Spey Mouth - Management Review

Kingston-upon-Spey

November 2012

Final Report

9y0428

The Moray Council

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SUMMARY

There is concern expressed by the community of Kingston-upon-Spey that, should the shingle ridge breach in front of the village, there would be significant risk of wave overtopping and potential erosion. This could then lead to extensive damage and potential loss of properties.

As part of this study a site visit was undertaken, followed by a meeting to discuss and exchange ideas and information. During this meeting the key points emerged:

- The principal concern was the condition and continuing change in the shingle ridge. Particularly following recent storms, when waves overtopped the ridge, creating sediment fans into the Lagoon behind.
- That the edge of the land behind the Lagoon was at least in part made of fill material, which would be rapidly eroded under wave action.
- That wave overtopping would cause flooding to Beach Road properties and to the village behind Beach Road.
- Concern was expressed that the whole beach frontage to the west of Kingston was subject to significant erosion, and that there was an overall loss of sediment within the shoreline system.
- There was a belief that changes in tidal currents might be inducing broader scale changes to the whole frontage.

The brief for the review was to examine these issues and to consider in outline, potential management of the frontage. The review has been undertaken based on existing information. While it is accepted that there remains significant uncertainty as to the detailed behaviour of the shoreline processes, this review aims to provide a high level interpretation of this behaviour and provide a sound basis for future decisions.

The review has demonstrated the complex nature of the area, subject to significant and often rapid changes occurring. It highlights important interactions between the coast and the entrance to the Spey. It is this interaction which is considered to dominate the way in which the shoreline behaves.

At the more local scale of the shingle ridge, the current monitoring, undertaken over the last three years, has shown that the shingle ridge in front of the village still provides a good level of protection. Despite now frequent occurrence of overtopping, the ridge acts to prevent significant wave action impinging on the bank to the rear of the Lagoon. As the ridge develops in the future, it is anticipated that the ridge will roll back but is likely to remain intact. Eventually the ridge would push up against the rear bank of the Lagoon and form a good beach, protecting the village.

It is recognised that under very severe storm events, the crest of the bank could flatten and allow waves across; that could potentially cause erosion and possibly damage to properties. The probability of this occurring has not been assessed in detail but is considered to be low.

Following such an event, the bank would tend to rebuild, again providing continued protection to the village.

The conclusion of this review is that major intervention to attempt to fix or substantially modify the natural behaviour of the shingle ridge, would involve works that would not be commensurate with the economic risk.

Furthermore, fixing the position of the shingle ridge with a rock revetment or even partially fixing the alignment through use of breakwaters; has the potential to cause major disruption to coastal processes both to the east and the west. Such major management intervention is not considered to be sustainable, creating on-going problems elsewhere within the system.

The overall assessment suggests that allowing the shingle ridge to develop naturally is a feasible option; effectively Do Nothing, in that the shingle ridge has the capacity to adjust and roll back quite probably without loss to property. However, given the complexity of the site and the potential for exceptional storm conditions; potentially causing unforeseen damage to the shingle ridge and to some property behind, a precautionary approach is taken in making recommendations.

It is not, however, considered sensible to attempt to fix the ridge in its current position. A more responsive approach is, therefore, recommended; in effect a Do Minimum approach.

These recommendations include continued monitoring and development of possible options for minor beach management. It is further recommended that consideration be given to works to locally protect the bank to the rear of the Lagoon. In considering this some further analysis would be required to assess the potential wave action across the Lagoon. The need for such would be considered to be precautionary, rather than from an assessment of actual risk, based on available information.

The report concludes with an assessment of monitoring practice.

CONTENTS

1 INTRODUCTION

1.1 General Description of the Area

Kingston upon Spey is located on the shoreline of Spey Bay, to the western side of where the Spey River runs through to the coast. Spey Bay is situated on the northerly facing coastline within the approaches to the Moray Firth (Figure 1.1). Spey Bay extends some 18km from the headland at Lossiemouth in the west, through to harder rock coastline continuing east from Buckie. To the eastern end of Spey Bay is Portgordon. The shoreline between Portgordon and the mouth of the Spey is formed as a relatively straight section of coast, comprising a sandy, shingly beach rising to slightly higher ground behind. The village of Tugnet is situated at the eastern mouth of the Spey.

The shingle banks and ridges at the mouth of the Spey extend some 1.5km across the lower valley of the Spey and form a complex pattern of ridges and spits, forming the seaward face of the Spey Delta. The Delta, itself, extends inland some 1km as an array of shingle and mud banks and braided channels before changing to a more meandering river system. Minor water courses such as the Black Burn, at Garmouth, and the Drainer Burn, behind Kingston, feed into the Spey Delta. The village of Kingston sits on the western side of the of the complex Spey Mouth system and is fronted by a partially enclosed Lagoon (The Hole) and a shingle ridge at the shoreline.

The whole Spey Mouth area is slightly further forward of the alignment of the shoreline to the west. This western shoreline comprises a shingle beach backed by relatively low lying land behind. The beach system extends as a shallowly indented bay through to Boar's Head Rock, and then continues further west through to Lossiemouth.

Figure 1.1 General Location Plan.

1.2 The Issues

The Spey ranks among the top ten rivers in the UK for its catchment area, its average and its peak flows. The river runs out through a relatively well defined section of coast. The flashy nature of flows in the river, the supply of sediment this brings to the lower delta and coastal fringe, coupled with the relatively large flood plain within the delta area means that the river has a major influence on the behaviour of the coastal system. This gives rise to significant changes occurring at the shoreline and, depending on the course of the river through the natural shingle bank at the shore, gives rise to substantial changes in sediment distribution across the local frontages.

Change in the shoreline over the last two decades is shown in Figure 1.2.

Figure 1.2 Change in configuration to the Mouth of the Spey 1988 - 2012.

In relation to the Kingston frontage, changes over the last decade, linked to broader scale variation across the mouth of the Spey, have raised significant concerns with the local residents as to the risk to their community. The principal concern and focus of this review is the condition of the shingle ridge seen as providing essential protection to the village (Figure 1.3). This ridge has visibly narrowed, decreased in height and moved landward.

Figure 1.3 Change in extent of the Kingston Shingle Ridge1991 - 2012.

There is concern expressed by the community that, should the shingle ridge breach, there would be significant risk of wave overtopping and potential erosion, which could then lead to extensive damage and potential loss of properties.

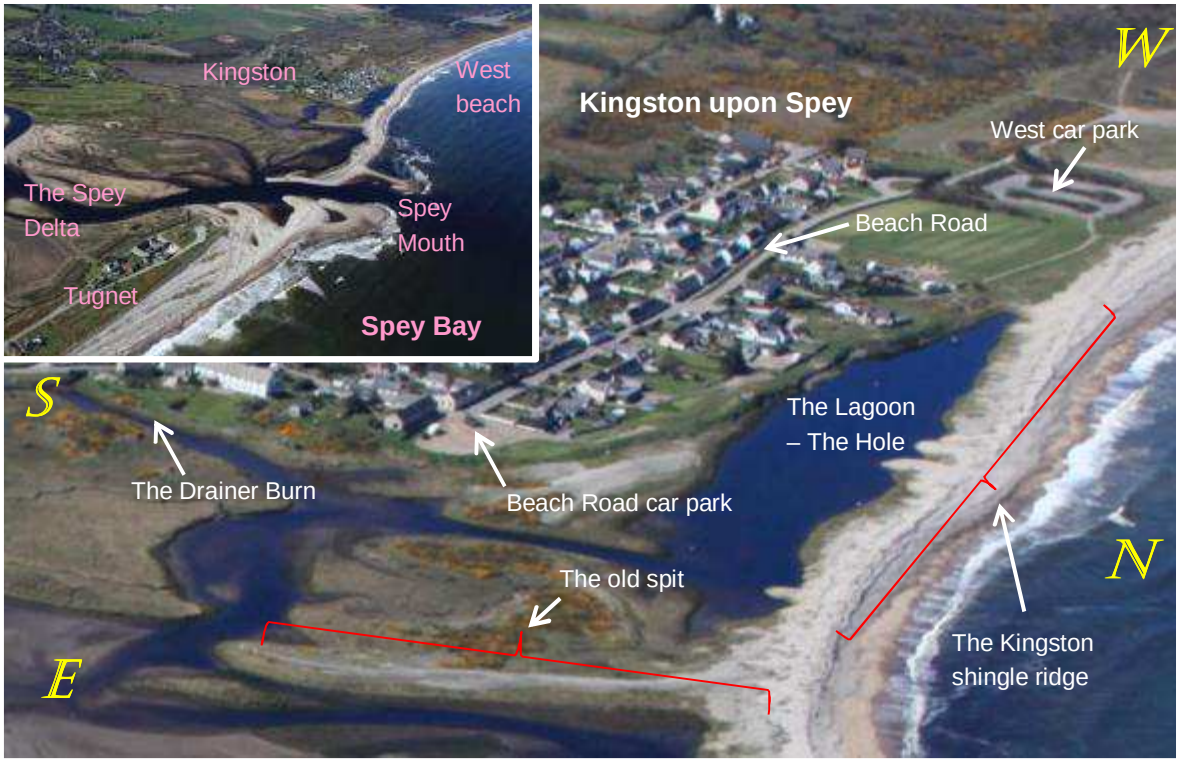
As part of this study a site visit was undertaken, followed by a meeting to discuss and exchange ideas and information. During this meeting the key points emerged:

- The principal concern was the condition and continuing change in the shingle ridge. Particularly following recent storms, when waves overtopped the ridge, creating sediment fans into the Lagoon behind.
- That the edge of the land behind the Lagoon was at least in part made of fill material, which would be rapidly eroded under wave action.
- That wave overtopping would cause flooding to Beach Road properties and to the village behind Beach Road.
- Concern was expressed that the whole beach frontage to the west of Kingston was subject to significant erosion, and that there was an overall loss of sediment within the shoreline system.
- There was a belief that changes in tidal currents might be inducing broader scale changes to the whole frontage.

In addition, in subsequent communication, It was suggested that far more intensive monitoring should be carried out to enable changes to be determined, if necessary on a monthly basis. There was also concern that possible options for management might have a detrimental impact on flood risk management along the Kingston to Garmouth road, further within the delta section of the estuary.

Figure 1.4, highlights key locations of features discussed above and within subsequent sections of the report.

Figure 1.4 Key Locations referenced within the report.



1.3 Scope of the Review

In addressing the issues discussed above, the study examines the behaviour of the overall regime (*Section 2*). This examines in more detail the past and present behaviour of the mouth of the Spey and the behaviour of the Kingston shingle ridge and the beach to the west. This examination is based on historical maps and photographs, alongside the review of previous studies undertaken for the area.

The study then considers the potential future behaviour of the shore at Kingston, and considers the potential risk to the community (*Section 3*).

A brief outline review of suggested management approaches is considered in *Section 4.*

All this information is then drawn together in the conclusion and recommendations in *Section 5*.

The review has undertaken a review and broad scale analysis of the current situation, with no new modelling. It is recognised, therefore, that the review is based on interpretation and analysis of existing information. There remains considerable uncertainty with respect to the detailed behaviour of the beach and coastal system. This has been highlighted particularly in assessing the risk and in making recommendations. The report does, however, provide a realistic assessment of the possible future scenarios, and forms basis for future detailed decision making.

