Lossiemouth Coastal Flood Study

The Moray Council

Options Appraisal Study

ND800400/002 | 0

01 October 2018

Lossiemouth Coastal Flood Study

Project No:	ND800400
Document Title:	Options Appraisal Study
Document No.:	ND800400/002
Revision:	0
Date:	01 October 2018
Client Name:	The Moray Council
Client No:	
Project Manager:	Jamie Scott
Author:	Paul Metcalf
File Name:	

Jacobs U.K. Limited

160 Dundee Street
Edinburgh
EH11 1DQ
United Kingdom
T +44 (0)131 659 1500
F +44 (0)131 228 6177
www.jacobs.com

© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright.

Limitation: This document has been prepared on behalf of, and for the exclusive use of Jacobs' client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this document by any third party.

Document history and status

Revision	Date	Description	By	Review	Approved
0	01/10/2018	Initial Issue for Client Review	PM	DD	JS

Contents

Executive Summary

The Seatown area of Lossiemouth sits on the banks of the estuary of the River Lossie. The 2017 Lossie Seatown Flood Assessment Desk Study[1], carried out by Jacobs, determined that there were several low-lying areas along the estuary banks that could result in to flooding of properties in Seatown, and adjacent areas, during a 1:200-year tidal event with 50 years of climate change taken into consideration. The 2017 study identified locations where existing defences could be overtopped and the report recommended that they should be raised and suggested possible structures that could be used to achieve this.

This Options Appraisal has developed on the 2017 study, with the objective of identifying and assessing Options on their individual technical, environmental and economic merits and proposing a preferred Option to be taken forward to detailed design. To achieve this high-level cost estimates were carried out for each of the identified Options. The proposed Options identified are:

- Do Nothing;
- Option 1A – Earth Embankments along edge of the estuary;
- Option 1B – Sheet Pile Wall with Cladding along edge of the estuary;
- Option 1C – Concrete retaining wall along edge of estuary;
- Option 2A – Earth Embankment along estuary and Spynie Canal (Excludes Caravan Park);
- Option 2B – Sheet Pile Wall with Cladding along the estuary and Spynie Canal (Excludes Caravan Park);
- Option 2C – Concrete retaining wall along the estuary and Spynie Canal (Excludes Caravan Park).

To inform this appraisal a ground investigation (GI) was carried out to determine whether seepage would be an issue for structures built along the estuary. Following the GI it was established that seepage was not an issue, which allowed a high level design of the proposed solutions along the estuary and canal to be carried out and a cost estimate prepared based on the outcome. An economics assessment was carried out so that the viability of each option could be directly compared based on their capital cost with a 60% optimism bias applied and the property damages that they protect against. This study also performs an environmental evaluation of the proposed Options and advises on how to proceed in gaining the appropriate approvals.

The outcome of the economic assessment, with the associated Net Present Value (NPV) and Benefit Cost Rations (BCR), for a 60% Optimism Bias, is summarised in the table below:

	NPV £	BCR
Do Nothing	£42,460,728	-
Option 1A	£41,240,557	34.80
Option 1B	£40,398,488	20.59
Option 1C	£41,234,584	34.63
Option 2A	£18,867,910	34.31
Option 2B	£18,343,594	17.82
Option 2C	£18,729,286	27.56

Due to the strong performance of the proposed Options it is recommended that these proposals are developed further, and protection works are carried out in due course. Option 1A was identified as the preferred Option due to it having the strongest performance in the economic assessment. It is also an option that protects all the properties at Seatown and the surrounding low-lying areas, inclusive of the caravan park. It was noted during the Public Consultation that the preferred approach was to install an earth embankment as it would be in keeping with the current aesthetics. From a constructability, technical design and an environmental perspective Option 1A would again hold preference over the other Options.

Due to the strong performance of the proposed Options it is recommended that these proposals are developed further, and protection works are carried out in due course

1. Introduction

1.1 Project Background

Jacobs undertook an initial flood study[1] for coastal flooding at Lossiemouth in 2017. This study identified flood levels that would occur during a 1 in 200-year tidal event with 50 years climate change and established areas of the town of Lossiemouth that are located along the estuary banks that could be at risk of flooding during significant tidal events.

Although significant coastal flooding has not yet been reported, recent storms have resulted in water levels in the Lossie estuary that have come close to overtopping existing estuary embankment, particularly in the area of Seatown. Seatown sits on a triangular area of land with watercourses on all sides. Seatown is low lying in comparison to the estuary bank and the topography drops as it moves inland. Properties within this area would be at risk of considerable damages should coastal waters breach the existing defences.

As part of the study, a topographical survey was also procured to establish the extent of flooding that would occur during the design event. Although the initial focus of the report was limited to Seatown, it was discovered that it was not only Seatown that was at risk from tidal flooding, but also the surrounding properties, and the caravan park to the South. Initial concept engineering solutions were proposed to mitigate the risk of coastal flooding from the estuary.

1.2 Objectives

The objectives of this study are to:

- Develop solutions identified previous study to mitigate flood risk by carrying out a cost estimate, constructability review and environmental discussion on the proposed solutions and their requirements going forward;
- Perform an economic assessment comparing the costs of the proposed solutions against the baseline damages that may occur to properties within Lossiemouth;
- Carry out an Options Appraisal to identify a preferred coastal mitigation scheme to protect against overtopping and flooding in Lossiemouth based on the findings of the economics assessment; and
- Develop a business case for the proposed protection works.

To fulfil these objectives Jacobs has supported a ground investigation (GI) on site, which has allowed for further assessment of the options identified during the 2017 study. This report has used the findings of the GI to develop cost estimates, which in turn feeds into the economic assessment of each option. The engineering and economic assessment of all Options will identify a preferred scheme, for which a full business case will be presented herein.

1.3 Project Location

Lossiemouth is located approximately 5 miles north of Elgin on the Moray Coast of Scotland as shown in Figure 1-1. Part of the town, including Seatown, is located on the banks of the estuary of the River Lossie. Seatown sits on a triangular area of land. The Spynie Canal, which flows towards the estuary from the south, bifurcates at the southern tip of Seatown. It then flows through two channels which bound the western and southern edges of Seatown before discharging into the estuary. In addition to the properties at risk in Seatown the area at risk of flooding extends north, west and south of Seatown, which includes many more residential properties in the town and the caravan park, which is to the south.

The River Lossie flows in a north-westerly direction through Lossiemouth before entering the Moray Firth as shown in Figure 1-2.

Figure 1-1: Location of Lossiemouth

Throughout this report, the following locations are referred to:

- Spynie Canal West – Section of the Spynie Canal flowing along the west side of Seatown.
- Spynie Canal South – Section of the Spynie Canal flowing along the south side of Seatown.
- Beach Access Footbridge – Footbridge from Seatown to Lossiemouth East Beach, accessed from Church Street.
- Church St. Road Bridge – Bridge over Spynie Canal West; used for vehicular access to Seatown from Lossiemouth.
- Gregory Place Foot Bridge – Footbridge over Spynie Canal West; can be used for pedestrian access to Seatown from Gregory Place.
- Gregory Place Car Park – Grasscrete surfaced public carpark, located to the west of Spynie Canal West.
- Caravan Park – Caravan Park to the south of Seatown, accessed from Church Street.

Each of these locations is identified in Figure 1-2, below.

Figure 1-2: Location of Seatown and Adjacent Areas Referenced within Report.

2. Flood Level Calculation and Mapping

2.1 Outline Methodology

Recognising how close the south west estuary bank has come to being overtopped in recent years, a Design Flood Water Level (DFWL) was developed during Stage 1 to identify the areas that may require to be modified, or bolstered, to enhance the existing flood protection along the estuary bank.

A number of factors need to be taken into consideration when developing an appropriate design water level for assessment purposes in coastal areas such as Lossiemouth. The Moray Firth is a meso-tidal coastal system (i.e. tides in the range of two to four metres) experiencing semi-diurnal tides. Lossiemouth has a spring tidal range of 3.5m and a neap tidal range of 1.6m. Extreme sea levels can occur in the Moray Firth when adverse weather conditions, such as storm surges, coincide with high tides; therefore, the effects of weather conditions should be combined with astronomical tides to give still water levels (SWL) for design purposes. In addition to tide and weather conditions, the effects of climate change should also be taken into account when considering water levels over the design life of a coastal structure. Current guidance on sea level rise in the UK is based on three alternative emissions level scenarios acknowledging that there is still scope for the climate to change in the 21st century by altering global emissions.

The DFWL developed for Lossiemouth takes cognisance of guidance from the Scottish Environmental Protection Agency (SEPA), Environment Agency (EA), UK Climate Projections 09 (UKCP09) and BS6349[2] to determine a water level deemed appropriate for a 200 year return period water level. The selected 1:200 year tidal event is consistent with SEPA's requirements for Flood Risk Assessments.

The development of the DFWL considers the following:

- 200-year return period tide level, which includes an allowance for storm surges and swells;
- Sea Level Rise, caused by Climate Change for 50 years;
- Freeboard allowance in accordance with SEPA guidance.

Each of these factors is discussed further in the following sections.

2.2 Assumptions and Limitations

Fluvial flooding is not a part of the scope of this study and, as such, has not been considered in determining flood levels. A joint probability study, where fluvial events are considered in conjunction with a coastal event, may influence the final flood level.

2.3 200 Year Return Period

The probability of an event occurring is characterised by a return period. It is a statistical definition of the average time that separates two occurrences of an event of the same or greater magnitude that is typically based on historic data. In general terms, the more extreme an event is, the longer its return period will be.

BS6349-1:2000[2] Maritime Structures describes that structures can generally be designed to withstand a range of extreme conditions. However, to withstand the more extreme events, costs could often become prohibitively expensive, and so an appropriate trade-off between cost and functionality is often sought. As such, an appropriate degree of risk usually must be accepted when determining the design water level for use in a flooding assessment such as this. For the purposes of this study, a 200-year return period tidal event has been selected to determine an initial still water level (SWL). For a 200-year return period event, there is a 0.5% probability of occurrence in any one year (inclusive of the year following an event of the same return period). Using binomial distribution, the probability of a 1 in 200-year event occurring at least once over a design life of 50 years can be determined to be 22%.

2.4 Tide Levels, Storm Surge and Swell

The current key astronomical tide levels for Lossiemouth are presented in Table 2-1below, taken from the Admiralty Tide Charts for Burghead, approximately 8 miles west of Lossiemouth. Chart Datum (CD) at Lossiemouth is defined as being 2.1m lower than Ordnance Datum (Newlyn) (ODN).

Table 2-1: Tidal Levels at Burghead

Astronomical Tide Level	Chart Datum (m)	Ordnance Datum (m)
Highest Astronomical Tide (HAT)	4.7	2.6
Mean High Water Springs (MHWS)	4.1	2
Mean High Water Neaps (MHWN)	3.2	1.1
Mean Low Water Neaps (MLWN)	1.6	-0.5
Mean Low Water Springs (MLWS)	0.6	-1.5
Lowest Astronomical Tide (LAT)	0.0	-2.1

Reference has been made to the SEPA and the Environment Agency (EA) Flood and Coastal Erosion Risk Management[3] programme to establish an appropriate design water level for a 200 year return period. The Flood and Coastal Erosion Risk Management programme has determined tidal data for return periods of up to 1 in 10,000 years based on up-to-date tidal records, storm tide curves, and computed statistical techniques. The tidal levels noted within the Flood and Coastal Erosion Risk Management programme include an allowance for storm surges and swell. For a 200-year return period the above guidance suggests a tidal level of 3.35mOD for the Moray Firth area. As can be seen from Table 2-1this is 0.75m higher than the current level of HAT.

Storm surges and swells have the potential to generate an elevated sea level caused by the combined effect of strong winds and low atmospheric pressure. An allowance for storm surge and swell has been included within the tidal levels identified in the Flood and Coastal Erosion Risk Management[3] programme guidance.

Historically, before the Flood and Coastal Erosion Risk Management study, the magnitude of storm surges would often be evaluated using guidance provided by the Department of Energy's Offshore Installations: Guidance on design, construction and certification[4]. Through consideration of this guidance document, it could be expected that a storm surge of approximately 1.375m above MHWS could occur for a return period of 200 years at Lossiemouth. This approach would result in a water level of 3.375m OD which correlates well with the more recent guidance.

2.5 Sea Level Rise

Sea-level rise predictions account for changes in sea and land levels over a defined period of time. Land levels in Scotland are observed to be rising; however, changes in land levels are generally considered less significant than the increase in sea levels and, as such, have conservatively not been taken into consideration in this study. Sea-level rise is primarily a consequence of climate change. The two factors contributing to sea level rise are typically thermal expansion of seawater and increased global mean temperatures causing ice melt, both of which increase the overall volume of seawater.

BS6349-1[2] notes that where allowances for long-term changes in sea level over the life of the maritime works are to be included in the design, the allowances for works in the United Kingdom should be assessed based upon UKCP09 guidance[5]. UKCP09 guidance utilises an online tool[5] which produces sea level rise information for low, medium and high carbon dioxide (CO_2) emissions scenarios for a specific location. Within each emission scenario, three differing percentiles of accuracy are noted (5th percentile, 50th percentile, and 95th percentile) to take account for the inaccuracies in projecting current emission levels forward. Climate change is considered to be directly linked to CO_2 emissions due to the ability of the gas to trap heat within the atmosphere. NASA[6] notes that there has been a 45% increase in CO_2 levels in the atmosphere since 1950. As such, it is increasingly difficult to accurately predict future increases in CO_2 levels, even when considering global policies such as that set out by the G8 to reduce CO_2 emissions in the future by up to 80% in order to stabilise further increases. In order to reflect this uncertainty, guidance has been sought from SEPA on the selection of an appropriate emissions scenario when assessing the effect of sea level rise. The SEPA guidance notes that due to the existing UKCP09 guidance now being 8 years old, and with an updated document not yet released, the 95th percentile value should be considered in the interim due to the published 50th percentile value no longer being considered as a central estimate.

As previously mentioned, although considered negligible, the information contained within UKCP09 takes account of land movement that is currently predicted over the same timeframe and for the same specific area.

Considering the guidance from SEPA and the information contained within UKCP09, a relative sea level rise of 350mm is considered appropriate for the Lossiemouth area by 2067 when considering a medium emissions scenario with a 95th percentile accuracy.

It should be noted that SEPA are due to be updating their climate change guidance from UKCP09 later this year. A conservative approach to UKCP09 has been used for this study but it may be prudent to review climate change predictions following the release of the new guidance.

2.6 Freeboard

An allowance for freeboard within a design flood level accounts for the uncertainty associated with wave and spray action, uncertainty with local refraction, reflection and shoaling of waves, a reduction in surveyed land levels due to erosion or settlement, and for the inherent uncertainty associated with design flood estimation.

SEPA recommends that a freeboard value of between 500mm and 600mm is added to the calculated still water level when considering mitigation against a coastal flood event. Due to the sheltered nature of the site, located in the estuary of the River Lossie as opposed to directly on the coast, it is considered appropriate to use the lower recommended value of 500mm freeboard. The resultant combination of a 200-year return period tide, 50 year sea level live and the recommended 500mm freeboard is referred to as the Design Flood Water Level.

2.7 Waves

Wave conditions are often the most dominant effect in the structural design of coastal protection works. When designing these structures, it is necessary to obtain comprehensive information defining the expected sea state for the site of interest. This information is essential in determining normal operating conditions, extreme operating conditions and environmental conditions to be considered in design situations.

However, due to the location of the affected properties on the banks of the estuary, the conditions are relatively sheltered from the North Sea due to the presence of the beach and sand dunes on the north side of the estuary. Coastal waves will break on this beach, and at the Old Pier Breakwater, resulting in only minor waves traveling up the estuary. Wind generated surface waves may also form but they are considered to be insignificant. As such, the effects of offshore waves have been discounted and it is assumed that the freeboard allowance will stop the effects of wind generated surface waves in this location. The analysis carried out for this report assumes that the existing beach will remain and will not be eroded during the next 50 years.

The JBA Consulting study[7] noted various wave heights for several areas located around the Old Pier Breakwater, based on a 200-year return period event. The wave height at the area around the old breakwater is not considered to be relevant to the area of interest in this study which is considerably more sheltered from the

North Sea. However, for information, wave heights within the Old Harbour (close to the northerly extent of topographic survey procured by Jacobs UK), based on the 2014 condition of the old breakwater, were predicted to be 0.54m. This gives a greater confidence that wave heights at Seatown, and its adjacent coastline, will be within the 500mm freeboard allowance.

2.8 Combination of Effects

Considering the combined effect of the actions outlined in this Section will give a DFWL appropriate for the next 50 years with a 200-year return period tide level. As discussed in Section 2.7 coastal wave action has not been included in the build-up of this water level. A DFWL of 4.2mOD in the estuary has been determined by combining the 1 in 200-year Tidal Level of 3.35mOD (recognising the effects of Storm Surge and Swell), Sea Level Rise of 0.35m and a Freeboard allowance of 0.5m. This equates to a level of 6.3m above CD.

Although this combination does not include an allowance for waves, it is concluded that the inclusion of a 500mm freeboard in the design of any flood defence structures will be sufficient for the purposes of a study with this level of maturity. Omitting the 500mm freeboard value from the DFWL could be considered to represent a ‘still water’ design level.

It is believed that coastal defences designed with a crest height of 4.2mOD would mitigate against overtopping during a 200-year return period event (due to the inclusion of a freeboard allowance), whereas coastal defences with a crest of 3.7mOD would be at risk of being overtopped due to the dynamic effects of waves and current.

2.9 Flood Maps

A flood map was developed to indicate the areas of Lossiemouth that are at a level below the calculated still water flood level of 3.7mOD, which identified the extent of the properties at risk of flooding. This is shown in Figure 2-1 below. The figure shows the extent of the risk posed from coastal flooding, with much of the banks being overtopped and the canal becoming flooded. The flood map shows that all properties in Seatown are at risk of damages during a significant coast flooding event. There are also many additional properties to the northwest of Seatown directly at risk of coastal flooding. There are also properties to the southwest of Seatown that are identified as being at risk of flooding during a 1:200-year event with climate change.

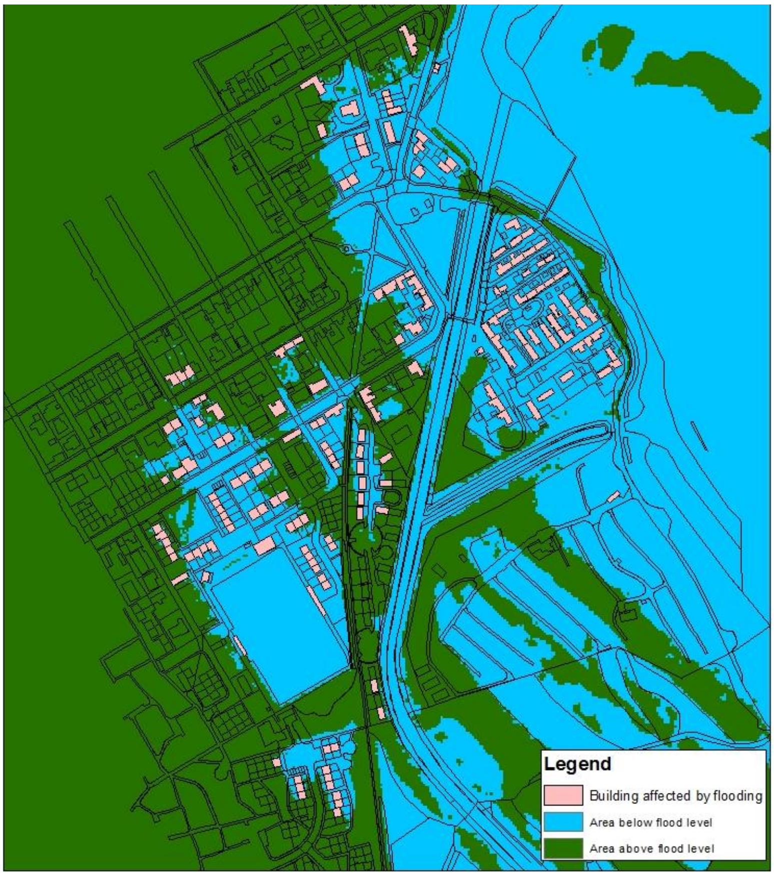


Figure 2-1: Flood map for 3.7mAODN

3. Existing Defences

During the Stage 1 Flood Study[1], a general visual inspection (GVI) of the area to the south west bank of the estuary of the River Lossie was carried out. The inspection concentrated on surveying the type, and condition, of the existing coastal defence structures and to comment as appropriate. This exercise also sought to provide an initial idea of where the low points of the defences may be.

A full GVI description can be found in the Stage 1 report; however, a short summary of the existing structures below has been given below. The descriptions of the existing coastal defences are noted to be correct at the time of inspection (December 2016). The description of the structures has been set out, such to align with the proposed flood defence options that are described in Section 4. The locations, which are identified below, are the locations where low points were established during the initial flood study and are where proposed protection works are to be installed.

Locations 1 to 5 are the low level areas that were identified for protection works from the previous study. However, following receipt and analysis of the LiDAR data, a possible alternative was identified which involves raising the embankment along a short distance of the Spynie Canal, adjacent to the caravan park. This would require a much smaller structure than would be required at Location 5 and it would protect all residential properties; however, it should be noted that it would provide no protection to the caravan site. The canal embankment is described in Location 6.

The location of each area is as shown in the Operation Location Plan Drawing ND800400-SK-001, which is appended to this report.

3.1 Location 1 – Seatown Road (North)

A blockwork masonry seawall is present along the north-western section of the estuary, which ranges between 3.55mAODN and 3.63mAODN in this area. Landward of the wall, the land slopes up to road level. The lowest level that would allow a breach of water on to the road and to the car park / canal is approximately 3.55mAOD.

Figure 3-1: Location 1 – From northern end, looking south

The topography of this area rises above the required 4.2mAOD towards the norther end of Seatown Road, around the junction with Clifton Road, this is where the required protection works would tie in to. The southern extent of works would be close to the culvert at the access to Seatown.

3.2 Location 2 – Beach Access Footbridge

The coastal protection system along Seatown road, to either side of the beach access footbridge, is grass covered earth embankments. They are typically, on the roadside, covered in rocks bedded into concrete to aid the retention of the slope, and to provide an improved aesthetic appearance.

The embankment is locally cut away at the point where the beach access footbridge lands, creating an opening such to facilitate pedestrian access between the pavement and the bridge. A short concrete ramp connects the footpath and the footbridge.

Figure 3-2: Location 2

The crest of the embankment is generally above the required 4.2mAOD; however, at the access point to the footbridge the level is recorded as being only 3.70mODN. The gap in the embankment presents an obvious low point in the sea defences along the frontage at Seatown. Breach of flood water at this location would allow water to flow to the low-lying areas to the far side of Seatown, causing extensive flooding to the properties.

3.3 Location 3 – Seatown Road (South)

The coastal embankments along the south-east of Seatown are grass covered, and more natural in their appearance than other areas surrounding Seatown. There are small amounts of rock armour at the foot of the seaward side of the embankment in discrete locations along its length. At the time of the inspection, the embankments appeared in a good, relatively uniform condition.

Figure 3-3: Location 5 – Estuary bank to the southern end of Seatown

The crest of the embankment generally drops away from Location 2 towards the road above the Spynie Canal culverts at the southern extent of Seatown. At this location the embankment crest is recorded as 3.66mAODN, having gradually dropped from the crest level adjacent to the footbridge opening. The length of embankment below 4.2mAODN is approximately 80m in length.

3.4 Location 4 – Road Across Spynie Canal

This location encompasses the Spynie Canal South outlet into the estuary. There are 3 No. flap valves, set through a concrete wing wall, which allow for water to transfer from the Spynie Canal into the River Lossie. The bank is protected by a small-scale rock armour solution adjacent to the wingwalls of the outlet.

