Stonehaven Bay Coastal Flood Protection Study

Natural Flood Management and River Basin Management Plan Report

Final Report

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www.jbaconsulting.com

JBA Project Manager

Nicci Buckley BSc MSc CSci MCIWEM C.WEM
Unit 2.1 Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

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Contract

This report describes work commissioned by Gavin Penman on behalf of Aberdeenshire Council by a letter dated 27 February 2018 and Purchase Order number 1002287. Dougall Baillie's representative for the contract was Scott Macphail and Aberdeenshire Council's representative for the contract was Graeme McCallum. Briony McIntosh and Douglas Pender of JBA Consulting carried out this work.

Prepared by ..... Briony McIntosh MEarthSci

Assistant Analyst

Reviewed by ..... Douglas Pender MEng PhD MCIWEM

Senior Engineer

..... Caroline Anderton BSc MSc CEnv CSci MCIWEM C.WEM

Technical Director

Purpose

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JBA thank SEPA for supplying the natural flood management, morphological pressures and river basin management plan datasets. JBA also thank Aberdeenshire Council for the supply of data.

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Executive summary

Under the Flood Risk Management Act 2009, this report forms part of the appraisal study for Stonehaven and Cowie commissioned by Aberdeenshire Council. The purpose of this report is to assess the current physical condition of the Stonehaven Bay coastline based on parameters set out in the River Basin Management Plan (RBMP), in particular considering any morphological constraints. In addition, the purpose of this report is to identify opportunities for Natural Flood Management (NFM).

Stonehaven Bay is located on the shore of the North Sea and lies within sediment cell 2 (Fife Ness to Cairnbulg Point)[3], sub-cell 2c (Milton Ness to Girdle Ness). The Bay is fronted by a relatively narrow sand and shingle beach with a rocky foreshore to the north. Sediment movement is generally from north to south. Storm wave action is understood to erode beach material and during high energy wave events gravel from the foreshore appears to be transported landward depositing material along, and in some cases nearly burying the sea wall. The River Carron and the River Cowie discharge into Stonehaven Bay at the southern and northern extents of the Bay respectively. Both are tidally influenced and shingle is deposited at the mouth of the River Cowie as a result of wave action; historically this has periodically been recycled and placed in the Bay to the south of the River Carron.

The Stonehaven Bay coastal waters as well as the River's Carron and Cowie are classified as being in 'Good' physical condition according to the 2016 RBMP classifications. There are however a number of morphological constraints along both the coastline and fluvial channels. These include:

- The Stonehaven coastal defences, which vary in form and height along the frontage.
- The banks of the River Carron are urbanised and a stone wall lines the channel upstream and downstream of the Bridgefield Road bridge. The mouth of the River Carron has also been engineered to direct flow south along the shoreline as a result of the installation of a breakwater feature.
- The River Cowie downstream of the B979 road bridge is concrete lined and sediment accumulation is high due to the combination of fluvial and tidally deposited material, which has narrowed the channel outlet.

Suggested RBMP actions to be considered during the options appraisal, specifically with respect to morphology are as follows:

- Opportunities to improve the physical condition of the coastline are limited. Removal of the coastal defences and/or managed realignment to set-back defences is not a viable option. The hard defences are the primary source of flood protection to Stonehaven and Cowie and should not be removed. Consideration should be given to limiting future additional hard-engineered structures to retain the 'Good' morphological status and limit disruption to natural coastal processes. Where additional defences are required use of 'green' materials should be considered, as are being developed for the Catterline coastal erosion project.
- Morphological improvements to the River Carron to encourage sediment transport to the foreshore area are also limited. A flood defence scheme is due to be constructed along the Carron from August 2018 which will likely change the morphological characteristics and RBMP status of the watercourse.
- The morphology of the River Cowie downstream of the B979 road bridge could be improved to increase velocities and outflux of accumulated sediment to naturally recharge the Stonehaven foreshore.

NFM opportunities at Stonehaven have also been considered and the three primary opportunities identified are:

1. **Coastal beach recharge.** Large-scale recharge to increase the shingle beach width and height along the shorefront to break wave energy. Detailed sediment modelling and analysis of Stonehaven Bay is however crucial in order to identify sediment sources, sinks and pathways to inform the suitability and location of any recharge. It is also suggested recharge be undertaken in conjunction with maintaining the existing hard defences, and additional groynes may be required to hold sediment within the Bay.
2. **Shingle restoration (coastal sediment recycling).** In addition to long-term recharge, short-term sediment recycling to maintain the restored beach profiles should be considered. Recycling involves redistribution of sediment within the local area (sediment cell) from areas of deposition to areas of erosion.
3. **Fluvial sediment management and morphological improvements.** Sediment deposition in the mouth of both the River Carron and River Cowie are indicated within the SEPA NFM potential mapping. Fluvial sediment deposition combined with the coastal influx of material reduces channel capacity and can increase the risk of flooding. Sediment management measures such as morphological alterations to the channel to increase velocities and flush sediment back into the foreshore are should be considered during options appraisal and has the multi-benefit of maintaining the 'Good' RBMP morphological status.

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Abbreviations

BGS	British Geological Survey
FRM	Flood Risk Mapping
ID	Identifier
RBMP	River Basin Management Plan
SEPA	Scottish Environment Protection Agency
SSSI	Site of Special Scientific Interest
WFD	Water Framework Directive

1 Introduction

The purpose of this report is to summarise the desk-based assessment of Stonehaven Bay to determine the current condition of the coastline based on parameters set out in the River Basin Management Plan (RBMP). In particular, the study aims to identify all morphological pressures on the coastline and fluvial waterbodies within the study area and potential to improve the RBMP status of these waterbodies. In addition, the purpose of this report is to summarise potential opportunities for Natural Flood Management (NFM).

1.1 RBMP

1.1.1 Legislation

The River Basin Management Plan forms part of the European Water Framework Directive (WFD) 2000. The WFD is currently in its second cycle (2015 - 2027) and sets out the objectives for protecting and improving the water environment; balancing the environmental, societal and economic costs and benefits. The Scottish Environment Protection Agency (SEPA) are responsible for managing this within Scotland.

The RBMP defines and classifies the environmental condition of water bodies, with the overall condition graded from poor to high based on a number of categories. For fluvial waterbodies these include: access for fish migration; water flows and levels; freedom from invasive species; water quality; ecology and physical condition. For coastal waterbodies overall condition is based on water quality, ecology and morphology.

1.1.2 Aim

The aim of this RBMP assessment was to consider the current overall status of the Stonehaven Bay coastal waters, as well as the morphological condition of the coastline and identify opportunities to improve morphology. In addition, the physical condition of the final reaches of the two fluvial watercourses discharging into Stonehaven Bay was assessed to identify opportunities to improve morphology. The results are discussed in further detail in the following chapters.

