# A Tidal Sill at West Bay

## Phase I: Feasibility Desk Study

## Prepared for West Dorset District Council

Interim Report EX 4063
August 1999

HR Wallingford

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## Contract

This report describes the work commissioned by West Dorset District Council whose representative was Mr Keith Cole, Engineering Manager. Funding for this project was provided by the South-West of England Rural Development Agency, whose representative was Mr Simon Cronk. The HR Wallingford job number was CFR 2658. The report was written by Mr Chris Pyne. The HR Wallingford Project Manager was Eur Ing Paul Sayers.

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# Summary

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A new harbour layout has been proposed at West Bay, Dorset. HR Wallingford has been commissioned by West Dorset District Council (WDDC) to undertake a series of desk, numerical and physical model studies to understand the behaviour of the existing harbour and coast defences and optimise the layout and design of any modifications. As part of these studies HR Wallingford was commissioned by WDDC to undertake an investigation into the feasibility of preventing the harbour basin at West Bay from drying out in areas at low tide by the provision of a half-tide sill (or other device) in the approach channel linking the inner harbour basin to the sea.

It is not feasible to construct a fixed sill at West Bay. A gate however could be constructed without significant impact on wave disturbance or navigation. Sector gates are preferred. These could also incorporate a walkway to facilitate circumnavigation of the Inner Harbour by foot. Such gates could also act as a storm surge barrier.

The gate arrangements considered worthy of further study are identified as:

- Sector gates (preffered)
- Single leaf vertically hinged gate
- Single leaf flap gate

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# 1. INTRODUCTION

## 1.1 Background

A new harbour layout has been proposed at West Bay, Dorset. HR Wallingford has been commissioned by West Dorset District Council (WDDC) to undertake a series of desk, numerical and physical model studies to understand the behaviour of the existing harbour and coast defences and optimise the layout and design of any modifications. As part of these studies HR Wallingford was commissioned by WDDC to undertake an investigation into the feasibility of preventing the harbour basin at West Bay from drying out in some areas at low tide by the provision of a half-tide sill (or other device) in the approach channel linking the inner harbour basin to the sea.

## 1.2 Terms of Reference

The Terms of Reference for the study are set out in a letter from HR Wallingford to WDDC on 16 July 1999 and can be summarised as follows:

- **Location:** Review the possible locations of the sill.
- **Type:** Review different types of sill and construction methods.
- **Impoundment level:** Review optimum sill crest level based on draft and dredge requirements.
- **Operational issues:** Review impact on navigation, access time, maintenance requirements and impact on siltation.
- **Wave disturbance:** Review likely impact on wave disturbance in combination with physical model tests.
- **Visual impact:** Comment on the change in appearance of the inner and outer harbour.

## 1.3 Outline of report

Following this brief introductory chapter, Chapter 2 outlines the design parameters, Chapter 3 provides a discussion of the operating options, Chapter 4 assesses in detail the various gate options. Chapter 5 provides an initial discussion of the likely impact on harbour dredging and siltation. Chapter 6 refers impact on navigation. Chapter 7 the likely increase in wave disturbance in the outer basin. Chapters 8 and 9 access visual impact and pedestrian access respectively. Conclusions are then drawn in Chapter 10.

# 2. DESIGN PARAMETERS

## 2.1 Water levels

Tide levels for Bridport Harbour have been derived from the Admiralty Tide Tables, Bridport being a secondary port of the standard port of Devonport. Extreme event surge levels in the English Channel are as reported by HR Wallingford under Task 2.3 "Joint Probability of Waves and Water Levels". Thus:-

| | |
|---|---|
| 1 in 200 year level | +3.14m OD |
| 1 in 100 year level | +3.08m |
| MHWST | +1.85m |
| MHWNT | +0.75m |
| MLWNT | -0.65m |
| MLWST | -1.65m |

Intermediate tide levels over both Spring and Neap Tides are indicated in Figure 1.

## 2.2 Wave heights

Data from specific physical model tests undertaken by HR Wallingford (1999), provided the necessary results to identify a significant wave height in the area of a sill and/or gate of 1.0m for a return period of 100 years.

## 2.3 Design vessel

The maximum size of vessel using the basin is identified as:-

| | |
|---|---|
| Length | 13.0m |
| Beam | 4.5m |
| Draught | 1.6 to 2.0m |

Under keel clearances (UKC) of 0.3m and 0.5m over the sill and in the basin are considered to be appropriate giving minimum water depth requirements of:-

| | |
|---|---|
| At the sill | 2.3m |
| In the basin | 2.5m (if the largest vessel is to remain afloat at all times) |

# 3. OPERATING OPTIONS

## 3.1 Sill only option

Ideally a sill should give a reasonable period of access over the top of each tide whilst preventing any part of the basin from drying out and if possible allowing all craft in the basin to remain afloat at all times. However, the small tidal range at West Bay makes this almost impossible to achieve using a fixed sill. The range of only 3.5m on Spring Tides compares with 10-12m in harbours in the Channel Islands where such features are in use. Below three sill level sitting options are considered with the following characteristics:-

| Option | 1 | 2 | 3 |
|---|---|---|---|
| Sill level | -0.25m OD | -0.5m | -0.75m |
| Lowest tide level for access over sill | +2.05m | +1.8m | +1.55m |
| Basin dredge level | -2.75m | -3.0m | -3.25m |

Option 1 would not allow access at all, even at the top of a Spring Tide, and Options 2 and 3 only allow access for ½ and 2½ hours respectively on Spring Tides. Neither Option 1, 2 or 3 would allow any access on Neap Tides. If we regard 3.0 hours access over the top of a Neap Tide as the minimum acceptable operating condition, then the lowest tide level during that period would be +0.6m OD (see Figure 1) and thus a sill level of -1.70m OD would be required. This level, however, is lower than that of MLWST and thus the sill would not impound water and would serve no purpose.

It will, therefore, be necessary to provide a gate system if reasonable access is to be maintained whilst at the same time drying out of the inner basin is to be avoided at low tide.

## 3.2 Wall-gate option

If a minimum access period of 3 hours on Neap Tides is still kept as the minimum acceptable access time then, by setting the sill level at -1.70m OD access to the basin is possible whenever the tide level is at +0.6mOD or above. In order to maintain water levels in the inner basin a gate or gates would be required and would have to be closed when the tide falls below +0.6mOD.

