InCom Working Group 26

Design of Movable Weirs and Storm Surge Barriers

EXTRAIT

Juin 2006

GATES OF MOVABLE WEIRS AND BARRIERS

1.1 PROJECT REVIEWS

Representative samples of each gate type included in this document are summarized in this chapter. Case studies of each of these gates are included on the WG25-CD /Directory A1/. The case studies include a more complete description of the gate, foundations, abutments, operating characteristics and, where available, cost. Photographs and select engineering drawings are also presented for many of the gates.

A. ARCH or VISOR GATES

An arch gate is a three-hinged arch that spans from abutment to abutment across the waterway. It is hinged at the abutments and rotates upward for storage and downward to close the channel.

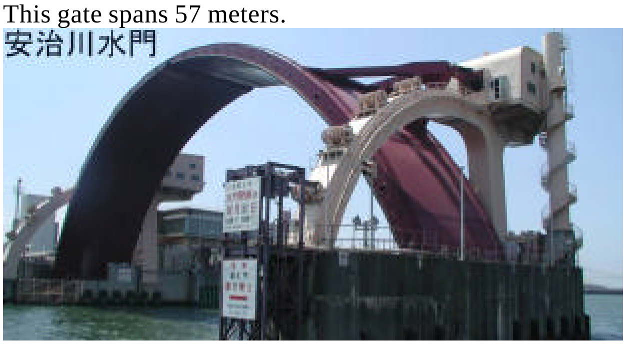
A.1 Rhine Visor Weirs

These double visor gates each span 54 meters and are used to control flow for power generation and navigation. This is one of 3 weirs of similar construction on the Rhine River.

Hagestein, The Netherlands (~1960)

A.2 Aji River Barrier

This is one of 3 lock gates constructed as flood protection measures from storm surges for the city of Osaka, Japan. This gate spans 57 meters.



Osaka, Japan, 1970

B FLAP GATES

Flap gates are hinged along the upstream edge of the gate and attached to a sill foundation. They are stored submerged and flat to the bottom. To close the flow, the downstream edge is rotated upward.

B.1 Lagan Weir (Storm surge barrier)

The barrier is composed of 5 Fish Belly, bottom hinged, flap gates. Each gate is 20m wide by 4.5m tall. These gates are used for flood control and to improve water quality.

Belfast, Northern Ireland, 1994

B.2 Tees Barrage (Tidal weir)

This barrage was established to improve water quality and to provide flood protection. The barrage has 4 bottom hinged fish-belly flap gates. Each gate is 13.5m wide by 8m high.

Stockton on Tees/Teesside, UK, 1995

B.3 Libcice-Dolany (river navigation weir)

The three sluiceway openings serve navigation and hydropower interests on the Vltava River. The right sluiceway is 19.85 m wide and the others are 43.0 m, with a control height of 3.3m.

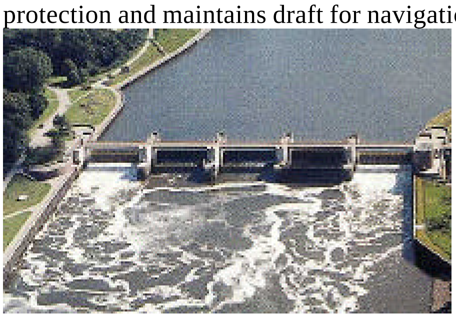
Libcice, Vltava River, Czech Republic, 1989

B.4 Veseli (24m long)

The weir Veselí consists of two 24.4 m wide hollow flap gates with a 1.4 mcontrol head. The dam provides support for navigation and hydropower. A fish ladder is also provided.