Figure 3-4: Location 4 – Road over culverts to south of Seatown

The road to the Caravan Park passes over the culvert and is typically at the same level as the crest of the embankments. The crest of the embankment is typically at a level of between 3.66mAODN and 3.51mAODN.

The steep, short rise from the culvert outlets limits the space available to install solution and is likely to rule out an earth embankment at this location.

3.5 Location 5 – Embankment in front of Caravan Park

The southwest estuary bank, adjacent to the Caravan Park, is more natural in appearance and at the time of inspection appeared to be in a stable condition.

Figure 3-5: Location 5 – Estuary bank adjacent to caravan park

The levels along the estuary bank were recorded as being below 4.2mAODN were in excess of 350m in length, extending from the culvert at the southern end of Seatown along the western bank of the estuary. The crest level of the existing topography varies greatly along this length of land, with low crest points being recorded as being as low as 3.14mAODN.

3.6 Location 6 – Spynie Canal Embankment

Each branch of the Spynie Canal to either side of Seatown is bounded by steep grassy embankments which serve to protect Seatown and the Gregory Place Car Park area from fluvial flooding. The Spynie Canal embankments to the west side of Seatown appear to be well in good order. There is significant vegetation in this area, which would need to be cleared before any works could be carried out. Construction works carried out here would also need to gain access through the caravan park.

Figure 3-6: Location 6 – Spynie Canal embankment

The embankments to either side of the Spynie Canal South are overgrown with vegetation and so could not be as readily inspected. However, they appeared to be intact and functioning appropriately. The screens protecting the culverts appeared to be clear of debris, allowing fluvial water to flow into the estuary. The flap valves appeared to be functioning as intended during the GVI.

4. Flood Defence Options

Two flood protection strategies have been identified as part of this Report; an arrangement that protects all properties, Option 1, and an arrangement that protects only residential properties and excludes the caravan park, Option 2. The works required for Option 2 will be less extensive and result in lower capital expenditure but will not have the economic benefit of protection the caravan park during a design flooding event. Each of these arrangements considers each of the three main proposed structures, earth embankment, sheet pile wall and concrete retaining wall. Therefore, the Options assessed in this report are as follows:

- Do Nothing;
- Option 1A – Earth Embankments along edge of the estuary;
- Option 1B – Sheet Pile Wall with Cladding along edge of the estuary;
- Option 1C – Concrete retaining wall along edge of estuary;
- Option 2A – Earth Embankment along estuary and Spynie Canal (Excludes Caravan Park);
- Option 2B – Sheet Pile Wall with Cladding along the estuary and Spynie Canal (Excludes Caravan Park);
- Option 2C – Concrete retaining wall along the estuary and Spynie Canal (Excludes Caravan Park).

Options 1A,1B and 1C will have protection works installed at Locations 1, 2, 3, 4, and 5. Options 2A,2B and 2C will have protection works installed at Locations 1, 2, 3, 4, and 6. See drawings ND800400-SK-001 to 007 for details.

4.1 Flood Defence Forms

4.1.1 Earth Embankment

An embankment, which would increase the height of the existing ground to a level of 4.20mODN, would be constructed from a material of low permeability, and have an impermeable liner extended into the existing ground to mitigate against the flow of water through the embankment. The embankment could be landscaped to compliment the surrounding areas. A typical embankment that would achieve the required elevations could be constructed through Locations 1, 3, 5, and 6. Given the spatial constraints at Location 4, highlighted in Section 3.4, it is assumed that an embankment is not a viable solution at this point.

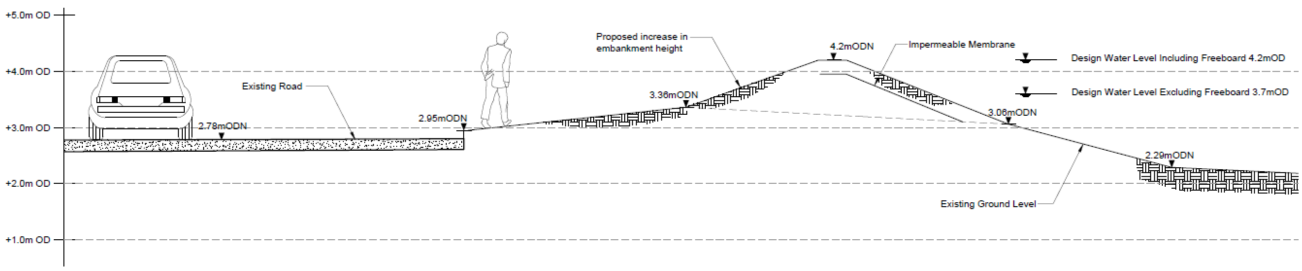


Figure 4-1: Typical Cross Section of Embankment

The earth embankment solution would be a relatively straight forward construction. This would likely be carried out by removal of the topsoil along the footprint of the embankment. The new embankment material would then be delivered to site and compacted in layers, with an impermeable membrane built into the structure to provide extra protection against water permeating through the structure. The structure would then be planted with vegetation in keeping with the local land make up. This would provide stability to the structure against erosion as well as providing a more aesthetically acceptable arrangement. A geotextile could be installed on the estuary side to provide extra protection to the structure. Concrete Retaining Structure

A reinforced concrete wall, which would raise the height of the existing flood defences to 4.20mODN, would be constructed either insitu, or with precast units. The wall would have a base slab to provide adequate stability against sliding, bearing and overturning. The wall could, if desired, be clad in brick or stone, and have a coping stone added to the top. A reinforced concrete retaining wall could be constructed through locations 1, 3, 4, 5, and 6.

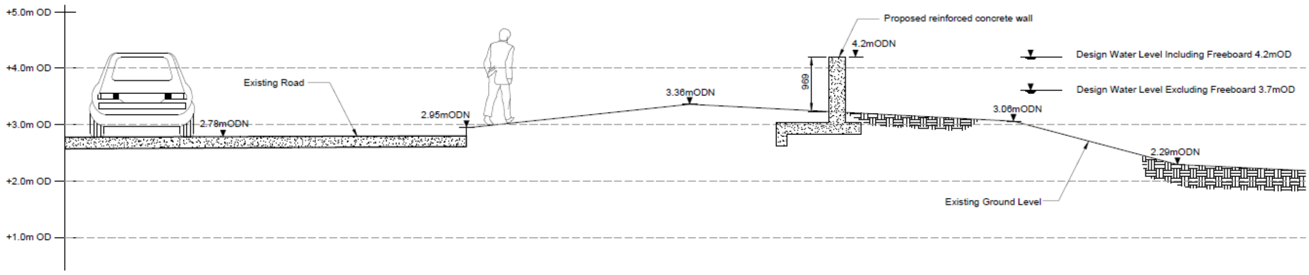


Figure 4-2: Typical Cross Section of Concrete Retaining Structure

To construct this solution a foundation trench will be excavated, and any required foundation material required for the design will be placed and compacted to the required sub level. Assuming an in situ installation, a concrete blinding layer would then be placed and the required steel reinforcement placed on top of this to form the base with starter bars for the stem. The base would then be poured and remaining steel reinforcement would then be fixed and the stem then poured. The ground to either side of the wall can then be reinstated to complete the works. For this solution specialist expansion joints will be required to ensure the structure is water tight.

4.1.2 Sheet Piled Solution with Cladding

A steel sheet piled cut off wall, which remains above ground to a level of 4.20mODN, could be driven into the ground deep enough to provide rotational stability under a hydrostatic load on one side. The above ground section of the sheet piles could be clad, if desired, in brick or stone, and have a coping stone added to the top to help with aesthetic integration in the area. A sheet piled solution with cladding could be constructed through locations 1, 3, 4, 5 and 6. It should be noted that for the design of this solution at Location 4 the proximity of the toe levels to the culverts below may mean that this solution is inappropriate. For the purposes of this study it is assumed that this is not the case and the sheet piles can be installed at all required locations.

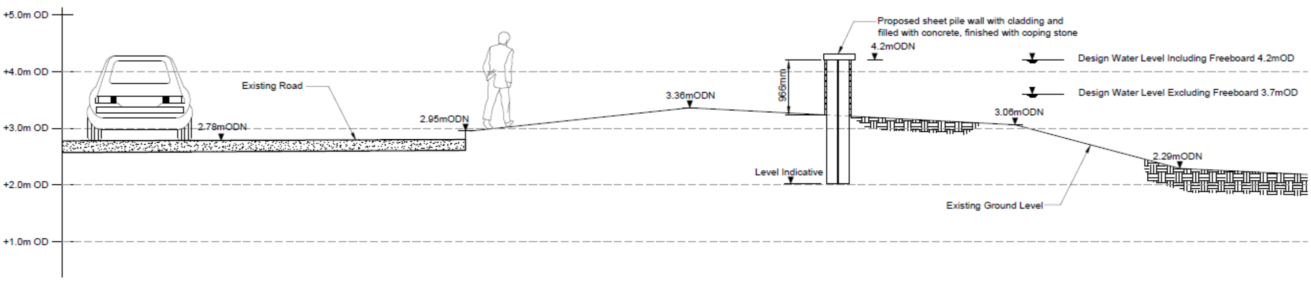


Figure 4-3: Typical Cross Section of Sheet Piled Solution with Cladding

Again, the constructability would be relatively straight forward but would require more specialist plant than the concrete and earth embankment solutions. It can, however, be installed with very little preparation in advance, with the steel piles being installed directly into the existing ground using a piling hammer. The cladding and cope are then installed on to the wall. There should be some assessment carried out at the design stage in order to establish if it likely that there would be any problem in driving sheet piles and avoiding obstructions.

4.1.3 Flood Gate

Any solution installed at Location 2 requires that access is maintained to the footbridge and, as such, the solutions discussed above are not suitable. A flood gate could be installed to mitigate against the risk coastal flooding water overtopping at the point where the beach access footbridge meets Church Street. However, it should be noted that the flood gate would require to be manually closed in the event of a forecasted high-water level. To construct the system, the existing embankment would be extended to maintain a crest height of 4.20mODN until it intersected with a new reinforced concrete retaining wall, that would house the gate mechanism. Once closed, the gate and extended embankment would provide a continual crest height of 4.20mODN. Given the specific nature of requirements at Location 2, the flood gate is only considered for construction at this location.

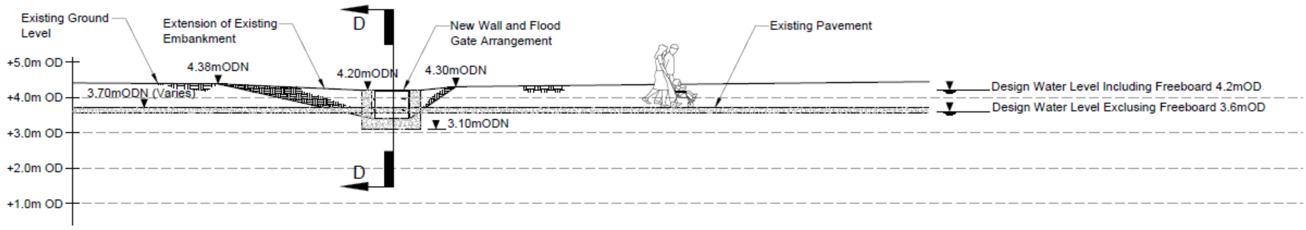


Figure 4-4: Indicative Elevation of Flood Gate

To construct the flood gate part of the embankment at either side would need to be cut back. The concrete footpath that leads down to the bridge would then need to be broken out so that the gate foundations could be put in place.

Formwork would then be set up and the base of the gate poured, following by the gate uprights, forming a ‘U’ shape. The gate would then be hung from the concrete frame, opening towards the estuary. A post would be put in place to hold this open. The embankment would then be filled up on either side to close all gaps.

Finally, the concrete footpath would be reinstated either side of the gate opening.

4.1.4 Closed Off Embankment with Concrete Ramp

A ramp, which increases the overtopping point of the coastal boundary to 4.20mODN could be constructed to allow access onto the beach access footbridge, without the requirement for a floodgate to be closed. The access ramp would slope downwards from the existing pavement from a height of 4.20mODN to the east of the existing footbridge access. The existing embankment would be removed such to allow the construction of the ramp directly adjacent to the existing footpath, before being rebuilt in places where required.

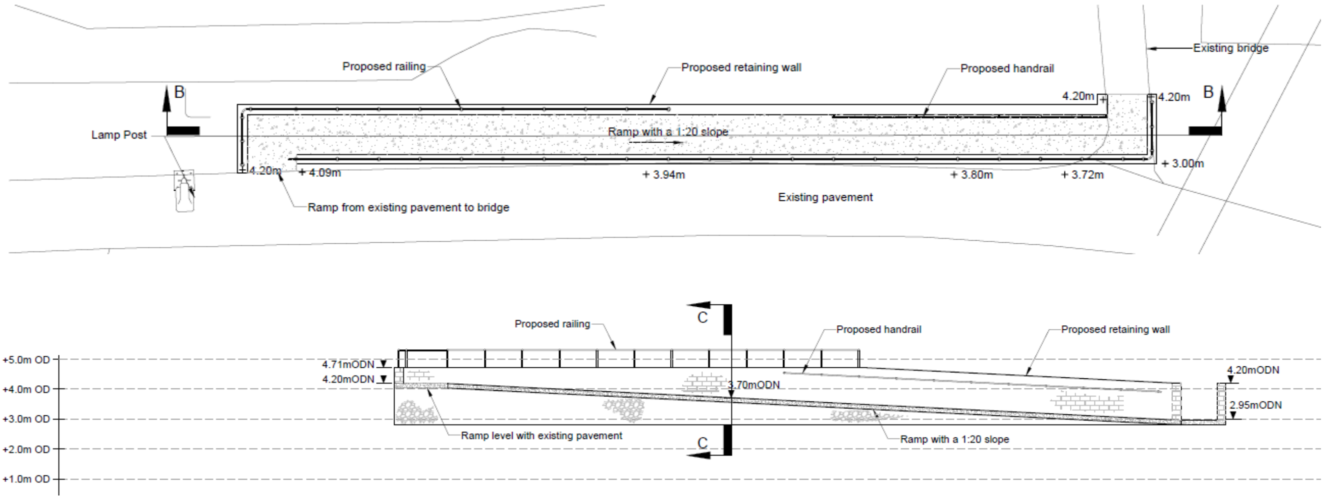


Figure 4-5: Plan and Indicative Cross Section of the Closed Off Embankment with 'U' Ramp

To construct this solution the existing embankment would need to be largely removed from the point of access at the footbridge up to the location where it can join the footpath at the required 4.2mAODN. this will involve excavation of some of the footpath, likely putting it out of use during construction. A blinding course of concrete would be laid, and the required steel fixed in place with started bars for the walls on either side. Concrete would then be poured to form the base of the slope, with a non-slip finish applied to the concrete.

The remaining steel to form the walls of the 'U' ramp would then be fixed in place, formwork arranged and the remaining concrete poured. The embankment can then be reinstated on the estuary side of the wall. This may involve tidal working for plant to place the material appropriately.

Finally, the pavement can be reinstated, and the handrails fixed to the concrete walkway.

4.1.5 Raised Road at Church Street

If a decision is taken to not protect the Caravan Park, and install flood protection measures at Location 6, instead of 5 (discussed in further detail below), then measures will be required to restrict flood waters entering Seatown via the section of Church Street road that is above the Spynie Canal South culverts.

To restrict flood water from entering the Spynie Canal at the culvert location, or flowing straight into Seatown via the road, the road would be required to be raised at this location, such that it could tie into the proposed flood protection measures at Location 3. Raising the road to achieve a crest level of 4.20mODN would provide continuity in flood defence levels. It is considered that the road could be raised by removing the existing surfacing, before building up the level at a complaint gradient, such that the topside of the crest was at a level of 4.20mODN.

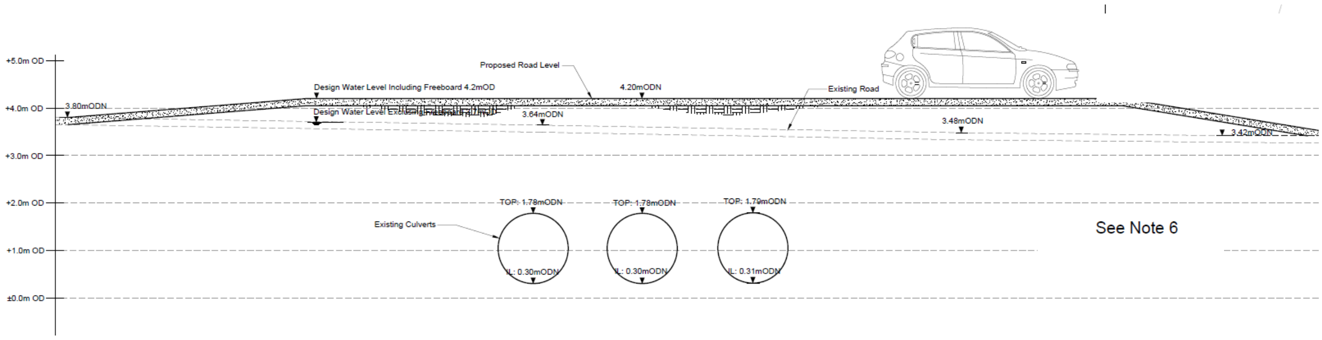


Figure 4-6: Indicative Cross Section of the Raised Road at Church Street

The construction of the road raising is relatively straight forward and involves excavating the existing road, placing the required sub layers and top layer. The main issue will be in maintaining the required access to the caravan site during construction.

4.2 Do Nothing

This Option assumes that no measures are put in place to protect against flooding to properties in the town and that significant tidal events cause extensive flooding. This is the baseline event up which projected damages are to be estimated. These are evaluated in Section 8.

4.3 Option 1A – Earth Embankment

Option 1A would see an embankment constructed through Locations 1, 3, and 5, with a flood gate installed at Location 2, and a concrete retaining wall at Location 4. As noted, continuation of the embankment through Location 4 is unlikely to be a suitable solution due to spatial constraints.

4.4 Option 1B - Concrete Retaining Structure

Option 1B would see a concrete retaining wall constructed through Locations 1, 3, 4 and 5, with a flood gate installed at Location 2.

4.5 Option 1C – Sheet Pile Solution with Cladding

Option 1C would see a sheet piled wall with cladding constructed through Locations 1, 3, 4 and 5, with a flood gate installed at Location 2. This option assumes that sheet piling could be installed at Location 4, and that the presence of the culverts allowing the Spynie Canal South to flow into the estuary does not inhibit this solution.

4.6 Option 2A – Earth Embankment, excluding Caravan Park Protection

Option 2A would see an embankment constructed as described in Option 1A but replacing works at Location 5 with works at Location 6 instead.

4.7 Option 2B – Concrete Retaining Structure, excluding Caravan Park Protection

Option 2B would see a concrete retaining wall constructed as described in Option 1B but replacing Location 5 with Location 6.

4.8 Option 2C – Sheet Pile Solution with Cladding, excluding Caravan Park Protection

Option 2C would see a sheet pile wall solution with cladding constructed as described in Option 1C but replacing Location 5 with Location 6.

5. Ground and Groundwater Conditions

5.1 Introduction

The previous 2017 Flood Study[1] established initial flood defence solutions and carried out a high-level cost estimate. It was assumed at that stage that there was no extensive cut off required to protect against seepage. To establish more certainty a Ground Investigation (GI) was carried out at various locations along the estuary and canal banks. This took the form of trial pitting to maintain a cost-effective approach, with soakaway tests carried out to establish any cut off requirement to mitigate seepage. Additional testing of the material was also carried out.

5.2 Geology

5.2.1 Superficial Geology

The British Geological Survey (BGS) GeoIndex online superficial deposits map[8] indicates the site to be underlain by Marine Beach Deposits comprising shingle, gravel, sand, silt and clay associated with the River Lossie.

The BGS Sheet 95 drift geological map[9] indicates the site to be underlain by Storm Beach Deposits (gravel). The map highlights the presence of elongated mounds, which are believed to be gravel ridges trending parallel to the coastline.

The thickness of the superficial deposits along the shoreline is unknown.

5.2.2 Solid Geology

The British Geological Survey (BGS) GeoIndex online bedrock geology map[10] indicates the solid geology to be the Kingsteps Sandstone Formation.

The BGS Sheet 95 solid geological map[9] indicates the solid geology to be Undivided Upper Old Red Sandstone.

5.3 Ground Investigation

A ground investigation comprising ten trial pits up to 2.80m deep was carried out by HoleQuest Ltd. in May 2018, with laboratory testing and reporting completed by August 2018[11]. The exploratory holes were positioned to provide high level geotechnical information in the areas listed below in Table 5-1 and identified on Dwg. ND800400-SK-001.

Table 5-1: Location of Exploratory holes

Area	Exploratory hole(s) undertaken
Location 1 – Seatown Road (North)	TP8
Location 2 – Beach Access Footbridge	TP7 & TP7A
Location 3 – Seatown Road (South)	TP6
Location 4 – Road Across Spynie Canal	TP5
Location 5 – Embankment in front of Caravan Park	TP1, TP2, TP3 & TP4
Location 6 – Spynie Canal Embankment	TP10

TP9 was removed from the scope due to the presence of underground services at the proposed locations.

5.4 Stratigraphy

Site plans showing the as-built exploratory hole locations can be found in the HoleQuest 2018 final factual report.[11]

The Superficial deposits comprised the following soil types:

- Topsoil;
- Made Ground (granular); and
- Marine Beach Deposits (granular).

Bedrock was not encountered in any of the exploratory holes undertaken during the 2018 ground investigation.

The 2018 ground investigation generally recorded the sequence of strata across the site as indicated in Table 5-2 below.

Table 5-2: General sequence of Strata

Stratum	Depth to top of stratum (m bgl)	Thickness of Stratum (m)
Topsoil / Turf	0.00	0.10 – 0.20
Made Ground (TP3, TP6, TP7, TP7A & TP8)	0.00	0.20 – 1.40
Marine Beach Deposits	0.10 – 1.40	1.20 – 2.65*

*Due to the limitations of the exploratory hole type and the ground conditions encountered, the thickness of Marine Beach Deposits is that encountered by the ground investigation and does not reflect the base of the deposit. Further ground investigation will be required to achieve the scope recommended in Eurocode 7, and to confirm the variation in ground conditions once a preferred option has been determined.

The majority of holes, with the exception of TP07 which terminated on a boulder at 1.1m bgl, terminated at shallow depth (<2.80m bgl) due to the collapse of the trial pit walls.

5.5 Made Ground

What appears to be Made Ground was encountered in five of the ten trial pits excavated during the 2018 ground investigation. The make-up comprised generally slightly silty sand and gravel, sandy silty gravel or very gravelly silty sand with varying proportions of sub-angular to sub-rounded cobbles and angular to sub-angular boulders.

Trial pit TP7 terminated at a depth of 1.10m below ground level (bgl), within the Made Ground stratum due to a boulder obstruction and as a result TP7 was re-dug at TP7A.

5.6 Marine Beach Deposits

Marine Beach Deposits were encountered in all exploratory holes (except TP07) during the 2018 ground investigation. The Marine Beach Deposits comprised generally very sandy slightly silty gravel or gravelly locally very gravelly slightly silty sand with varying proportions of sub-rounded to well-rounded cobbles and sub-rounded boulders.

5.7 Groundwater

Details of groundwater strikes during the 2018 ground investigation are detailed in Table 5-3. TP2, TP6, TP07, TP07A and TP8 were all recorded as dry during the 2018 ground investigation.

Table 5-3: Summary of Groundwater Strikes

Hole ID	Depth Encountered (m bgl)	Stratum	Remarks
TP1	2.60	Sand (Marine Beach Deposits)	
TP3	2.40	Sand (Marine Beach Deposits)	
TP4	-	Sand (Marine Beach Deposits)	Becoming damp at 2.50m
TP5	1.80	Sand (Marine Beach Deposits)	
TP10	-	Sand (Marine Beach Deposits)	Becoming damp at 2.30m

5.8 Testing

The following tests were undertaken during the 2018 ground investigation:

- In situ
  - Soakaway testing, in accordance with BRE Digest 365[12] (10 No.).
- Laboratory
  - Particle Size Distribution (17 No.);
  - Natural Moisture Content (15 No.);
  - Consolidated Drained Shear Box (2 No.); and
  - Geo-chemical testing.

