Executive Summary

Sediments are an integral but ambiguous part of water systems. On the one hand they provide the substrate for organisms and through interaction with the overlying waters (e.g. nutrient cycling) play an essential role to the aquatic ecosystem. On the other hand, hazardous chemicals from various sources stick to the sediment, and even if water quality improves, sediment contamination will remain ("legacy of the past").

Today relatively uncontaminated sediment surface layers cover older contaminated sediments deposited in low flow area sites in the rivers, such as flood plains, river reservoirs, and groyne fields. Nevertheless, there is an increasing risk with increasing water discharge and frequency of flood events for the resuspension of old contaminated sediment layers and the transport of particle-bound contaminants downstream in the river system. Contaminated material can also be introduced to river systems from contaminated soil during surface run-off or erosion events. This report focuses on historic sediment contamination, terrestrial sites will only be dealt with to a minor extent.

In the scope of this project risks for the Port of Rotterdam were assessed arising from resuspension of historical sediment contamination upstream following natural events (e.g. floods) or anthropogenic activities (e.g. dredging activities).

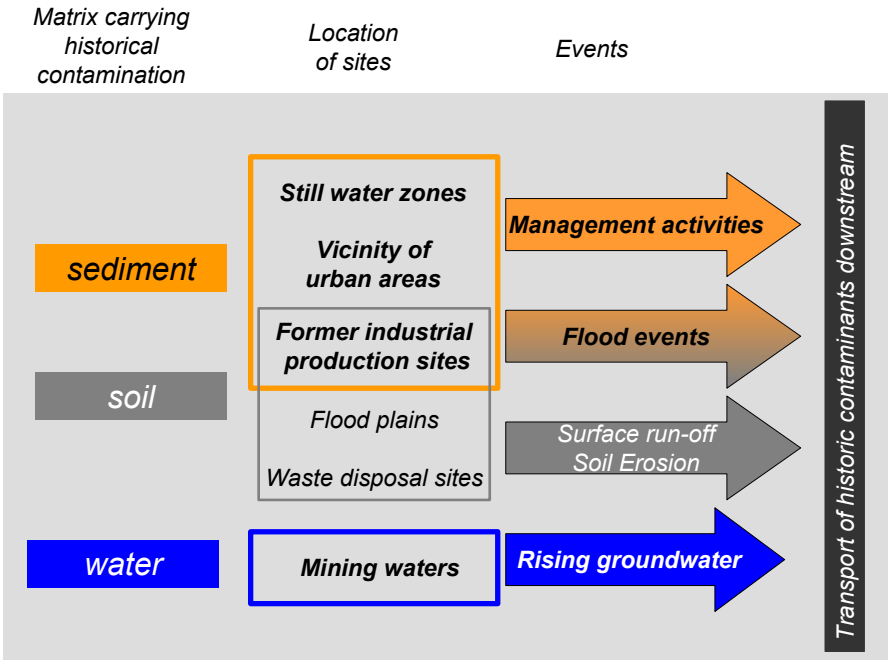

Figure ES.1 Pathways and processes for the transport of historic contamination downstream. Location of sites, that are of special importance in this report, are written in bold letters.

Until now, no comprehensive investigation on the current potentially buried sediment contamination in the river Rhine catchment had been performed nor has such a catchment wide assessment been carried out elsewhere. Hence a detailed review of relevant and scattered information was carried out as well as new conceptual approaches were developed.

Chapter 1 reviews the key processes controlling hydraulic and chemical mobilization as well as transfer of pollutants to organisms are described. Chapter 2 presents an overview on the requirements on sediment data quality, including strategies for water and sediment assessment as well as quality control of field and laboratory data. Quality requirements and uncertainties of hydraulic data, forming the key issue in the present study, are discussed. Chapter 3 summarizes recent developments in sediment management at the catchment scale. Information on chemical and biological sediment data from chapter 2 are discussed in relation to strategies for quality control in the analysis and monitoring of EU Water Framework Directive priority substances.