Thus the following operating conditions apply (see also Figure 1).

| | |
|---|---|
| Access time per Neap Tide | 3.0 hours |
| Access time per Spring Tide | 7.0 hours |
| Minimum water depth in basin dredged to -1.90m OD | 2.5m |

The gate(s) could also be closed at times of high surge levels in the English Channel to prevent the basin walls from being overtopped, subject to this factor being taken into account in the design of the gate.

The minimum width of the approach channel to the inner basin will be 17.5m wide at the seaward end (after cutting back and re-modelling of the existing west pier) widening to approximately 32m wide. In order to minimise the amount of construction it is advantageous to site the wall and gate as close as possible to the outer end of the channel. As the beam of the design vessel is 4.5m we consider that a clear opening at the gate of 10m will be sufficient given the protection afforded by the new West Pier and hence the low wave disturbance (subject to traffic being one-way only). This arrangement is shown in outline in Figure 3.

The exact form of the civil engineering works will vary depending on the type of gate used (see Section 4 below). All gates will require a vertical wall across the full width of the channel with a central 10m wide navigation opening. We envisage this wall extending from a level of approximately –7.0mOD up to the top of the channel walls, i.e. a nominal level of +4.0mOD. The lower 5m of the wall would be formed of steel sheet piling to provide a cut-off wall to reduce seepage under the gate from the reinforced concrete. With the exception of a vertically hinged single leaf gate all the types of gate considered will require a concrete invert to the channel incorporating sills against which the lower edges of the gates can form a watertight seal or recesses into which horizontally hinged gates can be retracted to open the navigation channel.

# 4. GATES

## 4.1 General

Gates for locks, flood protection and general impounding purposes take a great variety of forms. The following types have been considered for West Bay:

(a) Gates hinged on a vertical axis

- pairs of mitre gates
- pairs of sector gates
- single leaf gate

(b) Gates hinged on a horizontal axis

- radial tainter gate
- single leaf flap gate

## 4.2 Mitre gates

Mitre gates comprising twin leaves are symmetrical with respect to the centre-line of the channel and rotate on a vertical axis (see Figure 4). When closed both leaves point upstream and carry hydrostatic loading on the upstream side by acting structurally as a horizontal 3 - pin arch. A seal is made along the vertical edges of the gates by their being in intimate contact with the quoins formed in wall and along the bottom edges bearing against a sill formed in the floor of the channel. When open gates are retracted clear of the navigation channel general using rams and linkage mechanisms. These can be driven by small, compact electro-hydraulic power packs.

For small gates such as those required at West Bay construction can be of marine hardwood as well as the more generally used welded steel.

Because of their basic method of structural behaviour mitre gates are not well suited to loading from the downstream side. Various devices can be employed to prevent gates from swinging open completely but it is usually not possible to maintain a degree of sealing which is, or approaching a perfect seal, i.e. "drop tight".

## 4.3 Pairs of sector gates

Sector gates with a vertical axis of rotation have been used successfully for small locks in yacht marinas and for some larger scale applications such as the entrance to the Royal Seaforth Dock, Liverpool. Each gate is in the form of a vertical stiffened steel plate forming an arc of a circle in plan. Radial arms link the gate of trunnion hinges as shown in Figure 5.

The gates seal along their vertical edges against suitable sealing faces built into the side walls and against curved sills formed in a concrete floor to the channel. Sector gates need suitable recesses to house them when they are retracted into the open position. If used at West Bay they would have to be used at a location where the channel width was approximately 22-23m i.e. inland by approximately 12m from the mouth of the channel. These gates have more complex steel fabrication than plane faced gates but have the considerable advantage of being able to resist loading on either their convex or concave faces. Operation as with mitre gates can be by hydraulic rams and linkage mechanism.

## 4.4 Single leaf gate

A vertically hinged single leaf fate (see Figure 6) has considerable advantages over mitre gates and generally operates as the same way as a vertically hinged door in a building. The civil engineering works required are probably the simplest of all the gate options and involve a vertical wall with the vertical and horizontal edges of the gate opening suitably treated to form a true plane surface against which the gate could seal. As with the mitre gates opening and closing would be by a hydraulically powered ram and linkage mechanism. A suitable locking device will be required to prevent the gate unseating under storm conditions. This could possibly take the form of manually operated vertical steel bolt pins.

## 4.5 Radial tainter gate

A horizontally hinged radial tainter gate is essentially one leaf of a sector gate rotated through $90^0$ on to its side. As shown in Figure 6 such a gate seals against the sill and side walls. Into both of these are built machined stainless steel plates against which bear flexible rubber seals attached to the gate itself.

To open the gate it is lowered into a recess built into the floor of the channel. Raising and lowering can be by cables and winches, electrically synchronised winches being required on both sides of the channel.

Such a gate is ideal for loading from either the upstream or downstream side but has the disadvantage of requiring a deep pocket (approx 5m) in the channel bed into which it can be lowered for opening. Apart from construction costs there is the operational problem that such a pocket will almost certainly act as a silt trap and require in-built air jetting or other arrangements to enable silt removal to be carried out.

## 4.6 Single leaf flap gate

A single leaf flap gate hinged about a horizontal access along its bottom edge is shown in Figure 8. Such a gate would be very simple to fabricate and when open would be housed in a recess in the channel floor. The recess would not require to be much more than 1.0m deep and thus would have much less serious siltation problems than a tainter gate. Raising and lowering could be by either:-

(i) winches and cables
(ii) hydraulic rams and linkage mechanisms

As with the tainter gate they would be required on both sides of the channel, again powered by electrically synchronised motors. Alternatively a ballast tank could be built into the upstream top edge of the gate which would:

- be flooded to allow the gate to sink to its closed position
- emptied by blowing-out with compressed air to allow the buoyancy tone to raise the gate to its upright position.

The buoyancy tank system is simple and requires only a small compressor on the side wall and armoured hose to the gate. Such operating systems have been used successfully on large dock gates (e.g. No. 4 Dry-dock, Malta). However it would need additional mechanisms to prevent the gate unseating under storm surge conditions whereas the winch or hydraulic ram systems could provided this faculty automatically.

## 4.7 Construction of civil engineering works

All the gate systems involve the construction of all or some of the following in some form:-

- creation of a impermeable wall on the harbour side of the Dolos blocks
- a steel sheet pile cut-off wall to minimise seepage under the gate
- a concrete floor and/or recess in the bed of the channel
- a wall across the channel with an opening for the gate
- side walls incorporating sealing faces for gates
- low level gate hinges.

