North West Estuaries Processes Reports

Wyre Estuary

Prepared for
Sefton Council

December 2013

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Metadata

Addressee	Sefton Council
Audience	Coastal/Environmental Engineers
Contributor(s)	CH2M Hill, Kenneth Pye Associates Ltd
Coverage	North West estuaries
Creator	Halcrow Group Ltd, a CH2M Hill Company
Date	December 2013
Description	Review of coastal processes knowledge and issues in Wyre Estuary
Format	Text
Identifier	V3.0 December 2013
Keyword	Estuary, Strategic, Coastal, Processes
Language	English
Location	Wyre Estuary
Mandate	CERMS Regional Monitoring Framework
Publisher	Sefton Council
Status	Final
Subject	Coastal and estuarine processes
Title	North West Estuaries Processes Reports – Wyre Estuary
Type	Text/report
Date of metadata update	17 December 2013

Document History

North West Estuaries Processes Report

Wyre Estuary

Sefton Council

This document has been issued and amended as follows:

version	Date	Description	Created By	Verified By	Approved By
1.0	28/03/13	Internal Draft	Emma Allan, Nigel Pontee, Ken Pye	A Parsons	N/A
2.0	15/10/13	Draft for client comment	A Parsons,	K Pye	A Parsons
3.0	17/12/13	Finalised following comments and internal review	A Parsons	K Pye	A Parsons

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Glossary

Term	Definition
Accretion	Accumulation of sediment due to the natural action of waves, currents and wind.
Advance the Line (ATL)	Advance the Line. A Shoreline Management Plan policy to build new defences on the seaward side of the existing defence line to reclaim land.
AIMS	Asset Information Management System. National database being developed by Environment Agency to replace NFCDD.
Bathymetry	The seabed elevation and depth of water in relation to it.
Coastal Change	Physical change to the shoreline, i.e. erosion, coastal landslip, permanent inundation and coastal accretion.
CD	Chart Datum.
Clay	Sediment particles smaller than 0.002 mm.
Cell Eleven Regional Monitoring Strategy (CERMS)	Regional Monitoring Strategy for the area known as Cell 11, which extends from Llandudno to Solway Firth.
Cell Eleven Tide and Sediment Study (CETaSS)	Regional sediment transport study for coastal Cell 11, undertaken in two main stages to support the development and implementation of the second round shoreline management plan (SMP2). The study included modelling of tides, waves and sediment transport alongside desk based studies with a focus on issues and uncertainties identified in the SMP1s and the initial scoping phase.
Coastal Erosion	A natural process that occurs as a result of waves, tides or currents – in other words, the sea – striking the shore. Sediment or rocks are washed away (but can be a sediment source for elsewhere), and our coastline changes shape as a result. This may include cliff instability, where coastal processes result in landslides or rock falls.
Coastal Landsliding/Instability	Process that involves slope failure and mass movement of a coastal slope or cliff and may result in deposition of debris on the beach and foreshore. Some landslides are very large and extend a considerable distance inland, offshore and deep below beach level and care must be taken to ensure their true extent is recognised. Cliff instability and erosion is a four stage process involving detachment of particles or blocks of material, transport of this material through the cliff system, its deposition on the foreshore and its removal by wave and tidal action.
Coastal Narrowing (including Coastal Squeeze)	The process whereby rising sea levels and other factors such as increased storminess push the coastal habitats landwards. At the same time in areas where land claim or coastal defence has created a static, artificial margin between land and sea or where the land rises relative to the coastal plain, habitats become squeezed into a narrowing zone. Manifestation of this process is most obvious along the seaward margins of coastal habitats, especially salt marshes, when erosion takes place.
Coastal processes	A collective term covering the action of natural forces on the shoreline and nearshore seabed. Includes such processes as wave action tidal flows and sediment transport.
D_{50}	Median particle/ grain size in sediments; the 50^{th} percentile size of a distribution.
EA	Environment Agency.

Term	Definition
Ebb dominant	Stronger current on ebb tide than flood tide. Coarser sediments may be moved more by ebb direction currents than flood. The balance of net sediment transport depends on the relative strength and duration of ebb and flood currents.
Ebb-tide	The falling tide. Part of the tidal cycle between high water and the next low water.
Estuary	A semi-enclosed coastal body of water which has a free connection to the open sea and where freshwater mixes with saltwater.
Fetch	Distance over which a wind acts to produce waves - also termed fetch length.
Flood and Coastal Erosion Risk Management (FCERM)	Flood and coastal erosion risk management addresses the scientific and engineering issues of rainfall, runoff, rivers and flood inundation, and coastal erosion, as well as the human and socio-economic issues of planning, development and management.
Flood Defence Grant in Aid (FDGiA)	The mechanism by which most of the funding for flood and coastal defence works in England is provided by the Government. The grants are used to cover our operating costs and to fund capital projects.
Flood dominant	Stronger current on flood tide than ebb tide. Coarser sediments may be moved more by flood direction currents than ebb. The balance of net sediment transport depends on the relative strength and duration of ebb and flood currents.
Fluvial	Belonging to rivers streams or ponds. e.g. Fluvial flooding, fluvial plants.
Geomorphology/ Morphology	The form of the earth's surface including the distribution of the land and water and the processes responsible for their movement.
Hard structure of rock outcrop (Hard point)	Man-made feature or natural rock outcrop which acts to locally limit the natural movement of the shoreline e.g. sea wall, rock groyne.
HAT	Highest Astronomical Tide. See Tide Levels.
Headland	Hard feature (natural or artificial) forming local limit of longshore extent of a beach.
Hinterland	The area landward of flood or coastal defences.
Hold the Line (HTL)	Hold the Line. A Shoreline Management Plan policy to maintain or change the level of protection provided by defences in their present location.
Holocene	An epoch of the Quaternary period, spanning the time from the end of the Pleistocene (10,000 years ago) to the present.
Hydrographic Survey	A field survey carried out to map the sea bed features which affect maritime navigation, marine construction, dredging, offshore oil exploration/drilling and related disciplines.
Infrastructure	The basic facilities and equipment for the functioning of the country or area, such as roads, rail lines, pipelines and power lines.
Intertidal zone	The zone between the high and low water marks.
LAT	Lowest Astronomical Tide. See Tide Levels.

Term	Definition
LiDAR	Light Detection and Ranging – a method of measuring land elevations using a laser, often from a light aeroplane.
Littoral transport (drift)	The movement of beach material in the littoral zone by waves and currents. Includes movement parallel (longshore drift) and perpendicular (cross-shore transport) to the shore.
LLFA	Lead Local Flood Authority. Responsible body for local flood risk management in accordance with the Flood and Water Management Act (FWMA) (2010).
Managed Realignment (MR)	A Shoreline Management Plan policy that allows the shoreline position to move backwards (or forwards) with management to control or limit movement.
MHWS	Mean High Water Springs. See Tide Levels.
MHWN	Mean High Water Neaps. See Tide Levels.
MLWN	Mean Low Water Neaps. See Tide Levels.
MLWS	Mean Low Water Springs. See Tide Levels.
MSL	Mean Sea Level. See Tide Levels.
Mud	A type of sediment containing more than 50% silt and clay size particles; may also contain sand and/or gravel and be described as sandy mud, gravelly mud etc.
Mudflats	Expanses of mud which are periodically exposed at low tide, often found adjacent to saltmarshes.
NFCDD	National Flood and Costal Defence Database. Database of flood defence assets developed by EA. Now being superseded by AIMS.
NTL	Normal Tidal Limit. The point to which the tide reaches in an estuary, under normal conditions i.e. in absence of storm surge and with typical river flow.
Neap tide	Tides over a 14 day period with lowest tidal range between high and low water.
No Active Intervention (NAI)	A Shoreline Management Plan policy that assumes that existing defences are no longer maintained and will fail over time or undefended frontages will be allowed to evolve naturally.
OD	Ordnance Datum - the standard reference level for Ordnance Survey maps throughout the UK from which the height of the land is measured. Currently based on mean sea level at Newlyn in Cornwall.
Partnership Funding	Funding contributions for flood and coastal erosion risk management from beyond traditional flood and coastal erosion risk management budgets (e.g. Flood Defence Grant in Aid (FDGiA); the grant by which government funds its share of the costs of FCERM projects in England).
Policy Unit (PU)	Sections of coastline for which a certain coastal defence management policy has been defined in the Shoreline Management Plan – see SMP.
Progradation	Seaward movement of the shoreline (mean high water mark) due to sediment accumulation on a beach, dunes, delta etc.

Term	Definition
Ramsar	Ramsar sites are wetlands of international importance, designated under the Ramsar Convention of 1971.
Regression	A seaward movement of the shoreline due to a fall in sea level.
Risk	A combination of both the probability of an event occurring and the expected consequences if it does occur. In the case of coastal change adaptation planning, risk relates to the impact and consequences of a hazard, which may be coastal erosion, coastal landsliding, coastal accretion or coastal flooding resulting in regular or permanent inundation.
Risk Management Authorities	Organisations that have a key role in flood and coastal erosion risk management as defined by the Flood and Water Management Act (2010). These are the Environment Agency, lead local flood authorities, district councils where there is no unitary authority, internal drainage boards, water companies, and highways authorities.
SAC	Special Area of Conservation. An area which has been given special protection under the European Union's Habitats Directive.
Sand	Sediment particles, often mainly of quartz, with a diameter of between 0.063mm and 2mm, generally classified as `fine', `medium', `coarse' or `very coarse'.
Saltmarshes	An ecosystem in the mid- to high intertidal zone which is vegetated by salt-tolerant plants.
Sediment sink	An area in which transported sediment is deposited and accumulates over time.
Sediment source	An area from which sediment is derived and becomes available for transport to a sediment sink.
Shoreline Management Plan (SMP)	A plan providing a large-scale assessment of the risk to people and to the developed, historic and natural environment associated with coastal processes. SMP2 refers specifically to the second generation SMP.
Silt	Sediment particles with a grain size between 0.002mm and 0.063mm, i.e. coarser than clay particles but finer than sand.
SPA	Special Protection Area. An area of land, water or sea which has been identified as being of international importance for the breeding, feeding, wintering or the migration of rare and vulnerable species of birds found within the European Union.
Spring tide	Tides over a 14 day period with highest tidal range between high and low water.
SSSI	Site of Special Scientific Interest (SSSI) National conservation designation given to sites of biological or geological interest in England, Wales and Scotland.
Storm surge	The local change in sea level associated with a change in atmospheric pressure and/ or onshore winds. Surges may be either positive (higher than predicted astronomical sea level) or negative (lower than predicted), and typically have a duration of a few hours to a few days.

