STRANRAER WATERFRONT DEVELOPMENT

COASTAL FLOOD RISK ASSESSMENT FOR DUMFRIES & GALLOWAY COUNCIL

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1 INTRODUCTION

1.1 PREAMBLE

The town of Stranraer forms an important district centre for the Wigtownshire and south west Scotland area. It has an important historic and geographical status in the area, however, in more recent years the short sea crossing terminal to Northern Ireland has, to a certain extent, defined the town. The existing waterfront is dominated by the ferry terminals, the west pier, a variety of car parks, unused land and Agnew Park. Numerous changes over the years have resulted in the centre of the town becoming dislocated from the shorefront.

The proposed relocation of the Stena ferry operation is seen as offering an opportunity for Stranraer to redevelop the waterfront thus enhancing the town as a whole and reconnecting it with Loch Ryan. The waterfront is seen as having significant potential for water sports, leisure and tourism activities as well as providing space for commercial and residential development. Dumfries and Galloway Council (D&GC) and Scottish Enterprise Dumfries and Galloway approved a Stranraer Waterfronts Development Framework in July 2005:

> *"To reposition Stranraer and Loch Ryan as a distinctive and successful marine leisure destination."*

During 2001-2007 the Council undertook a Strategic Flood Risk Appraisal for the region as a whole. This study identified Stranraer to be chiefly at risk of fluvial flooding but that the shore line and harbour area was at risk of coastal inundation. A formal Flood Protection Scheme is currently addressing the fluvial flood risk in the area.

In 2009 Dumfries and Galloway Council Economic Regeneration Service commissioned an Urban Design Strategy and Masterplan for the Stranraer waterfront with the Masterplan being published in December of that year.

In July 2010 the Planning and Environmental Services department of the Council appointed Terrenus CDH Ltd to carry out a coastal flood risk assessment of the area for inclusion as part of the development strategy of the Masterplan.

February 2011 saw the completion of the combined DEFRA / Environment Agency project SC060064. This work (supported by SEPA) analysed new coastal flood boundary conditions for the UK mainland and islands via a new methodology. In order to update the flood risk assessment Terrenus CDH Ltd was asked to review the findings of the investigation in light of the new methodology. A detailed assessment of the base astronomical tide using the simple harmonic method and applied surge shape was not considered appropriate at this stage.

1.2 OBJECTIVES OF INVESTIGATION

From the project brief and subsequent discussions with the Council the principal aims of the assessment are to:

1. Develop an understanding of the potential coastal flood mechanisms at the site including exceptionally high tides, storm surges and, to a limited extent, wave influence;
2. Produce an assessment of the potential constraints to the proposed Masterplan so that an informed decision may be made concerning development along the waterfront;
3. Provide recommendations relating to possible mitigation measures that could be adopted within the development Masterplan.

1.3 REPORT STRUCTURE

The structure of this report firstly sets out the geography and environment of the waterfront prior to addressing the risk of flooding in the area. A discussion and recommendation of potential mitigation measures concludes the report.

The report is further broken down into the Character Areas as presented in the 2009 Masterplan and detailed below;

- Marina;
- Town Extension
- East Pier.
- East Pier Gateway;

1.4 LIMITATIONS OF REPORT

Terrenus CDH Ltd. has prepared this report for the sole use of Dumfries & Galloway Council, in accordance with generally accepted consulting practice and for the intended purpose as stated in the related contract agreement. No other warranty, expressed or implied, is made as to the professional advice included in this report.

To the best of our knowledge, information contained in this report is accurate at the date of issue. It should be noted, however, that this report is based on the information obtained from the sources listed in Section 2 below. There may be conditions pertaining at the site not disclosed by these sources, which might have a bearing on the recommendations provided if such conditions were known. We have, however, used our professional judgement in attempting to limit this during the investigation.

It is important therefore that these implications be clearly recognised when the findings of this study are being interpreted. In addition, this should be borne in mind if this report is used without further confirmatory investigation after a significant delay.

It is intended that this report will provide assistance for the Masterplan development of the Stranraer waterfront area. As such, approval is given for its distribution to all parties. The report is not however suitable for detailed planning and design purposes and it is recommended that for individual projects within the Masterplan further professional advice is sought.

2 DATA SOURCES, GEOGRAPHY AND ENVIRONMENT

2.1 DATA SOURCES

A wide variety of data sources were consulted during the course of the investigation including:

- D&GC Wigtown Local Plan;
- The Scottish Environment Protection Agency (SEPA) indicative flood risk map;
- Current Topographic Maps;
- Geological & Hydrogeological Maps;
- Stranraer Urban Design Strategy and Masterplan, dated 2009;
- Site layout, as supplied by the client, augmented by observational data collated by Terrenus CDH;
- Dumfries and Galloway Shoreline Management Plan;
- Loch Ryan Coastal Risk Assessment dated 2005;
- Stranraer West Pier and Harbour Area Study, Marine Consultancy dated 2005;
- Stranraer West Pier and Harbour Area Study, Breakwater Design dated 2005;
- Stranraer – Loch Ryan wave monitoring for Stranraer Marina dated 2010

Discussions were also held with the Harbour Master, Stena port authorities, Stranraer RNLI, Stranraer and Wigtownshire Free Press and the local SEPA offices.

A full list of references is included in the appendix to this report.

2.2 SITE DESCRIPTION & GENERAL CONDITION OF SEA DEFENCES

The waterfront area of Stranraer is located at National Grid Reference NX 0611 6103 as shown on Figure 1 enclosed in the appendix to this report. The following site description is based on a walkover inspection undertaken on the 1st and 2nd September 2010 and by examination of current Ordnance Survey maps and available topographic data provided by the Council. A photographic record is included within the appendix to this report.

The development Character Areas are set out on Drawing 1168-200-002 in the appendix.

2.2.1 Marina

The Marina area encloses the existing West Pier and marina area as well as the car park and un-used land immediately to the west. Whilst this report will focus on the development in this area the local topography requires that flood risk assessment be extended further to the west to include Agnew Park and Foreland Place. No significant sea defences exist along the foreshore with the area to the west of the West Pier generally low lying rising up very gently to the pier and the Breastworks Car Park to the east.

Maintenance of the foreshore works throughout the Marina area is understood to be the responsibility of the Local Authority. It is understood that dredging of the Marina area will require to be continued should its use by sailing boats and other vessels be encouraged in the future.

From the west, the shore area around Foreland Place and Sheuchan Street is flat lying with a gently sloping beach (Plates 3 & 4). Foreland Place is at a level in the order of 3.0m above Ordnance Datum (AOD) with a low concrete stepped structure in good overall condition forming the shore wall up to approximately the RNLI station. This wall is approximately 0.6m in height thus the shoreline protection may be considered to be 3.6m AOD. Elements of this structure are however absent and it is likely that waters above 3.0m AOD will inundate Foreland Place and beyond. Wave-break is known and reported along this section of the coast by the Harbour Master.

East of the RNLI station the low wall is absent and the shore line is at a low level of about 2.9m AOD and marked by a broad walkway. Landscape mounds lie to the south of the walkway, raising the general ground level to some 3.4m AOD. Any waters above 3.0m AOD are likely to enter the Agnew Park area via the low lying area in the vicinity of the RNLI station. Stranraer RNLI however reports that there have been no instances of high sea conditions entering their site since the construction of the building in the early to mid 1970s. The RNLI does however report that flooding due to the local drainage system along Sheuchan Street has occurred in the past. The condition of the shoreline concrete throughout this section is good.

Further to the east the shoreline rises up to a level of approximately 3.5m AOD with an additional concrete breakwater above. The condition of the breakwater is considered to be poor with some spalling evident. General maintenance will be required in the future.

The disused ground inshore of the breakwater forms part of the historic ‘Clayhole Bay’ which was later cut off from Loch Ryan as a marine lake. The ground lies at a level of 2-3m AOD. This area is below that of Agnew Park immediately to the west where levels of between 3 and 3.5m AOD are generally noted.

The West Pier forms a low connective barrier to water movement from west to east. Here a level of some 3.5m AOD or above is maintained throughout, including the weighbridge, Harbour Office and Breastworks Car Park immediately to the east.

The construction and condition of the West Pier is addressed in some detail in the Stranraer West Pier and Harbour Area Study carried out in 2005 by HR Wallingford (report EX 5058). Subsequent to this report, no significant maintenance work appears to have been carried out on the concrete breakwater that forms the western face of the wooden pier. Localised spalling is evident at a number of pile locations. It is, in addition, noted that much sand, shingle and seaweed has collected immediately to the west of the pier since the 2005 report. Whilst maintenance is required at this location it is likely that the ability of this structure to provide a breakwater to the marina area will endure for some time.

