Carrying capacity and intertidal morphology of the Western Scheldt.

Terms of reference for a comparative study

September 2006

Work Document RIKZ/ZDO/2006.802.w

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1. Introduction

1.1 Background and objective

From the onset of estuarine research, a large amount effort has been put into the prediction of species distribution and abundance. The abiotic factors governing the habitats that delimit the occurrences of specific species have been studied intensively. In addition, the biotic factors and the complex geochemistry of estuarine environments, including its effect on the ecology, have received a great deal of attention. The Western Scheldt, the most southerly located estuary in the Netherlands, has been subjected to research of this kind.

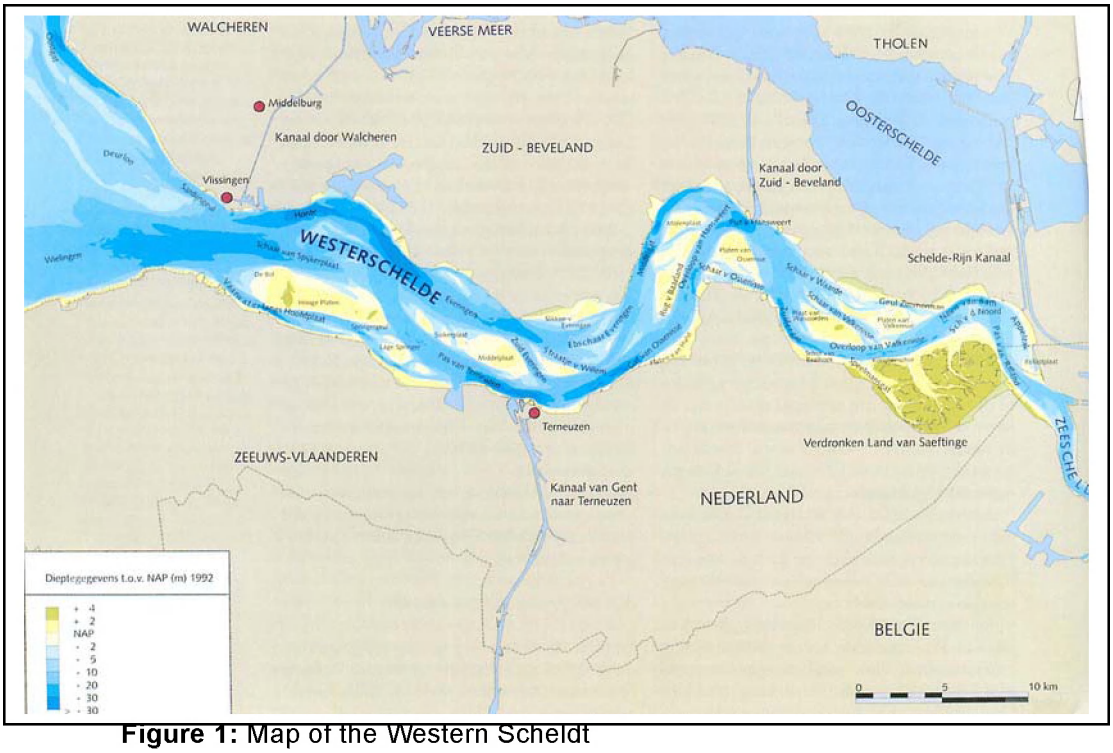

Figure 1: Map of the Western Scheldt

The Rijkswaterstaat “Zeekennis” project concluded that a habitat approach in which physical conditions were modelled for various organisms could not explain the actual appearance or disappearance of animals (Kater et al., 2005). The authors suggest that the input of nutrients, ecotoxicological quality, predator pressure and intra-species competition probably need to be incorporated into the model to explain the presence or absence of animals.

The need to explain and predict species distribution and abundance in the Western Scheldt and other estuaries has increased with the intensification of their use and the growing appreciation of their natural values. The use of estuaries for shipping, fishing, recreation and other human activities keeps pace with the growth of the population and economic activity in the estuary basin. The growing appreciation of the natural values of estuaries is also reflected in the increase in legislation for the protection of birds, habitats and water quality, especially through EU directives. Political and management decisions on the development of the Western Scheldt and the surrounding area require ever more accurate predictions of the effects of a whole range of measures.

One of the recommendations of the Zeekennis report (Kater, 2005) is that we improve our working knowledge of the Western Scheldt estuary by comparing a number of morphodynamic and ecological parameters in different estuaries. The comparison of estuaries should address two research questions:

1. What are the limiting factors for the ecological development of the Western Scheldt?
2. What factors determine the development (accretion and erosion) of the intertidal area in the Western Scheldt?

The first research question deals with the carrying capacity of the Western Scheldt. Carrying capacity can be defined on an aggregated scale as the total annual productivity of the estuary, and can be specified for animal groups or even species. If the productivity of an estuary is high compared to other estuaries, its carrying capacity is large and a high abundance of animals may be expected. The research question concerns the factors that limit the carrying capacity.

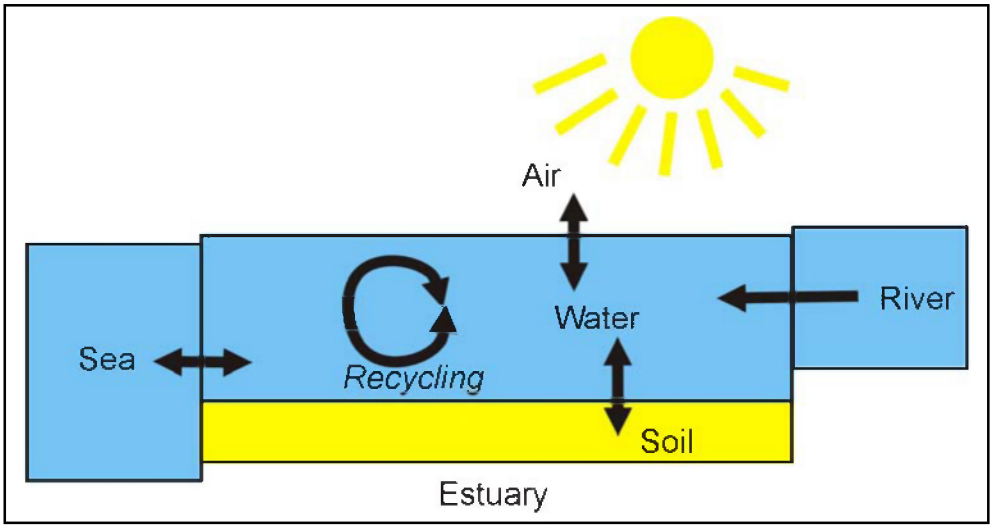

Figure 2: Illustration of the estuary as a “bio-reactor”; the arrows denote the fluxes of water, sediments, nutrients and particulate matter.