Term	Definition
Strategy Plan	A long term documented plan for coastal management, including all necessary work to meet defined flood or coastal defence objectives for the target area. It is designed to provide the basis for decision making and action related to the provision and management of flood or coastal defences. Strategy Plans develop the policies recommended in SMPs by defining the preferred approach to shoreline management requirements over a 100 year period.
Tidal range	Microtidal < 2m; Mesotidal 2m - 4m; Macrotidal >4m; Hypertidal > 8m.
Tide	The rise and fall of the sea caused by the gravitational pull of the moon and sun.
Tide levels	(1) High astronomical tide (HAT), lowest astronomical tide (LAT): the highest and lowest tidal levels, respectively, which can be predicted to occur under average meteorological conditions. (2) Mean high water springs (MHWS): the height of mean high water springs is the average throughout a year of the heights of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is greatest. (3) Mean low water springs (MLWS): the height of mean low water springs is the average height obtained by the two successive low waters during the same periods. (4) Mean high water neaps (MHWN): the height of mean high water neaps is the average of the heights throughout the year of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is least. (5) Mean low water neaps (MLWN): the height of mean low water neaps is the average height obtained by the two successive low waters during the same periods. (6) Mean high water (MHW), mean low water (MLW): mean high/low water, as shown on Ordnance Survey Maps, is defined as the arithmetic mean of the published values of mean high/low water springs and mean high/low water neaps.
Tidal prism	Volume of water entering and leaving an estuary during each tide, i.e. the difference between low water volume and high water volume.
Training walls	A wall typically constructed of rubble or masonry to constrain or guide the movement of an intertidal or sub-tidal channel.
Transgression	A rise in mean sea level responsible for landward movement of the shoreline.
Turbidity maximum	Location of high concentration of suspended sediment in an estuary; associated with fresh / seawater mixing with vertical and horizontal salinity gradient resulting in residual vertical circulation and flocculation of suspended sediment. Location varies during the tide and with variations in river flow.
Up-drift	Longshore drift is the movement of beach materials along the shore, if a location is described as up-drift; it is located further up the sediment pathway (closer to the sediment source) than an alternative area; the opposite of down-drift.
Wave Height	The vertical distance between a wave crest and the next trough.

Executive summary

The Wyre Estuary is a relatively small, macro-tidal estuary located on the southern shore of Morecambe Bay. The estuary is sinuous and has a 'bottle' shape in plan, not dissimilar to the Mersey. The estuary extends 18.3km from the mouth between Fleetwood and Knott-End-on-Sea and the normal tidal limit at St. Michael's on Wyre. The River Wyre drains a mainly rural catchment composed of unconsolidated glacial and fluvio-glacial sediments which form undulating topography of relatively low relief. The freshwater input to the Wyre is small (a peak flow 170 m^3/s at St. Michael's on Wyre since 1962) compared to the volume of sea water exchanged on each tide.

The estuary is macrotidal, with mean spring and mean neap tidal ranges at Fleetwood being 8.2m and 4.2m, respectively. Storm surges can raise predicted water levels by up to 2 m. A severe surge in 1977 caused sea defence breaching along parts of the northern Fylde Peninsula and caused flooding to areas around the Wyre Estuary. The estuary and surrounding areas remain vulnerable to tidal flooding.

The Wyre Estuary is important for nature conservation and the national and international habitats form part of the SAC, SSSI and SPA designations covering much of Morecambe Bay.

The northerly orientation and narrow nature of the estuary mouth means that significant wave energy does not enter the estuary. Within the estuary sediment transport is dominated by tidal currents and is concentrated in the main low water channel where water depths and flows are the greatest. The flood asymmetry promotes the import of sediment into the estuary from marine sources.

Inglis and Kestner (1958) concluded that the channel migration in the lower Wyre Estuary seemed to display cyclical behaviour, where channel configuration and position was similar every 20 years. Changes in channel position have been observed mostly in winter months, which suggests that changes could be driven by a combination of high freshwater flows, spring tides and storm surges. Channel meandering has kept the estuary volume relatively constant over time by initiating local cycles of erosion and deposition.

The port area near the former ferry berth was regularly dredged until 2010. Since that time there is anecdotal evidence of significant accretion in the outer estuary and the approach channel. Littoral drifting of sand and gravel along the intertidal zone between Rossall and Fleetwood has led to sedimentation within the estuary mouth and to problems of wind-blow sand accumulation on the promenade at Fleetwood.

The Wyre Estuary has been infilling with sediment since the end of the last glaciation, but the natural rate of change has been accelerated since the 19th century by man-made modifications within the estuary. The intertidal area decreased by approximately 50% from c. 1000ha in 1847-48 to c. 500ha in 2000, reducing the tidal prism and leading to a probable reduction in average current speeds. Developments within the estuary have included the construction of a railway embankment, training works, jetties, capital maintenance and aggregate dredging. Many of these developments, including the commencement of flood embankment construction and the railway line, occurred in the early 19th century. Training works have been built since the mid-1800s to control the position of channels and influence the water depths at particular jetties.

Over the next 100 years there is likely to be continuing littoral drift of sand along the Fleetwood frontage towards the mouth of the Wyre, derived mainly from foreshore or sub-tidal lowering along the northern Fylde. However, the quantity of sediment from this source is likely to be small in relation to that transported from southern Morecambe Bay. The Wyre itself will also continue to supply small quantities of muddy sediment from its catchment. Vertical accretion of saltmarshes is unlikely to be constrained by sediment supply, and changes in lateral extent are likely to be mostly dependent on fluctuations in low water channel alignment. Following the cessation of dredging, the main Wyre Channel is likely to become shallower, with possible implications for tidal propagation into the estuary.

The large areas of flood risk and development around the Wyre Estuary justify a long term plan in the SMP2 to continue to provide protection throughout its outer reaches, although this will constrain natural development of the outer estuary. In the upper reaches of the estuary, however, the long term SMP2 vision is to allow a more naturally functioning system and realignment opportunities will be pursued. These approaches will satisfy both local social objectives for protection of land and property, and environmental objectives to create additional intertidal habitat. At the estuary mouth the long term plan is to manage flood risks to the northern coast of Fleetwood and the large linked flood risk area which extends from the open coast into the estuary. Natural dune accretion along the present outer line of the promenade to the west of the Wyre may be sufficient to achieve this, and is a preferred approach because of the lower costs and greater environmental benefits. Should this trend reverse, a long term option might be to hold a secondary line at the road, allowing dunes to roll back but to provide primary protection.

A bathymetric survey of the estuary was undertaken in 2007 as part of the Wyre Estuary Management Study. LiDAR coverage is also available and a composite DEM of the estuary could be prepared using existing data. Further LiDAR data acquisition is scheduled as part of CERMS in the winter 2013/14. There is a requirement to continue monitoring changes in the estuary bathymetry and intertidal morphology following the cessation of dredging. The physical character and mobility of sediments within the estuary are at present poorly documented and require further investigation. This information will be essential in order to evaluate the potential impacts of possible managed realignment schemes within the inner estuary and proposals for tidal barrage construction.

1 Introduction

This report summarises the existing understanding of the Wyre Estuary (refer to Figure 1.1). It draws on information from the second round SMP, the Cell Eleven Tidal and Sediment Transport Study (CETaSS) and other more recent studies. It provides a summary of:

- The physical processes and evolution of the estuary;
- The SMP policies for the estuary;
- The existing monitoring data;
- Gaps in understanding and
- Recommendations for further monitoring, additional studies and review of flood risk ratings and SMP policies.

This report forms one of a series of similar reports for the major estuaries on the coast of North West England.

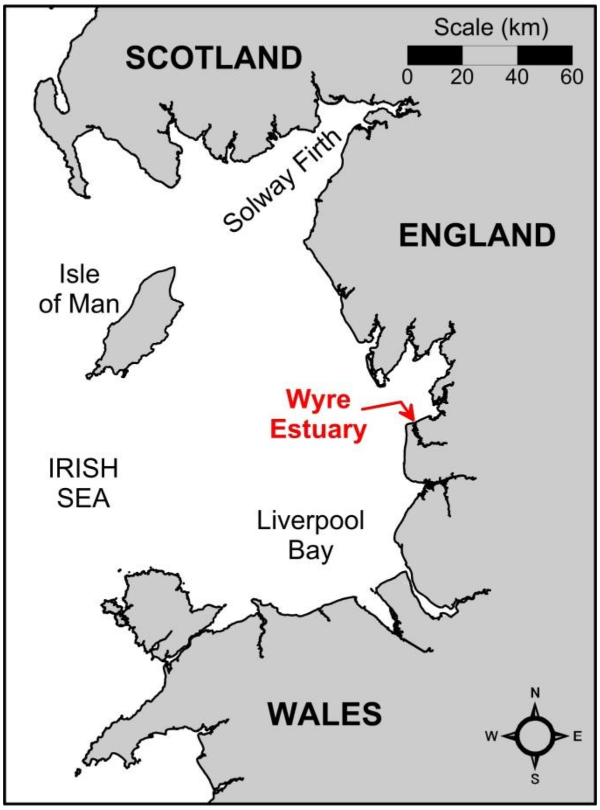

Figure 1.1 Location of the Wyre Estuary

2 Coastal Setting

The Wyre Estuary is located within the southern part of Morecambe Bay in sub-cell 11c, which extends from Rossall Point, Fleetwood to Hodbarrow Point on the Duddon, see Figure 2.1.

Figure 2.1 Overview of Cell 11 study area, showing SMP2 sub-cell frontages (source: Halcrow, 2010a).

The River Wyre drains a mainly rural catchment to the southwest of the Forest of Bowland (Figure 2.2). The river has several significant tributaries and a number of other streams flow directly into the estuary. The peak flow measured at St. Michael's on Wyre, close to the normal tidal limit, flow since 1962 is 170 m^3 / s. The total catchment area is approximately 450 km^2. Two artificial flood storage areas have been created in the mid part of the catchment to alleviate flooding (Environment Agency, 2009).