At present the deck of the wooden portion of the West Pier is out of bounds due to its condition and significant overall maintenance of this structure will be required in the future.

The hammerhead portion of the West Pier remains in reasonable condition as is the concrete deck above the open piled southern portion of the pier, although an underside inspection of the deck was not possible during the site visit. The open piles at this southern pier section are however in poor condition and additional maintenance should be considered in the future.

The condition of the older masonry wall on the western side of the pier and along the southern side of the Breastworks Car Park is similar to that described in the 2005 Wallingford report. General upkeep maintenance and pointing should be considered in the future along this section of the shore works.

2.2.2 Town Extension

The Town Extension area encompasses the entire Breastworks area as well as the Town Burn outfall and the West and East Slipways. Much of the foreshore works maintenance remains the responsibility of the Local Authority, however it is understood from the Harbour Master that maintenance responsibility is uncertain and possibly shared from the east slipway to the corner of the Ross Pier.

The Breastworks harbour wall up to the Town Burn outfall is in fair condition with general upkeep maintenance and pointing being required in places. Inshore of the Breastworks the car park lies at a level in the order of 3.4m to 3.5m AOD with a low brick wall some 0.6m high running along the edge of the car park on its seaward side.

The Town Burn issues from a stone culvert at the eastern end of the Breastworks. The burn outfall is topographically low as well as being partly choked by stones and debris. It is understood that localised flooding occurs within Stranraer itself due to the backing up of this burn during exceptionally high tides.

The West Slipway lies adjacent to the Town Burn culvert and is in a reasonable state of maintenance. The surrounding foreshore including the Stena Offices (Burns House) is at a datum level of below 3m AOD. Any peak waters above this level are likely to pass along Market Street and part of Harbour Street.

To the east of the West Slipway up to the Scottish Water Pumping Station the foreshore wall partly comprises stonework, partly concrete and partly concrete above a stone berm. Sections of this wall are in poor condition and partial collapses and localised repairs have been reported by the Harbour Master. The East Slipway lies between the West Slipway and the pumping station and is in a generally poor state. To the east of the pumping station the sea wall comprises a concrete wall above sheet piling.

Ground levels immediately behind the sea wall are in the order of 3.5m AOD between the burn outfall and the pumping station falling to about 3m AOD along the tarmac footpath to the east.

Further inland, between the Stena Offices and the pumping station there is a raised mound between the tourist information centre and the bus depot. Harbour Street to the south generally lies at a level of below 3.3m AOD rising slightly around the Port Rodie roundabout. The pumping station and car park to the east entails a raised ground level behind a concrete block retaining wall. Levels throughout this section are at approximately 4.5m AOD prior to falling gently to the east and a level of about 3.5m AOD. It is noted that water levels above 3.4m AOD will pass along the tarmac path noted above and may inundate portions of the car park and Stena marshalling yard to the east.

2.2.3 East Pier

The East Pier is made up of the Stena ferry terminal on the Ross Pier (western) side and the Railtrack Pier on the eastern side. Stena report that they are responsible for the upkeep of the eastern side of the Railtrack Pier as well as for the Ross Pier and western (harbour) side.

The south western side of the Ross Pier is made up of rock revetments in apparently good condition with the Ross Pier itself comprising an open pile construction with concrete platform above. Stena report that there are no current maintenance issues relating to the Ross Pier.

The Railtrack Pier is made up of sheet piles on its western and northern sides with harbour facilities along its western side. The north east of the pier is composed of a near vertical concrete wall with the railway station wall behind. The eastern side of the Railtrack Pier comprises stone built revetments with a stone wall above. Stena report no current maintenance issues on the western side of the Railtrack Pier however, the Harbour Master notes that some corrosion of the northern end of the Railtrack Pier has been addressed in the past by means of rock emplacement at the base of the sheet pile wall. The stone revetments on the eastern side of the pier are in poor condition with some slumping and general wave damage noted.

General maintenance of the eastern side of the Railtrack Pier should be considered at some time in the future.

Surveyed ground levels are not generally available for the East Pier area however a number of spot heights are available along the railway from 3.5m AOD in the south to 4.0m AOD in the north. With the ground being essentially flat the ground levels are anticipated to be between 3.3m and 3.8m AOD throughout.

2.2.4 East Pier Gateway

The East Pier Gateway encompasses the southern marshalling areas of the existing Stena port together with the ferry passenger terminal and the southern part of the railway line.

The eastern sea wall of the Railtrack Pier comprises stone built revetments with a stone wall above. This revetment is in poor condition with concrete degradation noted along with general wave damage. General maintenance of the revetment should be considered at some time in the future.

Further to the east the A77 Cairnryan Road lies well above the shore at the top of a concrete secured embankment. Some erosion of this embankment was noted and general maintenance is advised in the future.

Surveyed ground levels are available for the peripheral parts of this area, however, the central portion was not surveyed at the same time as the shore area as a whole. The general topography is however generally flat across the pier area prior to rising steeply to the south and Royal Crescent, Stair Drive and the bridge over the railway line.

Much of the marshalling yard is likely to be between 3m and 3.5m AOD with the eastern end of Port Rodie rising gently from a height of around 3m AOD to 8.5m AOD on the railway bridge. The Garden of Friendship however lies at a level of between 3m and 4m AOD.

2.3 GENERAL GEOLOGY & HYDROGEOLOGY

The strata below Stranraer comprise Quaternary coastal and river alluvium liable to contain concealed aquifers of limited or local potential.

The solid geology below Stranraer comprises Permian breccias (a sedimentary rock comprising angular rock fragments within a fine to medium grained matrix), sandstones and mudstones.

2.4 HYDROLOGY AND DRAINAGE

A number of watercourses drain into Loch Ryan in the vicinity of Stranraer;

- Sheuchan Burn;
- Town Burn including the Laundry Burn; and,
- Black Stank / Bishop Burn.

Of the above three watercourses the Sheuchan Burn and the Town Burn have the capacity to impact the waterfront area. The Black Stank / Bishop Burn outfalls approximately one kilometre to the east of the Railtrack Pier.

The Scottish Environment Protection Agency (SEPA) provide as a public service, an indicative River and Coastal Flood Map for Scotland. A review of the Indicative River & Coastal Flood Map (Scotland) 200-year outline (i.e. the flood with a 0.5% chance of occurring in any single year) indicates that the near shore area of Stranraer may be at risk from sea inundation. The map also suggests that portions of the Black Stank Burn will flood inland but that this will not affect the harbour area.

SEPA do however make the following statement about the above service:

"The Indicative River & Coastal Flood Map (Scotland) has been produced following a consistent, nationally-applied methodology for catchment areas equal to or greater than 3km^2 using a Digital Terrain Model (DTM) to define river cross-sections and low-lying coastal land. The outlines do not account for flooding arising from sources such as surface water runoff, surcharged culverts or drainage systems. The methodology was not designed to quantify the impacts of factors such as flood alleviation measures, buildings and transport infrastructure on flood conveyance & storage.

The Indicative River & Coastal Flood Map (Scotland) is designed to be used as a national strategic assessment of flood risk to support planning policy in Scotland."

The 200-year flood map should be treated with caution and SEPA make the following general comment:

"It (the flood map) does not provide enough detail to accurately estimate the flood risk associated with individual properties or specific point locations. Local factors such as flood defence schemes, structures in or around river channels such as bridges, buildings and other local influences, which might affect a flood, have not been included".

Issues of under capacity and the backing up of waters close to the outfalls of the Sheuchan have been identified in the past leading, in particular to localised flooding around the area of Sheuchan Street in the shore area of Stranraer. Flooding issues associated with the Town Burn lie outwith tidal influence. The Council Biennial Report on flooding published in June 2010 notes the following;

> *Stranraer has suffered flooding over the years at a number of locations and a flood study to identify a viable scheme has continued since the last major flood event in 2000.*
>
> *The* (flood protection) *scheme aims to address the remaining significant problem areas where economically justifiable. The design period has been extended due to the complex interaction between watercourses and drainage within the area under consideration.*

The aim of the flood protection scheme is to mitigate the risk of flooding associated with the three main watercourses in the area. The proposed works include the upgrading of the lower Town Burn culvert in order to increase its capacity and reduce the risk of this watercourse backing up. In addition, the scheme anticipates the building of a new lower Sheuchan Burn culvert below Sheuchan Street with a new outfall into Loch Ryan. This will bypass a section of culvert in very poor condition and an undersized twin pipe road crossing.