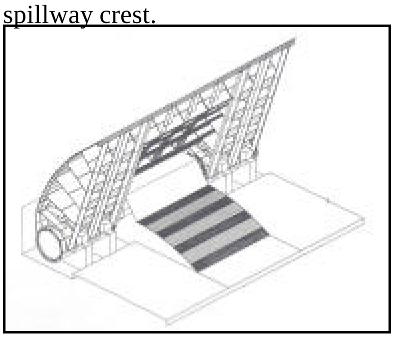
Veseli, Morava River, Czech Republic, 2002

B.5 Bremen Weser Weir (navigation weir)
The five fish belly flap gates span 31 m and provide a control height of 3.8m. The weir provides for flood protection and maintains draft for navigation.



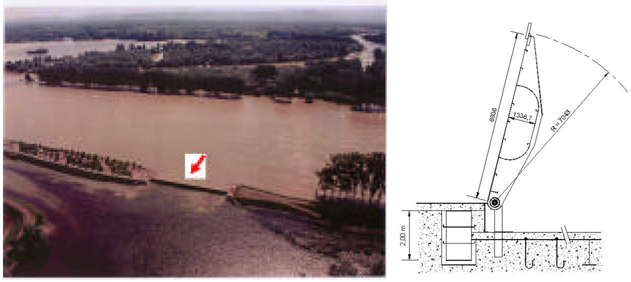
Bremen, Germany, 1993

B.6 Torque-tube at Montgomery Dam
The project consists of a navigation lock, a 91.4-m-wide controlled navigation pass spillway with 10 torque-tube gates, and a 61.0-m-wide fixed uncontrolled overflow spillway. Each gate is 9.1 m wide and rises 3.96 m above the spillway crest.



Desha County, Arkansas, USA, about 2004

B.7 Sauer Closure Gate
The goal of this project is the protection of cities and lands against flood created by the river Rhine. There is a single flap gate of 7.04 m high by 60 m long.

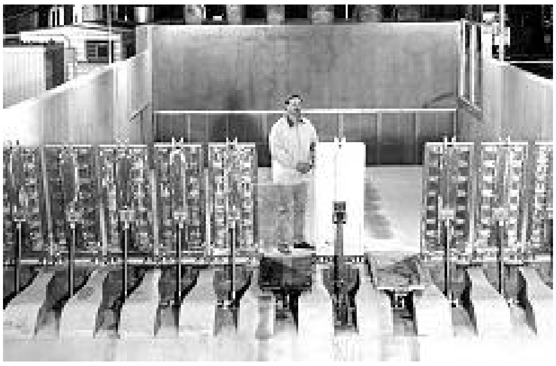


Sauer Flood Barrier – Munchhausen, France, 1993

B.8 Denouval Wicket Gates
These 30 wicket gates dam a river width of 70 m. Each wicket has a height of 3.3 m and a width of 2.5 m. The gates are hydraulically operated and can be placed in one of four possible positions. The gates facilitate navigation on the Seine.

Andresy, Seine River, France, 1980

B.9 Olmsted Wicket Gates
The navigable pass section of the dam will be 420-m long with 140 x 2.95-m wide, boat-operated steel wicket gates. The project provides navigation and flood control.



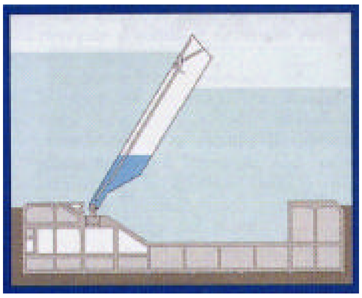
Olmsted, Illinois, USA, Estimated 2009.

B.10 Sinnissippi Dam
The dam has three 16m (48-foot) long and four 32m (96-foot) long pneumatically operated hinged-leaf gates and a 168m (504-foot) long conventional concrete ogee spillway and provides for flood protection, hydropower and navigation (Obermeyer system).

Sterling – Rock Falls, Illinois, 2002

B.11 Mose Buoyant Flap Gate

These oscillating buoyant retractable floodgates will provide flood protection to Venice. Seventy-eight flood gates will be provided at 4 locations. They will vary in width from 3.6m to 5m and the length will vary from 18 to 28m.