The basic schematisation in this approach is the estuary as one big bio-reactor, as illustrated in Figure 2. Biodiversity is included in the carrying capacity through the specification of food groups, illustrated in Figure 3. The food groups can be represented by designated species, to translate the carrying capacity to the functioning of the estuary.

The second research question is specifically related to the highest parts of the hypsometric curve. Intertidal areas play a key role in the ecosystem and landscape of an estuary. In order to understand the development of the intertidal areas of the Western Scheldt, we need to know their governing parameters. The net exchange of sediment (silt and sand) between the surrounding channels and shallows and the intertidal areas is very important in this respect. The migration and rotation of tidal channels can also change the total surface area of the intertidal zone. A process-based approach has not yet produced satisfying results for the simulation of the net sediment exchange and the morphodynamics of the tidal channels and flats. A behaviour-oriented approach is therefore proposed, whereby factors limiting the extent of intertidal flats are retrieved.

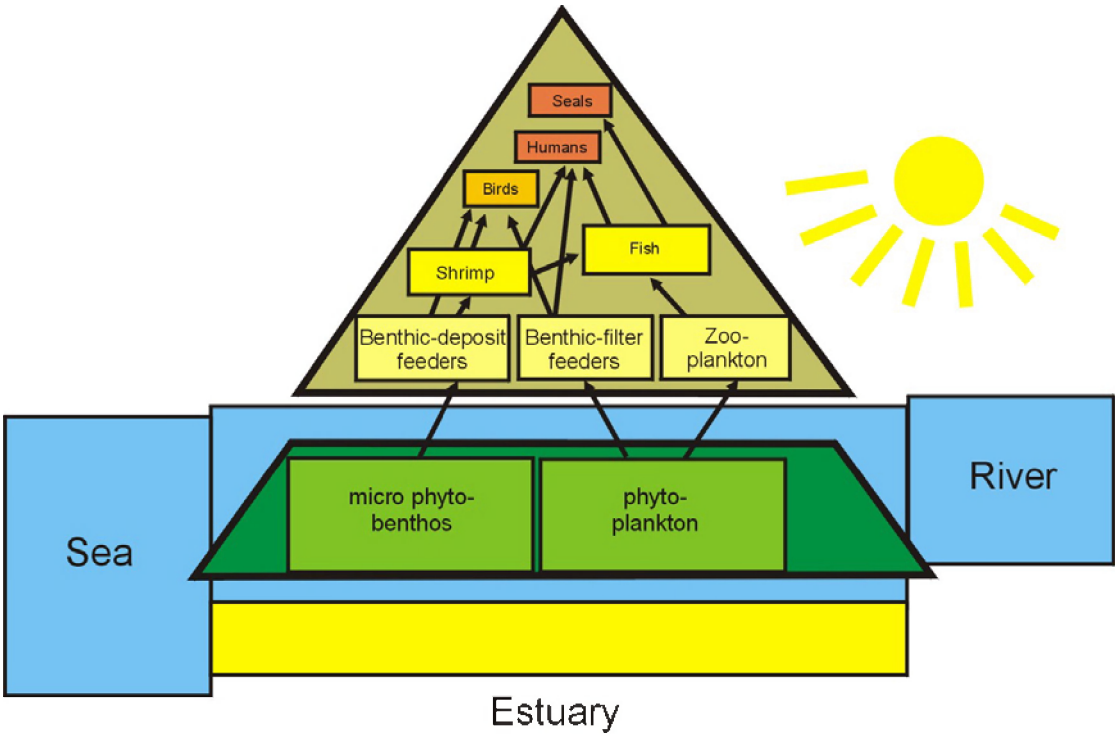

Figure 3: Expansion of the estuarine "bio-reactor" from primary production to different functional groups (groups and relationships adapted from Essink, 2005).

In summary: The objective of the study is to answer the two research questions set out above by comparing a number of morphodynamic, ecological and (geo)chemical parameters in different estuaries, including the Western Scheldt.

1.2 General approach

We are calling for a comparative study in which the Western Scheldt is related to other estuaries. The approach will not be entirely descriptive; neither should it be based on process-based numerical models.

The study is not descriptive as we are interested in quantifications and explanations. The ultimate goal is to be able to predict the carrying capacity and morphological development of the Western Scheldt after further human interventions.

The study is not based on numerical (habitat) modelling, because we are focusing on more aggregated ecological parameters (such as the productivity of the estuary), rather than on one species. Process-based numerical modelling may not yet be 'proven technology', but it has received a considerably greater share of the research effort than the aggregated approach proposed here.

The approach envisaged falls somewhere between a descriptive and a modelling approach. We need to identify the dominant parameters behind carrying capacity (first question) and the morphodynamics of the intertidal zone (second question). Then we must establish how these parameters interact. In morphology this is called a behavioural approach (De Vriend, 1994). It provides quantitative information, not on a detailed process scale, but on a process-averaged scale and uses field data or (if data are lacking) expert judgement. It is a robust approach if sufficient data are available and if the focus is on aggregated parameters (as is the case in this study). The underlying reasons for the existence and acceptance of behaviour models in morphology are presented in Cowell and Thom (1994). Inherent complexities in morphodynamic processes include positive and negative feedback mechanisms, thresholds, and self-organisation. These complexities hinder the up-scaling of short time-scales to a longer time span. It can be argued that similar reasoning is applicable to ecological modelling. Section 2 describes the approach in more detail.

1.3 Ecology and morphology

In general, we can say that "much depends on much" in ecology and morphology. At first glance minor changes influence a variety of other parameters, but all on different time and spatial scales. It is not easy and often simply impossible to find the actual cause-and-effect chain behind a particular observation. In order to understand real life, scientists look at certain parts of the natural system. Aquatic ecologists know a lot about marine life, while morphologists are well-versed in sand transport and morphodynamics.

In recent years, marine ecologists and coastal morphologists have explored the mutual interactions between the two disciplines. The ecologists have found that abiotic boundary conditions to a large extent determine the potential for species development (habitat). Conversely, morphologists are aware of the impact of biological processes on erosion / deposition processes.

Awareness of the importance of the biotic-abiotic interaction has prompted new research (eco-geomorphology). This interaction is important for the present study. Ecological and morphological parameters should not be addressed separately, but in an integrated manner. We are not therefore calling for two separate studies to be performed by an ecologist and a morphologist, but for a truly integrated study. All relevant relationships between the parameters governing estuarine development should be taken into account.

