ROYAL HASKONING

Appendix I
Estuaries Assessment

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Introduction

The following document provides an assessment of the three principal estuaries associated with the SMP2 sub-cell 3c: The Blyth, Alde/Ore and Deben. The assessment was carried out in line with the recommendations set out in the procedural guidance for the production of SMPs –appendix F (Defra 2006).

This report was produced during the early stages of work on the SMP2 and considered to what degree each estuary should be included within the SMP process. The main emphasis of the study was to examine in what way each estuary might be considered to impact upon the physical behaviour of the coast and, therefore, the extent to which estuary behaviour should be considered within the SMP. The study was undertaken against a background of flood risk management studies being undertaken for each of the estuaries with the intent that, as these studies were taken forward, there would be on-going collaboration between the SMP and the estuary strategies.

It was recognised that the strategies would be considering the estuaries in greater detail than is attempted by the SMP but that the SMP process would contribute important information with respect to issues relating to the coast. The following report provides an important overview of this interaction, together with a summary of information available from the estuary strategies.

It was however, further recognised during the development of the SMP2, that broader issues were being raised by the estuary strategies that required consideration, drawing upon the emerging findings of the flood risk management studies but developing this to include a more integrated approach to management.

The SMP has therefore, made full use of the initial assessment considering the interaction between the coast and the estuary regimes but, has subsequently incorporated the further information as the initiatives emerging for each estuary have developed. This developing approach has been discussed and agreed both within the client steering group and in consultation with managers for the estuary management plans. A brief summary of the approach taken by the SMP is set out below in relation to each of the estuaries.

The Blyth

Current position of Estuary Management

The estuary flood risk management strategy has been approved and this has provided the framework for further discussion of the management of flood defences within the estuary. In particular, discussion is now being undertaken with landowners as to private investment in the defences of Reydon and Tinkers Marshes and with the Highway Authority with respect to management of risk to the A12.

There is also an intent that the Southwold Harbour Lands Trust would take on the role of Harbour Authority.

Approach taken by SMP2

The SMP2 policy as been developed to reflect the recommendations set out in the strategy. The SMP has provided a higher level assessment of the overall estuary behaviour, in particular making recommendations for management of the harbour entrance structures, taking account of the interaction with the coast.

Based on the strategy conclusions, the SMP has defined policy over the whole estuary, extending beyond the initial boundaries defined within the estuary assessment report. The SMP, therefore, provides an integrated approach to both estuary and the open coast.

The Alde/Ore

Current position of Estuary Management

The original estuary strategy provided detailed modelling of the estuary hydrodynamics. It also identified complex issues that could not be fully resolved from a perspective of flood risk management. A decision was made that studies in this area should be taken forward in two interrelated ways. The technical approach is being taken forward by the Aldeburgh Coast and Estuaries Strategy (ACES), providing information that would be considered by the Alde/Ore Futures project. This Suffolk Coast Integrated Coastal Zone Management (ICZM) initiative is a partnership of organisations committed to developing an integrated approach to the management of the Suffolk coast. It includes East of England Development Agency, the Environment Agency, GO-East, Natural England, Suffolk County Council, Suffolk Coastal District Council and Waveney District Council.

Approach taken by SMP2

The SMP has identified several issues with respect to the internal management of the estuary during consultation and these have been highlighted within the main SMP2 report. The SMP has focussed on the critical interaction between the coast and the estuary, examining the options for coastal management with respect to different scenarios driven by decisions emerging from the above studies. The particular areas are the potential for allowing a breach to occur at Slaughden and the potential impact of estuary management on the coast at North Weir Point.

In the case of Slaughden, the SMP has highlighted the consequence of either maintaining defence at Slaughden or allowing or creating a new entrance to estuary at this location. The SMP makes recommendations solely from the perspective of management of coastal defences and discusses how adjacent sections of the coast might then be managed. These recommendations would then be considered through the Alde/Ore Futures initiative before final management decisions are made.

In the case of North Weir Point, the SMP has considered various estuary management scenarios and has concluded policy which would be adaptable to any of these scenarios.

It has been agreed through discussion that it would be inappropriate for the SMP to define policy over the full extent identified in the estuary assessment report as this would impose unnecessary constraints on the above studies. The SMP does, however, draw upon the findings of the assessment in providing important guidance which would be taken into account in the above studies.

The Deben

Current position of Estuary Management

The initial work undertaken by the estuary strategy provided a detailed hydrodynamic model of different scenarios for the estuary. The strategy identified the importance of the mouth of the Deben in management of the estuary. It is intended to take forward management of the Deben estuary in a manner similar to that being progressed by the Alde/Ore Futures initiative. At present the approach to management within the estuary is defined at a high level by the previous Suffolk Estuarine Strategy (2000).

Approach taken by SMP2

The SMP has considered the extent of the estuary defined by the assessment. This sets the boundary for consideration as being at Ramsholt, taking in to account issues identified further within the estuary identified by the earlier work on the estuary and through consultation.

The estuary assessment, together with the further examination of coastal processes undertaken more generally through the SMP2, has highlighted the critical constraints on management of the estuary with respect to maintaining sustainable management of the coast. The approach taken within the SMP has, therefore, been to make strong recommendations for management of the lower estuary. This takes account of previous issues raised with respect to estuary management and it is considered that SMP policy is both realistic and sustainable. The SMP recognises that there are detailed issues that will need to be addressed through the Deben Futures initiative but aims to provide a framework within which this initiative can be taken forward.

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Suffolk
Shoreline Management Plan Review: Estuaries Assessment

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Suffolk Shoreline Management Plan Review: Estuaries Assessment

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1. Introduction

ABP Marine Environmental Research Ltd. (ABPmer) was commissioned by Royal Haskoning in September 2007 to undertake a number of tasks in support of the production of the second generation Shoreline Management Plan (SMP) for the Suffolk coast. This project is being led by Royal Haskoning, on behalf of the Anglian Coastal Authorities Group (ACAG), with Suffolk Coastal District Council as the lead authority.

One of the key tasks being undertaken by ABPmer is the Estuaries Assessment, and this document reports the results of this assessment.

1.1 Report Aims

The main objective of this report is to assess the requirement (or otherwise) for the inclusion of the estuaries in the study area in the SMP process. An assessment has been undertaken and conclusions drawn for three estuaries:

1. Blyth;
2. Alde/Ore;
3. Deben.

A plan showing the location of the three estuaries is provided in Figure 1. Each estuary has been assessed to answer three key questions relating to its inclusion in the SMP process, as follows:

- Should the estuary be included in the SMP process?
- If so, how should the estuary be included?
- How far upstream should the estuary be included?

The conclusions and answers to each of these questions for each estuary inform the overall SMP development process. To address these questions Defra's 2006 Guidance for the Production of SMPs (Defra, 2006) has been followed, specifically Appendix F.

1.2 Report Structure

The report is divided into the following sections:

Section 2: Provides an overview of Defra's Guidance for the production of SMPs, with particular reference to the contents and approach outlined in Appendix F: integration of estuaries;
Sections 3-5: Provides an assessment for each of the three estuaries;
Section 6: Provides a summary of the conclusions for each estuary.

2. Shoreline Management Plans: Integration of Estuaries

The estuary assessment has been completed in accordance with Defra's 2006 Shoreline Management Plan Guidance (Defra, 2006). This guidance replaces the 2001 guide for local authorities (Defra, 2001) and updates the 2004 draft Guidance for the Production of SMPs (Defra, 2004). The guidance overall is aimed at those people responsible for defining and managing the production of SMPs and those carrying out the work to produce these plans; and Volume 2 provides guidance on how to produce an SMP in line with requirements specified in Volume 1. Volume 2 appendices of the guidance consist of technical appendices supporting the approaches recommended in Volume 2; setting out the methods to help in producing an SMP.

Appendix F: Integration of Estuaries provides guidance on determining whether, and how, estuarine shores should be included in the SMP process, where the critical process issue is whether there are important interactions in existence between the estuary and the open coast.

2.1 Overview of the Guidance

This section provides a brief overview of the guidance contained in Appendix F, to provide background and context to the remainder of the report.

2.1.1 Open Coast – Estuary Interactions

The inclusion of the estuary assessment within the SMP process has arisen in recognition of the need for further consideration of where estuaries sit within Defra's strategic approach to flood and coastal management. There is increased awareness of the importance of understanding physical processes in providing effective flood management, where the interaction of, and exchanges between, the open coast and estuaries results in management policies in one environment having a potential effect in the other.

The potential interactions between estuaries and the open coast may take a number of forms, including (after Defra, 2006):

- Sediment Supply: the open coast can provide a significant supply of sediment to the estuary and vice versa, and the volume of sediment transport can very according to management practice. Therefore any management policy that acts to alter this supply may have an impact on the estuary;
- Alteration to Longshore Drift: the flow of water through an estuary mouth can block or alter the longshore transport of coastal sediment, and high river flows can push sediment from the longshore transport system offshore;

- Flood and Ebb Tidal Deltas: sediment within the longshore sediment transport system can be transported into the mouth and stored in flood tide deltas before being transferred to the downdrift coastline. Similarly, ebb tide deltas may store sediments, and can also serve as a natural coastal defence to the estuary mouth and adjacent stretches of the open coast;
- Tidal Prism Changes: a change in the estuary tidal prism may alter the tidal asymmetry and/or flow velocities within the estuary, and hence change the erosion and deposition and/or the export and import of sediment within the estuary; and
- Landward Migration of the Whole Estuary: sea level rise will result in the progressive landward migration (roll-over) of the entire morphological form in many estuaries, through the erosion of the outer estuary and deposition of eroded sediments toward the head of the estuary.

2.1.2 Should the Estuary be Included in the SMP Process?

This is the first stage of the assessment process. To some extent all estuaries will interact physically with the open coast, however the type and scale of the physical interaction will vary from estuary to estuary. The question can be addressed by considering:

- The type and scale of physical interactions and their significance;
- Management issues and their significance.

2.1.3 How Far Upstream Should the Estuary be Included?

To cover completely any potential interactions, the estuary should theoretically be incorporated to the tidal limit, although this is not practical in many cases due to the tidal length of the estuary. The practical alternative is to determine an upstream limit beyond which no change in shoreline management policy is assumed. Defra (2006) provide a number of criteria to determine the upstream estuarine limit of an SMP:

- Approximate limit of tidal influence;
- Approximate limit of wave influence;
- Approximate limit of non-cohesive sediment exchange;
- Limit of continuity of habitats, development or risk zones;
- Limit of existing CFMP boundary;
- Limit as defined by existing Schedule IV boundary.

2.1.4 Estuary Guidance Tables

The guidance does not provide a prescriptive method for assessing estuaries and their inclusion in an SMP, however, a series of Estuary Guidance Tables (EGTs) have been produced to guide the user through a series of thought processes rather than a series of calculations. The aim of the EGTs is to provide consistency of approach. The

approach that has been developed enables the user to consider a range of parameters or issues in a relative manner and guides them towards a decision about the inclusion of a particular estuary, based upon identification of whether a particular aspect is significant, marginal or insignificant. For these purposes, insignificance is interpreted as being of no or low significance to the regional or SMP-wide coastal processes. The EGTs are reproduced in Appendix A.

2.1.5 Use of Futurecoast

The estuary assessment has made use of the Futurecoast database, the accompanying Futurecoast 'estuaries assessment' report (Halcrow, 2002), and the Suffolk Estuarine Strategies (ABP Research 1996a, 1996b, 1996c; Posford Duvivier, 1999a, 1999b, 1999c; HR Wallingford, 1999; Black & Veatch, 2004, 2005a, 2005b, 2005c, 2006a, 2006b; Environment Agency, 2007).

3. Blyth Estuary Assessment

This section represents a conceptual understanding of the Blyth Estuary, the estuary assessment table as per the Guidance (Table 1), and some brief conclusions of the key issues.

The Blyth is illustrated in Figure 2.

3.1 Conceptual Understanding

The Blyth Estuary is a small spit-enclosed, weakly ebb dominant estuary, the geometry of which has been altered by human development. The estuary is largely canalised with almost 1300 hectares of saltmarsh and intertidal flats having been reclaimed. A number of unsealed breaches about 3km inside the mouth at Bulcamp have allowed about 200 hectares to revert to intertidal mudflats. The mouth is constrained by a shingle spit from the north, and the narrow entrance is maintained by groynes on either side. The narrow entrance serves to constrain the tidal volume.

The tidal limit is at Blyford Bridge and the estuary then extends about 11 km (along the LW channel) to the North Sea between Southwold and Walberswick. The Blyth has several minor tributaries including the Dunwich and the Wang Rivers. The tidal range is 2.1 m on springs and 1.3 m on neaps at Southwold. At the mouth the tide is sinusoidal and as it propagates up estuary the level of high water is uniform. The time of low water is retarded as the tide propagates up estuary and in general the flood tide becomes shorter and the ebb longer. There is an asymmetrical flow regime at Southwold, with velocities on the ebb greater than on the flood, partly due to the canalisation and partly due to the intertidal area. The Blyth has a large complex marsh system 3 km upstream of the mouth, which is 3 km long and up to 1 km wide, and causes distortion to the flow velocities.

Waves are very small in all reaches, except those in close proximity of the mouth. Swell waves do progress into the lower reaches, but are very small by Reydon (approximately 3 km up the estuary). Wave heights increase at Bulcamp due to the large surface area, and coincide with high water, indicating that the wave energy is tidally dominated.

Sediments tend to coarsen towards the mouth of the estuary. Sand and gravel is present at Southwold, and there are silts upstream, towards Blythburgh Bridge. The estuary appears to divide in the vicinity of Buss Creek; downriver the sediments are predominantly sand and gravel, and upstream sediments are 65 to 80% silt. It has been suggested that at this location depositional estuarine processes change to more erosional coastal processes.

The entrance to the estuary is currently stabilised by embankments and breakwaters to north and south. Longshore sediment transport is generally southwards along the coast and as a result there has been net sediment accumulation against the north breakwater and erosion downdrift of the southern breakwater. The two structures severely constrain the mouth, maintaining the deep entrance channel. Velocities in the channel are 0.8 m/s on the flood and 1.3 m/s on the ebb.

