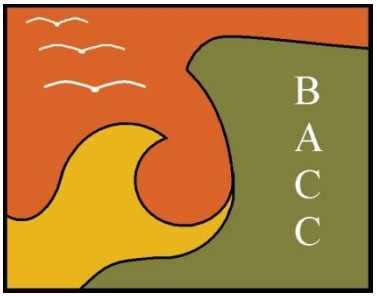
Bright Angel Coastal Consultants

Evaluation of 'River Engineering and Sediment Management Concept for the Tidal River Elbe'

Client:
Hamburg Port Authority & WSV

By

Roger Morris



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Conclusions

i. Environmental and economic problems concerning dredging in the Elbe Estuary arise from a complicated suite of anthropogenic influences. There are no obvious parallels in northern Europe. Other major estuaries exhibit a range of similar problems but differ in the physical size of the estuary or the scale of the problems. This means that whilst there are external models that can be drawn upon to find solutions, there are no directly applicable models. Hamburg Port Authority and WSV are therefore developing an approach that will be watched with interest by other ports that lie a long way up major estuaries.

ii. This assessment largely focuses on the relationship between the RESMC and various European environmental Directives, most notably the Birds and Habitats Directives, the Water Framework Directive and the Marine Strategy Framework Directive. The analysis therefore considers the interpretations that are relevant in a **legal** rather than a biological context. Biological, toxicological and geomorphological considerations are made by the five other specialists in the Expert Group.

iii. This analysis has been greatly hindered by the fragmented nature of information supplied on the biological attributes of the Elbe Estuary and the apparent weaknesses in the mechanisms of governance of the designated sites. The high-level message of this analysis is therefore that a coherent approach to estuary management has not been very obvious. Supplementary information has been supplied that provides some reassurance that the issue of fragmentation is being addressed. However I have been left with the impression the Port of Hamburg and WSV have been trying to find solutions without access to coherent and integrated Conservation Objectives for the estuary as a whole. High level objectives need to be qualified by descriptors of what constitutes favourable condition within various attributes within the estuary.

iv. Complaints about the lack of consistency by UK ports ultimately led to additional Commission guidance on what should be included within Natura "Estuaries" sites. Several Member States, including Germany and France were required to re-define estuary boundaries to include navigation channels (fairways). This means that by default the UK has longer experience of development of integrated plans and the issues relating to reconciling dredging with management of Natura 2000. Several models for strategic management initiatives are offered and emphasis is placed on the benefits of developing coherent and integrated Conservation Objectives combined with Favourable Condition tables.

v. The overall package of measures developed by evolution of the RESMC has the potential to address a variety of additional problems. Many relate to the need for climate change adaptation strategies and in particular measures to reduce the dangers associated with sea level rise. Increasing accommodation space will greatly assist in many ways, both as a measure that changes tidal propagation, but also as a means of absorbing additional sediment, nutrients and carbon. The RESMC therefore needs to be developed with reference to climate change mitigation and adaptation.

Q1. Assessment of the situation up to 2005 (initial situation)

Q1a. ***What is the assessment of the influence exerted by past expansion, river engineering and dredging strategy on the present-day ecological situation?***

1a.1. The modern geometry of the Elbe Estuary is heavily modified by a variety of interventions that include channel deepening, loss of accommodation space to sea walls (dykes), cutting off tributaries, groyne fields and removal and relocation of sediment.

1a.2. The loss of natural meanders and braided channels means that the Elbe estuary in its modern form lacks many of the structural and functional features that might be expected in one the biggest estuaries in northern Europe. Consequently it is difficult to argue that the estuary as a whole meets the desired state of 'good ecological potential' in relation to the Water Framework Directive.

1a.3. The current distribution of habitats within and adjacent to the tidal Elbe differs greatly from those existing in the original floodplain. These habitats would have supported a different, and doubtless richer assemblage. Some of the changes in fish breeding success may be attributable to these changes, but other more significant influences such as pollution levels, depressed oxygen availability and loss of spawning grounds are arguably as significant. In the case of Twaite Shad *Alosa fallax*, these influences combined with over-fishing are reported to be highly significant (Thiel *et al*., 2008).

1a.4. It must be recognised, however, that the modern distribution of habitats and species has been reflected in the suite of designations under the Birds and Habitats Directives. This means that the wildlife value is recognised **despite** the impact of changes. This is the baseline against which legal determination of the impacts of measures to address the need to reduce levels of dredging will be assessed.

1a.5. It is important to bear in mind that the changes to channel geometry and to the extent of accommodation space has a significant bearing on the ability of the estuary to respond to relative sea level rise. Current sediment loads appear to be sufficient to allow inter-tidal habitats to keep pace with rising sea levels and this is an important issue when considering the need to integrate climate change adaptation measures.

Q2. Assessment of the situation as of 2005 and with further implementation of the RESMC

Q2a. ***How do sediment management concepts of other European estuaries take into account the requirements of the WFD, MSFD and the Habitats Directive?***

2a.1. There are several initiatives to manage sediment in northern Europe. The reasons behind their development differ according to the port, its host country and the estuary concerned. There would appear to be no complete package of measures that in any way resembles that of the RESMC proposed by the Hamburg Port Authority and WSV. It is also worth emphasising that the problems faced by HPA and WSV appear to exceed those faced in virtually any other northern European estuary.

2a.2. There is very little to suggest that a comprehensive package of measures has been completely evaluated according to the provisions of the Birds, Habitats and Water Framework Directives at any other location. This is complicated by the inter-relationship between channel deepening, loss of accommodation space through land reclamation (poldering and industrial) and limiting the influence of tributaries and meanders.

2a.3. There are models in the UK that predict the possible loss of inter-tidal habitats and their implications for Natura 2000 (referred to as Coastal Habitat Management Plans [CHaMPs]), but that this has only been applied in relation to flood defences. Such approaches cannot be directly translated into a mechanism to assist in management of the Elbe Estuary but they do offer an additional way of responding to some of the problems that are being experienced on the Elbe.

Q2b. ***What is the assessment of the objective 'reducing 'tidal pumping' ' as a sediment management strategy in view of the requirements of the WFD, MSFD and Habitats Directive?***

2b.1. The principle of 'reducing tidal pumping' is a reasonable objective and **if** it can be achieved without the loss of key Natura 2000 Habitats and species then it is laudable and should be pursued.

2b.2. The big problem is that the measures to reduce tidal pumping involve major changes to the geometry of the estuary and in particular appear to be largely confined to areas within the boundary of the site(s). Measures that lead to the loss of existing Natura 2000 habitat (and species) may not be **legally** appropriate. Particular concern is raised about those measures that involve changing inter-tidal habitat into sub-tidal habitat.

2b.3. Although the EC has emphasised that no hierarchy exists between the various environmental Directives it is important to bear in mind that the most demanding objectives take priority. In this respect, achieving favourable conservation status for Birds and Habitats Directive attributes is likely to be the highest priority. In the UK, where I am most familiar with the relationship, this means that measures to meet WFD objectives cannot be pursued to the detriment of the Birds and Habitats Directive objectives. An alternative interpretation may be followed in Germany.

2b.4. Using high level objectives relating to the extent of habitat within the Natura 2000 site, it becomes clear that proposed measures within the RESMC are unlikely to be **legally** appropriate. However, it is also recognised that interpretations of the Directives may differ between Member States and that the German view may be at variance with UK experience. However, the Waddensee Cockling judgement is apposite and must be taken into account when making any assessment. It is important to remember that this Directive is highly precautionary - it must be proven that there will **not** be an adverse affect on the Conservation Objectives for the site(s).

Q2c. ***What is the assessment of the objective 'reducing cyclical dredging ' as a sediment management strategy in view of the requirements of the WFD, MSFD and Habitats Directive?***

2c.1. In principle, the objective of reducing cyclical dredging is a sound one and is not incompatible with the objectives of the various environmental objectives.

2c.2. Measures to achieve this may, however, involve changes to the geometry of the Elbe Estuary. These may have a bearing on the distribution and extent of Natura 2000 habitats and species, and consequently the overall package of measures is unlikely to meet the test 'can it be ascertained that there will not be an adverse affect on the Conservation Objectives'. (see Q2e.)

Q2d. ***Does the paper 'Waterways and Ports' in the Lower Elbe Integrated Management Plan, along with the measures presented there concerning optimization of maintenance dredging, represent an appropriate basis for implementing the Habitats Directive from a European perspective?***

2d.1. This paper has not been prepared as far as I am aware, and consequently it is not possible to comment on the paper itself. Analysis of the issues based on a paper drafted by Gűnther Eichwebber highlight the main problem; that the RESMC has progressed at a pace that far outstrips the progress by the three Länder who are responsible for preparation of the nature conservation components of the plan.

2d.2. The most significant impediment to the development of a dredging strategy is the degree to which

Natura 2000 designations are fragmented. Figures provided by Bioconsult indicate that there are 14 SAC and 5 SPA. At the moment, each will have Conservation Objectives but they may bear little resemblance to one another and the absence of any over-arching geomorphology- based principles means that further confusion is inevitable. Supplementary information supplied in July 2011 indicates that estuary-wide objectives have been agreed. These will help to resolve conflicting objectives for individual sites.

2d.3. It is important to bear in mind that the 'Integrated Plan' is a non-statutory document and as such does not form a legal basis for managing the estuary. This approach seems to be analogous to 'Estuary Management Plans' prepared in the UK in the 1990s, although the application of specific statutory powers may mean that there are parallels with Regulation 34 'Management Schemes' that have been prepared for European Marine Sites in the UK. Experience with both has given mixed results.

2d.4. Creation of new inter-tidal habitats may also be a small but useful positive contribution towards carbon sequestration, as saline mudflats and green foreshore has been shown to act as a carbon sink (e.g. Andrews *et. al*., 2008). Wider environmental benefits can therefore be gained from the total package developed around the objective of reducing cyclical dredging. However, these alone cannot be used to justify loss of Natura 2000; any losses would have to be offset by new habitat creation.

2d.5. Dredgers and associated equipment emit considerable levels of greenhouse gasses and consequently there is a great deal of sense in seeking a long-term reduction in dredging demands as part of a long-term climate change mitigation strategy

Q2e. ***What is the overall assessment of the RESMC and the measures specified there with respect to the objectives of the WFD, MSFD and Habitats Directive?***

2e.1. The RESMC focuses on the need to reduce dredging costs and the cost of remediation of contaminated sediments. Consequently, most confluence lies between the RESMC and the Water Framework Directive. However, it must be remembered that WFD objectives cannot be pursued without reference to the issues relating to both the Birds and Habitats Directives and the Marine Strategy Framework Directive.

2e.2. The RESMC appears to have been developed without access to the information needed to make sure that proposed measures conform to the requirements of the Habitats Directive. Consequently, this analysis concludes that it does not conform to the requirements of Natura 2000. Analyses at various stages relating to this and other questions highlights the major problem: that many measures will lead to significant loss of existing Natura habitat and creation of habitat that may or may not be of comparable value. At least in the short to medium-term the impacts will be highly detrimental.

2e.3. An impression is gained that the highest level of attention has been paid to problems with the breeding success of the protected fish *Allosa fallax* - the Twaite Shad or 'Red Herring'. This may have deflected attention away from the broader issue that shallow inter-tidal is linked to the extent of inter-tidal mudflats and green foreshore; which in turn is related to the extent of accommodation space.

2e.4. Measures that lead to an increase in accommodation space are highlighted as the most likely to be consistent with the requirements of the Habitats and Birds Directives; provided they do not lead to the loss of extent of another habitat. Consequently, the most promising proposal from this perspective is the Borstelle Biennenelbe, and the least appropriate is Haseldorfer Marsch.

Q2f. ***Are conflicts regarding objectives between protection of the estuary and marine protection***

reduced by virtue of the RESMC?

2f.1. The RESMC changes the nature of the conflicts. It may reduce levels of contaminated sediment entering the marine environment but in doing so it will exacerbate conflicts between nature protection and navigation.

2f.2. The most helpful way of determining whether the RESMC is consistent with the objectives of the Water Framework and Marine Strategy Framework Directives is to make sure that it meets the requirements of the Habitats Directive. This is because a significant component of EU environmental sustainability centres on the need to deliver favourable status [Favourable Conservation Status (FCS) - Habitats and Species; Good Environmental Condition (GEC) or Good Environmental Potential (GEP) - WFD]. A package of measures that takes a site or habitats away from Favourable Conservation Status will not meet GES or GEP because the habitats and species have been pushed further away from FCS.

Q3. Overall Assessment

Q3a. ***Are the objectives of the RESMC formulated in the work order sensible in your opinion, also in view of the situation in other European estuaries?***

3a.1. All of the objectives set by the RESMC in relation to volumes of dredging and levels of contamination make sense and can be reconciled with many strategic priorities within the Elbe estuary. They are consistent with other European estuaries in relation to sediment contamination remediation. It must therefore be concluded that the **strategic direction** of the RESMC is correct and that the objectives set provide a sound foundation for the development of specific measures.

3a.2. There is, however, considerable potential for conflict between strategic dredging objectives and objectives relating to nature conservation and other uses/activities within the Elbe estuary. In this respect, the RESMC differs from the most other established packages of measures used to manage estuaries as an entity.

3a.3. The most comprehensive packages in this respect emanate from the UK where assessment of dredging is made in combination with measures to remediate nature conservation problems and flood risk management. The strategic framework developed in the UK offers a model that is worthy of further examination.

Q3b. ***Do the measures outlined in the RESMC represent overall the right way to achieve the objectives? Are the aspects of nature conservation, water protection and marine protection given appropriate and equally weighted consideration?***

3b.1. There are a variety of possible benefits and drawbacks that may arise from the overall package of measures. If the total package were to be implemented it is difficult to see how the relevant environmental legislation will be satisfied.

3b.2. It would be inappropriate, however, to judge the RESMC without recognising the very peculiar circumstances that HPA and WSV face. The estuary is huge; it is much larger than the majority of other northern European estuaries whose management may be used to inform the analysis. Furthermore, the development of the RESMC has not been helped by what appears to me to be a fragmentary approach to development of the 'Integrated Plan' for the Elbe estuary.

3b.3. The conceptual thinking behind the RESMC has many merits, and the suite of possible options is

sufficiently comprehensive to generate debate. In this respect it is therefore an important advance and offers the basis for future dialogue and options development.

3b.4. **However**, some of the options will lead to loss of Natura 2000 habitat that cannot be regarded as viable from a strictly legal perspective.

3b.5. At this stage, it must therefore be concluded that the RESMC has identified a series of measures that maybe appropriate to delivering the sediment management objectives sought by HPA and WSV, but are inappropriate to delivery of Habitats and Birds Directive objectives, and by inference the objectives of the Water Framework and Marine Strategy Framework Directives.

4. **Q3c.** ***Recommendations for the further development of the RESMC.***

3c.1. A three stage approach to further development is suggested.

- In the short-term the issues relate to relationships with the Länder and development of a common vision.
- In the medium-term the focus should be on sensitivity testing and development of a clear understanding of the impacts of proposed remedial measures in the RESMC.
- Finally, live projects should focus on creation of new freshwater wetlands that will act as sinks for suspended sediment and will yield broader flood management and nature protection benefits.

3c.1. It is suggested that the model developed by the UK Marine SACs LIFE projects might form the basis for discussion with the Länder. However, it would not be appropriate to simply copy the UK approach. A German solution is needed.

3c.3. The critical issue for development of an integrated plan is the provision of a clear relationship between the different components. A plan developed as a series of independent units will never be 'integrated' because each party will simply follow its bit of the plan and over time will diverge further and further from any consideration of related issues . A model for the relationships is provided.

3c.4. It is recommended that the high-level framework for managing the Elbe Estuary should be geomorphologically driven. Simple 'Regime' analysis combined with existing knowledge of the way the system functions should help to explain the relative sensitivities of the estuary to interventions. The model of best practice is arguably the Humber Estuary Flood Risk Management Strategy (Planning for the Rising Tides). This approach should help to climate-proof the 'integrated plan'.

3c.5. Where physical changes are made to the location and structure of flood defences experience has shown that the case for change should focus on social and economic benefits rather than the nature protection issues.

1. Introduction

1.1. Hamburg Port Authority and WSV have appointed an Expert Group to evaluate their River Engineering and Sediment Management Concept for the Tidal River Elbe. Each evaluation has been set a series of specific focussed questions.

1.2. This report is structured according to the three principal questions and 10 sub-questions. It follows analysis of the documentation provided and additional research using internet-based information and reports available in my library. Sources are referred to as appropriate and are listed at the rear of the document.

1.3. The interpretations provided in this analysis must be accompanied by the **strong caveat that different Member States interpret the Directives according to their own domestic legislation**. This can have a significant bearing on decision-making. Furthermore, the national policy framework differs between Member States, and what may be anathema to one may be more acceptable to another. This means that where judgements have been made in this report, it is possible that conservation officials may not agree with the interpretations given.

1.4. The policy drivers in the UK that have always influenced my interpretations derive from English Nature's '*Campaign for a living coast*' in the early 1990s. This established the principle that wherever possible wildlife sites should be subjected to natural processes rather than engineering interventions to retain attributes in a particular place. This has led to the use of soft engineering solution such as managed realignment (de-poldering) and sediment feeding to offset the impacts of previous and ongoing engineering interventions. The approach is strongly driven by the application of geomorphological principles that often fail to register in the minds of many nature conservation professionals whose origins start on land where management involves deliberate intervention to maintain a desired state. As far as I can determine, a similar stated policy line has not evolved in other northern European states even though many of the principles are broadly embraced.

1.5. The application of geomorphological principles to coastal Natura 2000 sites in Europe seems to be less well understood and I am not sure about the degree to which the statutory or voluntary bodies in Germany embrace such approaches. It may therefore be the case that some interventions that I believe to be inconsistent with the Water Framework, Birds and Habitats Directives may be regarded as more acceptable in Germany.

2. Relevant environmental legislation

2.1. Council Directive 2000/60/EC establishing a framework for Community action in the field of water policy (The Water Framework Directive 9WFD)]

2.1.1. The objectives of the Water Framework Directive are to:

- Enhance the status and prevent further deterioration of aquatic ecosystems and associated wetlands, which depend on the aquatic ecosystems.
- Promote the sustainable use of water.
- Reduce pollution of water, especially by 'priority' and 'priority hazardous' substances (see Daughter Directives).
- Ensure progressive reduction of groundwater pollution.

Source Defra website: http://www.defra.gov.uk/environment/quality/water/wfd/

2.1.2. Key provisions of the Water Framework Directive:

- It should be transposed into the legislation of Member States by 22 December 2003.
- Member States are expected to develop programmes of measures to reach good chemical and ecological status in inland and coastal waters by 2015.
- Provisions are made to recognise the fact that some water bodies have been heavily modified by human activities (Heavily Modified Water Bodies) and some are artificial. Targets set for these water bodies are less onerous than those for unmodified water bodies, but are never-the-less extremely demanding.
- River Basin Districts are defined as the as the planning framework for management (Article 3).
- Article 5 required characterisation and reporting on River Basin Districts by 22 March 2005. It sought a detailed analysis of the characteristics of their river basin districts, including a review of the pressures and impacts of the human activity on surface and groundwater, and an economic analysis of the use of water.
- Member States are required (Article 8) to have established operational monitoring programmes by 22 December 2006 and to report to the Commission by 22 March 2007 (Article 15).
- Reporting of River Basin Management Plans, including the programme of measures should be submitted by 22 March 2010.

2.2. Council Directive 2009/147/EC on the Conservation of Wild Birds (Birds Directive)

2.2.1. The main provisions of the Directive include:

- The maintenance of the populations of all wild bird species across their natural range (Article 2) with the encouragement of various activities to that end (Article 3).
- The identification and classification of Special Protection Areas (SPAs) for rare or vulnerable species listed in Annex I of the Directive, as well as for all regularly occurring migratory species, paying particular attention to the protection of wetlands of international importance (Article 4). (Together with

Special Areas of Conservation designated under the Habitats Directive, SPAs form a network of European protected areas known as Natura 2000).

(Source JNCC website http://www.jncc.gov.uk/page-1373)

2.2.2. For the purposes of this analysis the legal means of managing Special Protection Areas is largely provided by the 'Habitats Directive.

2.3. Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (The Habitats Directive)

4.3.1. The provisions of the Directive require Member States to introduce a range of measures, including:

- Maintain or restore European protected habitats and species listed in the Annexes at a favourable conservation status as defined in Articles 1 and 2.
- Contribute to a coherent European ecological network of protected sites by designating Special Areas of Conservation (SACs) for habitats listed on Annex I and for species listed on Annex II. These measures are also to be applied to Special Protection Areas (SPAs) classified under Article 4 of the Birds Directive. Together SACs and SPAs make up the Natura 2000 network (Article 3).
- Ensure conservation measures are in place to appropriately manage SACs and ensure appropriate assessment of plans and projects likely to have a significant effect on the integrity of an SAC (& SPAs). Projects may still be permitted if there are no alternatives, and there are imperative reasons of overriding public interest. In such cases compensatory measures are necessary to ensure the overall coherence of the Natura 2000 network (Article 6).
- Member States shall also endeavour to encourage the management of features of the landscape that support the Natura 2000 network (Articles 3 and10).

(Source JNCC website: http://www.jncc.gov.uk/page-1374)

2.4. Council Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)

2.4.1. The provisions of the Directive require Member States to introduce a range of measures, including:

- Development of a marine strategy for its marine waters in accordance with the plan of action.
- Determine, for the marine waters, a set of characteristics for good environmental status, on the basis of the qualitative descriptors listed in Annex I.
- Establishment of a comprehensive set of environmental targets and associated indicators for their marine waters so as to guide progress towards achieving good environmental status in the marine environment, taking into account the indicative lists of pressures and impacts set out in Table 2 of Annex III, and of characteristics set out in Annex IV.
- Publish proposals for a coherent network of Marine Protected Areas by 2013.

2.4.2. This Directive sets very few absolute requirements apart from the need to establish a coherent network of Marine Protected Areas by 2013. Consequently, it would appear that the MSFD is unlikely to figure highly in the development of the RESMC which is largely served by the WFD, Habitats and Birds Directives. **The possible exception is**

how any German strategy might affect the use of the dump site at Buoy E3.

2.5. A central part of this analysis relates to the relationship between the RESM and the EC Birds Directive (2009/147/EC - replacing 79/409/EEC), Habitats Directive (92/43/EEC) and Water Framework Directive (2000/60/EC). In addition, the implications of the Marine Strategy Framework Directive needs to be considered. All three of the key Directives (Birds, Habitats & Water Framework) require Member States to deliver environmental improvements, variously described as Favourable Conservation Status ((HD), Good Environmental Status (WFD/MSFD) or Good Environmental Potential (WFD). Assessment of the contributory factors involves a variety of critical parameters *inter-alia*:

- Water quality
- Sediment quality
- Hydro-morphological modifications
- Impacts on Annex 1 habitats (under the Habitats Directive)
- Impacts on Annex II species (under the Habitats Directive)
- Impacts on Annex I birds (under the Birds Directive)
- Impacts on migratory waterfowl populations (under the Birds Directive)

2.6. The implications of the RESMC to European environmental legislation embraced in the Habitats Directive and the Birds Directive require particular attention because these Directives have had a significant bearing on port management in the past ten years. Both affect new projects to improve capacity and navigability in fairways (navigation channels), as well as ongoing measures to maintain fairways through the application of Article 6 of the Habitats Directive. In this respect it is important to bear in mind that the tidal components of the Elbe Estuary and its hinterlands comprises 19 Natura 2000 'sites' designated under one or other Directive:

Number	Name	Länder
HD 2527-303	Borghorster Elbe region	City of Hamburg
HD 2526-304	Kirckwerder Wiesen	City of Hamburg
HD 2526-305	Lower Elbe Hamburg	City of Hamburg
HD 2424-303	Asp sanctuary tidal Elbe Hamburg	City of Hamburg
HD 2424-302	Neßsand & Műhlenberger Loch	City of Hamburg
HD 2526-302	Heuckenlock & Sweenssand	City of Hamburg
HD 2526-331	Seeve	Lower Saxony
HD 2627-301	Zollenspieke & Kiebitzbrack	City of Hamburg
HD 2626-331	Luhe & the Lower Neetze	Lower Saxony
HD 2306-301	National Park Lower Saxony Wadden Sea	Lower Saxony
HD 2016-301	National Park Hamburg Wadden Sea	City of Hamburg
HD 2018-331	Lower Elbe	Lower Saxony
HD 2323-392	Elbe Estuary of Schleswig-Holstein and adjacent areas	Schleswig-Holstein
HD 0916-391	National Park Schleswig-Holstein Wadden Sea and adjacent coastal areas	Schleswig-Holstein
BD 2121-401	Lower Elbe	Lower Saxony
BD 2110-401	Wadden Sea Lower Saxony and adjacent coastal areas	Lower Saxony
BD 2526-402	Lower Seeve & lower Luhe-llmenau lowland	Lower Saxony
BD 0916-491	Ramsar Site Wadden Sea Schleswig-Holstein and adjacent coastal areas	Schleswig-Holstein
BD 2323-401	Lower Elbe to Weddel	Schleswig-Holstein

In addition, there are two sites that do not appear to be connected to the tidal Elbe, but which lie within the 5km corridor:

HD 2527-302	Dalbeckschlucht	Schleswig-Holstein
BD 2524-401	Marsh near Buxtehude	Lower Saxony

2.7. Conservation objectives for the various sites and details of the specific habitats present are not available in documentation supplied, although they are available in summary version. I have not attempted to compile a full list of the relevant habitats and species but the following appear to be the most significant:

Annex I Habitats:

H1130 Estuaries
H1140 Mudflats and sandflats not covered by seawater at low tide
H1330 Atlantic salt meadows (Glauco- Puccinellietalia maritimae)
H3270 rivers with mud banks with vegetation of *Chenopodion rubri* p.p. and *Bidention* p.p.
H6430-1 moist tall forb fringes of the Lower Elbe
H91E0 floodplain forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion,Alnion incanae, Salicion albae*)
H91F0 Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)

Annex II species:

ElbeWater Dropwort *Oenanthe conioides* (priority species)
River Lamprey *Lampetra fluviatilis*
Sea Lamprey *Petromyzom marinus*
Twaite Shad *Alosa fallax*
Asp *Aspius Aspius*
Salmon *Salmo salar*
Spined Loach *Cobitis taenia*
Great Crested Newt *Triturus cristatus*

Birds

Species listed on Annex I of Council directive 79/409/EEC
Regularly occurring Migratory Birds not listed on Annex I of Council directive 79/409/EEC

2.8. The Water Framework Directive (WFD) was establish to provide a framework for the protection of inland surface waters (rivers and lakes), transitional waters (estuaries), coastal waters and groundwater. The objectives focus on ensuring that all aquatic ecosystems within the terrestrial and near-shore coastal environments meet 'good status' by 2015.