Venice, Italy (planned project)

C INFLATABLE WEIRS

These are operable weirs that are composed of long bladders, secured to a bottom foundation. The weir is raised by inflating the bladders with air or water.

C.1 Canadian Inflatable Weir

An inflatable weir was built upstream of a fall, downstream from a power plant intake structure, to control and optimize the water level while maintaining a minimum flow over the weir at all times.

Chute Bell, Rivière Rouge, Québec, Canada, 1994

C.2 Ramspol Barrier

These 3 inflatable fabric bellows barriers with a width of 60m, provide 2.7m of flood protection from inland river flood waters. The water level inside the barrier matches the tail-water, the level above this is air supported.

Kampen, the Netherlands, 2002

C.3 Pocaply Inflatable Weir

This rubber dam is 21m wide with a design height of 1.6m. It is water filled and provides a pool for hydropower generation.

Pocaply, Loucna River, Czech Republic, 1998

C.4 German Inflatable Weir Reference Document

This pdf document shows a presentation on the operation and design of inflatable weirs (BAW, Germany).

C.5 Rubber Dam at the river Lech

This dam provides a pool for hydropower. Four sections are used, one with a width of 26.65m and a height of 3.35m. The other three are 46.67m wide by 1.25m high.

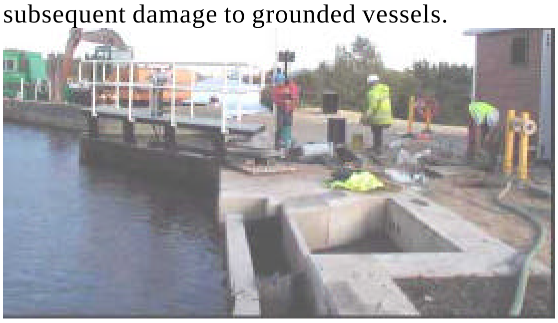
Füssen, Germany, 2001

D MITER GATES

Miter gates are typically used for navigation locks rather than flood control. However, they are used at Goole to prevent the harbour draining if the canal wall collapses. Miter gates are only operated when the water level is equal on both sides of the gate. A miter gate has two leaves that are hinged like doors on either side of the channel. They meet at an angle of about 30 degrees and rely on the mitering action to span the opening. This carries significant thrust to the abutments.

D.1 Goole Caisson

These gates are closed if a breach in the canal wall occurs. This prevents the harbour from draining with subsequent damage to grounded vessels.



Goole, Great Britain, 2002

E RADIAL GATES

A Radial or Tainter gate has a skin plate mounted on an open structural steel frame supported by strut arms at each side of the gate. The strut arms extend to trunnion bearings mounted on abutment walls on either side of the gate opening. Radial gates may have the trunnion bearing either upstream or downstream and the gates may be stored submerged and raised to close flow or stored overhead and lowered to close flow.

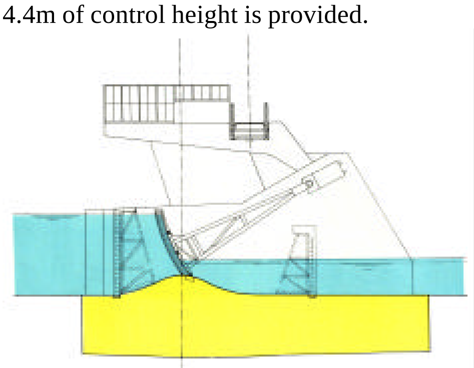
E.1 Upper Meuse

This project will rebuild a number of locks and dams on the upper Meuse River to improve navigation and power generation. These radial gates have an upper flap that allows more economical and precise flow control.

Upper Meuse Basin, Belgium, 1985-95

E.2 Steti Radial Gates

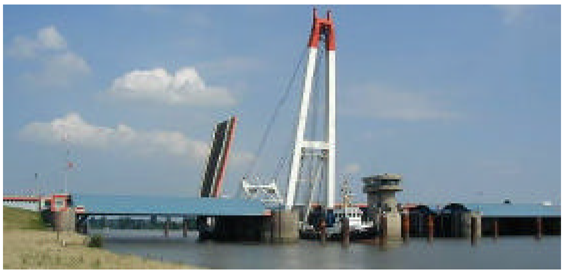
The weir is provided with seven sluiceway openings, two are fixed, two are locked by a steel radial gate, and three openings are locked by a steel radial gate with a control flap. 4.4m of control height is provided.