1.2 NFM

1.2.1 Legislation

The Flood Risk Management (Scotland) Act 2009 requires SEPA and Responsible Authorities to consider sustainable approaches to managing flood risk. This includes considering the role that NFM has in reducing flood risk, where NFM was defined by SAIFF (2011)[1] as follows:

'Natural Flood Management can be defined as those techniques that aim to work with natural hydrological and morphological processes, features and characteristics to manage the sources and pathways of flood waters. These techniques include the restoration, enhancement and alteration of natural features and characteristics, but exclude traditional flood defence engineering that works against or disrupts these natural processes.'

1.2.2 Aim

In the past, coastal flood management has typically focused on traditional methods of mitigating flood risk, such as the use of sea walls, groynes and revetments. Disruption to natural coastal processes because of 'hard' engineering, for example modification of natural sediment supply and transport as a result of groynes, potentially reduces the level of protection and design life offered, and such an approach is not considered to

1 Scottish Advisory and Implementation Forum for Flooding (SAIFF, 2011)

be sustainable on its own. Increased water depths as a result of sea level rise and the consequent increase in wave energy predicted to impact Scotland due to climate change further undermines the protection offered.

In contrast, NFM measures work together with the natural characteristics and processes of the landscape to help manage flooding. In isolation NFM measures may be more effective for smaller scale events, meaning traditional hard-engineering options are still typically required and have a role in terms of the level of protection offered and cost benefit analysis with respect to large magnitude events. Incorporation of NFM within the overall Flood Protection Scheme may however reduce the impact of large scale events and extend the design life of coastal defences.

NFM measures vary in scale and type depending on local conditions. The SEPA Natural Flood Management Handbook[2], Chapter 3, provides guidance on coastal based NFM measures. The goal of coastal NFM is to restore the coastline and stabilise coastal features to buffer wave energy and minimise its impact on existing defences, or provide a natural buffer in cases where no defences exist. Coastal processes and therefore NFM recommendations are highly site specific. There is also an interconnection between fluvial and coastal processes with fluvial flow and sediment potentially influencing beach sediment volumes. For areas such as Stonehaven Bay, it is therefore important to consider the impact of catchment based NFM measures. Types of coastal NFM measures considered in the NFM Handbook are given in Table 1-1.

Table 1-1 – Types of coastal NFM measures

Type of NFM measure	Example
Managed realignment	Breaching or removal of existing hard defences or creation of 'set-back' protection.
Saltmarsh and mudflat restoration	Habitat restoration to create an area of wave energy dissipation.
Sand dune restoration	Planting to restore stability, increasing their ability to dissipate wave energy.
Shingle restoration	Sediment nourishment in the foreshore to dissipate wave energy.
Recharge (beach or intertidal)	Placement of sediment in the foreshore to dissipate wave energy.

NFM measures often offer several multiple benefits (such as improvements in water quality or increased access to nature) and can be used in conjunction with traditional engineering approaches to reduce flood risk where appropriate.

The aim of this NFM assessment is to consider the current state of the coastline and identify locations where coastal NFM may be appropriate. Potential opportunities for NFM are discussed in further detail in the following chapters.

2 https://www.sepa.org.uk/media/163560/sepa-natural-flood-management-handbook1.pdf [Chapter 3. Page 38].

2 Stonehaven Bay

2.1 Geology, coastal and fluvial processes

The town of Stonehaven and village of Cowie are located approximately 20 km to the south of Aberdeen. They sit within Stonehaven Bay on the shore of the North Sea, which lies within sediment cell 2 (Fife Ness to Cairnbulg Point)[3], sub-cell 2c (Milton Ness to Girdle Ness, Figure 2-1). According to the British Geological Survey (BGS) 1:625,000 scale geological map of Britain[4] the coastline consists of sandstone bedrock (Figure 2-1) with small bands of volcanic lavas to the north of Stonehaven; with overlying glacial sand and gravel deposits. The northern foreshore of the bay is rocky with a small sandy beach, while the central-southern extent of Stonehaven is fronted by a moderately large sand and shingle beach (Figure 2-1). No significant littoral drift is believed to occur within sediment sub-cell 2c[3] and cliff erosion is low but general sediment distribution is from north to south and as such beach heights increase southwards.

Two rivers, the Carron and Cowie, flow through Stonehaven and discharge into Stonehaven Bay (Figure 2-1). Both rivers are tidally influenced and during storm conditions waves can propagate up the mouth of the River Cowie and break at the B979 road bridge. Shingle is also deposited in the mouth of the River Cowie and is periodically recycled and placed in the boardwalk region (Figure 2-1) in an attempt to reduce erosion. Engineering of a breakwater feature at the mouth of the River Carron has realigned the mouth of watercourse and appears to have directed flow south longshore towards the boardwalk area of the Bay. A flood defence scheme is scheduled for construction along the River Carron from August 2018.

Storm wave action is known to erode beach material at Stonehaven, with the timber walkway at the southern extent of the Bay (Figure 2-1) washed away in the December 2012 event. From observations during the site visits it and discussions with local residents, it is indicated that during high energy wave events the shingle from the foreshore is transported landward and is deposited in front of, and over, the sea wall between the River Carron and Cowie outlets, almost completely burying the seaward face (Figure 3-1, C). This appears to have resulted in a significant steepening of the beach face allowing for large waves to break closer to the shore and an increase in wave runup and overtopping. Sedimentation patterns will be investigated further in the erosion assessment report.

2.2 Review of Historical Mapping and Information

A review of historical mapping[5] as well as information provided by local resident Ian McDonald[6] indicated the shingle beach fronting Stonehaven was historically far more extensive than present. Pre-1930s no sea wall was present along the bay and the shingle beach appeared greater in both width and height, with shingle present up to road level. In addition, the River Cowie historically flowed south towards the River Carron (Figure 2-2), with historical maps showing its former course in 1950 and its present-day course in 1967. The exact date when it changed course is unknown but it is understood that the river broke through the shingle bar that was present during a storm event in 1948[6] and has run its present-day course into Stonehaven Bay since.

Historical accounts suggest shingle loss from Stonehaven Bay was rapid post-1940 when large quantities of material were excavated from the beach to cast concrete tank traps within the Kincardineshire region and form the foundations of the runways at

3 H.R.Wallingford. 1997. Coastal cells in Scotland. Scottish Natural Heritage Research, Survey & Monitoring Report. No. 56.
4 British Geological Survey http://mapapps.bgs.ac.uk/geologyofbritain/home.html [Accessed: June 2018]
5 National Library of Scotland. OS 25 Inch Scotland, 1892-1949. OS 1:25,000 maps of Great Britain, 1937-1961. http://maps.nls.uk/geo/explore/#zoom=17&lat=56.9643&lon=-2.2064&layers=10&b=1 [Accessed: June 2018]
6 Report on the history of Stonehaven Bay containing historical photographs and maps provided on 22 June 2018 by local resident Ian McDonald.