2.9. The WFD makes allowances for several levels of anthropogenic modification, requiring those water bodies that are judged to be relatively un-modified to meet 'good ecological status' whereas 'heavily modified water bodies' that are expected to achieve 'good ecological potential'. Dredging and sediment management have a variety of implications for the potential to achieve either 'good status', however these are greatly complicated by long-term historic impacts of contamination, largely arising in the headwaters in the headwaters in the Czech Republic and Slovakia.

2.10. The Marine Strategy Framework Directive is relatively new. It defines European Marine Regions on the basis of geographical and environmental criteria and requires each Member State to develop strategies for their marine waters, in co-operation with neighbouring states. The Directive focuses on the establishment of mechanisms to improving management of the marine environment to achieve Good Environmental Status. It places few absolute demands on Member States apart from Article 13, which requires publication of proposals for a coherent network of MPAs by 2013. In this respect, it seems likely that most of the provisions of the MSFD will be met in the Elbe by existing designations which cover it almost in its entirety.

2.11. Assessing the conformity of the RESMC to the requirements of the Birds, Habitats and Water Framework Directives is heavily dependent upon the way in which the Länder and the Federal Authorities interpret these Directives and apply particular policies to relevant influences. A key part of this is the degree to which these authorities seek to establish a tidal estuary with characteristics driven by the physical processes that govern natural systems or by engineering modifications that will achieve a particular set of objectives. For example, major engineering modifications such as tidal exclusion barrages, sills or throttles may achieve the desired effect of reducing tidal propagation, but may be contrary to policy drivers seeking the establishment of physical processes that replicate those normally found in the coastal environment. Such modifications may also have a strong bearing on whether the estuary is judged to be driven closer to 'good ecological potential' or 'good ecological status' according to the degree of modification that is judged to have taken place.

3. Question 1a. *What is the assessment of the influence exerted by past expansion, river engineering and dredging strategy on the present-day ecological situation?*

3.1. From evidence provided in briefing documents, a clear relationship can be discerned between changes to the geometry of the Elbe Estuary and tidal propagation (Figure 1). As part of the analysis of these impacts, particular attention has been paid to Google Earth to explore the modern estuarine form and features that are potentially important. Brief notes are provided on the various interventions and their geomorphological implications. This is important because the current ecological situation is strongly influenced by the geomorphological changes. Ecological implications are discussed in section 3.5.

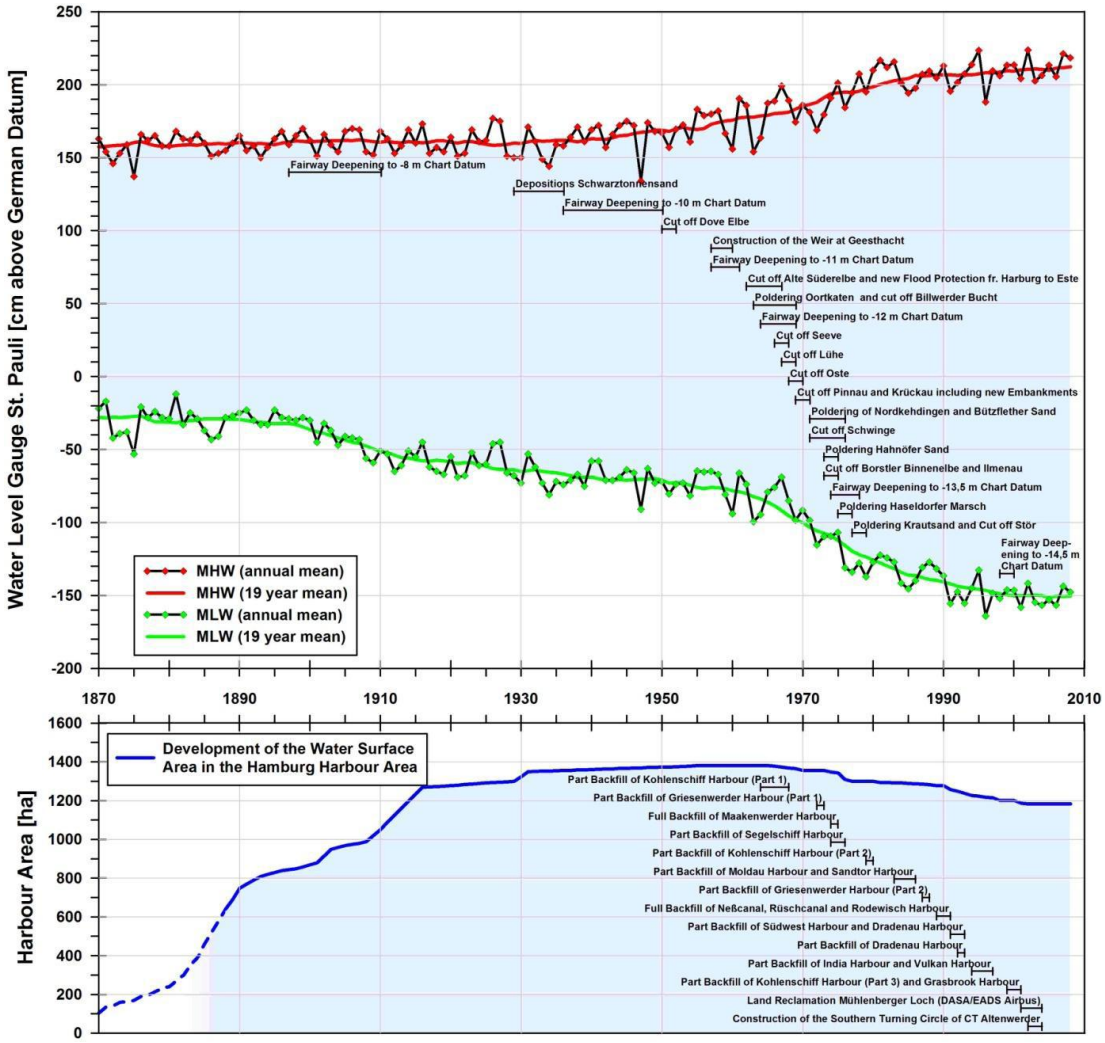

Figure 1. Morphological changes within the Elbe Estuary and the resulting changes to tidal propagation.

- **Weir at Geesthact** - this will have reduced the volume in the tidal prism. Available

information is insufficient to disaggregate this development from channel deepening from -10m CD to - 11m CD which took place around the same time. It is possible that the influence of the weir has a limited impact as it is a very long way upstream. This would also appear to be the first major impediment to movement of migratory fish within the River Elbe.

- **Removal of tributaries** - this has reduced the volume in the tidal prism. It is potentially quite significant as there are numerous tributaries along the tidal Elbe. Many of these appear to have control structures at their mouths rather than being completely cut off. Reduction in tidal prism would have led to an increase in sediment import. There are numerous analogues: the Dee, Ribble and Tees are obvious examples. In the case of the Dee and the Ribble (see EMPHASYS Consortium, 2000), infilling has led to the evolution of inter-tidal features that are themselves regarded as important wildlife features. On the Tees, the change is more recent (completed in 1995) and has been followed by sedimentation on Seal Sands that has changed its position in the tidal frame and has given rise to concerns that it will not perform the same ecological function as SPA habitat.

- **Meanders or braiding cut off** (e.g. Borsteller Binnenelbe/Hahnöfersand) - this has effectively turned the tidal river into a canal rather than a braided system. This would have reduced the volume in the tidal prism and would also have forced the estuary to become a single channel system in many places. This may be responsible for some of the extreme reductions in low tide levels.

- **Berthing basins** - within the port of Hamburg between 1890 and 1960 some 800 ha of additional berthing basins have been created. This would have increased the tidal prism by around 24 million cubic metres (at current tide levels circa 800ha x 3 metres tidal range). It is uncertain how much this would have offset other losses. However, since around 1967 infilling covering some 200 ha has reduced the tidal prism by approximately 6 million cubic metres and will have promoted greater flood dominance (albeit a tiny contribution).

- **Loss of accommodation space** - sea walls and summer dykes. This would have reduced the tidal prism on the biggest tides. The implications of this are complex. Accommodation space absorbs extra volume and therefore reduced space has the potential to increase funnelling effects, leading to elevation of high tide levels. But, this effective canalisation takes the system closer to its Regime form. In the longer term, and especially in the face of elevated tide levels, the capacity for sedimentation on the highest tides has been reduced. There is a possibility that this has a bearing on the levels of sediment in the estuary that can be re-mobilised on subsequent tides.

  Loss of accommodation space also leads to increased wave energy imparted on saltmarshes (green foreshore or summer dykes) which in turn can lead to erosion. This is referred to as 'coastal squeeze in the UK. This relationship is partially governed by sediment loads within the water column. In UK estuaries coastal squeeze is a major problem, often undermining sea walls. I am unfamiliar with the degree to which coastal squeeze influences German estuaries. Those I have seen tend to be quite heavily stoned to prevent erosion. Stoning also influences the extent of mudflat and saltmarsh and consequently will have a bearing on the ecology of the estuary.

- **Channel deepening** - at least 6 events that have taken the estuary from less than -8 CD to -14.5CD. The most critical changes appear to be the four dredging campaigns between 1958 and 2000 that saw the estuary deepened from -10CD to -14.5 CD. This has shifted the estuarine system far away from its 'Regime' form and tends to establish a single channel with deeper water, less hydraulic friction and hence greater tidal propagation. Increased tidal propagation leads to higher volumes of sediment entering the system and hence more sediment available for deposition in the sub- and inter-tidal. Greater saline intrusion also leads to flocculation further upstream and the deposition of thixotropic sediments in places where they might not previously have deposited. Effective loss of braiding means that side channels silt up and sediment sorting is less effective. This could be partially responsible for loss of sandy and gravelly habitats favoured by shads.

- **Groyne fields** - not shown on the diagram above. Sediment accumulates between the groynes, narrowing the channel and reducing the tidal volume. There is what appears to be a series of very long groynes north of Weddel that have led to considerable narrowing of the channel and advancement of mudflats at this point. Similar fields upstream from the Zollenspiecker Ferry do much the same thing. These must have reduced the tidal prism and hence would be contributing to the overall shift towards flood dominance and increased sedimentation.

- **Reclamation** - e.g. airbus factory at Mühlenberger Loch. Reduction in the tidal prism effectively shortens the estuary and contributes to an increase in flood dominance. The Airbus site involved the loss of 171ha of freshwater tidal mudflats designated as Ramsar, SAC and SPA and was consented on grounds of imperative reasons of over-riding public importance (IROPI). According to a REMEDE study (2008) the area of mudflat that was lost was the most productive part of the overall Natura site.

- **Deepening for seaplane station** - this would have led to an increase in tidal volume and would have formed a subsequent sediment sink once it ceased to be maintained.

- **Realignment at Hahnöfersand (compensation for the airbus factory)** - involving 100 ha of new inter-tidal will have created a small increase in tidal prism. This is a small positive adjustment that will have partially neutralised the geomorphological implications of the loss of volume within Mühlenberger Loch caused by land-claim to build the airbus factory (171ha). There are also important biological benefits with the creation of new mudflat, macrophyte communities and fringing riverine forests, but as will be noted later the measure was not sufficient to compensate for the loss of the mudflat at Mühlenberger Loch and it has failed to reach target populations of feeding migratory waterfowl (REMEDE, 2008).

- **Sediment placement within the tidal Elbe** - this practice largely minimises loss of sediment from an estuary and has geomorphological benefits.

- **Removal of sediment an placement on land** - effectively creates a sediment sink that pushes the sediment budget into deficit, or encourages further sediment import as the estuary strives to reduce tidal volumes in order to assume a 'Regime' form (see ABPmer, 2009).

2.2. **Geomorphological implications of the interventions listed above.**

3.2.1. Shortening of the tidal system decreases the time it takes for the tide to enter and lengthens the ebb duration. This increases tidal propagation and in particular leads to increased potential for sediment import and deposition because scouring effects of ebbing tides are lower. This is classic application of the O'Brien Rule (O'Brien, 1931, 1969) which argues that the relationship between the width of the mouth and the tidal prism is intimately linked. If the tidal prism is reduced then the mouth width also needs to narrow. To do this, the channel geometry also needs to change i.e. get shallower, and consequently sediment deposition can be expected. This relationship applies at any point within the tidal system and so it is not surprising that inter-tidal is gradually filling with sediment. These principles can be used in a simple model - Regime Model - see Spearman *et al*., (1996) and Wright & Townend (2006). The Regime model is described by Pethick & Lowe (2000).

3.2.2. Channel deepening reduces hydraulic friction, allowing tidal water to travel upstream more quickly and hence more water can enter the estuary and this increases upstream water levels. In some circumstances, deepening also facilitates faster drainage and hence lower low tides. This is clearly the case in the Elbe where the first channel deepening (to -8 CD) around the end of the 19th Century clearly precipitated lower low tides.

3.2.3. Rapid changes to the morphology of the Elbe Estuary from around 1958 onwards emphasise the relationship between tidal propagation and morphological interventions. Reductions in the available tidal prism through poldering and cutting off tributaries combined with four episodes of channel deepening are evidently the main reason for modern problems.

3.2.4. Changes to estuarine geometry can take a while to fully express themselves as the system does not adjust over night. Furthermore, it will undergo additional episodic adjustments as maintenance dredging returns the thalweg to the geometry that was imposed at the last deepening. It is therefore difficult to be sure that the level of change to tidal propagation as a consequence of previous modifications has fully expressed itself. Sedimentation in shallower waters will have a bearing on this, but this is causing reportedly undesirable ecological changes and needs to be addressed.

3.2.5. Evolution of estuarine geometry is closely related to the availability of sediment and consequently dredging regimes can have a profound impact on coastal evolution. The issue of sediment budgets is discussed in Section 4 (e.g. 4.7.4.) but in essence two scenarios can be described: the first involves loss of sediment that encourages erosion of inter-tidal and some sub-tidal sources. It is possible that some changes to the geometry of the mouth of the Elbe may be related to long-term removal of sediment from the system. Conversely, where sediment loads are high they contribute to evolution of the estuarine geometry, largely in the form of in-filling and vertical accretion within mudflats and green foreshores (saltmarshes and freshwater macrophyte communities).

3.3. There are a variety of analogues that can be used to help to verify the correlation between the changes to the geometry of the Elbe Estuary and tidal propagation and physical responses.

Such analogues simply provide an indication of how a system will respond at a macro-scale and cannot be used to explain localised responses. This is a form of modelling that provides the underpinning rationale used by modellers to develop mathematical models normally used to assess the likely responses to particular interventions (see Whitehouse *et al*., 2009) and it is therefore a simple way of explaining responses to non-specialists who may not understand why particular responses have occurred.

3.3.1. Analogues for shortening estuaries include the Ribble (UK), Dee (UK), Somme (France) and Tees (UK). They all exhibit similar characteristics of net sediment import, with expansion of mudflats, sandflats and green foreshore. In most of these examples, the end result has generally been favourable to modern conservation policy because it has created extensive new mudflats and saltmarshes. However, in strictly geomorphological terms the impacts can be regarded as a major anthropogenic perturbation.

3.3.2. Analogues for channel deepening are best represented on a small number of northern European estuaries: the Ems (Germany), Seine (France) and Western Schelde (Netherlands/Belgium) are the most extreme and potentially the most useful. Significantly reduced low tides are common to the Ems and the Seine, whereas the Western Schelde does not exhibit this feature so markedly. The Ems provides a further important analogue because 'tidal pumping' here also involves significant levels of sediment re-mobilisation that leads to major oxygen sags in summer months; this has serious impacts on water quality, benthic and pelagic organisms, and especially fish. Some of the problems on the Elbe may also be linked to fine sediment re-mobilisation. This is a poorly researched issue but similar oxygen sags are noted in the Humber Estuary around Trent Falls where tidal propagation can be sufficiently fast to create a 'bore'.

3.3.3. The Western Schelde is a useful analogue in relation to loss of braided channels. So far, the Western Scheldes braided channels have not ceased to operate independently on flood and ebb tides. This is a possible factor behind the degree to which this estuary has not seen a marked reduction in low tide heights (De Vrien - presentation at WWF Ems Conference in December 2010). The loss of braiding is possibly critical to the way an estuary will respond to channel deepening. In the case of the Elbe, four episodes of channel deepening from the mid-1960s have been interspersed with a combination of reduced braiding, poldering and reducing tributary inputs, all of which constrain accommodation space.

3.4. Implications of geomorphological changes on estuarine ecology

3.4.1. Increased tidal propagation and corresponding changes in tidal incursion will have had considerable influenced the ecology of the Elbe Estuary. In particular, there will have been significant changes to (*inter-alia*):

- Saline incursion.
- Marine sediment import and re-mobilisation.
- Spatial distribution of sediment deposition.
- The extent and type of inter-tidal habitats.
- The degree and duration of exposure of inter-tidal habitats.
- Sustainability of particular biotopes.

- Fish passage and spawning sites.

3.4.2. These changes have taken place over many decades and largely happened prior to the implementation of the various EU environmental directives. Consequently, the designated sites have been listed despite the negative impacts of the multiple morphological changes. It is therefore important to bear in mind the separate issues of maintaining existing ecological attributes that were recognised as importance during designation as SAC and SPA, as well as any measures to improve and restore ecological attributes.

3.4.3. There are four critical ecological influences that will have a long-term bearing on the ecology of the Elbe Estuary:

3.4.3.1. **Loss of accommodation space** means that there is much less scope for sedimentation and removal of fine sediments from the water column. This means that the natural sediment (and pollutant) sink has been lost. The reduced tidal prism means that the estuary has become comparatively canalised; lacking natural backwaters that support emergent macrophyte communities (FFD H6430) and tidally influenced wetlands such as reedswamp and floodplain forests (FFD H91E0). Some of this canalisation may also contribute to increased tidal propagation and sediment mobilisation.

3.4.3.2. **Loss of nutrient sinks and related primary productivity** associated with tidally influenced macrophyte communities means that elevated nutrient loads associated with agricultural run-off cannot be absorbed naturally. It is important to bear in mind that the relative absence of tidal macrophyte communities may limit some aspects of estuarine productivity because lower levels of decaying vegetation are present than would have been the case in a more natural estuarine basin. Studies in the Bay of Fundy have shown that decaying *Spartina alterniflora* stems are an important contributor to productivity within the water column and mudflats. In addition, studies of Thick-lipped Mullet *Chelon labrosus* (Laffaille *et al*., 2002) show that organic matter in mudflats contributes substantially to the food source of this species. Shortfalls im macrophyte communities on the Elbe are therefore likely to have had an important bearing on fish populations, including shads.

3.4.3.3. **Loss of shallow sub-tidal habitats** as a result of channel deepening has removed the environment in which economically and ecologically important species such as shads will spawn.

3.4.3.4. **Greater sediment mobilisation** as a consequence of the acts of maintenance dredging and disposal, and also as a result of elevated tidal energy. This means that contaminants are re-mobilised and organic matter is placed in the water column, increasing demand on dissolved oxygen.

3.4.4. It must be borne in mind, however, that some of the changes will have led to alternative ecological benefits that are now valued in their own right. For

example, removal of tidal wetlands for use as pasture creates short swards favoured by some feeding migratory geese such as the dark-bellied brent goose *Branta bernicla* and greylag goose *Anser anser*. These damp grasslands can also be important for breeding waterfowl, especially waders.

3.4.5. It must also be recognised that the geomorphological changes specific to the Elbe and Ems have some positive implications in relation to climate change and sea level rise. These changes are not, however translatable to all estuaries as shown in table 1 (see section 4) which illustrates how dredging can also cause sediment shortfalls and net export offshore.

3.4.5.1. Higher sediment mobilisation and import has increased sedimentation and where realignment into former accommodation space takes place there will be rapid accretion. This should lead to increased extent of tidally influenced wetland habitats. This situation is preferable to those estuaries where accommodation space has been lost and there are low sediment loads that limit the development of saltmarsh or tidal macrophyte communities (see photograph 1).

3.4.5.2. There would appear to be no shortfall of sediment in the Elbe to allow tidal wetlands to gain elevation in response to sea level rise. This may also have played an important part in allowing the estuary to adjust to increased tidal propagation and therefore has played an important part in the ecological response to channel deepening.

3.4.5.3. In geomorphological terms, increased sedimentation of existing inter-tidal and shallow sub-tidal habitats is analogous to sedimentation in the Dee and Ribble Estuaries that have led to changes in the distribution of habitats. The changes that happened largely occurred long before the Habitats Directive and the resulting saltmarsh has been seen as a positive rather than a negative asset. On the Elbe, however, the over-riding message that seems to be highlighted in briefing documents and other analyses such as Heise *et al*., (undated) is that sedimentation is a deleterious influence. Care needs to be taken over this issue.

Photograph 1. Managed realignment site at Tollesbury, Essex, UK. This estuary carries relatively little suspended sediment and it has taken many years for the realignment site to develop saltmarsh vegetation. Even now. much of the 'green' cover is algae (*Enteromorpha*).

3.6. Overall assessment of the current ecological situation

3.6.1. Channel deepening and loss of accommodation space have contributed to important changes in the ecology of the tidal Elbe. The loss of tidally influenced macrophyte communities which drive much of the ecology of the system is arguably the most significant loss. These habitats act as a sink for sediments and nutrients, and generate biological refuse that drives productivity as it is broken down the following year. This loss has considerable knock-on implications for many of the organisms that contribute to the overall 'health' and productivity of the estuary.

3.6.2. The current distribution of habitats within and adjacent to the tidal Elbe differs greatly from those existing in the original floodplain. These habitats would have supported a different, and doubtless richer fauna. Some of the changes in fish breeding success may be attributable to these changes, but other more significant influences such as pollution levels, depressed oxygen availability and loss of spawning grounds are arguably as significant. In the case of Twaite Shad *Alosa fallax*, these influences combined with over-fishing are reported to be highly significant (Thiel *et al*., 2008).

3.6.3. The loss of natural meanders and braided channels means that the Elbe estuary in its modern form lacks many of the structural and functional features that might be expected in one the biggest estuaries in northern Europe. The changes are not the

same as those affecting , say, the Rhine (which is now an estuarine canal). But, they are very substantial and consequently it would be difficult to argue that the estuary as a whole meets the desired state of 'good ecological potential' in relation to the Water Framework Directive. Assessment of the system in relation to the Birds and Habitats Directives is greatly challenged by the degree of fragmentation associated with multiple designations; however, as with the WFD it is difficult to reconcile major loss of habitat and shortfalls in accommodation space with 'favourable condition'. Never-the-less, it must also be recognised that highly modified estuaries such as the Humber that have very limited saltmarsh (Morris *et al*., 2004) are currently listed as achieving favourable condition in reporting by Natural England[1].

3.6.4. Determination of whether a particular site or suite of sites meets the definitions of 'favourable conservation status' which can be translated at a site level to 'favourable condition' is dependent upon the judgements of the statutory nature conservation advisers. Their opinions have not been available during the course of this analysis. Consequently there is a need for additional input from the relevant advisors in Lower Saxony, the City of Hamburg and Schleswig-Holstein to inform the development of the RESMC . The absence of this guidance makes further development of the RESMC extremely difficult.

[1] Natural England is the UK Government's nature conservation advisor for England. It was formed by merging English Nature, the Countryside Commission and the Rural Development Service of Defra in 2006. Site condition is monitored and reported in accordance with UK Government targets for the condition of Sites of Scientific Interest (SSSI) - the national designation that underpins all SPA and SAC.

4. Question 2a. *How do sediment management concepts of other European estuaries take into account the requirements of the WFD, MSFD and the Habitats Directive?*

4.1. A review of available web-based information suggests that the issue of sediment management in relation to the Habitats and Birds Directives, the Water Framework Directive and the Marine Strategy Framework Directive is generally in its infancy in Europe. The greatest level of activity seems to be within the UK, on the Western Schelde and on the Elbe Estuary, so there are relatively few models to draw upon. A variety of ideas have also been proposed for remediation of the Ems Estuary; some of which resemble those proposed for the Elbe but many have been greatly scaled back from their original design. Several major port development cases might also be used to help to inform the development of a sediment management strategy for the Elbe.

4.2. The size of the estuary and the catchment of the fluvial discharge have an important bearing on the issues of concern. For example, the Rhine, Elbe or Danube have substantially bigger catchments than UK estuaries. These catchments may cover several Member States, some of which have historically pursued differing environmental standards that have a significant bearing on contaminant loads in the lower reaches of the fluvial system and within transitional waters.

4.3. Contaminated sediments have particularly worried water managers for a very long time, irrespective of recently introduced European legislation. Indeed, some of these concerns are drivers behind the Water Framework Directive.

4.4. The majority of sediment management initiatives on mainland northern Europe therefore appear to be linked to the problem of how to manage contaminants rather than compliance with European environmental legislation (although there may be national legislation that precedes European legislation). Of these, the Slufter at the Port of Rotterdam is a prominent example of isolation and containment of contaminated sediments once they reach a coastal port. This is an unusual and bespoke solution that might not be appropriate elsewhere.

4.5. Organisations such as Sednet and the Dutch-German Exchange appear to have largely focussed on fluvial sediments whereas many port-related sediment issues derive from marine sediments, sometimes compounded by primary contamination from fluvial sources. In the UK, sediment is primarily driven by marine sources because the rivers are relatively small and there are nearby coastal erosion means that coastal waters are often sediment-laden. These differences highlight a key difference in focus because UK engagement over dredging has largely concentrated on sediment budgets and the impact of deficits in sediment supply.

4.6. The cost f maintenance dredging is clearly a major consideration in many ports. This is especially significant for inland ports such as Antwerp and Hamburg which compete with ports in coastal locations such as Rotterdam, Bremmerhaven and Zeebrugge. Consequently, whilst recent environmental legislation has become a factor in the design of disposal schemes they do not appear to be the primary driver for new initiatives. For example, disposal of sand within the Western Schelde that serves the Port of Antwerp is necessary because the costs of disposal further seaward are prohibitively expensive.

4.7. Long-term environmental issues arising from navigation dredging.

4.7.1. Navigation dredging generates a variety of concerns amongst environmental managers. Some impacts such as noise and sediment plumes are transient, whereas others have a longer-term impact. Furthermore, some issues are directly related to the morphological changes imposed by channel deepening, whereas others involve broader matters such as sediment quality and re-mobilisation of contaminants.

4.7.2. Finding a long-term solution to managing sediment within the Elbe Estuary demands evaluation of all of the issues but the over-riding concern must be to addresses the principle geomorphological changes and associated responses. These changes lie at the heart of the problem and drive the estuary's demand for sediment. HPA and WSVs River Engineering and Sediment Management Concept (RESMC) is therefore appropriately focussed and recognises the principal drivers.

