Guidance Document for Sediment Assessment

Methods to determine to what extent the realization of water quality objectives of a water system is impeded by contaminated sediments

Date	4 November 2010
Status	Approved by DWO

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Authors:
J.A. Hin (Rijkswaterstaat Centre for Water Management)
L.A. Osté (Deltares)
C.A. Schmidt (Rijkswaterstaat Centre for Water Management)

Colophon

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Executive summary

Main message

- Sediment management has changed fundamentally under the Dutch Water Act. Sediment is considered an integral part of the water system.
- The Guidance Document for Sediment Assessment is a technical planning tool to determine whether the sediment impedes the realization of water system quality objectives.
- The result of the assessment is used in the regional planning process for comparison of the most cost-effective measures to realize the water system objectives.
- The use of the Guidance Document for sediment assessment is not mandatory.

Motivation

On 22 December 2009 the Dutch Water Act came into force. Since then the remediation section of the Dutch Soil Protection Act is not applicable to sediments anymore. With this change, sediment quality in itself is no longer an objective as was the case under the Dutch Soil Protection Act. Sediment management is now regulated starting from the water system management, in which sediment is considered an integral part of the water system.

In the Dutch Implementation Act regarding the Water Act, the development of an assessment framework is announced with which one can determine whether the sediment impedes the realization of a certain chemical and ecological quality, as part of the regional quality as a whole (objectives defined in the regional planning process). This Guidance Document is the implementation of this assessment framework.

Elaboration of the assessment framework into a guidance document

The guidance document is a technical tool to determine whether and to what extent quality objectives for the water system are not achieved as a result of the presence of xenobiotic substances and nutrients in the sediment. This involves both general environmental quality standards, such as the objectives of the Water Framework Directive and quality objectives that originate from water functions. These water functions are assigned in the National Water Plan, the regional water plans and - insofar as the afore-mentioned plans allow for it - the State and water board management plans. Other planning processes in which sediments can play a part include planning processes for spatial development, nature management plans (Natura2000 areas) and municipal water plans.
The guidance document is primarily intended for the regional planning processes in the build-up to the second and next generation(s) of river basin management plans and the water authority management plans. Within the regional planning process possible measures are assessed with respect to their (cost-)effectiveness and public relevance. In this process all relationships between the different aspects of the water system are considered.

Within the regional planning process three situations can occur that give rise to the use of the guidance document:

- Water Framework Directive (WFD) monitoring shows that chemical or ecological WFD objectives for good surface water quality are not met.
- Quality objectives for surface waters that are not classified as WFD bodies of surface water are not met (for instance ponds, ditches, city canals).
- Quality objectives and standards based on the surface water functions are not met.

The guidance document for sediment assessment is a guidance document for the planning process. The guidance document is neither intended nor suitable as assessment framework for issuing permits for physical interventions in the water system.
For issuing permits in both national and regional waters, water quality assessment frameworks are developed.

Structure of the guidance document
Sediment assessment in accordance with the guidance document starts with listing the quality objectives that are at issue in the water system. Next, it is determined for which objectives and standards the effects of the sediment have to be assessed. This involves the chemical and ecological objectives for bodies of surface water as laid down in the Dutch Decree on Quality Requirements and Monitoring in Water 2009 and the Dutch Ministerial Monitoring Regulation. Furthermore, it may involve standards for agricultural and fishery products and other human risk limits that stem from the use of the body of surface water.

The assessment uses the results of an exploratory sediment survey. Flowcharts clearly depict the various steps to be followed. The assessment results in an appraisal of the contribution of the sediment to the fact that quality objectives are not met.

The selected default methods are easy to use. The competent water authority, an engineering firm or a consultancy can perform the sediment assessment with the support of a certified laboratory. In addition to the default methods, the guidance document presents specialistic methods for specific situations. These can be used by or supported by knowledge institutes or other specialists. The use of specialistic methods is recommended in the case of substances with unknown or complex environmental behaviour, if a decision on a physical intervention in the sediment has large financial consequences, or if extra certainty with respect to the effects of the sediment is needed for other reasons.

Feasibility test
Rijkswaterstaat and the Union of Water boards have conducted a feasibility test on the guidance document. As a result of this, it has been made more clear when and how the guidance document should be used. The role of the guidance document in the planning process, the legal obligations of the competent water authorities and the coordination with other laws (such as the Dutch Soil Protection Act and the Dutch Soil Quality Decree) have been clarified. The guidance document for sediment assessment is therefore ready to use.

Contents

1 Introduction

1.1 Background

Under the Dutch Water Act sediment management is regulated starting from managing the water system, of which sediment is considered an integral part. In accordance with chapter 5, section 3 of the Water Act, the concept of 'regional quality' is applied in assessing sediments. The concept of regional quality aims at the intended functions and goals for a region, that are formulated together with the stakeholders within the framework of the regional planning process and that are laid down in water plans. Regional quality for the water system involves safety, water quantity and water quality.

Functions and goals for the water systems are assigned in the National Water Plan, the regional water plans and - insofar as the afore-mentioned plans allow for it - the State and water board management plans. Other planning processes in which sediments can play a role include planning processes for spatial development, for nature in Natura2000 areas (nature management plans) and for municipal water management (municipal water management plans). The measures resulting from the last mentioned planning processes are partly input for the water plans.

By testing compliance against the WFD standards and standards based on the water functions, the competent water authority determines whether the water system 'is in order', i.e. has good surface water status. If this is not the case, the competent water authority evaluates, together with the stakeholders in the regional planning process, which factors contribute to this non-compliance. Based on this evaluation, possible measures are assessed within the regional planning process with respect to their (cost-) effectiveness and public relevance. In this process all relationships between the different aspects of the water system are considered. If measures to achieve the intended objectives are technically not feasible or disproportionately costly, it can be decided in the regional planning process to explore the possibilities of changing the water functions, of postponing the achievement of the objectives or of lowering the objectives. The water functions and objectives and the eventual set of measures are incorporated in the water (management) plan.

In case the water system is not in order with respect to the quality objectives, the possible causes are described within the framework of the planning process. In the Implementation Act regarding the Water Act, the development of an assessment framework is announced with which one can determine whether the sediment impedes the realization of a certain chemical and ecological quality, as part of the regional quality as a whole. The document at hand, in the form of a guidance document, is the implementation of this assessment framework.

1.2 Purpose of the guidance document

Tool for water authorities and other stakeholders in the regional planning process
The Water Act does not contain any direct legal obligations to conduct research or to take measures with respect to the sediment. The legal obligations for the water authorities that follow from the Water Act with respect to sediments, aim at achieving the water quality objectives and standards for the water system. The guidance document is not limited to legal standards relevant to the competent water authorities but also offers the possibility to determine the effects of the sediment on legal standards and risk limits relevant to other parties. In this way the guidance document offers support to the regional planning processes in water management.

It is obvious that the competent water authorities only use the guidance document for their legal obligations. In §2.7 an overview of the water functions that come up in this guidance document and of the attributed legal responsibilities, is presented.

Technical tool for assessing the effects of substances
The guidance document is a technical tool. With this tool it can be determined whether and to what extent quality objectives are not achieved as a result of the presence of xenobiotic substances and nutrients in the sediment. For this purpose the guidance document contains methods that calculate the effects of substances in the sediment with respect to the quality standards.

The guidance document is therefore restricted to the effects of substances. The guidance document does not contain methods to determine the effects of physical factors, such as oxygen content, transparency, hydromorphology and type of substrate on objectives.

Tool for the benefit of the planning process
The guidance document is a tool for the benefit of the planning process. Within the regional planning process three situations are distinguished that give rise to the use of the guidance document:

- Water Framework Directive (WFD) monitoring shows that chemical or ecological WFD objectives for surface water or groundwater are not met.
- Quality objectives for surface waters that are not classified as WFD bodies of surface water[1] are not met (for instance ponds, ditches, city canals).
- Quality objectives or standards based on the surface water functions are not met.

The competent water authority can use the results of applying the guidance document in order to assess whether a measure involving the sediment will be entered in the programme of measures of the second generation of river basin management plans (2016-2021) and next generations of management plans (see figure 1.1).
This assessment is based on (cost-)effectiveness and public relevance.

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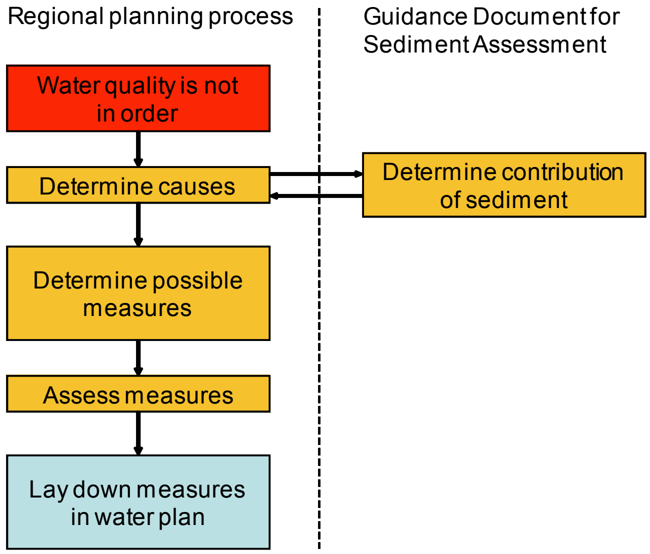
[1] The definition of a body of surface water in the Dutch Water Act is different from the definition in the European Water Framework Directive (see Glossary, Annex L). In this document 'body of surface water' refers to the definition in the Water Act, unless it is specifically mentioned that a WFD body of surface water is meant.

Possible measures include physical interventions in the sediment but also the (more detailed) study of the effects of the sediment can be included as measure in the management plan.

Figure 1.1
The role of the guidance document in water management



1.3 Starting points of the assessment

In this guidance document two starting points with respect to assessing the sediment[2] are distinguished: water quality as starting point and sediment quality as starting point (see figure 1.2).

Water quality as starting point
This is the default starting point of the guidance document. This starting point is used if monitoring shows that a standard has been exceeded.
Water quality as starting point can be used both for waters that fall within the scope of the Water Framework Directive (WFD waters) and for waters not classified as WFD bodies of surface water.

Sediment quality as starting point
This starting point can be used for surface waters where no monitoring occurs with respect to applicable local water system functions and objectives. This may be the case in waters not classified as WFD bodies of surface water. The fact that a certain objective may be at issue and that contaminated sediment is known to exist is a motive to use the guidance document with sediment quality as starting point.

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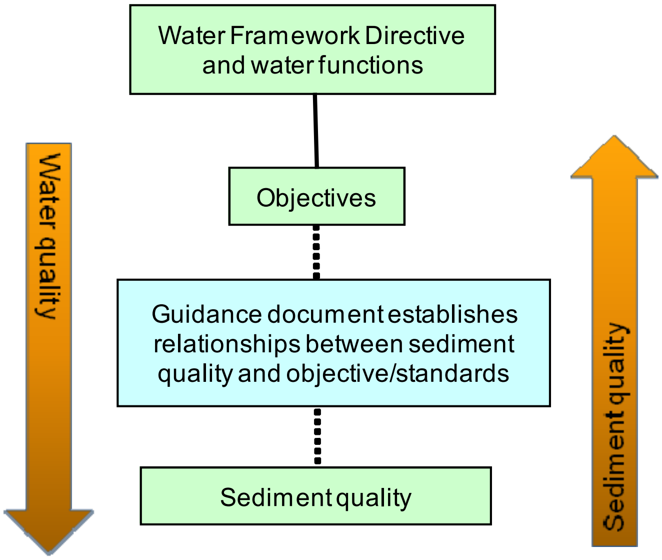
[2] This guidance document relates to both sediments at the bottom of surface waters and sediments in banks, water meadows, shores etc. The term 'sediment' includes both.

Figure 1.2
Starting points in assessing the sediment according to the guidance document: (1) the quality objectives or standards are not met or (2) suspicion that quality objectives or standards are not met and the sediment is contaminated.



Differences in procedure between both starting points
The starting points water quality and sediment quality both demand a different procedure in assessing to what extent the sediment contributes to not achieving the intended objectives.
With water quality as starting point it is first examined whether the sediment can potentially be partly responsible for not achieving the objectives or standards. If this is the case, data from an exploratory sediment survey are needed for further assessment. These sediment data are supplemented with other data concerning the characteristics of the location in order to determine to what extent the sediment contributes to the established exceeding of the standard.

Starting from sediment quality, the results from an exploratory sediment survey are the basis for the assessment. The guidance document is then first used to calculate if exceeding of the standards is possible in the local situation. If this is the case, the competent water authority can decide to check this by starting to monitor the (potentially) standard exceeding parameters. Similar to starting the assessment from water quality, the contribution of the sediment to the established exceeding of the standard is calculated.

1.4 Restrictions to the scope of this guidance document

1.4.1 Not intended for beneficial use of dredged material

This guidance document is meant for the planning process and for in situ sediments. The guidance document is not intended for the assessment of relocating or using dredged material in the water system, where the dredged material becomes sediment again.

1.4.2 Not intended for assessing physical interventions

The guidance document is not intended for defining the boundaries (in three dimensions) of contaminated sediments for the purpose of sediment remediation.

Besides a physical intervention due to contaminated sediment, an (already well-defined) physical intervention in the sediment for the purpose of maintenance of a watercourse or renovation of a region can be planned. The 'new sediment' that forms the new top layer after such physical interventions, can have a positive or negative effect (compared to the original sediment) on achieving the objectives and the intended functions in the region. A physical intervention can potentially also affect downstream waters. This guidance document has not been developed to assess the effects of potential and already well-defined physical interventions in the sediment on objectives and functions.

1.4.3 *Not for the purpose of issuing permits*

A physical intervention in water bodies as a consequence of a contamination as well as physical interventions for reasons of spatial renovation can, under Dutch law, be considered as the construction of a hydraulic engineering work. If the competent water authority itself carries out the construction, obtaining a permit is not required. In that case a project design suffices. If third parties carry out the construction, a permit is required. Due to the Water Framework Directive, both the project design and the permit require that it is assessed whether the physical intervention leads to deterioration with respect to the Water Framework Directive objectives. This assessment must be done with the water quality assessment frameworks for national and regional waters (see www.helpdeskwater.nl) – and therefore not with this guidance document. It is recommended to take this into account when planning physical interventions by examining the quality of the sediment that becomes the top layer after the physical intervention.

The water quality assessment frameworks for national and regional waters are developed for physical interventions in WFD-waters. The assessment frameworks are not applicable for measures that are included in the WFD management plan and neither for measures focussed at the water functions. It is emphasized that this 'Guidance document for Sediment Assessment' does not rectify these deficiencies. This guidance document is neither intended nor suitable for assessing the effects of physical sediment interventions for the purpose of issuing permits.

1.4.4 *Geographical scope*

The guidance document involves the sediment and banks and shores of bodies of surface water as defined in the Water Act. This includes sediments of water meadows, forelands, (parts of) brook valleys, salt marshes, mud flats and tidal marshes. The concept of body of surface water (Water Act definition) includes, besides sediment and bank/shore areas, also a category of 'dryer banks and shores'. Dryer banks and shores only exist insofar as they are specifically designated under the Water Decree or the Water Regulations (see www.waterwet.nl for representation of the areas on a map) or under a provincial act (for regional waters). These designated areas remain part of the body of surface water, but fall under the systematics of the Dutch Soil Protection Act. The guidance document is not applicable to the dryer banks and shores.

1.4.5 *Concurrence with adjoining contaminated terrestrial soil*

The Dutch Soil Protection Act (Wbb) distinguishes cases of heavily contaminated terrestrial soils. A case of heavily contaminated soil like this can extend over both terrestrial soil and the sediment or bank/shore area of a body of surface water. If prompt remediation is necessary and the source of the cross-boundary contamination lies in the terrestrial soil, the entire contaminated site must be treated according to the systematics of the Soil Protection Act (article 63c Wbb). This guidance document is not applicable in cases like this.

If the source of the contamination lies in the body of surface water but also extends to the terrestrial soil, the treatment of the soil contamination falls under the Water Act (article 5.17 Water Act). This means that handling the terrestrial part of the contamination does not fall under the Soil Protection Act.

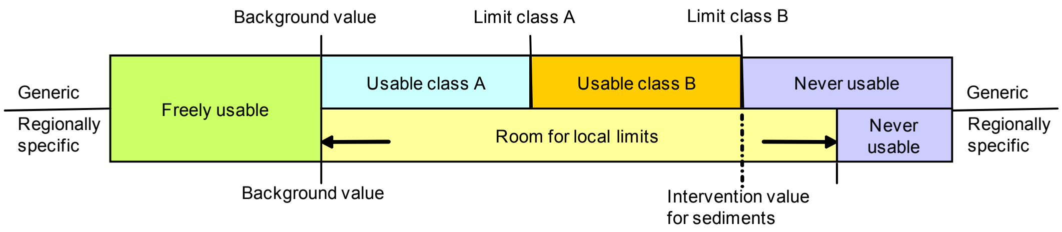
1.4.6 Contamination caused by a calamity

The guidance document is not suitable for situations in which sediment contamination is being caused or has been caused by a calamity and in which immediate action is necessary in order to prevent further negative environmental effects due to the contamination. In a situation like this an assessment in accordance with the guidance document takes too much time. If the pollutor is known, contaminations caused by calamities can be handled under the provisions of the Water Act based on the principle of a general duty of care for the environment. In other cases the regulation for unusual incidents is applicable.

1.5 Relation with the Soil Quality Decree

If measures to improve sediment quality are considered, one must take into account the rules for relocating and using dredged material in water systems. These rules are laid down in the Dutch Soil Quality Decree. The Soil Quality Decree distinguishes between a generic and a regionally specific framework. The generic framework sets quality criteria for the use and relocation of dredged material. Figure 1.3 shows the quality criteria for the use of dredged material. The competent water authority can decide on a regionally specific policy including 'local limits' for the relocation or use of dredged material that are higher or lower than the limit for class B material. A precondition for regionally specific policy is that the sediment quality on a regional scale may not deteriorate. Furthermore the limit for relocation in freshwater systems is not allowed to exceed the intervention value and in saltwater systems the 'limit for relocation in saltwater' may not be exceeded.

Figure 1.3
Limits of Soil Quality Decree for use of soil and dredged material in surface waters



In using the guidance document starting from water quality (see §1.4) it can turn out that specific sediments with a quality below:

- the limit for use (class A or B) or
- the limit for relocation in freshwater or saltwater,

still impede the quality objectives for the water system. In a case like this, the competent water authority, when comparing measures, has to consider the necessity to make local policy more stringent. The competent water authority can decide on a regionally specific policy with 'local limits' for relocation or use of dredged material that are more strict than within the generic framework.
For that matter, water authorities can also lay down 'limits' in policy guidelines based on the duty of care for the environment, for example to prevent the use of nutrient rich (eutrophic) dredged material.

Contrary, the use of the guidance document can give indications that the generic policy offers more protection than necessary for achieving the objectives. This might be a motive for the competent water authority to decide on a regionally specific policy containing less strict limits for the use of dredged material than in the generic policy.

1.6 Spatial scale and results of the assessment

The spatial scale of the area for which the effects of the sediment are assessed depends on the objectives that are considered. The effects of the sediment have to be assessed on each individual objective's own appropriate spatial scale.

The guidance document presents methods for the assessment of areas of approximately equal sediment quality. The assessment area has to be divided into subsectors if there are:

- Differences in sediment quality in different parts of the assessed area.
- Differences in properties of the water system that have influence on the effects of the sediment. The methods presented in this guidance document indicate whether relevant differences in properties exist.

The guidance document is used to assess each subsector separately. The results for a subsector have to be converted by the user of the guidance document to the appropriate spatial scale of the considered water function or objective. This may concern a body of surface water but also a designated nature reserve or a fishing or recreational area.

After translation to the appropriate spatial scale, the factor sediment can be compared within the regional planning process to other factors that affect the achievement of the objectives of interest. The results of the assessment therefore have to be interpreted and described in such a way that they can be used in the (regional) planning process by non-sediment experts for assessing measures. In water management, but also in for example nature management, regional planning processes act on different spatial scales. In water management plans, measures that are derived in various regional planning processes and on different spatial scales are geared to one another.

In order to allow comparison with other factors within the regional planning process, the types of information from the various factors have to be brought into line with each other. In this guidance document the effects of sediment on chemical objectives are therefore expressed in terms of source strength (g/m^2/year). Besides, to enable direct comparison with standards, it is indicated how the contribution to exceeding the standard can be quantified. When using the calculated source strength and contribution to exceeding the standard, one should take into account a margin of uncertainty. For the ecological objectives (ecological metrics), the impact of the different factors, among which the sediment, is harder to quantify than for the chemical objectives. Therefore, this guidance document estimates the effect of pollutants in the sediment on the (multi)metric score.

1.7 Assessment of bank/shore areas

Bank/shore areas are periodically flooded and run dry the remainder of time. During longer dry periods, substances behave in a different way than during permanent flooding. In addition to this, other objectives are at issue in bank/shore areas. Therefore, this guidance document contains separate methods for bank/shore areas.

When using the guidance document, the competent water authority determines the boundary between bank/shore and bottom of a body of surface water on the basis of the functions and objectives that are at issue in the area. In case of the function ‘nature’, parts of the area can have the character of a bank/shore area (terrestrial environment), whereas other parts of the area are permanently flooded (aquatic environment). In that case the boundary of the bank/shore area must be drawn on the basis of the existing vegetation.

Bank/shore areas can directly border on ‘dryer banks and shores’ that are considered terrestrial soil and to which this guidance document is not applicable (see §1.4.3). Terrestrial soils are assessed according to the rules of the Dutch Soil Protection Act (Wbb), in which it is determined whether unacceptable risks exist for humans, the ecosystem or further transport to groundwater or surface water. If unacceptable risks exist, there is a legal obligation for prompt remediation. Under the Water Act there are no legal criteria for physical sediment interventions. Based on the effects on the water system objectives, it is assessed whether a measure is (cost-)effective and publicly relevant.

On both sides of the boundary between bank/shore areas and ‘dryer banks and shores’, the sediment can be similar with respect to contamination and other properties. The policy in this situation is that the rules of both the Soil Protection Act (Wbb) and the guidance document arrive at similar conclusions. Therefore, the technical content of this guidance document is in keeping with the Wbb rules as much as possible for the functions in bank/shore areas (nature, agriculture and recreation). The main difference between Wbb rules and the guidance document is that Wbb criteria, such as the criteria for unacceptable risks, are not applicable in bank/shore areas. The assessment with respect to the function ‘nature’ in this guidance document is based on the Wbb rules for assessing the risks for the ecosystem. The assessment with respect to the functions ‘agriculture’ and ‘recreation’ is based on the Wbb rules for assessing the risks for humans. With respect to the function ‘recreation’ the guidance document aims at the exposure of the most vulnerable group of people, being playing children. For the assessment of effects on the groundwater, the guidance document also uses aspects of the technical content of the Wbb rules.

In bank/shore areas no regular monitoring takes place, the results of which could be used to test against objectives and standards that are linked with the functions that are potentially present. One motive to use the guidance document for bank/shore areas is a suspicion that objectives with respect to a function are not met and that contaminated sediment is present.

1.8 Default methods and specialistic methods

The assessment of the effects of xenobiotic substances and nutrients in the sediment on various chemical and ecological water system objectives is complex. In this guidance document default methods and techniqus have been selected that are easy to use. The purpose of this choice is that the competent water authority, an engineering firm or a consultancy can perform the sediment assessment with the support of a certified laboratory.

In addition to the default methods, the guidance document presents specialistic methods for specific situations in boxed text sections. The specialistic methods are not elaborated in this guidance document. Generally, the use of specialistic methods is recommended in the following situations:
- If substances with complex environmental behaviour (mercury, tributyltin, dioxins) are present or if the calculation tool associated with the default methods (SEDIAS, see §1.9.3) does not contain data with respect to the environmental behaviour of the substance;
- On large sites where a decision on a physical intervention in the sediment has large financial consequences;
- If other reasons call for extra certainty with respect to the effects of the sediment.

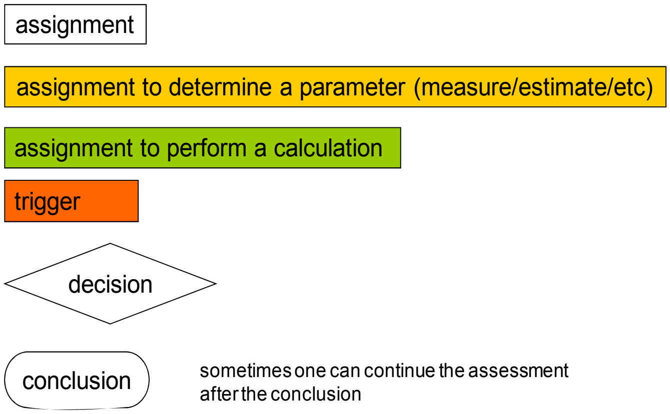
If specialistic methods are used, it is advised that a knowledge institute or an experienced expert of an engineering firm or a consultancy with a comparable level of knowledge performs the assessment.
It is further advised to have the quality assured by an (internal or external) independent expert who assesses both the Action Plan and the reported results.

The default methods and the choices made with respect to default parameter values and criteria are described in a technical background document to this guidance document (Osté, 2011). In this background document the specialistic methods are also somewhat more elaborated.

1.9 Directions for use

1.9.1 Explanation flowcharts

In this guidance document flowcharts are presented for illustrative purposes. The symbols and colours used in the flowcharts are presented in figure 1.4.



sometimes one can continue the assessment after the conclusion

Figure 1.4
Explanation of the use of colours and symbols in the flowcharts

In yellow boxed text sections, specialistic methods are mentioned, including specific reasons to use these.

In blue boxed text sections, background information, examples and explanatory illustrations are presented.

1.9.2 *Flowchart for assessing sediment according to the guidance document*

The use of this guidance document is illustrated step by step in figure 1.5.

Exceeding a standard in water quality management

If it is established or suspected within water quality management that a standard has been exceeded (see §1.3), this is a motive to use this guidance document. This may be a legal standard, but also a human risk limit.
If a standard is exceeded, not only the effects of substances in the sediment are examined, but also other possible causes. Local or upstream sources (‘external sources’) can also (partially) be responsible for exceeding the standard. Further possible causes for not achieving ecological objectives include physical factors, such as oxygen content, transparency, hydromorphology and type of substrate. The study of external sources and physical factors fall beyond the scope of this guidance document.

Have external sources and physical factors sufficiently been dealt with?

Often it is already known that external sources and physical factors are important causes for exceeding the standard. Studying and tackling these external sources and physical factors usually have priority over determining the effects of sediment on exceeding the standard. An indication that external sources have insufficiently been dealt with, is for example the fact that the same substance also exceeds the standard in upstream waters. In that case a (local) physical intervention in the sediment is not an effective measure. Moreover, recontamination after the intervention could lead to the original pollution level if external sources are not dealt with.

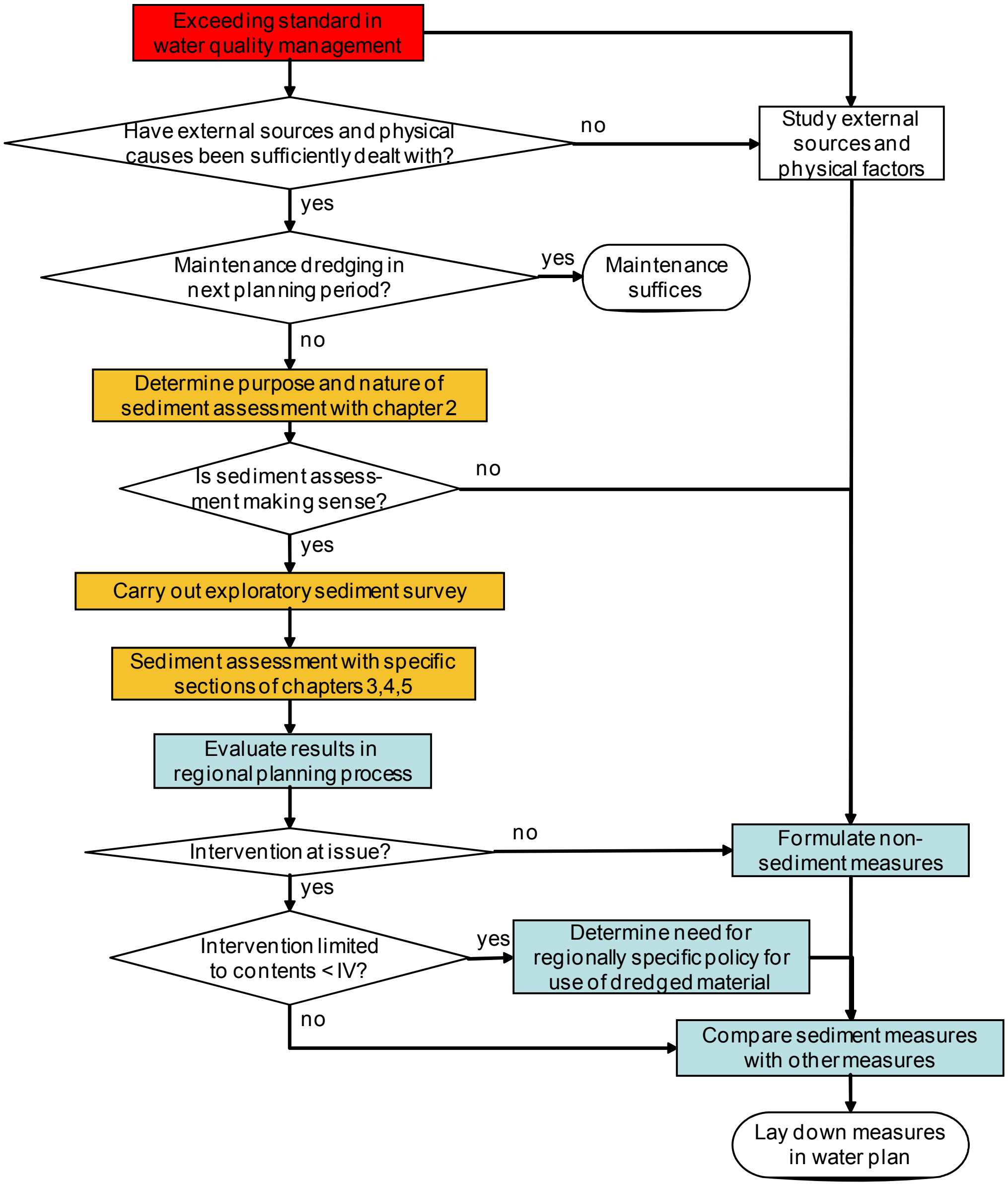
Is maintenance planned in the next planning period?
Many waterways are kept at a certain depth by (maintenance) dredging for the benefit of shipping or water discharge. Due to the fact that the in situ sediment is going to be removed, it is usually not making sense to assess the sediment with help of the guidance document. One reason to use the guidance document in such a situation nonetheless, may be that the cause of exceeding the standard has to be established in order to exclude other (unknown) causes.

If it is known that after dredging the ‘new’ sediment has a negative effect on water quality, one might consider dredging deeper than the planned maintenance requires, in order to remove the entire contaminated sediment. A more pronounced exceeding of standards in the surface water after maintenance dredging has been carried out, is an indication that the new sediment has an undesired effect on the surface water quality. This guidance document has not been developed to predict the effects of ‘new sediments’.

Determine purpose and character of sediment assessment with chapter 2
In chapter 2 an overview is presented of functions and objectives that can be affected by xenobiotic substances and nutrients in the sediment. The competent authorities, responsible for achieving these objectives, are included in this overview. By applying chapter 2, it becomes clear whether there is a motive to assess the sediment and, if so, with respect to which standards.

A (suspected) exceeding of a standard in a body of surface water is not always a motive to assess the sediment. After all, not every chemical standard involves substances that adsorb to the sediment. If ecological objectives are not met, usually other factors are more important than substances in the sediment.

Figure 1.5
Illustration of the functioning of the guidance document in assessing whether a physical intervention in the sediment should take place. From the figure the role of chapter 2 and chapters 3, 4 and 5 becomes clear.



Is sediment assessment considered to be making sense?
After reading chapter 2 it has become clear whether there is a motive to assess the sediment. If sediment assessment is considered to be making sense, one is referred to specific sections of chapters 3, 4 and 5 for the assessment.

Carry out an exploratory sediment survey
For assessing the effects of the sediment, the current data of an exploratory sediment survey in accordance with the Dutch standard NEN 5720 or a comparable survey are used (see annex E). In the exploratory sediment survey the top layer of

the sediment is examined. If a study into the effects on the groundwater is desirable, it may be necessary to also examine deeper contaminated layers. When examining eutrophication due to the sediment (§3.5), the list of substances for chemical analysis is supplemented with total phosphorus (P), total iron (Fe), total sulphur (S) and total aluminium (Al).

Part of an exploratory sediment survey exists of distinguishing suspected zones. Exceeding of standards in water quality management is often observed in larger bodies of surface water or water systems. The sediment survey can be limited by not or less intensively examining the unsuspected zones. Furthermore, sediment survey can be omitted in zones that, given the flow pattern, cannot influence the monitoring site where the standard was exceeded.

Sediment assessment with chapters 3, 4 and 5
The results of the exploratory sediment survey are used to determine the influence of the sediment on the exceeding of the relevant standards. Chapter 3 contains methods starting from water quality, chapter 4 contains methods starting from sediment quality. Chapter 5 contains methods for bank/shore areas.
It is advised only to carry out any sediment assessment starting from sediment quality if it has become clear from the exploratory sediment survey that an intervention value has been exceeded in the sediment (or a local limit if a regionally specific policy for the use of dredged material applies). The assessment will show whether and to what extent the sediment impedes achieving the standard.

Evaluate results in the regional planning process
The results of the sediment assessment will be put forward in the regional planning process. In the regional planning process also other factors that impede achieving the standard in the body of surface water are considered. From this it becomes clear whether a physical intervention in the sediment may have the desired effect.

Is a physical intervention at issue?
The evaluation leads to the decision whether a physical intervention in the sediment as part of the program of measures of the management plan is potentially at issue.

Is the physical intervention limited to contents < IV?
This is determined on the basis of the results of the exploratory sediment survey and the possible scale of the physical intervention. If the generic framework for using dredged material applies, dredged material with substance contents up to the intervention value (IV, limit class B) may be used, provided that the use criteria of the Soil Quality Decree are met (§1.5). If the standards for water management cannot be met due to these contents, there is a motive to consider developing regionally specific policy for the use of dredged material.

Compare sediment measures with other measures
In the regional planning process the physical intervention in the sediment is compared with other possible measures with respect to cost-effectiveness and public relevance. The resulting measures are laid down in the water plan.

1.9.3 The sediment assistant: SEDIAS

In the guidance document various formulas are presented to calculate the effects of the sediment. To facilitate the calculations with these formulas, an application called

Sediment Assistant or SEDIAS (in Dutch) comes with this guidance document. In Annex J SEDIAS is further explained. For bank/shore areas a separate application, ‘SEDIAS bank/shore areas’ (also in Dutch), has been developed (see www.sediasoever.nl). This application uses the same technical basis as the web application ‘Sanscrit’ (www.sanscrit.nl) uses for terrestrial soils. Contrary to Sanscrit, ‘SEDIAS bank/shore areas’ does not test against the criteria of the Dutch Soil Protection Act.

1.9.4 *User requirements*

This guidance document is meant for water authorities, engineering firms or consultancies. The guidance document and SEDIAS are set up in such a way that persons with knowledge of the environmental behaviour of substances, knowledge of ecology and general knowledge of soil contamination and hydrology can easily apply them to a certain area. Use of the guidance document however demands thorough knowledge of and experience with integral water (quality) management. This is required to:

- Be able to make the right choices on the basis of chapter 2 with respect to the necessary research or the applicability of certain sections of chapters 3, 4 and 5.
- Be able to convert the results of the assessment per subsector, including the SEDIAS calculations, to the spatial scale of a WFD body of surface water or the spatial scale relevant to the water function.
- Be able to present the results in such a way that they can be used in a regional planning process with non-sediment experts in order to compare measures.

2 Determine purpose and nature of sediment assessment

2.1 Introduction

This chapter describes under which conditions it makes sense to assess the effects of sediments. If a certain standard is exceeded and sediment assessment is considered to make sense, methods for sediment assessment are proposed. These methods are described in specific sections of chapters 3, 4 and 5 of this guidance document. In order to be able to use these specific methods, exploratory sediment survey data are needed.

As described in §1.2 three situations are distinguished that can give rise to the use of the guidance document:

- Chemical or ecological WFD objectives for surface water or groundwater are not met.
- Quality objectives for other surface waters, i.e. waters not classified as WFD bodies of surface water, are not met.
- Quality objectives or standards based on the surface water functions are not met.

An exceeding of a standard does not mean that the calculation of the effects of the sediment on the standard concerned, using chapters 3, 4 and 5, is started immediately. There is a motive to use specific sections of chapters 3, 4 and 5 if:

- An exceeding of a standard is at issue for which a structural measure has to be taken and
- A physical intervention in the sediment might be one of the possible structural measures and
- The user of the guidance document is responsible for the measure to be taken.

