Massarsch, K. R., 2006. Dams for flood and storm surge protection. Dams under debate. Eds: Johansson, B, Sellberg, B., Formas, Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning. R6:2006.

The Eastern Scheldt storm surge barrier between the islands Schouwen-Duiveland and Noord-Beveland, is the largest of 13 ambitious Delta works series of dams, designed to protect a large part of the Netherlands from flooding. Picture taken by D. Reiskoffer, publishing permission granted under the terms of the GNU Free Documentation License by the Free Software Foundation.

Introduction

Three main types of flooding occur: storm surges, river floods, and flash floods. This contribution addresses mainly protection measures against storm surges and river floods. Storm surges can occur along the coast or banks of large lakes. They have extreme loss potential and may cause hundreds of thousands of fatalities. The Bangladesh storm surges with death tolls of 300,000 (1970) and 140,000 (1991) are the best-known of the recent past but not the only ones. Even in Europe, storm surge events have claimed the lives of thousands of people in the second half of the twentieth century (North Sea storm surge in 1953: 2,000 dead). Major improvements in sea defences and, in particular, the enhancement of forecasting and early-warning facilities in recent years have led to great storm surge catastrophes becoming less common. However, an accelerating rise in sea levels will aggravate the risk of storm surge and coastal erosion in many coastal regions — and this will be one of the most detrimental effects of global warming. Figure 1 shows areas prone to storm surge within the EU, most of which are located in the northern part of Europe.

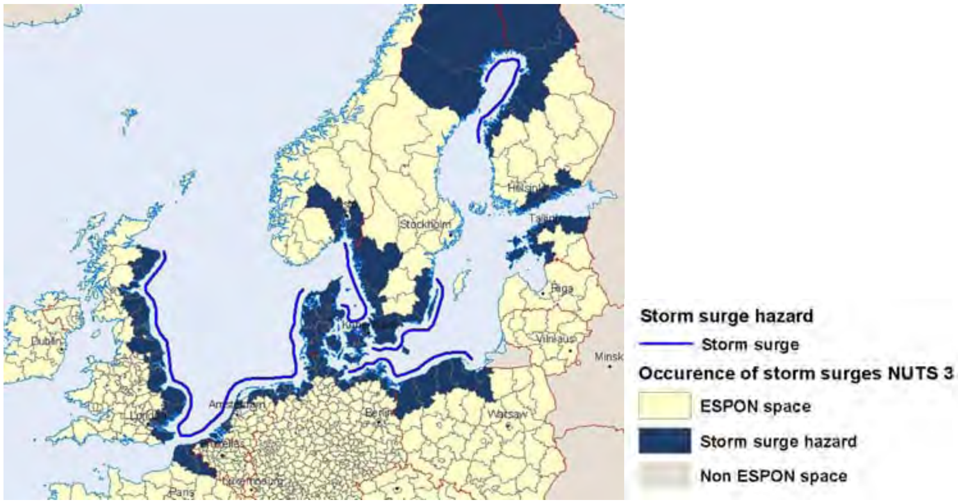

Figure 1. This map presents the approximate probability of having storm surges in the European Union. From ESPON Project Report 1.3.1, 2005.

River floods do not occur abruptly but build up gradually – although in some circumstances within a short time period. They last typically from a few days to a few weeks. The distruction of the affected area may be very extensive if the river valley is flat and broad and the river carries a large volume of water. River flooding emerged as an increasing problem as a result of human intervention, by straightening and even relocating rivers, while at the same time developing low-lying areas close to rivers. Increased soil sealing also resulted in higher flood levels and the water inflow to rivers is no longer delayed by natural soil retention. The European Spatial Planning Observation Network (ESPON) studied different types of technological and natural hazards and risks that in some way can have effects on the development of the European regions. According to this study, the highest amount of large flood events between 1987 and 2002 occurred in North-Western Romania, South-Eastern France, Central and Southern Germany and in the east of England.

Historic Perspective

Already early human civilizations protect their settlements, farmland and religious sites by earth-fill embankments and walls. Several thousand years ago, these earth structures were used to change and adapt the terrain in order to facilitate land use. Dams were also needed as reservoirs to store water for irrigation of farmland or as military defence against invasions. However, most of these early structures have been destroyed due to human impact and natural forces.

Human civilizations developed in four main regions: Egypt, Mesopotamia, China and India, all of which were located along large rivers where fertile soil deposits facilitated agriculture, cf. Table 1.

Table 1. Hydraulic characteristics of rivers in the four large civilisations, from Kerisel (1985).

	Egypt	Mesopotamia	China	India
River	Nile	Tigris and Euphrates	Yellow river (Huang Ho)	Indus
Annual precipitation (mm)	250	200	500	250
Origin	African lakes and Abyssinia	Mountain ranges of Armenia	Kulum mountains	Hindu Kush and Himalaya
Water level rise (m)	5 - 7	5	4 – 7	4 - 5
Amount of silt	0.17	0.75	1 – 2	0.43
Inclination	1:13 000	1:26 000	1:35 000	1:7 000

Probably the oldest known earth dam was built in 3200 BC near the city of Java in Jordan and consisted of an earth embankment protected by a layer of masonry. Its main purpose was to assure the water supply of the city. The dam was 4.5 m high and had a length of 80 m. Similar embankments were built along the river Tigris, where king Adad Nirari about 1300 BC let build a 1,500 m long protection wall outside the city of Ashur.