2 REVIEW OF COASTAL BEHAVIOUR

2.1 Environmental Conditions

2.1.1 Tidal Regime

The Admiralty Tide Tables identify secondary ports covering the study area as being Buckie and Lossiemouth. The astronomic tidal variation for these ports is related to those of Aberdeen. Table 2.1 sets out these levels and also, for reference, provides levels for Nairn and Inverness further within the Moray Firth, based on the standard port of Invergordon.

Table 2.1 Tide Levels

Location	Spring. Range	MLWS (m OD)	MLWN (m OD)	MHWN (m OD)	MHWS (m OD)	HAT (m OD)	Note:
Aberdeen	3.7	-1.65	-0.65	1.15	2.05	2.55	Standard port
Buckie	3.4	-1.4	-0.5	1.1	2	2.5	Secondary port
Lossiemouth	3.5	-1.5	-.0.5	1.1	2	2.5	Secondary port
Nairn	3.6	-1.4	-0.5	1.2	2.2	2.8	Secondary port
Inverness	3.9	-1.55	-0.55	1.35	2.35	2.95	Secondary port
Invergordon	3.7	-1.5	-0.6	1.2	2.2	2.8	Standard port

Notes: All values in metres. Levels to Ordnance Datum

Chart Datum correction:

- Aberdeen and Inverness -2.25m, - Buckie, Lossiemouth, Nairn & Invergordon -2.1m

Normal tides across the frontage are therefore consistent between Buckie and Lossiemouth, with tidal range increasing within the Moray Firth, as might be anticipated as the tide is confined within the narrowing firth. The time difference on spring tides between Buckie and Lossiemouth is typically 5 minutes, with tides delayed by 15 minutes at Inverness.

2.1.2 Extreme Water Levels

SEPA have undertaken a study of extreme water levels covering the coast of Scotland. Extreme water levels are a combination of normal tides, superimposed by surge conditions generated by meteorological conditions. Extremes are expressed as a probability of occurrence (the likelihood of any water level occurring in any year). This is frequently reported as a return period of occurrence, while recognising that such levels could occur at any time. The extremes for the study area are presented in Table 2.2.

Table 2.2 Extreme Water Levels

Location	Return period (1: years)						
	1	2	5	10	50	100	250
Spey Bay	2.62	2.69	2.77	2.84	2.97	3.03	3.11

Notes: All values in metres. Levels to Ordnance Datum

Typically, on more frequent events, water levels may be in excess of 0.5m above normal tides, increasing to 1m in excess of mean high water spring on a 1:100 year event.

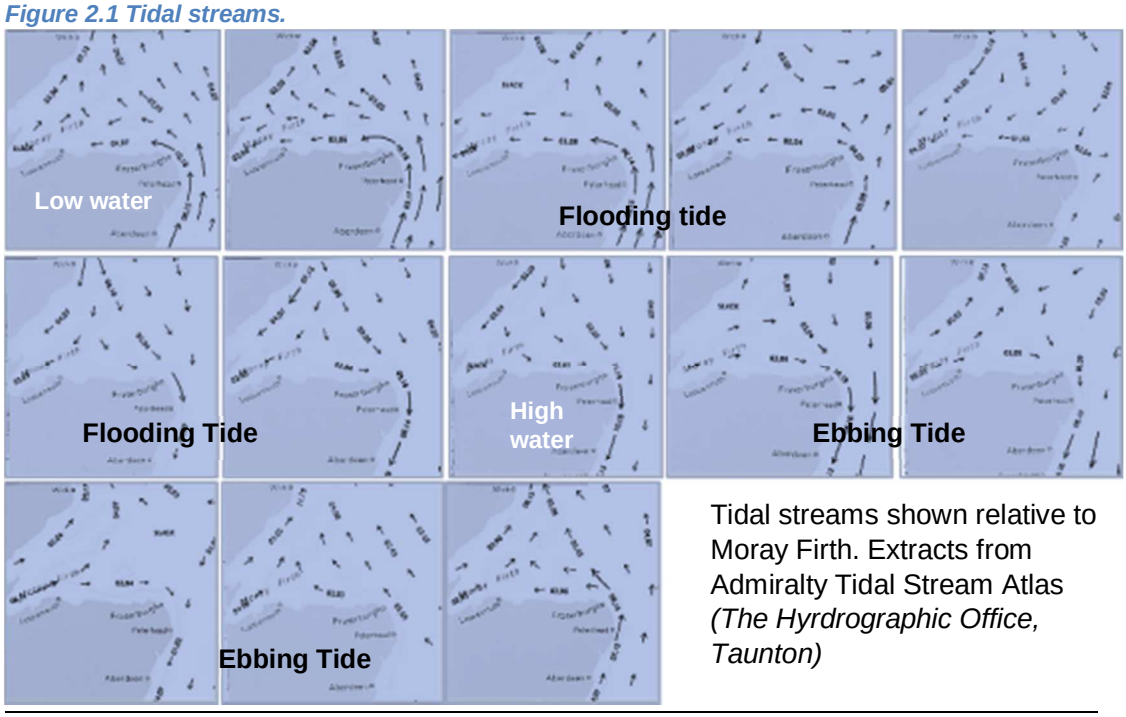
2.1.3 Tidal Currents and River Flows

Changes in flow rate in the river can occur rapidly. Typical long term average flow is reported as being 64 cumecs (Aberdeen University, *Boat O' Brig gauge*), with mean annual peak flows in the order of 300 cumecs (Babtie 1995). Notable extreme conditions events have been recorded or estimated for 1829, 1956, and 1970, with peak flows of 1917 cumecs, 968 cumecs and 1675 cumecs, respectively. More recently peak flows were recorded in February 1990 and January and September 1993 (Royal Haskoning) of 649 cumecs and 690 cumecs. Under extreme flows the river will have a major influence, locally, on the tidal flows more generally within the nearshore area.

Tidal flows into and out of the mouth of the Spey have not been recorded but are recognised to have a significant influence on the width and development of the main channel. The position of the main channel is known to vary; this both alters the position and direction of flow within the inner delta area, and impacts on the coastal regime. While extreme river flow is seen as a major influence on the ebb tide and will influence flows on the flood tide, it is highlighted that, over a normal tidal cycle, there are significant flows both on the ebb from the delta area and on the flood into the inner delta.

The tidal flows across the frontage have been examined, taking information from the Admiralty Tidal Streams Atlas (Figure 2.1. *The Hydrograph Office, Taunton*). Spring tide flood flows, associated with the east to west flooding tide into the Moray Firth, typically reach 0.8 knots (0.4 m/sec) within the nearshore area. The ebb flows (west to east) are typically lower at 0.6 knots (0.3 m/sec). The pattern of flow over the tide also indicates a longer period when flow is from east to west. This is shown in the figure, with flows indicated over the tidal cycle over the larger area. Local discussion suggested more variable and higher flow rates across the frontage. It is reported (*Coastal Cell Research SNH 2000*) that, due to the low tidal flows, wind and wave induced currents will have a significant influence on nearshore current velocities.

Figure 2.1 Tidal streams.



Tidal streams shown relative to Moray Firth. Extracts from Admiralty Tidal Stream Atlas *(The Hyrdrographic Office, Taunton)*

2.1.4 Wind and Wave Climate

The dominant wind direction is from the southwest sector, generally from the land towards the sea. The local wind patterns from this direction will be significantly altered by the topography of the land, tending to funnel winds through the valleys.

There is, however, significant occurrence of wind from the offshore directions, from the northwest and north east. The occurrence of winds for offshore directions was reported in the Spey Geomorphological Review (Babtie 1994) and wind roses are shown for the period 1976 to 1988 (Figure 2.2) and 1990 to 1992, highlighting the variability over different periods of time.

Due to the longer fetch length (the fetch over which the wind will generate waves impacting on the coast), the dominant average offshore wave direction within the outer Moray Firth, is from the north northeast sector. An analysis reported in Coastal Cells in Scotland, Cell 3 (*Coastal Cell Research, SNH, 2000*) is shown in Figure 2.2a. Swell waves occurrence is also reported (Figure 2,2b). Swell waves are longer period waves generated outside the local area.

Wave direction will tend to change as they approach the shoreline. The general bathymetry gradually shelves in to the shore and waves will tend to be modified, approaching the shoreline more normally.

2.2 Sediment Supply and Sediment Transport

Over the geological timescale, sediment has tended to be supplied to the shoreline as a reworking of sediments in the nearshore area (*Coastal Cell Research, SNH, 2000*). Contemporary sources are from the slow erosion of the shore, principally reworking of the major shingle source to the west of the Spey. The Spey, itself, is a significant source of sediment. It has been estimated (*Babtie 1994*) that the Spey can provide, on average 19,000 to 32,000 m^3 per year.

Along the general shoreline, sediment movement is principally determined by wave action. Overall, it may be seen (Figure 2.3) that the shoreline is relatively well aligned to the average wave direction (i.e. the average energy of the waves runs up the beach). It may also be seen from Figure 2.3 that there is significant spread in wave direction. For any specific wave condition, this will move sediment either to the west or to the east. Typically over a year some 30,000 m^3 may be moved in either direction (gross sediment transport). On average (net transport), there is a slight bias towards the west (slightly more sediment is moved to the west as compared to movement to the east). This gives rise to an average net drift of around 3000m^3(Babtie 1994). This will vary in any year and will vary along different sections of the shoreline, particularly around the mouth of the Spey, where the movement of sediment at the mouth of the river is dominated by flow into and out of the estuary. Where there are changes in the orientation of the shoreline, this also gives rise to different drift rates. .

This pattern of sediment movement is summarised in Figure 2.4. It has to be understood that the interaction between the shoreline system and that associated with the mouth of the estuary, critically depends on the location and orientation of the entrance channel. This entrance channel is undergoing continual change.

