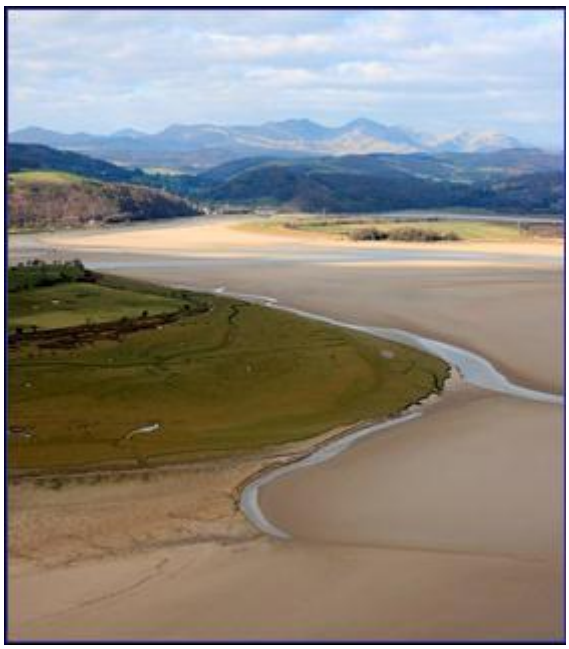
North West Estuaries Processes Reports



Overview Report

Prepared for
Sefton Council

December 2013

CH2MHILL
Halcrow
22 Lendal
York
YO1 8AA
GB
+44 (0) 1904 559 900

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 knowledge and issues in estuaries of north west England
Format	Text
Identifier	V3.1 Dec 2013
Keyword	Estuary, Strategic, Coastal, Processes
Language	English
Location	North West Estuaries
Mandate	CERMS Regional Monitoring Framework
Publisher	Sefton Council
Relation	Overview report, refers to individual estuary reports
Status	Final
Subject	Coastal and estuarine processes
Title	North West Estuaries Processes Reports – Overall Report
Type	Text/report
Date of metadata update	19 December 2013

Document History

North West Estuaries Processes Report

Overall Report

Sefton Council

This document has been issued and amended as follows:

version	Date	Description	Created By	Verified By	Approved By
1	22nd August 2013	1st draft for internal review	A Parsons	N Pontee	N/A
2	29th August 2013	Updated draft for issue for client comments	A Parsons, K Pye, N Pontee	N Pontee	A Parsons
3	11th November 2013	Final version	A Parsons	K Pye	A Parsons
3.1	19th Dec 2013	Minor edits / amendments following internal review	A Parsons	A Parsons	A Parsons

Halcrow Group Limited is a CH2M HILL company

Halcrow Group Limited has prepared this report in accordance with the instructions of client Sefton Council for the client's sole and specific use.

Any other persons who use any information contained herein do so at their own risk.

Contents

Tables

Figures

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.
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.

Term	Definition
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.
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).

Term	Definition
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.
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.

Term	Definition
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.
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.

Term	Definition
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 regional coastal monitoring programme for North West England commenced in 2004 and has primarily focussed on the collection and analysis of data for the open coast, with a more limited amount of data collection in estuaries. The design of the programme is based upon the Cell Eleven Regional Monitoring Strategy (CERMS), which was developed in 2004 and last reviewed in 2009. CERMS prioritised requirements for coastal monitoring based on understanding of Flood and Coastal Erosion Risk Management (FECRM) needs from the first round Shoreline Management Plans (SMPs) developed in the 1990s, which did not fully include estuaries. The second round SMP2 completed in 2010 includes all of the estuaries and has a significant number of items in the action plan that will require monitoring data for implementation. Sefton Council therefore commissioned a review of the current status of coastal process knowledge and monitoring requirements for the nine estuaries of North West England in order to inform future monitoring and coastal and estuary process studies.

This overview report is accompanied by separate reports for each of the following estuaries: Dee, Mersey, Ribble, Wyre, Lune, Kent, Leven, Duddon and the Ravenglass Estuary complex.

Flood and coastal defences in the estuaries of North West England are important to flood risk management at a regional and national scale. The SMP2 estimated that around 120,000 properties were at long term risk of flood and erosion risk across the whole SMP2 area (Great Orme's Head in North Wales to Scottish border in the Solway Firth) and more than half of these are located in the estuaries. There is also important infrastructure and industry located in the estuary flood plains, particularly those around the Dee and Mersey.

The Wyre estuary has the highest number of residential properties at risk (29,600), although they are also at risk from sea flooding from the open coast. The Ribble (12,200) and Lune (8,800) are second and third, closely followed by the Dee (5,500) and Mersey (3,000). The four smaller estuaries located to the north of Cell 11 have much lower risks, with just 1,300 properties between them.

The Dee, Mersey and Ribble are the three largest estuaries and there are strong coastal processes linkages between these three estuaries and Liverpool Bay. The Wyre, Lune, Kent and Leven are smaller estuaries located around Morecambe Bay, again each with strong coastal process linkages to the Bay. Monitoring of the estuaries and the adjacent coast and bays needs to be coordinated due to the strong linkages.

The SMP2 and supporting studies confirmed that the Cell 11 estuaries have historically had positive sediment budgets with sediment supplied mostly from offshore. This is expected to continue in future, with modelling studies indicating potential for increased supply with rising sea levels. Understanding how future sediment budgets may respond to future sea level rise and shoreline management changes such as managed realignment or withdrawal of maintenance of defences is important in all of the estuaries. However, in most of the estuaries there is limited field data available to calibrate or verify the modelling and in many cases there is inadequate bathymetry data.

The CERMS risk ratings and relative priorities for monitoring in the nine estuaries have been reviewed and compared. The Dee, Mersey, Ribble, Wyre and Lune are considered to be Medium Risk, while the Kent, Leven, Duddon and Ravenglass are Low Risk. Ordered with highest first, the priority ranking for monitoring studies, based on existing understanding and flood risk, is as follows: Ribble, Mersey, Dee, Lune, Wyre, Leven, Kent, Duddon and Ravenglass.

Preliminary conceptual understanding diagrams for each estuary, originally developed for the SMP2, have been reviewed and updated. The diagrams and some key statistics have been collated together in this report, with more details given in the individual estuary reports.

Recommendations for generic studies and data collection common to all estuaries are included in this report, whilst specific recommendations are given in the individual estuary reports.

1 Introduction and background

1.1 Background

The regional coastal monitoring strategy for the north west coast, which has become known as the Cell Eleven Regional Monitoring Strategy (CERMS) was developed between 2002 and 2004 and commenced operation in 2005 (CEUK, 2009). The programme has 12 partners across the North West England Region, with the work being coordinated by Sefton Council. The programme is funded by the Environment Agency and provides a coordinated monitoring system for the collection and analysis of coastal data. The data that is gathered will inform sustainable coastal defence management both on the open coast and within the major estuaries of North West England. The overall programme of data collection is 'risk based' in that it focuses on those areas where it will have most benefit to flood and coastal defence issues.

At the time of the first review of the programme (CEUK, 2009) data collection work had been largely limited to the open coast. Within estuaries, collation of existing and ongoing coastal process monitoring data was underway. Estuary monitoring that was underway included: tide gauge data, and collection of nearshore beach profiles and bathymetric surveys in or near to the mouths of some of the estuaries. The initial 5 year plan anticipated commencing a programme of detailed bathymetry surveys in the estuaries with higher flood and erosion risks during 2008-2011.

Since development of the original programme of work under CERMS the Shoreline Management Plan review (SMP2) has been completed (Halcrow, 2010a). The SMP2 included review of coastal risks, development and setting of policies for shoreline management, identification of data gaps and uncertainties and an action plan. The SMP2 included both the open coast and the tidal estuaries.

In support of the SMP2, CERMS and other initiatives there have been a number of studies and / or data collection activities that contribute towards knowledge of coastal and estuarine processes and have dealt with some of the previously identified uncertainties for shoreline management. The partner authorities therefore collectively agreed a need to undertake a review of existing knowledge and data gaps for the major estuaries within the region, excluding the Solway. The purpose of this review was to identifying priorities for future monitoring and coastal processes studies in estuaries throughout Cell 11. Figure 1.1 shows the location of the estuaries included within this review.

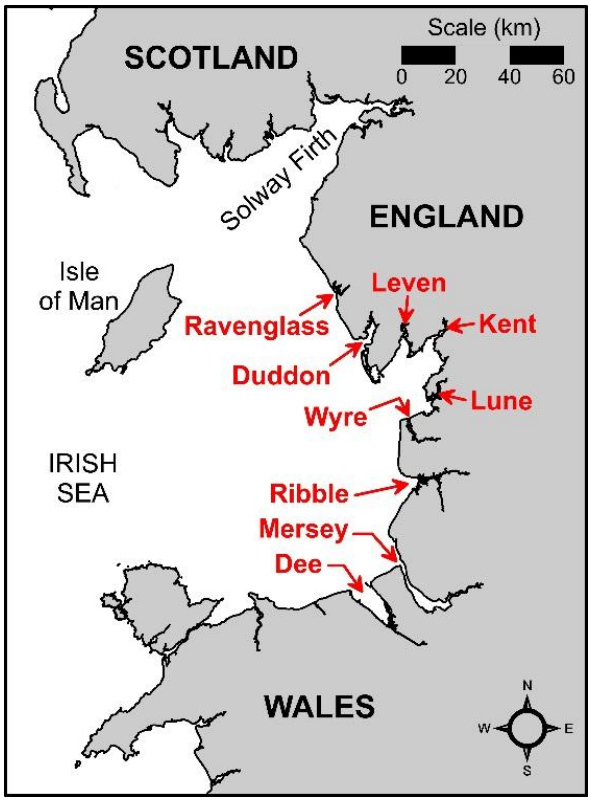


Figure 1.1 North West Estuaries included in the review

Separate reports have been produced for each estuary. The individual estuary reports summarise the existing understanding of the each estuary, drawing on information from the second round SMP, the Cell Eleven Tidal and Sediment Transport Study (CETaSS) and other more recent studies. They provide 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.

The present report summarises information from the estuary reviews, provides additional comparative information on the relative risks and also provides a prioritised list of generic recommendations across all estuaries where there are consistent requirements across the region.