The types of testing available were limited by the form of ground investigation.

Table 5-4 summarises the geotechnical test results below.

Table 5-4: Summary of Geotechnical test results

Geotechnical Test	Test Results
In situ Soakaway test (BRE Digest 365) m/s	$3.4x10^{-5}$ – $1.1x10^{-4}$
Natural Moisture Content %	2.3 – 10.0
pH Value	5.7 – 9.3
Sulphate (SO4, solid acid extract) %	0.07 – 0.10
Sulphur (total, solid 2:1 water extract) %	0.03 – 0.05
Shear Box (peak)	ϕ' = 42°, c' = 0 kPa. ϕ' = 31°, c' = 7.9kPa.

5.9 Geotechnical Assessment of Proposed Structures

The options identified for each area listed in Table 5-1 are shown on Dwgs. ND800400-SK-001 to ND800400-SK-007.

The options typically considered for each location are:

- Earth embankment;
- Concrete retaining structure; and
- Sheet piled solution with cladding.

Location 2 proposals include the construction of a floodgate or concrete ramp at the existing access point to the footbridge. The floodgate option proposes an extension of the existing embankment to a level of 4.20m ODN, to tie-in with the proposed floodgate. This represents an approximate level change of 0.5m at this location.

The ramp option proposes constructing a reinforced concrete 'U' section to form a ramp from the existing pavement level (4.20m ODN) leading down to the existing bridge access, with the existing embankments altered and raised to meet the new 'U' section and tie in with the required crest height.

An additional option, at location 4, proposes to raise the level of the existing road to the required level of 4.2mAODN. This solution would be to allow the raising of the adjacent canal embankment at Location 6.

5.9.1 Seepage

A high-level seepage analysis has been undertaken for Location 1 to Location 6, based on the following initial assumptions:

- Marine Beach Deposits have a permeability of 5.5×10^{-5} m/s in all six locations;
- The proposed earth embankment is of low permeability;
- Groundwater prior to the flood is ≤ 2.4m below ground level; and
- Flood level of 3.7m ODN (Ordnance Datum Newlyn) with a maximum duration of 6 hours, prior to receding.

The initial results from the seepage analysis indicate that a cut-off wall below the earth embankment option or the reinforced concrete retaining structure option is not a requirement. Further seepage analysis will be required during the detailed design stage to assess the effects of varying flood levels and flood duration, the latter being most critical to the need or not of a cut-off.

5.9.2 Earth Embankment

A key aspect of this solution is that the flood embankment is either constructed from a low permeability material (1×10^{-9} m/s) or constructed from a material with a lower permeability than the existing fill, complete with an impermeable liner extended a minimum of 1.0m into the existing ground, to prevent seepage through the embankment.

The stability of the proposed embankment slopes will require consideration in the detailed design to protect against erosion and stability issues. There is also the potential for settlement to occur within or below the embankment post construction. This will need to be considered at the detailed design stage if this option is chosen.

5.9.3 Concrete Retaining Structure

The design of the concrete retaining structure will need to satisfy sliding, bearing and overturning stability calculations. All potential load cases will need to be considered during the detailed design stage, including hydrostatic uplift pressure, and vehicular impact loading.

5.9.4 Sheet Piled Solution with Cladding

The ground conditions may prevent the sheet piles being driven to the design depth. The ground conditions should be considered further in the detailed design stage along with the method of installation. The toe level of the sheet piles will be determined in the detailed design stage.

5.10 Recommended Further Geotechnical

Limited ground investigation has been undertaken to date and it is recommended that further ground investigation is undertaken to establish the following:

- Baseline groundwater conditions, including long term monitoring to determine the tidal impact as well as the impact of seasonal changes on groundwater local to the proposed flood defences;
- Detailed ground conditions below the extent of the trial pits, which were 2.80m below ground level; and
- Strength and permeability characteristics of the ground to allow for a geotechnical assessment of the preferred option.

6. Planning and the Environment

6.1 Introduction

The purpose of this Planning and the Environment Section is guide the a preferred scheme, this will be achieved through a high level commentary on the planning requirements and the key environmental aspects, including any environmental designations, of the site and the immediate surrounding area. This Section will also identify the potential scope of further studies and environmental consents that may be required at subsequent project stages.

Given the high-level approach to this study no specific study area has been defined. Instead a broader overview of the locale has been adopted to identify key planning and environmental designations and constraints, which are detailed in Section 6.3.1.

6.2 Methods and Scope of Review

6.2.1 Methods

The assessment has been carried out as a desk-based review, utilising publicly accessible information and supplemented by studies undertaken for other aspects of this report.

As noted in 6.1, a broader area has been assumed as the 'Study Area' although where necessary for some environmental topics (e.g. ecology) a specific area has been reviewed (and defined) to identify designations.

6.2.2 Assumptions and Limitations

The section provides general advice in relation to the flood defence options set out above in Section 6 (Flood Defence Options).

Where differentiators in relation to potential environmental impacts or consents have been identified between options, these are noted in Section 6.5 (Summary).

No engagement with any statutory or determining authorities has been undertaken for this initial study. This will be required at a later stage to seek confirmation of any assumptions (See 6.3.3).

Assumptions have been made that will need to be confirmed upon reviewing the chosen detailed design. Where applicable, these assumptions have been identified throughout the chapter.

In addition, details of the activities to be undertaken (e.g. the specific method for chosen option) are required.

6.3 Planning Context

6.3.1 Policy Context

The Moray Council formally adopted The Moray Local Development Plan (MLDP) in July 2015, which details the planning policy requirements of the site, and replaces the previous Moray Structure Plan (2007) and Moray Local Plan (2008).

The strategy for the distribution of development across Moray is a continuation of that taken by the 2008 Local Plan which identified Lossiemouth as a "second tier settlement".

The objectives for Lossiemouth, outlined in the MLDP, of relevance to the study area include:

- Addressing constraints on where the town can expand.
- Full advantage should be taken of tourism potential.
- To maintain the areas of built and natural environment which contribute to the character of the town.

- To maintain public access to the surrounding beaches and wooded areas.

Figure 6-1: Lossiemouth Settlement Map, Moray Local Development Plan, 2015.

As noted in Figure 6-1 above taken from the MLDP, a number of key development planning allocations are identified in the Seatown area with relevant MLDP policies having to be considered, primarily for Environment and Tourism, these are noted as:

2015 MLDP Policy	Areas Covered in Policy	Relevant to Flood Options
ENV6 – Green Corridors / Natural / Semi Natural Greenspaces	Spynie Canal, Inchbroom Road / Sunbank East.	Location 3 Location 4 Location 5
ENV7 – Civic Space	Gregory Place, James Square.	Location 2
ENV8 – Foreshore Areas	Esplanade, West Foreshore (West Beach car park to Shore Street industrial area), North Foreshore.	Location 1
T1 – Caravan Park	Existing Caravan Park will be protected from development due to its importance as a tourist facility. The Plan notes that alternative activity will not be permitted. Access to allow cleaning and maintenance of the canal must be maintained along the western boundary of site T1.	Location 5
T2 – Caravan Park Extension	Proposed extension to the Caravan Park; the Plan acknowledges the site is at risk from coastal flooding and that a buffer would be required between watercourses and any proposed development.	Location 5

While it is considered that the majority of the proposed works will occur within the ENV6 and ENV7 allocations, consideration has also been given to any cumulative impacts on other allocations (See section 6.3.3).

6.3.2 Marine Planning

At this stage it is not considered that the proposed works will fall within the jurisdiction of Marine Scotland given the works are intended to be carried out on land above mean high water springs (MHWS). The boundary for MHWS broadly follows the mouth of the River Lossie southwards and includes the western half of Lossiemouth East Beach outwards, indicatively aligned to the dashed blue line shown in Figure 6-1above.

As such a Marine License is not envisaged (note consents required are set out below in section 6.4).

Furthermore, in line with the relevant Planning Circular[1], marine and terrestrial planning authorities should consult one another formally. If it is identified at the next stage that there is the potential to indirectly impact the marine environment, it is advised to liaise with Marine Scotland and discuss the proposal.

6.3.3 Further studies and recommendations

It is recommended that:

- A review of any extant planning applications in the local area is undertaken, particularly around potential allocation sites (see Figure 6-1), namely the Caravan Park and potential extension.
- Upon understanding the full extent of the proposed works and any residual impacts, contact should be made with The Moray Council Planning Department to discuss any potential impacts and to seek confirmation that Permitted Development rights would apply to the proposed works (see 6.4.1.2)

6.3.4 Ecological and Heritage Designations

While the extent of any proposed works will be specified in the next phase of work and the option selected, it is assumed that the construction works will take place within the broader (Easting / Northing Coordinates) area of **NGR 23854 70839** to the North and **NGR 24259 69437** to the South of the waterfront.

As can be seen in Figure 7-2 below, the following designations have been identified in the wider study area.

- Lossiemouth East Quarry Sites of Special Scientific Interest (SSSI) (Geological).
- Lossiemouth Shore SSSI (Geological).
- Moray Firth Special Area of Conservation (SAC).
- Lower River Spey - Spey Bay SAC.
- Spey Bay SSSI (Mixed).
- A number of A to C Listed Buildings.
- Other heritage aspects recorded in the National Monument Records of Scotland (not shown on figure).

[1] Planning Circular. The relationship between the statutory land use planning system and marine planning and licensing. http://www.gov.scot/topics/marine/seamanagement/national/circular

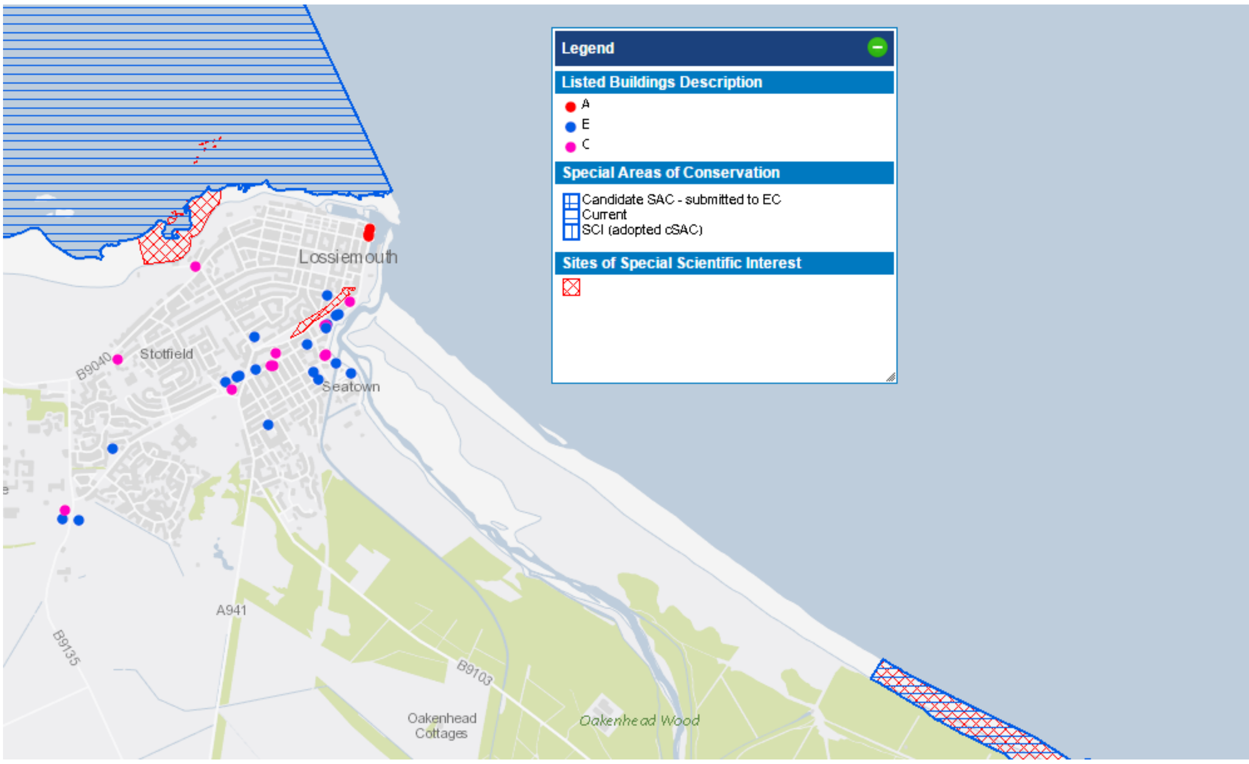


Figure 6-2: Identified Designations in the local area[2].

None of the follow designations have been identified in the wider study area:

- Conservation Areas
- Special Protection Areas
- Local Nature Reserves
- National Nature Reserves
- National Scenic Areas
- Wetlands of International Importance (Ramsar)

6.3.5 Heritage

As can be seen in Figure 6-2 above, a number of heritage assets have been identified, those of direct relevance are identified in Table 6-2 below.

Given the scope of works, it is not anticipated that there will be any direct impacts, or setting impacts, on any of these heritage assets, however further review will be required at the next stage to confirm.

[2] Image taken from 'Scotland's Environment', accessed 30/03/17 from here http://map.environment.scotland.gov.uk/seweb/map.htm?menutype=1

Table 6-1: Listed buildings in Seatown

Feature	Category (HES Reference)	NGR	Description
Seatown Bridge Over Spynie Canal	B (LB37613)	23697 70426	Circa 1810. Single span arched bridge with sluice gates at South side. Tooled squared rubble, tooled ashlar dressings. Segmental-headed segmental arch ring flanked on N (seaward side) by retaining walls of same height and materials and linked by continuous bandcourse and parapet.
Seatown, K6 Telephone Kiosk	B (LB37615)	23775 70378	Standard K6 telephone box designed by Sir Giles Gilbert Scott, 1935.
1, 2 Seatown Road And Garden Walls	B (LB37613)	23642 70490	Late 18th century. 2-storey and attic W facing house of 3 bays with early 19th century 2-storey, addition at NW forming L-plan. Further single storey and attic wing at S gable. Rubble, contrasting painted tooled ashlar margins; squared, dressed rubble masonry to projecting wing. Centre entrance to original house, now in re-entrant angle formed by wing. Further gable end entrance to wing flanked by larger multi-pane window, probably former shop. Small fenestration elsewhere, with 12-pane sashes. Substantial modern box dormer at rear. End and wallhead stacks, slate roofs. Mid-19th century single storey and attic, 2-bay wing at W gable. GARDEN WALLS: coped rubble walls enclose garden at E of house.

6.3.5.1 Further studies recommended

A high level heritage assessment should be undertaken to confirm that there will be no impacts on listed and other key receptors.

6.3.6 Noise, Vibration and Air Quality

Given the nature of this scheme it is considered unlikely that there will be operational noise, or air quality impacts, on sensitive receptors and therefore, an assessment has not been undertaken in this study. Upon understanding the full extent of the proposed works, including the provision of any piling, there will be a requirement to undertake an assessment at the next stage to further understand potential impacts.

It is considered that during the construction period of the scheme that there would be the potential for temporary disturbance to local receptors from noise, vibration and dust resulting from construction activities. However, these issues can be mitigated through the development of an appropriate Construction Environmental Management Plan. It is not anticipated that any formal surveys will be required, although it is recommended that liaison with the Council's Environmental Health service is undertaken to confirm this.

6.3.7 Marine Ecology and Nature Conservation

A desk-based review of freely available ecological data was carried out of the wider study area including statutory designated sites and other protected and notable ecological features that may be potentially impacted by the project.

Table 6-2below lists the statutory designated sites identified in Figure 6-2.

It is unlikely, given the nature of the scheme, that there will be potential impacts from operational noise or air quality. However, a further review will be required to confirm this during the next stage of the project.

Table 6-2: Statutory designated sites within search radius and their location relative to the site

Feature	Designation and Key Selection Criteria	Approx. distance from closest point of proposed site
Lossiemouth East Quarry	(SSSI) (GEOLOGICAL): Permian Triassic Reptilia	65m
Lossiemouth Shore	SSSI (GEOLOGICAL): Permian Triassic (red beds)	950m
Spey Bay	SSSI (MIXED): Various	2.3km
Loch Spynie	SSSI (BIOLOGICAL): Various	3.5km
Moray Firth	Special Area of Conservation (SAC): Subtidal sandbanks Bottlenose dolphin	400m
Lower River Spey	SAC: Broad-leaved, mixed and yew woodland: Alder woodland on floodplains Supralittoral sediment (Coast): Coastal shingle vegetation outside the reach of waves	2.3km
Loch Spynie	Special Protected Area (SPA): Greylag goose (*Anser anser*) – non breeding	3.5km

Although not a designated site the River Lossie is known to contain Atlantic salmon (*Salmo salar*), sea trout (*Salmo trutta trutta*) and European eel (*Anguilla Anguilla*), which are European Protected Species, and the study area is an important migratory route for these species.

6.3.7.1 Information Gaps

As noted above, the assessment comprises a desk-based review of publicly available information and previous published reports. A site walk over and full biological data centre search have not been undertaken to confirm the potential for protected species and habitats.

6.3.7.2 Further studies recommended

There is no detailed plan regarding construction footprints and construction methods which would be required to fully understand the predicted impacts of the scheme on ecological receptors.

Table 6-3 below lists the further studies recommended.

Table 6-3: Recommended Ecological Studies

Recommendation	Justification
Full biological record centre search	To obtain detailed protected species, habitat and site (statutory and non-statutory) information to inform a judgement on potential impacts from the scheme and inform the decision to conduct more targeted ecological surveys.
Preliminary Ecological Appraisal of the site	Obtain up to date habitat information and on what is likely to be impacted by the proposed works. Undertaken through a walkover and desk based survey. The results of this appraisal will determine whether further targeted ecological surveys are required.
Consultation with Local Planning Authority (LPA) and Scottish Natural Heritage (SNH)	Obtain opinion regarding likely effects from the scheme and potential impacts to the designated sites.
A Habitat Regulations Appraisal (HRA) Stage 1 Screening Report	Due to the proximity of the Natura 2000 sites (SACs and SPA) it is highly likely that a Stage 1 Habitats Regulations Assessment Screening report would be required to determine if there is the potential to have an adverse effect on site integrity of the designated sites.

Should European Protected Species, i.e. Otters, be identified in the next stage then appropriate mitigation licenses would be required.

6.3.8 Water Quality and Drainage

6.3.8.1 Summary

A desk-based review of watercourses within the study area was conducted using Ordnance Survey mapping and the Scottish Environmental Protection Agency (SEPA) Water Environment Hub[13]. The following Water Framework Directive (WFD) water bodies were identified:

- Spynie Canal - an artificial water body in the Moray Coastal catchment. The main stem is approximately 7.2km in length. The water body has been designated as artificial account of physical alterations that cannot be addressed without a significant impact on the drainage of agricultural land;
- Innes Canal / Lhanbryde Burn - a river in the Moray Coastal catchment. The main stem is approximately 12.0km in length;
- Lossie Estuary - a transitional water body that comprises the downstream tidal reach of the River Lossie, with an area of 0.5km^2;
- Lossiemouth to Portgordon - a coastal water body with an area of 79.0km^2; and
- Burghead to Lossiemouth - a coastal water body with an area of 122.3km^2.

No undesignated minor watercourses were noted.

Table 6-4: WFD status of coastal and estuary water bodies potentially impacted

Water Body (ID)	Component	2014	2021	2027	Long Term
Spynie Canal (23026)	**Overall**	**Good**	**Good**	**Good**	**Good**
	Access for fish migration	High	High	High	High
	Water flows and levels	Good	Good	Good	Good
	Physical condition	High	High	High	High
	Freedom from invasive species	Good	Good	Good	Good
	Water quality	High	High	High	High
Innes Canal (23377)	**Overall**	**Poor**	**Poor**	**Good**	**Good**
	Access for fish migration	High	High	High	High
	Water flows and levels	Moderate	Good	Good	Good
	Physical condition	Poor	Poor	Good	Good
	Freedom from invasive species	High	High	High	High
	Water quality	High	High	High	High
Lossie Estuary (200143)	**Overall**	**Good**	**Good**	**Good**	**Good**
	Physical condition	High	High	High	High
	Freedom from invasive species	High	High	High	High
	Water quality	High	High	High	High
Lossiemouth to Portgordon (200147)	**Overall**	**Good**	**Good**	**Good**	**Good**
	Physical condition	High	High	High	High
	Freedom from invasive species	High	High	High	High
	Water quality	Good	Good	Good	Good
Burghead to Lossiemouth (200148)	**Overall**	**Good**	**Good**	**Good**	**Good**
	Physical condition	High	High	High	High
	Freedom from invasive species	High	High	High	High
	Water quality	Good	Good	Good	Good

Table 6-4indicates that all water bodies were generally in good condition in 2014 with the exception of the Innes Canal which is noted to have issues associated with physical condition and water flows and levels. The physical condition is attributed to historic urban and rural land use which impacts the bed, banks and shores of the canal, while the use of the canal for agricultural irrigation through abstraction, has impacted water flows and levels. Both issues are the responsibility of SEPA and are anticipated to be addressed by 2027 (as indicated by the SEPA website).

6.3.8.2 Information Gaps

The following information is outstanding and would be required at the next phase of the project:

- Detailed drainage information (surface waters and foul waters) for the whole area potentially affected by the flood alleviation works.
- Information on potentially contaminated land sites in the immediate vicinity that may be disturbed by the works (including the contaminants that they may contain).
- Any water quality sampling/monitoring data from the SEPA monitored water bodies. Consultation with the SEPA will be required.

- Detailed topographical information to determine potential flow pathways for flood waters.
- Information on the Moray Council's existing surface water and foul water drainage networks that may be connected to the drainage within the working area. Consultation with the local authority will be required.

This information will indicate existing pollutant pathways to sensitive receptors.

6.3.8.3 Further studies recommended

Details of the location and extent of the works will inform the scope of future studies (Environmental Appraisal or similar).

6.4 Consenting Requirements

6.4.1.1 Environmental Impact Assessment

The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011 ("the EIA Regulations") define 'EIA development' as either a Schedule 1, EIA is mandatory, or Schedule 2, development that is likely to have significant effects on the environment by virtue of factors such as its nature, size or location.

Based on the nature and scale of the potential works options they would not fall under Schedule 1 development requirements. Schedule 2 listed activities which are considered relevant to the proposed works are listed below:

Schedule 2, Class 10 "Infrastructure Projects" has two categories related to the type of development proposed:

- Class 10 (h) "*Inland-waterway construction, canalisation and flood-relief works – applicable if the area of the works exceeds 1 hectare*"
- Class 10 (m) "*Coastal work to combat erosion and maritime works capable of altering the coast through the construction, for example, of dykes, moles, jetties and other sea defence works, excluding the maintenance and reconstruction of such works*"

Given the works being proposed are predominantly targeted works on existing coastal defences, the development is not of a type listed in column 1 of schedule 2, and as such it is anticipated that an **EIA would not be required**, however a review of the detailed plan will be required at the next stage to confirm.

6.4.1.2 Planning Consents

At this stage in the project it is assumed that the preferred flood mitigation options will likely require a planning consent to be granted. While this will be considered and confirmed at a future stage (section 6.3.3), it is worth noting at this point that there is the potential that the works could be undertaken without formal consent under The Town and Country Planning (General Permitted Development)(Scotland) Order 2011 ("PD rights").

PD rights enable certain works to be exercised without formal planning approval, providing they fall within the criteria and thresholds set out in the order.