Storm drainage in the immediate vicinity of the Stranraer shoreline will either be collected by the local drainage infrastructure or discharge directly to Loch Ryan.

2.5 HISTORICAL FLOODING

There are very few confirmed records of flooding in the Stranraer area however discussions with Mr Donny Nelson a local reporter, historian and former Councillor concluded that a number of local historical flooding events occurred including the following;

- January 1928 – peak tide and northerly storm leading to flooding of North Strand Street. Water level understood to be ‘about two feet deep’ at the road in front of the supporters club on North Strand Street. Confirmed by photograph.
- 1938/39 - inundation of north end of King Street with water between one and two feet deep in front of the Commercial Inn on Agnew Crescent. Wave height was noted to be modest.
- 1970/71 - inundation of ferry terminal marshalling yard due to overtopping of Black Stank / Bishop Burn leading to water passing along the railway from south to north.

From the available topographic data it is estimated that the 1928 event resulted in peak water levels in the order of 3.6m AOD at North Strand Street. The 1938/39 event is estimated to entail water levels of about 3.9m AOD at the corner of Agnew Crescent and King Street.

The 1970/71 event is the result of fluvial flooding and does not relate to tidal / storm water inundation.

3 POLICY AND ASSESSMENT OF PAST REPORTS

It is not the intention to review the complete policy framework in relation to the development potential for Stranraer and the associated shoreline management. A number of past reports relating to local flooding and the shoreline environment were however reviewed as part of this assessment. Selected relevant parts of these reports are provided below.

Issues relating directly to the assessment of tidal effects, storm surge and wave effects are dealt with in Section 4.

3.1 LOCAL PLANNING AND FLOOD POLICY

3.1.1 Planning Policy

The Wigtown Local Plan states that;

> *Stranraer's coastal location and reliance on the sea for part of its economic prosperity is recognised in the Plan, through the identification of the sea front area as an area of developed coast. This provides a basis for further coastal development within Stranraer. Recognition must however be given to the impact of new development along the coast.*

For areas of "Developed Coast", identified in the Local Plan, General Planning Policy 47 states:

> *"Within these areas, development proposals will be required to demonstrate that they:*
>
> *a) Require a coastal location; or*
>
> *b) Would result in the regeneration of derelict land; and*
>
> *c) Would not have a material adverse effect on the integrity of the coast or its environs; and*
>
> *d) Would not be at risk from erosion or flooding or increase the likelihood of erosion or flooding elsewhere".*

The Water Framework Directive (WFD) is likely to be an important factor in the future consideration of flood and coastal management in Scotland. It is likely that the WFD will act to regulate management of the coastline, for example influencing the types of coastal defence that might be installed, and as an extra factor in setting priorities for such management, for example preventing erosion of contaminated land. It is particularly important in the consideration of flood protection schemes, along coasts, in estuaries or along rivers. There will be a need to maintain or improve the ecological quality of the areas affected as well as the effects on hydrology/ hydrodynamics of any such scheme.

The Council Shoreline Management Plan anticipates the possibility of Global Climate Change (GCC) and notes:

> *... future coastal defence policy in Dumfries and Galloway needs to recognise the strong possibility of acceleration in the increase in mean sea level relative to the land.*

The Plan also notes in relation to local storm conditions that;

> *Current research, however, does not predict any major change in the frequency of occurrence, or magnitude of storm surges (Werrity et al., 2002). This is linked with the difficulties of predicting future values of the North Atlantic Oscillation, i.e. the variation in the atmospheric pressure gradient between the "Azores High" and the "Iceland Low", which is probably the major climatic factor in the occurrence of such surges around the UK coastline.*

The Town and Country Planning (Scotland) Act 1997 and associated legislation extends to the mean low water mark of ordinary spring tides. A new marine planning system is being introduced through the Marine (Scotland) Bill and will provide a framework for the sustainable development of the Scottish marine area. The powers of the marine planning system will extend up to the mean high water mark.

The terrestrial planning system and the marine planning system are legally and functionally separate but overlap in the inter-tidal area. Planning authorities should work closely with Marine Planning Partnerships and neighbouring authorities to ensure that development plans and regional marine plans are complementary, particularly with regard to the inter-tidal area but also for the wider coastal zone.

3.1.2 Flood Policy

The new Scottish Planning Policy (SPP) was published in February 2010 and is the statement of the Scottish Government's policy on nationally important land use planning matters. The SPP document supersedes the former SPP 7 – Planning and Flooding and sets out the general framework for development in relation to the issue of flooding in Scotland.

Concerning the issue of flooding in particular the SPP sets out the following broad policy

> *Development which would have a significant probability of being affected by flooding or would increase the probability of flooding elsewhere should not be permitted.*

The SPP notes that the Flood Risk Management (Scotland) Act 2009 places a duty on Scottish Ministers, SEPA, local authorities, Scottish Water and other responsible authorities to exercise their functions with a view to managing and reducing flood risk and to promote sustainable flood risk management. The policy does however accept that it is not possible to set planning policy solely according to the calculated probability of flooding. A precautionary approach should be taken when flood risk is considered an issue.

The SPP continues with the use of a risk based approach to Planning and in applying the flood risk framework, developers and planning authorities should, amongst other things, also take into account:

- the characteristics of the site;
- the use and design of the proposed development;
- the depth of water, rate of rise and duration;
- effects of a flood on access including by emergency services;
- effects of a flood on proposed open spaces including gardens; and,
- the extent to which the development, its materials and construction are designed to be water resistant.

The SPP risk framework applies to all types of flooding and considered three main categories namely

Little or No Risk (a 0.1% annual probability (1 in 1000 years)) where there would be no constraints,

Low to Medium Risk (a 0.1% to 0.5% annual probability (1 in 1000 to 1 in 200 years)) which would be suitable for most development with the use of water resistant construction materials recommended. This category is not suitable for essential civil infrastructure such as hospitals, fire stations and emergency depots.

Medium to High Risk (a greater than 0.5% annual probability (over 1 in 200 years) where development is discouraged. Land raising may be acceptable in this category and residential, institutional, commercial and industrial development may be possible provided flood protection measures to the appropriate standard already exist, are under construction or are planned as part of a long term development strategy. In addition, exceptions may arise if a location is essential for navigation and water based recreation uses, transport or some utilities infrastructure and an alternative lower risk location is not achievable. Such infrastructure should be designed and constructed to remain operational during floods. Otherwise adequate evacuation procedures should be in place.

The SPP notes that local development plans can identify where the promotion of managed coastal realignment or other measures could contribute to more a sustainable approach to flood management.

The issue of land raising can be considered in association with flood protection measures when assessing the impact of a development on the risk of flooding elsewhere. SPP notes that land raising may have a role in some circumstances. Proposals for land raising should amongst other things:

- be linked to the provision and maintenance of compensatory flood water storage ;
- have a neutral or better effect on the probability of flooding elsewhere, including existing properties; and,
- not create islands of development but should adjoin developed areas outwith the functional flood plain.

Engineering works in coastal waters are not normally regulated by SEPA under the Water Environment (Controlled Activities) (Scotland) regulations 2005. Such works are regulated under the Food and Environment Protection Act 1985.

With respect to coastal development SPP recognises that the coast is a major focus for economic activity, recreation and tourism and that the sustainable development of coastal areas is an important contributor to sustainable economic growth. The SPP notes that rising sea levels and more extreme weather events resulting from climate change will have a significant impact on coastal areas, and planning policy must respond to these challenges.

The SPP goes on to state:

> *New land-based development in coastal areas should not normally be permitted where it will require significant new defences against coastal erosion or coastal flooding, unless defences are planned as part of a long term strategy.*

The SPP recognises and favours coastal development in association with existing settlements and the re-use of brownfield land. The Policy goes on to note that;

> *Development plans should protect the coastal environment, indicate priority locations for enhancement and regeneration, identify areas at risk from coastal erosion and flooding and promote public access to and along the coast wherever possible.*
>
> *Planning authorities should take the likely effect of proposed development on the marine environment into account when preparing development plans and making decisions on planning applications.*

The Scottish Environment Protection Agency (SEPA) state in their Technical Flood Risk Guidance for Stakeholders that the functional flood plain term applies to both inland and coastal inundation and that land raising in coastal areas should be considered in the same way as that used to mitigate fluvial risk. SEPA state that an assessment of the likely impact of any displaced water on neighbouring or other locations should be made. Notwithstanding this SEPA has historically allowed a greater use of land raising as a coastal mitigation measure than with respect to inland flood risk alleviation.