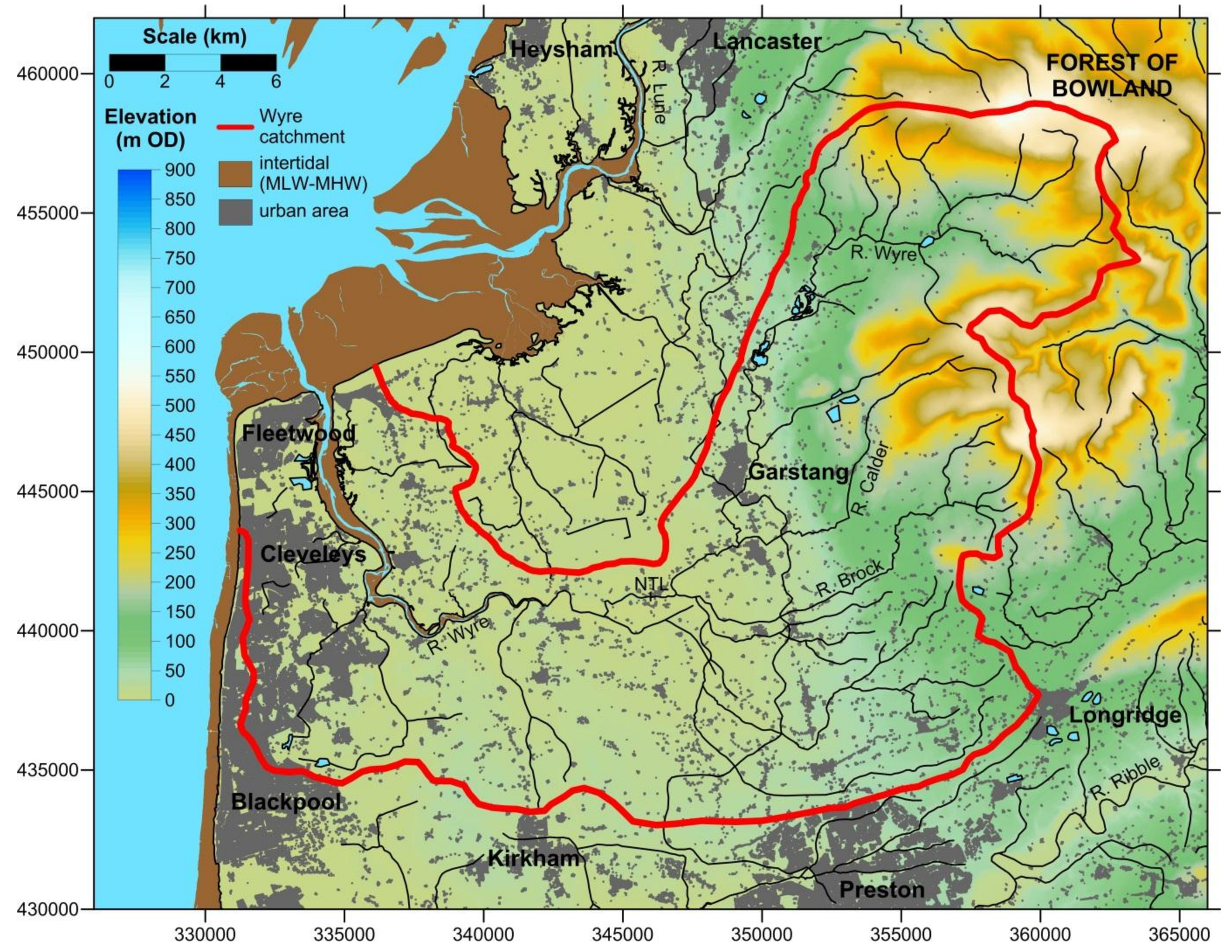

Figure 2.2 The River Wyre catchment, showing the main urban areas and general extent of the intertidal zone. Source: Modified from Ordnance Survey Open Data, after Pye & Blott (2013).

3 Estuary Review

3.1 Description

The Wyre Estuary is a relatively small, macro-tidal estuary, located along the southern shore of Morecambe Bay. The Wyre Estuary is located in an extensive coastal plain composed of unconsolidated glacial and fluvio-glacial sediments which form a topography of low hills around the estuary. The estuary extends 18.3km from the mouth between Fleetwood and Knott-End-on-Sea, and the normal tidal limit at the weir at St Michael's on Wyre (Halcrow, 2004) (Figure 3.1).

In plan, the estuary is sinuous and has a 'bottle' shape, not dissimilar to that of the Mersey. The mouth of the estuary represents the neck of the bottle after which the estuary width first increases and then decreases (Halcrow, 2010b).

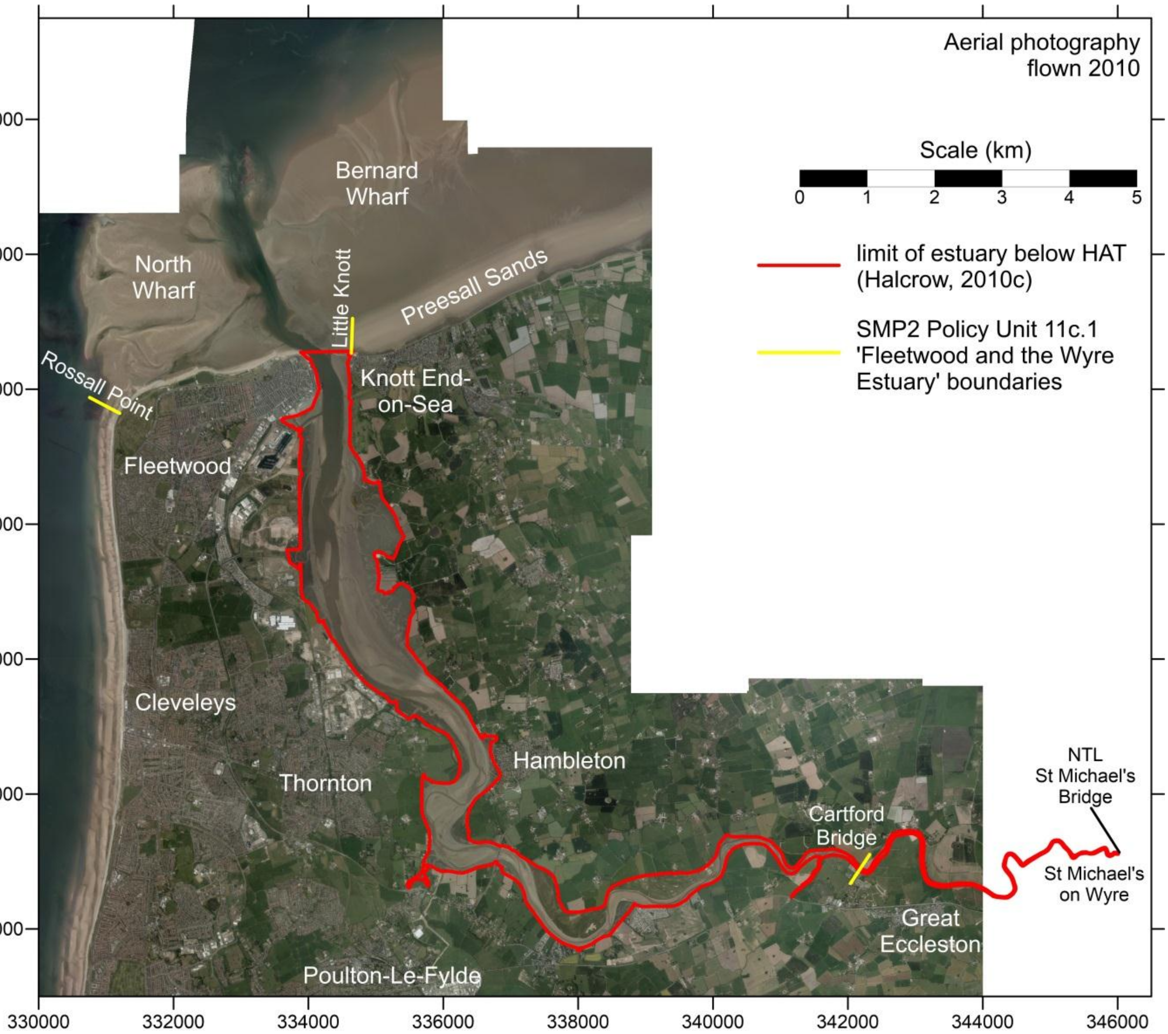

Figure 3.1 Limits of the Wyre Estuary and SMP2 Policy Unit 11c.1.

The shoreline management plan (SMP2) estimated that there would be around 29,600 residential and 1,900 non-residential properties along with 4,100ha of agricultural land at risk in the long term for a No Active Intervention (Do Nothing) approach to flood and erosion risk management. There are also industrial sites, the port of Fleetwood and regional infrastructure within the flood risk area. The large urban flood risk area on the west bank from the estuary mouth at Fleetwood to Stanah, east of Thornton, is also at flood risk from the open coast. There is also a large more rural flood risk area on the east bank extending east from Knott End.

The Wyre Estuary is important for nature conservation and the national and international habitats form part of, or are linked with, the designations covering much of Morecambe Bay (Figure 3.2).