The entrance to the estuary is not protected by offshore banks, therefore wave energy from offshore can penetrate into the estuary and bed sediments in the entrance indicate a marine source, probably a lag deposit. The narrow canalised form and the relatively large up estuary high water storage area ensure strong ebb flows which act to flush finer sediments from the estuary. Estuary processes occurring today likely to have only a small influence on the coastal processes and the harbour breakwaters cause the most significant interaction with the coast.

The estuary is weakly ebb-dominant, which prevents most sediment (both fine and coarse) from staying in the estuary, and the long narrow channel and narrow mouth configuration also discourage fine marine sediments from entering the estuary. Ebb dominance and wave action leads to the slow process of losing fine sediments into the sea. The adoption of a “do nothing” management option within the estuary is likely to increase the flood dominance, increasing sediment transport into the estuary, and increasing the likelihood of sediment accumulation in areas where the defences are not maintained. This will in turn increase the likelihood of saltmarsh and habitat re-creation. The “do nothing” option, including withdrawal of maintenance of the flood defences, will act to increase the velocities and shear stresses downstream, and decreases velocities and shear stresses upstream. If the harbour walls and breakwaters at the entrance were to be maintained, there would be an increase in flow velocities at the mouth, as a result of sea level rise.

The estuary has been divided into zones by the physical regime:

Zone 1, Blyford Bridge to Blythburgh Bridge (A12): a relatively narrow channel, which is confined to a historical meandering course. The channel was constricted by defence banks to either side but recently the flood defences on both banks have failed. The flow is slow. The A12 bridge acts as the main constraint to the upstream area, and the tidal prism contributed from this area is minimal.

Zone 2, Angel and Bulcamp Marshes: estuary is wide, with a meandering low water channel, only partly restrained by the old, now abandoned defences. Only as the estuary narrows at the eastern end are there pressures on the current defence line. Changes in sea level would result in a substantial increase in the tidal volume of the estuary.

Zone 3, Reydon and Tinkers Marsh: the channel is constricted by flood defence banks. Any increase in flow will result in increased erosion of both the channel bed and the edges of the channel. The channel flows through a series of curves, therefore there are significant interactions between the two sides of the estuary, and flood banks on both sides are subject to erosion.

Zone 4, Southwold and Walberswick Harbour: the flow is constricted by the flood banks on both sides, and at the eastern end by the works at the harbour entrance. The channel is straight, although turns into the zone from Zone 3 through a relatively sharp bend. The width of the channel is further constricted by moorings and landing stages.

3.1.1 Response to Sea Level Rise

An increase in sea level would cause an increase in peak flood flows in the entrance channel, if the existing flood defences are maintained, and the channel cross-section would try to increase in response. This will result in an increase in the depth of the entrance channel, and the estuary could potentially become weakly flood dominant with an increase in sea level.

3.1.2 Interaction with Coastal Processes

Sand and shingle cross the mouth of the Blyth via the ebb delta shoal. A bar would form across the mouth of the Blyth if the channelised flow in and out of the estuary was not strong enough. The ebb delta shoal is not permanent and stronger flows are probably responsible for its removal. The harbour arms form an obstruction to the net southward sediment transport along the upper beach, although there is potential for sediment by-passing to the south past the northern harbour arm, as material accumulated to the end of the breakwater soon after construction. Shingle material bypassing the harbour is able to return to the beaches to the south, very close to the harbour entrance. Any fine silts and muds leaving the Blyth on the ebb will be

maintained in suspension; plumes of sediment leave the estuary and move offshore in a NE direction, therefore some material moved along in the shoal will be lost offshore and the rest will be brought onshore at Walberswick. The effect of the harbour arm only appears to extend approximately 500 m downdrift. Locally generated waves at the mouth of the estuary, although small, are important for resuspending muddy sediments from intertidal areas.

The Lowestoft to Thorpeness Coastal Strategy has determined that the south pier and river training wall at Southwold Harbour are in very poor condition with an estimated residual life of up to 5 years. Should the structure fail, material will be drawn from beaches and dunes directly to the north and deposited in the harbour entrance. The failure of the south pier will have negligible effects on coast protection or sea defences, marginally reducing the standard of protection offered by these dunes to the village of Walberswick, which has secondary defence embankments. The more direct consequence of failure will be restricting access to the harbour as a result of the siltation in the channel.

In addition to this, partial blockage of the entrance could have an effect on flow regimes and water levels upstream in the estuary. The implications for flood defence have not been determined, but it is possible that there could be some increased risk of flooding. A change in the tidal regime within the estuary could also have implications for natural habitats, particularly areas of saltmarsh.

The Estuarine Strategy has proposed a withdrawal of maintenance to the defences predominantly in the lower reaches of the estuary, e.g. Reydon and Tinkers Marshes and others, where the channel is currently constrained and narrow, and in the longer term, areas downstream towards the mouth, whilst the mouth itself is to be maintained. The impact of this “do nothing” approach will be to increase the flows and tidal volume through the mouth of the estuary, increasing the pressure on the harbour defences and walls and affecting the interaction with the coastal processes. The modelling completed for the Estuarine Strategy predicts a 93% increase in flows through the mouth with a “do nothing” strategy, while the mouth is maintained. Therefore, whilst a “do nothing” approach at Reydon Marshes has little direct bearing on the coast, this change to Zone 3 of the estuary is relevant for the management of Zone 4 and the maintenance of the estuary mouth.

3.1.3 Importance of the Position of the Estuary Mouth

The coast from Lowestoft to Thorpeness is made up of a series of headlands or nesses and bays, of which one of the controlling headland points is the mouth of the Blyth at Southwold, in terms of the long-term development of the shoreline. Any change to the position of the mouth of the estuary will have an impact on the alignment of the coast, both to the north and south. Changes to the south would affect Walberswick and the shingle beach toward Dunwich.

3.2 Estuary Assessment Table

The table below presents an assessment of the inclusion of the Blyth Estuary in the open coast SMP. The Blyth Estuary is illustrated in Figure 2.

Table 1. Assessment of the Blyth Estuary

Estuary	Blyth
Location	Suffolk, east coast of England
Classification	Origin: Drowned river valley Type: Spit enclosed Sub-Type: Single spit
Main characteristics	Mesotidal, small to medium sized estuary.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002) Suffolk Estuarine Strategies: Blyth Estuary (ABP Research, 1996b; Posford Duvivier, 1999b; HR Wallingford, 1999; Black & Veatch 2004, 2006b; Environment Agency, 2007).
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Blyth is considered to be small to medium size in terms of the total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a large intertidal area relative to its total area, however, saltmarsh is only found in the middle section of the estuary. Channel length: The length of the estuary is considered to be small to moderate. Mouth cross-sectional area: The estuary has a very small cross-sectional mouth area. Mouth width: The estuary has a very small mouth, severely constrained by the presence of breakwaters on both sides. Tidal range: The tidal range in the estuary is small. Mean freshwater flow: The freshwater flows are considered to be small within the estuary; the mean river flow is 0.38 m^3/sec compared to a peak tidal flow of 200 m^3/sec at the mouth; the Estuarine Richardson Number (0.0047) confirms that the estuary is well-mixed. % Area: The estuary has a very large % area, i.e. the intertidal area ratio is very high, as the estuary almost empties at low water. Tidal velocities: in the entrance channel the velocities are approximately 0.8 m/s on the flood and up to 1.3 m/s on the ebb. Tidal prism: 1.8 x 10^6 m^3 and 2.9 x 10^6 m^3 on neaps and springs, respectively. The total tidal volume (accommodation space) of the estuary, taking into account areas below MHWS currently defended, is 4.9 million m^3.
	Verdict on significance: The estuary is small to medium in size. The cross-sectional area and the mouth width are small relative to the volume and the channel length, respectively, which is a consequence of the constriction at the mouth. The narrow mouth also serves to constrain the tidal volume, maintaining the deep entrance channel and relatively high flow velocities. Overall, in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant with respect to the interaction with the coast.

Estuary	Blyth
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: The estuary is strongly ebb-dominant according to Dronkers' gamma; although Black & Veatch (2006) states that the estuary is weakly ebb-dominant, from flow analysis. With sea level rise, ebb dominance is predicted to decrease, and flood dominance to increase. The draft Estuarine Strategy is proposing the withdrawal of maintenance of existing defences throughout most of the estuary, except the mouth, thereby increasing the intertidal area. The proposed changes are predicted to make the estuary weakly flood dominant. Morphological features: The estuary's lower reaches are canalised. The middle reaches have a large intertidal area dominated by saltmarsh. There is an ebb delta, the size of which depends on the volume of flows into and out of the estuary; it also provides local shelter to the adjacent coast. Source/sink relationship: The estuary is probably a weak source for fine sediment at the moment, especially during surges. The ebb-dominance and narrow channel and mouth mean that fine marine sediments are unlikely to enter or remain within the estuary. There is very little movement of coarser material in or out of the estuary. However, in the future, the proposed changes in management and an increase in sea level are both predicted to make the estuary weakly flood dominant, and a future sediment sink. Plume generation: The maximum flow ratio suggests that a plume of fine sediment may be formed on ebb tides.
	Verdict on significance: Interactions between the coast and estuary, in terms of sediment exchange, do occur but are relatively localised. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as insignificant in terms of the interaction with the coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of process issues: Step 1 – water exchange: marginal. Step 2 – sediment exchange: insignificant. Step 3, therefore, from EGT5, process issues are assessed as Grade C.
Stage 1 Step 4: significance of management issues (EGT4)	Historic reclamation: Reclamation since the construction of embankments in Roman Times, followed by enclosure of areas of high marsh in the 16th and 17th centuries. In the 18th century more areas of saltmarsh were enclosed and by the mid-19th century the estuary was a canalised channel. Breaching of embankments from 1953 onwards has resulted in a wide intertidal area in mid-estuary. However, from the mouth to upstream of Reydon Marshes the estuary remains constrained by canalisation, as it does upstream of Blythburgh. Presence/absence of jetties: Training works at the mouth of the estuary constructed in the 18 century to prevent silting of the harbour, extended in the 19th century. Stabilisation of the entrance is currently by embankments and breakwaters, both of which currently act as groynes, disrupting littoral drift, and having a very strong influence on the passage of material along the coast, the coast to the south has consequently a history of erosion. The position of the mouth of the Blyth at Southwold as a fixed headland/ness controls beach position both to the north and south along the coast. The draft Estuarine Strategy does not plan any changes to the breakwaters or harbour walls. Future management of the estuary: The draft Estuarine Strategy is currently proposing to withdraw maintenance from much of the flood defences throughout the estuary, over the next 1 to 20 years. This will increase the estuary area and volume, which will in turn increase flows through the harbour, mouth and entrance channel. One impact of this management will be an increase in the tidal volume flowing in and out of the estuary, and the second will be to change the dynamics of the estuary mouth and the nature of the interaction between estuary and open

Estuary	Blyth
	coast. Increased flows may increase the size of the ebb delta, potentially increasing downdrift erosion at Walberswick and the shingle beaches downdrift, due to a change in the sediment bypassing, whilst increasing deposition in the area protected by the shoal. A change in the bypassing may also have a wider impact on the shoreline position in this area on a wider scale. The residual life of much of the defences throughout the estuary is less than 20 years, and the Strategy proposes to withdraw maintenance over the next 1 to 20 years. Flood risk may increase as a result of the Strategy being taken forward, through the withdrawal of maintenance of much of the defences along the length of the estuary. However, this will only affect a few individual properties, for which solutions will be examined by the Strategy. The defences that protect Walberswick are to be maintained. Changes to the coastal management: The draft Estuarine Strategy is proposing the consideration of the construction of a rock groyne at Gun Hill, on the Southwold frontage to the north of the estuary mouth.
	Verdict on significance: significant.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade C. Step 4 – Management issues assessed as significant. Therefore from Step 5 of EGT5, the Blyth scores 2 in terms of overall significance and should be included within the SMP process.
Stage 2 Recommendation on how the estuary should be included in the SMP process (EGT6)	It is considered practicable for the estuary to be considered within the relevant open coast SMP.
	Verdict: Include within open coast SMP.
Stage 3 Recommendation on how far upstream the estuary should be included (EGT7)	The tidal limit is at Blyford Bridge 10 km inland of the mouth, and the Strategy the estuary is divided into four zones, of which Zone 1 extends up to the tidal limit. Zone 1, above the A12 Bridge changes to the estuary will have very little, if any, impact on the interaction of the estuary with the coast. Any change in the wide intertidal area around Bulcamp Marshes, up to Blythburgh, Zone 2, will also have very little impact on the coast. Changes to the estuary in Zone 3, immediately upstream of Reydon and downstream to the coast, Zone 4, where the estuary is constrained at the mouth, have potential to increase the flows through the estuary mouth and the management of Zone 3 (in particular Reydon Marshes) is considered to determine the future hydrodynamic sustainability of Zone 4 and the mouth of the estuary. Although, changes in sediment bypassing caused by the changes in the flows in and out of the mouth are thought to be secondary to the control exerted by the breakwaters on the sedimentary interactions on the coast. Therefore Zone 3 and 4 are the parts of the estuary thought to be significant with respect to the interaction between the estuary and the coast.
	Verdict: The inclusion of the Blyth within the open coast SMP should be limited to Zones 3 and 4, the Southwold and Walberswick Harbour areas at the mouth of the estuary and the areas of Reydon and Tinkers Marshes.

3.3 Conclusions

The above estuary assessment in terms of the interaction of the estuary with the coast has been summarised as a series of key points:

1. The position of the mouth of the Blyth at Southwold acts as a fixed headland controlling shoreline position both to the north and south;
2. Realignments or abandonments of the defences that currently constrain the channel in the narrow, lower estuary may cause substantial increases in the estuary's tidal prism;
3. Increases to the tidal prism within the estuary will increase tidal flows and tidal discharge volume through the mouth, with the potential to change or influence the location and size of the ebb shoal delta;
4. Changes to the flows through the mouth and potentially the ebb shoal delta could alter the interaction with longshore drift along the coast, and an increase in the tidal flows through the mouth could increase interruption to the littoral drift to the south. However, in terms of the littoral drift passing the estuary the influence of maintaining the breakwaters to either side of the estuary mouth will also be important.