With this chapter it can be determined:

- Who is responsible for (the assessment of) taking measures. The competent water authority is responsible for the achievement of the chemical and ecological (WFD) surface water objectives and for various environmental objectives related to water functions. With respect to the water functions, other parties also have legal responsibilities. The description in this guidance document is limited to naming the relevant legislation and regulations and to the basics of the corresponding responsibilities. In complex situations one is advised to consult the original text of law concerned.
- Whether the exceeding of a standard should lead to structural measures. In case of the exceeding of specific standards, restriction to the use of the water can be issued (a ban on swimming or fishing for example) and it is not necessary to take additional structural measures.
- Whether the sediment can potentially be (partly) responsible for exceeding the standard, in which case a physical intervention in the sediment could really contribute to solving the problem of exceeding the standard.

The description in this chapter involves objectives and standards which potentially can be exceeded as a result of nutrients and xenobiotic substances in the sediment:

- § 2.2 and 2.3: chemical standards and ecological objectives of the Water Framework Directive;
- § 2.4 and 2.5: chemical standards and ecological objectives for waters not classified as WFD bodies of surface water;
- § 2.6: groundwater objectives;
- § 2.7: relevant objectives and standards associated with water functions.

2.2 Chemical standards Water Framework Directive

2.2.1 Standards for xenobiotic substances

Xenobiotic substances in this guidance document include both the priority substances (and other substances with an EU standard) and 'other specific substances' of the Water Framework Directive. The Dutch Decree on Quality Requirements and Monitoring in Water (Bkmw 2009) contains the standards for priority substances, used for assessing the chemical status of WFD bodies of surface water. The Dutch Ministerial Monitoring Regulation (MR Monitoring, 2010) contains the standards for other xenobiotic substances, used for assessing the ecological status (natural waters) or the ecological potential (heavily modified and artificial waters) of WFD bodies of surface water.

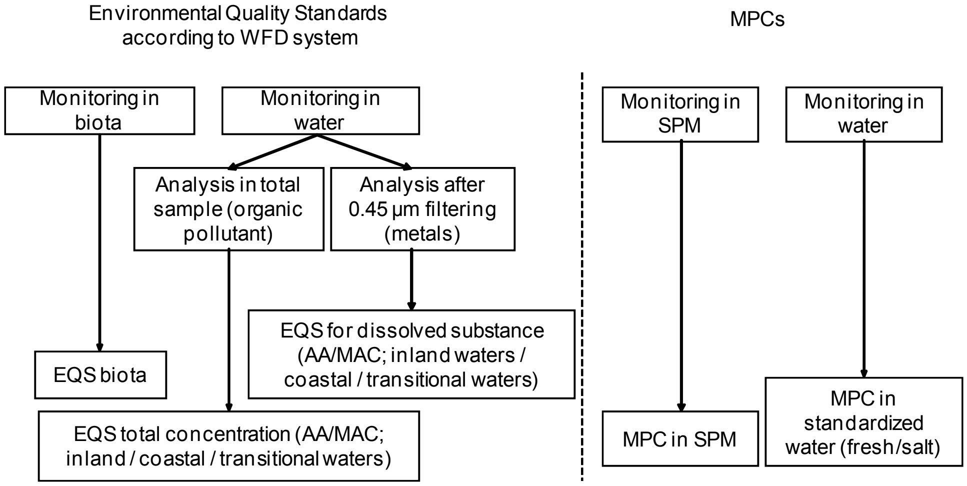
In Bkmw 2009 and MR Monitoring (2010) various types of standard have been laid down as objective for xenobiotic substances:

- Environmental Quality Standards (EQSs). These are standards that have been derived in accordance with the requirements of the WFD (EU method). Environmental quality standards have been derived by the EU for all priority substances. In addition to this, The Netherlands have derived standards in accordance with the EU for part of the other specific substances. These are used for assessing the ecological status. The following environmental quality standards are distinguished:
    1. EQSs for monitoring in surface water and EQSs for monitoring in biota. For three substances (mercury and its compounds, hexachlorobenzene and hexchlorobutadiene) EQSs for biota have been set, in addition to the EQSs for monitoring in surface water. In case of biota, the standards are set for the tissue of prey organisms (wet weight). Within the monitoring programme one must choose between fish, molluscs, crustaceans or other biota. The competent water authority can decide between monitoring in surface water and monitoring in biota.
    2. In case of monitoring in surface water, a distinction is made between EQSs for inland surface waters (rivers, lakes and associated artificial or heavily modified bodies of surface water) and EQSs for other surface waters (coastal waters and transitional water). Furthermore, annual average EQSs (AA-EQSs) and maximum acceptable concentrations (MAC-EQSs) are distinguished.
    3. In case of monitoring in surface water, metals are analysed as dissolved concentration (after filtration over a 0.45 µm filter). Organic pollutants are analysed as total concentration.

- MPC-values (Maximum Permissible Concentration). These are standards laid down in the Dutch Ministerial Monitoring Regulation for substances for which (so far) no environmental quality standards have been set. The values have been derived in accordance with a Dutch method. Some MPC-values are only valid for freshwater or for saltwater. When testing the measured concentration against the MPC, the concentration is converted to 'standardized water', i.e. water containing 30 mg/l suspended particulate matter (SPM) which contains 20% organic matter and 40% clay, prior to the test. The competent water authority can decide in the monitoring program to monitor substances with an MPC in SPM and to test against a value that corresponds with the Maximum Permissible Concentration (MPC) for SPM. For PCBs an MPC for suspended particulate matter is laid down in the Ministerial Monitoring Regulation.

An actual overview of the standards can be found on the website of the Helpdesk Water:
http://apps.helpdeskwater.nl/normen_zoeksysteem/normen.php
From this website a file containing a selection of standards from Bkmw 2009 and MR Monitoring (2010) can be downloaded.

Figure 2.1
Types of standards for xenobiotic substances in surface water.



Monitoring, testing and chemical assessment Water Framework Directive
For monitoring, testing and assessing xenobiotic substances in surface water, the competent water authority follows the Instruction 'Surface Water Monitoring Guideline and Testing and Assessment Protocol' (V&W, 2010). Monitoring involves all parameters of Bkmw 2009 and MR Monitoring (2010). For three substances (methylmercury, hexachlorobenzene and hexachlorobutadiene) standards in biota have been laid down in Bkmw 2009. The Netherlands has as yet decided not to conduct WFD monitoring in biota by default, but to use the legal option to monitor the substances for which standards in biota have been derived, in water and to test the concentration of these substances against values that offer the same level of protection as the EQSs in biota.

With the Testing and Assessment Protocol it is determined whether standards are exceeded. If one or more of the priority substances or other substance with an EU standard are not in compliance with the standard, the chemical status of the body of surface water is not in order. Exceeding a standard of other specific substances means that the preliminary assessment is 'not good' (see figure 2.2). This preliminary assessment is taken into account in assessing the ecological status or the ecological potential.

If a standard is exceeded, the competent water authority can use the 'Instruction for dealing with exceeding standards of micropollutants in surface water' (Royal Haskoning, 2010) and the corresponding background document (Roex *et al.*, 2009) to examine by means of a second-line assessment whether the substance in the surface water actually causes negative effects that require taking measures. For metals, in this second-line assessment, natural background levels and biological availability of the substance are taken into account.

2.2.2 *Is sediment a possible cause for exceeding the standard?*

If monitoring has established that a standard has been exceeded and second-line assessment (see text box 'Monitoring, testing and chemical assessment Water Framework Directive') reveals that measures are necessary, there is a motive to investigate whether the sediment is (partly) responsible for the exceeding of the standard.

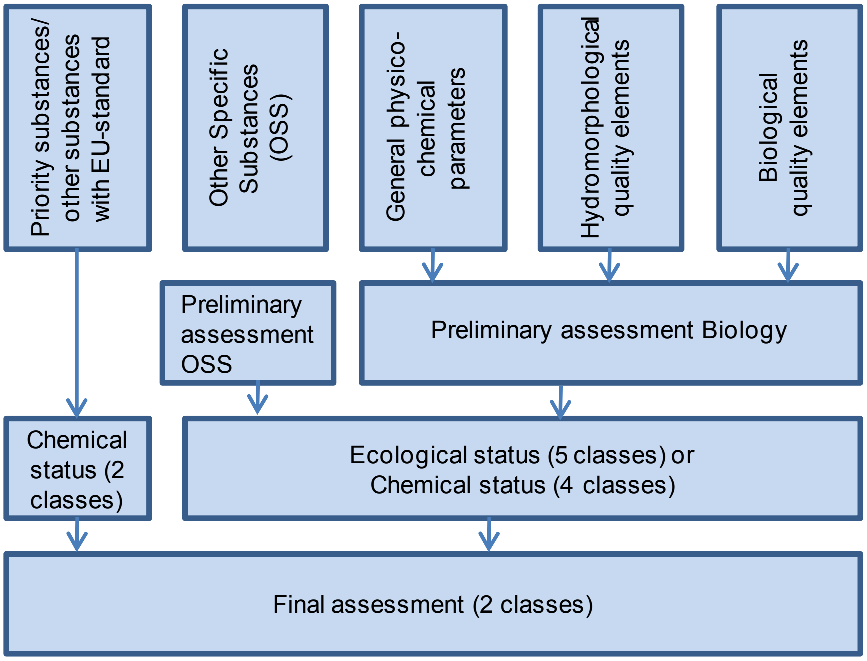
Some of the substances that are monitored in surface water are very mobile and will not adsorb to the sediment. In Annex A a list of sediment relevant substances is listed. With this list one can check whether a substance that exceeds the standard will adsorb to sediment. In that case it is 'sediment relevant'. If a substance that exceeds the standard in surface water is not a sediment relevant compound, the sediment cannot be the cause of the standard being exceeded and further assessment with this guidance document makes no sense.

2.2.3 *Which sections of this guidance document should be used?*

If there is a motive for assessing the sediment because the standard of a xenobiotic substance is exceeded, the following sections will be used to establish the contribution of the sediment (see figure 2.1):

- §3.1 if the EQS for a dissolved substance is exceeded;
- §3.2 if the EQS for the total concentration in surface water is exceeded;
- §3.3 if the MPC for surface water or the MPC for suspended particulate matter is exceeded;
- §3.4 if the EQS for biota[3] is exceeded.

Figure 2.2
Schematic representation of chemical and ecological assessment and testing under the Water Framework Directive.



2.3 Ecological objectives Water Framework Directive

2.3.1 Ecological standards

Under the Water Framework Directive, the ecological status (natural waters) or the ecological potential (heavily modified and artificial waters) is determined not only with respect to other specific substances (see §2.2) but also with respect to general physico-chemical parameters (oxygen content, nutrients, salinity, acidity), hydromorphological quality elements and biological quality elements (see figure 2.2).

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[3] Contrary to the general structure of this guidance document, one should not immediately start an exploratory sediment survey if a standard for biota is exceeded. First, one should follow §3.4 in order to determine whether sediment assessment is useful.

Monitoring, testing and ecological assessment Water Framework Directive
For monitoring, testing and assessing, the competent water authority follows the Instruction ‘Surface Water Monitoring Guideline and Testing and Assessment Protocol’ (V&W, 2010). Monitoring involves not only all other specific substances (§2.2) but also but general physico-chemical parameters, the hydromorphological quality elements and the biological quality elements phytoplankton, other water flora (phytobenthos, macrophytes, angiosperms, macroalgae), macrofauna and fish.
When testing, preliminary assessments for other specific substances and for biology are made. For each of the metrics for biological quality elements the Ecological Quality Ratio (EQR) is calculated. The EQR is a value on a scale where the value 1 represents the reference situation. The reference situation is the maximum possible ecological value for natural waters. For artificial and heavily modified waters, the Maximum Ecological Potential (MEP) is the maximum possible value. This MEP is also expressed in an EQR on the metric for natural waters. The scores of the biological quality elements and the biology-supporting parameters and the preliminary assessment for other specific substances are integrated into one final assessment with respect to the ecological status (natural waters) or the ecological potential (heavily modified and artificial waters).
If the ecological status is not in order, the possible cause for this has to be determined. Improvement of the ecological status is often best realized by adjusting the hydromorphology (construction of fish ladders, design of banks/shores etc.). An experienced ecologist can use the ‘Guidance document for the diagnostics of the ecological quality of water systems’ (Royal Haskoning, 2007) (www.helpdeskwater.nl) in order to determine what the possible relevant causes are for the unsatisfactory scores on the metrics in the specific situation at hand. Part of this assessment is to assess whether contaminants in the sediment (nutrients, xenobiotic substances) potentially are also (part of) the problem.

For the assessment of the ecology, the Dutch Ministerial Monitoring Regulation refers to the references and metrics for natural surface waters in the report ‘References and metrics for natural water types’ (STOWA, 2007; see www.stowa.nl). In the management plan for national waters or the regional plan, a good ecological potential (GEP) is derived as objective for artificial and heavily modified waters from the good ecological status (GES). Under the WFD, the metrics (Ecological Quality Ratio’s = EQR) are defined per water type. The general physico-chemical quality elements and the biological quality elements are supporting biology. For every water type, metrics have been defined for four biological quality elements (phytoplankton, other water flora, macrofauna and fish).

2.3.2 *Is sediment a possible cause for an unsatisfactory score on the metric?*

If monitoring shows that the ecological status or the ecological potential is not in order, this can be a motive to examine whether the sediment may (partly) cause the problem. Nutrients in the sediment can cause eutrophication of the water system and therefore have effect on the metric for phytoplankton. Experience shows that the effects of toxic substances reveal itself more in the numbers and diversity of macrofauna than in those of the other biological quality elements.

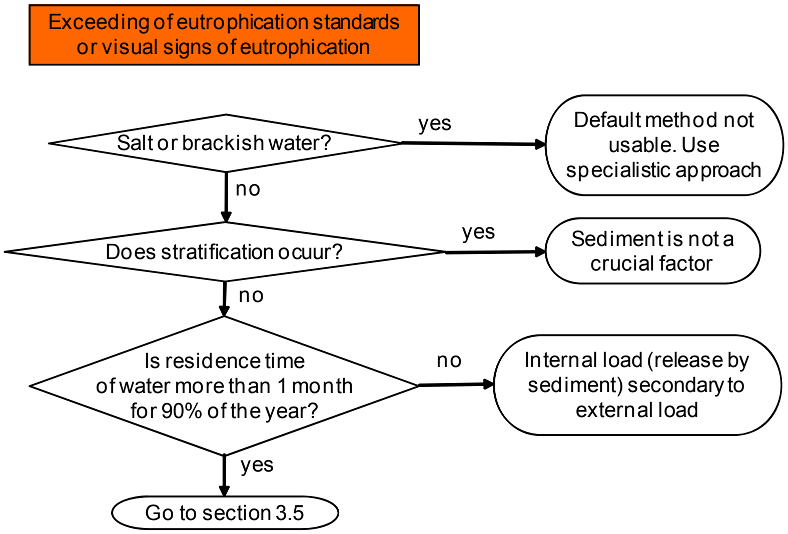
Therefore, in this guidance document only methods have been elaborated to determine the effect of the sediment on unsatisfactory scores on the phytoplankton and macrofauna metrics.

Unsatisfactory score on the phytoplankton metric or exceeding the P-standard
For eutrophication problems several standards exist. The main eutrophication problems are excessive growth of algae and duckweed and toxic algal bloom (cyanobacteria). In WFD waters the Ecological Quality Ratio (EQR) for phytoplankton is the final standard. In addition, standards apply in water for the biology-supporting parameters nitrogen, phosphate, transparency and oxygen content, that can be indicative for (the sensitivity of the water system for) eutrophication. The exceeding of a standard of a supporting parameter is formally only a problem in case of an unsatisfactory score on the phytoplankton metric. The possible effect of the sediment reveals itself mainly in total phosphate. If this goes hand in hand with an unsatisfactory score on the phytoplankton metric, there is reason for further examining the effect of the sediment. Even if the score on the phytoplankton metric is satisfactory, the exceeding of the standard of the supporting parameter total phosphate can make the competent water authority investigate the effect of the sediment. In this section it is described how to determine the contribution of the sediment both with respect to exceeding the P-standards and to unwanted eutrophication effects.

Release from the sediment mainly directed at P
The sediment contains both nitrogen and phosphate that can end up in the water phase. The release of nitrogen from the sediment adapts itself quickly after an increase or decrease of the external load (one to several years). For nitrogen one should therefore focus on reducing the external load. For nitrogen, an intervention in the sediment is not an efficient measure. For phosphate this can be different.

For the assessment figure 2.3 is used:

Figure 2.3
Flowchart to assess whether nutrients in sediment may potentially be responsible for eutrophication.



Salt or brackish water?
In brackish and salt waters eutrophication problems are mostly limited and not related to the in-situ sediment. If there is nevertheless a problem, one is advised to apply specialistic methods.

Does stratification occur?
In temperature-stratified systems (deep lakes) little or no exchange takes place between the lower and upper water layer. In these systems toxic algal bloom can occur, but most times this is the result of external loading by for example birds. In this situation, a sediment measure will hardly solve the problem of toxic algal bloom.

Is the residence time of water 90% of the year longer than 1 month?
In flowing waters, eutrophication usually is no problem for the system itself. Also for slow moving waters, such as canals, the sediment is supposed to be no cause of eutrophication problems. In these cases, the external load is the dominant factor. This means that if the residence time of the water is shorter than 1 month for 90% of the year, the contribution of the sediment is secondary to the external load.

The role of the sediment in temperature-stratified systems and in systems with shorter residence times

Temperature stratification

In deep temperature-stratified systems, in the summer half of the year, there is a (very) limited transport of nutrients from the lower layer to the upper layer. For isolated systems, spring is therefore the main season for algal growth, when the upper layer is (relatively) rich in nutrients due to the mixing of water in winter. High nutrient concentrations in spring lead to relatively higher concentrations in summer, but the deciding factor for high concentrations in summer is the external load. Algal bloom in spring in itself has little effect on (increased) algal bloom in summer.

In flowing systems the amount of nutrients transported to the upper layer can be so large in the summer half of the year, that also in summer considerable algal bloom can occur.

It can be concluded that deep stratified systems can have toxic algal bloom problems, but generally this is caused primarily by external loads. If the competent water authority nevertheless assumes that the sediment causes problems in a specific system, it is advised to use specialistic methods.

Residence time

The nutrient concentrations in the water column are determined by the internal and external loads on the surface water. In flowing waters the concentration is mainly determined by the transport of water and nutrients from upstream areas. Even though the contribution of the sediment, expressed in terms of load (kg), can be quite large, this is 'diluted' at once in the water flowing past. The slower the water moves, the larger the contribution of the sediment. In this guidance document, a relatively long residence time has been selected as criterion in the default method. In systems with shorter residence times, external loads will generally be the cause of problems. If the competent water authority thinks that the external load cannot fully account for the eutrophication problems, it can be decided to use the default method even in case of shorter residence times. It is however advised to use more specialistic methods in systems like this.

Compromising downstream waters by waters with short residence times

Although in waters with short residence times themselves no direct eutrophication effects may occur, these waters can act as a source for eutrophication problems in downstream lakes (compromising downstream waters). Especially after the reduction of external sources, the sediment can start releasing nutrients, due to which the load on downstream lakes does not or insufficiently diminish. In these situations the release of nutrient is relatively steady. If eutrophication standards threaten to be exceeded in downstream areas, this may be a motive to investigate the contribution of the upstream sediments. In order to determine the contribution of N and P from the upstream sediment, it is obvious to estimate the dissolved and suspended particulate matter bound concentrations that are transported by the flowing water (analogously to the calculation methods presented in § 3.1 and § 3.2 of this guidance document). For dissolved substances a flux per m^2 per day is calculated, based on advective flow and/or diffusion/dispersion. For nutrients bound to suspended particulate matter the resuspension flux is calculated. These fluxes can be used to calculate the contributions of N and P from the sediment with respect to the total loads.

Unsatisfactory score on the macrofauna metric
The macrofauna metric is usually based on the bank/shore zone[4], because this is where biodiversity is highest. No research has however been conducted into the effects of sediment contamination in the bank/shore zone on these metrics.
In the WFD water body type' freshwater tidal river' (R8), for the deeper bare parts of the surface water a relationship has been established between contaminated sediment and macrofauna composition (Peeters *et al.*, 2008). For water bodies other than R8, few research data are known. It is however obvious that contaminated sediment will affect macrofauna composition in other types of water body too, if these also have large parts of deeper bare sediment. The boundary between shallow and deeper surface waters can be set at a depth of approximately 1.5 m.

Solely for the WFD water body type R8, a (draft) macrofauna metric has been developed, which is partly based on deeper parts. From the above, it follows that contaminated sediment can contribute to an unsatisfactory score on the macrofauna metric.

In case of an unsatisfactory score on the metric for the bank/shore zone, one should first of all examine whether this can be caused by physical factors. For this examination one can use the 'Guidance document for the diagnostics of the ecological quality of water systems' (see text box 'Monitoring, testing and ecological assessment Water Framework Directive', page 30). If physical factors cannot explain the unsatisfactory score, this is a motive to assess the effects of the sediment.

2.3.3 *Which sections of this guidance document must be used?*

If from the previous sub-sections, sediment appears to be one of the causes of an unsatisfactory score on the biological metrics, the following sections can be used in order to further examine the effects of the sediment:

- §3.5 in case of an unsatisfactory score on the phytoplankton metric;
- §3.6 in case of an unsatisfactory score on the macrofauna metric.

2.4 Chemical standards in surface waters not classified as WFD bodies of surface water

For surface waters not classified as WFD bodies of surface water, the Bkmw 2009 contains no standards or indicators. Monitoring under the Water Framework Directive is not obligatory in these waters. However, the standards of the Bkmw 2009 indirectly involve the waters not classified as WFD bodies of surface water, because the water quality in these waters can affect the WFD surface water. Therefore it is laid down in the National Water Plan 2010-2015 that the values of the Bkmw 2009 and the corresponding Ministerial Monitoring Regulation can be used as starting point for assessment.
If these values are exceeded, or one suspects exceeding because a sediment contamination is known to be present, this can be reason to assess the effects of contaminated sediment in waters not classified as WFD bodies of surface water. This

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[4] The bank/shore zone (see glossary) involves the zone that is the subject of the biological WFD monitoring. This zone is situated in rivers and tidal rivers on the boundary between the 'bottom under the surface water' and the 'bank/shore' or the 'bank/shore area'. For the assessment of the effects of the sediment on the macrofauna in the bank/shore zone, one is referred to chapter 3 of this guidance document and not to chapter 5.

guidance document offers the opportunity to evaluate the effects with respect to the standards of the Bkmw 2009 and the Ministerial Monitoring Regulation[5].

If monitoring in waters not classified as WFD bodies of surface water has been conducted and an exceeding of the standard of a sediment relevant substance (see Annex A) has been established, the following sections of the guidance document can be used:

- §3.1 in case an EQS for dissolved substances is exceeded;
- §3.2 in case an EQS for total concentrations is exceeded;
- §3.3 in case an MPC for surface water or MPC for suspended particulate matter is exceeded;
- §3.4 in case an EQS for biota is exceeded.

If not enough monitoring data are available in waters not classified as WFD bodies of surface water, but contaminated sediment is present (see §1.3), the following sections can be used, starting from sediment quality:

- §4.1 for the effect of sediment on the EQS for dissolved substances;
- §4.2 for the effect of sediment on the EQS for total concentrations;
- §4.3 for the effect of sediment on the MPC for surface water or MPC for suspended particulate matter;
- §4.4 for the effect of sediment on the EQS for biota.

2.5 Ecological objectives in surface waters not classified as WFD bodies of surface water

When assessing the ecology of surface waters not classified as WFD bodies of surface water, water authorities can use their own methods, such as the Ecological Assessment Method (EBEO) by STOWA (http://themas.stowa.nl). Effects of the sediment are potentially reflected in eutrophication or in the macrofauna composition.

Eutrophication

If problems occur in waters not classified as WFD bodies of surface water that are related to eutrophication, such as:

- high concentrations of phytoplankton (chlorophyll-a), total phosphate, ortho-phosphate, total nitrogen, DIN (nitrate + nitrite + ammonium) in the surface water, or
- visual aspects of the surface water (cover of duckweed, algal bloom, low transparency),

the same (sub)sections can be used as in the case of WFD waters with an unsatisfactory score on the metric for phytoplankton (see §2.3.2 and figure 2.3). If from these sections the sediment turns out to contribute potentially to the eutrophication, §3.5 can be used to assess the effects of the sediment.

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[5] In this guidance document one can work with substances for which non-statutory MPC-values (such as the MPC-values of the 'Vierde Nota Waterhuishouding') or ad-hoc MPC-values have been derived, and with substances with statutory MPC-values (of the Ministerial Monitoring Regulation)

Figure 2.3 and (possibly) §3.5 can also be used if high nutrient contents have been established in the sediment, but no monitoring in the surface water has taken place or (visual) signs of eutrophication (algal bloom, cover of duckweed, low transparency) have been found.

Macrofauna composition
A metric for macrofauna is usually based on the bank/shore zone[6], because this is where biodiversity is highest. No research has however been conducted into the effects of sediment contamination in the bank/shore zone on the macrofauna composition. Research of bare sediments in deeper surface water (> approx. 1.5 m) however revealed a relationship between the level of sediment contamination and the macrofauna composition (Peeters *et al.*, 2008, see also §2.3.2).

An unsatisfactory score on the metric for macrofauna based on the deeper parts (> 1.5 m) of the surface water can (also) be the result of contaminated sediment. In case of an unsatisfactory score on the metric for macrofauna based on the bank/shore zone, one is advised to examine whether this can be caused by physical factors first (oxygen content, transparency, hydromorphology, type of substrate). If physical factors cannot explain the unsatisfactory score, one is advised to assess the possible effects of the sediment.

In case of an unsatisfactory score on the metric for macrofauna, §3.6 can be used to assess the effects of the sediment. If no data concerning the macrofauna composition are available, but sediment is known to be contaminated, §4.6 can be used to assess the potential effects on the macrofauna.

2.6 Groundwater objectives

The Water Framework Directive and the Groundwater Directive (GWD) dictate quality objectives for groundwater. Achieving the objectives of the WFD and GWD is a responsibility of all authorities. The Dutch provinces include objectives for bodies of groundwater in regional water plans and monitor the bodies of groundwater. The provinces are therefore primarily responsible for groundwater quality. The Dutch national government and the Dutch water boards also have certain responsibilities regarding groundwater quality and are required to take measures to achieve the WFD objectives (including the groundwater objectives).
These measures may include both preventing new contaminations (discharges) and addressing existing contaminations.

In the past it has been established that critical substances in sediment are immobile in most cases. As a result of this, the transport velocity is so low that the contamination in the sediment will not result in exceeding the statutory groundwater quality objectives, not even in cases of high groundwater flow rates induced by big differences in hydraulic head.

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[6] The bank/shore zone (see glossary) involves the zone that is the subject of the biological monitoring. This zone is situated in rivers and tidal rivers on the boundary between the 'bottom under the surface water' and the 'bank/shore' or the 'bank/shore area'. For the assessment of the effects of the sediment on the macrofauna in the bank/shore zone, one is referred to chapter 3 of this guidance document and not to chapter 5.

Exceptions are situations in which, due to the (former) use of the water system, a (mobile) groundwater contamination has evolved.
Examples of such situations include mineral oil contaminations that occur on and round the premises of former gasworks and transhipment ports. The professional assessment of the effects of such contaminations on the groundwater does not differ from the assessment in bank/shore areas (see below). Often the situation calls for a site-specific assessment with groundwater models.

Cases of concurrence with source in the sediment
The water authority is the competent authority in case of a land-water boundary-crossing soil contamination having its source in the aquatic sediment. This type of soil/sediment contamination is rare. For the assessment of the effects of the contamination on the groundwater, one can use ‘SEDIAS bank/shore areas’.

Bank/shore areas
In bank/shore areas certain pollutants from point sources can have impact on the in-situ (shallow) groundwater. Sites like this can be assessed with the technical elements of Dutch Soil Protection Act (Wbb) methods for terrestrial soils, on the understanding that the Wbb criteria have no intendment in bank/shore areas that fall under the Water Act. In §5.4 the methods for bank/shore areas is further explained.

2.7 Water functions

The functions of bodies of surface water are assigned in the National Water Plan, the regional water plans or the competent water authority’s management plan. The water functions matter to this guidance document insofar as xenobiotic substances or nutrients in the sediment potentially impede the achievement of objectives or standards associated with these functions.

Below, the water functions are described with respect to the responsibilities and other considerations that play a part in answering the question whether a physical intervention in the sediment can be a structural measure. Insofar as assessment of the sediment is advisable, one is referred to specific sections of this guidance document for this assessment. In this guidance document two types of water functions are distinguished:

Water functions with statutory standards relevant to the competent water authority
The areas with this type of function are designated as protected areas in the water plans. This involves the following functions:

- nature
- drinking water
- swimming water
- shellfish water
- fishing water

For the function of nature, objectives and measures are not determined in the regional planning processes for the water management plans, but in the regional planning processes for the nature management plans.

Water functions without statutory standards relevant to the competent water authority

This involves the following functions:
- fishery and sport fishing
- recreation
- water for agricultural use
- agriculture (in bank/shore areas)

These functions are determined by the actual use of the bodies of surface water.

For agricultural and fishery products that are marketed, statutory food standards of the Dutch Food and Drugs Act apply. These standards concern the product-selling company. Aside from these standards, reference values and other non-statutory standards exist that concern the producer.
During recreation people can be exposed to the contaminated sediment. For the exposure of people to contaminated soil or sediment, the Dutch RIVM has derived (non-statutory) risk limits (MPC_{humane}).

With respect to these functions, the competent water authority has no obligation to conduct any research and has no other legal responsibilities. Within the regional planning process for composing a water plan, it may however be advisable to list the risks of exposure and the corresponding causes. This information can then be considered in deciding about designating functions, limiting the use and taking other measures.

2.7.1 Nature

For protected nature reserves (Natura2000 areas or nature reserves protected under the Dutch Nature Conservation Act 1998) statutory preservation goals apply. The nature conservation authority is legally responsible for achieving the preservation goals and for taking measures in order to achieve these goals. These measures are laid down in a management plan under the Dutch Nature Conservation Act. In the water plans it is sufficient to refer to these measures.

In Natura2000 areas where several authorities act, just like in the Dutch river district, one authority is appointed to take the lead in the planning process. The authorities jointly set up the Natura2000 management plan. The authority responsible for the largest area within the Natura2000 area, takes the lead.

In the context of the planning process for nature, it is analysed to what extent the preservation goals have already been achieved, what the prospects are and which measures are needed to achieve the goals.
In the nature management plan it is laid down whether a specific species should remain stable or should expand. The nature authority can establish problems concerning the preservation or expansion of specific target species that, due to direct contact or through their food, depend on healthy sediment. Established problems can then induce measures for improvement. If problems with nature occur in bodies of surface water, the competent water authority is usually involved at an early stage.

Although in many cases the sediment does not contain a large diversity of species, it may contain specific species. More important is the siginificance of sediment in the food web, through secondary poisoning. If contaminated sediment is suspected of being a possibly cause for problems, it can be decided in the nature management plan to examine the sediment.

Xenobiotic substances
In order to assess the effects of xenobiotic substances, organisms lower and higher in the foodweb are distinguished. Lower organisms involve species that have direct contact with the sediment. Higher organisms involve birds and mammals. Furthermore, a distinction is made between the bank/shore areas (terrestrial organisms) and the other parts of the water system (aquatic organisms).
Effects on lower aquatic organisms involve mainly effects on macrofauna. In order to assess these effects, one can use the subsection of ecology in WFD surface waters (§2.3.2) or of surface waters not classified as WFD bodies of surface water (§2.5).
Effects on lower terrestrial organisms involve lower target species such as worms, nematodes, springtails, beetles and centipedes. If the preservation goals have not been achieved and the soil is contaminated, the effects of substances in the sediment can be assessed using §5.1.1.

Assessing the effects of xenobiotic substances in the sediment on higher aquatic and terrestrial target species is complex. Assessing the effects on higher organisms is only relevant if the surface area of the site is to a large extent part of the feeding area for Natura2000 species at risk, such as certain waders, fish eaters or diving ducks. If the site considered is considerably smaller that the feeding area of the target species at risk, the sediment cannot be the cause and an assessment with the guidance document makes no sense.

Xenobiotic sediment relevant substances can only contribute to the effect on higher organisms if the substance properties allow for secondary poisoning. In Annex B (table B.3) the substances that allow for secondary poisoning are listed. If the preservation goals have not been achieved and the soil or sediment is contaminated, the effects of substances in the sediment can be assessed using §4.7 (aquatic organisms) or §5.1.2 (terrestrial organisms).

Nutrients
Nutrients that are present in sediments can also affect the nature objectives. In case of eutrophication, methods described in §2.3.2 (‘unsatisfactory score on phytoplankton metric’) and corresponding figure 2.3 can be used. If eutrophication appears to be caused (partially) by the sediment, §3.5 offers methods for assessing the sediment.

2.7.2 Drinking water

For the production of drinking water, water is used that is either obtained directly from surface waters or from groundwater. In some situations river bank infiltration methods are used. For all drinking water abstraction points, site management plans are required that are periodically updated.
A site management plan describes the desired protection level of the water to be extracted as well as the (potential) threats to the water quality, and protective measures. Assessing the possible effects of the sediment on achieving the protection levels can be part of composing the site management plan. Site management plans are established in a stakeholders process in which the province, the drinking water company and other stakeholders take part. In the cases of

abstracting surface water and river bank filtration, the competent water authority take part in this process. The competent authority decides whether measures proposed in a site management plan, will be entered in the water management plan.

Surface water abstraction

The objectives for surface water to be used for the production of drinking water, have been laid down in the Dutch Decree on Quality Requirements and Monitoring in Water (Bkmw 2009). The competent water authority is responsible for achieving these objectives.
For direct abstraction from the surface water, standards apply for the abstraction site with respect to the surface water to be used for the production of water for human consumption (annex III, table 1 in Bkmw 2009). Furthermore, the policy of the competent water authority should be directed at improving the water quality down to the target value for surface water to be used for the production of water for human consumption (annex III, table 2 in Bkmw 2009). The standards and target values concern total concentrations in the water. The possible effects of contaminated sediment on this abstracted water can be assessed using the methods presented in §3.2 en §4.2 of this guidance document.

River bank filtration

For drinking water abstraction after river bank filtration, the standards of the Bkmw 2009 do not apply. The province is responsible for the fact that the groundwater is sufficiently clean for the production of drinking water. In the site management plan, for every abstraction point the required level of protection and the potential threats are determined. A site-specific assessment of the effects of contaminated sediment may be part of this, but is beyond the scope of this guidance document.

Other types of groundwater abstraction

Also in the case of other types of groundwater abstraction, the province is responsible for the fact that the groundwater is sufficiently clean for the production of drinking water. In case of groundwater abstraction for the production of drinking water (and industrial process water) effects of sediment contamination are unlikely (see §2.6).

2.7.3 Swimming water

The function of swimming water is assigned in the regional water plans, the National Water Plan and the management plan for the National Waters (BPRW). For swimming waters the Dutch Water Quality and Safety Act for Recreational Waters (Whvbz) sets statutory standards for faecal bacteria. The competent water authority is responsible for monitoring and for achieving the standards in the swimming waters. If the standards for faecal bacteria are exceeded, the sediment is very unlikely to be significant, so sediment assessment and sediment related measures are not called for.

In swimming waters where potentially problems with toxic algae (cyanobacteria) may occur (toxic algal bloom, surface layers), cyanobacteria are also monitored. For cyanobacteria no statutory standards exist. However, on a national scale, the authorities involved (Ministry of Housing, Spatial Planning and the Environment, provinces, water authorities) have agreed on the cyanobacteria limit, above which the province issues a warning to the swimmers by way of negative swimming instructions.

If negative swimming instructions due to cyanobacteria have to be issued on a regular basis, this may be a motive to examine the cause of the toxic algal bloom and to consider structural measures. Investigation and tackling of toxic algal bloom can only take place on the scale of the entire body of surface water or water system. In order to assess whether the sediment is at this spatial scale (partly) responsible for the toxic algal bloom, one can use the section on eutrophication in this guidance document, both for WFD surface waters and for surface waters not classified as WFD bodies of surface water. See ‘unsatisfactory score on phytoplankton metric’ in §2.3.2 (figure 2.3).

In swimming waters no statutory standards for xenobiotic substances apply. Risks caused by xenobiotic substances only occur in situations of extreme contamination. This kind of situation only occurs in case of calamities, for which the guidance document is not applicable. The WFD environmental quality standards offer adequate protection under normal conditions. For the risks swimmers encounter by being exposed to a contaminated bank/shore zone, one is referred to the function of recreation (§2.7.5).

2.7.4 *Shellfish water*

The European Shellfish Water Directive sets rules for the water quality. The standards aim at the safe consumption of shellfish. In 2013 the Shellfish Water Directive will be incorporated in the European Water Framework Directive. Until this moment the associated standards of the old Dutch Decree on Quality Requirements and Monitoring in Water (Bkmw old) apply for which the competent water authority is responsible. It is expected that after 2013 the water quality will be good enough to lift the specific shellfish water standards. Because this guidance document is directed at the second and next generations of river basin management plans, this function has not been further elaborated.