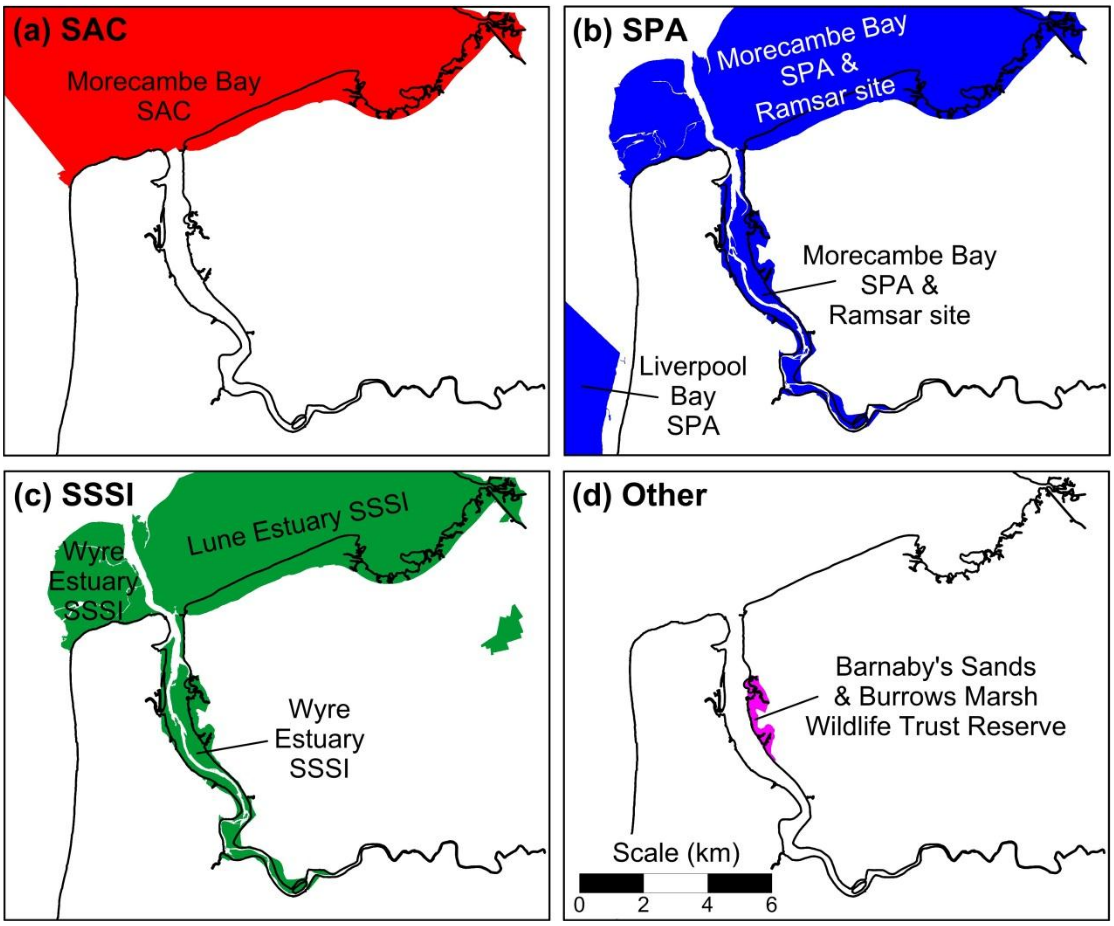

Figure 3.2 Nature conservation designations and reserves in and surrounding the Wyre Estuary.

3.2 Coastal Processes

The Wyre Estuary is macrotidal, with mean spring and mean neap tidal ranges at Fleetwood being 8.2m and 4.2m, respectively, see Table 3.1.

Table 3.1 Tidal levels (mOD) at Fleetwood at the mouth of the Wyre Estuary. Source: Admiralty Tide Tables (2012)

	LAT	MLWS	MLWN	MSL	MHWN	MHWS	HAT
Fleetwood	**nd**	**-3.70**	**-1.80**	**0.28**	**2.40**	**4.50**	**5.90**

Morecambe Bay experiences significant storm surges which can raise predicted water levels by up to 2 m. A severe surge in 1977 caused sea defence breaching along parts of the northern Fylde Peninsula and caused flooding to areas around the Wyre Estuary. The estuary and surrounding areas remain vulnerable to tidal flooding (Environment Agency, 2009).

The volumes of freshwater inputs to the Wyre are small compared to the total volumes of marine water exchanged on each tide. The influence of fluvial inputs is, however, likely to assume a greater importance in the upper reaches of the estuary. Extreme high water levels throughout the estuary are caused by a combination of marine surges and high tidal levels. In the inner estuary extreme water levels are exacerbated by fluvial floods. The freshwater inputs into the Wyre are strongly seasonal, being greater in the winter than the summer (Halcrow, 2010b).

The location of the mouth of the Wyre within Morecambe Bay means that coastal processes in the estuary and Bay are strongly linked. Littoral and subtidal annual average sediment transport vectors for Morecambe Bay and the surrounding area, based on numerical modelling from the CETaSS study (Halcrow, 2010c) are shown in Figure 3.3.

Inside Morecambe Bay the sediment pathways are complex; east of the Lune Deep on the southern part of the Bay's mouth, transport is flood dominated, whereas towards the northern two-thirds of the mouth, the potential sediment transport is ebb dominated out of the Bay. A little way into the Bay, analysis across a transect from Newbiggin to Pilling indicates overall flood dominance. Further into Morecambe Bay transport becomes increasingly flood dominated, due to increased asymmetry of the tides producing stronger flood current speeds and a net import of sediment into the adjoining estuaries.

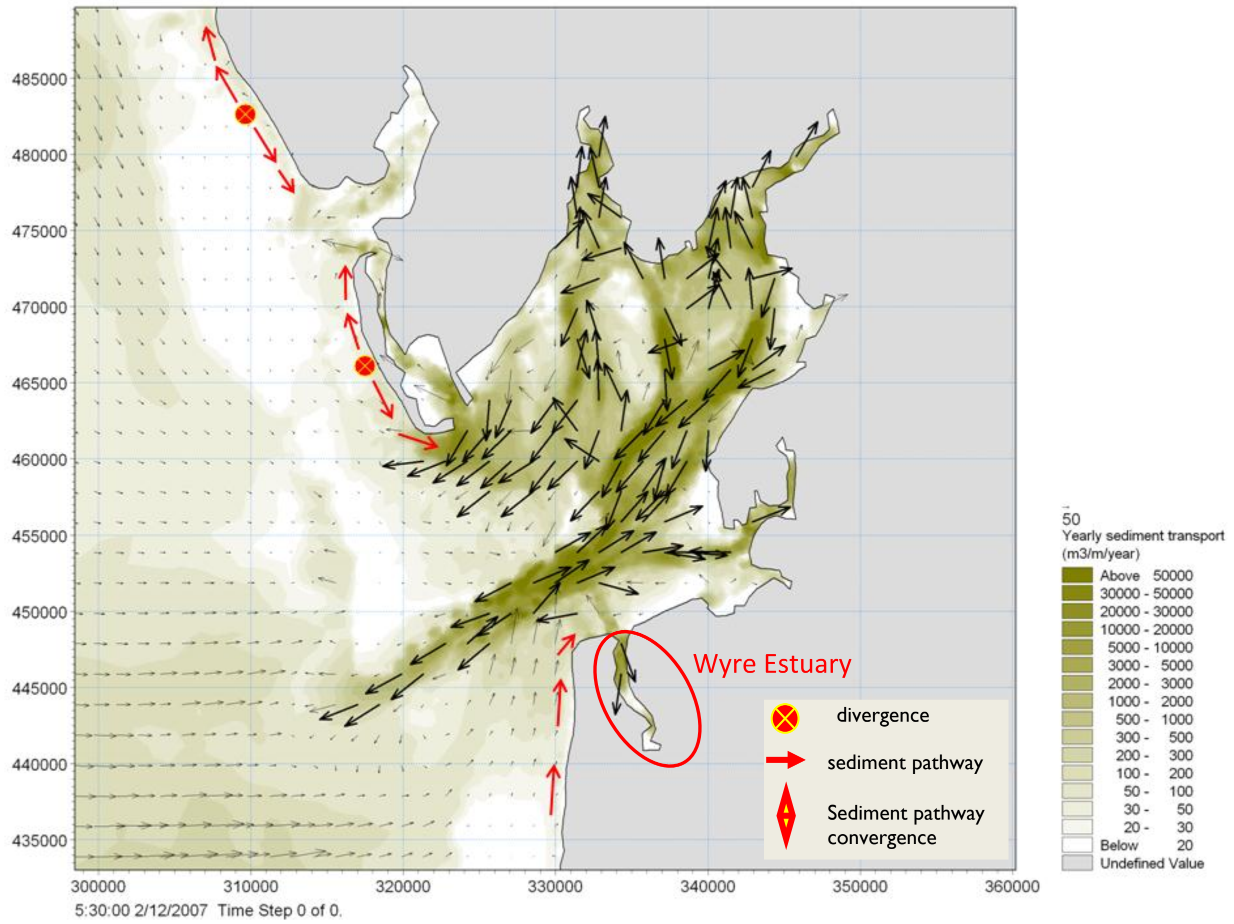

Figure 3.3 Annual sediment transport vectors in the vicinity of the Wyre Estuary (from Halcrow 2010d)

On the southern shore of Morecambe Bay the littoral drift is from west to east in response to the predominant wave direction. To the south-west of the estuary mouth, there is a northward littoral drift of sediment from the Fylde shoreline. This continues towards Fleetwood and across the estuary mouth. Accretion on the upper beaches of the area suggests there is also some cross-shore transport operating (Halcrow, 2002). Dunes are actively forming on the backshore and blown sand incursion onto the promenade is a problem at Fleetwood.

Within Morecambe Bay the strong tidal currents and plentiful sediment availability have led to the formation of a shifting system of banks and channels, such as those near Fleetwood. Seaward of the Wyre Estuary mouth, the low water channel continues in a northerly direction through a series of intertidal sandflats and banks. It is possible that changes in the tidal prism of the Wyre over the last 200 years may have led to changes in the low water channel seawards of the estuary mouth, although this has not been investigated. The estuary mouth is also flanked by Great Knott and Black Scar; these sand banks and scars aid in attenuating wave energy, offering some protection to the shoreline either side of the estuary mouth (Halcrow, 2010b).

The northerly orientation and narrow nature of the estuary mouth means that significant wave energy does not enter the estuary (Wyre Borough Council, 2002) and waves will be attenuated as they move up the estuary, such that wave heights are likely to be greatest in the northerly orientated outer section extending from the mouth to the first meander near Thornton (Halcrow, 2010b).

In the estuary itself, sediment transport, of fine sand and coarse silt, is dominated by tidal currents, although waves may have some influence at the estuary margins, especially at the mouth of the estuary, and is concentrated in the main low water channel where water depths and flows are the greatest. The flood asymmetry promotes the import of sediment into the estuary from marine sources (Halcrow, 2010b).

Inglis and Kestner (1958) concluded that the channel migration in the lower Wyre Estuary seemed to display cyclical behaviour, where channel configuration and position was similar every 20 years (Halcrow, 2004). An example of this was observed in the Burn Naze reach adjacent to the sewerage and dock reclamations. This behaviour was evident in four reaches or ‘unstable meander loops’ from near Thornton, to the study boundary at Little Eccleston. The low water channels in the Wyre shift in position and control local patterns of accretion and erosion within the estuary. Changes in channel position have been observed mostly in winter months, which suggests that changes in channel configurations could be driven by a combination of high freshwater flows, spring tides and storm surges, which together lead to higher flow speeds. Meandering behaviour is thought to have kept the estuary volume relatively constant over time by initiating cycles of erosion and deposition (Halcrow, 2010b).