Figure 2.2 Offshore wind climates 1976 to 1988, variation for 1990 to 1992. (Babtie 1994)

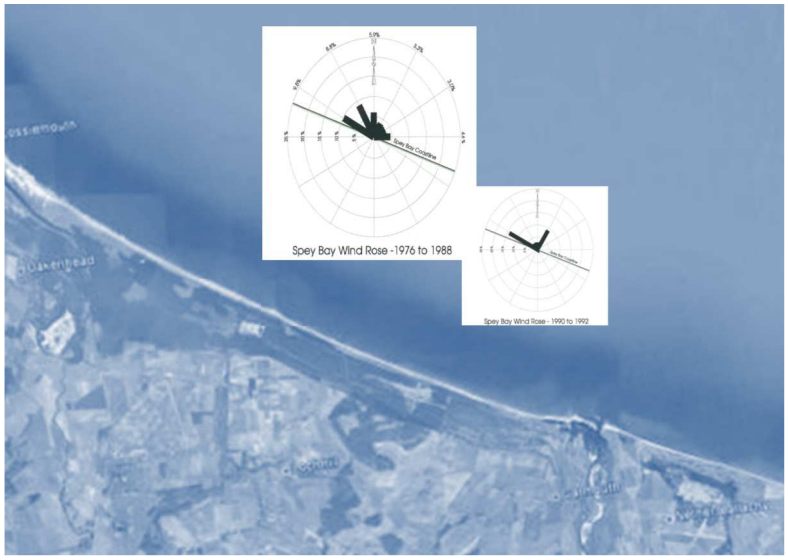


Figure 2.3a Wave Climate - Outer Moray Firth. (SNH 2000)

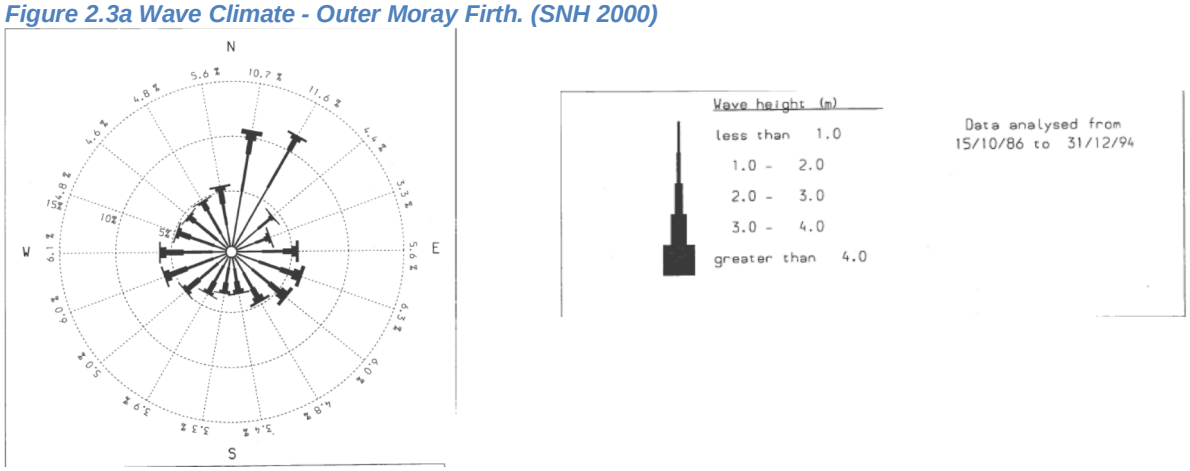


Figure 2.3b Swell Wave Climate - Outer Moray Firth. (SNH 2000)

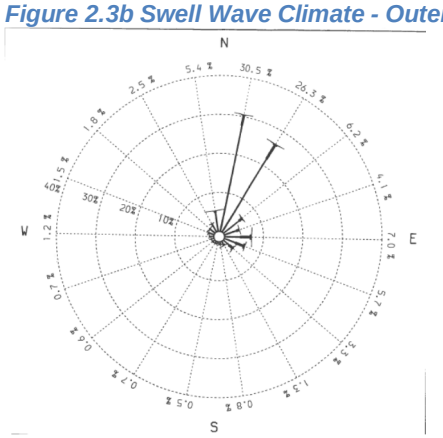
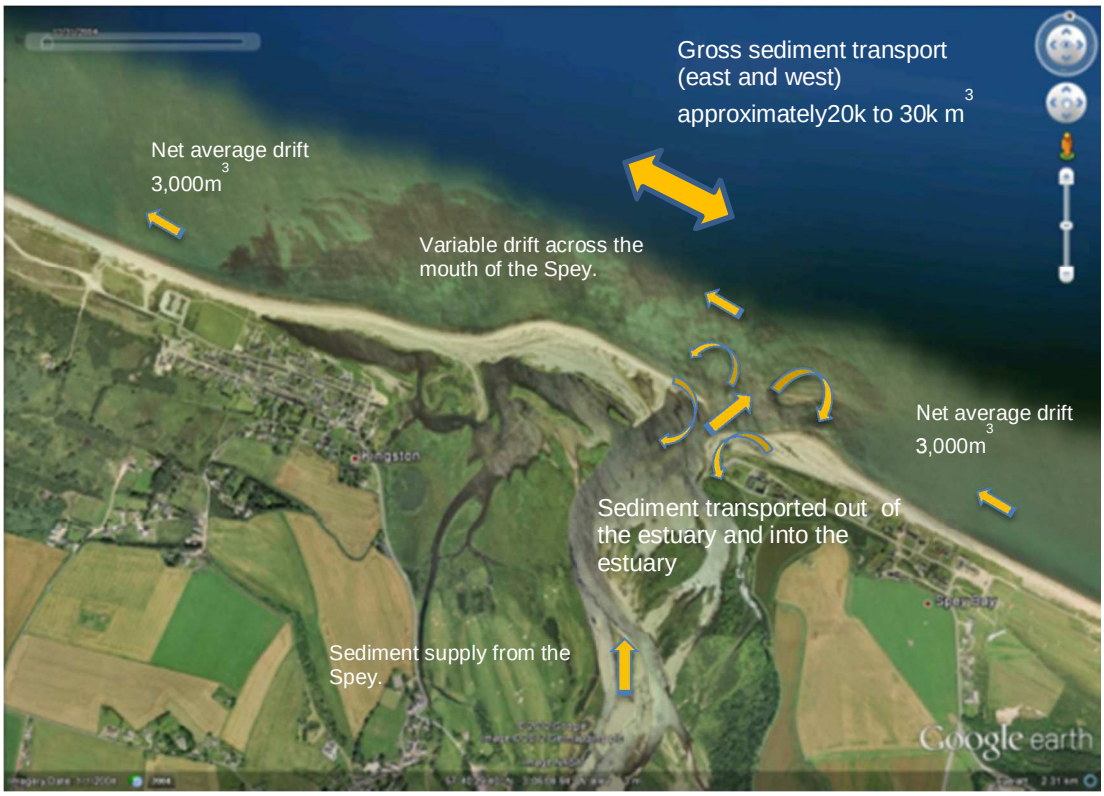


Figure 2.4 Synopsis on Sediment Movement



There is a significant step in the shoreline associated with overall mouth of the river. This is clearly seen in Figure 2.4. While the supply of sediment from the river may in part explain this step, there is also some indication of harder material making up the sea bed in this area. This would be consistent with a terminal moraine, tending to hold the shoreline forward over this area of the coast.

2.3 Climate Change and Sea Level Rise

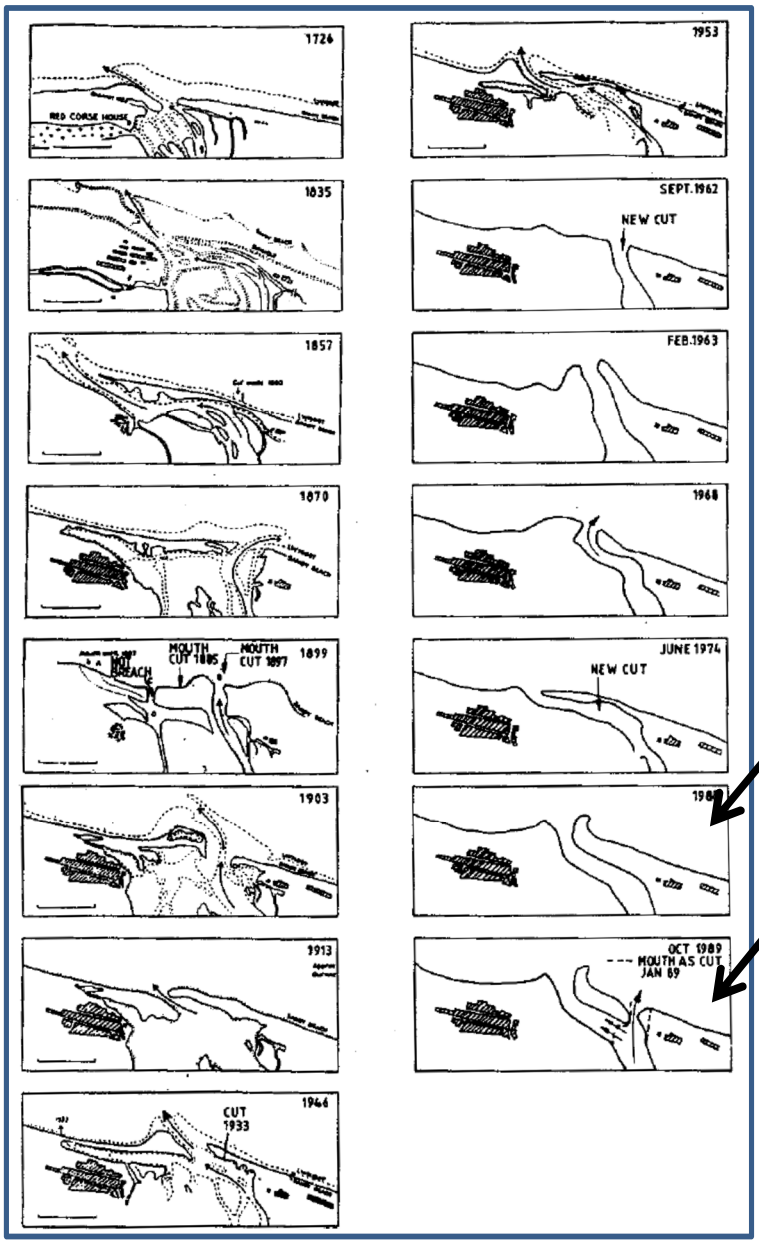
The general landmass in the area is undergoing uplift. It has been assessed that this is of the order of 0.5mm/year. In the past this has compensated for general sea level rise due to climate change. However, with anticipated future sea level rise, the rate of rise of tidal waters would be greater than the rate of uplift of the land. There would therefore be net sea level rise. This will increase pressure on the coast, tending to result in faster roll back of the shoreline and increased erosion, as well as the potential for increased flooding.

2.4 Historical Change

As highlighted earlier (Figure 1.1) the whole shoreline system under goes substantial and rapid change, over months, years and decades. There are clear long term trends underlying more local cyclical patterns of change.

The principal changes in the position and evolution of the Spey are shown in Figure 2.5,

Figure 2.5 Historical Change at the Mouth of the Spey



Analysis of changes from historical maps (*Grove 1955, K. Riddell, T Fuller 1994*)

Subsequent air photographs

Although Figure 2.5 does demonstrate the general westward movement of the entrance channel and subsequent breach or forced breach (excavation of a new channel to the east), it has to be recognised that major change can occur on a far more rapid timescales. This is highlighted between 1991 and 1998 and again in the recent photographs covering 2010 and 2012.

Prior to the Cut shown in 1962, the main channel is reported to have lain closer to the village of Kingston and, during this period properties to the western end of Kingston were lost due to erosion. It is suggested (*K. Riddell, T Fuller 1994)* that the movement of the entrance channel is both due to the weak net drift to the west at the coast but is also determined to a degree by changes in the channel positions within the inner delta area.

Associated with the position of the entrance channel, there is a tendency for the development of a local ebb tide delta at the shoreline. Sediment is swept out through the main channel and deposited either as banks to either side of the channel or as a bank across the entrance to the channel. On the ebb, sediment is drawn into the estuary as spits.

Sediment deposited on the ebb in the nearshore area is reworked by wave action, tending to push sediment back onto the shore. This typically results in a growth of the beach to either side of the entrance. When the entrance channel is in its easterly position this tends to draw the beach forward in front of Tugnet, as shown in the most recent air photograph (April 2012). The growth of the beach to the west of the entrance tends to be more local, such that at present there is a relatively healthy spit head immediately to the west of the entrance.

When the channel entrance is in its more westerly position, such as in July 1988, the beach in front Tugnet has tended to narrow. The beach or shingle ridge in front of Kingston tends to benefit when the entrance channel is further to the west. The beach was relatively healthy during 1988. If the main channel moves hard over the west (as in 1857 and again during the late 1950's/1960's), the channel can erode in front of the village, although creating a shingle bank in front of the village seaward of the channel. Since 1988, the shingle ridge in front of Kingston has narrowed and the ridge has moved landward. This is typical of the cyclic change associated with the change in position of the main channel.