1.4 This document

This document sets out the Terms of Reference for the requested study. Tenderers should base their proposal on this document.

We have deliberately chosen not to prescribe all the research activities in detail, as we want to give tenderers the opportunity to put forward their own ideas. However, the general approach as described in section 2 must be followed. The different research tasks have been summarised in section 2.7, and are discussed in further detail in section 3.

Procedural matters pertaining to this call for tender are examined in sections 4 and 5.

2. Approach

2.1 Introduction

Estuarine life is highly diverse and is controlled by numerous interrelated factors. These factors cover the whole range of biogeochemical and physical characteristics, including hydrology, sedimentology, trophic relations, ecotoxicology and many others. A proposal for a comparative study that focuses on carrying capacity and species diversity requires a clear conceptual vision that provides scientifically sound motivation for the selection of the key parameters of the study. Parameter selection and combinations must be embedded in a firm structure based on this conceptual vision. Not only must the parameter selection be based on an ecosystem view, arguments will also have to be presented as to how the parameter selection and the study will reduce the descriptive aspects of the study to a causal analysis. It is essential that the end results of this study highlight the ecological and morphological bottlenecks and their origin, and suggest how they can be remedied.

2.2 Carrying capacity and intertidal morphology

Ample knowledge of ecological functioning of the Western Scheldt is already available in numerous publications. A non-comprehensive summary of problems and knowledge gaps surrounding carrying capacity in the Western Scheldt is given below. The parameter choice for carrying capacity should be substantiated in relation to a problem analysis of this kind. Other conceptual approaches will be acceptable if it can be convincingly argued that they aim directly at providing a tool for assessing AND understanding the carrying capacity for species in the Western Scheldt system.

Questions that should be taken into account include:

- What are the factors that limit carrying capacity? The factors involved should be ranked in order of importance.
- How does productivity interfere with diversity? The aim is to find the optimal combination between production and diversity.

This concept is explained below, taking into account the most relevant species and the most relevant factors.

The intertidal flats of estuaries are recognized as important morphological elements with high ecological values. They are the main feeding ground for numerous waders, most of which are protected under the EU Birds Directive. Changes in the surface area of the intertidal flats or their height relative to the tides lead to changes in the carrying capacity for waders. Such a cause and effect relationship has been shown for the abundance of oystercatchers in the Eastern Scheldt, as shown in Figure 4. The relationship between the development of intertidal flats and other morphological and hydrodynamic aspects of the Western Scheldt is not fully understood. Analysis of the local development of intertidal flats in relation to other morphological and hydrodynamic parameters, and a comparison to similar relations and developments in other estuaries would improve our understanding of the Western Scheldt tidal flats.

2.3 Consideration of factors limiting ecological development

The carrying capacity for fish and wading bird species is largely dependent on their food source, which for many species consists of benthic macro-faunal biomass. It has been shown that estuarine benthic macro-faunal biomass is related to its food source, which consists of primary production (Herman et al., 1999). The abiotic factors controlling primary production have been incorporated into many ecological models (e.g. Soetaert et al., 1995). Light is one of the limiting factors for primary production. The light climate results from the combination of seasonal variations in solar radiation and cloud cover, the amount of suspended matter, discoloration of the water (mainly by humic acids) and the depth of the water column.

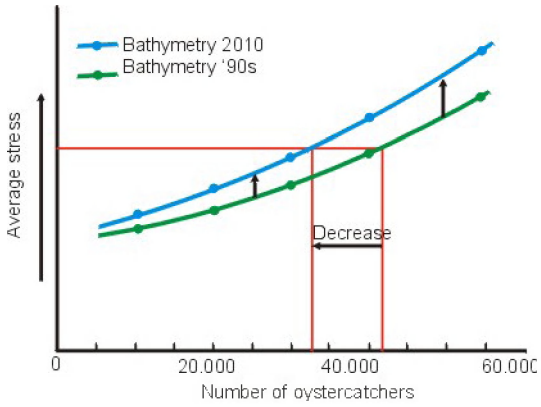

Figure 4: Model of relationship between an ecological parameter (the number of oyster catchers) and a morphological parameter (duration of feeding on tidal flats) expressed as a stress factor. Gradual indundation of the tidal flats will decrease the carrying capacity for oystercatchers. Figure redrawn after Geurts van Kessel et al. (2004).

It has been shown that the immission of sediment in the estuary through erosion in the watershed can be entirely induced by human activity (Van Oost et al., 2000; Van Rompaey et al., 2001). In addition to input from the river and the sea, hydrodynamics and morphology within the estuary undoubtedly have an impact on suspended matter. The status of the actual suspended matter concentrations in the Western Scheldt is still unknown. This aspect should be incorporated into the study and, more specifically, effort should go into unravelling the governing factors (maximum ebb and flood velocities, availability and behaviour of fine sediments). The impact of morphology and hydrodynamics on the spatial and temporal variation in current speed should be a focus of attention. This topic is also important because the estuarine dynamics are highly likely to result in considerable direct restrictions on carrying capacity, by reducing specific habitat area, preventing spawning or settling of larvae, etc.

It is recommended that carrying capacity at different trophic levels is included in the study, so that an overall diagnosis for all levels can be discussed. In the lower trophic levels, the role of detritus such as *Neomysis sp* could be considered. At the higher trophic levels the focus should be on a number of specific bird species, as stated in section 3.8.

The interaction between production and diversity must be scoped. The factors limiting diversity, including water quality effects, suspected toxic or disease factors, habitat availability (especially the abundance of low dynamic habitats in relation to their causal factors) must therefore be considered.

It is also recommended that the gaps in the knowledge mentioned in the Zeekennis report (Kater, 2005) be taken into account.

2.4 Carrying capacity in relation to Natura 2000 and the EU Water Framework Directive

The politics and management of the Western Scheldt require the effects of all sorts of measures to be reflected in characterizing parameters selected on the basis of EU directives. The EU Water Framework Directive provides parameters for ecological and chemical quality, while the Habitat Directive also gives indicators of ecological quality and the Birds Directive contains a comprehensive list of bird species. Expressing the ecological functioning of the Western Scheldt solely in terms of productivity and overall carrying capacity does not meet EU requirements.
However, the carrying capacity of estuaries directly relates to the Natura 2000 objectives and the EU Water Framework Directive in terms of the number and abundance of protected species and habitats. The objective of the study is therefore to present an approach that will translate changes at the basal trophic level, i.e. primary production of benthic and planktonic biomass, to species and habitats specified in environmental legislation. Such an exercise can never be exhaustive, given the large numbers of protected species and habitats. An intelligent choice would represent the important characteristics of the estuaries, facilitate translation between different trophic levels and enable comparison between estuaries. All parameters or elements in the study must be thoroughly assembled in a holistic approach, so that a tool for decision-making, such as selection from options including reclaiming land, reducing dynamics, deriving immission quotas, proposing local measures etc. is quantified to allow the ecological

values of the Western Scheldt to be managed on the basis of its limiting factors.

