Safety against flooding

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Verwaest, T., Thoon, D., Mertens, T., Monbaliu, J., Van Besien, P., Mostaert, F., Devriese, L., Pirlet, H. (2018). Safety against flooding. In: Devriese, L., Dauwe, S., Verleye, T., Pirlet, H., Mees, J. (Eds.) Knowledge Guide Coast and Sea 2018 - Compendium for Coast and Sea. p. 195-207.

In the 20th century, the average sea level on earth increased by 1.7 mm annually. Since the 1950s, a significant acceleration of the global sea level rise has been observed. Currently, the annual sea level increase has already reached 3.4 mm per year (global average), and thus exceeds the sustainability goal of a maximum increase of 2 cm each decennium (Brouwers et al. 2015). There is also increasing and explicit indication that man-made climate change is at the root of that acceleration. Thermal expansion of seawater and melting of ice sheets and glaciers accounted for 75% of sea level rise since 1971 (Source: https://en.milieurapport.be).

The statistical analysis of the measurements at the Belgian coast is not straightforward, given that the sea level is not only influenced by climate change but also by natural fluctuations. Nevertheless, the values show that the annual average sea level in 2017 was significantly higher than at the start of the measurements. In Ostend the trend line increased by 129 mm between 1951 and 2017 (figure 1) (Source: www.milieurapport.be). Significant increases have been recorded in Zeebrugge and Nieuwpoort as well. However, this increase does not seem to have continued in recent years (Brouwers et al. 2015). An approximate linear increase in flood levels of 20 cm per 100 years has been observed, with no significant acceleration or weakening of this long-term trend over the measurement period from 1925 to 2014 (Willems 2015). A study of the extreme high waters in Ostend shows that the storm surge – apart from the rise in the annual average sea level – does not show any separate or additional upward trend (Willems 2015). Climate change and the associated sea level rise also result in more intense erosion of coastal areas and a higher frequency of storm surges (EEA Technical Report 2010a, Balancing the future of Europe's coasts, EEA 2013), although no increase in the storm frequency in the Belgian part of the North Sea (BNS) has been observed so far (Van den Eynde et al. 2011, CLIMAR project BELSPO, Hossen and Akhter 2015). Neither has an increased erosion for the Belgian coast been demonstrated (see also CREST project). Brouwers et al. (2015) also provides an overview of the available scenarios with regard to sea level rise and storm surges off the Belgian coast.

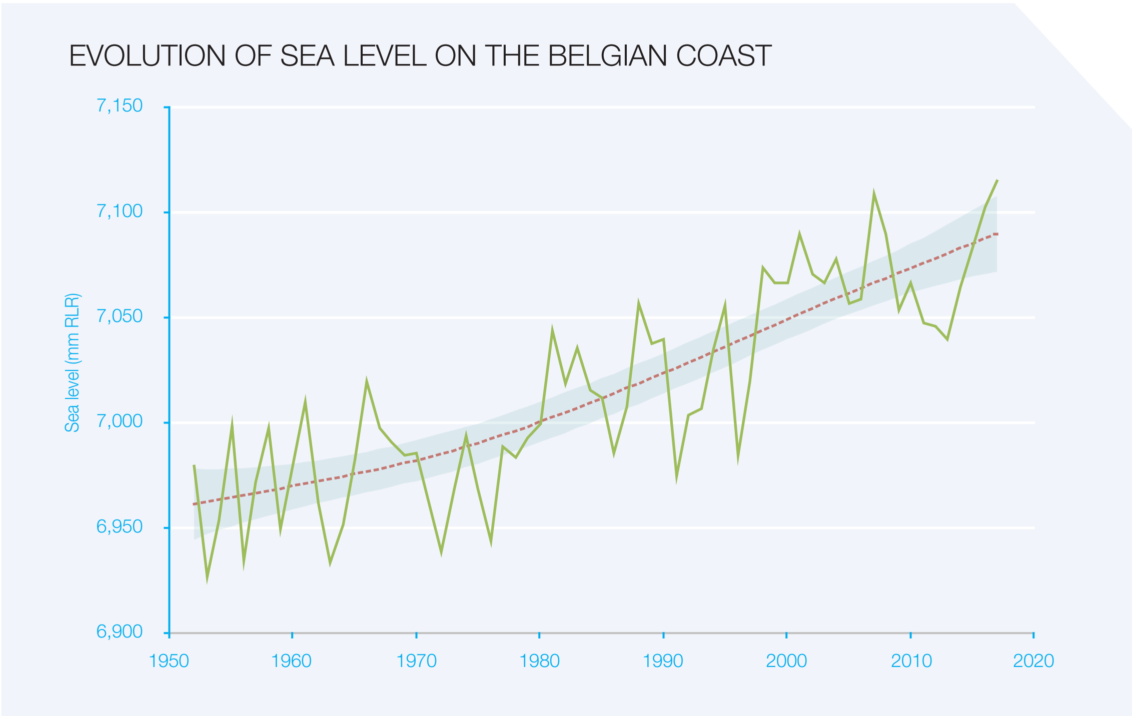

Figure 1. Evolution of sea level[1] on the Belgian coast (Ostend, 1951-2017) (Source: www.milieurapport.be).

The factors mentioned above increase the risk of flooding in low-lying coastal areas. A third of the EU citizens lives within 50 km of the coast. It is therefore estimated that coastal floods could impact up to 3.65 million people every year in Europe by 2100 (Vousdoukas et al. 2018). The regions with the highest risk of flooding driven by sea level rise and storm surges are the North Sea coasts of Belgium, the Netherlands and Germany, but also the Mediterranean coastal region of northern Italy (EEA Report 2017). The Netherlands and Belgium are among the most vulnerable

[1] Sea level is expressed in millimetres RLR (Revised Local Reference). The data from a local reference (for the Belgian coast it is the TAW or 'Tweede Algemene Waterpassing' (Second General Water Adjustment)) have been converted to the international reference level. Further on in the document, the usual TAW value is used, whereby instead of the average sea level at low tide in Ostend being used as the zero point, a 'fundamental point' was chosen, namely the point or reference mark GIKMN located in the Royal Observatory of Belgium in Ukkel. Since the RLR reference is an arbitrary agreement based on a fixed level, it is mainly used in time series as shown in this figure.