The port area near the former ferry berth was regularly dredged for navigation until 2010. Since that time there is anecdotal evidence of significant accretion in the outer estuary and the approach channel (Halcrow, 2012).

Sediment samples collected as part of the CERMS survey campaign 2009-10 are only available for three locations within the estuary, see Figure 3.4. These samples were taken from areas of muddy tidal flat and saltmarsh and are classified as sandy silts and slightly sandy silts (Pye *et al*., 2010).

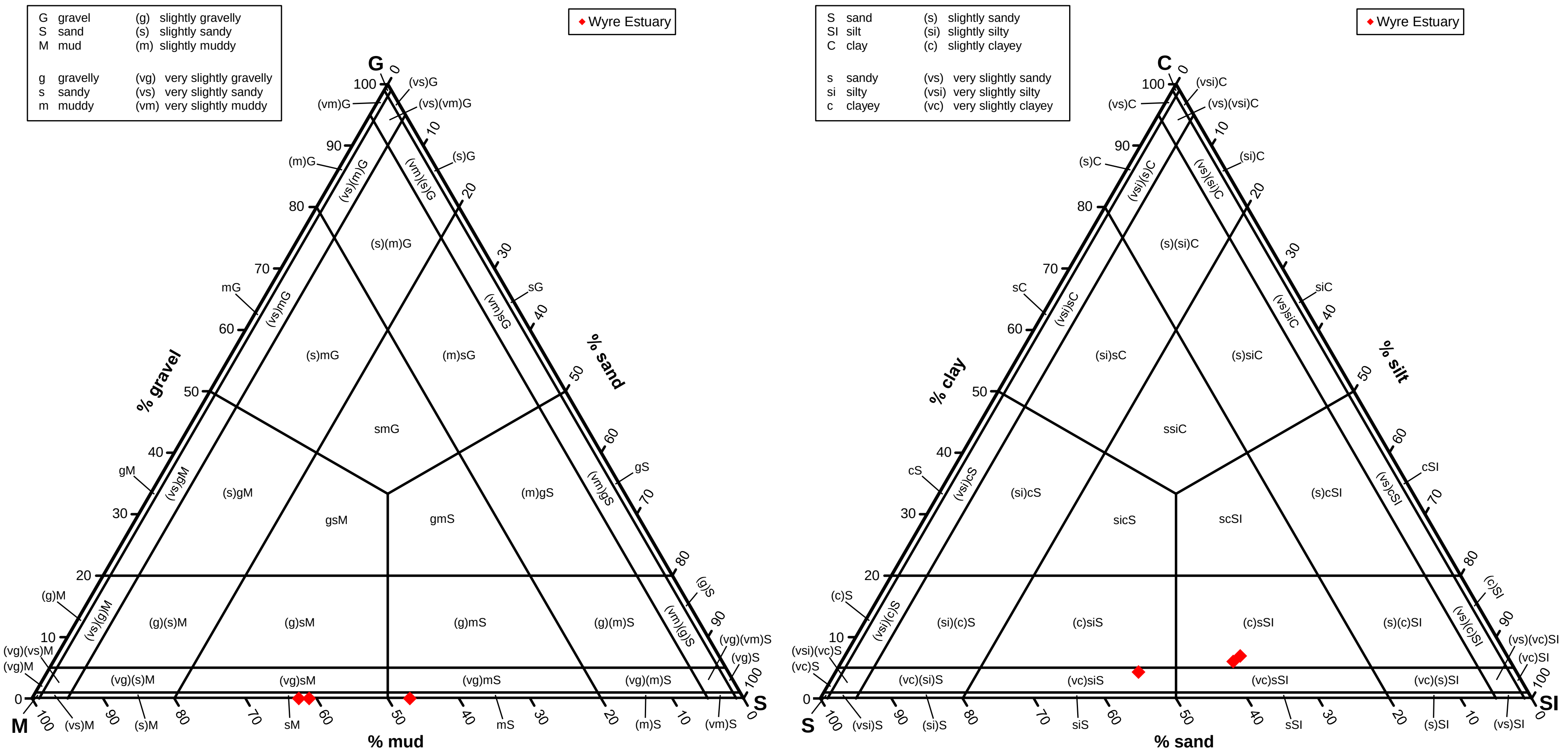

Figure 3.4 Gravel-Sand-Mud and Sand-Silt-Clay trigons, based on the classification of Blott & Pye (2012), for sediment samples collected within the Wyre Estuary in 2009-10 (data from Pye et al., 2010).

3.3 Past Changes

The Wyre Estuary lies within Morecambe Bay, which is a shallow open embayment created by the post-glacial submergence of a network of valleys over 10,000 years BP. The Wyre is likely to have been infilling since the last glaciation, but this slow rate of change is likely to have been accelerated by man-made modifications within the estuary. Previous analysis by Halcrow (2004) showed that the intertidal area of the estuary decreased by approximately 50% from around 1000ha in 1847-48, to around 500ha in 2000 (Halcrow, 2010b).

Developments within the estuary have included the construction of a railway embankment, various training works, jetties, capital maintenance and aggregate dredging. Many of these developments, including the commencement of flood embankment construction and the railway line, which was built along the estuary marshes, occurred in the early part of 19th century. Training works have been used in the Wyre since the mid-1800s to control the position of channels and influence the water depths at particular jetties. The lower reaches of the estuary were previously dredged to maintain access to the port (Wyre Borough Council, 2002), but regular dredging has ceased following closure of the Stena Ferry service in December 2010.

Previous analysis by Halcrow (2004) shows that the estuary underwent substantial reclamation from at least 1847. Significant changes occurred between 1847/8 and 1883-95 when there was extensive reclamation to the south of the Port of Fleetwood and reclamation behind the new railway line. Between 1883-95 and 1913 there was further reclamation south of the docks. From 1913 to 1955/6 there was relatively little change to the estuary; however, large changes subsequently occurred in the period from 1955/6 to 1986-94, when there was more reclamation behind the old railway line to the south of Fleetwood. Additionally, at this time Burrows Marsh seems to have accreted along the eastern side of the estuary (Halcrow, 2010b).

The decreases in estuary volume, due to reclamation and intertidal accretion, may have led to shallowing in the main channel (*c.f.* the Lune Estuary), although this has not been investigated in the Wyre. From 1847-48 to 2000, the area of the low water channel appears to have stayed relatively constant, although the position of the channel has varied, especially in the reaches of the estuary where meanders are free to migrate. Such reaches include: the middle and outer estuary between Hackensall Hall to Staynall; the middle estuary near Little Thornton; and the inner estuary between Liscoe and Waterside Farm (Halcrow, 2010b).

Recent studies show that the Wyre appears to be relatively stable in terms of the extent of mudflat and saltmarsh areas (Halcrow, 2007a). This would suggest a relative state of equilibrium, with the balance of localised erosion and deposition. This stability can be partially attributed to the presence of the training works. Where these have failed and secondary channels have formed, marsh edge erosion has increased (Halcrow, 2004).

There is anecdotal evidence of significant accretion in the outer estuary since maintenance dredging stopped at the end of 2010 (Halcrow, 2012). It has also been observed that there is an upper beach sediment pathway along the Fleetwood shoreline and into the mouth of the Wyre, with significant accumulation of sand around the RNLI berth area, causing problems for navigation

3.4 Future behaviour

Over the next 100 years there is likely to be some continuing littoral drift of sand past the Fleetwood frontage towards the mouth of the Wyre, derived mainly from further foreshore or sub-tidal lowering along the northern Fylde foreshore. However, the quantity from this source is likely to be small in relation to that transported from sources further offshore in southern Morecambe Bay. The Wyre itself will continue to supply small quantities of muddy sediment derived from its catchment, but the main source of continuing mud supply is likely to be the tidal waters of Morecambe Bay. Vertical accretion of saltmarshes is unlikely to be constrained by sediment supply, and changes in lateral extent are likely to be mostly dependent on possible fluctuations in low water channel position (Halcrow, 2010d). Following the cessation of dredging the main Wyre Channel is likely to become shallower, with possible implications for tidal propagation into the estuary.

3.5 Conceptual Model of Estuary Behaviour

A conceptual model for the Cell 11c area, showing regional sediment transport pathways, control features and sediment sources and stores is provided in Figure 3.5. A more detailed diagram has been developed for the Wyre Estuary in Figure 3.6.