Steti, Labe River, Czech Republic, 1972

E.3 Stör Storm Surge Barriers

Double Tainter gates are provided on each side of two lock chambers to provide redundant flood protection in support of navigation. The tainter gates span 43 m and are 13 m high.



Federal State Schleswig-Holstein, Germany, 1974

E.4 Braddock Dam

The 4 radial gates are 33.53m long with a total damming height of 6.4m. The gates are used for flood protection and navigation and are hydraulically operated.

Braddock, PA, USA, 2003

E.5 Iron Gates

The two spillway dams on each river branch with seven 21m wide gates, three of which are equipped with overflow flaps of 2.50 m height. The dams are used for navigation and power generation.

Danube, Romania and Yugoslavia, 2000

E.6 Olt River Lower Course

Five dams were constructed in 13.5m steps along the Olt River to provide for hydroelectric power generation. Each of them consist of a gated dam with 5 openings of 15 m each. The gates are radial gates with flaps.

Olt River – lower course, Romania, 1990

E.7 Eider Barrage (storm surge barrier)

The floodgate section consists of five 40m wide spillways. Each opening has two radial floodgates for double protection. Seaside: High: 10.1m Riverside: High: 11.10 m

Schleswig-Holstein/Nordfriesland, Germany, 1973

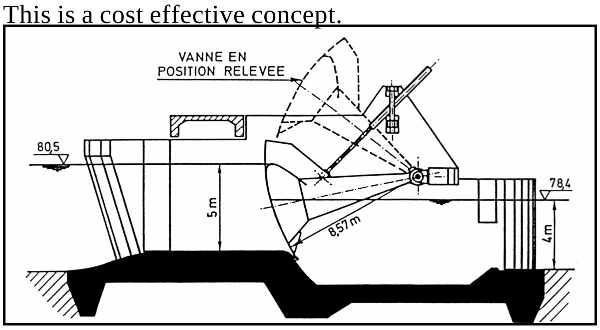
E.8 Haringvliet Storm Surge Barrier

This flood control structure provides two rows of 17 seaside and 17 riverside radial gates. The barrier is 1048.5m wide and the gates span 62m.

Hellevoetsluis, The Netherlands, 1970

E.9 Radial Gate with Under and Overflow

This gate concept has not yet been implemented, but would allow fine control of flow by lowering the gate and allowing surface flow over the top or would provide for high discharges and passage of sediment by raising the gate. This is a cost effective concept.



Upper-Meuse, Belgium (not built)

E.10 Prefabricated Floating Weirs - Innovative Concept

A series of 9 prefabricated navigation control weir sections are constructed in 4 floating sections that are transported afloat to the site and placed on a prepared foundation. Elements are made of aluminium to float in shallow water (60cm) steel can also be used. The structure (30m long, 29.5m wide and 7.6m high) includes 2 radial gates of 12m. The infill concrete is reinforced with steel fibbers rather than traditional rebar. This facilitates underwater placement.
The concept was developed for the Sambre river, Belgium, (not yet built).

F ROLLING or TROLLEY GATES

Rolling and Trolley gates are closure panels stored adjacent to the waterway. They are rolled into position in anticipation of a flood event. Rolling gates are bottom supported and trolley gates are top supported.

F.1 Selby Lock Rolling Gate

This flood control gate is stored in a slot at the side of the waterway and is winched across the canal. The gate is 6.4m wide, 3.85m high and 0.35m deep. It is partially buoyant and seals to a timber sill.