Should works be undertaken on the Spynie Canal, as an Inland waterway, the following class applies:

> **"Class 36: Works to inland waterways**
>
> *The improvement, maintenance or repair of an inland waterway (other than a commercial waterway or cruising waterway) to which section 104 of the Transport Act 1968(a) applies, and the repair or maintenance of a culvert, weir, lock, aqueduct, sluice, reservoir, let-off valve or other work used in connection with the control and operation of such a waterway."*

Furthermore, as the works are being undertaken on behalf of the Local Authority (The Moray Council), a number of rights are afforded to development by Local Authorities that have the potential to cover other aspects of any works, including:

> "**Class 30: The erection or construction and the maintenance, improvement or other alteration by a local authority of** –
>
> (a) *Any building, works or equipment not exceeding 4 metres in height or 200 cubic metres in capacity on land belonging to or maintained by them, being building works or equipment required for the purposes of any function exercised by them on that land otherwise than as statutory undertakers*;"

Should the works exceed or not meet the criteria listed above (or anything else within PD rights) then formal Planning would be required. Furthermore, should an EIA (as set out in 6.4.1.1) be required, PD rights would be removed.

6.4.1.3 CAR Licence

It is anticipated that the works will require to be licenced under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) and the Water Environment (Miscellaneous) Regulations 2017; once further detailed information is available, a scoping exercise will be required, which will include consultation with SEPA. Under the WFD, no deterioration of ecological staus is permitted and therefore any further studies will need to demonstrate that there will be no adverse impacts on the water bodies identified.

Option 1 (Earth Embankment) is proposed to be constructed of earth fill with an impermeable liner to prevent seepage through the embankment. Where lengths proposed are ≤50m in length, it is anticipated that a CAR Registration will be required for "Green bank reinforcement or re-profiling ≤50m in length". Lengths >50m are anticipated to require a CAR Simple Licence for "All other green bank reinforcement or reprofiling".

Option 2 (Concrete Retaining Structure) and Option 3 (Sheet Piled Solution with Cladding) will be considered 'grey bank reinforcement'. Where lengths of these structures are ≤100m, it is anticipated that a CAR Simple Licence will be required for "Grey bank reinforcement, floodwalls and embankments ≤100m in length in rivers >3m wide and lochs". Lengths >100m are anticipated to require a CAR Complex Licence for "All other grey bank reinforcement, floodwalls and embankments in rivers >3 wide and lochs".

In addition, a CAR Construction Site Licence is anticipated to be required for the construction phase.

Licencing requirements will be confirmed with SEPA as part of the scoping exercise as the designs are developed further.

6.5 Summary

As noted in section 6.1, the purpose of this section was to review potential planning or environmental constraints, and identify potential future survey work and consents that may be required to deliver the proposed scheme, based on the current information on the proposed works.

Given the information available at this date, there are no clear environmental constraints that would prevent the preferred flood mitigation options being undertaken. However, acknowledging that the preferred options still need to be confirmed, a number of additional environmental assessments will be required at future stages of the project, as noted throughout. As summarised in Table 6-5 below, a series of assumptions would require resolution prior to confirmation of consents requirements. This would need to be undertaken in due course when the designs have been confirmed.

Table 6-5: Summary of next stage requirements

Topic	Work required in next stage
Land Use Planning	• A review of any extant planning applications in the local area is undertaken, particularly around potential allocations sites (seeFigure 6-1), namely the Caravan Parks. • Upon understanding the full extent of the proposed works and any potential impacts, a discussion should be undertaken with the Moray Council Planning department to discuss consent requirements and seek confirmation that Permitted Development rights would apply to the proposed works.
Heritage, Noise, Vibration and Air	• A high level heritage assessment should be undertaken to confirm that there will be no impacts on listed and other key receptors. • A high level Noise, Vibration and Air assessment based on further detail of design
Water Quality	• Detailed drainage information (surface waters and foul waters) for the whole area potentially affected by the flood alleviation works. • Information on potentially contaminated land sites in the immediate vicinity that may be disturbed by the works (including the contaminants that they may contain). • Review of any water quality sampling/monitoring data from the SEPA monitored water bodies. Consultation with the SEPA will be required. • Information on the Moray Council's existing surface water and foul water drainage networks that may be connected to the drainage within the working area. Consultation with the Moray Council will be required. • Details of the location and extent of works will indicate the scope of future studies (Environmental Appraisal or similar).
Ecology (Marine and Terrestrial)	• Full biological record center search • Preliminary Ecological Appraisal of the site • Consultation with Moray Council and Scottish Natural Heritage (SNH) • A Habitat Regulations Appraisal (HRA) Stage 1 Screening Report

7. Cost Estimation

7.1 Introduction

Preliminary cost estimates have been developed for the six defence option arrangements identified in Section 4. These are based on approximate quantities informed by topographical survey information and engineering judgement. The rates used within the cost estimates have been derived from published cost data and supplier rates.

At this stage in the project, the cost estimates are based on concept designs, which will require review and refinement if taken forward. It should be noted that no preliminary design work has been undertaken at this stage. It is expected that the estimates within this report have an accuracy range of -30% to +60%. Costs are based on the following assumptions:

- All works are undertaken during normal working hours;
- No contaminated or hazardous materials are present on site;
- The contract will be competitively tendered;
- Suitable access is available for all plant and machinery required; and
- The flap valves from the Spynie Canal are maintained and, if required, replaced by others;

When preparing the cost estimates, the following items have been specifically excluded from the figures:

- Value Added Tax (VAT);
- Design fees;
- Additional ground investigation work;
- Cost of diverting, or protecting, existing services;
- Planning and environmental approvals;
- Consents and licences;
- Consultancy fees supporting The Moray Council during the tender and construction phases;
- Additional surveys recommended for the next phase of the project;
- Inflation beyond 4Q2018;
- Local authority fees;
- Land Purchase; and
- Legal or funding costs.

7.2 Options Cost Estimate

The preliminary cost estimate and accuracy range are presented in Table 7-1 for all 6 Options and are exclusive of assumed maintenance figures, which will be added for the Economic Assessment in Section 7. It should be noted that for consistency, all Options currently include only the flood gate solution at Location 2, Section 7.3 shows the cost comparison between the flood gate and concrete ramp solutions at Location 2.

Table 7-1: Cost estimates for each defence option.

Option	Approximate Capital Cost		
	Cost Estimate -30%	Cost Estimate	Cost Estimate +60%
Option 1A	£518,907	£741,296	£1,186,074
Option 1B	£887,312	£1,267,589	£2,028,142
Option 1C	£521,520	£745,029	£1,192,046
Option 2A	£232,901	£332,716	£532,345
Option 2B	£462,289	£660,413	£1,056,661
Option 2C	£293,549	£419,356	£670,970

Of the three types of the solution the earth embankment structure is estimated to be the cheapest to construct. Due to the length of the solution required to the south, the alternative arrangement of raising the canal embankment, and excluding the caravan park from protection, works out to be approximately half the cost of protecting all properties. This information will be developed in Section 8 to determine how these compare to the calculated baseline damages and determine a benefit cost ration (BCR) for each of the proposed Options.

7.3 Location 2 Options Cost Comparison

As discussed, the figures presented in the previous section all consider only the flood gate solution at Location 2 to keep the comparative costs consistent. Table 7-2 shows the cost estimates for the two proposed solutions at Location 2. Each figure is inclusive of the same assumptions outlined for the Options Cost Estimate.

Table 7-2: Cost estimates for each defence option.

Option	Approximate Capital Cost		
	Cost Estimate -30%	Cost Estimate	Cost Estimate +60%
Flood Gate	£24,576	£35,108	£56,173
Concrete Ramp	£29,597	£42,282	£67,651

Due to the relatively small difference in value in the two proposals, in comparison to overall cost of each Option, it can be assumed that either proposal could be selected with little impact to the Economics Assessment outcome. The preferred solution may be dependent on whether there is desire to avoid procedural requirements during a flood even that would be required of the flood gate options. There may also be a preference amongst residents for which solution would be more desirable. Additionally, the solution here could be impacted by any proposed development, or alteration, to the current timber bridge.

The preferred solution can be incorporated into any of the proposed Options.

8. Economic Assessment

8.1 Introduction

This section of the report presents the assessment of the consequence of flooding in monetary terms. The methodology compares the water levels associated with a 1:200-year tidal event with the levels of the existing coastal defences at Lossiemouth and will give consideration to the following:

- the consequence of coastal water overtopping the existing defences for a 1:200-year tidal event with a 50-year sea level rise due to climate change; and
- potential flood mitigation measures at each vulnerable location in the vicinity of Seatown.

Six options were identified and are described in more detail in Section 4. There are two outcomes from the six options, three protect all of Lossiemouth, while three protect all properties except from the caravan park. The results of the benefit cost analysis (CBA) will be used to rank all options to assist in determining a preferred course of action.

The economic damages (costs) and benefits (avoided costs) of the following options are considered within this assessment;

- Do Nothing
- Do Something Options:
  - Option 1A - Earth Embankments along edge of the estuary
  - Option 1B – Sheet Pile Wall with Cladding along edge of the estuary
  - Option 1C – Concrete retaining wall along edge of estuary
  - Option 2A – Earth Embankment along estuary and Spynie Canal (Excludes Caravan Park)
  - Option 2B – Sheet Pile Wall with Cladding along the estuary and Spynie Canal (Excludes Caravan Park)
  - Option 2C – Concrete retaining wall along the estuary and Spynie Canal (Excludes Caravan Park)

Details of the proposed defence options for the flood scenarios are provided in Section 4.

The methodology used for the economic assessment follows UK Treasury Green Book: Appraisal and Evaluation in Central Government[14], which is the industry standard method for economically assessing flood risk projects. Guidance provided in the Multi-coloured Manual (MCM) and its supporting Handbook[15] is used to assess the relationship between the benefits and costs of the options, allowing for the calculation of benefit cost ratios (BCRs) incremental benefit cost ratio (IBCR) and the Net Present Value (NPV) for each defence option. This chapter sets out the type of flood damages, how they are assessed and how they are incorporated into the CBA. The results of the CBA will identify the preferred option from a financial perspective.

In addition, guidance used to assess the impacts on the Lossiemouth Bay Caravan Park was provided by the Environment Agency[16].

8.1.1 Appraisal Period

It is estimated that the western estuary banks could provide protection against a still water level (without any surface wave action) equivalent to a 1 in 20-year event at present. This reduces further to between a 1 year return period and the HAT when considering the impact of sea level rise over a 50-year period.

These factors indicate that a 100-year appraisal period is appropriate for the CBA and economic assessment of the proposed options.

8.1.2 Flood Receptors and Damage Type

The economic damages associated with flooding can be split into four categories; direct damages, indirect damages, tangible and intangible damages[17].

Direct damages are those resulting from physical damage caused by the flood waters for example damage to residential buildings, risk to life and physical road repair. For non-residential properties, financial losses refer only to direct damage to stock or property as it is assumed that the financial loss at one flooded business would be offset by a financial increase at another nearby unaffected business, as the requirement for this trade would not be impacted by the flooding. Indirect damages are those which occur as a result of the flood such as the cost of temporary accommodation.

Intangible damages are calculated for residential properties following guidance from the Defra Supplementary Note on 'Appraisal of Human Related Intangible Impacts of Flooding' (R&D Technical Report FD2005/TR)[18]. These account for the human-related impacts of flooding such as increased stress and anxiety linked to flood effects i.e. the loss of personal belongings or moving to temporary accommodation.

Environmental damages to habitats and ecosystems are not included in this economic assessment, as no sensitive habitats or ecosystems are anticipated to suffer from flood damage in Lossiemouth.

Emergency services will be required to attend in both an emergency works and clean-up capacity.

The damages included in this assessment are seen in Figure 8-1.

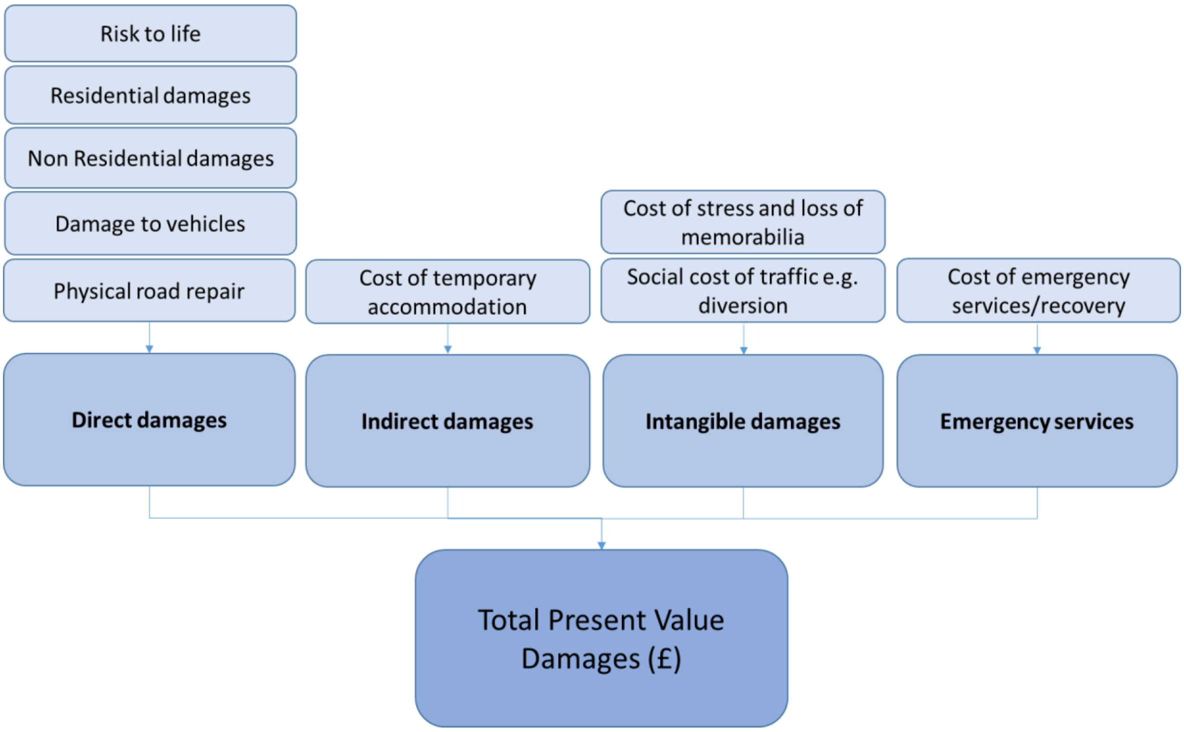


Figure 8-1 Damages included in the economic assessment

8.2 Direct Damages

8.2.1 Residential properties

Calculation of the direct damages to residential properties from flooding considers the geographical location of the property, the depth of the flood water, the saltwater uplift factor and the market value of the property. These factors are discussed in detail in this section.

8.2.1.1 Property dataset and threshold levels

The Ordanance Survey (OS) address base dataset was used to provide building footprints and property point data. In the absence of surveyed data, the value of the residential properties is taken as the average property price in Moray, provided on the Registers for Scotland website. It is recognised that this could result in an overestimate or underestimation of damages as properties with lower market values i.e. flats, are valued higher than their market value and properties with higher market values i.e. detached properties are valued lower than their true market value. This is noted as a limitation of the economic assessment.

Similarly, a manual review of the property dataset was conducted in order to remove non-ground floor properties. However, in absence of surveyed data, it is possible that costs may be applied to flats not on the ground level resulting in an overestimation of damages.

Property threshold levels are a key factor in assessing vulnerability to flooding. In the absence of surveyed threshold levels, 0.15m is applied to every residential property and 0m applied to commercial properties as recommended by the MCM Manual.

8.2.1.2 Flood Depths

Jacobs' in-house tool EcMap has been used to determine the flood damages at each property. This was based on the parameters from the MCM guidance (updated to a base year of 2018), and other factors discussed below.

LIDAR (Light Detection And Ranging) data was used in order to estimate the level of flooding at individual properties in Lossiemouth. LIDAR is a system that collects ground elevation information in order to simulate the flow of water during a flood. Flood maps were produced to estimate flood depth values for individual properties. These were extracted based on OS Mastermap building footprints using the QGIS-SAGA tool "Grid Statistics for Polygons".

8.2.1.3 Saltwater uplift factor

The impact of saltwater flooding compared to freshwater flooding is more severe with respect to the damage of properties. To account for this, an uplift factor of 1.22 has been applied to the damages calculated for both residential and non-residential properties, as per the MCM Manual[19].

8.2.1.4 Property valuations (capped damages)

Residential property values for Lossiemouth have been derived from the Land Registry[20] website and are based on the average property values within the Moray Council administrative area. Residential property values are inputted into EcMap in 2014 prices. The model automatically uplifts these to 2018 prices.

Individual whole life property damage has been capped at the April 2018 valuation of the property. Where a property has been determined to flood at a frequency greater than a 1 in 5 year (20% AEP) event, the property has been written off at its market value. In this case, the frequency of flooding is assumed to render the property uninhabitable. This is standard economic practice and effectively caps the economic damage for each property at its current market value.

8.2.2 Non-residential properties

The value of non-residential properties is calculated using the following equation[15]:

$$Market\ Value = Rateable\ Value * \left(\frac{100}{Equivalent\ Yield}\right)$$

Non-residential property rateable values[3] have been determined from the Scottish Assessors Association (SAA) website[4]. One non-residential property is located within the maximum flood extent in Lossiemouth; this was categorised as a retail property. The market value (£314,685) was calculated using the 2017 rateable value from the Scottish Assessors Association (SAA) website (£27,000) and the equivalent yield from North England (8.58%). ONS does not provide equivalent yield values for Scotland.

[3] Rateable value is a value assigned to a commercial building based on its size location etc. The value is used to determine the rates payable by the owner of the building.

[4] Scottish Assessors Association, 2018

Two home offices and two B&Bs have been considered to be residential in nature as they were originally built as residential properties with a commercial entity incorporated into the building.

8.2.2.1 Caravan Park

In absence of standard guidance on the valuation of caravans in the MCM handbook, guidance from the Environment Agency is used to assess the damages to the Lossiemouth Bay Caravan Park. Caravans are not robust structures, with walls made from materials like plywood which will not withstand long term inundation[16]. Recurring flood events will eventually lead to the loss of static caravans and the write-off value would be achieved. However, where caravans are semi-permanent, there is a further option to relocate the caravans to another site that is not prone to flooding. Damages would then be capped at the cost of relocation.

The Department for Environment, Food and Rural Affairs (Defra) will accept the damages within a permanent caravan park, provided there is a robust economic argument.

Lossiemouth Bay Caravan Park has approximately 130 static caravans as well as seven permanent facilities within the site. It is recommended by the Environment Agency[21] that caravans should be set at least 0.5m above sea levels. As the average flood depth of the caravan park across the 5 return periods exceeded 0.5m, the Environment Agency guidance was followed to assess the damage to the park.

In the Do Nothing scenario and the three scenarios that exclude the caravan park (Options 2A, B and C), where no work is undertaken, the caravan park will repeatedly flood. There are two ways of assessing the value of the caravan park these are:

- the cost of recurring damages, or
- the cost of relocation.

The cost of recurring damages is the chosen method in this assessment. Caravans were categorised as residential properties and were included in the EcMap model. Caravans were given a market value of £24,029 (2018 prices) as per EA guidance. The PV total damages of the caravan park were calculated as £9,883,737 this includes approximately £3.5million direct and £4.7million indirect damages.

8.2.3 Motor vehicles

The MCM recommends that for an “overview” project appraisal, the ratio of average property to vehicle damage should be considered. It assumes that the total number of vehicles likely to be damaged will equate to 28% of the total number of residential and non-residential properties at risk from flooding. This is then multiplied by £3,100, the damage sustained by the vehicle[15]. For each property this equates to an additional direct damage of £868.

This was considered a suitable approach due to the level of data available regarding property numbers and flood depth.

8.2.4 Physical road damage

The latest guidance from the SPONS manual[22] and DMRB[23], combined with professional experience for similar scale road reinstatement, has been used to estimate the cost per km for the reinstatement of affected roads in Lossiemouth. At this stage, the assessment has been kept high level and therefore excludes earthworks and structure such as footpaths, junctions, sign, road restraints etc. The cost of road repairs are based on the following:

- A road: £1.25 million per km
- Other roads: £625,000 per km

The cost to repair roads across the five return periods under the Do Nothing scenario have been calculated and the results are presented in Appendix E.

8.2.5 Risk to life

Risk to life assesses the likelihood of injuries and fatalities during a flood event. These fatalities and injuries are assigned a monetary value as indicated in the Treasury Green Book[14].

Defra's guidance[18] on assessing and valuing risk to life was used to calculate intangible damages of flooding on an individual or society. This method is based determining flood hazard, area vulnerability and people vulnerability resulting in an economic value of average annual individual or societal risk of fatality due to flooding. This Reference Valuation is applied within the CBA.

Nomis data provided population statistics including the prevalence of an elderly population, the number of residents suffering from long term illness and those receiving personal independence payments (PIP) and disability living allowance (DLA) payments, which was used to determine the 'at-risk' population. The value of cost per fatality and cost per serious injury were sourced from the Department for Transport (DfT), in line with Defra's guidance. DfT values the reduction of risk of death as £1.618m and the risk of injury at £128,650 (values uplifted to 2018 values). Risk to life calculations are provided in Appendix C.

8.3 Indirect Damages

8.3.1 Temporary accommodation (evacuation costs)

The indirect cost of flooding to residential properties is considered in this assessment. This includes costs of temporary accommodation and the costs of additional electricity consumption associated with drying and heating a property following each flood event.

8.3.2 Human-related impacts (intangible damages)

8.3.2.1 Intangible damages

Defra produced a Research & Development project looking into the impact of the intangible damages of flooding. This includes health effects such as increased stress and anxiety linked to flood effects i.e. the loss of personal belongings or moving to temporary accommodation.

Intangible damages are captured within EcMap. The intangible damages have been calculated in direct relation to the onset of flooding (taken as the event at which water levels first exceed property threshold levels) for every affected residential property.

8.3.2.2 Social cost of traffic

The estimation of social costs associated with flood damages in Lossiemouth was considered using diversion value methodology. This methodology is approved by the MCM and is based on The Highways Agency and Department for Transport's data on the estimated value associated with traveller's time. This methodology seeks to calculate the cost associated with individuals travelling extra distance to divert around flood damaged roads. The diversion value methodology assumed an 8-hour flood event with 400 cars per hour, travelling at a constant speed of 20mph (approx. 30km/h), being diverted to neighbouring roads.

The social cost of traffic calculations are provided in Appendix D.

8.3.2.3 Cost of emergency services and recovery

Emergency and recovery costs during flood events vary between local authorities but often consist of the repair and construction of infrastructure assets including the electrical supply.

The MCM guidance on the calculation of emergency service cost during a flood event was utilised as part of the CBA. The value of 10.7% of the total flood damages for a flood event, in accordance with the MCM Online Manual,[19] was incorporated into the model. A flood warning reduction factor was applied to account for properties who have precautionary measures in place e.g. sandbags. This applies a 2% reduction to all residential and non-residential properties.

8.4 Cost Estimates of Proposed Defence Options

Details of the cost estimates for the defence options have been supplied by Jacobs' engineering team. These values are presented in 2018 prices. Maintenance costs have been attributed to the relevant subject year. These base values have been uplifted to the subject year values, using the 3.5%, 3.0% and 2.5% social discount value in accordance with the Green Book[14].

Table 8-1 shows there is a significant difference in the capital costs between several of the options, ranging from £332,716 for Option 2A (Earth Embankmant along Spynie Canal) to £1,267,589 for Option 1B (Sheet Pile Wall with Cladding along the estuary bank of River Lossie). Maintenance costs are expected to be the constant for each option. Option 2a has the lowest Present Value (PV) costs of the defence options considered.

