Indicators for the Scheldt estuary

Safety against flooding

The mean high water levels in the Scheldt estuary show an increasing trend since 1888. The development of the mean low water levels is less straightforward. Since 1888 the location of the maximum mean high water level has moved upstream. The number of storm floods at Vlissingen and Antwerpen has increased in the period 1950 - 2000. Flood risks in the dike ring areas along the Westerschelde have, both in terms of number of casualties and economic values, decreased in 2005 compared with 1975. In the Zeeschelde basin the flood risk (damage) amounts to 1 billion euro per annum (situation 2006).

Why monitor this indicator?

Characteristic for the Scheldt estuary is the tidal influence. The tide penetrates the estuary from the North Sea and propagates far inland. The Westerschelde, Zeeschelde as far as the sluices in Merelbeke 160 km upstream of the mouth and (parts of the) tributaries Durme, Rupel, Kleine Nete, Grote Nete, Dijle and Zenne all experience this tidal influence. The tide has an important impact on a lot of factors, such as the development of 'ecotopes' or habitats, the distribution of species and habitats, the harbours and shipping, recreation, experience of the natural environment and safety against flooding. Storm floods, i.e. high water waves that exceed a certain level, also penetrate far into the estuary and can have serious consequences on the surrounding land and population. The floods of 1953 and 1976 have not been forgotten.

The target 2030 of the Long-Term Vision for the Scheldt estuary [1] therefore gives high priority to safety against flooding for people and economic values. Maximizing this safety is a crucial principle for both the Netherlands and Flanders. The safety level must be maximally maintained, within socially acceptable limits of risks and financial - technical feasibility.

Within the scope of the European Floods Directive [2], member states need to map flood risks in river basins and coastal areas by 2013. The subsequent reporting follows a six-year cycle. The flood risk is hereby defined as *the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event.* Before the end of 2015, member states need to establish flood risk management plans with special attention to prevention and protection against floods.

Flanders determines the safety objectives for the Zeeschelde basin, integrated with other aspects like naturalness, in the actualised Sigmaplan [3]. Specific measures are reinforcement and raising of dikes, giving back land to the estuary and the construction of Flood Control Areas (FCA's) or FCA's with Controlled Reduced Tide (FCA-CRT). In a FCA a specific volume of water is temporarily stored during storm flood, to reduce height of water levels. It is an area surrounded by dikes, that is sporadically flooded by the river. In a CRT, the tide daily penetrates tempered and an ecosystem adapted to floods may develop.

The National Water plan [4] gives the outlines on the Dutch policy concerning sustainable water management for the period 2009 - 2015. This plan focuses on the protection against floods, besides water use, quantity and quality. Prevention, sustainable spatial planning and disaster control are the three main pillars of the safety policy. In accordance with the 'Dutch Water Act' [5] the Netherlands also check every five years if the strength of the levees, such as sea and river dikes that protect against 'outside water', still comply with legal standards. For the dike ring areas along the Westerschelde (see figure 7) a mean exceedance frequency of 1/4.000 per annum is used as current safety standard. In other words, the dikes need to withstand high water levels expected in case of storms that occur once every 4.000 years. The national review in 2006 indicated that not all levees came up to the legal standards at that moment. For the dike ring areas along the Westerschelde 67 km of a total of 297 km of levees met the standards. 48 km did not meet the standards and for 182 km no judgement was available [6]. The 'Hoogwaterbeschermingsprogramma(('High water level protection programme') contains improvement measures to address those weak links.

As defined above, the flood risk consists of two components: the probability of flooding and the consequences. The probabilities of flooding depend on the strength of and pressure on the levees (see figure 1). High water levels and the occurrence of storm floods are some of the factors that determine the load to the levee (see part 1 under 'What does this indicator show?'). Low water levels influence on their turn the consequence of a flood: after a breach in the dike the following low water level determines whether - and to what extent - the flooded areas can drain before the next high tide[7]. The consequences of a flood can be split up into the amount of damage and the number of casualties, on their turn depending on the economic value and the population behind the dikes.

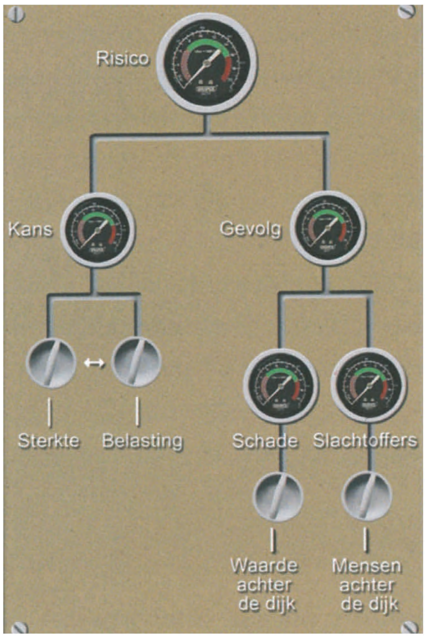

Figure 1: The flood risk is determined by the strength of and pressure on the dikes, the economic value and the population behind the dike. Source: Van Deen *et al.*, 2008 [8].

What does the indicator show?

Part 1: Water levels and storm floods in the Scheldt estuary

High water levels

The 10-year mean high water levels show a clear increasing trend in all 25 measuring stations in the Scheldt estuary. In the period 1991 – 2000 the mean high water level per measuring station was 37 to 127 cm higher than in the period 1888 – 1895. A historical reconstruction has shown that this trend has occured for a very long time (modelled data, see figure 2 [9]).

