Ecologiscal status of tidal freshwater sections of some rivers in Europe

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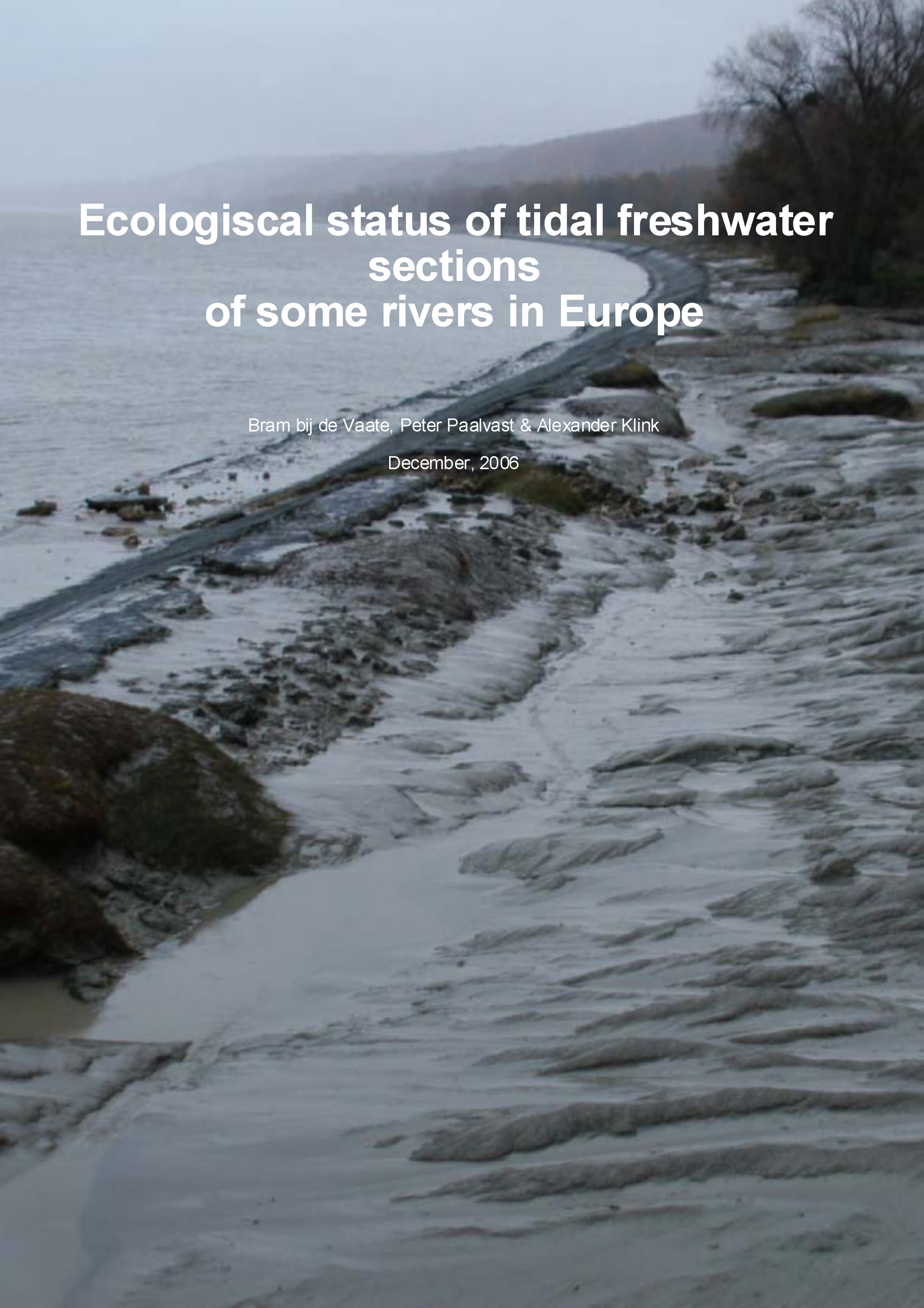

Ecological status of tidal freshwater sections of some rivers in Europe

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Contents

Summary

An overview is given of European Water Framework Directive related methods used for the classification and for ecological quality assessment, based on macroinvertebrates, of three European freshwater tidal river sections. In this desk study literature surveys were made and experts consulted. Although information was asked of several rivers in France, United Kingdom, Ireland and Germany, only information of the rivers Rhine, Scheldt and Elbe could be collected. These three rivers belong to the North Sea ecoregion. In general, it seemed that tidal freshwater zones are the last river sections receiving attention for monitoring and assessment in most of the EU countries. The three rivers mentioned above were identified by the national governments as heavily modified.

Results of the study show that there is lack of any joint method for the assessment of the ecological quality of European tidal freshwater zones. Each country uses its own (national) assessment method or has developed an adapted methodology. Also the classification of tidal freshwater zones differs per country; they are either part of the transitional zone or the lower section of the river. All assessment methods presented for rivers included in this study have the status of proposals to the European Union. The Maximum Ecological Potential or Good Ecological Potential was defined for none of the tidal freshwater zones of the rivers included in this report, although these ecological potentials should be considered leading factors in the development of an information strategy based on macroinvertebrates. Since it is not possible for Seine-Aval to take advantage of knowledge developed for other tidal freshwater zones in the same or neighbouring ecoregion, it was concluded that Seine Aval should join similar organisations for river management in France to develop a common information strategy for tidal freshwater zones. Seine Aval also should join information strategy development activities for the part of the river Seine directly upstream the transitional zone, especially to tune sampling strategies and assessment methods.

