DESIGN – TECHNICAL NOTE

JBA Project Code	2014s1358
Contract	Isle of Man Sea Defence Options
Client	Department of Infrastructure, Isle of Man Government
Day, Date and Time	26/08/2014
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Subject	Castletown Harbour – Option CH1 - Raised Harbour Walls

Project Title: Isle of Man Sea Defence Options			Sheet No: 1
Subject: Castletown Harbour – Option CH1 - Raised Harbour Walls			Calc No:
Job No: 2014s1358			Version:1.0
Developed By: Alec Dane	Date: 26/08/2014	Revised By: Alec Dane	Date: 11/09/2014
Checked By: Graham Kenn	Date: 11/09/2014	Approved By: Graham Kenn	Date: 27/11/14

1 Aim

JBA have been commissioned by the Department of Infrastructure (DoI) to develop a number of technically viable solutions to address the still water level flooding in harbour environments and wave overtopping in open coast environments, at seven coastal sites across the Isle of Man.

This technical note covers the design assumptions, decision making process and methodology for the concept design of Option CH1, an option to raise the existing harbour walls in Castletown to prevent still water level flooding. Still Water Level (SWL) flooding occurs where the water level exceeds the defence crest level and water inundates the hinterland. No consideration for the design of performance against wave overtopping has been undertaken as the environment is considered to be suitably sheltered from wave action.

The scope of works does not include a formal options appraisal process. However a high level Multi Criteria Analysis will be undertaken with input from key stakeholders to help determine which option best satisfies the project criteria. The option proposed has been developed based on technical feasibility, engineering judgement, environmental impact, cost and consideration of the long term vision and key criteria determined by the project stakeholders.

2 Assumptions

The following assumptions have been used during the development of the concept design.

2.1 Datum

All elevation and depth measurements presented in the conceptual design of defence options will be presented in Douglas02 datum.

2.2 Baseline conditions

The land surrounding Castletown Harbour is at risk of still water level flooding. In order to design an option that efficiently reduces still water level flood risk, it is important to look at the baseline conditions.

2.2.1 Existing defence geometry

The existing defences reflect a typical inner harbour environment. Quay walls situated at ground level throughout the harbour provide access to boat users while offering some level of protection against still water level flooding.

During the winter storms of 2013/2014, the water level exceeded the quay walls in the main harbour fronting brewery wharf and flooded residential and commercial property around. Hope Street to the west of the harbour flooded especially badly, due to its low lying topography. In addition, Mill Race drains to the East of Hope Street which backs up during a storm event and spills its bank to flood the hinterland.