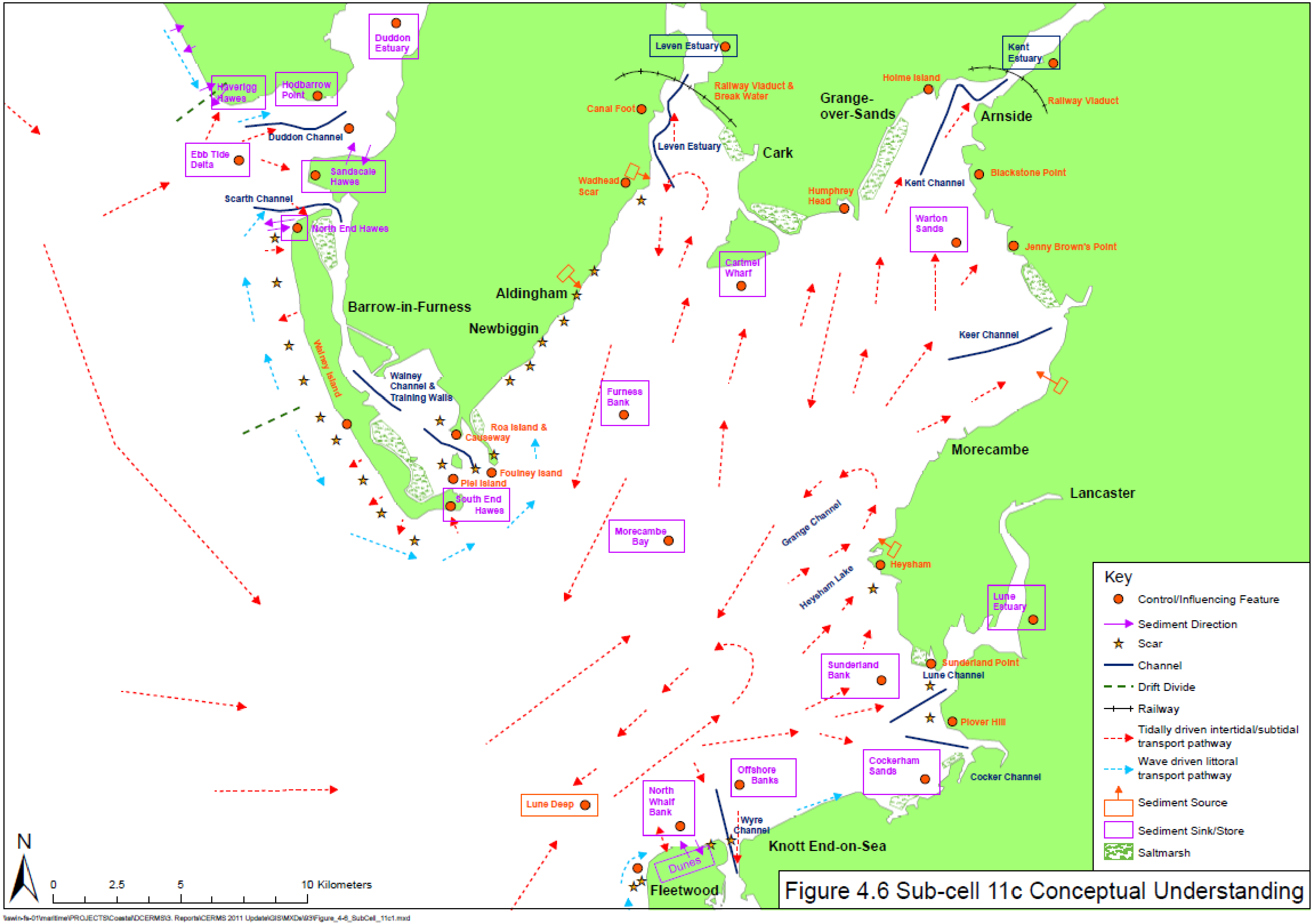

Figure 3.5 A simple conceptual model for Morecambe Bay and the Cell 11c area (source: Halcrow, 2010f)

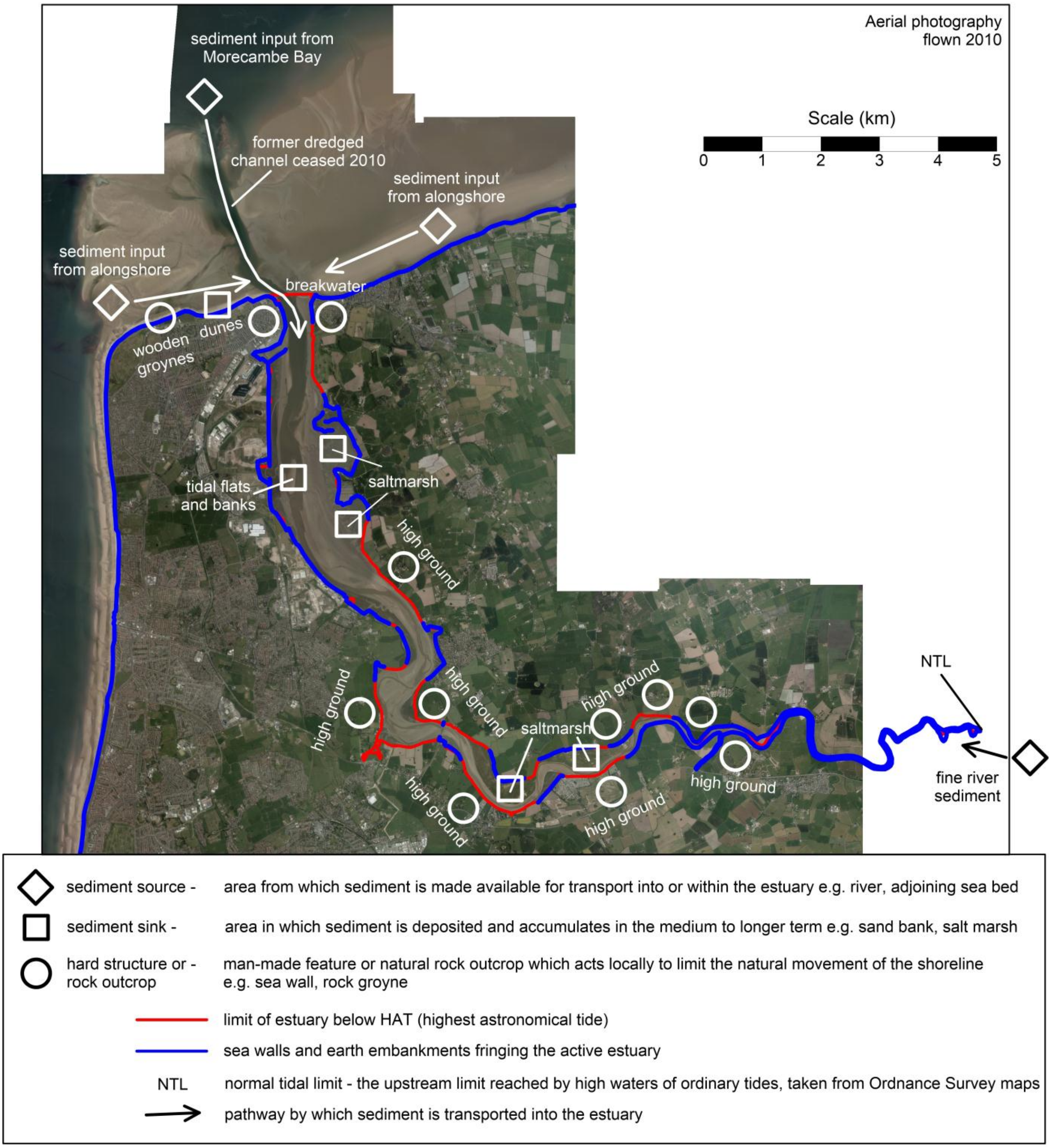

Figure 3.6 Conceptual diagram showing main sediment sources, geomorphological features and engineering structures which influence the morphology of the Wyre Estuary.

3.6 Coastal Defences and SMP policies

A list of the coastal defences in the Wyre Estuary from the SMP2 is provided in Appendix A (Halcrow, 2010a).

The vast areas of flood risk and development lying within areas surrounding the Wyre Estuary justify a long term plan to continue to provide protection throughout its outer reaches, although this will constrain natural development of the outer estuary. In the upper reaches of the estuary, however, the long term vision is to allow a more naturally functioning system and realignment opportunities will be pursued. These approaches will locally satisfy both social objectives for protection of land and property, and environmental objectives through providing additional intertidal habitats (Halcrow, 2010a).

At the mouth of the estuary, the long term plan is for the management of flood risks to the northern coast of Fleetwood and the large linked flood risk area which extends from the open coast into the estuary. Natural dune accretion along the present outer line of the promenade to the west of the Wyre may be sufficient to achieve this plan, and is a preferred approach because of the lower costs and greater environmental benefits. Should this trend reverse, a long term option might be to hold a secondary line at the road, allowing dunes to roll back but provide primary protection (Halcrow, 2010a). The adopted policies are shown on the maps in Figure 3.7.

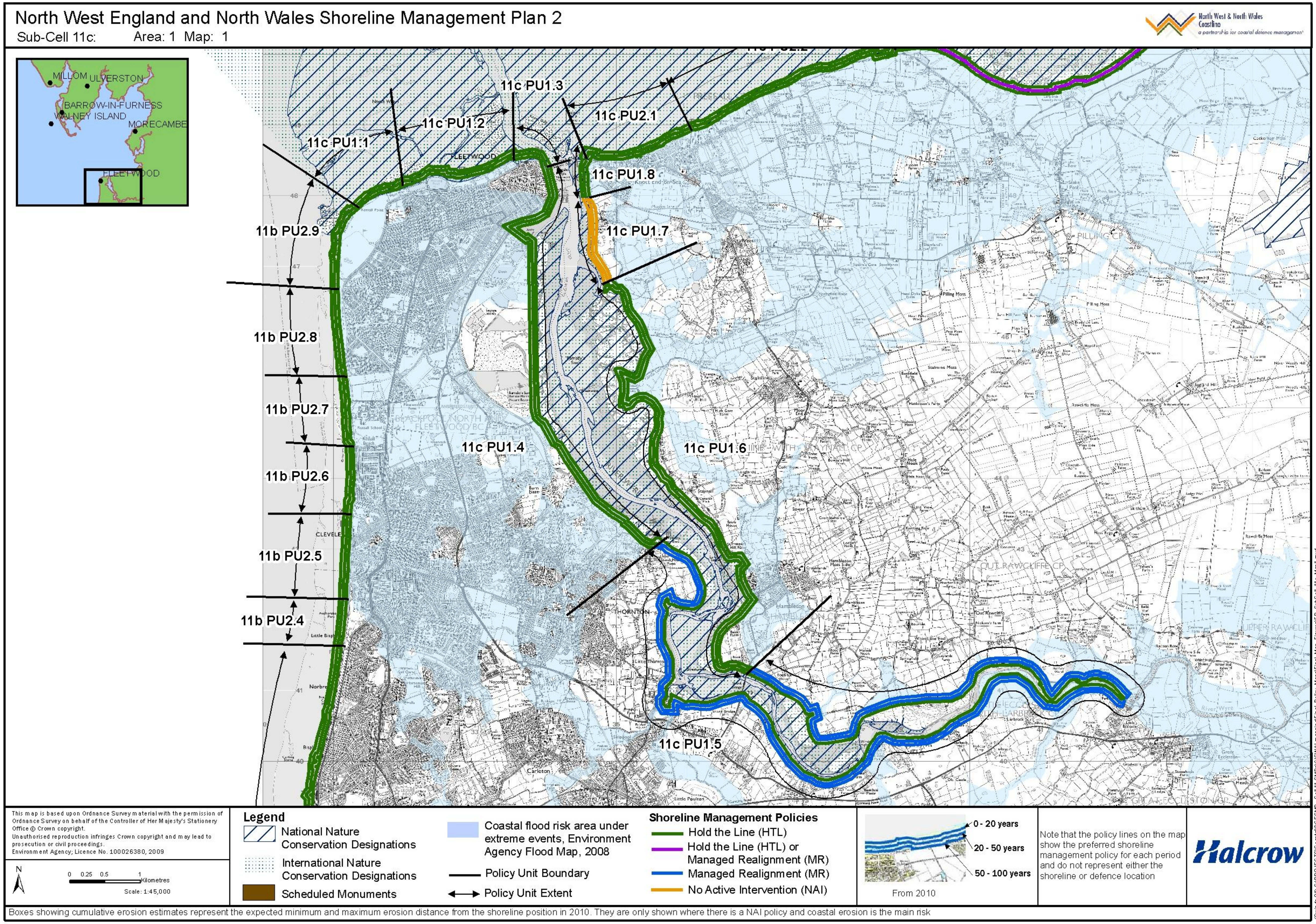

Figure 3.7 SMP2 Policy map for the Wyre Estuary (from Halcrow, 2010a).

