Cork City Tidal Barrier

Cost estimate

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Executive Summary

A flood relief scheme proposed for the City of Cork includes flood protection walls and embankments along the quays in the city. An alternative scheme has been proposed consisting of a tidal flood barrier for tidal flood risk and the use of existing reservoirs and catchment measures for fluvial flood risk. This report provides a cost estimate for a tidal barrier which is the largest cost element of the alternative scheme.

When considering costs for any project it is first necessary to examine whether it is a reasonable solution. A tidal barrier for Cork City will provide tidal flood protection for the city without the need to provide and maintain flood defences in the urban area of Cork. This will avoid the disruption that construction of the walls would cause and also avoid the impacts that walls would have on the city landscape. In addition a tidal barrier will protect more area of the city of Cork and more infrastructure from tidal flooding as it includes significant areas to the east of the walls proposal.

The other major source of flooding in the city is fluvial flooding from the River Lee. The walls and embankments of the flood relief scheme are also intended to provide protection against this type of flooding. The alternative scheme proposes using existing reservoirs to manage fluvial flood risk, together with a possible new reservoir and natural flood management measures in the catchment.

The proposed tidal barrier is located about 10 km downstream of the City of Cork. The proposed barrier structure is about 950m long and would consist of an embankment with a 60 m wide navigation opening and a number of smaller gates. The cost estimate is based on costs of tidal barriers around the world together with a high level estimate of quantities of construction materials and cost rates.

The estimated cost of the barrier at 2017 prices is **€140 Million.**

The main cost elements are the gates and the embankment, but the costs also include environmental mitigation measures and public amenity facilities. Further study will be needed to develop the design for a barrier and refine the cost estimates.

Cover photograph: Vertical axis radial gates on the St Petersburg storm surge barrier. Photograph taken by Peter Hunter, HR Wallingford.

Contents

1. Introduction

1.1. Background

1.1.1. Flooding in the City of Cork

A large part of the City of Cork lies in the floodplain of the River Lee. Flooding can occur from tidal inundation, fluvial (river) flows and combinations of the two. Tidal flooding occurs relatively frequently in Cork. Fluvial flooding is less frequent but can be more severe. The opportunity exists to alleviate fluvial flooding through the management of the two existing reservoirs upstream of the city impounded by the Inniscarra and Carrigadrohid dams.

1.1.2. The proposed flood relief scheme

A flood relief scheme has been developed for the city consisting of flood walls, embankments and pumping stations that would support higher water levels in the river channels of the city. The River Lee divides into two channels through the city: the North and South channels. Each of these channels is nearly 4 km long, giving a total length of river frontage of about 15 km, and there are over 20 river bridges. In addition, there are developed areas in the floodplains where the River Lee flows in a single channel upstream and downstream of the city. It is understood that the flood relief scheme will provide protection for the North and South channels and the River Lee upstream of Cork but will not include the areas east of the city centre containing the Docklands and Tivoli Docks.

1.1.3. The alternative scheme including a tidal barrier

The organisation Save Cork City has proposed an alternative flood alleviation scheme that does not require wall construction in the city. The proposed scheme is presented in their document “Potential Cork” and consists of:

1. A tidal barrier downriver of Cork, to prevent tidal inundation;
2. Utilising the existing hydro-electric dams and reservoirs to store fluvial flood water;
3. Slowing the flow of the River Lee catchment over time using ‘natural flood management’ measures to reduce fluvial flooding and improve water quality.

The Save Cork City solution also proposes repair of the historic quaysides and walls to conserve the landscape of the historic city.

A tidal barrier achieves the objective of preventing tidal flooding in the city including the Docklands and Tivoli areas to the east of the city centre. Measures to slow the flow in the River Lee catchment may only make a relatively small contribution to reducing a major fluvial flood because the volume of flood water would exceed the volume that could be retained. The effects of catchment management can however increase over time and can have significant benefits for water quality, soil quality and the environment.

The use of the two existing reservoirs upstream of Cork, impounded by the Inniscarra and Carrigadrohid dams respectively, could provide the required fluvial flood alleviation for the City. Following the major fluvial flood of 2009, it was shown in a court case that the reservoirs could store the flood volume and therefore provide flood mitigation for Cork. The purpose of the dams and reservoirs is to generate hydroelectricity and their use for fluvial flood alleviation is a matter for the Government of Ireland and the dam operators (the Electricity Supply Board) to consider. There is already a degree of management of the dams to provide flood alleviation. It is also understood that a proposal exists for additional water storage in a reservoir at Dromcarra. The use of these dams could be supplemented by the proposed catchment measures over time.