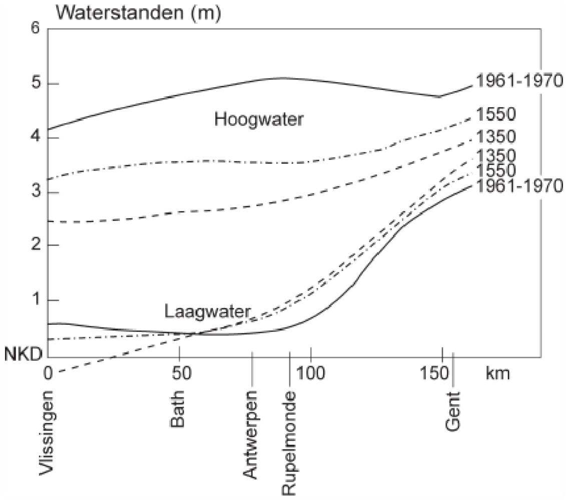

Figure 2: Historical development of the high and low water levels in the Scheldt estuary (expressed in metre NKD or 'Nul Krijgsdepot' this is m TAW - 8 cm (Tweede Algemene Waterpassing, 'Second General Levelling'). For more information on units the reader is referred to the technical fact sheet [10]). Source: modelled data; Coen, I., 2008 [9].

Figure 3 also shows that since the beginning of the more reliable measurements, the location of the maximum 10-year mean high water level has moved upstream along the Scheldt-axis (the value '0 km' on the x-axis corresponds the mouth of the Scheldt) for the 16 measuring stations in the Zee– and Westerschelde. Untill 1930 this location was situated at Antwerpen, 78 km from the mouth of the Scheldt, after which a gradual shift towards Temse, 98 km from the mouth of the Scheldt, appeared.

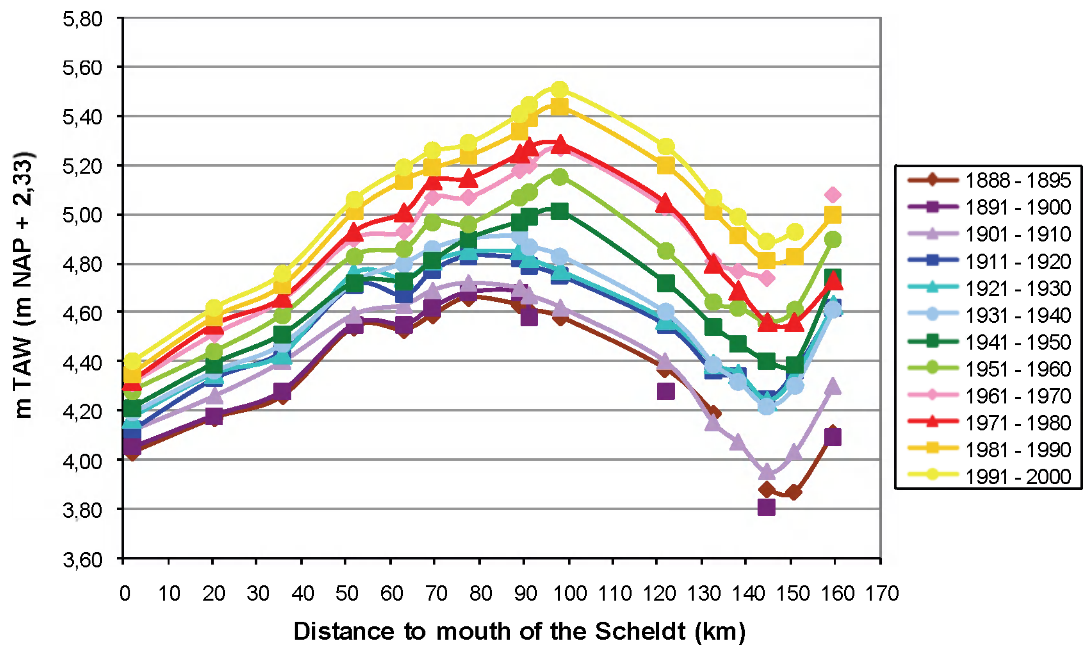

Figure 3: 10-year mean high water levels for the period 1888-2000 (Westerschelde - Zeeschelde). TAW = 'Tweede Algemene Waterpassing' ('Second General Levelling'); NAP = 'Normaal Amsterdams Peil', ('Normal Amsterdam Level'). Source: measurements Flanders Hydraulic Research.

Low water levels

Figure 4 shows that the development of the mean low water levels is less straightforward. In the eastern part of the Westerschelde and in the Zeeschelde (see e.g. reference point 100 km on the x-axis) they have (gently) decreased. On the contrary, mean low water levels have increased in the western part of the Westerschelde (see e.g. reference point 20 km on the x-axis). The curve of the mean low water levels from the mouth of the Scheldt (km 0) along the Scheldt gradient first shows a slight decline after which it strongly rises to smooth down further upstream. The beginning of the rise of the curve or the location of the minimum 10-year mean low water level has moved upstream since the beginning of the measurements. At the end of the 19th century it was situated at Lillo-Liefkenshoek (63 km from the mouth of the Scheldt) and on the end of the 20th century it was situated at Antwerpen (78 km from the mouth of the Scheldt).