This extensive review shows gaps in knowledge on the potential impacts of high discharge on deposited sediments, making it necessary to develop a deductive approach. This approach comprises three steps (chapters 4 and 5).

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

Step 1. Selection of substances of concern.

Only those substances were chosen for further evaluation, that are of concern for the management of the Port of Rotterdam as they frequently exceed or reach the new Dutch "Chemistry –Toxicity Tests (CTT)-levels". These **substances of concern** were then assigned to different hazard classes according to a classification based on their behavior in the environment and the potential danger that they present for organisms.

Step 2. Selection of geographical areas of concern

In a second step, existing sediment analysis data from the last 10 years were used to identify those areas in the Rhine and its tributaries, which show increased concentrations of these substances of

concern above CTT level and therewith potentially provide a danger of increasing concentration levels at the Port of Rotterdam. These **areas of concern** (figure ES.2) are classified with regard to the quantity of contamination and available data to give an overview over the distribution of persisting hazards in sediments along the river Rhine. A survey on information about historic emissions follows in order to a) clarify the sources of the sediment contamination; b) validate the possibility of persisting contamination at these sites; c) gather information on management options due to the potential persistence of sources and the distribution of contamination.

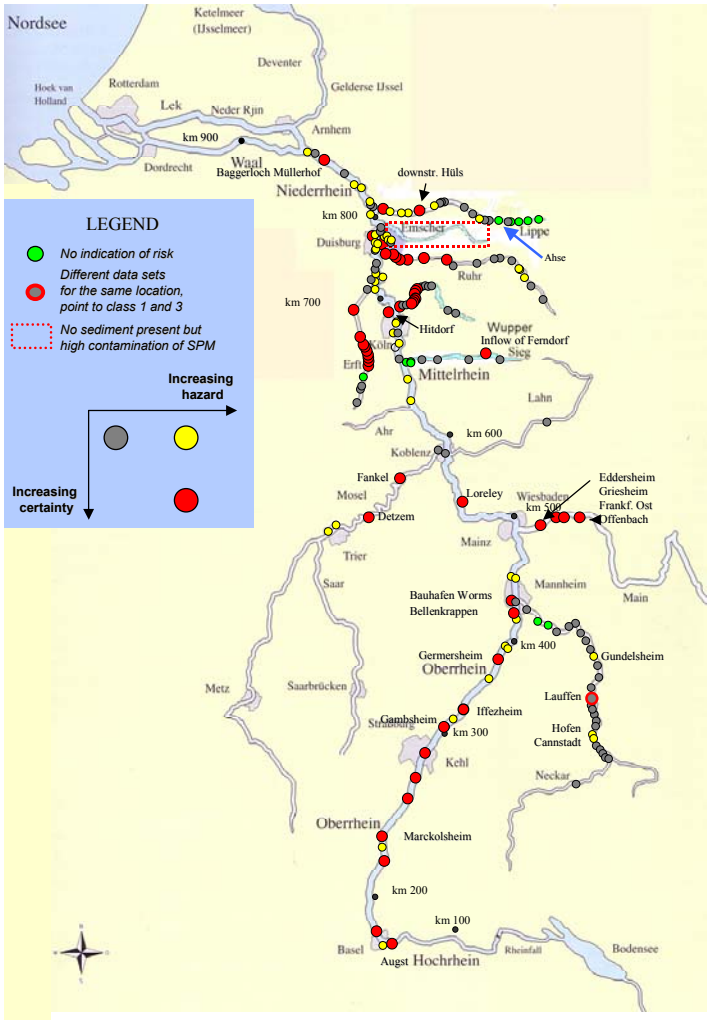

Figure ES.2 Areas of concern and their classification based on sediment contaminant concentrations