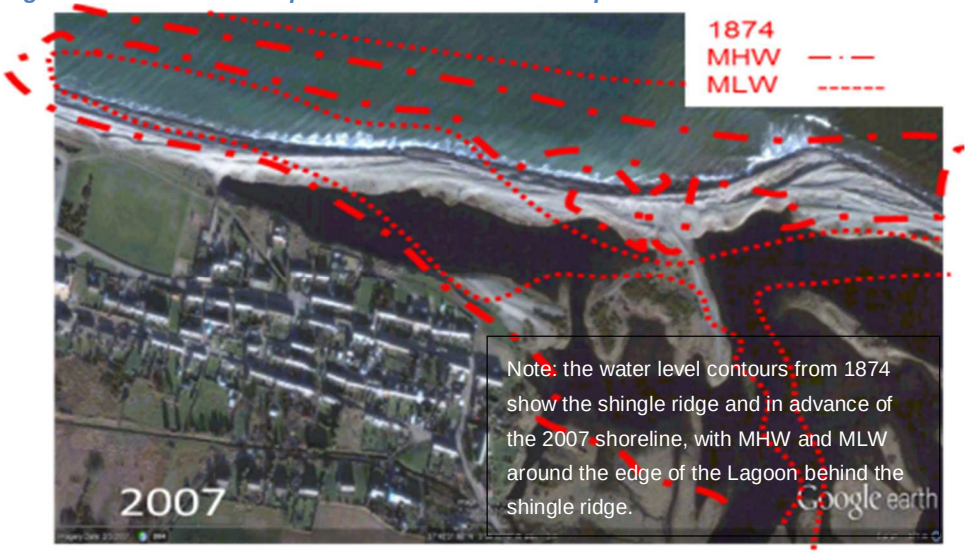
It was around this time (1988) that rock armour was placed in front of Tugnet. It is stressed that this action was in response to erosion caused by the narrowing of the beach, due to the change in position of the entrance channel. The subsequent growth in the beach in front of Tugnet is as a result of the repositioning of the entrance channel, not as a result of the construction of the rock revetment.

The more recent air photographs indicate the old positions of the entrance, evidenced by former spits and the Lagoon in front of Kingston. It is uncertain when the Lagoon was formed but this might date back to when the channel was in an extreme westerly position in the mid 1800's. It is uncertain whether the Lagoon formed the main entrance channel during the 1960's. The image of 1953 clearly shows the presence of the Lagoon and the spit, apparently formed at that time, in a similar position to that shown in more recent photographs.

Figure 2.6, shows a comparison of water level positions in 1874 (taken from an historic map) overlaid on the position of the shoreline in 2007. While it is evident that the shingle ridge shoreline directly in front of Kingston has moved back since its position in 1874, further east the position has remained relatively constant.

It is, however, noted that the beach to the west of Kingston has moved back significantly. This is a point made by local residents, arguing that the whole beach to the west is eroding landward. It should be noted that the inner shoreline as defined by the landward side of the Lagoon, has suffered far less erosion. This does suggest that the shoreline in 1874 still benefited from the deposition of shingle at the down drift end of the old channel. It may be concluded from this that, while erosion to the shoreline to the west of Kingston is clearly occurring, the long term rate of erosion may be significantly less than might be suggested from the comparison shown in Figure 2.6.

Figure 2.6 Indicative comparison of MHW 1874 with position of coast 2007



The other conclusion that may be drawn from the brief discussion given above, is that the movement of the entrance channel is probably a significant factor in distributing sediment across the frontage associated with the mouth of the Spey. It seems probable that, as the entrance moves to the west, sediment associated with the entrance is moved west. When the entrance switches back to the east, sediment is left on the western side of the Spey Mouth system.

Some of this sediment will be redistributed along the shoreline to the east, reforming into the banks associated with the entrance channel. However, a substantial amount of sediment would also continue further west feeding the main beach to the west. As part of this process, there will be a general roll back of the shingle ridge fronting Kingston. This is the current process cycle that is being seen at work over the last two decades.

When the most recent works were undertaken to cut a new channel close to Tugnet there remained a significant volume of sediment in front of Kingston (Figure 2.7 1991). This sediment has gradually been redistributed to the east and to the west, narrowing the ridge as shown in Figure 2.7 (2012). This local change is examined below.

Figure 2.7 Comparison of Kingston shingle ridge 1991 and 2012

2.5 Change Local to Kingston

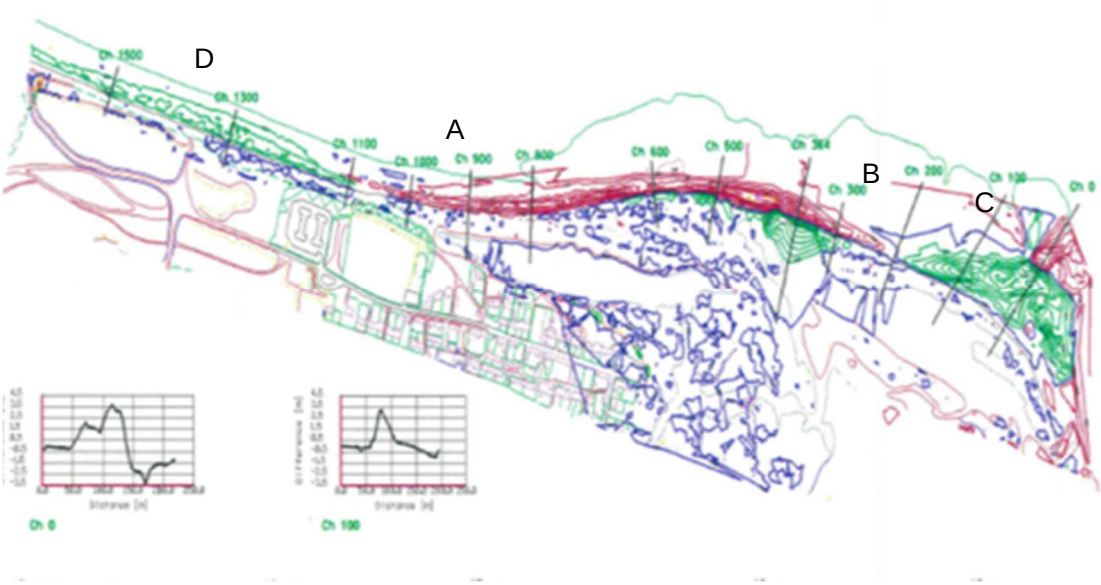
2.5.1 Evidence of Change

1990 to 1994

By 1990, there was concern both due to the erosion at Tugnet and that there was erosion principally to the western end of the shingle ridge in front of Kingston. Alongside specific protection works undertaken at Tugnet, a detailed study of the main frontage was undertaken at this time. This was reviewed in 1994 using survey information taken between 1990 and 1992.

Figure 2.7, shows the change in volume of the beach in front of Kingston.

Figure 2.7 Comparison of Kingston shingle ridge 1990 to 1992
(note: red areas show erosion, green areas show accretion)



Particular concern was expressed at the erosion to the western end of the ridge (point A in Figure 2.7) and the possibility of a breach (point B). It was noted that the main convex

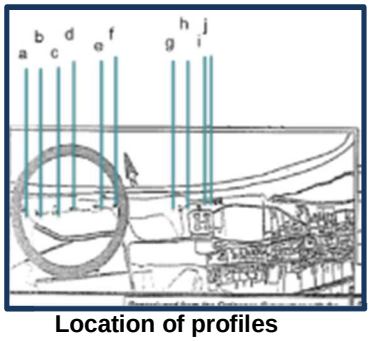
face of the shingle ridge was eroding and there was concern at that time that the ridge generally could breach.

It is noted that there was growth of sediment to the western side of the entrance channel (point C) and also growth in the beach area to the west (point D).

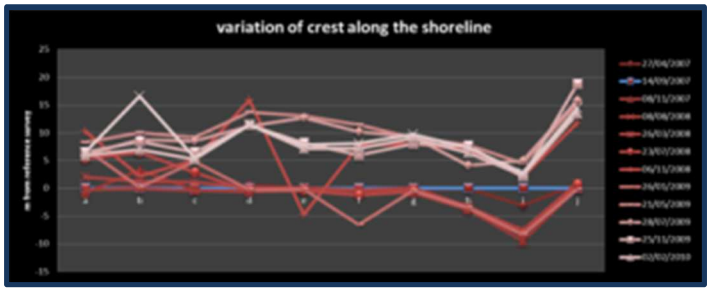
2007 to 2010

Although many of the specific concerns expressed in the 1994 report were not realised, there has been a continuing pattern of change to the frontage. During the mid 2000's, there was growing concern over erosion immediately to the western end of the village. Monitoring of this area was set up with the position of the beach crest being recorded at specific profiles. The results of this monitoring between 2007 and 2010 are shown in Figure 2.8.

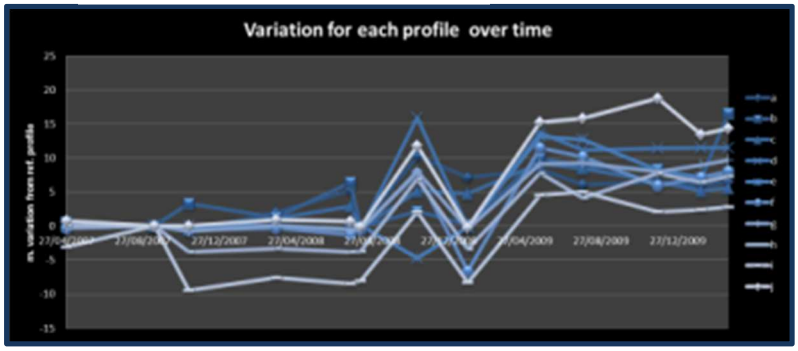
Figure 2.8 Comparison of crest of beach west of Kingston 2007 to 2010



Location of profiles



Variation along the shoreline:
This plot shows the variation forward (accretion) and landward (erosion) from a fixed point in time (09/ 2007) at each profile over time.



Variation for each profile:
This plot shows the variation in the position of the crest over time for each profile.

This shows that initially profiles at the western end of the area remained relatively stable but at the eastern end, in front of the car park, there was significant erosion of up to 10m in places. By the beginning of 2009, through to 2010 all profiles had moved forward with profile "i" changing from a crest position that had retreated, in 2007, by nearly 10m, to a position forward of the base line by nearly 5 m by 2010. While, as demonstrated in evidence given at the site meeting, there is clearly long term erosion of the beach generally to the west of Kingston (discussed below), this erosion is variable and, over the monitoring period covered above, this would appear generally to have been a period of accretion to the beach immediately to the west of Kingston.

Present monitoring 2010 – on-going

As the overall shingle ridge has eroded and moved landward, more detailed monitoring has been carried out. This has involved a full topographic survey of the ridge. Surveys are being taken on a quarterly basis and the extent of the survey is shown in Figure 2.9.

Figure 2.9 Monitoring Survey area and position of cross sections discussed in this report.