1.2. Purpose of the report

One of the most important issues affecting the Save Cork City solution is cost: the tidal barrier is a major item of infrastructure and early estimates of the cost suggest that it will be more expensive than the proposed flood alleviation scheme. Initial estimates by Save Cork City suggest that this might not be the case and that the cost of the flood walls could be greater. HR Wallingford was asked to provide an independent cost estimate for the tidal barrier and this report contains the requested cost estimate.

2. The proposed tidal barrier

2.1. Location and area protected

The proposed location of the barrier is on the River Lee at the south end of Lough Mahon, about 10 km downstream of the centre of Cork stretching between Little Island and Horse Head. The location in relation to the City of Cork is shown on Figure 2.1 (photograph taken at high tide) and the location is shown in greater detail in Figure 2.2 (photograph taken at low tide).

The area protected from tidal flooding covers the whole of the floodplain in Cork including industrial and commercial areas downstream of the city.

2.2. Outline design

The proposed barrier is about 950 m long and would consist of an embankment with a 60 m wide navigation opening. The proposed gates consist of vertical-axis sector gates for the navigation opening together with a number of smaller gated openings. Appendix A contains a brief summary of some of the main barrier gate types, and the proposed vertical-axis sector gates are considered to be a suitable choice for this location.

The smaller gates will allow discharge of fluvial flow as well as maintaining water quality by providing adequate water circulation without creating local areas of stagnation. These are not for navigation and are likely to be vertical lifting gates. The concrete structures are a major cost for these types of gates and it is suggested that the number of gate structures is as small as possible. The cost estimate includes three gate structures, each with two 15 m wide gates. All of the gates would be closed when necessary to provide protection against storm surges penetrating up the estuary.

Whilst it will not be possible to cross the estuary at the barrier, the sections of embankment north-east and south-west of the navigation opening provide an opportunity to provide access and facilities for the public, and provision of public access can be expected to be a key feature of the design that could attract significant numbers of visitors. There is an opportunity for environmental and landscape enhancement which, combined with good design, could give the barrier a unique character that could become a symbol for the city.

Figure 2.1: Location of the proposed barrier

Source: Google Earth

Figure 2.2: Proposed barrier at low tide

Source: "Potential Cork" by the Save Cork City Group

3. Requirements

This section briefly reviews some of the main requirements and considerations in the development of the tidal barrier design.

3.1. Concept

Options available for tidal flood mitigation include a tidal barrier, which is open under normal conditions, and a tidal barrage, which prevents tidal flows upstream. A tidal barrier is the preferred choice for Cork because the present tidal regime is maintained and the impacts on navigation, drainage, morphology, saline intrusion, water quality, fish passage and the environment are minimised by a barrier.

3.2. Area to be protected

The location of the barrier has been proposed by the Client as it is still within relatively shallow water and provides water storage in Lough Mahon for fluvial flows during barrier closures. It also provides protection to the City of Cork including the industrial and commercial areas east of the city centre.

3.3. Flood mitigation

The impact of the barrier on flooding would be as follows:

- The barrier will exclude storm surges and will therefore reduce flood risk from tidal flooding;
- The barrier will allow for the storage of fluvial water from upstream during surge tide events when the barrier is closed;
- The barrier will permit free discharge of fluvial flows to avoid increasing fluvial flood risk;
- The barrier will not worsen groundwater flooding, or damage by wave action, although these are expected to be minor considerations;

It is proposed that the method of operating the barrier will include closure at low tide during tidal flooding events in order to create a reservoir where fluvial flows could be stored during the high tide periods.

3.4. Navigation

The barrier should provide adequate provision for navigation taking account of periods when the barrier will be closed. This includes:

- Opening width that can accommodate the required size of vessels and volume of shipping, both now and in the future;
- Sufficient depth for shipping, both now and in the future;
- Acceptable navigation conditions taking account of approaches to the barrier, currents and wind effects;
- It is assumed that no restriction on air draught (headroom) will be permitted, both to accommodate large sailing craft including Tall Ships, and to avoid the visual intrusion of tall gate structures.