Resumé

1. Introduction

In this report an overview is given of European Water Framework Directive (WFD) related methods used for the classification and for ecological quality assessment, based on macroinvertebrates, of freshwater tidal river sections in the rivers Rhine, Scheldt and Elbe. The work was done from the perspective for Seine-Aval to take advantage of knowledge developed for other tidal freshwater zones in the same or neighbouring ecoregion.

The WFD (figure 1) establishes a framework for the protection of all water types (including inland surface waters, transitional waters, coastal waters and groundwater) in order to achieve a good (ecological) quality status by 2015. Important ecological aims are:

- to protect and enhance the status of water resources;
- to prevent further deterioration of water bodies;
- to promote sustainable water use,
- improvement of the aquatic environment through specific measures for the progressive reduction of discharges, emissions and losses of priority substances.

The ecological status is assessed from results of monitoring programs covering several so-called “Water Quality Elements” (WQE’s). The lists of WQE’s for each surface water category are subdivided into 3 groups:

a. biological elements, to which the element “macro-invertebrates” belongs;
b. hydromorphological elements supporting the biological elements;
c. chemical and physico-chemical elements also supporting the biological elements.

Although monitoring of all prescribed WQE’s is obliged, member states are free to exclude some of them from their monitoring program, if well argued. However, composition of macroinvertebrate communities in freshwater tidal river section is an accepted WQE for all European rivers examined in this desk study.

Figure 1
Promoting the Water Framework Directive

For the preparation of this report literature surveys were made and experts consulted. After the introduction the report the classification of freshwater tidal river sections is described (Chapter 2), followed by the assessment of their ecological status based on macroinvertebrates (Chapter 3). In chapter 4 the results obtained are discussed.

2. River classifications

Reference freshwater tidal river sections for the river Seine are scarce, taking into account the conditions they have to meet, being:

a. comparable size of the riverbed,
b. length of the section,
c. the same ecoregion,
d. sufficient tidal amplitude.

Information was collected of three rivers: Rhine, Scheldt and Elbe. All these rivers were identified as heavily modified, which means their ecological quality should at least meet the so-called “Good Ecological Potential” (GEP) in 2015. This status is derived from the “Maximum Ecological Potential” (MEP), which is the highest ecological status for heavily modified or artificial water bodies in the European Union

2.1 The River Rhine

The river Rhine is one of the longest and most important rivers in Europe. Its length is about 1,320 km and the catchment area comprises 185,000 km^2. Average discharge at the German-Dutch border is 2,300 $m^3.sec^{-1}$ (Middelkoop, 1997). Large parts of the catchment area are heavily urbanized and industrialized.

The Rhine delta is situated in The Netherlands; its first bifurcation is located 5 km west of the German-Dutch border (Bij de Vaate *et al.*, 2003). At that point the name of the river changes into the Waal and Pannerdensch Canal for the distributaries flowing west and north-west respectively (Fig. 2). On average 2/3 of the Rhine discharge flows through the river Waal. The next bifurcation, in the Panner-densch Canal, is east of Arnhem. The north flowing river IJssel empties into Lake Ketelmeer, an artificial lake and part of Lake IJsselmeer which is, in its turn, part of the former Zuiderzee, an inland sea dammed in 1932 (De Jong & Bij de Vaate, 1989). The river Nederrijn (called river Lek further downstream) flows west. Three weirs and accompanying locks were built in this distributary for discharge control and to allow navigation in both the rivers IJssel and Nederrijn during periods of low discharge in the Rhine River. Discharge distribution between the rivers IJssel and Nederrijn is 1:2 on discharges above 2.350 $m^3.sec^{-1}$ at the German-Dutch border.

In the west part of the Rhine delta, the river empties in the North Sea through the Nieuwe Waterweg and the Haringvliet, both connected through a network of distributaries with the rivers Nederrijn and Waal. The Nieuwe Waterweg is a man-made canal constructed in the 1860's to improve the connection of the Rotterdam harbours with the North Sea, and forms the only open connection with the sea. The Haringvliet, a former estuary, was dammed in the 1970s after a severe flooding in the south-west part of The Netherlands in 1953. In both the dam

Figure 2
The river Rhine in the Netherlands. Details of the Rhine delta in which tidal freshwater zones are found (indicated in the rectangle) are given in figure 3.

separating Lake IJsselmeer from the Wadden Sea (Afsluitdijk) and the Haringvliet Dam, sluices were built for the discharge of river water.
Due to the closure of river outlets the tidal freshwater area of the river Rhine was reduced to relatively small parts, mainly in the distributaries called rivers Lek, Oude Maas and Spui (figure 3 and 4).