Step 3. Quantification of risk for the Port of Rotterdam

The risk assessment for the port sediments due to those "substances of concern" that could derive from the identified "areas of concern" required estimating the extent of contamination, erosion and subsequent transport in the catchment. Due to lack of data on flood events, suspended contaminant load, and models to achieve a complete and comprehensive picture of areas of risk, an approach was used, in which results were based on different lines of evidence: In order to assess, whether the extent of contamination was high enough to exceed the CTT threshold in the Port of Rotterdam, a "worst case approach" was used taking into account normal water flow, and subsequently addressing "average high water" and "highest water discharge observed". Furthermore it was assumed that suspended matter sediment concentrations are directly related to water flow resulting in concentrations of 20, 150 and 250 mg/l, that the whole sediment contamination at a specific site is transferred to the water phase, and that, sediment concentration equals the concentration of contaminants in the suspended material. In the port of Rotterdam no mixing with former deposited sediments was taken into account. Therewith CTT-values were directly compared with the calculated concentrations.

As a result of this final step, the number of "areas of concern" could be reduced from twelve to five:

1) The barrages in the Upper Rhine are the only ones, that may already present a risk during business as usual conditions (average water discharge, no management activities): Already at normal discharges, increased concentrations of hexachlorobenzene (HCB) have been measured in suspended matter at Iffezheim. With increasing discharges HCB (and possibly mercury) becomes resuspended and transported downstream. With the continuous inflow of contaminated sediments from the barrages further south, the existing sediment disposal sites reaching their upper limits, combined with still high HCB concentrations in the sediment and significant gaps in the understanding of its transport processes, this area becomes an important challenge for future sediment management.

2) The Ruhr currently represents a certain risk at increased water discharges. High concentrations of polycyclic aromatic hydrocarbons (PAHs) but also of the other substances that are of concern in that river, especially cadmium, are likely to be resuspended and transported downstream. It should be noted that there are a number of management projects initiated in the Ruhr, which may positively affect (decrease) the contaminant contribution of this river to the Rhine.

3) The Neckar may also represent a risk. A resuspension of cadmium in the barrage Lauffen has been predicted due to its low sediment stability, and increases in cadmium concentration in suspended matter at this site have been measured. However, whether this load arrives at the Rhine after passing 13 more barrages, is uncertain due to missing data during flood events from the measuring station Feudenheim near Mannheim, the last barrage before the Neckar reaches the Rhine. However, no cadmium source could be identified other than the Neckar that could account for the observed cadmiumloads of more than 1000 mg/s at stations Koblenz (Rhine) and Bad Honnef.

4) Evidence of a risk from old contamination in the Wupper is derived from a comparison of contamination patterns of this tributary's sediments with those of the harbours in the Lower Rhine (downstream of the Wupper confluence) and here especially the monitoring station Hitdorf-Harbour. All show a similar contamination pattern, suggesting an influence of the Wupper's effluents on the Rhine sediments. However, available information is insufficient to determine whether this material is likely to be transported further downstream as the erosion thresholds of the sediments in these harbours are unknown.

5) There is some indication that the Lippe may contribute to the HCB load in the Rhine under high water situations. If the crest of the flood wave reaches the Rhine before the flood of the main river arrives, dilution of suspended matter from the Lippe may even be that low, that its contaminated suspended material could lead to an increase in the HCB concentration in the Port of Rotterdam. The latter case shows the complexity of making predictions in view of the inherent variability in discharge regimes in the Rhine catchment.

A review of the current regulations (chapter 3) showed that erosion of contaminated sediments and their potential impacts downstream and subsequently in deltaic and coastal regions is not covered by existing regulations. Existing regulations are focused on local impacts of the relocation of contaminated sediments and do not take the whole catchment into account. On the other hand, the Water Framework Directive, which focuses on the catchment scale, does not explicitly mention sediments nor sediment quality and quantity. However, the strategies against chemical pollution of surface

waters (WFD article 16), i.e. implementation of monitoring programs until 2006 and establishment of the program of measures until 2009, have to consider sediment quality at the catchment scale. With respect to the latter date, already the first step – screening of all generic sources that can result in releases of priority substances and priority hazardous substances – will include the specific source/-pathway "historical contamination from sediment".