4.7.3. This analysis will therefore focus primarily on gromorphological manipulation and its implications for meeting the multiple requirements of the various EC environmental Directives. Issues relating to sediment quality are at the heart of separate expert evaluation.

4.7.4. Increased sub-tidal sedimentation and greater demands on the sediment budget for the estuary have led to analysis using sediment budgets. From a geomorphological perspective net import suggests that the system is capable of responding to challenges such as sea level rise, whereas net export indicates that the system will be unable to adjust.

Basic components of an estuarine sediment budget	
Imports	**Exports**
Fluvial sources (usually small) Cliff erosion Sub-tidal erosion Foreshore lowering (mudflats) Saltmarsh erosion	Sub-tidal deposition Inter-tidal deposition Export as bedload Deposition on mudflats Deposition on saltmarshes Export as dredged sediment

4.7.5. In many cases where sediment sources are limited this can mean that disposal at sea will lead to a deficit of sediment that translates into erosion of mudflats and saltmarshes. Such problems are most pronounced where the supply of marine sediments has also been attenuated. This is best illustrated by the sediment budget for Southampton Water (Table 1). It is a situation that is a particular concern in the UK and appears to be less significant in other estuaries in northern Europe. There are two possible reasons for the differences:

- UK estuaries suffer sediment shortfalls that are not present elsewhere in northern Europe; or
- the problem has not been recognised in northern Europe.

4.7.6. Changes to tidal propagation depend upon the scale of the changes and their influence on the geometry of the coastline and estuary concerned. For example, channel deepening by Harwich Haven Authority in 1998-2000 was accompanied

by a small rise in tide heights that effectively drowned a narrow strip of inter-tidal habitat. Conversely, in the Elbe, Ems and Seine, channel deepening has led to a combination of elevated high tides and reduced low tides. The problem of reduced low tides is much less an issue in the Western Schelde as noted in section 3.3.3.

4.7.7. Changes to sediment loads within the water column. This is particularly marked within the Ems Estuary but is likely to happen in the Elbe too, albeit at a much less significant level. Increased sediment loads are potentially responsible for higher levels of fine-sediment deposition in shallow sub-tidal environments and are implicated in reduced levels of oxygenation in tidal waters during summer months (e.g. the Ems). Similar mechanisms can be seen to occur naturally in estuaries such as the Severn (UK) and Pettitcodiac (New Brunswick – Canada) where tidal ranges are extreme, but a similar mechanism may also be responsible in estuaries with smaller tidal ranges such as the Humber.

Table 1: Sediment budget for Southampton Water, illustrating the shortfall of sediment entering the system and the net export of sediment through dredging. Source: the online estuaries guide http://www.estuary-guide.net/ (Townend, undated).

Sources of Sediment x10^3 m^3/year			**Sinks and Removal of Sediment x10^3 m^3/year**		
Intertidal erosion	Southampton Water	53	Intertidal siltation	Southampton Water	-
	Test	23		Test	-
	Itchen	-		Itchen	2
	Hamble	3		Hamble	-
Subtidal erosion	Southampton Water	35	Subtidal siltation	Southampton Water	-
	Test	13		Test	-
	Itchen	2		Itchen	-
	Hamble	-		Hamble	-
Cliff	Southampton Water	5	Dredging	Southampton Water	285
Rivers	Test	10		Test	170
	Itchen	6		Itchen	7
	Hamble	1		Hamble	13
Saltmarsh		6	Saltmarsh		4
Marine Import		321			
Total		480		**Total**	480

4.7.8. Changes to flood and ebb current speeds affect the positions and extents of sediment sorting and deposition. This problem appears to be most markedly detectable in the Elbe, where fine sediment deposition is noteworthy and is reported to be causing problems by eliminating shallow sub-tidal habitats.

4.7.9. Changes in the level of saline penetration, which in turn will have a bearing upon the point at which flocculation becomes a significant mechanism in promoting sedimentation.

4.8. Established mechanisms for sediment management in other northern European Member States.

4.8.1. Apart from the ongoing initiative by Hamburg Port Authority & WSV, there are three additional models:

- Contaminated sediment management at the Port of Rotterdam. This focuses on the use of a containment basin (The Slufter) to accommodate the most seriously contaminated sediments.

- Sediment engineering in the Western Schelde seeks to return maintenance dredged sediment to the Estuary and to use placement to build sandbanks within the estuary.
- The Maintenance Dredging Protocol (UK) is a mechanism that is primarily designed to capture existing environmental information and to present it in a manner that helps decision-makers follow the provisions of the Habitats Directive. So far, it has built upon sediment management regimes agreed when consent has been granted for channel deepening or for infrastructure improvement.

4.8.2. Each of these approaches have been developed to fit local concerns, which may be summarised as follows:

- Cost-effective sediment management.
- Meeting specific environmental concerns.
- Development of a cost-effective regulatory approach.

4.8.3. None of the other northern European mechanisms are primarily driven by the need to resolve long-standing problems that have been caused by the combined influences of channel deepening and attenuation of accommodation space. It is therefore also worth drawing attention to the concept of Coastal Habitat Management Plans (CHaMPs), an initiative tailored to a particularly British problem, but which may be relevant to other northern European countries where sea level rise affects the extent and condition of inter-tidal Natura 2000. A guide to CHaMPs can be found in the UK National Archive (see English Nature *et. al*. undated in the references).

4.8.4. Coastal Habitat Management Plans are actually a misnomer because the 'plans' do not actually advocate a particular management measures. They are actually an audit of potential inter-tidal gains and losses within Natura 2000 sites as a consequence of coastal squeeze (see loss of accommodation space in section 3.1.). Preparation of a CHaMP for a particular Natura site (Estuary) is now a component of the work undertaken to prepare an Estuary Shoreline Management Plan (see 4.12.5.).

4.8.5. Finally, where estuaries that have lost significant areas of accommodation space some of the sediment management problems may be attributed to the limited availability of sediment sinks. This is especially important where erosion is occurring in the outer parts of an estuary and there is insufficient capacity to absorb that sediment upstream (as might have happened on an un-modified coastline). Some of these principles have been recognised in the UK where shoreline management planning in larger estuaries has started to include detailed geomorphological assessments. Estuary shoreline management plans vary in their capacity to relate sediment absorption to flood risk management, but this is an issue that will become increasingly important as the impacts of Relative Sea Level Rise are imposed on an over-engineered coastline.

4.9. Sediment management in the Western Schelde

4.9.1. Studies were commissioned by the Port of Antwerp to investigate the implications of further channel deepening. They concluded that there was a need to develop a new dredging strategy to resolve problems with erosion that threatened to break

down the system of sandbanks that separate flood and ebb channels within the Western Schelde Estuary.

4.9.2. There have been two trial placements of maintenance dredged sand in the vicinity of the Walsoorden sandbar. In the first, some 500,000 m^3 of sand was deposited at the seaward end of the sandbar using a diffuser. In 2006 a further 500,000 m^3 were placed by conventional disposal in deeper water.

4.9.2. Monitoring of both trials suggests that they were effective in placing sediment so that it reinforced the Walsoorden sandbar. No negative ecological effects are reported (Peters & Planck, 2010), but there is no definition of what might constitute a negative ecological effect..

4.10. Sustainable sediment management in the UK

4.10.1. Most concern about dredging in the UK relates to impacts on sediment budgets. It works on the thesis that dredging contributes to foreshore erosion by creating a sediment sink that starves mudflats and saltmarshes of the sediment they need to maintain resilience to wave energy and to sea level rise. There are relatively few places where sediment quality and ongoing inputs of contaminants is a major issue (although there are problems in estuaries such as the Tees and Tyne where a historic legacy of industrial contaminants lie within the sediments).

4.10.2. Problems with sediment shortfalls are best illustrated by the package of measures developed to offset the impact of channel deepening by Harwich Haven Authority in the late 1990s. When this deepening was modelled and evaluated it was found that it would exacerbate existing rates of foreshore erosion within the Stour Estuary. A programme of sediment feeding was agreed. This involved some 500,000 wet tonnes (Morris & Gibson, 2007) of sediment per year and has been adjusted downwards over time.

4.10.3. Sediment feeding to offset erosion within the Stour Estuary seems to have been effective. Monitoring even suggests that it has been sufficient to reverse a small proportion of the ongoing trend in erosion. However, there have been subtle changes in the assemblage of birds feeding within the estuary (Marchant *et. al*. 2009) and this possibly reflects a change in particle size (getting coarser).

4.11. The maintenance dredging protocol

4.11.1. In the UK, consent to deposit dredged sediment is granted under the Food and Environmental Protection Act (1985). Consents generally last for one year and at most for 3 years. Most port-related dredging occurs within or adjacent to Natura 2000 sites and consequently the Environmental Impact Assessment Directive (EEC, 1985) also applies. The proximity of a Natura site means that applications for maintenance dredging had to be accompanied by an Environmental Impact Statement. This can be very expensive, especially if new assessments are required on a yearly basis. The process placed unrealistic and inappropriate demands upon Regulators, Advisors (e.g. Natural England – previously English Nature) and the ports industry. The main beneficiaries were the consultancies who prepared the environmental statements.

4.11.2. Although initial Government guidance (DETR, 1998) took the view that maintenance dredging should be treated as an ongoing activity, subsequent legal advice concluded that the process of consenting meant that each application had to be processed in accordance with Article 6(3) of the Habitats Directive.

4.11.3. This situation was judged to be unsustainable, especially as the UK Government's aspirations towards 'Better Regulation' (i.e. streamlined and fit for purpose) clearly fitted this scenario. Decision-makers, Advisers and the ports industry were all agreed that an alternative, cost-effective and transparent system was required. This meant that whilst there remained disagreements over the application of Article 6(3) there was sufficient common ground to find a solution.

4.11.4. When this dialogue commenced, most of the major ports were expanding and there were proposals for channel improvements at Bathside Bay, Liverpool, London, Plymouth, Poole Harbour and Southampton. Deepening at Harwich and Southampton in the late 1990s were also relatively recent and had been accompanied by detailed modelling. It was consequently felt that there should be sufficient information to evaluate the impacts of maintenance dredging and that this information could be re-used to populate a standard document that could be designed to support maintenance dredging applications.

4.11.5. The concept of a baseline document therefore emerged as a mechanism for capturing the analysis of dredging impacts and as a vehicle for undertaking an 'appropriate assessment' of the combined influences of all ongoing maintenance dredging within a coherent estuarine system. In many estuaries there were several ports, all of whom dredged to some degree or another, and consequently there were good grounds for a combined approach to preparing a baseline document.

4.11.6. The Protocol called for the preparation of a single baseline document for a coherent estuary and for a lead port in each estuary. If a port within the estuary chooses not to participate and contribute financially, it is at liberty to follow the previous system and submit an Environmental Impact Statement every time consent is sought for a maintenance campaign.

4.11.7. Once the baseline document has been compiled and the 'appropriate assessment' has been undertaken, it stands as an agreed record of the implications of dredging within a given estuary. This allows regulators and advisors to determine the consent using standard letters.

4.11.8. The concept of the Protocol remains sound, but there have been drawbacks. Firstly, English Nature declared a moratorium on seeking EIA for maintenance dredging whilst the Maintenance Dredging Protocol was developed. In the end, this took 5 years. Once implemented, there was to remain a moratorium for a further three years whilst baseline documents were produced. Unfortunately, this timescale saw a major turnover in staff and a loss of corporate memory on the part of the Regulators, Advisors and Ports. Despite being invited to participate, uptake by ports was patchy and it has still to be completely implemented.

4.11.9. The Maintenance Dredging Protocol was designed to resolve a regulatory conundrum. It is useful in a European context because it illustrates how assessment of ongoing maintenance activities can be integrated into a broader

package of management of Natura sites, but it should not be regarded as a solution in other Member States. This is because:

- Different legislative provisions apply across Europe.
- Responsibility for maintenance of navigation channels is often vested in public bodies rather than private operators.
- The levels of dredging in many UK estuaries are relatively small, and in many others the existing management regime is considered not to be having a detrimental impact on Natura 2000 interest.
- This system has not been tested on an estuary where there could be a need for management measures to secure Favourable Conservation Status (although there are examples where this may be necessary).

4.12. Water Framework Directive arrangements

4.12.1. So far, the only protocol for assessing the impacts of maintenance dredging on the application of the Water Framework Directive appears to be one developed by the 'Environment Agency' in England. This is a web-based tool that can be followed to establish whether there are any likely implications from maintenance dredging in relation to specific water bodies. http://www.environment-agency.gov.uk/business/sectors/116352.aspx

4.12.2. This framework guidance has four stages:

- Screening
- Scoping
- Assessment
- Identification of measures

4.12.3. This assessment process may be used to investigate how maintenance dredging in the Elbe would be evaluated under UK transposition, but in essence the most useful part of the system is stage 4: identification and evaluation of measures. http://www.environment-agency.gov.uk/static/documents/Business/Stage_four_indentification_and_evaluation_of_measures.pdf

4.12.4. Initial identification and evaluation of potentially-relevant measures (Steps 1–7) involve options that:

- are not already in place; and
- are technically feasible; and
- make an effective contribution to 'closing the gap '; and
- are not obviously disproportionately costly.

4.12.5. The second part (steps 8–14) applies only where necessary (and permissible under the WFD). It is designed to help the applicant evaluate each measure (steps 1-7) in terms of cost and whether it is 'disproportionate'. This evaluation should lead to:

- a list of selected measures that are technically feasible and not disproportionately costly and that will be applied to the activity; and/or
- a list of measures that will not be required, for example because they:
  a. are already in place to the maximum extent possible; or
  b. are not technically feasible; or

c. do not make a meaningful contribution to WFD objectives (they do not adequately address the problem); and /or
d. are disproportionately costly.

4.13. Overall assessment of sediment management in northern Europe

4.13.1. There are several initiatives to manage sediment in northern Europe. The reasons for establishing such initiatives differ according to the port, its host country and the estuary concerned. There would appear to be no complete package of measures that in any way resembles that of the RESMC proposed by the Hamburg Port Authority and WSV.

4.13.2. There is very little to suggest that a comprehensive package of measures has been completely evaluated according to the provisions of the Birds, Habitats and Water Framework Directives. This is complicated by the inter-relationship between channel deepening, loss of accommodation space through land reclamation (poldering and industrial) and limiting the influence of tributaries and meanders.

4.13.3. It is worth bearing in mind that there are models in the UK that predict the possible loss of inter-tidal habitats and their implications for Natura 2000, but that this has only been applied in relation to flood defences. CHaMPs cannot be directly translated into a mechanism to assist in management of the Elbe Estuary but they do offer an additional way of responding to the problems that are being experienced on the Elbe.

5. **Question 2b**. What is the assessment of the objective 'reducing tidal pumping ' as a sediment management strategy in view of the requirements of the WFD, MSFD and Habitats Directive?

5.1. 'Tidal pumping' is a problem that is peculiar to over-deepened estuaries but can also be recognised in natural systems. The best examples are the Severn Estuary (UK) and Pettitcodiac Estuary (New Brunswick, Canada) which exhibit very high levels of sediment mobilisation. In these estuaries there is so much tidal energy that suspended sediment loads vary considerably between spring and neap tides. This has been particularly well publicised on the Severn Estuary (Kirby & Parker, 1983) where it has been blamed for low biological productivity (e.g. Kirby & Shaw, 2005).

5.2. Variable suspended sediment loads, both spatially and temporally throughout the Elbe Estuary are illustrated by ACDP readings noted by Boehlich & Strotmann (2008) referring to studies by Maushake & Aardom, (2007). The factors behind these variations are complex, but at least part of the process is attributable to the level of tidal propagation on individual tides. This is highlighted by differences in sediment loads between spring and neap tides on the Severn Estuary (Kirby & Parker, 1983) but has also been recognised in the Elbe (Kappenberger *et al*., 1996). Consequently, the overall aim of reducing tidal propagation must be a central part of the strategy to reduce 'tidal pumping' within the Elbe Estuary. This is what the various remedies listed in tables on pages 15-17 of the RESMC seek to achieve.

5.3. It is important to bear in mind that the WFD, MSFD and Habitats Directive all focus on the establishment of measures either to maintain, restore or enhance the natural environment. A critical part of this process is the development of a sound understanding of the issues and possible measures to rectify problems. In this respect, the RESMC goes a long way to meeting the underpinning principles. It has clearly highlighted the main reasons behind failures of the Elbe Estuary to attain the environmental standards that are required to meet 'good condition' under the WFD and 'Favourable Conservation Status' under the Habitats Directive. These are elevated sediment loads and the input of contaminants from fluvial sources.

5.4. The close inter-relationship between the WFD and Habitats Directive means that there is a hierarchy of priorities between the two. In effect, whichever measures are required to meet desired environmental status takes priority, but the onus is on attainment of conditions necessary to satisfy the Habitats Directive.

5.5. The relationship between the MSFD and the WFD and Habitats Directive is less clearly defined (at the moment), but there are important indications that the latter Directives will take precedence in the Elbe Estuary because:

- There is an established network of sites that can be readily defined as marine protected areas.
- The WFD establishes the spatial planning framework for the 'marine' elements of the estuary through the River Basin Management Plan.
- The MSFD (para 2.4.1.) defines Member States' responsibilities in terms of setting standards, 'defining good environmental status' and setting targets for delivery. Both the WFD and Habitats Directive already cover the relevant parameters.

5.6. Transposition of the various Directives into the legislation of individual Member States varies. I am not sufficiently familiar with the German transpositions to comment on the minutiae of local interpretation and so the analysis set out below represents a 'broad picture' view of overall compliance. Recent Commission guidance on interactions between Natura 2000 and Ports in estuaries and coastal zones (European Commission, 2011) indicates that locally developed approaches are appropriate in this situation.

5.7. European environmental legislation takes two forms. The strategic approach is established in the MSFD and WFD whereas the Birds and Habitats Directives focus much more at an individual site and species level. Analysis of the RESMC may therefore be best served by looking at the two issues separately and in relation to particular requirements.

5.8. Strategic frameworks

5.8.1. The RESMC provides an important stage in meeting the requirements of the MSFD and the WFD because it sets a strategic framework for addressing certain issue. It has clearly identified the major engineering problems and a suite of possible remedies. The document as it stands establishes a framework for addressing port and navigation concerns but, drawing on the experience of a former nature conservationist, the following comments are offered on the basis that the RESMC will need to secure multi-stakeholder agreement.

5.8.2. Whilst the RESMC does cross-reference to recognise the issues of meeting Natura 2000 and WFD objectives, it has a very strong 'feel' of a document that has developed in parallel with developing ideas on meeting objectives set for these Directives. For example, the issues raised are strongly focussed on the high levels of maintenance dredging and the stress this places on the economics of maintaining navigation channels.

5.8.3. Sediment contamination is also amply reflected in the opening section. This is an issue that deserves considerable attention for a variety of environmental reasons, most of which primarily pertain to the WFD and perhaps to the MSFD. However, once contaminants are contained within deposited sediment they are not necessarily as problematic as they were when they were when moving freely in the water column. Bioaccumulation remains an issue, but this may not be a primary concern in relation to the objectives set for the Birds and Habitats Directives. In this respect it is worth bearing in mind that Conservation Objectives for populations of species relate as much to the availability of sufficient habitat as they do to biotic influences.

5.8.4. Apart from sediment quality, passing reference is made to siltation of shallow inter-tidal but it is not clear whether this is a problem for all parts of Natura 2000 interest or whether it is mainly one for a narrow component of the Natura 2000 interest (i.e. Twaite Shad *Alosa fallax*). In this respect, the RESMC does not give the feel of a strategy that has drawn in Natura objectives during its conception. Instead, one gains the impression of a strategy that is developing and must then be evaluated for compliance with the Habitats Directive.

5.8.5. Part of the problem appears to be the multitude of Natura designations and presumably responsible bodies. Heinze (2011) quotes 17 SAC and 9 SPAs.

Klocke (2009) reports 10 SACs and 5 SPAs. The latest map provided by BioConsult suggests that there are 19 sites within the tidal Elbe. Regardless of which is the correct figure, this complexity is both confusing and unhelpful where the principal component of the interest is a contiguous feature that is driven by the same physical processes.

5.8.6. A critical part of drawing the RESMC and Natura 2000 management together is to emphasise the links between proposed remediation measures and the conservation objectives for the various sites. This is complex and may work best at a strategic level using the summarised objectives listed by Schuckhardt (2010):

- coastal protection;
- water-body maintenance/shipping;
- morphological modifications;
- material discharges;
- cooling water removal;
- fisheries; and
- agriculture

5.8.7. Strategy development includes options evaluation and for this to be effective it needs to be transparent. In this respect, the table in the RESMC of possible interventions fits this description. However the RESMC is probably best interpreted as a framework for management of port and navigation infrastructure. A brief analysis of the critical environmental drivers might be included within the 'Overview' to add balance and to draw attention to the natural environmental issues that the RESMC will serve to resolve.

5.9. Management frameworks

5.9.1. The essential part of the RESMC is the table of possible measures (pages 15-17). This describes a suite of actions that include 'soft engineering' such as 'managed realignment' or 'de-poldering', as well as possible 'hard engineering' interventions such as the use of a tidal barrier around km715. These proposals are based on the geomorphological drivers that influence tidal propagation and 'tidal pumping' and seek to:

- Increase hydraulic roughness.
- Create sediment sinks.
- Increase accommodation space.
- Lengthen the system and increasing the tidal prism.
- Create constrictions to increase roughness and lengthen the duration of the flood tide.

5.9.2. 'Tidal pumping' results in a combination of positive and deleterious effects on estuarine systems:

- It gives the system a tendency to accrete and so there is less of a problem with inter-tidal erosion than might be the case in an ebb-dominated system. (**Positive**)
- It leads to re-mobilisation of some contaminated sediments (through erosion) that might otherwise be locked in estuarine sediments. (**Negative**)

- It has the potential to elevate suspended sediment loads which give rise to additional Biological Oxygen Demand (BOD), especially in the summer months. (**Negative**)
- It is associated with a broader tidal range, which on the one hand increases exposure of mudflats for feeding waterfowl, but on the other leads to changes in sedimentation patterns that may be detrimental to attributes such as fish spawning grounds. (**Mixed positive/negative**).

5.9.2. It is important to bear in mind that the Natura 2000 designations of the Elbe Estuary have been defined long after the major changes that increased 'tidal pumping' and a much greater tidal range. This means that whilst the aspiration is to reduce the tidal range and therefore tidal pumping, there will be a loss of inter-tidal extent associated with raising the low tide mark and depressing the high tide mark. This could be very significant in terms of the reporting process for Natura 2000 and may be seen as a reduction in the extent of available habitat (especially for migratory waterfowl in the winter.

5.10. Implications in relation to the requirements of the Habitats and Water Framework Directives.

5.10.1. In the first instance, measures to achieve good condition (WFD)/favourable condition (HD) need to be evaluated in a hierarchical manner, with the primary assessment against the objectives of the Habitats Directive.

5.10.2. Technically, the measures needed to achieve favourable condition (Favourable Conservation Status) within Natura 2000 sites take priority over those that might be required to achieve the objectives of the Water Framework Directive (see para 5.2. above). Consequently a great deal of the debate rests upon the absolute objectives set for the various Natura 2000 sites and in particular the specific attributes (i.e. at the highest level those habitats and species listed within annexes 1 & 2 of the Directive).

5.10.3. In terms of reporting to the Commission, the assessments must reflect a variety of key determinants, including the extent of each listed habitat within the individual Natura 2000 sites. If there has been a change, then there is scope for losses and gains resulting from natural processes, but anthropogenically induced changes may not be considered so favourably. In an estuary where there are several component sites, this complicates matters because remedial measures may mean gains in one place and losses in others that cumulatively yield an overall benefit both in functionality and in the extent of individual habitats.

Table 2: Aggregated measures to address 'tidal pumping' in the Elbe Estuary.

Measure	Sites	Extent Ha	Uncertain interpretation	Extent Ha	Notes
Barriers	1				Major negative morphological change in relation to WFD - increases modification.
Change mouth morphology	1				May involve loss of sub-tidal and increase of inter-tidal. Dependent upon N2k attributes and policy.
Deepening			1	500	Uncertain impact on natural environment
De-silting harbour basins	1	250			No major impact on Natura 2000 interest
Managed realignment	5	800			Mainly **positive** *as long as not affecting SPA or SAC*. Initial analysis suggests that the majority of land is Natura habitat - this means impacts are difficult to reconcile with both WFD and Natura 2000. Effectively loss of a Natura habitat to create a sub-tidal habitat that is not Natura listed.
New channels	1	10			Uncertain impact on natural environment
Reconnection	6	1198	1	500	Mainly **positive** *as long as not affecting terrestrial SPA*. Initial analysis suggests that the majority of land is Natura habitat - this means impacts are difficult to reconcile with both WFD and Natura 2000. There are places where this may be an effective improvement.
Reduce channel depth	1				Probably minor impact on SAC interest.
Optimisation of through-flow in Norderelbe and Süderelbe.	1				Not quite sure what this will involve so difficult to assess Natura 2000 impact.
Remove inter-tidal	8	922			Major **negative** impact on SPA and SAC. Loss of inter-tidal and supra-tidal habitats.
Weir management	1				May not be major impact on SAC/SPA.

5.10.4. Many of the measures proposed in the RESMC might be regarded as consistent with the requirements of the Water Framework Directive (WFD) if simply viewed as measures to address contaminated sediments. The high level objective is primarily to reverse some of the more deleterious impacts of the various morphological changes that have contributed to 'tidal pumping'. 'tidal pumping' itself is less of an issue in terms of the strategic approach which focuses on the degree to which the Estuary has been anthropogenically modified how this relates to biological and physical responses.

5.10.4. The measures identified in the table on pages 15-17 of the RESMC include several engineering interventions such as new structures within the estuary, and removal of mudflats that take a highly modified system further away from good ecological potential, and consequently they are unlikely to resonate with the objectives of the Water Framework Directive.

5.11. High level effects of reducing the tidal range (and hence 'tidal pumping').

5.11.1. The most obvious result of interventions to reduce 'tidal pumping' will be a

reduction in the top end of Spring tides and raised low tides (figure 2). The absolute changes will be dependent upon the level of intervention undertaken and of course the sequence and scale of individual interventions. However, both changes can be expected to reduce the extent of tidal exposure.

5.11.2. Reducing tidal influences at the top end of the tidal frame can be expected to reduce the frequency of wetting of the green foreshore, and within alluvial forests. Some drying effects must be anticipated and consequently this will have a bearing on the extent of particular plant and animal assemblages. (Particular care needs to be taken in relation to the Elbe Water Dropwort *Oenanthe conioides*. There is therefore a need to be very certain about the levels of inundation and humidity that this species requires.)