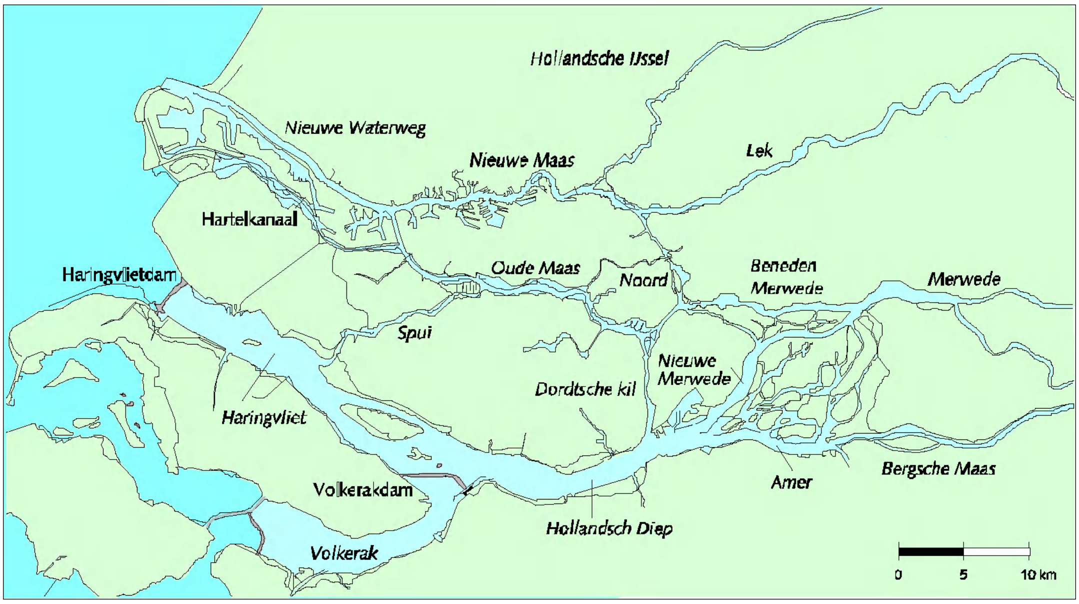

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Figure 3
The south-western part of the Rhine delta.

For the differentiation of water bodies in The Netherlands system B was chosen as described in Annex II paragraph 1.1 of the WFD (European Union 2000). Descriptors used for water body characterization are listed in table 1 (Elbersen *et al*., 2003).

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Table 1
Descriptors used in The Netherlands for the characterization of water bodies.

Descriptor	Rivers	Lakes	Transitional water bodies	Coastal water bodies
Altitude	X	X		
Latitude	X	X	X	X
Longitude	X	X	X	X
Geology	X	X		
Size	Width	Surface area		
Depth		X		
Permanence	X			
Tidal amplitude			X	X
Tidal movements	X			
Chloride concentration		X		X
Fall	X			
Mean width	X			
Shape		X		
Source	X			
River influence		X		
Buffer capacity		X		
Substrate				X

All Dutch transitional water bodies belong to the Atlantic/North Sea Ecoregion Complex, which comprises the North Atlantic Ocean, the North Sea, the Norwegian Sea and the Barents Sea ecoregions (European Union, 2003[A]). Salinity was considered not to differentiate for the transitional water bodies because the presence of a salinity gradient is characteristic for this type of water bodies. On the basis of the descriptor 'tidal amplitude', two types of transitional water bodies are distinguished:

1. Type O_1: tidal amplitude <1 m;
2. Type O_2: tidal amplitude 1-5 m.

The tidal freshwater sections in the distributaries of the river Rhine, however, were not arranged in both transitional water body types. They belong to the so-called "tidal freshwater bodies on sand/clay", indicated as type R8 (Van der Molen & Pot, 2006), which means they are considered to be part of the river and not of the transitional zone as part of the estuary.

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Figure 4
A typical freshwater tidal creek of the Oude Maas.

2.2 The River Scheldt

The catchment area of the river Scheldt is about 21,500 km^2 (Van Damme *et al*., 1995) and belongs to an international river basin district of 36,146 km^2 (figure 5) defined for this river in the framework of the WFD (Scaldit, 2004), which is heavily urbanized and industrialized. The recent history of the river is characterized by serious pollution and considerable reduction of intertidal areas such as mudflats and salt marshes. Domestic and industrial wastewater emissions had critically affected water and sediment quality and were the cause of virtually anoxic and hypertrophic conditions in the tidal freshwater and low-salinity zones of the estuary in the 1970s (Van Damme *et al*., 1995). Since the mid-1980's the Scheldt estuary has been benefited from a gradual water quality improvement, resulting in improved conditions for macroinvertebrates and fish (Van Damme *et al*., 1995). However the low species diversity in these groups of animals is ascribed to the still occurring relatively bad oxygen conditions (Brys *et al*. 2005)
Average discharge of the river Scheldt in the period 1991-2002 was 161 $m^3.sec^{-1}$, measured at the Belgian-Dutch border (Scaldit, 2004).