The Blyth Estuary should therefore be included in the open coast SMP, to the upstream limit of Zone 3 (see Figure 2).

4. Deben Estuary Assessment

This section represents a conceptual understanding of the Deben Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Deben is illustrated in Figure 3.

4.1 Conceptual Understanding

The mouth of the Deben Estuary is at Felixstowe Ferry, and has its upper tidal limit just above the Wilford Railway Bridge at Bromeswell, a distance of 18 km upstream. The shape of the estuary has been altered by historical reclamation of marshes, mainly in the middle and lower reaches, downstream from Martlesham Creek, and it is now fairly narrow along much of its length. The flow into and out of the estuary is constrained by the maintained, narrow mouth at Felixstowe Ferry. The estuary is formed on soft rock geology and has been relatively stable over the last 1000 years, with only small-scale fluctuations of the estuary mouth and sand/shingle bodies. However, it has been suggested that the mouth has in the past been to the north of East Lane, making Bawdsey an island, with the sea flowing over what is now Ramsholt Marshes. The human influence in the estuary probably dates back to Roman Times, and the 16th and

17th centuries the estuary was a thriving port, with reclamation for agriculture mainly in the lower reaches of the estuary. The estuary is currently experiencing some saltmarsh loss, both through erosion of the front edge and through processes of creek widening within the marsh. Land use within the estuary is predominantly agricultural, with some important areas for archaeology and cultural heritage, including Sutton Hoo, opposite Woodbridge.

Along the coast the tide floods southward and ebbs northward. The tidal range at the mouth is 3.2 m on springs and 1.9 m on neaps and the estuary can be classified as mesotidal. There is mild amplification of the tidal range upstream, so that the spring tidal range at Woodbridge is 3.6 m. However, as the Deben is fairly wide there is little difference in tidal phase from the mouth to the tidal limit. The river inflow is 0.6 m^3/s and the mean tidal flow is 1700 m^3/s, indicating that the estuary is dominated by tidal processes. During occasional river flood events the influence of fresh water may be more significant, but most of the time it is restricted to the upper parts of the estuary.

Sediments in the Deben are generally silt or silty sand in the upper and middle reaches, and dominated by gravel near the mouth, most of which is immobile. The estuary is thought to be ebb-dominant in the lower and middle reaches and possibly flood dominant in the upper reaches.

The estuary is generally well sheltered from offshore waves due to the narrow mouth and dynamic shifting shingle banks called The Knolls. The narrow cross-section limits the fetch lengths for local wave generation, with the exception of the wider middle section. Here waves are still small, but large enough to be the main cause of sediment resuspension.

The estuary can be divided into three zones by virtue of the physical form and processes:

Zone 1, Upper Reach: There is relatively high ground to the east and the hard defences of Woodbridge on the west bank constrict the channel. The upper reaches have a relatively narrow low water channel that almost completely dries up at low water to the north of Woodbridge, and increases in depth and width southward and downstream. Martlesham Creek enters the Deben on the western side just to the south of Woodbridge. There are only relatively small fringes of saltmarsh, except on the east bank near Sutton, where the flood embankments were breached, re-creating intertidal saltmarshes and mudflats.

Zone 2, Middle Reach: here river widens downstream and the meanders lengthen, although fixed in places by higher ground or flood defences. There are isolated areas of low-lying land and large areas of intertidal mudflats and saltmarsh. The high water and low water channel widths become more constant, and the depths are generally deeper and more variable than in the upper reaches. Shottisham Creek enters on the eastern side towards the southern boundary of this reach.

Zone 3, Lower Reach: the meandering channel becomes more constricted and restricted in alignment due to almost continuous embankments and areas of higher ground. Kirton Creek enters south of Hemley on the west bank. The channel further narrows and is constricted by hard defences at the estuary's mouth. There is fringing saltmarsh along most of its length, particularly on the eastern side of the channel and in Falkenham Creek on the western bank.

The estuarine strategy has examined options for the future management of the Deben, including "do nothing", "hold the line" and "managed realignment" of certain areas. The "do nothing" policy removes most of the defences from the estuary with the effect of a significant decrease in shear stress on both east and west banks over the few sections where defences have remained. The increased intertidal area allows for greater energy dissipation, a decrease in velocity and therefore a decrease in pressure. However, the tidal prism increases (by up to 78%), as does the tidal flow rate at the mouth, with a noticeable increase in shear stress, which would lead to some degree of erosion over the long term. Widening of the mouth is likely to affect the flow into the estuary and the estuary interaction with the adjacent coastline.

The "do nothing" option presumes the defences at the mouth are maintained, although it is uncertain as to whether the mouth could be maintained under these conditions. In contrast, a wider estuary mouth is predicted to produce higher maximum water levels throughout the estuary. Removal of the Knolls is also predicted to cause an increase in maximum water levels, although smaller, suggesting that the Knolls have a regulatory effect on water levels in the estuary. Removal of the Knolls is also predicted to cause a decrease in the minimum water levels upstream to Waldringfield, suggesting that the Knolls has an impact on draining of the estuary, whereas increasing the mouth has a limited effect on minimum water levels. This is only an initial insight into the interaction between the Knolls, a widened mouth and the rest of the estuary, but it does suggest a degree of interdependence between the Knolls and the estuary.

The managed realignment options also assume the defences at the mouth are maintained and all produce increased flows at the mouth, with the smaller the realignments the smaller the increase, although realignments generally decrease flows elsewhere in the estuary. The realignment options also show a general decrease in maximum water elevations and should therefore reduce flooding return periods for the defences. However, the increase in the tidal prism will cause an increase in the erosion pressure at the mouth, encouraging it to widen, which could then in turn enable a larger tidal volume to enter the estuary and increase the water levels. Under the managed realignment options it is uncertain if it would be possible to maintain the defences and structures at the mouth of the estuary, resulting in erosion of the banks and possible movement of the mouth.

4.1.1 Response to Sea Level Rise

A qualitative conceptual assessment has been made of the potential future changes within the estuary as a result of sea level rise, based on work carried out for the Estuarine Strategy. An increase in sea level will almost always cause an increase in the tidal volume, and in the case of the Deben where there are extensive intertidal areas, there is likely to be a large increase, with a concurrent increase in tidal velocities. The large intertidal areas also allow space for readjustment of the cross-section, through erosion of the lower intertidal mudflats, which in turn provide a source of material that can contribute to the accretion of the upper areas of the intertidal.

In the upper reaches of the estuary the increased cross-section as a result of increased sea level will outweigh the increased tidal volume and slow accretion in the intertidal could be expected. In the longer term, there will still be a net loss of intertidal unless the high water line of the estuary is allowed to expand outwards, indicating that there will be increased pressure on flood defences. In the lower reaches of the estuary the increased tidal volume due to sea level rise will have a greater effect than the increase in cross-section leading to widening and deepening of the estuary channel. This will occur mainly through erosion of the lower intertidal flats, although in some areas erosion on the outside of channel bends will lead to erosion of the saltmarsh, e.g. in the middle reaches of the estuary at Hemley.

At the mouth of the estuary an increase in sea level will cause expansion of the ebb delta shoal, through the trapping of a larger proportion of the net southerly littoral drift, and possibly causing erosion of the beach to the south. In response the mouth will attempt to widen, increasing erosion within the estuary entrance. This is explained more fully in the following section.

4.1.2 Interaction with Coastal Processes

A qualitative conceptual assessment, based on the Estuarine Strategy modelling, has been made of the interaction of the estuary with the coastal processes. There is a net southward littoral transport along the coastline, and sand and shingle cross the estuary mouth via the ebb shoal delta (The Knolls). The coastline on either side of the estuary is a barrier beach with low-lying land at risk of flooding immediately behind it. The Knolls are a very dynamic part of the sea bed, changing shape continually as a result of the action of waves, tidal currents, and longshore drift processes. Within a kilometre of the estuary mouth the beaches are dominated by wave action. Any change in the management of the estuary, that result in a change in the defences for example, will not affect wave action. Therefore the effects of any works will, at least initially, be localised to the area and to either side of the mouth, for example, through changes in the volume of water entering and leaving the estuary, which will then in turn affect the currents and sediment transport through the entrance. Any changes in the immediate area of the mouth could then extend both up and down drift to impact on the beaches along the coast.

If the tidal volume increases, e.g. through an increase in the tidal prism as a result of sea level rise or realignment policies within the estuary, or by widening the mouth, the size of the ebb shoal delta will also increase. The extra sediment required would be obtained from the longshore drift of sand and shingle across the mouth, rather than from within the estuary itself, resulting, in the short term, in a reduction of sediment reaching the downdrift beaches. However, an increase in the size of the delta will provide more protection to the coastline to landward and may then lead to deposition of beach material near the estuary entrance. The scale of such changes depends on the peak ebb tide velocity, which in turn is dependent on the scale of the tidal prism changes, for example, caused by sea level rise or changes in the management policy within the estuary. If the changes are small, then it is unlikely that any changes in the morphology of the delta/coastline can be distinguished from variations in wave conditions, though if large changes in peak ebb current speeds are predicted then changes at the mouth will be more noticeable and correspondingly the downdrift area to the south will be more at risk of erosion.

4.2 Estuary Assessment Table

The table below presents an assessment of the inclusion of the Deben Estuary in the open coast SMP. The Deben Estuary is illustrated in Figure 3.

Table 2. Assessment of the Deben Estuary

Estuary	Deben
Location	Suffolk, East coast of England
Classification	Origin: Drowned river valley Type: Spit enclosed Sub-Type: Double spit
Main characteristics	Mesotidal, medium sized estuary. Long and narrow, with considerable reclamation, and a narrow constrained mouth.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002). Suffolk Estuarine Strategies: Deben Estuary (ABP Research, 1996c; Posford Duvivier, 1999c; HR Wallingford, 1999; Black & Veatch 2005b, 2005c; Environment Agency, 2005).
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Deben is considered to be of medium size in terms of the total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a large intertidal area relative to its total area, with the intertidal area dominated by mudflats, with some saltmarsh, which is generally in decline. Channel length: The length of the estuary is considered to be moderate. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area. Mouth width: The estuary has a small mouth. Tidal range: The tidal range in the estuary is small. Mean freshwater flow: Insignificant. The freshwater flows are considered to be small within the estuary. The Futurecoast Estuaries Assessment states that the river flow is very low, with only small variability and Posford Duvivier (1999) states that freshwater input is minimal in relation to the saline input and estuary processes are driven by the tidal influx. The peak spring tidal flow at the mouth is 1700 m^3/s, compared to the mean fluvial flow of the River Deben, which is 0.6 m^3/s, indicating that flows within the estuary are tidally dominated. % Area: The estuary has a very large % area. Tidal velocities: Peak spring tidal velocities are 0.5 m/s, and peak ebb velocities are 0.75 m/s, with neap tidal velocities 0.1 to 0.2 m/s slower. The Richardson Number of the estuary indicates it is well-mixed (0.0015) and that the influence of fresh water is very small and can be ignored. Tidal prism: Regime analysis predicts that there would be a pressure for deepening and widening of the river at the mouth in response to sea level rise. The greater channel discharge resulting from increased tidal prism would create a pressure for the meanders to increase in size.
	Verdict on significance: The interaction and stability of the banks (The Knolls) at the estuary mouth, depends on the volume of flow into and out of the estuary. Overall, in accordance with EGT2, in terms of water exchange the estuary is assessed as 'marginal'.

Estuary	Deben
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: The estuary is strongly ebb-dominant according to Dronkers' gamma. According to the Strategy studies the Deben is currently weakly ebb-dominant in the middle reaches, and there is a suggestion that the estuary could be flood dominant in the upper reaches, aiding sediment accumulation. However, with sea level rise it is predicted that all parts of the estuary will become more ebb-dominant. Morphological features: The Deben has larger areas of intertidal than the other Suffolk estuaries; the intertidal is made up of mudflats and saltmarsh; in the middle and lower reaches the flood embankments are some distance back from the low water channel and the mudflats and saltmarsh allow a more natural cross-section to form. The mouth has sand and shingle spits on both sides, with that from the north originating from the Bawdsey frontage and actively extending. Within the entrance to the estuary there is an ebb shoal delta made up of a system of banks or shingle bars called the Knolls, the size and position of which vary greatly. As a result the topography at the entrance constantly changes due to wave and tide (in and out of estuary) driven processes. Sediment transport on the coast is from the north to the south, and material is deposited on the Knolls in the mouth of the estuary, as it is transported toward the south. Under normal conditions the Knolls protects the estuary from wave action, but during extreme conditions, the banks of the Knolls rapidly change shape, orientation and location, and can breach and be eroded by offshore transport of sediment, with resulting changes in tidal flows in the lower estuary. Changes in the Knolls are thought to be cyclical. The position of the channel through the mouth is linked to the position of the Knolls; it currently runs along the south-western side, by Felixstowe Ferry, causing erosion to the defences present. The northern side, Bawdsey Manor, also has defences present, indicating the channel has moved position in the past. Source/sink relationship: The estuary is probably a source for fine sediment at the moment, because of a combination of low river flow and ebb asymmetry. Refraction of waves around the mouth of the estuary promotes transport into the estuary. In the upper estuary, there is some erosion and deposition of sand, and no net exchange for cohesive sediment. In the middle and lower reaches there is no net erosion or deposition for cohesive sediments, for sands both erosion and deposition occur. Plume generation: The suspended sediment concentrations are generally very low mid-estuary, with very little possibility of plume generation. Sediment erodibility: Intertidal sediments in the Deben are relatively soft and adjustments to a new equilibrium within the Deben may take place more quickly than in the other Suffolk estuaries.
	Verdict on significance: The intertidal ratio is high, and the system is capable of accumulating more sediment. The flow ratio is low, and the estuary is ebb dominant. The estuary entrance is known to be dynamic, with considerable interaction with the coastal processes, via the Knolls. Overall, in accordance with EGT3, in terms of sediment exchange the estuary is assessed as 'marginal'.