A high level analysis of the sizes of ships that will pass through the barrier based on the water depths and port facilities upstream indicates that the maximum beam of vessels might be up to 20 m. A 60 m opening is considered reasonable but this aspect would be considered in more detail during the detailed design.

3.5. Environment

The barrier should minimise adverse environmental impacts and, if possible, provide environmental enhancement. This includes:

- No adverse impacts on water circulation when the barrier is open;
- No adverse impacts on fish passage when the barrier is open;
- Mitigation of any potential sediment, water quality, ecology and other environmental impacts, particularly during periods when the barrier is closed.

Whilst these issues must be considered in the final design, no particular problems have been identified at this preliminary stage. Care will be needed undertaking works which are in the vicinity of Natura 2000 designated sites, indicated on Figure 3.1 (from the Natura 2000 website).

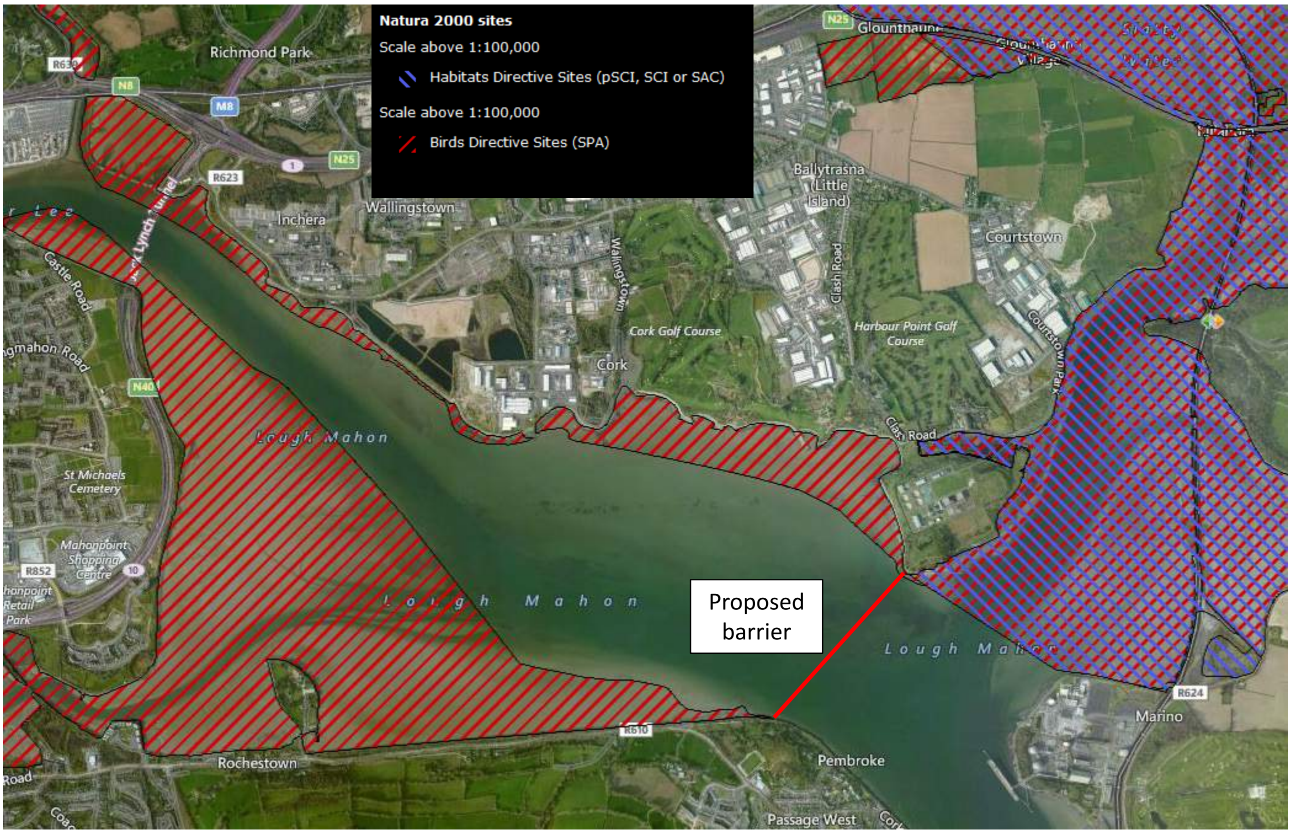

Figure 3.1: Natura 2000 sites near the proposed barrier

Source: http://natura2000.eea.europa.eu/#

There is however an opportunity to provide environmental enhancement, for example by using dredged material to enhance the intertidal habitat or creating enhancements on or adjacent to the embankment as part of the construction work.