2.7.5 *Fishing water*

The European Freshwater Fish Directive sets rules for the quality of cyprinid waters and salmonid waters. This Directive will expire in 2013, just as the Shellfish Water Directive. Until this moment the associated standards of the old Decree on Quality Requirements and Monitoring in Water (Bkmw old) apply for which the competent water authority is responsible. It is expected that after 2013 the water quality will be good enough to lift the specific standards for cyprinid waters and salmonid waters. Because this guidance document is directed at the second and next generations of river basin management plans, this function has not been further elaborated.

2.7.6 *Fishery and sport fishing*

If fishery or sport fishing takes place in a body of surface water containing contaminated sediment, there is a risk that the landed fish contains high contents of these contaminants. For fish consumption standards apply, that concern the party that markets the fish.

When monitoring fish according to the Dutch Food and Drugs Act, conducted by Imares by order of the Ministry of Agriculture, Nature and Food Quality (LNV), it can turn out that the fish contains substance contents that do not meet the statutory (European) consumption standards. Monitoring data from angling clubs can also be a motive to investigate substance levels in fish that exceed the standard. European

consumption standards for cadmium, mercury, lead, benzo(a)pyrene and dioxin-like substances such as dioxins, furans and dioxin-like PCBs have been established for fish products. In The Netherland, the standard most likely to be exceeded, is the standard for dioxin-like substances (TEQ) in eel. Especially in the large Dutch rivers, eel does not meet the consumption standards. The mercury content generally is below the standard. Benzo(a)pyrene (a PAH) can metabolize into non-toxic substances. This substance therefore hardly poses a problem for consumption.
For PAHs, lead and cadmium few data are available. In 2007 these substances have been analysed within the context of monitoring sport fishing (Van der Lee *et al.*, 2009). The highest contents of cadmium and lead measured in eel are 0.086 and <0.05 mg/kg fresh product respectively. This is below the standard, but for sediments containing high cadmium contents, exceeding of the standard (0.1 mg/kg fresh product) is conceivable. The standards for these substances are listed in Annex B.

Relationship PCBs and dioxins
Dioxin-like substances are usually not monitored, but it is known that for eel in diffusely contaminated areas a relationship can be established between the PCB153 contents and dioxins (expressed in Toxic EQuivalents: TEQ). This relationship shows that, if the intervention value for PCBs is exceeded, TEQ contents in eel almost certainly exceed the consumption standard.

If the standard for especially dioxin-like substances (TEQ) and cadmium are exceeded in fish, §3.8 can be used to assess the possible effects of the sediment. Furthermore, in cases where sites or substances are not monitored, professional and sport fishers can be worried about the effects of sediment that is contaminated with dioxin-like substances, cadmium or lead. In that case §4.8 can be used to determine whether the sediment leads to the exceeding of standards in fish. This section also contains a method to assess whether the consumption of self-landed fish (sport fishing) will lead to the exceeding of the maximum permissible concentration for humans (MPC_{human})

2.7.7 *Recreation*

This concerns activities such as bank/shore recreation, pleasure cruising and water sports. Especially when recreating in the bank/shore zone, including swimming, people can be exposed to contaminations. (Suspicion of) contaminated sediments or bank/shore areas can in this case be a motive to conduct research. In Annex B a table has been included with substances that potentially can lead to risks for humans that recreate on a contaminated soil or bank/shore. In §4.8 the method is described to determine whether contaminated sediment may lead to the exceeding of the maximum permissible concentration for recreants (MPC_{human}). §5.3 contains the method to assess a contaminated bank/shore area.

2.7.8 *Water for agricultural use*

Surface water can be used to supply agriculture with sufficient water. This water can be used for sprinkling or watering the cattle. For several metals reference values (total concentrations) have been derived with respect to the quality of drinking water for cattle (see Annex D). These reference values are used by the Animal Health Service, concern the farmers and have no statutory status. If the reference value is exceeded, the farmer is advised not to use surface water for watering the cattle. Exceeding of the reference values can be a motive for agricultural organizations to address this fact in the regional water management process. In case the cause of the high concentrations is examined, the effects of the sediments can be included. It should be mentioned however that all reference values for metals are higher than the environmental quality standards of the Bkmw 2009 and the Ministerial Monitoring Regulation. Therefore, within WFD waters there is no reason to conduct extra sediment research or to take extra measures because of the quality of the water for agricultural use.

If a reference value is exceeded, §3.2 of this guidance document can be used to assess the effects of the sediments on this. The effects of a known sediment contamination on the reference values can be assessed with the method described in §4.2.

2.7.9 Agriculture in bank/shore areas

Many bank/shore areas, such as river forelands, are in agricultural use. Agricultural products that are marketed for consumption have to meet the standards laid down in the Food and Drugs Acts.

If the exceeding of a standard is established in an agricultural product, the soil can be a significant factor in this. For soil LAC-values (LAC=Agricultural Advisory Commission) have been derived that are based on the quality standards for agricultural products. In deriving these, different soil types and cultures have been distinguished. These LAC-values have been laid down in the Alterra-report 'The basis of the LAC-2006 values and overview of soil-plant relationships for the purpose of the Risk toolbox' (Römkens *et al.*, 2007), digitally available (in Dutch) on www.alterra.wur.nl.

For the comparison with the LAC-values, the measured soil content has to be converted to the content in standard soil. In §5.2 the assessment of exceeding this value is further examined.

3 Methods starting from water quality

3.1 Environmental quality standards for dissolved concentrations in surface water

The contribution of the sediment to dissolved concentrations is assumed to be equal to the flux from the pore water to the surface water as schematically represented in figure 3.1.

Figure 3.1
Schematic representation of the relationship between dissolved substance concentrations in sediment and in surface water. The site to be assessed is represented by the box.

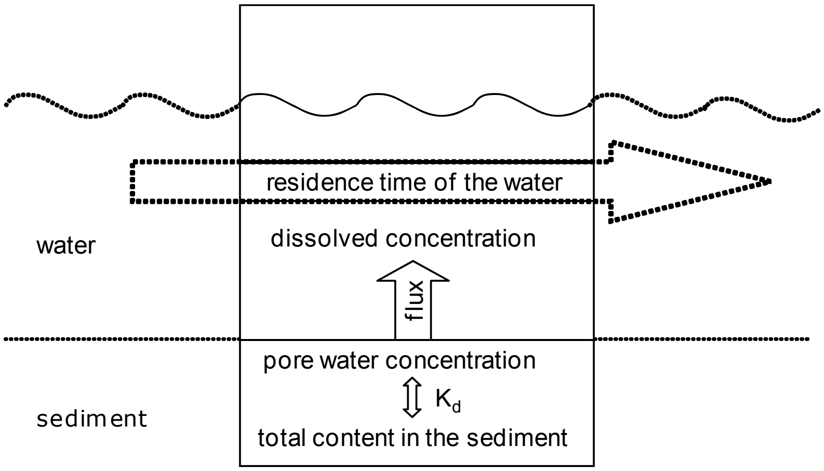
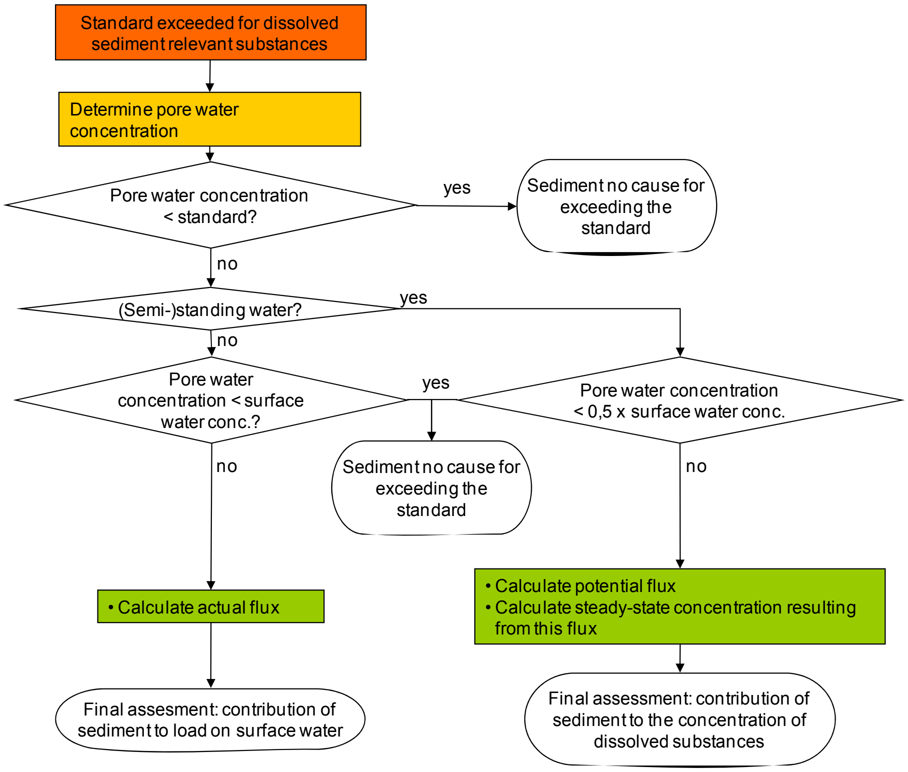


Figure 3.2 shows the necessary steps to determine the contribution of the sediment to the load of dissolved (sediment relevant) substances on the surface water, in case the standard for dissolved concentrations in the surface water is exceeded.

Determine the pore water concentration in the sediment
The default method determines the concentration in the pore water of the sediment by equilibrium partitioning. This means that chemical equilibrium is assumed between the substance in the sediment and in the pore water. In SEDIAS (Sheet 1.Partitioning) the partitioning coefficients (K_d values) of the metals are given.

Figure 3.2
Flowchart for assessing the sediment in case the standard for dissolved sediment relevant substances is exceeded.



The total content in the sediment is determined in compliance with NEN 5720 (see Annex E).

De pore water concentration of metals is calculated according to:
$C_{pw} = Q_{stand.sed} / K_d$

in which:
C_{pw} = concentration of dissolved metal in pore water [mg/l]
$Q_{stand.sed}$ = content in sediment converted to standard soil [mg/kg$_{ds}$][7]
K_d = partitioning coefficient for soil [l/kg]

For organic micropollutants the pore water concentration is calculated according to:

$C_{pw} = Q_{measured,sed} / (f_{oc} \times K_{oc})$

in which:
C_{pw} = concentration of dissolved pollutant in pore water [mg/l]
$Q_{measured,sed}$ = content measured in sediment[mg/kg$_{ds}$]
f_{oc} = fraction organic carbon [-]
K_{oc} = partitioning coefficient for organic carbon [l/kg$_{OC}$]

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[7] In SEDIAS it is possible to enter the measured content. The soil type correction is then performed automatically.

Specialistic methods for determining the pore water concentration
A more accurate estimate of the concentrations in the pore water can be obtained by measuring the available concentration in the pore water, instead of starting from the total content. If the pore water concentration is a principal parameter in deciding to take measures or not, it is advised to measure the available fraction of the pollutant. The two methods most applied in assessing sediments are the Tenax-extraction for organic contaminants and the $CaCl_2$-extraction for metals. These methods are further explained in Annex F.

Pore water concentration < standard for surface water
Release from the sediment can at most lead to equal concentrations in surface water and pore water. Therefore, if the pore water concentration is below the annual average standard (AA-EQS) for surface water, the sediment cannot be responsible for the fact that the standard has been exceeded. In order to facilitate the comparison of the pore water concentration with the standard, SEDIAS (sheet 1.Partitioning) offers the possibility to enter the standard.

After this step, two possible pathways can be followed in figure 3.2: (semi-) standing waters and flowing waters. Standing waters are waters that receive hardly any input of water from other surface waters and that therefore have long residence times. As a rule of thumb it is assumed that standing waters have residence times that exceed one month for the greater part of the year. Waters that do not meet this criterion are considered flowing waters.

Pathway for flowing waters

Pore water concentration < surface water concentration
If the sediment releases substances into a flowing system, the surface water quality will improve continuously as a result of the inflowing water. If the pore water concentration is not (considerably) higher than the surface water concentration, no release of substances can take place.

Calculation of the actual flux
The total flux is calculated with SEDIAS (sheet 2 Diffusion/dispersion and seepage) by adding the fluxes resulting from advection (transport by the water, caused by seepage) and diffusion.

In flowing waters the actual flux is calculated on the basis of the concentrations measured in the surface water. In cases of high water replacement, such as in rivers, the flux from the sediment will normally have no significant effects on the surface water concentration. In these cases dilution is (very) strong. The actual flux can however give a rough estimate of the contaminant load that is released and transported downstream.
The total flux (the sum of advection and diffusion) results in a steady contribution of the sediment in $g/(m^2.day)$. The result represents the actual absolute contribution of the sediment.

Final assessment
The final assessment is presented as the absolute contribution of the sediment expressed in $g/(m^2.day)$. For flowing waters this flux from the sediment can (also)

be used in the analysis of possible sources of contamination for the body of surface water and for the comparison of measures. If necessary, the flux can be converted to an (annual) load by multiplying it by the contaminated surface area.
The final assessment can also be presented as the addition to the concentration in µg/l. In that case the addition is determined on the basis of the flow rate of the water.

Pathway for (semi-)standing waters

Pore water concentration < 0,5 x surface water concentration
In (semi-)standing waters the measured surface water concentration can achieve equilibrium and become equal to the pore water concentration due to the release from the sediment. In this case there is no flux, but the sediment is in fact determining the surface water concentration. In standing waters therefore, it is checked whether ‘the pore water concentration is less than half the surface water concentration’, taking into account measuring errors. In other (flowing) waters it is tested whether ‘the pore water concentration is less than the surface water concentration’.

Calculation of the actual flux
The total flux is calculated with SEDIAS (Sheet 2 Diffusion/dispersion and seepage) by adding the fluxes resulting from advection (transport by the water, caused by seepage) and diffusion/dispersion.

In standing waters, such as isolated lakes, the actual flux can become very small, because the sediment and the surface water are near equilibrium. This means that, although the sediment entirely determines the surface water concentration, the actual pollutant flux is very small. In order to assess whether a measure (dredging or capping of the sediment) can be effective in such (semi-)standing waters, it is advisable to include the potential flux in the assessment. The potential flux is calculated by assuming a surface water concentration that meets the standard for surface water.

Calculation of the total concentration caused by this flux
The effect of this flux on the water system can be calculated by also calculating the total surface water concentration (see SEDIAS, sheet 4 Contribution total concentration). This calculation takes into account any replacement of the surface water by mixing or flowing, because this affects the contaminant concentration in the water.

Final assessment
The final assessment is presented as the relative contribution of the sediment to the exceeding of the standard. The total concentration resulting from the flux from the sediment is divided by the actual surface water concentration.

Specialistic methods for determining the flux
The method described here calculates the flux on the basis of easily acquirable data. Instead of this indirect calculation, one can also use a more direct experimental approach. The most common approach is using undisturbed columns, in which the supernatant layer of water is depleted or refreshed. Another possibility is the in situ use of a benthic chamber.

3.2 Environmental quality standards for total concentrations in surface water

This section is used in case the total concentration of a sediment relevant substance (see § 2.2.2) exceeds its environmental quality standard.
The Bkmw 2009 environmental quality standards are defined as standards for the total concentration in water, i.e. water including its suspended particulate matter. This is also the case for the standards for abstracting drinking water and for the reference values for watering cattle (see Annex D).
In § 2.2.1 it is indicated that two types of environmental quality standards for the total concentration are distinguished:

- the annual average concentration (AA-EQS);
- the maximum acceptable concentration (MAC-EQS).

For the compliance testing of organic substances against the standards, an unfiltered sample, so including suspended particulate matter, is analysed. This section examines the contribution of the fraction bound to suspended particulate matter in relation to the total concentration in water. This depends on the concentration and quality of the suspended particulate matter. The quality of the suspended particulate matter depends on the adsorption properties of the contaminant and the composition of the suspended particulate matter. Resuspension of contaminated sediment contributes to the total concentration in the surface water.

Resuspension can be caused by:

- current;
- shipping;
- wind;
- bioturbation.

In order to assess the effect of the sediment on the exceeding of surface water standards, two types of surface waters are distinguished:

- Flowing waters. This includes the R-, O- and K-water types of the WFD classification.
- (Semi-)standing waters. This includes the M-water types of the WFD classification.

3.2.1 Flowing waters

Whenever a standard is exceeded in flowing waters, there is a high probability that transport from upstream areas is the main cause. This might be one substantial upstream source, but in many cases it will be an assembly of sources. One or more sites with contaminated sediment may be part of these upstream sources. This applies to both the exceeding of the MAC-EQS and the exceeding of the AA-EQS. In the case of exceeding the MAC-EQS it concerns mainly peak concentrations that

may occur during peak flows. In these cases (upstream) sediment can surely act as a source. This might imply that the achievement of objectives in downstream bodies of surface water is compromised by upstream sources. In cases like this, one is advised to analyse the problems on a (partial) river basin scale. This guidance document is not equipped for such an approach, but elements of this guidance document can be used in such an analysis.
If the transport from upstream areas appears not to be the dominant factor (anymore), a local scale assessment can be carried out. In that case the flowchart in §3.2.2 can be used (see figure 3.3).

Specialistic methods to assess the compromising of downstream objectives as a result of the erosion of contaminated sediment
A major part of the sediment is transported during high flow rates. Sedimentation areas can turn into erosion areas under extreme conditions. As a result of this, historically contaminated sediment is transported downstream and can result in the exceeding of standards in downstream (WFD) bodies of surface water. If a standard is (threatening to be) exceeded in this downstream body of surface water, there is a motive to assess the (possible) contribution of upstream historically contaminated sediments. It can be determined whether and how often the critical shear stress is exceeded in the upstream area as a result of occurring flow rates and wind speeds, resulting in the resuspension and downstream transport of contaminated sediment. Measuring this process before, during and after extreme conditions is difficult because of the unpredictability of high flow rates and sometimes because the field conditions do not allow for making high quality measurements. For estimating the sediment transport, sophisticated hydraulic models, in which sediment and suspended matter can be incorporated, such as BRETRO, WAQUA or Delft-3D are available.

3.2.2 *(Semi-)standing waters*

The water flow rate in (semi-)standing waters is too low to induce resuspension. Shipping, wind and bioturbation however, can cause resuspension. Figure 3.3 shows the steps.

Is there a relationship between suspended particulate matter concentrations and contaminant concentrations?
First it is checked whether the contaminants bound to suspended particulate matter are relevant with respect to the exceeding of the standard. For more mobile organic pollutants the dissolved phase can (also) be very relevant. If no relationship can be established between the suspended particulate matter and the contaminants, one is referred to §3.1.

Is the standard exceeded during a period of increased suspended particulate matter concentrations?
It is sensible to further analyse the monitoring data first. If the sediment is a cause for exceeding the standard, this is caused by the resuspension of high concentrations of suspended particulate matter. In case the suspended particulate matter concentration has been monitored, the monitoring data of the substances not meeting the standard can be compared with the suspended particulate matter concentrations. In shallow waters one can determine from this comparison which aspects cause the exceeding of the standard and at which suspended particulate matter concentration this occurs. In deeper waters (> approx. 5 metres), the result

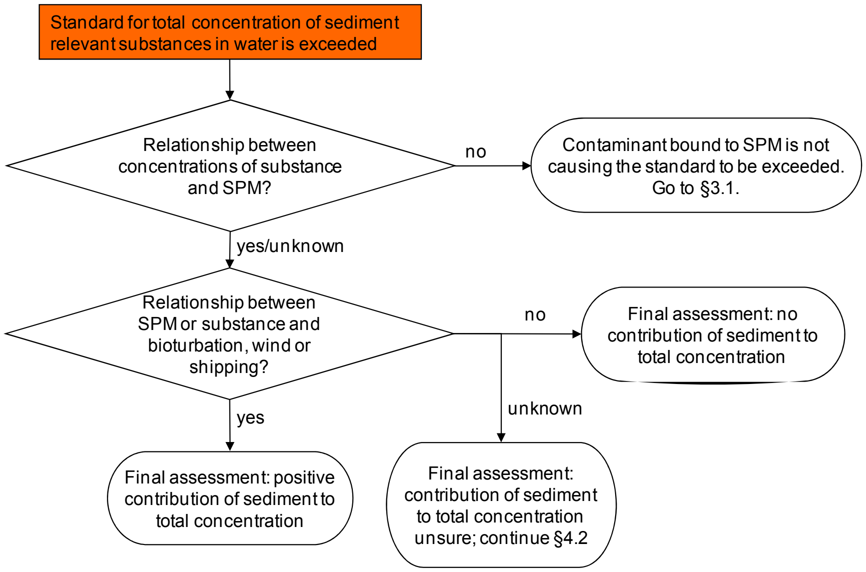
of a suspended particulate matter measurement near the water surface is hard to relate to resuspended sediment. In case of deeper waters one is therefore advised to conduct specialistic research into the effect of resuspendend sediment on suspended particulate matter measurements.

Can the suspended particulate matter concentrations be related to resuspension events (induced by wind, shipping or bioturbation)?

Wind-induced resuspension events

The wind speeds and directions that occurred during the measurement of the water quality can be found at http://www.knmi.nl/klimatologie for the nearest meteorological station. The web-page contains timeseries. In order to find a relation between wind speed, suspended particulate matter (SPM) concentrations (if measured) and concentrations of the standard-exceeding substance(s), one can examine data covering a longer period. In the text box an example has been elaborated.

Figure 3.3
Flowchart for assessing the sediment in case the standard for total concentrations in surface water[8] is exceeded



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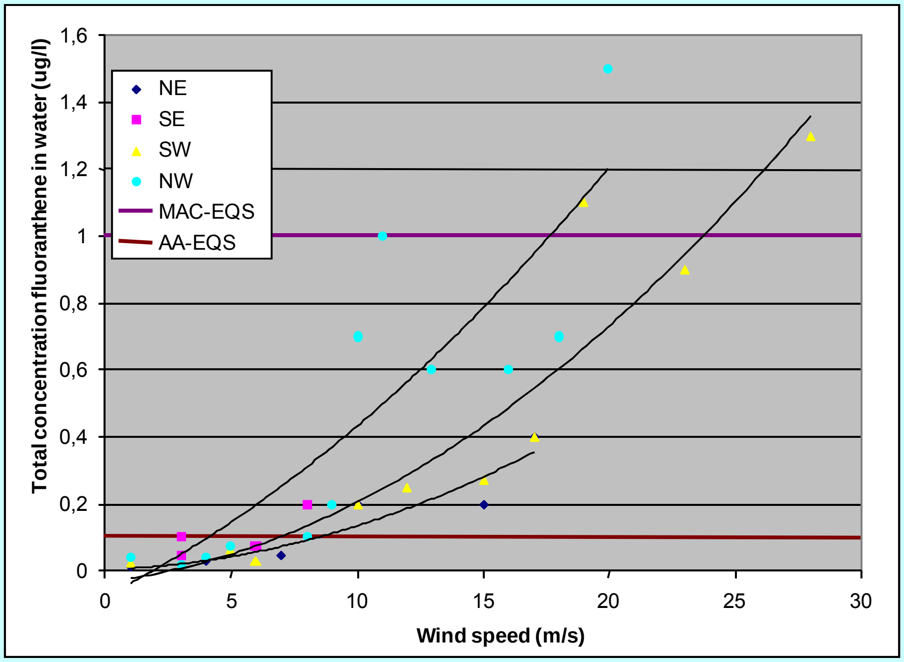
[8] Total concentrations in surface water are relevant for testing against the chemical standards in WFD waters and for the water functions of drinking water and water for agricultural use (reference values for watering cattle).

Example

Monitoring data from a lake show that fluoranthene concentrations regularly exceed the MAC-EQS. Plotting total concentrations against wind speed (grouped per wind direction) during and (if data are available) in the hours prior to the measurements, reveals that higher fluoranthene concentrations are measured at higher wind speeds. In addition, northwesterly winds (NW) result in higher concentrations than southwesterly winds (SW). By means of the diagram below, one can establish that the MAC-EQS is exceeded at westerly winds with wind speeds exceeding 15 to 25 meter per second.



<u>Resuspension caused by shipping</u>

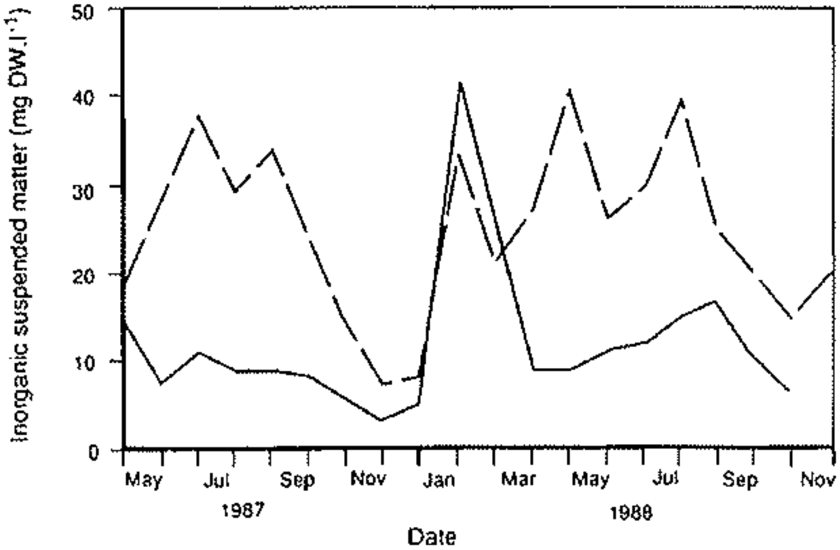
Shipping is a more or less continuous activity, which makes it difficult to establish a relationship between shipping intensity and standards being exceeded. On a local scale though, one might try to find a relationship between shipping intensity, suspended particulate matter concentrations (if measured) and the exceeding of standards. In doing this, one can use information concerning periods with varying shipping intensity as well as information concerning differences between summer and winter, day and night or weekday and weekend.

<u>Resuspension caused by bioturbation</u>

Bioturbation can cause resuspension especially in shallow waters (< 3-4 metres). Resuspension by bioturbation in (semi-)standing waters is mainly determined by benthivorous fish, such as Common bream. The effects of benthivorous fish on the suspended matter concentrations are illustrated in figure 3.4, in which the suspended matter concentrations in a lake are presented in the presence and absence of benthivorous fish.

Figure 3.4 shows that the suspended matter concentration is relatively low (approx. 10 mg/l) throughout the year in the absence of benthivorous fish. The peak in January is probably caused by a storm. In the part of the lake with benthivorous fish the suspended matter concentration is higher (approx. 30 mg/l) except in winter (November-December). If the suspended matter concentrations show a clear 'winter dip' that cannot be explained by other factors such as wind and shipping, this is a symptom of bioturbation.

Figure 3.4
Inorganic suspended matter concentrations in Lake Bleiswijkse Zoom, in the presence (dotted line) and the absence of benthivorous fish (continuous line) [Meijer *et al.*, 1990].



If fish stock inventories are carried out in the body of surface water, one can use the amount of benthivorous fish to estimate the resuspension by bioturbation. The equation presented below by Meijer *et al.* (1990), gives an estimate of the suspended particulate matter concentrations that can be caused by bioturbation by fish in lakes not deeper than 2 metres:

Suspended particulate matter [mg/l] = 8 + 0,062 benthivorous fish [kg/ha)]

The equation may be applicable in other situations, but one is advised not to use the equation in flowing waters or waters deeper than 3 to 4 metres. Bioturbation can only be a factor of importance in shallow standing waters (De Lange *et al.*, 2006).

Final assessments
In case a clear relationship has been established between resuspension events and the exceeding of standards, it is clear that the sediment contributes to these exceedings. The extent of this contribution can usually be estimated on the basis of the established relationship.
In case it still remains uncertain whether resuspended particulate matter contributes to exceeding the standard, one can also try to assess its significance by using the sections of this guidance document that use sediment quality as starting point. In §4.2 resuspension by wind, shipping or bioturbation is quantified on the basis of local data, such as fetch and occurring wind speeds, number of ships and volume of fish.

3.3 MPC for surface water and MPC for suspended particulate matter

This section involves the exceeding of two types of standards:

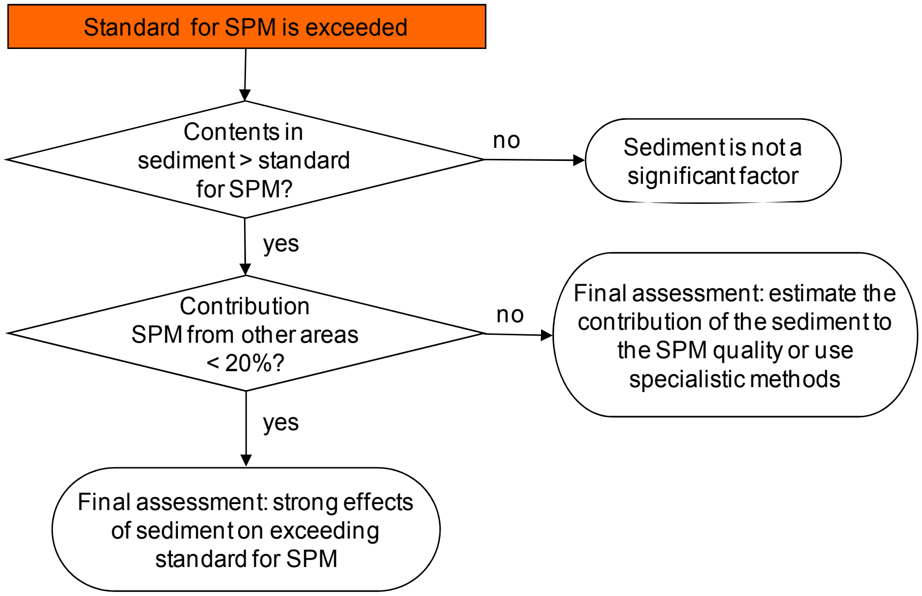
1. MPC for suspended particulate matter. In the Dutch Ministerial Monitoring Regulation PCB-standards for suspended particulate matter have been laid down.
2. MPC for surface water. Compliance testing against this standard is done after standardizing the measured concentration to standard water containing 30 mg/l suspended particulate matter, which in its turn contains 40% clay and 20% organic matter.

With respect to standards in suspended particulate matter and standards in water with a standardized suspended particulate matter concentration, the effects of the sediment mainly occur in (semi-)standing waters, just as in case of total concentrations (§3.2). In flowing waters the suspended particulate matter usually is transported from upstream areas. This calls for a larger spatial scale approach (see §3.2.1). Figure 3.5 is only used if it is established that transport from upstream areas is not the main cause for exceeding the standard.

3.3.1 MPC for suspended particulate matter

Figure 3.5 shows the method to be used in case the standard for suspended particulate matter (SPM) is exceeded.

Figure 3.5
Flowchart for assessing the sediment in case the standard for suspended particulate matter (SPM) is exceeded.



Contents in sediment (converted) > suspended matter standard
If the contents in the sediment (converted) do not exceed the suspended particulate matter standard, the sediment cannot be the reason for exceeding the standard. In order to be able to compare the contents in the sediment, they have to be converted to standardized suspended particulate matter in accordance with the following equation:

$$Q_{stand.spm} = C_{measured\ sed} \times 20 / (\%OM)$$

in which:

$\%OM$ = % organic matter (minimally 2% and maximally 30%)

$C_{measured\ sed}$ = content of contaminant in sediment [mg/kg dry matter]

$Q_{stand.spm}$ = standardized content of contaminant in suspended particulate matter[mg/kg dry matter]

If the input data on SEDIAS sheet 1.Partitioning are correct for the substances of concern, the conversion above is calculated in SEDIAS sheet 6.Susp. matter&MPC.

Does the suspended particulate matter mainly originate from the contaminated site or is it transported from other areas?
The limit of 20% transport from other areas is an arbitrary one. The intention is to differentiate between waters where hardly any transport of suspended particulate matter from other areas takes place (for example only through sluices) and (flowing) waters where transport of sediment does occur.

Final assessments
If the answer is yes, it is concluded that sediment is the main factor affecting the suspended particulate matter quality.
If the answer is no, it is more complex. On the basis of expert assessment one can estimate the contribution of the sediment to the suspended particulate matter quality. Residence time of the water and magnitude of the resuspension (wind/shipping/ bioturbation) are important factors in this estimate.

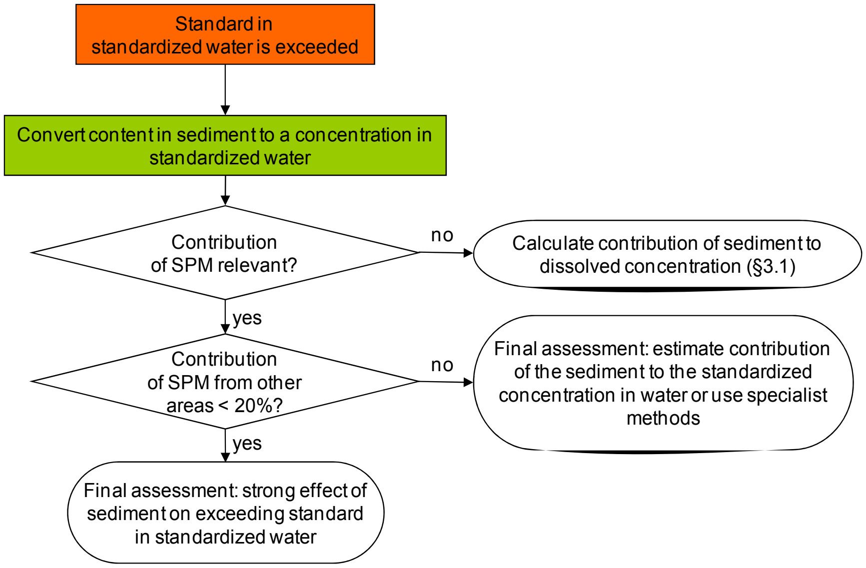
Specialistic methods for constructing a suspended particulate matter (SPM) mass balance
This subsection is used in cases where the standard for suspended particulate matter quality has been exceeded. Deployment of for example sediment traps will yield little new information in these cases. However, constructing a SPM mass balance with models can produce better insight. Usually this is done with hydraulic models, such as WAQUA, BRETPRO, SOBEK of DELFT3D, to which a suspended particulate matter module is coupled.

3.3.2 *MPC for surface water*

Figure 3.6 shows the method that is used in case the MPC for surface water is exceeded. In this case the standard for 'standardized water' is exceeded.

Convert the content in the sediment to a concentration in standardized water
Standardizing concentrations that are measured in water involves assuming a suspended particulate matter content of 30 mg/l and this suspended particulate matter containing 20% organic matter and 40% clay. This standardization deviates from the standardization of soil (10% organic matter and 25% clay). In order to assess whether the sediment causes the standard for standardized water to be exceeded, the contribution of 30 mg/l suspended particulate matter to the total concentration and to 'filling up' the standard is calculated.

Figure 3.6
Flowchart for assessing the sediment in case the standard for concentrations in standardized water is exceeded.



The content measured in the sediment is first converted to a standardized content in suspended particulate matter (SPM) in accordance with the following equation:

$$Q_{\text{stand, spm}} = Q_{\text{measured, sed}} * \frac{a + b*40 + c*20}{a + b*\%\text{clay} + c*\%\text{org. matter}} \text{ (for metals) or}$$

$$Q_{\text{stand, spm}} = Q_{\text{measured, sed}} * \frac{20}{\%\text{org. matter}} \text{ (for organic contaminants)}$$

in which:

$Q_{\text{stand, spm}}$ = standardized content in suspended particulate matter derived from resuspended sediment (mg/kg)
$Q_{\text{measured, sed}}$ = content measured in sediment (mg/kg)
%clay = clay percentage
%org.matter = organic matter percentage
a, b, c = contaminant specific parameters for soil type correction (see annex G of Soil Quality Regulation)

Next the standardized content is converted to standardized water in accordance with the following equation:

$$C_{\text{standard water by spm}} = Q_{\text{stand, spm}} * 30 * 10^{-3}$$

in which:

$C_{\text{standard water by spm}}$ = contribution of 30 mg/l standardized suspended particulate matter to concentration in standardized water (µg/l).

$Q_{\text{stand, spm}}$ = standardized content in suspended particulate matter derived from resuspended sediment (mg/kg). The factor 30 stems from the prescribed 30 mg suspended particulate matter per litre. The factor 10^{-3} is necessary in order to arrive at the correct units.

In SEDIAS sheet 6.Susp. matter&MPC these calculations have been carried out for substances for which an MPC exists, provided that the input data in sheet 1.Partitioning are correct. Now the contribution of the sediment to the exceeding of the standard, resulting from resuspension, can be calculated.

Is the contribution of suspended particulate matter relevant to the concentration in standardized water?
The calculation presented above is only relevant if suspended particulate matter contributes significantly to the total concentration in water. In case (much) more than half of the concentration consists of dissolved contaminant, §3.1 can be used to determine the contribution of the dissolved contaminant.

Does the suspended particulate matter mainly originate from the contaminated site or is it transported from other areas?
The limit of 20% transport from other areas is an arbitrary one. The intention is to differentiate between waters where hardly any transport of suspended particulate matter from other areas takes place (for example only through sluices) and (flowing) waters where transport of sediment does occur.