3.7 Existing Monitoring Data

Details of the monitoring data being collected for the Wyre Estuary, and an assessment of the value that these data bring, is summarised in Table 3.1. The map in Figure 3.4 and Figure 3.5 shows the location of beach profiles and data collection stations that are stored within the SANDS coastal monitoring database system used by a number of Local Authorities within the Cell 11 region.

A bathymetric survey of the estuary was undertaken in 2007 as part of the Wyre Estuary Management Study (Halcrow, 2007b). LiDAR coverage is also available and a composite DEM of the estuary could be prepared using existing data. Further LiDAR data acquisition is scheduled as part of CERMS in the winter 2013/14.

Table 3.2 Existing monitoring data collected and value assessment.

Description of monitoring data collected	Assessment of value of data collection	Reference to further information
Tide gauge 1 (Fleetwood EA), located on the west bank at the mouth of the estuary. Operated by the Environment Agency (EA) as part of their water level monitoring and flood warning systems. Captures water level for high tides but dries out at around mid-tide level. Data is available from July 2003 to present.	Useful for monitoring long-term trends in water level (particularly extreme water levels) and use in hydrodynamic modelling.	CERMS Update Report, Section 2.4.2 (Halcrow, 2010e). CERMS Tide Gauge Review (Halcrow, 2010f). Environment Agency website.
Tide gauge 2 (Fleetwood Stena), located on the west bank at the mouth of the estuary. Owned by Stena Line, formerly ABP. Captures water level. Data is available from February 1988 to April 1998.	Useful for monitoring long-term trends in water level (particularly extreme water levels) and use in hydrodynamic modelling.	CERMS Update Report, Section 2.4.2 (Halcrow, 2010e). CERMS Tide Gauge Review (Halcrow, 2010f).
Tide gauge 3 - tide / river level gauge at St Michaels on Wyre, close to the tidal limit. Owned/maintained by Environment Agency NW. Digital data is available from 10/07/2003 to 03/07/2009.	Useful for monitoring long-term trends in water level (particularly extreme water levels) and use in hydrodynamic modelling, which can then be used for the purpose of flood forecasting.	Halcrow (2007). CERMS Tide Gauge Review (Halcrow, 2010f). Environment Agency website.

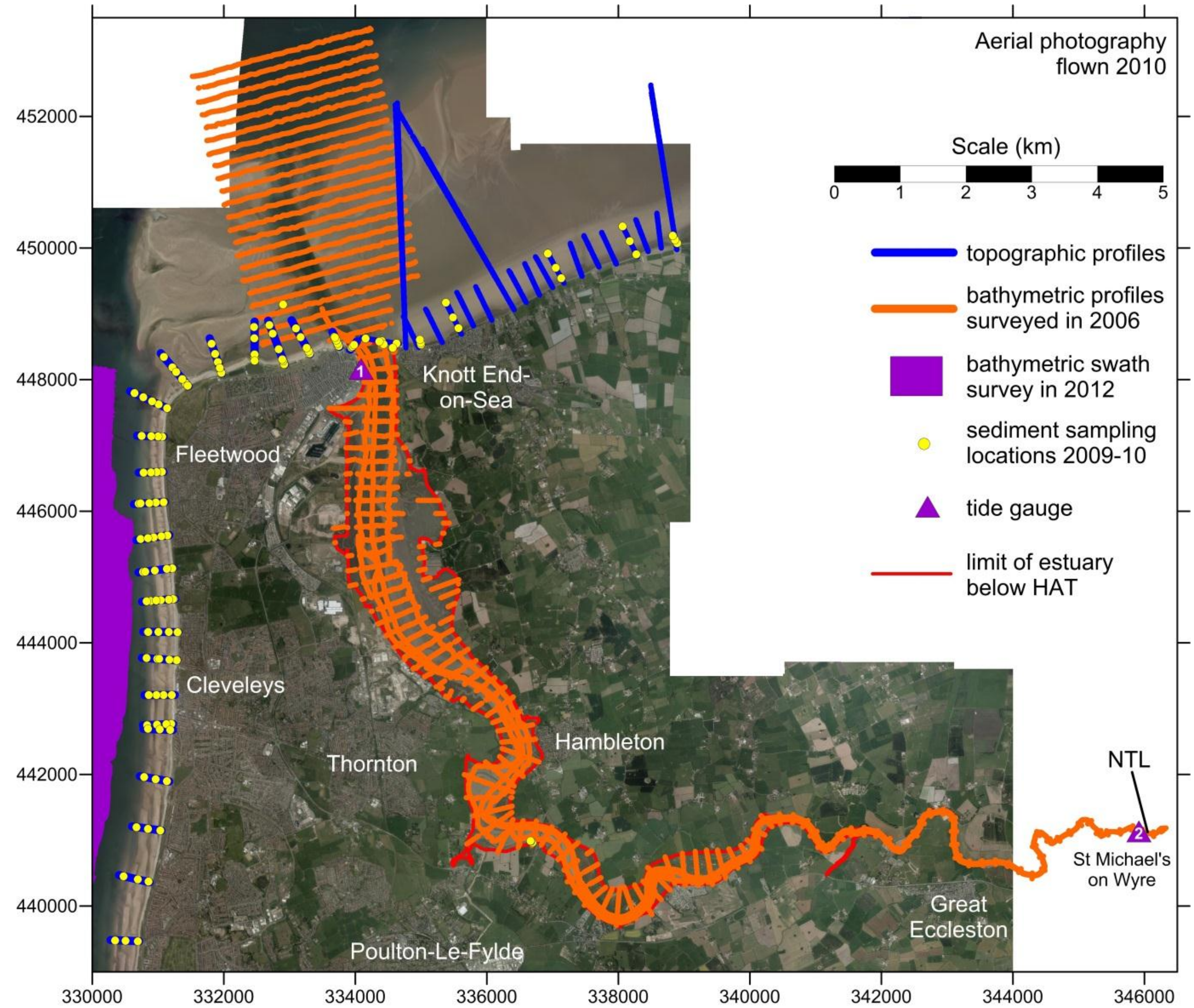

Figure 3.3 Summary of monitoring data available for the Wyre Estuary. Water level gauges located at (1) Fleetwood and (2) St Michael's on Wyre are both operated by the EA.

3.8 Gaps in Understanding

In Cell 11 a number of previous reports have been identified gaps in understanding, including issues and uncertainties related to coastal and estuarine processes and shoreline management. Some of the uncertainties identified in the earlier studies (e.g. SMP1, Futurecoast) were subsequently addressed by the later studies (e.g. CETaSS, SMP2, CERMS; EA, 2011). The CERMS regional baseline understanding report (Halcrow, 2010b) provided a full listing of previous uncertainties in the Cell 11 area.

For the present report we have reviewed the list of uncertainties previously identified for the Wyre Estuary and have identified the most important areas where future studies/monitoring are required (Table 3.3). We have organised these by thematic areas:

- Flood and coastal defences
- Habitat losses and creation
- Coastal and estuary morphodynamics
- Port developments

- Water quality
- Data collation

We have noted where these actions might be best undertaken by the CERMS group or by other parties.

Due to the strong linkages between coastal processes in the whole of Morecame Bay and the Wyre Estuary, the issues and recommendations listed below should be considered alongside the wider issues and generic recommendations for the other Cell 11 estuaries. This is considered within the main overarching report (CH2M Hill, 2013).

In the context of the other estuaries in Cell 11, the Wyre has been studied in more details and more recently than the others within Morecambe Bay and further north.

The generic gaps and recommendations considered in the accompanying overview report for the NW estuaries (CH2M Hill, 2013) should also be considered alongside those described below.

Table 3.3 Data gaps and recommendations

Issue	Location	Comments	Recommendations
Flood and coastal defences Defence condition, ownership condition and maintenance data require review.	Whole estuary	The defence data in Appendix A is taken from the SMP2 and was based on previous studies of the estuary and so is over 10 years old.	1. Update defence database to have a consistent data set prior to the next SMP review. Also needed to inform consultations with stakeholders regarding withdrawal from maintenance and adaptation in the upper estuary and to inform regional / national studies such as NaFRA. Continue to monitor and manage defences on HTL frontages. (See item 1 in Appendix B) **Urgency – low** **Importance – medium** **Difficulty – low** **Overall Priority - medium**
Flood and coastal defences Management of defences and delivery of SMP2 policies.	Policy Unit 11c 1.5 Both banks upstream of Shard bridge and left bank upstream of Stanah.	The SMP2 recommends undertaking a strategic adaptation study to assess and consult on the implications of withdrawing from areas of defences in the upper Wyre Estuary, including land drainage aspects and flood risks and access routes and rights of way and potential for BAP habitat creation to confirm the approach to SMP policy delivery.	2. The adaptation study will need to be supported by a coastal process study, based on and presenting the latest data, and providing revised estimates of losses and gains of habitats for potential management options (See item 2 in Appendix B) **Urgency – medium** **Importance – medium** **Difficulty – high** **Overall Priority - medium**
Habitat losses and creation Management of defences and delivery of SMP2 policies. - viability of managed realignment	Policy Unit 11c 1.6 Right bank from Shard Bridge to Golf course	Consider potential for managed realignment for habitat creation where continuation of localised defences are not viable.	3. Include options for MR in 11c1.6 in the modelling and analysis of adaptation in the upper estuary. (See item 2 in Appendix B) **Urgency – low** **Importance – low** **Difficulty – high** **Overall Priority – very low**
Coastal and estuary morphodynamics Bathymetric survey	Estuary and adjacent coast	Monitor morphological change in the estuary to inform management at both the policy unit and estuarine level. There was a hydrographic survey in 2006 (transects shown in Figure 3.3). Cessation of dredging has resulted in accretion which should be monitored. Dredging data held by ABP (Barrow) are available for analysis. Further sampling of intertidal and subtidal sediments is required.	4. Undertake detailed swath bathymetric survey to provide good baseline. Review against 2006 data before confirming future frequency of surveys. (See item 3 in Appendix B) **Urgency – medium** **Importance – medium** **Difficulty – medium** **Overall Priority - medium**

4 Discussion and Conclusions

Within the context of flood and coastal erosion risk management across the Cell 11 estuaries, the Wyre Estuary has a relatively high number of properties and land area at flood risk. The large number of properties at risk are located to the west of the estuary and so these properties are also at risk from flooding pathways from the adjacent open coast defences which are more exposed. Wyre Borough Council has a strategy in place for managing tidal flood risk in this area, but this only includes the west bank of the estuary seawards of Stanah.