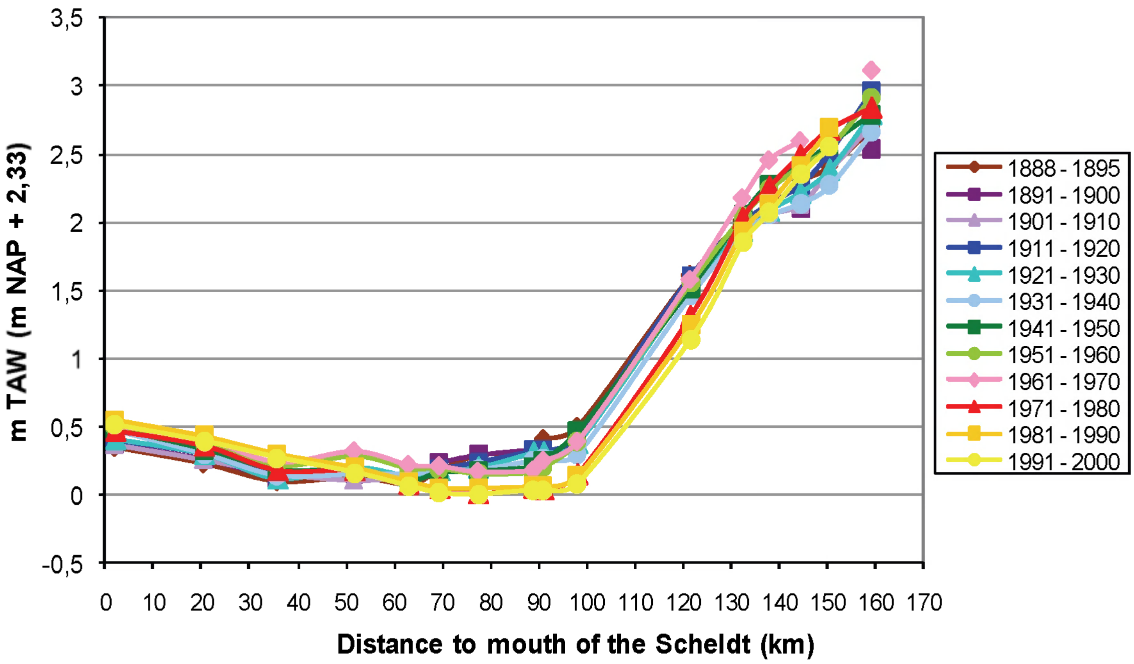

Figure 4: 10-year mean low water levels for the period 1888-2000 (Westerschelde - Zeeschelde). Source: measurements Flanders Hydraulic Research.

Storm floods

Flanders and the Netherlands use different classifications for storm floods.

In Flanders the term storm flood is used for a high water wave that penetrates the Scheldt estuary and propagates, with a high water level higher than 6,60 m TAW or 4,27 m NAP at the measuring point 'Antwerpen - Loodsgebouw' (storm tide). One speaks of an extraordinary storm flood respectively at high water levels higher than 7,00 m TAW or 4,67 m NAP (dangerous storm tide). The technical fact sheet of the measurement [10] gives further information on the units used.

Figure 5 shows the number of (storm) floods (floods higher than 6,50 m TAW together with storm floods higher than 6,60 m TAW, cf. data availability) and extraordinary storm floods (higher than 7,00 m TAW) that have ocurred sinds 1901 at Antwerpen - Loodsgebouw, for every decade. Since 1961 this number shows an increasing trend. In the current decade 23 storm floods have occurred already (based on data till 2008).

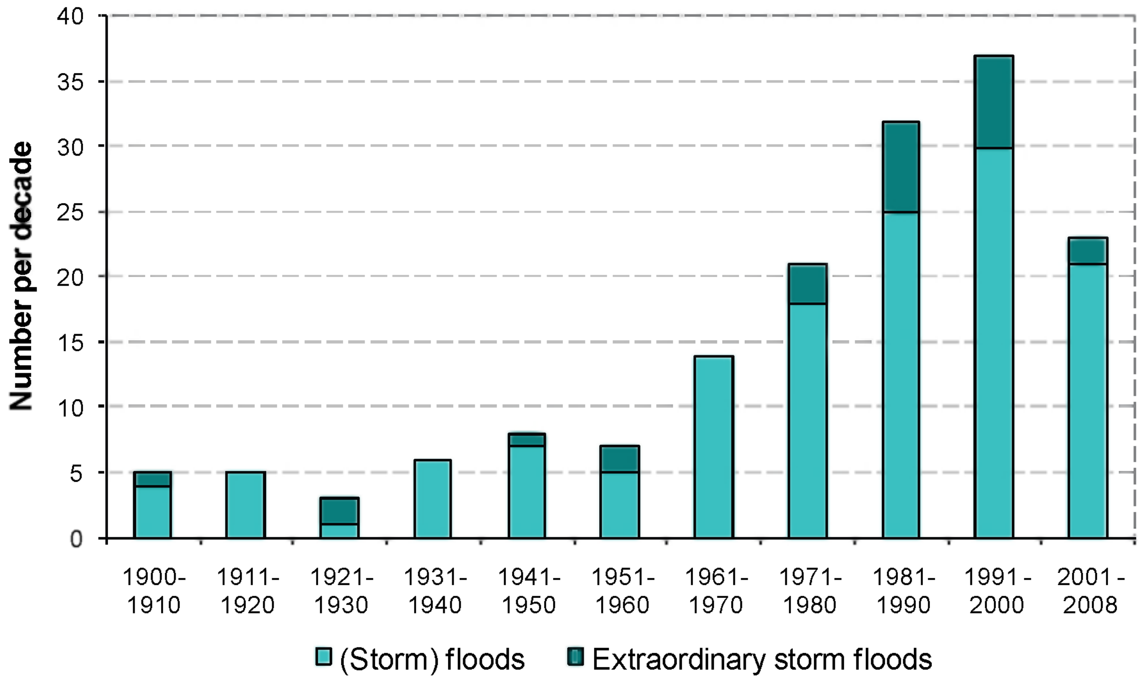

Figure 5: Number of storm floods per decade at Antwerpen - Loodsgebouw in the period 1900-2008. Source: measurements Flanders Hydraulic Research.