Sealing faces both horizontal and vertical have to be constructed of stainless steel or high quality pre-cast concrete units set to a very high degree of accuracy using micrometers or laser based positioning systems. Gate hinges need to be positioned to mechanical engineering tolerances. This work will therefore have to be carried out in the dry within a cofferdam in two stages, closing off half the channel at a time in order to maintain access to the basin.

The cofferdams could be of a simple rectangular arrangement of steel sheet-piling, which, because of the low hydrostatic heads to be resisted, would not require internal propping, leaving a clear internal working space. Economy of construction could be achieved by leaving the lower end of the cofferdam sheet-piling in the ground to form the permanent works anti-seepage cut-off wall.

## 4.8 Stepping of gates

After completion of the civil engineering works, including the installation of gate hinges, and removal of the cofferdam, stepping i.e. installation, of the gates could be carried out in the wet. Because of the size of the gates they could be stepping using land based mobile cranes of modest capacity. There would be no requirement for heavy duty floating cranes or shear-legs.

## 4.9 Comparison of gate options

In comparing gate options account must be taken of two particular factors over and above the normal hydrostatic head on the upstream face of the gates viz:

(i) Gates have to be able to resist a reverse hydrostatic head when there are high surge water levels in the English Channel and the gates are closed to prevent overtopping of the walls of the basin.

(ii) Hydraulic model tests have shown that overtopping of the proposed new west breakwater under severe storm conditions leads to large volumes of water being deposited in the outer basin. The attendant increase in water level generates a head difference between the outer and inner basins thus generating a flow through the approach channel into the inner basin. After a short period the build up of water level in the inner basin then generates an outflow back to the outer basin; flow velocities can be as high as 2m/sec i.e. 4 knots.

We consider that under the above conditions mitre gates will not give good overall performance and should be ruled out of further consideration.

Sector gates are suitable for resisting head on either face and can also be opened or closed against a flow of water.

Single leaf vertical hinged gates are most suited to narrow but very high left locks for small craft or barges where the height of the gate is, say, twice it's width. However such a gate doe offer an option with the simplest civil engineering works but will require a suitable locking system to avoid being unseated under reverse head conditions.

A radial tainter gate would perform well under all conditions and like a sector gate can be opened or closed against a flow. However the deep pocket required to house the opened gate will be difficult to keep clear of silt and require the most expensive civil engineering works.

A single leaf horizontally hinged flap gate is a very simple system and the operating mechanism, suitably designed, can also be used to prevent unseating under surge conditions.

To summarise we consider that the following gates are worthy of further consideration:
- A pair of sector gates
- A single leaf vertically hinged gate
- A single leaf flap gate

# 5. BASIN

## 5.1 Dredging
From the existing survey data the bed level of the basin varies generally between a level of -1.0m and (-2.0m OD). If dredged to a minimum all over level of -1.9m OD then vessels will be able to remain afloat at all times with the exception of the times of periodic sluicing using water from the River Brit. It is unlikely that the removal of a thickness of say 1.0 to 1.5m of silt around the sides of the basin will cause any structural instability of the walls but that will have to be confirmed in due course.

## 5.2 Siltation
The River Brit discharges into the basin, the flow at the point of discharge being controlled by a sluice. Current practice is for the sluice to be "normally closed" but opened on an intermittent basis at low tide. This sets up a short term but fast flow through the approach channel which is reasonably effective in removing accumulated silt.

To enable this practice to continue it will be necessary to leave the proposed new gate open over a low tide to allow the sluice operation to be carried (frequency to be discussed with harbourmaster). As an alternative to allowing the basin to fall to low tide level we have considered incorporating a value in the sill structure which could be opened at low tide and at the same time as the River Brit sluice, incoming and outgoing flow rates being balanced. However there is not guarantee that the incoming river flow would be along the bed of the channel primarily because the water will be of a lower density than the sea water in the basin. It is thus not likely that there will be any significant scouring action to remove silt in the channel.

# 6. NAVIGATION

As discussed the channel width at the gate will be reduced from a minimum of 17.5m (approximately) to 10.0m. This will cause some increase in flow velocities which will be at their maximum just before the gate is closed. At that time we estimate the average flow velocity across the gate sill as 0.2m/sec (0.4 knots).

We consider it advisable that the gate and cross-wall, and in particular the gate quoins, are protected from accidental vessel impact. This could be done by placing simple dolphins both upstream and downstream of the gate on both sides of the channel. The dolphins could take the form of single tubular steel piles driven at the same time as the cofferdams are constructed to avoid separate mobilisation of piling equipment solely for the purpose of driving four piles.

In addition to the normal hydrostatic and wave forces the gate would be designed to resist a degree of accidental vessel impact. General good practice in the UK is for lock and dry-dock gates, where ocean-going vessels are being handled, to be able to withstand a single point load of 100 tonnes anywhere on the gate from vessel impact. A similar approach would be used for the West Bay gate but with a lower force value.

Suitable interdict lights will be required upstream and downstream of the gate to warn vessels of a gate closed situation.

## 7. WAVES IN THE OUTER BASIN

The wave climate in the outer basin formed by the proposed new west breakwater will be slightly modified by reflections of the cross-wall and closed gate. It is not expected that these reflections will cause any undue problem and they will be investigated as part of the hydraulic model test programme.

## 8. VISUAL IMPACT

The gate and cross-wall will not extend above the level of the existing harbour walls. It might be possible for all operating machinery to be located below the top of the existing walls but if machinery/control houses are needed they would be very small, say 5 x 3m in plan. Thus they could, if require, have stone facings without undue cost.

## 9. PEDESTRIAN ACCESS

Walkways for use by the general public could be provided along the tops of all the gates considered as possible solutions. We would recommend that the width of the walkway on the vertical flap gate be not greater than 1.5m as this has to be accommodated in the recess in the channel floor when the gate opens and it is desirable to keep this recess as shallow as possible.

## 10. CONCLUSIONS

It is not feasible to construct a fixed sill at West Bay. A gate however could be constructed without significant impact on wave disturbance or navigation. Sector gates are preferred. These could also incorporate a walkway to facilitate circumnavigation of the Inner Harbour by foot. Such gates could also act as a storm surge barrier.

The gate arrangements considered worthy of further study are identified as:

- Sector gates (preferred)
- Single leaf vertically hinged gate
- Single leaf flap gate

The preferred location of the gates has been identified as at the point of exit from the inner harbour between the Dolos blocks and the root of East Pier. An impermeable cut off wall would also need to be constructed on the harbour side of the Dolos to facilitate impoundment of the inner harbour.