countries in the European Union, as more than 85% of the Belgian and Dutch coastal areas (zone up to 10 km inland) is below the level of an annual storm surge (+5 m TAW) (*EEA Report 2006*, *Eurosion*, *Balancing the future of Europe's coasts, EEA 2013*, *EEA Report 2017*). In Flanders, 15% of the surface area is less than 5 metres above the average sea level. Moreover, the Belgian coastline is the most built-up area in Europe: in 2000, over 30% of the coastal strip (up to 10 km inland) and almost 50% of the area up to 1 km inland was built-up. In West Flanders, 33% of the population live in low-lying polder areas that are prone to flooding caused by the sea (*Brouwers et al. 2015*). In addition to housing, the coastal zones of the Netherlands and Belgium are also home to important economic activities, partly due to the presence of seaports. As a result, in the event of a flooding, the loss of human life and property damage can be very high (*The European environment: state and outlook 2010. Adapting to climate change 2010*, *Kellens 2011*, *The Ports of Flanders 2017*, *EEA Report 2017*, *Coppens et al. 2018*).

The North Sea coast of Belgium is characterised by coastal dunes, sandy beaches and naturally soft foreshores (*North Sea Region Climate Change Assessment 2016*). A review of the Flemish coastal protection measures in 2007 and 2008 showed that approximately one third of the straight coast[2] and coastal ports needed additional protection against the impact of severe storm surges. Reference is made to design storms with water levels with a return period of 1/1,000 (*Brouwers et al. 2015*). The term 'superstorm' is sometimes used for super extreme storm surges (water level of +8 m TAW, from the NW, return period 1/17,000) (*Reyns et al. 2010*). The *Masterplan Coastal Safety* (approved by the Government of Flanders on 10 June 2011) describes the measures to be taken to ensure adequate protection of the coastline and the adjacent low-lying polders against a storm surge with a return period of 1,000 years with a time horizon[3] of 2050. Both 'soft' (beach nourishment, dune nourishment, etc.) and 'hard' coastal protection measures (storm walls, wave-damping extension of the seawall, etc.) will be realised.

In the meantime, the implementation of the *Masterplan Coastal Safety* is well advanced (see **13.5.2 An integrated approach to coastal protection**).

- Some of the most vulnerable zones, namely De Panne, Koksijde, Ostend (East Bank, Centre, Mariakerke, Raversijde), Middelkerke and Westende, and De Haan-Wenduine were already provided with beach nourishments.
- The seawall of De Haan-Wenduine was renovated and fitted with flood protection measures;
- In Blankenberge and Knokke-Heist, a pre-take of the beach nourishment as provided for in the *Masterplan Coastal Safety* has already been carried out;
- In 2014, the first phase of the flood protection measures was carried out in the port of Ostend;
- In June 2018, the first phase of the construction of a storm wall in the port of Blankenberge was completed and, in February 2018, preparatory works for the construction of the storm surge barrier were started in Nieuwpoort;
- In the near future, the security of the vulnerable zone Ostend-Raversijde-Mariakerke will be supplemented by a storm wall (Source: *website Coastal Division*);
- The adjustments to the seawall in Middelkerke-Westende and further flood protection measures in the ports of Ostend, Blankenberge and Zeebrugge are in the design stage.

The most recent review (situation 2015) has shown that approximately 10% of the straight coast does not meet the requirements set out in the *Masterplan Coastal Safety*. This is partly due to the fact that this Masterplan Coastal Safety has not yet been fully implemented and partly due to the need for maintenance of the nourishments provided. A maintenance programme for sandy coastal protection measures was therefore drawn up based on the recent assessment.

Flooding of low-lying polders due to heavy rainfall also occurs in the coastal area, but is not restricted to this zone. Nevertheless, it is important to take this kind of floods into account, especially given that by 2100, the change of rainfall may be 10% higher in the coastal area compared to the hinterland (*Van Steertegem 2009*). Due to the sharp increase in extreme, short-term rain showers, sewerage and other drainage systems will be placed under additional pressure in the future (*Brouwers et al. 2015*). An additional challenge in the coastal zone concerns the integration of flood risks from inland waters (such as the Yser) on the one hand and from the sea on the other (e.g. *Willems 2013*). However, this theme text largely excludes flooding of the hinterland.

Parallel to the drafting of the *Masterplan Coastal Safety* in 2009 an innovative vision was presented on the future development of the Flemish Coast, called 'Flemish Bays 2100' (*Projectgroep Vlaamse Baaien 2012*) through a new collaboration between a number of Flemish consultancy firms and entrepreneurs. Because of its innovative and sustainable character, several subprojects were considered by the Government of Flanders in an independent trajectory that culminated in the *Masterplan Vlaamse Baaien 2014* (see **13.5.2 An integrated approach to coastal protection**). In December 2017, the Government of Flanders initiated the Complex Project Coastal Vision, which aims

[2] Straight coast: the whole of the beaches, foreshore, dunes and seawalls.
[3] At present, the water level at sea is approximately 7 m TAW during a 1,000-year storm surge. The water level will rise as a result of sea level rise. The Masterplan Coastal Safety uses the following assumptions about sea level rise: + 30 cm by 2050, + 80 cm by 2100 (compared to the year 2000).

to develop a long-term approach for the protection of the Flemish coast, with a time horizon of 2100. It is important to note that even after 2050 the average annual sea level and the level of a 1,000-year storm surge will continue to rise under the influence of global climate change.

In cooperation with the Coastal Department, VMM has drawn up the '*Flanders Climate Portal*' in which the state of the climate is mapped out using maps, key figures and graphs. In this portal, the current climate situation (temperature, precipitation, etc.), the effects (flooding, heat, drought) and the impact (victims, costs) of climate change can be consulted, but also climate scenarios up to 2100 can be framed. Comprehensive long-term climate scenarios are published by the Intergovernmental Panel on Climate Change (*IPCC*). Such estimates provide a deeper insight into the social importance of coastal protection measures and safety against flooding in general.

13.1 Policy context

In 2007, the *High Waters- or Floods Directive* (2007/60/EC) was adopted in response to concerns about the harmful effects of floods on people, nature, heritage, economy, etc., and the possible increase in the number of floods in the context of climate change. The directive applies to all European coastal and inland waterways. Furthermore, since 2013, Europe has a strategy for adapting to climate change (COM (2013) 216, *website Climate Adapt*) which includes the impact on coastal areas. The opinion of the European Committee of the Regions (*2017/C 207/18*) makes policy recommendations based on the mid-term evaluation of the LIFE programme on a European strategy for climate change adaptation.