3.6. Legislation

The barriers shall comply with national and international legislation including consents and approvals that would be needed.

3.7. City planning

The barrier should be integrated into city planning so that future development is not impeded and opportunities are taken to maximise potential benefits. This includes:

- Integration with development and other plans;
- Innovative appearance and landscaping;
- Provision of public access and amenity including water based recreation if appropriate;
- Minimising adverse impacts on existing culture and heritage sites;
- Potential integration with and facility of other functions, for example:
  - Urban regeneration;
  - Development of existing waterfronts;
  - Port development (commercial, fisheries, marinas) at or upriver of the barrier.

3.8. Design

The barrier will be designed to achieve specified design criteria, including:

- Surge tide design standard (e.g. the estimated 0.1% annual probability surge tide, sometimes referred to as the 1 in 1,000-year return period surge tide);
- Futureproof design with a long term design life (120 years used for bridges);
- Adaptability requirements for future change including the climate change scenarios to be used for adaptation planning.

The design of the barrier should also take account of the following requirements:

- Failsafe design including an assessment of the probability and impacts of failure;
- Operating procedures that are safe and minimise ‘false alarms’, where the barrier is closed unnecessarily;
- Optimised whole-life costs taking into consideration construction costs, operating and maintenance costs, and reliability and safety.

3.9. Construction

The construction of the barrier should minimise adverse impacts. Issues to consider include:

- Maintenance of safe navigation;
- Site access routes;
- Sources, extraction and transport of construction materials;
- Use of floating or land-based plant;
- Use of prefabricated or float-in elements;
- Noise and vibration;
- Dust;
- Construction traffic;
- Labour accommodation and transport;

- Water and air pollution;
- Effects of dredging and reclamation;
- Construction waste management.

3.10. Maintenance

The design of the barrier should facilitate maintenance operations to ensure continuous satisfactory operation at reasonable cost. This includes:

- Maintaining adequate reliability including provision of back-up systems for gate operation, power supplies and other systems;
- Regular testing of all gates;
- Regular testing of all flood management procedures including full closure of the barrier.

3.11. Future adaptation

As the sea level rises and the barrier has to be closed more frequently, the point may be reached when sea locks are preferred to maintain navigation when the barrier is closed, and ultimately a barrage may be needed (which would exclude the tide). This is a long-term consideration but should be taken into account at the design stage so that the design allows for simple future adaptation measures if and when required.

4. Tidal Barrier Costs

4.1. Method of calculation

There is no doubt that a barrier could be built at the proposed location. Such a barrier would be a substantial civil engineering project, although no larger than numbers of existing projects built elsewhere in recent decades.

A cost estimate has been prepared based on the costs of various comparable barriers and barrages elsewhere for which HR Wallingford already has relevant data. In addition, a high level estimate has been made using estimated quantities of construction materials and cost rates

The main factors affecting the costs of tidal barrier projects are:

- Type of barrier;
- Gated openings (number and dimensions);
- Barrier length (from shore to shore);
- Water depth;
- Foundation conditions;
- Height of barrier;
- Hydraulic head difference;
- Wave climate;
- Availability and cost of human resources;
- Availability of construction materials.

Of these, the most important factors are the number and dimensions of the gated openings to be provided for navigation and water circulation, and the total length of the barrier from shore to shore.

The cost estimate is based on the outline design described in Section 2.2. Various types of gate could be provided: vertical-axis sector gates for the navigation channel and vertical lifting gates for the smaller openings are proposed. These must provide adequate capacity to handle total tidal and fluvial flows.

Figure 4.1 shows an example of sector gates combined with sluice gates. The Cork tidal barrier would be a low level structure where the lifting gates would not rise above the crest level of the embankment. These gates are not navigation openings and a low level profile would be achieved by dividing each gate into two overlapping segments. Further information on gate types is given in Appendix A.