Final assessments
If the answer is yes, it is concluded that sediment is the main factor affecting the suspended particulate matter quality. On this point it must be mentioned that after resuspension of the sediment only the finest fraction of the suspended particulate matter will reach the top of the water column. At increasing depths the relationship between the sediment and the suspended particulate matter becomes weaker. For that reason it is advised to use specialistic methods to determine the contribution of the sediment to the exceeding of standards in surface waters deeper than 5 meters.

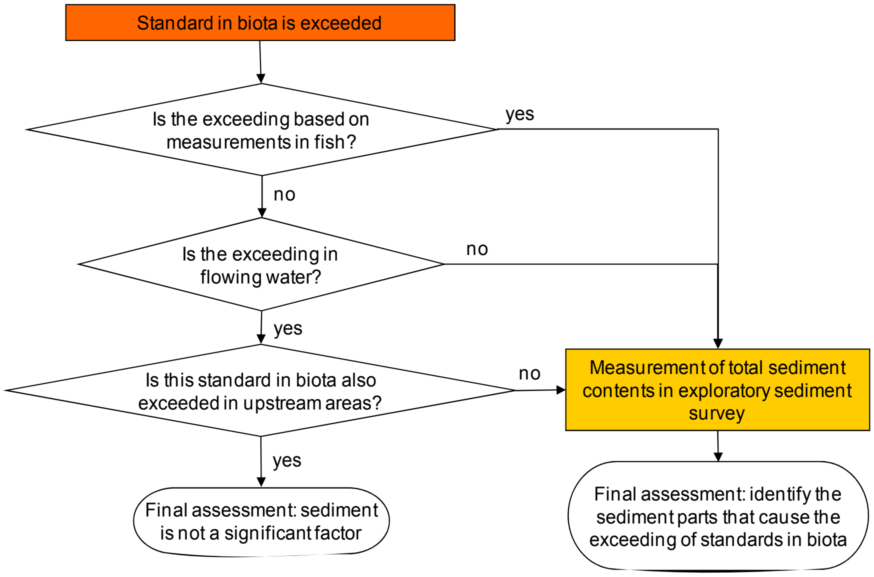
If the answer is no, it is more complex. On the basis of expert assessment one can estimate the contribution of the sediment to the suspended particulate matter quality. Residence time of the water and magnitude of the resuspension (wind/shipping/ bioturbation) are important factors in this estimate.

Specialistic methods
This subsection is used in cases where the standard has been exceeded due to the suspended particulate matter (SPM) quality. Deployment of for example sediment traps will yield little new information in these cases. However, constructing a SPM mass balance with models can produce better insight. Usually this is done with hydraulic models, such as WAQUA, BRETPRO, SOBEK of DELFT3D, to which a suspended matter module is coupled.

3.4 Standards in biota

Exceeding a standard in biota mainly depends on the substance content in the sediment and/or suspended particulate matter due to the partitioning over water, sediment and organic matter. Figure 3.7 shows the methods that can be used if one or more standards in biota are exceeded.

Figure 3.7
Flowchart for assessing the sediment in case the standard in biota is exceeded.



Is the exceeding based on measurements in fish or on measurement in the water column, in for example shellfish?
The exceeding of a standard in biota can have been established in different species. Contents measured in shellfish hung out in cages in the water column mainly reflect the quality of the suspended particulate matter in the water column. Contents measured in fish mainly reflect the quality of the food the fish ingested.
The food the fish ingests, depending on the specific species, comes to a smaller or larger extent from the top layer of the sediment. The sediment is therefore examined if the exceeding has been established in fish.

Is the exceeding in flowing water?
First, if an exceeding has been established in the water column, it is verified whether this exceeding occurred in flowing or (semi-)standing waters. (Semi-) standing waters are classified as such if the water has a residence time of more than a month for the greater part of the year. In (semi-)standing waters it is very well possible that the contents measured in biota are related to the sediment quality (comparable to the situation sketched above for fish). In that case the same method is used as in case of exceeding the standard in fish.

Is this standard in biota also exceeded in upstream areas?
If the exceeding of the standard has been established in biota that take their food exclusively from the water column, such as zebra mussels (*Dreissena polymorpha*) that are hung out in cages, it is important to know whether the water quality is

mainly determined by the sediment or by the upstream flow of water. In flowing waters one should try to find the cause of exceeding the standard in biota that live in the water column in upstream areas and not in the sediment near the monitoring point. In case of flowing waters one should therefore first check whether the standard in biota is also exceeded in the upstream waters. The sediment is only examined if no problems are found in the upstream areas.

Measure total contents in the sediment

The sediment is examined by measuring the total contents in an exploratory sediment survey. In defining the study area, one should not only consider the general requirements of the preliminary investigation (see Annex E) but also the size of the habitat and the travelling range of the species in which standards have been exceeded.

Final assessments

The total contents in the sediment, measured in accordance with NEN 5720 (Annex E) in the exploratory sediment survey, can subsequently be used to identify the areas that are causing the exceeding of the standard.

Specialistic methods for assessing whether the sediment causes the standard in fish or shellfish to be exceeded

By measuring contents in sediment dwelling biota, such as the Golden Clam (*Corbicula fluminea*) or worms and mosquito larvae, one can determine with greater certainty whether the sediment is (partially) causing the established exceeding of the standards in biota. The advantage of measuring in sediment dwelling biota is that the availability for uptake of these bioaccumulating substances in the food web is determined in a direct way. This is especially important in case of contamination with mercury, because this metal is microbially converted into methylmercury in the environment. Methylmercury is much more toxic, partly due to the fact that it is taken up much quicker by higher organisms.

It is also possible to conduct bioaccumulation experiments with sediment samples in the laboratory, where bioaccumulation levels in the biota are measured after 4 weeks of exposure. The measured bioaccumulation levels and knowledge of the food web can subsequently be used to determine the relationship between sediment quality and (shell)fish quality.

3.5 Eutrophication standards

The rapid seasonal nutrient cycles (sediment fi water fi organisms fi detritus fi sediment) demand an approach that takes these dynamics into account. This is different from the toxic substances approach, where a constant flux from the sediment to the surface water is assumed (figure 3.1). In figure 3.8 the phosphate dynamics are presented.

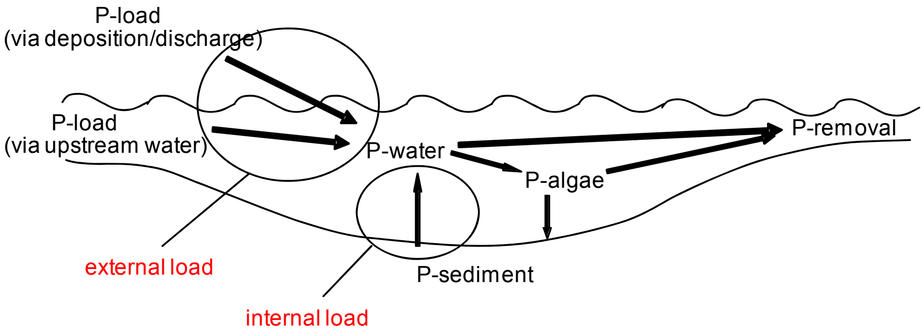


Figure 3.8
Illustration of the phosphate dynamics in the water system.

In figure 3.8 the external load is the only P-source that is added to the system. A constant external load will in time result in a steady-state, in which the amounts of P released from the sediment and entering the sediment have become equal. The amounts of P entering the sediment mainly consist of decayed organic matter (detritus).

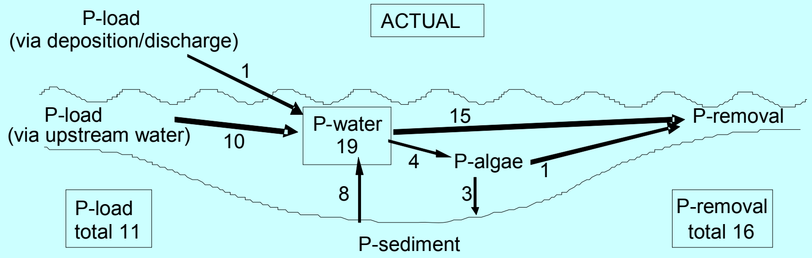
In a steady-state the external load and the removal from the system are equal. In case of eutrophication problems, reducing the external load is the structural solution. If the external load is sufficiently reduced, the system will shift to a new steady-state, having less or no eutrophication problems. For phosphorous, reaching the new steady-state can take decades because the sediment releases the phosphorous needed for the growth of algae to the water column. If the pool in the sediment is dredged or capped, the sediment cannot release P anymore and the new steady-state can be attained quicker. Especially in shallow fresh waters with relatively long residence times, the sediment can act as an important source.

In the text box below the concept of steady-state is illustrated with a computational example.

Actual load versus steady-state load

In the (simplified) example below P is given in quantities instead of concentrations for the sake of simplifying reality.

In a system where the total external load had been reduced to 11 (see figure), the sediment can release P. The amount of P in the water is not 11, but 19 because the sediment releases 8. The consequence is that the removal from the system is higher than the load, but also that algal growth is higher than one would estimate on the basis of the external load.



In due time the system will reach steady-state, i.e. the removal of P is equal to the load (steady at 11). The sediment will adjust to this steady-state. Further it is expected that algal growth will diminish. Eventually this can lead to the steady-state P-load presented below. Load and removal are equal (11), algal growth has been halved, but this is only possible if the release from the sediment declines strongly. This can take a long time and especially in these cases it can be interesting to take measures that reduce the internal load.

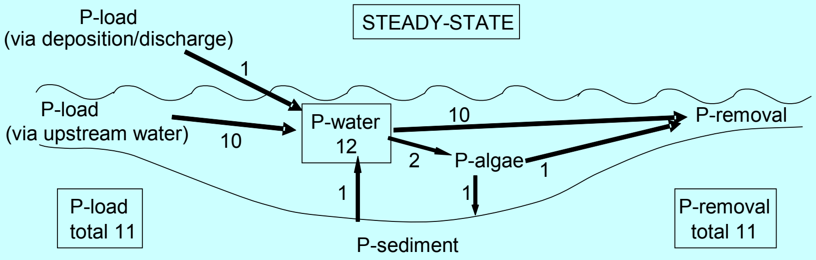
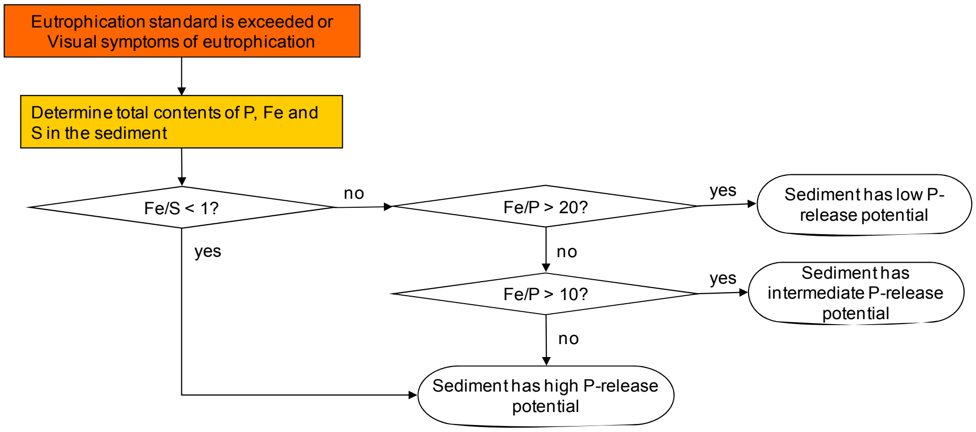


Figure 3.9
Flowchart for assessing the sediment in case the standard for eutrophication is exceeded or in case of visual symptoms of eutrophication .



The method[9] for assessing the effects of the sediment (see figure 3.9) assumes that the total-P, total-Fe and total-S contents have been determined in the top layer of the sediment.This is because iron and sulphur are significant elements in binding P in the sediment. The following rules of thumb can be used to determine whether the sediment is an important source with respect to eutrophication.

Fe/S < 1?
Whether the iron in the sediment is able to bind P sufficiently is determined by the Fe/S ratio. If the Fe/S ratio (g/g) < 1, there is chance that all Fe in the sediment is present as FeS, due to which the Fe in the sediment does not contribute to the binding of P. In that case the sediment has a high potential for the release of P.
If the Fe/S ratio > 1, not all Fe is present as FeS and subsequently the ratio between Fe and P is checked.

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[9] With the default method for eutrophication standards it is attempted to fulfil the wish to be able to assess the nutrient releasing potential of the sediment in a simple way. Contrary to the other parts of this guidance document, for which experience has been acquired in research conducted within the framework of the Soil Protection Act, hardly any experience has been gained with this part. For this part it is advised to use specialistic methods in a relatively early stage (in case of larger sites). For this reason relatively much attention is given to the description of specialistic methods in the text boxes.

Specialistic methods for determining P-release from the sediment

1. Measuring (for details: see Annex G)
Various methods exist that provide a better insight in the transport of P from the sediment to the surface water. In addition to measuring total contents, it is possible to determine:
- the potentially available pool that can be released;
- the actual available concentration.

Arcadis (2009) made an inventory of methods.

Potentially available pool
The potentially available pool is the pool in the sediment that can be released. It also gives an indication of the extent to which a system is loaded with P. With the available fraction one can determine whether the loading of the sediment relates to the external load. Especially if the sediment is much more loaded than the external load would account for, an intervention in the sediment can be useful. An example of such a situation is described in the report 'From clear to troubled and back' (Jaarsma *et al.*, 2008). Various methods are available to determine the available fraction, such as: oxalate extraction, lactate-acetate extraction and Fe-paper extraction.

Actual available concentration
In recent years much research has been conducted on the Fe/P ratio as indicator for P-release from the sediment (Jaarsma *et al.*, 2008). Pore water is extracted from a fresh sediment sample and analysed for Fe, P and S. Ecological problems occur mainly in sediments with Fe/P ratios in the pore water < 5 (Jaarsma *et al*., 2008).
Another method is measuring the actual available P-concentration under aerobe conditions. For this, one can use the same method as used for metals, which is a $CaCl_2$-extraction in open Erlenmeyer flasks (Annex F). In that case the transition from anaerobe (sediment) to aerobe water is simulated. Since there is little experience yet with this method, it is difficult to derive limits above which eutrophication problems arise.
The actual concentration can also be determined by measuring fluxes in column or aquarium experiments. Different methods are available. In most cases the supernatant water is changed in order to maximize the flux (Arcadis, 2009). It is also possible to measure fluxes under field conditions by applying enclosures or a benthic chamber (De Lange *et al*., 2009).

2. Modelling (for details: see Annex H)
Deltares has developed a screening model that specifically aims at the contribution of the sediment to nutrients in the surface water (Smits and Van Beek, 2010). The screening model is a water system model that includes all relevant processes (water flow, organic matter cycle, sorption, precipitation, diffusion in the sediment and across boundaries, etc.). The model is based on a detailed model, but many parameters have been assigned a preset value. The other parameters have to be entered by the user. If needed, a user interface will be developed in the future, in which in addition to the input, also the output will be presented in an orderly way.
Another model that simulates eutrophication is PC Lake. In this model the sediment is modelled with less detail, whereas the effects of fish and plants are described in more detail.

Fe/P ratio
The total-P analysis yields information about the total amount of phosphorous in the system. With the Fe/P ratio the P-binding capacity is estimated, which indirectly determines the P-availability. If the Fe/P ratio is for example very high, it is

assumed that a major part of P is bound to Fe and thus not available. If the Fe/P ratio is low, the potential for P-release is high.

Fe/P ratio (g/g)	**Potential for P-release**
Fe/P > 20	Low
10 < Fe/P < 20	Moderate
Fe/P < 10	High

3.6 Ecological objectives for macrofauna

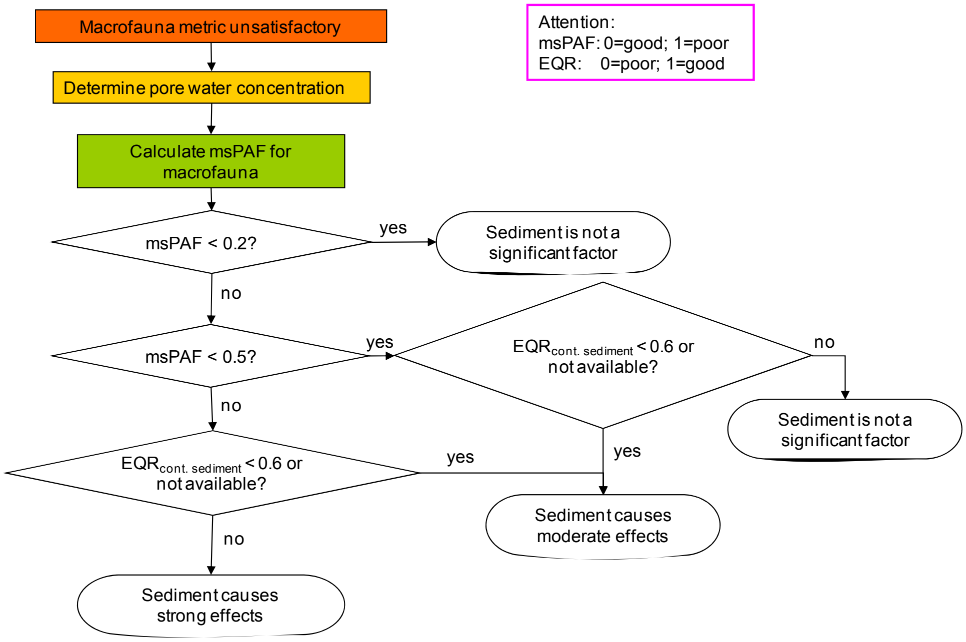
Figure 3.10 shows the flowchart to assess whether sediment quality has negative effects on the macrofauna population. The assessment starts if it is established that the macrofauna population is classified as unsatisfactory. This classification may have been done in accordance with the WFD systematics, but also with national or regional methods if it involves waters not classified as WFD bodies of surface water.

Determine the pore water concentration

Initially the equilibrium concentration in the pore water of the top layer of the sediment is determined. For this purpose the total contents of (heavy) metals and organic contaminants in the sediment are used. See Annex E for the measurement of total contents.

Figure 3.10

Flowchart for assessing the sediment in case of an unsatisfactory score on the macrofauna metric.



The concentration of organic contaminants in pore water is calculated according to the following equation:

$$C_{pw} = Q_{measured,sed} / (f_{oc} \times K_{oc})$$

in which:
C_{pw} = concentration in pore water [mg/l]
$Q_{measured,sed}$ = measured content in sediment [mg/kg$_{ds}$]
f_{oc} = fraction organic carbon [-]
K_{oc} = partitioning constant for organic carbon [l/kg$_{OC}$]

For metals the pore water concentration is calculated according to the following equation:

$$C_{pw} = Q_{stand,sed} / K_d$$

in which:
C_{pw} = dissolved metal concentration in pore water [mg/l]
$Q_{stand,sed}$ = content in sediment converted to standard sediment [mg/kg$_{ds}$][10]
K_d = partitioning constant for sediment [l/kg]

In order to achieve a higher reliability, the pore water concentration can be measured with specialistic methods (see text box in §3.1 and Annex F).

Calculate msPAF for macrofauna

By calculating the msPAF it is checked whether the sediment quality is actually likely to affect the macrofauna. More information on the backgrounds of the msPAF can be found in Annex K. With SEDIAS (sheet 5.msPAF, see also Annex J) the msPAF can be calculated in various ways. For assessing the effects on the macrofauna, the msPAF based on chronic EC50s has been selected. The reason for this is that the guidance document is used in cases of long-term exposure and that only actual effects (effect level EC50) are considered important.
The input of monitoring data from the sediment have to be entered only once in SEDIAS sheet 1.Partitioning.

Because the msPAF is a combined standard, many substances with a low individual PAF can still result in a considerable msPAF. Therefore at least the contents of the following substances have to be entered in SEDIAS in order to calculate the msPAF:

- metals (arsenic, barium, cobalt, cadmium, chromium, copper, mercury, molybdenum, nickel, lead and zinc);
- 10 PAHs (VROM);
- organochlorine pesticides on the default analysis list for substances in sediments in the Dutch national waters (see NEN 5720);
- pentachlorophenol, pentachlorobenzene and hexachlorobenzene.

If one or more of these substances have not been measured, for example because the site is not suspected to be contaminated with these substances, the same method is used as applied in the Dutch Soil Quality Regulation (Rbk) for relocating dredged material on an adjoining parcel of land. That implies that the minimum value to be entered equals 0.7 times the intralaboratory reproducible limit of detection (annex L of the Rbk). Measurements of suspect substances that are not on

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[10] In SEDIAS it is possible to enter the measured content. The soil type conversion is then automatically performed.

the default analysis list have to be entered additionally. PCBs are not relevant for calculating the msPAF because these substances do not affect macrofauna.

msPAF < 0.2?
A low score on the metric for macrofauna cannot be related to the sediment quality if the msPAF < 0.2. If the msPAF > 0.2 the flowchart is continued.

msPAF > 0.2?
Effects cannot be ruled out if the msPAF is between 0.2 and 0.5. If the msPAF > 0.5 one should expect strong effects.

Influence $EQR_{cont.sediment}$
An unofficial 'metric' that is sensitive for contaminated sediments has been derived (exclusively) for R8 water types (Peeters *et al.*, 2008; Reeze *et al.*, 2010). This metric, the $EQR_{cont.sediment}$, can be applied in R8 waters to assess to what extent the sediment quality negatively affects the macrofauna population.
If the score on this metric is satisfactory ($EQR_{cont.sediment} > 0.6$) the final assessment based on the msPAF is softened (from strong to moderate effects; from moderate to no effects).

Specialistic methods for assessing the effects of the sediment on macrofauna
The effects of the sediment on macrofauna can be assessed with the following additional measurements:

1. Bioassays: Bioassays can demonstrate that the contents of contaminants in the sediment of concern actually can cause effects. Bioassays can be used in the assessment method (figure 3.10) in a way that is comparable to the sediment metric for macrofauna. If the msPAF > 0.5 and the bioassays reveal no effects, the final assessment can be softened from strong to moderate.
2. Additional field inventory: Additional fieldwork for example involves sampling macrofauna and/or nematodes in deeper situated sediments instead of sampling in the shallow bank/shore zone. This additional field monitoring can show that the part of the ecosystem most influenced by the sediment is indeed negatively affected.

3.7 Nature objectives

If the nature authority detects problems with respect to preserving or extending specific target species that, due to direct contact or food, depend on healthy sediment, the presence of bioaccumulating substances (Annex B) in the sediment can (partially) be the cause. In that case one is advised to examine the sediment for bioaccumulating substances. The assessment can then be carried out with the method described in §4.7

3.8 Standards for protecting humans

Monitoring takes place on behalf of both fishery and sport fishing. In this monitoring it can be established that the EU food standard for fish has been exceeded. In figure 3.11 the approach after establishing the exceeding of the EU food standard is presented. The substances most likely to be exceeded in fish in The Netherlands are dioxins in eel (TEQ). Especially in the large Dutch rivers eel is not meeting the standard. Mercury contents usually are below the standard and PAHs are hardly found in fresh fish because of the biotransformation of these substances. It is not known whether the standards of the other regulated substances (Pb and Cd) are met in eel.

The EU food standard applies to fish that is marketed. Fish landed and consumed by sport fishers is not structurally monitored or checked. In order to assess the risks of consuming fish from sport fishing, it is possible to test this fish against the MPC_{human}. This approach, starting from contaminated sediment, is elaborated in §4.8. The risks of contaminated sediment for people recreating in the bank/shore zone can also be assessed with a method presented in §4.8.

Is the sediment contaminated with substances exceeding the food standard?
If the substances exceeding the food standard in fish also show increased contents in the sediment, one can assume that the sediment contributes to the exceeding of the EU food standard.

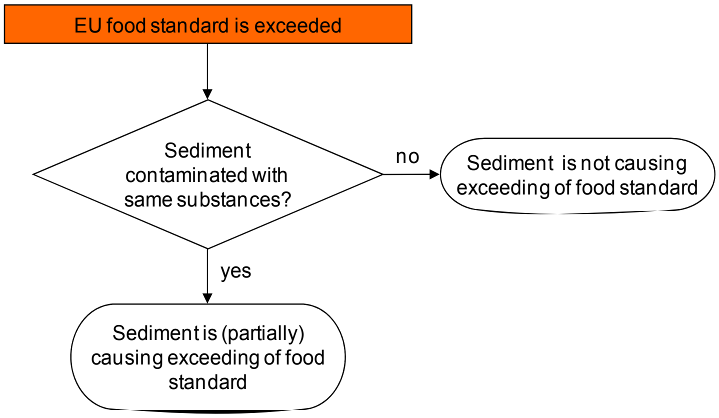


Figure 3.11
Flowchart for assessing sediment in case an EU food standard is exceeded.

Specialistic methods for explaining the exceeding of food standards
Fish is situated high in the food web. The exposure of fish occurs partially through the water phase, but mainly through the food chain. The accumulation of substances in fish is generally comparable to the accumulation in other higher organisms. If standards in fish are exceeded, one can use OMEGA45 as an instrument to examine the cause. Background information specifically on dioxins and mercury in eel can be found in Van den Heuvel *et al.* (2009).

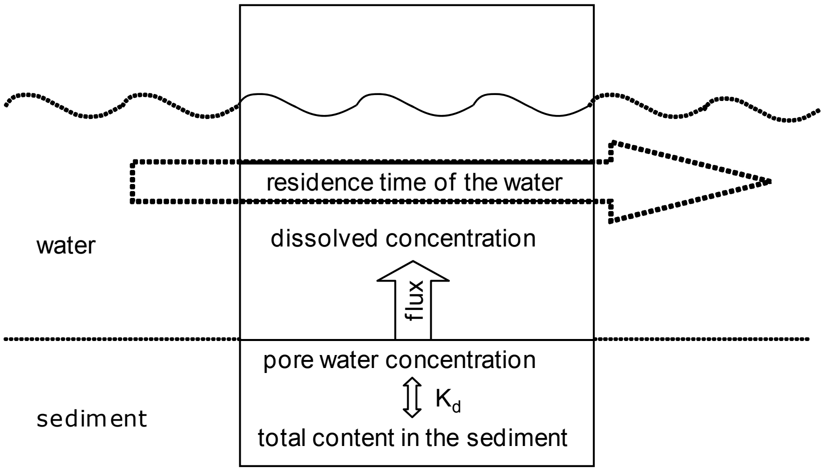
4 Methods starting from sediment quality

4.1 Environmental quality standards for dissolved concentrations in surface water

Substances in surface water can be dissolved or bound to suspended particles. Whether the sediment affects the dissolved concentration in the surface water can be determined first of all by estimating the dissolved concentrations caused by the sediment. This estimate may give cause to decide to monitor the surface water.

In this estimate it is assumed that the contribution of the sediment to the dissolved concentrations in the water column equals the flux from the pore water to the water column, as represented in figure 4.1.

Figure 4.1
Schematic representation of the relationship between dissolved substance concentrations in sediment and in surface water. The site to be assessed is represented by the box.



The flux of dissolved substances to the water column results from diffusion/dispersion and advection (seepage). In this section the flux is estimated on the basis of total contents measured in the sediment. The contribution of the flux from the sediment to the concentration in the surface water also depends on the residence time of the surface water.

Standards for dissolved concentrations in surface water only exist for (heavy) metals. The flowchart is also used if it appears from §4.2 that the water system contains mobile organic contaminants and/or very low suspended particulate matter concentrations, due to which the dissolved fraction dominates the total concentration. Figure 4.2 shows the flowchart to be used in order to determine the contribution of the sediment to the total load on the surface water.

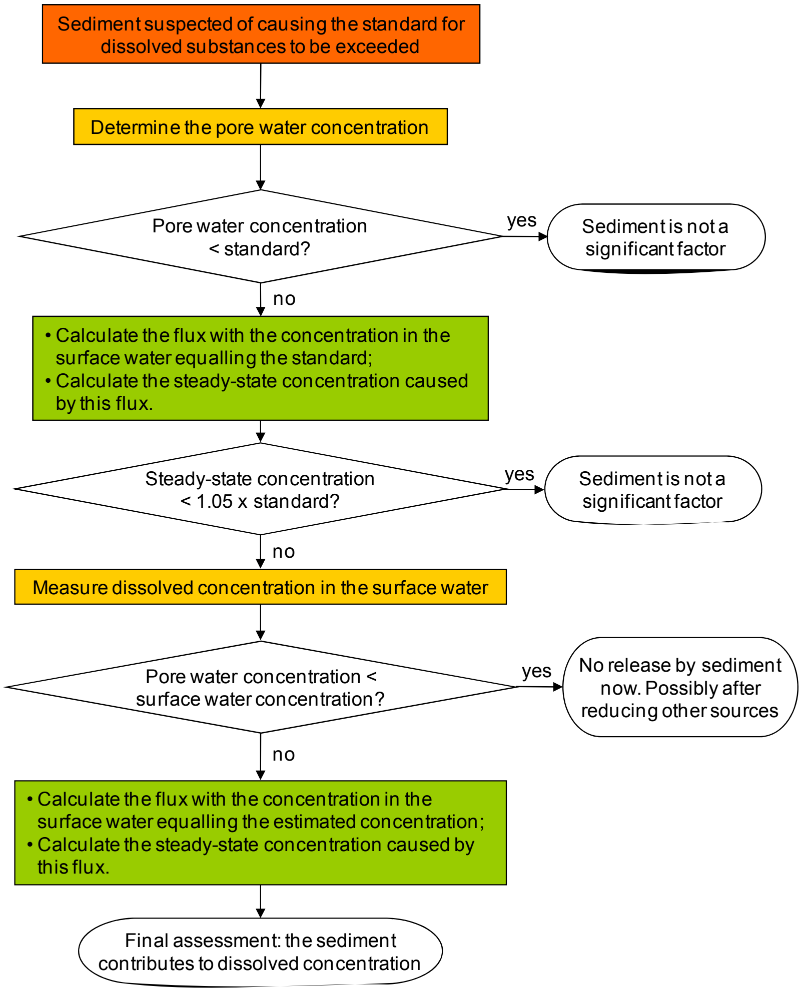


Figure 4.2
Flowchart for assessing sediment suspected of causing the standard for dissolved substance to be exceeded. The steady-state concentration involves the result of the calculation under constant conditions, such as flow rate etc.

Determine the pore water concentration in the sediment
The equilibrium concentration in the pore water of the top layer of the sediment is determined by equilibrium partitioning. In SEDIAS the K_d-values of the heavy metals are given (sheet 1.Partitioning).

The total content in the sediment can be determined in accordance with NEN5720 (see Annex E). The pore water concentration of metals is calculated according:
$C_{pw} = Q_{stand,sed} / K_d$

in which:
C_{pw} = dissolved metal concentration in pore water [mg/l]
$Q_{stand.sed}$ = content in sediment converted to standard sediment [mg/kg_{ds}][11]
K_d = partitioning constant for sediment [l/kg]

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[11] In SEDIAS it is possible to enter the measured content. The soil type conversion is then automatically performed.

The concentration of organic contaminants in pore water is calculated according to the following equation:

$$C_{pw} = Q_{measured,sed} / (f_{oc} \times K_{oc})$$

in which:
C_{pw} = concentration in pore water [mg/l]
$Q_{measured,sed}$ = measured content in sediment [mg/kg$_{ds}$]
f_{oc} = fraction organic carbon [-]
K_{oc} = partitioning constant for organic carbon [l/kg$_{OC}$]

Specialistic methods for determining the pore water concentration
A more accurate estimate of the concentrations in the pore water can be obtained by measuring the available concentration in the pore water, instead of starting from the total content. If the pore water concentration is a principal parameter in deciding to take measures or not, it is advised to measure the available fraction of the pollutant. The two methods most applied in assessing sediments are the Tenax-extraction for organic contaminants and the $CaCl_2$-extraction for metals. These methods are further explained in Annex F. The results of these extractions can be entered in SEDIAS and used in the same method.

Pore water concentration < standard in surface water
It is assumed that release from the sediment cannot result in surface water concentrations higher than those in the pore water. If the pore water concentration is lower than the standard in the surface water, the sediment cannot be the cause for exceeding the standard. In order to facilitate the comparison of the pore water concentration with the standard, SEDIAS (sheet 1.Partitioning) offers the possibility to enter the standard.

Calculation of the (potential) flux
The total flux resulting from advection (transport by the water, caused by seepage) and diffusion/dispersion is calculated with SEDIAS (Sheet 2.Diffusion/dispersion and seepage).

In standing waters, such as isolated lakes, the actual flux can become very small, because the sediment and the surface water are near equilibrium. This means that, although the sediment entirely determines the surface water concentration, the actual pollutant flux is very small. It is therefore advisable to include the potential flux in the assessment, i.e. the flux at a low concentration in the surface water.
In (semi-)standing waters it is therefore advised to calculate the potential flux, i.e. the flux at a surface water concentration that meets the standard for surface water.

In flowing waters the actual flux is calculated on the basis of the concentrations measured in the surface water. In cases of high water replacement (rivers, brooks) the flux from the sediment will normally have no significant effects on the surface water concentration. In these cases dilution is (very) strong. The actual flux can however give a rough estimate of the contaminant load that is released and transported downstream.

The total flux (the sum of advection and diffusion) results in a steady contribution of the sediment in g/(m^2.day). The result represents the actual absolute contribution of the sediment.

Specialistic methods for determining the flux
The method described here calculates the flux on the basis of easily acquirable data. Instead of this indirect calculation, one can also use a more direct experimental approach. The most common approach is using undisturbed columns, in which the supernatant layer of water is depleted or refreshed. Another possibility is the in situ use of a benthic chamber.

Calculate the steady-state concentration caused by this flux
The effect of this flux on the water system can be calculated by also calculating the steady-state concentration in the surface water resulting from this flux (see SEDIAS, sheet 2.Diffusion/dispersion and seepage). This calculation takes into account any replacement of the surface water by mixing or flowing, because this affects the contaminant concentration in the water.

Steady-state concentration resulting from this flux > 1.05 x standard
It is advisable to start monitoring if it is calculated that the total flux results in a steady-state concentration exceeding 1.05 times the standard. The factor 1.05 (5% increase) is arbitrary here. In case the competent water authority wants to get a better underpinned estimate, it can always decide to start monitoring in the surface water.

Measure the concentration in the surface water
In order to determine in a reliable way whether the sediment actually releases substances, the surface water concentration needs to be monitored by sampling on different moments and analysing these samples. It is advised to attune this monitoring as much as possible to the regular monitoring (see Annex I).

The surface water sampled in this monitoring is filtered over a 0.45 µm-filter, which removes the suspended particulate matter from the sample and which allows for analysing the dissolved substances (such as dissolved organic matter, DOC). This method of analysis is required by the WFD for metals.

Pore water concentration < surface water concentration
The sediment is not primarily causing the concentration in the surface water if the pore water concentration exceeds the standard in surface water, but is still lower than the measured surface water concentration. Sources other than the sediment are then determining the concentration in the surface water.

In standing waters the surface water concentration may equal the pore water concentration as a result of the release of substances from the sediment. In that case the flux is zero, but the sediment is determining the surface water concentration. In standing water systems, the flowchart is continued if the concentration in the pore water and the measured concentration in surface water deviate from one another less than a factor 2.

Calculate the flux on the basis of the surface water concentration
If the equilibrium concentration in the pore water is higher than the surface water concentration, the sediment can cause the exceeding of a standard. If this is the case, the flux and resulting steady-state concentration in the mixing area are calculated again, but this time on the basis of the actual concentration in the surface water.

The flux is calculated on the basis of:
- advection: transport caused by seepage;
- diffusion/dispersion.

The calculation of these fluxes is described in the instructions for SEDIAS and the fluxes can be calculated with SEDIAS[12] (Sheet 2.Diffusion/dispersion and seepage).

The calculation of the actual flux is based on the measured concentration in the surface water, whereas the potential flux is calculated on the basis of a surface water quality that meets the quality objective.
Both fluxes are subsequently summed. This calculation results in a constant contribution of the sediment in g/(m^2.day), which represents the actual absolute contribution of the sediment.

Final assessment
The final assessment is presented in two ways:
1. as absolute contribution of the sediment, expressed in g/(m^2.day). This sediment-based source strength can be used in assessing the intended measures (sediment vs. other sources).
2. as relative contribution of the sediment to the exceeding of the standard. If this contribution is small, one can conclude that a physical intervention in the sediment will not solve the problem of the exceeded standard, even if the contribution of other sources is unknown.

The significance of the calculated fluxes can vary per site. Especially the water replacement rate is important here. In cases of high water replacement (rivers, brooks) the flux from the sediment will normally have no significant effects on the surface water concentration. In these cases dilution is (very) strong. The flux can however give a rough estimate of the contaminant load that is released and transported downstream.

In (semi-)standing waters, such as isolated lakes, the actual flux can become very small, because the sediment and the surface water are near equilibrium. This means that, although the sediment entirely determines the surface water concentration, the actual pollutant flux is very small. It is therefore advisable to include the potential flux in the assessment, i.e. the flux at a low concentration in the surface water.