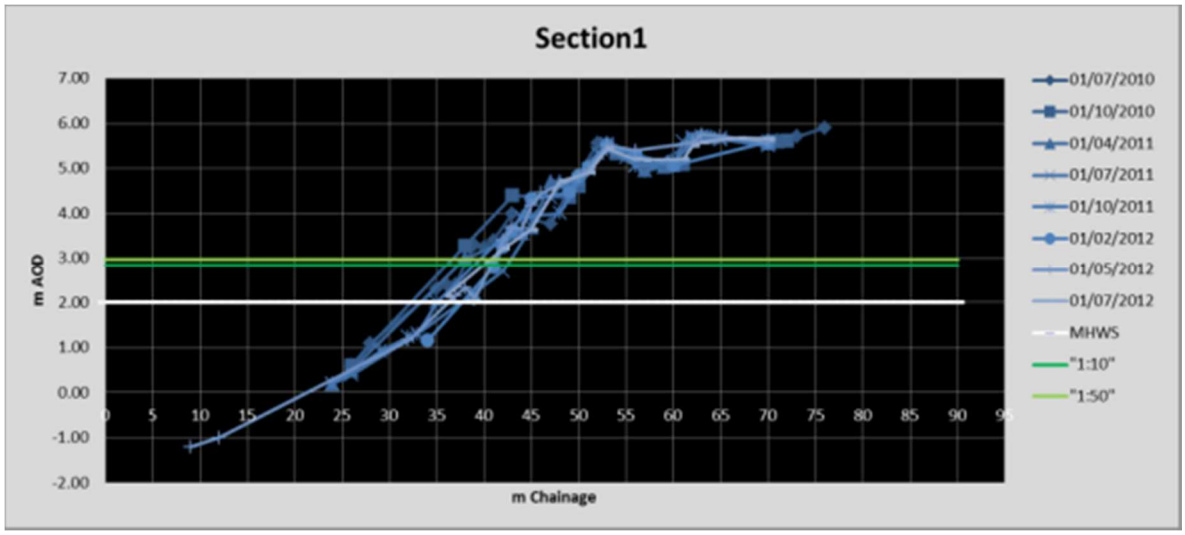
A series of cross section profiles are generated from the survey. This report has focussed on just six of the eight cross sections shown in Figure 2.9; these being sections 1 – 5 and section 7.

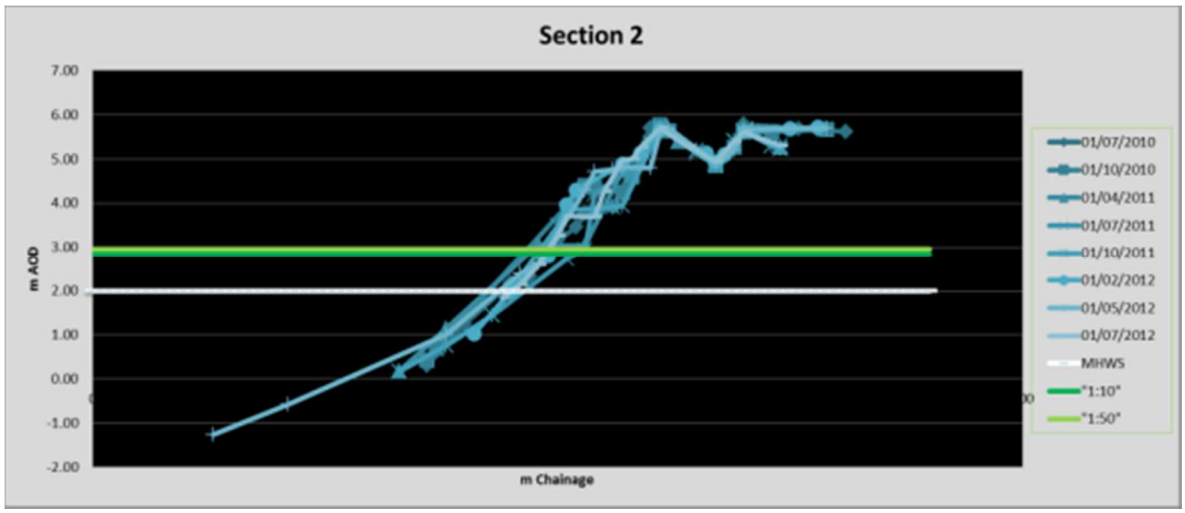
Sections 1 and 2 are taken through the beach to the west of Kingston, in a similar position that was covered by the monitoring in 2007. It was also in the area in 1990 that there was considered to be concern from erosion. The comparison of profiles for these sections is shown in Figure 2.10. The most changeable area of the beach is at the main tide level, with significant variation up to a level of around 4.5m AOD. The crest of the beach shows some change to the two principal storm ridges between 5 and 6m AOD.

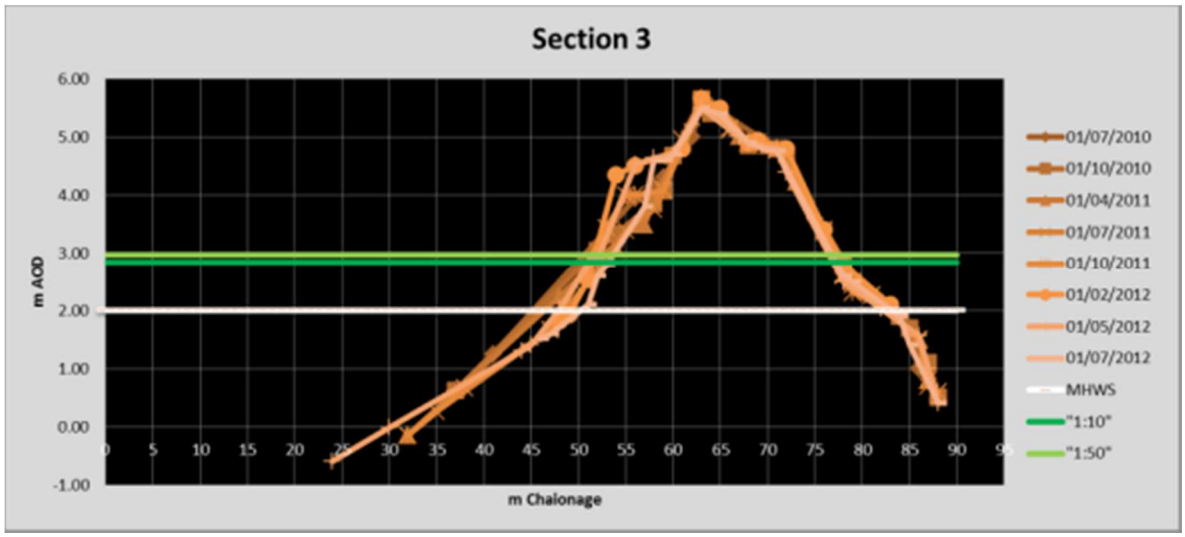
Overall it can be seen that while the beach on the front face has possibly varied over time by as much as 10m, there is little consistent erosion or accretion. This is similar to behaviour seen earlier from monitoring in 2007 to 2010.

With Section 3, also shown in Figure 2.10, there is a similar pattern with respect to water levels with maximum movement around the mean high water spring (MHWS) level. Section 3 is at the point where the shingle ridge starts to run in front of the Lagoon.

Figure 2.10 Comparison of survey cross sections for sections 1, 2 and 3



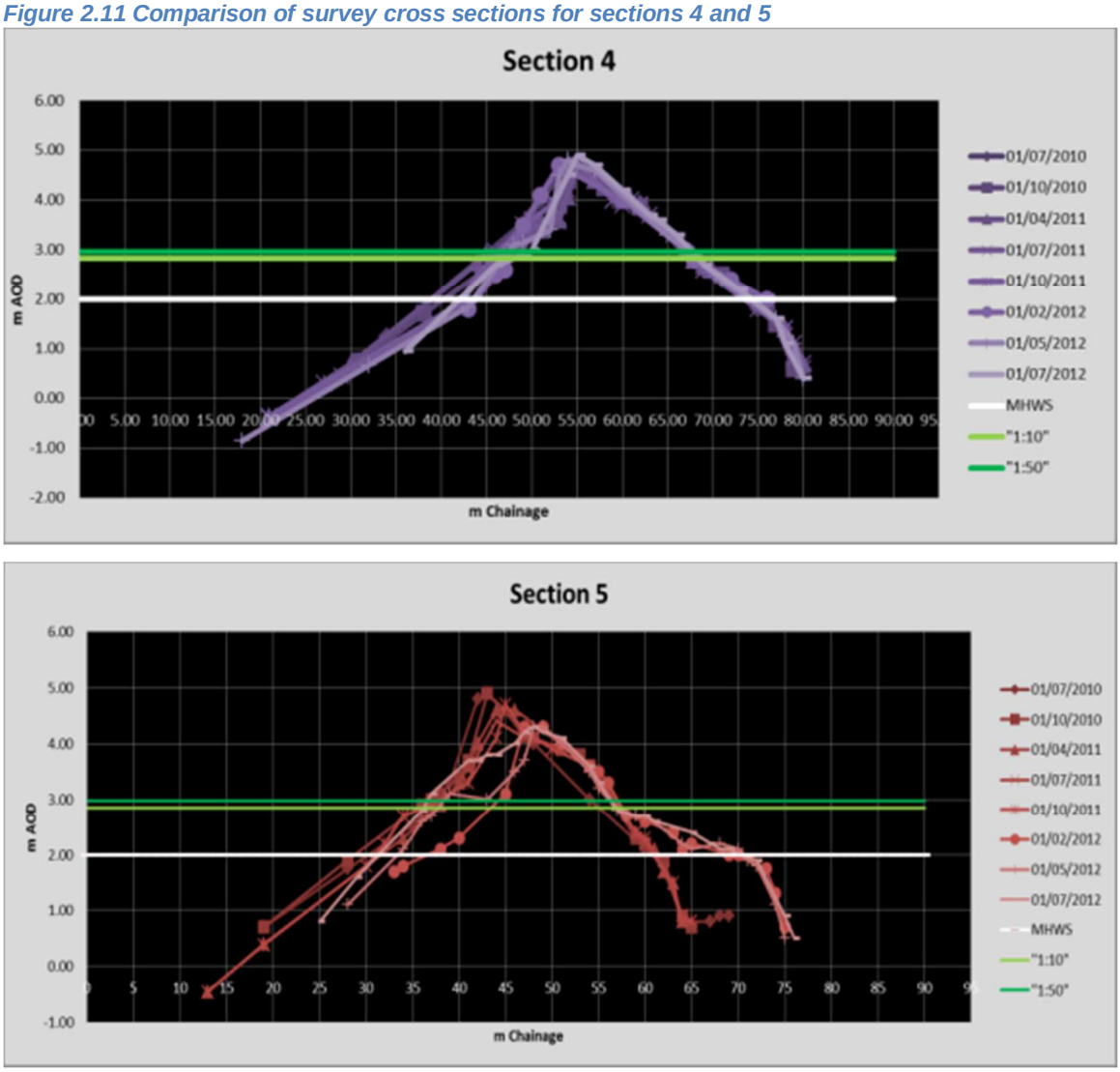




The process of steepening and slackening can be seen around this active tidal level on the beach face, particularly over the last six to nine months. As the beach steepens material is mounded up the beach as a new storm crest.

Section 4 and 5 (Figure 2.11), both lie on the main section of the ridge in front of the Lagoon and the village.