2.5 Determination of relationships for carrying capacity and intertidal area development

Determining the carrying capacity of estuaries starts with the selection of physical, chemical and biological parameters, and of estuaries. The parameter values for the selected estuaries must be entered into a database. Bearing the aforementioned interdependencies between productivity and physical characteristics in mind, statistical data-mining should focus on proposing relationships between the parameters (see the example in Figure 5). The analysis will have to focus on the limiting factors, and the choice of the statistical tools in the data-mining operation should support this approach. Arguments must be presented in support of the applicability and validity of the statistical approach.

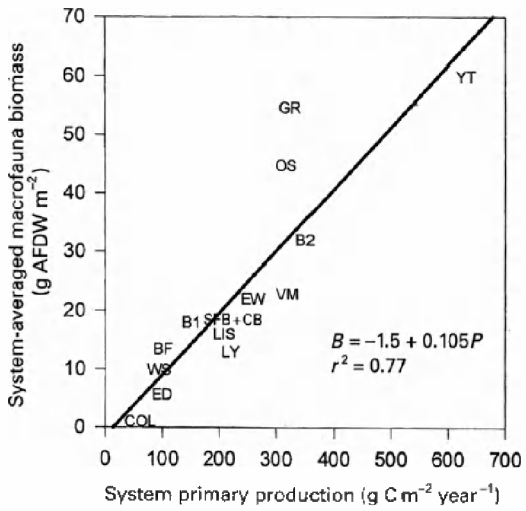

Figure 5: Relation between primary production and averaged macro-fauna biomass in shallow well-mixed estuaries. YT: Ythan, GR: Grevelingen, OS: Eastern Scheldt, B1, B2: Balgzand, VM: Veerse Meer, EW: Outer realm of Eems estuary, ED: Dollard, SFB: San Francisco Bay, LY: Lynher, WS: Western Scheldt, BF: Bay of Fundy, COL: Columbia River, LIS: Long Island Sound, CB: Chesapeake Bay. Figure from: Herman et al, 1999.

The physical, biological and chemical significance of the proposed relationships between the parameters will require thorough discussion, in order to lift the study above the level of 'meaningless' statistics. The discussion should include a comparison with established relationships from the literature and may be supported by models and expert knowledge.

A similar approach is proposed for intertidal area development. Earlier research from the Dutch Wadden Sea (for instance Eysink and Biegel, 1992) and other tidal environments will provide a framework for the analysis as well as relationships for comparison.

2.6 Scale and boundary considerations

The hierarchy of scales is a well-established concept in morphological studies: morphodynamics at the large scale and over long time scales govern the morphodynamics at a smaller scale. An assessment of the spatial and time scale of change in the estuaries under consideration would therefore be appropriate from a morphological point of view. Furthermore, a clear view of boundaries and boundary conditions in relation to the scale of the estuary must be presented. If for instance the average water level at sea is important for tidal wave propagation into an estuary, then we are dealing with a phenomenon on a global scale. If the waves generated by passing ships are decisive for marsh development, we have a local phenomenon. In the envisaged study, the focus should be on the spatial scale of the entire estuary. The corresponding time scale is decades: say 20 years.

The next question is: what are the boundaries of an estuary? An estuary is defined as a semi-closed body of water connected freely with the open sea, within which measurable dilution of seawater by fresh water occurs. This definition covers the whole range from the Western Scheldt, Thames and Elbe estuaries to the Norwegian fjords. Since the ultimate goal of the study concerns the Western Scheldt, the working definition in the study needs to be narrowed down to comparable estuaries (section 3).

Although the parameters from the estuaries themselves will be compared in this study, it should be clear that the estuaries should not be considered closed “estuarine ecosystems”, independent of outside forcing. Clearly, these outside forces must be taken into account if they have a limiting effect on the carrying capacity or intertidal zone development.

2.7 Summary of research tasks

The study should address the following research questions:

1. How is the ecology of the Western Scheldt functioning, in comparison to other estuaries?
   a. What factors determine the carrying capacity? The answer to this question should include a ranking of the importance of these factors.
   b. How does productivity interfere with diversity? The aim is to find the optimal combination between production and diversity.
2. How does the surface area of intertidal flats in the Western Scheldt relate to the hypsometry and hydrodynamics of the basin, and how do the intertidal flats develop?

The research questions will be answered by means of data-driven comparison with other estuaries. Relationships between parameters should address the ecological bottlenecks. Data collection and the construction of a database will be important elements of the study.

The research tasks can be summarised as follows, in chronological order:

1. Literature review
2. Selection of estuaries
3. Boundaries and averages
4. Determination of governing parameters
5. Data collection & establishment of database
6. Derivation of relationships for carrying capacity
7. Derivation of intertidal surface area relationships
8. Assessment of ecological functioning of the Western Scheldt

9. Assessment of intertidal surface area development in the Western Scheldt
10. Synthesis and discussion, including knowledge gaps
11. Scientific review
12. Reporting and products

Please note that process-based modelling of ecological and morphological relationships is not within the scope of this study. Nor is it expected to include a habitat approach focusing on the a-biotic factors that delimit the distribution of species. The research tasks listed above are further specified in the following section.

3. Research tasks

3.1 Literature review

Part of the study

The existing literature offers the latest state of the knowledge on estuarine processes and available data. The literature review should focus on carrying capacity, limiting factors, intertidal surface area relationships and approaches to data analysis. Reports of recent research, management and restoration projects are abundantly available, and will add relevant information to the review by Cadée (1994). The literature review should be an intrinsic part of the study and provide data, approaches for data analysis and a basis for the discussion of the results.

Part of the proposal

The proposal is expected to include a literature review, covering at least the lists of references provided.

3.2 Selection of estuaries

Part of the study

First, all relevant estuaries – the target estuaries – should be listed. This list should include all estuaries that have been the subject of published peer-reviewed ecological or hydro-morphological studies. The target estuaries should then be evaluated in terms of data availability, relevance for the selected parameter combinations, presence of natural reference features, presence of quantified human impact knowledge, etc. The study report should include a table containing the target estuaries' scores for the selection criteria. This will create a tool at an early stage of the project that allows external experts to assess the quality of the selection.