Similar structures were found along the Indus river, dating back to 2000 BC, where one of the capital cities of that period, Mohenjo Dara, needed protection against flooding. The dam was 1,500 m long and constructed of compacted earth fill.

Also in China many earth dams were built to protect populated areas against flooding but most of these have vanished. One of the oldest preserved dams is located near the city of Shiouxian in Central China where Emperor Sun Shu'ao built a 30 km long earth dam. This structure dates back more than 3000 years is still in use and fully functional.

Egypt is one of the foremost examples where hydraulic engineering has played an important role in the development of human civilisation. The Nile is one of the longest rivers in the world and irrigates in Egypt a small but fertile valley, Figure 2. Prior to the regulation of the Nile during the 1960ies the water level varied annually by on average 6 m. These regular floods were important as the river carried along fertile sediments and cleared the ground from salts and human waste.


Figure 2. Nile valley at Luxor showing the fertile land in the narrow river valley.

Pharaoh Cheops (also known as Khufu) was probably one of the greatest civil engineers of all times. During 2589-2566 BC he initiated the construction of the great pyramid at Giza. In addition, Cheops also planned and implemented extensive irrigation and flood protection schemes.

During the Middle Kingdom (2055 – 1650 BC) the capital of Egypt was moved from Thebes (now Luxor) to the north near Memphis, which then was located close by the river Nile. In order to protect the city a 450 m long and 15 m high earth dam was constructed. At the base the embankment had a width of 60 m. This is probably the oldest dam in history which was built specially for flood protection purposes.

The Need of Flood Protection

Flooding can have devastating consequences in many developing countries where low-lying coastal regions face the threat of flooding. For instance in Bangladesh flooding affects at least twenty percent of its area in a normal year because of the vulnerable topography. In extreme cases, the flood-affected area could be as high as 67%. Flood control and drainage is used to reduce the depth of flooding or eliminate it through 'controlled flooding', so as to provide greater security for crop production.

Flood protection is also important in industrialized countries. Extreme floods occur also along major German rivers and at the coast, predominantly in the winter and spring months. Flood-control structures and reservoirs, created by concrete or earth fill dams, not only store the flood water but also reduce the peak flow and considerably slow down the discharge in the river reaches downstream of the dam.

Prior to their implementation, not only the locally achievable flood protection but also their impacts as a whole on the discharge behaviour of the water course system, the ecology and the landscape appearance are to be taken into account. Due to their economic efficiency, earth fill dams are mostly preferred. The heights of them reach from a few meters to 30 m referring in particular to the mentioned flood control reservoirs.

Delta Works Project, the Netherlands

In the Netherlands, more than one third of the land is located below sea level. The devastating North Sea Flood of 1953 breached many dikes and seawalls in the Netherlands, killing 1,835 people and forcing the evacuation of many more. Over 150,000 hectares of land were flooded. The Delta Works project was implemented to prevent the reoccurrence of similar disasters. The islands in Zeeland province were joined together by dams and other large-scale constructions to shorten the coastline.

Figure 3. Oosterschelde barrier. Copy right Rijkswaterstaat - Adviesdienst Geo-Informatie en ICT (AGI).

The nine kilometre long barrier was initially designed, and partly built, as a closed dam, but after public protest, huge sluice-gate-type doors were installed in the remaining four kilometres. These doors are normally open, but can be closed under adverse weather conditions while preserving the saltwater river delta for wildlife and the fishing industry. The construction started in 1978 and was finished in 1986. The costs for the Oosterschelde barrier are estimated to 2.5 billion Euros.

Figure 4. Aerial view of the Oosterschelde storm surge barrier. Embankment dam near the Veerse gat. Copy right Rijkswaterstaat - Adviesdienst Geo-Informatie en ICT (AGI).

Less known, but not less impressive, is the Maeslantkering storm surge barrier near the port of Rotterdam. A year after the opening of the Oosterschelde barrier, the Ministry of Waterways and Public Works held a competition for the construction of another storm surge barrier. The most important demand for the design was that the barrier should not hinder the shipping. The barrier should only be closed under exceptional circumstances - no more than once or twice every ten years. In 1991, four years after the competition was held, construction started. The Maeslant barrier would consist of two steel doors which could be sunk down and could be turned away in the docks in the shores. In 1997, the storm surge barrier New Waterway near the Hoek of Holland was officially opened.

Figure 5. Closed Maeslantkering storm surge barrier near the port of Rotterdam, photographed from the sky. Copyright: Rijkswaterstaat - Adviesdienst Geo-Informatie en ICT (AGI).