Fordoun aerodrome[6]. Additionally, the breakthrough of the Cowie is believed to have increased the rate of shingle loss due to increased fluvial velocities increasing the north south longshore drift velocities[6].

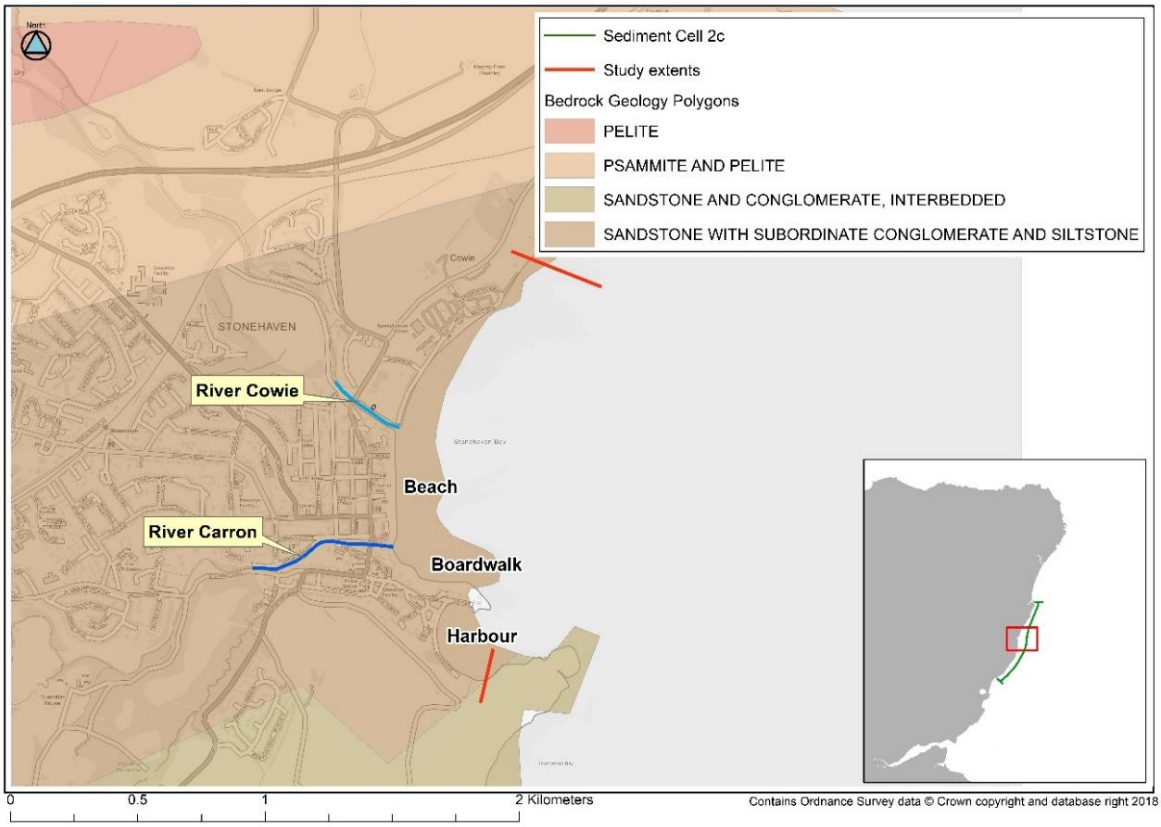

Figure 2-1: Stonehaven study area

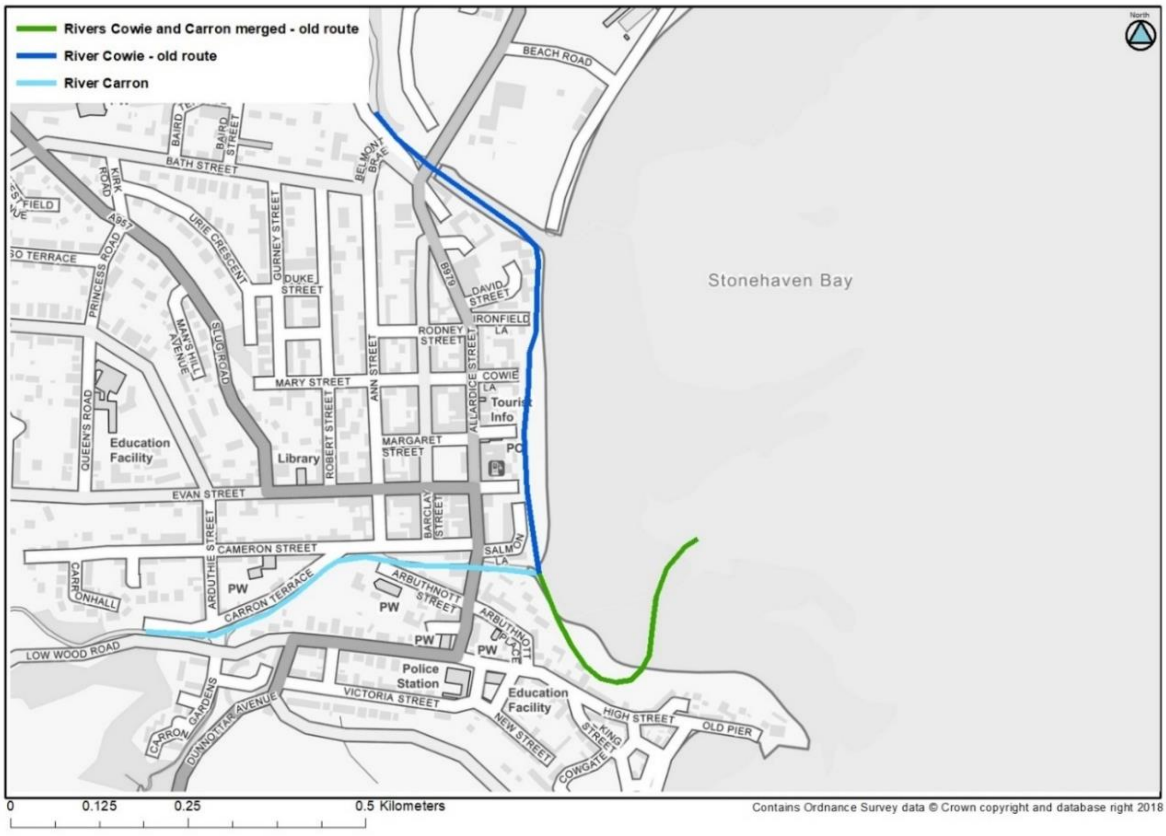

Figure 2-2: Historical configuration of the Rivers Cowie and Carron at the coast

2.3 Coastal defences

There are several formal and informal coastal defences within the study area which include (south to north, Figure 2-3):