3.2 SHORELINE ECOLOGY

The Dumfries and Galloway Shoreline Management Plan raises the following points of note.

3.2.1 Coastal Overview

> *The shoreline from some 250m north of McCulloch's Point to just east of Bishop Burn Bridge contains the low-lying heavily developed frontage of Stranraer. Within this frontage, the defences (seawalls and harbour jetties) are considered from the coast protection viewpoint, rather than harbour usage viewpoint. The problems of siltation within the harbour are therefore not considered, although it is recognised that siltation and pollution risk are factors that affect both the harbour and adjacent beaches.*

> *.... along the main town frontage there are wide sandy beaches, which, if not accreting any more, are certainly not eroding significantly. The harbour has a marked influence on the littoral processes and to the east of it beach levels are much lower. Thus, although the waves propagating into the loch must hit the beach contours almost perpendicularly, there does appear to be a potential west to east transport of sand (possibly aided by tidal current influences).*

3.2.2 Condition of the defences

To the south of Broadstone Road there is an area of amenity land, Agnew Park, protected by a massive concrete wall which extends almost to the mouth of a small stream that discharges across the foreshore to the north of Foreland Place. The wall is in good condition, but has a relatively narrow sand and pebble beach in front of it. There is some risk that people using the cycle track immediately behind the wall could be affected by "wave splash" if beach levels were to fall. If the pebble beach were eroded there would be a slight risk of backshore erosion, which would affect amenity land only. The beach appears to be stable, but there is certainly now little supply of material to make good any losses.

The frontage from Foreland Place to the West Pier of Stranraer Harbour is protected by a continuous line of concrete walls, in front of which sand accretion is taking place. The walls are in good condition and there is very little risk of waves affecting the backshore.

The main problem, especially towards the harbour, is seaweed pollution. The beaches are regularly harrowed, but the problem is difficult to eradicate, especially in the corner between the eastern end of the seawall and the western harbour arm, where the rotting seaweed badly despoils the upper beach, making this particular corner unusable. If the defences were allowed to fall into disrepair there would be little risk to the backshore.

The town frontage between the West and East Piers is well sheltered against wave action and is protected by vertical masonry/concrete walls that are in good condition. The foreshore of muddy sand is flat and there is no beach at high tide. This is a very sheltered environment and the lack of beach build up indicates that supplies of coarse grained sediment are limited.

4 FLOOD RISK ASSESSMENT

4.1 GENERAL

Flooding occurs when the amount of water arriving on land exceeds the capacity of the land to discharge that water. Flooding can therefore occur by river inundation, overland flow, groundwater rise, failed drainage systems or sea water inundation. It can occur on any level or near-level area of land but the main concern for the shore area of Stranraer is its proximity to Loch Ryan.

Due to the size and nature of the outfalls from the local burns in the Stranraer area these watercourses will have no impact on the risk of tidal inundation; however the risk of local flooding due to backing up of waters at the outfalls and under capacity of the system remains an issue. The ongoing Stranraer fluvial flood protection scheme aims to mitigate the risk of flooding associated with the existing watercourses and drainage system within the town including potential backing up of the Sheuchan and Town Burns. For the purposes of this report it is assumed that the ongoing Stranraer Flood Prevention Scheme will address the issue of flooding due to the local watercourses and that fluvial inundation or overland flow of surface waters will not present a risk to the shoreline area.

The local topography provides a gentle fall to the sea with the geology comprising, coastal and river alluvium of moderate permeability. The watercourses in the area indicate that the local water table is some two to three metres below existing ground level in the Stranraer area. Along the course of the Town Burn the local water table may be slightly deeper due to historical land raising in the vicinity. Given the potential of rapid drainage to the sea and the local watercourses the ground water is unlikely to rise significantly during a peak rainfall event. Sea water inundation will raise the local ground water, however, the duration of such an event is short and the risk of a substantial rise in groundwater leading to flooding from this source is not considered to be significant.

A single primary flooding mechanism therefore exists for the shore area of Stranraer from Loch Ryan to the north.

For outline design purposes in relation to the flood risk assessment an allowable freeboard of 300mm should if possible be adopted for the ground level with an additional 300mm for property floor levels.

4.2 ASSESSMENT METHODOLOGY

4.2.1 General Guidance

Flooding from the sea occurs where water levels exceed the normal tidal range and inundate portions of the lower lying coast line. SEPA recognises four physical elements that may impact the potential for extreme sea levels;

- Predicted Highest Astronomical Tide (HAT) due to solar and lunar gravitational effects;
- Storm surge where elevated sea level occurs due to the effect of low atmospheric pressure and strong wind;
- Wave effects relating to wind direction, strength and open water ‘fetch’ (available distance for wave to propagate); and,

- Local bathymetric effects where funnelling of open waters by tide or storm can lead to elevated water levels at the head of sea lochs etc.

The HAT can be calculated and generally the effect of local funnelling is well known in a particular area. Storm surge and wave effect often occur in tandem during low pressure storm events.

Up until the end of 2010 the SEPA Technical Flood Risk Guidance for Stakeholders recommended the use of the Proudman Oceanographic Laboratory (POL) Internal Report 112 methodology and related guidance from POL Internal Report 65 and POL Internal Report 72 to derive coastal flood levels.

In February 2011 a new methodology relating to coastal flood boundary conditions for UK mainland and islands was produced by DEFRA and the Environment Agency under project SC060064 (with support from SEPA). This project assessment tool supersedes the previous methodology based on the Proudman Oceanographic Laboratory reports including the POL Internal Report 112 and one of the aims of the new methodology was to replace POL 112 by providing a consistent set of extreme sea levels. The new methodology results in a scientifically robust evidence base and practical guidance on appropriate design sea level and swell wave conditions around the UK. The new assessment tool uses the Skew Surge Joint Probability Method (SSJPM) as a more robust method for estimating design sea levels.

In order to update the flood risk assessment of the Stranraer harbour area the new DEFRA/EA project SC060064 methodology was applied to the area and a comparative exercise carried out between the results from the two methodologies.

4.2.2 General Sea Level Information

The tidal levels experienced around the Scottish coastline are predictable and generally made up of two components, an astronomical component and residual component due to weather effects. The major contribution to peak still water is the relative motions of the Earth, Moon and Sun.

All this tidal energy stems from the Atlantic Ocean, which, when it reaches the continental shelf becomes concentrated by the reducing water depth and converging land masses where numerous complex processes including reflections and amplitude of wave energy occur.

The still tidal level can be increased by strong winds and rapid atmospheric pressure falls creating storm surges. If storm surges are amplified by a narrowing estuary or channel then they can attain significant wave height. Such effects can happen at any state of the tide although if the resulting surge coincides with a high astronomical tide then this can have devastating effects as it is often the combination of a surge and high tide which causes flooding or damage along a coastline.

4.2.3 Historical and Inferred Sea Level Information

The astronomical effects on still sea water levels around the Scottish coast are predictable. These tidal levels are calculated relative to Chart Datum (CD) and require to be corrected for direct comparison with Ordnance Datum (OD) levels.

The methodology outlined within the Proudman Oceanographic Laboratory (POL) Internal Report 112 'Spatial Analyses for the UK Coast' was used in the calculation of extreme sea levels at Stranraer.

The report states:

> *"The aim of the project is to develop a spatial model for the entire coastline so that estimates of extreme sea levels can be given for any coastal position and not just at data sites."*

The spatial model utilises a 39 year run of hydrological data for tides and surges on a grid over the north-west European continental shelf and observed historical sea level data from 41 sites along the UK coastline. This data enables the estimation of extreme sea return levels at any location along the UK coastline via a series of 89 nodes.

Past reports prepared by HR Wallingford in relation to the assessment and development of Stranraer harbour for Dumfries & Galloway Council adopted a uniform increase to the value calculated from POL 112 of 0.48m for Stranraer. For the 1 in 100 year return period HR Wallingford adopted a peak still water level (HAT) of 3.38m AOD.

4.2.4 Climate Change Policy and Sea Level Rise

Due to a variety of factors the sea level around the shores of the UK is predicted to rise in the future. As noted by SEPA during consultations, the Scottish Executive Central Research Unit Environment Group (Research Findings No. 19) states that:

> *"by 2050 sea levels are predicted to rise by an additional 80-300mm which, when combined with future storm surges, could make most of Scotland's coasts below the 5m contour more vulnerable to flood risk".*

The Scottish Executive Climate Change Flood Occurrences Review recognises the effect of isostatic rebound following past glacial periods. When combined with the known rebound for the southwest of Scotland, the report notes that such effects may be limited in the Wigtownshire, Kirkcudbright and the Solway area with the relative sea level rise 'best estimate' being between 145mm and 170mm .