Estuary	Deben
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of process issues: Step 1 – water exchange: marginal Step 2 – sediment exchange: marginal Step 3, therefore, from EGT5, process issues are assessed as Grade B.
Stage 1 Step 4: significance of management issues (EGT4)	Historic reclamation: The Deben has been subject to historic reclamation of large areas of high intertidal, most of which was in the middle and lower reaches of the estuary and was mainly enclosed for grazing and agriculture (approximately 76% of the total original area of intertidal). The lower reaches now have almost continuous embankments along each side, as well as areas of higher ground, both of which act to constrain the channel. More recent breaches of embankments in the upper and middle reaches have led to a slight increase in saltmarsh area. There have also been recent reclamations on the northern bank of Martlesham Creek in the upper estuary and on the western bank of the Deben, opposite Methersgate Quay in the middle reaches. Presence/absence of jetties: There are no jetty structures at the mouth of the Deben, although there are protection works on both the north and south banks of the mouth, including groynes, and flood defences. Flood risk: There are approximately 475 properties in the 1 in 200 year floodplain, 350 of which are in Woodbridge, and 100 commercial properties. Future intervention potential: Changes in the volume of water entering and leaving the estuary as a result of changes in the management strategy have the potential to affect the currents and sediment transport through the entrance. The options for the Management Strategy include realignment of areas of saltmarsh in the lower and upper reaches of the estuary, whilst the mouth width is maintained. Realignment or "do nothing"/"withdrawal of maintenance" for the large areas of saltmarsh in the lower estuary, i.e. Bawdsey, Falkenham North, Falkenham South and Felixstowe Marshes, are predicted to have a large impact on flows through the mouth, as the large tidal prism of these areas would increase the tidal volume entering and leaving the estuary. The tendency to widen and deepen at the mouth would increase pressure on the defences, as well as cause changes to the Knolls. Changes to or loss of the Knolls will impact on the maximum water levels within the estuary and may increase the risk of flooding.
	Verdict on significance: In terms of management issues, the interaction between the coast and the estuary is significant, as changes in the estuary have the potential to significantly affect the Knolls, which in turn may impact on sediment transport along the coast, as well on the mouth of the estuary itself. Therefore due to the importance of the Knolls and the estuary mouth in terms of coastal processes, in accordance with EGT4, management issues are assessed as 'significant'.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade B. Step 4 – Management issues assessed as significant. Therefore from Step 5 of EGT5, the Deben scores 1 in terms of overall significance and should be included in the SMP process.

Estuary	Deben
Stage 2 Recommendation on how the estuary should be included in the SMP process (EGT6)	It remains practicable to consider the estuary within the open coast SMP.
	Verdict: Include the estuary within the open coast SMP.
Stage 3 Recommendation on how far upstream the estuary should be included (EGT7)	The tidal limit is at Bromeswell, approximately 18 km upstream of the estuary mouth. In the Strategy Studies the Deben has been separated into two or three zones or reaches, where the inner reach extends to the weir at the tidal limit. Changes in the management of the estuary within Zones 1 and 2 (the upper and middle reaches) are not thought to have a significant impact on the interaction of the estuary with the coast. Changes within Zone 3, the lower estuary, have potential to increase the tidal prism substantially and therefore may affect the interaction with the coast, through changes to the Knolls.
	Verdict: The Deben should be considered to the upper limit of Zone 3, at Ramsholt.

4.3 Conclusions

The above estuary assessment in terms of the interaction of the estuary with the coast has been summarised as a series of key points:

1. Realignment or "do nothing"/withdrawal of maintenance for the large areas of reclaimed and defended marshes in the lower estuary (Zone 3), i.e. Bawdsey, Falkenham North, Falkenham South and Felixstowe Marshes, is predicted to have a large impact on flows through the mouth, as the large additional tidal prism of these areas would increase the tidal volume entering and leaving the estuary. The tendency to widen and deepen at the mouth is likely to increase pressure on the defences, as well as cause changes to the Knolls.
2. Reduction in size of the Knolls will impact on the maximum water levels within the estuary and may increase the risk of flooding. The Knolls have two interactions with the coast, the dissipation of wave energy, therefore providing protection to the shoreline directly adjacent to the estuary mouth; and affecting the transfer of sediment within the longshore drift system from north to south along the coast.

The Deben Estuary should therefore be included in the open coast SMP, to the upstream limit of Zone 3, at Ramsholt (see Figure 3).

5. Alde and Ore Estuary Assessment

This section represents a conceptual understanding of the Alde and Ore Estuary, the estuary assessment table as per the Guidance, and some brief conclusions of the key issues.

The Alde and Ore is illustrated in Figure 4.

5.1 Conceptual Understanding

The estuary comprises the combined estuaries of the Ore, Alde and Butley Rivers, that have been brought together because of their deflection by the extremely long shingle spit of Orfordness, which has extended from the north. The tidal limit is a weir just upriver from the road bridge at Snape, just over 26 km from the mouth at Orford Haven. The estuary is constrained by higher ground and defences in its upper reaches and by the coastal geomorphological constraint of Orford Spit. From Snape the river runs southwards in a narrow channel, with saltmarsh on the western side, flooded through a series of high level breaches. For about the next 4 km the low water channel passes almost centrally between intertidal areas about 500 m wide. The estuary then narrows before turning sharply southwards within 200 m of the open sea at Slaughden

and from here it runs approximately parallel to the shoreline for about 15 km on the landward side of the shingle bank of Orford Spit. It flows initially behind Sudbourne Beach, meanders inland between King's and Town Marshes past Orford, before dividing around Havergate Island and joining the Butley River. It then flows along behind the Orford Spit for 3 km, before entering North Sea at Orford Haven.

The mouth of the Alde and Ore joins the sea at Shingle Street, and to the north, the shingle spit extends back to Orford Ness and to Aldeburgh. Immediately to the south, the shoreline at Shingle Street is fronted by shingle ridges and beyond this, towards East Lane, there is a long, shallow and fairly stable shingle embayment backed by low-lying land.

In geological terms, the Suffolk Estuaries are of recent origin, as they were formed approximately 7,000 years ago as sea level rose at the end of the last ice age and flooded the river valleys. However, the evolution of the Ore was by a different process. Approximately 2,000 years ago, the Alde flowed into the sea through a wide breach at Slaughden. Since then, deposition of the shingle spit has deflected the course of the Alde and Ore southwards, so that it now flows parallel to the coast, and extending the estuary by some 15 km. Shingle is largely flint derived from the glacial erosion of chalk deposits and through coastal erosion and longshore drift has moved south, extending Orford Spit and forming the Ore estuary. The build-up of Orford Spit has been estimated at approximately 12 m per year over the last 800 years.

The first human influence within the Alde and Ore was probably construction of embankments during Roman Times, although the most significant reclamations took place between the 11th and 13th centuries, and during the 16th and 17th centuries, due to increased demand for agricultural land. Approximately 1450 ha of saltmarsh and 2515 ha of mudflat have been reclaimed, and currently only about 341 ha of saltmarsh and 536 ha of mudflat remain within the Alde, Ore and Butley estuarine system. Land use within the estuary floodplain is predominantly agricultural, with large areas of grazing marsh on areas of former saltmarsh and mudflat. The recent breaches in the upper part of the estuary, near Snape, have returned an area of grazing marsh to mudflat.

The mean spring and neap tidal ranges are 2.9 and 1.7 m, respectively, meaning the estuary is mesotidal. At the mouth of the estuary the tidal shape has equal flood and ebb phases and distortion of the tidal phase only really occurs where the estuary widens at Iken and Hazlewood Marshes, where the length of the flood decreases and the ebb increases. In terms of tidal propagation, high and low water are both delayed upstream in comparison with that of the entrance. The tidal range decreases at Orford and around Havergate Island, and then increases upstream from Orford and continues to increase above Slaughden.

The estuary is well sheltered from offshore waves due to the narrow mouth, and the narrow form limits the fetch lengths for local wave generation, with the exception of the basin type area in the upper reaches. In these areas the waves are still small but can be large enough to be the main cause of sediment resuspension.

The estuary can be divided in zones, based on its physical processes and form:

Zone 1, Snape: Snape is the upstream end of the study area. The Iken Cliffs and high land at Snape Warren create a narrow, meandering main channel with generally very low flows and little internal interaction and little stress of the defences. It opens out downstream becoming less well-defined. The defences were largely abandoned in the 1960s, although the remains of the defences provide some control to the channel at low tide. Should the remaining defences on the north bank fail there would be a slight increase in tidal volume, as there is low land behind, however, these changes would make little or no difference in the rest of the estuary.

Zone 2, Long Reach: This zone extends from the headland at Snape Warren to the line from Yarn Hill on the south bank to Round Hill on the north bank, and includes the reclaimed areas of Iken and Hazlewood Marshes. There is a wide meandering channel, largely unrestricted in alignment and flanked by extensive intertidal areas in front of the embankments and high ground. The flows are generally low, only exceeding 0.25 m/s on the later part of the ebb. It has a long fetch and consequently high wave activity. Substantial areas are currently protected, which amount to an additional 20% of the tidal volume of the estuary, which could have a significant impact on estuary behaviour if regularly flooded by increasing flows elsewhere. However, this zone is little affected by change elsewhere.

Zone 3, Barber's Point to Home Reach: The zone extends from Yarn Hill on the south bank to Round Hill on the north bank, to the northern end of Lantern Marshes on Home Reach and includes the reclaimed areas of Iken East Marshes, Aldeburgh Marshes and the northern part of Sudbourne Marshes. The channel meanders within tightly confined limits of high ground and flood defences. There is little or no room for channel to widen and the banks are already under pressure from erosion on the northern part of Sudbourne Marshes and along the banks of the Aldeburgh Marshes. Any increase in flow through the area, as a result of changes in management or sea level rise, will result in increased erosion of both the channel bed and the edges of the channel. The channel flows through a series of curves, therefore there is significant interaction between the two sides of the estuary, although the pressure for a breach at Slaughden is thought to come from coastal processes, rather than from inside the estuary. However, a breach at Slaughden that is not then closed, i.e. the result of a "do nothing" option, would increase the tidal volume by 20% across the estuary and 50% within this zone. However, maintaining Iken East and Aldeburgh Marshes and a "do nothing" policy in the northern area of Sudbourne Marshes would minimise the impact.

Zone 4, Sudbourne Marshes to Orford: The zone extends from just south of Slaughden to Orford and includes the reclaimed areas of Sudbourne Marshes and Town Marshes on the western side, and Lantern Marshes and King's Marshes on the shingle bank side. Here the channel broadens but is still relatively constricted by flood defence banks and is locally restrained from further development of its alignment, including at the eastern end of the channel by harbour entrance works. The zone has a relatively straight channel, although there is a sharp bend at the northern end and it starts to meander at the southern end. There is little intertidal area, but a local, critical constriction of the channel area due to the defended bank. Increased water levels in the estuary will decrease return periods of the defences. Increased flow will increase conflict between defences on both sides of the estuary. If the defences were to fail there would be a massive increase in tidal volume and flow, as the flood compartments of Sudbourne and Orford to the west of the channel constitute the largest area of defended land within the estuary, containing over 30% of the defended assets of the estuary. The northern section of Lantern Marshes is already in effect abandoned, but further setback of Lantern and King's Marshes would result in major changes to estuary regime.

Zone 5, Butley: The zone of the River Butley, extends from the tidal limit at Butley Mills, to the south of Chilesford, downstream towards the confluence of the Butley and the Ore, but ending where the two areas of high ground abut the river, at Burrow Hill on the southern bank and the Cliff on the northern bank. The channel is relatively broad and unconstrained, with a little width for expansion. There is limited pressure on the intertidal areas and only local restraint on the long meanders, in the form of embankments. There would be a massive increase in tidal volume if defences were to fail, significant impact on the confluence and defence of Zone 6.

Zone 6, Gedgrave Marshes to Boyton: The zone includes the confluence of the Rivers Ore and Butley. This zone includes the reclaimed areas of the Gedgrave Marshes, Boyton Marshes and Havergate Island. The division of the River Ore by Havergate Island into two channels (The Gull and The Narrows) relieves much of the constriction on flow, but at the confluence of the Butley and in other areas where the direction of flow changes rapidly, there is some restraint imposed by the channel banks. All channels in the Ore are relatively narrow and fully restricted by banks or the shingle coastal bank, but the division of the flow into the separate channels reduces the velocities. A continuation of the current processes will lead to a gradual increase in tidal volume, leading to increased erosion of the banks. If the defences were to fail on Havergate Island and at Boyton and Gedgrave Marshes there would be an additional increase in the tidal volume, a weakening of the shingle bank, and potentially a disruption of the sediment drift along the coast. This would in turn result in an increased likelihood of breaches in the defences to the south.

Zone 7, Orford Haven: The mouth of the Alde/Ore, which extends to the tip of the shingle bank at North Weir Point. The channel is relatively straight and, apart from at the mouth, is only restrained by the shingle bank between the channel and the sea.

Any increase in flow will result in the channel attempting to widen and deepen. A slight increase in tidal volume will have little impact on the estuary but may allow the shingle bank to move inland. If defences upstream of this zone are allowed to fail the defences here could not be maintained, and the increased tidal volume would result in a significant increase in the flow through the mouth. The inside face of the shingle spit would be eroded, and the channel would attempt to widen. Any weakening of the spit would increase the process by which the spit is breached and a breach in this location would expose defences at Hollesley to direct wave attack. Retreat of the Spit would starve areas to the south of beach material, putting Shingle Street and other defences to the south at risk.

5.1.1 Interaction with Coastal Processes

The estuary can influence the open coast in a number of ways:

1. Changes in the volume of water entering and leaving the estuary, which will in turn affect the currents and sediment transport through the entrance;
2. Changes in the currents and morphology within the estuary that might provoke formation of a new estuary entrance.