Table 8-1 Cost Estimates and calculation of Total PV cost

	Capital costs (£)	Maintenance costs (£)	Total PV costs (£)
Do Nothing			
Option 1A	£741,296	£21,311	£762,607
Option 1B	£1,267,589	£21,311	£1,288,900
Option 1C	£745,029	£21,311	£766,340
Option 2A	£332,716	£21,311	£354,027
Option 2B	£660,413	£21,311	£681,724
Option 2C	£419,356	£21,311	£440,667

8.5 Flood Damages

8.5.1 Climate Change

The impacts of climate change over the 100-year appraisal period has been considered as part of the economic assessment. This has occurred by factoring in sea level rise predications as per MCM guidance.

8.5.2 Residential Properties at Risk

Table 8-2 shows damages to residential properties is avoided with Option 1A, B and C across all flood events modelled. Options 2A, B and C protect all properties with the exception of the caravan park, therefore 127 properties (caravans) are at risk across each flood event modelled. In the Do Nothing scenario, the number of properties at risk increases as the severity of the flood increases.

Table 8-2 Number of Properties at risk across varying return periods

	Properties at Risk						
	Do Nothing	Option 1A	Option 1B	Option 1C	Option 2A	Option 2B	Option 2C
1:5	191	-	-	-	127	127	127
1:10	203	-	-	-	127	127	127
1:50	225	-	-	-	127	127	127
1:100	241	-	-	-	127	127	127
1:200	248	-	-	-	127	127	127

8.5.3 Economic Damages of Flooding

In Options 1A, B and C, no damages are expected. This is because these options are designed to protect from flooding altogether. Therefore, the assessment considers the damages avoided for Options 2A, B and C, as these only options will experience flood damages. The Do Nothing scenario is used as a baseline against which, damages avoided were modelled.

8.5.3.1 Damages and avoided damages

The benefits (damages avoided) for each option have been calculated by using the Do Nothing option as the baseline against which the other options are compared. The results are presented in Table 8-3.

Damages include property damages calculated in EcMap and the additional costs (e.g. risk to life) calculated separately.

Table 8-3 Damages and avoided damages for all options (benefits)

	PV (£)						
	Do Nothing	Option 1A	Option 1B	Option 1C	Option 2A	Option 2B	Option 2C
Damages	£42,460,728	-	-	-	£23,026,375	£23,026,375	£23,026,375
Avoided Damages	-	£42,460,728	£42,460,728	£42,460,728	£19,434,353	£19,434,353	£19,434,353

8.6 Benefit Cost Analysis

8.6.1 NPV, BCR & IBCR

The BCR is derived by dividing PV benefits by PV costs; a BCR of 1 indicates a net neutral opportunity, that is there is no financial incentive or disincentive to progress that option. A BCR greater than 1.0 indicates a positive return on investment (from a financial standpoint) and should be further investigated.

The NPV is obtained by subtracting the PV costs from the PV benefits. A NPV of 0 indicates a net neutral opportunity, that is there is no financial incentive or disincentive to progress that option. A NPV greater than 0 indicates a positive return on investment (from a financial standpoint) and should be further investigated.

The IBCR is derived by the following formula is used to determine if the additional benefits attributed to an option merits the additional spend compared to a cheaper option. The IBCR is used to rank mutually exclusive options in order of preference. A IBCR greater than 1 indicates that the more expensive option is preferred over the cheaper scenario.

$$\frac{Expensive\ Option\ Benefits - Cheap\ Option\ Benefits}{Expensive\ Option\ Costs - Cheaper\ Option\ Costs}$$

CBA calculations are presented in detail in Appendix B.

8.6.2 Optimism Bias 60%

As per the Environmental Agency guidance, a 60% optimism bias has been applied to the PV costs to allow for optimism and uncertainty at this initial project appraisal stage. As shown in Table 8-4, all options considered achieve a positive NPV and a BCR greater than 1 when a 60% optimism bias is modelled. All options indicate a strong economically viable solution. Option 1a yields the most favourable BCR of the options considered at 60% optimism bias (34.80). The IBCR indicates that the cheapest option 1 (Option 1A) is a stronger option than the most expensive Option 2 (Option 2B). Option 1A, B and C have a stronger average BCR compared to Option 2A, B and C. Therefore, the options to protect Lossiemouth (including the caravan park) are more economically viable than allowing the caravan park to flood.

Table 8-4 NPV, BCR & IBCR of all options at 60% Optimism Bias

	NPV £	BCR	IBCR
Do Nothing	£42,460,728	-	-
Option 1A	£41,240,557	34.80	177.93
Option 1B	£40,398,488	20.59	0
Option 1C	£41,234,584	34.63	0
Option 2A	£18,867,910	34.31	0
Option 2B	£18,343,594	17.82	0
Option 2C	£18,729,286	27.56	0

8.6.3 Optimism Bias 30%

A 30% optimism bias has been applied to the PV costs to allow for a sensitivity check. Table 8-5 shows the same ranking options from applying the 60% optimism bias are still applicable. Option 1A is the strongest while 2B is the weakest according to the BCRs

Table 8-5 NPV, BCR & IBCR of all options at 30% Optimism Bias

	NPV £	BCR	IBCR
Do Nothing	£42,460,728	-	-
Option 1A	£41,469,339	42.83	218.99
Option 1B	£40,785,158	25.34	0
Option 1C	£41,464,486	42.62	0
Option 2A	£18,974,118	42.23	0
Option 2B	£18,548,112	21.93	0
Option 2C	£18,861,486	33.92	0

8.6.4 NPV and BCR of all option with No Optimism Bias

When no optimism bias is applied the benefits still significantly outweigh the cost for all options. Table 8-6 shows that there is approximately £23,000,000 difference in NPV between the options that protect all Lossiemouth and the options that exclude the caravan park.

Table 8-6 NPV, BCR and IBCR of all options with no Optimism Bias

	NPV £	BCR	IBCR
Do Nothing	£42,460,728	-	-
Option 1A	£41,698,121	55.68	284.69
Option 1B	£41,171,828	32.94	0
Option 1C	£41,694,388	55.41	0
Option 2A	£19,080,326	54.90	0
Option 2B	£18,752,629	28.51	0
Option 2C	£18,993,686	44.10	0

8.6.5 Discussion

All options present an economically viable solution as they all have BCRs greater than 1 and NPVs greater than £0. Option 1A is the preferred option as indicated by the high IBCR in the 60%, 30% and 0% optimism bias models. This suggests that the benefits of protecting the caravan park from flooding outweighs the additional cost of building and maintaining defence Options 1A, B or C. With Option 1A, B or C, no residential or commercial properties are put at risk.

When considering the options that protect all of Lossiemouth including the caravan park, the total capital expenditure estimate for Option 1A is the lowest of the three options. As Option 1A, B and C offer the same benefit (avoided damages) (£42,460,728), the lower cost of defence Option 1A, results in the greatest BCR and therefore is the preferred option.

9. Public Consultation

A Public Consultation was held in Lossiemouth on 20 February 2018. The purpose of the event was to exhibit the latest drawings of the proposed coastal defences for the scheme and gain feedback from the residents of Lossiemouth, also allowing for raising of any other concerns regarding potential flooding to the town.

The event was reasonably well attended, with more than 30 attendees signing in and 12 feedback forms returned with additional verbal feedback also recorded.

The main concern voiced by residents was with regards to the visual impacts of the solutions on the estuary view. Due to the modest nature of the solutions required it was largely agreed that visual impact would be minimal for pedestrians when adjacent to the structure. There may be some minor impact to the views from a property to the southern corner of Seatown.

Feedback from the owner of the Caravan site was that he had little concern regarding the visual impact of a new structure, despite it raising the existing crest of the bank over 1m in some locations. His main concern, as could be expected, was with the inclusion of his properties and business within the proposed scheme.

The general feedback from residents was that the earth embankment option would be the preferred as it would largely tie in with the existing arrangement of the estuary bank. The sheet piled wall solution was considered the least favourable by many of the attendees. Visual representation was taken from a single source and alternative cladding could be presented to residents if required.

Additional concerns were noted but are not part of the scope of this study. Some of the points raised were:

- There was concern raised regarding access over canal for campervan during some of the proposed construction works;
- Many residents noted concern with the gaps between the sand dunes on the far side of the estuary appearing to be increasing. Many believe that these should be closed off as it would lead to exposure to the North Sea waves;
- Residents informed the Council that in 2012 a storm event caused water to get on to Seatown Road and 4 properties required the use sandbags protect against flooding;
- There was concern raised regarding the condition of the timber breakwater, which is considered by many to be poor. There is a feeling that if that degraded further the town would be at more risk from the waves. JBA assessment[7] determined that the removal of the breakwater would not result in a significant increase in wave climate;
- It is believed the wooden bridge that leads across to the beach on the far bank requires urgent repair;
- A general concern was raised regarding rising water levels in the Spynie Canal adjacent to Seatown; and
- The Spynie Canal needs to be cleared of debris to allow efficient functioning.

10. Options Appraisal

10.1 Preferred Option

The purpose of this Section is to carry out an assessment of the Options based on the findings of this study to establish a preferred solution. The economic assessment showed that there was added value in protecting the caravan park, with the average benefit cost ratios (BCR) of Options 1A to 1C outperforming those of Options 2A to 2C. Therefore, Options 2A to 2C can be discounted as they protect less properties and do not perform as well as the solutions that protect all properties, despite the initial capital costs being lower. Feedback from the owner of the caravan park would suggest that there would be no objection to the forming on a new structure in front of his site as it would be to protect the property and business.

Option 1A provides the strongest BCR at 34.80, and, as such, has the strongest business case in terms of gaining approval for funding. The capital expenditure would be £1,186,074 with a 60% optimism bias, as shown in Table 7-1. The sheet piled solutions, Options 1B and 2B, performed the poorest in terms of BCR. Option 2A was the lowest capital expenditure at £532,345 with a 60% optimism bias and has a BCR very close to that of Option 1A at 34.31. As discussed Option 2A is discounted due to it not protecting all properties in the area, though it could be revisited should funding be significantly limited. Therefore, Option 1A is identified as the Preferred Option of this study.

The earth embankment, being a soft engineering solution, would be the simplest to install, requiring standard site plant to carry out the works. The earth embankment solution does not provide any significant technical challenges in design or installation, and the extent of the construction works are comparable to the alternative solutions of the sheet piled wall and the concrete solution. The exception being at Location 4, where there is a special constraint and an earth embankment cannot be installed. A concrete retaining wall is proposed at this location as part of Option 1A.

Following the outcome of the ground investigation seepage, at this stage, is not considered a risk. Therefore, there is no preference on a particular solution in terms of geotechnical design as a cut off is not required to retain the flood waters. The only concern at this stage would be the risk of obstructions for the sheet pile solution.

Option 1A is preferred from an environmental and aesthetic perspective as it can be formed to tie in with the adjacent landscapes. For this reason, it was also identified as the preferred solution of the local residents who gave their opinion during the Public Consultation.

The outcome of the economics assessments shows that the proposed flood protection works have a very strong business case. It should be noted that due to the strong performance of all Options there is flexibility in selection of the preferred defence arrangement, should there be specific preferences at each location.

10.2 Location 2

At Location 2 the preferred Option is the flood gate arrangement due to it being the lower cost solution. This solution should be relatively straight forward to implement and would be a smaller scale construction than the concrete ramp. It would also be more consistent with the current aesthetic, leaving the majority of the embankment in tact. However, as noted in Section 7.3 there may be a preference to remove the procedural element of having to close a flood gate prior to a significant tidal event, which would then lead to the concrete 'U' ramp solution being the preferred option. It should be noted that the concrete ramp provides a little more technical challenge than the flood gate as it involves excavation of a significant length of the embankment and potentially some tidal work to reinstate the embankment on the estuary side.

Future plans for the timber footbridge are unknown and have not been considered as part of this appraisal, it is recommended that this should be given some consideration prior to finalising the appropriate flood protection scheme.

11. Conclusions and Recommendations

During a 1 in 200-year tidal event, with 50 years' climate change taken into consideration, it is concluded that there are several points on the west estuary bank of the River Lossie at risk of overtopping, which would result in flooding to the low-lying properties in Seatown, residential properties adjacent to Seatown and the Caravan park to the south of Seatown. The Design Flood Water Level during such an event was established as 4.2mODN, and was developed through consideration of tidal, storm surge, swell and climate change data. This figure includes a freeboard allowance of 500mm above the calculated still water level, as recommended by SEPA guidance[3].

A Ground Investigation was carried out as part of this study and established that a cut off to prevent seepage is unlikely to be required as part of the proposed protection works based on the findings of the GI, the established water levels and the local topography of the estuary banks. On this basis six established Options were progressed, and a cost estimate carried out for each. Three types of defences were proposed; an earth embankment, a sheet pile wall with cladding, and a concrete retaining wall.

The cost estimate determined that the earth embankment was the cheapest of the three proposed structures. Additionally, this was the preferred solution from the residents who documented their opinion during the public consultation. The outcome of the economics assessment determined that providing protection to the caravan park offered significant benefit to the proposed scheme, to the extent that the larger embankment solution of Option 1A offered the best Benefit Cost Ratio (BCR) of all the proposed solutions. An extract of Table 8-4 below shows the BCR values for all Options with a 60% optimism bias applied.

	NPV £	BCR
Do Nothing	£42,460,728	-
Option 1A	£41,240,557	34.80
Option 1B	£40,398,488	20.59
Option 1C	£41,234,584	34.63
Option 2A	£18,867,910	34.31
Option 2B	£18,343,594	17.82
Option 2C	£18,729,286	27.56

Consequently, Option 1A is considered to be the preferred Option of those identified, providing the strongest BCR value of 34.80. Initial capital expenditure for the Option is £1,186,074, inclusive of 60% optimism bias, as shown in Table 7-1. The outcome of the economics assessments shows that all the proposed flood protection works have a very strong business case. It should be noted that due to the strong performance of all Options there is flexibility in selection of the preferred defence arrangement, should there be specific preferences at each location. However, as discussed in Section 10 of this study, the earth embankment is the simpler solution to install and will provide a soft solution that ties in with the existing landscape.

At Location 2 the preferred option is the flood gate as it is has a lower capital cost than the concrete ramp and is much simpler and smaller scale construction. The flood gate option would also allow for a more consistent aesthetic with what is currently there as it does not involve altering much of the existing embankment. However, the concrete ramp option does remove the procedural element of closing the gate during a flood event. This may be preferable and could be implemented in the scheme for development in future if required, with little impact on the current BCR.

It is recommended that this flood protection scheme is developed further, and defences implemented to protect the properties at Lossiemouth. This will require selecting of the final defence arrangement and development of the design. The Environmental studies recommended in Section 6 should be carried out as part of this development. Additional ground investigation is recommended before the detailed design of the scheme is carried out.

Additionally, it should be noted that SEPA are due to be updating their climate change guidance from UKCP09 later this year. It may be prudent to update the calculate design flood level from this report following the release of that update. A conservative approach to UKCP09 was used for this report so any increase in flood level would be expected to be minimal. The strength of the business case of this Options Appraisal should mean that any increase would not affect the validity of the proposed scheme.

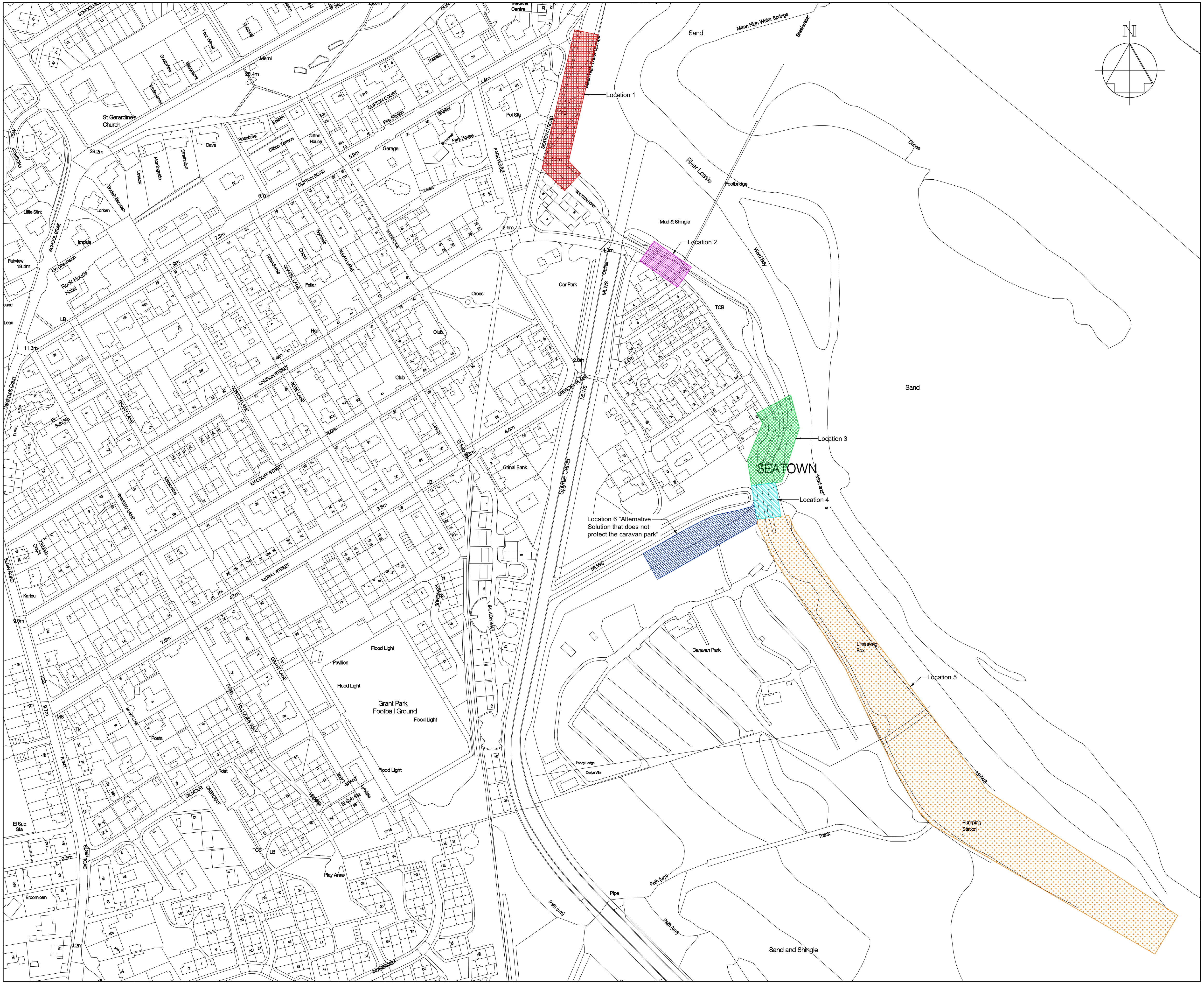
References

[1] Jacobs (2017). *Lossie Seatown Flood Assessment Desk Study, ND800400/01.*
[2] British Standards Institute *Maritime Structures – Part 1: Code of practice for general criteria.* BS6349-1:2000 inc. Amendment No.1(2003).

[3] DEFRA, SEPA*, EA Coastal Flood Boundary Conditions for UK Mainland and Islands*, SC060064/TR2: Design Sea Levels
[4] Department of Energy – *Offshore Installations: Guidance on design, construction and certification* 4th Edition 1990.
[5] UKCP09 Online User Interface – *Available at: http://ukclimateprojections-ui.metoffice.gov.uk/ui/admin/login.php* Accessed 13/04/2017
[6] NASA Carbon Dioxide Information – *Available at: https://climate.nasa.gov/vital-signs/carbon-dioxide/* Accessed 13/04/2017
[7] Lossiemouth Breakwater Assessment, *JBA Consulting, Draft Report*. January 2015.
[8] British Geological Survey. *GeoIndex Onshore Superficial deposits, 1:50,000* – Available: http://mapapps2.bgs.ac.uk/geoindex/home.html Accessed August 2018
[9] British Geological Survey, *Map Sheet 95 Drift Geology, 1:63,360*. 1969.
[10] British Geological Survey*. GeoIndex Onshore Bedrock geology, 1:50,000.* Available: http://mapapps2.bgs.ac.uk/geoindex/home.html Last accessed August 2018.
[11] HoleQuest Ltd. *Ground Investigation Seatown Lossiemouth Flood Assessment Rev 2.* (June 2018).
[12] The Building Research Establishment (BRE), *BRE Digest365, Soakaway Design.* 2016.
[13] SEPA Water Environment Hub – *Available at http://www.sepa.org.uk/data-visualisation/water-environment-hub/*

[14] HM Treasury The Green Book: appraisal and evaluation in central government. (2016).
[15] Penning-Rowsell *et al*., Handbook for Economic Appraisal 2018.
[16] Environment Agency Economic evaluation of damages for flood risk management projects. (2007).
[17] Penning-Rowsell *et al*.,. Handbook for Economic Appraisal, Table 3.12013
[18] Defra Supplementary Note on *'Appraisal of Human Related Intangible Impacts of Flooding'* (R&D Technical Report FD2005/TR)
[19] Penning-Rowsell *et al.. MCM-Online Manual.* 2013
[20] HM Land Registry https://www.gov.uk/government/organisations/land-registry (2017),
[21] Environmental Agency Flood risk assessments: climate change allowances (2016)
[22] SPON'S Civil Engineering and Highway Works (2018)
[23] Highways Agency. 2002. Design Manual for Roads and Bridges. Volume 6. TD9/93

Appendix A. Drawings



PLAN
(Scale - 1:1500)

Notes :

1. Do not scale from this drawing.

Key :

- Location 1. Refer to: Drawing No: ND800400-SK-002.
- Location 2. Refer to: Drawing No: ND800400-SK-003.
- Location 3. Refer to: Drawing No: ND800400-SK-004.
- Location 4. Refer to: Drawing No: ND800400-SK-005.
- Location 5. Refer to: Drawing No: ND800400-SK-006.
- Location 6. Refer to: Drawing No: ND800400-SK-007.

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
P02	SEPT. 2018	FOR INFORMATION	KMA	PM	AK	JS
P01	FEB. 2018	FOR INFORMATION	KMA	PM	KD	JS

JACOBS
160 Dundee Street, Edinburgh, EH11 1DQ
Tel:+44(0)131 659 1500 Fax:+44(0)131 228 6177
www.jacobs.com

Client

Project
LOSSIEMOUTH
COASTAL FLOODING BUSINESS CASE

Drawing title
LOCATION PLAN

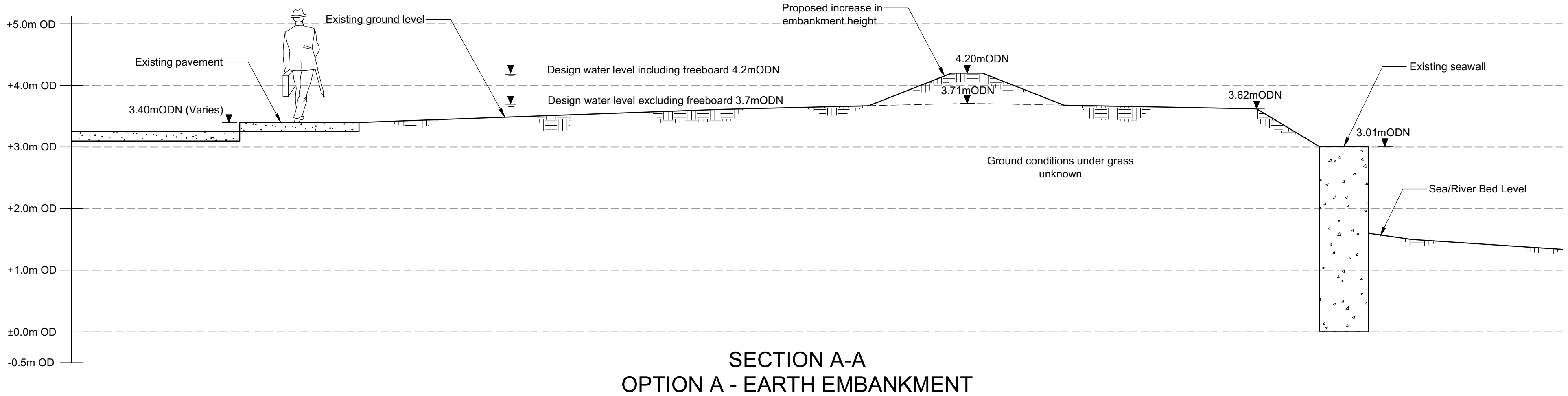
Drawing status
FOR INFORMATION

Scale	1:1500 @ A1	DO NOT SCALE
Jacobs No.	ND800400	Rev P02
Client no.		