Since 1980, the policy concerning water management has been a competence of the regions (law of 8 August 1980). The most important legislative instrument within this policy concerns the *decree on integrated water management* of 18 July 2003, amended in 19 July 2013, which since 2010 provides for the Flemish transportation of the European Floods Directive. The *Coordination Commission Integrated Water Policy* hosts the deliberation in Flanders between the various policy domains and administrative levels involved in water policy. The policy context and the division of competences in Belgium and Flanders with regard to water policy is discussed in detail in the river basin management plan for the Scheldt and the Maas (*Programme of measures for the River Basin Management Plans for Scheldt and Maas 2016-2021*, *River basin management plans for Scheldt and Maas 2016-2021*), and a river basin management plan for the Belgian coastal waters (2016-2021) (*River basin management plan Belgian coastal waters 2016-2021*) (see also themes **Nature and environment** and **Scheldt Estuary**).

In Belgium, almost all coastal policy is regulated at the Flemish level. Although the federal government is competent seaward from the baseline (low-water line), the Government of Flanders also has some powers with an impact beyond the baseline, e.g. coastal protection measures (coastal safety) and the maintenance of the navigation channels to the four Flemish seaports. Specifically for floods from the sea, the *Coastal Division* (part of the Maritime Services and Coastal Agency – MDK, which falls under the Flemish policy area of Mobility and Public Works - *MOW*) is responsible for the safety of the Flemish coast against flooding. A policy is followed whereby the coastal protection measures are subjected to a safety test every six years. For this test, basic safety must be guaranteed in all coastal zones, namely protection against a storm surge with a statistical return period of 1,000 years. Within the framework of the *Masterplan Coastal Safety*, *Flanders Hydraulics*, in collaboration with the Coastal Division, also has drawn up flood maps and associated estimates of casualties and damage to the coastal area in the event of a storm surge (see also: the *geoloket* of waterinfo.be). These flood risk calculations will be updated on a regular basis. The most recent results have been determined for the situation in 2015 (*Ruiz Parrado et al. 2017*, *Vanneste et al. 2018*). The Masterplan Coastal Safety with time horizon 2050 and the *Complex Project Coastal Vision* (partly building on the project 'Vlaamse Baaien', which was initiated by a number of market parties but later adopted in the policy domain Mobility and Public Works) with time horizon 2100 of the Government of Flanders are elaborated in more detail in the section **13.5 Sustainable use**. In addition, the *Sigmaplan* of the Government of Flanders should also be mentioned. This plan regulates flood protection from the Scheldt and its tributaries, and runs until 2030, but is not discussed in detail here (see also theme **Scheldt Estuary**, *ScheldeMonitor* and the *VNSC* website).

Belgium and Flanders, each within their own competences, are committed to both mitigation and adaptation to climate change. This involves adaptation of natural and human systems to the current and expected consequences of climate change and is translated into the Flemish Adaptation Plan (FAP), part of the Flemish Climate Policy Plan (VKP) (*Voortgangsrapport 2015 Vlaams Klimaatbeleidsplan 2013-2020*). In order to realise all coastal protection measures, the environmental legislation needs to be respected by the drafting of Environmental Impact Assessments (EIA). Moreover, building permits must also be granted for the implementation of hard measures. This means close cooperation with, in particular, the Royal Belgian Institute of Natural Sciences (RBINS), the Agency for Nature and Forest (*ANB*), which falls under the Flemish policy domain Environment, and the Environment Department (*Omgeving*) with regard to the issue of building permits.

Since 100% safety can never be guaranteed, emergency plans are still needed. All coastal municipalities have to develop a municipal emergency plan against flooding from the sea (Special Emergency and Intervention Plan for flooding, in short 'BNIP floods'). If the (expected) impact of a storm surge exceeds the municipal level, the emergency planning is scaled up to the provincial level or even to the national level if this is no longer possible within the provincial emergency planning. The *province of West Flanders* is competent for the format and coordination of a provincial BNIP floods. The Crisis Centre of the FPS Home Affairs can take over the coordination by e.g. deploying the National Emergency Plan for 'Floods and High Water'.

13.2 Spatial use

The *Masterplan Coastal Safety* discusses the demarcation of areas of particular attention along the Flemish coast, as well as the necessary protection measures for each of these zones (see **13.5.2 An integrated approach to coastal protection**). The status of the works in these zones can be found on the following website: *www.afdelingkust.be*. The spatial distribution of the flood hazard (the physical characteristics of floods such as extent and depth) and the flood risks (potential negative consequences for humans, environment, heritage, etc.) are available for Flanders on the *geoportal* of waterinfo.be. For the Complex Project Coastal Vision, the use of space is elaborated in the alternative study (AON – Alternatives Research Note).

The protection of the coast is also discussed in the marine spatial plan (MSP, RD of 20 March 2014, see also *Van de Velde et al. 2014*). This vision paper stipulates certain spatial policy choices with regard to coastal safety (the raising and widening of beaches, raising of sandbanks off the coast). In the context of the implementation and support of the Masterplan Coastal Safety, sufficient sand and gravel extraction areas are demarcated in function of soft coastal protection (see also theme **Sand and gravel extraction**). In addition, a zone has been demarcated for the study of wave propagation in shallow coastal areas in the proximity of the Broers Bank in cooperation with the Coastal Division (*studieproject Meetnet Vlaamse Kust – Broersbank*). In consultation with the Flemish minister responsible for Coastal Safety, the new MSP for the period 2020-2026 will also include provisions to support the guarantee of safety against flooding of the coastal zone in the longer term. One of the provisions anticipates an area intended for the construction of a pilot island for coastal protection (*MSP 2020-2026, public consultation 2018*). As the plan is not yet final, changes may still occur.