4.2 Environmental quality standards for total concentrations in surface water

Several water standards are defined as standards for total concentrations, i.e. concentrations in an unfiltered water sample including the suspended particulate matter. The environmental quality standards for organic substances, the standards for the abstraction of water for the production of drinking water and the reference values for watering cattle are examples of standards for total concentrations. Depending on the adsorption properties of the contaminant, the adsorption properties of the suspended particulate matter (SPM) and the SPM concentration, the SPM bound contaminant can contribute significantly to the total surface water concentration.

[12] When calculating the flux, one can additionally make use of corrections for bioirrigation/bioturbation.

In this way resuspension of contaminated sediment can contribute to the exceeding of a standard.

On this point it must be mentioned that after resuspension of the sediment only the finest fraction of the suspended particulate matter will reach the top of the water column. At increasing depths the relationship between the sediment and the suspended particulate matter becomes weaker. That is why specialistic methods are advised for waters deeper than 5 metres when determining the contribution of the sediment to the exceeding of standards in surface water.

Two types of standard can be distinguished (see §2.2.1):
- the annual average concentration (AA-EQS)[13].
- the maximum acceptable concentration (MAC-EQS)[14].

For the compliance testing of organic substances against the standards, an unfiltered sample, so including suspended particulate matter, is analysed. The contribution of the fraction bound to suspended particulate matter in relation to the total concentration in water depends on the concentration and quality of the suspended particulate matter. The quality of the suspended particulate matter depends on the adsorption properties of the contaminant and the composition of the suspended particulate matter. Resuspension of contaminated sediment contributes to the total concentration in the surface water. Resuspension can be caused by:
- current;
- shipping;
- wind;
- bioturbation.

In order to assess the effect of the sediment on the exceeding of surface water standards, two types of surface waters are distinguished:
- Flowing waters. This includes the R-, O- and K-water types of the WFD classification.
- (Semi-)standing waters. This includes the M-water types of the WFD classification.

4.2.1 *Flowing waters*

In flowing waters the water quality is mainly determined by transport from upstream areas. On site, the resuspended sediment is transported immediately to more downstream areas of the water system. A surface water standard is therefore unlikely to be exceeded on the site of erosion itself.
If erosion is causing or threatening to cause a standard to be exceeded in a downstream WFD body of surface water, this erosion is considered as an upstream source of contamination for this downstream WFD body of surface water (see §3.2.1).

4.2.2 *Semi-(standing) waters*

In (semi)standing waters resuspension can be caused by:

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[13] The reference values for watering cattle (water for agricultural purposes) can be considered annual average concentrations

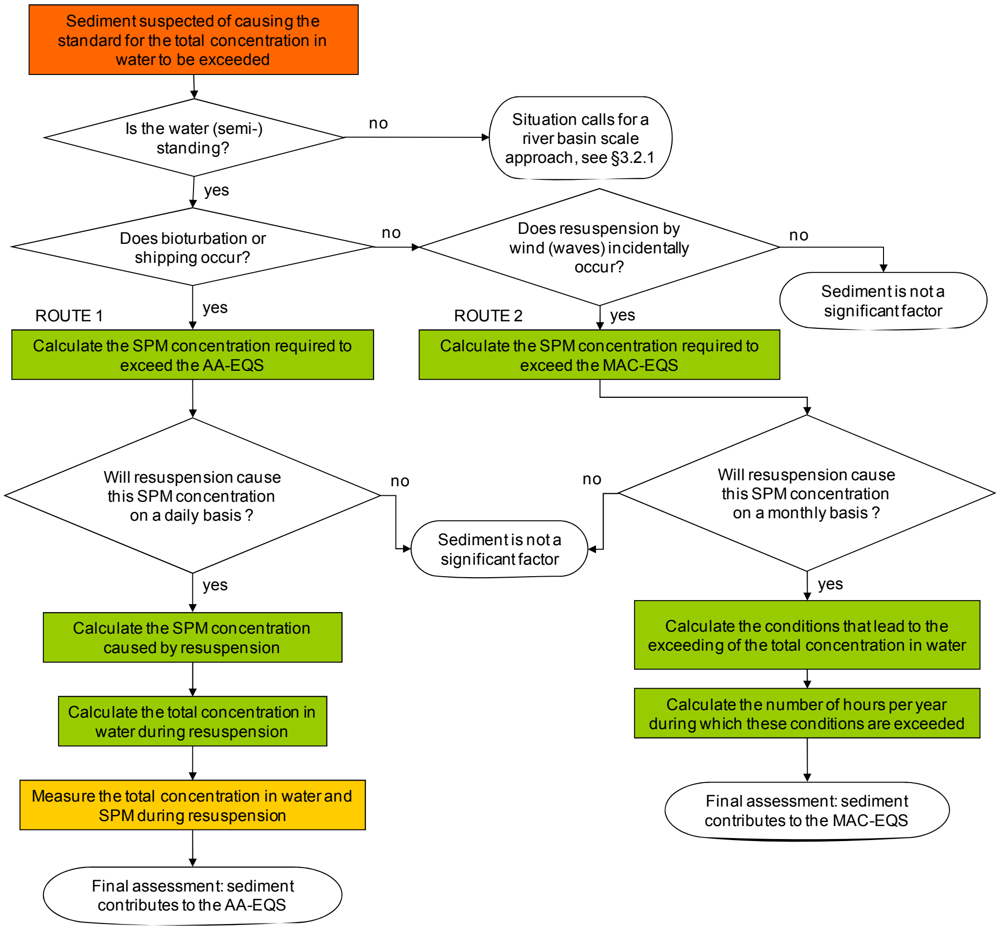
[14] Compliance with the drinking water standards is tested with individual measurementst, just as in the case of testing compliance with the MAC-EQS

- shipping;
- wind;
- bioturbation.

In (semi)standing waters the water flow rate is considered too low to induce resuspension. Resuspension by shipping and bioturbation are considered (semi-) continuous processes, of which the effects can best be tested against the annual average standard (for example AA-EQS). Resuspension by wind (waves) on the other hand is considered to occur incidentally. The effects of this are best tested against the MAC-EQS.

Figure 4.3 only considers the contribution of suspended particulate matter (SPM) to the total concentration. If the dissolved fraction of the substances is relevant with respect to exceeding the standard, one can determine the dissolved contaminant flux by following figure 4.2.

Figure 4.3
Flowchart for assessing sediment suspected of causing the total concentration[15] resulting from resuspension in (semi)-standing waters to be exceeded.



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[15] Total concentrations in surface water are relevant for compliance testing against the chemical standards in WFD waters and for the water functions drinking water production and water for agricultural use (reference values for watering cattle)

Is the site situated in a standing or (semi-)standing water?
(Semi-)standing waters include waters such as ditches, canals, lakes and the M-type water as classified by the WFD.

Because this section mainly involves the contribution of suspended particulate matter (SPM) to the total concentration, one must first check whether the total concentration is actually significantly controlled by SPM. In cases of very low SPM concentrations or of mobile substances, the contribution of dissolved concentrations can exceed the contribution of the SPM bound fraction. For organic contaminants it is therefore advisable to first estimate the contribution of suspended particulate matter to the total concentration.

In SEDIAS sheet 1.Partitioning, the button 'fraction dissolved' calculates the fraction of dissolved contaminant according to the following equation:

$$C_{water} = C_{dissolved,water} + Q_{measured,sed} \times \frac{SPM}{1000}$$

in which:
C_{water} = total concentration in water in µg/l
$C_{dissolved,water}$ = dissolved concentration in water in µg/l
$Q_{measured,sed}$ = content in sediment in mg/kg
SPM = the suspended particulate matter concentration [mg/l]

For a first estimate one can assume standard conditions:
SPM = 30 mg suspended particulate matter per litre
This can be adjusted in SEDIAS if it is known that much higher suspended particulate matter concentrations occur due to, for example, wind.

In the equation above it is assumed that the quality of the suspended particulate matter is entirely determined by the local sediment and that the surface water is in equilibrium with the sediment. It therefore gives only a rough estimate of the ratio between dissolved contaminant and contaminant bound to suspended particulate matter.

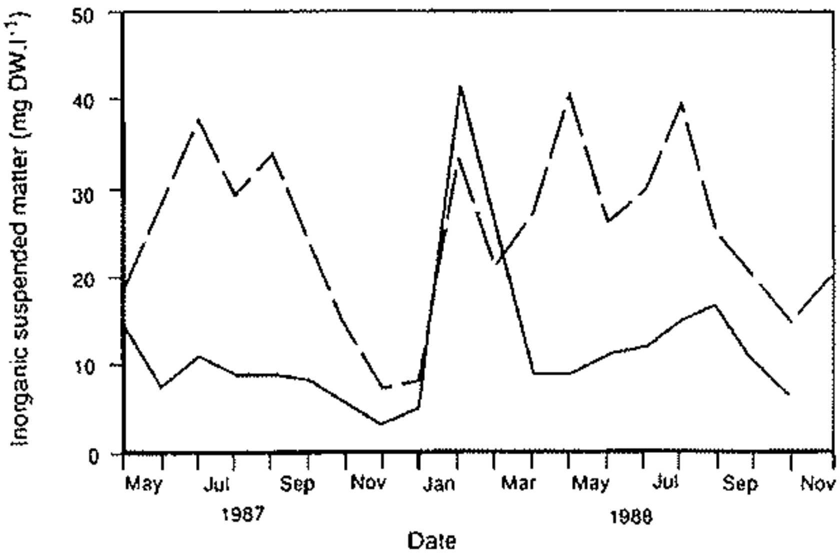
Exceeding of the annual average standard (AA)

Does bioturbation or shipping occur?
In the next step of the flowchart it is checked whether bioturbation and/or shipping cause substantial resuspension. In the text below rules of thumb are presented that give a first indication whether these processes are significant. Furthermore, occasional measurements or information of the competent water authority on the specific area can be used to answer this question.

Resuspension caused by bioturbation

Resuspension by bioturbation in (semi-)standing waters is mainly determined by benthivorous fish, such as Common bream. The effects of bioturbation are illustrated in figure 4.4, in which the suspended matter concentrations in a lake are sketched in both the presence and absence of benthivorous fish. The figure shows that resuspension is less in winter. The peak in January in the absence of fish is possibly caused by a storm.

Figure 4.4
Inorganic suspended matter concentrations in Lake Bleiswijkse Zoom, in the presence (dotted line) and absence of benthivorous fish (continuous line)
[Meijer *et al.*, 1990].



A first assessment of bioturbation being a possible cause for not meeting the environmental quality standard can be done by estimating the mass of benthivorous fish. This is possible if fish stock inventories are carried out on a regular basis. The equation presented below by Meijer *et al.* (1990), gives an estimate of the suspended particulate matter concentrations that can be caused by bioturbation by fish in lakes not deeper than 2 metres:

SPM [mg/l] = 8 + 0,062 x benthivorous fish [kg/ha)]

in which SPM = suspended particulate matter

The equation may be applicable in other situations, but one is advised not to use the equation in flowing waters or waters deeper than 3 to 4 metres. Bioturbation can only be a factor of importance in shallow standing waters (De Lange *et al.*, 2006). The equation is included in sheet 3. Resuspension of SEDIAS.

Resuspension caused by shipping

Resuspension always occurs in case of merchant shipping and in case of recreational navigation in waters not deeper than 3.5 m.
The rate of resuspension caused by shipping depends on the under keel clearance, the engine power, the diameter of the screw propeller and the speed of the passing ship. These factors determine the water flow rate at the bottom under the ship and with that the resuspension rate.
In nearly all canals and shallow lakes in The Netherlands where merchant shipping occurs, resuspension is caused by the small under keel clearance (shallow water depth in relation to the ship's draught). This resuspension caused by merchant shipping is not necessarily restricted to the navigation channel: in shallow lakes

(less than 2 metres deep) the ship-induced waves can cause resuspension at distances up to 80 metres from the channel.

In case of recreational navigation it is assumed that resuspension occurs at an under keel clearance less than 2 metres. If it is further assumed that the draught of recreational boats is maximally 1.5 metres, one can suppose that resuspension is caused by recreational navigation in waters less than 3.5 metres deep (Eelkema, 2006).

For those cases where the competent water authority has doubts whether merchant shipping or recreational navigation indeed causes resuspension in the water body of concern, one can use SEDIAS (sheet 3. Resuspension). SEDIAS calculates the resuspension flux and resulting suspended particulate matter concentrations in the water column on the basis of water depth, the degree of consolidation of the sediment and the type of ship(s) sailing in the body of surface water.

If the calculated resuspension flux per passing ship exceeds zero, theoretically resuspension by shipping occurs and the flowchart of figure 4.3 can be continued to calculate the resulting suspended particulate matter concentrations and the total substance concentrations.

Exceeding of the annual average standard (AA)

Calculate the suspended particulate matter concentration required to exceed the AA-EQS

Assuming that wind is the determining factor for suspended particulate matter in (semi-) standing waters, the contribution of resuspension by wind is calculated according to the following equation:

$$C_{\text{water by spm}} = \text{SPM} \times Q_{\text{measured,sed}} \times 10^{-3}$$

in which:

$C_{\text{water by spm}}$ = the contribution of suspended particulate matter to the total concentration in water (µg/l)

SPM = the calculated suspended particulate matter concentration (mg/l)

$Q_{\text{measured,sed}}$ = the content in the sediment (mg/kg$_{\text{ds}}$)

The contribution of resuspension to the total concentration in water is calculated in sheet 4. Contribution total conc. of SEDIAS.

By varying the suspended particulate matter concentration, one can determine the suspended particulate matter concentration at which the AA-EQS is exceeded.

Will resuspension cause this suspended particulate matter concentration on a daily basis?

It is unsure whether the calculated required suspended particulate matter concentration is realistic. This question might be answered by expert assessment or monitoring on other (more or less comparable) locations. In case of doubt the flowchart is continued along the path ‘yes’.

Calculate the suspended particulate matter concentration caused by shipping
In order to calculate the total contaminant concentration one must know the suspended particulate matter concentration (mg/l) and the contaminant content in the suspended particulate matter (mg/kg).
SEDIAS (sheet 3. Resuspension) calculates the resuspension flux and resulting suspended particulate matter concentrations in the water column on the basis of water depth, the degree of consolidation of the sediment and the number and type of ships sailing in the body of surface water.

Calculate the total contaminant concentration in water resulting from resuspension
The (annual average) total contaminant concentration (mg/l) is calculated from the (if necessary summed) steady-state suspended particulate matter concentration in the surface water (mg/l) and the total contaminant content of the top layer of the sediment (mg/kg_{ds}).

Calculation of the total concentration in water:

$$C_{\text{water by spm}} = SPM \times Q_{\text{measured,sed}} \times 10^{-3}$$

in which:
$C_{\text{water by spm}}$ = the contribution of suspended particulate matter to the total concentration in water (µg/l)
SPM = the calculated suspended particulate matter concentration (mg/l)
$Q_{\text{measured,sed}}$ = the content in the sediment (mg/kg_{ds})

The contribution of resuspension to the total concentration in water is calculated in sheet 4. Contribution total conc. of SEDIAS. The contribution of bioturbation is also included in this calculation.

Measure the total concentration and (if possible) suspended particulate matter during or shortly after the resuspension event
If the calculated total concentration indicates that the standard may be exceeded, the competent water authority can decide to verify this by field sampling at various moments and analysing these samples.
It is advised to attune this monitoring as much as possible to the regular monitoring of surface waters (see Annex I).

Final assessment contribution sediment tot total concentration
The calculated and possibly measured concentration is tested for compliance with the annual average environmental quality standard for total concentrations. If this standard is exceeded, one can assume that the sediment is (partly) responsible for not meeting the local water quality objectives.

Exceeding of the MAC

Can wind waves incidentally cause resuspension?
Resuspension by wind waves can be neglected in linear and small waters (deeper than 1 metre and fetch < 1 km everywhere).
In other waters it is assessed in a simple way whether wind waves can result in resuspension of sediment: In SEDIAS the critical bottom orbital velocity for

resuspension is calculated on the basis of a critical shear stress for the sediment. A table has been build which gives the wind speed at which the critical bottom orbital velocities is exceeded as function of water depth and fetch.

Calculate the suspended particulate matter concentration required to exceed the Maximum Acceptable Concentration (MAC)
Assuming that wind is the determining factor for suspended particulate matter in (semi-) standing waters, the contribution of resuspension by wind is calculated according to the following equation:

$$C_{\text{water by spm}} = SPM \times Q_{\text{measured,sed}} \times 10^{-3}$$

in which:

$C_{\text{water by spm}}$ = the contribution of suspended particulate matter to the total concentration in water (µg/l)
SPM = the calculated suspended particulate matter concentration (mg/l)
$Q_{\text{measured,sed}}$ = the content in the sediment (mg/kg_{ds})

The contribution of resuspension to the total concentration in water is calculated in sheet 4. Contribution total conc. of SEDIAS.

By varying the suspended particulate matter concentration, one can determine the suspended particulate matter concentration at which the MAC is exceeded.

Will resuspension by wind cause this suspended particulate matter concentration on a monthly basis?
This question is a first check whether an exceeding of the environmental quality standard is indeed to be expected. This question is answered on the basis of regionally specific (expert) knowledge and possibly on the basis of available monitoring data. In case of doubt the answer is 'yes'

Calculate the number of hours per year during which the MAC is exceeded due to resuspension by wind
The frequency and duration of exceeding a MAC is calculated.
The amount of resuspended sediment that is calculated with the simplified equations of SEDIAS, readily result in high suspended particulate matter concentrations. An example: if the critical bottom orbital velocity is 0.22 m/s, the calculated suspended particulate matter concentration at 0.23 m/s already amounts to 400 mg/l. For this reason it can be assumed that the number of hours during which the standard is exceeded equals the number of hours during which the critical bottom orbital velocity is exceeded.
The number of hours during which a certain wind speed and direction (fetch) occurs can be found in the (wind) monitoring data of the nearest meteorological station. In SEDIAS sheet ad 3 'calculation resuspension wind' the number of hours during which the standard is exceeded is calculated.

Final assessment contribution of sediment to the total concentration due to wind waves
The sum of frequencies of all relevant wind directions and wind speeds during which de MAC-value of a substance is exceeded, determines the importance of the sediment with respect to meeting the water quality objectives or not.

Specialistic methods for determining the exceeding of a MAC
Actually measuring the exceeding of a MAC is difficult because resuspension by wind occurs incidentally and conditions for sampling are unfavourable during these events. The simplest assessment method therefore does not include the actual measurement of the exceeding. It is however possible. This requires field work to be conducted during high winds and sampling of suspended particulate matter and possibly of surface water.
An alternative method for determining the effects of resuspension by wind is using sophisticated water transport models that allow the components sediment and suspended particulate matter to be coupled to the model, such as BRETRO, WAQUA or Delft-3D.
More background information on resuspension and sediment erosion can be found in Eelkema (2006).

4.3 MPC for surface water and MPC for suspended particulate matter

This section involves the exceeding of two types of standards:

1. MPC for suspended particulate matter. In the Dutch Ministerial Monitoring Regulation PCB-standards for suspended particulate matter have been laid down.
2. MPC for surface water. Compliance testing against this standard is done after standardizing the measured concentration to standard water containing 30 mg/l suspended particulate matter.

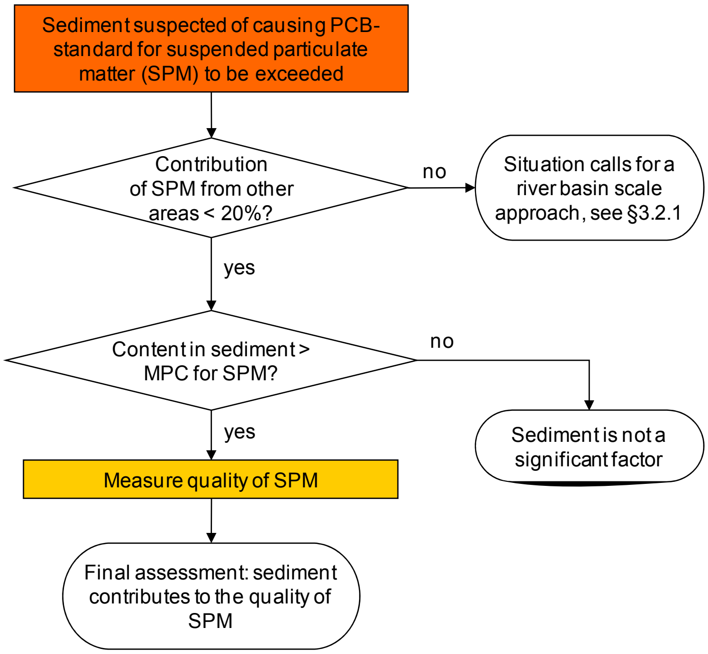
With respect to standards in suspended particulate matter and in water with a standardized suspended particulate matter concentration, the effects of the sediment are particularly of significance in (semi-)standing waters, just as in case of total concentrations (§4.2).

4.3.1 *MPC for suspended particulate matter*

In the Dutch Ministerial Monitoring Regulation PCB-standards for suspended particulate matter have been laid down
The relationship between suspended particulate matter standards and sediment quality resembles the approach for environmental quality standards for total concentrations in §4.2. On various occasions one is referred to this section. As mentioned in § 4.2 only the finest fraction of the suspended particulate matter will reach the top of the water column after resuspension of the sediment. At increasing depths the relationship between the sediment and the suspended particulate matter becomes weaker. In the method presented below this is not taken into account. Specialistic methods are advised for waters deeper than 5 metres

Figure 4.5 shows the method to be used in case the suspended particulate matter standard for PCBs is exceeded.

Figure 4.5
Flowchart for assessing sediment suspected of causing the standard for suspended particulate matter to be exceeded.



Does the suspended particulate matter (SPM) mainly originate from the contaminated site or is > 20% transported from other areas?
The limit of 20% transport form other areas is an arbitrary one. The intention is to differentiate between waters where hardly any transport of suspended particulate matter from other areas takes place (for example only through sluices) and (flowing) waters where transport of sediment does occur.

Just as in case of the environmental quality standards for the total concentration, the transport from upstream areas constitutes in most cases the main contribution in flowing waters. This means that the resulting concentration depends on the quality occurring in the river basin. This can best be assessed by determining whether a standard is exceeded or threatens to be exceeded in the upstream (WFD) body of surface water and – if this is the case – by considering the upstream erosion as a possible contaminant source (see §3.2.1).
In (semi-)standing waters (lakes, canals and ditches) the suspended particulate matter concentration is mainly determined by the local sediment and not originating from other areas.

Does the substance content in the sediment exceed the standard for suspended particulate matter (SPM)?
The standard for the 7 individual PCBs in suspended particulate matter amounts to 8 µg/kg dry sediment. No standard for the sum of PCBs has been derived. The PCB content in the sediment has to be standardized to the suspended particulate matter properties prior to compliance testing according to the following equation:

$Q_{stand,spm} = Q_{measured,sed} \times 20 / (\%OM)$

in which:

$\%OM$ = the organic matter percentage (minimally 2% and maximally 30%)
$Q_{measured,sed}$ = the measured substance content in the sediment [µg/kg ds]
$Q_{standard,spm}$ = the standardized substance content in suspended particulate matter (µg/kg ds)

If the data have been correctly entered in SEDIAD sheet 1.Partitioning, this calculation is performed in SEDIAS sheet 6.Susp. matter&MPC.

If the calculated standardized content in suspended particulate matter exceeds 8 µg/kg, the sediment can contribute to the exceeding of the standard. The amount of suspended particulate matter is not significant here, but mixing with suspended particulate matter transported from other areas is.

Measure the quality of suspended particulate matter (SPM)
By regularly taking suspended particulate matter samples and measuring its quality, one can determine to what extent the MPC-value actually is exceeded. If one decides to start monitoring, it is advised to attune this monitoring as much as possible to the regular monitoring (see Annex I).

Final assessment
If the substance contents in suspended particulate matter (SPM) indeed prove to exceed the standard, one can conclude that sediment is a significant source with respect to this exceeding. If no exceeding of standards is established, the sediment is not a significant factor with respect to this standard.

4.3.2 MPC for surface water

Figure 4.6 shows the method to be used if one wants to examine whether the MPC for surface water is exceeded. In the Dutch Ministerial Monitoring Regulation MPCs have been established for the following sediment relevant substances: arsenic (As), boron (B), copper (Cu), antimony (Sb), tellurium (Te), titanium (Ti), uranium (U), vanadium (V), silver (Ag), benzo(a)anthracene, chrysene, phenantrene, heptachlor, heptachlor epoxide and tetrabutyltin.

Convert the content in sediment to a concentration in standardized water
Standardizing concentrations that are measured in water involves assuming a suspended particulate matter (SPM) content of 30 mg/l and this suspended particulate matter containing 20% organic matter and 40% clay. This standardization deviates from the standardization of soil (10% organic matter and 25% clay). In order to assess whether the sediment causes the standard for standardized water to be exceeded, the contribution of 30 mg/l suspended particulate matter to the total concentration and to ‘filling up’ the standard is calculated.

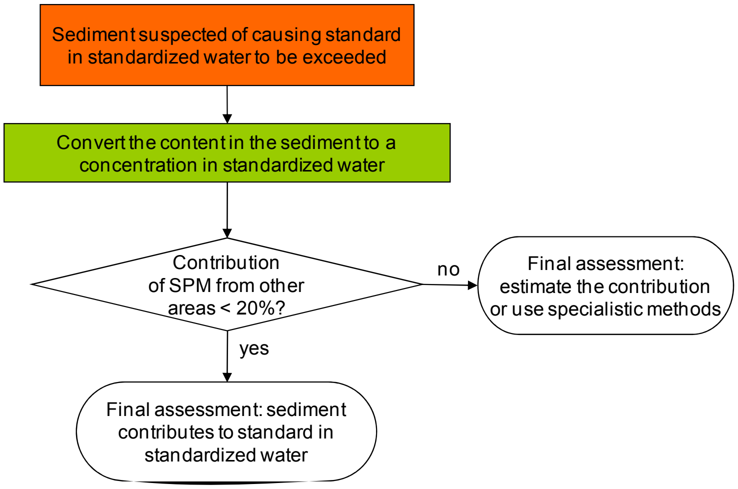


Figure 4.6
Flowchart for assessing sediment suspected of causing the standard in standardized water to be exceeded.

The content measured in the sediment is first converted to a standardized content in suspended particulate matter (SPM) in accordance with the following equation:

$$Q_{stand,\ spm} = Q_{measured,\ sed} * \frac{a + b*40 + c*20}{a + b*\%clay + c*\%org.\ matter} \text{ (for metals) or}$$

$$Q_{stand,\ spm} = Q_{measured,\ sed} * \frac{20}{\%org.\ matter} \text{ (for organic contaminants)}$$

in which:

$Q_{stand,\ spm}$ = standardized content in suspended particulate matter derived from resuspended sediment (mg/kg)
$Q_{measured,\ sed}$ = content measured in sediment (mg/kg)
%clay = clay percentage
%org.matter = organic matter percentage
a, b, c = contaminant specific parameters for soil type correction (see annex G of the Dutch Soil Quality Regulation)

If desired, this calculation can be performed with the Towabo computer program for compliance testing, by standardizing the sediment for suspended particulate matter.

Next the standardized content is converted to standardized water in accordance with the following equation:

$$C_{standard\ water\ by\ spm} = Q_{stand,\ spm} * 30 * 10^{-3}$$

in which:

$C_{standard\ water\ by\ spm}$ = contribution of 30 mg/l standardized suspended particulate matter to concentration in standardized water (µg/l).

$Q_{stand,\ spm}$ = standardized content in suspended particulate matter derived from resuspended sediment (mg/kg). The factor 30 stems from the prescribed 30 mg suspended particulate matter per litre. The factor 10^{-3} is necessary in order to arrive at the correct units.

In SEDIAS sheet 6.Susp. matter&MPC these calculations have been carried out for substances for which an MPC exists, provided that the input data in sheet 1.Partitioning are correct. Now the contribution of the sediment to the exceeding of the standard, resulting from resuspension, can be calculated.

Does the suspended particulate matter (SPM) mainly originate from the contaminated site or is > 20% transported from other areas?

The limit of 20% transport from other areas is an arbitrary one. The intention is to differentiate between waters where hardly any transport of suspended particulate matter from other areas takes place (for example only through sluices) and (flowing) waters where transport of sediment does occur.

Final assessments

If the answer is yes, it is concluded that sediment is the main factor affecting the suspended particulate matter quality.

If the answer is no, it is more complex. In this case one should estimate the contribution of the sediment to the suspended particulate matter quality. Residence time of the water and magnitude of the resuspension (wind/shipping/ bioturbation) are important factors in this estimate. This estimate is made on the basis of expert assessment or specialistic methods.

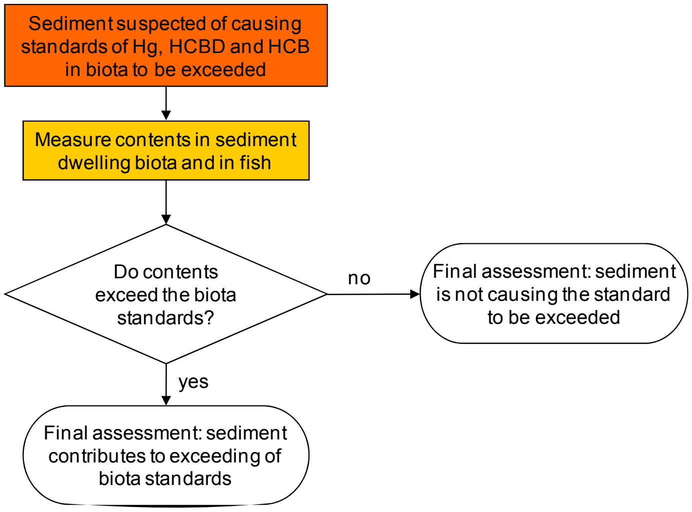
Specialistic methods for constructing the suspended particulate matter (SPM) mass balance

This subsection is used in cases where the standard has been exceeded due to the SPM quality. Deployment of for example sediment traps will yield little new information in these cases with respect to the contribution of the sediment. However, constructing an SPM mass balance with models can produce better insight. Usually this is done with hydraulic models, such as WAQUA, BRETPRO, SOBEK of DELFT3D, to which an SPM module is coupled.

4.4 Standards in biota

Exceeding a biota standard mainly depends on the substance content in the sediment and/or suspended particulate matter due to the partitioning over water, sediment and organic matter. If the sediment is contaminated with one or more substances for which biota standards have been derived, figure 4.7 can be used to determine whether biota standards are actually exceeded.

Figure 4.7
Flowchart for assessing sediment suspected of causing biota standards to be exceeded.



Measure contents in sediment dwelling biota and in fish
Subsequently the contents in sediment dwelling organisms are measured in various spots within the most contaminated parts of the sediment. In addition the contents in fish are measured within the area of concern. It is advised to use the results of existing monitoring networks concerning bioaccumulated contents (especially in fish) as much as possible. If no data are available the way of monitoring in biota should be attuned to that of existing monitoring networks (see Annex I). For measurements in fish, one can often take advantage of the catch of anglers and/or fishermen.

Do one or more substances exceed the biota standard?
The contents in biota, expressed in [µg/kg fresh weight] can be directly tested for compliance against the standards. If biota standards in fish or shellfish are exceeded, one can assume that the sediment quality is contributing to this. Bioaccumulation of mercury in fish is affected by the surface water and suspended particulate matter quality. Especially in flowing waters one should take this into account.

Final assessment
If biota standards in fish or sediment dwelling shellfish are exceeded, one can assume that sediment quality contributes to this. Surface water and suspended particulate matter quality affect bioaccumulation of mercury in fish. Especially in flowing waters one should take this into account. The final assessment with respect to the contribution of sediment to the exceeding of biota standards depends largely on the size of the contaminated site in relation to the feeding area of the species.

Specialistic methods for assessing whether the sediment causes the standard in fish or shellfish to be exceeded

By measuring contents in sediment dwelling biota, such as the Golden Clam (*Corbicula fluminea*) or worms and mosquito larvae, one can determine with greater certainty whether the sediment is (partially) causing the established exceeding of the standards in biota. The advantage of measuring in sediment dwelling biota is that the availability for uptake of these bioaccumulating substances in the food web is determined in a direct way. This is especially important in case of contamination with mercury, because this metal is microbially converted into methylmercury in the environment. Methylmercury is much more toxic, partly due to the fact that it is taken up much quicker by higher organisms.

It is also possible to conduct bioaccumulation experiments with sediment samples in the laboratory, where bioaccumulation levels in the biota are measured after 4 weeks of exposure. The measured bioaccumulation levels and knowledge of the food web can subsequently be used to determine the relationship between sediment quality and (shell)fish quality.

For this type of research one is referred to organizations that are specialized in this.

4.5 Standards for eutrophication

In the regular management of water systems nutrients in sediment are, contrary to toxic substances, usually not monitored. Intervention values for nutrients in sediment do not exist. The measurement of nutrients in the sediment is only started if signs of eutrophication of the water system become clear or if there are indications that the water quality of the water system of concern is causing eutrophication problems in downstream waters. In these cases the effects of nutrients in the sediment are assessed as described in §3.5.

4.6 Ecological macrofauna objectives

Figure 4.8 shows the flowchart to assess whether the sediment quality affects the score on the macrofauna metric.

Determine the pore water concentration

Initially the equilibrium concentration in the pore water of the top layer of the sediment is determined. The K_d values of metals and the K_{oc} values of organic contaminants are listed in the Sediment Assistant (SEDIAS) (Sheet 1.Partitioning).

The concentration of metals in pore water is calculated according to the following equation:

$$C_{pw} = Q_{stand,sed} / K_d$$

in which:

C_{pw} = dissolved metal concentration in pore water [mg/l]

$Q_{stand.sed}$ = content in sediment converted to standard sediment [mg/kg_{ds}][16]

K_d = partitioning constant for sediment [l/kg]

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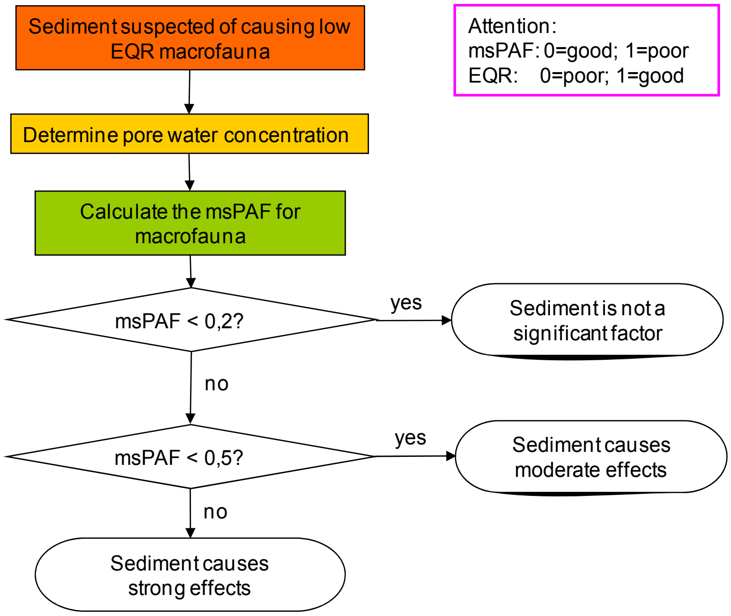
[16] In SEDIAS it is possible to enter the measured content. The soil type conversion is then automatically performed.

Figure 4.8
Flowchart for assessing sediment suspected of causing low scores on the macrofauna metric.



The concentration of organic contaminants in pore water is calculated according to the following equation:

$$C_{pw} = Q_{measured,sed} / (f_{oc} \times K_{oc})$$

in which:
C_{pw} = concentration in pore water [mg/l]
$Q_{measured,sed}$ = measured content in sediment [mg/kg$_{ds}$]
f_{oc} = fraction organic carbon [-]
K_{oc} = partitioning constant for organic carbon [l/kg$_{OC}$]

Calculate msPAF for macrofauna
By calculating the msPAF it is checked whether the sediment quality is actually likely to affect the macrofauna. More information on the backgrounds of the msPAF can be found in Annex K. With SEDIAS (sheet 5.msPAF, see also Annex J) the msPAF can be calculated in various ways. For assessing the effects on the macrofauna, the msPAF based on chronic EC50s has been selected. The reason for this is that the guidance document is used in cases of long-term exposure and that only actual effects (effect level EC50) are considered important.
The input of monitoring data from the sediment have to be entered only once in SEDIAS sheet 1.Partitioning.

Because the msPAF is a combined standard, many substances with a low individual PAF can still result in a considerable msPAF. Therefore at least the contents of the following substances have to be entered in SEDIAS in order to calculate the msPAF:

- metals (arsenic, barium, cobalt, cadmium, chromium, copper, mercury, molybdenum, nickel, lead and zinc);
- 10 PAHs (VROM);
- organochlorine pesticides on the default analysis list for substances in sediments in the Dutch national waters (see NEN 5720);
- pentachlorophenol, pentachlorobenzene and hexachlorobenzene.