1.2 Importance of North West Estuaries

The flood and coastal defences within the major estuaries of the North West are important to flood risk management at a regional and national scale. In the Shoreline Management Plan (SMP2), (Halcrow, 2010a) it was estimated that around 120,000 properties were at long term risk of coastal flood and erosion risk across the whole SMP2 area (Great Orme's Head in North Wales to Scottish border in the Solway Firth). More than half of these are located in the estuaries considered in this review (Table 2.2). In many of the estuaries there is also extensive industry and regionally and nationally important infrastructure located on the tidal flood plain, including ports, power generation, manufacturing, petro-chemicals, waste water treatment and major road and rail linkages. Provision of sustainable flood defence in the estuaries is therefore highly important to the social and economic prosperity of the region.

In addition to the economic and social importance of the estuaries for the development in the hinterland the estuaries are of national and international significance for the habitats and species that they support. All of the North West Estuaries contain are areas designated as Sites of Special Scientific Interest (SSSI), Special Protection Areas (SPA), and Special Areas of Conservation (SAC). Most are also Ramsar Sites.

1.3 Contents of this report

The present study has reviewed the baseline coastal process understanding of the estuaries and the more recent studies and has prepared a review report for each estuary (see Section 2.1). This report should therefore be read in conjunction with the more detailed individual reports that have been prepared for each of the nine estuaries that have been reviewed (CH2M HILL, 2013a to i).

This overview report is divided into the following sections:

- Section 1: Introduction and background (this section);
- Section 2: Summarises the estuary reviews; first summary characteristics of the estuaries are compared and priorities for future data collection and studies are discussed. It also includes a review of the existing risk ratings under the regional monitoring strategy. This is followed by conceptual diagrams for each estuary.
- Section 3: Provides a prioritised list of generic recommendations across all estuaries where there are consistent requirements across the region; and
- Section 4: Conclusions

2 Estuary review summary

2.1 Summary characteristics and interactions

Selected key characteristics of the North West estuaries included in this review have been compiled in Table 2.1 below.

Table 2.1 Key characteristics for estuaries considered

Estuary	Length (km) (Halcrow, 2010b)	Surface area[1] (ha) (Halcrow, 2010b)	Saltmarsh extent (EA, 2011)
Dee	37	12743	2571
Mersey	47	8808	896
Ribble	26	6772	2383
Wyre	22	934	332
Lune	14	1084	396
Kent[2]	12	1017	1050
Leven	13	2062	417
Duddon	16	3950	623
Ravenglass	9	526	164

Notes: 1: Surface area derived from LiDAR data at Highest Astronomical Tide level
2: Estuary extents used in the two studies differ

2.1.1 Liverpool Bay estuaries

The Dee, Mersey and Ribble are significantly larger, in terms of length and area, than the other estuaries located further north. These three larger estuaries also have the most heavily developed flood plains (see below).

Previous studies (e.g. Futurecoast, Halcrow, 2002) have found that there are strong coastal process linkages between these three major estuaries surrounding Liverpool Bay and that coastal processes in each should not be considered in isolation.

2.1.2 Morecambe Bay estuaries

The four estuaries that drain into Morecambe Bay – the Wyre, Lune, Kent and Leven all have low water channels that extend across Morecambe Bay. Previous national studies within the Defra and Environment Agency Estuaries Research programme (e.g. http://www.estuary-guide.net/estuaries_research.asp) considered these as part of an overall Morecambe Bay 'estuary'. There are strong coastal process links between the estuaries and the wider Bay and the moving low water channels also influence flood and erosion risks around the Bay itself. For this reason it is recommended that issues related to coastal processes, data collection and analysis in the wider Morecambe Bay needs to be considered alongside the issues in the estuaries.

2.2 Flood risks surrounding NW estuaries

The SMP2 appendices (Halcrow, 2010a) provide summary details of properties and land that would be at risk of flooding and / or erosion in each of the estuaries under a No Active Intervention (do nothing) policy option. This was used as a theoretical baseline scenario to identify the benefits of other 'do something' options for shoreline management rather than a policy that would be considered feasible at all locations. The data from this assessment in the SMP2 has been used to compile the estuary comparison presented in Table 2.2. The data presented from the SMP2 are based on tidal flood plain mapping and property data from 2008 and it should be noted that a number of studies that have locally ground truthed the National Receptor Database (NRD) data that was used in the SMP2 found that property counts tend to be slightly underestimated.

Table 2.2 Assets at FCERM risk in the NW estuaries

Estuary	Residential Properties	Non-residential properties	Agricultural Land (Ha)
Dee	5,500	1,700	3,700
Mersey	3,000	400	1,000
Ribble	12,200	700	10,300
Wyre	29,600	1,900	4,100
Lune	8,800	1,000	1,800
Kent	100	-	3,600
Leven	300	100	1,700
Duddon	800	-	1,200
Ravenglass	100	-	500
Total	60,400	5,800	27,900

Source: SMP2 (Halcrow, 2010a)

The data in Table 3.2 show that the Ribble has most agricultural land and the second highest number of residential properties at risk. The large numbers of properties identified in the Wyre are located in the large flood cell around Fleetwood that is also at risk from direct tidal flooding from the open coast between Fleetwood and Cleveleys. The more northerly estuaries of the Kent, Leven, Duddon and Ravenglass are smaller and relatively low risk in terms of numbers of properties in the flood plain as together they represent only about 2% of the overall properties at risk in the estuaries.

2.3 Sensitivity to climate change and changes in management policy

Historically the Cell 11 estuaries have shown positive sediment budgets with accretion believed to have been supplied mainly from offshore sources, with additional material being supplied by eroding cliffs (Halcrow, 2010c). This is expected to continue over the next 100 years even with sea level rise with numerical modelling showing a general tendency for increase import of material under rising sea levels (Halcrow, 2010c).

An initial analysis of existing estuary datasets suggested that shallow estuaries with mean depths of less than 5m are likely to be highly sensitive to sea level rise (Halcrow, 2010b). This covers the majority of the Cell 11 estuaries with the exceptions of the Dee, Mersey and Solway. However, this analysis makes no allowance for the possibility that 'average' bed levels will keep pace with rising sea level due to continued landward movement and import of sediment. Despite its deeper mean depth, the more detailed assessment for the

Mersey (CH2M HILL 2013b) notes that previous major changes to the morphology have principally related to dredging and training wall construction – in the future significant management actions are likely to be an important influence on morphological change, but if the hydraulic regime stays the same in future changes due to climate change may become more important.

The most likely future management changes in the majority of estuaries are likely to be the adoption of managed realignment (MR) schemes or the withdrawal from maintenance of defences under a No Active Intervention (NAI) policy. The Dee, Mersey, Ribble and Duddon all have significant potential for managed realignment. To the south of Cell 11, managed realignment sites within estuaries tend to be lower in the tidal frame. The implication is that substantial managed realignment in the inner parts of estuaries could increase flow speeds and erosion in outer parts of these estuaries. The potential for greatest relative sea level rise is also greatest in the more southern estuaries due to the ongoing land level changes. In the north of Cell 11, the estuaries in Morecambe Bay and Cumbria have potential managed realignment sites which are generally higher in the tidal frame. This suggests that the hydrodynamic impacts of these realignments are likely to be relatively small.

2.4 Review of existing risk ratings

The NW (Cell Eleven) Regional Monitoring Strategy originally used a system of risk ratings for the coastal and estuary frontages in order to prioritise the monitoring to be undertaken. For example on the open coast the risk rating assessments were used to specify the local frequency of beach profiles. The data for the existing risk assessments in the estuaries were made available by Sefton Council for review. The data set appears to have been last updated in 2010. The risk ratings use a score from 1 (lowest) to 10 (highest) to rate the exposure due to waves, tides, the defence type and the consequence of failure to derive a risk factor score, which is then ranked as high, medium or low.

It is noted that the original risk based assessment of monitoring requirements was undertaken prior to the last review of the shoreline management plan and so the sub-division of the shoreline into frontages differs from the policy units that have been established in the SMP2.

In order to review the existing ratings the GIS data supplied was loaded into SANDS for viewing alongside SMP2 policy mapping, and the latest flood mapping including areas benefiting from defences, as supplied by Environment Agency, North West for this project in April 2013. Commentary on the review is provided in Table 2.3 below.

In general it should be noted that the specification of monitoring requirements in the estuaries needs to take into consideration the linkages between individual frontages and the overall estuary processes. Large scale change in defence policy such as managed realignment can have significant impacts on tidal volumes and flows in the estuary downstream and this can impact on the whole estuary systems. Most of the NW estuaries are heavily designated for their environmental importance and environmental impact assessments for flood and coastal defence schemes are likely to need to assess impacts on the whole site. Estuary models generally require consistent data sets through the whole estuary to set up models and analyse changes. Impacts of sea level rise could also have implications to flood risk through whole estuary systems, for example modelling of impacts of mean sea level rise in the Ribble (Halcrow, 2010d) found that in the absence of morphological feedback extreme sea levels would increase more in the inner estuary than the change in mean sea level alone due to impacts on the amplification of the tide. So, although it is accepted that greater data collection should be warranted in locations where there are high numbers of assets at risk and that more exposed defences mean that flood defence schemes are likely to be required to manage changing risks, the approach used on the open coast to specify monitoring requirements may not be fully applicable in estuaries. The same applies to Morecambe Bay, where coastal flooding and erosion risks are strongly influenced by channel migration; changes in these channels could be influenced by large scale changes to defence policy in the estuaries, for example if the tidal volume is significantly changed by managed realignment of defences.

The review of risk ratings in relation to the overall coastal monitoring strategy presented in Table 2.3 should be considered alongside the prioritisation between the nine estuaries considered in this review in Section 3.5 below.