An update of the data availability review by Cadée (1994) might form a starting point for estuary selection.

The following 'key' estuaries have been the subject of ecological studies as referred to above, or offer so much opportunity for comparative study that they cannot be omitted. Because of its direct link to the Western Scheldt it is essential that the upstream part of the Scheldt estuary, the Zeeschelde, be incorporated into the study.

- Humber
- Seine
- Elbe
- Gironde
- Weser
- Chesapeake Bay

Part of the proposal

Tenderers should provide a list of estuaries for inclusion in the study, giving reasons for their choice. It is recommended that estuaries in roughly the same climate zone as the Western Scheldt be chosen. However, any estuary may be proposed provided its relevance can be convincingly argued.
Tenderers must demonstrate their ability to evaluate the estuaries by including a list of estuaries already studied.

3.3 Boundaries and averages

Part of the study

Within estuaries, large local and temporal differences exist in physical, morphological, ecological and chemical characteristics. Examples include local maxima in the amount of dissolved inorganic matter and the occurrence of a turbidity maximum. Spatial and temporal variation must be taken into account in determining the parameters. Values will have to be averaged for the whole estuary, and over time. If appropriate, additional values for sections of estuary (for instance fluvial, marine and estuarine sections) and for different seasons must be collected and analysed.
The seaward limit of the estuaries is positioned at the estuary mouth. In case of the Western Scheldt, the line Vlissingen – Breskens is

usually taken as the estuary mouth. The landward boundary lies at the transition from fluvial to estuarine and is usually set at the point of influence of horizontal or vertical tides or saltwater intrusion. For reasons of comparison the Western Scheldt and Zeeschelde must be addressed separately.

Part of the proposal

The proposal should include a research task on boundaries and averages, preferably supported by an example.

3.4 Determination of governing parameters

Part of the study

A comprehensive list of parameters for characterizing estuaries has been presented by Cadée (1994). Cadée's list is presented below, with additional parameters. The morphological elements in this list are comparable to those presented by the ABP-MER Estuary Guide (http://www.estuary-guide.net/index.asp) and various studies on the morphology of the Wadden Sea (as for instance in Louters and Gerritsen, 1994).

Climate

- Light intensity: hours of sun / cloud cover
- Temperature: seasonal averages, minimum and maximum temperatures (air and water)
- Precipitation and evaporation
- Ice coverage

Hydrodynamic and morphological parameters

- River discharge
- Surface area of water catchment
- Tidal levels
- Tidal range
- Tidal volume
- Total volume
- Length
- Average width

- Average depth
- Hypsometric curve
- Hydraulic roughness
- Bed composition & exposed bed-rock
- Number of parallel channels
- Surface area of channels, sub-, inter- and supra-tidal flats and marshes
- Sediment balance
- Turbidity

Hydrodynamic and morphological criteria for intertidal area development

In addition to the parameters mentioned above, the assessment of the intertidal area development requires time series of sufficient length to distinguish the 18.6-year tidal cycle and sea-level changes of:

- Tidal levels at several stations along the estuary.
- Tidal volume along several transects in the estuary
- River discharge (normal and peak values with frequency of occurrence)
- Storm surge set-up and volume with frequency of occurrence
- Hypsometric curves of the entire estuary and between transects
- Number of parallel channels
- Surface area of channels, sub-, inter- and supra-tidal flats and marshes
- Sediment balance

Ecomorphological criteria

- Surface area of mussel and oyster beds
- Surface area of sea-grass fields
- Surface area of salt marshes

Chemical parameters

(at the estuary entrance, within the estuary and in the river)

These chemical parameters relate to the total load and include anthropogenic contributions. If the anthropogenic contributions are known, individual and combined values should be presented for natural and anthropogenic contributions.

- Seston concentration
- POC
- NO_3
- PO_4
- Si
- O_2
- Salinity

Biological parameters

- Phytoplankton biomass
- Phytoplankton production
- Phytobenthos biomass
- Phytobenthos production
- Macrobenthos biomass
- Bird population (numbers, number of species)
- Fish population (numbers, biomass, number of species)
- Mammal population (numbers, number of species)

Bird species

The abundance of a representative number of bird species should be included, to facilitate the translation of carrying capacity and ecological functioning to the level of EU directives. The first step in the compilation of the bird species priority list is to identify all relevant species. This list should at least include all wintering bird species from the designation reports and from the Birds Directive annex I. Next, each of the species in the target list receives a relative priority score based on three main groups of criteria.

- Legal criteria: legal aspects at international, European, national and regional level, e.g. Ramsar
- Rarity criteria: rarity of the species at the local level
- Specificity criteria: indications of the ecological relevance of the species for the given region. Species occurring naturally in a region are distinguished from exotics and species present due to artificially created habitats.

The criteria and their scores are listed in a table. The final species priority score is the product of the scores for all sub-criteria. Detailed examples of how species can be selected and scored can be found in Van Hove et al. (2004) or Adriaensen et al. (2005). Bird species from

several functional groups should at any rate be included: piscivores and herbivores and benthivores, the latter to be subdivided in waders that feed mainly on worms, waders that feed mainly on molluscs, and shell ducks. This gives an insight into several functional aspects of the estuaries. It is recommended that the following species be considered:

Benthivore waders (shellfish)

Eurasian Oystercatcher (*Haematopus ostralegus*)

Red Knot (*Calidris canutus*)

Benthivore waders (other than shellfish)

Dunlin (*Calidris alpina*)

Grey Plover (*Pluvialis squatarola*)

Pied Avocet (*Recurvirostra avosetta*)

Benthivore ducks (shellfish)

Common Eider (*Somateria mollissima*) or Common Shellduck (*Tadorna tadorna*)

Herbivores

Greylag Goose (*Anser anser*) or Eurasian Wigeon (*Mareca penelope*)

Piscivores

Little Tern (*Sterna albifrons*) or Common Tern (*Sterna hirundo*)

Omnivores

Common Redshank (*Tringa tetanus*)

Breeding birds

Kentish Plover (*Charadrius alexandrinus*)

Sandwich Tern (*Sterna sandvicensis*).

Anthropogenic parameters

- Sand mining, capital and maintenance dredging
- Land reclamation
- Shipping intensity
- Fisheries and aquaculture (fish, crustaceans, molluscs)
- Recreational activities and urbanization

Parameters for ecotoxicological influences and human-induced chemical fluxes

For comparison, the concentrations in water, sediment and species of some widely recognized and measured individual toxic substances are proposed. In addition, it is advisable to include one or more integrated parameters for toxic 'stress'. Integrated parameters are useful because the toxicity of individual substance differs from a 'cocktail' and varies for different organisms. One such parameter is the PAF value (Potentially Affected Fraction), which is the percentage of species for which the concentration of toxic substances exceeds a threshold. If sufficient bioassay data is available internationally, these results should also be compared.