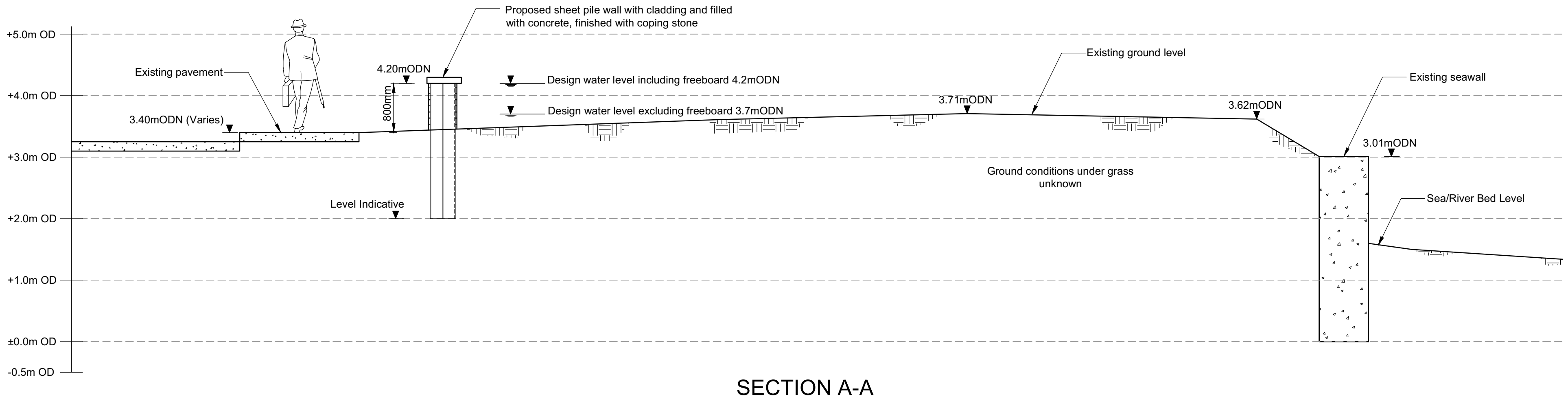
Drawing number
ND800400-SK-001

© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright. Limitation: This drawing has been prepared on behalf of, and for the exclusive use of Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this drawing by any third party.

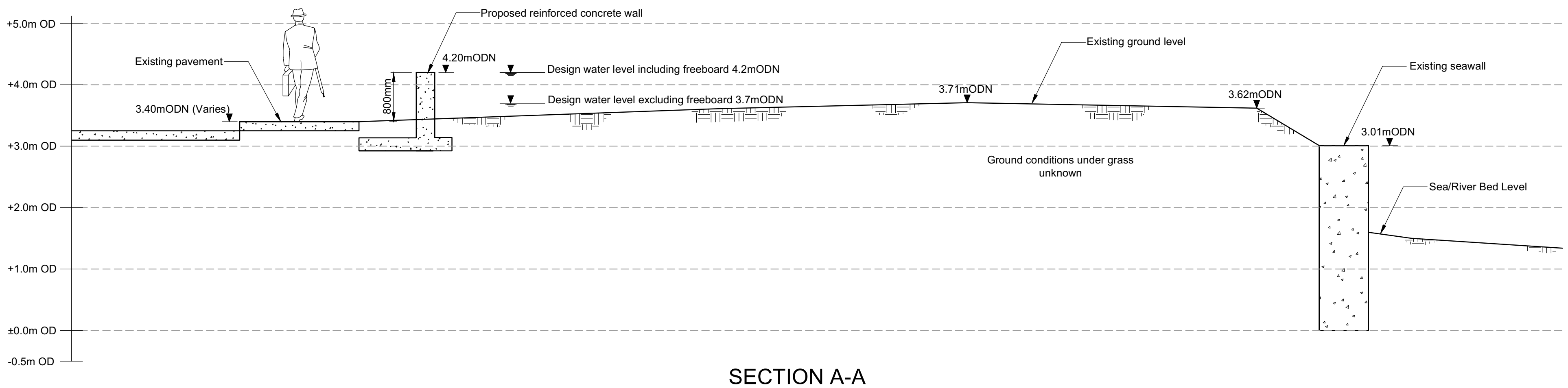
P:\Data\NuDeUK\ND800400 Flood Study - Lossie Seatown\2.Technical\5.Drawings\ND800400-SK-001 P02 Location Plan.dwg - 01/10/2018 16:28:35 - A1Frame - metcalfp



SECTION A-A
OPTION A - EARTH EMBANKMENT
(Scale - 1:50)

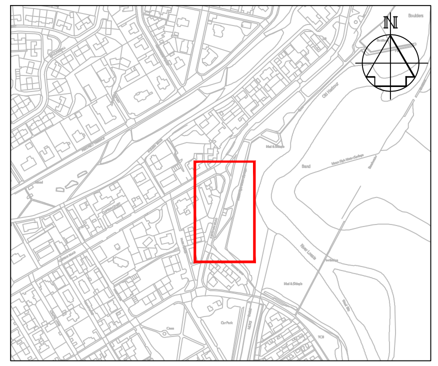


SECTION A-A
OPTION B - SHEET PILED SOLUTION WITH CLADDING
(Scale - 1:50)



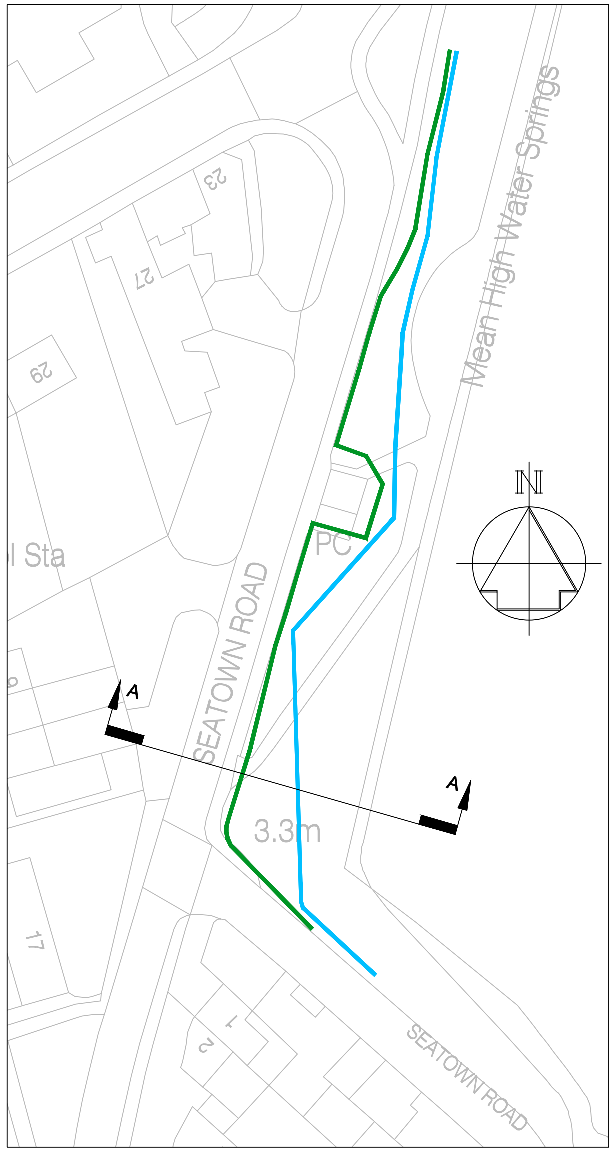
SECTION A-A
OPTION C - CONCRETE RETAINING STRUCTURE
(Scale - 1:50)

0 1 2 3 4 5 m
SCALE 1 : 50



LOCATION PLAN
(Scale - 1:5000)

0 100 200 300 400 500 m
SCALE 1 : 5000



PLAN
(Scale - 1:500)

0 10 20 30 40 50 m
SCALE 1 : 500

Notes :

1. Do not scale from this drawing.
2. All dimensions are in metres unless stated otherwise.
3. All levels are in metres to Ordnance Datum (Newlyn) unless noted otherwise.
4. Section drawings are indicative only.
5. Section A-A is used for all options within this drawing.
6. Drawing to be read in conjunction with Drawing No: ND800400-SK-001 Location Plan.

Key :

Embankment. (Option A)

Concrete and Sheet Pile Wall. (Option B and C)

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
P02	SEPT. 2018	FOR INFORMATION	KMA	PM	AK	JS
P01	FEB. 2018	FOR INFORMATION	KMA	PM	KD	JS

JACOBS
160 Dundee Street, Edinburgh, EH11 1DQ
Tel:+44(0)131 659 1500 Fax:+44(0)131 228 6177
www.jacobs.com

Client
moray council

Project
LOSSIEMOUTH
COASTAL FLOODING BUSINESS CASE

Drawing title
LOCATION 1
TYPICAL SECTIONS OF OPTIONS

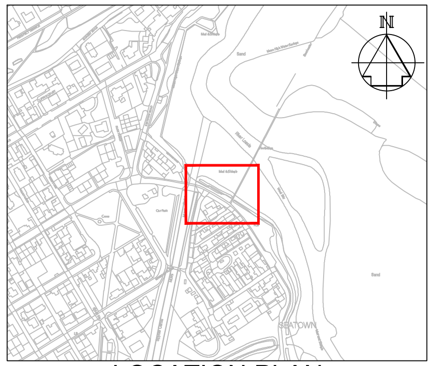
Drawing status
FOR INFORMATION

Scale	AS SHOWN @ A1	DO NOT SCALE
Jacobs No.	ND800400	Rev
Client no.		P02

Drawing number
ND800400-SK-002

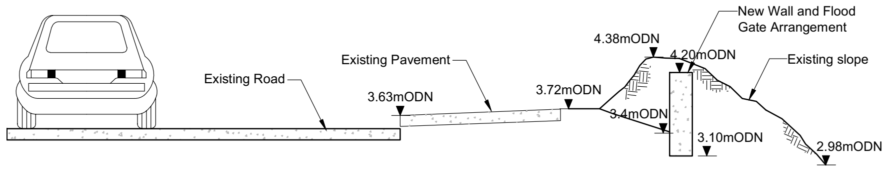
© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright. Limitation: This drawing has been prepared on behalf of, and for the exclusive use of Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this drawing by any third party.

P:\Data\NuDe\UK\ND800400 Flood Study - Lossie Seatown\2.Technical\5.Drawings\ND800400-SK-002 P02 Location 1 Typical Sections of Options.dwg - 01/10/2018 16:28:48 - A1Frame - metcalfp

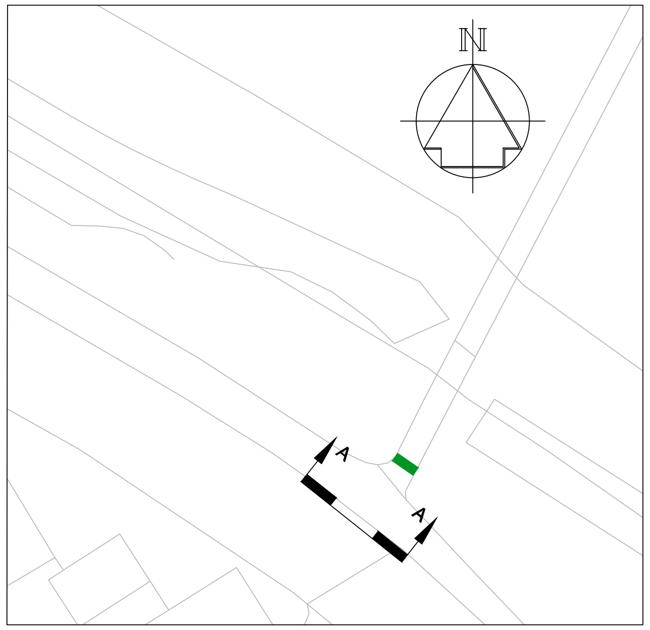


LOCATION PLAN
(Scale - 1:5000)

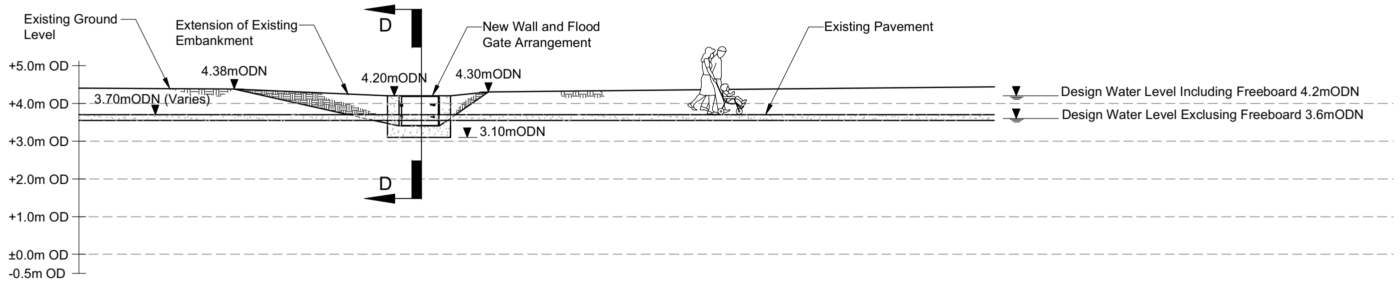
0 100 200 300 400 500 m
SCALE 1 : 5000



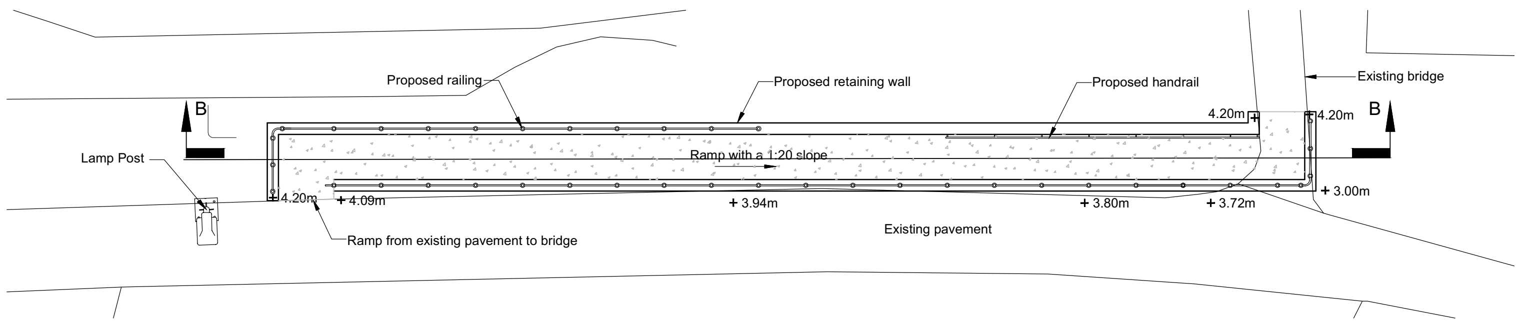
SECTION D-D
FLOODGATE OPTION
(Scale - 1:50)



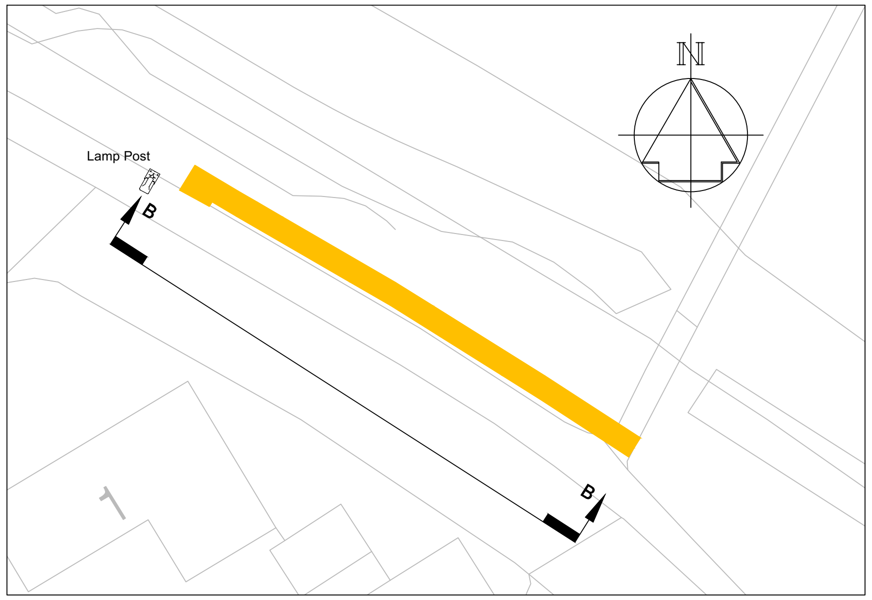
PLAN
FLOODGATE OPTION
(Scale - 1:200)



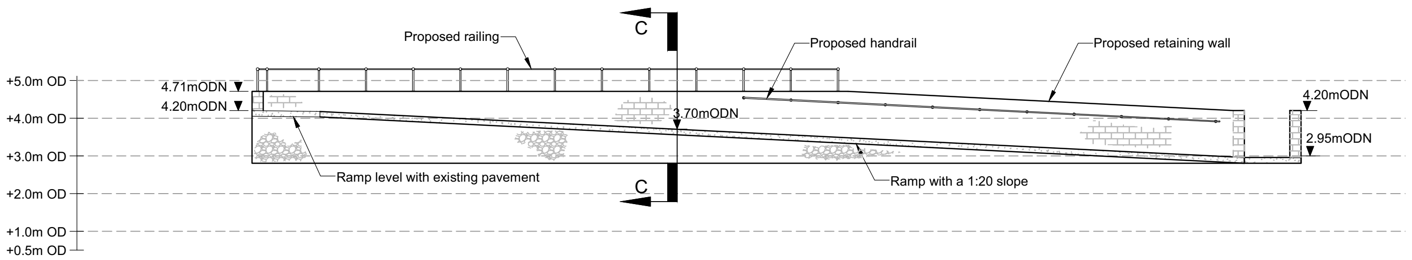
SECTION A-A
FLOODGATE OPTION
(Scale - 1:100)



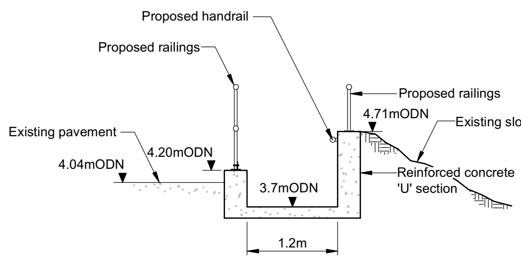
PLAN
CONCRETE RAMP OPTION
(Scale - 1:100)



PLAN
CONCRETE RAMP OPTION
(Scale - 1:200)



SECTION B-B
CONCRETE RAMP OPTION
(Scale - 1:100)



SECTION C-C
CONCRETE RAMP OPTION
(Scale - 1:50)

0 1 2 3 4 5 m
SCALE 1 : 50

0 1 2 3 4 5 6 7 8 9 10 m
SCALE 1 : 100

0 5 10 15 20 m
SCALE 1 : 200

Notes :

1. Do note scale from this drawing.
2. All dimensions are in metres unless stated otherwise.
3. All levels are in metres to Ordnance Datum (Newlyn) unless noted otherwise.
4. Section drawings are indicative only.
5. Drawing to be read in conjunction with Drawing No: ND800400-SK-001 Location Plan.

Key :

Approx. Location of Concrete Ramp
Approx. Location of Floodgate

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
P02	SEPT. 2018	FOR INFORMATION	KMA	PM	AK	JS
P01	JAN. 2018	FOR INFORMATION	KMA	PM	JS	CEP

JACOBS
160 Dundee Street, Edinburgh, EH11 1DQ
Tel:+44(0)131 659 1500 Fax:+44(0)131 228 6177
www.jacobs.com

Client

the moray council

Project

LOSSIEMOUTH
COASTAL FLOODING BUSINESS CASE

Drawing title

LOCATION 2
TYPICAL SECTIONS OF OPTIONS

Drawing status

FOR INFORMATION

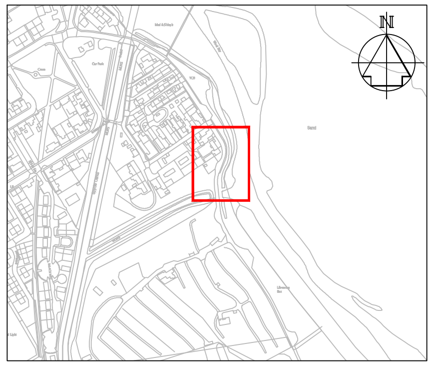
Scale	AS SHOWN @ A1	DO NOT SCALE
Jacobs No.	ND800400	Rev P02
Client no.		

Drawing number

ND800400-SK-003

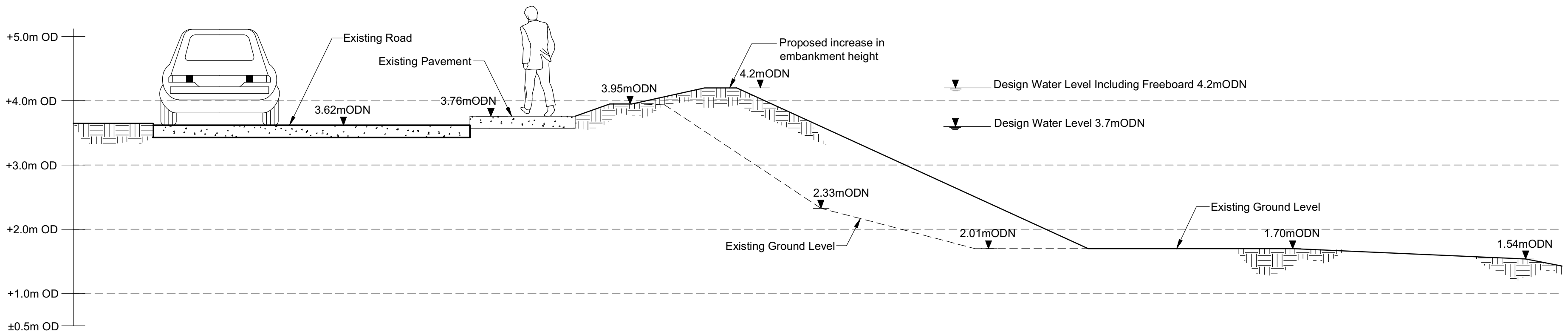
© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright. Limitation: This drawing has been prepared on behalf of, and for the exclusive use of Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this drawing by any third party.