5.1.1.1 Changes to the ebb shoal delta

At the entrance to the estuary, the coastline has a net southward longshore drift, with sand and shingle crossing the estuary mouth, via an ebb shoal delta, and changes to this delta can have an influence on the coast to either side of the mouth. If the volume of water entering or leaving an estuary decreases, e.g. as a result of reclamation, then the ebb shoal delta will decrease in size. This will allow larger waves to reach the shoreline on either side of the mouth, potentially leading to erosion of the shoreline, and the potential transport of sediment from the ebb shoal delta into the estuary by wave action. In the opposite situation if the tidal volume increases the size of the ebb shoal delta increases. The extra sediment required will be obtained from the longshore drift of sand and shingle across the mouth, rather than from within the estuary. This will result in the short term, in a reduction in the amount of sediment reaching downdrift beaches. However, an increase in the size of the delta will provide more protection to the coastline to landward and may then lead to deposition of beach material near the estuary entrance.

The coastline on one side of the Alde and Ore Estuary mouth is a barrier beach (spit) with low-lying land at risk of flooding immediately behind it, as well as the estuary itself. The stability of the spit depends at least partly on the volume of flow in and out of the estuary and the interaction with the ebb shoal delta. The mouth is very narrow, with major shingle ridges forming the ebb shoal delta. The ebb shoal delta is usually a very dynamic part of the sea bed, changing shape continually as a result of the action of waves, tidal currents, and longshore drift processes, as beach sediment is transferred across the estuary mouth from north to south. The ridges are thought to be the

mechanism by which sediment is transferred across the mouth. These are frequently submerged, and extend south along the shore down to Shingle Street. At the time of a past breach in the spit, the ridges have been driven onshore. Any change in the pattern of the sediment supply, either due to greater quantity trapped in ebb delta as described above, or due to changes in the Spit, may have significant consequences for the downdrift coast and such a development could be due to an increase in tidal volume or flow.

Although the estuary processes dominate the coast at the mouth, within a kilometre of the estuary mouth the beaches are dominated by wave action. Any works within the estuaries will not affect the wave action, therefore any effect of works will, at least initially, be localised to the area and either side of the mouth. However, any changes could then extend both up and downdrift along the coast.

The coastline has changed considerably over the years, and the entrance has migrated a considerable distance south, due to the southward shingle transport. Orford Spit has evolved in a series of breaches and extensions, and growth of the spit is controlled by long term variation in sediment transport as well as storm events. The build-up of the spit has encouraged accretion of mudflats and saltmarsh on the landward side of the spit, due to the sheltering effect from waves and the decrease in tidal current speeds. The position of North Weir Point at the end of the Spit is known to have varied by 3 to 4 km in response to wave and storm activity breaching the spit, and recent changes to the distal end of the spit indicate it is still active. The coastline to the north of Orford Ness is retreating at a rate of 0.5 to 1 m/yr, whereas to the south of the Spit the coastline is advancing at about 0.5 m/yr. Just to the south of the mouth, the village of Shingle Street is vulnerable to changes in sediment supply and a switch from an accretional to an erosional regime, as it is located on low-lying land and protected from flooding by a clay embankment and the shingle beach.

Offshore the spit is protected from North Sea swells by a series of offshore banks, the first being the Inner Gabbard, 30 km offshore. Whiting Bank, about 3 km offshore of Hollesley Bay, is substantial in form and influences wave energy and directions by wave refraction. Changes in the form and location of this bank are thought to influence the location of the mouth of the Ore, or breaches within Orford Spit. Offshore of Slaughden, Aldeburgh Ridge lies within 800 m of the shore; this bank also controls wave energy too, where the narrow spit is most vulnerable.

An increase in the tidal volume of the estuary will increase the erosional forces inside the estuary mouth, increasing erosion on the inside of the Spit. The overall process of growth and collapse is likely to continue, but changes in the estuary could result in a fundamental change in the size or position of the spit and the network of banks and ridges forming the ebb shoal delta.

In general, managed realignment of defences upstream of Slaughden results in an increase in the shear stress in the main channel between Orford and Slaughden, which

is generally proportional to the area being setback, with a lesser increase at the mouth. Any realignment within the estuary causes an increase in the tidal volume and therefore the tidal velocity through the mouth, however, the further upstream the realignment the less the impact it has on the velocity changes at the mouth. Setting back or effectively doing nothing in the lower areas of the estuary, i.e. Boyton Marshes or Butley Marshes, tends to reduce the flow velocities in the estuary, except at the mouth, and decreases the erosional pressure between Havergate Island and Slaughden (except at Butley Marshes itself, where realignment creates a very large increase in flows). However, doing nothing in the estuary and setting back at Sudbourne decreases the shear stress upstream of this area to the tidal limit at Snape. This suggests that the increase in shear stress caused by setting back in the upstream sections of the estuary can be to some extent countered by setting back in the downstream sections. However, managed realignment of Hazlewood Marshes causes very little velocity change throughout the estuary, and realignment of Iken Marshes also causes very little change of tidal velocity at the mouth but does create a large increase at Slaughden.

All the realignment options show very little change or a decrease in water levels throughout the estuary, which are therefore likely to reduce the return period of overtopping. However, these options also cause an increase in the erosion pressure at the mouth, which could then allow a greater tidal volume to enter at the mouth, raising water levels within the estuary. The benefits of lower water levels within the estuary could therefore be short-lived.

5.1.1.2 Impact of a breach at Slaughden

Increasing flows within the estuary, due to changes in the tidal volume, will increase the erosion of the landward side of the shingle bank at Slaughden. The neck of the shingle spit at Slaughden is currently protected by hard defences and more recently by beach recharge. In the future a breach at the thinnest section between southern limits of Aldeburgh Marshes and the northern limits of Lantern Marshes is likely if control measures on both sides the spit were not continued, although the weakest section of the spit is considered to be perhaps just to the south of the Martello Tower. Net annual sediment drift is small along the Aldeburgh frontage, with gross movement to both north and south. Further south around Orford Ness this changes and sediment is transported to the south only. Therefore despite the relatively small net movement, any sediment moved south as far as the Ness will generally continue to move south around the Ness and onwards. A breach at Slaughden may change this sediment movement pattern and therefore may cause changes to the spit, the Ness and the mouth of the estuary. Due to the low net drift along the Slaughden frontage an ebb tide delta is unlikely to form and therefore may not prevent sediment movement to the south. Therefore any breach is unlikely to be of benefit to Aldeburgh in terms of sediment movement, unless control structures are constructed at the breach. However, these processes and their interaction is subject to some uncertainty.

A breach at Slaughden, if the channel is maintained between Slaughden and Orford, would create two entrances to the estuary, at Shingle Street and at the new breach. The flow through a breach at Slaughden will largely control the hydrodynamic processes in the upper part of the estuary due to the phase advance of the flow at this point, compared with the area to the south. Tide levels and flow within the upper estuary would be relatively unchanged, although there would be an increase in shear stress in the upper part of the estuary as far as Iken Cliffs. Sites downstream with the exception of the River Butley would experience a decrease in shear stress and the tidal flows in this stretch would reduce significantly. However, the interaction of the tide as it approaches Orford from both north and south may produce an increase in water levels at Orford creating a need to increase the levels of the tidal defences here. There would be increased wave action in the reach of the estuary immediately upstream from the breach, increasing pressure on the existing defences of Sudbourne Marshes and those fronting High Street.

Closing the channel to the south of Aldeburgh, with a breach in the spit at Slaughden, would create two separate estuaries, although this could be further complicated if the spit were to breach at what might be the weakest point to the south of the Martello Tower. This is predicted to decrease the shear stress at Slaughden breach, suggesting that the estuary is more stable with one mouth. In time the velocities experienced at breach will be the same those at the existing mouth, although the immediate effect of the breach would be to increase velocities through it to 2-3 m/s. By closing the existing mouth maximum water levels are reduced throughout the estuary. The estuary of the Alde above Aldeburgh would respond in much the same way as at present, apart from an increased wave climate around the breach.

In the southern section of the estuary, the impact would be to reduce flows upstream of the Butley; however, there would be an increase in shear stress at the Butley (Creek) itself. There would be no increase in water levels at Orford itself, although might be an increase above Orford, due to the narrowing of the estuary toward the new head. Reduced flow in the upper reach of the Ore might result in increased sediment deposition and accretion. The tidal volume flowing through the mouth would be decreased by up to 50%, with a reduction in peak velocities. There would not be the same force maintaining the channel width, therefore any shingle deposited by wave action in the channel would tend to stay. This reduction in channel width would tend to push the Spit inland and the effect on the position of the mouth near Shingle Street may result in the erosion of places previously considered stable.

If no breach were to occur, the management of the estuary is thought to be of little importance to the management of the coast. However, if the spit were to breach the interaction of the estuary with the coast becomes of greater importance. Net sediment drift at Slaughden is low and whether the breach were to remain open naturally would be dependent on the interactions of the flow through the breach and the sediment drift, thereby determining the scale of the interaction with the coast.

5.1.2 Response to Sea Level Rise

It is assumed that the present situation has reached an equilibrium between the coast and estuary processes, so that the sediment drift to the south is maintained. However, in the future this may change due to a rise in sea level. An increase in sea level will result in an increased water volume propagating up the estuary. This will result in an increased risk of flooding near the mouth of the Butley, around the back of Havergate Island and in the vicinity of Orford in the lower estuary, and in the vicinity of Iken Cliff and Snape Maltings in the upper estuary. A sea level rise of 0.5 m is predicted to increase peak ebb velocities by about 0.1 m/s from the estuary mouth to the confluence with the River Butley, a rise of between 10 and 20 %, thereby increasing the potential to scour the bed and banks in these locations. However, the existing bed is gravel, therefore an increase in erosion unlikely at except at the entrance itself. Erosion of the banks is possible but the increased sediment load may cause deposition of coarser material at times of lower flows. Any sand material entering the estuary is currently deposited downstream of Havergate Island, and this will continue with sea level rise.

The tidal volume flowing in and out of the estuary over a spring tide is approximately 9.6 Mm^3, whereas the total area of the estuary taking into account the floodplain defended at present is approximately 15 Mm^2. If the defences within the estuary were to be abandoned and with a sea level rise of 0.5 m, the total tidal volume of the Alde/Ore system would be 43 Mm^3, an increase of 4.5 times that at present.

The increase in tidal volume would cause a widening and deepening of the estuary mouth, increasing the possibility of the spit breaching, or at a minimum retaining a greater quantity of sediment within the ebb tidal delta, which would have a serious impact on the downdrift coast. The decrease in sediment supply to the downdrift area of Shingle Street is likely to increase the vulnerability of this stretch of coast, by creating a switch from accretional to erosional behaviour.

Regime theory predicts that there would be increasing pressure as a result of sea level rise for deepening and widening of the estuary at the mouth; and the increase in channel discharge, resulting from an increased tidal prism, would create a pressure for the radius of the curvature of the meanders to increase. This is most important at Slaughden where such an increase in the size meander may result in a breach of the shingle spit to the south of Aldeburgh.

5.2 Estuary Assessment Table

The table below presents an assessment of the inclusion of the Alde and Ore Estuary in the open coast SMP. The Alde and Ore Estuary is illustrated in Figure 4.

Table 3. Assessment of the Alde and Ore Estuary

Estuary	Alde and Ore
Location	Suffolk, east coast of England
Classification	Origin: Drowned river valley Type: Spit enclosed Sub-Type: Single spit
Main characteristics	Mesotidal, medium to large sized estuary system, including the combined estuaries of the Alde, Ore and Butley, brought together by deflection caused by the shingle spit of Orford Ness.
Data availability	Futurecoast Estuaries Assessment (Halcrow, 2002) Suffolk Estuarine Strategies: Alde/Ore Estuary (ABP Research, 1996a; Posford Duvivier, 1999a; HR Wallingford, 1999; Black & Veatch 2005a, 2006a).
Stage 1 Step 1: significance of water exchange (EGT2)	Total area: The Alde/Ore is considered to be medium to large size in terms of the total estuary area relative to the range of estuaries in England and Wales. Intertidal area: The estuary has a medium sized intertidal area relative to its total area. Channel length: The length of the estuary is considered to be medium to large. Mouth cross-sectional area: The estuary has a small cross-sectional mouth area, compared with the tidal volume, as is typical of a sediment dominated system. Mouth width: The estuary has a small mouth, as a consequence of the restrictions at the mouth caused by the coastal processes of the spit. Tidal range: The tidal range in the estuary is small, and tidal propagation is complex. Mean freshwater flow: The freshwater flows are considered to be small within the estuary. The mean river inflow is 0.62 m^3/s compared to a peak tidal flow at the mouth of 1500 m^3/s, therefore estuary processes are driven by the tidal flow. The estuarine Richardson Number of 0.0032 confirms that the estuary is well-mixed. % Area: The estuary has a moderate % area indicating that further sediment accumulation is possible. Tidal velocities: The maximum velocity at the mouth is 1.63 m/s. Tidal prism: The tidal volume flowing in and out of the estuary over a spring tide is approximately $9.6 \times 10^6 m^3$; currently constrained by the narrow entrance. The potential total tidal volume (accommodation space) of the estuary, taking into account areas below MHWS currently defended, is approximately $14 \times 10^6 m^3$.