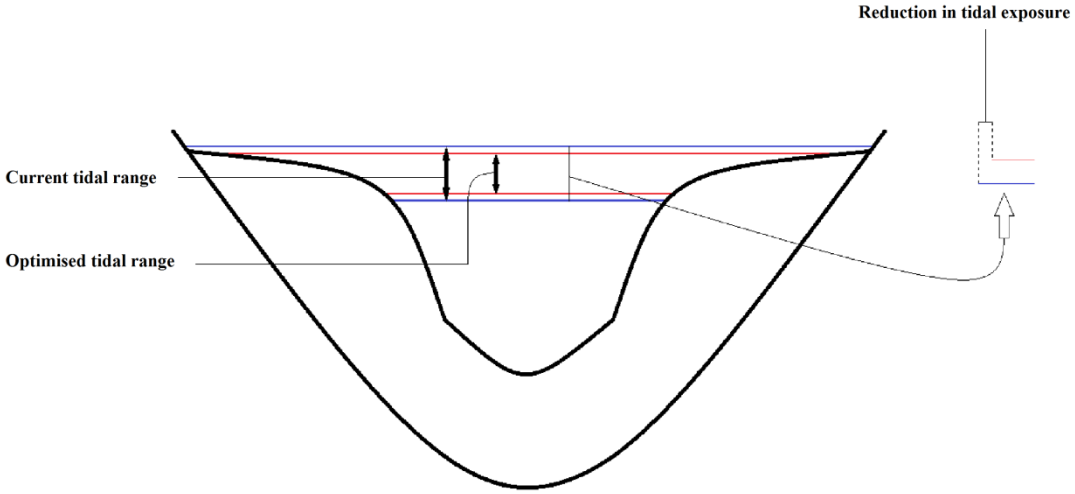

Figure 2. Schematic representation of reduced tidal propagation showing the relationship between reduced tidal exposure and the extent of Natura 2000 inter-tidal habitat.

5.11.3. Elevating low tide levels will reduce the extent of tidal exposure on mudflats and sandflats and so the overall extent of this inter-tidal will decline. This in turn can be expected to reduce overall habitat available for feeding migratory waterfowl and can also be expected to reduce the duration of exposure i.e. there will be less time on each tide for birds to feed.

5.11.4. Reduced tidal propagation may reduce levels of suspended sediment in some parts of the estuary. This in turn will reduce the ability of the estuary to accrete over inter-tidal areas. This is of course one of the objectives of the RESMC in relation to impacts on breeding Twaite Shad *Alosa fallax* but it must also be remembered that this will also potentially affect the ability of mudflats and green foreshores to keep pace with sea level rise. The level of sediment availability may, however, be an insignificant issue here provided levels imported from the Waddensee remain high.

5.11.5. Reduced suspended sediment loads should moderate the demand on the oxygen budget of the estuary, but this will in turn lead to higher levels of primary

productivity and possibly increased potential for algal blooms.

5.12. Implications of proposed interventions in relation to the Habitats Directive

5.12.1. Table 2, above, (also see Appendix 1 for more detailed analysis of individual proposals) briefly explores the range of options proposed in the RESMC. Several stand out as potentially beneficial or deleterious to the wildlife attributes for which the various Elbe Estuary Natura 2000 sites have been designated. There are others whose implications are not wholly clear (e.g. Alte Süderelbe). This section therefore concentrates on those measures that are relatively clear.

5.12.2. **Barrage near the mouth**. This can be expected to have a substantial bearing on tidal propagation. It will lead to reduced tidal exposure and possibly also to inter-tidal erosion, tipping the estuary from an accreting to an eroding system (e.g. see Morris 2009; Pethick *et al*. 2009). Increased levels of erosion would feed sub-tidal sedimentation as is currently happening in the Eastern Schelde (see Van Zanten and Adriaanse, 2008). Such a scheme would undoubtedly lead to a need to provide substantial areas of replacement habitat (compensation), many of which are likely to involve locations chosen for other geomorphological interventions if an alternative soft engineering approach was to be adopted.

5.12.3. **Change mouth morphology**. In effect, this would involve the development of new sandbars to influence the rate of tidal ingress. One parallel might be the morphological engineering that has been trialled in the Western Schelde.

The implications of this option depend upon the degree to which sub-tidal habitats contribute to the suite of attributes of importance within the Natura 2000 series. On the positive side new inter-tidal sanbanks might provide additional feeding habitat for a proportion of the over-wintering waterfowl that visit the Elbe Estuary Natura 2000 sites. However, there may be impacts on the extent of subtidal SAC attributes. This approach is worth further investigation but this should be undertaken after dialogue with relevant conservation bodies to ensure that the policy implications of such a project are fully understood.

5.12.4. **Managed realignment/de-poldering**. This is a useful way of improving the overall ecology of an estuary and in the short to medium term may be a useful way of increasing accommodation space and the tidal prism. As such it can be seen as a potentially positive intervention that benefits Natura 2000. However, these positive benefits will only arise if the sites chosen are not designated for other Natura interest (e.g. SPA). If such designations apply, then additional habitat creation will be needed and the benefits may be less cost-effective. **Note**: *maps of suitable accommodation space seem to coincide very substantially with areas allocated as SPA behind sea walls.*

It is important to remember that managed realignment sites within sediment-laden estuaries act as efficient sit traps and will ultimately become green foreshore, emergent macrophyte communities or alluvial forest rather than mudflats and sandflats. This means that if they are to be used to offset losses of other inter-tidal there is a need for a sound policy steer and for the measures to fit within the objectives of an overall Natura 2000 management plan.

5.12.5. **New channels**. The precise nature of these proposals and their implications for Natura 2000 are unclear. No judgement can be made at this point.

5.12.6. **Re-connection of tributaries**. In theory this has considerable potential to increase the tidal prism and could be geomorphologically beneficial. However, it is less clear how these proposals interact with Natura 2000 interest. If the process of deepening and reconnection involves loss of Natura 2000 attributes this is likely to lead to a need for compensatory measures. In some cases such as the Borsteller Binnenelbe modifications within the Natura 2000 sites to allow reconnection should be readily offset by new habitat creation, so the profit and loss account will be broadly positive in favour of the Natura 2000 attributes.

5.12.7. **Remove inter-tidal to create sediment sinks**. Whilst this may increase accommodation space (temporarily), the loss of extensive areas of inter-tidal mud and sand is unlikely to be regarded favourably, especially as other less damaging interventions are possible. This option should be discarded as incompatible with the objectives of the Birds and Habitats Directives.

6. **Question 2c**. What is the assessment of the objective 'reducing cyclical dredging ' as a sediment management strategy in view of the requirements of the WFD, MSFD and Habitats Directive?

6.1. Dredging must be regarded as an anthropogenic intervention that is not required for managing estuaries from an ecological perspective. Consequently, setting an objective to reduce the levels of dredging must be regarded as a positive measure in the delivery of 'good' condition within the water body. This statement needs to be qualified, however:

6.1.1. The mechanisms used to achieve the objective do need to be considered carefully. In section 5, attention has been drawn to the possible implications of some of the proposed interventions within the RESMC. On balance, the major issues probably lie more with the Birds and Habitats Directives than they do with the Water Framework and Marine Strategy Framework Directives. However, if the Habitats Directive is not satisfied then the WFD and MSFD will not be satisfied either.

6.1.2. The abbreviated legal opinion offered by Brueur (2010) presents the view that the RESMC is in accordance with the WFD and MSFD. This view may be acceptable in a German context but may not be accepted elsewhere.

6.1.3. Bearing in mind the inter-relationship between the Habitats Directive and the Water Framework Directive, the question of compatibility with both becomes more complex. If the RESMC becomes a committed 'plan' then it is likely to need to be assessed in the context of Article 6(3) of the Habitats Directive and as discussed in section 5 above some measures have considerable potential to be deleterious to some aspects of the Natura 2000 sites. If so, it seems to follow that neither the WFD or the Habitats Directive will be satisfied.

6.1.4. It must also be borne in mind that apart from a strategic assessment of the RESMC, individual components of the plan may require assessment under Article 6(3) of the Habitats Directive. This need not be a major issue if the overall outcome of the intervention is positive for the critical attributes of the Natura 2000 sites. The situation is complicated, however, because many of the proposed measure will inevitably involve some modification of the key physical attributes and there are multiple sites with differing levels of impact imparted on them.

6.1.5. It is therefore important to separate the main objectives of the RESMC from the final interpretation of its relationship with relevant European environmental legislation. The latter judgement can only be made when the RESMC has been reviewed and refined as a consequence of the Expert Panel's analyses.

6.2. Analysis of reducing cyclical dredging highlights the following broad-scale 'environmental' changes that may contribute or detract from delivery of the objectives of the Water Framework Directive:

6.2.1. Development of a plan to address factors responsible for failure of the water body to meet 'good' status. (**Positive**)

6.2.2. Reduced anthropogenic intervention (in certain respects) and hence moving towards 'good' status in a 'heavily modified' water body. (**Positive**)

6.2.3. Increased anthropogenic modification in respect of removal of existing habitat. (**Negative**)

6.2.4. Removal and treatment of highly contaminated sediments from port areas. (**Positive**)

6.2.5. Reduced sediment mobilisation and hence water quality will be improved, especially during summer months when sediment loads may affect biological oxygen demand. (**Positive**)

6.2.6. Improvements to biological functioning by creating new inter-tidal and sub-tidal environments. (**Positive**)

6.2.7. Loss of existing biological functions through removal of tidally influenced habitats. (**Negative**)

6.2.8. Improvements to conditions within the tidal estuary that might impede movement of migratory fish or survival of larval stages. (**Positive**)

6.2.9. Loss of Natura 2000 attributes in terms of extent. (**Negative**)

6.3. A similar analysis highlights a mixture of benefits and drawbacks in relation to the Habitats Directive.

6.3.1. Improvements to conditions within the tidal estuary that might impede movement of migratory fish and reduce their breeding potential or survival of larval stages. This is especially important for those species listed on Annex II of the Directive, and in particular Twaite Shad *Alosa fallax*. (**Positive**)

6.3.2. Reductions in the extent of ongoing modification arising from high levels of sediment disposal. This too may be of particular benefit if recycled sediment is responsible for changing the conditions in shallow subtidal for spawning Twaite Shad *Alosa fallax*. (**Positive**)

6.3.3. Possible increases in the extent of inter-tidal habitat that will ultimately form a complex mosaic of mudflats, reedbeds and alluvial forests. (**Positive**)

6.3.4. Improved resilience within the system arising from increased accommodation space. (**Positive**)

6.3.5. Possible loss of existing habitats - either within the Elbe itself or through re-engineering of terrestrial SPA habitat. Losses of extent of individual habitats may be interpreted as a loss of site integrity depending on the Conservation Objectives set for the sites. (**Negative**)

Note: *Maps of suitable accommodation space seem to coincide very substantially with areas allocated as SPA behind sea walls.*

6.3.6. Reduced tidal influences over the top end of the tide that have the potential to change the hydrology favoured by the Elbe Water Dropwort *Oenanthe conioides*. (**Negative**)

6.3.7. Changes in the hydrology of tidally inundated alluvial forests, leading to dryer conditions and succession to dryer forest types. (**Negative**)

6.3.8. Loss of extent of inter-tidal exposure (see Figure 2 above). (**Negative**)

6.4. At the moment, implementation of the Marine Strategy Framework Directive (MSFD) is developing. Comments on the relationship between reducing cyclical dredging and the Directive must therefore be treated with caution. Two basic observations are possible:

6.4.1. The MSFD emphasises the need for strategic planning to reduce the impact of human interventions on the natural environment. The RESMC provides strategic direction in relation to navigation dredging and will therefore contributes to the overall process of developing a planning framework.

6.4.2. Reducing dredge disposal at Buoy E3 will limit the levels of contaminants entering the marine environment and being absorbed into the food chain.

6.5. Arguably the most significant impediment to the development of a dredging strategy is the degree to which Natura 2000 designations are fragmented. The absolute number of sites is immaterial but, using the figures provided by Bioconsult of 14 SAC and 5 SPA, problems are inevitable because individual sites may have conflicting objectives. For example, objectives to deliver favourable status within a tidal component may be met by realignment landward through a separate SPA, which will then cease to exhibit all of the critical attributes that underpin its designation. Supplementary comments and information provided by Bioconsult in July 2011 indicate that overarching objectives have been prepared. These are inevitably high level descriptions and there remains the issue of actually defining the state of particular attributes that the plan seeks to achieve.

6.6. Taking a broader view, dredgers and associated equipment emit considerable levels of greenhouse gasses and consequently there is a great deal of sense in seeking a long-term reduction in dredging demands. Creation of new inter-tidal habitats may also be a small but useful positive contribution towards carbon sequestration, as saline mudflats and green foreshore has been shown to act as a carbon sink (e.g. Andrews *et. al*., 2008). Consequently, there are wider environmental benefits to be gained from the total package developed around the objective of reducing cyclical dredging. However, these alone cannot be used to justify loss of Natura 2000 and any losses would have to be offset by new habitat creation.

7. **Question 2d**. Does the paper 'Waterways and Ports' in the Lower Elbe Integrated Management Plan, along with the measures presented there concerning optimization of maintenance dredging, represent an appropriate basis for implementing the Habitats Directive from a European perspective?

7.1. This initial analysis relies heavily on the briefing paper by Gűnther Eichwebber (undated). A further important component of relevant information was given in a briefing paper by Schuchard (2010) which was augmented by supplementary information provided in July 2011. The combination of these three documents provides a partial picture of the emerging process of defining Conservation Objectives which form the foundation for delivering management actions and for making assessments of proposed interventions to address the issue of cyclical dredging.

7.2. Responding to this question has complicated because the 'Integrated Plan' does not appear to have been completed and information pertaining to some parts has not been supplied in a form that readily lends itself to interpretation. Supplementary information supplied in July 2011 includes example Conservation Objectives for 'functional unit 3' but this does not make it possible to form a comprehensive picture of the inter-relationship between differing levels of objectives. Furthermore, this supplementary information highlights the non-statutory nature of the plan and the fact that it does not have any influence over individual owners and occupiers. This latter issue deserves specific comment and will be addressed at the end of this section.

7.3. The Integrated Management Plan is under preparation in two parts; one contribution by the City of Hamburg and Schleswig Holstein; and a second part developed by Lower Saxony. Supplementary comments from Bioconnsult, provided in July 2011 indicate that the problem of drawing together separate units has been recognised. The degree to which this will be achieved remains to be seen as I have gained the strong impression of the plan comprising a series of sub-units rather than a cohesive single entity.

7.4. As a relevant comparison, it is worth reflecting on the situation on the Humber Estuary in 1995 when a similar approach was proposed for development of a flood defence strategy. The first proposal was for the three regions of the National Rivers Authority to prepare their own 'sector plans' and the combination of these would constitute the 'strategy'. However, this led to major problems because it was not always possible Natura 2000 issues could not always be addressed within a particular sector, and there was no underpinning science to provide a framework for intervention. Ultimately the three Regions were driven to work on a single plan, underpinned by sound geomorphological understanding of the sensitivities. The outcome (Environment Agency, 2000) has been a set of measures endorsed by all of the Competent Authorities and largely supported by the commercial and local communities served by the flood defences. Critically, this strategy was underpinned by morphological modelling that demonstrated differing levels of sensitivity within the estuary.

7.5. Without seeing the actual Integrated Management Plan, the following observations are

offered, based on UK experience of developing management schemes (see e.g. Natural England, 2007) for European Marine Sites (i.e. Natura 2000), development of Estuary Management Plans (Morris, 2008) and for shoreline management plans. Such schemes cannot be argued to be the pinnacle of best practice but they do provide valuable baselines that could be improved upon.

7.6. Strategic overview

7.6.1. Shoreline management plans for flood defence in estuaries are greatly improved when there is a sound understanding of the geomorphology and the physical processes that govern morphological evolution. Similarly, some of the solutions found to offset the impact of port development and dredging in the UK draw upon similar principles. **In this respect, work on physical processes by HPA and WSV conforms with this stage in the process**.

7.6.2. Understanding of physical processes is only part of the issue, however. There is also a need to be clear about the relative sensitivity of the estuary to particular interventions. This was a crucial stage in the development of the Humber Estuary Shoreline Management Plan because it showed where the greatest gains and risks existed in terms of flood risk management and ecological responses.

7.6.3. This work needs to be integrated into the development of the Natura Conservation Objectives. It is far from clear whether the understanding of physical processes and related management issues has been migrated into the formulation of policy-driven objectives for the multiple Natura 2000 sites across the Elbe Estuary. Those objectives I have seen (Schuchardt, 2010) appear to be summaries and do not cover all of the listed attributes. Supplementary information supplied by Bioconsult in July 2011 expands upon this information but the Conservation Objectives remain very high level and contain no descriptors of the point at which the objectives have been achieved (i.e. something analogous to 'favourable condition tables' illustrated in appendix 3).

7.6.4. Part of the integration process is the need to relate current ecological situations to the driving physical processes. It seems unlikely that this will be achieved by two groups working separately to prepare their individual parts of the Integrated Management Plan. In this respect, it must also be highlighted that the RESMC which underpins the navigation management component of the Integrated Management Plan seems to focus more heavily on sediment loads and contaminants than it does in relating proposed management measures to Natura 2000 objectives. In this respect, it is more closely aligned to the Water Framework and Marine Strategy Framework Directives than it is to the Habitats Directive.

7.6.5. High level objective-setting must include development of a common policy towards the way in which the Estuary SAC(s) and its SPA hinterlands will be managed. For example, one policy line might be to seek to maintain the existing distribution and extent of particular habitats. An alternative approach might be to recognise that change is inevitable and that the processes that drive change can be harnessed to yield a more ecologically sustainable environment. This is a key issue because it will help to determine whether some of the proposed interventions are consistent with the policy and management measures that statutory and voluntary conservation bodies aspire to achieve.

7.6.6. Supplementary information supplied by Bioconsult in July 2011 indicates that common agreement has been reached on the need to manage the estuary as a dynamic system. This is a wise approach that is consistent with practices adopted in the UK. This supplementary information also highlights the adoption of 'functional units' within the estuary. It is not entirely clear how these have been arrived at, especially as the estuary mouth appears to exclude inter-tidal habitats to the north (BD 0916-491 Ramsar Site Wadden Sea Schleswig-Holstein and adjacent coastal areas). Similarly, I would have expected the tributaries to have contributed to the functionality of the specific sections of the main estuary. If these areas have been defined using physical processes and sensitivity then this makes sense and will be helpful. If the geomorphological sensitivity has not been tested then it is possible that these functional units will not make sense when a final plan is agreed on the measures needed to reduce maintenance dredging.

7.7. Agreed management interventions

7.7.1. Initial evaluation of the Elbe Estuary Natura sites highlighted several critical issues:

- There are at least 19 different Natura 2000 sites, all of which will have a set of attributes whose conservation status must be reported in accordance with the requirements of the Habitats Directive.
- The Estuary has three governing bodies (City of Hamburg, Schleswig Holstein and Lower Saxony). This means that unless common agreement is reached on high level physical process-based objectives it will be very difficult to integrate the RESMC into the Plan.
- Without common agreement on the overall approach to setting management objectives and targets, a fragmented and disjoined relationship may develop.

7.7.2. Information provided by Bioconsult in July 2011 suggests that common agreement has been reached on an approach to managing the complex of Natura 2000 sites as a cohesive unit. This is an important stage in the process of developing an integrated management strategy. However, words such as conservation and preservation are open to differing interpretations and consequently there is a need to develop of supplementary information that describes precisely what it is hoped will be achieved. A good example is provided by the Regulation 33 advice prepared for the Severn Estuary (Natural England & the Countryside Council for Wales, 2009).

7.7.3. The limited detail provided means that it is not possible to make a full evaluation of the potential for convergence between meeting Natura 2000 and navigation management objectives. Bearing in mind that this analysis can only reflect the information provided, it is possible that there is further supplementary information that I am not aware of. The following observations therefore approximate to a best guess analysis of the potential for the RESMC to an appropriate mechanism for delivering Natura 2000 objectives.

7.8. Management measures proposed within the RESMC

7.8.1. The proposed management measures in the RESMC to improve the ecological coherence of the estuary involve a mixture of loss and gain of habitat. On balance, the major losses are likely to be inter- and supra-tidal habitats as well as wet grassland that lie behind the sea walls and form SPA habitat.

7.8.2. Four principle interventions within the Natura sites are described in the table on pages 15-17 of the RESMC:

- Managed realignment
- Reconnection of tributaries
- New channels
- Removal of inter-tidal

7.8.3. The table of possible measures (pages 15-17 of the RESMC) refers to an assessment of ecological impacts but it is unclear whether this evaluation involves Natura interest features and any attempt to develop a 'feel' for the likely implications in relation to application of the Habitats Directive. Consequently, in this report some evaluation of Natura 2000 implications has been included; it is very superficial, however.

7.8.4. In addition, developing ideas about re-engineering the mouth of the Elbe to reduce tidal propagation would have a potentially high bearing on the existing fabric of the Natura 2000 attributes. There are two principal reasons:

- Reduced tidal propagation will lead to a smaller area of regularly inundated inter-tidal which will be listed as Natura Habitat [e.g. H1140 Mudflats and sandflats not covered by seawater at low tide; and H1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae)].
- There will be a shift in the extent of inter-tidal and subtidal habitats which may be regarded as positive or negative depending on the policy line adopted by the conservation bodies.

7.9. Managed realignment - consistency with other European examples

7.9.1. Managed realignment (de-poldering) increases accommodation space and the volume of water within the tidal prism. It is the best-known and tested mechanism for improving the condition of Natura 2000 inter-tidal habitat. It has been used as a measure for compensation for losses at Harwich and at Immingham Outer Harbour (Morris & Gibson, 2008), and was the way the UK Government offset losses resulting from Developments at Felixstowe and Sheerness in the early 1990s (Dixon *et. al*, 2008). It has also been used in Germany under federal legislation for offsetting the impacts of the Wilhelm Kaisen container terminal at Bremerhaven (Hansestadt Bremisches Amt, 1997) and for partial offsetting of the Műhlenberger Loch Airbus factory. Managed realignment is also the approach that is embraced in the concept of Coastal Habitat Management Plans (CHaMPs) developed by the *Living with the Sea* LIFE project in the UK (e.g. see Frost, undated; Anon., undated).

7.9.2. As managed realignment has an established track record of delivering Natura 2000 objectives, it deserves investigation as a priority approach to resolving some problems with sediment management in the Elbe Estuary.

7.9.3. Increasing accommodation space will lead to removal of sediment from the tidal system and there is potential to substantially reduce levels of suspended sediment in the estuary (possibly even returning them to background levels in the Waddensee). If this is achieved, it needs to be recognised that sedimentation along foreshores and in realignment sites will slow down. This will have several beneficial consequences, especially for fine sediment loads reaching the port of Hamburg. It should also lead to a reduction in the overall intensity and location of the turbidity maximum. However, reduced sedimentation on foreshores may mean that they will not keep pace with sea level rise in the long-term.

7.9.4. Realignment to create additional accommodation space will create more tidal volume and, depending on the size of the void, will exert an influence over tidal propagation. Bigger realignments will have more profound impacts. However, short term gains in sub-tidal habitat will be followed by sedimentation that will create new inter-tidal habitat. Eventually this new habitat will lead to a reduction in the tidal prism and gradual re-establishment of the conditions currently experienced in the estuary.

7.9.5. If the RESMC were to be adopted in full, there is the potential for difficulty in reporting condition assessment in to the European Commission. Loss of habitat through removal to create volume, or by realignment will appear as a negative value in relation to the extent of individual attributes. To some extent the significance of this will depend upon high level policy in Germany that dictates whether conservation *in situ* takes precedence over physical processes or vice-versa.

7.9.6. The measures may benefit sediment transport and reduce the costs of dredging and sediment remediation but they are likely to involve concomitant reductions in the extent of some Natura 2000 attributes. The final significance of the changes depends upon the chosen solutions and the sequence in which they are delivered.

7.10. Reconnection of tributaries

7.10.1. Loss of accommodation space from tributaries has parallels with some of the shortening of English estuaries such as the Dee and the Ribble, in the sense that it would have removed tidal ingress to the upper foreshore and would therefore have reduced accommodation space. Consequently, from a morphological perspective re-opening tributaries makes a good deal of sense and in theory this would be consistent with the objectives of Natura 2000.

7.10.2. The main outcome of re-opening tributaries would be a rise in tidal influences and sedimentation on areas currently functioning as green foreshore or possibly wet grasslands. Several look to be designated as SAC or SPA, so a functional change can be anticipated. Depending on the policy lines adopted by the conservation bodies, this may be interpreted either positively or negatively.

7.11. New channels

7.11.1. The main project of this type appears to be at km 640, described as: 're-connection of the Borsteler Binnenelbe and creation of additional flooding area by partial excavation of the areas south of the Inner Elbe'. This has three possible benefits:

- Increasing the tidal prism and thus making a contribution towards reducing tidal propagation.
- Creating a partial meander that would possibly reintroduce a small variation in the distribution of the flood and ebb currents.
- Creation of new areas of shallow sub-tidal in an area known to be favoured as a spawning ground by Twaite Shad *Alosa fallax*.

7.11.2. This site appears to comprise a mixture of Natura and non-Natura habitat. As such it looks to have more potential than many other proposals because any Natura losses could be argued to be offset by gains in new habitat. As such this is a project that is likely to be supported by conservation bodies.

7.11.3. The other project within this category is the project at km 659 Pagensander Nebenelbe: 'dredging of a current channel in order to reduce the high sedimentation rates in the Steinloch area'. This is a relatively modest contribution of 10ha and as such cannot be expected to impart a major morphological change.

7.12. Removal of inter-tidal

7.12.1. There are eight proposals for this option, totalling 920 ha. The objective of this approach is to create a void that creates additional tidal volume and so reduce tidal propagation.

7.12.2. It is difficult to be sure how effective such a measure might be in countering tidal propagation. Conceptually it may be effective, but there are noteworthy drawbacks, not least two of particular concern:

- Where the dredged material will be placed; and
- What happens when the mudflats re-develop?

This can only be a temporary measure, and would require much further investigation before its effectiveness can be assessed.

7.12.3. From a wildlife perspective, the benefits are difficult to envisage. Possibly some shallow inter-tidal that might benefit some fisheries, but it seems unlikely to offer real benefits in resolving issues such as low populations of Twaite Shad *Alosa fallax*. This is because there can be no guarantee that such measures would deliver suitable habitat and more importantly the majority of proposed locations are seaward or upstream from critical shad breeding grounds (see figure 3, below).

7.12.4. The principal drawback of this approach is that it involves the removal of a substantial area of inter-tidal habitat - both H1140 mudflats and sandflats not covered by seawater at low tide (Habitats Directive) and a major feeding ground for over-wintering migratory waterfowl. As such, it is difficult to see how this type of proposal is might gain acceptance from the conservation world.