If one or more of these substances have not been measured, for example because the site is not suspected to be contaminated with these substances, the same method is used as applied in the Dutch Soil Quality Regulation (Rbk) for relocating dredged material on an adjoining parcel of land. That implies that the minimum value to be entered equals 0.7 times the intralaboratory reproducible limit of detection (annex L of the Rbk). Measurements of suspect substances not on the default analysis list have to be entered additionally. PCBs are not relevant for calculating the msPAF because these substances do not affect macrofauna.

msPAF < 0.2?
A low score on the metric for macrofauna cannot be related to the sediment quality if the msPAF < 0.2. If the msPAF > 0.2 the flowchart is continued.

msPAF > 0.2 and msPAF < 0.5?
Effects cannot be ruled out if the msPAF is between 0.2 and 0.5. If taking measures in the sediment can be assumed to be favourable for several reasons, such as nature restoration or recreation, it makes sense to further investigate the effects on macrofauna by doing field inventories (see text box ‘Specialistic methods for assessing the effects of the sediment on macrofauna’)

msPAF > 0.5?
If the msPAF > 0.5 one should expect strong effects. These effects can also be further investigated by doing field inventories.

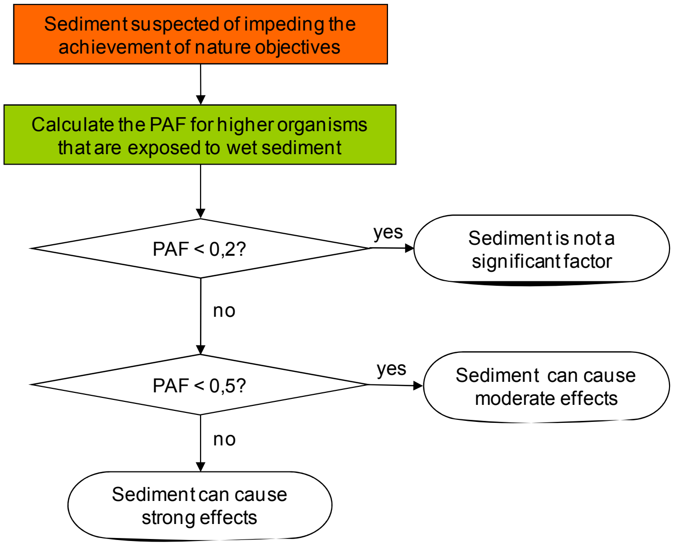
Specialistic methods for assessing the effects of the sediment on macrofauna
The effects of the sediment on macrofauna can be assessed with the following additional measurements:

1. Bioassays: Bioassays can demonstrate that the contents of contaminants in the sediment of concern actually can cause effects. Bioassays can be used in the assessment method (figure 3.10) in a way that is comparable to the sediment metric for macrofauna. If the msPAF > 0.5 and the bioassays reveal no effects, the final assessment can be softened from strong to moderate.
2. Field inventory: Fieldwork for example involves sampling macrofauna and/or nematodes in deeper situated sediments instead of sampling in the shallow bank/shore zone. This additional field monitoring can show that the part of the ecosystem most influenced by the sediment is indeed negatively affected.

4.7 Nature conservation objectives

Figure 4.9 describes the method to assess suspected sediment that, through the food chain, may affect higher organisms that should specifically be protected according to the nature objectives.

Figure 4.9
Flowchart for assessing sediment suspected of impeding the achievement of the nature conservation objectives.



Calculate the PAF for higher organisms
In SEDIAS, sheet 5, the PAF for higher organisms can be calculated for a number of substances. This involves PAF-curves that are different from those for macrofauna as described in section 4.6. In order to be able to calculate a PAF for higher organisms, assumptions with respect to the exposure of these higher organisms have to be made.

In the absence of chronic EC50 data for higher organisms, NOEC data have been used. Furthermore, the number of substances is limited and the individual PAFs are not combined into an msPAF. Hence, the calculated PAFs are individually tested against the limits 0.2 and 0.5. This makes the compliance testing less strict whereas the use of NOEC data makes it stricter. The limits have therefore been set at the same levels as in case of the msPAF for macrofauna. More background information on the (ms)PAF can be found in Annex K. The input data have to be entered in SEDIAS sheet 1.Partitioning only once.

PAF < 0.2?
If the PAF < 0.2 it can be assumed that the sediment does not affect the achievement of nature conservation objectives.

PAF >0.2 and PAF < 0.5?
A PAF between 0.2 and 0.5 indicates that effects are possible. Effects are assessed by the competent authority with respect to the nature objectives. For most nature reserves these objectives have been laid down in nature management plans. The organisms most susceptible to secondary poisoning are the higher organisms that have both their habitat and feeding area in the contaminated area.

PAF > 0.5?
A PAF > 0.5 indicates that contaminant concentrations can cause substantial effects. If target species susceptible to bioaccumulation are present, it must be assumed that these species are actually affected.

Specialistic methods to assess sediments in relation to nature conservation objectives
If it has become clear that certain target species (higher organisms) are affected by contaminants, it is advisable to carry out a food web analysis. The model OMEGA45 (not to be confused with OMEGA23 that calculates a 'standard' msPAF) enables building a food web and searching for specific accumulation data.
On the basis of these regionally specific data one can assess to what extent vulnerable target species are exposed to contaminated sediment.

4.8 Standards for the protection of humans

With respect to human risks two subjects are distinguished:

- Safe consumption of fish. Relevant standards are the food standards for fish under European law (§4.8.1) and the MPC_{humane} for the consumption of fish landed by anglers (§4.8.2);
- Recreation in the bank/shore zone. For this type of risk the MPC_{humane} is also used, but the exposure pathways are different from those used to determine the risks of fish consumption (§4.8.3).

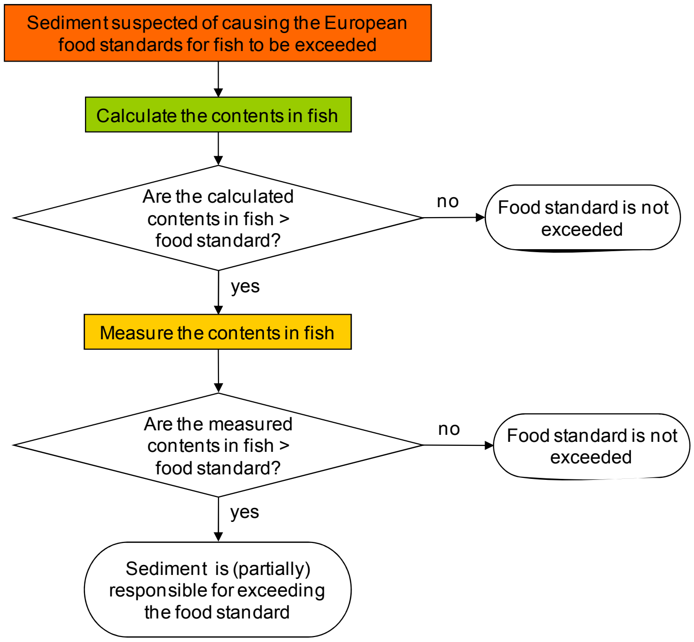
4.8.1 *The European food standards for fish*

Food standards only apply to products marketed by professional fishermen.
In figure 4.10 the approach for testing against food standards is presented.

Is the sediment contaminated with substances for which food standards have been derived?
European food standards for fish products have been derived for cadmium, mercury, lead, benzo(a)pyrene and dioxin-like substances (TEQ). The assessment scheme is only used if one of these substances exceeds the Intervention Value (or the local limit). Benzo(a)pyrene (a PAH) can metabolize into non-toxic substances. This substance therefore hardly poses a problem for consumption.

Calculate the contents in fish and test against the food standard
The calculation method differs per substance. Metals are calculated with the Sedisoil model. Sediment contents are entered on the input page. On the same page the concentrations in water (using a K_d) and subsequently the contents in fish (using a BCF) are calculated directly. If the calculated contents in fish exceed the standard or in case the contamination concerns PCBs, the assessment is continued by measuring the contents in fish.

Figure 4.10
Flowchart for assessing sediment suspected of causing European food standards to be exceeded.



Measure the contents in fish and test against the food standard
Actually determining whether the sediment releases contaminants requires the measurement of contents in fish living in a representative area. It is advised to attune this monitoring to the regular monitoring (Annex I) or to take advantage of fish locally landed by professional fishermen or anglers. One is further advised to measure all substances for which food standards have been derived (dioxins and heavy metals, see Annex B).

Final assessment
If the food standard is exceeded it can be concluded that the sediment is (partially) responsible for this exceeding.

Specialistic methods for explaining the exceeding of food standards
Fish is situated high in the food web. The exposure of fish occurs partially through the water phase, but mainly through the food chain. The accumulation of substances in fish is generally comparable to the accumulation in other higher organisms. If standards in fish are exceeded, one can use OMEGA45 as an instrument to examine the cause. Background information specifically on dioxins and mercury in eel can be found in a recent report by Van den Heuvel *et al.* (2009).

4.8.2 *MPC$_{humane}$ through fish consumption*

The assessment method calculates the exposure resulting from the contents in sediment or fish. This is done with the Sedisoil model. How to use Sedisoil is explained in the corresponding manual. Exposure of humans to toxic substances in fish is calculated using a scenario specifically adapted to anglers that consume their self landed fish on a regular basis. This scenario assumes the consumption of 150 grams of self landed eel per month. Research conducted in 2003 into fish consumption within this group showed that monthly consumption of 150 grams of eel is common (Weijs and Wijnen, 2003). The total dose to which a person is exposed is tested against the Maximum Permissible Concentration (MPC$_{humane}$).

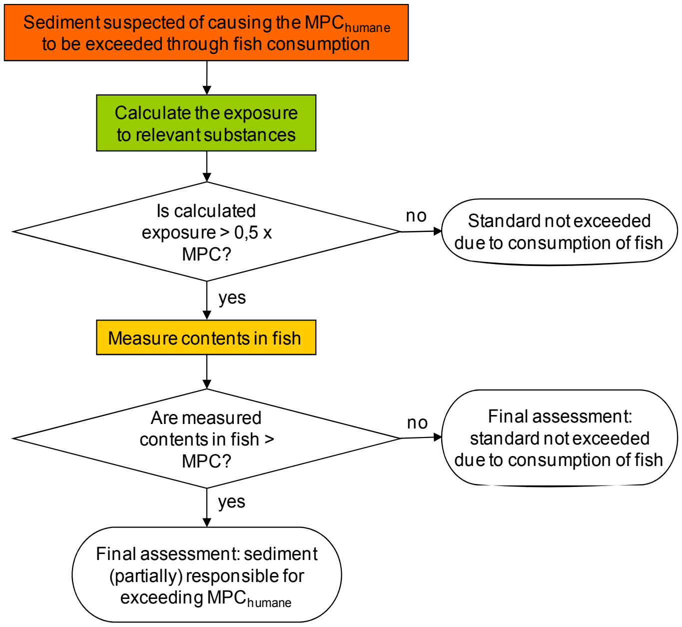


Figure 4.11
Flowchart for assessing sediment suspected of causing human risks (based on the MPC-humane) through fish consumption.

Calculate the exposure to relevant substances

The average contents (per sector) of relevant substances in the top sediment layer are entered in Sedisoil. If the organic matter and clay contents have also been measured, the non-standardized data are entered. If these have not been measured, one can also choose to use default values for clay (25%) and organic matter (10%). One can select several scenarios in Sedisoil. The model (plus manual) recommends the most relevant scenario.

Calculation of total TEQ of dioxin-like substances in sediment

In The Netherlands (and elsewhere) there is particular interest in the exposure route sediment-eel-humans for dioxin-like PCBs, furans and dioxins. Eel caught on site is representative for the area because this fish species is, outside the migration period to the Sargasso Sea, rather immobile.

One can already estimate the total TEQ content if the contents of the 7 indicator PCBs are available and not the whole set of dioxins and dioxin-like substances yet.

Is the calculated exposure > 0.5 x MPC_{humane}?
The result of Sedisoil is a ratio (exposure / MPC_{humane}) which gives an indication of the extent to which the MPC_{humane} is exceeded. The ratios for substances that show combined toxicity (see table 4.3) are first calculated individually and subsequently added. This results in the so-called additive risk. In risk assessment only the resulting additive risk counts. Because the calculated contents in fish have limited reliability, the contents are tested against 0.5 x MPC_{humane}.

Measure contents in fish
Measurements in (fatty) fish for consumption can be done to validate the modelling results. If applicable it is advised to attune the monitoring to existing monitoring networks or to obtain the fish from anglers of professional fishermen (see also Annex I). The main route of human exposure to contaminants is consumption of fish. Fatty fish usually contains the highest contaminant contents, certainly in case of organic contaminants, but exposure through consumption of less fatty fish can also be determined. If the surface water of concern houses no consumable fish species it is clear that no fish is landed here for private consumption.

Calculation of total TEQ of dioxin-like substances in fish, based on PCB153
If only PCB153 has been measured in fish, the total TEQ content is estimated according to the following equation (De Boer, 1995):

$$\text{PCB-TEQ } (\text{ng/kg}_{\text{product}}) = 0.428 \times [\text{PCB153 } (\mu\text{g/kg}_{\text{product}})]^{0,737}$$

This estimated TEQ content can be used to estimate the exposure to dioxin-like substances. If this estimate reveals that the MPC_{humane} threatens to be exceeded, the other substances still have to be measured in eel.
If only dioxin-like PCBs have been measured (and no dioxins or furans), the TEQ content is multiplied with a factor 1.5 before compliance testing in Sedisoil. If this testing reveals that the MPC_{humane} threatens to be exceeded, the other substances again still have to be measured in eel.
If only dioxins (and no furans or PCBs) have been measured the TEQ content is multiplied with a factor 3. If all dioxin-like substances have been measured, no factor is required.

Is the calculated exposure > MPC_{humane}?
Now the exposure calculated in Sedisoil is tested against the MPC_{humane}. If this MPC_{humane} is exceeded, it can be concluded that the sediment is partially responsible for the humane risks existing at the specific site.

4.8.3 MPC_{humane} through recreation in the bank/shore zone
The assessment method calculates the exposure resulting from the contents in sediment. This is done with the Sedisoil model. How to use Sedisoil is explained in the corresponding manual. The exposure is calculated using a scenario specifically adapted to recreation. Exposure has two routes:

- ingestion of sediment, surface water and suspended particulate matter;
- dermal uptake through sediment and surface water.

The scenario assumes a default number of recreational days with default exposure times for the distinguished routes.

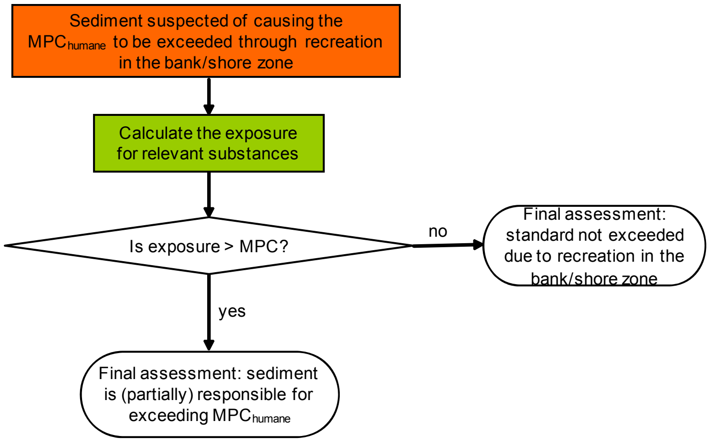


Figure 4.12
Flowchart for assessing sediment suspected of causing human risks (based on MPC humane) through recreation in the bank/shore zone.

Calculate the exposure for relevant substances
The average contents (per sector) of relevant substances in the top sediment layer are entered in Sedisoil. If the organic matter and clay contents have also been measured, the non-standardized data are entered. If these have not been measured, one can also choose to use default values for clay (25%) and organic matter (10%). In Sedisoil one default scenario for recreation is included plus an option for custom-made scenarios. This is explained in the model and manual.

Is the calculated exposure > MPC_{humane}?
The exposure calculated in Sedisoil is tested against the MPC_{humane}. If this MPC_{humane} is exceeded, it can be concluded that the sediment is partially responsible for the humane risks existing at the specific site and that there is reason to take measures in order to prevent exposure.

5 Methods for bank/shore areas

5.1 Nature conservation objectives

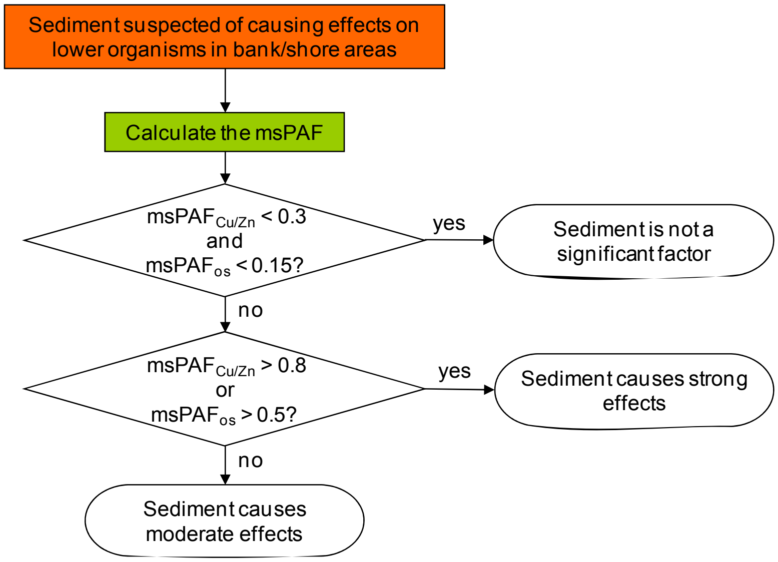
For every Natura2000 area a management plan has been composed, in which species are designated that are to be protected. It is also described whether the population of a specific species has to remain stable or has to grow. If the competent authority observes problems regarding the stability or grow of the population of specific target species and the sediment is contaminated, this can be a motive for conducting research into the effects of the sediment.

In §5.1.1 it is described how the effects on lower target species can be determined. This involves species that are in direct contact with the sediment and that are situated in the lower food chain, such as worms, nematodes, springtails, beetles and centipedes.
In §5.1.2 assessing the effects on higher organisms is described. Higher organisms depend on healthy sediment due to direct contact or through their food. This involves birds and mammals.

5.1.1 Effects on lower organisms

Direct risks for lower organisms that are caused by the sediment can be calculated with the same msPAF method as used for terrestrial soils. Figure 5.1 shows the method for assessing the effects of sediment on lower organisms in bank/shore areas.

Figure 5.1
Flowchart for assessing sediment suspected of causing effects on lower organisms in bank/shore areas (msPAFos = msPAF other substances).



Calculate the msPAF
For this calculation the bank/shore version of SEDIAS can be used. This tool calculates msPAF values for the upper sediment on the basis of acute EC_{50} values.

In this case an msPAF value of 0.1 indicates that acute effects occur in half of the individual organisms in10% of all species. This protection level is lower than the one used in sediments so far and that is based on NOECs (No Observed Effect Concentrations). Because the msPAF combines the effects of all different contaminants, it is important that at least all substances of the default analysis list (NEN 5720, see Annex E) are entered, even if not all substances have been analysed and no suspected substances have been found. More information on the msPAF can be found in Annex K.

As in the case of terrestrial soils, two msPAF values are calculated for sediments, i.e. the msPAF for Cu/Zn and the msPAF for other substances. Three categories of msPAF related effects are distinguished:

$\text{msPAF}_{\text{Cu/Zn}} < 0.3$ and $\text{msPAF}_{\text{other substances}} <0.15$	no significant effects
$\text{msPAF}_{\text{Cu/Zn}} > 0.8$ or $\text{msPAF}_{\text{other substances}} > 0.5$	strong effects
msPAFs between these lower and upper limits	moderate effects

Specialistic methods for assessing the effects on the ecosystem in bank/shore areas

Further underpinning of the effects can be achieved by performing additional measurements. Chemistry (incl. msPAF), ecotoxicology and ecology are combined in the TRIADE approach that has been well elaborated for terrestrial soils (Mesman *et al.*, 2007). The TRIADE approach includes bioassays and additional field inventories. Bioassays can be used to prove that contaminants in the sediment of concern actually can cause effects.

5.1.2 *Effects on higher organisms*

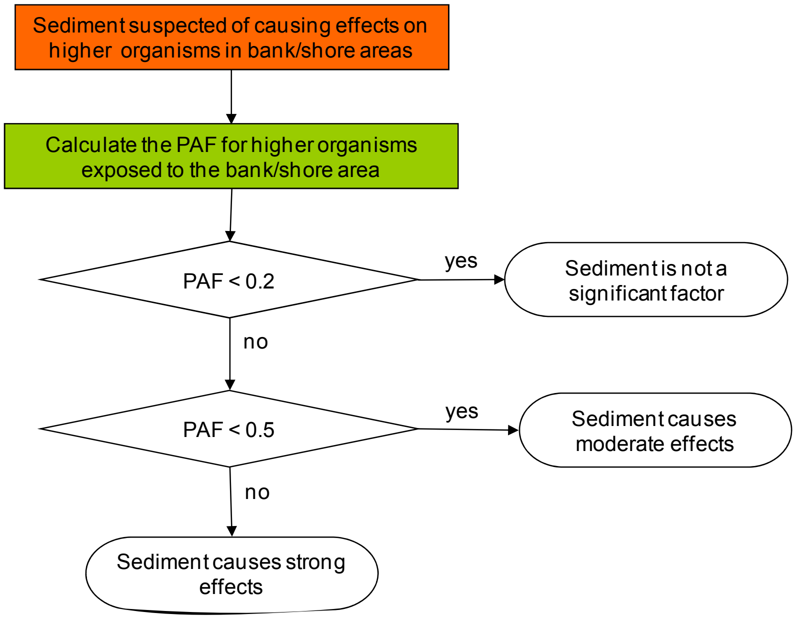
Lower organisms can sometimes assimilate substances from the sediment without being affected, whereas organisms situated in the higher food chain are affected as a result of secondary poisoning.

Figure 5.2 shows the method for assessing sediments that may impede the achievement of the objectives for higher organisms. A first impression of the effects of the sediment on higher organisms can be obtained by calculating the PAF for higher terrestrial organisms. In Annex B.3 the substances are listed for which secondary poisoning might apply.

Calculate the PAF for higher organisms

The PAF for higher organisms and relevant substances can be calculated with the bank/shore version of SEDIAS. For some bioaccumulating substances no PAF curve is available, but an MPC for higher organisms is. In that case the concentration is tested against 10 times this MPC. This compliance testing is also part of SEDIAS for bank/shore areas.

Figure 5.2
Flowchart for assessing sediment suspected of causing effects on higher target species in bank/shore areas.



PAF < 0.2 for all individual substances?
The sediment is assumed not to cause significant effects if the PAF < 0.2 for all substances.

PAF > 0.2 and PAF < 0.5 for all individual substances?
A PAF value between 0.2 and 0.5 indicates that effects are possible. Effects are assessed by the competent authority with respect to the nature objectives. For most nature reserves these objectives have been laid down in management plans. The organisms most susceptible to secondary poisoning are the higher organisms that have both their habitat and feeding area in the contaminated area.

PAF > 0,5 for all individual substances
A PAF > 0.5 indicates that contaminant concentrations can cause substantial effects. If target species susceptible to bioaccumulation are present, it must be assumed that these species are actually affected.

Specialistic methods to assess sediments in relation to nature objectives
It is advisable to carry out a food web analysis if it has become clear that certain target species (higher organisms) are affected by contaminants,. The model OMEGA45 (not to be confused with OMEGA23 that calculates a 'standard' (ms)PAF, see Annex K) enables building a food web and researching bioaccumulation and biomagnification. On the basis of these regionally specific data one can assess to what extent vulnerable target species are exposed and to what extent contaminated sediment is significant in this matter.

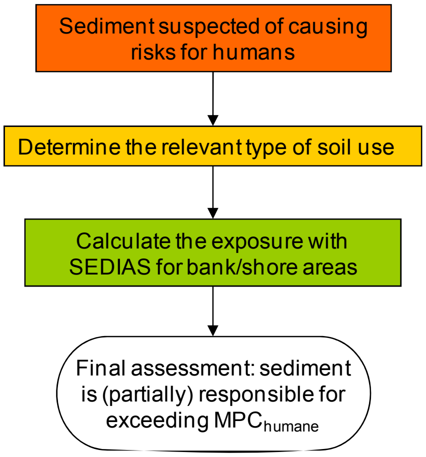
5.2 Standards for agricultural products

If a standard is exceeded in an agricultural product, the soil almost certainly is a significant factor. For soil LAC-values (LAC=Agricultural Advisory Commission) have been derived that are based on the quality standards for agricultural products. Standardized contents in soil can directly be tested against the LAC-values laid down in the Alterra-report 'The basis of the LAC-2006 values and overview of soil-plant relationships for the purpose of the Risk toolbox' (Römkens *et al.*, 2007), (in Dutch, see www.alterra.wur.nl).
In deriving the LAC values, different soil types and cultures have been distinguished.

5.3 Standards for protecting humans

For contaminated sediment in a bank/shore area it can be calculated whether a human being is exposed to concentrations exceeding the MPC_{humane}. The basis of this calculation is the recreational activity in bank/shore areas causing the highest risk, which is constituted by children playing on the sediment. The calculation involves the contaminant contents in the top layer. Figure 5.3 shows the method for assessing the risks of contaminated sediment for humans in bank/shore areas.

Figure 5.3
Flowchart for assessing sediment suspected of causing risks for humans in bank/shore areas.



Calculate the exposure with SEDIAS for bank/shore areas
After entering the measured total substance contents and the organic matter content, the model calculates the exposure of children playing on the sediment to all entered substances. For every substance a risk index is calculated by dividing the calculated exposure (dose) by the MPC_{humane} of the substance concerned. If the calculated index < 1 the exposed human is not subjected to irresponsible risks. In case of values > 1 there is a motive to take measures to prevent exposure.

5.4 Groundwater objectives

Assessing the effects of the sediment in a bank/shore area on groundwater quality is only making sense if point sources of contamination are involved, such as former landfills. Two situations can present a motive to assess the effects of the sediment in a bank/shore area on groundwater quality:

- If contaminated groundwater has been found under a bank/shore area, a point source in the sediment can be the cause of this contamination. Using hydrological knowledge one can estimate where water is infiltrating contaminated sediment. On its way through the contaminated sediment, the infiltrating water can cause substances to leach from the sediment and to be transported to the groundwater.
- If a point source is known to be present, this can be a motive to examine whether this point source affects the groundwater quality.

Assessing the effects of sediments in bank/shore areas on groundwater is technically similar to assessing the effects of terrestrial soils. SEDIAS for bank/shore areas can be used to assess the extent to which the sediment is responsible for the groundwater contamination.

Specialistic methods for calculating the leaching of substances from bank/shore areas to the groundwater

Calculating the leaching from bank/shore areas to the groundwater can be carried out with sophisticated groundwater models that model the transport of substances from the unsaturated zone and calculate the load to the groundwater. Examples are Modflow/MD3T for the unsaturated zone and HYDRUS for the saturated zone.

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Annex A Sediment relevant substances

In the following tables overviews are presented of priority substances and other substances determining the Good Chemical Status (GCS) (source: Bkmw 2009) and of the other specific substances determining the Good Ecological Status (GES) or the Good Ecological Potential (GEP) (source: MR Monitoring, 2010). In the right column it is indicated whether the substance can adsorb to the sediment, based on its partitioning constant K_{oc} (organic substances) or K_d (metals). If log K_d or K_{oc} > 3 the substance is called 'sediment relevant'.

Priority and other substances determining the GCS

Priority substance	**Sediment relevant?**[1]
Alachlor	-
Anthracene	+
Atrazine	-
Benzene	-
Polybrominated diphenyl ethers	+
C10-13 – chloroalkanes	+
Chlorfenvinphos	(±)
Chlorpyriphos	(±)
1,2-dichlorethane	-
Dichloromethane (methylene chloride)	-
Di(2-ethyl-hexyl) phthalate (DEHP)	+
Diuron (DCMU)	-
Endosulfan	+
Fluoranthene	+
Hexachlorobenzene	+
Hexachlorobutadiene	+
Hexachlorocyclohexane (gamma)	+
Isoproturon	-
Naphthalene	+
Nonylphenols	+
Octylphenols	+
Pentachlorobenzene	+
PCP (Pentachlorophenol)	+
Simazine	-
Trichlorobenzenes	(±)
Trichloromethane	-
Trifluralin	-
Tributyltin	+
Benzo(a)pyrene (PAH)	+
Sum of BbF and BkF	+
Sum of BghiPe and InP	+
Cadmium	+
Lead	+
Mercury	+
Nickel	+
Other substances	

Priority substance	**Sediment relevant?**[1]
Tetrachloroethylene (perc)	-
Tetrachloromethane (carbon tet)	-
Trichloroethylene (chlorothene)	-
Sum of drins (aldrin, dieldrin, endrin and isodrin)	+
Sum of DDT/DDD/DDE	+
4,4-DDT	+

[1] + is sediment relevant, - is not sediment relevant, ± is in-between.

Other (sediment relevant) specific substances partially determining GES/GEP

Other specific substance	**Sediment relevant?**[1]
PCB-28	+
PCB-52	+
PCB-101	+
PCB-118	+
PCB-138	+
PCB-153	+
PCB-180	+
Benz(a)anthracene	+
Phenantrene	+
Chrysene	+
Arsenic	+
Boron	+
Antimony	+
Barium	+
Beryllium	+
Cobalt	+
Copper	+
Molybdenum	+
Selenium	+
Tellurium	+
Thallium	+
Tin	+
Titanium	+
Uranium	+
Vanadium	+
Silver	+
Zinc	+
Dibutyltin	+
Tetrabutyltin	+
Triphenyltin acetate	+
Triphenyltin chloride	+
Triophenyltin hydroxide	+
Chlordane	+
Heptachlor	+
Heptachlor epoxide	+
Hexachloroethane	+

[1] + is sediment relevant, - is not sediment relevant, ± is in-between.

Annex B Sediment relevant substances, substances relevant with respect to human risks and substances relevant with respect to secondary poisoning in higher organisms

Table B.1: Substances relevant with respect to human risks.

Substances relevant with respect to risks through consumption of privately landed fish*	**Substances relevant with respect to legal food standards**	**Substances relevant with respect to risks through recreation**
dioxin-like substances (dioxins, furans, dioxin-like PCBs) cadmium (Cd) mercury (Hg) copper (Cu) lead (Pb) drins endosulfan pentachlorophenol pentachlorobenzene hexachlorobenzene DDD/DDE/DDT heptachlor heptachlor epoxide HCHs chlordane	dioxin-like substances (dioxins, furans, dioxin-like PCBs) lead (Pb) cadmium (Cd) mercury (Hg)	PAHs pesticides

Table B.2: EU-standards for fish, eel, shellfish and molluscs for human consumption.

Relevant standards as laid down in EG document no. 1881/2006			
fish	Pb	0.3	mg/kg fresh weight
shellfish	Pb	0.5	mg/kg fresh weight
bivalve molluscs	Pb	1.5	mg/kg fresh weight
fish	Cd	0.05	mg/kg fresh weight
eel	Cd	0.1	mg/kg fresh weight
shellfish	Cd	0.5	mg/kg fresh weight
bivalve molluscs	Cd	1	mg/kg fresh weight
fish	Hg	0.5	mg/kg fresh weight
eel	Hg	1	mg/kg fresh weight
pike	Hg	1	mg/kg fresh weight
shellfish	Hg	0.5	mg/kg fresh weight
fish	sum of dioxins/furans	4	pg TEQ/g fresh weight
eel	sum of dioxins/furans	4	pg TEQ/g fresh weight
shellfish	sum of dioxins/furans	4	pg TEQ/g fresh weight
fish	total of dioxin-likes	8	pg TEQ/g fresh weight
eel	total of dioxin-likes	12	pg TEQ/g fresh weight
shellfish	total of dioxin-likes	8	pg TEQ/g fresh weight

Table B.3: Substances bioaccumulating in the food chain, affecting higher organisms.

Metals	**PCBs**	**OCBs**	**Other substances**
Cadmium	28*	Aldrin	PBDE*
Mercury	52*	Dieldrin	C10-C13 Chloroalkanes*
Copper	101*	Endrin	Chlorpyriphos
	118*	Endosulfan	DEHP*
	138*	pentachlorophenol	Nonylphenol*
	153*	pentachlorobenzene*	Octylphenol*
	180*	hexachlorobenzene	TBT*
	Dioxin-like PCBs*	DDD	Dioxins*
		DDE	Furans*
		DDT	
		heptachlor	
		heptachlor epoxide*	
		a-HCH *	
		b-HCH*	
		lindane	
		chlordane*	

* No PAF curve available, because too little data are available. These substances are tested against 10 times the MPC for secondary poisoning (Beek, 2002).

Annex C Intervention values for sediment

The table below lists the interventions values for aquatic sediments, as published in the Dutch 'Staatscourant' of 8 April 2009, as part of the Dutch 'Amendment of the Circular concerning the remediation of sediments 2008'. Indicative intervention values are not listed in the table. For actual intervention values, including indicative intervention values, one is referred to:
http://apps.helpdeskwater.nl/normen_zoeksysteem/normen.php

Substance(group)[1]	Intervention value sediment (mg/kg d.s.)
1. Metals	
antimony (Sb)	15
arsenic (As)	85
cadmium (Cd)	14
chrome (Cr)	380
cobalt (Co)	240
copper (Cu)	190
mercury (Hg)	10
lead (Pb)	580
molybdenum (Mo)	200
nickel (Ni)	210
zinc (Zn)	2000
2. Other inorganic substances	
cyanide (free)	20
cyanide-complex	50
thiocyanates (sum)	20
3. Aromatic substances	
benzene	1
ethylbenzene	50
toluene	130
xylenes (sum)	25
styrene (vinyl benzene)	100
phenol	40
cresols (sum)	5
4. Polycyclic aromatic hydrocarbons (PAHs)	
PAHs total (sum of 10)	40
5. Chlorinated hydrocarbons	
a. (volatile) chlorinated hydrocarbons	
chloroethene (vinyl chloride)[2]	0.1
dichloromethane	10
1,1-dichloroethane	15
1,2-dichloroethane	4
1,1-dichloroethene[2]	0.3[3]

1,2-dichloroethene (sum)	1
dichloropropanes	2
trichloromethane (chloroform)	10
1,1,1-trichloroethane	15
1,1,2-trichloroethane	10
trichloroethylene (chlorothene)	60
tetrachloromethane (carbon tet)	1
tetrachloroethylene (perc)	4
b. chlorobenzenes	
chlorobenzenes (sum)	30
c. chlorophenols	
pentachlorophenol	5
chlorophenols (sum)	10
d. polychlorinated biphenyls (PCBs)	
PCBs (sum 7)	1
e. other chlorinated hydrocarbons	
mono-chloroanilins (sum)	50
chloronaphthalene (sum)	10
6. Pesticides	
a. organochlorine pesticides	
chlordane (sum)	4
DDT/DDE/DDD (sum)	4
drins (sum)	4
α-endosulfan	4
HCH-compounds (sum)	2
heptachlor	4
heptachlor epoxide (sum)	4
c. organotin pesticides	
organotin compounds (sum)	2.5
d. chlorophenoxy-acetic acid herbicides	
MCPA	4
e. other pesticides	
atrazine	6
carbaryl	5
carbofuran	2
7. Other substances	
Asbestos[4]	100
cyclohexanone	45
phthalates (sum)	60
mineral oil[5]	5000
pyridine	0.5
tetrahydrofuran	2
tetrahydrothiophene	90
tribromomethane (bromoform)	75

References in the table:

[1] For the definition of the combined parameters (sum) one is referred to annex N of the Soil Quality Regulation. For some combined parameters the definition for terrestrial soils is different from the one for aquatic sediments. The definition that is applicable is mentioned in the table.

[2] The Intervention values of these substances are smaller than or equal to the detection limits (intra laboratory reproducibility).

[3] The Intervention value for sediment is (set) equal to the detection limit (intra laboratory reproducibility).

[4] I.e. the content of serpentine asbestos plus ten times the contents of amphibole asbestos. This standard is set to 0 mg/kg d.s. if the conditions of article 2, paragraph b, of the Dutch Decree on asbestos products are not met.

[5] Mineral oil involves the sum of both branched and straight alkanes. Whenever traces of mineral oil contamination are detected in sediment/dredged material, not only mineral oil contents have to be measured but also the levels of aromatic and/or polycyclic aromatic hydrocarbons.

Annex D Reference values drinking water for cattle

In the table below, reference values are listed that are used by the Dutch Animal Health Service in assessing the quality of surface water to be used for watering cattle (source: Practical manual for Ruminants, Laboratory of the Animal Health Service, May 2007).

Parameter	**Reference value cattle drinking water**	**Remark**
Acidity (pH)	< 10	
Chloride	< 2000 mg/l	
Sulphate	< 250 mg/l	
Nitrite	< 1 mg/l	
Nitrate	< 100 mg/l	
Cadmium	< 5 µg/l	Total concentration
Mercury	< 1 µg/l	Inorganic and methyl mercury
Cooper	< 50 µg/l	Total concentration
Nickel	< 100 µg/l	Total concentration
Lead	< 50 µg/l	Total concentration
Zinc	< 250 µg/l	Total concentration
Chrome	< 50 µg/l	Chrome III: < 1000 µg/l
Arsenic	< 100 µg/l	Total concentration

Annex E Preliminary and exploratory sediment surveys

Preliminary survey
For collecting site specific data for the purpose of an exploratory sediment survey the following NEN (NEderlandse Norm= Dutch Standard) protocol is available:

NEN 5717 Soil - Sediment – Strategy for carrying out a preliminary survey for the purpose of exploratory and more specific surveys.