F.2 Berendrecht Flood Control Rolling Gate

These rolling lock gates are used to provide navigation access through a flood control barrier. The gates are buoyant and supported by a submerged trolley on the leading edge and an above water trolley on the aft end. The gates are 69.69 m long and have a height of circa 22.60 m. The average width is 9 m.

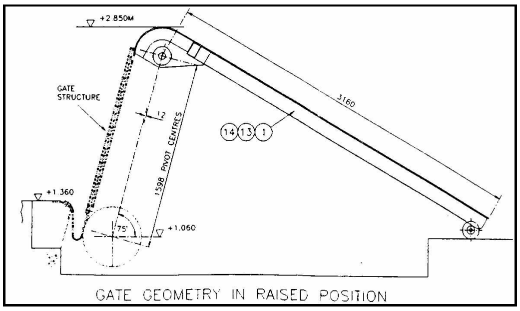
Antwerp, Belgium, 1989

G ROOF or BEAR TRAP GATES

Bear trap gates are not as common today as in years past. A bear trap gate is constructed of two leaves that slide over one another and seal together. They are stored on the bottom of the waterway. Typically water is allowed to enter the space beneath the gate and the upstream water pressurizes the space beneath the leaves and the gate leaves rise to block the flow. Resurgence has been found in two projects in England. They are used in recreational water parks to provide a “whitewater” rafting and canoeing experience. The course is configurable by adjusting the bear trap gates to adjust the flow characteristics. One example is provided at Tees Barrage in England.

G.1 Tees Barrage Bear Trap Gate

This bear trap gate is 5.950 m wide. The upstream leaf is 1.598 m centre to centre and the downstream leaf is 3.160m. The gate is used to control flows for white water canoe and kayak recreation.



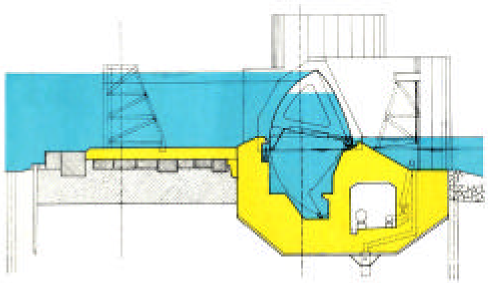
Tees, United Kingdom,1984

H SECTOR GATES - HORIZONTAL AXIS

Horizontal axis sector gates are circular sections hinged on the downstream side with a skin plate on the upper 2 sides. A horizontal axis sector gate rotates in a vertical plane about a horizontal axis. When lowered the upper skin plate of the gate coincides with the overflow section of the sill. Rotating or Rising sector gates are included here also. These gates provide skin plates on a segment of a circular arc and are supported at the sides of the spillway.

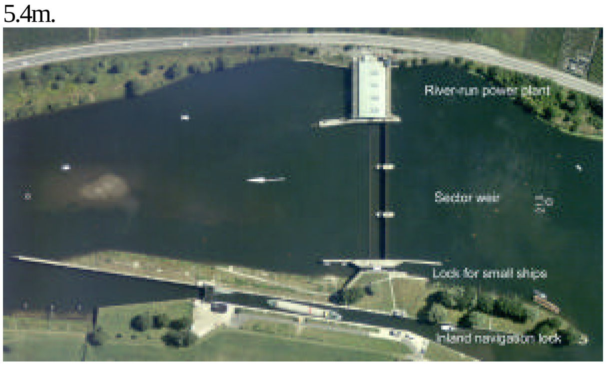
H.1 Roudnice

These gates are used for navigation and irrigation. Three sluiceways of the same clear width of 54.05m span the river with a dam height of 2.70 m


Roudnice, Labe River, Czech Republic, 1972

H.2 Mosel River Weir Lehmen (Navigation Weir)

11 of the 14 weirs built on this section of the Mosel use sector gates to control flows for navigation and hydropower generation. Three 40m spans dam an upstream head of 5.4m.