Table 2.3 Review of existing risk ratings for NW estuaries

Estuary	2010 Risk Ratings	2013 Risk Review
Dee	Generally = Medium, apart from Mostyn to Greenfield = Low and Sealand Rifle Range to Neston = Low	The previous risk ratings do not include the inner Dee estuary landward of the Hawarden bridge. The SMP2 extends landwards to Chester Weir. In the canalised inner Dee the SMP2 policy is HTL, but recommends consideration of localised MR and habitat creation through regulated tidal exchange to mitigate potential long term impacts of defences on designated sites and provide flood storage. The two frontages rated as low include Policy Units with proposed MR policies in the future. Due to the need to consider the whole estuary strategically it is recommended that the overall rating for the whole of the Dee Estuary is revised to Medium Risk. **Overall risk = Medium**
Mersey	Seaforth Dock = Medium Perch Rock to Seacombe Ferry = Medium Rest of estuary not rated.	Almost all of the Mersey was excluded from the previous risk ratings. Much of the surrounding land is relatively high and so not at tidal flood risk; the large flood risk area around Stanlow and Frodsham is protected from tidal flooding by the Manchester Ship Canal. In the upper estuary, landward of Runcorn-Widnes bridge the SMP2 proposes significant lengths of MR in the medium and long term. Elsewhere the policy is mainly HTL, apart from the north shore between Garston Industrial estate and Hale Bank where the policy is NAI. As much of the inner Mersey is a SSSI, SPA and Ramsar site there is a need to consider the long term impacts of all the defences and sea level rise on the environmental sites. Much of the inner estuary, where there is a long term MR policy is potentially affected by contaminated land. Therefore it is recommended that the Mersey Estuary is fully included in the overall monitoring strategy with an overall risk rating of Medium. **Overall risk = Medium**
Ribble	St Annes from northern boundary to Pier = High St Annes Pier to former Land registry = Medium Land Registry to Penwortham bridge = Low Penwortham Bridge to Hesketh Out marsh (inc tidal river Douglas) = Low Hesketh to Weld Road Southport = Medium	The SMP2 policy for the north bank is HTL apart from a short length of possible MR around Freckleton marsh and NAI for the relatively high ground from Warton Bank to Naze Point. However, there are large areas with MR recommended in the medium and / or long term on the south bank inland of Crossens, including the Douglas. The High risk frontage is agreed as this is essentially the west facing open coast. Due to the large scale potential for future management change, the high environmental importance and the large numbers of properties and land in the tidal risk zone it is recommended that the whole of the Ribble Estuary (St Annes to tidal limit to Southport) is revised to a Medium. **Overall risk = Medium**
Wyre	Fleetwood Docks to Stanah = Medium Remainder of estuary = Low	In the Wyre Estuary the 15 previous risk rating units extend to the tidal limit at St Michael's whereas the SMP2 policies only go up to Cartford Bridge at Little Eccleston. The Fleetwood to Stanah frontage is the estuary boundary of the large north Fylde Peninsula tidal flood cell that extends around the open coast to Cleveleys with >30,000 properties at risk under extreme floods; the SMP2 policy here is HTL. On the east bank the SMP2 policy is HTL from Knott End to the Shard Road bridge apart from the higher ground at the golf course which is NAI. Elsewhere in the estuary the policy is for change from HTL to MR in the medium and / or long term. Due to the consequences of flood linkages from the east bank across to the open coast at Knott End and Pilling it is recommended that both banks of lower estuary should be rated as Medium and due to the future policy changes in the upper estuary this should also be rated Medium. **Overall risk = Medium**
Lune	Whole estuary = Low	There were 7 previous risk rating units, but all were rated as Low. The SMP2 policy for most of the estuary is NAI, apart from MR in long term between Sunderland and Overton, MR in all epochs at Sunderland Point, MR in medium or long term at Lythe Bridge and HTL for both banks upstream of Oxcliffe, where most of the properties at risk are located. The Lune Estuary has a relatively high number of properties at risk for its size, ranking 3rd out of the 9 NE Estuaries. As there are planned policy changes and uncertain impacts as the training walls deteriorate the overall risk rating for the Lune

Estuary	2010 Risk Ratings	2013 Risk Review
		Estuary is recommended to be revised to medium. **Overall risk = Medium**
Kent	Humphrey head to Viaduct (Grange) = medium Inner estuary (landward of railway viaduct) = Low Arnside & Silverdale shoreline = Low	From the railway viaduct to the tidal limits the SMP2 policy is for a change from HTL to MR in medium and long term, apart from at Sandside where it is HTL in all epochs. On the north shoreline there is a HTL policy from Humphrey Head to the viaduct and locally at Arnside. From Arnside to Jenny Browns Point the policy is NAI. There have been significant changes in the morphology in the outer estuary with erosion at Arnside and major marsh accretion at Grange. In terms of flood risk there is a very large area of agricultural land benefiting from the defences (in part provided by the railway) east of Grange. This is reflected by the previous medium risk rating on the outer estuary north shore. However, the defended area is continuous along the west bank of the inner estuary. Comparing the Kent Estuary with others in the north west it is small and has the equal lowest number of properties at risk. It is recommended that the ratings are made consistent throughout and revised to Low Risk. **Overall Risk = Low**
Leven	Bardsea to Canal Foot = Low Canal Foot to Greenodd = Medium Greenodd to Tidal limit = Low Tidal limit to Viaduct (east side) = Low Viaduct to Cark = Medium	Generally landward of the railway viaduct the SMP2 policy is for a change from HTL to MR in medium term and NAI in long term, with exceptions at Greenodd, where it is HTL in all epochs. Seawards of the viaduct the SMP policy is NAI, apart from locally HTL at Canal Foot and Conishead. The low risk to the inner estuary is agreed. For consistency across the estuary it is recommended that the risk ratings are revised to Low Risk throughout. **Overall Risk = Low**
Duddon	Haverigg to tidal limit = medium Tidal limit to Dunnerholme = Medium Dunnerholme to Sandscale haws = medium	The EA flood mapping only recognises the defences on the northern shoreline from Millom Marsh to the tidal limit. The SMP2 policy is for MR on the north shoreline and in the inner estuary in the medium and long term. Elsewhere significant lengths have NAI policy. There are significant management changes proposed in the SMP2 and the estuary is of high environmental importance. However, due to the low numbers of properties at risk the overall CERMS rating is recommended to be revised to Low Risk. **Overall Risk = Low**
Ravenglass	Esk estuary = Medium	Only part of the estuary complex is included in the single unit mapped in the previous risk ratings. Although rated as Medium, there is only a short length of defence at Ravenglass village and in the SMP2 apart from the HTL policy at the village the whole complex has NAI policy. There are very few properties and relatively small areas of land at flood risk. It is therefore considered that the estuary could be re-assigned from medium to Low Risk. **Overall Risk = Low**

2.5 Prioritisation of coastal flood and erosion issues in the NW estuaries

In order to help inform prioritisation of coastal process issues across the nine estuaries that have been considered in this review the assessments presented in sections 3.1, to 3.4 have been brought together in Table 2.4 to give an overall comparison and ranked with 1/9 considered highest risk and 9/9 lowest. The prioritisation in Table 2.4 also takes into account the data gaps and recentness of survey coverage, as discussed in the individual estuary reports (CH2M HILL, 2013a – i).

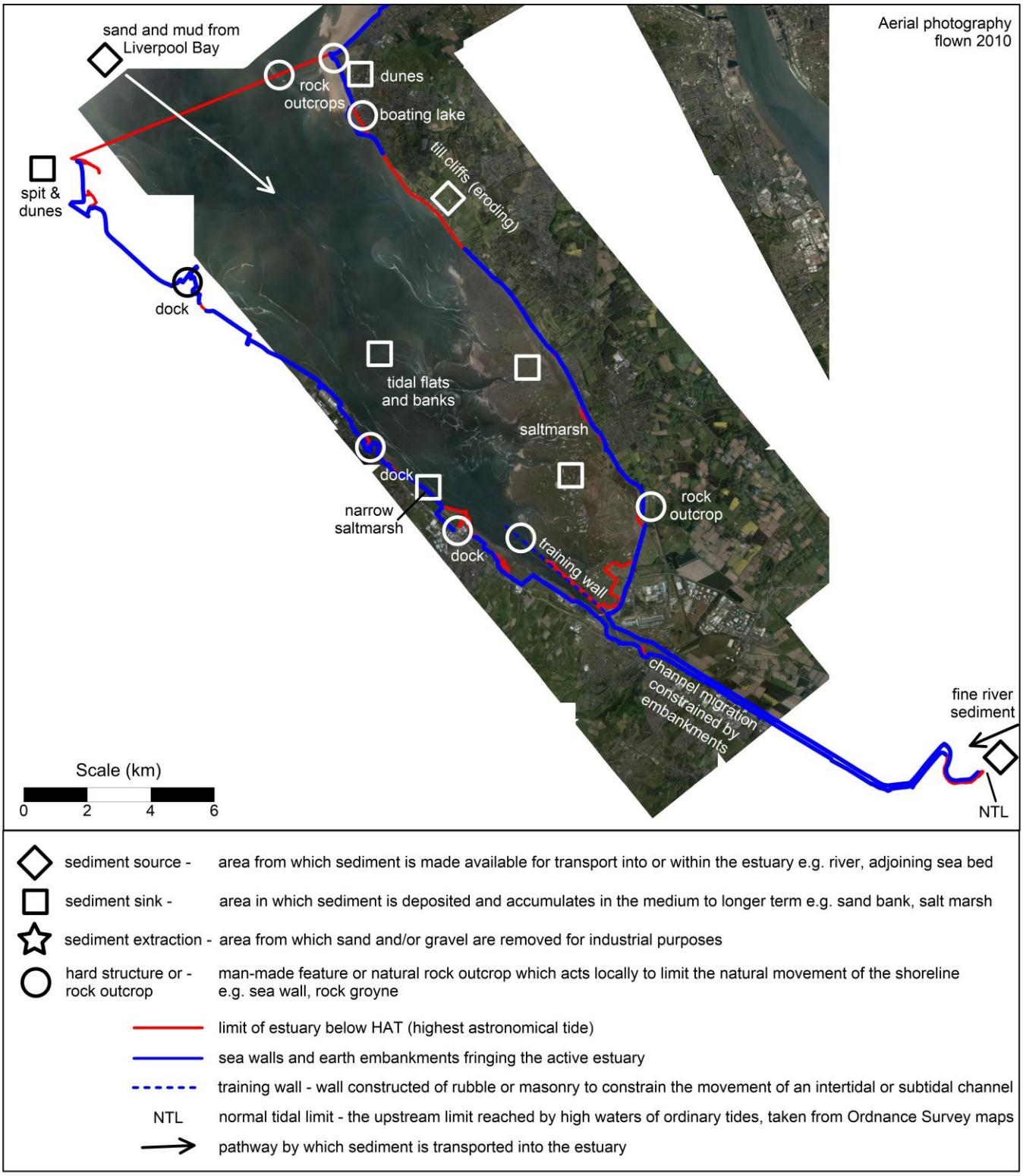
Table 2.4 Prioritisation for NW estuaries on the basis of flood and erosion risk