In the Netherlands one uses the term storm flood if the water is pushed up to a level that is on average exceeded once in two years or 0,5 times a year. In contrast with Flanders this definition is not based on water levels but on excess frequencies and normative water levels can rise as a consequence of sea level rise. The current classification for the measuring point Vlissingen is shown in table 1. At Vlissingen one speaks of a storm flood in current if legal context if water level reaches or exceeds 3,50 m NAP or 5,83 m TAW.

Table 1: Classification of high floods and storm floods based on excess frequencies and linked water levels at Vlissingen. In this information sea level rise up to and including 2011 is already accounted for. Source: Tide-tables for the Netherlands 2010 [11] .

Name of flood	***Excess frequency (average number of times per year)***	***Water level at Vlissingen (m NAP)***
High flood	5 to 0,5	3,05 – 3,50
Low storm floods	0,5 to 0,1	3,50 – 3,85
Middle storm floods	10^{-1} to 10^{-2}	3,85 – 4,40
High strom floods	10^{-2} to 10^{-3}	4,40 – 4,95
Exceptional high storm floods	10^{-3} to 10^{-4}	4,95 – 5,50
Extreme storm floods	$\leq 10^{-4}$	$\geq$ 5,50

Figure 6 shows, per decade, the number of high floods and storm floods that occurred in Vlissingen since 1881. From 1951 onwards, this number also shows a rising trend. In the current decade, only one (low) storm flood occurred (based on data until 2008).

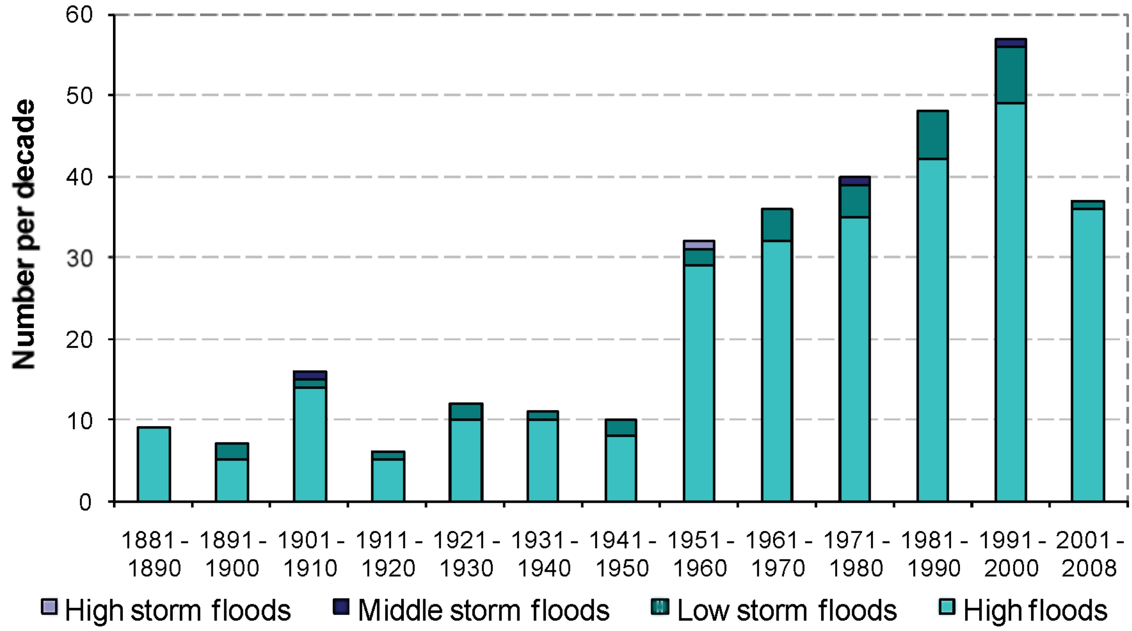

Figure 6: Number of high floods and storm floods per decade at Vlissingen following current classiffication for the period 1888-2008. Source: measurements Helpdesk Water, Directorate General for Public Works and Water Management (RWS).

Part 2: Flood risks

The Netherlands and Flanders use different modeling and source data to determine flood risks, based on the characteristics of a flood and its consequences. The currently calculated flood risks in Flanders and the Netherlands can not be visualized in the same graph. For more information see the technical fact sheets of the measurement [12].

This measurement includes, for the Netherlands, the estimated flood risks in terms of economic damage and fatalities per annum for the four dike ring areas along the Westerschelde (see figure 7). To estimate the flooding probabilities and consequences, which together form part of the estimation of flood risks, was departed from the situation in 2005. The probabilities and consequences in 1950 and 1975 were calculated back in time on this basis. With the results of the project 'Mapping Safety of the Netherlands 2'(Veiligheid Nederland in Kaart 2, VNK2, [13]) it is expected to have comprehensively calculated and (more) reliable data in 2012. The 'risk maps' that are currently available on the website http://www.risicokaart.nl include flood depth maps. This set has no information on flood risks in the sense of the definition (risk = probability x consequence) expressed in the number of casualties per annum and economic losses each year. The results of VNK2 will be used to improve the risk maps, to actualize the current system of standards and to set priorities in the 'Hoogwaterbeschermingsprogramma' ('High water level protection programme').

