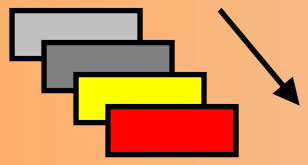
Tab. 7.2: Überschreitungen der Zielvorgaben für die einzelnen Substances of Concern in verschiedenen Regionen entlang der Elbe.

	Diox	PAH	As	Cu	Cd	Hg	Pb	Zn	HCH	DDT	PCB	HCB	TBT	TeBT[21]
Valy														
Lysa														
Obristvi														
Zelcin/Moldau														
Decin														
Schmilka														
Zehren														
Dommitzsch														
Schwarze E.														
Mulde														

Freiberger Mulde (Sulfidic Pb-Zn-As ores)
Slag heaps (erosion)
Ehrenfriedersdorf (smelting)

The Elbe Basin: S.o.C. and A.o.C.

Sediment Risk Assessment on River Basin Level



Increasing exceedance of target values

CR

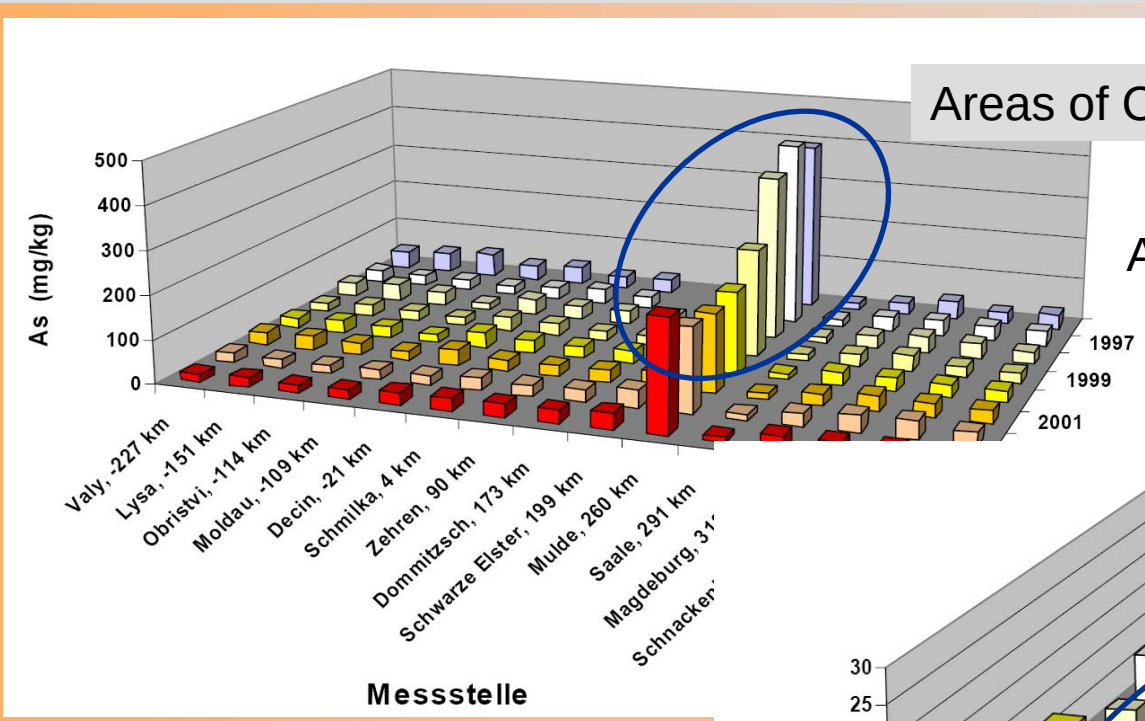
North Sea

Tab. 7.2: Überschreitungen der Zielvorgaben für die einzelnen Substances of Concern in verschiedenen Regionen entlang der Elbe.