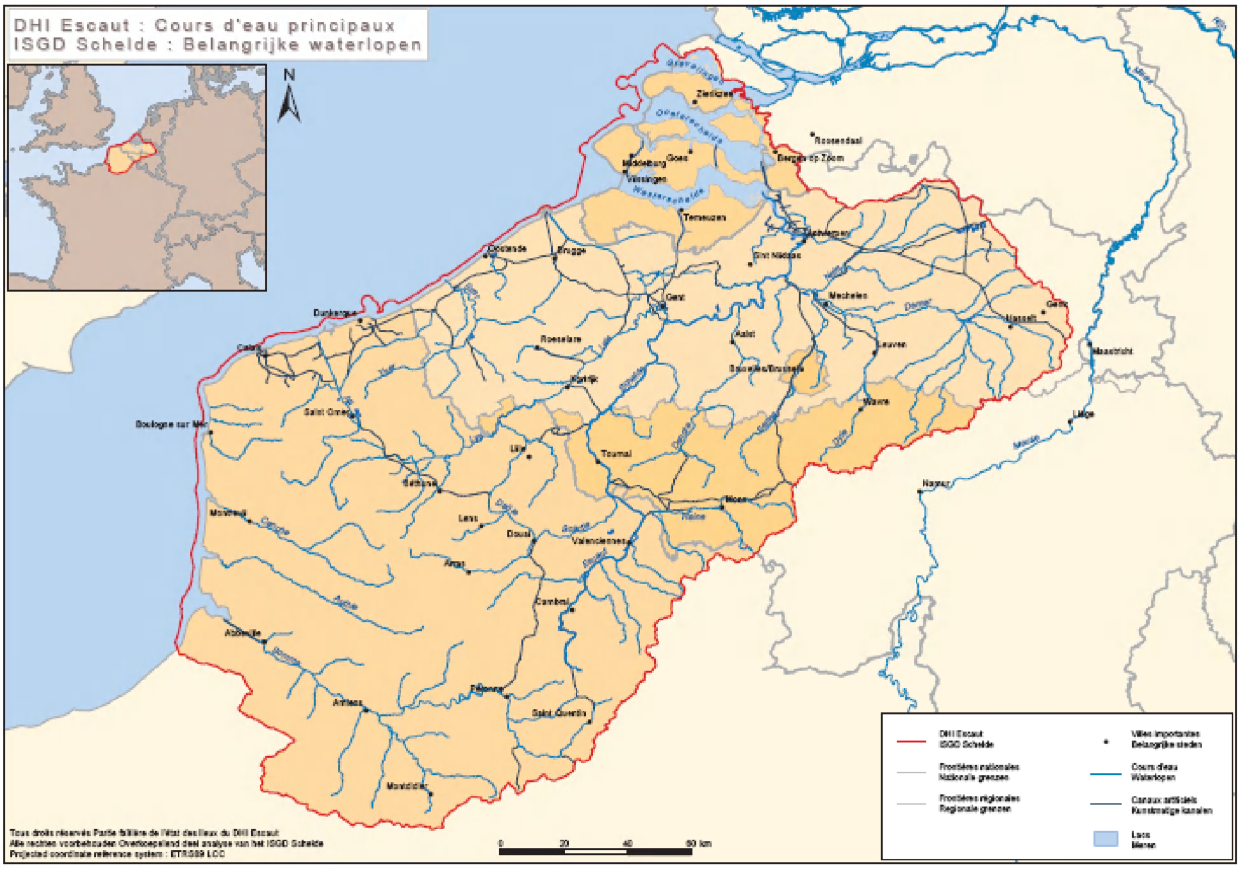

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Figure 5
The international river basin district to which the river Scheldt belongs.

For the differentiation of water bodies in Flanders system B was chosen as described in Annex II paragraph 1.1 of the WFD (European Union, 2000). Descriptors used for water body characterization are listed in table #2 (Jochems *et al.*, 2002)

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Table 2
Descriptors used in Flanders for the characterization of water bodies.

Descriptor	Rivers	Lakes	Transitional water bodies	Coastal water bodies
Altitude	X	X		
Latitude	X	X	X	X
Longitude	X	X	X	X
Geology	X	X		
Size (drainage area)	X	X		
Tidal amplitude			X	X
Stream velocity/fall	X	X		

All Belgian transitional water bodies belong to the Atlantic/North Sea Ecoregion Co mplex, which comprises the North Atlantic Ocean, the North Sea, the Norwegian Sea and the Barents Sea ecoregions (European Union, 2003[A]). Only on the basis of the descriptor 'tidal amplitude', two types of transitional water bodies are distinguished (Brys *et al.*, 2005):

1. Type O_1: macrotidal lowland estuary, maximal mean spring tide >5 m;
2. Type O_2: mesotidal lowland estuary, maximal mean spring tide >1 m and <5 m.

Five subtypes of transitional water bodies are distinguished on the basis of the descriptors 'stream velocity' and 'substrate' (Kornman *et al*. 2004):

Subtype 1: Macrotidal, mixed sediment, moderate to high stream velocity (estuary)
Subtype 2: Mesotidal, silty and sandy sediment, high stream velocity (estuary)
Subtype 3: Macrotidal, silty and sandy sediment, low stream velocity (estuary)
Subtype 4: Macrotidal, silty and sandy sediment, low stream velocity (harbour)
Subtype 5: Macrotidal, silty and sandy sediment, moderate to high stream velocity (harbour)

Status of all transitional water bodies in Flanders is heavily modified (Brys *et al.*, 2005).

The tidal freshwater zone of the river Scheldt belongs to subtype 2. A good or maximal ecological potential (GEP or MEP) for this river section is still lacking.

2.3 The River Elbe

The river Elbe is a regulated river with a length of 1,094 km. Surface of the catchment area is 148,286 km² (Riedel-Lorjé *et al.*, 1992) of which 65% is situated in Germany. The catchment area of the estuary is densely populated and industrialized. Based on fall of the river and on the sea influence, the river Elbe is divided into three sections: the upper, middle and tidal Elbe (ARGE-Elbe, 1984). The upstream boundary of the estuary and of the tidal zone is located at the Greesthacht weir, about 20 km upstream of Hamburg. Also the estuary is subdivided into three sections based on salinity; upstream the Limnic Elbe which is the tidal freshwater section, the downstream part as far as the mouth to the river at Cuxhaven is considered to be the transitional zone and a brackish environment (Carstens *et al.*, 2004), and the third section is formed by the coastal waters at both sides of the river mouth (Bergemann, 2006).
For monitoring and assessment in the framework of the WFD, system A was chosen for the differentiation of water bodies in the Elbe floodplain, including an extra factor from system B being the substrate composition of the riverbed (FGG-Elbe, undated). The tidal Elbe was characterized as a heavily modified water body (ARGE-Elbe, 2004).