- Metals: Cd and Zn concentration
- Total Polycyclic Aromatic Hydrocarbons (PAHs)
- Total PCB
- Total DDD/DDT/DDE
- TBT
- Total drins
- Bioassay results

This list is too long for direct use. A careful selection of parameters and derived parameters will have to take place before the statistical analysis is carried out. Great care must be taken to avoid a biased or prejudged selection of 'important' parameters.

Part of the proposal

We expect the proposal to include a list similar to the above, with reasons stated for any omissions, additions, and changes. Tenderers must present a representative choice of parameters to demonstrate the state of the ecological functioning in accordance with the EU Water Framework Directive, the Habitat Directive and the Birds Directive, including reasons for their specific choice.

3.5 Data collection & establishment of database

Part of the study

Data must be gathered for the selected estuaries. An initial quick analysis should show if sufficient data is available. Data can be acquired from the scientific literature and reports, EU and national databases, and institutes and researchers. The data must be stored in a rapidly accessible database, in a format that is supported by regular software packages. It should be a simple matter to extend the database in terms of the number of fields and number of entries. It is recommended that a number of calculated quotients that offer an insight into the carrying capacity be incorporated into the database. One example would be the quotient between the biomass of benthic animals and the number of feeding birds. This indicates the use of available food by birds. A non-comprehensive list of derived parameters is presented here.

Derived hydrodynamic and morphological parameters

- Estuarine number
- Tidal velocity
- Hydrodynamic classification after Prichard (1967) & Biggs and Cronin (1981)
- Morphodynamic classification after Fairbridge (1980) & Hume and Herdendorf (1988)

Derived chemical parameters

- Gradients within the estuary
- Balances (import, export and conservation)

Derived biological parameters

- Birds per square kilometre
- Ratio of phytoplankton production to phytobenthos production
- Ratio of local production to import

Part of the proposal

The proposal should include data collection, with at least an estimate of the effort that will be devoted to:
- compiling a brief inventory of the selected estuaries to establish whether sufficient data is available.;
- data acquisition from the scientific literature and reports, EU and national databases, and institutes and researchers.

Furthermore, the proposal should contain:
- A list of derived parameters similar to the list shown above, stating reasons for any omissions, additions, and changes.
- An option to purchase data, with the consent of Rijkswaterstaat.
- A proposal for the format of the database.

3.6 Derivation of relationships for carrying capacity

Part of the study

The carrying capacity of estuaries is determined by the mutual interaction and dependence between their morphological and biological characteristics. To determine the most important relations between characteristics, the data collected must be analysed using statistical methods such as cluster techniques, correspondence analyses and ordinations. Tenderers must present arguments for the appropriate statistical methods, possibly supported by literature references and their own previous experience.

The analyses will result in numerous relationships between parameters of varying quality. An understanding of the processes underlying the most important, relevant or significant relationships must be demonstrated. Arguments may be drawn from the literature, expert judgment, or (numerical) process-based models. It is specifically not the aim of the study to build a 'black-box model' solely based on statistical relationships. The aim is to retrieve quantitative relationships, with a firm understanding of their meaning. A discussion of the overall validity of the relationships is therefore required. At the end of this part of the study it should be possible to backtrack the origin of all relationships and decisions to include or exclude certain parameters.

Part of the proposal

This research task encompasses the scientifically complex task of reducing the large number of variables and parameters to a limited number of relationships with a clear validity. We expect the tenderer to:
- present a plan for the statistical analysis (types, tools), including reasons in brief;
- make some suggestions as to the governing parameters, again giving reasons in brief;
- present a plan for the discussion of the validity of the relationships, with emphasis on the methods (literature review, models, expert judgement).

Tenderers must demonstrate their ability to combine parameters from different scientific fields by the quality and range of researchers involved in their study.

3.7 Derivation of intertidal surface area relationships

Part of the study

Morphological relations between the tidal volume or tidal prism of the entire basin and inlet cross-sectional area are well established (see for instance Hughes, 2002). Relations between local tidal volume and channel cross-section have been established for the Wadden Sea (in the ISOS-project, Eysink, 1991, 1992 and 1993 and Eysink and Biegel, 1992) and the estuaries from the southwestern Netherlands (in the 1950s and '60s, determined by Haring and presented in de Jong and Gerittsen, 1984, amongst others). Relations between tidal volume and the surface area of tidal flats for the Wadden Sea have also been identified in the ISOS project and presented in Louters and Gerittsen (1994).

The morphological relations within estuaries require more detailed knowledge of the hydrodynamic and morphological parameters than is needed for the analysis of carrying capacity. In situations where the tidal wave is distorted within the basin, as for instance happens in the Western Scheldt, or where seasonal changes may temporarily lead to high discharges, additional information concerning space and time will be required.

To enable conclusions to be drawn concerning the development of intertidal areas, the relationships must include the effects of changes. This implies that the development of the hydrodynamic parameters must be known. The response time of the morphology needs to be addressed, and knowledge of the sediment budget as a function of time becomes increasingly important.
Estuaries that deviate from the norm yield important observations on the mechanisms that determine the development of intertidal flats. Examples from the Netherlands include the Eastern Scheldt, where the sediment exchange with the coastal system has ceased (Geurts van Kessel et al., 2004), the Texel tidal inlet, which has barely any intertidal flats (Elias et al., 2003) and the Friesche Zeegat, which experienced a drastic and sudden reduction of tidal volume (Biegel and Hoekstra, 1995).

Part of the proposal

In contrast to the previous task, the actual retrieval of intertidal surface area relationships is relatively straightforward once the data have been collected. We expect tenderers to:
- present a plan for the statistical analysis, including brief reasons, making reference to earlier studies;
- present a plan for the discussion of the validity of the relationships.
The involvement of an experienced coastal morphologist with a track record in inlet research is a prerequisite for this study.

3.8 Assessment of the ecological functioning of the Western Scheldt

Part of the study

The ecological functioning of the Western Scheldt with respect to other estuaries should be expressed in terms of productivity and of characterizing parameters from EU directives. The EU Water Framework Directive provides parameters for ecological and chemical quality, while the Habitat Directive also gives indicators of ecological quality and the Birds Directive contains a comprehensive list of bird species. Using the aforementioned parameters and bird species,

tenderers will have to demonstrate the state of the ecological functioning of the estuaries according to these Directives.