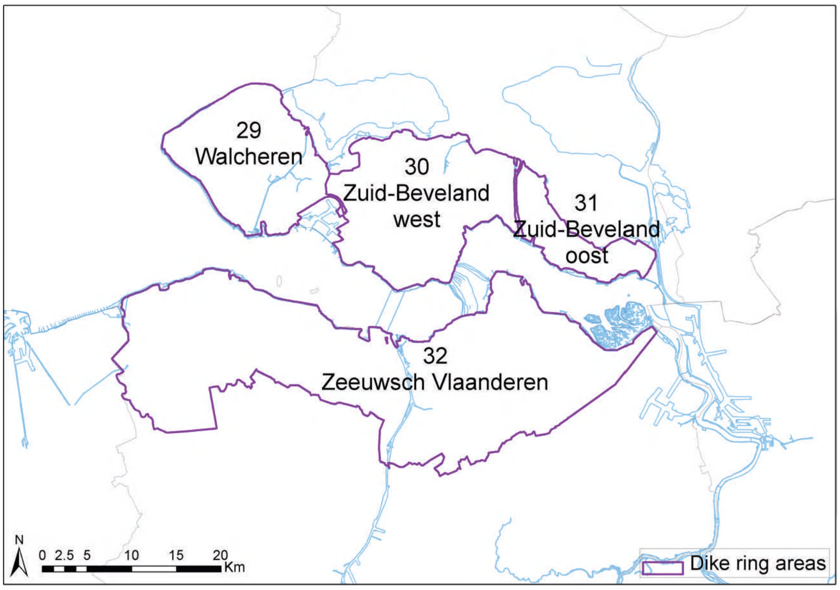

Figure 7: Map of the four dike ring areas (29, 30, 31 and 32) along the Westerschelde. Source: Directorate General for Public Works and Water Management (RWS), 2009.

Despite the fact that the estimated number of potential casualties in a flood has increased (because of the increase in population and population density), the estimated risk of victims (number / annum) has declined since 1950 for the four dike ring areas along the Westerschelde (see figure 8): the flooding probabilities in 2005 were ten times as small.

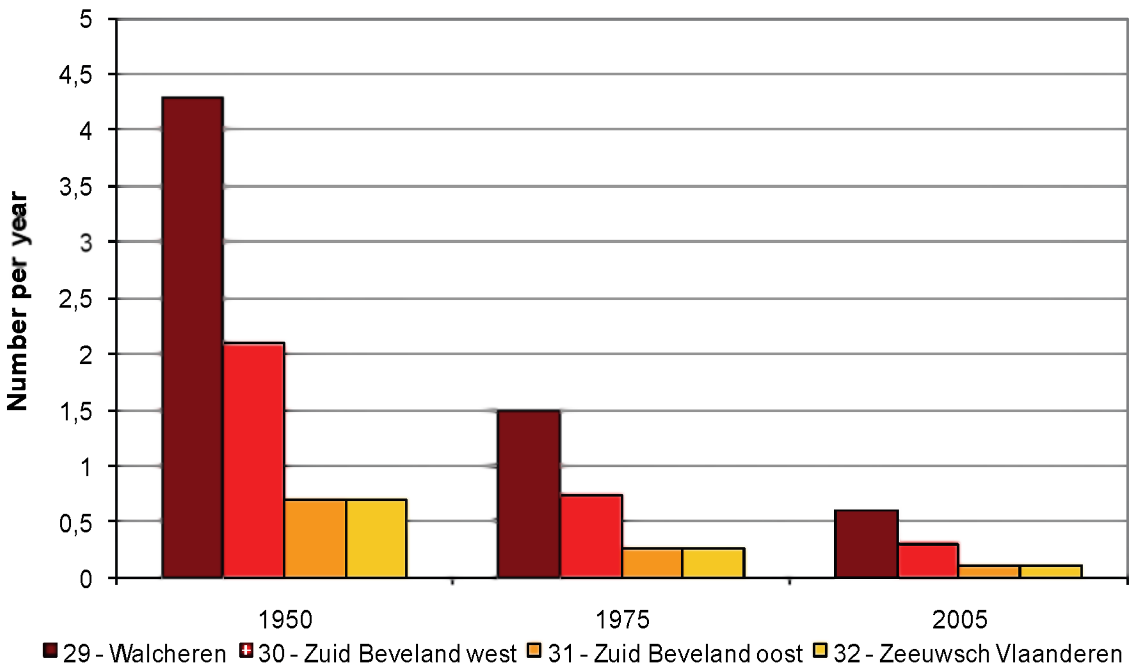

Figure 8: Estimated casualty risks (number per annum) for the dike ring areas along the Westerschelde 1950, 1975 en 2005. Source: van der Klis *et al.,* 2005 [14] .

The estimated flood risks for economic values (million euros per annum, in constant prices 2004) have increased in 2005 compared to 1950 (see figure 9). The estimated economic loss per dike ring in case of flooding in 1975 was on average six times higher than in 1950, while during the same period the flooding probability had only decreased by a factor of four. In the period 1975 - 2005, the rate of increase in potential economic losses in case of a flood (x 2) was slower than the rate of decrease in flooding probability (x 1/3), as a result of which the flood risks decreased again.