Descriptors used for the characterization of water bodies in the Elbe floodplain (ARGE-Elbe, 2004) :

- Altitude
- Latitude
- Longitude
- Geology
- Size (drainage area)
- Distance from source
- Depth
- Tidal amplitude
- Salt concentration
- Stream power
- Mean width
- Mean depth
- Mean fall
- Discharge
- Bed and profile shape
- Valley shape
- Transport of solids
- Acid neutralising capacity
- Mean composition substrate
- Chloride concentration
- Range air temperature
- Mean air temperature
- Precipitation

The tidal freshwater zone of the river Elbe belongs to type 20 (figure 6), stream with sandy bottom (ARGE-Elbe, 2005).

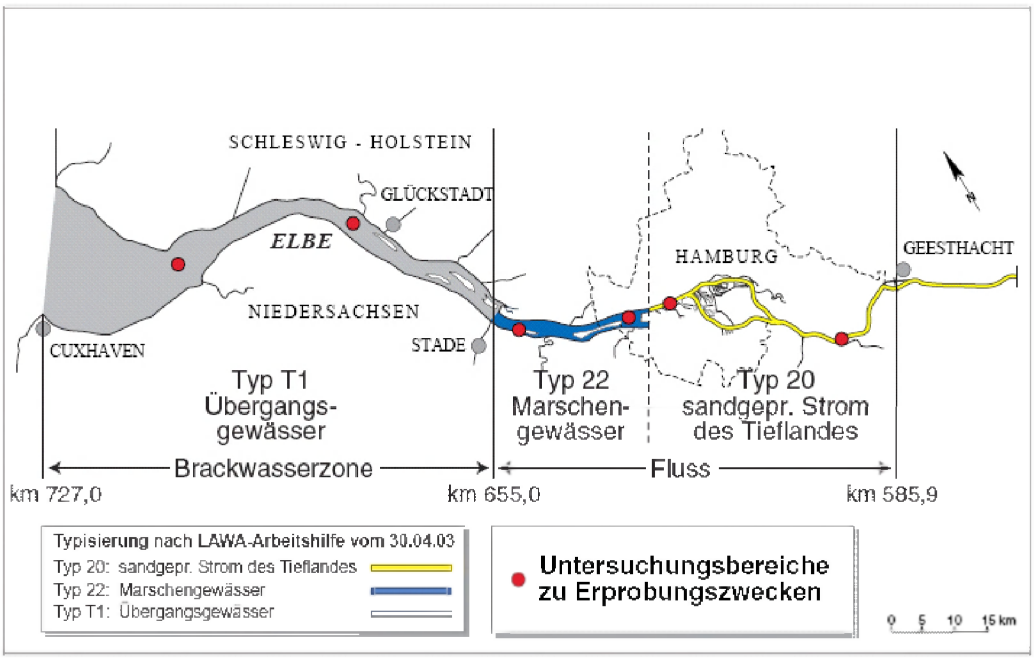

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Figure 6
The Elbe estuary including the tidal freshwater zone (yellow)(Krieg, 2006).

3. Assessment of the ecological status

The assessment of the ecological status of tidal freshwater sections in rivers in Europe varies for the rivers in each EU country. All countries developed their own index mostly based on multimetrics. These metrics are either new developed or existing indices.

3.1 The River Rhine

For description of the ecological status of a water body based on the occurrence of macrozoobenthos, a multimetric index of groups of indicator species is used in The Netherlands (Knoben & Kamsma, 2004). Indicator species distinguished for each water body type are:

a. characteristic species,
b. positive dominant species,
c. negative dominant species.

Ascription of species to these three groups took place on the basis of their traits. Characteristic species have their centre of existence in specific water body types. Positive dominant are species occurring dominantly in the reference situation, while negative dominant species dominantly occur in water bodies with a moderate ecological status or lower. Traits of the species were derived from auto-ecological information of species, historical data, the Handbook for Nature Target Types (Bal *et al.*, 2001) and expert judgement (Van der Molen & Pot, 2006).
The multimetric index combines next metrics:

1. percentage of characteristic species;
2. percentage of individuals belonging to the group of positive dominant and characteristic species (relative abundance).
3. percentage of individuals belonging to the group of negative dominant species (relative abundance);

Based on these multimetrics the index calculation for tidal freshwater zones in rivers is (Van der Molen & Pot, 2006):

$$\text{Value} = (200*(CS/CS_{max}) + 200*(1-(ND/ND_{max})) + (CS+PD))/500$$

in which:

CS = percentage of characteristic species
CS_{max} = percentage of characteristic species in the reference situation
ND = percentage of negative dominant species
ND_{max} = percentage of negative dominant species in the reference situation
PD = percentage of positive dominant species

Classification of the index values into quality classes according to the WFD is in development because reference conditions (MEP and GEP) for tidal freshwater bodies are still lacking (situation November 2007).