- Stonehaven Harbour which contains rock armour revetments, a breakwater, piers and quay walls.
- A large rock armour revetment to the north of Stonehaven harbour.
- A boardwalk section north of the harbour consisting of rock armour and a shingle beach which suffers erosion and damage during storm events. The Carron outfalls within this area.
- A concrete wall and shingle beach area fronting the Stonehaven properties.
- The outlet of the River Cowie consists of a combination of concrete walls, concrete revetments, and steel sheet piles.
- Stepped revetments between the mouth of the River Cowie and open air pool form the main coastal defence along the south Cowie frontage. It consists of a stepped concrete revetment with small wave return wall at the crest.
- A concrete and masonry wall defends the coast north of the pool, in front of Cowie village.
- It is understood that construction of the River Carron fluvial flood protection scheme is due to commence from August 2018.

Figure 2-3: Area and defence types within Stonehaven Bay

2.4 Land management

2.4.1 Land use

Figure 2-4 illustrates land cover types in the Stonehaven Bay area based on the Land Cover Map 2012[7]. Land use to the northern and southern extents of the study area is pastural land, while the remaining coastline is backed by the urban extent of Stonehaven. The banks of the River Carron and Cowie are constrained through their lower reaches as a result of urbanisation. The coastal reach of the study area is classified as beaches, dunes and sands; however, no sand dunes are present, with Stonehaven fronted by a relatively narrow sand and shingle beach.

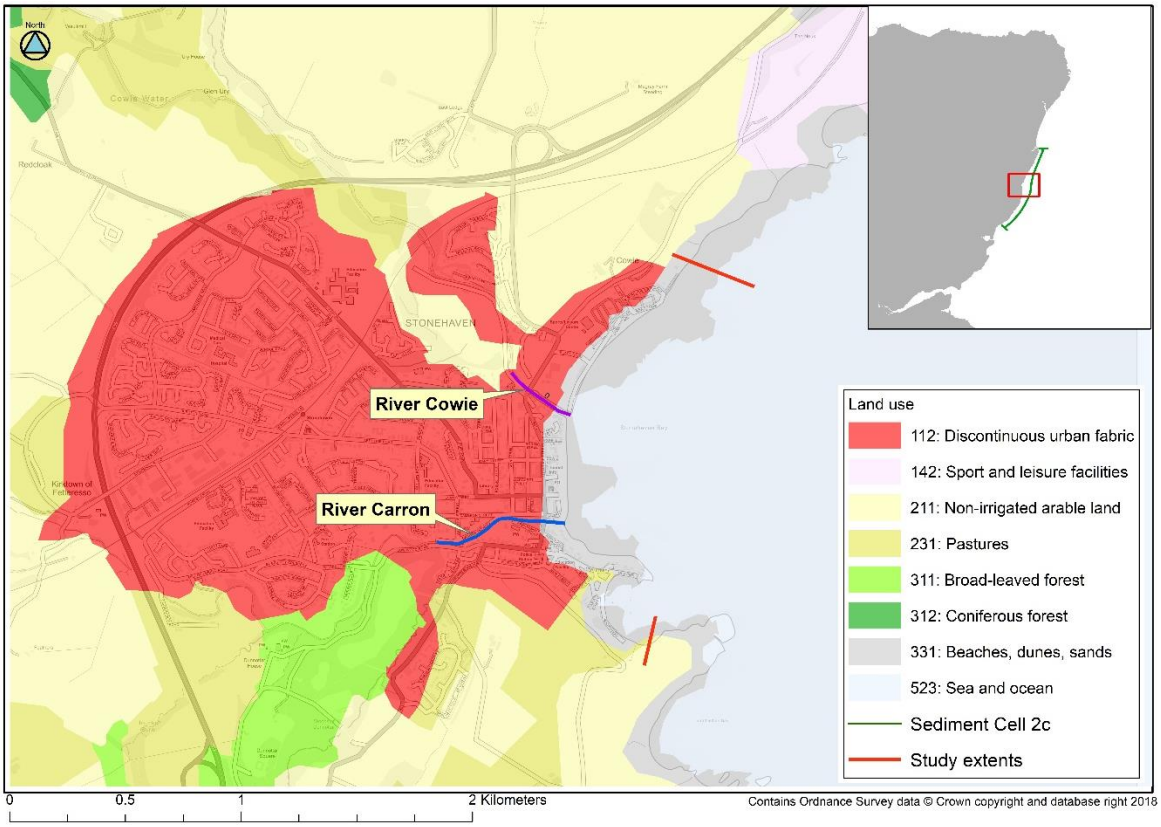

Figure 2-4: Land use

7 Corine Land Cover European seamless vector database. Release v18_5 (02/2016) http://land.copernicus.eu/pan-european/corine-land-cover

2.4.2 Scottish Natural Heritage Landscape Designations

Scottish Natural Heritage (SNH) datasets indicate within the study area north of the River Cowie outlet, by the open air swimming pool, Stonehaven Bay northwards falls under the Garron Point Site of Special Scientific Interest (SSSI) which is of both geological and botanical interest. In addition, Stonehaven Bay is part of the Muchalls to Stonehaven Bay Local Nature Conservation Site (LNCS)[8], which reflects the biological and geological importance of the site at a regional level. Castle of Cowie scheduled monument lies just outwith the study area to the north of Stonehaven, but several listed buildings are located within the study area including Stonehaven Harbour.