	Diox	PAH	As	Cu	Cd	Hg	Pb	Zn	HCH	DDT	PCB	HCB	TBT	TeBT[21]
Valy														
Lysa														
Obristvi														
Zelcin/Moldau														
Decin														
Schmilka														
Zehren														
Dommitzsch														
Schwarze E.														
Mulde														
Saale														
Magdeburg														
Schnackenbg.														
inthaus														
emannsht.														

Areas of Concern → Areas of Risk

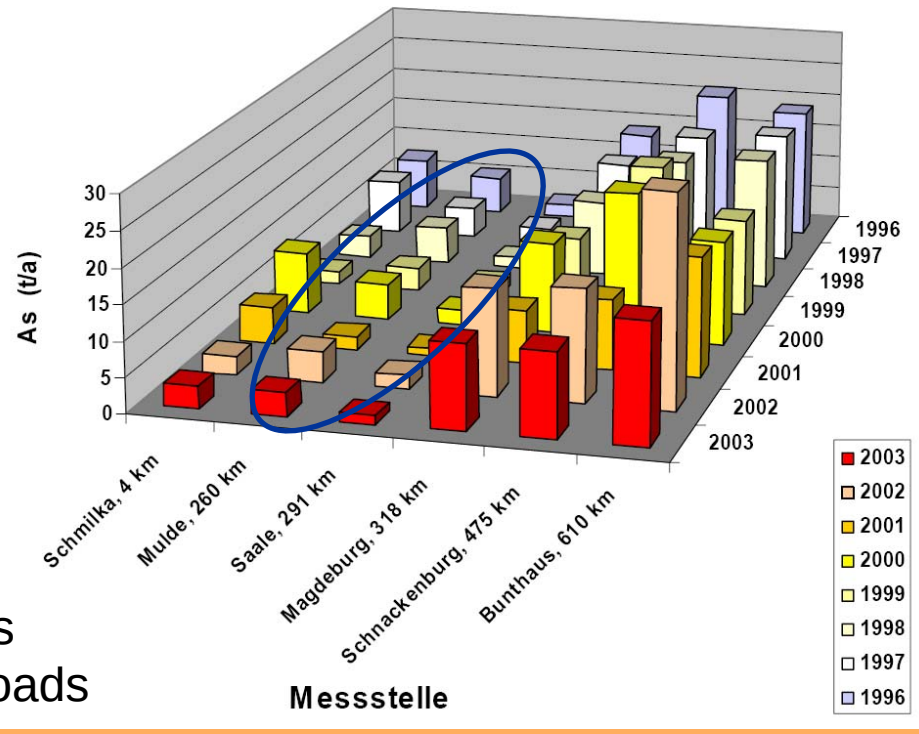
Sediment Risk Assessment on River Basin Level



Areas of Concern: Mulde

As concentration in SPM

Areas of RISK?



As
-loads

Conclusions

Prioritization of Risks in River Catchments:

- transparent process
- scientifically sound (weight of evidence approach)
- addressing confidence levels

Which site poses the largest risk to the RB objectives?

What are requirements of potential **measures**?

(→ programme of measures 2009)

It is then up to the decision makers to decide, which functions they value most and where to invest / direct financial resources