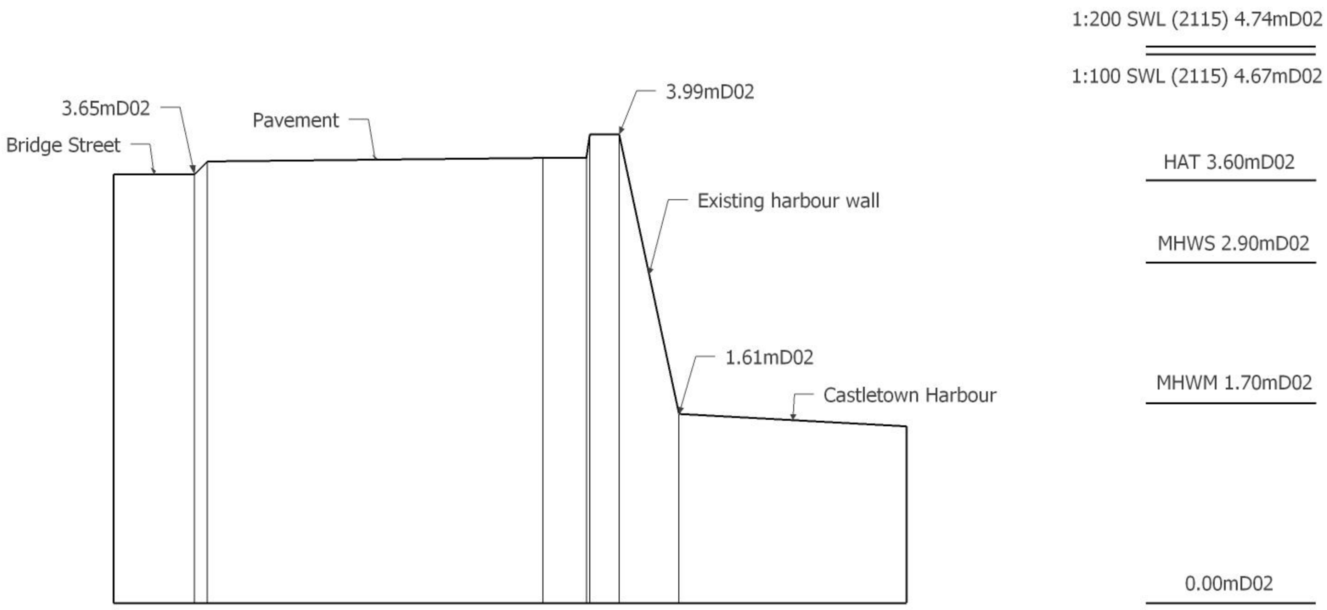

Figure 2-1: Existing section through Castletown Harbour

The existing defence geometry has been summarised in the table below:

Attribute	Dimension
Quay wall crest level	3.5 - 4mD02
Quay wall toe level	~1.5mD02
Quay wall height	2-2.5m

Table 2-1: Existing defence geometry summary

2.2.2 Current still water level flood risk

Based on the predicted extreme water levels from the Environment Agency Coastal flood boundary conditions for UK mainland and islands project[1], the existing defences are offering a 1 in 10-year level of protection under the present day scenario and less than a 1 in 1-year level of protection against still water level flooding in 2115 (including the effects of climate change).

2.3 Design life and level of protection

The structure has been designed to achieve the following design standards:

- **Design life**: 100 years
- **Design storm event:** 1 in 200-year event

2.4 Climate change

By selecting a design life of 100 years, it is important to factor in the predicted effects of climate change.

Within UKCP09 estimates for sea level rise are provided under low, medium and high emissions scenarios. Within the three scenarios the estimate is further refined by 5th, 50th and 95th percentile confidence ratings. In simple terms this should be interpreted as the relative likelihood of the projected change being at, or less than, the given change. For this study it is proposed that the medium emissions scenario is considered and

[1] Coastal flood boundary conditions for UK mainland and islands, Project: SC060064/TR2: Design sea-levels. Environment Agency, Feb 2011.

that the 95th percentile confidence rating is used. This gives a projected sea level rise of 650mm by the year 2115 for Castletown.

2.5 Hydrodynamic data

The hydrodynamic data, used to design the harbour defences to a 1 in 200-year standard of protection in 2115, has been sourced from the Environment Agency Coastal flood boundary conditions for UK mainland and islands project[2], which developed a consistent set of design sea levels for Scotland, England and Wales.

The extraction point used for this project is located at Port Erin. Other ports located around the Isle of Man have used the JBA Coastal flood boundary data model, to interpolate the values around the Isle of Man, based on Port Erin extreme water levels. Table 2.2 provides the estimate for high water extremes in Castletown, including sea level rise for the year 2115.

Table 2-2: Extreme Sea Levels in Castletown

Return Period (year)	mD02	Extreme Still Water Level in Castletown
1	2014	3.48
2		3.57
5		3.68
10		3.76
20		3.84
25		3.87
50		3.95
75		3.99
100		4.02
150		4.06
200		4.09
250		4.11
300		4.13
500		4.18
1,000		4.25
10,000		4.44
1	2115	4.12
2		4.21
5		4.33
10		4.41
20		4.49
25		4.52
50		4.60
75		4.64
100		4.67
150		4.71
200		4.74
250		4.76
300		4.78
500		4.83
1,000		4.90
10,000		5.09

2.6 Performance standards

For coastal defences, the performance standards can typically be split into two areas, the still water level performance and wave overtopping performance.

2.6.1 Performance standard 1 – still water level flood risk

The structure will be designed to prevent still water level flooding from the design storm event (1 in 200-

[2] Coastal flood boundary conditions for UK mainland and islands, Project: SC060064/TR2: Design sea-levels. Environment Agency, Feb 2011.

year storm) in 2115 (including an allowance for climate change). The structure crest will therefore be designed at this level plus an additional freeboard allowance (150mm for hard defences).

2.6.2 Performance standard 2 – wave overtopping risk

Due to the enclosed nature of Castletown Harbour, it is assumed that the quay walls are subject to minimal wave overtopping. Therefore, this option will not be designed to meet any wave overtopping performance standard.

2.7 Ground conditions

No geotechnical or ground condition information has been made available as part of this study. Therefore, all designs of defence structures have been progressed assuming poor ground conditions e.g. low bearing capacity. This should provide a conservative approach to the development of the concept design. The levels presented in the drawings represent finished defence levels, so would require consideration of potential settlement which would be taken into account during detailed design.