Sampling methods prescribed consist of a combination of handnet and grab sampling and brushing off hard substrates. In this way most of the habitats present are sampled. However, the current sampling strategy for large rivers is under revision (situation November 2007).

3.2 The River Scheldt

For the assessment of the ecological status of the tidal freshwater section of the river Scheldt macroinvertebrates are sampled by means of kick sampling with a handnet. For the deeper part of the river an artificial substrate is used as described by De Pauw *et al.* (1986, 1994). The animals collected are identified to next identification levels:
Hydracarina: suborder level;
Oligochaeta, *Crustacea*, *Coleoptera*, *Trichoptera*, *Diptera*: family level (except Chironomidae);
Chironomidae: groups of *thummi-plumosus* and non *thummi-plumosus*;
Plathelminthes, *Hirudinae*, *Mollusca*, *Ephemeroptera*, *Odonata*, *Plecoptera*, *Hemiptera*, *Megaloptera*: genus level.

A multimetric index is used for assessment of the ecological status, consisting of (Gabriels *et al.*, 2004):

a. number of taxa
b. number of EPT taxa (*Ephemeroptera*, *Plecoptera*, *Trichoptera*)
c. sensitive taxa other than *Ephemeroptera*, *Plecoptera*, *Trichoptera*
d. Shannon-Wiener index
e. ATS (average tolerance score)

The metric calculations are integrated into an index value by transforming them into scores with a range of 0-4. The index value is sum of the scores divided by 20, which means range of the index value is between 0 and 1. Quality classes were derived by proportional division of the range into five classes.

3.3 The River Elbe

The new assessment method for the ecological quality of surface waters in Germany, based on macroinvertebrates, is a multimetric index (Meier *et al.*, 2005). However, this index is not applicable for transitional and coastal water bodies. For these water bodies the so-called Aestuar-Typie-Index (AeTI) was developed, which is a modification of the Potamo-Typie-Index (PTI) (Schöll & Haybach, 2001; Schöll *et al.*, 2005). The AeTI has been proposed to use for the assessment of the water quality element "macroinvertebrates" in the tidal freshwater zone of the river Elbe (Krieg 2005, 2006).
The index is bases on a species which have their centre of existence in the estuarine part of North-German rivers. An ecological value was assigned to each species which indicates its indicator value. The more characteristic the species is for estuary, the higher its indicator value assigned. For the calculation of the AeTI the relative abundance of the species is used as a weighting factor. After that the mean of all "weighted" indicator values is the result of the AeTI calculation. Its range is between 1.0 and 5.0. Quality classes were derived by a non-equidistance division of the range into five classes (table 3) (Krieg, 2005).

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Table 3
Classification of AeTI values into quality classes according to the WFD.

AeTI value	Quality status	Class
1.0 – 1.9	High	1
1.91 – 2.6	Good	2
2.61 – 3.4	Moderate	3
3.41 – 4.1	Poor	4
4.11 – 5.0	Bad	5

The macrozoobenthos is sampled with a Van Veen grab with a sampling surface of 0.1 m^2. At each location eight samples are taken in the cross-section of the river (Krieg, 2005).

4. Discussion

The development of ecological assessment and classification systems is one of the most important and technically challenging parts of the implementation of the WFD. It is the first time such systems have been required under community legislation and all member states are in a position of needing to significantly expand their technical knowledge and experience. Consequently, the development and improvement of appropriate systems will involve a learning process. The guidance documents of the EU (http://forum.europa.eu.int/Public/irc/env/wfd/library?l=/framework_directive&vm=detailed&sb=Title) provide a starting point for this learning process. It sets out some key principles and ideas on practical approaches. The aim is to help member states to build on their existing expertise to develop practical and reliable systems for assessment and classification that satisfy the requirements of the WFD (European Union, 2003[B]).
Guidance document no 5 (European Union, 2003[A]) describes the typology, reference conditions and classification systems for transitional and coastal waters.

Transitional waters are usually characterised by their morphological and chemical features in relation to the size and nature of the inflowing rivers. Many different methods might be used to define them but the method should be relevant ecologically. This will ensure reliable derivation of type-specific biological reference conditions.The WFD defines transitional waters as: “*bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows*” When defining transitional waters for the purposes of the WFD, it is clear that the setting of boundaries between transitional waters, freshwaters and coastal waters must be ecologically relevant. From this definition it can be concluded that transitional waters are close to the end of a river where it mixes with coastal waters, that their salinity is generally lower than in the adjacent coastal water, and there is a change to salinity or flow (European Union, 2003[A]).

For the purpose of defining the seaward boundary of transitional waters four strategies are recommended:

1. the use of boundaries defined under other European and national legislation such as the European Urban Waste Water Treatment Directive;
2. estimation of the salinity gradient;
3. use of physiographic features;
4. modelling.

The upstream boundary can be defined by either the fresh /salt boundary or the tidal limit (figure 7). Member states are free to make their choice. However, from international point of view, this possibility causes confusion in the classification of tidal freshwater zones; they are either part of the transitional zone or the lower section of the river.