7.13. Implications in relation to Twaite Shad *Alosa fallax*

7.13.1. During the briefing meeting on 12-13 January 2011 there was discussion about the measures needed to resolve the limited breeding success of Twaite Shad *Alosa fallax* in the Elbe Estuary. Sedimentation of spawning grounds has been raised as a likely reason for the problems. This deserves some further investigation as it

may have a bearing on the merits, or otherwise of creation of shallow inter-tidal habitats.

7.13.2. Studies by Gerkens & Thiel (2001) suggest that breeding sites are within close proximity of Műhlenberger Loch - see figure 3 below. The occurrence of yolk-sac larvae at Km 631 (location 4) indicates that breeding is very closely approximated to the port. Evidence presented suggests that breeding sites are within the Műhlenberger Loch area

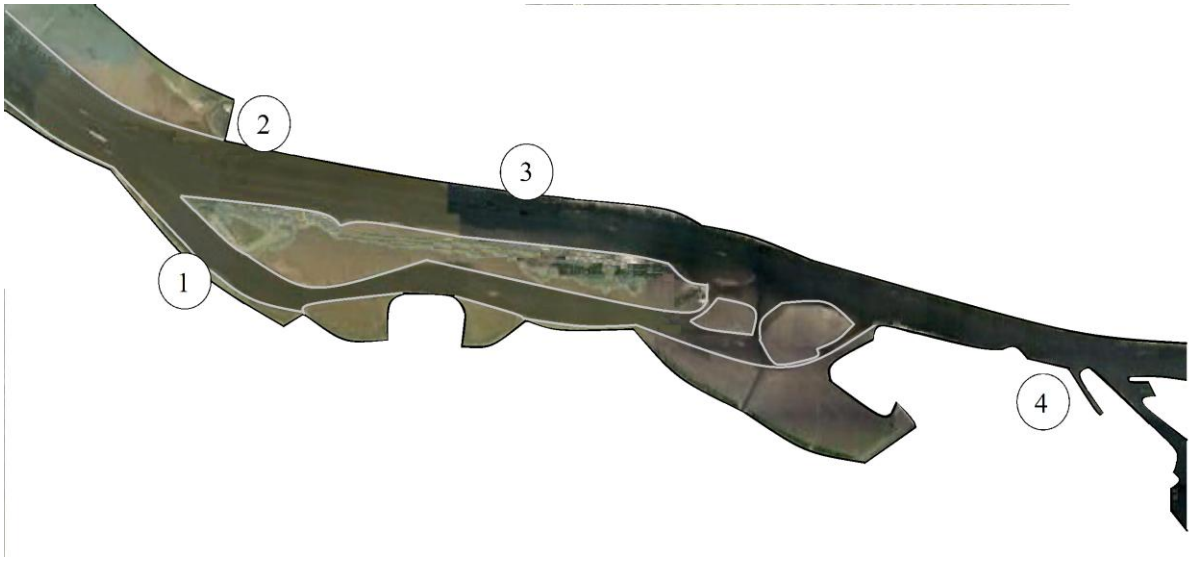

Figure 3. Locations of reported captures of recently hatched shad larvae in the vicinity of Műhlenberger Loch. Areas bordered grey comprise mudflats and inter-tidal habitats. (after Gerkens & Thiel (2001). Map based on Googleearth image downloaded 21 February 2011.

7.13.3. Gerkens & Thiel (2001) report several other studies that describe downstream displacement of shad breeding grounds to locations between km 660 and 680 between 1960 and 1986; however, it seems that this has since moved upstream to the vicinity of Műhlenberger Loch, initially to the area between km 645 and 660, and since 2000 to the area described in Figure 3 which coincides with historic localities reported between 1891 and 1941.

7.13.4. Reasons for changes in shad breeding grounds are variously attributed to declining/improving water quality and to increased water depth. Consequently, measures within the RESMC that would facilitate improvements in water quality and availability of shallow water will be likely to be beneficial to breeding shad.

7.13.5. It is important to bear in mind, however, that delivery of the objectives of the Habitats Directive relate to the entire suite of Annex I habitats and Annex II species, and consequently measures that benefit one attribute to the detriment of another may require justification and assessment. Consequently, depletion of inter-tidal habitats to create shallow sub-tidal are potentially inappropriate.

7.13.5. Realignment and reconnection projects offer the best opportunities for positive improvements and so reconnection of Borsteler Binnenelbe may offer a potentially beneficial solution. Depending upon the configuration of this project, any detrimental impacts on Natura 2000 may be offset by habitat creation where

agricultural land is returned to tidal influences.

7.14 Comments on non-statutory plans

7.14.1. It seems that the 'Integrated Management Plan' will effectively be a non-statutory document. In other words, whilst it has the potential to be used to inform thinking its objectives and actions are not binding on any party. There is considerable experience of this approach in the UK and some lessons can be learned.

7.14.2. There are several obvious UK analogues to the 'Integrated Management Plan'. Shoreline Management Plans (SMP)for flood risk management provide the most obvious example. Estuary Management Plans produced in the 1990s also bear some resemblance. And, Regulation 34 'Management Schemes' also have features in common with the 'Integrated Management Plan'. However, until the final plan is unwrapped it is not possible to draw direct parallels.

7.14.3. For the purpose of this analysis some generic comments are therefore offered. Each model offers positive messages but all highlight the basic tension between plans that must be followed and those that are aspirational but have no legal teeth.

7.14.4. The most positive message to emerge from all strategic planning initiatives is that they form the basis for dialogue between statutory bodies that might not previously have communicated well. On estuaries this can be especially valuable where there are overlapping jurisdictions between statutory bodies with differing remits.

7.14.5. Strategic planning and related dialogue also means that there is much greater understanding of the issues within each participating body. This is probably the most important benefit because it leads to a long-term evolution of culture and practice. However, when the time comes for actions that are not in the interests of a particular stakeholder the non-statutory nature of the plan rapidly exposes its weaknesses.

7.14.6. Shoreline Management Plans (see Environment Agency website) are an evolving process of designing management of coast cells based on sediment transport (see Motyka & Brampton, 1993). These plans relate four basic measures to coastal processes:

- Hold the line
- Advance the line
- Managed realignment
- No active intervention

7.14.7. Two generations of SMP have been prepared and the second generation included much greater emphasis on adaptation measures such as managed realignment and no active intervention. However, these options have proved to be very unpopular and several local authorities have indicated that they will not permit managed realignment to proceed. Consequently, the plans can no longer achieve their objectives.

7.14.8. Estuary Management Plans were a first attempt to develop sustainable development plans for Estuaries (see Morris, 2008). They had no legal foundations and the majority have ceased to play any part in the management of estuaries. A few have been maintained because they created the environment for partnership working that has proved invaluable to the participants (e.g. the Thames Estuary).

7.14.9. Natura 2000 Management Schemes, developed in accordance with regulation 34 of the Conservation (Natural Habitats &c.) Regulations (HM Govt. 1994 & 2010) appear to offer the closest model to the 'Integrated Management Plan'. Most of these plans were developed in the late 1990s and were designed to recognise the overlapping designations of SPA, SAC and Ramsar. The specific Regulation stated that there should be a single plan and where there were contiguous designations they were all included within the plan. An obvious example is the plan for the Essex Estuaries, which comprised one SAC but several SPA.

7.14.10. Reviews of some 'Management Schemes' are currently underway and the findings do not appear to have been published. However, experienced I gained whilst working for English Nature/Natural England, suggested that these schemes were not likely to deliver the necessary measures needed to secure and manintain favourable condition. This is because action could really only be taken where a particular authority had jurisdiction over an activity. Where there is no legal mechanism for action then nothing is likely to be done simply because it lies too far down the list of priorities facing each authority. Moreover, the measures needed to resolve some problems may conflict with the strategic objectives of a particular authority and consequently action may not follow to rectify a problem. This has been seen in the case of some shellfish fisheries in the past and there are examples of poor practice in some parts of the ports industry.

8. **Question 2e**. What is the overall assessment of the RESMC and the measures specified there with respect to the objectives of the WFD, MSFD and Habitats Directive?

8.1. The Elbe Estuary is one of a relatively small suite of extremely large European estuaries. This means that it differs substantially from many Atlantic coast estuaries that are comparatively small and are therefore very different from a management perspective. The problems faced by HPA and WSV are perhaps comparable to those of the Western Schelde because it too is a major artery for the biggest container vessels.

8.2. The RESMC is a major advance in the development of a package of measures to resolve problems arising from channel deepening. It offers a broad suite of options for developing solutions to existing and future problems. Part of this package is specifically needed to address the problem of long-term contaminant input and the need to reduce contaminant levels remaining within the tidal Elbe.

8.3. From the 'big picture' perspective, the RESMC contains several highly innovative ideas and is set at a scale that is pretty well unheard of in other European Estuaries. This means that past case-law and experience elsewhere in Europe may not be helpful in the development of a solution for the Elbe Estuary. There is no single mechanism developed by another member state that resolves the procedural problems faced in implementing the RESMC.

8.4. One way of testing the compatibility of the RESMC with the various environmental Directives is to determine which of the specific objectives set by the Directives actually overlap with those of the RESMC. Table 3 is an initial attempt to do so and this is helpful because it emphasises the close relationship between the RESMC and some objectives set by the Water Framework Directive. At the same time, it also highlights the differences in approach between the two framework Directives and the Habitats Directive and suggests that this is the area where the most likely weaknesses will be detected.

Table 3. The relationship between the objectives of the Water Framework, Habitats and Marine Strategy Framework Directives and the objectives of the RESMC.

1. WATER FRAMEWORK DIRECTIVE		
Objective	**Relevant RESMC objectives**	**Notes**
Enhance the status and prevent further deterioration of aquatic ecosystems and associated wetlands, which depend on the aquatic ecosystems.	• Reduction of total dredging quantities (river engineering, hydrology). • Optimising dredging (sediment traps, river engineering).	
Promote the sustainable use of water.	• Minimising the impact associated with maintenance (dredging). • Minimising the pollution of dredged material.	

Reduce pollution of water, especially by 'priority' and 'priority hazardous' substances (see Daughter Directives).	• Minimising the pollution of dredged material.	
Ensure progressive reduction of groundwater pollution.	• Minimising the pollution of dredged material.	
2. HABITATS DIRECTIVE		
Objective	**Relevant RESMC objectives**	**Notes**
Maintain or restore European protected habitats and species listed in the Annexes at a favourable conservation status as defined in Articles 1 and 2.	• Minimising the pollution of dredged material.	Removal of contaminants would help to restore favourable conservation status, but it is only a part of the process of improving the ecological coherence of the sites..
Contribute to a coherent European ecological network of protected sites by designating Special Areas of Conservation (SACs) for habitats listed on Annex I and for species listed on Annex II. These measures are also to be applied to Special Protection Areas (SPAs) classified under Article 4 of the Birds Directive. Together SACs and SPAs make up the Natura 2000 network (Article 3).	N/A	The coherent network is dependent upon designations - 26 in the case of the Elbe according to Heinze (2011) but currently reported as 19 within the tidal Elbe.
Ensure conservation measures are in place to appropriately manage SACs and ensure appropriate assessment of plans and projects likely to have a significant effect on the integrity of an SAC (& SPAs). Projects may still be permitted if there are no alternatives, and there are imperative reasons of overriding public interest. In such cases compensatory measures are necessary to ensure the overall coherence of the Natura 2000 network (Article 6).	• Reduction of total dredging quantities (river engineering, hydrology). • Optimising dredging (sediment traps, river engineering). • Minimising the pollution of dredged material.	There should be a very large number of measures, including habitat restoration and creation measures, so the precise relationship is unclear.
Member States shall also endeavour to encourage the management of features of the landscape that support the Natura 2000 network (Articles 3 and10).	N/A	It is possible that some RESMC measures might incorporate wider landscape management measures but these do not stand out at the moment.
3. MARINE STRATEGY FRAMEWORK DIRECTIVE		
Objective	**Relevant RESMC objectives**	**Notes**
Development of a marine strategy for its marine waters in accordance with the plan of action.	N/A	RESMC might be a contributor.
Determine, for the marine waters, a set of characteristics for good environmental status, on the basis of the qualitative descriptors listed in	N/A	Characteristics would be immensely helpful for informing the RESMC.

Annex I.		
Establishment of a comprehensive set of environmental targets and associated indicators for their marine waters so as to guide progress towards achieving good environmental status in the marine environment, taking into account the indicative lists of pressures and impacts set out in Table 2 of Annex III, and of characteristics set out in Annex IV.	N/A	RESMC does not really contain environmental targets - these may have a bearing on implementation of RESMC.
Publish of proposals for a coherent network of Marine Protected Areas by 2013.	N/A	N/A

8.5. The RESMC has been under development for several years and consequently it has progressed at a different rate to other elements of the developing integrated plan for management of the Elbe Estuary. More-over, the focus on problems with contaminated sediment means that it is inevitably far better aligned with the objectives of the Water Framework Directive than the nature protection Directives (Birds and Habitats Directives).

8.6. The main challenge that the RESMC faces is the need to reconcile the relationship between specific interventions and conservation objectives for particular Annex I habitats and Annex II species, and for those objectives pertaining to areas designated as Special Protection Areas behind sea walls. In this respect the analysis within the RESMC table of measures does not convey the information needed to understand possible Natura 2000 concerns because the term 'ecological impact' could draw upon a much wider set of issues and concerns.

8.7. The information on the proposed suite of interventions involves brief descriptions of the measures but there is insufficient detail to undertake an in-depth analysis of the likely implications of individual measures in relation to the Habitats Directive. Table 4 sets out as far as possible the degree to which proposed measures are likely to occur within or beyond the boundaries of the various Natura 2000 sites. This initial analysis suggests that the majority of proposals involve changes within the Natura 2000 sites rather than measures beyond the site boundaries. This places significant limitations on likely compatibility with the Habitats Directive. This in turn means that compatibility with the Water Framework Directive is also impaired.

Table 4. Analysis of the degree to which proposed measures lie within or beyond Natura 2000 boundaries.

Measure	Sites	Km	Within N2k	Outside N2k
Barriers	Measures in the mouth area	~ km 715	Yes	
Change mouth morphology	Upstream tide theory			
Weir management	Weir control at Geesthacht	km 580	Yes	No
Reduce channel depth	Between Cuxhaven and Störkurve as well as in the Störbogen area as far as Hamburg.		Yes	No
Remove inter-tidal	St. Margarethen	km 690	Yes	No
	Schwarztonnensand	km 667	Yes	No
	Bishorstersand	km 657	Yes	No
	Fährmannssander Watt	km 646	Yes	No
	Hanskalbsand	km 640	Yes	No
	Ellerholz	km 612	Yes	No
	Spadenländer Spitze	km 619	Yes	No
	Spadenländer Busch / Kreetsand	km 614	Yes	No
Re-connection	Borsteler Binnenelbe	km 640	Yes	Yes
	Water works/Billwerder Insel	km 621	Unclear	Unclear
	Doveelbe	km 619	Yes	Unclear
	Untere Seeveniederung	km 605	Unclear	Unclear
	Durchstich Heuckenlock / Norderelbe	km 612		
	NSG Rhee	km 619		
Reconnection?/ Deepening?	Alte Süderelbe	Km 629	No	Yes
Managed realignment	Spadenländer Ausschlag	km 615	Unclear	Unclear
	Neuland	Km 610	Yes	Unclear
	Hohendeicher sea	km 607	Yes	Unclear
	Haseldorfer Marsch	km 650	Yes	No
	Kiesteich / tidal channel		Unclear	Unclear
New channels	Pagensander Nebenelbe	km 659	Yes	No
Optimisation of through-flow in Norderelbe and Süderelbe.	Reshaping of Bunthäuser Spitze	km 610	Yes	Unclear

8.8. Assessment of the precise implications of the proposals in relation to the delivery of favourable conservation status within the Elbe Estuary Natura 2000 suite of sites is not possible at this stage, but some strategic messages can be highlighted (Appendix 1). Table 5 summarises the broad-scale implications of the proposals.

Table 5. Summary of high level Natura 2000 implications arising from the proposed RESMC measures.

Gains	Losses	Changes
• Improved fish mobility if weir management allows better upstream/downstream access.	• Non-tidal freshwater wetlands (both SPA and SAC) behind existing sea walls.	• Terrestrial SPA habitat to tidal habitat.
• Increased overall extent of Natura habitat where non-Natura land is converted to tidal influences.	• Reduction in extent of inter-tidal habitats (mudflats, sandflats and alluvial forests).	• Inter-tidal/supra-tidal habitat to sub-tidal habitat that may not equate to a listed Annex 1 habitat.

8.9. Achieving compatibility with the Habitats Directive and subsequently with the Water Framework and Marine Strategy Framework Directives is heavily dependent upon the way the Habitats Directive is interpreted and managed in Germany. The level of administrative fragmentation resulting from designations by 3 separate Länder creates potential for poor integration of Conservation Objectives and potentially conflicting interpretations of what can and cannot be done, or indeed is desirable.

8.10. At the moment it is not clear whether HPA/WSV have developed the RESMC in conjunction with the relevant specialists in the environment and conservation divisions within the three Länder. Assuming that this dialogue has not occurred and that establishing integration is a later stage in the development of the Natura 2000 management plan, the following issues are likely to give rise to problems:

- Different organisations will have differing priorities and interpretations of the Habitats, Water Framework and Marine Strategy Framework Directives.
- Interpretations of ecological benefits by HPA & WSV may not accord with those of conservation specialists in the Länder or at a Federal level.
- Measures that have a potentially beneficial outcome for dredging may be incompatible with Conservation Objectives for protected areas.
- The balance of measures may lead to a neutral impact on some Natura habitats, but there may be losses and gains in differing 'sites' even though the Elbe as a whole might benefit. This may not be compatible with local or national application of the Habitats Directive (beyond my competency because I am not familiar with German transposition of the Directive).

8.11. Overall assessment of the RESMC with respect to the objectives of the WFD, MSFD and Habitats Directive

8.11.1. At this stage, the analysis suggests that the RESMC is most closely aligned to the Water Framework Directive and to some aspects of the Marine Strategy Framework Directive but even in these cases the relationship is ambiguous. It is weakly aligned with the Habitats Directive and several measures are inconsistent with the objectives of this Directive. In particular, it appears as though the net outcome of the proposed measures is a substantial loss of inter-tidal habitats within several Habitat classes and that these losses do not appear to confer particular benefits to the majority of designated attributes.

8.11.2. It is also worth reflecting on the issue of breeding shads, which have been highlighted as a specific problem that some measures within the RESMC might resolve; namely the silting up of shallow inter-tidal. It is noteworthy that shad breeding grounds have moved up and down the estuary in response to water quality changes (Gerkens & Thiel, 2001). Modern breeding grounds in the vicinity of

Mühlenberger Loch suggest that they are now about as far upstream as conditions will allow. Therefore removal of inter-tidal to create sub-tidal habitats further towards the estuary mouth is unlikely to significantly alter the breeding success of this fish. Coincidentally, this also suggests that the Airbus factory development is likely to have much more significant implications than its highlighted effects on migratory waterfowl.

8.11.3. It is far more probable that shad populations have been most seriously affected by a combination of historic impacts of habitat loss to gravel extraction, barriers to migration, depressed water quality and over-fishing (see Thiel *et al*., 2008). Some benefits may accrue from re-connection of tributaries and in this respect it is possible that attention needs to focus on tributaries between Hamburg and the sea.

9. **Question 2f**. Are conflicts regarding objectives between protection of the estuary and marine protection reduced by virtue of the RESMC?

9.1. Sections (3 to 8) highlight problem of designing a package of measures to address the specific issues. The combination of increased tidal propagation, elevated sediment loads, increased mixing between clean and contaminated sediments, and the cost of continuing to maintain a port that is competitive at a trans-European scale make this an especially difficult task. The issues are extremely complex and individual aspects of estuarine and marine protection do not readily lend themselves to a single set of measures that will resolve all of the problems.

9.2. Available information on the measures needed to deliver the objectives of the Birds, Habitats, Water Framework and Marine Strategy Framework Directives is too limited to develop a comprehensive overview of the issues and necessary remedies. Consequently, the following analysis focuses on the processes needed to determine the benefits and drawbacks of outcomes delivered by the RESMC.

9.3. As the provisions of the Habitats Directive effectively take priority over those of the Water Framework Directive and partially help to deliver the objectives of the Marine Strategy Framework Directive, we must focus on processes established to deliver Favourable Conservation Status. Article 6(3) is particularly important in this respect. It comprises four sections:

Article 6(1)	*For special areas of conservation, Member States shall establish the necessary conservation measures involving, if need be, appropriate management plans specifically designed for the sites or integrated into other development plans, and appropriate statutory, administrative or contractual measures which correspond to the ecological requirements of the natural habitat types in Annex I and the species in Annex II present on the sites.*
Article 6(2)	*Member States shall take appropriate steps to avoid, in the special areas of conservation, the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which the areas have been designated, in so far as such disturbance could be significant in relation to the objectives of this Directive.*
Article 6(3)	*Any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives. In the light of the conclusions of the assessment of the implications for the site and subject to the provisions of paragraph 4, the competent national authorities shall agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned and, if appropriate, after having obtained the opinion of the general public.*
Article 6(4)	*If, in spite of a negative assessment of the implications for the site and in the absence of alternative solutions, a plan or project must nevertheless be carried out for imperative reasons of overriding public interest, including those of a social or*

economic nature, the Member State shall take all compensatory measures necessary to ensure that the overall coherence of Natura 2000 is protected. It shall inform the Commission of the compensatory measures adopted.

Where the site concerned hosts a priority natural habitat type and/or a priority species, the only considerations which may be raised are those relating to human health or public safety, to beneficial consequences of primary importance for the environment or, further to an opinion from the Commission, to other imperative reasons of overriding public interest.

9.4. Addressing the provisions of Article 6(1) of the Habitats Directive.

9.4.1. This Article establishes the principle of integrated management involving the multiple objectives needed to deliver an environmentally and economically sustainable solution. It is the driver behind the development of the Integrated Management Plan for the Elbe Estuary Natura sites.

9.4.2. The various environmental, social and economic interests can only be integrated if there is a clear framework for the development of individual work-streams. During this analysis it has become apparent that the high level framework is either missing, or it has not been sufficiently well articulated to play a significant role in the development of the RESMC.

9.4.3. There are models that might be adopted to develop the critical framework required to inform the broad spectrum of economic and social interests whose needs must be accounted for within the 'Integrated Management Plan'. There is no 'perfect' solution and it is generally wise to adopt a system that is adapted to meet the provisions of transposition within individual Member States. However, the Conservation Objectives and related Favourable Condition Tables developed by the UK Marine SACs LIFE project do offer the basis for discussion and adaptation.

9.4.4. At this stage, it therefore feels as though the RESMC has been developed without ready access to all of the strategic guidance it requires. Water and sediment quality issues are clearly primary drivers; whilst issues such as the extent of particular Annex I habitats and the conditions that lead to their maintenance do not appear to have been given particular consideration.

9.4.5. This clearly highlights the importance of the relationship between Hamburg Port Authority, WSV and the relevant statutory and NGO environmental interests in the Natura sites. The nature-protection staff are of particular importance in this respect.

9.4.6. Available information suggests that there is also a weakness in the relationship between the three Länder (The City of Hamburg, Schleswig Holstein and Lower Saxony). This is because there seems to be a lack of recognition that managing a dynamic estuarine environment depends to a very large extent on manipulating and responding to the physical processes that are responsible for maintaining estuarine ecosystems.

9.4.7. However, it must also be emphasised that the Habitats Directive gives the appearance of a package that was predominantly developed by terrestrial ecologists. Whilst management measures in terrestrial environments often involves pushing a

system away from the state it wishes to achieve by successive changes in vegetation, the marine and coastal environment is largely dictated by chance and a desire to achieve entropy (i.e. as near a stable state as possible).

9.4.8. The achievement of a state of entropy is heavily manipulated by measures such as channel deepening and maintenance dredging. Consequently, any management objectives for Natura 2000 estuaries will always involve a compromise. At this stage, the nature of the compromise within the Integrated Management Plan is unclear and there appears to be inadequate guidance to inform HPA and WSV as to the level of compromise that is possible. The RESMC has therefore been developed in what appears to be a policy vacuum and consequently it has focussed on those issues that appear to be most significant from a water-management perspective.

9.4.9. At this stage, several parts of the proposals within the RESMC drive the tidal system away from the stable state it seeks and as such there are components that cannot be regarded as compatible with overall objectives of achieving favourable conservation status.

9.4.10. Favourable Conservation Status for habitats is defined within Article 1(e) of the Habitats Directive as:

Conservation status of natural habitats means the sum of influences acting on a natural habitat and its typical species that may affect its long-term natural distribution, structure and functions as well as the long-term survival of its typical species within the territory referred to in Article 2.

9.4.11. Many of the remedies described in the table on pages 15-17 of the RESMC comprise measures that involve damage to existing habitats. It would therefore be unwise to assume that the RESMC in its current form will be compatible with Conservation Objectives defined for the Natura 2000 sites.

9.5. Conformity with Article 6(2): avoidance of deterioration of habitats.

9.5.1. This Article, in the UK, includes provisions to review existing consents that might have a negative bearing on the condition of particular attributes within Natura 2000 sites. I am unfamiliar with German transposition of the Habitats Directive and therefore there may be no direct equivalent. However, it is important to bear in mind that where specific activities do have a negative influence on Natura 2000 attributes, either habitats or species, there is an onus on rectifying the impact without increasing a problem elsewhere. Consequently it is important to test the RESMC in this respect.

9.5.2. The analysis of high level outcomes that might arise from the implementation of the RESMC (Table 5|) clearly shows that there will be three significant broad-scale short- to medium-term impacts:

- Losses of inter-tidal habitats. These are attributes specifically recognised in Annex I of the Habitats Directive.
- Gains of sub-tidal habitat that may or may not be alternative Annex I habitats.
- Gains in overall extent where realignments involve non-natura 2000 land.

9.5.3. In addition to possible benefits/losses of habitats, there may be additional benefits for those Annex II species that transit the tidal Elbe or breed in the tidal freshwater areas. These gains cannot be quantified.

9.5.4. It must be borne in mind however, that contamination within sediments may actually be perceived as a critical issue in relation to avoiding deterioration of habitats. If contaminant remediation is a critical Natura 2000 policy position, then it may take a more elevated position than loss of habitat in a prioritised list of concerns.

9.6. Addressing Article 6(3) concerning plans and projects.

9.6.1. The role of Article 6(3) in the delivery of the RESMC is potentially complex, depending upon the degree of confluence between the Conservation Objectives for the Natura 2000 sites and the outcomes sought in relation to management of dredged sediment.