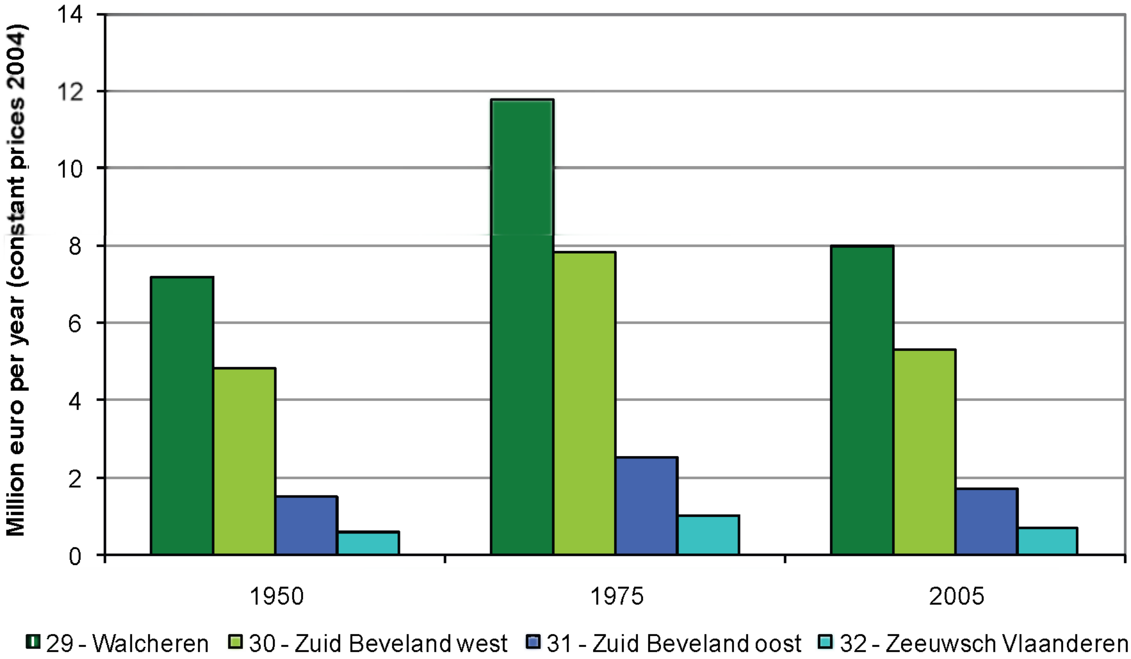

Figure 9: Estimated economical flood risks (billion euro per annum, constant prices 2004) for the dike ring areas along the Westerschelde 1950, 1975, 2005. Source: van der Klis *et al.*, 2005 [14] .

In Flanders, flood risk maps will be available when the visualization method for flood risks in the context of reporting for the European Flood Directive (starting in 2013) is standardized. A preliminary flood map - economic loss risk per annum - is available from one study, based on 1x1 km grids (see figure 10) [15]. Because of the coarse scaling of this map, the local conditions may be very different from this image. The global flood risk (damage risk) for the Scheldt basin or Sigma plan area is approximately 1 billion euros per annum according to this study (situation 2006).

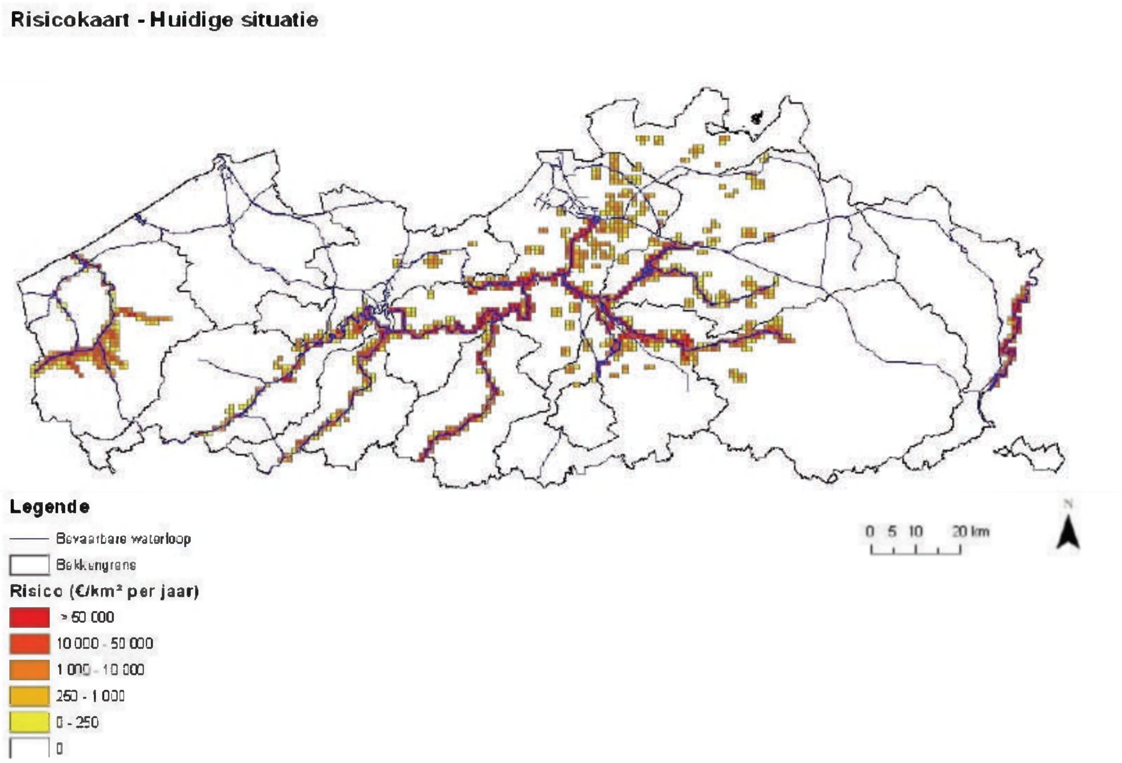

Figure 10: Risk map of Flanders. The map only contains economic loss risks and no casualty risks. Source: Vanneuville *et al.*, 2006 [15] .

Where do the data come from?