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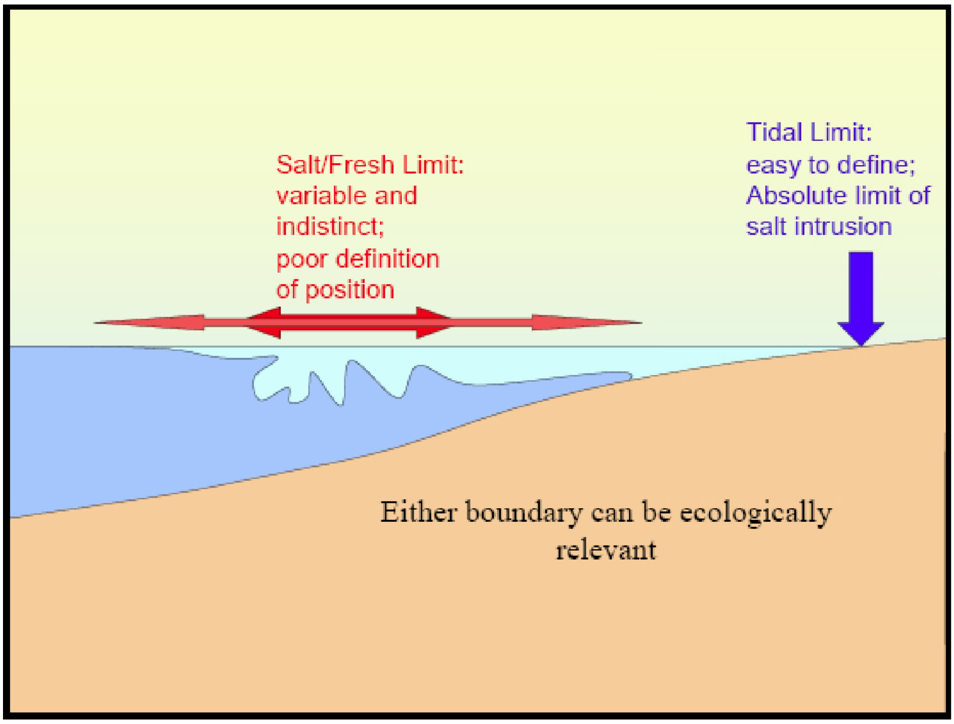
Figure 7
Two definition possibilities for the upstream boundary of transitional waters (European Union 2003[A]).



For the comparison of classification and assessment methods of European tidal freshwater zones it was aspired to compare rivers from the same size and ecoregion. In practice it was only possible to obtain information from three rivers in the North Sea region; de rivers Rhine, Elbe and Scheldt. Much effort was put in obtaining information from other rivers in the same ecoregion and in the Atlantic Ocean ecoregion, however, without result. In general, tidal freshwater zones are the last river sections receiving attention for monitoring and assessment in most of the EU countries.

All three rivers compared are heavily modified, which means their ecological status should meet the MEP in 2015. Four categories are distinguished for description of the ecological status (figure 8): the bad, poor, moderate and good status. For the rivers Elbe and Scheldt, the assessment procedure proposed does not refer to reference conditions since neither a GEP nor MEP has been described. Also for the river Rhine a GEP and MEP is still lacking, but for the current assessment activities the tidal freshwater zone is considered to be part of type R7.

What can be learned for the tidal freshwater zone of the river Seine from what has been done for other European rivers in the framework of the WFD? Looking at the information cycle (figure 9) (Timmerman *et al.*, 2000) most of the member states are not yet or in the beginning of the process for development of an information strategy for their tidal freshwater zones. This should mean an iterative process matching information needs with possibilities for information supply.