13.3 Societal interest

13.3.1 Damage and casualties in case of floods

A study has been conducted to determine the protection measures of the *Masterplan Coastal Safety*. In addition to the safety tests of the sea barrier, flood risk calculations have been executed. In these calculations, the number of casualties and economic damage to be expected in 2006 for a range of (super)storms were examined (*Meire et al. 2011*). In 2015, the 2006 calculations were updated (*Vanneste et al. 2018*). Table 1 summarises the updated calculation results for a range of extreme storm surge levels. It is noteworthy that direct economic damage in absolute terms is higher than previously reported figures. This is due, on the one hand, to improvements in the LATIS software (developed by the department of Mobility and Public Works of the Government of Flanders and Ghent University) and, on the other hand, to an update of the monetary value of the buildings and infrastructure on the coastal protection measures and the coastal plain. The ongoing spatial developments in the coastal region further increase the potential economic and human losses. The damage that a storm with a certain probability of occurrence can cause is becoming ever greater (*Plan-MER for the Integrated Coastal Safety Plan: notification 2009*, *Kellens 2011*). However, compared to the previous calculation in 2006, a decrease in the damage and the number of victims is observed for the situation in 2015, if the same (monetary) basic data are used as input in the calculations. This is due to the measures already implemented in the framework of the Masterplan Coastal Safety.

The return period indicates the repeat period of an event (storm, storm surge). A return period of 100 years means that there is an average of 1 chance out of 100 that a certain event will occur in the coming year. It is interesting to note that with an additional sea level rise of about 50 cm, the current return period for a level of + 7.5 m TAW will shift from 1 change of 1,000 to 1 change of 100 per year (table 1).

In the context of the Masterplan Coastal Safety a map has been drafted with the distribution of the inundated area during a 1,000-year storm surge under the conditions present in 2015 (figure 2). The largest damage risk is situated in the four ports, which are also the weakest areas in terms of coastal safety. Prior to the implementation of the Masterplan Coastal Safety, the seaside resorts scored badly in the areas of Ostend centre, Ostend-Raversijde, Ostend-Mariakerke, Ostend-Wellington and De Haan-Wenduine. Also, the damage risk in Middelkerke-Westende was

Table 1. **An overview of the flood risks in 2015 in the Belgian coastal area for different storm surge levels and return periods, with the associated deaths and the direct economic damage (*Vanneste et al. 2018*). (These figures also include flood risks in the outskirts of Zeebrugge, albeit with simplified assumptions.)**

Flood risks in the Belgian coastal zone			
Storm surge level	Return period	Deaths	Direct economic damage
+ 6,5 m TAW	~100 year	40	1.061 billion euro
+ 7,0 m TAW	~1,000 year	215	3.884 billion euro
+ 7,5 m TAW	~4,000 year	570	6.873 billion euro
+ 8,0 m TAW	~17,000 year	2147	10.491 billion euro

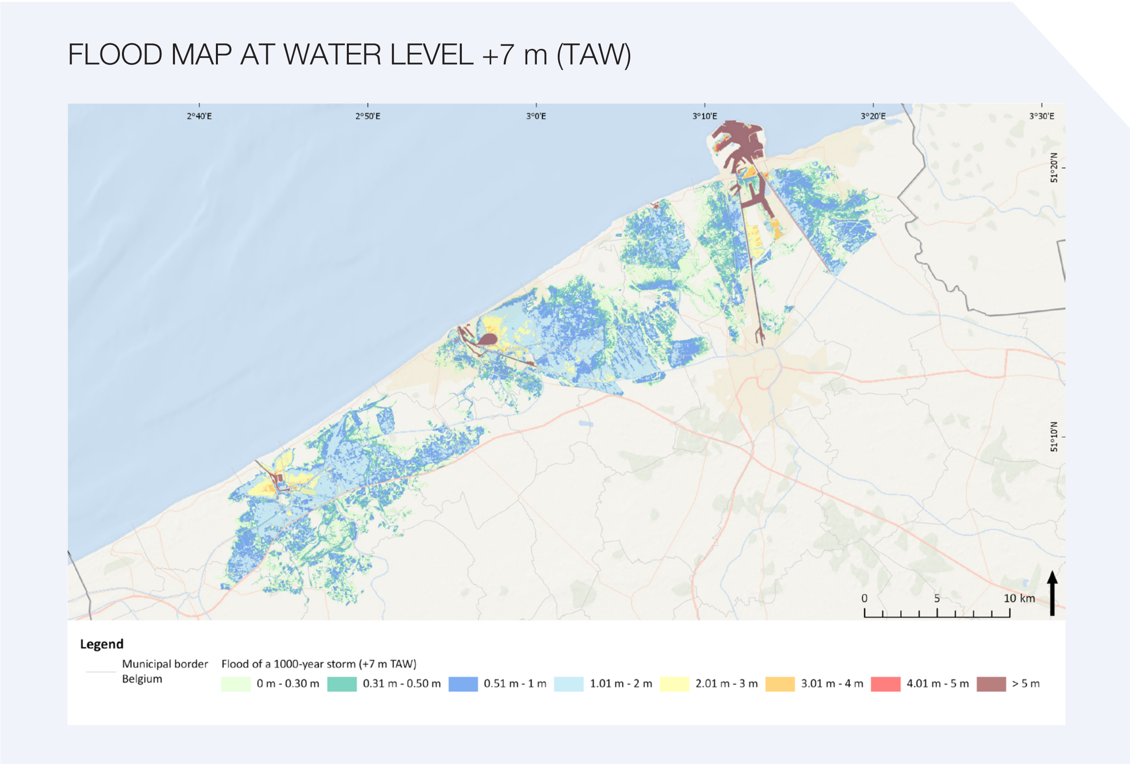

Figure 2. Calculation of the spread of flooding during a 1,000-year storm surge (+7.0 m TAW storm) under the conditions in 2015 (*Masterplan Coastal Safety*, *Ruiz Parrado et al. 2017*).

relatively high and the expected number of casualties in these zones was not socially acceptable. In the meantime, the risk has been reduced in the seaside resorts by carrying out the nourishments provided for in the Masterplan Coastal Safety.

The LATIS software was developed in Flanders, which calculates both risk and damage for the Flemish region. This instrument allows to determine the economic and human losses in case of a flood. The software is currently being extended with new modules that make it possible to chart the ecological, social and cultural impact of floods (LATIS version 4) (*Beullens et al. 2017*).

The potential economic loss and economic risks in the event of flooding can be consulted for the Flemish region using the following *geoportal* on waterinfo.be.

13.3.2 Investments in coastal safety

In Europe, it has been estimated that a total of 15.8 billion euro will have been invested between 1998 and 2015 in order to protect the coastline against floods and erosion (*Balancing the future of Europe's coasts, EEA 2013*). In the *ClimateCost* project (2009-2011), the associated costs have been calculated using different future scenarios (*Brown* *et al. 2011*). Other European projects dealing with this issue include *Theseus* (2009-2013), *CLAMER* (2010-2011), *ANCORIM* (2009-2012), *COASTANCE* (2007-2013), *CoastAdapt* (2009-2011) and *SCAPE* (2016-2020).