Figure 4.1: Example of sector gates and sluice gates (New Orleans)

Consultation and study is necessary to confirm the required width of the navigation opening and its orientation, which should be along the line of the navigation channel. Geotechnical investigations are also required.

Local water circulation and its impact on siltation and on water quality need to be assessed to determine the number and location of the additional smaller sluice gates. It has been assumed for the purposes of this cost estimate that there will be three sets of sluice gates, each with two 15 m wide gates.

Reliability of the selected designs is essential, not only to enable the gates to be closed whenever necessary but also to ensure that the gates can always be reopened after closure to avoid trapping fluvial flows.

4.2. Cost estimate

Analysis by HR Wallingford of the costs of existing major storm surge barriers worldwide, particularly those on which we have first-hand experience as well as others where published data is available, has shown that barrier costs can be approximately estimated on the basis of total length of gated openings plus total length of embankment, with an accuracy of about +/- 20%. A first-order review of the estimate has then been made by considering in broad terms the sizes of the main structures and gates. On this basis the barrier described in this report is estimated to cost €140 Million (Table 4.1) at 2017 prices.

Uncertainty in the estimate means that the estimated cost could range from €110 Million and the lower end of the range to €170 Million at the higher end (i.e. +/- 20%). The price of €140 million contains a contingency of about €30 million.

In addition to the use of cost data from existing barriers and barrages, costs have been estimated using approximate quantities and rates. In addition, the following percentages have been used in reaching the €140million estimate:

- Mobilisation and de-mobilisation: 10% of the construction cost;
- Construction contingencies: 30% of the construction cost including mobilisation and de-mobilisation;
- Employer's costs: 15% of the overall construction cost including contingencies.

These figures are particularly sensitive to the dimensions of the gates, and reductions to gate requirements would change the range of costs given above. Further examination is needed to confirm the dimensions and numbers of gated openings for water flows and navigation, which can be followed by preparation of an outline design. As the design is developed there will be less uncertainty and a more defined cost estimate may then be prepared.

The cost estimate does not include operation and maintenance costs. UNCTAD Guidelines for port planning suggest that maintenance costs of civil structures can be 1% of capital cost per annum. The Cardiff Bay Barrage has an annual operating cost of about €2.4 Million (2014-15), but this is a much more complex structure with three locks and a complex fish pass as well as sluice gates that are permanently operating. Costs used for planning on the Thames estuary in the UK include about €900,000 per year for operation, maintenance, repairs and refurbishment of each of the tidal barriers on tributaries of the tidal Thames. These structures are generally smaller than the proposed Cork structure with navigation openings of 30 to 40 m and shorter embankments.

It is suggested that an allowance of €1 Million per year is made for operation and maintenance costs. Thus the cost of operation and maintenance for the first 25 years would be €25 Million

Costs may vary based on local economic conditions such as:

- Construction cost indices;
- Exchange rates;
- Costs of environmental mitigation works;
- Uncertainties regarding future costs of steel, concrete, fuel, and other construction materials and operations.

Table 4.1: Cost estimate for a tidal barrier for Cork

1	**Sector Gates (60 m navigation channel)**		
	Dredging (removal and disposal of soft materials)		
	Foundation works		
	Concrete Structures		
	Gates (two vertical-axis sector gates, plus docking chamber gates)	€	48,000,000
2	**Sluice Gates (three complexes, each comprising two 15 m wide gates)**		
	Dredging (removal and disposal of soft materials)		
	Foundation works		
	Concrete		
	Gates (three sets of two lifting sluice gates)	€	11,000,000
3	**Embankment (900 m length)**		
	Dredging (removal and disposal of soft materials)		
	Earthworks (Embankment fill and armour including marine placing)	€	23,000,000
4	**Mitigation measures and enhancements**		
	Environmental mitigation and enhancement measures; public access and amenity	€	3,000,000
5	**Mobilisation and De-Mobilisation**	€	9,000,000
	Sub-total	€	94,000,000
6	**Contingencies** (unpriced items and price variations)	€	28,000,000
	SUB-TOTAL (Construction Costs)	**€**	**122,000,000**
7	**Employer's costs:** Planning; consents & approvals, design, engineering, procurement, supervision and management	€	18,000,000
	TOTAL	**€**	**140,000,000**
	It is also estimated that the cost of operation and maintenance will be about €25 Million for the first 25 years to give a total of **€165 Million** including 25 years of operation and maintenance		