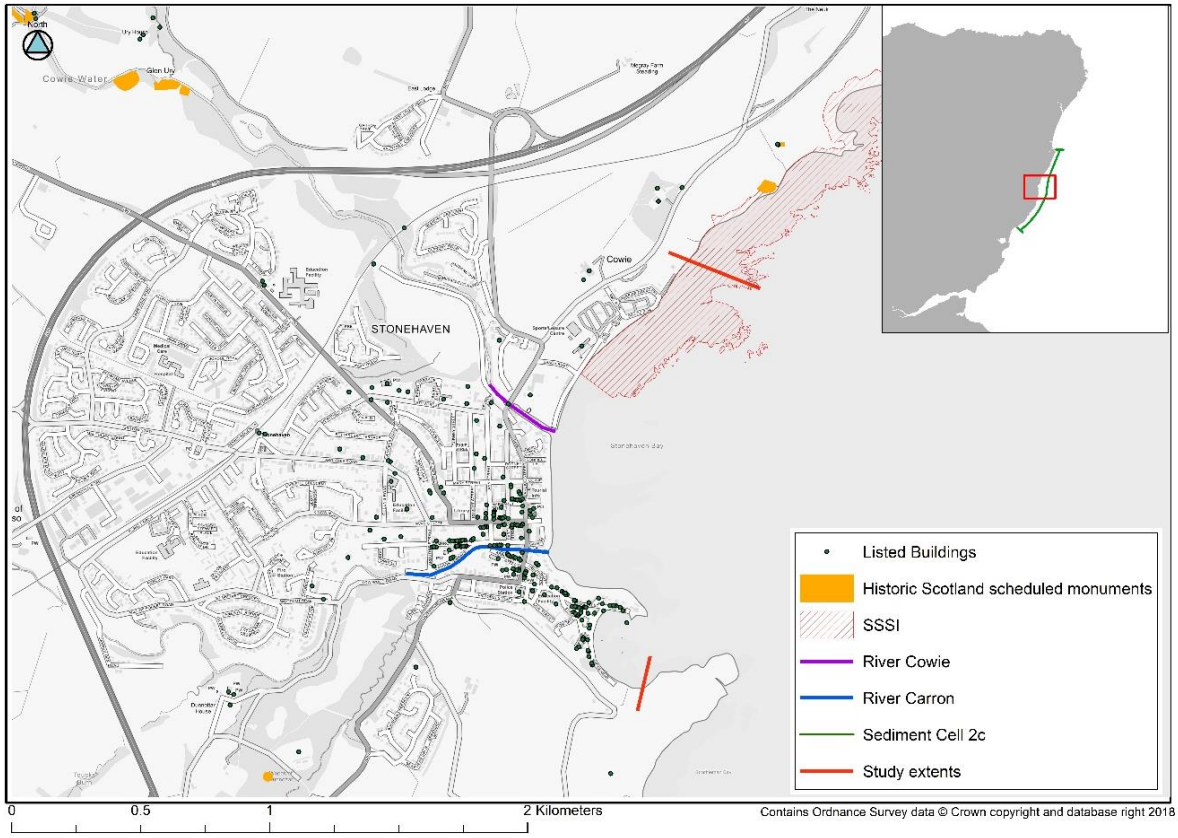

Figure 2-5: Landscape designations

8 Aberdeenshire Local Development Plan. April 2017. Supplementary Guidance. Local Conservation Sites. https://www.aberdeenshire.gov.uk/media/20028/5a-local-nature-conservation-sites-index.pdf [Accessed: June 2018]

3 RBMP Review

3.1 Introduction

RBMP data were examined using the Water Environment Hub[9] and RBMP datasets supplied by SEPA. Coastal and fluvial waterbodies are classified in the RBMP based on several parameters (detailed in Chapter 1). This report will focus on morphological pressures affecting the Stonehaven coastline and fluvial watercourses downstream of the Bridgefield Road and B979 road bridges.

Morphological pressures which can result in the downgrade in status of coastal and fluvial waters include:

- Hard engineering of the coastline. For example, groynes which can exacerbate erosion downstream of the defence as well as modify natural sediment supply and transport pathways; sea walls and revetments.
- Land claim. Numerous intertidal or sub-tidal areas have been claimed for agriculture, housing, industry, ports and harbours which have reduced the capacity of intertidal systems to buffer flooding from the sea.
- Channel realignment and constraint e.g. straightening and canalisation of fluvial watercourses.

Measures to restore and improve the physical condition of coastlines and fluvial watercourses therefore include:

- Removing redundant or setting back coastal structures i.e. managed realignment.
- Land reclamation and habitat restoration to restore saltmarshes, mudflats, sand dunes and increase the foreshore area for wave energy dissipation.
- Restoring channel sinuosity, habitats and flows.

3.2 Coastal Morphological Pressures and Recommendations

Stonehaven Bay is located within the Garron Point to Downie Point (Stonehaven) coastal water body, ID 200517, with an area of approximately 17 km^2. The water body is classified as being in 'Good' overall and physical condition (2016 classification), and this overall status has been consistent every year from 2008 to 2016.

Despite being of 'Good' morphological condition the coastline has been highly modified with coastal defences present along the entire study extent. These include a sea wall in Stonehaven Harbour (Figure 3-1, A), rock armour north of the harbour (Figure 3-1, B) stepped revetments with a small wave return wall at the crest through the centre and northern extent of Stonehaven Bay (Figure 3-1, C and E) and a sea wall at Cowie village (Figure 3-1, F).

Removal of the defences is not a viable option as they are the primary source of protection to the town, and managed realignment to set-back defences is not viable as land claim means the town backs directly onto the coastline. Limiting future additional hard-engineering along the coastline to maintain the 'Good' morphological RBMP status should be considered during the options appraisal. Where additional defences are required use of 'green' materials could be considered. For example, as is being developed through the EU funded Catterline coastal erosion project which is aiming to use trees, reclaimed timber, debris and biodegradable material to shore up the bay's defences to protect it from coastal erosion and landslides[10].

9 SEPA Water Environment Hub https://www.sepa.org.uk/data-visualisation/water-environment-hub/ [Accessed: June 2018]
10 The Press and Journal. Catterline to benefit from £10.8 million eco-friendly coastal erosion project. 17 May 2018. https://www.pressandjournal.co.uk/fp/news/aberdeenshire/1476762/catterline-to-benefit-from-10-8million-eco-friendly-coastal-erosion-project/ [Accessed@ June 2018]

Figure 3-1: Coastal morphological pressures

A: Stonehaven Harbour backed by a sea wall.

B: Rock armour and boardwalk north of the harbour.

C: Sea wall almost buried by sediment deposited during storm events.

D: Outlet of the River Cowie. Sedimentation from coastal waters evident which has narrowed the fluvial channel. Small groyne feature on the southern right bank.

E: Concrete revetments fronting the northern extent of Stonehaven Bay.

F: Northern rocky foreshore with small sandy beach and defence wall.

3.3 Fluvial Morphological Pressures and Recommendations

3.3.1 River Carron

The Carron Water (ID 23257) is classified as being in 'Poor' overall condition, downgraded based on its ecology and pollutants but is of 'Good' morphological condition. The banks of the Carron are however heavily constrained through Stonehaven due to urbanisation, and upstream and downstream of the Bridgefield Road bridge the channel is lined by masonry walls on either side (Figure 3-3, A), as indicated by the grey-bank reinforcement in the SEPA morphological pressures dataset[11], which also indicates the lower reach of the River Carron has undergone high impact realignment (Figure 3-2). Additionally, the mouth has been engineered to direct flow longshore in a rock sided channel towards the boardwalk area of the bay. Redirection of fluvial flows may be exacerbating erosion in this region in addition to inhibiting fluvial sediment redistribution to the area because of the 'dog-legged' channel potentially reducing velocities.