2.8 Structural design

A full structural design has not been included within this study as the scope of works did not include geotechnical investigation or analysis. All designs have been reviewed by a structural engineer to confirm that the design principles adopted are acceptable.

2.9 Existing defences

This option seeks to raise the flood defence crest level on top of the existing line of defence. This provides a technical risk, whereby the overall design life of the structure will be dictated by the current condition of the asset and the estimated residual life, rather than that of the newly designed defence. In these circumstances, the design will not conform to the target design life of 100 years.

For the purpose of progressing the concept design option, it is assumed that the existing quay wall will be maintained to preserve and improve the current condition of the asset for the length of the 100 year design life of the newly proposed superstructure.

2.10 Fluvial flood risk

The analysis of the fluvial flood risk has not been included as part of this commission. The defence option proposed does not seek to reduce the fluvial flood risk to a given performance standard.

2.11 Services information

No detailed services information was provided as part of this study and a services search is not included within the scope of works. However, the location of more critical services has been identified by DoI. These critical services were considered in the development of the concept design options. If the project progresses to outline and detailed design it will be essential that a full service plan is developed.

2.12 Environmental Impact

This commission does not include any formal Environmental Impact Assessment or Landscape Visual Impact Assessment. If the project progresses to outline and detailed design, a more in depth study of the environmental impacts will be required.

2.13 Reinstatement and finish details

The development of landscape and architectural enhancements are outside the current project scope of works. It is assumed that following construction the surrounding area will be re-instated to a condition similar to the present. However, during the detailed design stage further architectural and landscape enhancements could be considered.

2.14 Contaminated land

No information regarding the location of areas of contaminated land has been provided as part of this commission. Therefore all design options have been developed with the assumption that none of the areas are subject to contaminated land constraints. An invasive contaminated land survey should be undertaken at all locations prior to detailed design to enable detailed assessment of suitable construction techniques and options for removal or re-use of excavated material.

To progress concept design options as part of this study the following have been assumed:

- No investigation of contamination issues at individual development sites; and
- Development flood defence options may require some contaminated land treatment depending on the result of the investigations.

2.15 Tie in details

Tie-in details between old and new defences have been considered at a conceptual level. The key consideration has been to develop an option that does not create an area of outflanking or weak point, where flood water can bypass the defences and flood the hinterland. Careful consideration of the joint between the existing and new defences will be required during the detailed design phase.

3 Standards, guidance & reference documents

All design assumptions have been developed using the following reference material:

- BS 6180 1999: Barriers in and about buildings, code of practice
- BS EN 6349-1-1:2013, Maritime works, General, Code of practise for planning and design.
- CIRIA (2010), The use of concrete in maritime engineering – a guide to good practise
- Cobb, F (2009), Structural Engineers Pocket Book (2nd Edition)
- DEFRA (2009) UK Climate Projections 09
- Environment Agency. (2010). Fluvial Design Guide.

4 Design development

The following provides a brief summary of how the key design elements were selected.

4.1 General form of defence

The raised harbour walls have been designed as reinforced concrete cantilever retaining walls:

- to offer a 1 in 200-year standard of protection against still water level flooding (including climate change);
- to increase the defence freeboard on the existing line of defence; and
- to reduce the total land take from the harbour community.

Due to the unknown condition of the existing harbour walls, it is assumed that the structures are in poor condition. This means that tying the superstructure onto the quay walls will not be a suitable option to connect the new and old wall. Instead it is assumed that the wall will be placed on top of the existing defences and achieve its stability against sliding and overturning through a cantilever and base key.

4.1.1 Defence crest level

The defence crest level is situated at 4.90mD02. This has been calculated using:

- 1 in 200-year still water level in 100 years time (including the effects of climate change) – 4.75mD02
- Freeboard allowance for hard defences – 150mm.

4.1.2 Wall height and foundation cover

To aid in the constructability of the defence, a shallow foundation is proposed. This specifies a minimum cover of 300mm from the top of the foundation to ground level. This gives the wall a total height of 1700mm. The wall height above ground level is equal to 1000mm which is in compliance with BS 6180 for the minimum height of concrete barriers and handrails for horizontal guarding (1100mm).

The foundation cover is to be made of suitably compacted fill topped with a paved surface to be in keeping with the existing landscaping design.

4.1.3 Wall thickness and reinforcement cover

The wall thickness has been defined, allowing for 200mm wide reinforcement cage with a minimum 50mm concrete cover. This allows for a wall thickness of minimum 300mm.