Sediments carry the memory of an industrial history into our present

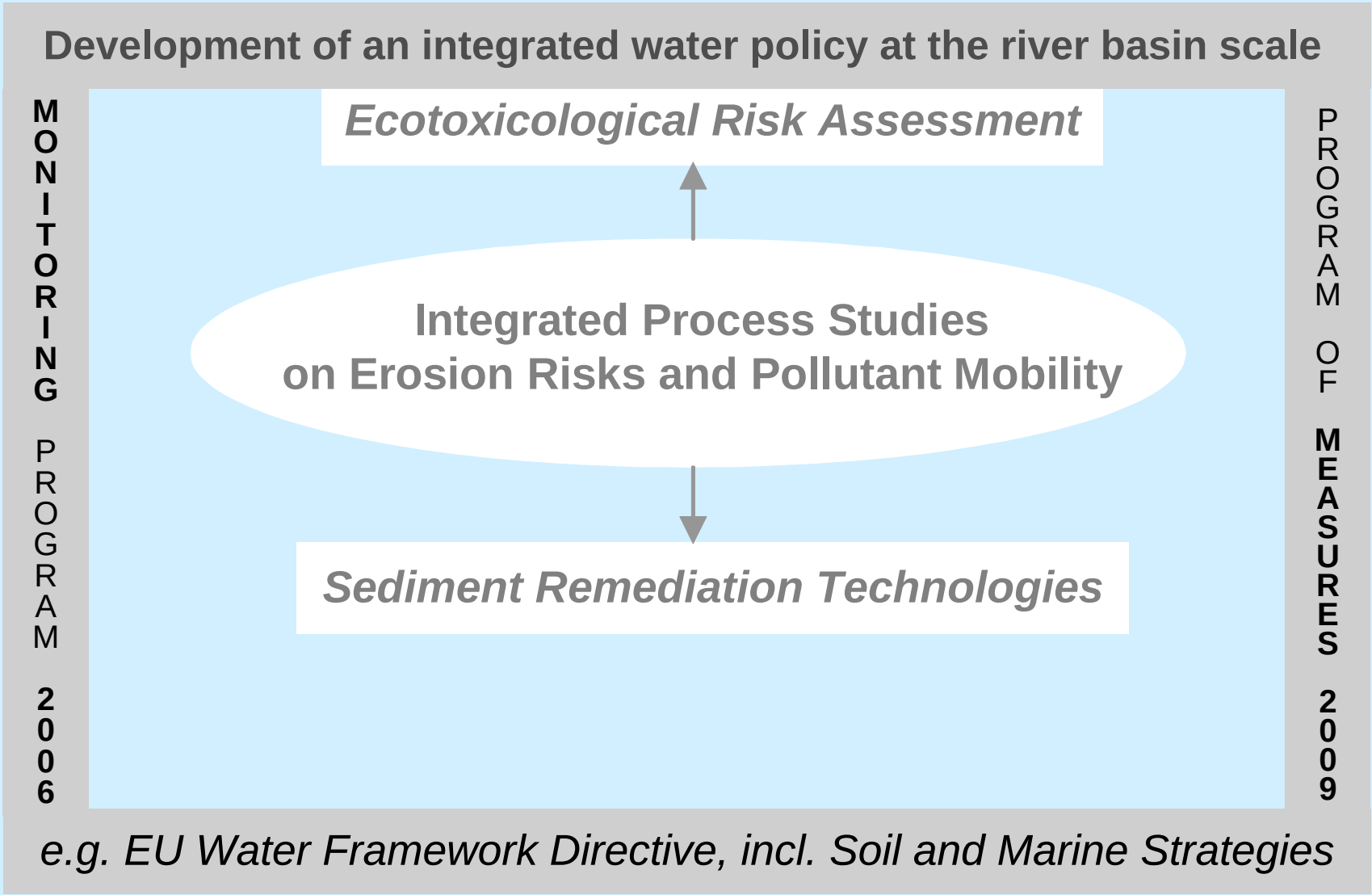
Thank you for your attention.

Co-workers of the studies:

Rhine [Heise et al, 2004]:
Ulrich Förstner
Thomas Jancke
Joachim Karnahl
Wim Salomons
Harald Schönberger
Bernhard Westrich