9.6.2. It is possible that the RESMC might be interpreted as a 'plan' under Article 6(3) because it is being developed by bodies with vested 'competency' in managing the various Natura sites. This issue was tested when the UK Government was challenged over its implementation of the Habitats Directive in relation to land use plans. It was ruled not to have properly transposed the Directive in relation to 'plans' (Case C-6/04 – see http://vlex.com/vid/commission-united-kingdom-457808).

9.6.3. Guidance subsequently issued by the UK Government's Department for Environment, Food and Rural Affairs (Defra) advised that the tests of Article 6(3) applied to a variety of land–use plans, including shoreline management plans. (see http://www.defra.gov.uk/environment/flooding/documents/policy/guidance/smpguide/smphdleg.pdf).

9.6.4. In addition, each project within the proposed remedial measures (table on pages 15-17 in the RESMC) will (I assume) require consent and local consultation. If this is so, two possible paths may emerge:

- Consent because the measures are needed to deliver the Conservation Objectives for the Natura 2000 sites.
- Appropriate assessment of the proposals to determine their implications for the Natura 2000 sites.

9.6.5. Until the Conservation Objectives are underpinned by detailed explanations of the conditions that represent favourable condition, it is not possible to assess the package of measures or individual proposals. The best that can be achieved is to provide general pointers as to a likely judgement.

9.6.6. Those proposals that involve a substantially greater level of loss of one habitat type than gain by the same habitat type are vulnerable to challenge because a loss of extent will occur. Extent is one of the most important determinants of favourable conservation status for habitats and for specific attributes within Natura 2000 sites.

9.6.7. At the moment, the primary objectives of the RESMC are concerned with the long-term cost of maintaining the navigation channels of the Elbe Estuary and finding ways of reducing the need to use processing on land. Consequently, although some of the proposed remedies may have some ecological benefits, the outcomes will not necessarily be regarded as wholly beneficial to the Natura 2000 attributes. This means that there is a strong possibility that Article 6(3) tests will apply to individual projects and that 'appropriate assessment' will be necessary.

9.6.8. If individual projects involve losses of particular attributes, then it cannot be assumed that gains in others will necessarily be regarded as appropriate offsetting. This is particularly challenging where loss of attributes relevant to SPA designations result in gains in attributes relevant to SAC designation. Furthermore, those impacts that affect priority habitats or species are afforded particular scrutiny. On the Elbe, this means that those proposals that have the potential to affect populations of the Elbe water Dropwort *Oenanthe conioides* will attract particular attention.

9.7. Applying Article 6(4)

9.7.1. Where plans or projects are judged to have an adverse affect on the Natura 2000 attributes, appropriate offsetting measures are necessary. These measures are referred to as 'compensation' which is a term that is very distinct from the more general term 'mitigation' which has particular connotations in relation to the Habitats Directive.

9.7.2. Compensatory measures involve the creation of new habitat beyond the existing Natura 2000 boundaries. It is assumed that at some point, when the habitat has achieved the desired state, the Natura 2000 boundary will be expanded to incorporate this habitat and in so doing the coherence of Natura 2000 will be maintained.

9.7.3. In theory, compensatory measures should be in place before any losses occur. However, in practice this is not always possible. Interpretation of this approach may be dependent upon the legal frameworks of individual Member States.

9.7.4. When planning a comprehensive package of measures, it is therefore important to consider potential for loss and gain of individual Annex I habitats.

9.7.5. Initial analysis of the RESMC suggests that the majority of interventions lie within the boundaries of the various Natura 2000 sites. Relatively few of the proposals involve any potential for extension of site boundaries and so it is possible that losses and gains will not be balanced. If this is the case, then there will be a need to consider two options:

- Investigate and introduce additional habitat creation proposals equivalent to the extent of losses.
- Modify the extent of proposed interventions in the RESMC.

9.8. The analysis of confluence between the RESMC and the Habitats Directive (above) highlights the potential risks. If the RESMC is consistent with the Habitats Directive, then it is likely to be compatible with the objectives of both the Water Framework and Marine Strategy

Framework Directives.

9.9. At this stage, there are many uncertainties about the degree to which the RESMC conforms to the provisions of the Habitats Directive. There is therefore no definitive answer to the question of whether conflicts between protection of the estuary and marine protection reduced by virtue of the RESMC. However, on the balance of probabilities there are likely to be important issues to consider further.

10. **Question 3a**. Are the objectives of the RESMC formulated in the work order sensible in your opinion, also in view of the situation in other European estuaries?

10.1. Sediment management in other European estuaries varies hugely, and no consistent picture emerges when comparing the issues in the Germany, The Netherlands, Belgium, France or the UK. As a general rule, dredging is one of the most costly aspects of maintaining port infrastructure, and this is most significant where the port lies a long way upstream in an estuary that was formerly much shallower. The ongoing trend in the size of Ultra Large Container Carriers (ULCC) is generating and magnifying the problem of reconciling dredging with the need to deliver environmental improvements within tidal rivers.

10.2. The problems faced in the Elbe are by no means unique, but they do appear to be considerably more problematic than in many other places. The issue of river-borne contaminants is familiar to ports such as Rotterdam, but is much less apparent in UK ports for example. This means that there is a case for the development of an approach that is tailored specifically to the Elbe Estuary.

10.3. It is not possible to compile a consistent picture of the issues that drive the approach to sediment management used in individual estuaries. Nor is it realistic to develop a 'one size fits all' approach. This is because the fluvial and marine drivers vary greatly according to a combination of:

- the length of the river and the volume of sediment it carries;
- the hinterlands that generate water entering the river system and the degree to which contaminants are mobilised;
- the morphology of the estuary and its Holocene evolution;
- the geology of the associated coastal cell; and
- marine sediment sources that enter the estuary.

10.4. The RESMC establishes two high level objectives:

- Reducing tidal pumping.
- Reducing sediment cycling.

It also draws attention to four subordinate objectives:

- Reduction of total dredging quantities (river engineering, hydrology).
- Optimising dredging (sediment traps, river engineering).
- Minimising the impact associated with maintenance (dredging).
- Minimising the pollution of dredged material.

Each of the objectives has a particular resonance with situations elsewhere and therefore each is discussed separately below:

10.5. Reducing tidal pumping

10.5.1. As discussed earlier, 'tidal pumping' is the product of a combination of issues that comprise channel deepening, shortening of tidal influences and reductions in tidal volume, and loss of accommodation space. These combined influences have an important bearing on wider environmental parameters such as water quality and wildlife management. There is therefore a strong case for the development of a combination of measures that will counteract 'tidal pumping' in the context of the Elbe Estuary.

10.5.2. The concept of 'tidal pumping' is, however, only an issue where there is an economic case for maintaining a particular depth within the thalweg. In other cases such as the Dee, Ribble or Somme estuaries, reductions in the tidal prism of the estuary have led high levels of sedimentation and creation of new inter-tidal habitat. The processes involved are very similar to those currently happening in the Elbe estuary and other over-deepened estuaries such as the Ems.

10.5.3. Changes in the Dee, Ribble and Somme Estuaries occurred well before recent environmental legislation and have yielded habitat that is now considered to be of great wildlife importance in a European context. The level of anthropgenic change in the, for example, is well described by Fahy *et al*., (1993). It is therefore important to separate the issue of 'tidal pumping' in the Elbe Estuary from similar processes elsewhere that have led to rapid sedimentation.

10.5.4. In the context of the Elbe Estuary, where 'tidal pumping' is effectively maintained by repeated maintenance of the navigation channel, there is a justifiable case for counter measures. Many of the wider environmentally negative impacts such as elevated sediment loads and changes in the distribution of particular types of sediment are largely associated with the maintenance process rather than the actual sedimentation. This is because the sedimentation on its own would lead to the establishment of a new dynamically stable state similar to, say, the Dee Estuary. Consequently inter-tidal sedimentation may not specifically be a nature conservation or environmental issue.

10.5.5. Solutions to 'tidal pumping' therefore follow two possible directions:

- Allow the estuary to evolve towards a new 'Regime' form in which the tidal prism is greatly reduced and the thalweg is much shallower; or
- Maintain the thalweg in its modified form and declared depth to meet economic priorities.

Clearly, the economic case is paramount given the role of the port of Hamburg in the context of northern European transport strategies. Consequently the option of allowing the estuary to evolve towards its 'Regime' form can be discounted.

10.5.6. If 'tidal pumping' cannot be resolved by allowing the development of a new 'Regime' form, there are a number of possible alternative strategies, most of which involve measures to increase the tidal prism, thus lengthening the duration of the flood tide and shortening that of the ebb tide. This 're-balancing' of tidal propagation must inevitably involve increasing the dimensions of the tidal Elbe.

10.5.7. It is therefore reasonable to conclude that the objective to reduce 'tidal pumping' is appropriate because there will be environmental and economic benefits.

10.6. Reducing sediment cycling

10.6.1. At the moment, considerable volumes of sediment are effectively maintained in a mobile state, either in suspension or as bedload by constant dredging and disposal. This is not desirable because it has a wide variety of economic and environmental drawbacks. These include:

- Elevated levels of suspended sediments affecting biological oxygen demand.
- Elevated levels of suspended sediments reducing phytoplankton growth and associated primary productivity.
- Associated reduction in food sources for larval stages of some migratory fish such as Twaite Shad *Alosa fallax*.
- Increased potential for mixing between contaminated and uncontaminated sediments.
- Elevated levels of underwater noise.
- Elevated greenhouse gas production.
- High costs of dredging and reduced port competitiveness.

10.6.2. Dredging volumes appear to have been substantially reduced as a consequence of recent disposal offshore at Buoy E3, thus emphasising the possible benefits of securing disposal locations where sand is not re-mobilised and driven further upstream.

10.6.3. The current situation in which substantial volumes of dredged material are placed at an offshore disposal ground is not sustainable. This is especially important in the context of the Marine Strategy Framework Directive and the Water Framework Directive because the sediment contains elevated levels of contaminants. This means that at the moment levels of contaminants in the offshore environment are effectively rising.

10.6.4. There is therefore a compelling case for development of an alternative sediment placement strategy that avoids the need for offshore disposal. Consequently the overall objective of reducing sediment cycling is entirely consistent with broad-scale ecological and environmental priorities.

10.7. Reduction of total dredging quantities

10. 7.1. At the moment, the ecology of the Tidal Elbe is heavily influenced by the levels of dredging being undertaken and the locations where this sediment is disposed. This means that there is constant flux with artificially elevated sediment loads within the water column and at particular points on the estuary bed.

10. 7.2. Dredge disposal has played an important part in the development of certain inter-tidal and sub-tidal features within the Elbe, and this must not be overlooked when considering current environmental designations. Some features, such as sandbanks (e.g. Pagensand) now form part of the ecology of the river and may

even be considered important for particular attributes in their own right.

10. 7.3. The locations where disposal of dredged sediment is currently occurring will inevitably be influencing the current form and function of the estuary. This means that it is extremely difficult to associate the current ecological features that are valued with strictly natural processes. It is therefore important that the relevant environmental specialists in regional and Federal authorities, as well as within the NGOs should have a clear understanding of the influences dredging currently confers on the estuary.

10. 7.4. As the Elbe is a comparatively large estuary, and the majority of dredged sediment disposal occurs within its boundaries, there is already a good level of consistency with sediment strategies developed in other Member States, especially Belgium and the UK. Modifying the strategy for the Elbe so that less sediment enters the navigation channel but at least the same amount remains within the estuary is consistent with the general principles established elsewhere.

10. 7.5. It would appear that in general the problems of insufficient sediment within the water column to feed mudflat and sandflats is less of a problem on the Elbe than in many UK estuaries, for example. This means that there are important differences in the drivers for particular solutions. Consequently, the mechanisms proposed for management in the UK may not be relevant to the Elbe, and consequently the associated UK management arrangements may not be relevant.

10. 7.6. Reducing total dredged volumes does therefore make sense and are consistent with the situation in other northern European estuaries. The means of achieving such reductions are more problematic, however. This is because the river engineering measures that are proposed are largely untested elsewhere, or have been employed to deliver different environmental benefits.

10.8. Optimising dredging (sediment traps, river engineering)

10.8.1. The possibility of optimising dredging by engineering alternative structures such as sediment traps suggests the development of additional morphological interventions that take the estuary further away from its ‘Regime’ form without necessarily generating environmental benefits.

10.8.2. This is an approach that may be relevant to the Elbe estuary because the circumstances are so unusual. As far as I am aware there are no comparable programmes in Europe and consequently the theory remains un-tested. The concept clearly has economic attractions, and using an over-deepened channel may be effectively environmentally neutral.

10.8.3. Other river engineering techniques such as creating shoals in the mouth, or use of a barrage are techniques that may have been considered elsewhere but do not appear to have been deployed. Possible remedies for the Ems estuary include engineering responses such as constrictions and a tidal sill that may help to reduce tidal propagation but which will be accompanied by a new suite of negative environmental impacts.

10.9. Minimising the impact associated with maintenance (dredging)

10.9.1. This must be a high priority for variety of reasons, both economic and environmental. In this respect, this objective accords fully with the provisions of the various environmental Directives.

10.9.2. The UK approach to maintenance dredging through the 'Maintenance Dredging Protocol' embraces this principle because the assessment process relating to Natura 2000 specifically takes account of the need to avoid deterioration of the Natura 2000 attributes.

10.10. Minimising the pollution of dredged material

10.10.1. Managing the impact of contaminated sediments is exemplified by existing measures on the Elbe Estuary through the use of the METHA plant, and also by the Slufter at Rotterdam. Both are designed to address issues highlighted by the Water Framework Directive.

10.10.2. The cost and wider environmental impact of managing high volumes of contaminated sediment (e.g. greenhouse gas emissions) provide a sound case for reducing mixing between contaminated and uncontaminated sediments.

10.10.3. Clearly the critical focus of efforts has to comprise:

- Prevention of contaminated sediments reaching tidal waters;
- Minimisation of contaminants reaching sedimentation points in Hamburg and further downstream; and
- Minimisation of mixing between 'clean' marine-sourced sediments and contaminated river-borne sediments.

10.10.4. Consequently, the emphasis on measures to minimise mixing between contaminated and uncontaminated sediments must be seen as a priority.

10.11. All of the objectives set by the RESMC in relation to volumes of dredging and levels of contamination therefore make sense and can be reconciled with many strategic priorities within the Elbe estuary.

10.12. It must therefore be concluded that the strategic direction of the RESMC is correct and that the objectives set provide a sound foundation for the development of specific measures. However, there is potential for conflict between strategic dredging objectives and objectives relating to nature conservation and other uses/activities within the Elbe estuary.

11. **Question 3b**. Do the measures outlined in the RESMC represent overall the right way to achieve the objectives? Are the aspects of nature conservation, water protection and marine protection given appropriate and equally weighted consideration?

11.1. At several points in this analysis the apparent lack of integration between nature conservation objectives and the strategy for resolving 'tidal pumping' has been highlighted. Consequently, whilst the overall package of proposed remedies may appear to be rational in terms of achieving the desired sediment management outcome, the broader environmental implications have not been reconciled.

11.2. It is also important to bear in mind that at various points in European environmental legislation, the emphasis is not on equally weighted consideration. A hierarchy of emphasis has been created in which the tests of sustainability have to be applied to plans and projects. This is not strictly confined to the Habitats Directive, but this Directive is most heavily implicated in the development of the RESMC.

11.3. The proposed measures broadly fall into four main categories:

- Managed realignment
- Reconnection of tributaries
- New channels
- Removal of inter-tidal

Each is assessed separately

11.4. Managed realignment

11.4.1. The majority of realignment projects are proposed for areas upstream from Hamburg, although the biggest proposal at Haseldorfer Marsch is a long way downstream. The proposals upstream of Hamburg can almost be regarded as performing a separate function because apart from creating accommodation space and extra tidal volume, they also provide a sink for some of the most heavily contaminated sediments.

11.4.2. There is considerable sense in intercepting contaminated sediments before they mix with cleaner sediments driven upstream by ‘tidal pumping’. In this respect, these proposals accord with the logic of reducing the volumes of sediments reaching Hamburg. However, it is debateable whether the suite of sites will be enough to intercept a sufficiently high volume of fluvial sediment to make a significant difference to contaminant loads in Hamburg. This of course partly depends upon the design and the volume created in each realignment basin.

11.4.3. The second purpose of realignment upstream from Hamburg is to shift tidal influences so that there is a greater volume of water draining on the ebb tide. The volume added to the tidal prism on a spring tide is relatively small in the context

of the Elbe Estuary as a whole. It can be estimated to be in the order of a maximum of 10m cubic metres (350ha x 3m tidal range) which on its own would not be enough to significantly change ebb tide duration. However, bearing in mind that the void will fill with fine sediment to generate new inter-tidal mudflats and alluvial wetlands, this might be a major contribution to reductions in the levels of contaminants reaching the berthing basins in Hamburg.

11.4.4. Realignment at Haseldorfer Marsch is potentially beneficial in providing a sink for suspended sediments in the outer estuary. Again, is also unlikely on its own to result in a sufficiently large influence on tidal propagation to substantially reduce 'tidal pumping' but in combination with other measures it may be beneficial. Depending upon how the position of the turbidity maximum is influenced, this site may usefully intercept fine sediment that might otherwise mix with contaminated sediment in Hamburg.

11.4.5. Realignment as a general approach is undoubtedly a suitable mechanism for addressing some of the environmental problems in the Elbe estuary. However, at the moment the emphasis seems to be primarily on areas of land that are already designated for conservation management. This will be problematic and some proposals such as the Haseldorfer Marsch are unlikely to be realised.

11.4.6. Evaluation of the balance between the emphasis on nature protection, water protection and marine protection is extremely difficult to judge in the absence of the type of tightly defined definitions of favourable condition that such as those used in the UK and an over-arching high-level strategy for management of the Natura 2000 sites. Even so, the relative paucity of measures that might offset interventions within the tidal estuary for sediment management purposes is indicative that the plan requires refinement and further development.

11.5. Reconnection of tributaries

11.5.1. This is an approach that has also been suggested for the Ems estuary and clearly offers some demonstrable benefits because there is scope for making a noticeable increase in tidal volume.

11.5.2. As with managed realignment, the majority of projects appear to be upstream from Hamburg but unlike realignment it has not been quite so noticeable that the emphasis is on existing Natura 2000 sites. These options appear to comprise a mixture of Natura and non-Natura habitat and consequently there may be a combination of benefits and drawbacks that could be presented as a combined package of loss and gain.

11.5.3. Initial analysis suggests that the proposed reconnection of the Borsteler Binnenelbe together with associated realignments offers a genuine possibility of a win-win solution because it appears to involve a mixture of land within and beyond the Natura 2000 site. If this is so, this project may be viable as a win-win solution.

11.5.4. Taken as a complete package, it appears at a superficial level that re-opening tributaries may provide a package that combines measures to deliver nature conservation, water protection and marine protection. The crucial point is that the

total package needs to be evaluated in the context of Natura 2000 as a whole because individual projects lie within different SAC and consequently they may be judged not to deliver the necessary improvements to meet the Conservation Objectives for the site in question.

11.6. New channels

11. 6.1. It is difficult to make any judgement of this proposal and any likely benefits/disbenefits. On balance, it is a minor adjustment in the context of the estuary as a whole.

11.7. Removal of inter-tidal

11.7.1. This measure may add significantly to the overall tidal prism and may therefore offers potential benefits as a sink for sediment and as an increase in volume within the estuary. However, at this stage it is difficult to see how the removal of large areas of habitat from within the tidal estuary can be reconciled with nature conservation objectives, and therefore also with water protection and marine protection objectives.

11.7.2. It is not possible to make a judgement of their likely impact and/or benefits of individual proposals because the Conservation Objectives that I have seen are insufficient detailed. Crucially, neither the Water Framework nor Marine Framework Directives advocate manipulation of the nature conservation objectives to deliver other environmental outcomes. This is exemplified by the one absolute requirement of the Marine Strategy Framework Directive: to establish marine protected areas.

11.7.3. Removal of inter-tidal is the least compatible with the general principles of managing Natura 2000 and as a consequence it casts an unhelpful shadow over the other suite of measures, which as a combined package might yield a neutral impact on the suite of nature conservation attributes.

11.8. Overall assessment

11.8.1. At this stage, the RESMC is disadvantaged because each component of the Integrated Management Plan for the Elbe estuary is progressing independently. This means that the outcome of planning for sediment management will not be satisfactory, despite the greatest willingness on the part of HPA and WSV to find solutions that would equally satisfy nature protection, water protection and marine protection legislation.

11.8.2. However, it should also be noted that the development of the RESMC is founded in a problem that has been ongoing well before recent environmental legislation, and indeed some of the legislation reflects the problem that HPA and WSV are tackling. Consequently, the focus of the RESMC inevitably concentrates on water quality and contamination issues together with the problem of elevated sediment import ('tidal pumping').

11.8.3. Bearing in mind the various concerns raised above, it is not possible to conclude that the RESMC satisfies nature conservation, water protection and marine

protection objectives and does not appear to weight each aspect equally. Some of this problem can be attributed to the immense pressure that contaminant loads place on water managers and consequently this will inevitably have influenced the solutions that have been proposed.

11.9. Do the measures outlined in the RESMC represent overall the right way to achieve the objectives?

11.9.1. This analysis has highlighted a variety of possible benefits and drawbacks that may arise from the overall package of measures. If the total package were to be implemented it is difficult to see how the relevant environmental legislation will be satisfied, and consequently the RESMC has clearly defined limitations.

11.9.2. It would be inappropriate, however, to judge the RESMC without recognising the very peculiar circumstances that HPA and WSV face. The estuary is huge – much larger than the majority of other northern European estuaries whose management may be used to inform the analysis. Furthermore, the development of the RESMC has not been helped by the fragmentary approach to development of the 'Integrated Plan' for the Elbe estuary.

11.9.3. The conceptual thinking behind the RESMC has many merits, and the suite of possible options is sufficiently comprehensive to generate debate and of course to alert all interested parties to the scale of the issue. In this respect it is therefore an important advance and offers the basis for future dialogue and options development.

11.9.4. However, some of the options have the potential to create a point of friction and polarisation of views that will not help to create the relationships that are needed to deliver solutions to the sediment management problems.

11.9.5. Experience in the UK has shown that even where a predominantly beneficial outcome can be expected from a project such as managed realignment, individual officers and local communities may not react favourably. Where proposals have a recognisable detrimental effect on Natura interests it has also been found that this legislation has been used against the project by local interest groups with no nature conservation concerns.

11.9.6. At this stage, it must therefore be concluded that the RESMC has identified a series of measures that maybe appropriate to delivering the sediment management objectives sought by HPA and WSV, but that there are considerable hurdles to be overcome before a final package of measures can be agreed.

12. **Question 3c**. Recommendations for the further development of the RESMC.

12.2. Short-term (next 6 months)

12.1.1. This analysis suggests that the biggest impediment to development of the RESMC lies in the absence of an integrated management plan for Natura 2000 and in particular the lack of clarity about conservation objectives for the estuary as a whole. Consequently, the highest priority should be given to encouraging the three Länder to develop a single and unified set of objectives based on the morphology and physical functioning of the tidal Elbe.

12.1.2. A simple model to describe the relationship between physical processes and development of both high level conservation objectives and individual sectoral strategies is given in figure 4 (below).

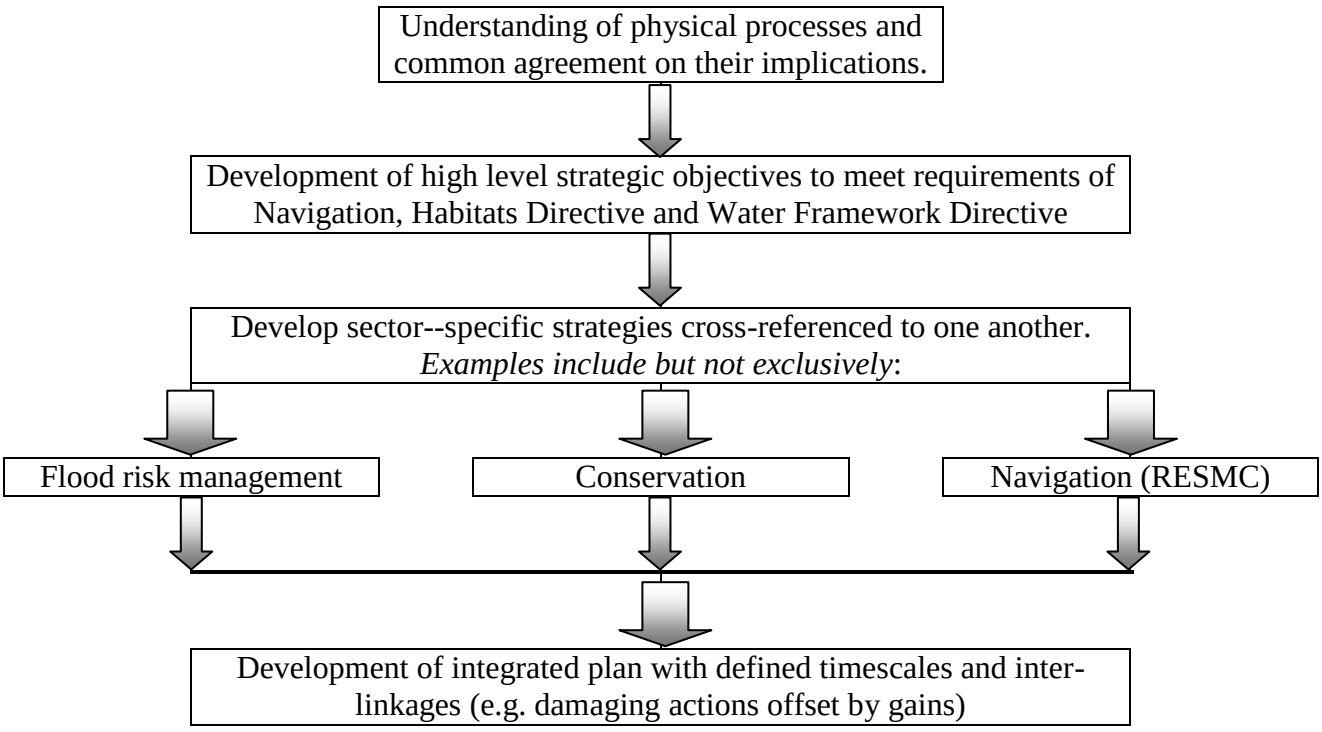

Figure 4. Schematic of relationship between high level objective-setting and sector specific plans.

12.1.3. A unified package of information pertaining to the Natura 2000 sites needs to be considered (e.g. see English Nature, 2001). This could be modelled on Regulation 33 packages developed in the UK as part of the UK Marine SACs LIFE project. Essential information comprises:

- Maps of all sites. In this respect it would be wise to include both the estuarine sites and any adjacent terrestrial sites so that possible realignments (de-poldering) can be put into context. (the map prepared

by BioConsult is potentially suitable for this)
- A list of all of the relevant sites - this should include adjacent sites within the Waddensee. This too has effectively been prepared by BioConsult
- A table of qualifying features against each Natura 2000 site.
- A set of conservation objectives relevant to the qualifying interest features in the estuary as a whole, and any objectives specific to individual Natura 2000 sites.