Estuary	Comments on sensitivity to change	FCRM priority for data collection and studies
Dee	Large estuary, hence larger change in equilibrium length and depth expected due to increasing freshwater flow and SLR, but strongly flood dominated, has low freshwater flow for size, limiting flushing, so is a strong sink for sediments and can react to climate change. Large sediment supply available from Liverpool Bay. Managed realignment proposals.	Recent FCRM strategy studies and scientific studies undertaken. Baseline bathy exists from 2006, so priority = **High (3/9)**.
Mersey	Large estuary, hence large change in equilibrium length and depth expected due to increasing freshwater flow and SLR. Estuary is a strong sink for sediments, with capacity to accumulate in the middle estuary. Can react to climate change by importing sediment provided hydrodynamic regime remains favourable and supply is not restricted by changes to dredging and channel training works. Large availability of sediment in Liverpool Bay. Managed realignment proposals from the SMP2 are unlikely to have significant effects on overall estuary.	FCRM risks lower than other estuaries, main issues relate to WFD and navigation. Limited recent data available; Limited consideration of FCRM risks previously, although studied for water quality and navigation. Priority = **High (2/9)**
Ribble	Medium size estuary, has had large sediment incursion in the past, although nearly at full capacity still expected to continue to infill with sea level rise. Sediment supply from Liverpool Bay / North East Irish Sea. Impacts of large scale managed realignment proposals in SMP2 were tested in CETaSS.	Due to large areas of land at risk, high property numbers and scale of changes proposed FCRM Priority for data collection and further study = **High (1/9)**.
Wyre	Medium size estuary. Large lengths of shoreline have long term change to MR. Potential managed realignment proposals similar to SMP2 tested in previous model studies indicated limited impact on wider estuary as they are high in tidal frame. Strong sink for sediment and large supply available from Morecambe Bay.	Very large property numbers at risk in Fleetwood area are also at risk from the open coast. Property numbers and scale of changes proposed FCRM Priority for data collection and further study = **medium (5/9)**
Lune	Small estuary. Previous processes study for strategy prior to SMP2. Significantly modified in past with training walls which are now deteriorating. Large lengths of shoreline now NAI & / or MR, so potential for significant changes to habitats. Large sediment supply available from Morecambe Bay limits sensitivity to climate change.	Due to large areas of land, large property numbers and scale of changes proposed FCRM Priority for data collection and further study = **High (4/9)**
Kent	Small estuary. The saltmarsh erosion and accretion patterns within the estuary are highly dependent on the channel and bank positions The channels are highly mobile and are known to move significant distances within a few days. Large portion of estuary has long term MR policy. Large availability of sediment from Morecambe Bay.	Limited properties at risk, but large area of agricultural land. Due to limited previous study and scale of changes proposed FCRM Priority for data collection and further study = **medium (=6/9)**
Leven	Large portion of estuary has long term MR or NAI policy. Relatively small shallow estuary, ample sediment supply from Morecambe Bay.	Relatively smaller areas of land at risk and low property numbers. Large scale changes proposed to FCRM. Limited previous study, so priority for data collection and further study = medium **(=6/9)**
Duddon	Medium size estuary, weak sink for sediment, sediment supply	Low numbers of property at risk, but

Estuary	Comments on sensitivity to change	FCRM priority for data collection and studies
	more limited than estuaries in Morecambe Bay or Liverpool Bay. Significant realignment / policy changes proposed in SMP2, some model testing in CETaSS.	significant policy changes proposed and important environmental assets. Relatively less studied than other estuaries, FCRM Priority for data collection and further study = **low (8/9)**.
Ravenglass	Small estuary, weak sink for sediment, low river flow for size, limited sediment supply from offshore. Limited defences present.	Limited FCRM risks relative to other estuaries. Priority for data collection and further study = **low (9/9)**.

2.6 Conceptual summaries for the NW estuaries

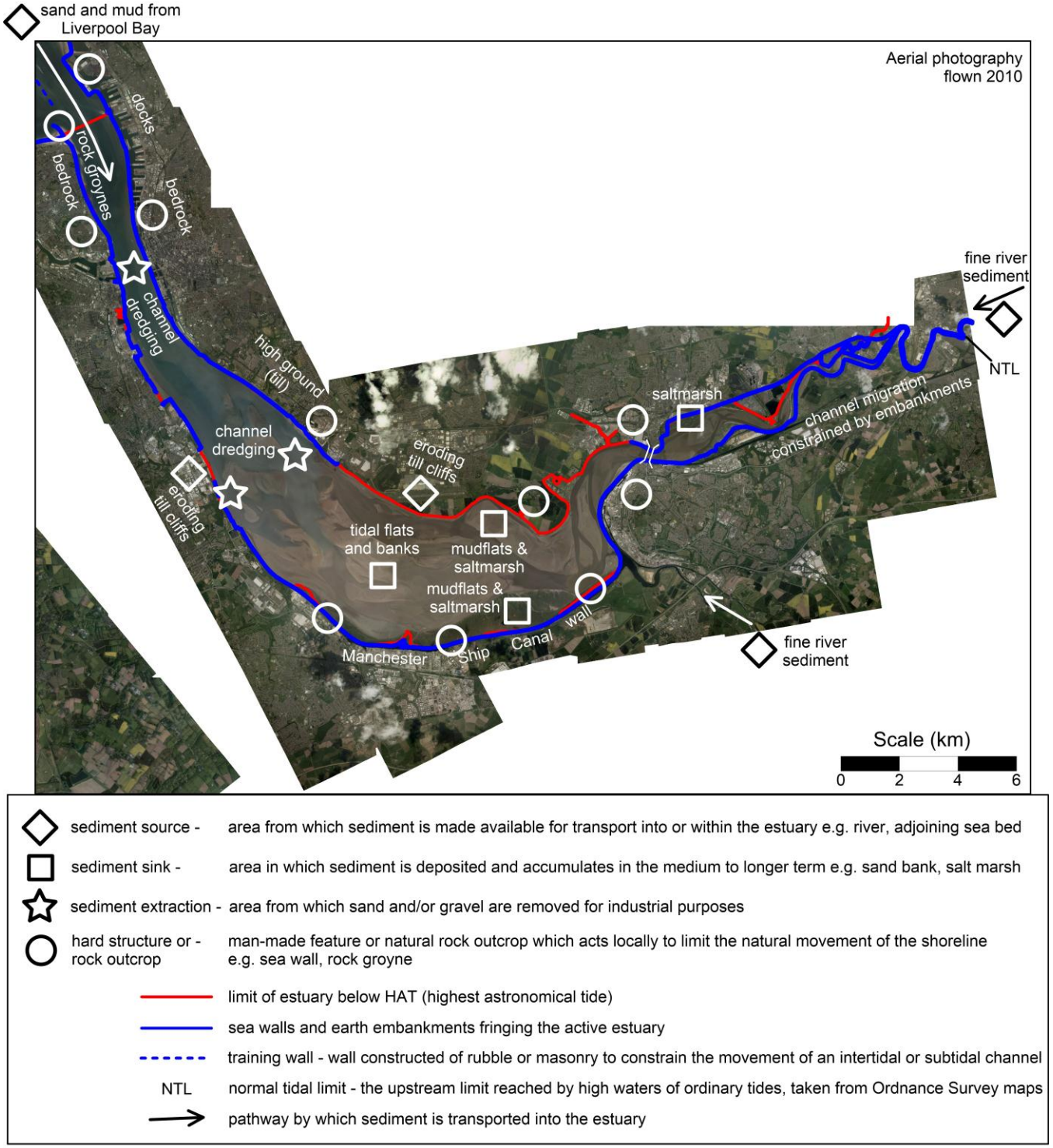
2.6.1 Dee Estuary



Level of existing knowledge	High	Sensitivity to change	Medium	Properties at risk	7,200
Environmental importance	High	Revised CERMS rating	Medium	Estuary priority	High (3/9)

Figure 2.1 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures which influence the morphology of the Dee Estuary.

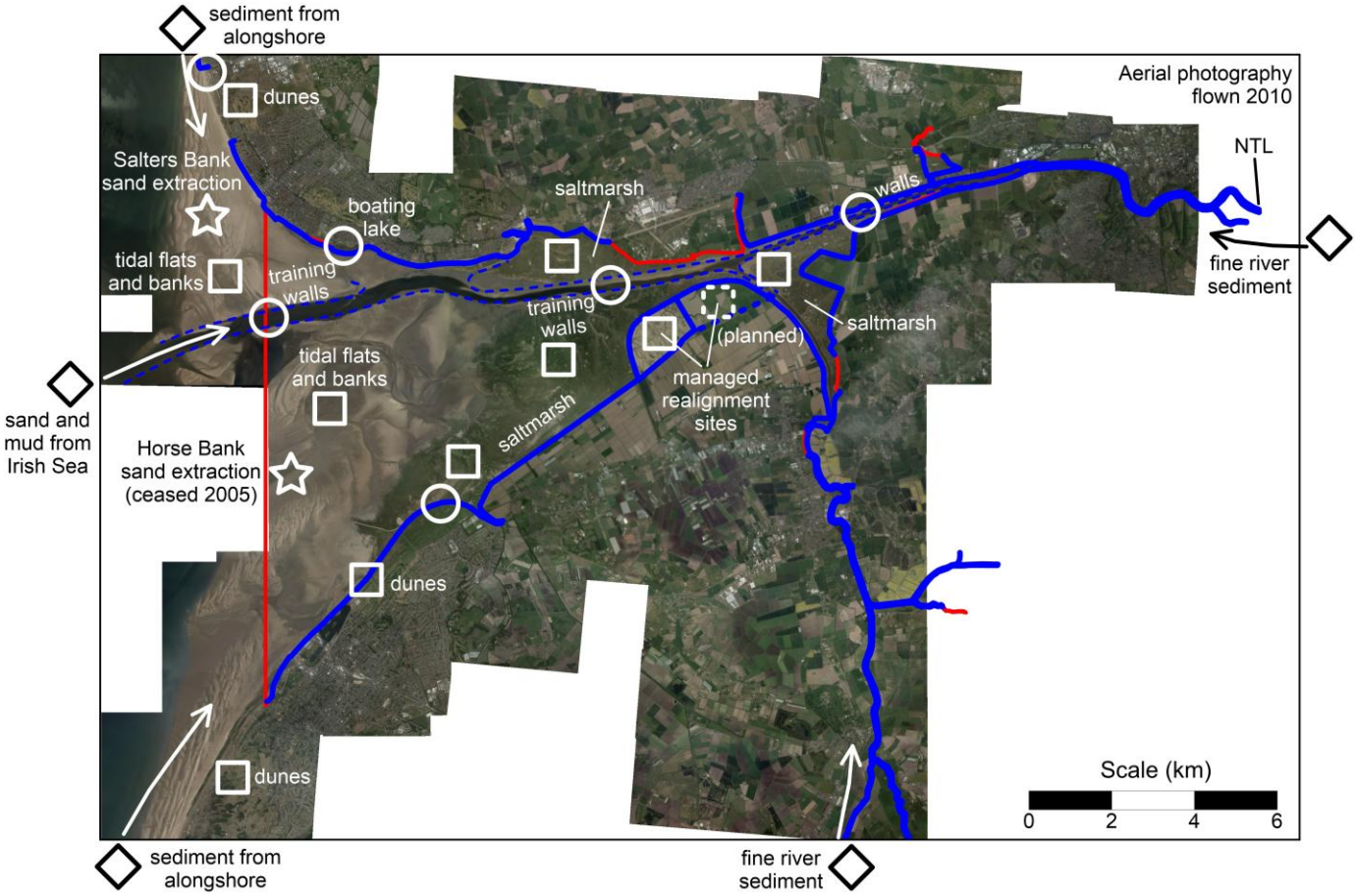
2.6.2 Mersey Estuary



Level of existing knowledge	Medium	Sensitivity to change	Medium/ High	Properties at risk	3,400
Environmental importance	High	Revised CERMS rating	Medium	Estuary priority	High (2/9)

Figure 2.2 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures which influence the morphology of the Mersey Estuary.