When the sea level rises, the arms of the barrier are activated. The waterway, with a width of 360 metres, can then be closed completely. It is the only storm surge barrier in the world with such large moveable parts. The storm surging doors have a length of 240 metres each. Normally, these doors are fully opened, to allow ships access to the port of Rotterdam. The doors are stored in docks with a length of 210 metres, which lie along both shores. During storm tide the docks are flooded and the hollow doors begin to float. They are driven into the water by means of a small train. This lasts for about half an hour. When the doors are situated in the middle of the river, valves are opened and as a result the doors are flooded. Consequently, the doors sink to the bottom because of their weight. The water level on the seaside is then higher than the water on the riverside. The force against the surging wall during a storm is about 350 MN

Thames Barrier, England

The earliest recorded flood on the River Thames was in AD 9. Some 29 years later another flood occurred that reportedly drowned 10,000 people. In 1774 another great flood on the Thames washed away Henley Bridge. Other floods occurred in 1848, 1852 and 1875. One of the worst floods on the non-tidal Thames in recent history occurred in 1894 and was due to exceptionally heavy rainfall. In 1953, the combination of a north westerly gale, a very deep area of low pressure, a high spring tide and the topography of the North Sea caused a massive storm at the southern end of the North Sea. The sea level rose nearly nine feet above normal high spring tide levels causing exceptional flooding along the East Coast and Thames Estuary, during which 307 people died, 24,000 homes were damaged or destroyed and 46,000 of livestock were lost.

This disaster prompted the construction of the Thames Barrier at Woolwich at a cost of around £535 million. The main problem with building the barrier was that any constructed barrier would require an opening of around 500 m. The Thames Barrier consists of 10 gates weighing 1500 tonnes, each operated by hydraulic beams. The roof is made of stainless steel, Figure 6. All the gates are made of steel and can be raised in high or low tide and when in the open position rest level with the river bed, so navigation is not impeded.

Figure 6. Thames Barrier - built in 1983 to prevent London flooding. Copyrights: Colin Green, Flood Hazard Research Centre (FHRC)

Since it became operational in 1982 and until the end of 2004, the Thames Barrier has been closed on 88 occasions to protect London from flooding (54 times against surge tides and 34 times to stop high tides meeting heavy rainfall) but in the 6 month period from November 2000 to March 2001 the emergency closures happened 23 times. During the extensive flooding in the first week of January 2003, the Barrier was closed on 13 consecutive tides - a record breaking sequence, preventing the flooding of a number of properties at the top end of the tidal reach. Nearly all these closures were the result of a combination of factors including high spring tides, depressions in the North Sea, wind effects in the English Channel and high River flows.

St Petersburg, Russia

The City of St. Petersburg is located in the shallow and narrow Neva Bay in the east extremity of the Gulf of Finland of the Baltic Sea. Due to this location, long waves generated by storm winds accompanying deep cyclones passing over the Baltic Sea region are increased several times and this may lead to floods in the City. Floods with water height above 210 cm are referred to as very dangerous and above 300 cm as catastrophic ones. Since it's founding in 1703 there were about 300 floods in St. Petersburg and among them three catastrophic ones. Very close to catastrophic was the 1955 flood with 293 cm. As floods lead to significant damages and loss of human life, St. Petersburg is in need of flood protection.

The construction of the first local dams was started in the harbour after the flood of 1924. The project was revised only in the early 1960'ies, after the flood in October 1955. After 20 years of design studies, the construction was started in 1979. However, construction of the Barrier was suspended in 1987 as a result of concerns about the perceived negative environmental impacts of the barrier on the Neva Bay. An International Commission determined in 1990 that the impact of the Barrier on the environment was negligible and recommended prompt completion. The Barrier comprises eleven rock and earth embankment dams, six water discharge sluices to accommodate outflow from the river Neva and two navigation channels equipped with closing gates. The overall length of the Barrier is 25.4 km. In 2002, the European Bank for Reconstruction and Development (EBRD) funded a complex feasibility study, which led to the EBRD granting a $240 million loan to the Government of Russia. The works to construct the Barrier were restarted in 2004.

Venice, Italy

High flood waters have become a serious problem for the city of Venice. The risk of flooding has increased strongly since the beginning of the century. Severe inundations, when more than 90% of the city's surface is under water, are becoming more frequent. Besides the inconvenience this brings to Venetians and tourists, salty water lapping above Venice's foundations is eating away at the fabric and treasures of this unique and historic city. The city's total movement with regard to sea level is about 2.3 mm a year.

Another disastrous flood, such as the one the city suffered in 1966, may occur again in the near future. To reduce the hazard to the city and the negative impact on the activities in the lagoon, a flood warning system composed of statistical and hydrodynamic models has been developed. In the future this warning system will also be fundamental during the construction and for the efficient operation of storm surge barriers covering the three existing inlets of the lagoon.

The flood barrier gates are often referred to as MOSE, or the Moses gates, a name that comes from an experimental prototype called the modulo sperimentale elettromeccanico. The nearly €3 billion ($3.4 billion) scheme will comprise about 80 hollow gates embedded in the seabed at the three inlets to Venice's lagoon. When not needed, the gates will rest on the seabed, full of water. But when high tides threaten the city, compressed air will force water out of the gates. This will cause them to rise and act as a barrier to water trying to enter the lagoon. Despite lingering doubts over the gates, construction has begun with a breakwater at the Malamocco inlet into the lagoon.

Further Reading

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