The distribution and density of birds is not necessarily determined by parameters from within the estuaries. Other factors, like the availability of resting grounds, the situation on the breeding grounds, predation or even hunting, may play an equally important or even limiting role for certain bird species. The complexity of such relationships has been shown recently in studies on the effects of shellfish fisheries in the Wadden Sea and Eastern Scheldt (EVA II). Whenever such limiting factors are known, they should be mentioned.

Part of the proposal

This research task consists of three parts
- A representative choice of parameters to demonstrate the functioning of estuary, including reasons for the specific choice.
- A plan for the demonstration of the functioning of the Western Scheldt in comparison with other estuaries.
- A plan for the discussion of the functioning of estuaries and the applicability of the parameters.

3.9 Assessment of intertidal surface area development in the Western Scheldt

Part of the study

Assessing the development of the intertidal surface area requires an analysis of development over time and a comparison with the relationships in other estuaries. Examples of such analyses are presented for the Dutch Wadden Sea in the aforementioned ISOS study. In addition to the analysis, a discussion of the developed and observed limiting factors should be presented.

Part of the proposal

Again, this research task consists of three parts
- A representative choice of parameters to demonstrate the development of the intertidal surface area, including reasons for the specific choice.

- A plan for the demonstration of the development of the intertidal surface area of the estuaries.
- A plan for the discussion of the development of the intertidal surface area of the estuaries and the applicability of the parameters.

3.10 Synthesis and discussion, identifying any knowledge gaps

Part of the study

The findings must be summarised in a synthesis, with emphasis on the selection criteria, data collection and data-mining. Consideration of the statistical methods and the value of the relationships and ecological bottlenecks should constitute a major part of the discussion, as should the translation from productivity to species abundance. Similarly, a discussion of methods and results in terms of the evolution of intertidal flats should be included.
In addition, an overview of the major gaps in the knowledge of estuaries should be presented, with a suggestion as to appropriate ways of filling these gaps. Inevitably, more research will be needed, but what research?

Part of the proposal

Tenderers are requested to demonstrate how they intend to arrive at a synthesis.

3.11 Scientific review

Part of the study

The report must be scrutinised by a scientific review committee. The members of the committee must all have a clear track record in the field of estuarine research. The questions and comments of the review committee must be addressed in the report, either in the form of changes to the text and figures, or in an appendix.

Part of the proposal

The review committee will be organised and paid for by Rijkswaterstaat. However, tenderers may propose suitable members, presenting arguments for their involvement. Tenderers are also asked to demonstrate when and what types of product will be presented to the review committee, and how any suggestions will be incorporated in the study.

3.12 Reporting and products

Part of the study

The study has two main deliverables: a report and a database.

The report should present a thorough yet readable account of the results of the above activities. Emphasis should be on the method or methods, data acquisition and a discussion of the results. The conclusions should focus on the carrying capacity, selected species and habitats, and intertidal flats development. A translation of the scientific results to issues relevant for policymakers is imperative.
The report should include:

- Summary
- Introduction
- Data (including selection criteria for estuaries and parameters)
- Method(s)
- Results – carrying capacity
- Results – intertidal surface area development
- Discussion
- Conclusions
- Appendix: user manual for the database

The database must be easily accessible by Rijkswaterstaat.

Part of the proposal

Tenderers are asked to present a draft list of contents and a plan for the writing and editing of the report

4. Project management

4.1 Rijkswaterstaat's involvement

The successful tenderer will have to present his findings to Rijkswaterstaat on a regular basis. We envisage meetings between the successful tenderer and Rijkswaterstaat at the following points, and possibly others:

- start-up
- shortly after selection of the estuaries and parameters
- shortly after finalisation of the database
- shortly after the statistical analysis and identification of relationships
- shortly after synthesis and
- shortly after delivery of the draft report.

The successful tenderer will send brief and to-the-point progress reports one week prior to each meeting (except the start-up meeting). He will also draw up minutes of each meeting, with a list of decisions and actions.

4.2 Data management

At the start of the project, Rijkswaterstaat will provide the successful tenderer with the following information:

- relevant reports from the Zeekennis project
- relevant data for the Western Scheldt

The successful tenderer will be solely responsible for the collection of suitable, sufficient and adequate data. The tenderer will present an optional price quotation for data acquisition as part of the proposal, including a maximum amount. If some of the data needs to be purchased, approval must first be obtained from Rijkswaterstaat.

We expect that all data can be found in relevant data sources (reports, internet, etc.); we do not expect the tenderer to conduct additional field investigations. Neither do we expect the tenderer to set up and run

computer models. The application of existing models will of course be permitted, but we suggest that models be used only if this gives more efficient access to parameter values.

A data list will be prepared and delivered in advance of the third progress meeting.

4.3 Quality management

Tenderers must indicate how they will guarantee internal quality assurance. If applicable, a description of the specific tasks of the internal quality assurance officer(s) should be provided. The internal quality procedures for intermediate products (like the progress reports) should also be made clear.

In addition to the tenderer's own internal quality assurance procedures, an external quality check will be carried out. To this end, a scientific review by an expert group will be organised by Rijkswaterstaat. One week before each progress meeting, the successful tenderer will send his findings to this expert group (by email). It is expected that, depending on the subject and result, some experts will join the progress meetings to discuss these findings and recommend follow-up activities.

4.4 Timetable

The timetable below is indicative. Tenderers are requested to provide their own project timetable.

Research task	Execution period (in months after start-up)
1. Literature review	0 – 1
2. Selection of estuaries and parameters	1 – 2
3. Boundaries and averages	1 – 2
4. Selection of parameters	1 – 2
5. Data collection & establishment of database	2 – 5
6. Derivation of relationships and carrying capacity	5 – 7
7. Derivation of intertidal surface area relationships	5 – 7
8. Assessment of ecological functioning of the Western Scheldt	7 – 8
9. Assessment of intertidal surface area development of the Western Scheldt	7 – 8
10. Synthesis and discussion	8 – 9
11. Scientific review	10
12. Reporting and products	11
Delivery of end-products (end of project)	12

4.5 Project deliverables

The project deliverables are:

- Progress reports with main findings two weeks in advance of each progress meeting (except start-up meeting). These reports may be sent by email
- Minutes of meetings (by email)
- Ten bound copies of a draft version of the final report
- One CD or DVD with the draft version of the report in pdf-format
- Twenty bound copies of the final report
- One CD or DVD with the final version of the report both in pdf- and Word format.
- One CD or DVD containing the database

The working language for the project will be English (UK); reports, progress reports and minutes of meetings must be written in English (UK).