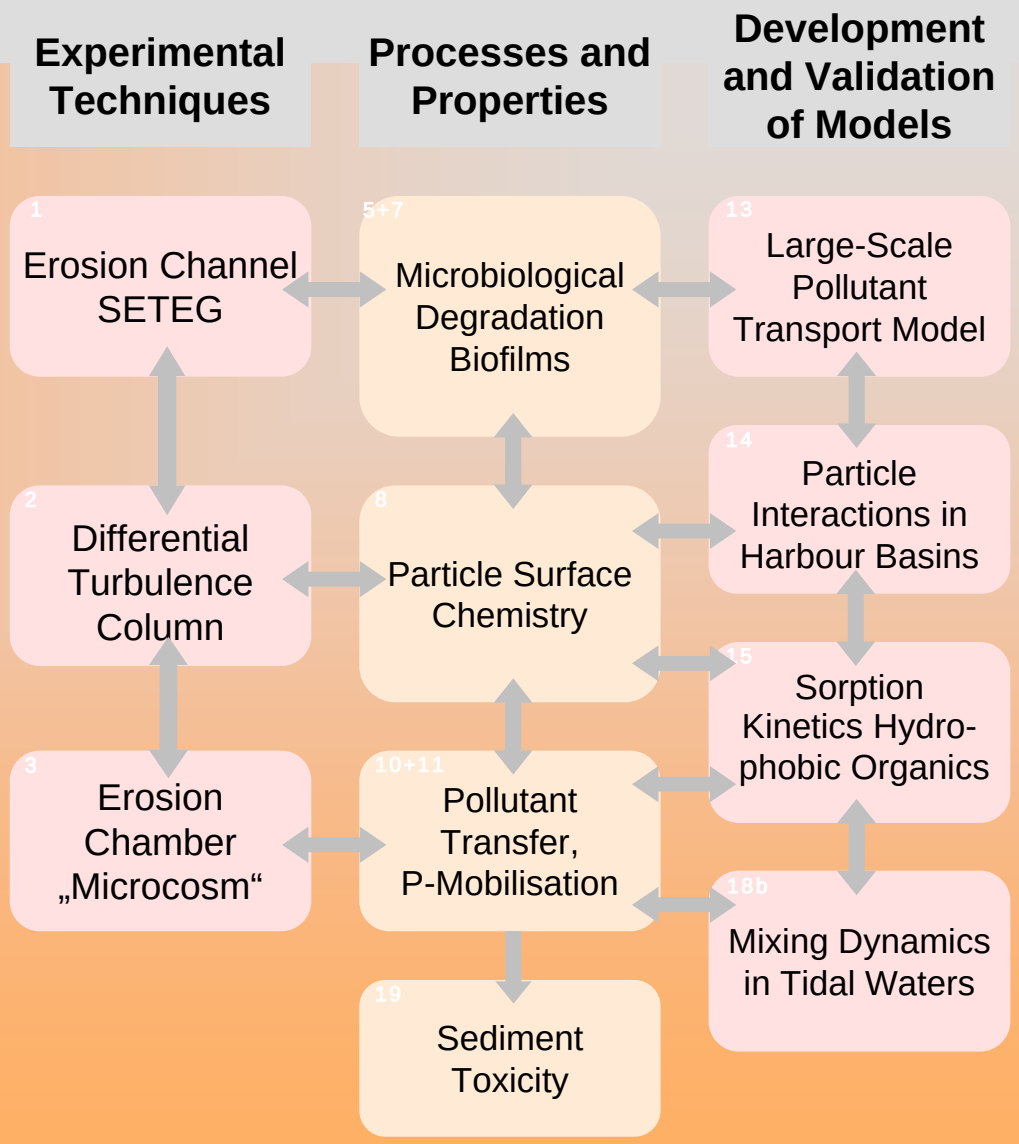
Elbe [Heise et al, 2006 & 2007]:
Evelyn Claus (BfG)
Ulrich Förstner (TUHH)
Peter Heininger (BfG)
Thomas Krämer (BfG)
Frank Krüger (Elana)
René Schwartz (TUHH)
& Martina Barborowski (UFZ)
& Daniel Schwandt (BfG)