The Dumfries and Galloway Shoreline Management Plan (Volume 1, June 2005) supports the above and states that an annual increase of 7-8.5mm per annum is occurring.

The above Reviews suggest that the most profound effects of sea level rise will be experienced in low lying estuary areas. The report goes on to note however that uncertainties exist about the magnitude of future sea level rises and the potential threats of coastal flooding.

The report states:

> *"that the design levels of coastal flood protection structures should take into account the 'worse case' predictions…until such time when revised estimates of sea level rises and storminess might be forthcoming"*

Uncertainties therefore surround the combination of risks associated with tidal flooding. These combined risks are considered in the methodology section of the appendices.

Flooding of coastal land and property normally takes place when storm surges occur, although the largest surge effects can be expected to occur only infrequently. Nevertheless, the effects of combining sea level rise with estimated storm surge effects lead to most of the Scottish coastline up to 4 or 5m OD becoming vulnerable to low risk coastal flooding by the 2050's.

4.3 ADDITIONAL INFORMATION

The astronomical effects on still sea water levels around the Scottish coast are predictable. These tidal levels are calculated relative to Chart Datum (CD) and require to be corrected for direct comparison with Ordnance Datum (OD) levels.

Admiralty data or monitoring data is not available for Stranraer or the wider Loch Ryan area with the nearest gauged monitoring location available at Portpatrick approximately 9.5 kilometres to the south west. A second gauged monitoring location is available at Millport some 95 kilometres to the north of Stranraer.

At Portpatrick the Admiralty Chart Datum lies 1.80m below Ordnance Datum (OD).

4.4 ESTIMATION OF PEAK SEA LEVELS USING POL 112

4.4.1 Historical Sea Level Information

Information provided by Proudman Oceanographic Laboratory and the British Oceanographic Data Centre shows the maximum observed sea level value since July 1990, at the gauging station at Portpatrick, is 5.17m CD or 3.37m OD which occurred on the 1st February 2002. During this peak event a storm surge of 0.97m magnitude was calculated to have coincided with the high astronomical tide level. The gauging station at Millport recorded a peak sea level of 3.45m AOD on 5th January 1991 with a storm surge of 1.36m.

The largest storm surge noted at Portpatrick was 1.60m which correlated with an observed sea level of 0.75m AOD. At Millport the largest storm surge was 1.78m coinciding with an observed sea level of 1.29m AOD. This indicates that larger storm surges may be created at lower tidal values.

The historical flooding caused by tidal / storm surge effects in Stranraer are anecdotal and date from 1928 and 1938/39. During these events it is estimated that peak water levels were approximately 3.6m and 3.9m AOD respectively. Tidal monitoring did not commence in the region until the 1960s with the first being Portpatrick in 1968. It is therefore not possible to correlate these flooding events to known high tides and associated storm surges. It is however understood that the 1928 flooding event was the result of an exceptional tide coupled with a northerly storm.

4.4.2 Inferred Highest Astronomical Tide (HAT) Level

Under the Proudman Oceanographic Laboratory (POL) Internal Report 112 the nearest nodes to Stranraer are nodes 72 and 73 with an approximate distance ratio of 1 to 10 respectively.

As noted in POL IR72 tidal level measurements at Portpatrick gave results that were approximately 0.5m higher than if the IR112 method was used. A comparison between the IR72 and IR112 methods was carried out for Portpatrick which revealed that the IR112 methodology was some 0.25m below that of IR72. A uniform increase of 0.25m was therefore applied to the adopted Stranraer still water levels.

A summary of the estimated (adjusted) extreme water levels for nodes 72 and 73 and the inferred levels for Stranraer are provided in the table below. Full calculation sheets are enclosed within the appendix.

	Extreme Water Level for Stranraer			
	Return Period (years)	Node 72 (m AOD)	Stranraer (m AOD)	Node 73 (m AOD)
Estimated Sea Level adjusted to Ordnance Datum Newlyn	10	2.69	2.75	3.30
	25	2.83	2.90	3.49
	50	2.92	2.99	3.60
	100	3.06	3.13	3.79
	200	3.15	**3.23**	3.91
	250	3.20	3.28	3.98
	500	3.29	3.37	4.09
	1000	3.40	3.48	4.24
	10000	3.78	3.88	4.74

From the above table the POL 112 analysis indicates a HAT with a 1 in 200 year return period of 3.23m AOD for Stranraer.

4.5 ESTIMATION OF PEAK SEA LEVELS USING NEW SC060064 METHODOLOGY

The methodology outlined within the SC060064 project 'Coastal flood boundary conditions for UK mainland and islands' was used in the calculation of extreme sea levels at the site.

This methodology produces extreme sea levels at a 2km resolution around the coast of the UK. The method used to determine the return period of total sea level (astronomical tide and surge) is the skew surge joint probability method (SSJPM). Skew surge being the difference between the predicted astronomical high tide and the nearest observed high water

Under the SC060064 methodology the coverage of extreme sea levels extends to the boundary between estuaries and the open coast. Estuary values themselves are not provided under the methodology. The use of the methodology within the estuary area is not recommended with separate studies using the shape file data as downstream boundary conditions generally advised. Although Loch Ryan forms a sea loch with little significant river inflow when compared with the tidal movement the methodology coverage stops at the mouth of the loch. Whilst the use of the methodology will provide useful data, its limitations with respect to the Stranraer waterfront should be recognised.

The initial steps of the SC060064 provide an output for extreme sea levels with an additional allowance for uncertainty. It is important to note that these outputs comprise the sum of the astronomical tide and the surge value.

Information provided by project SC060064 at the mouth of Loch Ryan shows the 1 in 200 yr exceedance probability peak sea level to be 3.50m OD including the surge element and an allowance for uncertainty. Details of this calculation are provided in Table 5 in the appendix.

Additional information on the base astronomical tide and surge shape was not considered appropriate for the Stranraer waterfront at this time.

4.6 SEA LEVEL RISE

Estimates of sea level rise due to climatic change have changed in recent years. However, for the coastlines of Wigtownshire, Kirkcudbright and the Solway Firth the 'best estimate' was that levels would rise by between 145mm and 170mm. Adopting the 'worst case' 170mm scenario for Stranraer results in the maximum still sea level for a 200 year return period being in the order of 3.40m OD using the POL 112 methodology and 3.67m OD using the SC060064 methodology.

It is important to note however, that the increase in extreme tidal levels may not be the same as the increase in the mean sea level.

4.7 STORM SURGE

It is important to note that the outputs of the SC060064 methodology comprise the sum of the astronomical tide and the surge value. An additional surge value does however need to be added to the estimated peak water level using the POL 112 methodology.

Climate change/global warming is not anticipated to increase the severity of storm surges in the area, however surges will continue to be an important factor in producing extreme sea levels.

Collated information with respect to peak sea levels in the Stranraer area suggests that levels below 3.0m AOD may be affected by wave splash (RNLI station on Foreland Place during the last twenty five years). Anecdotal information from a number of older residents in the area suggests that Agnew Crescent and the level of 3.4m AOD has not been affected by high sea levels in living memory.

The location and orientation of Loch Ryan indicates that the loch is not at risk from the dominant wind direction and that storm surges are likely to be less extreme than those recorded at Portpatrick and Millport.

If the peak storm surge were aligned to the peak HAT water level this would lead to very conservative and costly design parameters, thus the adoption of the historical peak surge value of 1.6m noted at the Portpatrick gauging station is considered excessive for Stranraer. If the surge and HAT are independent then the design conditions would lead to either i) the peak surge outwith the peak tide or ii) a low or no surge with peak HAT level. Either of these outcomes would lead to a probable under design of defence works. The best estimate of the true situation lies between the extremes of dependence and independence.

Peak storm surges on the west of Scotland generally occur during storms from the western sector and, based on previous studies it is noted that, in general, only high tide levels are of interest when considering the effects of peak storms. Surges may persist for several hours but are unlikely to persist over two consecutive high water periods. Each high water can thus be regarded as an independent event and the duration of the peak conditions relate to the duration of the high water level: a period of some two hours duration over the high tide period.