2.6.3 Ribble Estuary

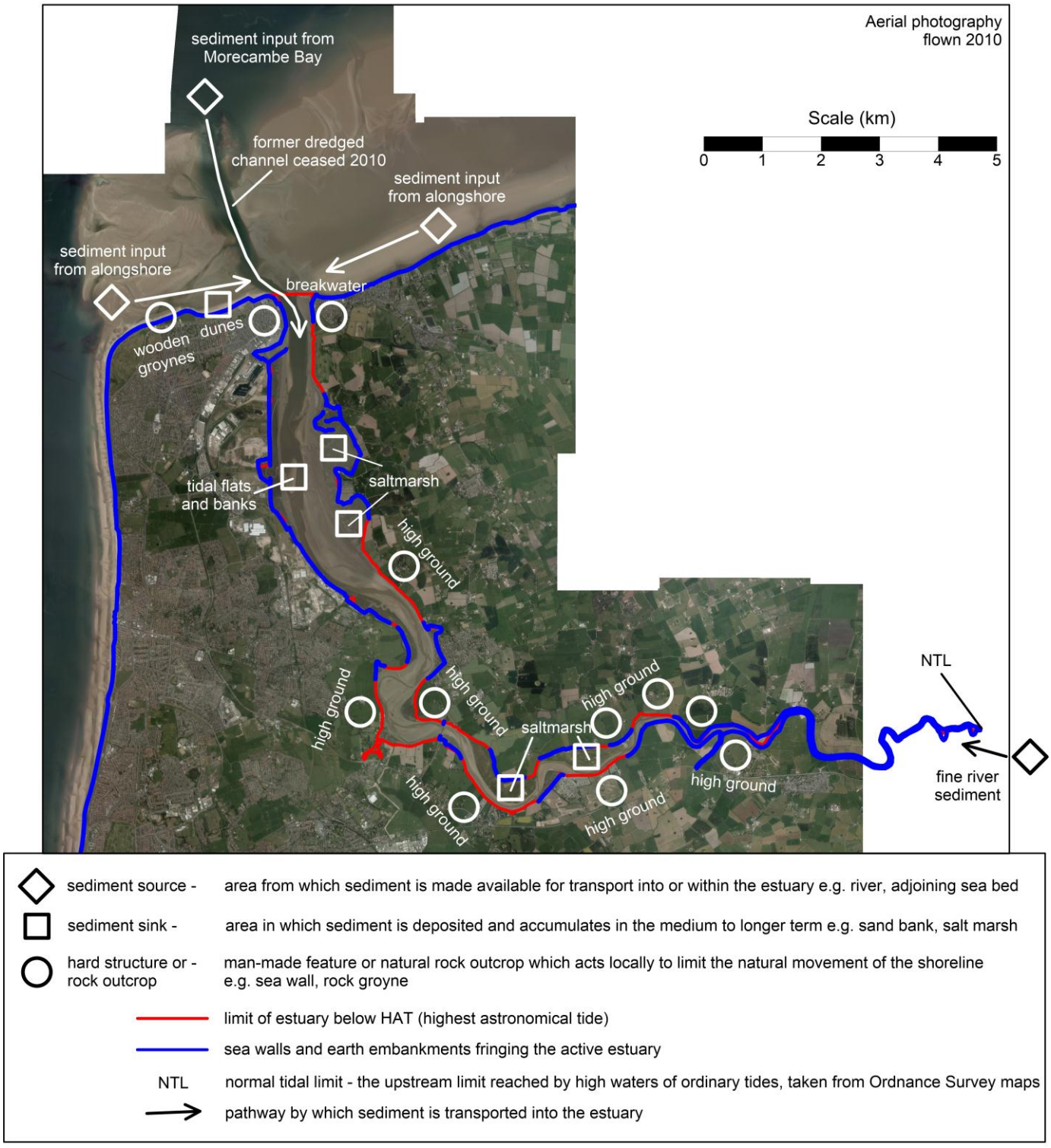


sediment source -	area from which sediment is made available for transport into or within the estuary e.g. river, adjoining sea bed	
sediment sink -	area in which sediment is deposited and accumulates in the medium to longer term e.g. sand bank, salt marsh	
sediment extraction -	area from which sand and/or gravel are removed for industrial purposes	
hard structure or rock outcrop -	man-made feature or natural rock outcrop which acts locally to limit the natural movement of the shoreline e.g. sea wall, rock groyne	
	limit of estuary below HAT (highest astronomical tide)	
	sea walls and earth embankments fringing the active estuary	
	training wall - wall constructed of rubble or masonry to constrain the movement of an intertidal or subtidal channel	
NTL	normal tidal limit - the upstream limit reached by high waters of ordinary tides, taken from Ordnance Survey maps	
	pathway by which sediment is transported into the estuary	

Level of existing knowledge	Medium	Sensitivity to change	Medium	Properties at risk	12,900
Environmental importance	High	Revised CERMS rating	Medium	Estuary priority	High (1/9)

Figure 2.3 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures which influence the morphology of the Ribble Estuary.

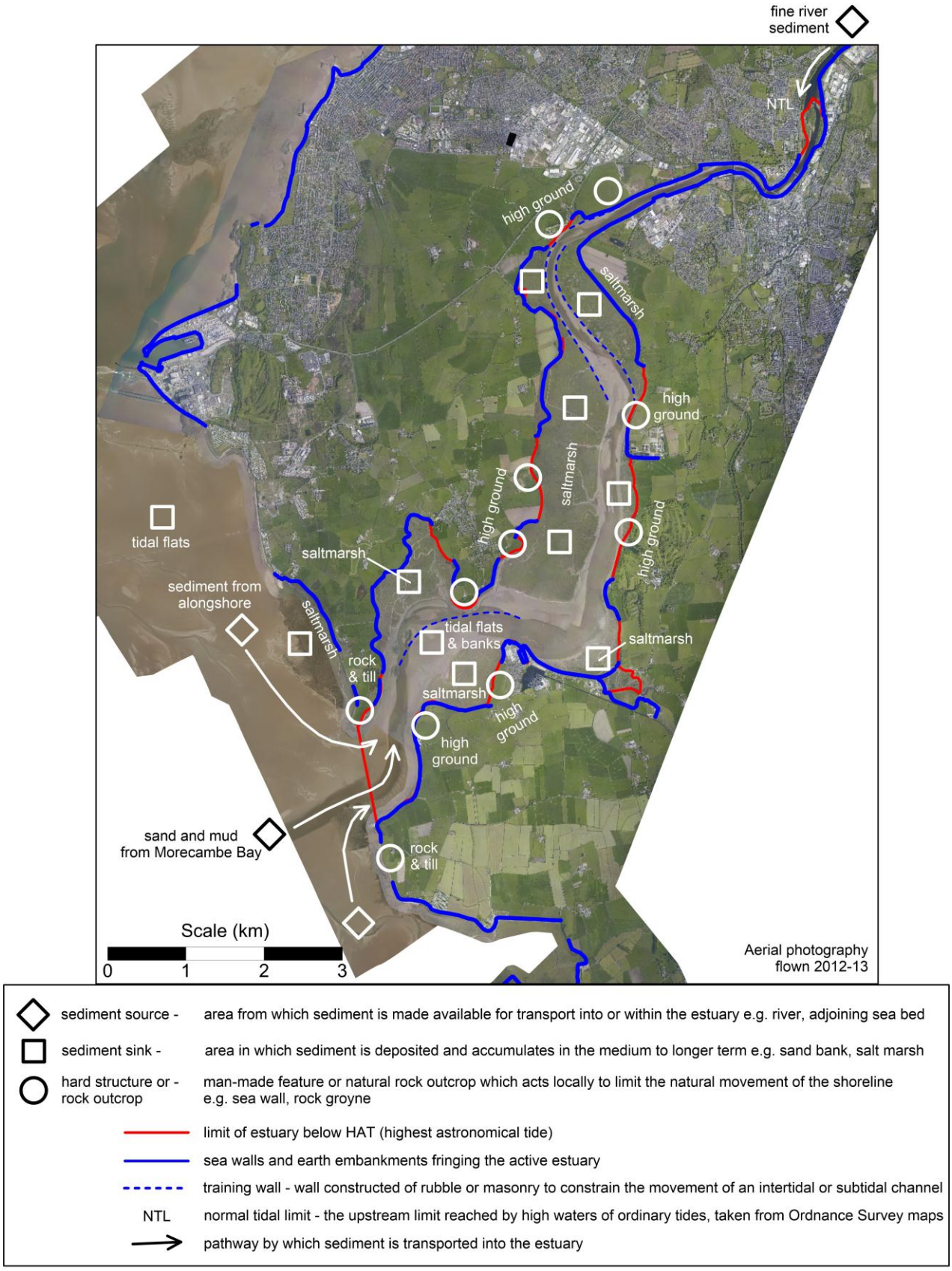
2.6.4 Wyre Estuary



Level of existing knowledge	Medium/High	Sensitivity to change	Medium	Properties at risk	31,500
Environmental importance	High	Revised CERMS rating	Medium	Estuary priority	Medium (5/9)

Figure 2.4 Conceptual diagram showing main sediment sources, geomorphological features and engineering structures which influence the morphology of the Wyre Estuary.