Heise, S., & U. Förstner (in press). JEM. Manuscript available from authors

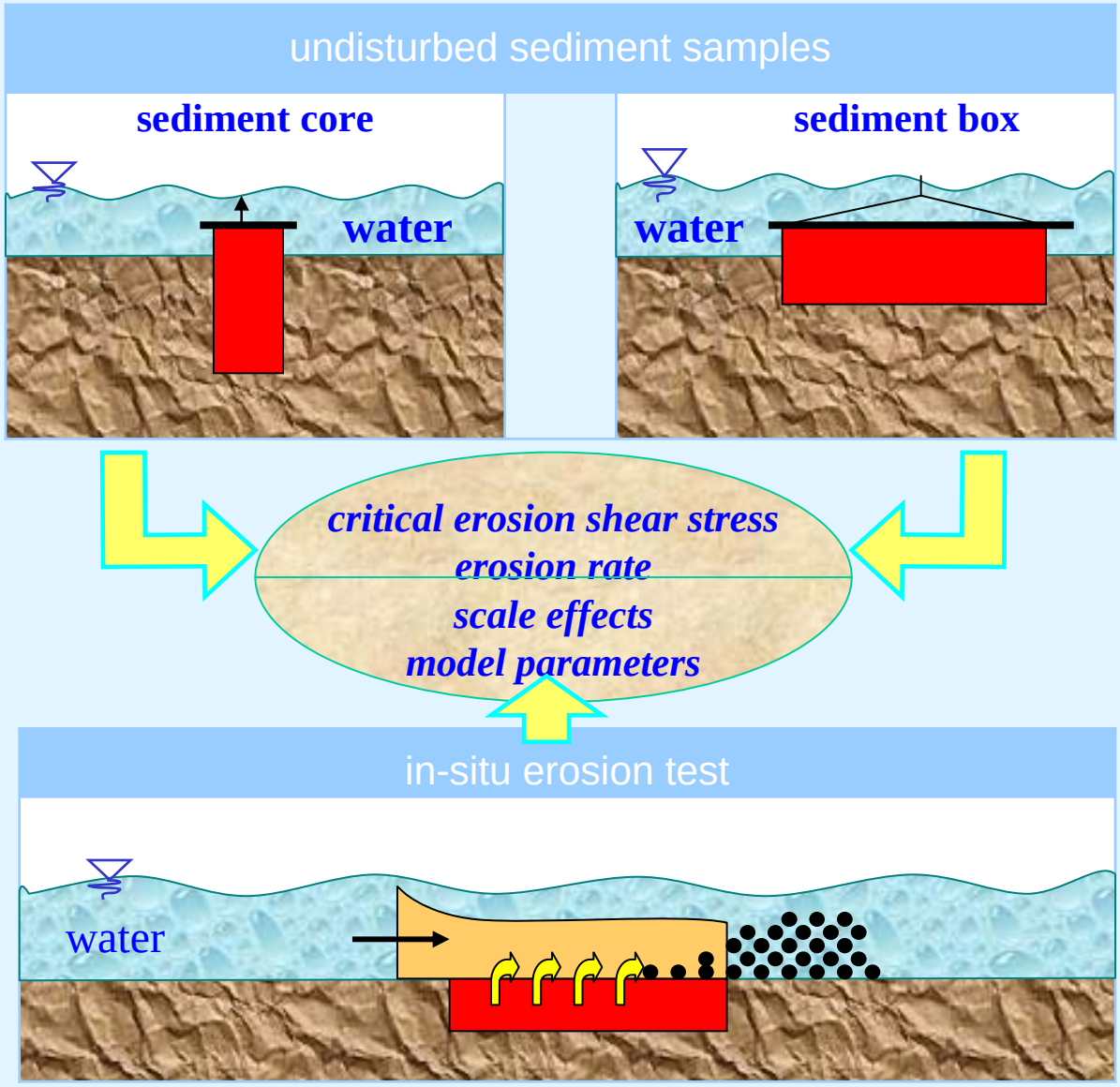

Development of an integrated water policy at the river basin scale
MONITORING PROGRAM 2006
Ecotoxicological Risk Assessment
Integrated Process Studies
on Erosion Risks and Pollutant Mobility
Sediment Remediation Technologies
PROGRAM OF MEASURES 2009
e.g. EU Water Framework Directive, incl. Soil and Marine Strategies

The joint research project **SEDYMO** (‘Sediment Dynamics and Pollutant Mobility in Rivers’) has been funded by the German Federal Ministry of Education and Research (**BMBF**) from 2002 to 2006.