The total cost of the investment of the *Masterplan Coastal Safety* is estimated to be more than 300 million euro. The renovation and reinforcement of sea locks, weirs and other constructions in the ports constitute a considerable share of this estimate.

The estimated volume of sand for maintaining the new beaches amounts to an annual average of 600,000 to 700,000 m^3. Prior to the Masterplan Coastal Safety, the Flemish beaches were replenished with an annual average of 550,000 m^3 of sand (both by means of pressure pipes and trucks) (figure 3) (*Maelfait and Belpaeme 2007*, *Vandewalle et al. 2008*, *Masterplan Coastal Safety*). Figure 3 shows the annual volumes of sand supplied for beach and foreshore nourishment. Beach nourishment contributes directly to coastal safety, foreshore nourishments rather indirectly as a possible method of beach maintenance. An important reason for the large quantities of sand supplied in 2014 and 2017 is the emergency nourishment after major storms (e.g. *Sinterklaasstorm* in December 2013, storm Dieter in January 2017) (see also theme **Sand and gravel extraction**). The foreshore nourishment in 2014 was constructed in Ostend-Mariakerke and is a pilot project in which the Coastal Department and Flanders Hydraulics wish to assess the effectiveness of a foreshore nourishment as an 'alternate feeding method' for the beaches. The data and results of this research project also serve to build up further knowledge about coastal morphology. In 2017, a foreshore nourishment was erected to the east of the port of Nieuwpoort, as nature compensation for works in and around the port of Ostend. This foreshore supplementation is also being monitored in the context of the research into 'alternative feeding methods' for the beaches.

In addition, the Government of Flanders is investing in research into how to incorporate coastal safety in the spatial development of the coastal zone in a sustainable and cost-effective manner. This is done, for example, in the *CREST project* (SBO programme, *Innovation and Business Agency 'VLAIO'*) (see also **13.5 Sustainable Use**; *Status Crest Research 2017*).

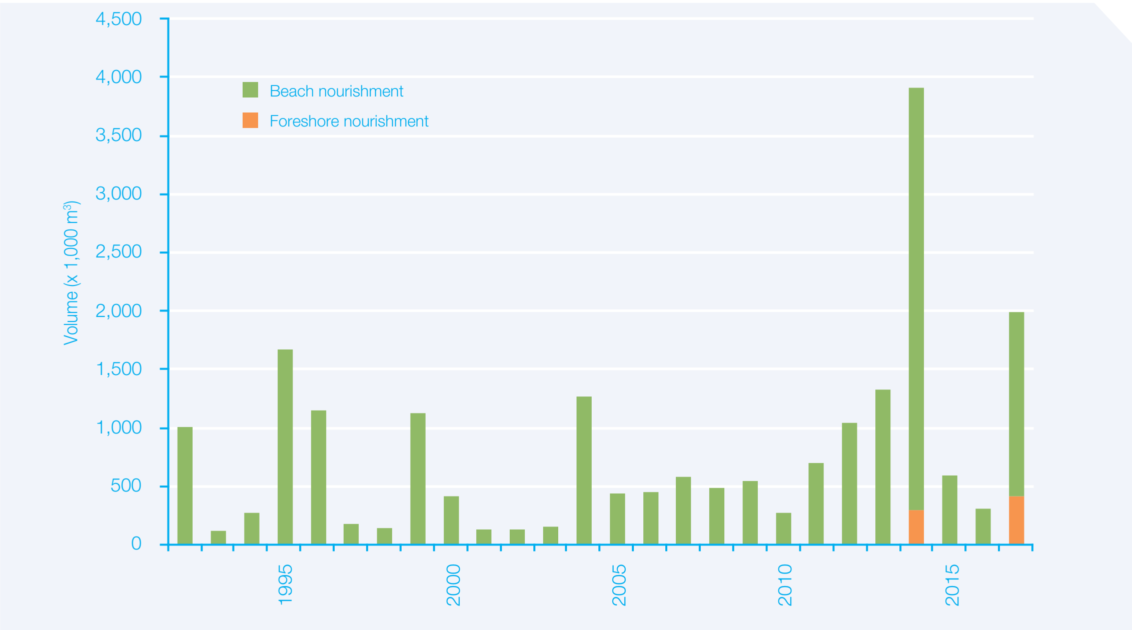

Figure 3. Evolution of the annual volumes of sand supplied for beach and foreshore nourishment (Source: Coastal Department). In the case of beach nourishment, sea sand is applied via dredgers above the low-water line. For pre-shore nourishment, the sand is applied below the low-water line.

13.4 Impact

The coastal protection works and infrastructure along the Flemish coast have, depending on the technique used, an impact on certain environmental aspects. The hard and the soft protection works are therefore subject to the European *EIA Directive* (2014/52/EU), which implies that an environmental impact assessment (EIA) report needs to be drafted prior to the granting of any environmental permit.

In general, the EIA studies of the *Masterplan Coastal Safety* estimate the environmental impact that may appear during the construction, subsequent to the execution and during the maintenance works. The effects need to be considered as potential effects, which depend on the section of the coast. The impact of the extraction of the necessary raw materials (e.g. offshore sand extraction) has been included in separate EIAs. Table 2 provides an overview of the potential effects which need to be considered during the assessment of coastal protection measures, as well as the associated literature which deals with these effects. A more detailed description is given in the following publications: *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting (2009)*, *Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende (2007)*.

In addition to a general EIA plan that maps out the environmental effects of the protection measures of the *Masterplan Coastal Safety* as a whole, a project-EIA may be needed to evaluate the local effects of the individual projects. In 2016, for example, the project-EIA for the storm surge barrier in Nieuwpoort was approved (*Environment, Nature and Energy Department 2016*). However, in most cases an exemption from the project-EIA can be requested.

Table 2. An overview of the potential effects that have to be taken into account when evaluating coastal protection measures, as well as the related literature.