Mosel river, Germany,1963

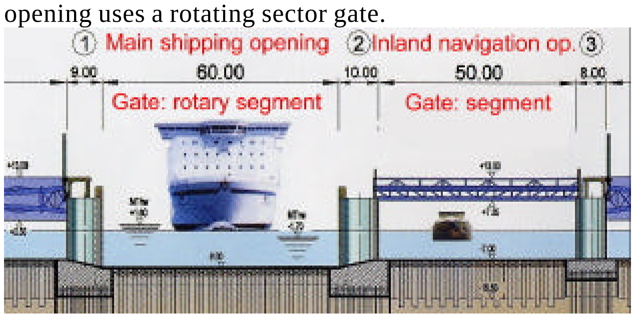
H.3 Thames River Barrier

This massive flood protection barrier protects London from flooding on the river Thames. The barrier extends 520m across the river and uses four 20 m high rising sector gates that span 61m.


London, United Kingdom, (1982)

H.4 Ems Barrier

The Ems barrier provides flood protection and supports navigation, it has a length of 476m between bank lines with 7 openings. The main shipping opening uses a rotating sector gate.



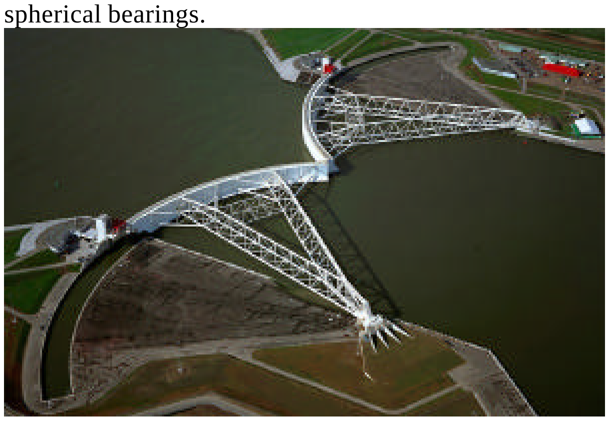
Ems river, Germany, 2002

I SECTOR GATES - VERTICAL AXIS

Vertical Axis Sector Gates are circular sections supported on a vertical hinge at the center of a circular arc. The skin plate is only on the face of the circular arc. Because the hydraulic thrust is directed radially inward toward the vertical axis there is very little unbalanced load and they can be opened and closed with differential head across the gate.

I.1 Maeslant Storm Surge Barrier

This flood protection barrier spans 360m. The gate is made buoyant when it is moved by locomotive engines on each shore. The gates pivot on specially fabricated spherical bearings.


Hoek van Holland, Netherlands, 1997

I.2 Maeslant Alternative Barriers

This paper discusses the alternatives to the sector gates finally selected for the Maeslant barrier. A pneumatic tumble gate, a segment gate, hydraulic tumble gate, sliding gate, boat gate and floating sector gates are discussed.

I.3 Amagasaki lock gate

These Vertical axis sector gates provide 17m wide lock access for navigation while providing flood protection to the lowland city from offshore storms and surges.

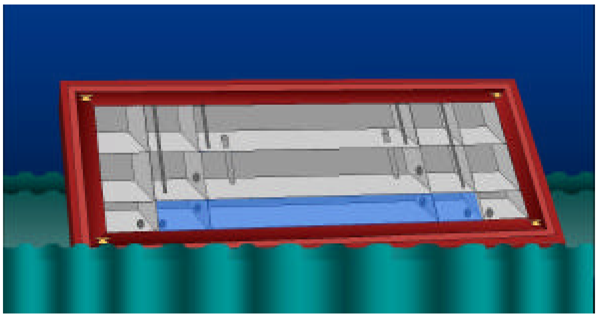
Amagasaki City, Japan, 2003

J STOPLOGS and BULKHEADS

Stop Logs and Maintenance bulkheads are typically constructed with a pair of horizontal trusses supporting a vertical skin plate on one face. They are stored separately from the gate opening and lifted into place by an overhead or mobile crane. They are designed to span across the opening or between intermediate posts that can be installed at intervals across the opening. They may extend vertically from the sill to the top in one piece or smaller units may be stacked and seal against one another to close the opening.