5. Conclusions

1. A flood relief scheme is planned for Cork consisting of flood protection walls and banks.
2. An alternative scheme has been proposed consisting of a tidal barrier to prevent flooding from surge tides in conjunction with additional measures to reduce the fluvial flood risk.
3. The alternative scheme has the major benefit of not requiring the construction of walls along the quays in the city, thus helping to maintain the historic landscape of the city and avoiding the disruption that the construction of walls would cause. The alternative scheme would also avoid the scenario of overtopping or failure of flood walls in the city, which could cause a serious risk to life as well as damage to the city.
4. The estimated cost of a tidal barrier is €140 Million at 2017 prices.

Appendix

A. Barrier gate types

A.1. Introduction

Gate selection for storm surge barriers is a critical issue having a major effect on the performance, reliability and whole life costs of a project. The following sections describe the key properties of alternative types of gate that can be used in barriers and barrages. Suggestions for the most suitable gate types for Cork are given in Section A.14.

A.2. Vertical-axis sector gates

Vertical-axis sector gates are circular sections with a buoyant skin plate on the circumference of the circular arc, and with hinges on a vertical axis. Because the hydraulic thrust is directed radially towards the hinge there is little or no unbalanced load and they can therefore withstand a head difference in either direction and be opened and closed with differential head across the gate.

Vertical axis sector gates have the following features:

- Can open with head of water on either side of gate;
- Can close while there are water flows through the opening;
- Low operating forces;
- No headroom constraint;
- Not vulnerable to siltation problems.

A disadvantage of vertical-axis radial gates is that deep recesses are required to house the open gates. This may not be feasible for all installations and locations.

A.3. Vertical-axis radial gates

Vertical-axis radial gates are similar to the sector gates described in the previous section, but are defined as being without a buoyant skin plate on the circumference of the circular arc. They are generally used only for small openings such as in navigation locks up to about 10 m width.

A.4. Flap gates

Flap gates lie on the channel bed and are hinged along the upstream edge of the gates. They are lifted to stop flow, usually using hydraulic cylinders jacking against a concrete sill structure. The flaps are usually flat or with a curved ‘fish-belly’ cross section. Widths can range from multiple narrow ‘wicket’ gates less than 3m wide, up to widths of about 30m, or even up to 60 or 90m in sheltered locations with low head differences.

Flap gates are rarely used for barriers and barrages, primarily because of the difficulties of inspecting and maintaining gates stored underwater, as well as their perceived vulnerability to siltation. However a significant advantage is that they do not create a height limit above the waterway.

A.5. Buoyant flap gates

A particular form of flap gate is being used for the Venice Flood Protection Barrier, currently approaching completion. These gates are supported entirely by their own buoyancy, and lifting and retracting are controlled by adjusting the amount of buoyancy in the gates using compressed air.

An important advantage of this type of gate is that side piers are not required, so that navigation openings of any width can be obtained by installing a number of gates. One disadvantage is storage of the gates underwater when not in use, which makes maintenance more difficult. This also increases their vulnerability to siltation problems. Another disadvantage is that the limited experience to date indicates that buoyant flap gates are a costly solution.

A.6. Rising sector gates

Horizontal axis sector gates are normally circular sections hinged on the low water level side with skin plates on two sides (the circumference and the upper radius). In overshot conditions the upper skin plate of the gate can form an overflow surface. The whole sector can be lifted to allow undershot flow, with maximum flow when the gate is clear above the water. The gate is dropped into a pit below river bed level when the gate is open. Rising sector gates are used on the Thames Barrier where they are used to close navigation channels of 61m width. They are also used on the Ems Barrier in Germany.

A.7. Vertical lift gates

Vertical lift gates have vertical leaves that are raised and lowered vertically. They can either be single leaf, or double leaf to permit both undershot and overshot flows. This arrangement allows precise control of water levels and discharges but is typically used only for relatively small gates on barrages. Other arrangements include storing them underwater to be raised for closure, or storing at high level to be lowered to close flow. This type of gate has been used for navigation openings up to 100 m wide. Vertical lift gates are commonly used for the smaller gates on tidal barriers.