P:\Data\NuDeUK\ND800400 Flood Study - Lossie Seatown\2.Technical\5.Drawings\ND800400-SK-003 P02 Location 2 Typical Sections of Options.dwg - 01/10/2018 16:29:09 - A1Frame - metcalfp

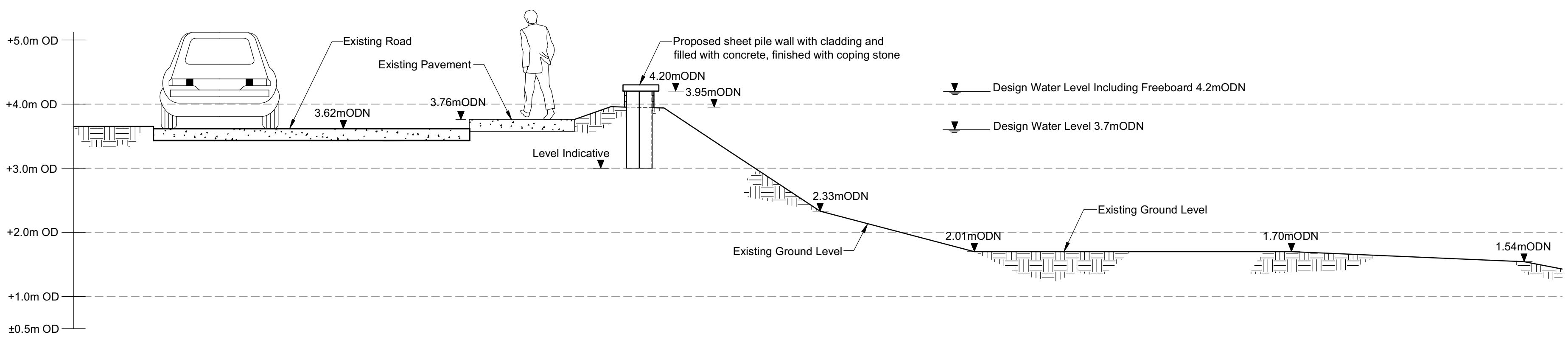


LOCATION PLAN
(Scale - 1:5000)

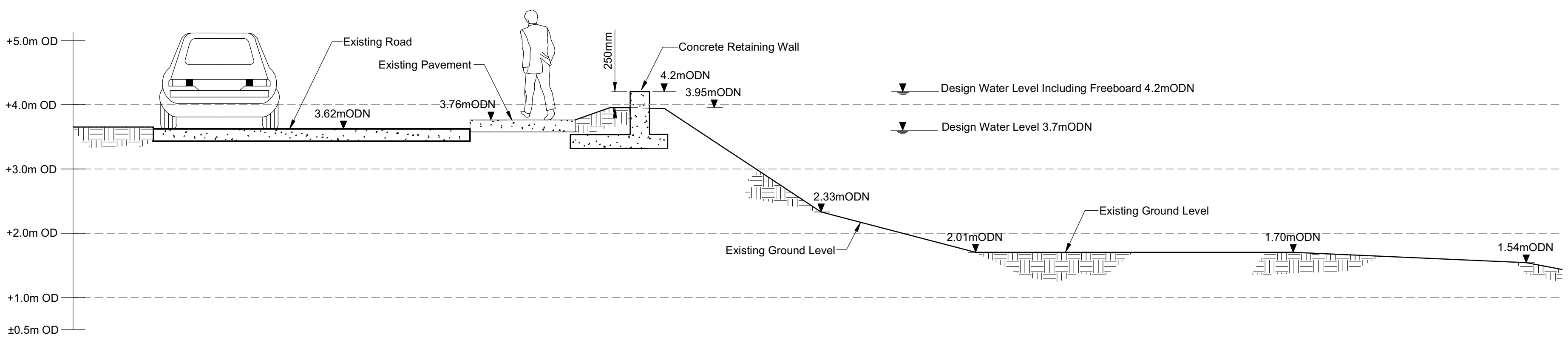
0 100 200 300 400 500 m
SCALE 1 : 5000



SECTION A-A
OPTION A - EARTH EMBANKMENT
(Scale - 1:50)

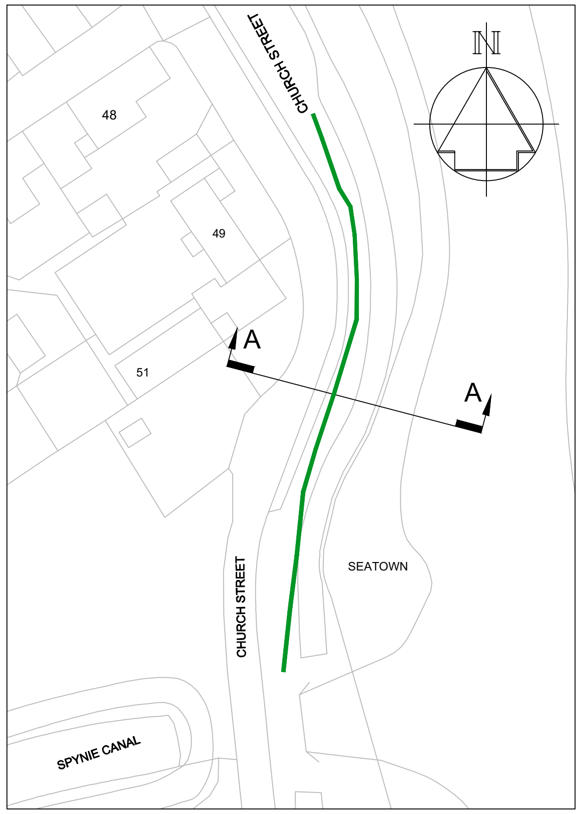


SECTION A-A
OPTION B - SHEET PILED SOLUTION WITH CLADDING
(Scale - 1:50)



SECTION A-A
OPTION C - CONCRETE RETAINING STRUCTURE
(Scale - 1:50)

0 1 2 3 4 5 m
SCALE 1 : 50



PLAN
(Scale - 1:500)

0 10 20 30 40 50 m
SCALE 1 : 500

Notes :

1. Do note scale from this drawing.
2. All dimensions are in metres unless stated otherwise.
3. All levels are in metres to Ordnance Datum (Newlyn) unless noted otherwise.
4. Section drawings are indicative only.
5. Drawing to be read in conjunction with Drawing No: ND800400-SK-001 Location Plan.

Key :

Approx. Location of Wall / Sheet Piles or Embankment.

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
P02	SEPT. 2018	FOR INFORMATION	KMA	PM	AK	JS
P01	FEB. 2018	FOR INFORMATION	KMA	PM	JS	CEP

JACOBS
160 Dundee Street, Edinburgh, EH11 1DQ
Tel:+44(0)131 659 1500 Fax:+44(0)131 228 6177
www.jacobs.com

Client

the moray council

Project

LOSSIEMOUTH
COASTAL FLOODING BUSINESS CASE

Drawing title

LOCATION 3
TYPICAL SECTIONS OF OPTIONS

Drawing status

FOR INFORMATION

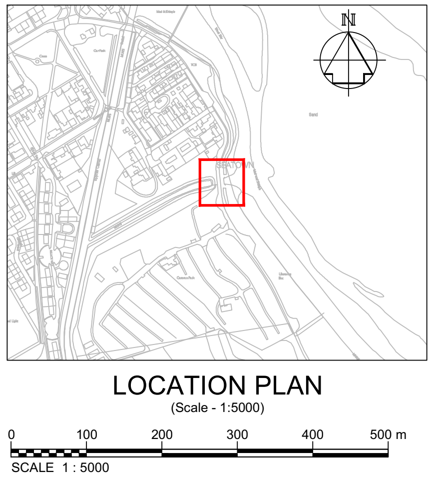
Scale	AS SHOWN @ A1	DO NOT SCALE
Jacobs No.	ND800400	Rev P02
Client no.		

Drawing number

ND800400-SK-004

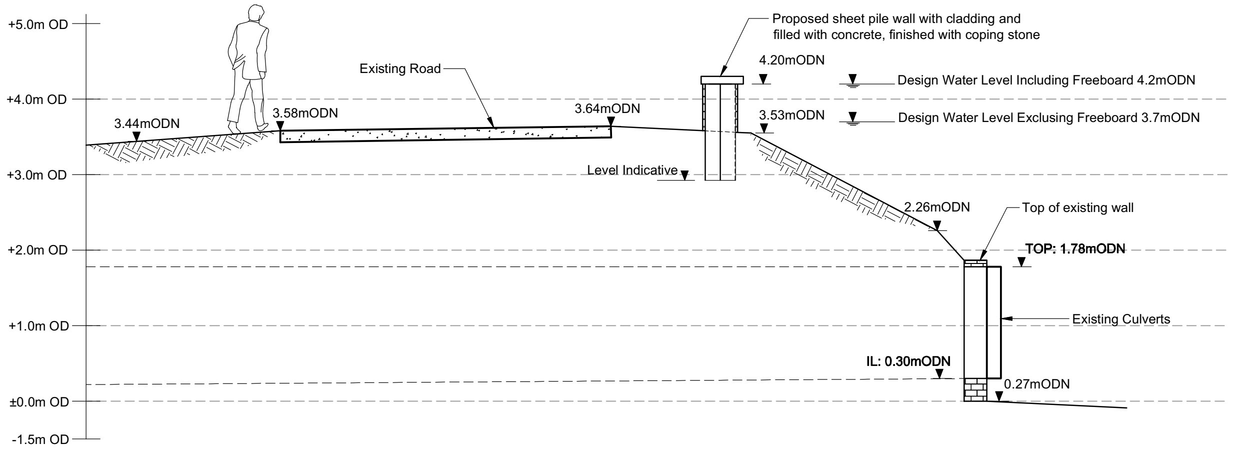
© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright. Limitation: This drawing has been prepared on behalf of, and for the exclusive use of Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this drawing by any third party.

P:\Data\NuDeUK\ND800400 Flood Study - Lossie Seatown\2.Technical\5.Drawings\ND800400-SK-004 P02 Location 3 Typical Sections of Options.dwg - 01/10/2018 16:29:24 - A1Frame - metcalfp



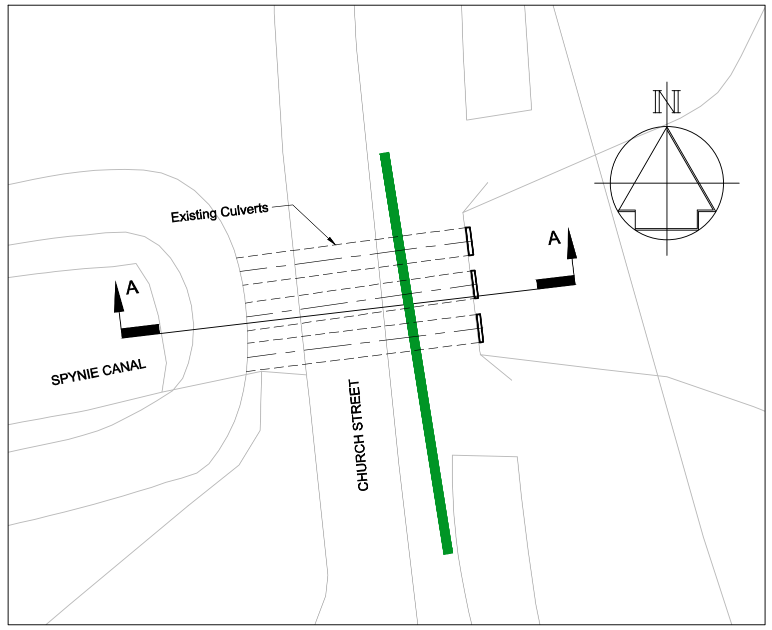
LOCATION PLAN

(Scale - 1:5000)



SECTION A-A
OPTION 1B - SHEET PILE WALL

(Scale - 1:50)



PLAN
OPTION 1A, 1B & 1C - CONCRETE WALL & SHEET PILE WALL

(Scale - 1:200)

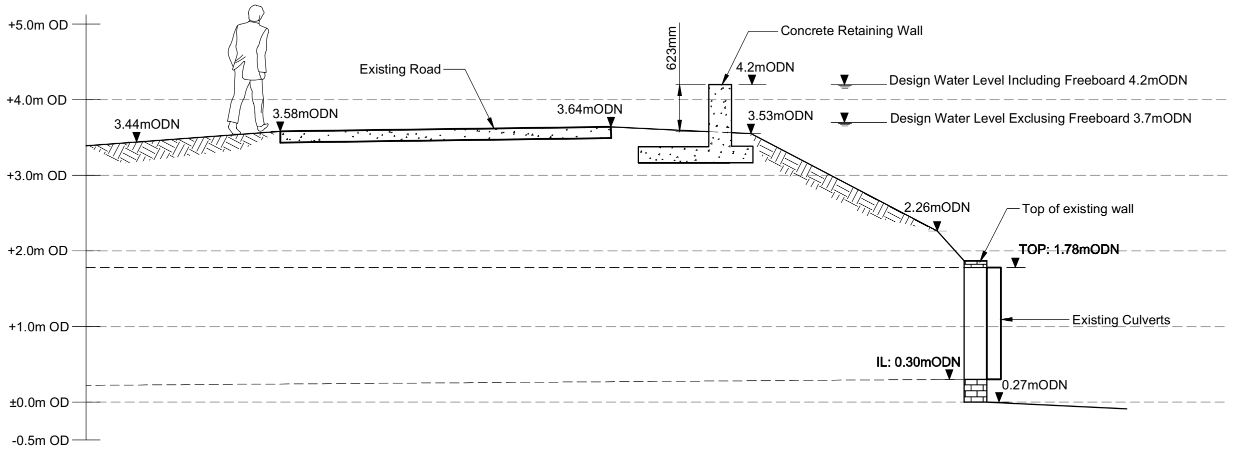
Notes :

1. Do note scale from this drawing.
2. All dimensions are in metres unless stated otherwise.
3. All levels are in metres to Ordnance Datum (Newlyn) unless noted otherwise.
4. Section drawings are indicative only.
5. Drawing to be read in conjunction with Drawing No: ND800400-SK-001 Location Plan.
6. Road raising Option to be used in conjunction with alternative solution at Location 6. See Drawing No. ND800400-SK-007.
7. Earth embankment is not shown due to spatial constraints at this location.

Key :

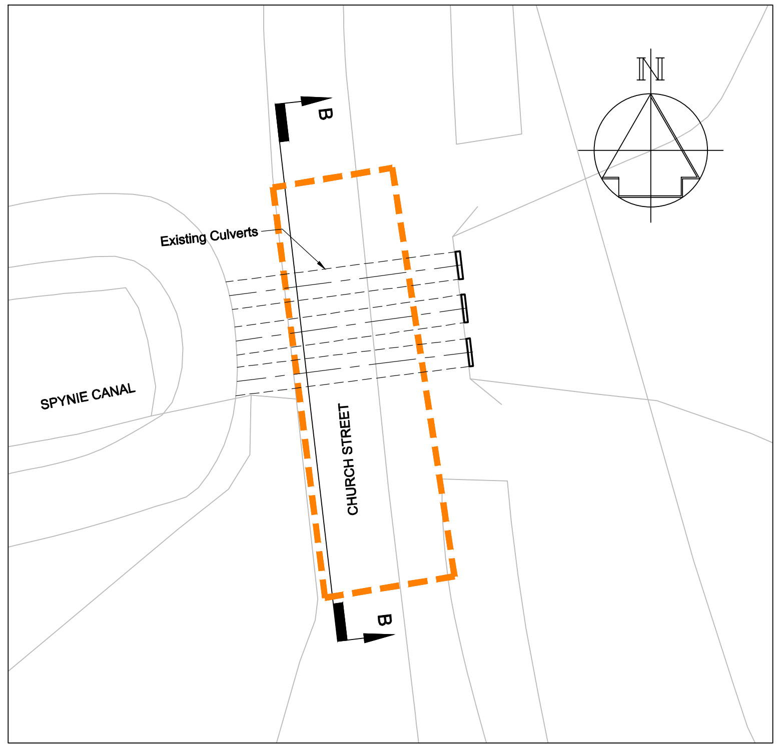
Approx. Location of Concrete and Sheet Pile Wall. Options 1A, 1B and 1C.

Approx. Location of Road Raising Option for Options 2A, 2B and 2C.



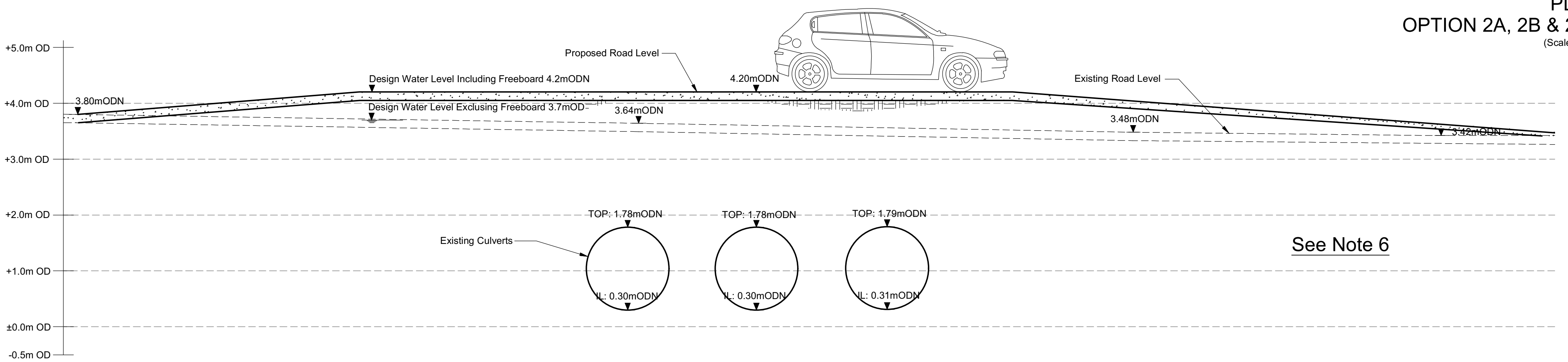
SECTION A-A
OPTION 1A & 1C - CONCRETE WALL

(Scale - 1:50)



PLAN
OPTION 2A, 2B & 2C - ROAD RAISING

(Scale - 1:200)



See Note 6

SECTION B-B
OPTION 2A, 2B & 2C - ROAD RAISING

(Scale - 1:50)

SCALE 1 : 50

SCALE 1 : 200

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
P02	SEPT. 2018	FOR INFORMATION	KMA	PM	DD	JS
P01	FEB. 2018	FOR INFORMATION	KMA	PM	JS	CEP

JACOBS
160 Dundee Street, Edinburgh, EH11 1DQ
Tel:+44(0)131 659 1500 Fax:+44(0)131 228 6177
www.jacobs.com

Client

Project

LOSSIEMOUTH
COASTAL FLOODING BUSINESS CASE

Drawing title

LOCATION 4
TYPICAL SECTIONS OF OPTIONS

Drawing status

FOR INFORMATION

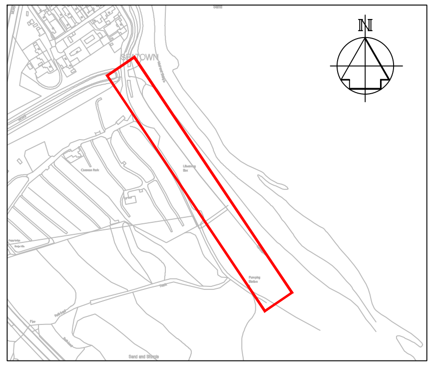
Scale	AS SHOWN @ A1	DO NOT SCALE
Jacobs No.	ND800400	Rev P02
Client no.		

Drawing number

ND800400-SK-005

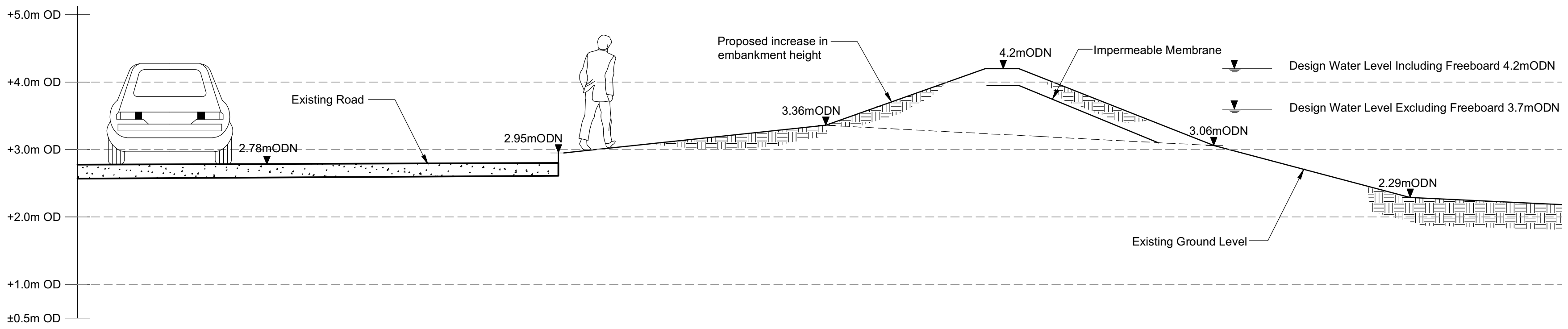
© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright. Limitation: This drawing has been prepared on behalf of, and for the exclusive use of Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this drawing by any third party.