Discipline	Potential effects	Literature
Water	-Turbidity of the water column -Modification of the flow pattern and the currents of the sea water -Hydrological effects – changing groundwater levels in the dunes and adjacent areas -Changes in the groundwater quality (depending on the quality of the replenished sand)	*Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*, *Lebbe 2011*
Sea	Impact on the present seabed, beach, dune and polder soils (degree of soil disturbance) and the effect on the morphology	*Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*, *Houthuys 2012*, *Van den Eynde et al. 2012*, *Janssens et al. 2013 (QUEST4D project BELSPO)*, *Houthuys et al. 2014*, *Colson et al., 2016*, *INDI67 BELSPO project*
Air	Emissions into the air and their impact on human health	*Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*
Noise and vibrations	Noise impact on humans and animals and the effects on human health	*Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*
Landscape, archaeology and architectural heritage	-Functional fragmentation of the spatial use -Visual-spatial effects of adding or changing landscape elements -Disappearance and disturbance of the historical geographical elements and structures -Effects on the architectural heritage and archaeology	*Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*
Fauna and flora	-Effects on the habitat, vegetation, benthos and avifauna -Creation of habitats due to the expansion of dry beaches and dunes -Barrier function for benthos	*Engledow et al. 2001*, *Speybroeck et al. 2004*, *Volckaert et al. 2004*, *Speybroeck et al. 2006a*, *Speybroeck et al. 2006b*, *Speybroeck et al. 2007*, *Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Van Ginderdeuren et al. 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*, *Janssen and Rozemeijer 2009*, *Braarup Cuykens et al. 2010*, *Vanden Eede and Vinckx 2011*, *Vanden Eede 2013*, *Van Tomme 2013*, *Van Tomme et al. 2013*, *Vanden Eede et al. 2014*, *Colson et al. 2016*
Mobility	Modifications in the accessibility	*Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*
Spatial use (Human - Space)	-Modifications in the access possibilities -Modifications of the recreational area -Modification of functions -Nuisance	*Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*
Human – health and safety aspects	-Possible health effects, due to the exposure to polluted air, noise emissions and vibrations -Changes in the safety of recreationists or inhabitants, due to changing sea currents, or due to the placement or removal of obstacles, or general modification of coastal safety	*Plan-MER – Plan voor kustverdediging en maritieme toegankelijkheid van Oostende 2007*, *Geïntegreerd Kustveiligheidsplan. Niet-technische samenvatting 2009*

13.5 Sustainable use

13.5.1 Floods directive

In the context of the *EU Floods Directive* (2007/60/EC), the Member States monitor the river basins and associated coastal areas that are vulnerable to floods. Flood hazard maps (physical properties of a flood such as the distribution and depth) and flood risk maps (potential negative effects on humans, environment, heritage, etc.) need to be elaborated by the Member States in accordance with this directive. In the case of Flanders, these maps can be consulted on the following *geoportal* (waterinfo.be).

The Member States need to develop flood risk management plans at river basin level, and align them with the neighbouring countries. In Flanders, these flood risk management plans are integrated into the river basin management plans that have been drafted in the context of the *European Water Framework Directive* (2000/60/EC) (WFD; see theme **Nature and environment**). The flood risk management plans of the Flemish coastal area are integrated in the river basin management plan of the Scheldt river (*Programme of measures for the River Basin Management Plans for Scheldt and Maas 2016-2021*, *River basin management plans for Scheldt and Maas 2016-2021*), and a river basin management plan for Belgian coastal waters (2016-2012) (*River basin management plan Belgian coastal waters 2016-2021*) (see themes **Nature and environment** and **Scheldt Estuary**).

This thematic document largely excludes flood risks from inland waterways. In Flanders, the Coordination Committee on Integrated Water Policy (*CIW*) coordinates the procedures for the drafting of all required documents for the WFD and the Floods Directive. Furthermore, an instrument such as the *water test* (*watertoets*) also contributed preventively to the restriction of the damage caused by floods.

13.5.2 An integrated approach to coastal protection

Considering the many user functions that are active in the coastal zone, Europe formulated a recommendation on integrated coastal zone management (ICZM, *2002/413/EC*). In this context, deliberations between services with competences with regard to the coastal zone are organised by the *Coastal Territorial Cooperation* of the province of West Flanders. The following section will elaborate on policies, studies, projects and initiatives which deal with coastal safety in an integrated way.

A resilient coast can withstand influences or fluctuations in the environment and will not change substantially due to natural processes and sustainable use. Dynamic coastal protection measures were defined as a core element for a sustainable coastal ecosystem in Flanders according to the Ecosystem Vision for the Flemish Coast (2017), which provides an ecological assessment framework for further development of coastal protection measures in the long term (*Van der Biest et al. 2017a*, *Van der Biest et al. 2017b*). At the end of the 20th century, the vision of coastal safety changed from a focus on 'hard measures' (such as seawalls) to a focus on 'soft measures' (sand). The coastal protection measures most used in Flanders is sand nourishment. This has contributed to an increase in the demand for sand (see also theme **Sand and gravel extraction** and figure 3). The Ecosystem Vision for the Flemish Coast (2017) is a supporting document for new interventions in the field of flood safety.

VISION FOR AN INTEGRATED APPROACH TO COASTAL SAFETY

In 2017, the Flemish Bays Initiative was reformed into the *Complex Project Coastal Vision*. A complex project is a new process approach developed by the Government of Flanders for projects with a major social and spatial impact. The aim is to realise projects within an acceptable period of time and with the widest possible support. The process approach consists of four phases: the exploration phase, the research phase, the development phase and the implementation phase. In December 2017, the initial decision of the Complex Project Coastal Vision was approved and the research phase was started. This specific complex project focuses in the first place on coastal safety but also looks at possible economic, social and natural benefits (see also *Rondelez et al. 2018* with the East Coast as focus area). In addition, the potential of pilot projects is being investigated in order to gather knowledge. In *Rondelez et al. (2018)* an overview is provided of the scientific knowledge available for these topics in recent years (table 3).

The new Ecosystem Vision for the Flemish Coast (*Van der Biest et al. 2017a*, *Van der Biest et al. 2017b*) deals with various potential natural flood protection measures, such as shallow sandbanks, foreshores and nourishments, submerged reefs, mud flats, tidal marshes and intertidal sandbanks; and dunes. The objectives of these studies were to develop an integrated vision for the Flemish coastal region and the development of an ecological assessment framework to assess the long-term future development of coastal protection measures in terms of its impact on the feasibility of the desired situation. The second sub-report, *Van der Biest et al. (2017b)*, describes the methodology for an ecological status assessment and a tool for ecological effect assessments. The latter is being tested in case of the construction of an artificial island off the coast of Knokke-Heist. A number of initiatives, demonstration and innovation projects for integrated coastal protection are shown below in table 3.