Adopting a pragmatic view based on the historical data the storm surge value of 0.97m noted to have coincided with the high astronomical tide at Portpatrick on the 1st February 2002 provides a useful estimate when compared with the peak surge of 1.6m and is considered to be appropriate for the Stranraer waterfront. The figure of 0.97m is therefore added to the POL 112 estimate of 200 year return period extreme still sea level and a peak storm water level of 4.37m OD arrived at.

4.8 COMPARISON BETWEEN POL 112 AND THE SC060064 METHODOLOGIES

The POL 112 methodology provides an estimate of peak still water level of 3.23m OD excluding an effect of surge at Stranraer. With the addition of an estimate of surge to the POL 112 figure the above peak value rises to 4.37m OD.

The new SC060064 methodology provides an estimate of combined still water with surge of 3.5m OD at the mouth of Loch Ryan.

The POL 112 therefore provides, in this instance, a more conservative value for peak water level at Stranraer.

It is established above that the lower elements of the Stranraer waterfront have in living memory been subject to tidal flooding during storm events. The outputs from POL 112 with additional surge element provide a reasonable fit between the peak water level and the known peak water levels in Stranraer and it is concluded that the SC060064 methodology peak water level may represent an under estimation of surge for the waterfront at Stranraer.

Discussions with SEPA concerning the results of the two methodologies suggest that further refinement of SC060064 may be carried out in the future. The use of a single site analysis using gauged data was suggested however discussions with the Stranraer Harbour Master and the British Oceanographic Data Centre confirms that there is no relevant gauged data for Stranraer itself. Using gauged data from Portpatrick is considered appropriate for Stranraer when the influence and direction of the sea loch is taken into consideration.

In conclusion, it is considered prudent to apply a larger surge value for the southern part of Loch Ryan than has been considered necessary by SC060064 for the mouth of the loch. The peak water level (excluding any wave effect) of **4.37m OD** is therefore adopted for Stranraer.

4.9 WAVES

The Dumfries and Galloway Shoreline Management Plan Study: Stage 1 (June 2005) states that:

> *"Current research, does not predict any major change in the frequency of occurrence, or magnitude of storm surges (Werrity et al., 2002). This is linked with the difficulties of predicting future values of the North Atlantic Oscillation, i.e. the variation in the atmospheric pressure gradient between the "Azores High" and the "Iceland Low". Which is probably the major climatic factor in the occurrence of such surges around the UK coastline."*

Climate change/global warming is not anticipated to increase the severity of wave heights in the Stranraer area.

Loch Ryan is not exposed to the dominant westerly wind direction hence storm 'fetch' during the most aggressive storms is limited by the geography of the area.

The peak wave event, similar to the peak surge event, is linked to the occurrence of storms and, as described in Section 4.7 above, the best estimate of the likely peak wave situation lies between the extremes of dependence and independence of the storm event to the peak HAT water level. As above each high water can be regarded as an independent event and the duration of the peak conditions relate to the duration of the high water level: a period of some two hours duration over the high tide period.

HR Wallingford carried out a wave analysis for the southern part of Loch Ryan for the Stranraer West Pier and Harbour Area and Breakwater Design reports in January and September 2005 respectively. In these reports Wallingford concludes that generally the fastest wind speeds were in the 270^{o}N sector. The fastest long return period wind speeds are in the 300^{o}N sector where speeds of 36.5m/s are predicted for a 1 in 100 year return period. This information was found to translate to a wave height of 6.4m during a 1 in 100 year storm event. The length of Loch Ryan suggests that such waves would however not impact Stranraer directly.

With respect to locally generated waves within Loch Ryan the Wallingford modelling concluded that Stranraer is well sheltered against offshore waves and that local wave conditions are mostly due to wind waves generated within the short fetch of Loch Ryan itself. The Wallingford report modelled wave generation over a number of return periods between 0.02 years and 100 years. Longer term modelling including the 1 in 200 year event was not carried out. The Wallingford report concludes that at the Stranraer harbour entrance a peak wave height of 1.1m during a 1 in 100 year event may be adopted. Swell waves near the harbour entrance may be 0.29m high during the same probability event.

From the Wallingford report the difference between the 50 year and 100 year return period wave heights is modest with a variation of 0.1m at the harbour entrance and 0.01m within the harbour being estimated. It is concluded that the 200 year peak wave height will be similar to the 100 year event and that a reasonable estimate of 1.1m wave height outwith the harbour and 0.3m wave height within the harbour during a 1 in 200 year event may be adopted. Adding this potential wave height to the peak storm water level suggests a maximum water level of **5.47m AOD** outside the harbour and **4.67m AOD** within the harbour can be adopted in relation to the Stranraer area.

Due to the relatively long run up in the marina area and the presence of the harbour wall elsewhere storm waves are unlikely to impact the inshore part of the Stranraer waterfront with a great deal of force. Anecdotal evidence corroborates this conclusion and suggests that wave height will be small along Agnew Crescent should the Marina area become inundated.

With respect to wave heights along the Marina foreshore a brief examination of overtopping was carried out using the Eurotop Wave Overtopping methodology issued in August 2007. A shoreline profile comprising a composite slope with wall section was used and the empirical calculation method was adopted. Other methodologies covered by Eurotop do not conform to the shoreline profile (as is the case with the PC Overtopping calculation method) or are no longer supported (as with the Neural Network calculation tool). An outline description of this exercise and further consideration of the output results is provided in Section 5.3.1 below.

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

For new developments the acceptable risk of flooding should take into account various factors including risk to human health and the direct and indirect financial losses relating to flooding.

For the purposes of this report it is assumed that the ongoing Stranraer Flood Prevention Scheme will address the issue of flooding due to the local watercourses and that fluvial inundation or overland flow of surface waters will not present a risk to the shoreline area. The risk of a rise in groundwater leading to flooding is not considered to be significant.

A number of peak storm events have been assessed with respect to the site including the 0.5% probability (1 in 200 year) event using both the POL 112 and the SC060064 methodologies. The assessment includes astronomical peak tides, an appropriate uplift and consideration of potential global climate change over the next 50 to 75 years, storm surge and potential for high waves. The funnelling effect is not considered to be great within Loch Ryan due to its orientation.

It should be noted that, whilst an exceptional storm may continue for many hours the peak tide will not. The cumulative effect of tide, surge and wave is therefore limited in time. Furthermore, the distance of the existing shoreline from Agnew Crescent, Market Street and Harbour Street mitigates the risk of inundation during the time period of peak water.

The recommendations below attempt to take into consideration the risk of flooding to vulnerable groups and commercial activities within the proposed Masterplan development.

5.2 SUMMARY OF FLOOD RISK ASSESSMENT

The chief risk of flooding to the Stranraer harbour area arises from Loch Ryan during a peak storm and high tide event.

A comparison between the POL 112 and SC060064 methodologies has been carried out and indicates that, in this instance, POL 112 provides a more conservative value for peak water level at Stranraer. The outputs from POL 112 with additional surge element provide a reasonable fit between the peak water level and the known historic peak water levels in Stranraer and it is considered that the SC060064 methodology peak water level may represent an under estimation of surge for the waterfront at Stranraer.

It is considered prudent therefore to apply a larger surge value for the southern part of Loch Ryan than has been considered necessary by SC060064 for the mouth of the loch. A peak water level (excluding any wave effect) for the 1 in 200 year event of **4.37m OD** has been adopted for Stranraer.

Given the extensive nature of the Stranraer waterfront it is considered prudent to adopt a peak still water level for design purposes but to adopt coping mechanisms for developments that may be affected by storm waves.

A summary of the peak water levels adopted for Stranraer is provided below;

Adopted Sea Levels for Stranraer

	25 yr return period	50 yr return period	100 yr return period	200 yr return period
Highest Astronomical Tide Levels	2.90	2.99	3.13	3.23
Potential Sea Rise due to Climate Change	3.07	3.16	3.30	3.40
Additional Adopted Surge	4.04	4.13	4.27	4.37
Adopted Still Water Design Maximum	**4.04**	**4.13**	**4.27**	**4.37**
Adopted Wave Maximum in Harbour	4.34	4.43	4.57	4.67
Adopted Wave Maximum outwith Harbour	5.14	5.23	5.37	5.47

* all levels to Ordnance Datum (mOD)

It should be noted that the adoption of more extreme storm surge and wave values would result in higher design criteria (possibly in excess of 6m AOD for the 1 in 200 year event including waves). Available historical anecdotal information suggests that sea inundation in the Stranraer area is rare with historic instances in 1928 and 1938/39 where estimated water levels of approximately 3.6m and 3.9m AOD respectively were noted. Whilst these flood events cannot be correlated to recorded data it is likely that they resulted from a combination of extreme tide and storm surge resulting from a northerly gale.