Estuary	Alde and Ore
	Verdict on significance: The estuary is medium to large in size. The cross sectional area and the mouth width are small relative to the volume and the channel length, respectively, which is a consequence of the constriction at the mouth caused by the natural coastal processes. The stability of the spit is at least partly dependent on the volume of the tidal flow through the mouth of the estuary. Overall, in accordance with EGT2, in terms of water exchange, the estuary is assessed as significant in terms of the interaction with the coast.
Stage 1 Step 2: significance of sediment exchange (EGT3)	Tidal asymmetry: The estuary is thought to be weakly flood dominant, with upstream areas of the estuary becoming increasingly flood dominant. Sea level rise will increase the flood dominance within the estuary, as would set back of the defences, although flood or ebb dominance would vary with the tide and location within the estuary. Morphological features: The Alde and Ore Estuary is formed of distinct areas; a narrow meandering upper reach constricted by high ground and flood defences; a wide middle reach, with a extensive intertidal areas; and a long, narrow lower reach constrained on the seaward side by the shingle bank of Orford Spit. The confluence with the River Butley is in the lower reaches. The narrow entrance at Orford Haven is dominated by the coastal processes. Major shingle banks, forming the ebb shoal delta, are important for the movement of sediment along the coast from north to south. Source/sink relationship: The estuary is thought to be a weak sink for fine sediment. Plume generation: There is no evidence of plume generation. Sediment erodibility: Channel sides and bottom are composed of consolidated but erodible muddy material, adjustment to a new form would take time but the strength of the sediments is not sufficient to prevent long-term erosion. Where there are flood defences the channel cross-section is not easily able to expand but if the channel is constricted speeds will increase under on-going sea level rise until erosion of the embankments can occur.
	Verdict on significance: Current interactions between the coast and estuary, in terms of sediment exchange, do occur but are relatively localised. Overall, in accordance with EGT3, in terms of sediment exchange, the estuary is assessed as insignificant in terms of the interaction with the coast.
Stage 1 Step 3: relevance of process issues (EGT5)	Verdict on relevance of process issues: Step 1 – water exchange: significant. Step 2 – sediment exchange: insignificant. Step 3, therefore, from EGT5, process issues are assessed as Grade B.
Stage 1 Step 4: significance of management issues (EGT4)	Historic reclamation: Reclamation since the construction of embankments in Roman Times, although the most significant reclamations took place between the 11th and 13th centuries, and in the 16th and 17th centuries. There are extensive flood defences on the western side of the lower reaches of the estuary. Recent breaches in the upper part of the estuary have returned areas of grazing marsh to mudflat. Presence/absence of jetties: There are no jetties or other structures at the mouth, and the mouth is maintained by the interaction between the coastal and estuarine processes. Flood risk: The villages of Snape and Orford are at least partly protected by flood embankments, and there are some properties to the south of Aldeburgh within the Aldeburgh Marshes flood compartment. Future intervention potential: Changes in the volume of water entering and leaving the estuary as a result of changes in the management strategy have the potential to affect the tidal flow through the entrance. The options for the Estuarine Management Strategy include realignment or "do nothing" in large areas currently defended throughout the estuary, as well as a breach at Slaughden. Changes in management i.e. "do nothing" or managed realignment of flood defences, in Zone 1, in the upper reaches of the estuary at Snape, are predicted to have little impact on the rest of the estuary. Changes in the management elsewhere in the estuary, including within the Butley, will increase the tidal volume and tidal flows through the mouth, due to the large areas

Estuary	Alde and Ore
	of low-lying land currently protected. A breach at Slaughden, creating a separate mouth to the estuary will have an impact of the coastal sediment transport processes both at the location of the breach, and at the mouth, due to the changes to flows within the estuary and at the existing mouth.
	Verdict on significance: In terms of management issues, the interaction between the coast and the estuary is significant, as possible future changes within the estuary have the potential to significantly affect the coastline of both Orford Spit and Shingle Street to the south. Changes both to the mouth of the estuary and to the spit itself due to a breach at Slaughden would alter the longshore sediment transport processes. Therefore due to the importance of Orford Spit and the estuary mouth in terms of coastal processes, in accordance with EGT4, management issues are assessed as 'significant'.
Stage 1 Step 5: recommendation on whether the estuary should be included in the SMP process (EGT5)	Verdict: Step 3 – Process issues assessed as Grade B. Step 4 – Management issues assessed as significant Therefore from Step 5 of EGT5, the Alde and Ore scores 1 in terms of overall significance and should be included within the SMP process.
Stage 2 Recommendation on how the estuary should be included in the SMP process (EGT6)	At present the future management of the Alde and Ore is subject to considerable uncertainty due to the ongoing Flood Risk Management Strategy, and therefore, the future response of the estuary to the management decisions is also extremely uncertain. The interaction of the estuary with the coast is determined by the future changes at the mouth.
	Verdict: The Alde and Ore Estuary is included within the open coast SMP. Due to the uncertainties over the future management of the estuary, it is vital that links are maintained between the SMP and the Estuarine Strategy currently being undertaken.
Stage 3 Recommendation on how far upstream the estuary should be included (EGT7)	The tidal limit is at Snape, approximately 26 km from the mouth at Orford Haven. The estuary can be divided into seven zones by its physical characteristics. There is currently little interaction with the coast from the upstream Zone 1; however, the likelihood of a breach at Slaughden means that in the future the interaction of the estuary with the coast may increase at this location.
	Verdict: The estuary should be considered to the upper limit of Zone 3, at Barber's Point, in order to include the future potential location of a breach at Slaughden and increased interaction with the coast.

5.3 Conclusions

The above estuary assessment in terms of the interaction of the estuary with the coast has been summarised as a series of key points:

1. A breach at Slaughden would change the form of the existing mouth of the estuary, as well as create an additional mouth to the north. The scale of the impact on the coast will depend on the interaction of the flow through the breach and the sediment transport rates. However, the likelihood is that any breach will be a result of coastal processes rather than from pressures within the estuary.
2. Realignment of the defences within the estuary is likely to cause an increase in the tidal volume, therefore increasing flows through the mouth, however, the further upstream the realignment the less the impact it has on the mouth.
3. Setting back defences in the lower estuary may to some extent counter setting back defences in the upper estuary, in terms of the effects on the tidal volume and peak tidal flows.
4. Changes to the tidal flows through the existing mouth may have a significant impact on sediment storage within the ebb shoal delta, which in turn may impact on sediment supply to downdrift areas of the coast.

The interactions listed above are subject to significant uncertainty due to both the future management and the estuary's physical response, however, these interactions with the coast are deemed to be significant as a result of the current Estuaries Assessment. The potential consequences on the coast as a result of a future breach at Slaughden will depend on whether an ebb tidal delta is formed, which is in turn dependent on the interaction between longshore drift and flows through the breach.

Therefore the estuary should be included in the open coast SMP to the upstream limit of Zone 3 at Barber's Point, in order to include the location of a potential breach at Slaughden, and the site of future interaction with the coast. However, it is important that the SMP process and the ongoing Flood Management Strategy maintain strong links in order to develop coherent policies for both the estuary and the open coast.

6. Summary

An assessment has been made of the Blyth, Deben and Alde and Ore estuaries to determine the requirement to include each estuary in the Suffolk SMP3c review. This assessment has been undertaken in accordance with Defra's Shoreline management plan guidance (Defra, 2006).

The recommendations for each of the three estuaries are as follows:

- The Blyth: The estuary should be included in the open coast SMP and due to the influence of the future management of Reydon Marshes on the mouth of the estuary and therefore the interaction with the coast, the boundary should be at the upstream end of Reydon Marshes (at the upstream limit of Zone 3, see Figure 2).
- The Deben: The estuary should be included in the open coast SMP and the boundary should be at Ramsholt (at the upstream limit of Zone 3, see Figure 3).
- The Alde and Ore: The estuary should be included in the open coast SMP to Barber's Point (at the upstream limit of Zone 3, see Figure 4). This inclusion is a result of the current uncertainty in the estuary's future management and therefore the extent of the future interaction with, and influence on, the coast in light of the potential future breach at Slaughden.

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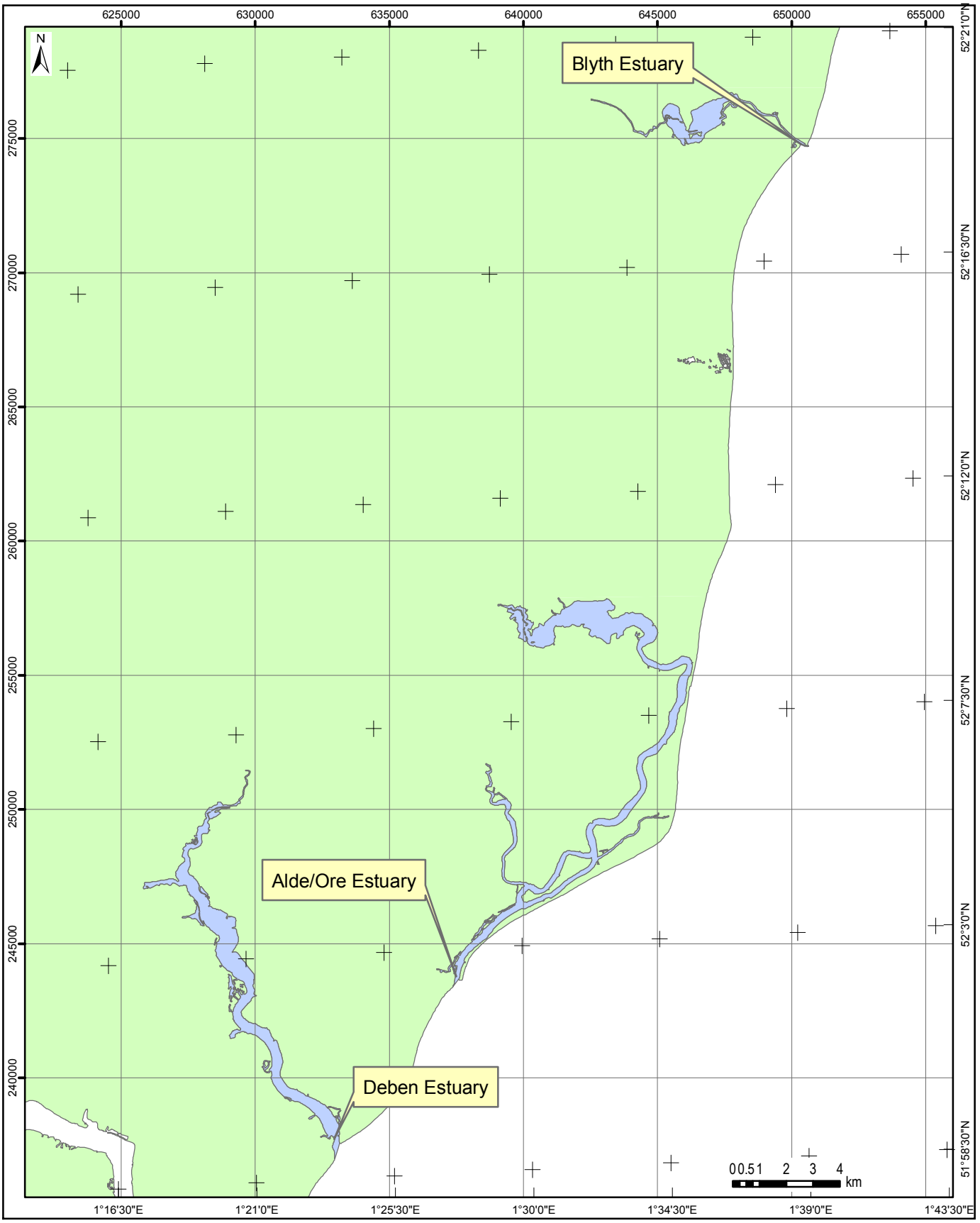
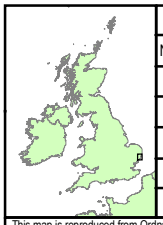
Figures





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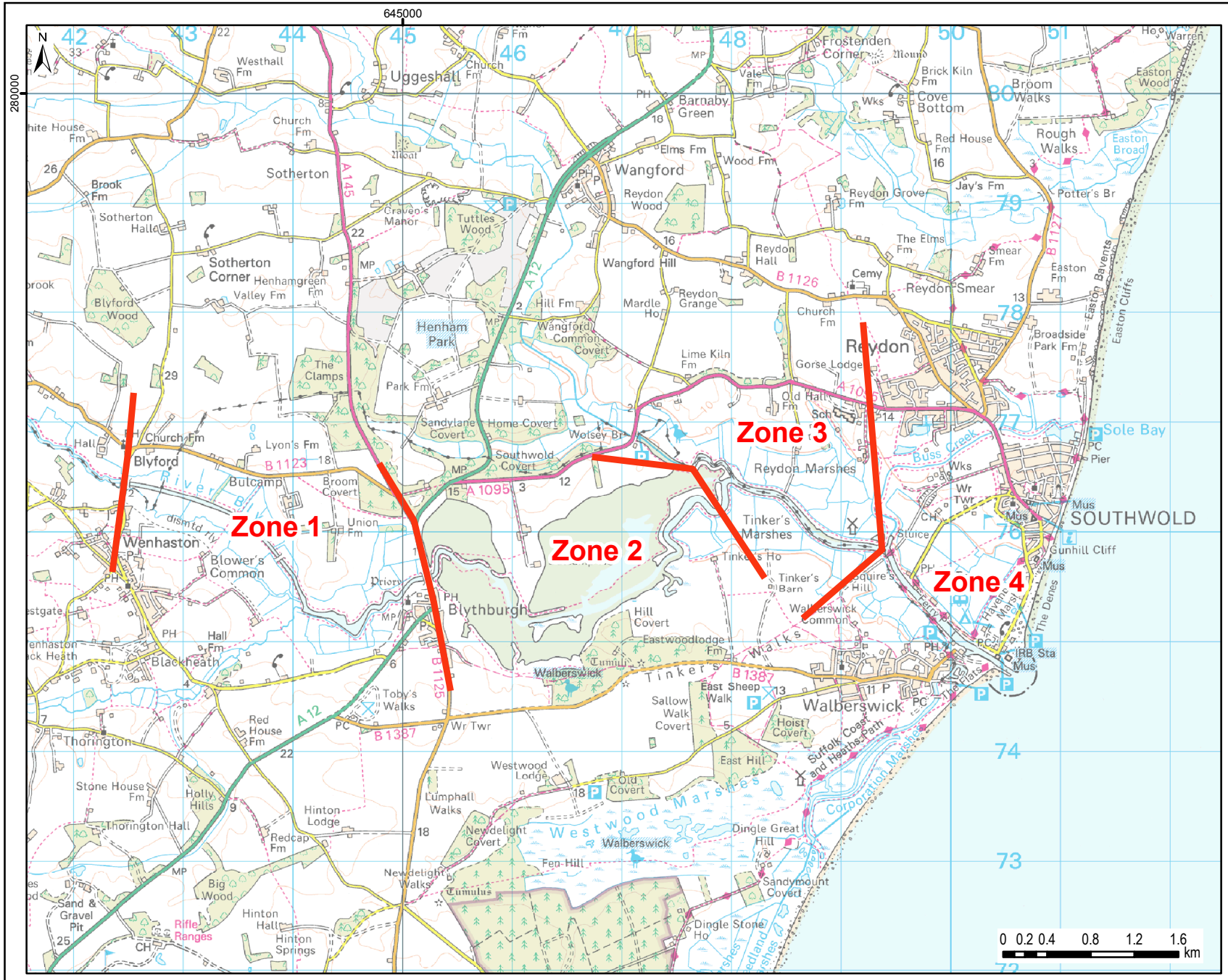
Estuary Location Plan