MASTERPLAN COASTAL SAFETY

With the *Masterplan Coastal Safety*, the Coastal Division aims to protect the coast from at least a 1,000-year storm surge, and wants to reduce the residual risk of serious economic damage and casualties, based on a cost/benefit approach. The masterplan follows an approach according to the principles of ICZM (see *Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe*). Since its approval by the Government of Flanders on 10 June 2011, the plan has been gradually implemented. The website *afdelingkust.be* gives a description of the measures for each of the attention zones along the coast, as well as the status of the implementation (table 4).

Table 3. An overview of studies, projects and initiatives in the context of integrated coastal protection.

Studies, projects and initiatives	Running time	Explanation
Kappa plan (*Kustwerkgroep Natuurpunt 2010*)	2010	Natuurpunt and the West Flanders Environmental Federation (WMF) advocate an integrated climate adaptation plan for a sustainable vision for coastal protection. In this Kappa plan, coastal protection is worked out with natural climate buffers against climate change and flooding.
CcASPAR (Climate change and changes in spatial structures in Flanders) project (*Allaert et al. 2012*)	2009-2012	This project conducts research on the spatial impact of climate change with the aim to develop spatial adaptation strategies and sustainable policies for Flanders on various spatial levels. The developed strategies have been tested for the coast and the Yser Valley.
Metropolitaan Kustlandschap 2100 (exploratory and methodological analysis of the Belgian Coast, design assignments and exploratory design research part 1, 2 and 3) (*Geldof and De Bock 2014*)	2012 - 2014	This initiative from LABO Ruimte (Ruimte Vlaanderen and Team Vlaams Bouwmeester)- in association with the Department Mobility and Public Works and the Agency for Maritime and Coastal Services – explores various possible future scenarios for the Flemish coast from a metropolitan perspective.
The *BELSPO project CLIMAR* (*Van der Biest et al. 2009*, *Van den Eynde et al. 2009*, *Van den Eynde et al. 2011*)	2006 - 2011	This project developed a framework in which adaptation measures, implemented to control the impacts of climate change, can be evaluated for the ecological as well as the social and economic aspects of the North Sea environment.
Coastal communities 2150 (*Stratton 2012*)	2011 - 2014	This project aims to inform stakeholders in coastal areas about climate change and its effects on the coast (erosion, floods, etc.).
4shore project(Colson et al. 2016)	2013 - 2016	Over a period of 3 years, this project has mapped out the ecological changes in foreshore and beach nourishments on a temporal and spatial scale for the beach and the shallow coastal zone.
4shorebis	2014 - 2016	This subproject is part of the 4shore project and evaluates the macrobenthos and physio-chemical properties of the soil sediment at the beach of Middelkerke after a nourishment activity.
Provoost et al. 2014	2014	In this ecosystem service report of the nature report 2014, the protection against floods from the sea by means of natural sea barrier elements is elaborated.
CREST project	2015 - 2019	Since 1 November 2015, the *CREST consortium* (*Climate Resilient Coast*) has been studying the robustness of the Flemish coast under a changing climate regime. In particular, effects on coastal dynamics and impact for future safety strategies will be investigated. This innovation project will allow a better insight into near coastal and inland physical processes, but also into the flood risks along the coast and the impact of the wave transfer; to determine the resilience of the natural coastal system in relation to storms and wind; and to develop climate scenarios for the Belgian coast. The *CREST project* is divided into three core activities: (1) integrated modelling of waves, currents and sediments on a multi-scale, (2) advanced modelling of wave overtopping risks in coastal municipalities and (3) improved knowledge of coastal processes.
Meetnet Vlaamse Kust – project Broersbank (*Thoon 2016*)	2013 - 2016	This study project has built up a unique data set and model set of instruments that will contribute to further research into a safe, robust coastline. In order to investigate the impact of sandbanks on the reduction of wave energy in detail, a monitoring network consisting of seven buoys was developed off the coast.

Coastbusters project	2017 - 2020	In the Coastbusters demonstration project, the partners are going to construct a reef of 100 m² off the coast of De Panne. The reef must hold the loose sand that would otherwise be released and washed away during heavy storms. The natural reef is made up of three parts: seaweed or sea grass, mussel reef and a reef of sand mason worms.
The BELSPO *QUEST4D project (Van Lancker et al. 2012*)	2007-2011	This project quantified erosion/ sedimentation patterns and distinguished the natural from anthropogenic induced sediment dynamics.
Blue Cluster	2018 - running	The proposal for the spearhead cluster the 'Blue Cluster' proposes an extensive innovation process for the design, development, testing and validation of the building blocks for future coastal protection projects. This process covers different aspects of coastal protection and climate change adaptation which are all interlinked, ranging from the assessment of new technologies and concepts to enhancing the resilience, sustainability and economic viability of coastal protection measures.
SCAPE project	2016 - 2020	The aim of this project is to protect coastal areas against the consequences of climate change, such as floods and extreme rainfall, on the basis of a landscape guided design. Water managers, planners and architects are developping a joint approach deploying the landscape against the water-related consequences of climate change.
Territoriaal Ontwikkelingsprogramma (T.OP) Kustzone	2017 - running	T.OP Coastal Zone was started up by the Department of Environment in cooperation with the province of West Flanders to draw up an action-oriented programme for the spatial development of the coastal zone in the short and medium term.
The BELSPO *CORDEX.be project*	2014 - 2017	The aim of the CORDEX.be project is to combine the existing and new research activities of nine Belgian partners in the field of climate modelling in order to create a consistent scientific basis for climate services in Belgium.
The BELSPO *TILES project* (*Van Lancker et al. 2017*)	2013 - 2017	The *TILES project* (*Transnational and Integrated Long-term marine Exploitation Strategies*) is focused on forecasting and adaptive long-term management strategy for the exploitation of geological resources in the North Sea. The methodology has been elaborated in *van Heteren (2015)*, *Van Lancker et al. (2017)* and *De Tré et al. (2017)*.
The BELSPO *INDI67 project*	2014-2019	Development of methods to improve the monitoring of MSFD indicators 6 (sea floor integrity) and 7 (hydrographical conditions).
ARGONAUTS	2013-2018	'ARGus and in-situ mONitoring of beAch and shoreface NoUrishmenT for Sustainable coastal safety'. The aim of the project is to evaluate a foreshore nourishment in Ostend (Mariakerke) as an alternative measure to maintain extended/replenished beaches.
The BELSPO *RS4MoDy project*	2017-2020	This project aims to investigate the morphodynamics of a tidal beach from short (storm event) to long term (> 25 years). This project will allow a better understanding of the morphodynamics of the beach and will provide some implications for coastal management.
The Interreg 2 Seas project *ENDURE*	2018-2020	This project focuses on dune management to make the 2 Seas area resilient to climate change. In order to visualise the advantages of different dune management approaches (hard engineering versus ecosystem-based approach), a call for tenders was launched for the development of new cartographic solutions. With a clear visualisation, coastal managers should be able to better understand how their measures are changing the coastal zone.