The adoption of the pragmatic yet robust peak water levels provided above takes into consideration the statistical flood analysis, a comparison of the POL 112 and SC060064 methodologies, the available historic flood data and a general understanding of the local environment.

It should be noted that during such a peak event the wind speeds in the area are also likely to be high and that during extreme storms debris may be thrown ashore.

5.3 OUTLINE RECOMMENDATIONS & DISCUSSION

The proposed Masterplan anticipates a broad range of development opportunities along the shore front of Stranraer that will invigorate the town as well as to re-establish its link with the coast. As with all coastal developments the presence of the sea during extreme events should be taken into consideration and, in the case of Stranraer, the low lying nature of the sea front which lies at an approximate level of 3-3.5m AOD over much of its length. As a result, much of the flat-lying developed area along the shore front currently forms part of the functional flood plain according to the SPP risk framework.

In order to allow the Masterplan to proceed, consideration should be given to appropriate flood mitigation measures. Such measures may involve land raising, construction of flood bunds or the adoption of water resistant construction techniques.

The complete land raising or flood bunding of the Masterplan area could result in a loss of some 100,000m^3 of sea water storage. Given the nature and location of the Stranraer shore front, the fact that recorded flooding incidents are rare, the nature of Loch Ryan itself and the low incidence of high waves and aggressive surges, it is considered that a storage loss as a result of land raising will have no effect on the general coastal environment and no significant effect on the sea environment during a peak storm and tidal event. The cost and aesthetic implications of land raising or bunding are however considerable and for this reason other mitigation measures are considered in this report.

Outline appropriate mitigation and maintenance measures are considered for each development area below and presented as a summary in the appendix.

5.3.1 Marina

The marina development envisions a growth in the current capacity, new related facilities, boat storage, access to the West Pier and improved car parking.

No residential development is considered in this area and the assessed anticipated stakeholder sensitivity to sea level flooding is set out below

Receptors	Potential Effects	Sensitivity of Receptor
Commercial & Leisure Activities	Inundation of proposed buildings, detrimental effect on boats stored on land.	Low – Human Health Moderate – Financial Loss
Car Parking	Detrimental effect on cars within car park.	Low – Human Health Low – Financial Loss (most cars would not be in the car park during a peak storm event)
Existing Buildings	Possible inundation of homes, businesses and offices along Agnew Crescent.	High – Human Health Moderate – Financial Loss

Should peak water levels rise above the level of about 3.2m AOD water will inundate the western part of the Marina area from Agnew Park to the west. The risk to human health in the near shore area is currently low and no additional human health risk is being introduced as part of the Masterplan. As part of the overall Masterplan consideration may be given to the mitigation of flood risk to Agnew Park and the reduction of flooding risk to the existing properties along Agnew Crescent. The aesthetics of Agnew Park however, as well as cost considerations weigh against a general upfilling solution.

In consideration of the above it is recommended that a low wall be constructed from Foreland Place in the west to join the existing shorefront wall that extends from the West Pier. The overall aim of such a structure is to mitigate the risk of inundation during more frequent high water levels and to protect against general wave splash under lesser storm return periods. It is recommended that a wall crest height of 4m OD be adopted generally in line with a 1 in 25 year peak still water level.

Using the Eurotop Wave Overtopping methodology described in Section 4.3.5 it is estimated that under a 1 in 10 year peak still water level of 3.89m OD will not breach the proposed wall. Adding a 1 in 25 year storm with wind direction directly down Loch Ryan will however result in wave overtopping such that the peak water level throughout the Marina area will be in the order of 3.5m OD.

Under the design 1 in 25 year peak still water level the amount of overtopping is considerably increased such that the peak water level throughout the Marina is likely to be about 4m OD. The benefit of the wall structure will be to reduce the wave energy under such circumstances.

It should be noted that it is relatively unlikely that a peak storm with high wind speeds directly down Loch Ryan will coincide with a peak tide and it is considered that the above measures form a pragmatic solution to the identified risks for the limited commercial development of the Marina area.

The existing brick wall along the Breastworks is understood to be at a level in the order of 4m AOD and may be essentially retained. The flood defences between the marina area and the town extension area must be maintained at the same level whilst retaining access to and from the West Pier. It is recommended that a broad bund or mound (similar to traffic calming measures used elsewhere) be placed across the pier access on the seaward side of the current weighbridge. This bund would be some 0.5m in height and constructed to allow vehicular access to the pier whilst maintaining the flood protection measures. Such flood mitigation works may be carried out as part of Phase 1 of the Masterplan.

Enhanced protection within the Marina area by the use of water resistant construction techniques and raised electrical utilities should be considered. In addition, in order to manage the residual flood risk in the event of overtopping of the Marina sea wall, it is recommended that final floor levels be set at 4.0m OD or above. This may entail locally raised ground levels and result in a background risk of isolation should the Marina area become inundated. Appropriate management of staff and visitor movement during exceptional tides and storms is therefore recommended. Alternatively raised pedestrian walkways could be considered that link to the West Pier.

In addition, as part of the Masterplan, maintenance work will be required for the West Pier and elements of the Breastworks wall. The current sea barriers and checks on wave splash are however in a reasonable state of repair.

5.3.2 Town Extension

The Town Extension sees development of the existing car parks inshore of the Breastworks car park for residential as well as retail / hotel use. Further residential units are anticipated to the west together with an upgrading of the Scottish Water pumping station. An increased human health sensitivity is therefore anticipated together with the retention of key utilities in the area. The assessed anticipated stakeholder sensitivity to sea level flooding is set out below

Receptors	Potential Effects	Sensitivity of Receptor
Commercial & Leisure Activities	Inundation of proposed buildings including possible hotels.	Moderate – Human Health High – Financial Loss
New Residential Buildings	Inundation of proposed buildings.	High – Human Health High – Financial Loss
Car Parking	Detrimental effect on cars within car park.	Low – Human Health Low – Financial Loss (most cars would not be in the car park during a peak storm event)
Existing Buildings	Possible inundation of library, businesses and offices along Market Street and Harbour Street.	Low – Human Health Moderate – Financial Loss

Key elements in the assessment of this area with respect to existing flood risk include the two areas of elevated ground immediately to the west of Burns House and that occupied and to the west of the existing Scottish Water pumping station. These areas form islands should the water level reach 4m AOD. Secondly, the low lying area around the Town Burn outfall and western slipway currently allows potential high waters at a level of 3m AOD to enter the area of Market Street and inundate the vicinity of the Library.

The risk of high waves throughout this portion of the waterfront is considered to be low due to the protection of the harbour itself.

It is considered prudent however to continue the 4m AOD protection along the entire waterfront of the Town Extension. In addition the proposed residential and leisure / commercial development in the west should have enhanced protection with final floor levels at or above 4.37m AOD. This may entail locally raised ground levels. Risks however remain to these properties should they become isolated during high tides. The surrounding water may be some 0.8m deep. In order to allow egress from these residential units during a peak tide / storm consideration may therefore be given to raising the road level in lower Princes Street.

The topographically high area to the west of Burn House should be exploited for the proposed residential units so that final floor levels are above 4.37m AOD. Profiling of Harbour Street to allow assured ingress and egress to these areas is recommended.

The proposed Port Rodie Park lies on an existing topographic high. Such a development may be allowed an additional degree of flooding risk whilst allowing advantageous sightlines and access to the east pier. It is therefore recommended that this area be lowered and the adjacent housing and retail development to the east raised to provide a floor level of 4.47m AOD or above. A materials balance for the Town Extension as a whole is considered possible.

Being a key utility, the finished floor level of the Scottish Water pumping station should be placed at a height of 4.67m AOD or above. Other flood resilience measures may also be considered appropriate for this utility.

Further protection throughout the Town Extension by the use of water resistant construction techniques and raised electrical utilities should be considered. In addition, attention should be given to the layout of the ground floor residential units so that they comprise a lower and upper storey. Such measures will further mitigate the risk of harm from flooding.

Maintenance of the sea wall should be considered as part of the Masterplan, particularly with respect to the eastern end which has seen some minor collapses in the past.

5.3.3 East Pier

The development of the East Pier sees the establishment of a new street together with commercial / retail, leisure and residential facilities. The addition of a combined heat and power (CHP) unit, cultural centre and landmark building at the end of the main body of the pier will add a sense of place and attract visitors. It is assumed at this point that the CHP unit will form an important item of infrastructure in the area.