A.8. Swing gates

A swing gate is typically a rectangular tank that is stored on one side of a channel and is hinged about a vertical axis at one end (similar to one of a pair of mitre gates). In the closed position it is retained by abutments on each side of the channel. It is closed in advance of a forecast flood, by winching or towing, and cannot be closed in flowing water. The gate can be buoyant to reduce forces on the hinges.

A.9. Visor gates

Visor gates are arch gates that span across a channel. They have horizontal-axis hinges at each abutment and are rotated upwards for storage, forming an arch across the channel. Navigation through the gates is possible when they are open, but with a headroom constraint.

A.10. Radial (Tainter) gates

A Radial or Tainter gate has a cylindrical skin plate mounted on an open structural steel frame supported by arms at each side of the gate. The arms extend to trunnion bearings forming a horizontal hinge axis. Radial gates may have the bearings either upstream or downstream, and the gates can be stored underwater in pits below the river bed level, or raised above the water. They can be used purely as flow control gates but can also be used on navigation channels (if stored below the river bed level), although with a typical width limitation of about 50 m.

A.11. Inflatable weirs

These have been developed primarily as small control structures on rivers, and the largest example acts as a storm surge barrier on a river east of the Ijsselmeer in the Netherlands (the Ramspol Barrier). The durability and robustness of such structures is likely to be less than conventional steel gates, although the installation at Ramspol has a guaranteed life of 25 years and might achieve 40 years before replacement is needed.

Although this type of gate appears suitable where relatively small head differences are likely, a further factor is likely to be the need to avoid ultra-violet degradation of the inflatable membrane. At Ramspol the dam is stored underwater, and it is exposed to sunlight only when in use.

A.12. Mitre gates

Mitre gates can withstand a head difference from one direction only, and if their normal function is to retain upstream water (e.g. in rivers or impounded docks) they are therefore unsuitable for use in flood protection barriers. Mitre gates can be provided when their sole function is resisting storm surges, such as the flood barrier on the River Colne at Wivenhoe, Essex. Mitre gates can only be operated (opened or closed) when water levels are equal on both sides of the gate, and when current velocities are zero (or very low). They are also limited in size and for channels or locks more than 35m wide they are unlikely to be the preferred solution.

A.13. Rolling gates

Rolling gates (also known as wheelbarrow gates) are used in the widest locks in the world (e.g. in Antwerp and Ijmuiden, and the new Panama Third Lane Locks) and have proven reliability for large sea locks. This type of rectangular gate rolls across the lock to close it, and is then withdrawn into its gate recess to open the lock. Such gates are partly buoyant and supported by a submerged trolley on the leading edge and an above-water trolley on the aft end. They can withstand a head difference in either direction, and can be designed to have resistance to collisions from ships.

Maintenance of the whole gate is possible in dry conditions with the gate in its dewatered gate recess. Provision of gates in pairs at each end of a lock provides redundancy in respect of maintenance or accidental damage.

One variation of a rolling gate is a Sliding Gate. This is similar to a rolling gate except that instead of wheels, it travels on sliding bearings (typically water-lubricated ‘hover’ bearings).

A.14. Gate options for Cork

The gate types that are considered to be most suitable for Cork are:

- Vertical-Axis Sector Gates (similar to the New Orleans and St Petersburg barriers);
- Rising sector gates (similar to the Thames Barrier);
- Vertical lift gates (but visually restrictive for navigation openings).

The vertical-axis sector gate is considered to be a suitable option for the navigation opening at Cork. Vertical sluice gates would be suitable for the smaller gates.

Report authors

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	David Ramsbottom is a Technical Director at HR Wallingford. He has 40 years' experience in water engineering and management since graduating from Cambridge University in 1975. He has experience of tidal flood barriers and barrages including the technical development of the Thames Estuary 2100 (TE2100) Plan, which includes improvements to existing barriers and new barriers. He also has experience of catchment flood management planning including the use of reservoirs for flood control and nature flood management measures.
	Peter Hunter has forty years' experience as a civil engineer responsible for planning, design and supervision of port, maritime and coastal engineering projects in the United Kingdom and throughout the world. He was the project manager for planning, design and construction supervision of the Cardiff Bay Barrage and is the Lender's Supervisor for a group of European banks for the $3 billion St Petersburg Flood Defence Barrier, overseeing all aspects of design and construction. This has included a study of the resilience of the Barrier to future climate change impacts.

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