P:\Data\NuDeUK\ND800400 Flood Study - Lossie Seatown\2.Technical\5.Drawings\ND800400-SK-005 P02 Location 4 Typical Sections of Options.dwg - 01/10/2018 16:29:40 - A1Frame - metcalfp

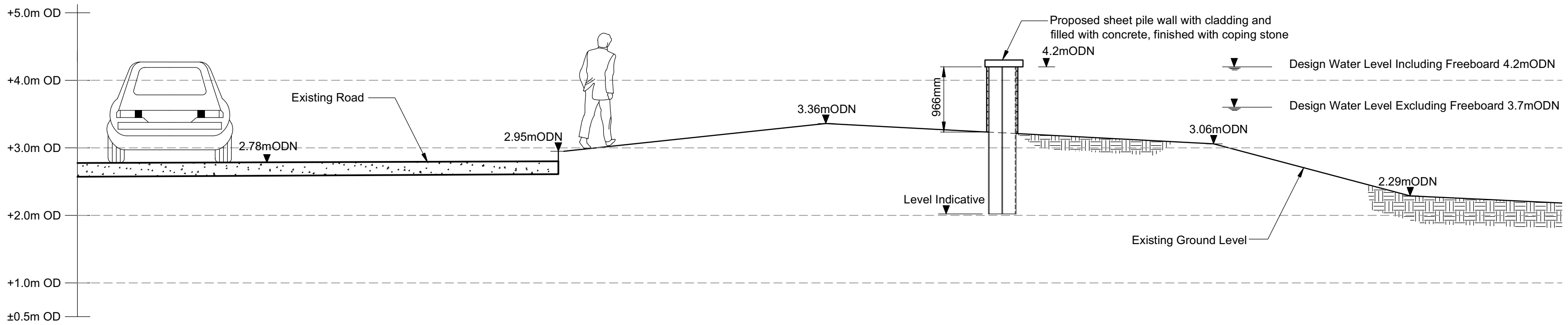


LOCATION PLAN
(Scale - 1:5000)

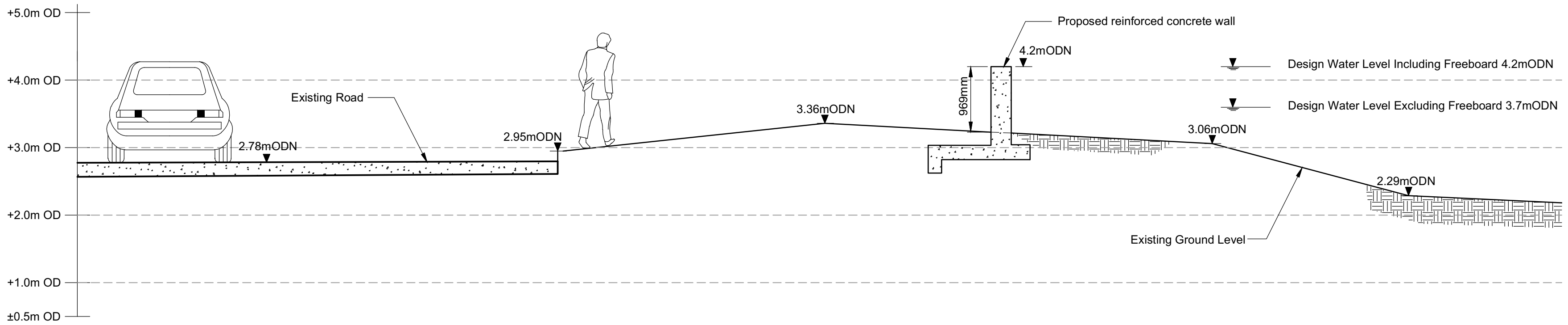
0 100 200 300 400 500 m
SCALE 1 : 5000



SECTION A-A
OPTION 1A - EARTH EMBANKMENT
(Scale - 1:50)

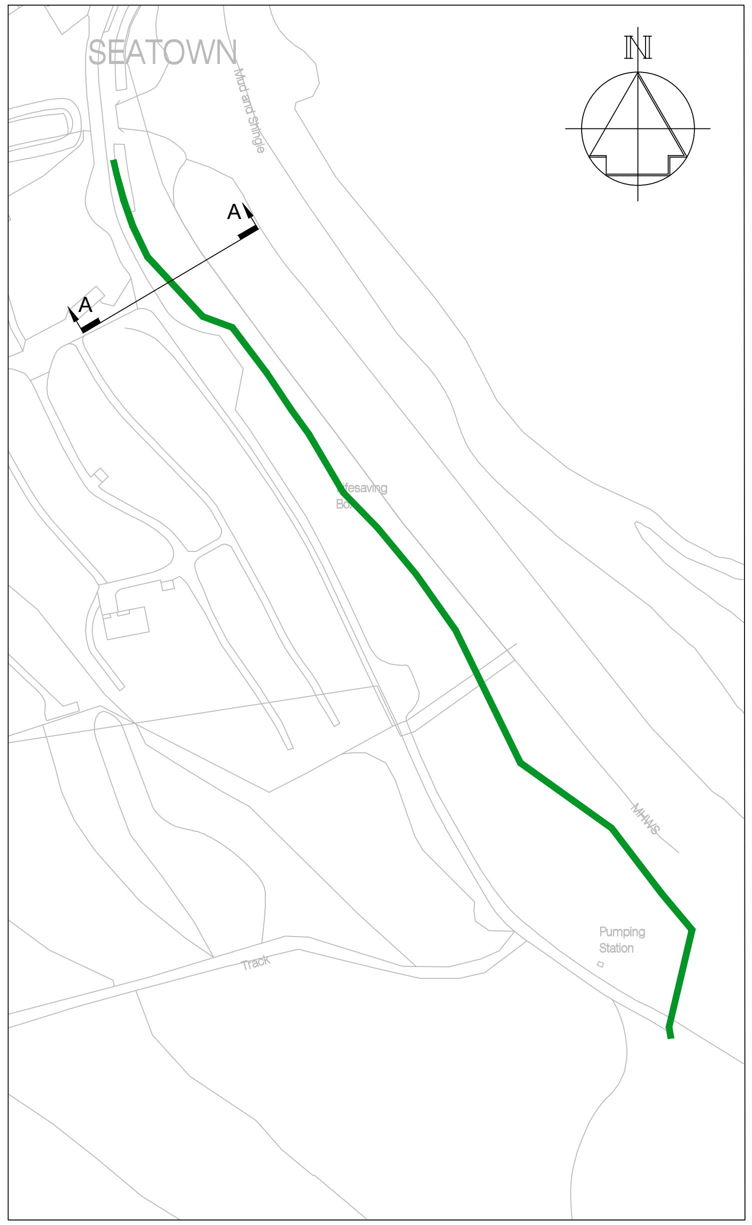


SECTION A-A
OPTION 1B - SHEET PILED SOLUTION WITH CLADDING
(Scale - 1:50)



SECTION A-A
OPTION 1C - CONCRETE RETAINING STRUCTURE
(Scale - 1:50)

0 1 2 3 4 5 m
SCALE 1 : 50



PLAN
(Scale - 1:1250)

0 50 100 150 m
SCALE 1 : 1250

Notes :

1. Do note scale from this drawing.
2. All dimensions are in metres unless stated otherwise.
3. All levels are in metres to Ordnance Datum (Newlyn) unless noted otherwise.
4. Section drawings are indicative only.
5. Drawing to be read in conjunction with Drawing No: ND800400-SK-001 Location Plan.

Key :

Approx. Location of:
Earth Embankment - Option1A
Concrete Retaining Structure - Option 1B
Sheet Pile Solution - Option 1C.

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
P02	SEPT. 2018	FOR INFORMATION	KMA	PM	AK	JS
P01	FEB. 2018	FOR INFORMATION	KMA	PM	JS	CEP

JACOBS
160 Dundee Street, Edinburgh, EH11 1DQ
Tel:+44(0)131 659 1500 Fax:+44(0)131 228 6177
www.jacobs.com

Client
The Moray Council

Project
LOSSIEMOUTH
COASTAL FLOODING BUSINESS CASE

Drawing title
LOCATION 5
TYPICAL SECTIONS OF OPTIONS

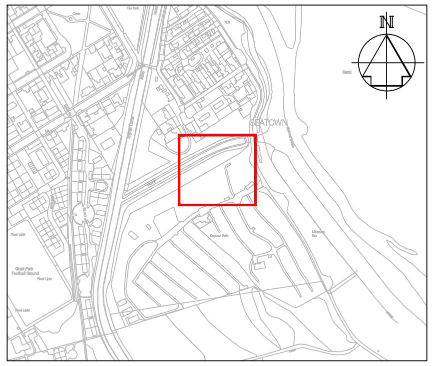
Drawing status
FOR INFORMATION

Scale	AS SHOWN @ A1	DO NOT SCALE
Jacobs No.	ND800400	Rev P02
Client no.		

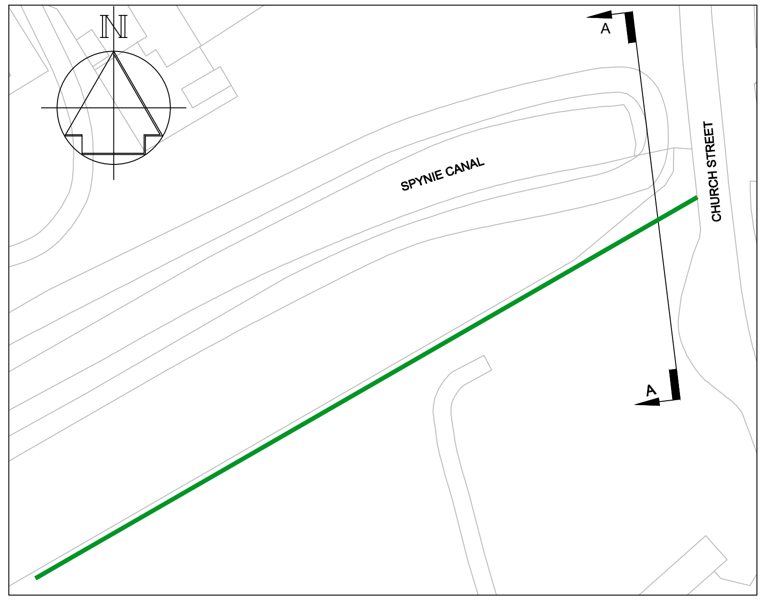
Drawing number
ND800400-SK-006

© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright. Limitation: This drawing has been prepared on behalf of, and for the exclusive use of Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this drawing by any third party.

P:\Data\NuDeUK\ND800400 Flood Study - Lossie Seatown\2.Technical\5.Drawings\ND800400-SK-006 P02 Location 5 Typical Sections of Options.dwg - 01/10/2018 16:29:54 - A1Frame - metcalfp



LOCATION PLAN
(Scale - 1:5000)



See Note 6

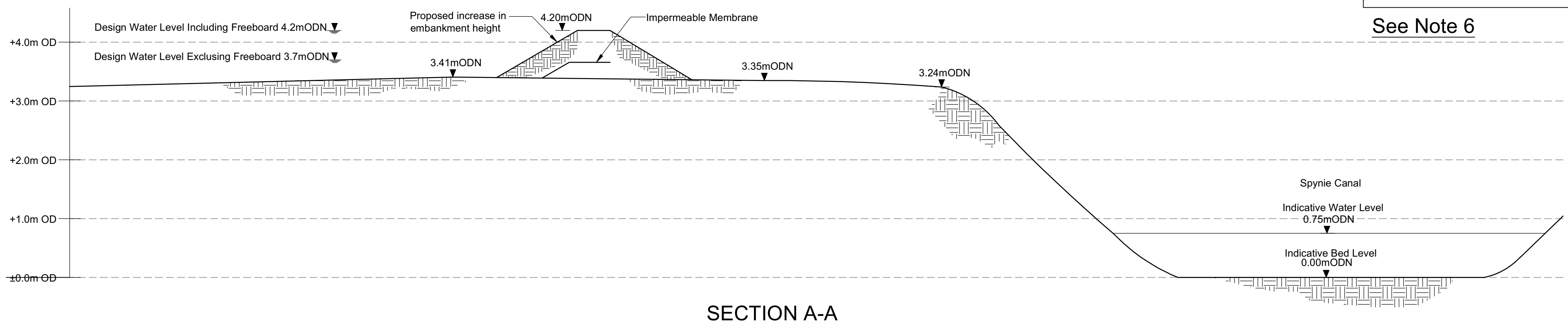
PLAN
(Scale - 1:500)

Notes :

1. Do note scale from this drawing.
2. All dimensions are in metres unless stated otherwise.
3. All levels are in metres to Ordnance Datum (Newlyn) unless noted otherwise.
4. Section drawings are indicative only.
5. Drawing to be read in conjunction with Drawing No: ND800400-SK-001 Location Plan.
6. Solution at Location 6 are alternative solutions that do not protect the Caravan Park. These options would tie into the road raising option at Location 4. See Drawing No. ND800400-SK-005.

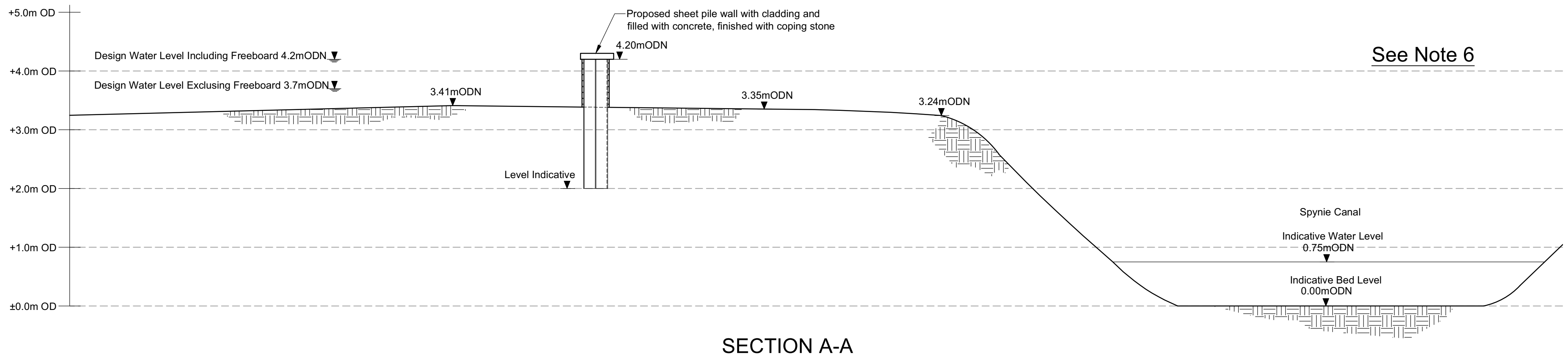
Key :

Approx. Location of Embankment, Sheet Pile Wall and Concrete Retaining Structure



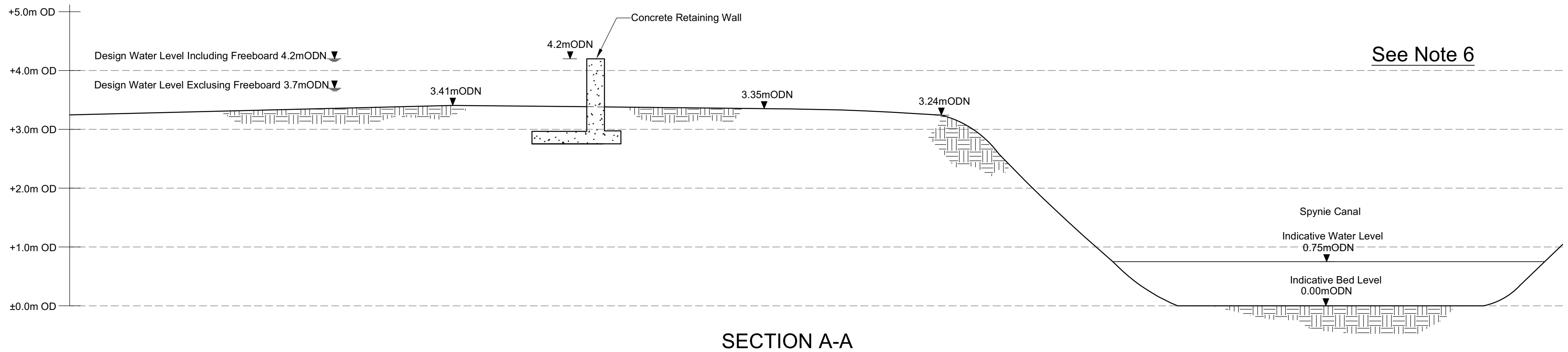
See Note 6

SECTION A-A
OPTION 2A - EARTH EMBANKMENT
(Scale - 1:50)



See Note 6

SECTION A-A
OPTION 2B - SHEET PILED SOLUTION WITH CLADDING
(Scale - 1:50)



See Note 6

SECTION A-A
OPTION 2C - CONCRETE RETAINING STRUCTURE
(Scale - 1:50)

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
P02	SEPT. 2018	FOR INFORMATION	KMA	PM	AK	JS
P01	FEB. 2018	FOR INFORMATION	KMA	PM	JS	CEP

JACOBS
160 Dundee Street, Edinburgh, EH11 1DQ
Tel:+44(0)131 659 1500 Fax:+44(0)131 228 6177
www.jacobs.com

Client

the moray council

Project

LOSSIEMOUTH
COASTAL FLOODING BUSINESS CASE

Drawing title

LOCATION No. 6
TYPICAL SECTIONS OF OPTIONS

Drawing status

FOR INFORMATION

Scale	AS SHOWN @ A1	DO NOT SCALE
Jacobs No.	ND800400	Rev P02
Client no.		

Drawing number

ND800400-SK-007

© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright. Limitation: This drawing has been prepared on behalf of, and for the exclusive use of Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this drawing by any third party.

P:\Data\NuDe\UK\ND800400 Flood Study - Lossie Seatown\2.Technical\5.Drawings\ND800400-SK-007 P02 Location 6 Typical Sections of Options.dwg - 01/10/2018 16:30:09 - A1Frame - metcalfp

P:\Data\NuDeUK\ND800400 Flood Study - Lossie Seatown\2.Technical\5.Drawings\ND800400-SK-008 P02 Flood Plan.dwg - 01/10/2018 16:30:36 - A1Frame - metcalfp

PLAN
(Scale - 1:1500)

Notes :

1. Do not scale from this drawing.

Key :

= Flood Level +3.7mODN

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
P02	SEPT. 2018	FOR INFORMATION	KMA	PM	AK	JS
P01	FEB. 2018	FOR INFORMATION	KMA	PM	KD	JS

JACOBS
160 Dundee Street, Edinburgh, EH11 1DQ
Tel:+44(0)131 659 1500 Fax:+44(0)131 228 6177
www.jacobs.com

Client

the moray council

Project

LOSSIEMOUTH
COASTAL FLOODING BUSINESS CASE

Drawing title

FLOOD PLAN

Drawing status

FOR INFORMATION

Scale	1:1500 @ A1	DO NOT SCALE
Jacobs No.	ND800400	Rev P02
Client no.		

Drawing number

ND800400-SK-008

© Copyright 2018 Jacobs U.K. Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright. Limitation: This drawing has been prepared on behalf of, and for the exclusive use of Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this drawing by any third party.

Appendix B. CBA Calculation

Cost-benefit Analysis

	Costs and benefits £						
Option number		Option2 a	Option 2c	Option 2b	Option 1a	Option 1c	Option 1b
Option name	Do-nothing	exclude caravans	exclude caravans	exclude caravans	All	All	All
AEP or SoP (where relevant)	0%, breaching in year 10	0%	0%	0%	0%	0%	0%
COSTS:							
PV capital costs	0	332,716	419,356	660,413	741,296	745,029	1,267,589
PV operation and maintenance costs	0	21,311	21,311	21,311	21,311	21,311	21,311
PV other	0	0	0	0	0	0	0
Optimism bias adjustment	0	212,416	264,400	409,035	457,564	459,804	773,340
PV negative costs (e.g. sales)	0	0	0	0	0	0	0
PV contributions							
Total PV Costs £ excluding contributions	0	566,444	705,068	1,090,759	1,220,172	1,226,145	2,062,241
Total PV Costs £ taking contributions into account	0	566,444	705,068	1,090,759	1,220,172	1,226,145	2,062,241
BENEFITS:							
PV monetised flood damages	16,102,989	13,142,638	13,142,638	13,142,638	0	0	0
PV EcMap Damage	26,357,739	9,883,737	9,883,737	9,883,737	0	0	0
PV Total Damage	42,460,728	23,026,375	23,026,375	23,026,375	0	0	0
PV monetised flood damages avoided		19,434,353	19,434,353	19,434,353	42,460,728	42,460,728	42,460,728
PV monetised erosion damages	0	0	0	0	0	0	0
PV monetised erosion damages avoided (protected)		0	0	0	0	0	0
Total monetised PV damages £	42,460,728	23,026,375	23,026,375	23,026,375	0	0	0
Total monetised PV benefits £		19,434,353	19,434,353	19,434,353	42,460,728	42,460,728	42,460,728
PV damages (from scoring and weighting)							
PV damages avoided/benefits (from scoring and weighting)							
PV benefits from ecosystem services							
Total PV damages £	42,460,728	23,026,375	23,026,375	23,026,375	0	0	0
Total PV benefits £		19,434,353	19,434,353	19,434,353	42,460,728	42,460,728	42,460,728

NPV, BCR and IBCR

Based on monetised PV benefits (excludes benefits from scoring and weighting and ecosystem services)							
Net Present Value **NPV**		18,867,910	18,729,286	18,343,594	41,240,557	41,234,584	40,398,488
Average benefit/cost ratio **BCR**		34.31	27.56	17.82	34.80	34.63	20.59
Incremental benefit/cost ratio **IBCR**			-	-	177.93	-	-
					Highest bcr IBCR>1		

Appendix C. Risk to Life Calculation

Risk to life Calculation	Scenario												
	Do Nothing					Option 1a	Option 1b	Option 1c	Option 2a, b and c				
	1/5	1/10	1/50	1/100	1/200	All	All	All	1/5	1/10	1/50	1/100	1/200
Depth (m)	0.3	0.34	0.43	0.49	0.53	0	0	0	0.56	0.61	0.7	0.64	0.78
Velocity (m/sec)	1.575	1.575	1.575	1.575	1.575	1.575	1.575	1.575	1.575	1.575	1.575	1.575	1.575
debris factor (DF)	1	1	1	1	1	1	1	1	1	1	1	1	1
Flood Hazard Rating (HR)	**1.6225**	**1.7055**	**1.89225**	**2.01675**	**2.09975**	**1**	**1**	**1**	**2.162**	**2.26575**	**2.4525**	**2.328**	**2.6185**
Flood warning	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
speed of onset	2	2	2	2	2	2	2	2	2	2	2	2	2
nature of area	2	2	2	2	2	2	2	2	2	2	2	2	2
Area Vulnerability (AV)	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**	**6.15**
% residents suffering from long-term illness	5.03%	5.03%	5.03%	5.03%	5.03%	5.03%	5.03%	5.03%	5.03%	5.03%	5.03%	5.03%	5.03%
%residents aged 75 or over	9.12%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%
People Vulnerability (Y)	**14%**	**14%**	**14%**	**14%**	**14%**	**14%**	**14%**	**14%**	**14%**	**14%**	**14%**	**14%**	**14%**
N(Z) is the population within the flooding zone **	219.65	233.45	258.75	277.15	285.20	0	0	0	146.05	146.05	146.05	146.05	146.05
Flood Hazard Rating	1.623	1.706	1.892	2.017	2.100	1	1	1	2.162	2.26575	2.4525	2.328	2.6185
Area Vulnerability	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15
Value of X Population exposed to risk	0.09978375	0.10488825	0.116373375	0.124030125	0.129134625	0.0615	0.0615	0.0615	0.132963	0.139343625	0.15082875	0.143172	0.16103775
People Vulnerability	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
N(ZE)	**21.92**	**24.49**	**30.11**	**34.37**	**36.83**	**0**	**0**	**0**	**19**	**20**	**22**	**21**	**24**
N# of Injuries	***6.20***	***6.93***	***8.52***	***9.73***	***10.42***	***0.00***	***0.00***	***0.00***	***5.49***	***5.76***	***6.23***	***5.92***	***6.65***
N# of Deaths	***0.71***	***0.84***	***1.14***	***1.39***	***1.55***	***0.00***	***0.00***	***0.00***	***0.84***	***0.92***	***1.08***	***0.97***	***1.23***
Total cost of injury (uplifted to 2022 prices)	£797,800.74	£891,300.45	£1,096,067.74	£1,251,253.98	£1,340,588.95	-	-	-	£706,863.85	£740,784.82	£801,842.55	£761,137.40	£856,116.10
Total cost of fatality (uplifted to 2022 prices)	£1,150,758.65	£1,351,390.79	£1,843,830.59	£2,243,378.96	£2,502,466.83	-	-	-	£1,358,615.51	£1,492,138.61	£1,748,248.73	£1,575,256.00	£1,992,922.21
Total Cost (£k)	**£1,948,559.39**	**£2,242,691.24**	**£2,939,898.33**	**£3,494,632.94**	**£3,843,055.78**	-	-	-	**£2,065,479.37**	**£2,232,923.43**	**£2,550,091.29**	**£2,336,393.40**	**£2,849,038.30**
Cost per fatality	£ 1,618,000.00												
Cost per injury	£ 128,650.00												

Appendix D. Social cost to traffic (Diversion Value Methodology)

METHOD 2: THE DIVERSION-VALUE METHOD

The simplest way of applying the above equation is to assume that cars will be diverted on to neighbouring roads and therefore the distance that they travel will increase; however their speed will be unaffected. For example, suppose that 15,000 vehicles travel through the local network each hour and will have to travel on average 2 kilometres further but their average speed (40 kph) will not be reduced. In this scenario, the cost of that flood event will be equal to 15,000 * 0.40[1] * 2 for each hour of the disruption due to flooding. If the flood lasts six hours, the costs of traffic disruption amounts to £72,000. In this instance, the figure is small and therefore it is disproportionate to refine this value further using more sophisticated modelling.

	Diversion (Yes/NO)
1 in 5	No
1 in 10	No
1 in 50	Yes
1 in 100	Yes
1 in 200	Yes

flood hours	8

	Do nothing	Option 1	Option 2
Vehicles per hour (B road)	400	0	0
Speed travelled (km/h)	30	0	0
Resource cost	0.55	0	0
Extra distance travelled	0.808	0	0
Cost per hour flood event	178	0	0
8 hour flood	£1,422.08	£0.00	£0.00

Appendix E. Highways Reinstatement Costs

Physical Cost to roads	Do Nothing				
	1/5	1/10	1/50	1/100	1/200
Total A Roads (m)	109	149	248	282.9	298.4
Total Other Roads (m)	1833.5	1925.5	2457.2	2459.25	2477.25
Cost from A Roads (£)	136250	186250	310000	353625	373000
Costs from Other Roads (£)	1145937.5	1203437.5	1535750	1537031.25	1548281.25
Probability of reinstatement occurring	5%	10%	50%	75%	100%
Total damage costs	**£64,109.38**	**£138,968.75**	**£922,875.00**	**£1,417,992.19**	**£1,921,281.25**