In case of using the NEN 5717 in the context of this guidance document, the research goal 'on behalf of other management responsibilities' is applicable in defining the research hypothesis. If data have been gathered on the basis of the research goal 'dredging activities', these can also be used in defining the research hypothesis, provided that these data are still up-to-date and the period of validity has not expired yet.

Sampling strategy
After carrying out NEN 5717, it is decided whether an exploratory sediment survey is required. For carrying out this exploratory sediment survey the following NEN protocol is applicable:

NEN 5720 Soil – Sediment – Strategy for carrying out an exploratory survey – Examination of the environmental quality of sediments and dredged material.

For use in the context of this guidance document the section 'on behalf of other management responsibilities' is applicable. Data gathered on the basis of 'dredging activities' can also be used, provided that the sediment has not been dredged yet, that the period of data validity has not expired yet and that the correct sediment layer has been sampled.

The objective of this guidance document is to assess whether the sediment is impeding the achievement of the quality objectives. This means that one has to gain a clear insight in the type, extent and spatial distribution of any sediment contamination. The NEN 5720 can be used to compartmentalize the area, provided that the compartments do not differ from each other with respect to the properties of the water system that – according to the methods in this guidance document - determine the effects of the sediment on the objectives and functions considered (see §1.6 of this guidance document).
As stated in §5.3.3 of the NEN 5720, the research strategy may be adjusted by changing the compartmentalization, the number of sediment cores, the thickness of the sampled layer or the number of analyses. Although the number of sediment cores may be limited, enough cores have to be taken in order to get a clear insight into the spatial distribution of the sediment contamination. Sampling of the top sediment layer suffices. This is the sediment layer that interacts with the water column. The thickness of this interactive layer depends on factors such as water type and water dynamics (flow rate, number of passing ships etc.). It is advisable to include a layer of 20-50 cm thickness in the survey.

In bank/shore areas that are part of a Natura2000 area it may be necessary to examine the sediment up to a depth of 100 cm in order to be able to assess the effects on terrestrial target species. This only makes sense in situations where the preliminary survey indicated that the heaviest contamination is not located in the top layer but at a depth between 50 and 100 cm. In that case contents have to be averaged over the entire depth of 100 cm in order to be used to assess the sediment with this guidance document.

It is advised to transport the individual samples per core to the laboratory and to analyze composite samples, in accordance with NEN 5720, that are composed of maximally three individual samples.

In case of sampling individual and composite samples in bank/shore areas that are contaminated by point sources, the NEN 5720 refers to the sampling strategy of the NEN 5740 for terrestrial soils.

> The research goal ‘other management responsibilities’ of the NEN 5720 allows for the application of innovative techniques that give an equally reliable insight into the sediment quality.

Analysing strategy

Default analysis lists have been included in the NEN 5720. These default analysis lists only contain substances that occur regularly. If, from water quality data (chapter 3 and §5.4) or from the preliminary sediment survey (see above, chapters 4 and 5 of this guidance document), it becomes clear that other substances might be significant, the default analysis list is supplemented with these substances. Bank/shore areas that are periodically flooded with diffusely contaminated surface water are managed under the jurisdiction of the Dutch Water Act. It is therefore advised to use the NEN 5720 default analysis list also in case of investigating point sources in bank/shore areas.

Especially if starting from water quality, situations can arise for which the guidance document suggests to analyse just a couple of parameters in the sediment, such as one or two metals and additionally clay and organic matter for the purpose of standardizing. In that case one might be inclined to think that it is cheaper not to analyse all the substances of the default analysis list. One should however bear in mind that commercial laboratories often offer the analysis of the default list for a good price and that it is actually only in exceptional cases cheaper to have a more limited set of substances analysed.

The above described strategy of the exploratory sediment survey can also be used to measure eutrophication parameters in the sediment. This involves the measurement of the following parameters in the top layer of the sediment:

- total-P
- total-Fe
- total-Al (optional)
- total-S

If the sediment is only assessed because of eutrophication problems and not because of other contaminants, the analysis of the substances on the default analysis list can be omitted.

Annex F Measuring concentrations in pore water

Freely dissolved concentrations in the pore water of contaminated sediments often give a better indication of the uptake by organisms and of the transport to surface water and groundwater than total contents in the sediment. This annex gives an explanation of the relevant ideas with respect to pore water concentrations and of protocols for measuring pore water concentrations with Tenax extraction (organic contaminants) or $CaCl_2$ extraction (metals).

Terminology

- (Pore) water concentration: the total concentration of a substance in the (pore) water. This total concentrations consists of:
  - Freely dissolved fraction: the concentration of non-bound substance
  - DOC-bound fraction: the concentration of a substance that is bound to dissolved organic matter (this fraction is part of the pore water concentration)
  - Complexed fraction (only metals): the concentration of a substance that has formed a dissolved complex with other inorganic elements, such as $CdCl^+$ or $Cu(OH)^+$.
- Available fraction: the fraction of the total contaminant content that can be extracted from the solid phase with a specific extraction technique. For organic contaminants this fraction can be determined with for example Tenax or persulphate. For inorganic contaminants comparable extractants exists (such as ammonium acetate or EDTA), but direct analysis of the pore water is preferred.
  Technically speaking these are chemical availability measurements, but they are often defined as biological availability measurements. This implies that it is assumed that a relationship exists between chemical availability and biological effects.
- Total content: the total content of a substance in the sediment.

Explanation for organic contaminants

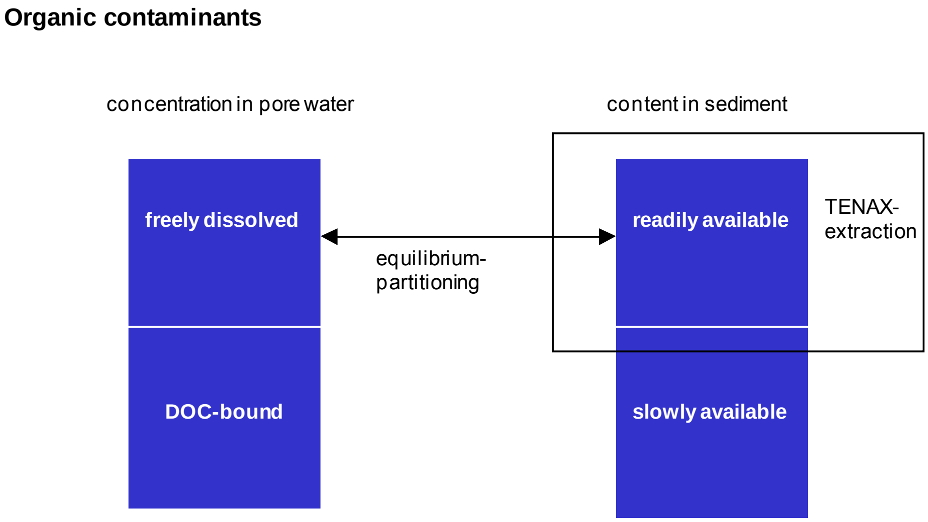
Figure 1 shows the relationship between the total content in the sediment, the available fraction in the sediment and the concentrations in the pore water for organic contaminants. In the case of organic contaminants two fractions can be distinguished: a fraction that desorbs quickly and that is relevant for uptake and effects and a fraction that desorbs more slowly. The (biological) available fraction is determined by the properties of the sediment and the contaminant. Organic contaminants adsorb more or less tightly to the organic components of the sediment.

Because pore water concentrations are often below the detection limit, they cannot be measured directly. However, extraction techniques have been developed that give an indication of the availability of substances. Extraction with TENAX is the best known technique. The costs of this technique are comparable to the costs of measuring total contents. In order to be able to assess effects, the available fraction is converted to the concentration in the pore water according to:

$$C_{\text{freely dissolved}} = (\ \text{fraction}_{\text{available}} * \text{total content}_{\text{sediment}}\ ) \ / \ K_D$$

where K_D is the partitioning constant between water and sediment.

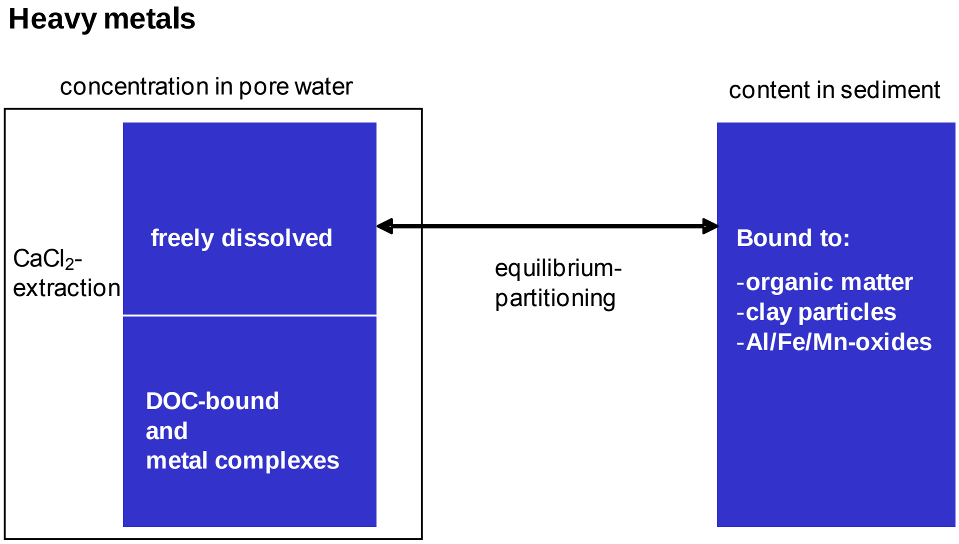
Figure 1
Schematic representation of the presence of organic contaminants in sediment and pore water.



Detailed information on the extraction and the calculations can be found in Ten Hulscher and Van Noort, 2006.

Explanation for metals
Figure 2 shows the situation for metals. Metals not only bind to organic matter but also to clay particles and Al/Fe/Mn-oxides. The availability of metals is furthermore strongly determined by the presence of oxygen and macro parameters, such as sulphur, iron, calcium and chloride. In the first step of this guidance document for sediment assessment equilibrium partitioning is used to calculate concentrations in the pore water. Contrary to organic contaminants, pore water concentrations of metals can be analysed. In specialistic methods the calculation on the basis of equilibrium partitioning is replaced by measuring the pore water concentration directly.

Figure 2
Schematic representation of the presence of heavy metals in sediment and pore water.



Although aquatic sediments are mainly anaerobic, the thin top layer is aerobic and very important in the interaction between sediment and surface water. (Sediment dwelling) organisms also live mainly in this boundary layer. Sediment dwelling organisms get their oxygen and food from the aerobic water layer directly bordering the sediment or oxidize their environment by active of passive ventilation.

Both for the interaction between sediment and water and the interaction between sediment and organisms, the pore water concentration in oxidized sediment is a better indicator than the concentration in anaerobic pore water. This means that extraction of wet sediment in a closed tube is not satisfactory because after a short time a lack of oxygen will develop with a corresponding lowering of the redox potential.

The concentrations of heavy metals in pore water can be estimated with a so-called weak extraction technique. The technique most used so far is extraction with $CaCl_2$ (Osté *et al.*, 2009). The protocol for this extraction technique is included in this annex. Furthermore methods exist for measuring freely dissolved concentration in pore water. Measuring pore water concentration under anaerobic conditions requires specific expertise.

Protocol for the extraction of sediment with 0.0025 mol/l $CaCl_2$ under aerobic conditions for the measurement of inorganic contaminants (version December 2009).

1. Aim and scope

1.1 Aim

This protocol describes a method for the extraction of heavy metals with a 0.0025 mol/l $CaCl_2$ solution. The method is derived from the method for terrestrial soils[1] where a higher ionic strength is used. For different reasons the method is adjusted to make it suitable for use in sediment[2].

1.2 Scope

This protocol is applicable to sediment. In order to get an extraction technique that gives an estimate of the biological availability, the ionic strength needs to be of the same order of magnitude as the pore water. A concentration of 0.0025 mol/l $CaCl_2$ (100 mg/l Ca) approximates this ionic strength but can be adjusted.

2. Principle

The wet sediment sample is shaken for 20 hours with 0.0025 mol/l $CaCl_2$ in a 1:10 (kg/l) sediment to liquid ratio. The volume of the solution is corrected for the moisture content of the sediment, which may cause the ionic strength to differ a little. After 20 hours shaking the pH is measured in the suspension. Then the suspension is centrifuged, the super natant solution is removed by use of a pipette[3] and preserved with ultra pure HNO_3. The heavy metals of interest are analysed by means of ICP-OES and, if desired, by means of ICP-MS.

3. Chemicals

3.1. Required chemicals

o Calcium chloride dihydrate

o Buffer pH4

o Buffer pH7

o Buffer pH10

o Ultra pure HNO_3

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[1] Houba *et al.*, 1999. Soil analysis Procedures Extraction with 0.01 M CaCl2, Wageningen Agricultural University.

[2] Osté, L.A., 2010. The $CaCl_2$ extraction technique applied to 10 sites in the river Waal. In Dutch. Report, Deltares, Delft.

[3] If DOC and DIC are also to be analysed, an extra sample has to be taken that is not acidified and in which dissolved carbon is analysed quickly.

3.2 Reagents and catalysts

- Milli-Q Water

- Calcium chloride solution 0.0025 mol/l
  Accurately weigh 0.735 grams of calcium chloride. Wash this quantitatively into a 2 litre calibrated flask, dissolve in Milli-Q Water and fill up.

4. Equipment and materials

- Analytical balance

- Mechanical shaker or shaking incubator, suitable for upright swerving of 100 ml Erlenmeyer flasks.

- pH meter

- Centrifuge

- Erlenmeyer flasks (100 ml)

- Greiner centrifuge tubes (50 ml)

- Whatman syringe filters SPARTAN 30/0.45 RC

- Synthetic syringes (20 ml)

5. Method

5.1 Safety

The usual laboratory safety rules apply.

5.2 Extraction

- Calculate, using the dry substance content, how much wet sediment equals 4 grams of dry sediment. Weigh this amount of wet sediment into a 100 ml Erlenmeyer flask and pipette such a volume of 0.0025 mol/l $CaCl2$ solution into the flask that the Erlenmeyer flask contains a total of approximately 44 grams of suspension (4 grams sediment and 40 ml solution).

- Take 40 ml of 0.0025 mol/l $CaCl2$ solution as a blank without sediment and treat this blank in the same way as the samples.

- Swerve the open Erlenmeyer flasks for 20 hours at room temperature.

- Measure the pH in the suspension.

- Pour the suspensions in the centrifuge tubes. Do not rinse, because the solution will then be diluted. It is not a problem if some of the sediment remains in the Erlenmeyer flask.

- Centrifuge for 15 minutes at 4000 g.

- Remove the centrifuge tubes from the centrifuge and pipette the super natant solution until approximately 1 cm above the solid material.

- Filter the centrifugated solution over a 0.45 μm syringe filter.

- Pipette 10 ml of the filtered centrifugated solution in a tube and preserve with 0.1 ml concentrated ultra pure $HNO_{3.}$

- Analyse the samples by means of ICP-OES.

- Analyse the samples by means of ICP-MS if not all elements could be analysed with the desired accuracy. Depending on the ICP-MS it may be necessary to dilute the sample 2 times.

- If one wishes to calculate the speciation of the elements in the extract in order to determine for example the freely dissolved concentration, it is necessary to analysze Dissolved Organic Carbon (DOC) and bicarbonate (DIC) in the extract as well. This requires an extra sample.

6. Calculation of the analysis results

Correct the results for the blank, for dilution by preservation and for possible dilution on behalf of the analysis. Report the results in μg/l in the $CaCl_2$ extract.

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Extraction protocol	Version: 1	December 2009
	A.1.1.1 Extraction of available concentrations of organic contaminants in aquatic sediments, dredged material, terrestrial soils, sediments and suspended particulate matter with Tenax®	

1. Aim

1.1. Scope

This protocol describes a method for the extraction of available concentrations of organic contaminants by means of single extraction with Tenax® for exact 24 hours. The protocol is applicable to all sorts of aquatic sediments, dredged material, terrestrial soils, sediment and suspended particulate matter. This protocol can be used for the organic contaminants listed in the table below, which are derived from the default analysis lists (C1 Sediments and dredged material from fresh national surface waters, remaining within fresh surface water, C2 Dredged material from fresh surface waters to be applied outside national waters and C3 Sediments and dredged material from salt national waters, remaining within salt national waters). The protocol can furthermore be used for substances on the list described by Van Noort[1]. The substances of the default analysis lists are part of this list.

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[1] Van Noort, P., Instruments for Sediment quality – Methods to measure available concentrations of organic contaminants in sediment and soil; In Dutch. Deltares (2009).

Polycyclic aromatic hydrocarbons		Organochloride pestcides		Polychlorinated biphenyls		Phenols	
naphtalene	91-20-3	a-HCH	319-84-6	PCB28	7012-37-5	pentachlorophenol	87-86-5
phenantrene	85-01-8	b-HCH	319-85-7	PCB52	35693-99-3		
anthracene	120-12-7	g-HCH	58-89-9	PCB101	37680-73-2		
fluorantene	206-44-0	d-HCH	198-86-8	PCB118	31508-00-6		
chrysene	218-01-9	aldrin	309-00-2	PCB138	35065-28-2		
benzo(a)anthracene	56-55-3	dieldrin	60-57-1	PCB153	35065-27-1		
benzo(a)pyrene	50-32-8	endrin	72-20-8	PCB180	35065-29-3		
benzo(k)fluorantene	207-08-9	isodrin	465-73-6				
indeno[1,2,3-c,d]pyrene	193-39-5	telodrin	297-78-9				
benzo(ghi)perylene	191-24-2	o,p-DDD	53-19-0				
acenaphtene	83329-32-9	p,p-DDD	72-54-8				
acenaphtylene	20896-96-8	o,p-DDE	3424-82-6				
benzo(b)fluorantene	20599-99-2	p,p-DDE	72-55-9				
benzo[b]fluorene	30777-19-6	o,p-DDT	789-02-6				
fluorene	86737-73-7	p,p-DDT	50-29-3				
pyrene	12900-00-0	heptachlor	76-44-8				
		a-endosulfan	959-98-8				
		b-endosulfan	33213-65-9				
		endosulfan sulphate	1031-07-8				
		cis-heptachlor epoxide	1024-57-3				
		trans-heptachlor epoxide	28044-83-9				
		cis-chloordane	5103-71-9				
		trans-chloordane	5103-74-2				
		hexachloro-1,3-butadiene	87-68-3				
		pentachlorobenzene	608-93-5				
		hexachlorobenzene	118-74-1				

2. PRINCIPLE

The (freeze-dried) sample is shaken for 24 hours in the presence of Milli-Q water and Tenax® (the extraction is also possible with wet material provided that the dry matter content is known). Subsequently the water-sediment mixture (remaining fraction) and the Tenax® (24 hours' Tenax® extractable fraction) are separated. After extracting the organic contaminants from the Tenax® derived from the sample, their concentrations are analysed in the extract. The concentrations of the organic contaminants must be quantified with calibration standards composed of the components of interest. Using the remaining content in the sediment and the 24 hours' Tenax® extractable (T-24h) concentration, one can determine the T-24h fraction. By multiplying the measured T-24h fraction with a factor, one can estimate the fraction that is absorbed by the amorphous part of the sediment. This part is also known as the available fraction of the sediment[2]

Remark: For quality assurance of the method, one can also determine the total content in the sediment. This content should equal the sum of 24 hours' extractable content and the remaining content (mass balance).

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[2] Cornelissen, G., Rigterink, H., Ten Hulscher, Th.E.M., Vrind, B.A. and Van Noort, P.C.M.: A simple Tenax extraction method to determine the availability of sediment-sorbed organic compounds; Environ. Tox. Chem. (2001), 20, 706-711.

3. CHEMICALS AND REFERENCE MATERIALS

3.1. Overview of chemicals and primary reference material

3.1.1. n-Hexane >99.8%

3.1.2. Acetone >99.8%

3.1.3. Tenax® TA 60-80 mesh

3.1.4. Mercury(II) chloride >99.5%

3.1.5. Sodium azide >99%

3.1.6. Milli-Q® water.

3.2. Preparation and storage life of reagents

3.2.1. Milli-Q® water (3.1.6) with added mercury(II) chloride (3.1.4) having a final concentration of 25 mg/l and sodium azide (3.1.5) having a final concentration of 160 mg/l. Adding these components prevents microbial decomposition of organic contaminants.

4. EQUIPMENT AND MATERIALS

4.1. Equipment

4.1.1. Top pan balance for weighing with an accuracy of 0.01 gram and a range up to 200 grams or higher.

4.1.2. Analytical balance for weighing with an accuracy of 0.0001 gram and a range up to 100 grams or higher.

4.1.3. Shaking machine, horizontal movement at least 160 movements per minute.

4.1.4. Stove suited for drying glassware and Tenax® at 125°C.

4.2. Materials

4.2.1. Test sieve of 1 mm.

4.2.2. Separatory funnel 100 ml rinsed with acetone and subsequently dried.

4.2.3. Erlenmeyer 300 ml rinsed with acetone and subsequently dried.

4.2.4. Reflux configuration.

4.2.5. Evaporation configuration.

5. METHOD

5.1. Working conditions

The organic substances mentioned in this protocol are very toxic. Consider the contaminated samples as chemical waste and dispose of them accordingly. Exclusively work in a fume cupboard and wear accessories for personal protection (lab-coat, safety glasses and gloves).

Acetone, n-Hexane and Sodium azide irritate the eyes, the skin and the respiratory organs and affect the nervous system. Mercury(II) chloride and Sodium azide are very toxic.

Consult the safety handbook.

5.2. Sample receipt and storage

Preserve the samples by storing them in a closed glass jar in a cool and dark environment. See o-NEN-EN-ISO 5667-15.

5.3. Sample preparation

Clean the necessary glassware thoroughly by rinsing it with acetone and washing it subsequently. Dry the glassware for a night in the stove at 105°C. Before using the glassware, rinse it with the solvent to be used. Very dirty glassware must be soaked in an extracting solvent for 12 hours before use or be replaced.

5.3.1. Sediment preparation

Pass the sediment through a 1 mm test sieve. This prevents clogging of the valve of the separatory funnel during separation of the sediment-water mixture and the Tenax®.

Remark: If for whatever reason it is not possible to pass the sediment through the sieve it is advised to use a 250 ml separatory funnel in step 6.4.1 which has a bigger valve than a 100 ml separatory funnel.

5.3.2. Extraction procedure Tenax® (T-24h content)

Carry out the 24 hours' Tenax® extraction method in duplicate.
Transfer approximately 1 gram of sieved sediment (dry weight – in case of wet sediment determine the dry substance content) and 70 ml Milli-Q water (3.2.1) to a 100 ml separatory funnel (for non-sieved sediment see remark 6.3).
Add 1.5 grams of Tenax® (3.1.3).

Shake the whole for exactly 24 hours at 160 revolutions per minute.
Take the separatory funnel out of the shaking machine and place it upright. Leave the layers to separate.
Separate the sediment-water sample from the Tenax® by draining the sediment-water mixture from the separatory funnel (collect in an Erlenmeyer flask that already contains a stirring rod). The Tenax® adheres to the glass.
Rinse the Tenax® with approximately 70 ml Milli-Q water (3.1.6). Collect this water in the same Erlenmeyer flask already containing the sediment.
Limit the loss of Tenax® from the separatory funnel by using a low flow in separating the sediment-water mixture.

Remark: in practise it often occurs that, in separating the sediment-water mixture and the Tenax®, a small fraction of the Tenax® (<5%) ends up with the sediment in the Erlenmeyer flask. Also a small fraction of the sediment stays behind in the Tenax® in the separatory funnel.

Extract the organic contaminants from the Tenax® by adding (exactly) 20 ml hexane (3.1.1) to the separatory funnel.
Shake the Tenax®-hexane mixture for at least 20 seconds.
Leave the layers to separate (hexane above).
Weigh an empty point tube (15 ml).

Pipette as much as possible of the n-hexane from the separatory funnel into the point tube. Weigh the filled point tube.
Rinse the separatory funnel with acetone and collect the Tenax® in an Erlenmeyer flask. Regenerate the Tenax® TA (6.6).
Remark: Preferably extract the Tenax® within 2 hours. If waiting longer, the extraction with hexane possibly is less successful (lower recovery; pers. communication Cornelissen).

Evaporate the extract to approx. 2 ml (determine the exact quantity by weighing).
Take approx. 1 ml of the extract for the analysis of organochloride pesticides and polychlorinated biphenyls.

If necessary, convert this part of the extract to the solvent required for the analysis of organochloride pesticides and polychlorinated biphenyls.
Determine the exact quantity of this solvent by weighing. It is advisable to perform an extra clean-up step before analysing the extract. It is also advised to add copper powder to the extract in order to prevent a sulphur peak in the chromatogram.
If necessary, convert the remaining part of the extract to the solvent required for the analysis of polycyclic aromatic hydrocarbons or pentachlorophenol.
Evaporate the extract to 1 ml (determine the exact quantity by weighing).
Remark: splitting the extract according to the method above is only required if different groups of substances have to be analyzed by chromatography in different ways.

Transfer the extract into an autosampler vial.
Determine the content in the sample (µg/kg) (6.5.2).
Determine the T-24h fraction in the sample (6.5.3).
Remark: when integrating the chromatographic analysis, use manual integration as often as possible instead of using automatic integration. This enhances the quality of measuring the probably low concentration s in the Tenax® extract.

5.3.3. Extraction procedure Remaining content

Add 20 ml acetone to the sediment-water mixture collected in the Erlenmeyer flask (3.1.2).
Weigh the Erlenmeyer flask with the sediment-water-acetone mixture and subsequently 50 ml hexane (3.1.1).
Place the Erlenmeyer flask in the reflux configuration.
Reflux the sediment-water-acetone-hexane mixture for at least 6 hours at 175 C and 1400 rpm.
Leave the layers to separate.
Rinse the reflux configuration with approx. 10 ml hexane per Erlenmeyer flask and also collect this in the Erlenmeyer flask. Determine the exact quantity of hexane by weighing the Erlenmeyer flask after refluxing.
Weigh an empty 15 ml point tube.
Pipette as much as possible hexane from the Erlenmeyer flask into the point tube. Weigh the filled point tube.
Evaporate the extract to approx. 2 ml (determine the exact quantity by weighing).
Take approx. 1 ml of the extract for the analysis of organochloride pesticides and polychlorinated biphenyls.

If necessary, convert this part of the extract to the solvent required for the analysis of organochloride pesticides and polychlorinated biphenyls.
Determine the exact quantity of this solvent by weighing. It is advisable to perform an extra clean-up step before analysing the extract. It is also advised to add copper powder to the extract in order to prevent a sulphur peak in the chromatogram.
If necessary, convert the remaining part of the extract to the solvent required for the analysis of polycyclic aromatic hydrocarbons or pentachlorophenol.
Evaporate the extract to 1 ml (determine the exact quantity by weighing).
Transfer the extract into an autosampler vial.
Determine the content in the sample (µg/kg) (6.5.2).
Determine the remaining fraction in the sample (6.5.3).

5.3.4. Recovery experiment (mass balance)

Regularly determine the recovery, preferably in every series of measurements. Preferably use certified sediment with known contents for this.
Treat this sediment as a sample (5.3).
Calculate the mass balance according to 5.4.6. This balance should amount to 80 to 120%.

5.3.5. Procedural blank and verification

Regularly measure a blank. For this, one takes 70 ml Milli-Q water and treats this like a sample (5.3). Do this at least if a new lot of reagents or catalysts is used and preferably in every series of measurements. For measuring a blank of only Tenax®

5.4. Determining the content

5.4.1. Quantifying the extract

Use a method of choice that is appropriate for quantifying the content of the target substances in the extract.

5.4.2. Calculating the Tenax® extractable concentration.

$$c_{\text{T-24h}} = \frac{A_M \; c_S}{A_S} \; \frac{V_E \; V_T}{I \; V_I}$$

in which:

$c_{\text{T-24h}}$	is the Tenax® extractable concentration of the parameter in the sample after extracting for 24 hours, in µg/kg.
A_M	is the peak height of the parameter in the sample extract.
A_S	is the peak height of the parameter in the standard.
c_S	is the concentration of the parameter in the standard, in µg/l.
V_E	is the volume of extract, in ml.
I	is the used weight of sediment (ds), in g.
V_T	is the added volume of hexane, in ml.
V_I	is the volume of hexane dealt with, in ml.

If applicable, take into account the possible splitting of the extract.

5.4.3. Calculating the available concentration

The available fraction can be determined according to the following equation:

$$c_{available} = f_{ext.} \quad c_{T-24h}$$

in which:

$c_{available}$	is the calculated absorbing fraction in the amorphous part of the sediment (available concentration).
c_{T-24h}	is the Tenax® extractable concentration of the parameter in the sample after extracting for 24hours, in µg/kg.
$f_{ext.}$	is the extrapolation factor described by Van Noort[1], see 6. Extrapolation factors.

$C_{available}$ can be entered in SEDIAS as a measured content and subsequently the pore water concentration can be calculated, corrected for bioavailability.

5.4.4. Calculating fractions

Calculate the T-24h fraction according to the following equation:

$$F_{T-24h} = \frac{c_{T-24h}}{c_{total}}$$

in which:

F_{T-24h}	is the Tenax® extractable fraction after 24 hours.
c_{T-24h}	is the Tenax® extractable concentration of the parameter in the sample after extracting for 24hours, in µg/kg.
c_{total}	is the concentration in the sample for determining the total content, in µg/kg.

Calculate the remaining fraction according to the following equation:

$$F_{remaining} = \frac{c_{remaining}}{c_{total}}$$

in which:

$F_{remaining}$	is the remaining fraction (also called the slow fraction)
$C_{remaining}$	is the concentration in the sample for determining the remaining content, in µg/kg
C_{total}	is the concentration in the sample for determining the total content, in µg/kg.

---

[1]

5.4.5. Estimating the absorbing fraction in amorphous part of the sediment (available fraction)

The available fraction can be calculated according to the following equation:

$$F_{available} = f_{ext.} \quad F_{T-24h}$$

in which:

$F_{available}$	is the calculated absorbing fraction in the amorphous part of the sediment (available fraction).
F_{T-24h}	is the Tenax® extractable fraction after 24 hours.
$f_{ext.}$	is the extrapolation factor described by Van Noort[1], see 6. Extrapolation factors.

5.4.6. Mass balance

If the total content has been determined, one can verify whether the analysis has gone well by means of the mass balance. Use the following equation for this:

$$c_{total} \gg c_{T-24h} + c_{remaining}$$

in which:

C_{total}	is the concentration in the sample for determining the total content, in µg/kg.
c_{T-24h}	is the Tenax® extractable concentration of the parameter in the sample after extracting for 24 hours, in µg/kg.
$C_{remaining}$	is the concentration in the sample for determining the remaining content, in µg/kg.

5.5. Regenerating the Tenax®

Rinse the separatory funnel with acetone and collect the Tenax® and acetone (3.1.2) in an Erlenmeyer flask. Carefully decant the acetone. Dry the Tenax® at 125 C until it is dry.
The Tenax® is regenerated by washing the Tenax® with respectively Milli-Q water (3.1.6), acetone (3.1.2) and hexane (3.1.1) (each 3 times using 10 ml per gram of Tenax®).
Dry the Tenax® at 125 C until it is dry.

Remark: In order to obtain extra clean Tenax®, one can do an extra clean-up with ASE (Dionex Corp.). Methanol, acetone, hexane and a mixture of acetone/hexane are successively led through the Tenax®-filled extraction cells at a temperature of 100°C and a pressure of 103 bar. Dry the Tenax® at 125°C.Fresh Tenax® must be washed with Milli-Q water in order to remove fine particles.

After regenerating Tenax®, always check if it is free of contaminants.

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[1]

For this purpose, take 1.5 gram of Tenax® and extract it with hexane. Determine the contents of target substances. If substances are detected in the Tenax®, it has to be regenerated again.

6. Extrapolation factors

Substance	CAS nr.	log K_{ow}	k_d, amorph. (1/hr)	Extrapolation factor	
				6h	24 h
naphtalene	91-20-3	3.41	2.74	0.90	0.72
phenantrene	85-01-8	4.65	0.95	0.90	0.72
anthracene	120-12-7	4.65	0.95	0.90	0.72
fluorantene	206-44-0	5.27	0.56	0.93	0.72
chrysene	218-01-9	5.89	0.33	1.02	0.72
benzo(a)antracene	56-55-3	5.89	0.33	1.02	0.72
benzo(a)pyrene	50-32-8	6.51	0.20	1.24	0.73
benzo(k)fluorantene	207-08-9	6.51	0.20	1.24	0.73
indeno[1,2,3-c,d]pyrene	193-39-5	7.13	0.12	1.63	0.76
benzo(ghi)perylene	191-24-2	7.13	0.12	1.63	0.76
acenaphtene	83329-32-9	4.12	1.50	0.90	0.72
acenaphtylene	20896-96-8	4.03	1.62	0.90	0.72
benzo(b)fluorantene	20599-99-2	6.51	0.20	1.24	0.73
benzo[b]fluorene	30777-19-6	6.24	0.25	1.13	0.73
fluorene	86737-73-7	4.38	1.20	0.90	0.72
pyrene	12900-00-0	5.27	0.56	0.93	0.72
PCB28	7012-37-5	5.60	0.43	0.97	0.72
PCB52	35693-99-3	5.90	0.33	1.03	0.72
PCB101	37680-73-2	6.35	0.22	1.17	0.73
PCB118	31508-00-6	6.50	0.20	1.24	0.73
PCB138	35065-28-2	6.80	0.15	1.40	0.74
PCB153	35065-27-1	6.80	0.15	1.40	0.74
PCB180	35065-29-3	7.25	0.11	1.72	0.76
α-HCH	319-84-6	3.81	1.95	0.90	0.72
ß-HCH	319-85-7	3.80	1.97	0.90	0.72
γ-HCH	58-89-9	3.70	2.14	0.90	0.72
δ-HCH	198-86-8	4.14	1.47	0.90	0.72
aldrin	309-00-2	6.50	0.20	1.24	0.73
dieldrin	60-57-1	5.40	0.50	0.94	0.72
endrin	72-20-8	5.20	0.60	0.92	0.72
isodrin	465-73-6	6.75	0.16	1.37	0.74
telodrin	297-78-9	4.51	1.07	0.90	0.72
o,p-DDD	53-19-0			1.24	0.73
p,p-DDD	72-54-8	6.51	0.20	1.24	0.73
o,p-DDE	3424-82-6			1.24	0.73
p,p-DDE	72-55-9	6.51	0.20	1.24	0.73
o,p-DDT	789-02-6			1.47	0.74
p,p-DDT	50-29-3	6.91	0.14	1.47	0.74
heptachlor	76-44-8	5.27	0.56	0.93	0.72
endosulfan (mix of isomeres)	115-29-7	3.83	1.92	0.90	0.72
α-endosulfan	959-98-8			0.90	0.72
ß-endosulfan	33213-65-9			0.90	0.72
endosulfan sulphate	1031-07-8	3.66	2.22	0.90	0.72
cis-heptachlor epoxide (exo)	1024-57-3	5.00	0.71	0.91	0.72
trans-heptachlor epoxide (endo)	28044-83-9			0.91	0.72
chloordane (mix of isomeres)	577-74-9	6.00	0.30	1.05	0.72
cis-chloordane	5103-71-9			1.05	0.72
trans-chloordane	5103-74-2			1.05	0.72
hexachloro-1,3-butadiene	87-68-3	4.70	0.91	0.90	0.72
pentachlorobenzene	608-93-5	4.94	0.75	0.91	0.72
hexachlorobenzenen	118-74-1	5.39	0.51	0.94	0.72
pentachlorophenol	87-86-5	5.12	0.64	0.92	0.72

Annex G Measuring indicators for the release of phosphate

This annex can be used if the method for eutrophication problems (chapter 3 of this guidance document) gives cause for extra measurements. It is then, in addition to measuring total contents, advised to measure the readily available phosphate fraction (P-fraction) with a P_{water} or calciumchloride ($CaCl_2$) extraction or to measure the long term available P-fraction with an ammonium oxalate extraction. Instead of measuring the readily available phosphate fraction with an aerobic extraction, one can also determine the iron and phosphate concentrations in anaerobic pore water. The methods mentioned above can be applied in a specialized laboratory.