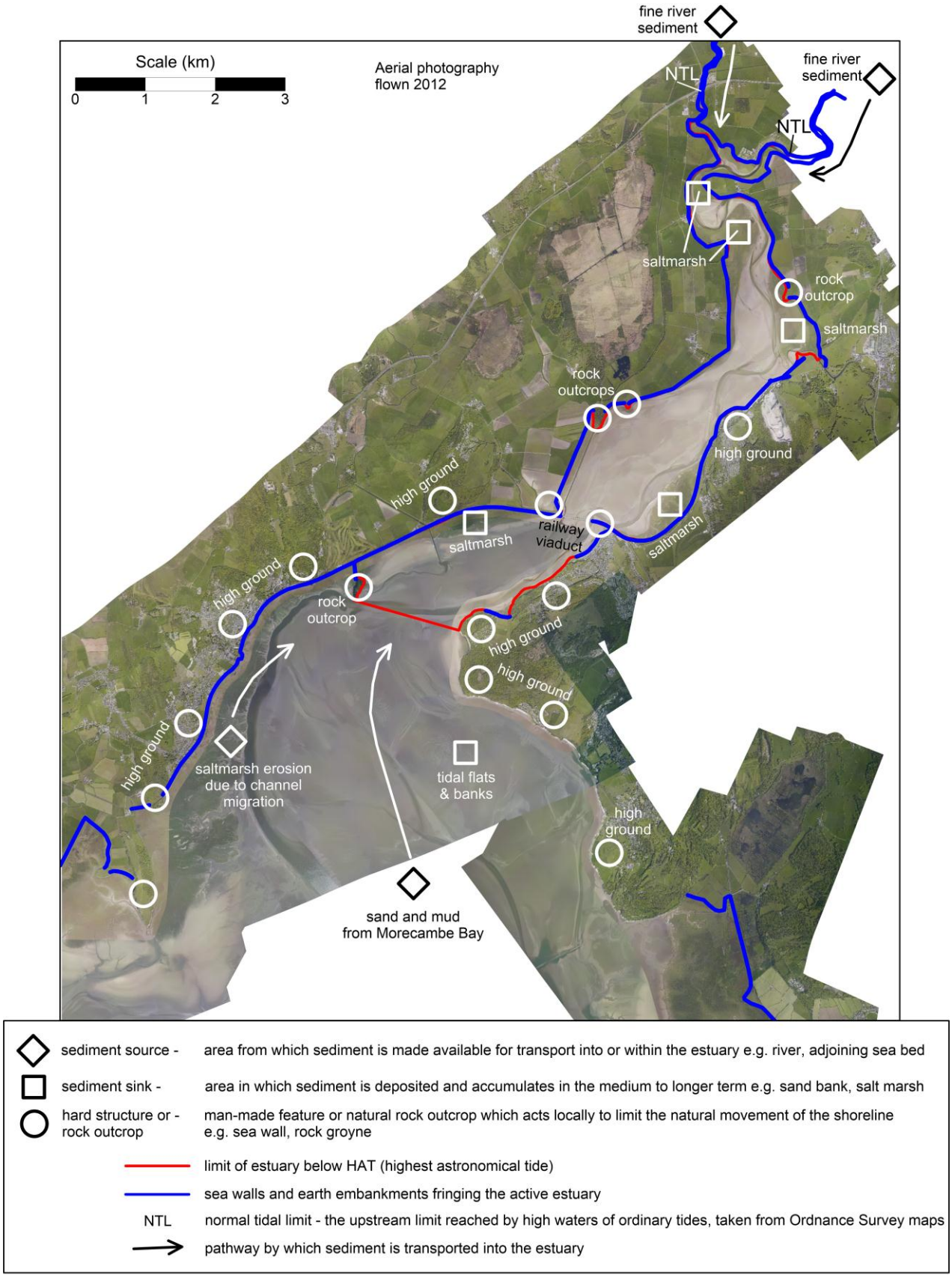
2.6.5 Lune Estuary



Level of existing knowledge	Medium	Sensitivity to change	Medium	Properties at risk	9,800
Environmental importance	High	Revised CERMS rating	Medium	Estuary priority	High (4/9)

Figure 2.5 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures which influence the morphology of the Lune estuary.

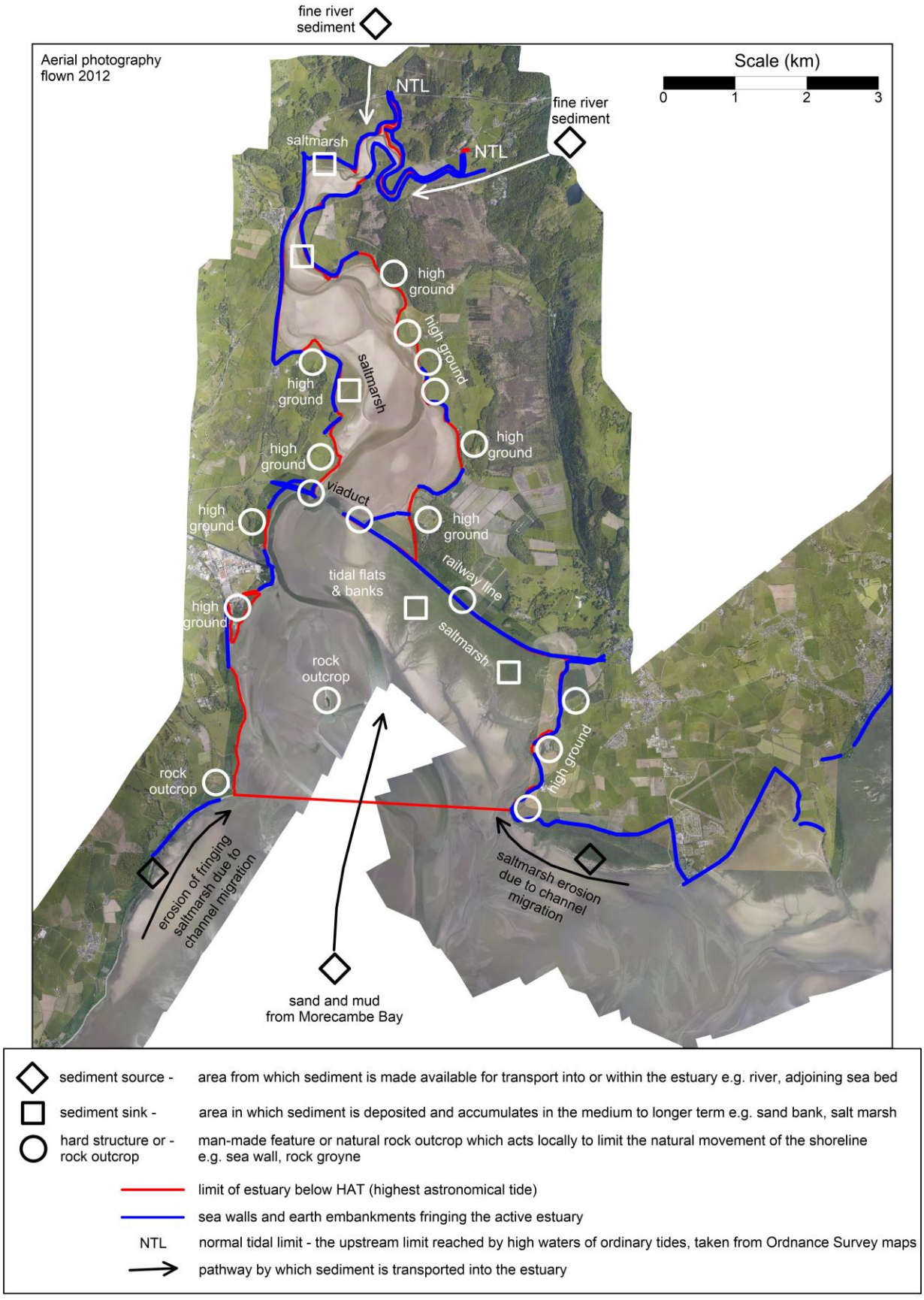
2.6.6 Kent Estuary



Level of existing knowledge	Low	Sensitivity to change	Medium	Properties at risk	100
Environmental importance	High	Revised CERMS rating	Low	Estuary priority	Medium(=6/9)

Figure 2.6 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures within the Kent Estuary.