Figure 1



Zone Boundary

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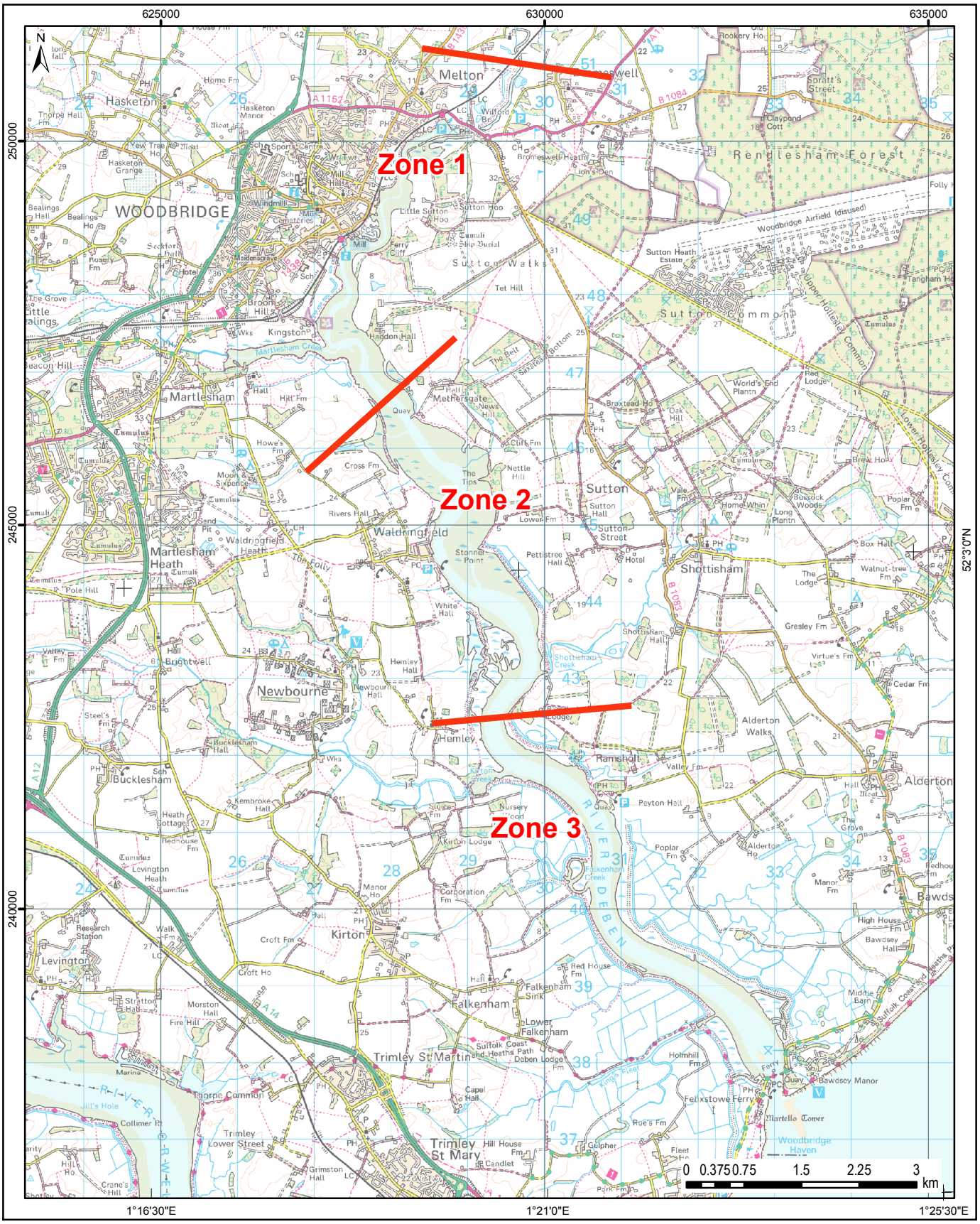
Blyth Estuary
Physical Process Zones

Figure 2



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Zone Boundary

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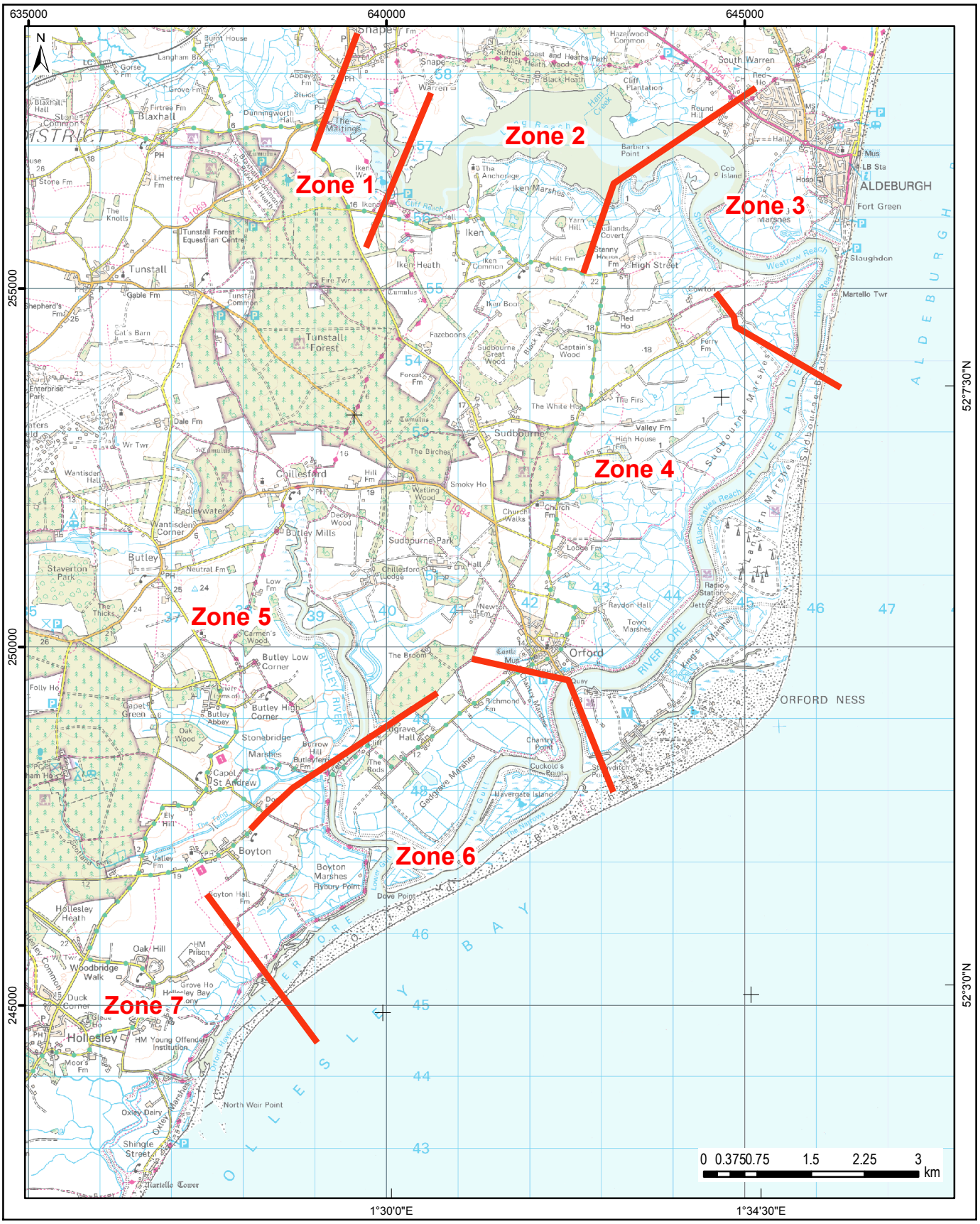
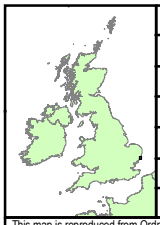
Deben Estuary
Physical Process Zones

Figure 3





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Zone Boundary

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Alde/Ore Estuary
Physical Process Zones

Figure 4

Appendix A

Estuary Guidance Tables
(Appendix F of the SMP Guidance)

Appendix A. Estuary Guidance Tables (Appendix F of the SMP Guidance)

Estuary Guidance Table 1 General Decision-Support Framework

The purpose of this Table is to provide the overall context within which decisions will be made concerning the inclusion, or otherwise, of estuaries within the SMP process. EGT1 is supported by further tables EGT2-EGT7.

Key Question	Key Issues for Consideration	Indicators	Reference Tables
Should the estuary be included in the SMP process?	Type, scale and significance* of physical** interactions	▪ Physical size parameters of the estuary ▪ Physical process parameters of the estuary, and degree of sediment supply from river(s) and sediment exchange with the open coast ▪ Presence/absence of morphological features within estuary and/or at estuary mouth ▪ Physical constraints within estuary and/or along adjacent coast (e.g. defences and/or geological controls) ▪ Potential for large-scale changes in alignment of defences within estuary and/or along open coast	EGT2-5
	Nature and complexity of management issues	▪ Presence/absence of control structures at the estuary mouth and/or within the estuary and/or along the open coast ▪ Common sources of risk between the estuary and open coast (e.g. tidal flooding, wave erosion) ▪ Continuity, location and/or scale of receptors at risk close to the estuary /coast interface (e.g. life, development, nature conservation, natural heritage, existing land and water uses) ▪ Limits of other 'strategic' flood and coastal management initiatives (e.g. CFMPs and/or CHaMPs)	
How should the estuary be included?	SMP eSMP	▪ Physical size (logistics) ▪ Complexity of management issues	EGT6
How far upstream should the estuary be included?	Consideration of estuarine processes	▪ Balance in fluvial, tidal and coastal processes throughout estuary and extent of interactions (physical and logistical) ▪ Presence of natural or man-made constraints and assessment of cross-sectional morphological form	EGT7
	Selection of shoreline management policy	▪ Presence/absence of morphological features and their interconnectivity between different environments ▪ Location, extent and type of management issues	

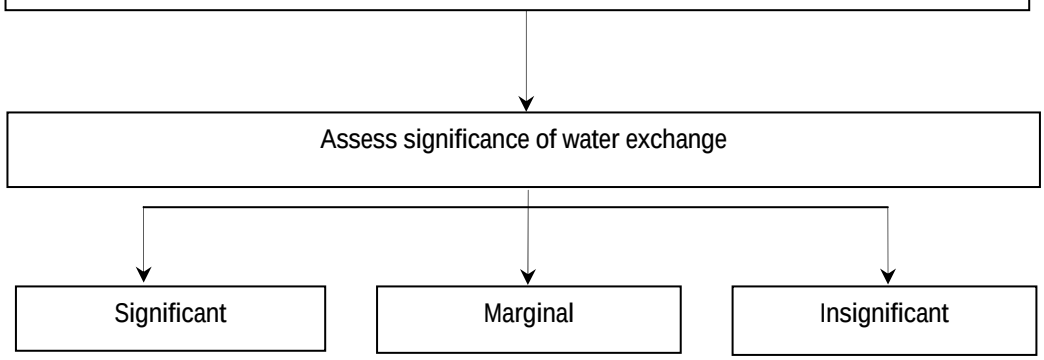
* 'Significant' interaction need not necessarily only be confined to 'large', but could relate to other factors key to the development of either the coast or estuary (i.e. complexity of interactions). Assessment of 'significance', therefore, needs to take account of the scale of the interaction relative to other factors (e.g. resistance of geology, availability of sediment).

** Physical interactions principally relate to water and sediment exchanges between the estuary and open coast. Chemical and biological interactions and water quality issues may be incorporated, if appropriate, in consideration of 'management issues'.

Estuary Guidance Table 2 Significance of Water Exchange

This table assists the user in determining the significance of water exchange between the estuary and the open coast in order to inform the decision about whether or not an estuary should be included in the SMP process.

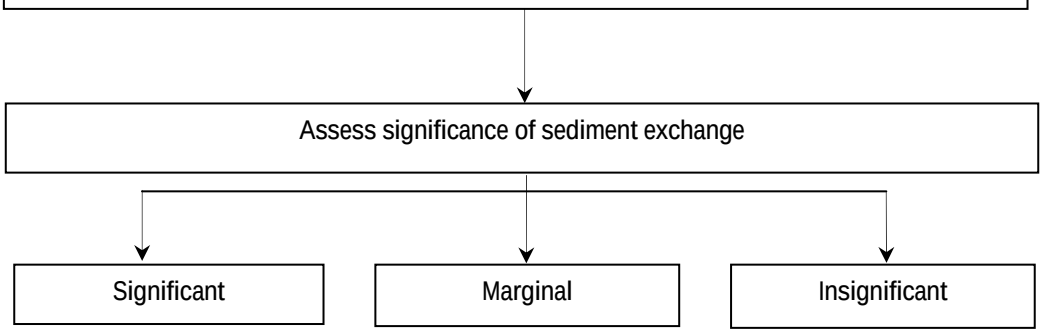
1. Make an informed assessment about the overall scale of water exchange between the estuary and the open coast by considering the following estuary parameters from the *Futurecoast* estuaries database and judging whether they fall into the range 'insignificant to low', 'moderate' or 'high to extensive':
   - Total area
   - Inter-tidal area
   - Channel length
   - Mouth area
   - Mouth width
   - Tidal range
   - Mean freshwater flow
2. Supplement the above information with local or specific knowledge about the following estuary parameters:
   - Tidal prism
   - Tidal velocities
3. Use the above understanding to make an informed assessment of the significance of the water exchange between the estuary and the open coast. This may be assisted by consideration of the following factors, although there may some anomalies, usually large estuaries or inlets, where the ratios do not apply:
   - Ratio of total area to channel length (large = wide embayment more likely to be subject to wave processes, small = longer, narrower estuary more likely to be dominated by tidal processes)
   - Ratio of tidal range to mean freshwater flow (large = tidal processes dominate, small = river process dominate)
   - Ratio of mouth area to mouth width (large = large average mouth depth and hence large water exchange, small = small average mouth depth)
   - Geology of mouth and adjacent coast (hard = relatively erosion resistant even with high flows associated with high water exchange, soft = erodible even with marginal water exchange)
   - Degree of development of adjacent coast (low = less significant, high = more significant).