Figure 2.11 Comparison of survey cross sections for sections 4 and 5

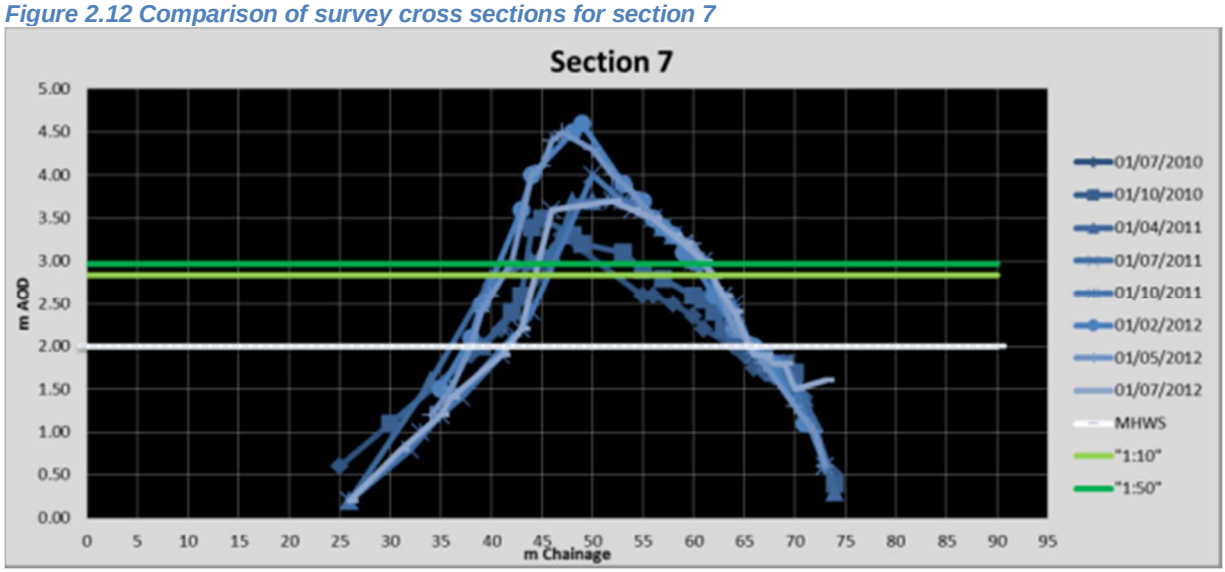


It may be seen that the crest level is lower than sections further to the west. For section 4, the trend over the last six months (Feb. 2012 to July 2012) has been for steepening of the upper beach, slightly raising the crest with erosion to the main beach face. There is little evidence of significant over wash of the crest at this section, although it is recognised that local over wash has occurred in the area. There remains a substantial width of sediment (in excess of 20m) forming the ridge at the level of the extreme water levels shown on the profile.

Section 5 shows a lowering of the crest over the last year. In particular, the profile taken in January 2012 shows a substantial loss of the upper front face with much of this sediment driven back across the crest to build on the landward face of the ridge. Since February 2012, the front face of the ridge has rebuilt, although at present the crest has not increased significantly. The net effect of change over the last year has been for a slight movement back of the crest (by about 5m), coupled with an overall increase in the width of the ridge by a similar amount. While immediately after the storm that occurred during December 2011, the width of the ridge (measured at the extreme water levels) reduced from 20m to about 12m, the width over the last 6 months has rebuilt to around 20m. As significantly, the width of the ridge at normal tidal level (MHWS) has increased from about 30m to around 40m. The implication is that, despite the lowering of the crest during the storm, there has been sufficient sediment available to rebuild the ridge in a slightly set back position. This demonstrates classic shingle beach behaviour of rolling back.

The final representative section take in this review is section 7 (shown in Figure 2.12). The section is slightly to the east of the Kingston village, in a position considered in 1994 as being vulnerable to breach.

Figure 2.12 Comparison of survey cross sections for section 7



This section shows very clearly the natural variability in the behaviour of the ridge along its length, highlighting how different sections respond differently and how this is linked to the changes in a broader sense seen along the whole frontage.

During the early period of the monitoring, the crest level was quite low, around the 3.5m AOD level. Between 2010 and 2011, there was a significant shift landward of the crest, depositing sediment on the back face and building the crest to around 4m AOD. Over the winter 2011/2012, the front face of the ridge accreted and built to a level of 4.5m AOD (this compares to erosion and over wash in section 5). Since May 2012 the front face of the beach has eroded and the crest has reduced in level to around 3.7m AOD. Importantly, and coupled to the over wash during 2010/2011, the overall crest width has increased (measured at the extreme water level) by nearly 10m.

Overall, the monitoring is showing a reasonable degree of stability of the beach to the west. Across the main ridge, there has been a typical retreat of the ridge by possibly some 5m during storm activity, although this has been restored to a degree over the last 6 months such that the net rate of retreat is possibly only in the order of some 2m since the start of the monitoring. Associated with this retreat and the natural over wash, the basic integrity of the ridge and the width of the crest has been maintained.

The monitoring to date has shown that there is a substantial volume of sediment being reworked along the frontage, such that the ridge is able to repair itself under normal storm and wave action.

Some sections of the ridge are vulnerable to over wash. On a major storm event, with higher water levels, there would be significant overtopping and over wash of sediment. This would tend to reduce the crest level but would typically increase the width of the ridge at a lower level. The strong indication, therefore, is that a complete breach of the ridge is unlikely under normal storm conditions. The ridge is, however, likely to continue to roll back. This assumes that there will not be a major change in sediment supply such as might occur if there were a substantial change in the position of the main entrance channel to the Spey.

Anecdotal data

Local residents highlighted concern over the retreat of the long section of beach to the west of Kingston. There is limited direct measurement along this frontage, although local monitoring has been undertaken based on photographs. The area is outside the scope of this review but is useful in assessing the back ground change, providing a broader context to the concerns with respect to the shingle ridge in front of Kingston.

Recent photographs show how at the Targets, and further along the beach at Boar's Head Rock, the beach has undergone significant change. In the case of the former area, the old tank traps, presumably placed behind the shingle ridge during the late 1930's, are a useful reference point for assessing change. Figure 2.13 show a sequence of photographs in the area.

It was reported that the tank traps were behind the shingle ridge in the past. Underlying Figure 2.13, is an aerial photograph (2007) showing the position of the Targets and Boar's Head Rock. Looking in detail along the frontage it may be seen that the general shape of the West Beach is formed of two very shallow bays, with a slight growth of the beach forward just to the west of the Targets. To the west of this slight forward point in the beach, the tanks traps are set back further than those to the east (closer to Kingston). The alignment of the tank traps at the Targets tends to be curving slightly seaward, this aligns well with the old ridges of shingle visible behind the current shoreline. The suggestion is that the shoreline area to the east of the Targets is formed in association with the way in which the shore adjusts under the influence of the shape and supply of sediment from the area around the Spey. The shoreline to the west of the Targets acts more as a simple open beach frontage.

Both sections have slowly eroded and both sections will change depending on specific wave conditions and periods of change in overall wave climate. While the behaviour of the beach at the Targets is potentially more sensitive to sediment supply from the area

of the Spey, the change in the beach at this location does not appear to pose a significant risk to the village of Kingston.

Figure 2.13 Photographs at the Targets

2.6 Overview

The area of shoreline associated with the Spey is recognised to be complex, subject to rapid changes on a day by day basis and over longer periods of time. There are, however, clear dominant features of behaviour that influence the overall system. It is within this overall behaviour that more local changes can then be interpreted.

The main influence on the behaviour of the frontage is linked to the position of the main entrance channel. Associated with this feature is the major redistribution of sediment linked to the way in which sediment builds around the entrance channel. In effect, as the position of the entrance moves, large volumes of sediment are redistributed across the area. Locally these large volumes are then manipulated by wave action, creating the banks and ridges associated with the frontage.

There is a trend for the entrance to move to the west, but then either artificially or due to natural processes, a breach develops further east. This general westerly movement is not continuous. With the relatively high gross movement of sediment (east and west), the weak westerly net drift may be lost over a period of time.

At any point in time, the position of the entrance tends to draw sediment in to its influence from both the east and the west. Further west of the entrance, in sections of the beach outside of this influence, sediment will tend to move in a net westerly direction. This appears to have been the situation over the last two decades with respect to the Kingston shingle ridge.

The entrance was over towards Kingston in the late 1980's. When the channel repositioned to the east, a large volume of sediment was left in front of Kingston. Outside of the influence of the entrance channel, this sediment was redistributed both back to the east and to the west, feeding the West Beach. As the width of the ridge narrowed, the local natural response of the ridge has been to roll back.

The West Beach initially benefited and continued to benefit through to the present time and the current condition of this beach is relatively healthy but possibly narrower than it was. The main shingle ridge has narrowed to a point where there is more regular over wash. However, over the last three years it has maintained its overall integrity. The future development of the frontage will depend of future change in the position of the entrance channel; this is discussed in relation to the potential risk to the village of Kingston in the following section.

3 FUTURE BEHAVIOUR AND ASSESSMENT OF RISK

At present the Kingston shingle ridge is narrow and relatively low and is rolling back. Under present conditions, with the entrance channel to the Spey remaining to the eastern side of the estuary frontage, this process of roll back is likely to continue. Under this scenario there is likely to be limited longshore drift feeding the ridge and the principal source of sediment comes from local reworking of sediment along the ridge and some supply feeding the ridge from the lower foreshore. This scenario is discussed in more detail below.

A second scenario would be that the entrance channel moves gradually to the west, bringing with it the movement of a large volume of sediment; replenishing the Kingston frontage. Clearly, depending on how far the entrance moves, there could be a reopening of the Lagoon, with the potential for increased direct flow pressure on the Kingston frontage in front of Beach Road. Such a development is not seen as being linked to the behaviour of the Kingston ridge. Even if the ridge rolled back across the Lagoon, any sustained breach would require a repositioning of the channels within the inner part of the estuary. Any actual initial breach in the general frontage, forming a new entrance channel is likely to occur to the east of the old spit (Figure 1.4), to the east of Kingston.

Without significant change in the position of the entrance channel, the Kingston ridge will continue to roll back. The evidence is that this will occur progressively, with storms tending to cause over wash of sediment to the back face. Sediment is then drawn from the front face rebuilding the crest in a slightly set back position. At present this process might typically be at rate of some 5m to 10m over a 10 year period. The volume of sediment at present, within the bank, is such that it is unlikely that a full breach would develop. Figure 2.14 shows the pattern of development of the ridge based on typical present day rates of retreat. This can only be indicative, as there would be local variation and the process may be affected by broader scale change across the wider area.

Figure 2.14 Indicative roll back of the shingle ridge based on present day rates.

Even with such caveats, Figure 2.14 provides a realistic scenario. It can be seen that as the ridge rolls back, at the western end, the ridge aligns itself more with the position of the West Beach. This beach is likely to set back at a slower rate than the main ridge, as evidenced by the monitoring.

At the eastern end of the ridge, the ridge would gradually incorporate additional sediment at present within the old spit. Clearly as one moves eastward, the shoreline position is more influenced by the position of the main entrance channel to the estuary.

Should a major storm event occur (1:50 year or greater) this would tend to flatten the ridge moving more sediment to the rear. This would increase the rate of roll back. While this could result in more wave action across the ridge during the actual storm event, sediment would tend to be pushed up against the shoreline in front of Beach Road. The experience during the major storm of 1953 (well in excess of a 1:50 year return period) on the east coast of England, was for a flattening of shingle ridges with significant over wash of sediment behind. The main breaches during this extreme event on the east coast occurred where embankments or dune and shingle ridges formed a barrier protecting significantly lower land lying behind. The breach was then developed as water flowed into and across the low laying land. This would not be the case at Kingston, where land levels to the front part of the village are substantially higher than extreme water levels.