J.1 Kentucky Lock Floating Caisson

This floating gate is used to dewater lock chambers for maintenance. The bulkhead is towed from one site to another as a barge. It is then filled with water in a sequence to rotate it vertically, move it into position, and lower it into final position. The gate is 34.3m wide and 9m high with a depth of 3.2m.



Locks on Tennessee & Kentucky Rivers, USA, 1969

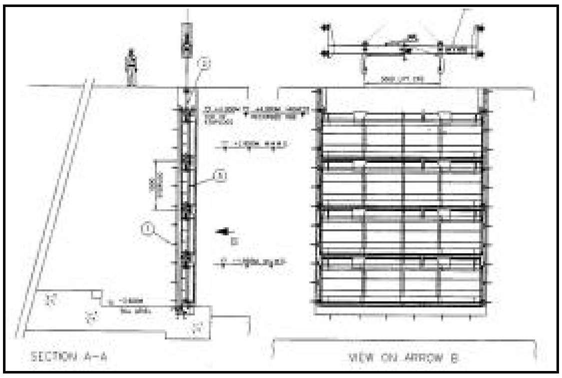
J.2 Olmsted Maintenance Bulkheads

Four bulkhead sections were built to allow maintenance dewatering of the locks and radial gates. The bulkheads are stacked to meeting varying site conditions. Two lower sections 3.4m and 5.5m high are designed to support one of 2 upper sections 11.6m high. The bulkheads span 34.1m.

Olmsted, Illinois, USA, 2004

J.3 Tees Stoplog

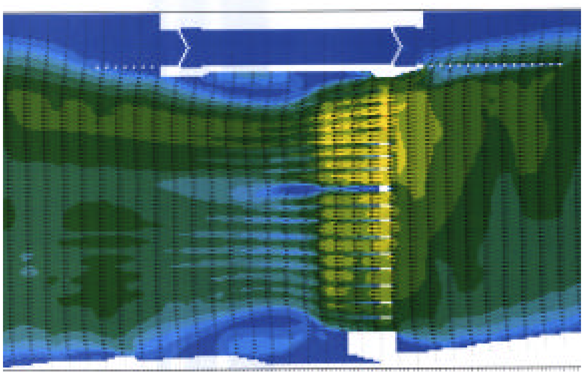
Thirteen stoplogs, 1.25 m high, close an opening 13.89m wide. Eight are used on the downstream side of a gate bay and 5 are used upstream. They are placed with a crane and a lifting beam that will automatically engage or disengage from the stoplog.



Stockton on Tees/Teeside, UK,1995

J.4 Murray River Stop Logs

These stop logs are used in support of navigation and flood control. They resist heads varying from 4.5 to 6m



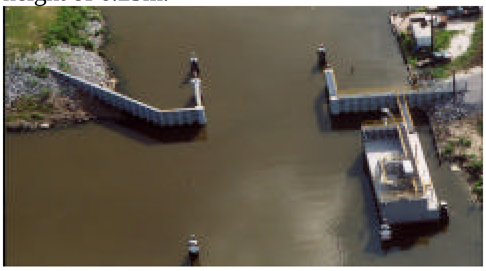
Between Adelaide and Mildura, Australia, around 2000

K SWING GATES

A swing gate is stored on one side of a waterway and pivots about a vertical axis to close against abutments on either side of the waterway. A Swing Gate may be buoyant to reduce hinge and operating forces.

K.1 Bayou DuLarge Barge Gate

This flood control barrier is made buoyant and floated into position by winches in advance of a flood. It spans 18.3m. When in position, it is ballasted onto the sill and has a height of 6.25m.