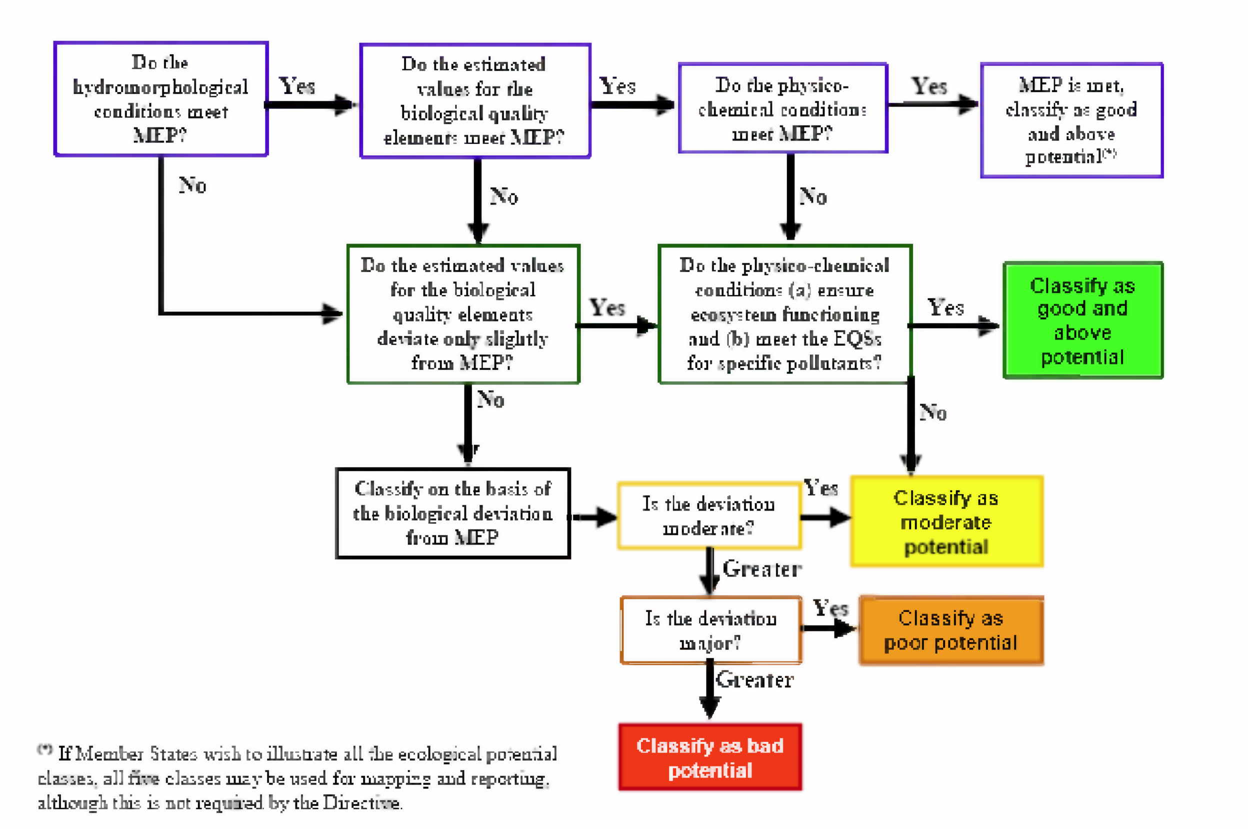


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Figure 8
Classification of assessment results according to the WFD (European Union, 2003[B]).

The needs are clear (described in the WFD), the strategy to collect and to analyse data is in different stages of elaboration. Since member states are free to develop their information strategy including monitoring and assessment procedures, most obvious policy for Seine Aval is to pass jointly, with similar organisations for river management in France, through the above mentioned iterative process for tidal freshwater zones.

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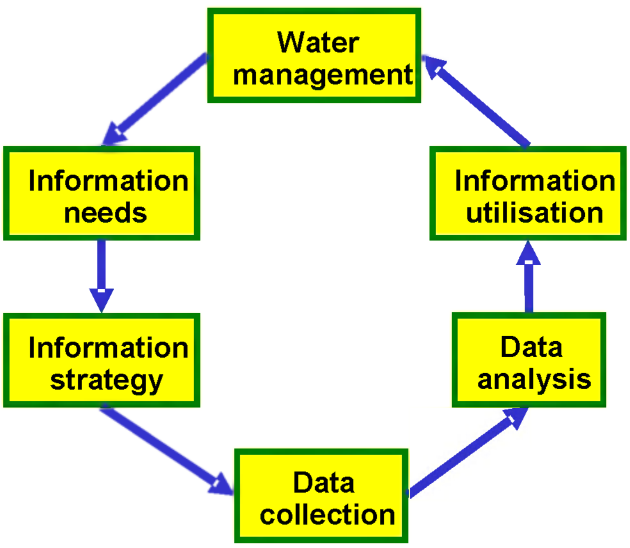
Figure 9
The information cycle (Timmerman *et al.*, 2000).



Based on the information obtained during this desk study, at least all large rivers in the Atlantic Ocean region still have to start with this process. This means all parties are in the same starting position.
On the other hand it is also needed to join similar activities for the part of river Seine directly upstream the transitional zone, especially to tune sampling strategies and assessment methods.

The current situation is that Seine Aval can not take advantage of knowledge developed for other tidal freshwater zones in similar transitional zones of rivers in the EU due to lack of information. Important for assessment, and therefore also for the development of an information strategy, are descriptions of the GEP and MEP for macroinvertebrates. These ecological potentials should be considered leading factors in this strategy.

5. Conclusions

Literature survey and consultation of experts (Annex 1) during the preparation of this report (August-December 2006) made clear tidal that:

a. Classification of tidal freshwater zones differs per country; they are either part of the transitional zone or the lower section of the river.
b. Development of procedures for assessment of the ecological quality of tidal freshwater zones in a lot European rivers is still lacking. This is especially the case in the United Kingdom, Ireland and France. It was impossible to receive any information from these countries (Annex 1). Little attention for this river zone is understandable since it is mostly the minor part of the river. However, the result is that in the current situation is Seine Aval can not take advantage of knowledge developed for other tidal freshwater zones in the same or neighbouring ecoregion.
c. There is lack of any joint method for the assessment of the ecological quality of European tidal freshwater zones. Each country uses its own (national) assessment method or has been developed an adapted methodology.
d. All assessment methods presented for rivers included in this study have the status of proposals on the level of the European Union.
e. For none of the tidal freshwater zones of the rivers included in this report the Maximum Ecological Potential or Good Ecological Potential was defined.
f. Descriptions of the GEP and MEP for macroinvertebrates should be considered leading factors in the development of an information strategy.
g. Seine Aval should join similar organisations for river management in France to develop a common information strategy for tidal freshwater zones.
h. Seine Aval also should join information strategy development activities for the part of the river Seine directly upstream the transitional zone, especially to tune sampling strategies and assessment methods.

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Annex 1

Annex 1

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Irish estuaries:

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- Francis O'Beirn, Marine Institute, Ireland
- Shane O'Boyle, Environmental Protection Agency, Ireland
- Grahan Phillips, Environment Agency, UK
- Ann Rochford, Environmental Protection Agency, Ireland

UK estuaries

- Alison Miles, Environment Agency, UK
- Geoff Phillips, Environment Agency, UK
- Mike Elliott, Institute of Estuarine and Coastal Studies, University of Hull, UK

French estuaries:

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- Martine Staebler, GIP Loire Estuaire, France

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