3.1 Assessment of Risk

There continues to be the risk that the main entrance channel moves hard over to the western end of the estuary frontage. This would be a progressive movement west of the channel over many years. Any effort put in to manage this goes beyond the scope of this review. It would not be associated with the changes seen in the shingle ridge in front of the village. It is worth noting, however, that any effort put in to fixing the position of the main entrance channel would be difficult, would have major consequences for the whole system and, if the held hard over to the eastern position is likely to reduce the occasional large supply of sediment feeding the shoreline to the west.

Based on the scenario where there is no major change in the river entrance and, therefore, no substantive increase in sediment to the Kingston ridge, the expected behaviour would be for the ridge to roll back in a naturally controlled manner as discussed above.

On significant storm events, such as seen over the 2011/2012 winter, there will be over wash and overtopping of the shingle ridge. The basic shape of the ridge is highly likely to be retained and as such waves will tend to break on the ridge and flow into the Lagoon. This may set up some wave action across the Lagoon, which could impact on the bank on the far side (along the Beach Road frontage). Such local wave action would not be to the same degree as on the open coast. There is the potential for some erosion of the steep bank, where fill material overlays the natural old shingle bank. However this would not be seen as significant enough to impact upon property.

A full wave overtopping analysis would be required to assess the wave action across a reduced crest of the shingle ridge, and subsequent wave generation within the Lagoon, to determine actual waves impacting on the rear bank. This is beyond the scope of this

review. However, from the photographic evidence of wave overtopping of the ridge under recent storm conditions, it is not considered that wave heights would be high enough to cause significant overtopping or erosion of the earth bank.

On a more major storm the crest of the shingle bank may be lowered sufficiently such that waves travel directly over the ridge and across the Lagoon. The height of the waves would still be reduced but more erosion might occur to the bank behind.

As the shingle bank rolls back over time, the shingle ridge would effectively attach itself as a beach to the western end of the village. This would result in a more efficient and raised profile backed by the land behind. Wave action would tend to dissipate on this beach profile. Further east along Beach Road the ridge would tend to consolidate more, providing a good level of defence to the area behind.

Except in a very major storm, is seems unlikely that there would be any significant damage due to erosion or direct wave action.

Concern has been expressed that water entering the Lagoon, due to overtopping, could result in raising water levels that could cause flooding to the back of the village, along the course of the Drainer Burn. As can be seen from the various air photographs, the Lagoon remains connected to the main inner delta area of the estuary. As such the water level in the Lagoon will be at approximately the same level as the inner estuary and effectively at the same level as sea level. Any wave discharge over the shingle bank would locally raise water levels in the Lagoon and water would flow from the Lagoon through to the estuary, equalising levels.

Therefore, there would be no significant influence on flow or levels in the Drainer Burn. The area remains at the same risk of direct flooding as at present.

In summary, there is seen as being a slight risk on more significant storms for minor erosion of the bank along Beach Road, with the possibility of some overtopping of this bank under such extreme conditions. This could be assessed in more detail but it is considered that properties along the frontage are not at substantial risk.

In the longer term, with sea level rise, there is an increased risk of flooding more generally within the area, and some increasing risk of the whole shoreline setting back with subsequent potential loss of properties. Depending on sea level rise, such an increased risk is seen as coming in to play, typically, 50 to 100 years in the future.

4 POTENTIAL MANAGEMENT OPTIONS

4.1 Scope of Response

Previous studies have suggested various approached to defence and management. These range from Do Nothing through to construction of a revetment to the whole length of the shingle ridge. Bringing these options together, they may be grouped in terms of their function and performance.

4.1.1 Resisting Change

This group of options includes construction of a rock revetment across the whole area, or use of rock more locally to infill vulnerable sections of the ridge. The aim of this approach is to prevent development of a breach, to anchor the ridge in its current position and to prevent substantial overtopping.

It is shown in the above discussion that the ridge is a highly mobile system. It relies on this mobility to transfer sediment along its length, gradually adjust as a complete structure to maintain its overall integrity. Importantly, sediment is seen as being moved both along the ridge but also further to the west and to a degree to the east, feeding into the large banks associated with the main entrance channel. One of the difficulties in addressing local areas of vulnerability is in actually predicting which lengths will be vulnerable in the future. Indeed, it should be noted that from the above discussion of risk, the idea that the ridge will breach is not considered likely.

If works were undertaken in any local location that appears weak, following a storm, this would require import of large rock armour to form a substantial rock revetment. A typical example of the scale of works is shown in the adjacent photograph, taken at Hurst Spit on the south coast. It should be noted that Hurst Spit does not show the same degree of change as that experienced at Kingston. It is also noted that these works tie into a fixed shoreline further to the west and that an offshore breakwater has been constructed at the western end to prevent outflanking. Even within a less mobile location, there has been no build-up of sediment in front of this revetment.

This highlights the difficulty of fixing a mobile feature such as the shingle ridge. By constructing a short section of revetment along one section of the Kingston ridge, the adjacent sections of the ridge would still change and roll back. In fact, because the section of rock revetment would prevent natural distribution of sediment along the ridge as a whole, adjacent sections would become more vulnerable. Under such an approach, there would be a commitment to extending the revetment further along the ridge in response. In effect, by starting to fix the ridge in this way would end up with a commitment to reinforce the ridge over its full length, typically, as a minimum a distance of some 600m.

To limit overtopping such that the integrity revetment is maintained, (noting that the revetment is fixed and cannot roll back) the crest of the structure would need to be substantially higher than the shingle ridge. Alternatively, the revetment would need to be constructed more as a breakwater (protecting the back face). As such, the typical cost of such a structure would be of the order of £15,000 per m (minimum estimated cost of £9M).

The revetment would have a major impact of the behaviour of the whole frontage. It would impact of the behaviour of the shoreline to the east, dislocating the overall movement of shingle along the whole frontage. If the main entrance to the estuary moved further west, there would be the need for further works to withstand and further manage the pressure imposed by the main channel flow. The consequences of this are likely to be: the need for further future management of the estuary, increasing reliance on defence management and gradually forcing the need to clamp down on the natural variation of the whole system. Given the massive forces at work, such an approach is not considered to be sustainable.

The revetment would also reduce interaction between the ridge and the estuary frontage with the West Beach. This would need to be considered in greater detail but could quite possibly, reduce supply to this beach, increasing trends of erosion.

The various options for fixing the coastline in this way are not considered to be technically viable, would be very difficult to justify economically and would drive management of the system in an unsustainable direction.

4.1.2 Modification and Control of Coastal Processes.

It was proposed in 1990, and in subsequent reports, that an offshore breakwater be constructed to the western end of the ridge. The intent was to build the beach and ridge along this area, which was at that time considered to be particularly vulnerable. The further intent was that the sediment would build gradually along the frontage further east, reinforcing the position of the ridge.

Changes in the behaviour of the area over the last 20 years have resulted in a reduction of sediment to the east of the proposed structure. It was recognised in earlier reports that more detailed development of this option would be required, with significant further investigation required.

Any form of breakwater, shore connected, nearshore or submerged, including the use of sunken barges as used in Essex over the last decade, aim to modify the way in which waves approach the coast. This not only reduces the wave height behind the structure but also changes the direction of the waves over length either side of the structure. This tends to draw sediment in to the lee of the structure but with the potential to move sediment from

adjacent beaches. This affect can be seen in the adjacent photograph taken at Borth on the West of Wales coastline.

The example shown, which again is not totally analogous to the situation at Kingston, demonstrates how a series of structures have been constructed, working in unison, to maintain a minimum width of shingle beach. The photograph highlights how nearshore structures build sediment within their lee and where this might then have reduced sediment along adjacent sections of the beach, further structures are constructed to reduce this impact.

In the current situation faced at Kingston, there is significant risk that a single breakwater would draw sediment away from the adjacent beach areas, potentially increasing vulnerability across such a section and reducing the ability of the ridge as a whole to respond to different wave conditions. This could be mitigated through detailed design but it is likely to result in the need for a series of structures over the area.

While this would still allow sediment to move within the control imposed on the shape of the ridge, allowing a degree of natural adjustment, it would still necessarily impose a control on sediment movement along the whole frontage. This could impact both on the beach to the west and on the way in which the shingle ridge further east behaves. One of the significant difficulties in designing such an approach would be in attempting to fully model the system. A model relies upon examining how imposed management affects the way in which an existing system behaves. Given the rapid change seen along the frontage, the problem is in establishing a base model of the existing system. Over time, the changes anticipated in the position of the main estuary channel will change the baseline situation. As the entrance channel moves to the west, so the entrance channel would interact with the control structures in front of Kingston.

This could be overcome by considering different scenarios, or could be addressed by over design of the control imposed on the eastern end of the Kingston frontage. Typically an approach could be taken whereby quite a rigid approach is taken to management in the area of the old spit, effectively separating behaviour of the Kingston frontage from that naturally developing further to the east.

It is difficult to estimate the cost of such works but costs are likely to be in excess of that associated with a revetment.

An alternative approach could be taken, more local to the beach face, through construction of groynes. These would typically be constructed of rock. While this approach would be significantly cheaper, the approach would aim merely to stabilise the present condition of the shingle bank.

The groynes would limit movement along the front face of the ridge, tending to build the face within groyne bays. Without recharge of beach material, while the groynes would strengthen the ridge, there would still be overtopping and over wash of shingle. Since much of the wave energy is relatively normal to the alignment of the ridge, the spacing of the groynes would need to be quite tight. This would depend on the length of the groynes and the degree to which they are shaped at their seaward end. Typically based

on the suggested size proposed by the Community Council, with a length of 50m, spacing would be in the order of 50m to 75m (a total number of around 10 groynes).

There would be concern that the groynes would limit movement of sediment along the beach to the west, quite probably causing erosion at the western end. The groynes on their own would slow the process of change but would not stop the process of roll back. Over time the structures would be outflanked. This could be addressed by combining groynes with a crest revetment but this would significantly increase the cost.

Potentially the cost of groynes and a smaller revetment would be in the order of £3M.

As with other approaches, further study would be necessary to provide detailed design of such a system.

4.1.3 Beach Management

The most obvious approach to management would be in attempting to restore the width of the beach to levels approaching those present in the late 1980's. In the 1994 report it was suggested that recharge volume would be in the order of 70,000m^3 to 160,000m^3. Depending on the initial volume imported, there would be a need for further recharge to take place typically every 10 years. Costs reported for this work in 2006 were between £5M and £8M, with a longer term present value cost in the order of £20M.

While this approach would increase sediment supply generally to the area, avoiding impacts of the beach to the west, the large changes that have been seen in the past, coupled to the high cost makes this approach uncertain.

Local beach management could provide an option, whereby shingle is artificially redistributed across the area. This would need to be developed locally with agreement as to where shingle could be won without damage to the natural system. This would be a responsive approach, determined from monitoring, with the intent to support the natural process of roll back, maintaining the integrity of local sections of the ridge.

Overall, major beach recharge is not seen as a cost effective approach. Local beach management might be viable subject to continued monitoring.