Bayou DuLarge, Louisiana, USA, 1996

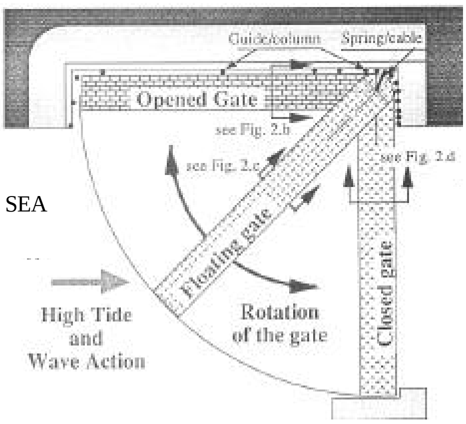
K.2 Bayou Lafourche Barge Gate

This flood control barrier is similar to Bayou DuLarge. It spans 22.9m and has a depth of 3m with a water-tight parapet extending up an additional 1.5m.

Bayou Lafourche, Louisiana, USA

K.3 Antwerp and Rotterdam Swing barriers

This innovative concept of floating rotating barrier was developed for closure of large spans (up to 400m) without any limitation on draft or air clearance, during construction or operation (Rigo et al. 1996).



Project in Belgium and The Netherlands (not built)

L VERTICAL LIFT GATES

Vertical lift gates are raised and lowered vertically. They may be stored underwater and raised to close flow, or stored above a channel on towers and lowered to close flow.

L.1 Beernem Weir

This vertical lift gate provides flood protection and is 8.05m high and 17.9m wide.

Beernem, Flanders, Belgium, 1998

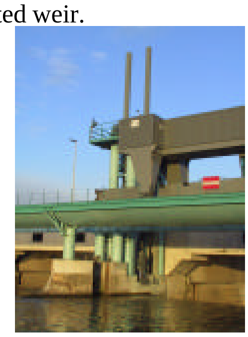
L.2 Hartel Canal Barrier

This large storm surge barrier consists of two lens-shaped vertical lift gates with spans of 98m and 49.3 m with a height of 9.3m. To facilitate water storage the gate never fully closes and at high flood stages the gates are overtopped.

Spijkenisse, Netherlands, 1996

L.3 Ivoz-Ramet

This is a nice example of a rehabilitated weir.



Liege, Belgium, 2000-2001

L.4 Kamihirai Gate

These 4 gates are closed in advance of a flood event. Each gate is 30m wide, 2 gates are 9.2m high and the other 2 are 9.5m

Tokyo, Japan, 1990

L.5 Shinanogawa River Gate

This flood protection structure has 3 spans each 30m wide with a height of 24.5m.

Niigata prefecture, Japan, 1974

L.6 Blanc Pain

This emergency lift gate protects the 73m high shiplift at Strépy and the surrounding countryside from a flood event in the event of riverbank or structural collapse. The gate closes a channel width of 32.4m and has an air clearance of 7m when raised.

La Louvière, Canal du Centre, Belgium 2003

L.7 Hull

The flood protection barrier is a vertical lift gate which provides a 30 meter wide navigation opening and provides 6.3 m of flood protection.

Hull, UK, 1979

The gate is designed to be aesthetically pleasing and the gate rotates 90 degrees when raised to maximize navigation clearance and minimize visual impact.

L.8 Cardiff Bay Barrier

Cardiff Bay Barrage is a tidal exclusion barrier designed for flood control with 5 sluices (9m wide x 7.5 m high) with double-leaf vertical lifting gates (Faganello E., 2004).

Cardiff Bay, UK, 1998-99.

M UNCLASSIFIED GATES

M.1 Ice Boom - Lac St. Pierre

This floating structure protects a major shipping channel from closure by ice. The floating boom segments are restrained by steel cables to anchors on the lake bottom.

Trois Rivières, Québec, Canada, 1994

M.2 Curtain Barriers – Temporary

This curtain barrier was designed to create a headloss and temporarily force the diversion of the flow away from a tributary. The barrier consists of a long steel pipes with a curtain attached to the bottom. The curtain can be a rubber liner or a plastic pipe(s).

Laboratory test and the field deployment of a curtain, 2004.