Its interdisciplinary approach focused on the transport and release of nutrients or pollutants into the water phase due to hydrodynamic processes.



Combined laboratory and field testing for sediment erosion stability (B. Westrich)



Problems with data quality control in water and sediment quality assessment

Data quality control and quality assurance (QC/QA) is a complex activity in water quality assessments. Problem areas have been identified by the European thematic framework METROPOLIS, for example:

Lack of representativeness: data do not reflect the reality that we want to represent – are simply not fit for purpose.

A too **high level of uncertainty** associated with the data collected makes the process of decision-making critical (in some cases the uncertainty is not expressed at all!).

Traceability: This concept implies that measurement data are linked to stated references through an unbroken chain of comparison, all with stated uncertainties (e.g., *Philippe Quevauviller, Trends Anal Chem 23, 2004, pp. 217-236*).

Traceability in sediment sampling, sample preparation and analysis (Förstner 2004)

Surveillance Monitoring

Sampling

Dry Sample

Bulk Analysis

Grain Size Normalization

Standard scheme, ± unbroken chain.

Uncertainties: Low

In-Situ Sediment Characterization

Wet Sediment Sample

Measurement of pH and Eh

CEC ← Sub-sampling → AVS

Sub-sampling (anaerobic)

Porewater Extraction

Sequential Leaching

Selected chemical methods, interpretation by specialists.

Uncertainties: Intermediate

Spatial and Temporal Prognosis

Chemical Stability	Hydraulic Stability
Redox Processes	Erosion Processes
Buffer Capacity	Transport Models
Ageing Effects	Physical Effects

Extreme variations of water flow: Scenarios

Uncertainties: High

Particulate matter quality assessment in rivers (after Thomas & Meybeck 1992)

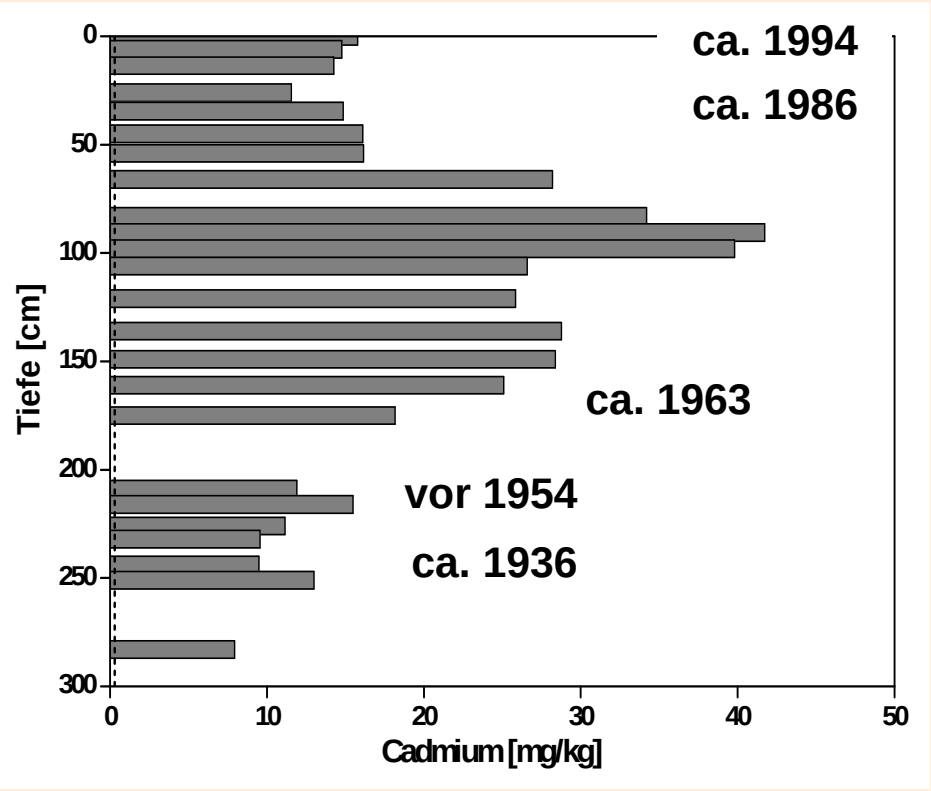
	Level A	Level B	Level C
Suspended matter (SPM)	Survey of SPM quantity through-out flood stage (when rising)	Survey of SPM quality at high flow (filtration or centrifugation)	Full cover of SPM quality throughout flood stage
Deposited sediment	Grab sample at station (end of low flow period)	Longitudinal profiles of grab samples (end of low flow period)	Cores at selected sites where conti-nuous sedimenta-tion is observed