Removal of the final engineered section of channel is ultimately suggested to improve the RBMP status and encourage sediment outflux to the foreshore. However, the structure was built with the aim of trapping shingle on the beach to the north and to allow the Carron to drain freely across the beach. There are also issues surrounding waves propagating up the channel of the Carron[12]. A sewage conduit located under the channel mouth also constrains any channel redesign[12]. In addition, construction of a flood defence scheme is scheduled for August 2018 along the Carron which is likely to change the morphological characteristics and RBMP status of the watercourse.

3.3.2 River Cowie

The Cowie Water (Rickarton to sea, ID 23253) is classified as being in 'Good' overall and physical condition. This has been the case since 2007 except for 2015 when it was classified as being in 'Moderate' condition on the basis of its ecology.

The morphology of the Cowie Water at its downstream extent has been highly modified. Downstream of the B979 road bridge the watercourse flows in a straightened, wide, flat, concrete and sheet-piled channel, as indicated by the grey-bank reinforcement in the SEPA morphological pressures dataset (Figure 3-2). Sediment accumulation within the channel is observed to be high due to the tidal influx of material as well as deposition of fluvial material as the channel slope decreases in the lower reaches. Over time this may increase the risk of fluvial flooding from the Cowie through a reduction in channel capacity (Figure 3-3, B). Fluvial sediment transport when the river is in spate may however remove a proportion of the accumulated material. Fluvial flood risk is considered greater from the River Carron which has a longer and more extensive flood history dating back to 1829[13]. Sediment accumulation has also narrowed the fluvial outlet of the channel (Figure 3-3, C). These characteristics would suggest sediment is not easily, naturally transported back into Stonehaven Bay, with the main mechanism of re-distribution being periodic dredging of material that is then recycled in Stonehaven Bay, south of the River Carron. It is suggested the morphology of the channel could be improved to encourage fluvial transport of material by increasing velocities. This could be achieved through engineering the channel further or a store and release mechanism to naturally recharge the Stonehaven foreshore. In addition, consideration could be taken of measures that may limit the coastal influx of material to the mouth of the channel.

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11 Only the significant morphological pressures have been considered which are defined as: impoundments; set back embankments; embankments with and without reinforcement; green and grey bank reinforcement; high and low impact realignment and culverts. It should also be noted the SEPA morphological pressures mapping does not necessarily follow the watercourses as they are plotted as straight lines based on their start and end point.

12 JBA Consulting. River Carron Rock Armour Study. Final Report. January 2015.

13 SEPA North East Local Plan District Stonehaven Potentially Vulnerable Area 06/23 http://apps.sepa.org.uk/frmstrategies/pdf/pva/PVA_06_23_Full.pdf [Accessed: July 2018]

Figure 3-2: SEPA fluvial morphological pressures

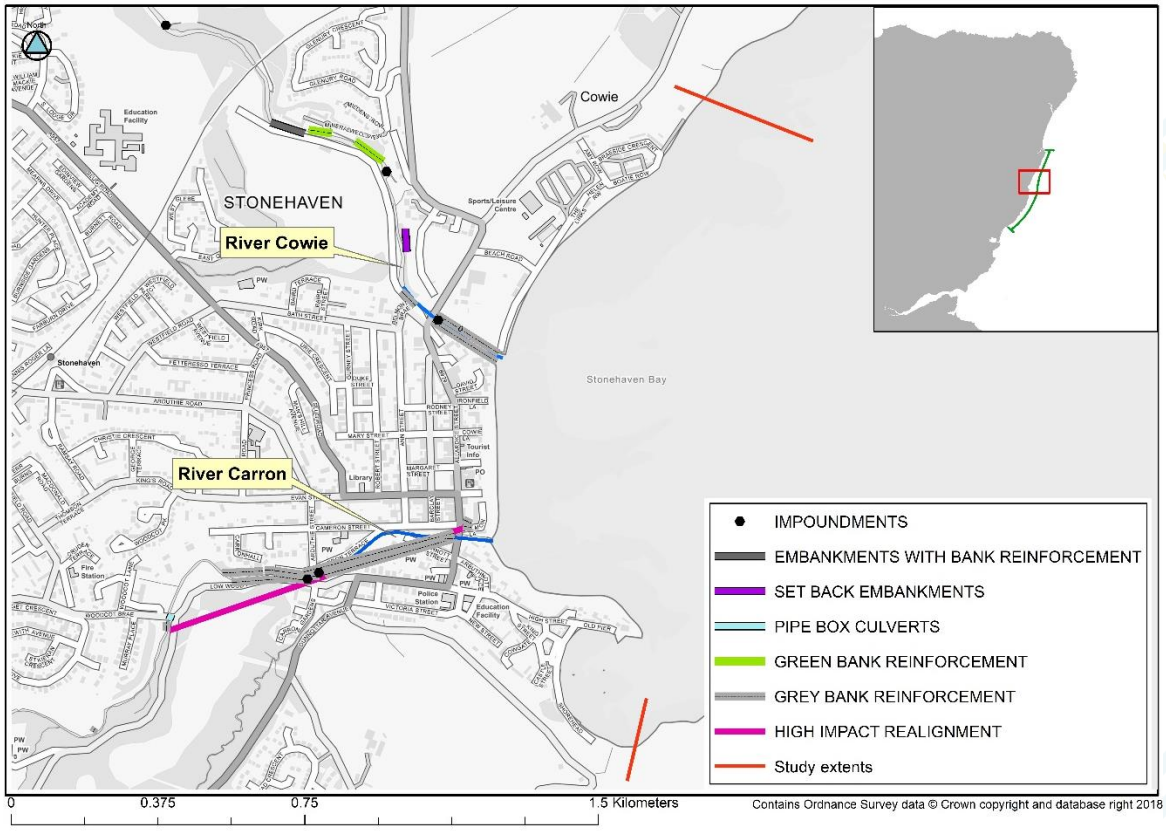
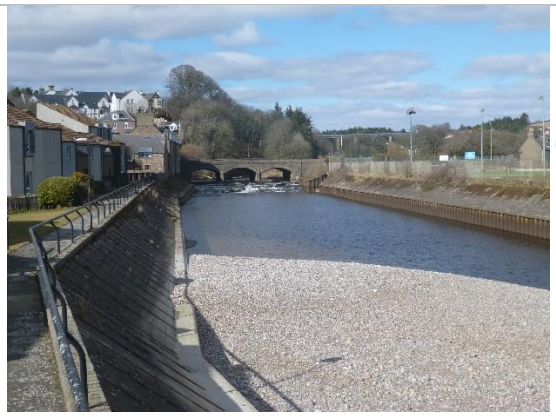


Figure 3-3: Fluvial morphological pressures - photographs

	
A: Looking upstream along the Carron Water. The channel is constrained on both banks by a large stone wall. A flood defence scheme is scheduled for construction along this reach in August 2018.	B: Looking upstream along the River Cowie. Flat, wide channel constrained by concrete walls and sheet-pile along both banks. Sediment accumulation is high (evident in the foreground) reducing channel capacity.
	