The cessation of maintenance dredging to the port since the closure of the ferry terminal has resulted in significant accretion in the formerly dredged areas. The impacts on the wider estuary, if any, are unknown at present. Collection of new bathymetry data to monitor morphological change is therefore recommended. A new baseline swath bathymetry survey can be compared to the previous line bathymetry survey taken in 2006.

The recommended further studies build on recommendations in the SMP2 action plan. In the upper estuary the SMP2 found that there was likely to be insufficient justification for a business case to maintain and in future replace or improve the flood defences in the upper estuary. Recommendations 2 and 3 in Table 3.3 therefore prioritise studies recommended in the SMP2 to progress the SMP2 medium and long term policy of Managed Realignment.

A number of additional studies are recommended to address the gaps in understanding identified in Section 4 of this report. Details of the issue/ uncertainty, the source, nature and purpose of recommended studies, including their priority, are presented in Table 3.3. Further details on specific recommendations are given in Appendix B. These recommendations should also be considered alongside the generic recommendations made in the overview report (CH2M Hill, 2013).

5 References

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Appendix A
Coastal Defences in the Wyre Estuary

Appendix A Coastal Defences in the Wyre Estuary

This data has been sourced from the SMP2 (Halcrow, 2010b).

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Fleetwood West of Ferry Dock National Grid: (333870E 448530N) to (333980E 448420N)	Seawall built in 1920, groynes built in 1950.	Seawall with timber groynes which are all buried and natural sand dunes.	10-15	Sandy lower shore with shingle upper shore, beach ridge and sand dunes.	Wyre flood and coastal defence strategy study 2002. Residual life reduced to estimate present day value.
Fleetwood Ferry Slip to Fleetwood Dock National Grid: (333980E 448420N) to (334000E 448390N)	N/A	No defences	N/A	Sandy foreshore	Wyre Estuary SMP 2002
Fleetwood Ferry to Ro-Ro Footbridge National Grid: (334000E 448390N) to (334140E 447950N)	Unknown	Revetment	5-25	Sandy foreshore	Wyre flood and coastal defence strategy study 2002. Residual life reduced to estimate present day value.
Fleetwood Jubilee Dock and Quay National Grid: (334140E 447950N) to (333780E 447440N)	Unknown	Quayside structures and revetments	5-20	Silt and mud foreshore with some saltmarsh growth.	Wyre flood and coastal defence strategy study 2002. Residual life reduced to estimate present day value.

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Fleetwood Power Station to Stanah National Grid: (335450E 443120N) to (333800E 447400N)	Unknown	Earth embankment supplemented by rubble or masonry in sections. Some sections are in poor condition requiring maintenance.	<10	Saltmarsh and mudflats	Wyre flood and coastal defence strategy study 2002. Residual life reduced to estimate present day value.
Stanah Clough to SE Silcock's Cottages National Grid: (335400E 443100N) to (336100E 442200N)	N/A	No defences	N/A	Saltmarsh and mudflats	Wyre Estuary SMP 2002
Skippool Marsh National Grid: (335700E 442100N) to (336100E 442200N)	Unknown	Earth embankment	<10	Saltmarsh and mudflats	Wyre flood and coastal defence strategy study 2002. Residual life reduced to estimate present day value.
Waderbank Thornton National Grid: (335700E 442100N) to (336100E 442200N)	Unknown	Earth embankment	10-25	Saltmarsh	Wyre flood and coastal defence strategy study 2002.
SE Silcock's Cottages to Tatham House Yacht Club National Grid: (335800E 442100N) to (335800E 441200N)	N/A	No defences	N/A	Saltmarsh	Wyre Estuary SMP 2002

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Skippool Marsh to Bankfield Farm National Grid: (335800E 441000N) to (338400E 439900N)	N/A	No defences	N/A	Saltmarsh	Wyre Estuary SMP 2002
Bankfield to Windy Harbour National Grid: (338900E 440200N) to (338500E 439800N)	Unknown	Earth embankment	>20	Saltmarsh	Wyre flood and coastal defence strategy study 2002. Residual life from NFCDD data 2008.
Windy Harbour Holiday Centre National Grid: (338800E 440300N) to (340100E 440700N)	N/A	No defences	N/A	Saltmarsh	Wyre flood and coastal defence strategy study 2002.
Cartford Bridge to Larbeck National Grid: (342000E 441000N) to (340200E 440900N)	Unknown	Earth embankment	20-25	Saltmarsh	Wyre flood and coastal defence strategy study 2002. Minimum residual life not changed.
S of Richford House, Town End to Waterside Farm National Grid: (340700E 441300N) to (333400E 440800N)	N/A	No defences	N/A	Saltmarsh	Wyre Estuary SMP 2002

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Waterside Farm to Liscoe National Grid: (339500E 440900N) to (338500E 440600N)	Constructed 1970	Earth embankment	>20	Saltmarsh	Wyre Estuary SMP 2002. Residual life from NFCDD data 2008.
Moors Farm to Liscoe National Grid: (337636E 440785N) to (338496E 440632N)	Unknown	Earth embankment protected by concrete slabs on front side. Some slumping by outfall.	>20	Saltmarsh	NFCDD 2008 and Wyre Estuary Habitat Management Study TN.
SW of Moors Farm to N of Point Shard National Grid: (337600E 440700N) to (336300E 441600N)	N/A	No defences	N/A	Saltmarsh	Wyre Estuary SMP 2002
Wardleys to Bank Farm National Grid: (336500E 442800N) to (336300E 441700N)	Constructed 1970-1977	Earth embankment supplemented by membrane wall for 250m.	20-50	Saltmarsh	Wyre Estuary SMP 2002. Residual life reduced to estimate present day value.
Wardleys Pool to Burrows Marsh National Grid: (336500E 442800N) to (335500E 444700N)	N/A	No defences	N/A	Saltmarsh	Wyre Estuary SMP 2002

Location	Defence History	Present Defences	Residual Life – (Do Nothing Scenario) Years	Natural Features	Source and Assumptions
Arm Hill to Burrows Marsh National Grid: (334800E 446800N) to (335500E 444800N)	Constructed 1960	Earth embankment supplemented by gabions and stone revetment for 100m.	5-15	Saltmarsh	Wyre Estuary SMP 2002. Residual life reduced to estimate present day value.
Hackensall Sewage Works National Grid: (334800E 446800N) to (334600E 448000N)	N/A	No defences	N/A	Saltmarsh	Wyre Estuary SMP 2002
Knott End Ferry to Spring Bank National Grid: (334600E 447900N) to (334600E 448500N)	Constructed 1960	Membrane embankment	5-15	Saltmarsh	Wyre Estuary SMP 2002. Residual life reduced to estimate present day value.
Knott End Ferry Slipway National Grid: (334633E 448512N) to (334670E 448565N)	Defences date from early 20th century. Refurbished in 1950,1979 and 1991.	Sloped concrete revetment backed by vertical wall. Cracks in wall.	>20	Estuarine mudflat	NFCDD 2007.

Appendix B
Recommendations for further studies

Appendix B Recommended further studies for the Wyre Estuary

Recommended study (See Table 3.3)	Outline scope	Outline cost estimate and priority
1. Update of flood and coastal defence database.	Study assumed to be EA led, but could be led by Wyre BC or Sefton. Review data in Appendix A against latest held by EA on their Asset Information Management System (AIMS) or the LLFA in their FWMA S21 register to check for any updates to information available through the SMP2. Compile latest data and undertake initial review using latest aerial photography from coastal group. Undertake walkover inspections selected visits including photographs of each defence length and significant defects. Update database.	Estimated cost £10 to £15k, if packaged with other similar work on other defences. Priority – rated as medium in Table 3.3, but needed to feed into adaptation study before next SMP review.
2. Coastal process study to inform upper estuary adaptation study (PU 11c1.5	Study assumed to be led by EA or Wyre BC or Sefton. [Assume that this study runs in parallel with and supports (or is part of) the upper estuary adaptation study recommended in the SMP2.] Review the previous MR and habitat creation studies undertaken in 2007/8. Take into account latest defence condition data if collected under 1 above, alternatively inspect defences for this specific area. Update morphological change analysis using LiDAR and photography since 2008. Update model previously developed for EA by Halcrow with latest LiDAR and bathymetry data and link to fluvial model developed by EdenVale for EA upstream of Cartford Bridge. Review combined fluvial and tidal flood risk in upper estuary. Undertake modelling of impacts of potential adaptation options in PU 11c1.5 and 11c1.6 (defined by others through consultation with stakeholders in the overall adaptation study). Obtain and review dredging data and review changes identified since cessation of maintenance dredging and implications for future change in the estuary, including an assessment of impacts on siltation generally in the estuary and in particular upstream of Cartford Bridge where there . Include modelling of sensitivity tests for potential future changes to the estuary mouth and approach channel. Develop quantitative estimate of losses and gains of habitats due to sea level rise and coastal squeeze, taking account of adaptation / MR options. Prepare a coastal and estuary processes report that documents the findings and can support consultation with stakeholders and development of a HRA for adaptation strategy.	At risk land areas are smaller than in some of the other estuaries hence relative priority is low to medium. Estimated cost - £50k to £80k.
3. LiDAR and bathymetric surveys.	Undertake detailed swath bathymetry survey and concurrent LiDAR survey to provide seamless baseline data set of estuary, intertidal zone and adjacent land. Ensure overlap between LiDAR and bathymetry data and that the survey periods	Estimated cost - £80k Priority – low to medium

Recommended study (See Table 3.3)	Outline scope	Outline cost estimate and priority
	are close enough together to give consistency. Review the survey against 2006 data and identify areas of erosion and accretion. Establish recommendations for future frequency of surveys, both overall and for erosion / accretion hot-spots.	