In addition, there would be merit in developing a set of 'favourable condition tables' that define what favourable condition looks like, and an annotated list of operations likely to damage (i.e. those activities that could have a negative effect on Natura 2000 attributes) with a clear justification for the choice.

This would be helpful to all parties involved in the development of the integrated management plan, and especially to commercial operators working within the Elbe Estuary such as Hamburg Port Authority & WSV.

12.1.4. The above are predominantly jobs for the three Länder but facilitation by HPA and WVS may encourage greater integration, especially if the officers responsible start to see the relevance of greater integration.

12.2. Medium-term (6 months to 2 years)

12.2.1. Development of an integrated plan is largely dependent upon the understanding of how sensitive the estuary is to particular types of intervention and where these interventions are most likely to yield benefits in terms of flood risk management, sediment management and wildlife management. Thus, there is sense in developing a geomorphological map to describe the points where the greatest sensitivity exists and where most benefits can be gained. A map is suggested because this will have greater resonance with the geomorphologically illiterate.

12.2.2. The Elbe Estuary is highly dynamic and will be subjected to natural drivers such as sea level rise. It is therefore suggested that the strategic objectives for conservation management should be linked to a common understanding of the physical drivers that govern the current distribution of habitats and species. This would provide the underpinning for measures to deliver an agreed ecological outcomes. Greater focus on physical processes may also help all parties avoid the complications encountered in creating new habitat to offset habitat loss at Mühlenberger Loch.

12.2.3. There is a need for much greater clarity about the environmental consequences of the various remedial measures described in the table on pages 15-17 in the RESMC (see table 4 -page 56). In particular there is a need to recognise the likely impact on the **extent** of specific Natura 2000 attributes, both in the marine environment and on adjacent terrestrial sites. Proper evaluation of the effects is not possible without such detail.

12.2.4. If new accommodation space is to be created, it would make sense to investigate the levels of sedimentation that might be expected and the degree to which this could reduce fine sediment loads within the estuary. On a broader scale, it would

help to develop an understanding of the timescales involved before accommodation space is only inundated on the highest tides.

12.2.5. It would be helpful to develop an assessment of the likely contributions of individual proposals to the overall tidal prism and hence their likely influence over adjustments to tidal propagation.

12.2.6. It would be helpful to tabulate an analysis of the implications of proposed remedial measures in relation to the Conservation Objectives for individual Annex I habitats, Annex II species and SPA conservation objectives. This will establish a much clearer picture of the possible issues and places where specific problems may be offset by actions elsewhere.

12.2.7. It would be wise to apply the equivalent of the UK's 'Habitats Regulations Assessment' to the RESMC in order to assess the degree to which it converges or diverges from the measures needed to maintain the Elbe Estuary Natura 2000 sites in 'favourable condition'. This appears to be referred to as a FFH Assessment in Germany.

12.2.8. Once a more detailed analysis of the implications of the RESMC has been prepared, it should be possible to evaluate the likely areas of conflict and risk so that a better refined package can be adopted. However, as there are some proposals that have been highlighted as potential 'show-stoppers' further thought needs to be given to the ways in which additional tidal volume might be created between Hamburg and the sea.

12.3. Long-term (beyond 2 years)

12.3.1. Consideration needs to be given to ways of creating freshwater mudflats and shallow sub-tidal analogous to Műhlenberger Loch to create suitable for shad breeding and for migratory water fowl. The main drivers for this are resolution of existing concerns about shads and about the negative impacts of the Airbus factory project.

12.3.1. It may be possible to design a realignment that will absorb fine sediment but that will not become vegetated. There are useful analogues to draw upon from a suite of estuaries in the UK that have failed to evolve from mudflat to saltmarsh. Such a project would be a positive example of securing multiple benefits that have a bearing upon the outcome of the RESMC.

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Appendix 1. High-level analysis of benefits and drawbacks of proposed measures in relation to Natura 2000.

Measure	Sites	Km	Natura impacts (positive)	Natura impacts (negative)
Barriers	Measures in the mouth area	~ km 715		
Change mouth morphology	Upstream tide theory			
Weir management	Weir control at Geesthacht to increase fluvial input during flood tides.	km 580	Possible improved fish movement?	
Reduce channel depth	Between Cuxhaven and Störkurve as well as in the Störbogen area as far as Hamburg.		None	Probably none - involves change to bed levels and temporary smothering.
Remove inter-tidal	St. Margarethen	km 690	Perhaps increased extent of newly sedimenting systems.	Loss of inter-tidal and supra-tidal habitats
	Schwarztonnensand	km 667		
	Bishorstersand	km 657		
	Fährmannssander Watt	km 646		
	Hanskalbsand	km 640		
	Ellerholz	km 612		
	Spadenländer Spitze	km 615		
	Spadenländer Busch / Kreetsand	km 614		
Re-connection	Borsteler Binnenelbe	km 640	Re-establishment of tidal influences.	Very unclear - probably some localised loss where excavation work is needed, but this may be offset by gains in habitat. Needs much more detail.
	Water works/Billwerder Insel	km 621		
	Doveelbe	km 619		
	Untere Seeveniederung	km 605		
	Durchstich Heuckenlock / Norderelbe	km 612		
	NSG Rhee	km 619		
Reconnection?	Alte Süderelbe	Km 629	Uncertain - possibly improved fish movement?	Uncertain - possibly none.
Managed realignment	Spadenländer Ausschlag	km 615	Creation of new inter-tidal or new mudflats.	Possibly loss of existing extent. This is especially true at Haseldorfer Marsch.
	Neuland	Km 610		
	Hohendeicher sea	km 607		
	Haseldorfer Marsch	km 650		
	Kiesteich / tidal channel			
New channels	Pagensander Nebenelbe	km 659	Limited	Possibly loss of existing extent of inter-tidal habitat.
Deepening?	Alte Süderelbe	Km 629		
Optimisation of through-flow in Norderelbe and Süderelbe.	Reshaping of Bunthäuser Spitze	km 610		

APPENDIX 2 Conservation Objectives as supplied by Schuchard (2010)

Conservation Objective	Site	Habitats	Species
Preservation of the relationships between the subareas of the entire region and the adjacent areas while minimizing disturbance of the natural processes, particularly the biotic and abiotic exchange and transport of substances.	FFH site 'NTP S-H Wadden Sea and adjacent coastal areas' (DE 0916-391).		
Conservation of the biotope complexes as well as of the typical habitat structures and functions as occurring naturally.	FFH site 'NTP S-H Wadden Sea and adjacent coastal areas' (DE 0916-391).		
Conservation of the site with the FFH habitat types and FFH species occurring there so as to guarantee biodiversity and coherence of the Natura 2000 European ecological network on a long-term basis.	FFH site 'Schleswig-Holstein Elbe estuary and adjacent areas' (DE 2323-392).		
A favourable state of conservation shall be restored particularly for the species Elbe Water Dropwort and Allis Shad.	FFH site 'Schleswig-Holstein Elbe estuary and adjacent areas' (DE 2323-392).		Elbe Water Dropwort Allis Shad
Conservation of the Elbe estuary with its saltwater, brackish water and freshwater zones and adjacent areas as a near-natural large-scale ecosystem with all structures and functions, as far as possible.	FFH site 'Schleswig-Holstein Elbe estuary and adjacent areas' (DE 2323-392).		
Preservation of undisturbed zonation from river tidal flats to hardwood floodplain forests under unimpaired tidal influence, tidal flat channels and Elbe side arms influenced by tidal and flow dynamics in front of and behind the dikes as well as green areas with unhindered high tide influence.	FFH site 'Schleswig-Holstein Elbe estuary and adjacent areas' (DE 2323-392).		
Protection and development of a coherent, predominantly near-natural estuary region with freshwater and brackish water tidal flat areas (including as a habitat for the endemic Elbe Water Dropwort).	FFH site 'Lower Elbe' (DE 2018-331).		Elbe Water Dropwort
Conservation and development of an ecologically continuous river course as a (sub) habitat for FFH Annex II fish species (River Lamprey, Sea Lamprey, Twaite Shad and Asp).	FFH site 'Lower Elbe' (DE 2018-331).		River Lamprey Sea Lamprey Twaite Shad Asp
Protection and development of floodplain forests in a complex with reeds and moist tall forb meadows.	FFH site 'Lower Elbe' (DE 2018-331).		
Preservation and development of the functional capacity of the richly structured habitats of the shallow-water zones dependent on dynamic processes of the tidal Elbe, of the freshwater influenced sand flats and mudflats criss-crossed	FFH site 'Complex comprising Neßsand nature reserve and Mühlenberger Loch landscape protection area' (DE 2424-302).		

by tidal flat channels, of the sandy beaches, of the tidal reeds, of the tall forb meadows, willow bushes and tidal floodplain forests.			
In particular, conservation and development of the FFH habitat types [1130] 'estuaries' and [91E0] 'floodplain forests' with *Alnus glutinosa* and *Fraxinus excelsior* as well as protection of the FFH Annex II fish species (River Lamprey, Sea Lamprey, Twaite Shad and Asp).	FFH site 'Complex comprising Neßsand nature reserve and Mühlenberger Loch landscape protection area' (DE 2424-302).	[1130] Estuaries	River Lamprey
		[91E0] Floodplain forests with *Alnus glutinosa* and *Fraxinus excelsior*	Sea Lamprey
			Twaite Shad
			Asp
Conservation of freshwater and brackish water tidal flats (including as a habitat for the endemic Elbe Water Dropwort).	FFH site 'Complex comprising Neßsand nature reserve and Mühlenberger Loch landscape protection area' (DE 2424-302).		Elbe Water Dropwort
Conservation and development of an ecologically continuous river course as (sub) habitat for FFH Annex II fish species *Lampetra fluviatilis* (River Lamprey), *Petromyzom marinus* (Sea Lamprey), *Alosa fallax* (Twaite Shad) and *Aspius Aspius* (Asp) as well as in the freshwater area of the Salmon *Salmo salar*.	FFH site 'Protected areas for Asp in the current-carrying Elbe in Hamburg' (DE 2424-303).		River Lamprey
			Sea Lamprey
			Twaite Shad
			Asp
			Salmon
Conservation and development of the FFH habitat types [3270] 'rivers with mud banks with vegetation of Chenopodion rubri p.p. and Bidention p.p.', [6430-1] 'moist tall forb fringes of the Lower Elbe' and [91E0] 'floodplain forests' with Alnus glutinosa and Fraxinus excelsior as well as protection of FFH Annex II fish species (River Lamprey, Sea Lamprey, Twaite Shad, Asp and Salmon).	FFH site 'Hamburg Lower Elbe' (DE 2526-305).	[3270] Rivers with mud banks with vegetation of Chenopodion rubri p.p. and Bidention p.p.	River Lamprey
			Sea Lamprey
			Twaite Shad
			Asp
			Salmon
		6430-1] Moist tall forb fringes of the Lower Elbe	
		[91E0] Floodplain forests' with Alnus glutinosa and Fraxinus excelsior	
Conservation and/or restoration of the structures and functions typical of the habitat as breeding, moulting, resting, feeding and wintering grounds of wading and aquatic birds as well as seabird species; in particular, however, for the species of Annex I of the Birds Directive (in the national park process protection has priority over all other nature conservation objectives and is thus the paramount conservation objective; this objective includes conservation of the bird world typical of the location in its natural dynamics).	SPA 'Ramsar site Schleswig Holstein Wadden Sea and adjacent coastal areas' (DE 0916-491).		
Conservation and development of, for example, the FFH habitat types [3270] 'rivers with mud banks with vegetation of *Chenopodion rubri* p.p. and *Bidention* p.p.', [91F0] 'hardwood floodplain forests' with *Quecus robur*, *Ulmus laevis*, *Ulmus minor* and *Fraxinus excelsior* as well as protection of the FFH Annex II fish species	FFH site 'Borghorster landscape of the Elbe' (DE 2527-303).	[3270] Rivers with mud banks with vegetation of *Chenopodion rubri* p.p. and *Bidention* p.p.', [91F0]	River Lamprey
			Sea Lamprey
			Twaite Shad
			Asp
			Turbot
			Crested Newt

(River Lamprey, Sea Lamprey, Twaite Shad, Asp, Turbot and Crested Newt).			
		[91F0] Hardwood floodplain forests with *Quecus robur*, *Ulmus laevis*, *Ulmus minor* and *Fraxinus excelsior*	
Restoration of FFH habitat types [6430-1] 'moist tall forb fringes of the Lower Elbe' and [91E0] 'floodplain forests with *Alnus glutinosa* and *Fraxinus excelsior*' as well as the habitats of the Elbe Water Dropwort.	FFH site 'Borghorster landscape of the Elbe' (DE 2527-303).	[6430-1] Moist tall forb fringes of the Lower Elbe	
		[91E0] Floodplain forests with *Alnus glutinosa* and *Fraxinus excelsior*	
Conservation of the structures and functions typical of the habitat as breeding grounds for birds of prey, bluethroat, common terns and birds of grasslands and reeds and as resting grounds particularly for waders, terns and ducks. The green areas must be preserved as important wintering grounds for various geese (the overriding objective is preservation of adequately high water levels and conservation of moist habitats with undisturbed water dynamics typical of the estuary, as far as possible, is also of special importance; extension of the area subject to tidal influence with the characteristic bird communities shall be given priority).	SPA 'Lower Elbe to Wedel' (DE 2323-401).		

Appendix 3. Notes on Conservation Objectives and favourable condition tables from the UK

The following sections are adapted from information presented in the Regulation 33[2] package for the Severn Estuary (Natural England & Countryside Council for Wales, 2009) which is the closest fit in terms of size to the Elbe. There are two components to the critical information. Firstly an analysis of the relative contributions of individual interest features (Natura Habitats and Species) describes how individual parts of the estuary contribute to the overall designations of SAC, SPA and Ramsar Site. Secondly, the Conservation Objectives describe the high level 'desired state'; and finally the Favorable Condition Tables describe the state of the attributes that make up individual habitats.

[2] Regulation 33 of the Habitats Regulations (1994) has recently been superseded by Regulation 35 of the Habitats & Species Regulations 2010 which states:

35. *(1) The appropriate nature conservation body may install markers indicating the existence and extent of a European marine site.*

(2) This power is exercisable subject to the obtaining of any necessary consent under section 34 of the Coast Protection Act 1949(1) (restriction of works detrimental to navigation).

(3) As soon as possible after a site becomes a European marine site, the appropriate nature conservation body must advise other relevant authorities as to—

(a)the conservation objectives for that site; and

(b)any operations which may cause deterioration of natural habitats or the habitats of species, or disturbance of species, for which the site has been designated.

Table 1. List of designations and qualifying features.

Feature	SAC	SPA	Ramsar Site
H1130 Estuaries.	Yes	*Supporting habitat to designated bird interests*	Yes
H1110 Sandbanks which are slightly covered by seawater all the time.	Yes	No – outside boundary of SPA	No – outside boundary of Ramsar Site
H1140 Mudflats and sandflats not covered by seawater at low tide.	Yes	*Supporting habitat to designated bird interests*	*Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests*
H1330Atlantic salt meadows (*Glauco puccinellietalia maritimae*).	Yes	*Supporting habitat to designated bird interests*	*Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests*
H1170 Reefs	Yes	No	*Intertidal* Sabellaria *contiguous with subtidal reefs is a component of the hard substrates subfeature of the Ramsar "estuaries" feature*
Migratory fish: (River Lamprey S1099), Sea Lamprey S1095 & Twaite Shad S1103)	Yes	No	Yes
Migratory fish (Salmon, Eel, sea trout and Allis Shad)	*Part of notable species sub-feature of estuary feature*	No	Yes
Assemblage of fish species (>100 species)	*Notable species sub-feature of estuary feature*	No	*Notable species sub-feature of estuary feature)*
Internationally important populations of migratory bird species	*Notable species sub-feature of estuary feature*	Yes	Yes Internationally important populations of waterfowl
Internationally important populations of wintering bird species	*Notable species sub-feature of estuary feature*	Yes	
Assemblage of nationally important populations of waterfowl	*Notable species sub-feature of estuary feature*	Yes	Yes
Hard substrate habitats (Rocky shores)	*Notable species sub-feature of estuary feature*	*Supporting habitat to designated bird interests*	*Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests*
Freshwater grazing marsh / Neutral grassland	No	*Supporting habitat to designated bird interests within SPA but outside European Marine Site* ***and therefore not addressed in this Regulation 33 advice document***	

There are several approaches to writing Conservation Objectives, depending on the agencies involved in the UK. The Severn Estuary is useful in this respect because its lies within the administrative boundaries of both England and Wales. The challenges of reaching common agreement between these two countries is probably no less challenging than gaining common agreement between the Länder in Germany.

Conservation objective for the "estuaries"	
The feature will be considered to be in favourable condition when, subject to natural processes, each of the following conditions are met:	
1.	The total extent of the estuary is maintained.
2.	The characteristic physical form (tidal prism/cross sectional area) and flow (tidal regime) of the estuary is maintained.
3.	The characteristic range and relative proportions of sediment sizes and sediment budget within the site is maintained.
4.	The extent, variety and spatial distribution of estuarine habitat communities within the site is maintained.
5.	The extent, variety, spatial distribution and community composition of hard substrate habitats and their notable communities is maintained.
6.	The abundance of the notable estuarine species assemblages is maintained or increased;
7.	The physico-chemical characteristics of the water column support the ecological objectives described above.
8.	Toxic contaminants in water column and sediment are below levels which would pose a risk to the ecological objectives described above.
9.	Airborne nutrient and contaminant loads are below levels which would pose a risk to the ecological objectives described above.

Conservation objective for the "subtidal sandbanks"	
The feature will be considered to be in favourable condition when, subject to natural processes, each of the following conditions are met:	
1.	The total extent of the subtidal sandbanks within the site is maintained.
2.	The extent and distribution of the individual subtidal sandbank communities within the site is maintained.
3.	The community composition of the subtidal sandbank feature within the site is maintained.
4.	The variety and distribution of sediment types across the subtidal sandbank feature is maintained.
5.	The gross morphology (depth, distribution and profile) of the subtidal sandbank feature within the site is maintained.

Conservation objective for "mudflats and sandflats"	
The feature will be considered to be in favourable condition when, subject to natural processes, each of the following conditions are met:	
1.	The total extent of the mudflats and sandflats feature is maintained.
2.	The variety and extent of individual mudflats and sandflats communities within the site is maintained.
3.	The distribution of individual mudflats and sandflats communities within the site is maintained.
4.	The community composition of the mudflats and sandflats feature within the site is maintained.
5.	The topography of the intertidal flats and the morphology (dynamic processes of sediment movement and channel migration across the flats) are maintained.

Conservation objective for the "Atlantic salt meadow"
The feature will be considered to be in favourable condition when, subject to natural processes, each of the following conditions are met:

1.	The total extent of Atlantic salt meadow and associated transitional vegetation communities within the site is maintained.
2.	The extent and distribution of the individual Atlantic salt meadow and associated transitional vegetation communities within the site is maintained.
3.	The zonation of Atlantic salt meadow vegetation communities and their associated transitions to other estuary habitats is maintained.
4.	The relative abundance of the typical species of the Atlantic salt meadow and associated transitional vegetation communities is maintained.
5.	The abundance of the notable species of the Atlantic salt meadow and associated transitional vegetation communities is maintained.
6.	The structural variation of the salt marsh sward (resulting from grazing) is maintained within limits sufficient to satisfy the requirements of conditions iv and v above and the requirements of the Ramsar and SPA features**.**
7.	The characteristic stepped morphology of the salt marshes and associated creeks, pills, drainage ditches and pans, and the estuarine processes that enable their development, is maintained.
8.	Any areas of *Spartina anglica* salt marsh (SM6) are capable of developing naturally into other saltmarsh communities.

Conservation objective for the "reefs"	
The feature will be considered to be in favourable condition when, subject to natural processes, each of the following conditions are met:	
1.	The total extent and distribution of *Sabellaria* reef is maintained.
2.	The community composition of the *Sabellaria* reef is maintained.
3.	The full range of different age structures of *Sabellaria* reef are present.
4.	The physical and ecological processes necessary to support *Sabellaria* reef are maintained.

Conservation objective for the River Lamprey *Lampetra fluviatilis*	
The feature will be considered to be in favourable condition when, subject to natural processes, each of the following conditions are met:	
1.	The migratory passage of both adult and juvenile river lamprey through the Severn Estuary between the Bristol Channel and any of their spawning rivers is not obstructed or impeded by physical barriers, changes in flows, or poor water quality.
2.	The size of the river lamprey population in the Severn Estuary and the rivers which drain into it, is at least maintained and is at a level that is sustainable in the long term.
3.	The abundance of prey species forming the river lamprey's food resource within the estuary, is maintained.
4.	Toxic contaminants in the water column and sediment are below levels which would pose a risk to the ecological objectives described above.

Conservation objective for the Sea Lamprey *Petromyzon marinus*	
The feature will be considered to be in favourable condition when, subject to natural processes, each of the following conditions are met:	
1.	The migratory passage of both adult and juvenile river lamprey through the Severn Estuary between the Bristol Channel and any of their spawning rivers is not obstructed or impeded by physical barriers, changes in flows, or poor water quality.
2.	The size of the river lamprey population in the Severn Estuary, and the rivers which drain into it, is at least maintained and is at a level that is sustainable in the long term.
3.	The abundance of prey species forming the river lamprey's food resource within the estuary, is maintained.

4.	Toxic contaminants in the water column and sediment are below levels which would pose a risk to the ecological objectives described above.

Conservation objective for the Twaite Shad *Alosa fallax*	
The feature will be considered to be in favourable condition when, subject to natural processes, each of the following conditions are met:	
1.	The migratory passage of both adult and juvenile Twaite Shad through the Severn Estuary between the Bristol Channel and their spawning rivers is not obstructed or impeded by physical barriers, changes in flows or poor water quality.
2.	The size of the twaite shad population within the Severn Estuary and the rivers draining into it is at least maintained and is at a level that is sustainable in the long term.
3.	The abundance of prey species forming the twaite shad's food resource within the estuary, in particular at the salt wedge, is maintained.
4.	Toxic contaminants in the water column and sediment are below levels which would pose a risk to the ecological objectives described above.

Favourable condition tables.

The following table is simply an excerpt from a much larger tabulation that describes all of the Natura 2000 attributes. In the case of the 'Estuaries' H1130 feature in this table there are 21 attributes. These tables are an essential part of the advice provided by the Conservation Agencies (Natural England, Countryside Council for Wales and Scottish Natural Heritage) because they provide detailed information on the nature of changes that might be interpreted to lead to a shift away from Favourable Condition and hence Favourable Conservation Status.

***SAC interest feature 1:* Estuaries**				
Sub-feature	**Attribute**	**Measure**	**Target**	**Comments**
Hard substrate habitats and their notable communities	**Community composition** *(extent, variety, spatial distribution and community composition of notable communities - section 4.1.1.v of the conservation objectives)*	Assessment of community quality through survey of species composition (presence of typical species) within the notable communities measured periodically	No decline in community quality due to changes in species composition or loss of typical species from an established baseline *Baseline to be established : Data to be used : CCW and English Nature Intertidal Biotope Surveys 2006 and future surveys*	Different associations of plants, animals and their habitat are an important structural and functional aspect of the feature. Changes in the communities present within an area of a particular type may indicate long-term changes in physical conditions at the site. Typical species of the notable communities to be determined.
Notable estuarine species assemblages : **Assemblage of fish species**	**Abundance** *(abundance of notable estuarine species assemblages - section 4.1.1.vi of the conservation objectives)*	Numbers of species and population estimates	No significant reduction in overall diversity of species or in individual populations against an established baseline *Baseline to be established : Data to be used : Environment Agency and relevant Sea Fisheries Committee data*	Loss of notable communities may indicate long term changes in the physical conditions of the estuaries interest feature or individual subfeatures. **Assemblage of fish species:** (Refer to section 4.1.1 note 7) • Migratory species (see also section of this table which relates to the River Lamprey, Sea Lamprey and Twaite Shad features) • Estuarine species • Marine species • Freshwater species Refer also to section 4.3.2 in relation to the assemblage of migratory fish species of the Ramsar Site.
Notable estuarine species assemblages : **Assemblage of waterfowl species**	**Abundance** *(abundance of notable estuarine species assemblages - section 4.1.1.vi of the conservation objectives)*	Numbers of species and individual population sizes	No significant reduction in overall diversity of species or in individual populations against an established baseline *Baselines are identified in the SPA section of this advice – see section 4.2*	Loss of notable communities may indicate long term changes in the physical conditions of the estuaries interest feature or individual subfeatures. Refer also to section 4.2.7 in relation to the Internationally important **assemblage of waterfowl** of the Severn Estuary SPA and section 4.3.9 in relation to the Internationally

				important assemblage of waterfowl of the Severn Estuary Ramsar Site
Notable estuarine species assemblages : **Assemblage of vascular plant species**	**Abundance of saltmarsh species** *(abundance of notable estuarine species assemblages - section 4.1.1.vi of the conservation objectives)*	Number of species and population sizes	No significant reduction in overall diversity of species or in individual populations against an established baseline *Baselines to be established: Data to be used is 1998 NVC Scarce plant survey, county botanical records and CCW/NE site records*	Loss of notable communities may indicate long term changes in the physical conditions of the estuaries interest feature or individual subfeatures. **Assemblage of vascular plant species includes**: • Salt marsh species Note : maintaining the conditions necessary for these species are covered by the Atlantic salt meadows table attributes Table 11

Appendix 4. Analysis of the possible application of the Maintenance Dredging Protocol to the Elbe Estuary

A4.1. Initial understanding

A4.1.1. The integration of maintenance dredging into management plans for Natura 2000 sites is a matter of concern for many northern European ports. This is especially important where maintenance dredging is a major component of fairway management.

A4.1.2. In theory, the issue of maintenance dredging would be analysed within the environmental statement associated with channel deepening. Critical wildlife management issues would then be addressed through a package of compensation or mitigation measures. However, in many cases this has not happened because the channel deepening took place before designation of Natura interest. It is my understanding that this is the situation that obtains within the Elbe Estuary.

A4.1.3. The following notes are therefore based on what is understood to be the existing legal situation and experience of similar situations elsewhere.

A4.2. Possible impacts arising from channel deepening and subsequent maintenance dredging

A4.2.1. Channel deepening reverses some 10,000 years of coastal evolution and changes the geometry of estuaries. It is often also linked to the loss of accommodation space that is the critical means of energy attenuation and sediment management in estuaries. So, the geometry of the estuary concerned is often far removed from its original form. These issues are covered in the analysis of the Sediment Management Concept for the Tidal River Elbe in the main body of this report.