C: Looking downstream across the River Cowie. Narrowing of the channel outlet due to sedimentation.	

4 Opportunities for Natural Flood Management

SEPA, as part of the FRM Act Section 20 screening process, has undertaken a high-level strategic analysis of Scotland to determine the areas in which NFM measures could be most effective[14]. As the priority for this study is to reduce coastal flood risk at Stonehaven in particular, this broad-scale analysis has demonstrated where opportunities exist for the following:

- Coastal wave energy dissipation.
- Fluvial sediment management.

4.1 Coastal Wave Energy Dissipation

SEPA has produced a map identifying areas with potential to dissipate wave energy arriving at the shore. The mapping was generated by considering the fetch (distance over which wind blows to create waves) as a proxy for wave power and the space available (the distance between Mean High Water Spring and Mean Low Water Spring) to attenuate it.

Areas with high and medium potential for wave energy dissipation are shown in Figure 4-1. It can be seen that high potential is indicated along most of the Stonehaven coastline with the exception of Stonehaven Harbour where medium potential is indicated. Means to achieve wave energy dissipation include:

- Managed realignment.
- Saltmarsh and mudflat restoration.
- Sand dune restoration.
- Shingle restoration.
- Recharge.

Based on the constraints identified previously, shingle restoration and recharge are the only appropriate options.

4.2 Fluvial Sediment Management

SEPA has also produced a map identifying areas of sediment erosion, deposition and transport within Scottish rivers, thus identifying where sediment management measures may be appropriate for implementation to decrease flood risk. This was achieved using a model to estimate the amount of sediment entering and leaving a given reach and calculating the overall sediment balance.

A sediment management potential map for the River Carron and River Cowie is also illustrated in Figure 4-1. It can be seen the lower reaches of both watercourses are indicated to be depositing material as they approach the coast. This is combined with the wave driven influx of material (Figure 3-3, B) making sediment management a key consideration along the final reaches of both watercourses to reduce fluvial flood risk and in terms of sediment loss from the coastal sediment cell.

14 Nutt, N. 2012. Flood Risk Management (Scotland) Act 2009. Methods to screen and quantify natural flood management effects. Report commissioned by SEPA and Forestry Commission Scotland, May 2012.

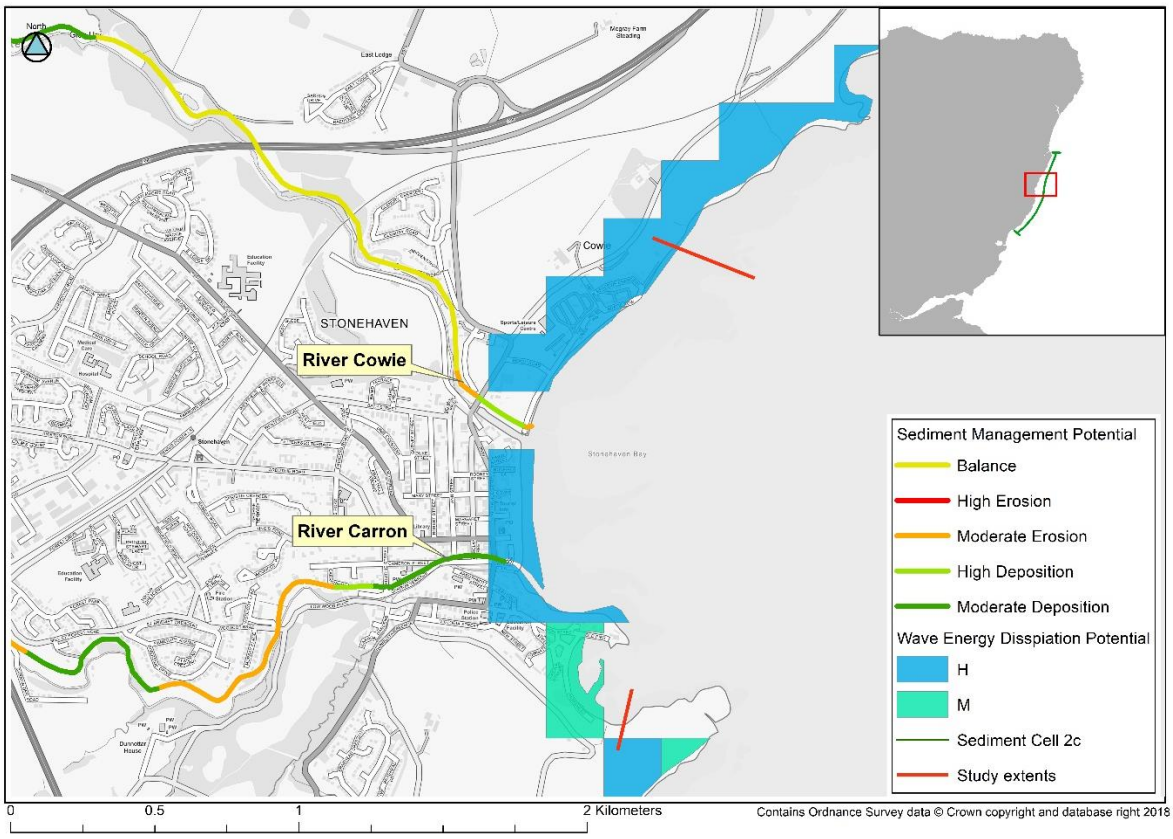


Figure 4-1: Stonehaven NFM potential mapping

4.3 NFM Recommendations

4.3.1 Beach Recharge

The SEPA NFM mapping indicates the potential to reduce wave energy is high along most of the Stonehaven coastline within the study area. Beach recharge is one mechanism of wave energy dissipation and involves the large-scale placement of sediment on the intertidal foreshore. Sediment is imported from an offshore source and particle size and composition should be like that of the existing foreshore. It is often undertaken alongside hard engineering to limit sediment loss from the system and is most appropriate where loss of sediment is the root cause of coastal flood risk.

Beach profiles at Stonehaven are actively evolving, with sediment generally moving north to south but also believed to be being transported landward during storm events. Sediment is being lost from the system, with a previous report by JBA Consulting[15] indicating the entire foreshore of Stonehaven Bay was eroding. There is also believed to be ongoing erosion of the beach south of the River Carron. Sediment loss reduces the wave energy reduction potential of the foreshore and natural beach profiles requires continued sediment supplies to remain effective at dissipating energy. During storm events, landward movement of sediment appears to have naturally steepened beach profiles north of the River Carron and in some cases nearly buried the sea wall. This natural steepening of the beach profile is acting as a means for waves to runup and overtop the defences; the proximity of the defences to the properties results in the potential for an increased risk of flooding.