4.1.4 Do Nothing

The above options all consider ways in which the shingle ridge might be managed. The earlier discussion suggests that this is unnecessary and that such major intervention would not be cost effective. Furthermore, the review of options demonstrates that such approaches could have broader consequences that would then need to be addressed.

Under a Do Nothing option, no action would be taken to manage the ridge, to provide additional protection or in undertaking any further monitoring. The assessment of the likely future behaviour of the ridge based on its recent performance, discussed in section 3, indicates that under such an option the immediate risk to property is low. Under very exceptional conditions, the ridge might be flattened during a storm event and this could allow wave action to work directly of the rear bank of the Lagoon. This could give rise to erosion of the upper portion of the bank and could result in a degree of over topping;

properties might be at risk. The probability of this occurring, however, is low and the ridge would be expected to rebuild, if in a position further back than before the storm.

Against such a low risk, the major options considered above would be difficult to justify, particularly considering the concerns expressed above as to their long term sustainability and the potential risk they would impose on management to the broader area.

However, there is acknowledged to be some uncertainty as to the longer term and wider changes that may occur across the whole estuary frontage. As such a Do Nothing approach is not considered fully appropriate. Two further, more responsive options are therefore considered.

4.1.5 Local Defence

Although the assessment of risk does indicate that there is no substantial increase in risk to the village due to the change in the shingle ridge, it is accepted that there is very real concern being expressed by the local community. As such, a further approach to management might be to take a precautionary approach to defence along the landward face of the Lagoon.

Two principal options are considered. The first would assume that there were a major failure of the shingle bank under very extreme conditions. The ridge might potentially be lowered such that the landward bank to the Lagoon is exposed to significant wave action. Should such an event occur, which as highlighted is not likely, then defence to the rear face might need to be constructed. Under these conditions the approach might be to construct a rock revetment along the length of the Beach Road frontage. This would typically be raised such as to reduce the risk of overtopping. Works would extend typically over a length of some 400m, at an outline cost of possibly £6,000/m (total cost approximately £2.5M.). This is considered to be an overreaction to the immediate risk based on the existing condition and probable response of the shingle bank.

A second response might be considered more measured to the inherent uncertainties and potential residual risk. This would assume that, while the shingle ridge could, under extreme wave action be flattened but would still provide a reasonable defence against direct wave action on the bank to the rear of the Lagoon. Under these conditions a practical option would be to encase the rear bank with relatively light, flexible concrete block matting. An example of this is shown from the Suffolk coast at Felixstowe Ferry.

It would be suggested that such works would only be extended possibly over a length of some 200m, providing additional security to properties along Beach Road. The matting could be extended up over a slightly raised earth ridge at the back of the slope, making use of the width of open space generally along the frontage.

The cost of such works would depend on the distance down the slope and the approach taken to toeing in the matting. It is considered that as the ridge retreats back, the shingle beach would provide a suitable toe to the revetment. An outline cost might be in the order of £1500/m (approximate total cost of £300,000).

4.1.6 Do Minimum

This option recognises the uncertainty associated with the assessment of behaviour of the frontage, and the uncertainty associated with the aspects such as storm occurrence. The option would continue monitoring of the area, reporting back findings such that the local community continue to be involved with decisions.

Should the basis for this current review change significantly, then a further review of options would be under taken.

As suggested earlier, one form of management in response to monitoring would be local beach management. In taking this forward, discussions would need to be held with statutory organisations to confirm in advance, and under what criteria donor sites would be acceptable. This would also need to be developed further in identifying, more specifically, what local conditions might trigger specific intervention.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Assessment of the Coastal Behaviour and Risk.

5.1.1 General

The review is based on existing information obtained from previous reports and from on-going monitoring.

The obvious conclusion from the review is that the area is highly complex in its behaviour and is subject to rapid change. Notwithstanding this, the review has been able to identify basic underlying processes that provide a coherent context for assessing the potential risk and the assessment of management options.

The general conclusions are set out below:

- The movement of the position of the main entrance channel to the Spey has a significant influence on the behaviour of the whole area. It is suggested that the movement of the entrance may be significant in transferring sediment across the frontage and that associated with the entrance there tends to be a build-up of sediment.
- As such, the continued movement of the entrance is seen as being an important mechanism whereby, in the future, further sediment would be supplied to the Kingston frontage.
- There is an important link between the Kingston shingle spit and the beach to the west. There is the potential for sediment to move in both directions between these two areas and this maintains an important natural balance.

Associated with the above, it is highlighted that due to the complex nature of the area and the degree of change that takes place, detailed modelling of the area is problematic. Detailed analysis of the area could not be based purely on the existing conditions at any one time. Different configurations would have to be considered, examining different futures. This general uncertainty has to be taken into account in future management.

5.1.2 Specific to the Kingston Frontage

Based on a combination of monitoring undertaken in 1990-1992, 2007- 2010, detailed survey 2010 – 2012 (on going) and general anecdotal information provided by the Community Council, an assessment of recent change across the Kingston frontage has been made. The main conclusions are set out below:

- There has been a substantial loss of sediment from the Kingston shingle ridge over the last two decades. Sediment has been lost most probably to both the east and west shorelines, consistent with the variation from year to year in the wave climate.
- Associated with the loss has been a progressive movement landward of the shingle ridge.
- The ridge is now subject to overtopping and over wash of sediment. While in the past the retreat of the ridge has been largely down to loss of volume, the process now is seen as being a progressive roll back of the ridge.
- Following over wash, the ridge is maintaining its overall integrity and still provides a substantial barrier to wave action entering the Lagoon.

- The rate of retreat is seen as being in the order of 1m to 2m per year. In any single event the lowered crest of the beach may be set back by as much as 5m but the trend is for the ridge to rebuild forward of this.
- The volume of the ridge is seen as being retained and assuming no major changes to the wider frontage, which may restore the ridge to a more advanced position, the expectation is for the ridge to roll back without significant breach into the future.
- On this basis, except in the case of a very severe storm, the ridge will provide protection to the village with no anticipated loss of property, in the immediate future.
- Detailed wave overtopping analysis would be required to confirm this and to assess in more detail the standard of defence provided by the shingle ridge. It is assessed that protection is provided up to a 1:50 year level with the present condition of the shingle ridge
- As the ridge rolls back, it would be expected to eventually form a beach in front of Beach Road. This will continue to provide a good level of protection.
- While the behaviour of the beach to the west of Kingston is linked to the main estuary frontage in terms of sediment supply, this beach will continue to respond relatively independently from the shingle ridge in front of Kingston. The rollback of this beach poses no direct risk to the Village.

5.2 Management Options

Notwithstanding the conclusions above that there is only a very low risk to properties within the village of Kingston, different management options have been considered.

The conclusion of this review is that major intervention to attempt to fix or substantially modify the natural behaviour of the shingle ridge would involve works that would not be commensurate with the economic risk.

Furthermore, fixing the position of the shingle ridge with a rock revetment or even partially fixing the alignment through use of breakwaters has the potential to cause major disruption to coastal processes, both to the east and the west. This is likely to drive management in the longer term down a path where further management intervention is required in the future. Setting in motion a need for continual management, which would not be sustainable in the longer term.

The review does highlight that local beach management might be feasible in addressing specific local concerns over the integrity of the shingle ridge. This would need to be developed further in discussion with statutory organisations.

Recognising the uncertainties limits associated with the assessment of future conditions and recognising the concerns of expressed by local residents, options for local defence to the bank along Beach Road have been assessed. Two options have been considered. The first, that of a full rock revetment, is considered to be excessively cautious given the assessment of risk. The second provides for a more measured response, still taking a precaution approach. This would include cladding the bank with a flexible concrete block matting, potentially raising the crest of the bank with and earth bank.

Based strictly on the assessment of the level of risk, it is considered that a Do Minimum approach would be sufficient in addressing the immediate level of risk; continuing monitoring and potentially setting up discussion with the relevant bodies agreeing an approach to local beach management in advance of the need for possible action of the type being taken.

5.3 Recommendations

It is recommended that the Council accept the findings of this brief review, and that this report is shared with the local community to maintain their continued involvement with the process and decision making.

5.3.1 Management

Subject to acceptance of the findings, the following recommendations are made.

The overall assessment suggests that allowing the shingle ridge to develop naturally is a feasible option; effectively Do Nothing, in that the shingle ridge has the capacity to adjust and roll back quite probably without loss to property. However, given the complexity of the site and the potential for exceptional storm conditions; potentially causing unforeseen damage to the shingle ridge and to some property behind, a precautionary approach is taken in making recommendations.

It is not, however, considered sensible to attempt to fix the ridge in its current position. It is, therefore, recommended that a more realistic approach would be to continue monitoring, sharing the results with the local community and undertaking a review of behaviour in confirming the findings of this review; in effect a Do Minimum approach.

Recommendations on monitoring are set out later but would form the basis for on-going decisions.

Should it be found that local weak spots do develop in the ridge, then it would be recommended that these are addressed through local beach management. It is considered important, under this recommendation, that this review is used as the basis for initial discussion with statutory organisations. In this way, such minor local redistribution of shingle along the ridge and from adjacent sections of the frontage, should be agreed in advance of the need for such action. This would confirm acceptable donor sites and define the parameters under which such sites might be exploited.

It is accepted that this may not fully allay the concerns of local residents and a more precautionary approach could be taken and, while not specifically recommending this action based on the findings of the review, it is recommended that consideration is given to this in discussion with the community. This would involve some further work to support the bank to the rear of the Lagoon by cladding its face with a flexible concrete block revetment.

In taking this forward:

- Consideration might be given to some further analysis of potential wave action across the ridge, examining in more detail the possibility of damage under extreme conditions, while also establishing potential design conditions.
- That discussions are held with statutory organisations and with those with a local interest in the area, to ascertain acceptability of such an approach to management.
- Further and subject to a decision to progress this approach, it would be recommended that detailed design of an appropriate level of defences is undertaken.

5.3.2 Monitoring

The present monitoring is seen as covering the critical areas of the frontage. Monitoring is undertaken on a quarterly basis and it is recommended that this should be continued over the next two years. Monitoring results should be examined on receipt of data, as is undertaken at present, and a summary report would be recommended as a means of continued involvement with the community.

On completion of a five year monitoring programme, it is recommended that monitoring should be reviewed in more detail in line with the findings of this report.

At a broader scale, it is recommended that oblique air photography is continued, covering both the Spey and the shoreline extending between Portgordon and Lossiemouth.

It would be beneficial to obtain vertical (rectified) air photography of the area on a more regular basis as a means of recoding larger scale changes to the coast. This might be considered in conjunction with SEPA, with the potential to put in place a regional monitoring programme for the whole of the Moray Firth shoreline. This might include regular LIDAR imagery providing long term detailed measurement of change.

This would require further examination based on definition of areas of concern defined around the shoreline.

The monitoring undertaken by local residents has been valuable in assessing the overall behaviour of the area. While this would be encouraged and supported, it would be beneficial to co-ordinate such efforts within a broader monitoring process. It is not considered necessary to record in detail, with detailed survey, the performance of the West Beach although the broader scale monitoring with LIDAR, possibly on a 5 yearly programme would pick up long term change. This could then be supplemented by local monitoring to better understand individual patterns of change.

The aim and scale of monitoring should be driven and defined against clearly defined objectives, either in terms of specific management of risk or with the specific aim to better understand critical behaviour of the shoreline.

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