4.1.4 Base slab dimensions

The cantilever base slab has been designed at a conceptual level to provide stability to the wall. This has been achieved through using rules of thumb (Cobb, 2009), considered acceptable for the structural design of concept walls:

- Base slab width 1H (for wall with no toe protrusion) = 1700mm
- Base slab thickness = stem thickness = 300mm

This design option does not provide allowance for a toe projection, due to the requirements to place the wall on the existing line of defence.

4.1.5 Structure reinforcement

The proposed new concrete wall will have a nominal 200mm wide steel reinforcement cage, this should be considered in more detail during the detailed design phase. The structural design of the proposed raised wall is beyond the scope of this study.

4.1.6 Concrete mix design

The concrete mix design should consider a number of factors, firstly issues associated with the heat of hydration and thermal cracking as detailed above should be investigated. Secondly, the type of exposure that the concrete is subjected to and it's resistance to the ingress of chlorides which will cause corrosion to any reinforced elements must be assessed. The properties of the concrete for the raised harbour walls are suggested below based on guidance from EN 206-1:2000:

- **Density**: A typical concrete density of 2.4t/m^3
- **Grade**: C40/C50
- **Exposure class**: XS3 for concrete in a tidal, splash and spray zone
- **Aggregate diameter**: 20-40mm selected in accordance with EN 12620:2002
- **Workability**: Slump class S2 (50-90mm)

However, this specification will be subject to modification during refinement in detailed design.

4.2 Placing the superstructure on top of the existing quay wall

The cantilever wall specifies a 300mm foundation cover to the rear of the wall. To bed the wall below the existing ground levels, the structure will require the excavation of 600mm from the existing levels (300mm cover plus 300mm base slab depth). The quay wall will therefore need to be trimmed by ~600mm to allow placement of the superstructure on top. This provides a technical risk and would require careful consideration should this option be taken forward to detailed design.

4.3 Maintaining hydraulic impermeability

It is essential that the flow path between the old and new defences is cut off to prevent water infiltrating under the new defence. It is assumed that the use of a 300mm deep shear key will increase the flow path to such an extent that the infiltration of water under the new defence will be minimal. This will need to be considered in more detail during detailed design to ensure water cannot bypass the defence. The use of an expansion joint, grouted between the old and new defences may prove to be a viable option to eliminate the flow path.

4.4 Culvert relief at Mill Race

Mill race is culverted as it drains under the southern extent of Back Hope Street. Currently there is no outlet control that prevents tidal waters from flooding up Mill Race, backing up the river water and overtopping its banks at Hope Street. This design specifies a culvert relief to prevent return flow up Mill Race, through the use of a penstock or flap valve system. Here a chamber has been created just north of the culvert with flap valves fitted on the outer edge. A trash screen, access platform and access hatch have been fitted to the flap valve chamber to ensure that the gates can be maintained safely.

The culvert relief has been designed at a conceptual level to indicate a solution to prevent tidal water from inundating Hope Street. However, no analysis of the impacts of fitting these flap valves will have on the fluvial flood risk. It is likely that this constriction may back up water travelling down Mill Race which could increase fluvial flood risk. This should be explored more during detailed design.

4.5 Drainage

The design does not provide additional open drainage through the new structure, due to the need to provide a still water flood protection. If the existing highway drainage is insufficient to drain any surface water in the hinterland, flap valve drainage could be installed through the new raised wall.

4.6 Wall cladding

Additional cladding may be incorporated into the visible wall faces to keep the defences in-keeping with the surrounding environment. The use of different forms of cladding and capping kerbs will be explored in more detail during detailed design.

4.7 Tie in details

It is anticipated that the defences will tie in with the infrastructure so as to avoid creating a point of weakness. Where access is considered critical, demountable defences will be required to ensure the defence level is maintained while allowing normal usage during normal conditions.

4.8 Architectural enhancements

The new walls provide the opportunity to re-develop the harbour area, with more architectural enhancements, creating a more visually pleasing environment. This has not been considered during concept design, but the new walls could incorporate additional seating, material textures and forms, plant boxes and trees that could improve the current landscape.

4.9 Public safety

Public safety has formed a key consideration during the concept design development phase. The main risks associated with this option are the issues surrounding the future public usage of the structure. In providing a physical barrier between the public and the harbour, the risk of injury from accidents is reduced. However, the possibility for the public to climb onto and over the structure has been increased which poses a significant health and safety issue. The wall is situated at 1100mm above the promenade deck level which complies with the recommended guidance for minimum barrier height for horizontal guarding. However, the use of signage should be considered to warn members of the public of the risks associated with climbing on the quay wall.