The cost associated with construction of a pair of sector gates and associated cut-off wall and operating equipment has been preliminarily estimated as £500,000.

### 10.1 Recommendation for further work (Phase II)

This report represents the first phase in the investigation into the feasibility and design of a tidal sill at West Bay. To progress this concept, it will be necessary to:

- Undertake further outline design of the preferred option (i.e. Sector Gates).
- Seek advice from specialist Mechanical and Electrical Engineers on the design and cost of the necessary operating equipment.
- Seek detailed estimates from specialist Quantity Surveyors in the cost of the fabrication and construction of the gates to provide a more reliable cost estimate. (This is considered necessary given the complexity of the gate system and the specialist knowledge required).

## 11. REFERENCES

HR Wallingford (1999) West Bay Physical Model Study EX 4064 August 1999

# *Figures*

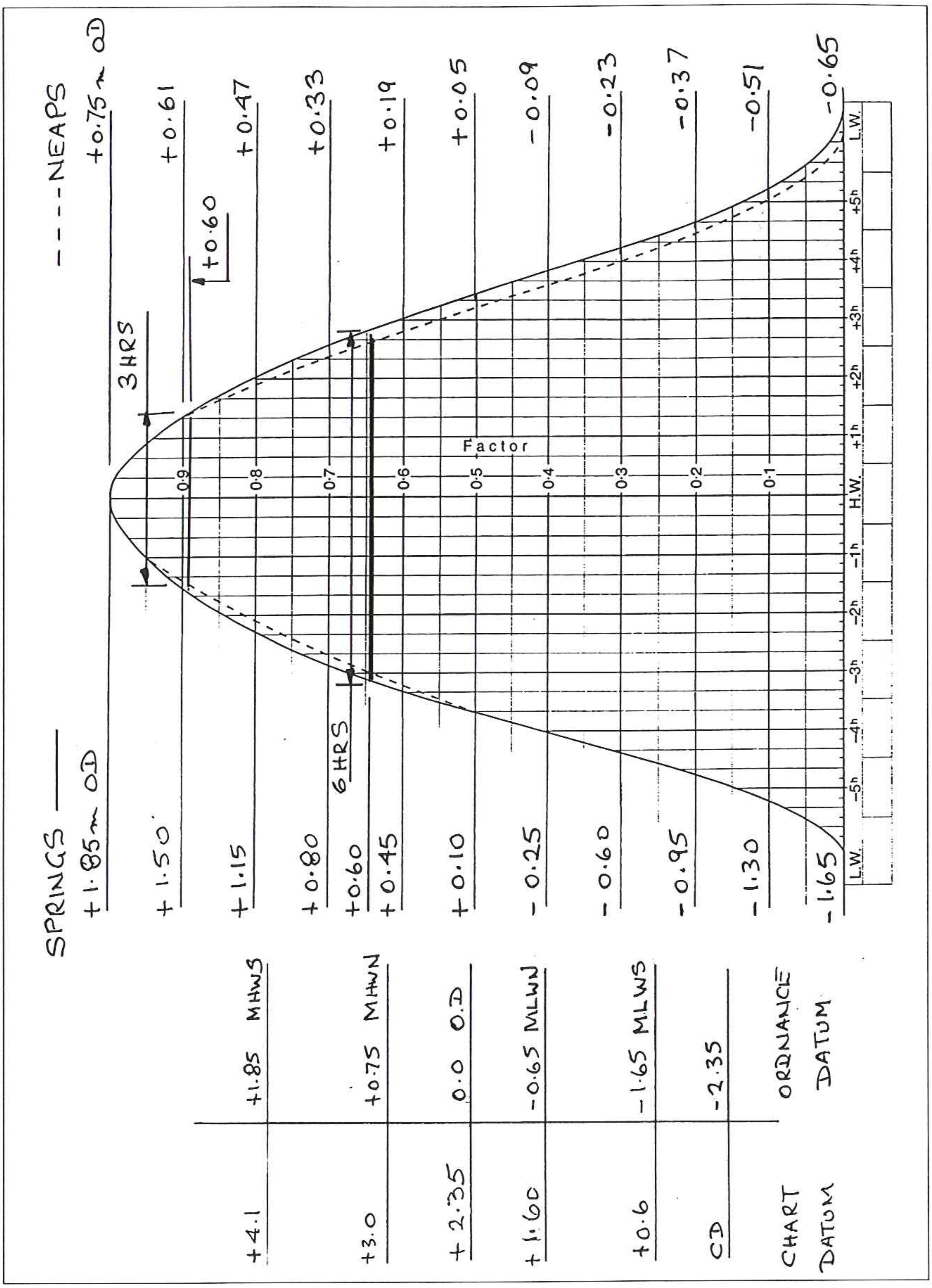


**Figure 1 Tidal conditions**

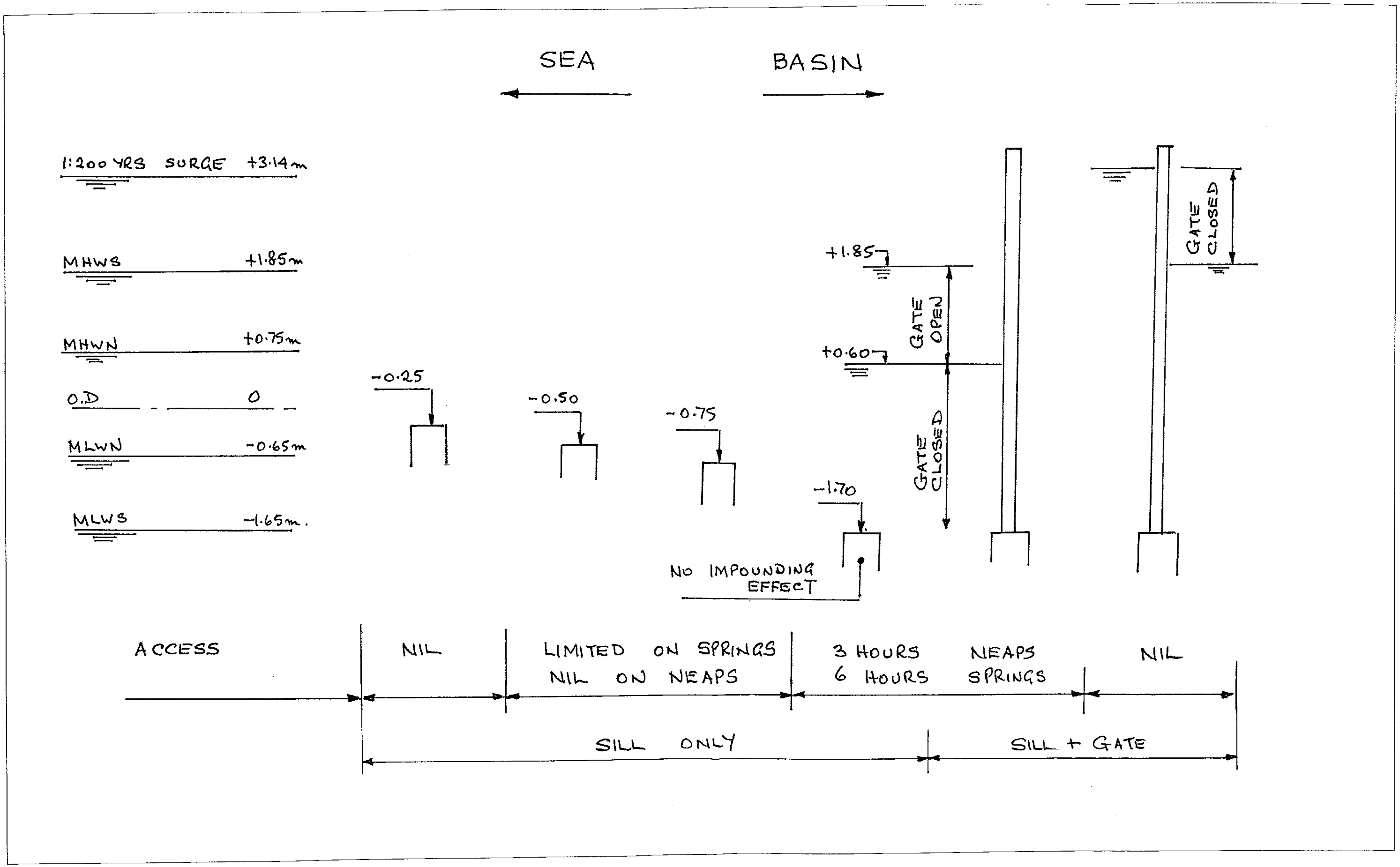


Figure 2 Operating options

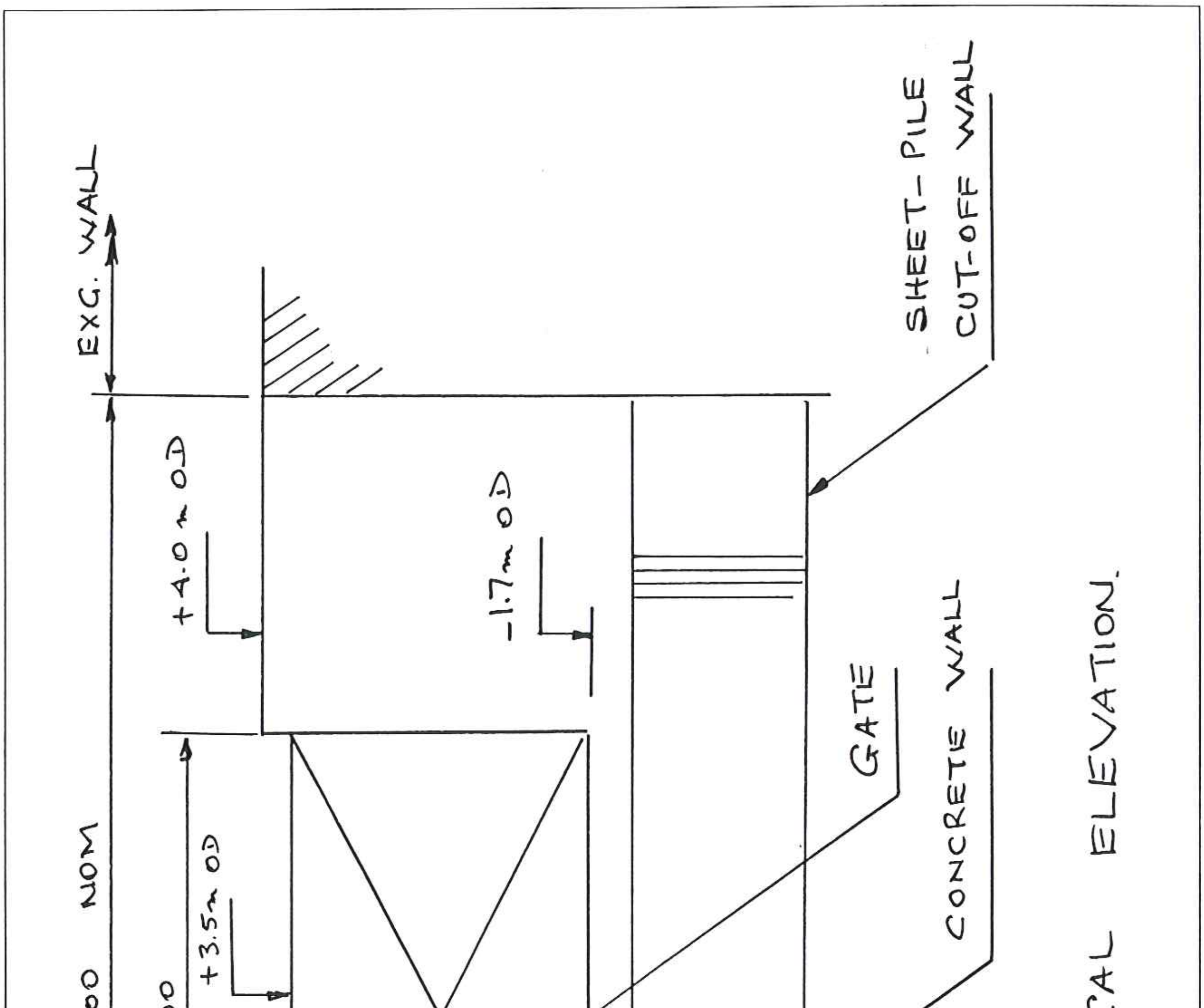


**Figure 3 General gate arrangements**

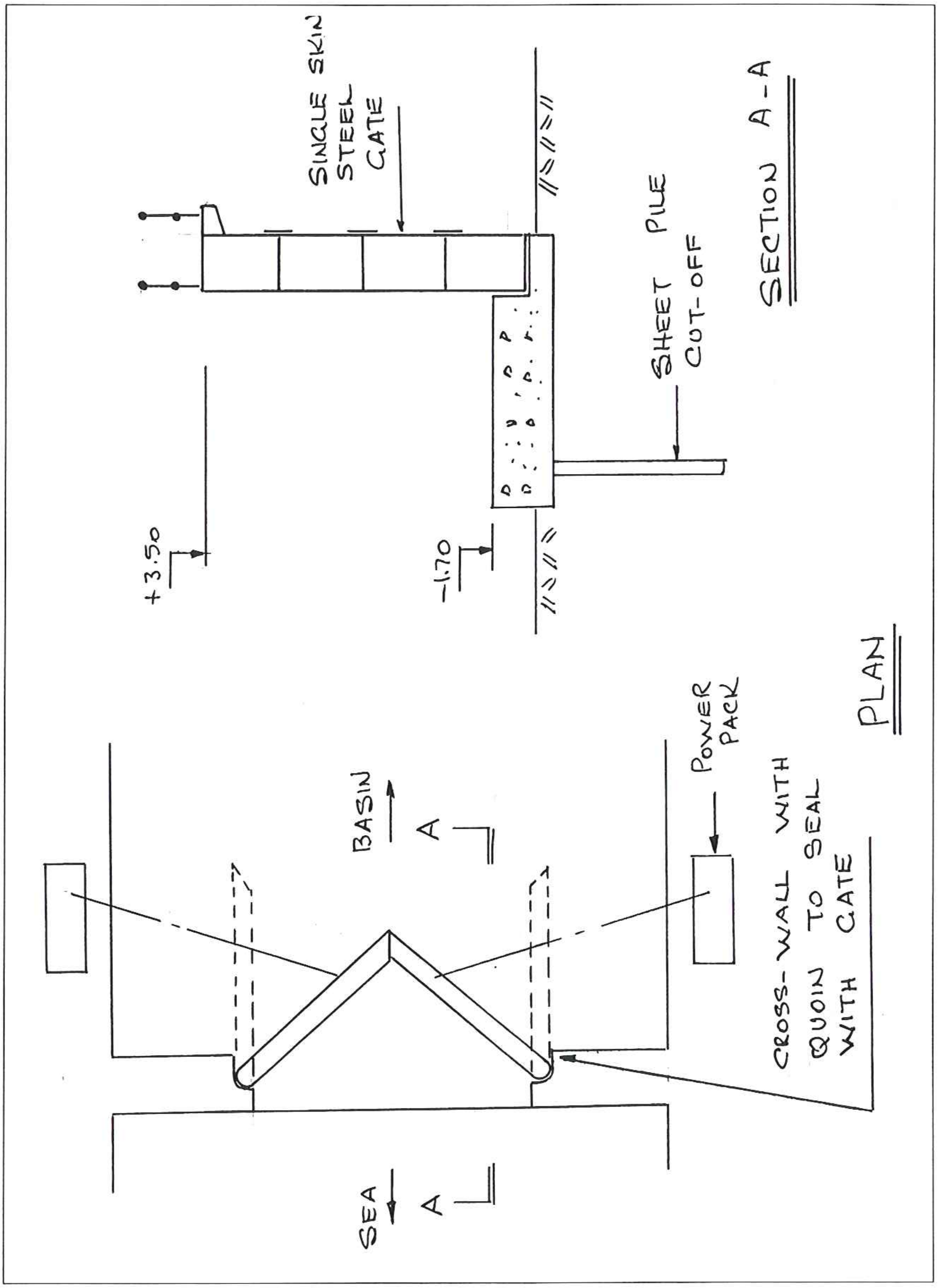