5. The requested proposal

Contents

The proposal should provide or demonstrate at least the following:

- Tenderer's overall understanding of the requested study
- Tenderer's comments on specific questions that have been put forward in these Terms of Reference
- Tenderer's approach to the comparative study
- CVs of the proposed project team
- A list of estuarine projects carried out by the tenderer
- A list of eco-geomorphology projects carried out by the tenderer
- Timetable
- Financial tender

Tenderers are encouraged to form a consortium with other parties, as long as the responsibilities are clearly defined in the proposal. There are no regulations with respect to the exclusivity of any party, as long as more than two decent proposals are received.

The financial tender should be on a lump sum basis including a proposed payment schedule. This payment schedule must coincide with distinct moments of deliveries, for instance after each proposed progress meeting.

Rijkswaterstaat reserves the right to halt or make changes to the project after each phase. After each project meeting a Go / No Go decision may be taken, for instance if the availability of data is hindering progress.

The costs of the external expert panel need not be incorporated in the financial tender, as they will be borne directly by Rijkswaterstaat.

A breakdown of the total all-inclusive costs of the project should be provided, including a breakdown per research task. This breakdown should show the number of person-days that each project member is expected to spend on the project, multiplied by his / her daily rate. A

distinction should be made between person-hour costs and material costs (reproduction costs, computer infrastructure, travel costs, miscellaneous).

Evaluation of proposals

The proposals will be evaluated and scored on the following aspects:

- - The quality of the proposed project team and its members (15%)

- The quality of the proposal in terms of:
  - Tenderer's interpretation and understanding of the study objectives (20%)
  - Tenderer's response to questions raised in this ToR (20%)
  - Readiness of the proposal (10%)
- Tenderer's experience of similar studies (10%)
- Total all-inclusive costs (25 %)

Presentation of the proposal

Two of the tenderers will be invited to present their proposal to Rijkswaterstaat, to elucidate their approach. The selection of the two tenderers will be based on a first assessment of the proposals, in accordance with the criteria presented above. The quality of the presentation, including the tenderer's response to questions and overall grasp of the subject, will be the final selection criterion. The quality of the presentation may also affect the score for the quality of the proposal.

6. Kostenraming, selectiecriteria en risicoanalyse (RWS-intern)

(OPMERKING: dit hoofdstuk maakt geen onderdeel uit van de Terms of Reference. Het is bedoeld als intern stuk voor RWS dat gebruikt kan worden bij de voorbereiding van de uitbesteding en de beoordeling van de ontvangen offertes. Om die reden is de tekst van dit hoofdstuk in het Nederlands gesteld.)

6.1 Kostenraming

Het uitgangspunt van de kostenraming is tien estuaria, waarvan de gegevens kunnen worden verzameld uit literatuur. Er zijn geen veldbezoeken gepland of reizen naar het buitenland om de betreffende gegevens op te halen.

Activiteit (alles inclusief rapportage)	Geraamd aantal mandagen
Voorstudie en vaststellen van relevante parameters	10
Verzamelen van gegevens van de tien estuaria	40
Uniformeren van de data / opstellen database	20
Statistische analyse	20
Vaststellen relaties	50
Voedselpiramides (synthese)	30
Specifieke doorvertaling naar Westerschelde	10
Overleg en project management	20

Totaal komen we zo op 200 mandagen werk. Tegen een globaal gemiddeld tarief van 1 kEUR/dag betekent dit een post personele kosten van 200 kEUR ex BTW. Met 20% additionele kosten, komt het totaal geraamde bedrag op orde 240 kEUR uit.

Een doorlooptijd van 1 jaar is realistisch. Een kortere doorlooptijd is in theorie ook mogelijk. Negen maanden kan een redelijke maat zijn. De

twee flessenhalzen in het onderzoek zijn: 1. Het verkrijgen van de gegevens; en 2. Het opstellen en onderbouwen van de referentielijnen. Bij beide punten is het waarschijnlijk dat een langere doorlooptijd zal leidden tot betere resultaten.

Voor de eventuele aankoop van gegevens wordt gevraagd om een stelpost. Een eerste schatting voor het plafond aan deze stelpost is EUR 20.000,- (inclusief VAT).

6.2 Risicoanalyse van de projectuitvoering

De risico's zijn gesplitst in risico's voor de opdrachtnemer en risico's voor de opdrachtgever. In onderstaande twee risicotabellen staan drie kolommen die tezamen de keten "aanleiding -> gevolg -> mitigatie" weergeven. In de linker kolom staat de aanleiding tot een mogelijk projectprobleem. In de middelste kolom staat aangegeven wat dit kan betekenen voor de projectuitvoering. De rechter kolom tenslotte, geeft aan welke maatregelen er genomen kunnen of moeten worden, in het geval zich de geschetste situatie daadwerkelijk voordoet.

Risico's voor de opdrachtgever

	Aanleiding	Gevolg	Maatregelen
1	Offerte opstellen is te groot risico voor opdrachtnemer	Geen offertes	Betaalde offertes
2	Minder dan 2 offertes worden ingediend	Geen commerciële afweging mogelijk tussen aanbieders	Bij 1: opdracht verlenen mits opdracht aan voorwaarden voldoet Bij geen: Nieuwe call uitschrijven
3	Reorganisatie projectbegeleidende dienst van RWS	Onduidelijke communicatie met opdrachtnemer kan leiden tot niet optimaal bruikbare eindproducten	Project overdragen aan andere projectbegeleiders. Eventueel project tussentijds aanpassen.
4	Veel data moet worden aangekocht	Stelpost voor aankoop wordt overschreden	Niet honoreren boven stelpost, of extra budget vrijmaken

Risico's voor de opdrachtnemer

	Aanleiding	Gevolg	Maatregelen
5	Onvoldoende gegevens	Geen relaties vast te stellen waardoor onderzoek vastloopt	Ontbrekende informatie laten invullen via expert judgement; Overleg met expertpanel; Eventueel stopzetten onderzoek.
6	Onvoldoende capaciteit beschikbaar om werk uit te voeren	Producten worden niet op tijd geleverd	Rek toestaan zolang eindtermijn maar blijft staan.
7	Data moet worden gekocht	Extra kosten	Noodbudget reserveren van 30 Keuro als stelpost.
8	Grote kwaliteit en variatie in aangeleverde data	Meer nabewerking noodzakelijk dan begroot in de offerte betekent einde databewerking, dus mindere kwaliteit database	Meerwerk optie toestaan, dus hoger kosten

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