In addition, the public should be discouraged from accessing the penstock through use of barrier fencing and signage. For further information on all the risks considered, mitigated or reduced please refer to the Designers Hazard Inventory.

5 Technical risks summary

The following are considered to represent the key risks highlighted during the development of this concept design.

5.1 Unknown ground conditions

Due to the unknown ground conditions it is possible that the current design will require modification in order to achieve structural and geotechnical stability.

5.2 Integrity of the quay walls

The wall has been designed to sit on top of the trimmed quay walls. Due to the unknown integrity of the existing walls, a conservative assumption has been taken which states that the wall will achieve structural stability from its mass and form and act independently from the existing walls. This eliminates the risks associated with tying the superstructure onto the quay wall.

Nevertheless, the integrity of the existing quay walls represents a technical risk during construction. Care should be taken to minimise plant movements on the existing walls and limit excavations directly behind the wall.

In addition, the 100 year design life of the flood defence is dependent on the structural integrity of the quay walls. This design assumes that the quay walls will not be allowed to deteriorate further as this may undermine the newly proposed superstructure. It is recommended that a full asset inspection be undertaken prior to detailed design, to quantify the residual life of the structure and allow for the development of more tailored remediation measures.

5.2.1 Trimming quay walls

To found the wall below the existing ground levels, the design specifies removal of the top 600mm of the existing quay walls. If the wall is in a poor condition, this may not be a viable solution. The feasibility of this design and construction method should be explored in more detail during detailed design, where advice from a competent contractor would be beneficial.

5.3 Tie-ins with existing defence

It is essential that the design level is maintained throughout the harbour to prevent the development of a low point where water can bypass the defences. The tie-ins have been considered at a conceptual level but will require careful consideration during detailed design.

5.4 Maintaining hydraulic impermeability

Currently no flow path investigation has been completed to determine the potential route of water levels that exceed the connection between the new and old defences. For the purposes of progressing the concept option, it is assumed that the shear key will extend the flow path to such an extent that water ingress is considered to be minimal. The use of expansion joints and waterbars may provide a sufficient solution to mitigate this risk.

5.5 Fluvial flood risk

No analysis of the impacts of this scheme on fluvial flood risk has been undertaken as part of this study. By adding a flap valves to the culvert at Mill Race, the fluvial flood risk may be increased. This should be explored in more detail during detailed design.

5.6 Access for mariners

Ladders are located throughout the harbour to allow mariners to access their boats. These ladders will become redundant by placing an additional raised wall on the quayside. To maintain access there are three possibilities. Their advantages and disadvantages are discussed in Table 5-1. Should this option be taken forward, the best method to facilitate public access to the harbour should be explored in more detail during the detailed design phase.

Table 5-1: Possibilities to maintain public access to the harbour

Option	Advantages	Disadvantages
Place gaps in the wall with fittings for demountable barriers	- No increase in health and safety risk	- Technical risks associated with demountables and short design life - Performance of wall is reliant on demountables being deployed manually - Likely to be a costly solution
Place ladders over new wall	- Cheap - Maintains continuous line of defence preventing still water level flooding	- Greatly increase health and safety risk associated with using the ladders
Place concrete platforms at strategic locations to allow users to access ladders at ground level	- No increase in health and safety risk - Maintains continuous line of defence preventing still water level flooding	- Expensive - Concrete platform would have a significant footprint which may require the number of ladder access points to be reduced

5.7 Services

No services information has been provided as part of this study. If the project progresses to outline and detailed design it will be essential that a full service plan is developed.

5.8 Construction accessibility

Prior to the development of outline designs it would be advisable to appoint a construction contractor to provide constructability advice. Although the site is considered reasonably accessible it would be beneficial to confirm the proposed methods of construction and temporary works required.

5.9 Stakeholder requirements

A Multi Criteria Analysis was completed as part of this study to try and determine the key considerations of the project stakeholders. It is anticipated that during the course of a formal options appraisal project stage that more in depth stakeholder consultation will be completed. The results of which may lead to changes in the concept designs that have already been developed.

5.10 Environmental Impacts

No formal Environmental Impact Assessment was completed during this project stage. It is anticipated that during the course of an options appraisal stage that an in depth assessment of the environmental impacts associated with all proposed options would be considered. This process may result in changes being made to the proposed designs.