Estuary Guidance Table 3 Significance of Sediment Exchange

This table assists the user in determining the significance of sediment exchange between the estuary and the open coast in order to inform the decision about whether or not an estuary should be included in the SMP process.

1. Make an informed assessment about the overall scale of sediment exchange between the estuary and the open coast by considering the following estuary parameters from the *Futurecoast* estuaries database or 'estuaries assessment' report (not presented here) and judging whether they fall into the range 'insignificant to low', 'moderate' or 'high to extensive':
   - Tidal asymmetry
   - Presence or absence of morphological features such as banks and deltas
   - Source or sink relationship with open coast (for both cohesive and non-cohesive sediments) – (see 'estuaries assessment' report)
   - Potential for plume generation during river spate (see 'estuaries assessment' report)
2. Supplement the above information with local or specific knowledge about the following issues:
   - Catchment area and existing/planned catchment land uses (influences sediment supply from estuary to coast)
3. Use the above understanding to make an informed assessment of the significance of the sediment exchange between the estuary and the open coast, taking into consideration the following factors:
   - Availability of sediment (both cohesive and non-cohesive) to feed transport potential
   - Critical thresholds for erosion, transport and deposition of estuarine and coastal sediments.



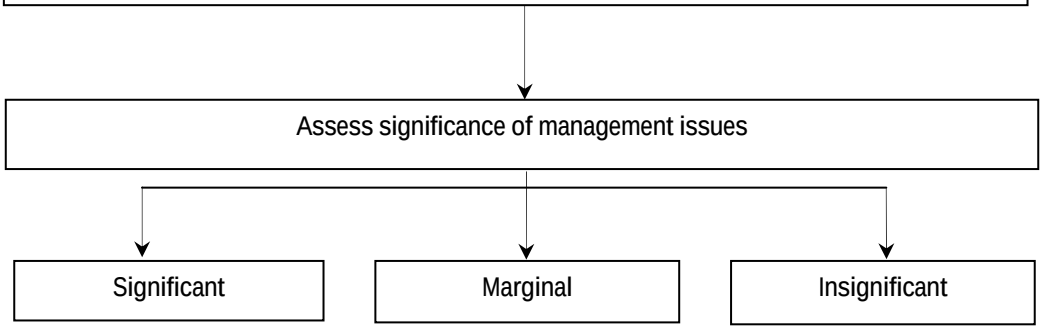
Estuary Guidance Table 4 Significance of Management Issues

This table assists the user in determining the scale of management issues between the estuary and the open coast in order to inform the decision about whether or not an estuary should be included in the SMP process.

1. Take an informed assessment about the scale of management issues by considering the following factors from the Futurecoast estuaries database:
   - Historic reclamation
   - Presence / absence of jetties at the mouth

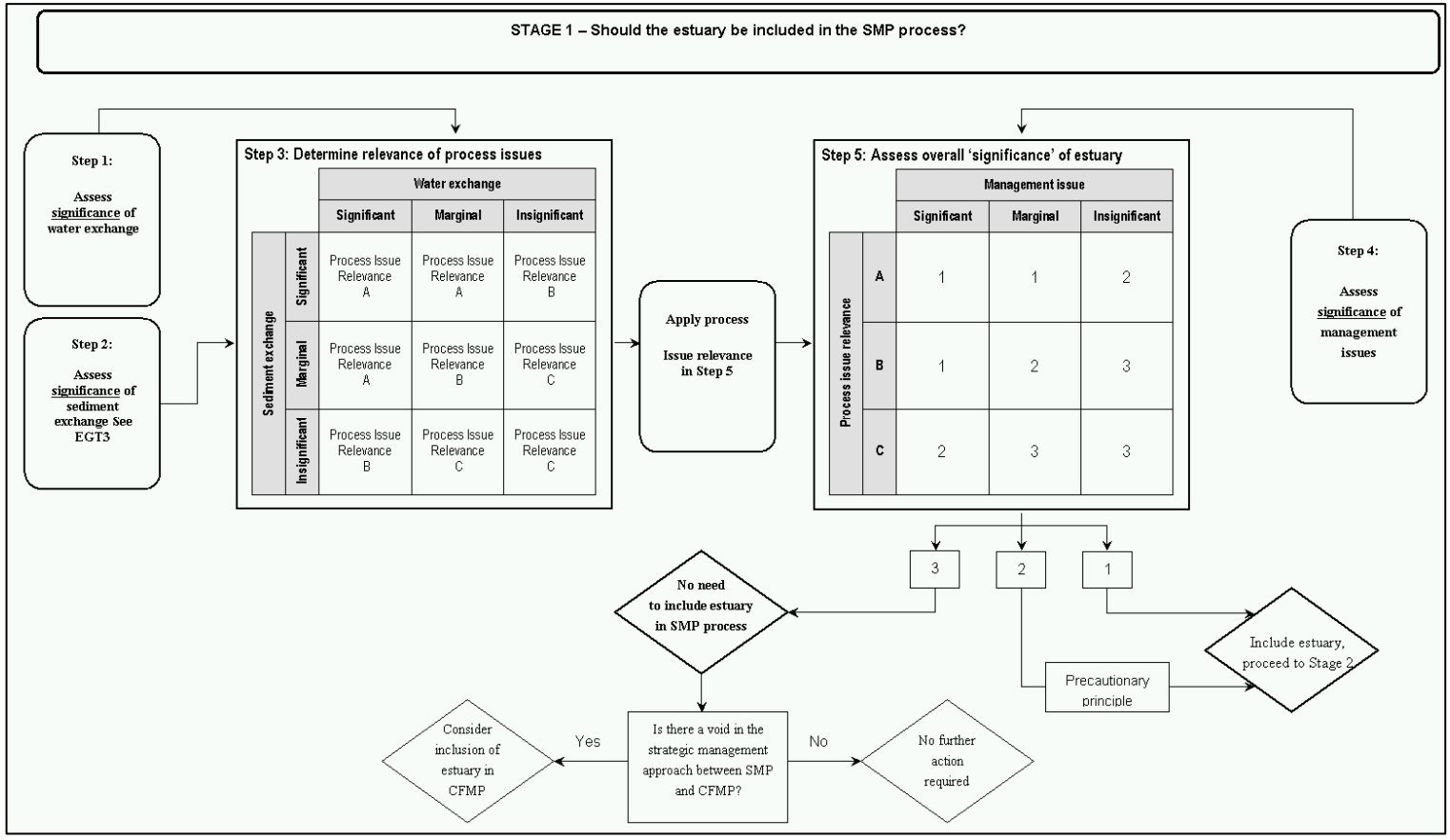
2. Supplement the above understanding with local or specific knowledge about the following issues:
   - Scope for large-scale anthropogenic intervention (e.g. barrage construction, development proposals)
   - Presence or absence of continuous 'at risk' zones between the estuary and coast (e.g. flood risk zones, designated habitat areas, historic environment)
   - Indicative residual life of existing estuarine and coastal defences and scope for widespread changes in shoreline management policy to 'managed realignment', 'hold the line' (with new defences on eroding cliffs) or 'advance the line' (thereby significantly changing existing estuarine tidal prism, or supply of sediment from the coast)
   - Consistency of approach with adjacent SMPs and relevant CHaMPs
   - Relevance of other management issues which can influence the physical interactions between the estuary and coast (e.g. beach replenishment, weirs and sluices, navigation and aggregate dredging, bridges and causeways, training works)

3. Combine the above information to make an informed assessment of the significance of the management issues.



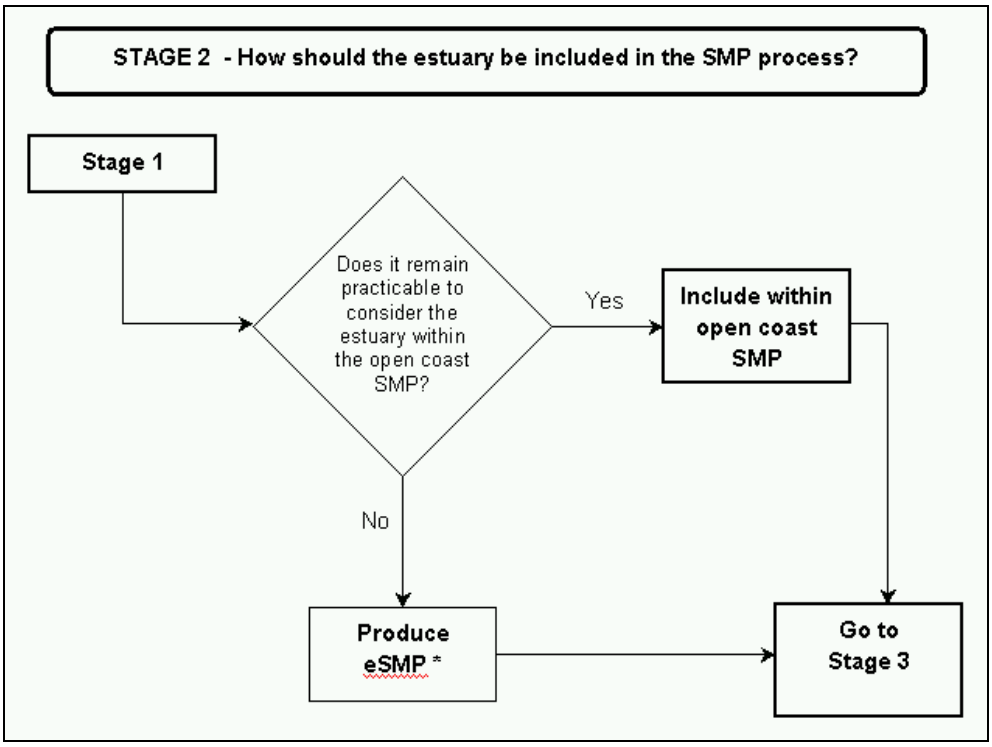
Estuary Guidance Table 5 Assessment of Estuarine Inclusion in SMP Process

The purpose of Estuary Guidance Table 5 is to assist the user in combining findings from EGT2-4 to determine whether or not an estuary should be included in the SMP process. The sensitivity of the decision from this table to changes in the outputs from tables 2, 3 and 4.



Estuary Guidance Table 6 Assessment of Method for Inclusion of Estuaries in SMP Process

This table assists the user in determining how an estuary should be included in the SMP process. It is clearly a qualitative appraisal and should only be undertaken by those familiar with the estuary and its issues.



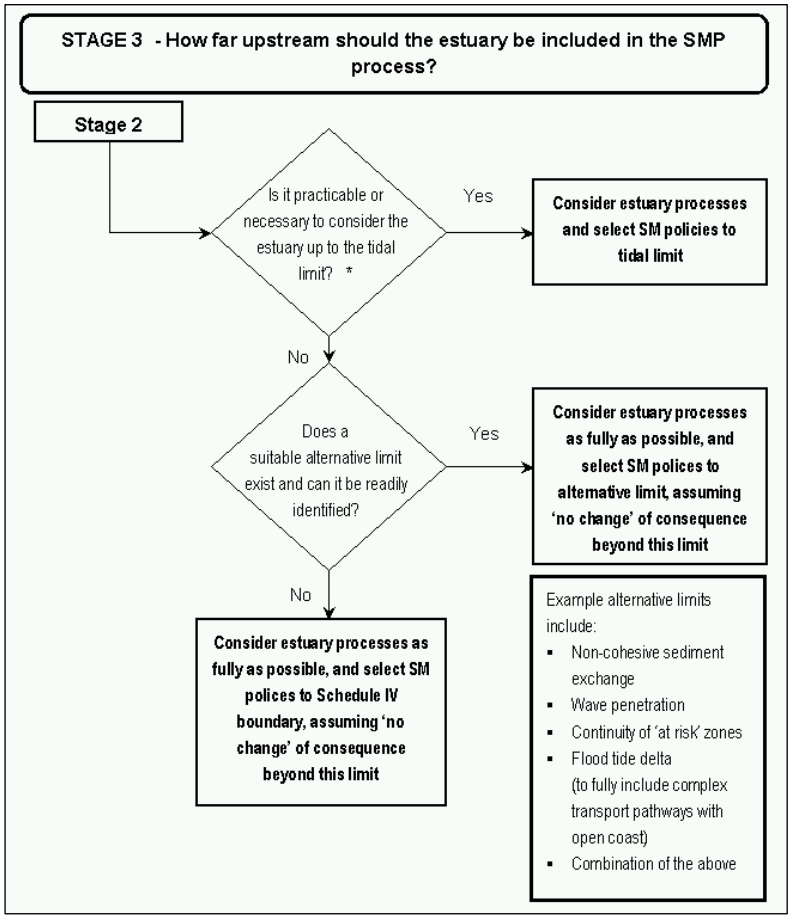
* eSMP must overlap with open coast SMP and those producing each plan must maintain information exchange throughout the plan preparation process

Examples of where it is not practicable to include estuary within open coast SMP are:

- Where the estuary is sufficiently large to necessitate consideration of its process and management policies outside of the open coast SMP.
- Where the estuarine management issues are too complex or diverse to consider within the open coast SMP.

Estuary Guidance Table 7 Assessment of Extent of Estuarine Inclusion in SMP Process

This table assists the user in determining how an estuary should be included in the SMP process.



* It may be necessary to consider an estuary to the tidal limit where there is potential for large-scale change in tidal prism or the estuary is morphologically dynamic (i.e. high natural variability).

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