**Figure 4 Mitre gates**

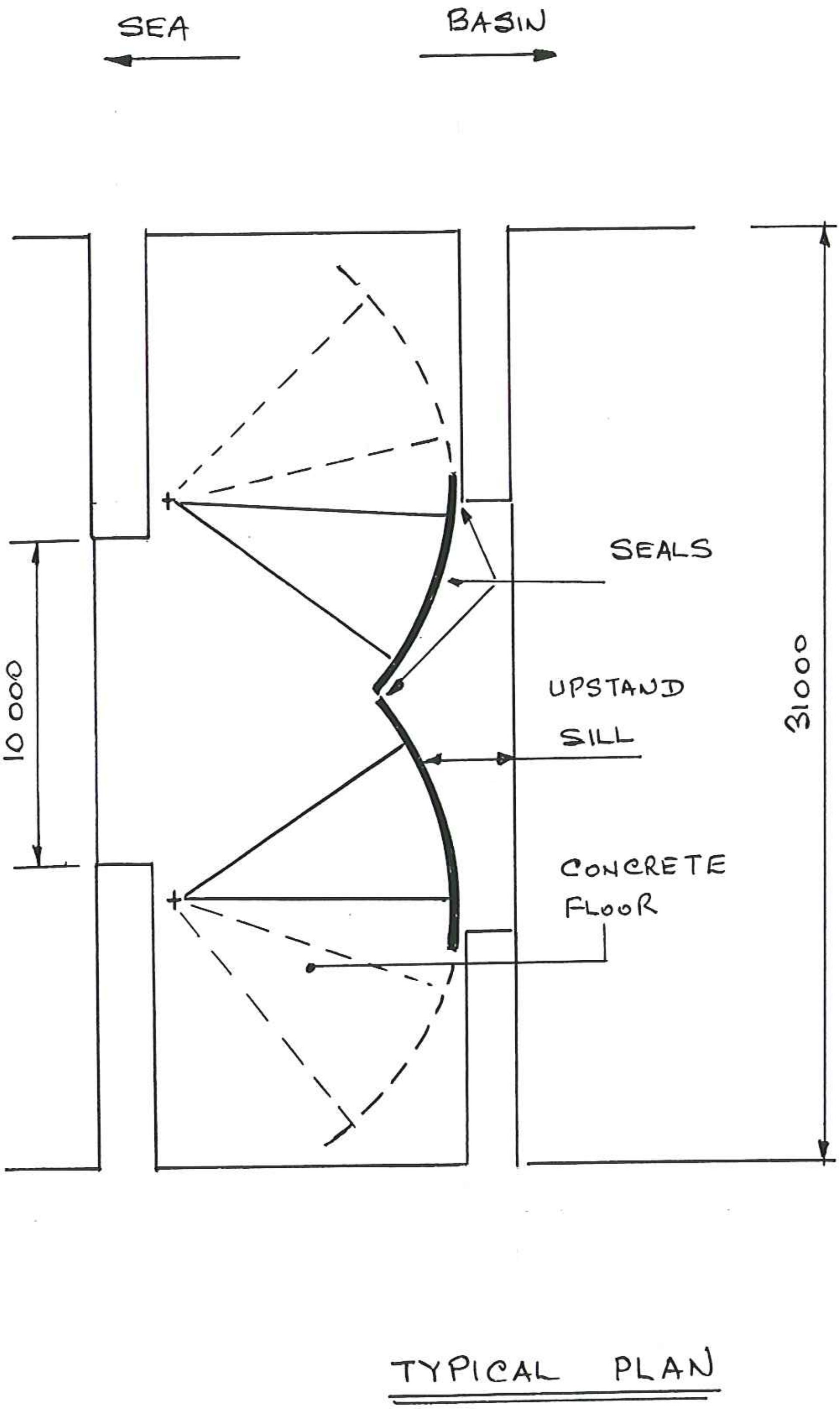


**Figure 5 Sector gates**

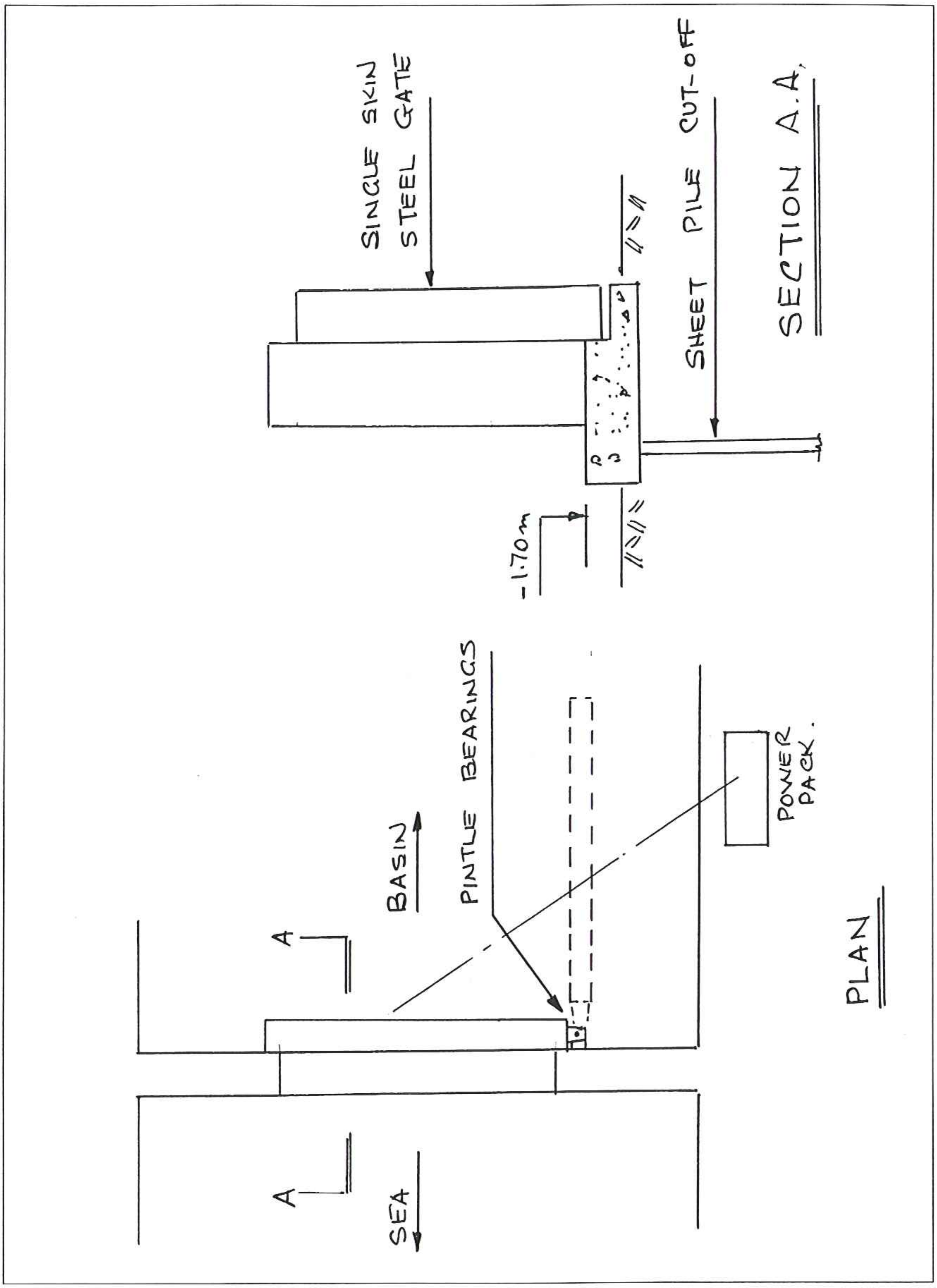


**Figure 6 Single leaf gate**

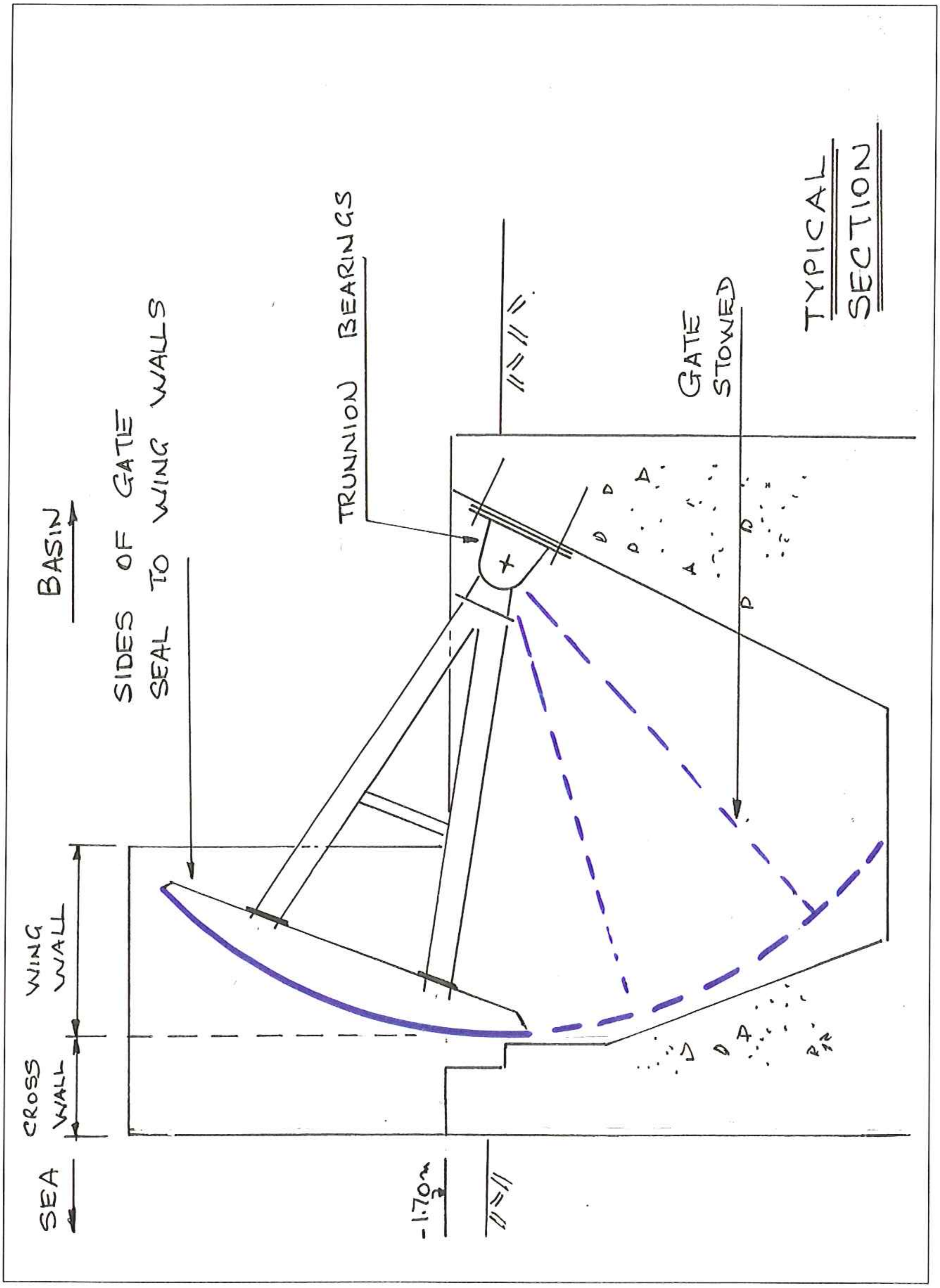


**Figure 7** **Radial tainter gate**

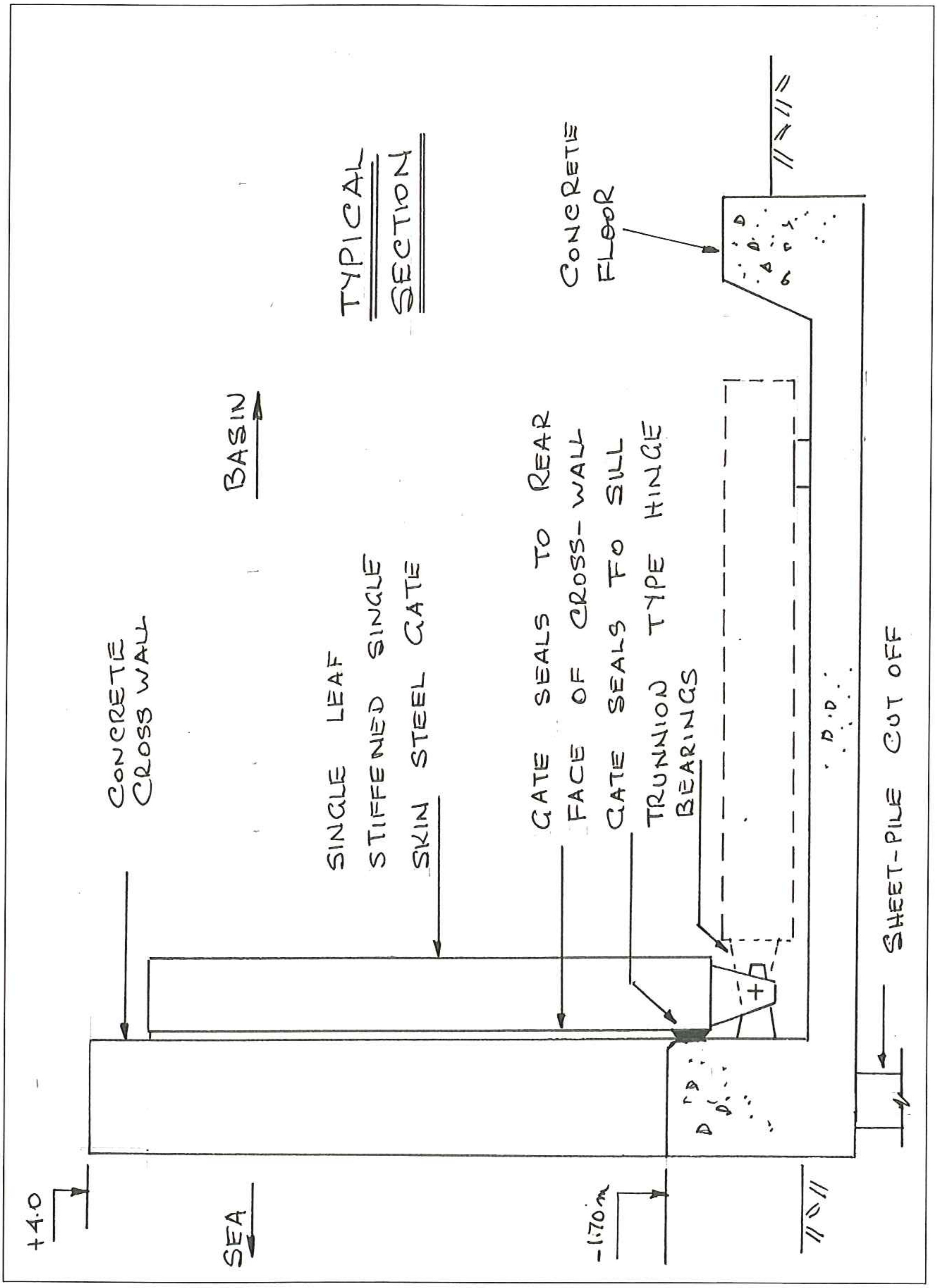


**Figure 8 Flap gate**