Given wave overtopping is the primary source of flood risk to Stonehaven, large scale shingle recharge is one option for reducing this. The beach at Stonehaven has historically been far more extensive with significant reductions in shingle volumes

15 JBA Consulting. Stonehaven Coastal Frontage Assessment. Final Report. September 2014.

appearing to be a result of historical excavation[6]. Therefore, recharge to restore beach width and height could restore the natural wave energy buffering capacity of the shoreline. More detailed modelling and analysis within Stonehaven Bay is however crucial to identify the sources, sinks and transport mechanisms within the Bay to inform the suitability, appropriate locations and volumes required for a recharge scheme. Consideration should also be given to maintaining/repair of the existing hard defences along with new defence control measures that may be required to retain sediment on the beach.

4.3.2 Shingle restoration (coastal sediment recycling)

Supplementary to large scale beach nourishment, short term shingle restoration (sediment recycling) to maintain beach volumes at Stonehaven could also be used to widen the beach and shallow the slope and should be considered further in the options appraisal. Recycling involves the movement of sediment within the same coastal cell from areas of accumulation to areas of erosion. Sediment sources and the appropriate location(s) for deposition will be considered should beach management be taken forward as an option.

There is a history of recycling shingle at Stonehaven Bay with sediment from the mouth of the River Cowie periodically excavated and placed in the boardwalk area south of the River Carron. Recycling operations have been undertaken since 2001 and are summarised in Table 4-1[17]. The latest recycling operation occurred in March 2016 when 3000 tonnes of material was excavated from the mouth of the River Cowie and deposited south of the River Carron[18]. Continuation of sediment recycling in Stonehaven to maintain beach width, particularly if a large-scale beach recharge scheme is carried forward is suggested as a potential option. As with the recharge, sediment redistribution at Stonehaven would however benefit from a more detailed analysis to better understand the coastal processes responsible for sediment transport. Particularly as local residents note that during storm events the recycled material south of the River Carron is often washed offshore[6].

17 JBA Consulting. Stonehaven Coastal Frontage Assessment. Final Report. September 2014.
18 Information provided by Aberdeenshire Council. Stonehaven Beach Recycling Works – March 2016. Liam Rochford 6 April 2016.

Table 4-1 – Stonehaven beach recycling operations

	Collected (tonnes)		Deposited (tonnes)		
Year	From mouth of Cowie	From mouth of Carron	South of mouth of Carron	North of stepped seawall	South of mouth of Cowie
2001	2000	0	2000	0	0
2002	2000	0	2000	0	0
2003	2000	0	2000	0	0
2004	2000	0	2000	0	0
2005	2000	0	2000	0	0
2006	2000	0	500*	2000	0
2007	2000	150	2150	0	0
2008	2000	150	2150	0	0
2009	4350	0	4000	0	350!
2010	3000	0	3000	0	0
2011	1500	0	1500	0	0
2012	1000	0	1000	0	0
2013	0	0	0	0	0
2014	2500	0	2500	0	0
2015	0	0	0	0	0
2016	3000	0	3000	0	0
2017	3250	0	3250	0	0

Notes:

* Shingle placed over manhole cover just north of groyne at Carron.

t c150 tonnes of rock armour transferred from groyne at the mouth of the Cowie to improve groyne at mouth of the Carron.

! Shingle placed c50m south of the mouth of the Cowie.

4.3.3 Fluvial Sediment Management

The SEPA NFM mapping indicated fluvial sediment deposition is dominant in the lower reaches of both the River Cowie and Carron. This is in addition to the material supplied from coastal sources during high tide and storm events. Sediment accumulation in the channel may increase the risk of fluvial flooding through a reduction in channel capacity, and the current morphology of both watercourses inhibit sediment outflux to the foreshore impacting coastal processes. Effective management of the fluvial sediment should therefore be considered in the appraisal of options.

As discussed in Section 3.3, alterations to the watercourses to increase fluvial velocities and thus sediment outflux to the foreshore, as well as continued dredging of the channels to re-deposit local material back into the coastal sediment cell for short term recycling should be considered during the appraisal phase.

5 Conclusions and recommendations

5.1 RBMP

Stonehaven Bay is classified as being in 'Good' overall and physical condition (2016 classification). The coastline has however been modified and is backed by a range of coastal defences. Removal of these defences and/or managed realignment are not viable options, with the hard defences providing the primary form of coastal flood protection to the town.

The Carron Water is classified as being in 'Poor' overall condition, downgraded based on its ecology and pollutants, but is of 'Good' morphological condition. The mouth of the Carron has been engineered to direct flow south longshore in a rock sided channel towards the boardwalk area of Stonehaven Bay. This channel realignment is believed to have restricted sediment redistribution to the foreshore and redirection of fluvial flows may be exacerbating erosion of the foreshore south of the Carron outlet. Alterations to the channel should be considered during the appraisal phase to improve sediment transport potential at the mouth. Flood protection scheme works are scheduled to be undertaken from August 2018 along the River Carron which is likely to change the morphological characteristics and RBMP status of the watercourse.

The Cowie is classified as being in 'Good' overall and physical condition. Downstream of the B979 road bridge the watercourse flows in a wide, flat, concrete and sheet-piled sided channel. Sediment accumulation is high due to the combination of the fluvial and tidal influx of material and has narrowed the channel outlet. This may increase the risk of fluvial flooding from the Cowie due to a reduction in channel capacity resulting in an increased risk of overtopping of the concrete lined banks. Redistribution of material back into the coastal sediment cell is observed to be limited and requires periodic dredging of the channel. The options appraisal phase should therefore consider improvements to the morphology of the River Cowie to encourage fluvial outflux of material naturally recharging the Stonehaven foreshore. Channel improvements such as improving morphological diversity also works towards achieving the RBMP objectives and maintaining a 'Good' status.

5.2 NFM

Three NFM opportunities at Stonehaven Bay have been identified. These are: (i) beach recharge, (ii) shingle restoration (recycling) and (iii) fluvial sediment management to maintain beach profiles and thus encourage wave energy dissipation. Large-scale recharge would be the primary NFM measure with short-term sediment recycling undertaken to maintain the recharge volumes.

Detailed sediment modelling and analysis of Stonehaven Bay is however crucial in informing re-charge suitability, locations and volumes. In addition, the suggested NFM measures above are made in conjunction with maintaining the existing hard defences, not as an alternative. Additional groynes may be required to hold sediment within the Bay. Use of 'green' materials in construction should be considered as are being developed in the EU funded Catterline coastal erosion project[10].

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BD23 3AE
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
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