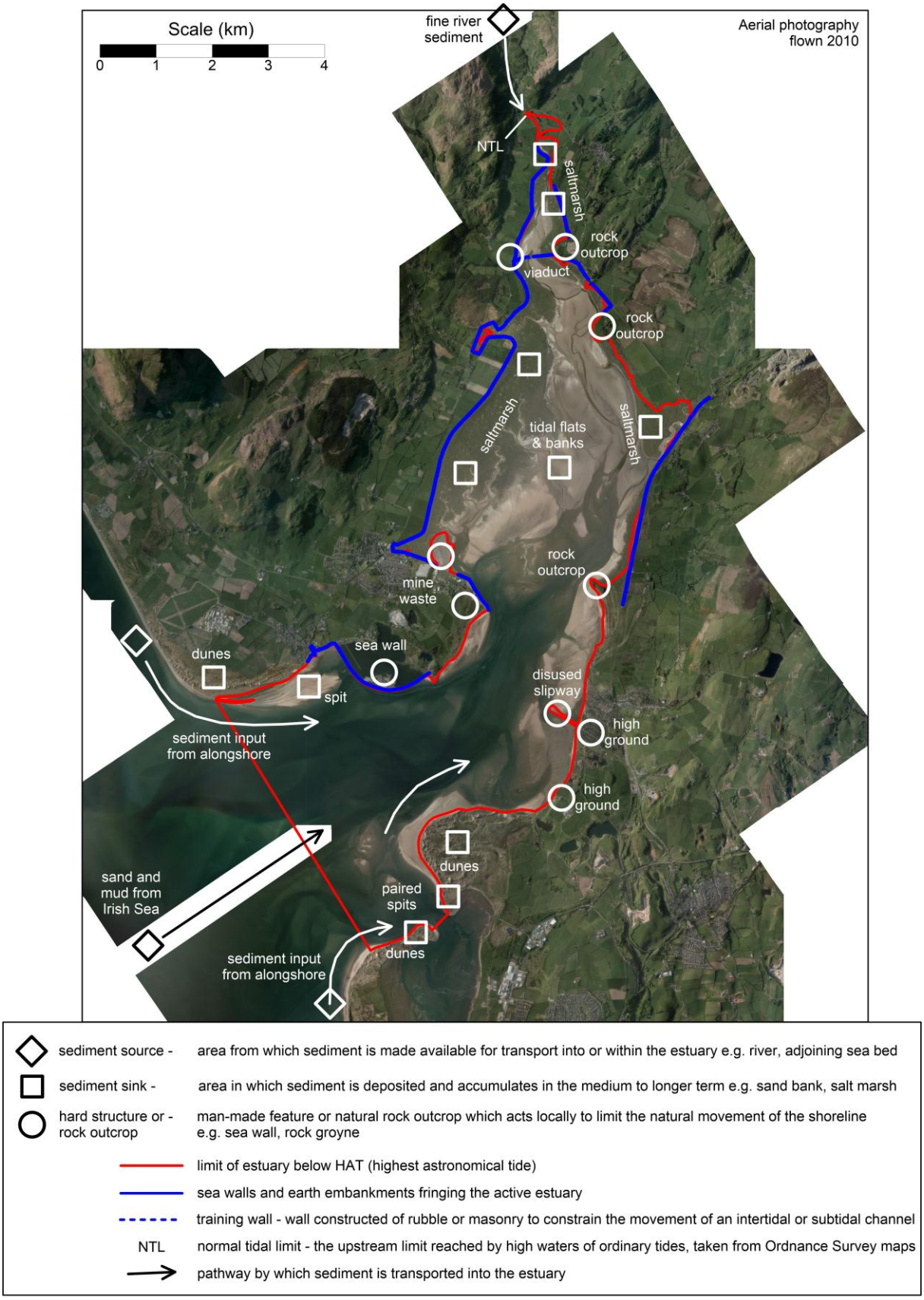
2.6.7 Leven Estuary



Level of existing knowledge	Low	Sensitivity to change	Medium	Properties at risk	400
Environmental importance	High	Revised CERMS rating	Low	Estuary priority	Medium (=6/9)

Figure 2.7 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures which influence the morphology of the Leven Estuary.

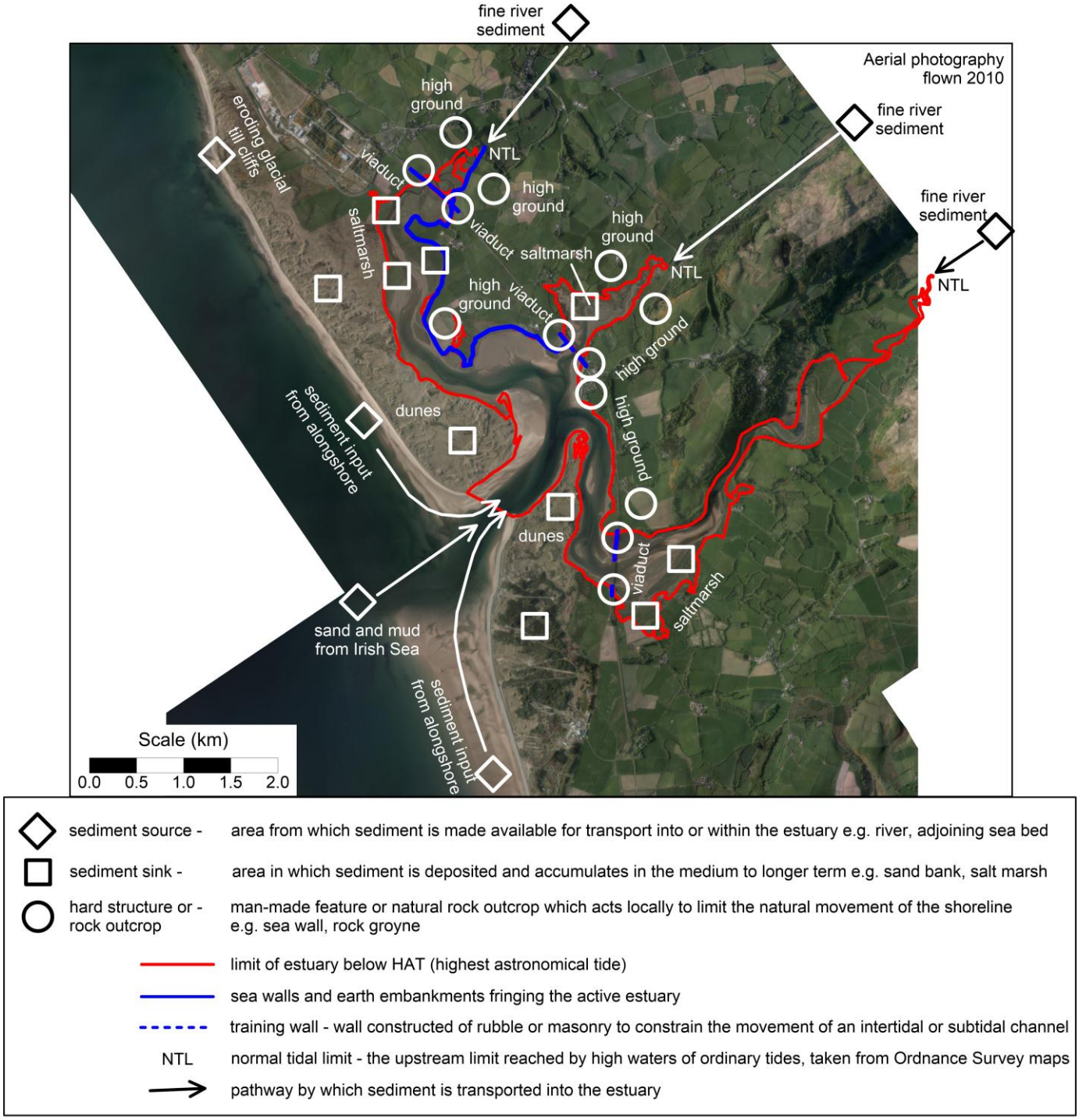
2.6.8 Duddon Estuary



Level of existing knowledge	Medium	Sensitivity to change	Medium	Properties at risk	800
Environmental importance	High	Revised CERMS rating	Low	Estuary priority	low (8/9)

Figure 2.8 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures which influence the morphology of the Duddon Estuary.

2.6.9 Ravenglass Estuary



Level of existing knowledge	Low	Sensitivity to change	Medium	Properties at risk	100
Environmental importance	High	Revised CERMS rating	Low	Estuary priority	Low (9/9)

Figure 2.9 Conceptual diagram showing the main sediment sources, geomorphological features and engineering structures which influence the morphology of the Ravenglass Estuary.

3 Generic study recommendations

The individual estuary reports (CH2M HILL 2013a –i) include recommendations for specific studies and / or data collection in each estuary. However, there are a number of issues and related data collection and study requirements that are common across all of the North West Estuaries. Rather than repeat the common requirements in each report they have been collated together in this overview report. The actions have been prioritised using the approach developed in Section 3 and are summarised in Table 3.1 below.

When specifying monitoring activities or studies it is important that the linkages between the estuaries and the adjacent coast are considered. Surveys in the Liverpool Bay Estuaries should therefore be linked to surveys in the approaches since accurate hydrodynamic modelling would require synchronous bathymetry.

Table 3.1 Generic recommendations for NW estuaries

Study name	Problem	Rationale for study and potential beneficiaries	Study scope	Priority and estimate of costs.
1. Update of flood and coastal defence database.	The defence data used in the SMP2 is based on a range of sources, inconsistent and in places out of date.	Up to date defence database is required to support various activities at local, regional and national level, including NaFRA, NCERM, developing strategies, asset management plans and the next review of the SMP. Study included here because there are consistent requirements across the region, there would be benefits from a consistent approach and economies of scale if the work is packaged together. Potential Beneficiaries: Defra/EA/NRW/LAs/NR/UU	To be led by Sefton as regional monitoring lead, Blackpool as SMP lead or EA NW. See individual estuary reports for more details on scope.. General scope: Review data used in the SMP2, as identified in the individual estuary reports 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. Check for updates from strategy or scheme appraisals. Compile latest data including mapping and undertake initial quality review using latest aerial photography from coastal group. Undertake walkover inspections / visits to selected locations taking photographs of defence lengths inspected and significant defects. Update database and make available on SANDS and AIMS.	Priority medium to high; varies by estuary, depending on plans for future studies, see individual reports. Estimated cost £10 to £25k per estuary, assuming work packaged across several estuaries.
2. Sediment pathways analysis study	Uncertainty over quantification of sediment supply to estuaries and their ability to respond to future climate change.	The CETaSS study modelling identified sediment pathways and linkages between the estuaries, the Cell 11 seabed and the coast. However, there was limited sediment data available at the time to verify the pathways using evidence from the field. Although potential transport rates were available from the models, field evidence was lacking to quantify transport. The individual estuary reports all include recommendations for similar studies and that certain studies are packaged together, see scope. Potential Beneficiaries: EA/NRW/LAs/NR/UU/Conservators of Mersey and Dee	To be led by Sefton as regional monitoring lead, Blackpool as SMP lead or EA NW. The studies recommended in the estuary reports should be packaged for efficiency and consistency. It is suggested that the Dee, Mersey and Ribble are considered together with the wider Liverpool Bay. The four Morecambe Bay estuaries – Wyre, Lune, Kent and Leven should be considered together with wider assessment of Morecambe Bay. In addition to the work recommended in the individual estuary reports the large number of sediment samples collected through CERMS coastal monitoring for particle size analysis should be further analysed in a sediment mineralogy and chemical fingerprinting study to test the qualitative model results from CETaSS. The study should be undertaken in conjunction with similar recommendations made in the individual estuary reports. Further regional scale modelling should be undertaken to provide quantitative results to inform an updated sediment budget.	Priority: High Estimated costs (in addition to those stated in individual estuary reports): Data collection and analysis £20k to £35k Additional regional modelling £30k to £50k