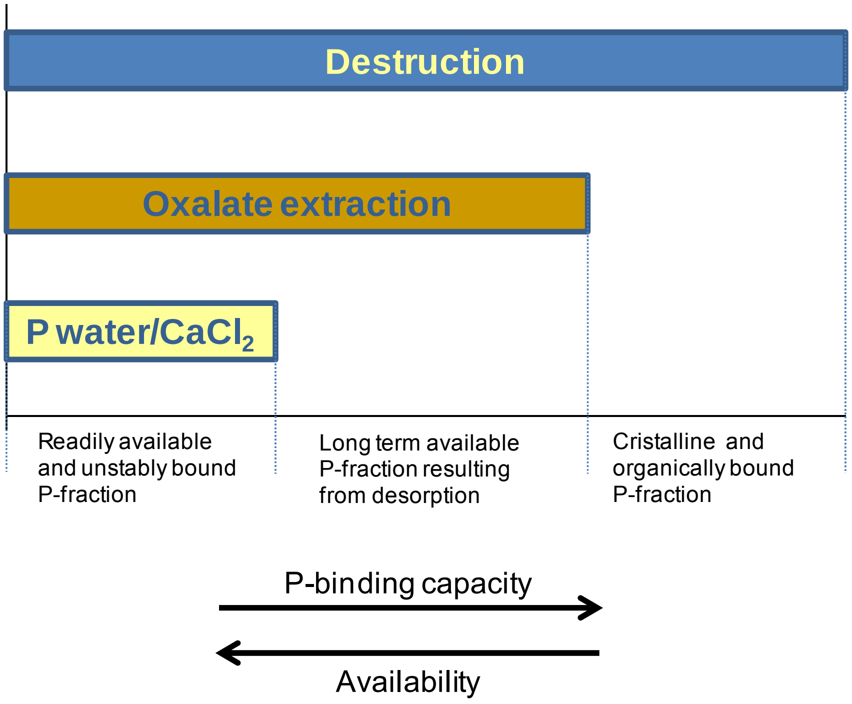


Figure 1
Measurement of various fractions as indicators for the release of phosphate from the sediment.

Aerobic $CaCl_2$ extraction of P
This method is the same method as used for the extraction of metals (see Annex F). If, in the context of this guidance document, metals are extracted with $CaCl_2$, P can be measured in the same extract (and the other way round). Because the extraction is carried out under aerobic conditions, iron, if present, will oxidize and P will bind to it. Normally, this also occurs in the top layer of the aquatic sediment. The P that remains dissolved during this extraction is available for release from the sediment to the overlying water. The results can be tested against standards for surface waters.

Anaerobic $Fe:PO_4$ ratio in pore water
Much experience has been gained in determining the $Fe:PO_4$ ratio, see for example the report 'From clear to troubled waters……and back' (Jaarsma *et al.* , 2008). The $Fe:PO_4$ ratio in anaerobic pore water, usually sampled from field moist sediment with a pore water sampler, appears to be a good indicator for estimating the

potential P-release from the sediment. Moreover it has been established that certain indicators for good ecology, such as threatened species of the red list, are only found where the Fe:PO_4 ratio is high. Whereas the $CaCl_2$ extraction is a resultant of Fe-oxidation and P-sorption, in the Fe:PO_4 pore water method both components are measured before oxygen had a chance to influence the chemistry.

Oxalate extraction

Oxalate extractable P is an indicator of the pool of P that can become available in the long term. With that it is an indicator for the amount of P with which the sediment has been loaded. A system in which the external load and the sediment are in equilibrium will show a certain ratio between oxalate extractable P and the external load.

In as study by Witteveen+Bos (2006), commissioned by the Water board of Schieland and Krimpenerwaard, this relationship was found for lactate acetate-extractable P, which is comparable to oxalate-extractable P (see Figure 2). In this graph the outliers are particularly interesting. These data points indicate that here the system is not in equilibrium. If in a water system the available amount of P is much larger than the external load of P, release of P from the sediment is possible. In the graph this is the case for Lake Bergse Plassen (5) and Lake Koornmolengat (6).

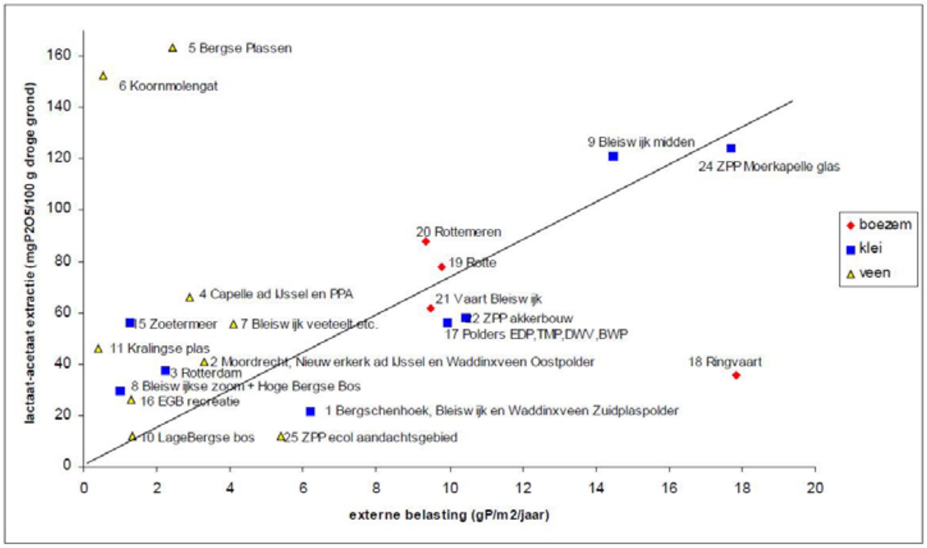


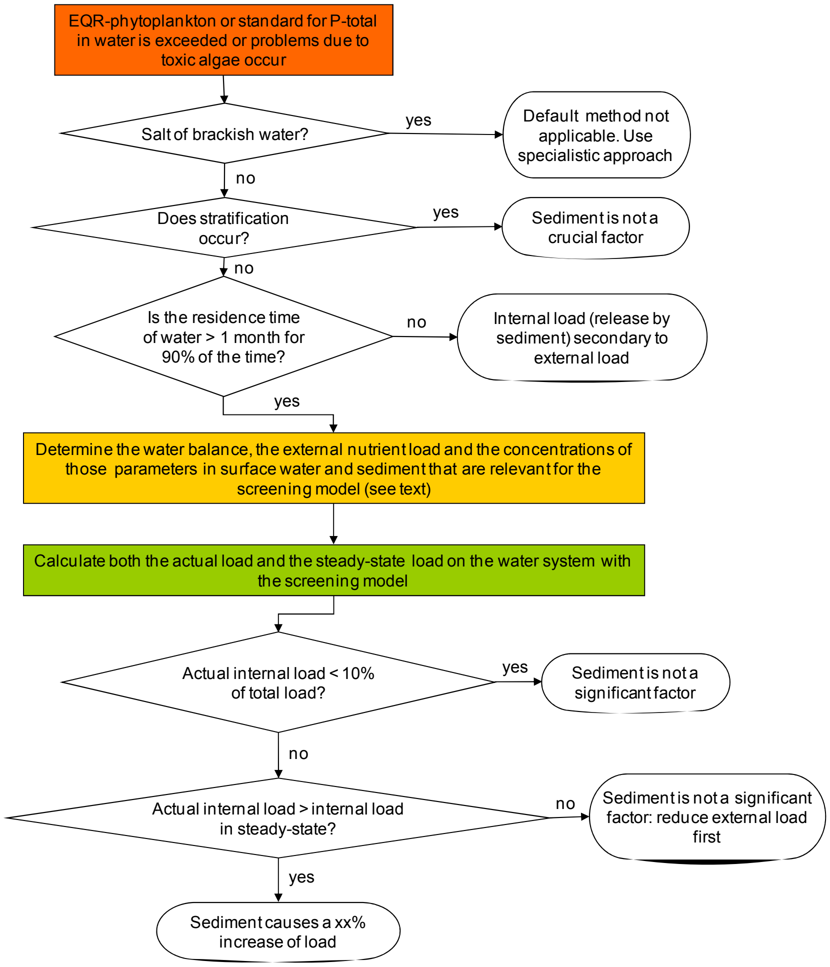
Figure 2
Relationship between lactate acetate-extractable P (Y-axis in mg P_2O_5 per 100 g dry sediment) and the external load (X-axis in g P per m^2 per year).
Red diamonds = 'boezem' waters (where water from polders is collected);
Blue squares = waters in clay areas;
Brown triangles = waters in peat areas.
[Jaarsma *et al.*, 2008]

For more information one is referred to the reports 'An overview of indicators for the release of phosphate from the sediment' (Arcadis, 2009) and 'From clear to troubled waters……and back' (Jaarsma *et al.*, 2008).

Annex H Screening model for nutrients

The standard method for eutrophication problems is described in §3.5. An alternative to this method is using a screening model. With this screening model one can assess the effects of nutrients from the sediment in shallow, more or less isolated, lakes. With this model one can get an indication whether the sediment contributes significantly to the total nutrients load on the water system or not.

Assessing with the screening model differs somewhat from the method described in §3.5, see the flowchart below. The first part is however identical to the flowchart of figure 2.3. If the site of concern is situated in a fresh water system with a relatively long residence time, the flowchart is continued with the yellow block. The user has to enter a limited number of site specific data into the model. The model subsequently calculates the contribution of the sediment to the total nutrient load on the water system.



Determine the water balance, the external nutrient load and the concentrations of those parameters in surface water and sediment that are relevant for the screening model.

For instructions with respect to the use of the model one is referred to the user manual. In this guidance document only the outlines of the model are discussed. The user has to enter the following water system specific parameters, obtained by measurements, calculations or estimates:

- the water type with respect to the sediment type (3 choices: peat, waters with silty sediment, waters with sandy sediment);
- the average depth of the water (m) and its surface area (km^2);
- the monthly volume of water flowing into the water system in an average year (m^3/month);
- the external nutrient load (g N/month and g P/month), excluding atmospheric deposition (this is calculated by the model);
- the measured water quality (N, P, chlorophyll) at the beginning of a representative year;
- the measured sediment quality (% organic matter, g P/kg_{ds} and optionally g N/kg_{ds}).

The other process parameters (chemical and biological processes) depend on the water type and have default values in the model. Optionally, the user can enter more parameter values, such as:

- the monthly measured concentrations in water of
    - NH_4-N [mg N/l],
    - NO_3-N [mg N/l],
    - total-N [mg N/l],
    - ortho-PO_4-P [mg P/l]
    - total-P [mg P/l]
    - chlorophyll-a [µg chl-a/l]
- the winter and summer average rates of seepage (both upward and downward) (mm/dag).

Calculate both the actual and steady-state loads with the screening model

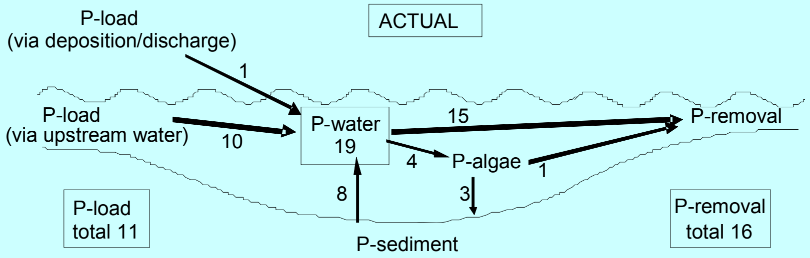
The model subsequently calculates the yearly average internal and external loads of N (g N/m^2.day) and P (g P/m^2.day) and also calculates the relative contributions with respect to the total load. These loads are calculated for one year.

The model can also simulate a number of continuous years until the system has reached a steady-state (see figure 3.8 and corresponding text). If the system is in equilibrium, the actual load equals the steady-state load. An example has been elaborated in the text box.

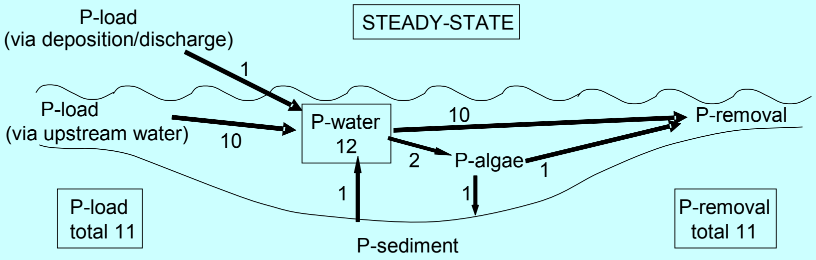
Actual load versus steady-state load

In the (simplified) example below P is given in quantities instead of concentrations for the sake of simplifying reality.

In a system where the total external load had been reduced to 11 (see figure), the sediment can release P. The amount of P in the water is not 11, but 19 because the sediment releases 8. The consequence is that the removal from the system is higher than the load, but also that algal growth is higher than one would estimate on the basis of the external load.



In due time the system will reach steady-state, i.e. the removal of P is equal to the load (steady at 11). The sediment will adjust to this steady-state. Further it is expected that algal growth will diminish. Eventually this can lead to the steady-state P-load presented below. Load and removal are equal (11), algal growth has been halved, but this is only possible if the release from the sediment declines strongly. This can take a long time and especially in these cases it can be interesting to take measures that reduce the internal load.



Actual internal load < 10% of the total load and > internal steady-state load

The results of the nutrient screening model indicate that the sediment is a significant factor with respect to eutrophication if the following conditions are met:

1. the actual internal load is relatively large with respect to the external load;
2. the actual internal load is larger than may be expected on the basis of a steady-state. This indicates that the external load has been reduced and that the sediment continues to release nutrients at a high rate, due to which the eutrophication problems will not diminish.

This has led (see flowchart) to the following associated criteria:

1. the contribution of the sediment to the total load must at least be10%.
2. the actual internal load must exceed the steady-state internal load.

If these criteria are met, the contribution of the sediment to the total load on the water system is expressed as the actual increase with respect to the total steady-state load:

$$\text{contribution} = \frac{\text{actual internal load} - \text{steady-state internal load}}{\text{steady-state total load}} * 100$$

Many parameters in the screening model have been assigned default values. If a higher reliability is required, one can use the more sophisticated model on which the screening model has been based: Delwaq-G or comparable models. In these models it is possible to assign site specific values to many parameters. This often calls for extra measurements. Furthermore, hydrodynamic models can be coupled to these models, which allow the user to treat the water system as a dynamic system instead of as one homogenously mixed compartment.

For more information one is referred to Smits and Van Beek (2010).

Annex I Monitoring in surface water

Regular monitoring aims at determining the status of WFD bodies of surface water. In designing the monitoring network ones take into account possible variations in water quality. WFD monitoring is not specifically intended for determining the possible exceeding of additional standards based on surface water functions in protected areas. In protected areas extra monitoring can be conducted, such as monitoring in Natura2000 areas or monitoring at drinking water abstraction points.

There are however surface waters that have not been classified as WFD bodies of surface water. To assess the effects of the sediment with respect to standards in these waters with this ‘Guidance document for sediment assessment’, one therefore cannot use WFD monitoring data. For these situations chapters 4 and 5 of the guidance document have been written. In the sections concerned, it is first assessed on theoretical grounds whether the sediment can (partially) cause a chemical or ecological standard to be exceeded. If this seems possible, the competent water authority can decide to verify this by (temporarily) adding an extra monitoring point. Monitoring at this extra monitoring point can be limited to those parameters that appear to exceed the standard, (partially) due to the sediment. Contrary to the results of the regular WFD monitoring, the competent water authority is not obliged to report the results for the extra monitoring point(s) to the European Commission.

With respect to the manner of monitoring and (compliance) testing it is advised to attune this monitoring as much as possible to the existing monitoring practise for surface waters. This is described in the instruction ‘Surface Water Monitoring Guideline and Testing and Assessment Protocol’ (V&W, 2009).
If assessing the sediment requires the monitoring of biota (mussels, fish), it is advised to check whether samples can be obtained from anglers of professional fishermen. Sometimes one can also seek cooperation with nature conservation organizations for monitoring.

Selecting extra monitoring points for assessing the effects of sediments
Depending on the spatial variability of the body of surface water and of the sediment, one should in flowing waters select one or more extra chemical monitoring points upstream and downstream of the contaminated sediment site. In standing waters one should select at least one monitoring point at the contaminated site and at least one monitoring point at a (relatively) clean reference site. With respect to ecology one should select one monitoring point at or near the contaminated site and one monitoring point at a reference site.

Duration and frequency of monitoring
The competent water authority can limit the operational monitoring to, for example, one year. In determining the duration and frequency of monitoring one should take into account possible seasonal and random fluctuations in the chemical and ecological parameter values.

Sampling methods and methods of analysis

Also with respect to sampling methods and methods of analysis it is advised to use methods that are already used in regular monitoring. For this one is referred to the annexes of the Guidelines for monitoring surface waters (Van Splunder *et al.*, 2006).

Assessment and testing monitoring results

In order to assess the sediment one is advised first to assess the results of each extra monitoring point separately. Then the results can be compared to any other monitoring point near the body of surface water.

Annex J Description of SEDIAS

The calculations proposed in this Guidance Document for Sediment Assessment are elaborated as much as possible in a supporting spreadsheet called SEDIAS, which is short for SEDImentASsitant. For bank/shore areas the calculations are supported by 'SEDIAS bank/shore areas'

SEDIAS

SEDIAS (in Dutch) contains three general sheets and five calculation sheets with supporting sheets. The general sheets are check lists, with which one can check the completeness of the problem analysis. Sheets 1 to 5 are calculation sheets in which the results are calculated. Some sheets are supporting. This is indicated by the prefix 'ad'.

This results in the following scheme of sheets:

Sheet checklist water quality
Sheet checklist sediment quality
Sheet explanation of the calculations

Sheet 1.	Partitioning
	Button Colour scheme input (explanation of the colours)
	Button Partitioning constants (basic info; no calculation)
	Button Contribution dissolved (calculation of ratio dissolved/suspended particulate matter)
Sheet 2.	Diffusion/dispersion and seepage
Sheet 3.	Resuspension
	Button Ship parameters (basic info on ships; no calculation)
	Button Calculation of resuspension by wind (supporting sheets for sheet 3)
Sheet 4.	Contribution total concentration
Sheet 5.	msPAF
Sheet 6.	Susp. matter& MPC

In this guidance document one is referred to SEDIAS in relevant cases. In all cases one starts with sheet 1, because here the data of the substances are entered. Total contents can be entered, from which pore water concentrations are calculated. One can also enter (measured) pore water concentrations.
The other sheets are only used if they are relevant to the situation, i.e. if a problem occurs or is expected to occur with respect to the dissolved concentration (sheet 2), the total concentration sheet 3 and 4) or the score on the macrofauna metric (sheet 5).

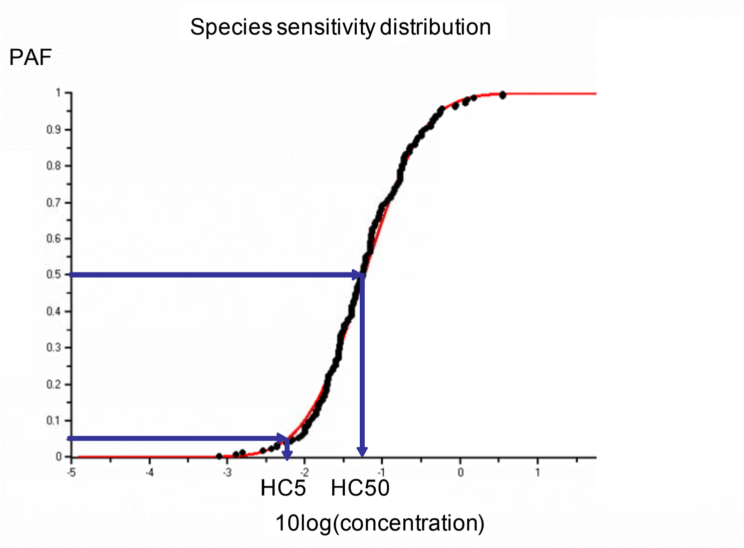
The spreadsheet has been built in such a way that the user can easily see what happens. All formulas in the spreadsheet are shown if one places the cursor on the cell.

SEDIAS bank/shore areas
In many cases bank/shore areas rather contain terrestrial ecosystems than aquatic ecosystems. That is why the application uses the same technical basis for assessing sediments in bank/shore areas as is prescribed for terrestrial soils by the Dutch Soil Protection Act (Wbb) in the Soil Quality Decree. Under the Soil Protection Act the web application 'Sanscrit' (www.sanscrit.nl) (in Dutch) has been developed for assessing the urgency of remediating cases of heavy soil contamination. For this assessment Sanscrit uses the legal criteria that are laid down in the Wbb. In bank/shore areas that do not fall under the Wbb, these criteria do not apply. Sanscrit is therefore not suited to assess sediments in a way as intended in this guidance document for sediment assessment. Therefore another application has been developed specifically for bank/shore areas: 'SEDIAS bank/shore areas'. This application uses the same technical basis as 'Sanscrit.

SEDIAS bank/shore areas is a web application (in Dutch) that can be found on www.sediasoever.nl. The sections of chapter 5 are dealt with in SEDIAS bank/shore areas step by step, through a menu including the following choices:
- Nature objectives subdivided in lower and higher organisms;
- Food safety of agricultural products;
- Protection of human beings:
- Protection of groundwater.

Annex K Explanation of (ms)PAF

The msPAF is based on laboratory experiments in which the effects of a certain substance on a certain species are investigated. Subsequently a curve is constructed for this substance in which each species is represented by one data point. This results in a species sensitivity distribution (Posthuma *et al.*, 2002). The risks are expressed in a Potentially Affected Fraction (PAF), which gives an indication of the fraction of the potentially present organisms that is negatively affected. The higher the PAF, the higher the number of species in a water, sediment or soil system that is affected by the contaminants present in the system. A protection level (or intervention value) can be determined on the basis of this PAF curve. The choice of the HC_5 (Hazardous Concentration for 5% of the species) as protection level means that 5% of the species represented in the sensitivity distribution is possibly affected as a result of the presence of the substance considered. The individual PAF-scores can be summed by means of a specific equation.



Choices within the method

Several important factors have great effect on the assessment. The table below lists these factors and presents the most common choices:

Factor	**Choices**
Effect level	NOEC, EC_{50}, LC_{50}
Character of the experiment	chronic or acute
Species	Number of species and trophic levels may vary
Database	Quality of the accepted data

Effect level
Toxicity experiments can be focussed on the concentration at which just no effects on the test organism are observed (No Observed Effect Concentration, NOEC). The experiments can also be focussed on the concentration at which half of the organisms is affected, for example in their growth or reproduction (EC_{50}). If this involves a mortality rate of 50%, it is called the lethal concentration (LC_{50}). A species sensitivity distribution based on LC_{50} values is situated somewhat more to the right in the graph than a curve based on NOEC values.

Character of the experiment
Experiments can have longer or shorter durations. Depending on the type of organisms, two types of experiments are distinguished, chronic and acute experiments. The exposure time can vary roughly between 24 hours and 3 weeks, but shorter and longer experiments occur.

Species
In aquatic experiments usually the following basic groups of species are distinguished: algae, crustaceans and fish. In most PAF-curves all groups are included, but it is also possible to determine an msPAF for just fish. In that case one condition must however be met: sufficient data have to be available.
Experiments have also been conducted with higher organisms, but usually not in the aquatic environment. Results of experiments with for example chickens, pigeons or pigs have been converted as well as possible to fish and mussel eating species, such as certain water birds and otters.

Database
The underlying experimental data are essential for the quality of the PAF-curves. This quality depends on the number of data, the quality of the data and the species represented (or not) in the database.

Choices made in this guidance document
For wet ecosystems in this guidance document it has been decided to use species sensitivity distributions based on chronic EC_{50} levels. This fits in best with the character of the exposure and the activities: contaminated sediments cause long term exposure (chronic), the contamination is already present in the environment and physical interventions only take place in case of substantial risks (EC_{50}). PAF-curves for the following groups of species have been used:

- Aquatic macrofauna is assessed on the basis of an msPAF specifically developed for macrofauna.
- Bioaccumulation through aquatic organisms is assessed on the basis of msPAF-curves for fish eating and/or mussel eating species.

Terrestrial organisms are assessed in accordance with Sanscrit, which uses acute EC_{50}-curves. Sanscrit uses only lower terrestrial organisms. The corresponding PAF-curves are also used for assessing ecological risks in bank/shore areas. Although bioaccumulation in terrestrial organisms can be assessed in a way comparable to that for fish and mussel eating species, this is not an option in Sanscrit.

Annex L Glossary

AA-EQS
Environmental Quality Standard (EQS) for the Annual Average (AA) concentration of the substance. The standard has been derived for chronic exposure of organisms according to the method prescribed in the Water Framework Directive.

Advective transport
Transport of dissolved substances by groundwater flow.

Available fraction
The fraction of the total content or total concentration of a substance that is available for uptake by organisms.

Bank/shore area
An area within a body of surface water that runs dry part of the time, such as water meadows, forelands, (parts of) brook valleys, salt marshes, mud flats and tidal marshes. In this guidance document, 'dryer bank/shore areas', as laid down in maps of the Water Regulations and where the Dutch Soil Protection Act is in force, are explicitly excluded from bank/shore areas.

Bank/shore zone
An area near the shore of a sea or a lake or near the bank of a river. Within this bank/shore zone (= littoral) two sub zones are distinguished:

- The intertidal area: the zone between the low tide mark and the high tide mark.
- The sublittoral: the zone that basically is always under water between the low-water level and the profundal zone (the zone usually deeper than 2 m).

Benthic macrofauna
Sediment dwelling macrofauna.

Bioaccumulation
The accumulation of a substance in organisms or parts of organisms, due to which the concentration in the organisms becomes higher than in the surrounding environment.

Biological quality elements
The biological parameters (macrophytes & phytobenthos, angiosperms, macroalgae, phytoplankton, benthic invertebrates (macrofauna) and fish) used under the Water Framework Directive to assess the ecological status of surface waters.

Biomagnification
Stepwise increase of the concentration of persistent substances in organisms observed when going up the food chain.

Biota
Living organisms (fauna, flora, fungi, micro organisms).

Bkmw 2009
Dutch Decree of 30 November 2009, involving rules for implementing the environmental quality objectives of the Water Framework Directive (Decree on Quality Requirements and Monitoring in Water 2009).

Body of groundwater
A separate volume of groundwater in one or more aquifers.

Body of surface water (defined according to art. 1.1 Dutch Water Act)
Coherent entity of water occurring at the earth's surface, including the substances present in the water, as well as the associated sediments, banks and shores and, insofar as explicitly designated under the law of the Water Act, 'dryer bank/shore areas', as well as flora and fauna.

Body of surface water (defined according to the Water Framework Directive)
Coherent unit of surface water of substantial size within a river basin area, such as a lake, a reservoir, a stream, a river, a canal, a part of a stream, river or canal, a transitional water or a coastal water.

Body of water
Body of surface water or groundwater.

Composite sample
A (sediment) sample composed by mixing (sub)samples obtained from two or more locations.

Concentration
Measure for the mass of an analysed substance per standard volume of the substance (for example mg/l)/

Content
In this guidance document: mass of a substance per unit of weight (mg/kg), mostly expressed in dry soil/sediment.

Diffusion
Transport of a substance resulting from a gradient in concentration (or more general: activity), due to the random (thermodynamic) movement of molecules of the substance.

Dissolved concentration
The concentration of a dissolved substance in water, including the DOC-bound fraction.

DOC
Dissolved Organic Carbon.

Dryer bank/shore areas
Bank/shore areas that are almost permanently dry and where –contrary to the other parts of the body of surface water – the Dutch Soil Protection Act applies. These dryer bank/shore areas have been laid down in maps in the Dutch Water Regulations.

Ecological Quality Ratio (EQR)
The ratio between the observed value of a WFD quality element and a reference value (virtually unmodified body of surface water) or the MEP (heavily modified/artificial bodies of surface water) of this element.

Environmental Quality Standard (EQS)
The concentration of a certain contaminant or group of contaminants that is not allowed to be exceeded in the surface water, sediment or biota for reasons of protecting humans and the environment (WFD, article 2). The standard is derived according to the EU-WFD method.

$EQR_{macrofauna}$
EQR score for the biological quality element macrofauna.

$EQR_{phytoplankton}$
EQR score for the biological quality element phytoplankton.

Equilibrium partitioning
Partitioning of a substance over two phases, for example sediment and water, assuming chemical equilibrium between these phases. Equilibrium partitioning between sediment and water is determined in the laboratory using contaminated sediment.

Erosion
The process in which sediment is resuspended by current, waves, bioturbation or shipping and is transported downstream.

Eutrophication
The ecological effects that high nutrient concentrations can cause in surface water, characterized by low transparency, (toxic) algal bloom in summer, low numbers of predators such as pike, high numbers of whitefish, low biodiversity and water with a low oxygen content.

Eutrophication parameters
Parameters measured in surface waters in order to determine eutrophication, such as total phosphate, ortho-phosphate, total nitrogen, DIN (nitrate + nitrite + ammonium) and chlorophyll-a.

External load
Substances that enter the body of surface water through external sources, for example through atmospheric deposition, superficial flow of water, discharges or transport from upstream areas.

Flowing water
In this guidance document: one-way sea bound flowing surface water. In the Water Framework Directive this would be the R-type waters.

Flux
The transport of a unit (of weight) of a substance per unit of time over a certain surface area, expressed in for example kg/(m^2.day).

Freely dissolved concentration
The dissolved substance concentration that is not bound to DOC.

Good ecological potential (GEP)
Status to be achieved by heavily modified and artificial bodies of surface water. The status is classified according to the applicable provisions of annex V, WFD (WFD, article 2). The lower limit of the GEP is usually set at an EQR of 0.6.

Good ecological status (GES)
The status to be achieved by a body of surface water classified as a natural water according to annex V (WFD). The lower limit of the GES is usually set at an EQR of 0.6.

Good surface water chemical status (GCS)
The chemical status required to meet the quality objectives for surface water, as laid down in article 4, paragraph 1, section a) of the WFD.

Good surface water status
Status in which both the chemical and ecological status are good (in WFD terms).

Groundwater
All water below the soil surface in the saturated zone and in direct contact with soil or subsoil.

Hydraulic engineering work
(Artificial) body of surface water, water storage area, dam, dike or supporting construction.

Hydromorphology
Description of the structure of sediment and banks/shores of surface waters.

Internal load
Substances that enter the water column of a body of surface water by internal circulation, such as substances from the sediment. Substances that enter the water system by seepage are formally not classified as internal load but are difficult to be separated from it.

Local limit
The maximum content, laid down by the competent authorities in regionally specific policy under the Dutch Soil Quality Decree, of a substance in dredged material. Below this limit the dredged material may be used or relocated within the area boundaries without additional requirements.

MAC-EQS
Environmental Quality Standard (EQS) for the Maximum Acceptable Concentration (MAC). This standard applies to individual measurements of substances in surface water. It has been derived for the acute exposure of organisms according to the method prescribed in the Water Framework Directive.

Macrofauna
Invertebrate fauna, living in water systems and visible to the eye (molluscs, shellfish, insects).

Management plan (= water management plan)
Management plan laid down by the competent water authority under article 4.6, first paragraph of the Dutch Water Act. In this plan the competent water authority describes how its waters are set or kept in order and at what costs. The management plan is set for a period of 6 years.

Maximum Ecological Potential (MEP)
The high status of a heavily modified or artificial body of surface water (WFD).

Metric
One or more parameters that are elements of the multi-metric (EQR) for a biological quality element.

(Multi-)Metric
Graduated scale to classify the status of a body of surface water (WFD) as being ‘high’, ‘good’, ‘moderate’, ‘poor’ or ‘bad’.

MPC
A minimum water quality, laid down in the Dutch Fourth Memorandum for Water Management, theoretically protecting 95% of species potentially present in the ecosystem concerned.

$\text{MPC}_{\text{humane}}$
The scientifically derived content or concentration of a substance at which no harmful effects occur in humans or in the ecosystem (in case of humans based on an assumed lifetime exposure).

msPAF
The multi substance Potentially Affected Fraction. The fraction of species that is unprotected at a given content or concentration of substances in sediment and/or water and that is therefore affected.

Mud flat
Bare land that has silted up outside the dikes and that floods during nearly every high tide.

N2000 area
An area that is part of the Natura 2000 network.

National waters
All bodies of surface water that fall under the responsibility of the National government.

Nature Conservation Act 1998
Dutch Act for the protection of Nature reserves and N2000-area designated under the European Bird- and Habitat Directive.

Natura 2000 (N2000)
A coherent network of protected nature reserves in the territories of the EU-member states. This network is the foundation of the EU-policy for conservation and restoration of biodiversity. The Bird- and Habitat Directive for these areas is implemented through the Dutch Nature Conservation Act 1998.

OMEGA
A computer programme developed to produce information on the effects of the exposure of flora and fauna to toxic substances. It calculates the (ms)PAF for species or for the most threatened groups of species.

Physico-chemical parameters
'Substances' naturally occurring in the water system (oxygen content, nutrients, salinity, acidity) and physical parameters for natural characteristics of the water system (transparency and temperature).

Phytoplankton
Small autotrophic organisms of the plankton community, suspended in water.
The organisms include single-celled organisms, diatoms, green algae, golden algae, dinoflagellates and cyanobacteria.

Pollutant
Any polluting substance, especially the substances listed in annex VIII of the WFD (WFD, article 2).

Pore water concentration
The concentration of a substance in the pore water of the soil or sediment.

Potentially Affected Fraction (PAF)
The fraction of species that is unprotected at a given content or concentration of a substance in sediment and/or water and that is therefore affected.

Preservation goal
Goal as formulated in the decision to designate a N2000 area, which describes the sustainable existence of species and/or habitats concerned.

Priority substances
Substances designated according to article 6, paragraph 2 of the Water Framework Directive and stated in annex A. This also includes the priority hazardous substances, i.e. substances identified according to article 16, paragraphs 3 and 6, for which measures are taken according to article 16, paragraphs 1 and 8 of the Water Framework Directive.

Programme of measures
List of measures included in the river basin management plan, in the management plan for the national waters or in for example the regional water plan.

Random sample
An instantaneously taken individual (sediment) sample.

Recontamination
Level of sediment contamination that develops as a result of autonomous developments after a physical intervention in the sediment.

Regional quality
The whole of functions and objectives for a region, as agreed with the stakeholders in the regional planning process.

Regional planning
Planning process for a region.

Regional waters
Bodies of surface water that fall under the responsibility of a water board.

Register of waterways
Public register of the competent water authority, in which have been laid down: the duty of maintenance, the desired or required status of maintenance of the water ways, dikes and other hydraulic engineering works, as well as the statutable boundaries.

Release
The process in which substances are transported from the sediment to the surface water.

Resuspension
The process in which sediment is resuspended by current, waves, bioturbation or shipping and is transported downstream.

River basin
An area from which all surface water (through streams, rivers and possibly lakes) finally reaches the sea via one river mouth, estuary or delta.

River basin management plan
Plan as intended in article 13 of the Water Framework Directive. In The Netherlands the river basin management plans are included in the National Water Plan.

River basin district
The terrestrial and marine territory consisting of one or more adjacent river basins and associated groundwater and coastal waters, as intended in article 2, paragraph 15 of the Water Framework Directive.

Salt marsh
Land that has silted up outside the dikes and that only floods during high tide.

Sediment (product of a process)
A layer, consisting of natural materials such as gravel, sand or clay, deposited by sedimentation.

Sediment (part of an aquatic system)
The bottom and bank/shore of a body of surface water.

Sedimentation
Deposition of sediment transported by wind, water or ice.

Sediment quality
The contents of xenobiotic substances in the sediment.

Sediment relevant substances
Substances of which the partitioning constant (log K_d for metals of log K_{oc} for organic contaminant) exceeds 3 and that therefore adsorb to the sediment.

SEDISOIL
Computer programme which calculates the exposure of human beings to contaminated sediment depending on the use of a site. The exposure is tested against the MPC_{humane}.

Seepage
The percolation of water from the groundwater due to higher hydraulic heads in other parts of the hydraulic system.

Semi standing water
Surface waters with moderate water replacement rates, such as polder outlets, canals and ditches.

Standing water
Surface waters that are mainly fed by rain and sometimes by groundwater. In these waters there is no substantial contribution from rivers, brooks or other adjacent waters. Examples are ponds, pools and (many) lakes.

Steady-state concentration
A constant concentration indicating a balance between the different physico-chemical processes.

Stratification
Stratification of the surface water due to differences in salinity or water temperature. This results in a limited exchange of substances between layers of water.

Surface water body type
The categories of bodies of surface water are further classified to type of water (according to the WFD method , annex II, paragraph 1.2).

Top layer
The top layer of the sediment.

Total concentration in water
The concentration of the substance in the surface water including the suspended particles-bound concentration.

Transitional water
A body of surface water near a river mouth that partly consist s of salt water due to the vicinity of coastal waters, but that is substantially influenced by fresh water (WFD, article 2).

Water Framework Directive (WFD)
Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

Water quality
The chemical and ecological quality of a body of surface water.

Water plan
Plan under the law of the Dutch Water Act, i.e. the National Water plan, management plan for the national waters, regional water plan or management plan for regional waters. The term is also used for municipal water plans that describe all aspects of waters within municipal boundaries for the purpose of a coherent approach and improvement.

Water system (as defined in the Dutch Water Act)
Coherent whole of one or more bodies of surface water and groundwater, with associated water storage areas, dams, dikes and supporting constructions.

Xenobiotic substances
Substances that do not naturally occur in the environment or that naturally occur in much lower concentrations.