Given the fundamental change of use for the pier from ferry terminal to mixed use including residential there will be an increase in human health sensitivity. The assessed anticipated stakeholder sensitivity to sea level flooding is set out below

Receptors	Potential Effects	Sensitivity of Receptor
Commercial, Retail, Leisure & Cultural Activities	Inundation of proposed buildings including possible hotels.	Moderate – Human Health High – Financial Loss
New Residential Buildings	Inundation of proposed buildings.	High – Human Health High – Financial Loss
Existing Railtrack Buildings	Inundation of rail station area.	Low – Human Health Low – Financial Loss

The increased stakeholder sensitivity associated with the East Pier and it's generally exposed nature suggests that robust mitigation measures will be required for this area. Topographic levels in this area are not complete however the current railway track along the eastern edge of the East Pier lies at a level of approximately 3.5m AOD in the south rising to some 4.0m AOD at the northern end of the pier. The railway is however known to lie on an embankment in the southern part of the pier suggesting that the land level below the south of the East Pier area is at a level of about 3.3m rising to some 3.8m closer to the existing loading ramp.

Mitigation of the risk of flooding should be incorporated as part of the Masterplan in this area and consideration should be given to raising the land level throughout the development area of the East Pier to a level of approximately 4.37m AOD with finished floor levels being set at 4.67m AOD or above. Further protection by the use of water resistant construction techniques should be considered and as elsewhere the layout of the ground floor residential units should comprise a potential for lower and upper storey. Such measures will further mitigate the risk of harm from flooding.

Furthermore the eastern sea wall of the East Pier should be set at a level of 5.47m AOD in order to counter the bulk of the potential wave effects. The western sea wall may be set at a lower level thus retaining the desired sight lines for the Masterplan.

The Railtrack pier and Ross pier may remain at their current level.

Little urgent maintenance is anticipated for the western side of the East Pier including the Ross Pier, however, the north end of the Railtrack pier and associated eastern sea wall requires maintenance and should be considered as part of the Masterplan.

5.3.4 East Pier Gateway

The Gateway area will see considerable change from the current car park, ferry passenger terminal and lorry marshalling yard to residential accommodation in the east and commercial and retail in the west. A possible relocated railway station is also envisioned on the eastern edge of the pier.

An increase in human health sensitivity is anticipated and the assessed stakeholder sensitivity to sea level flooding is set out below

Receptors	Potential Effects	Sensitivity of Receptor
Commercial, Retail Activities	Inundation of proposed buildings.	Moderate – Human Health High – Financial Loss
New Residential Buildings	Inundation of proposed buildings.	High – Human Health High – Financial Loss
Proposed Railtrack Buildings	Inundation of rail station area.	Low – Human Health Low – Financial Loss

The increased stakeholder sensitivity suggests that mitigation measures will be required for the area. As with the East Pier, the ground levels are not complete in this area. Available information suggests that the ground level is between about 3m and 3.5m AOD and for the area as a whole to be at risk of inundation during a peak tide and storm.

Consideration should be given to raising the land level throughout the development area of the Gateway to a level of approximately 4.37m AOD with finished floor levels being set at 4.67m AOD or above. Further protection by the use of water resistant construction techniques should be considered and as elsewhere the layout of the ground floor residential units should comprise a potential for lower and upper storey.

Maintenance of the eastern sea wall should be considered as part of the Masterplan with the development setting the height of the sea wall at a level of 5.47m AOD in order to counter the bulk of the potential wave effects.

APPENDICES

5.4 ADDITIONAL COMMENTS

Consideration of the above recommendations and their place in the overall Masterplan should be carried out with the inclusion of interested regulatory and advisory bodies including SEPA.

Such discussions are recommended to take place at an early point in the development process for each element of the waterfront Masterplan.

Having recently been introduced, the application of the new DEFRA / EA SC060064 peak sea level estimation methodology is expected to mature and be refined over the coming years. At this point it is considered prudent to adopt a more onerous surge value for Stranraer than that utilised by the SC060064 methodology at the mouth of Loch Ryan.

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Terrenus CDH Ltd wishes to thank Dumfries and Galloway Council for the opportunity to prepare this report. We trust that the report meets with your requirements at this stage. However, should you wish to discuss the contents of the report then please contact the undersigned.

Signed for and on behalf of

Terrenus CDH Ltd

W. Hume	**S. Curran**
Director	**Director**

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STAKEHOLDER RISK ASSESSMENT SUMMARY

Summary of Stakeholder Flood Risk Assessment following Proposed Mitigation Measures

	Potential Flooding	Receptor(s)	Overall Sensitivity	Effect Before Mitigation		Mitigation	Residual Effect	
				Magnitude	Significance		Likelihood	Residual Significance
Marina	Still water inundation coupled with potential wave run up onto the Agnew Park area and thereafter to the east.	Commercial & Leisure Activities	Moderate	Substantial	**Moderate**	Raised sea wall to 4.0m AOD to reduce inundation during peak tide / storm. Protection from inundation along West Pier and at Breastworks.	Possible	**Minor**
		Car Parking	Low	Medium	**Minor**		Possible	**Insignificant**
		Existing Buildings	High	Slight (due to distance from shore front)	**Moderate**		Unlikely	**Insignificant**
Town Extension	Still water inundation around Town Burn coupled with low lying ground around Burn House and North Strand Street.	Commercial & Leisure Activities	High	Medium (within harbour area)	**Moderate**	Continuation of the 4m AOD protection along the entire waterfront of the Town Extension. Final floor levels for proposed residential and leisure / commercial development at or above 4.37m AOD.	Unlikely (within harbour area)	**Insignificant**
		New Residential Buildings	High	Medium (within harbour area)	**Moderate**			**Insignificant**
		Car Parking	Low	Medium (within harbour area)	**Minor**			**Insignificant**
		Existing Buildings	Moderate	Medium (due to distance from shore front)	**Moderate**			**Insignificant**

	Potential Flooding	Receptor(s)	Overall Sensitivity	Effect Before Mitigation		Mitigation	Residual Effect	
				Magnitude	Significance		Likelihood	Residual Significance
East Pier	Still water inundation coupled with potential wave effect on eastern side of pier.	Commercial, Retail, Leisure & Cultural Activities	High	Substantial (due to exposed location)	**Major**	Raising land level throughout the development area of the East Pier to 4.37m AOD with finished floor levels being set at 4.67m AOD. Extension to eastern sea wall to a level of 5.47m AOD.	Unlikely	**Minor**
		New Residential Buildings	High	Substantial (due to exposed location)	**Major**			**Minor**
		Existing Railtrack Buildings	Low	Substantial (due to exposed location)	**Minor**			**Insignificant**
East Pier Gateway	Still water inundation coupled with potential wave effect on eastern side of pier. Possible inundation from west and low lying shore walkway.	Commercial, Retail Activities	High	Substantial (due to exposed location)	**Major**	Raising land level throughout the development area of the East Pier to 4.37m AOD with finished floor levels being set at 4.67m AOD. Extension to eastern sea wall to a level of 5.47m AOD.	Unlikely	**Minor**
		New Residential Buildings	High	Medium (due to distance from eastern shore front)	**Moderate**			**Insignificant**
		Proposed Railtrack Buildings	Low	Substantial (due to exposed location)	**Minor**			**Insignificant**

Stakeholder Risk Assessment Summary Background

A brief risk Matrix was carried out as part of the Flood Risk Assessment. The matrix below illustrates the significance of unmitigated effects:

	Sensitivity		
Magnitude	**High**	**Moderate**	**Low**
Substantial	Major	Moderate	Minor
Medium	Moderate	Moderate	Minor
Slight	Moderate	Minor	Insignificant
Negligible	Insignificant	Insignificant	Insignificant

The residual significance after the Masterplan development and implementation of mitigation measures is a function of the unmitigated significance combined with the likelihood of an event occurring with mitigation in place. The table below outlines this methodology. In line with the precautionary principle all significant unmitigated risks are assessed as being likely to occur.

	Likelihood		
Unmitigated Significance	**Likely**	**Possible**	**Unlikely**
Major	Major	Moderate	Minor
Moderate	Moderate	Minor	Insignificant
Minor	Minor	Insignificant	Insignificant
Insignificant	Insignificant	Insignificant	Insignificant

The conclusions in the Summary table state whether residual significance is categorised as being major, moderate, minor or insignificant, once appropriate mitigation has been implemented. This assessment relies on professional judgment to ensure that the effects are appropriately assessed. Effects of moderate or major significance (as shaded above) are considered to be of significant concern.