Level A: simple monitoring, no requirement for special field and laboratory equipment

Level B: more advanced monitoring requiring special equipment and more manpower

Level C: specialised monitoring which can only be undertaken by fully trained and equipped teams of personal

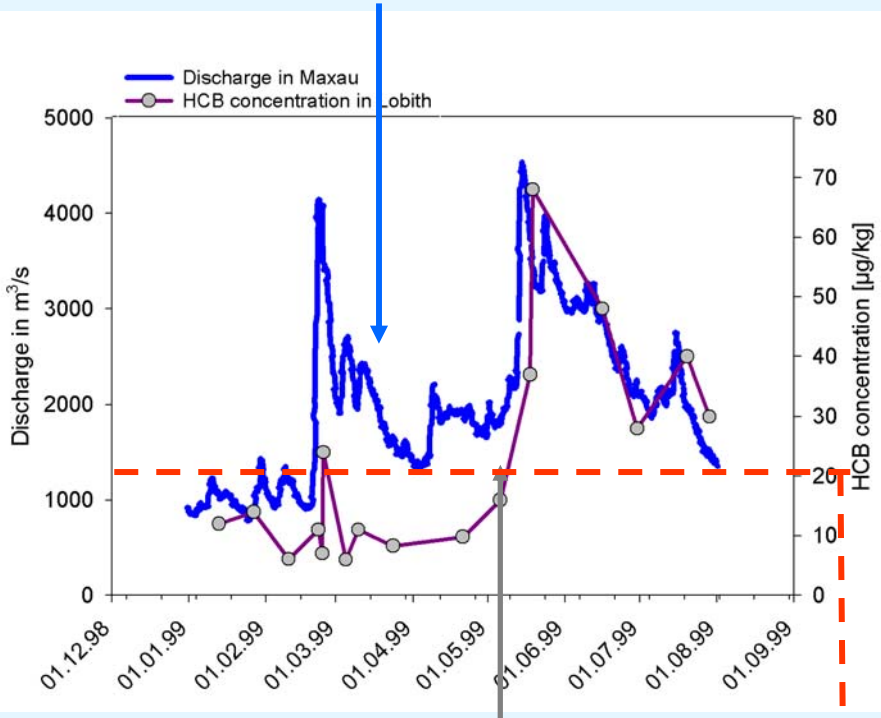
Progressive studies at sediments and suspended matter in Elbe and Rhine



Cadmium [mg/kg] in sediment coresim of Bucher Bracks (Elbe-km 376-385)

Data of fraction < 20 µm, after Prange et al. 1997, Forschungszentrum Geesthacht

Blue line: High water discharges at Maxau, Rhine-km 362.3, in 1999



HCB concentration (SPM) at the D / NL border (Lobith)

CTT-action level for relocation at land or sea. E.g. HCB = 20 µg/kg

Hexachlorobenzene in reservoirs of the High and Upper Rhine

Indication of sediment resuspension due to high water discharges

Discharge	Erosion-potential	Load increase	Risk to Rotterdam
BAU	+/-	+	Existing
> HQ_1	+	+++	Very high
> HQ_{10}	++		Very high
> HQ_{50}	+++		Very high

BAU = Business as usual; HQ_1, HQ_{10}, HQ_{50} = Frequency of discharge event in number of years,; +/- no significant effect, + low effect, ++ significant effect and +++ strong effect