Table 4. An overview of the protection measures chosen and the state of implementation per focus area in the spring of 2018 (*Masterplan Coastal Safety*). The planned quantities of sand for the nourishments originate from the Masterplan Coastal Safety.

Zone of particular attention	Selected measures	State of implementation
De Panne - section 8	Dune nourishment Planned: 22.000 m³ sand	The essential volumes of dunes will be further budgeted for in 2018. Timing of the execution depends on the results of this actualisation.
De Panne - centre (sectie 13 tot 18)	Beach nourishment with an elevated beach Planned: 85.000 m³ sand	2011: construction of beach nourishment 2017: maintenance
St. Idesbald - Koksijde-centre (section 21 to 31)	Beach nourishment with an elevated beach Planned: 248.000 m³ sand	2011: construction of beach nourishment 2017: maintenance
Koksijde - section 39	Raising the road by the nourishment of the dune passage in combination with the reconstruction of the road Planned: 1.800 m³ sand	2013: dune passage raised and rebuilt
Port of Nieuwpoort	Construction of a storm surge barrier	2018: start of construction of the storm surge barrier; the construction works will take more than 3 years
Middelkerke - Westende (section 74 to 88)	Beach nourishment with a low-lying beach in combination with wave absorbing expansions and a storm wall seawards of the casino Planned: 1.700.000 m³ sand	2013-2015: phased construction of nourishment for a beach lower than the seawall level 2017: maintenance Future: new seawall with wave-damping extension, grass dyke and reconstruction of the zone around the planned new casino
Raversijde - Ostend Wellington (section 97 to 108)	Beach nourishment with a low-lying beach in combination with a high storm wall or adapted seawall ramp and wave absorbing expansion or widening of the seawall at Raversijde Planned: 1.500.000 m³ sand	2013-2014: widening of the beaches 2014: construction of nourishment 2018: maintenance Future: storm wall of about 50 cm high on the seawall of Mariakerke
Ostend centre (section 109 to 117) + port of Ostend + Ostend-East (section 118 to 120)	OW-Plan Ostend (storm walls in the port, beach nourishment and wave-damping expansion seawall, mobile storm walls on seawall Ostend centre)	2012: sea dyke Albert I promenade along the entire strengthened and equipped with a fully removable mobile storm wall; Zeeheldenplein near Klein Strand completely renovated and strengthened 2013: construction of nourishment 2018: maintenance Since 2014: construction of a storm wall on the quays in the Vismijnlaan, Wandelaarskaai and Slijkense Steenweg Further stages in study phase. Important subprojects are: protection measures in the Montgomerydock area and protection measures in the inner port. These are carried out in several stages.
Ostend-East (section 121)	Beach nourishment in line with OW-plan, partial plan for integrated coastal zone management Oosteroever (sections 199 and 120) Planned: 85,000 m³ sand	2014: construction of nourishment
De Haan - Wenduine (section 172 to 176)	Beach nourishment with low beach in combination storm walls on roundabout and seawall/widening seawall Planned: 700,000 m³ of sand	2012: construction of a nourishment from west to east at the level of the entire seawall 2014, 2016, 2017, 2018: maintenance 2015: renovated widened seawall, equipped with waterproofing elements and storm walls
Port of Blankenberge	Construction of a storm wall on + 8 m TAW in combination with an erosion protection embankment around the harbour	2016 - 2018: construction of a storm wall (phase 1) Further stages in the study phase: adaptation of the drainage structures in the Blankenbergse Vaart and mobile barriers
Blankenberge (section 185 to 195)	Beach nourishment with low beach Planned: 384,000 m³ sand	2014-2015: phased construction of nourishment; use of dredged sand from the port channel
Port of Zeebrugge	Construction of a storm wall at + 8.0 m TAW around Prince Albert I dock and then at locks in combination with an erosion barrier around the harbour	2018: Construction of the storm walls in design
Knokke-Heist (section 225 to 243)	Beach nourishment (profile between steep and low beach) Planned: 3,620,000 m³ sand	2012, 2013, 2014, 2015, 2017: planned nourishments
Zwin (section 250 to 255)	Zwin project	2016-2019: construction of 4 km long Zwindijk, in combination with the digging of canals and construction of walls for expansion Zwin
Rehabilitation of locks and weirs	Ports of Blankenberge, Ostend and Zeebrugge	These projects are carried out in several phases

Legislation reference list

Overview of the relevant legislation at the international, European, federal and Flemish level. For the consolidated European legislation we refer to *Eurlex*, the national legislation can be consulted in the *Belgisch staatsblad* and the *Justel-databanken*.

European legislation

Title	Year	Number
COM: Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of integrated Coastal Zone Management in Europe	2002	413
COM: Communication from the commission to the European economic and social committee and the committee of the regions. An EU Strategy on adaptation to climate change	2013	216
Directive establishing a framework for Community action in the field or water policy (Water Framework Directive)	2000	60
Directive on the assessment and management of flood risks (Floods Directive)	2007	60
Directive amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (EIA Directive)	2014	52
Directive establishing a framework for maritime spatial planning (MSP Directive)	2014	89

Belgian and Flemish legislation

Abbreviation	Title	File number
Decree of 18 July 2003	Decreet betreffende het integraal waterbeleid	2003-07-18/72
RD of 20 March 2014	Koninklijk besluit tot vaststelling van het marien ruimtelijk plan	2014-03-20/03
Law of 8 August 1980	Bijzondere wet tot hervorming der instellingen	1980-08-08/02