- Data on storm floods in Antwerpen, flood risks of the navigable waterways in Flanders and water levels are from Flanders Hydraulic Research. Data on storm floods in Vlissingen are based on tide data from the Directorate General for Public Works and Water Management (RWS), Helpdesk Water.

- The estimated flood risks of dike ring areas in the Netherlands are available from a publication of Deltares [14]. In the future, calculated flood risks will become available from the project 'Mapping Safety of the Netherlands 2' (VNK2) [13].

Opportunities and threats

The safety against flooding is not regarded as standalone function and objective any more. It goes hand in hand with other aspects in the Scheldt estuary and is, where possible, integrated with nature development and economic functions. The Flemish and Dutch policies are clearly focusing on this.

Both the Flemish and Dutch concept of safety has evolved towards a flood risk approach. The water safety policy does not focus solely on the further raising and/or strengthening of the levees (reducing flood probabilities) but also on aspects such as spatial planning and enforcing the appropriate safety levels (reducing the impact on economic values and casualties) in case of flooding. Based on this more integrated approach, the water safety policy can be monitored and adjusted. This approach will be developed, i.a. within the framework of the European Flood Directive.

The methods for calculating flood risks, differ in Flanders and the Netherlands and require further matching to evaluate the impact of policies in the future on a uniform and comparable way for the entire Scheldt estuary. Clearly defined targets for flood risks in relation to the assessment and reporting under the Long-term Vision can also help. In addition, the exceedance frequencies of the levees in the Netherlands are established in a legal framework (Wow, [5]).

The continuous change in physical conditions (climate change and rising sea level, frequency of storm floods, higher water levels, rainfall patterns ...) forces policy makers and water managers to stay alert concerning water safety.

Next to the raising and strengthening of the levees, 13 flood control areas or FCAs were defined in the Zeeschelde basin with the first Sigma plan in 1977 [16]. The total area of these FCAs was 1,133 ha, of which 533 hectares has already been realized (see figure 10). The most important FCA 'polders of Kruibeke - Basel - Rupelmonde (KBR)' is currently constructed and must be operational in 2011. Achieving sufficient safety against flooding due to storm floods from the North Sea was the only objective of the first Sigma plan. Since then, new insights in terms of multifunctionality of the estuary, water control and integrated water management led to a more sustainable approach of the safety issue. With the updated Sigma plan (2005, [3]), apart from the construction of FCAs, controlled reduced tidal areas (CRTs) are arranged in such a way that new estuarine nature can develop (see above). Furthermore, also tidal (depoldering: *allowing* reclaimed land to revert to flooding) and non-tidal (wetlands) natural areas are constructed that do not primarily have a water storage function (see indicator 'protection and development of natural areas'). Figure 10 gives an overview of the planned are of the water storage and flood control areas that need to be realized, following the phasing of the Most Desirable Alternative ('Meest Wenselijk Alternatief').

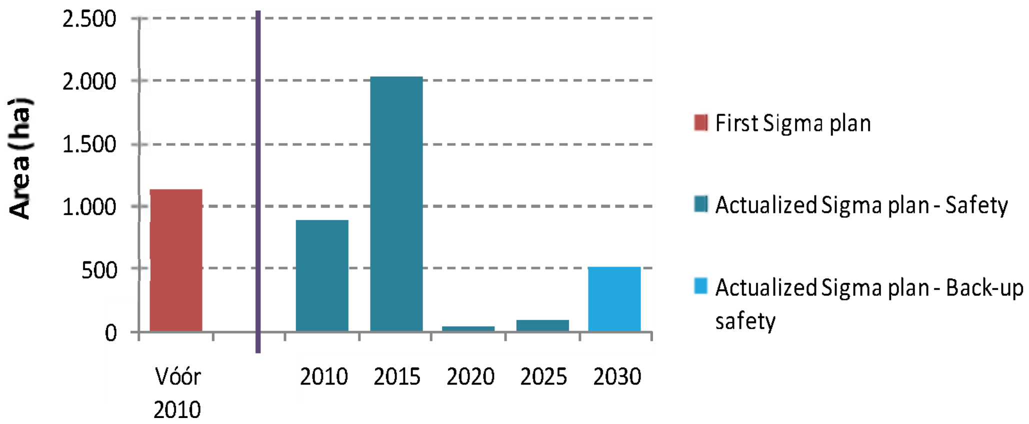

Figure 10: Overview of the planned area of the water storage infrastructure that needs to be realized under the first Sigma plan (1977) and following the phasing of the Most Desirable Alternative ('Meest Wenselijk Alternatief') of the actualized Sigma plan. Certain currently existing FCAs from the first Sigma plan, will be arranged in the updated Sigma plan, as a result of which the areas can not be added up. Source: Waterways and Sea Canal Agency ('Waterwegen en Zeekanaal') [16].

The effects of the measures from the (first and updated) Sigma plan on flooding probabilities and flood risks, normally should become evident by displaying the trend in flood risks along the Scheldt basin over time. The trend in the average high water levels was clearly rising until the last decade for which a full dataset was available (1991-2000). This trend continued, for the available years of the recent decade until 2008, at Antwerpen - Loodsgebouw. The delta works in the Netherlands (Delta plan 1954-1988, full project completed in 1997) have reduced the estimated flooding probabilities of the dike ring areas along the Westerschelde since 1950, but the economic risks have increased slightly because of the sharp rise in economic values within this dike ring areas.

The technical fact sheets from the measurements of this indicator describe the definitions, data, methodology and limitations. The sheets are available at: http://www.scheldemonitor.org/indicatorfiche.php?id=9

Integration with other indicators / measurements?