A4.2.2. There are several possible responses to these changes in geometry that have a bearing on the extent and condition of designated habitats. The following list is not exhaustive:

- Increased high tide levels leading to drowning of inter-tidal habitats.
- Reduced low tide levels and reductions in the extent of shallow sub-tidal habitats.
- Increased sediment import from marine sources in the water column.
- Increased sediment import or export as bedload.
- Changes to the relationship between sediment deposition and erosion on inter-tidal. Where sediment loads are increased there is potential for accretion but where they are suppressed this will lead to increased bank erosion and loss of inter-tidal habitats.
- Increased sediment load within the water column.
- Increased need to export dredged sediment to an offshore disposal ground.

A4.2.3. The process of maintaining the deepened channel has a variety of possible wildlife implications too, *inter-alia*:

- Elevated sediment loads in the water column affecting fish movement.
- Under water noise affecting fish behaviour.
- Possible smothering effects.

- Elevated Biological Oxygen Demand.

A4.3. Legal interpretations

A4.3.1. Several cases in the UK and in Europe have explored whether maintenance dredging involves a distinct 'plan or project' under Article 6(3) of the Habitats Directive. There are also related cases such as the Waddensee cockling judgement that consider the issue in relation to consents for shellfish management. These cases suggest that maintenance dredging should be considered as a separate plan or project.

A4.3.2. In my opinion, the most compelling cases for treating maintenance dredging as a plan or project can be made where distinct consents are required to permit maintenance dredging or disposal of such material. This is the situation in the UK where disposal licenses are required.

A4.3.3. The question may arise in other circumstances as to the degree to which Natura designations were taken into account when the original deepening consent was granted. Moreover, if it was inferred that maintenance dredging was accepted as a natural follow-up component of the project then there may be a case for interpreting maintenance dredging as consented already. In these cases it could be argued that Article 6 calls for extant consents to be reviewed where they permit ongoing operations that may have detrimental impacts on protected sites or species. In other words, taking measures to ensure that 'favourable conservation status' is maintained.

A4.3.4. Review of existing consents will depend upon the provisions within individual Member States' transposition of the Habitats Directive. I can only draw upon UK examples, the majority of which relate to water abstraction and discharge licenses which have been reviewed, affirmed, amended or revoked. In theory, this could be applied to underpinning permits to dredge, but the political and economic implications are such that this route is unlikely to be followed.

A4.3.5. Commission guidance on ports and the Habitats Directive is emphasises the need for maintenance dredging to be incorporated into the management plan for the Natura site. There are numerous ways in which this might be achieved. In the UK, the 'Maintenance Dredging Protocol' was designed to work in this way and was designed in part to avoid the need to apply Regulation 63 (http://www.legislation.gov.uk/uksi/2010/490/regulation/63/made).

A4.4. Maintenance dredging protocol

A4.4.1. In the UK, the majority of Habitat 1130 'Estuaries' were designated in 1994. There were three exceptions: the Humber, Tweed and Alde-Ore-Butley which were selected and designated as a consequence of the Kilkee moderation process. Only the Humber is a major port and is significantly affected by dredging. All key sites were, however, Special Protection Areas and all significant port developments had been assessed according to the provisions of Article 6(3) and 6(4) of the Habitats Directive since 1994 when the Directive was transposed into UK law. In addition, all estuary SAC included navigation channels and consequently the relationship between channel deepening, maintenance dredging and Natura 2000 management has been well established and understood for the past 17 years.

A4.4.2. The approach adopted within the Maintenance Dredging Protocol was designed to take

account of the very large amount of work that has taken place evaluating the impacts of dredging on Natura 2000 sites. Up until 2002 when the Protocol was first designed, all maintenance dredging events of any magnitude were accompanied by an Environmental Statement and associated modelling. Also, many of the major ports had recently sought consent for channel deepening and had detailed analyses of the anticipated impacts. There was generally a large body of information and analysis that could be drawn upon.

A4.4.3. It is also worth bearing in mind that most UK ports lie close to the mouth of estuaries and in very few cases (e.g. the Thames) does channel maintenance occur a long way upstream. Furthermore, UK most UK estuaries are relatively small and unsuitable for major channel deepening. Consequently, the scale of impacts of channel deepening and subsequent maintenance is generally small compared to those within the Elbe, Ems, Western Schelde or Seine. There are, however, impacts and issues that are being addressed through the Protocol and through consents for subsequent channel deepening.

A4.4.4. The critical issues of concern in the UK relate to the impact of maintenance dredging on sediment budgets within estuaries. These budgets comprise several counter-acting impacts:

Imports	**Exports**
Fluvial sources (usually small)	Sub-tidal deposition
Cliff erosion	Inter-tidal deposition
Sub-tidal erosion	Export as bedload
Foreshore lowering (mudflats)	Deposition on mudflats
Saltmarsh erosion	Deposition on saltmarshes
	Export as dredged sediment

A4.4.5. There are several estuaries such as Southampton Water and its related estuaries where the net sediment budget is in deficit (see table 1 in section 4 of the main report) , which means that saltmarshes and inter-tidal mudflats are losing sediment and are moving away from favourable conservation status. It is in places such as these that sediment feeding programmes are essential.

A4.5. Could the Maintenance Dredging Protocol be applied in the Elbe Estuary?

A4.5.1. If, as has been assumed in section A4.1, the last consent for channel deepening did not include assessment of impact on Natura interest, it is difficult to see how a system based on the Maintenance Dredging Protocol could be introduced. At this stage I have not been able to assess the implications for the various Natura 2000 interest such as:

- Gain/loss of inter-tidal habitats (saltmarsh/mudflat/FW mudflats and wetlands).
- Sediment budget - is the estuary likely to suffer a shortfall in sediment required to maintain inter-tidal habitats? (the answer to this is likely to be no!).
- Changes in distribution of coarse/fine sediments and related habitats - e.g. the sandbanks used by *Alosa fallax* as spawning grounds.

A4.5.2. The ongoing development of an Integrated Management Plan for the various Natura Sites. Initial analysis of these proposals suggest that this offers a useful way forward that in many ways is analogous to some provisions within the Maintenance Dredging Protocol. There are some important differences to bear in mind:

A4.5.2.1. UK and German legal processes differ and although the transposition of the Habitats Directive should look similar the local legislation also has a significant bearing on what can and cannot be done.

A4.5.2.2. It appears as though the Natura designations on the Elbe Estuary took place somewhat later. In particular, unlike the UK, the German approach had originally been to exclude navigation channels and so it seems likely that the impacts of channel deepening on Natura 2000 were not fully evaluated when the last consent was sought.

A4.5.2.3. There is a possible need to undertake retrospective analysis of the impacts of the last channel deepening on Natura interest in order to develop a clear understanding of its effects.

A4.6. Recommendations

A4.6.1. At this stage the Integrated Management Plan for the Elbe Estuary appears to be the most suitable vehicle for addressing maintenance dredging and its implications for Natura 2000 sites. There are several obvious drawbacks to using the Maintenance Dredging Protocol, which has been developed for the peculiarly British situation, but the main one is that it assumes that much of the assessment process has already occurred and the issues have been highlighted.

A4.6.2. There are likely to be a sequence of cumulative impacts associated with channel deepening, so there is a need to give careful thought to the baseline against which impacts can be judged. However, it is also noteworthy that there have been at least 6 deepening events and numerous other modifications whose combined effects are better understood than those associated with specific events.

A4.6.3. Preparation of the EIA for the next phase of channel deepening provides a useful point at which analysis of impacts to date can be quantified and set in context. This could feed into the development of a dredging management plan and could be incorporated into the developing Integrated Management Plan. However, the assessment of any channel deepening needs to follow the provisions of Article 6(3) and possibly Article 6(4) depending on the findings of Appropriate Assessment.

Appendix 5 - explanation of Natura 2000 issues arising from interventions proposed by the RESMC.

The concept of engineering changes in an estuary that is designated as a Natura 2000 site (s) to address non-Natura 2000 issues is one that causes a great deal of confusion and might best be illustrated by a simple diagram. Two illustrations are shown below. The first gives a very rough outline of the position of Natura 2000 habitat within a 'conceptual estuary'. The second describes two possible interventions based on conceptual understanding of the proposals within the RESMC.

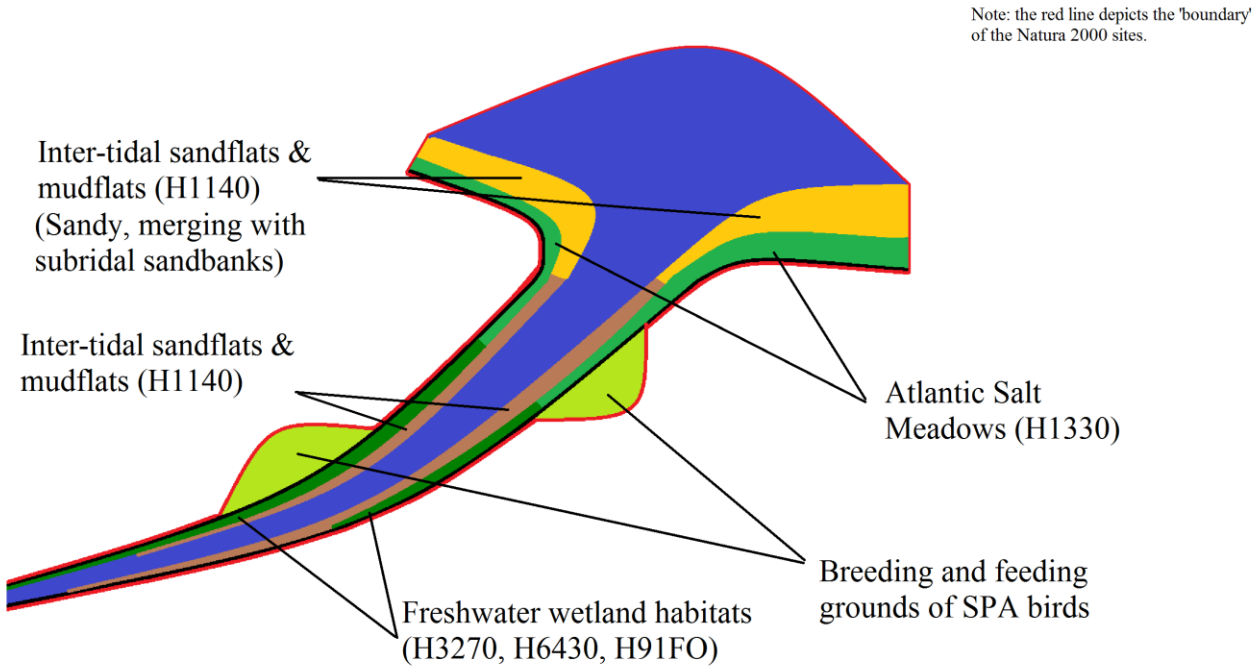

Figure 5. Conceptual estuary in which the estuary as a whole is designated as an 'Estuary' H1130 and one or more sites form a series of SAC and SPA that together form the overall Natura 2000 designated features. The mudflat and sandflat element of H1140 is split to reflect the general trend of greater sandiness towards the mouth (as seen in many UK estuaries). Tidal macrophyte communities are separated into saline and freshwater influenced areas but are not depicted in detail. Two areas of grassland behind the sea walls are also depicted where feeding and breeding wildfowl and waders form the SPA interest.

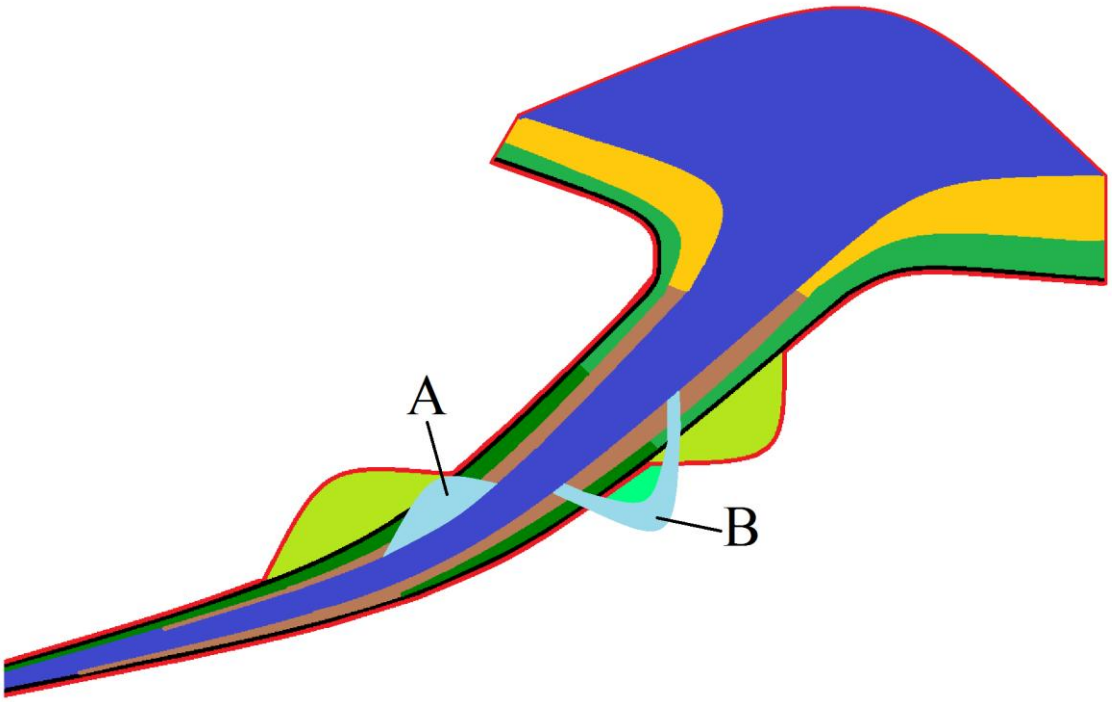

Figure 6. Two conceptual interventions are depicted. Intervention 'A' involves creation of a shallow sub-tidal environment suitable as a sediment sink and arguably creating additional habitat for Twaite Shad *Alosa fallax*. Intervention 'B' represents reconnection of a former meander.

Intervention 'A' will lead to a reduction in extent of H1140 mudflats that may also be used by SPA waterfowl. It will also lead to a reduction in extent of various freshwater macrophyte communities (H3270, H6430 & H91FO) and perhaps also part of the terrestrial SPA area. All of these are negative impacts in the accounting process. On the positive side, there will be a greater extent of shallow subtidal suitable for Twaite Shad *Alosa fallax* spawning. But, as the primary purpose of the proposal is for sediment management relating to dredging demand, this is not a project specifically required for conservation management and consequently the losses must be considered in 'appropriate assessment'. Such losses are likely to be on a scale that is sufficient for the Competent Authorities to be unable to conclude that there will not be an adverse affect on the integrity of the SAC/SPA. If there is a view that the project should progress for imperative reasons of over-riding public interest, then compensatory measures (managed realignment) would be required to rectify the shortfall in extent of the lost habitats.

Intervention 'B' involves a combination of impacts. On the one hand, it will lead to the creation of shallow inter-tidal through existing H1140 mudflats and freshwater macrophyte communities (H3270, H6430 & H91FO). On the other, new habitat will be created **outside** the existing site boundary. This new habitat is likely to be sufficient to offset the loss of habitat within the Natura 2000 site boundary. The combined effects of loss and gain are likely to be neutral or even positive in relation to the extent of particular Natura 2000 attributes and consequently the consent process should be more straightforward in relation the Birds and Habitats Directives. Once created and functioning, this new habitat needs to be designated as SPA/SAC.

Appendix 6. The RESMC and climate change

Client feedback after submission of the first draft of this report sought consideration of climate change issues relating to the RESMC and its implications for development of the Integrated Management Plan for the Elbe Estuary. This brief note is intended to provide a short synopsis of the issues as I perceive them. It has not been researched in detail because climate change issues were not a specific question in the original specification. I have interpreted the questions as posed - the issues relating to the period up to 2005.

A6.1. Climate change impacts on estuaries predominantly fall into two categories:

- Sea level rise comprising the combined influences of isostatic and eustatic changes. This may involve rising sea levels as seen in much of northern Europe, or a gradual shift from rising land masses and gradual inundation of recently raised land.
- Changes in rainfall that lead to more episodic high fluvial outflow, possibly accompanied by longer periods of low fluvial input.

A6.2. The changes that arise from these climate induced influences cannot be modeled with any certainty. Models can generally be trained to hindcast relatively accurately, but forecasting becomes increasingly uncertain the further into the future one goes. Consequently, adoption of a strategic approach to these issues is the wise course of events. Within this, there will be a need to evaluate the likely impact of bigger episodic fluvial events and their impact on the supply of contaminated sediments to the Tidal Elbe.

A6.3. Sea level rise is an issue that has become embedded in some national flood risk management strategies. I am particularly aware of the UK approach and this is raised as an example for the purposes of this note. UK guidance requires flood risk managers to factor in projected sea level rise (UKCP09) when developing flood risk management strategies. Details can be found at http://archive.defra.gov.uk/environment/flooding/documents/policy/guidance/fcdpag/fcd3climate.pdf

A6.4. Sea level rise is accompanied by a variety of coastal evolutionary processes, which are described by a set of principles. In the case of estuaries the concept involves erosion at the mouth and deposition upstream, described as 'rollover' Rollover is as yet a conceptual idea that was first described by Allen (1990) and refined by Pethick (2000).

A6.5. Sea level rise is considered to be one factor behind the problem of 'coastal squeeze' and the loss of inter-tidal habitats through erosion because there is insufficient accommodation space to absorb eroded sediment and to generate new inter-tidal. Thus inter-tidal is squeezed between rising sea levels and flood defences. This creates a higher energy environment that precipitates erosion. Examples of such erosion are very common on the English east coast, such as the Humber, as illustrated in the photographs below.

Photograph 2. Foreshore at North Killingholme, Humber Estuary showing exposure of the toe of the sea wall as a result of lowered mudflats. This mudflat lowering is attributed to 'coastal squeeze'.

Photograph 3. Foreshore at Barton on Humber, Humber Estuary showing sea wall toe extension and further exposed toe. Again, this mudflat lowering is attributed to 'coastal squeeze'.

A6.6. Integration of flood risk management strategies and Natura 2000 attributes has led to the development of a strategic approach to offsetting coastal squeeze. This is the concept of Coastal Habitat Management Plans (CHaMPs) - discussed in section 4.8.3. to 4.8.5. above.

A6.7. Where there is sufficient accommodation space, existing tidally inundated macrophyte communities and mudflats need to absorb additional sediment to maintain their position in the tidal frame, and consequently relatively high sediment loads within the water column can be regarded as potentially beneficial. Provided this sediment is sufficient to allow inter-tidal to keep pace with sea level rise it will deliver two critical strategic functions:

- Maintenance of the biological functioning of the estuary; and
- Maintenance of the flood management role of mudflats and tidally inundated

macrophyte communities. The role of these habitats in flood management is described in a series of papers (e.g. Brampton, 1992; Empson et al., 1997)

A6.8. It has been argued by some developers in the UK that as sea levels rise, habitat will be lost anyway and that this means that losses due to other factors such as coastal engineering or development projects have a much lower impact in the long term. This argument highlights a crucial point about the determination of impacts of proposals on the Natura 2000 interest. Taking the UK as an example, this approach would not be acceptable because the analysis of impacts relates to what exists at the time and not what might or might not exist at some point in the future. HPA and WSV should investigate how German authorities view this subject, but the following is advice based on experience in the UK.

A6.9. Projected climate change issues are dealt with at a strategic level e.g. through CHaMPs and a long-term programme of adjustment to the geometry of the coast. It is not used as a reason to justify damaging activities and where damage is expected Government policy is to make sure that losses are offset within a strategic framework.

A6.10. Bearing in mind paragraph A6.9., my analysis of the RESMC has focused on the current situation rather than future projections that are not available to me.

Appendix 7. The significance of Conservation Objectives in the context of the RESMC

A7.1. This report includes the recommendation that the RESMC should be subjected to the equivalent of a 'Habitats Regulations Assessment' which in Germany appears to be referred to as a FFH Assessment (see para 12.2.7.). There are several reasons for this.

A7.1.1. The RESMC involves a plan for very substantial changes to the Elbe Estuary and to both its form and function. Any one of these changes might be expected to have an influence over the degree to which individual Conservation Objectives are achieved. Some may benefit one attribute over another and until it is clear where priorities lie the negative impacts are more likely to be reflected in the views of interested observers (either NGOs or local communities).

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A7.1.2. If the RESMC is to move from an aspirational plan to an active management package it must be robust enough to withstand challenges that may go as far as the European Courts. This means that it must be capable of showing how it delivers the conservation objectives as well as the need to reduce cyclical dredging and overall dredging demand.

A7.1.3. Experience in the UK has shown that, where insufficient attention has been paid to documentation of the rationale for allowing a project to proceed, decisions have been successfully challenged by third parties ranging from NGOs to special interest groups.

A7.2. Consequently, the structure and presentation of Conservation Objectives is an important mechanism for enabling the delivery of the RESMC. If Conservation Objectives contain un-quantified aspirations it is very simple for objectors to challenge or to present alternative interpretations. Analysis of one of the objectives supplied by Bioconsult in July may help to explain this:

'Conservation and restoration of near-natural estuary areas and tide-influenced meadows and their biotic communities with a dynamic mosaic of shallow and deep water areas, river arms, mudflats and reed areas, channels in North Sea shallows, islands, sand and terrestrial areas as well as with near-natural conditions among the types of biotope typical of the estuary and meadows as far as possible.'

Questions that might be posed include:

- What does a near-natural estuary look like?
- How much new habitat is required?
- Where should that habitat be?
- What does 'as far as possible' mean

A7.3. Given these initial questions it is a relatively straightforward transition to the situation where the RESMC might be travelling in one direction in the belief that one scenario is anticipated; whilst another group might conclude that a very different scenario had been described.

A7.4. The provision of a tabulation of the conditions that contribute towards 'favourable condition' or 'favourable conservation status' therefore provides the basis for decision-making and for recording whether specific management actions actually contribute towards the achievement of the overall objective. Examples have been given in Appendix 3.

A7.5. One relevant example of this issue is provided in the correspondence accompanying the additional

information supplied in July 2011.

> '*The river engineering and sediment management concept is part of the cross-border specialist contribution on navigation in the Integrated Management Plan. The specialist contribution was evaluated within the framework of development of the Integrated Management Plan. In this context all proposals for measures in connection with the river engineering and sediment management concept that appeared meaningful from the viewpoint of Natura 2000 were included in the concept on measures in the Integrated Management Plan. In the case that proposals for measures were only conceivable in altered form (e.g. activation of side arms of the Elbe) from the viewpoint of Natura 2000, they were included in appropriately altered form. Entirely unacceptable proposals were not included.*'

A7.6. If the options development has been assessed within the framework of the Integrated Management Plan there should be relevant paperwork and written agreements between the statutory nature conservation bodies and HPA/WSV. This is the type of audit trail that will be needed to back up specific proposals.

Appendix 8. CV of Roger Morris

Bright Angel Coastal Consultants Ltd.
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EXPERTISE

Port development

Coastal processes

Habitats Directive Assessment (HDA)

Coastal zone planning

Policy development

Roger Morris is a coastal management specialist with extensive experience of port development projects (including dredging), flood risk management strategies, tidal energy projects, physical processes (analogue-based modelling) and integrated coastal zone management. He has over 20 years experience of marine and coastal conservation management with the NCC and its successors, including assessment of EIA, Habitats Directive interpretation and policy-making. He was, *inter-alia*, English Nature's 'Head of Estuaries Conservation' from 1998 to 2006 where he was responsible for ports policy development and for managing the residual parts of English Nature's Estuaries Initiative. He left Natural England in 2009 to establish BACC. He has subsequently joined the Board of Harwich Haven Authority as the non-executive Director responsible for environment (a DfT appointment). In the past year he has undertaken a variety of international expert projects, including advice for WWF on the Ems Estuary. Roger is Defra's representative on the European Commission's *Rivers Expert Group* and *Estuaries Expert Group*. He is also an internationally published author of policy and technical papers relating to coastal zone management, ports policy and application of the Habitats Directive.

CREDENTIALS

BSc Zoology with Applied Zoology, UCNW Bangor (1980)

Fellow Institute of Ecology and Environmental Management (IEEM)

Chartered Environmentalist

Fellow Royal Entomological Society

Associate Member Institution of Civil Engineers

2010-2011

- Review of planning consents affecting the Humber Estuary (North Lincolnshire Council).
- Review of proposed remedies for increased tidal propagation in the Ems Estuary (WWF Deutschland).
- Review of SAC proposals at Portland (Portland Harbour Authority), and offshore sandbanks in Eire (Saorgus).
- DG Environment Rivers Expert Group - UK representative on behalf of Defra.

1994-2009 – Key projects (*inter-alia*)

- DG Environment Estuaries Advisory Group – Representative for Natural England and Defra. Specific contributor to dredging module. (*Ongoing representative on behalf of Defra*
- English Nature Ports Position Statement and Sector Analysis Lead contact for strategic relations with Department for Transport and relations with UKMPG & British Ports Association.
- Maintenance Dredging Protocol – English Nature lead and initiator of the concept.
- Evaluation of habitat banking – led on EN considerations of the prospects of success for habitat banking.
- Port development projects: Bathside Bay, Bristol Containerport, Dibden Bay, Felixstowe South, London Gateway, Immingham Outer Harbour.
- Dialogue with ports on SAC designations - especially the Port of Bristol.
- Thames Estuary 2100 – Member of EA Quality Review Panel.
- Humber Estuary Shoreline Management Plan – Management and Advisory Groups – represented English Nature and provided specialist nature conservation advice to the development of the HESMP.
- Humber Estuary Management Strategy (HEMS) – Delivered strategy and supporting documentation after taking on project at late stage when it was about to collapse.

PUBLICATIONS

Extensive portfolio of books, peer-reviewed papers and newsletter items. Examples include:

Morris, R.K.A., 2011. The application of the Habitats Directive in the UK: Compliance or gold plating? *Land Use Policy*. **28**: 361-369

Morris, R.K.A., 2008. English Nature's Estuaries Initiative: a review of its contribution to ICZM. *Ocean & Coastal Management* **51**: 25-42.

Morris, R.K.A.& Gibson, C., 2007. Port development and nature conservation – experiences in England between 1994 and 2005. *Ocean & Coastal Management* **50**: 443-462.

Pethick, J.S., Morris, R.K.A. & Evans, D.H., 2009. Nature conservation implications of a Severn Tidal Barrage – a preliminary assessment of geomorphological change. *Journal for Nature Conservation*.