Study name	Problem	Rationale for study and potential beneficiaries	Study scope	Priority and estimate of costs.
3. Better Quantification of erosion risk in estuaries	Very limited information on erosion risks in estuaries	The national coastal erosion risk mapping (NCERM) project found a general lack of erosion risk data for estuarine frontages. Data is needed in order to provide consistent risk assessment data nationally through the EA WIMBY website alongside flood risk maps. Potential Beneficiaries: LAs/EA/NRW/NR/individual property owners	To be led by Sefton or Blackpool (SMP lead authority). Undertake erosion risk assessment as a single study for all NW estuaries covering identified SMP2 erosion risk policy units. Identify the erosion risk frontages from SMP2 policy mapping. Obtain historical mapping and photography data and load into GIS for analysis. Analysis of erosion data to derive risk zones using NCERM methodology. Feed results into NCERM updates and database for next SMP review.	Priority Medium Estimated costs £20k to £50k
4. Extreme water levels in Cell 11 estuaries	Uncertainty of extreme water levels in estuaries, and the effects of proposed managed realignments and sea level rise.	The EA Coastal Flood boundary (CFB) data study that reported in 2011 provides data around the coast but does not go into the estuaries. There is a need to extend the study into the estuaries. Although the study does include Morecambe Bay, the effects of changing channels and banks may be important for estimating surge levels in the bay and appears not to have been considered. The situation is more complex in estuaries due to the need to consider potential impacts of managed realignment on future projected extreme levels, the joint probability of tidal surge and fresh water flows and the sensitivity of extreme levels to changing estuary morphology. Potential Beneficiaries: LAs/EA/NRW /NR/individual property owners	To be led by Sefton as coastal monitoring lead, Blackpool as SMP lead or EA NW. This study would build on the national EA study which looked at the open coast and reported in 2011 as well as the Cell 11 Joint Probability study and CETaSS study. The studies should start with an initial scoping phase that reviews existing 2D models, collates and reviews available tide gauge data and compares the data from the December 5th surge event to the CFB 2011 assessments. For selected high priority estuaries, e.g. Ribble, Wyre and Lune sensitivity tests should be undertaken to identify the implications of ongoing morphological changes in banks and channels at the mouth on extreme water levels in the estuaries. The study should scope out the requirements for the full study investigating current and future extreme sea levels for all the NW estuaries. The full study should consider the Morecambe Bay estuaries together as well as reviewing the implications of channel and bank movements on extreme levels around the Bay.	Priority – High Estimated costs for scoping phase, not including modelling £20k. Preliminary modelling sensitivity tests £15k to £30k. Estimated costs for full study: £100k to £200k, but could be prioritised by estuary and undertaken in stages.

Study name	Problem	Rationale for study and potential beneficiaries	Study scope	Priority and estimate of costs.
5. Review of land drainage Outfall issues	In many estuaries, especially around Morecambe Bay, accretion of saltmarsh and intertidal banks is causing problems with blockages or restrictions to land drainage outfalls.	Issue impacts on large number of outfalls and so warrants being tackled strategically. Potential Beneficiaries: LAs/EA/NE/NR/land owners	To be led by EA NW. Need to review numbers of sites impacted now and expected to be in future. Liaison with Natural England, investigation of generic approaches and consents. Trial approaches and agree protocol for dealing with the issues between EA and NE.	Priority: Medium Estimated cost: £25k
6. Cell 11 estuary bathymetric surveys	Comprehensive baseline bathymetric data sets are not available for the estuaries.	A key lesson from CETaSS was the need for modelling to be informed by up to date bathymetry. The only NW estuary with comprehensive data coverage is the Dee. Swath bathymetry combined with inter-tidal LiDAR surveys should be programmed in for all of the estuaries. Potential Beneficiaries: EA/NRW/LAs/NE/NR/Navigation authorities	To be led by Sefton. Availability of data set for Dee, produced for Dee Tidal User Group, needs to be checked. Revised specification for LiDAR in estuaries (and on open coast) to be produced to ensure capture to LW and incorporating flood plain in potential MR areas. LiDAR to be flown at same time as swath bathy survey. Recommend comprehensive baseline for each estuary (prioritised on risk) then updates in future to be programmed based on risk and rate of expected change – e.g. more frequent around sand banks at mouths etc. Single beam surveys of the Ribble and Lune have already been undertaken or will be completed in 2013, so these have lower priority.	Priority High overall. Priority list as follows: 1. Mersey 2. Outer Morecambe Bay with Wyre 3. Inner Morecambe Bay with outer Lune, Leven and Kent 4. Dee (assuming existing data can be made available) 5. Duddon 6. Ribble 8. Ravenglass Estimated cost £50k to £100k per estuary (depends how packaged)

Study name	Problem	Rationale for study and potential beneficiaries	Study scope	Priority and estimate of costs.
7. Estuary wave / current / sediment monitoring (Data collection)	There is a general lack of current, wave and suspended sediment data in all estuaries.	Data is needed for calibration of models needed for assessment of future managed realignment etc. Potential Beneficiaries: EA/NRW/LAs/NE/NR/Navigation authorities	To be led by Sefton. AWAC devices, such as deployed on coastal areas as part of the current programmes can also be used in estuaries. The cost is about £10-15k per AWAC per year. The devices should be deployed to coincide with periods when the bathymetry survey is underway.	Medium, with priority between estuaries based on existing knowledge and flood risk as follows: 1. Morecambe Bay 2. Mersey 3. Ribble 4. Lune 5. Wyre 6. Kent / Leven / Duddon / Ravenglass
8. Impact of channel and bank movements in Morecambe Bay on future flood risk (study)	The movement of banks and channels has large implications for management of flood risk, but there has not been a comprehensive study of the history of movements, links to driving forces or assessment of future change.	The study will inform strategies and schemes around the bay and the next SMP review. It will also feed into future Habitat Risk Assessments. Note that the SMP Action Plan recommends a bay wide habitats study and this could be linked. Potential Beneficiaries: EA/LAs/NE/NR/Navigation authorities	To be led by Sefton or Lancaster or EA. Some data has been collated by Lancaster local monitoring programme on the movements. However, their database need to be reviewed and updated. Freshwater flow data available from EA / CEH; time series wind and wave data available through JPS offshore from the bay. The Morecambe Bay wave model developed for the EA Cockersands study (or similar) could be used to test impacts of morphological change and sea level change on nearshore conditions. The outcome of the study should be a SANDS database with GIS vector mapping of past change, data sets for surges and high river flow events that can be added to in future and a short initial interpretative report.	Medium, required before next SMP review. Estimated cost: Historical mapping data review and development / update of GIS database: £20k to £30k Preparation of database of flow data, wind data and surge events in SANDS £15k Analysis and interpretation £15k

4 Conclusions and recommendations

The review of the CERMS risk ratings for the NW estuaries found that the approach used on the open coast is not fully transferrable to the estuaries due to the differing forcing and response systems. Many of the estuaries are fully or largely designated for their environmental importance. FCERM management changes such as managed realignment or withdrawal from defence maintenance could have potential impacts on whole estuary systems. Rather than specifying differing risk ratings for individual frontages in the estuaries it has been recommended that the monitoring and studies takes a strategic, overall approach to each estuary.

Rather than specifying beach profiles or bathymetry profile extensions in outer estuaries and adjacent coast, as has been the case in the past, it is recommended that a move is made to swath / multi-beam bathymetry surveys giving full coverage below low water and overlapping LiDAR surveys that extend to low water to give full coverage at, as near as possible, the same time.

In this report a series of six (6) generic studies that link the estuaries or reflect common needs have been recommended. The highest priority of these are a sediment sampling and analysis study and a study to extend the National 2011 extreme water level study into the estuaries.

Prioritised recommendations for each of the Individual estuaries are given in the nine (9) individual estuary reports that should be considered alongside this overview report.

Although not considered as an individual estuary in the study, Morecambe Bay is already considered as a separate entity in the CERMS programme due to the different coastal processes in the Bay compared to the open coast. The low water channels from the four estuaries considered in this study all drain across the Bay and the consideration of these channel movements is identified as a high priority for coastal monitoring.

As it is understood that LiDAR surveys have recently been undertaken in some areas of Cell 11 this year, highest priority for further bathymetry monitoring is to obtain swath bathymetry surveys in the estuaries covered by the LiDAR survey in order to derive as near as possible synoptic full bathymetry and topographic surveys.

5 References

Coastal Engineering UK (2009) Cell 11 Regional Monitoring Strategy, Project Review 2009, 37pp+Figures and appendices.

CH2M HILL (2013a) North West Estuaries Processes Reports, Dee Estuary. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

CH2M HILL (2013b) North West Estuaries Processes Reports, Mersey Estuary. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

CH2M HILL (2013c) North West Estuaries Processes Reports, Ribble Estuary. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

CH2M HILL (2013d) North West Estuaries Processes Reports, Wyre Estuary. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

CH2M HILL (2013e) North West Estuaries Processes Reports, Lune Estuary. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

CH2M HILL (2013f) North West Estuaries Processes Reports, Kent Estuary. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

CH2M HILL (2013g) North West Estuaries Processes Reports, Leven Estuary. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

CH2M HILL (2013h) North West Estuaries Processes Reports, Duddon Estuary. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

CH2M HILL (2013i) North West Estuaries Processes Reports, Ravenglass Estuary complex. Report prepared by CH2M HILL for the North West and North Wales Coastal Group, August 2013

Environment Agency (2011). The extent of saltmarsh in England and Wales: 2006–2009. Report produced by the Environment Agency, October 2011, 57pp.

Halcrow, 2002. Futurecoast. CD produced as part of the Futurecoast project for Defra.

Halcrow, 2010a. North West England and North Wales Shoreline Management Plan SMP2. Main Report and Annex 1 - Policy Statements. Report prepared by Halcrow Group Ltd for the North West and North Wales Coastal Group, February 2011.

Halcrow, 2010b. North West England and North Wales Shoreline Management Plan SMP2. Appendix D – Assessment of Cell 11 estuary dynamics. Report prepared by Halcrow Group Ltd for the North West and North Wales Coastal Group, February 2011, 63pp + Tables + Figures.

Halcrow, 2010c. North West England and North Wales Shoreline Management Plan SMP2. Supporting Studies. Cell Eleven Tide and Sediment Transport Study (CETaSS) Phase 2 (ii). Main Report – Summary of Findings. Report prepared by Halcrow Group Ltd for the North West and North Wales Coastal Group, September 2010, 152pp.

Halcrow, 2010d. North West England and North Wales Shoreline Management Plan SMP2. Supporting Studies. Cell Eleven Tide and Sediment transport Study (CETaSS) Phase 2 (ii). Appendix F - Modelling studies for the Ribble. Report prepared by Halcrow Group Ltd for the North West and North Wales Coastal Group, 2010, 117pp.