The tidal influence in the Scheldt estuary has a major impact on people and nature. The relative contributions of issues such as climate change, sea level rise, land reclamations and expansion of the navigation channel (see indicator 'soil interfering activities') on the occurrence of high water levels, increased tidal penetration and an increase in storm floods should be investigated in more detail [9, 17].

The flood risk approach entails that - next to flooding probabilities arising from water levels, strength of the levees and others aspects - land use and spatial planning (including development and distribution of residential areas) are important for the water safety policies (see indicator 'population pressure'). With the development of measures for flood protection in the updated Sigma plan and the Nature Plan ('natuurpakket') Westerschelde (estuarine) nature will be realized that creates new opportunities for the typical species and habitats of the Scheldt estuary (see indicators 'protection and development of natural areas', 'status of species and habitats'). 'Opportunities for the tourist and recreational sector' are created with the integration of walking and cycling routes and infrastructure for active perception of the natural environment. In this way, the social costs of maintaining safety standards are recovered and public support is created by broadening the social benefits.

How to refer to this fact sheet?

Anon. (2010). Safety against flooding. Indicators for the Scheldt estuary. Commissioned by the Maritime Access Division, project group EcoWaMorSe, Flemish-Dutch Scheldt Commission. *VLIZ Information Sheets*, 219. Vlaams Instituut voor de Zee (VLIZ): Oostende. 12 pp.

Online available at http://www.scheldemonitor.org/indicatoren.php

References

[1] **Directie Zeeland; Administratie Waterwegen en Zeewezen** (2001). Langetermijnvisie Schelde-estuarium. Ministerie van Verkeer en Waterstaat. Directoraat-Generaal Rijkswaterstaat. Directie Zeeland/ Ministerie van de Vlaamse Gemeenschap. Departement Leefmilieu en Infrastructuur. Administratie Waterwegen en Zeewezen: Middelburg, The Netherlands. 86 pp. + toelichting 98 pp., details

[2] Flood Directive (Directive 2007/60/EC)
http://ec.europa.eu/environment/water/flood_risk/index.htm

[3] **Couderé, K.; Vincke, J.; Nachtergaele, L.; Van den Bergh, E.; Dauwe, W.; Bulckaen, D.; Gauderis, J.** (2005). Geactualiseerd Sigmaplan voor veiligheid en natuurlijkheid in het bekken van de Zeeschelde: synthesenota. Waterwegen & Zeekanaal NV: Antwerpen, Belgium. II, 74 pp., details
http://www.sigmaplan.be

[4] National Water plan (NL): http://www.nationaalwaterplan.nl

[5] Water Act: http://www.rijkswaterstaat.nl/water/wetten_en_regelgeving/waterwet/

[6] **Inspectie Verkeer en Waterstaat; Rijkswaterstaat Dienst Weg- en Waterbouwkunde; Tekstbureau Met Andere Woorden** (2006). Primaire waterkeringen getoetst: landelijke rapportage toetsing 2006. Inspectie Verkeer en Waterstaat. Waterbeheer: Lelystad, The Netherlands. 16 + CD-ROM pp., details

[7] **Asselman, N.E.M.; Coen, L.; Peeters, P.; Vatvani, D.; Verhoeven, G.** (2009). LTV-O&M thema veiligheid deelproject 2: vergelijking Nederlandse en Vlaamse (maatgevende) waterstandsverlopen en modelleringswijzen voor de bepaling van overstromingskarakteristieken bij een doorbraak langs het Schelde-estuarium. Deltares: [S.l.]. ii, 87 pp., details

[8] **Van Deen, J.; Karstens, S.; Löffler, M.; Taal, M.; Wolters, H.** (2009). Onze Delta, onze toekomst: Staat en Toekomst van de Delta 2009. Deltares. ISBN 90-814067-3-4. 92 pp., details

[9] **Coen, I.** (2008). De eeuwige Schelde? Ontstaan en ontwikkeling van de Schelde. Waterbouwkundig Laboratorium 1933 - 2008. Waterbouwkundig Laboratorium: Borgerhout, Belgium. 112 pp., details

[10] http://www.scheldemonitor.org/indicatoren/pdf/SIF_waterstanden.pdf

[11] Tide tables for the Netherlands 2010, http://www.getij.nl/

[12] http://www.scheldemonitor.org/indicatoren/pdf/SIF_overstromingsrisico's.pdf

[13] Project 'Mapping Safety of the Netherlands (VNK 2)': http://www.projectvnk.nl

[14] **van der Klis, H.; Baan, P.; Asselman, N.E.M.** (2005). Historische analyse van de gevolgen van overstromingen in Nederland: Een globale schatting van de situatie rond 1950, 1975 en 2005. 44 pp., details

[15] **Vanneuville, W.; Maddens, R.; Collard, C.; Bogaert, P.; De Maeyer, Ph.; Antrop, M.** (2006). Impact op mens en economie t.g.v. overstromingen bekeken in het licht van wijzigende hydraulische condities, omgevingsfactoren en klimatologische omstandigheden. MIRA-onderzoeksrapporten, 02. 120 pp., details

[16] **Anon.** (1977). SIGMAPLAN: voor de beveiliging van het Zeescheldebekken tegen stormvloeden op de Noordzee. Ministerie van Openbare Werken. Bestuur der Waterwegen: Brussel, Belgium. 49 pp., details

[17] **Jeuken, C.; Hordijk, D.; Ides, S.; Kuijper, C.; Peeters, P.; de Sonneville, B.; Vanlede, J.** (2007). Koploperproject LTV-O&M - Thema Veiligheid: deelproject 1. Inventarisatie historische ontwikkeling van de hoogwaterstanden in het Schelde-estuarium. WL/Delft Hydraulics: Delft, Netherlands. 92 pp., details